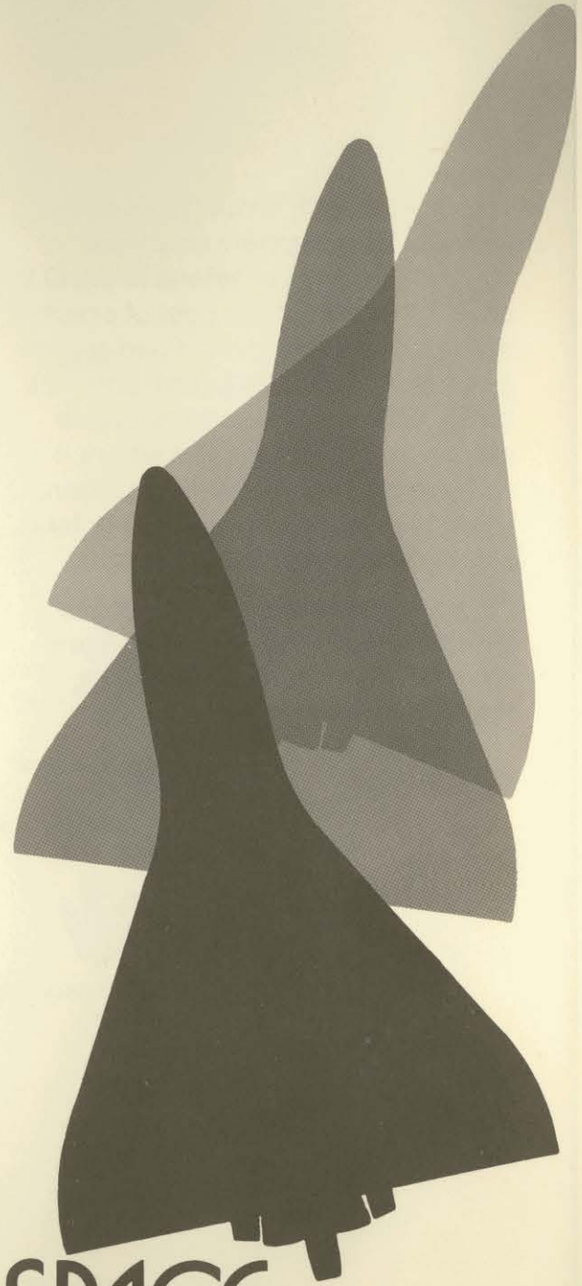
MSC

MANNED SPACECRAFT CENTER — HOUSTON, TEXAS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MERCURY CHRONOLOGY

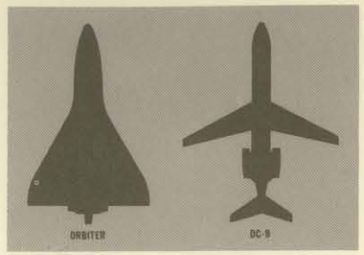
MISSION	PILOT	DATE(S)	DURATION (ORBITS/ HRS:MIN:SEC)	SC NUMBER	DURATION
Little Joe 1	--	Aug. 21, 1959	/0:00:20	BP	Evaluation of escape and recovery systems. Accidental ignition of escape rocket terminated mission. (Failure)
Big Joe	--	Sept. 9, 1959	/0:13:00	BP	Spacecraft survived high heat and air loads, validating Mercury concept. (Success)
Little Joe 6	--	Oct. 4, 1959	/0:05:10	BP	To check mating of launch vehicle and spacecraft. (Partial Success)
Little Joe 1A	--	Nov. 4, 1959	/0:08:11	BP	Evaluation of low altitude abort conditions. (Partial Success)
Little Joe 2	"Sam" Monkey	Dec. 4, 1959	/0:11:06	BP	Check high-altitude performance of the escape system. (Success)
Little Joe 1B	"Miss Sam" Monkey	Jan. 21, 1960	/0:08:35	BP	Evaluate the escape system under high air loads. (Success)
Beach Abort	--	May 9, 1960	/0:01:16	1	First production spacecraft flight tested in off-the-pad abort test. (Success)
MA-1	--	July 29, 1960	/0:03:18	4	Spacecraft qualification during reentry. (Unsuccessful)
Little Joe 5	--	Nov. 8, 1960	/0:02:22	3	Qualify spacecraft at max. q. (Failure)
MR-1	--	Nov. 21, 1960	/0:00:02	2	Qualify Redstone-Mercury combination. Premature engine shut-off. (Failure)
MR-1A	--	Dec. 19, 1960	/0:15:45	2A	Qualify systems for suborbital. (Successful)
MR-2	"Ham" Chimp	Jan. 31, 1961	/0:16:39	5	Primate suborbital and auto abort. (Successful)
MA-2	--	Feb. 21, 1961	/0:17:56	6	Qualify Mercury-Atlas interface. (Successful)
Little Joe 5A	--	Mar. 18, 1961	/0:23:48	14	Max. q escape and impact. (Partial Success)
MRBD	--	Mar. 24, 1961	/0:08:23	BP	To perfect Mercury-Redstone booster. (Success)
MA-3	Robot	Apr. 25, 1961	/0:07:19	8	Quick test of spacecraft Atlas orbit. (Failure)
Little Joe 5B	--	Apr. 28, 1961	/0:05:25	14A	Max. q escape and sequence. (Success)
MR-3	Shepard: Freedom 7	May 5, 1961	/0:15:28	7	Evaluate man in space. (Success)
MR-4	Grissom: Liberty Bell 7	July 21, 1961	/0:15:37	11	Corroborate man-in-space. Spacecraft lost at sea. (Success)
MA-4	Robot	Sept. 13, 1961	1/1:49:20	8A	Validate man in orbit. (Partial Success)
Mercury-Scout 1	--	Nov. 1, 1961	/0:00:43	NA	Communications package orbit. (Failure)
MA-5	"Enos" Chimp	Nov. 29, 1961	2/3:20:59	9	Primate test of ECS in orbit. (Partial Success)
MA-6	Glenn: Friendship 7	Feb. 20, 1962	3/4:55:23	13	Evaluate man in orbit. (Success)
MA-7	Carpenter: Aurora 7	May 24, 1962	3/4:56:05	18	Corroborate man in orbit. (Success)
MA-8	Schirra: Sigma 7	Oct. 3, 1962	6/9:13:11	16	Man-machine in orbit for 9 hours. (Success)
MA-9	Cooper: Faith 7	May 15-16, 1963	22.5/34:19:49	20	Manned 1-day mission in orbit. (Success)



SPACE SHUTTLE

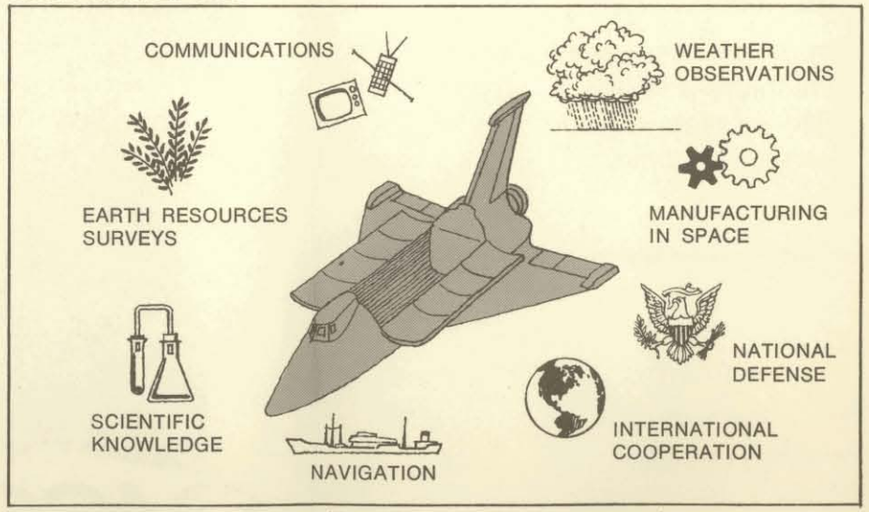
The Space Shuttle will be a space transportation system designed to carry out various missions in Earth orbit at a fraction of the cost of present systems. It will consist of two stages, a booster for launch from Earth, and an airplane-like manned reusable orbiter for flight into orbit where it will conduct space missions. Then, the orbiter will be flown back to land at a conventionally sized airstrip.

Four main reasons why the space shuttle is important have been presented by Dr. James C. Fletcher, NASA Administrator.



First, the space shuttle is needed to do useful things. The shuttle will be able to send most unmanned applications spacecraft into orbit; for example, communications, weather, navigation, Earth resources observation satellites and military spacecraft.

SPACE SHUTTLE USES



The uses of the space shuttle will include launching of unmanned spacecraft into orbit for missions such as those indicated.

It will also launch scientific spacecraft for study of space near and far. With the shuttle, men will supervise the launch and placement of the satellites and will be able to service and repair them as needed. Thus, launch vehicle and satellite failures, which require the construction of a whole new satellite, will become things of the past.

"The United States should proceed at once with development of an entirely new transportation system designed to help transform the space frontier of the 1970's into familiar territory, easily accessible for human endeavor in the 1980's and 1990's . . . The continued preeminence of America and American industry in the aerospace field will be an important part of the shuttle's payload."

President Richard M. Nixon, January 5, 1972.

Second, the space shuttle is needed to make space operations less complex and less costly. Today, NASA has to mount an enormous effort for a space mission. And the costly launch vehicle is used but once. The space shuttle will launch payloads into Earth orbit at costs substantially less than the expense of current space operations.

The key to this cost reduction is that major parts of the shuttle system are reused rather than thrown away. Such a next step in space is appropriate and logical. After all, a transcontinental airliner is not discarded after a single trip. The shuttle will greatly reduce the cost and difficulty of preparing payloads because of its easier environment, its volume and weight capacity and its capability for retrieval and repair.

Third, the shuttle is the only meaningful new manned space program which can be accomplished on a modest budget. Man has worked hard to achieve freedom of mobility on land and sea, and in the air. In the past dozen years, he has gained the freedom of space. The Space Shuttle will extend man's ability to do useful work in space while contributing to economy of space operations. The Space Shuttle will make launching of payloads into Earth orbit a virtually routine event.

Fourth, the shuttle will encourage far greater participation in space flight. With the shuttle's easy and routine access to space, scientists, engineers and astronauts will be able to go into orbit to supervise and check on their space experiments. You don't have to be an astronaut to ride the Space Shuttle. Healthy individuals will be able to withstand the mild forces of acceleration and deceleration experienced when the shuttle is launched and reenters the atmosphere. In addition, the shuttle will be built and pressurized so that passengers such as scientists, engineers and others will be able to ride in ordinary clothing, as in an airliner. Also by lowering the cost of space operations, the shuttle will encourage more nations to participate in space activities. Such joint experiments, joint environmental monitoring, and perhaps other joint enterprises will contribute toward making the benefits of space exploration available to all people.

The shuttle will be launched vertically. The orbiter will separate from its booster and go into orbit under its own power. When it accomplishes its mission, its pilots will fire its rockets to slow it down, fly it through the atmosphere, and land it like an airplane on a jet size airstrip.

The delta-winged manned orbiter will be about the size of a DC-9 airplane. The cargo compartment, which can accommodate experiments and passengers, will be about 4½ meters (15 feet) in diameter and up to 18 meters (60 feet) long. The orbiter will be able to carry cargo and/or passengers weighing in total as much as 29,500 kilograms (65,000 pounds).

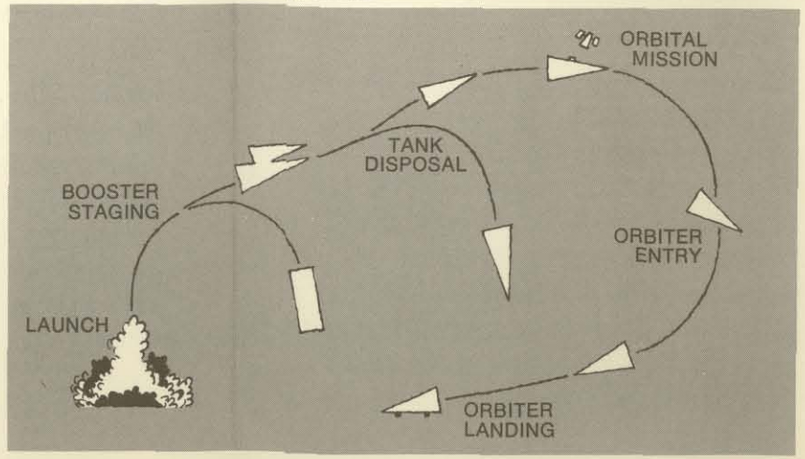
The shuttle orbiter crew will consist of two pilots and two flight engineers. Maximum G forces on launch and reentry will be no more than a mild 3G.

The shuttle after entry will not have to follow a ballistic trajectory to the ground. It will be able to maneuver right or left some 1760 kilometers (1100 nautical miles). Each orbiter will be designed for reuse up to a hundred times.

The Space Shuttle is expected to be ready to play its major role in space by the end of this decade. It will then be used to launch all but the very smallest and very largest payloads. It will send some spacecraft into orbit from which the spacecraft's own rockets would send them into higher orbits or toward the Moon and other planets.

The shuttle represents an investment in mankind's future. It can provide dividends that will continue for decades to come.

SPACE SHUTTLE MISSION PROFILE



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Manned Spacecraft Center
Houston, Texas 77058

Robert V. Gordon
713/483-5111

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SKYLAB SIMULATION

The prime and backup crews for the first manned Skylab mission Wednesday began an 11-day simulation during which they will duplicate flight tasks in Skylab simulators and trainers at the NASA Manned Spacecraft Center.

Prime crew members Charles P. Conrad, Jr., Dr. Joseph P. Kerwin and Paul J. Weitz and backup crew members Russell L. Schweickart, Dr. Story Musgrave and Bruce McCandless, II, will work alternately in the command module and Skylab simulators and five trainers -- orbital workshop, multiple docking adapter, airlock module, Apollo Telescope Mount, and command module 1-g trainer -- which are located in the Building 5 Mission Simulation and Training Facility at MSC. The realistic trainers represent the elements of the total Skylab spacecraft.

The Skylab assembly will be launched unmanned aboard at Saturn V in the spring of 1973, and will be visited three times by three-man crews over an eight-month period. Twenty-four hours after the Saturn V launch, the first crew of Conrad, Kerwin and Weitz will be launched aboard a Saturn 1B, and will rendezvous and dock with the orbital assembly for a stay of 28-days.

The Orbital Workshop,which has approximately 9,555 cubic feet of working and living area, houses most of the Skylab experiments, has two solar array panels for power generation, and the complete crew quarters and commodities for sleeping,

- more -

eating and housekeeping during all mission operations. The OWS is the fourth stage of a Saturn V launch vehicle which has been modified for Skylab.

The Multiple Docking Adapter provides facilities for docking the command and service module and crew working areas for operation of the Apollo Telescope Mount, earth resources and space manufacturing experiments. The MDA which has 1,140 cubic feet of working space, also provides transfer of personnel, equipment, power, and electrical signals between the CSM and the OWS.

The Airlock Module has a special hatch airlock compartment and services for supporting extravehicular activity by astronauts who will leave the vehicle to replace and retrieve the film in the telescope mount. The airlock module also provides the main power distribution control and atmosphere supply and conditioning equipment for the entire orbital assembly.

The Apollo Telescope Mount provides a mounting structure, electric power system, the pointing system, and environmental control system for the six solar experiments.

The simulation, which will occur on consecutive days exclusive of weekends, will operationally test 11 selected days of the first Skylab mission and will consist of the following:

During the first 8 days, crew members (prime and backup) will participate in activities concerned with launch (in the Command Module Simulator), operational and experiment activities in the Skylab Simulator, and in the orbital workshop, docking adapter, airlock module, and Apollo telescope mount trainers.

The final three days will be devoted to deactivation of the Skylab assembly and undocking and will be conducted using the simulators and trainers.

Purpose of the simulation is to evaluate spacecraft systems, crew systems, and experiment procedures in addition to evaluating checklists, flight data files, and stowage control in a continuous time line. The simulation will be conducted as a nominal mission without the introduction of planned malfunctions, however, should problems occur, they will be handled in real time, as would any actual flight problem.

The work day will commence at crew awakening and terminate at the beginning of the scheduled flight plan sleep period. The crew will eat their meals in the orbital workshop utilizing the vehicle's food and water system and will eat the food items scheduled for Skylab.

"Air to ground" communications will be conducted between the crew members and a special Operations Center established in Building 5. Communications and voice transmissions will follow the Skylab flight plan protocol and transmissions will simulate flight plan protocol at time periods when the vehicle is in contact with a ground station.

The Operations Center will be staffed by specialists in operations and systems and will include a test conductor, capsule communicator, flight activities officer, systems specialist, experiment operations specialist, and flight plan specialist.

On the fourth day of the simulation, shortly after the evening meal, there will be change of crews with the on-duty crew going home and the new crew remaining in the workshop for several hours completing various simulation activities, reviewing the next day's flight plan and configuring the trainers for the next day. The new crew returns the following day at 6 a.m. to continue with the simulation, picking up where they left off the night before, after relieving the previous crew.

This exchange of crews continues from the fourth through the ninth day of the simulation. Schedule, mission phase, date and time, crew and location are:

Sim Day	Mission Phase	Date	Time Start/Stop	Crew	Location
1	Launch	9-6-72	8 am-6 pm	Backup	CSM Simulator
2	Activation Orbital Assembly (OA)	9-7-72	6 am-10 pm	Prime	CM 1-g trainer
3	Activation OA	9-8-72	6 am-10 pm	Prime	Orbital Workshop
4	In-orbit	9-11-72	6 am-8 pm	Prime	" "
			7 pm-10 pm	Backup	" "
5	In-orbit	9-12-72	6 am-8 pm	Backup	" "
			7 pm-10 pm	Prime	" "
6	In-orbit	9-13-72	5 am-8 pm	Prime	" "
			7 pm- 10 pm	Backup	" "
7	In-orbit	9-14-72	6 am-8 pm	Backup	" "
			7 pm - 10 pm	Prime	" "
8	In-orbit	9-15-72	6 am-8 pm	Prime	" "
			7 pm-10 pm	Backup	" "
9	Deactivation	9-18-72	6 am-8 pm	Backup	" "
			7 pm-10 pm	Prime	" "
10	Deactivation	9-19-72	7 am-9 pm	Prime	" "
11	Deactivation	9-20-72	9 am-2 pm	Backup	" "

- end -

MSC-04066

NASA FACTS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

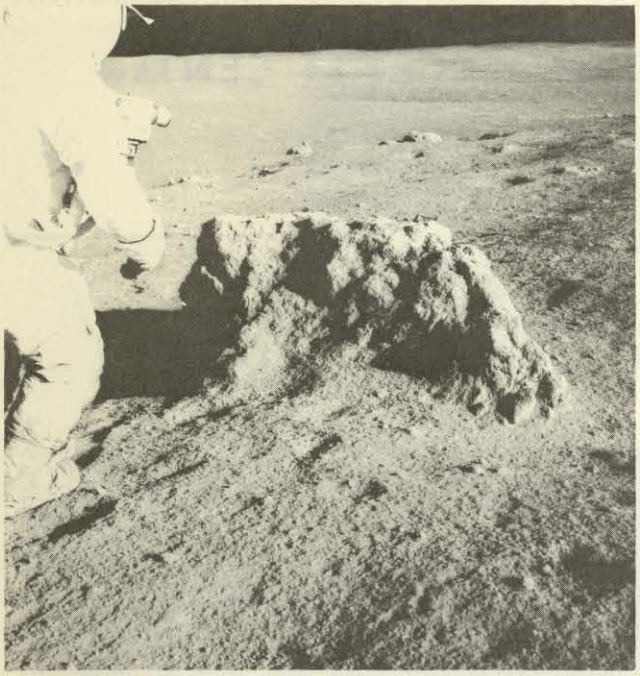
MANNED SPACECRAFT CENTER

PUBLIC AFFAIRS OFFICE

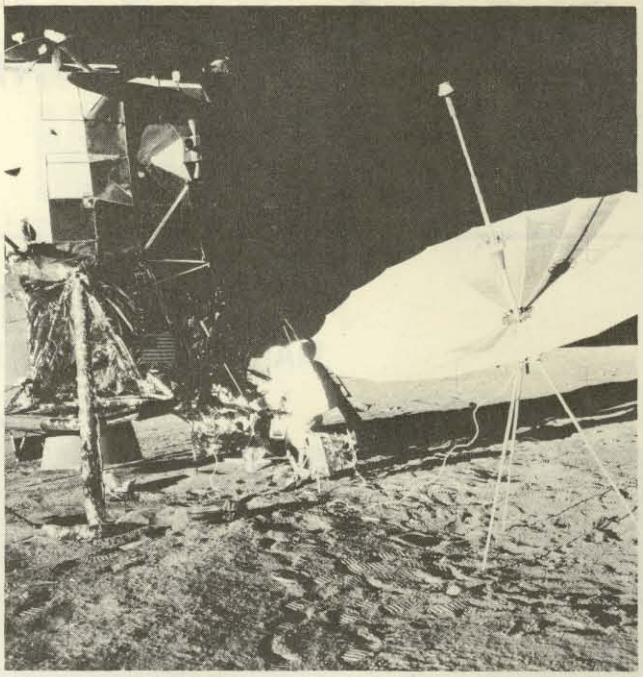
Houston, Texas

PROJECT APOLLO

MANNED EXPLORATION OF THE MOON



Obtaining samples of lunar soil and rock is one of the important goals of each Apollo lunar landing mission. Early Apollo landing sites were relatively smooth and free of large rocks. However, the missions were designed to progress ambitiously to landings in areas strewn with large boulders, like the one shown in this photograph, and even to mountain ranges and canyons.



The lunar surface experiments, which were designed to continue collecting data long after the Apollo astronauts have returned home, are packaged on earth for easy deployment on the moon. The experiments are unloaded from the lunar module storage bay and set up a short distance from the spacecraft. The umbrella-like antenna is aimed at the earth.

INITIAL GOALS OF THE APOLLO PROGRAM

The initial goals of the Apollo Program were achieved in July 1969 when the Apollo 11 astronauts landed in the Pacific Ocean. The goals were:

1. To land American explorers on the moon and return them safely to earth
2. To establish the technology required to meet other national interests in space
3. To achieve for the United States preeminence in space.

The Apollo Program is scheduled to continue through 1972 with the following objectives: (1) carry out a program of scientific exploration of the moon, (2) maintain the United States' preeminence in space, and (3) develop man's capability to work in the lunar environment.

To achieve these objectives, Apollo missions have been designed to increase progressively the scientific payload transported to lunar orbit and to the lunar surface, to achieve increasing flexibility in landing-site selection, to increase the lunar-orbit and lunar-surface stay time, and to increase lunar surface mobility.

HISTORY OF THE APOLLO PROGRAM

Initial planning for a launch vehicle with the heavy payload capability necessary for a manned lunar mission began in April 1957. In August 1958, studies concluded that a clustered booster generating a total of 1.5 million pounds thrust was feasible, and the research and development effort was started to build the booster. Rocketdyne, a division of North American Rockwell Corporation, developed the 200 000-pound-thrust version of the H-1 engine from the previously used Thor and Jupiter H-1 engine by updating the engine and by increasing its thrust. Concurrently, from more advanced studies, the 1.5-million-pound-thrust F-1 engine was conceived for even larger boosters. In October 1958, the Army started the development of a high-performance booster for advanced space missions. Tentatively called Juno V and finally designated Saturn, the booster was turned over to NASA in late 1959.

NASA proposed a manned flight program designated Project Apollo in July 1960. Its goals at that time were earth-orbital and circumlunar flights of a three-man spacecraft. During 1960, McDonnell Douglas Corporation 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 and establish as a national goal a manned lunar landing and return by the end of the 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.

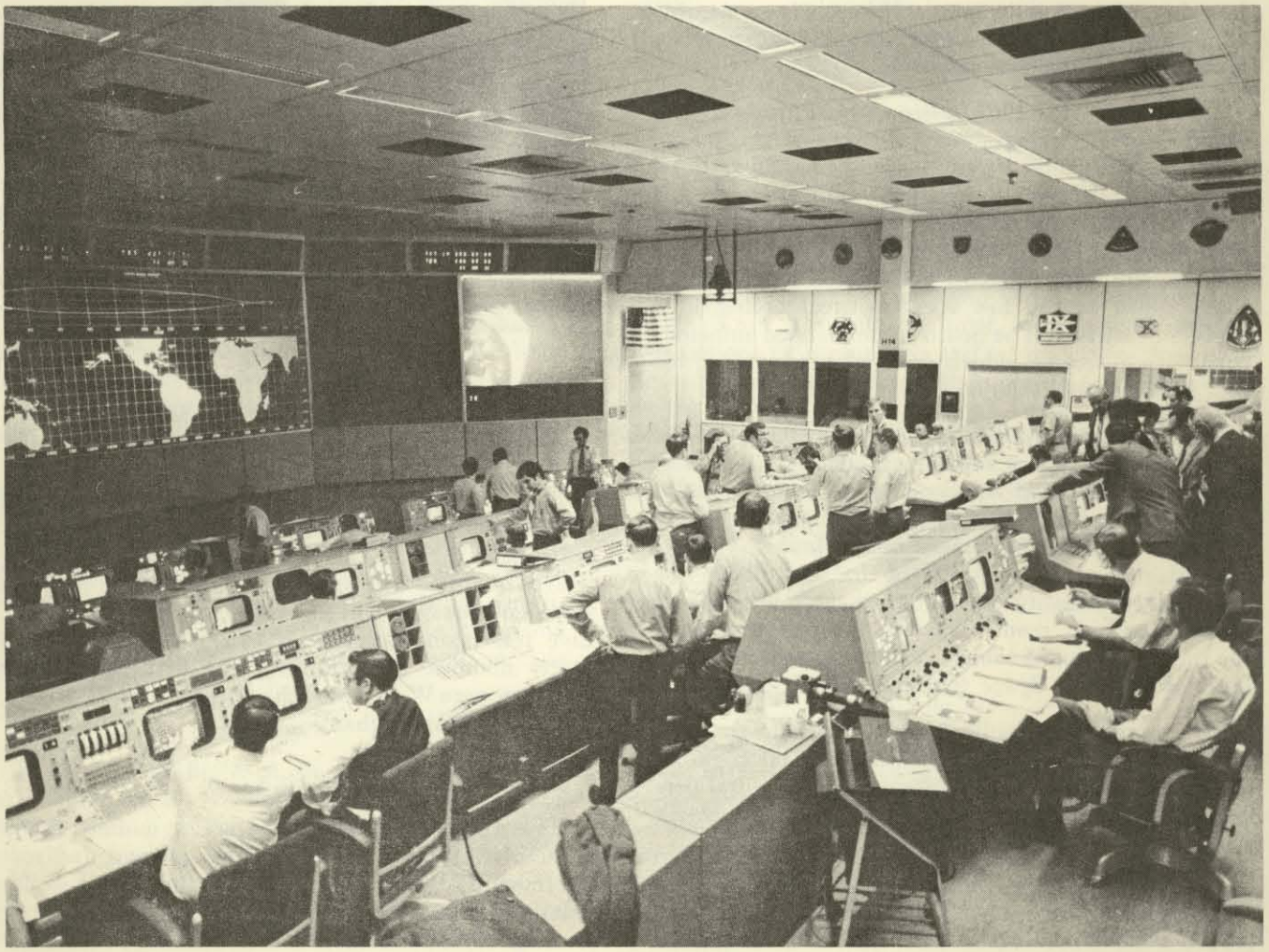
"No single space project in this period will be more impressive to mankind or more important for the long-range exploration of space . . .

"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."

On August 9, 1961, the Massachusetts Institute of Technology was selected to develop the Apollo spacecraft guidance and navigation system. Three and a half months later, NASA selected North American Rockwell Corporation as the principal contractor for the Apollo spacecraft command and service modules.

With an endorsement by Congress, the national objective of manned lunar exploration hastened the need for more powerful boosters, which were designated the Saturn family of boosters. For earth-orbital flights, the Apollo spacecraft would be launched by the two-stage Saturn IB booster, which was built by Chrysler Corporation. The Saturn IB was an uprated version of the original Saturn I and produced 1.6 million pounds of thrust (rather than the 1.5 million pounds of thrust produced by the Saturn I) from eight clustered H-1 engines. The second stage J-2 engine used liquid hydrogen as the fuel and liquid oxygen as the oxidizer to produce about a quarter of a million pounds of thrust. The second stage of the Saturn IB, also used as the third stage of the Saturn V booster, was built by McDonnell Douglas Corporation. The Saturn V launch vehicle generates a total of 7.5 million pounds of thrust in its five F-1 first-stage engines and can boost nearly 100 000 pounds of payload on its way to the moon. Five J-2 engines power the second stage of the Saturn V. The National Aeronautics and Space Administration awarded contracts to The Boeing Company for construction of the first stage and to the North American Rockwell Corporation for construction of the second stage.

In July 1962, NASA selected the lunar orbital rendezvous method for the lunar-landing mission. The method called for the development of a two-man



The Apollo flight controllers in the Mission Operations Control Room at the Manned Spacecraft Center in Houston watch the television picture (on the wall projection screen at the top-center of the photograph) from space. The picture on the screen shows the launch vehicle third stage and the lunar module as the command module moves in for docking shortly after leaving earth orbit for the moon.

lunar module to be used for landing on the moon and returning to lunar orbit. On November 7, 1962, Grumman Aerospace Corporation was selected to design and build the lunar module.

One year later, the first boilerplate Apollo command module was flown at White Sands Missile Range, New Mexico, in a launch-pad abort test. The first high altitude abort was successfully demonstrated on May 13, 1964, at White Sands. Fifteen days later, a Saturn I placed the first unmanned Apollo command module into orbit from Cape Kennedy, Florida. The first phase of the Saturn launch vehicle program was completed in 1965. All 10 flights of the Saturn I had been successful.

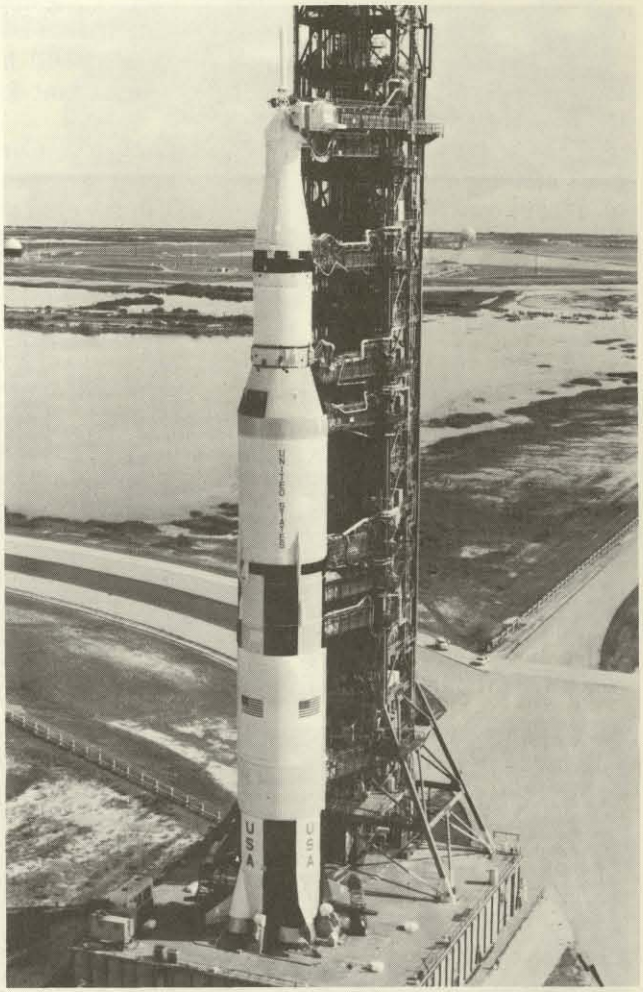
On February 26, 1966, the first full-systems Apollo command module was launched aboard a Saturn IB. The flight successfully tested the command module's reentry heat shield. The test was also the first flight of a Saturn IB. Saturn IB launch vehicles were successfully flown three times in three attempts in 1966. Two of the launches carried unmanned command and service modules, and the third flight was a test of the launch vehicle without a spacecraft. The two launches of the Apollo spacecraft met all test requirements and qualified the command and service modules for manned earth-orbit operations.

On January 27, 1967, a fire erupted inside a command module during ground testing at Cape Kennedy. Astronauts Virgil I. Grissom, Edward H. White II, and Roger B. Chaffee, who were to fly the first manned Apollo mission, died in the fire. After 2-1/2 months of investigation, which involved 1500 persons, the inquiry board determined that the most likely cause of the fire was electrical arcing from spacecraft wiring. The board recommended numerous corrective measures, which were adopted prior to the first manned Apollo flight.

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 the performance of the previously unflown first and second stages of the launch vehicle, the restart-in-orbit capability of the third stage, the spacecraft capability of reentering earth atmosphere at lunar-mission reentry speeds, the performance of the integrated space vehicle, and the operational readiness of Kennedy Space Center Launch Complex 39.

The unmanned Apollo 5 mission was flown January 22 and 23, 1968. This was the first flight of the lunar module, and its systems and structural performances met all objectives. The launch vehicle was a Saturn IB.

The Apollo 6 mission, on April 4, 1968, was the second unmanned Saturn V mission to demonstrate launch vehicle and spacecraft systems performance specifications. On the basis of the unmanned flight history, the spacecraft and launch vehicle were declared ready for manned earth-orbit missions.



The Saturn V launch vehicle with the Apollo spacecraft in place moves slowly from the assembly building to the launch pad. Note the comparative size of the men standing at the base of the crawler that carries the big rocket.

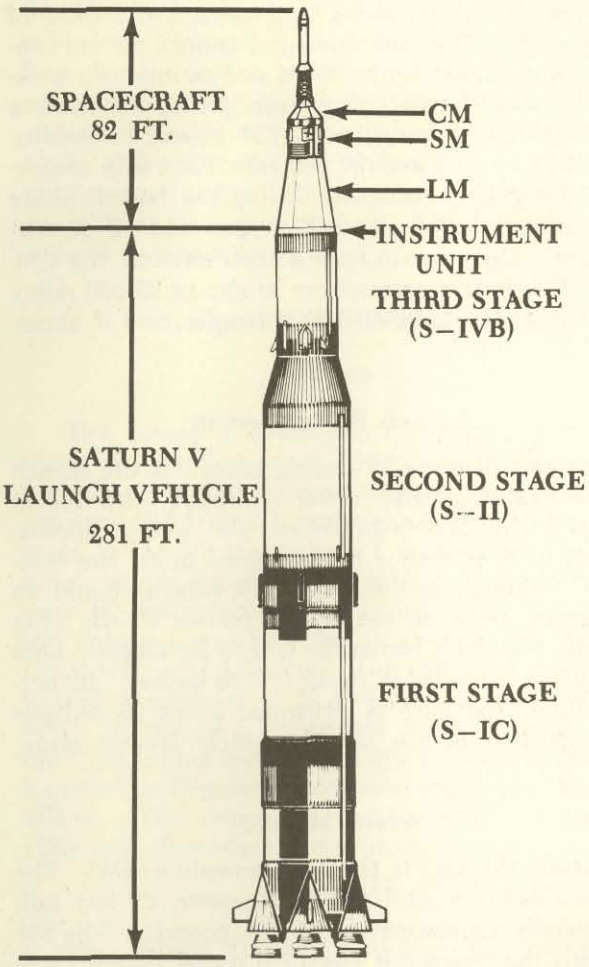
APOLLO MANNED MISSIONS

Apollo 7

The Apollo 7 mission was the first manned flight in the Apollo series and the first United States three-man space flight. The Apollo 7 earth-orbit mission, which qualified the command and service modules for lunar missions, was flown October 11 to 22, 1968. Live television was beamed to earth from a United States manned spacecraft for the first time. The crewmen were Walter M. Schirra, Jr., Donn F. Eisele, and Walter Cunningham.

Apollo 8

The Apollo 8 mission was the first manned flight to the vicinity of the moon. The command and service modules orbited the moon 10 times. The mission, which marked the first time man had visited the neighborhood of another celestial body, was flown December 21 to 27, 1968. Live television was broadcast from lunar orbit. The crewmen were Frank Borman, James A. Lovell, Jr., and William A. Anders.



Apollo 9

The Apollo 9 mission was the first of the complete Apollo spacecraft (command, service, and lunar modules) and was conducted in earth orbit March 3 to 13, 1969. The successful manned checkout of the lunar module and the portable life support system to be used by astronauts on the lunar surface indicated the readiness of the vehicle and equipment for lunar-landing missions. The Apollo 9 mission accomplished the first docking of two manned spacecraft and the first Apollo extravehicular activity (EVA). The crewmen were James A. McDivitt, David R. Scott, and Russell L. Schweickart. The command module was called Gumdrop, and the lunar module was named Spider.

Apollo 10

The Apollo 10 flight, flown May 18 to 26, 1969, was a lunar mission in which everything required for a lunar landing mission was demonstrated, except the actual landing. The crewmen were Thomas P. Stafford, John W. Young, and Eugene A. Cernan. In lunar orbit, Stafford and Cernan detached the lunar module from the command module and descended in the lunar module to within 9.7 miles of the lunar surface to inspect the site for Apollo 11 lunar-landing attempt in the Sea of Tranquility. Young remained in the orbiting command module. Apollo 10 remained in lunar orbit for 31 revolutions and transmitted live color television to earth. The command module was named Charlie Brown and the lunar module was called Snoopy.

Apollo 11

The Apollo 11 mission was the first lunar-landing mission and fulfilled the national goal to land men on the moon and return them safely to earth before 1970. It was flown July 16 to 24, 1969, by Neil A. Armstrong, Michael Collins, and Edwin E. Aldrin, Jr. The lunar module touched down on the moon at 3:18 p.m., c.d.t., July 20. Armstrong and Aldrin explored the lunar surface while Collins remained in orbit around the moon. Armstrong, the first man on the moon, stepped onto the lunar surface at 9:56 p.m., c.d.t., July 20. The lunar surface activity of the astronauts was televised throughout the world and was seen by the largest television audience in history. Scientific instruments were left on the lunar surface to continue broadcasting information long after the astronauts had returned to earth, and samples of the lunar surface material were returned to earth for scientific study. The command module was named Columbia, and the lunar module was called Eagle.

Apollo 12

The Apollo 12 flight was the second lunar landing mission. It was flown November 14 to 24, 1969, by Charles Conrad, Jr., Richard F. Gordon, Jr., and Alan L. Bean. Conrad and Bean, during their 31-1/2 hour stay on the lunar surface, conducted two periods of exploration and set up a more sophisticated scientific package than had been deployed during the Apollo 11 mission. The mission also demonstrated the capability for precise point landings. The lunar module touched down on the Ocean of Storms near the unmanned Surveyor III spacecraft, which had been on the moon 2-1/2 years. The crew returned several pieces of the Surveyor III spacecraft to earth. Apollo 12's command module was called Yankee Clipper, and the lunar module was named Intrepid.

Apollo 13

The Apollo 13 mission was launched April 11, 1970, with the objective of landing on the Fra Mauro lunar upland area, where the crew was to collect surface samples and set up geophysical instruments during two EVA periods. The crewmen were James A. Lovell, Jr., John L. Swigert, and Fred W. Haise, Jr. Swigert, a member of the backup crew, had replaced prime crewman Thomas K. Mattingly 2 days before the launch. Mattingly was replaced by Swigert because he had been exposed to the 3-day measles and was found to have no immunity to the

disease. Two and a half days after the launch, an explosion caused the loss of all oxygen stored in the service module. The oxygen is used in fuel cells to produce electric power as well as in the environmental control system of the command module for life support. The crew was forced to abort the mission and use the attached lunar module as a "life boat." By using the lunar module descent engine for propulsion, the crew looped their crippled spacecraft around the moon and returned safely to earth on April 17. The command module was named Odyssey, and the lunar module was called Aquarius.

The Apollo 13 Review Board determined that a short circuit had ignited electrical insulation in the spacecraft oxygen tank No. 2. The resulting fire caused the tank to rupture. The oxygen system was modified to eliminate potential combustion hazards.

Apollo 14

America's first man in space, Alan B. Shepard, Jr., commanded the Apollo 14 mission, with Stuart A. Roosa and Edgar D. Mitchell as his crew. The January 31 to February 9, 1971, flight was to the Fra Mauro highlands, which had been the objective of the Apollo 13 mission. The 33-hour stay on the lunar surface included two EVA periods, which lasted almost 5 hours each. The second EVA was a long-distance traverse to Cone Crater. A color television camera enabled viewers on earth to watch much of the activity. While Shepard and Mitchell set up the scientific experiments and gathered geologic samples on the lunar surface, Roosa continued to orbit the moon. From the command module Kitty Hawk, Roosa conducted several electronic experiments and photographic programs. The lunar module was named Antares after the brightest star in the constellation Scorpius, which appeared in the LM window when the craft pitched over into its landing trajectory.

APOLLO SPACECRAFT

The Apollo spacecraft assembly is 82 feet tall and weighs about 45 tons. It is composed of three modules (separable units) plus an adapter and a launch escape system.

Command Module

The command module (CM) is the only module which returns to earth from a mission. The CM contains the crew's living compartment and all the controls for the inflight maneuvers. The coneshaped spacecraft is 12.8 feet in diameter at the bottom and stands about 12 feet high. It consists of two shells, which are a pressurized inner crew compartment and an outer heat shield. Launch weight of the CM is about 12 000 pounds. The CM has two side windows, a hatch window, and two rendezvous windows. The rendezvous windows face toward the nose of the module. The environmental control system supplies pure oxygen in the cabin and maintains a pressure of approximately 5 pounds per square inch, a temperature of approximately 75° F, and a humidity index between 40 and 70 percent. The cabin atmosphere for ground tests and during the launch phase of a mission is 60 percent oxygen and 40 percent nitrogen. Upon return from a lunar mission, the CM enters the earth's atmosphere at almost 25 000 miles per hour and is subjected to a temperature of about 5000° F.

Launch Escape System

On top of the CM during launch is the launch escape system (LES) tower equipped with rocket motors. The LES is 33 feet tall and weighs approximately 8200 pounds. It is designed to lift the command module from the rest of the vehicle should an emergency occur on the launch pad or shortly after launch. The LES boosts the CM to an altitude high enough for parachutes in the CM to deploy. In normal flight, the LES is jettisoned about 35 seconds after ignition of the launch vehicle second stage.

Service Module

Behind the CM is the service module (SM). The SM is a cylinder 12.8 feet in diameter, 22 feet tall, and weighs approximately 55 000 pounds. The SM contains the spacecraft electrical power source, cryogenic oxygen and hydrogen tanks, and the primary propulsion system, which produces 20 500 pounds of thrust. This multiple-start engine is used for maneuvers during the translunar and transearth periods of a mission, to slow the spacecraft for insertion into a lunar orbit, and to add velocity to boost the spacecraft out of lunar orbit. The SM is jettisoned just before the CM enters the earth atmosphere.

Spacecraft Lunar Module Adapter

The spacecraft lunar module adapter (SLA) connects the command and service module to the third stage of the Saturn V launch vehicle and serves as a protective covering for the lunar module during launch and in earth orbit. The SLA is a fairing 28 feet tall, 12.8 feet in diameter at the top to match the width of the Apollo spacecraft, and 22 feet in diameter at the bottom to match the width of the launch vehicle third stage. The weight of the adapter section is approximately 4000 pounds.

Lunar Module

The lunar module (LM) is the flight unit that descends to the lunar surface with two of the three astronauts aboard. The LM is a two-stage vehicle.

The bottom stage contains the descent engine and the four-legged landing gear. For lift-off from the moon, the descent stage serves as the launch platform for the upper stage, which includes the crew cabin and the ascent engine. The LM has its own complete guidance, computer, control, communications, and environmental systems. The descent propulsion system has a throttle control which can vary the thrust for a soft landing. The LM is designed to land on slopes up to 12°.

LAUNCH VEHICLES

Saturn I

The Saturn I developed 1.5 million pounds of thrust in its first stage (S-1) through the clustering of eight H-1 rocket engines burning refined kerosene (RP-1) and liquid oxygen (lox). The second stage (S-IV) of the Saturn I had six RL-10-A3 engines, which burned liquid hydrogen and lox to produce 90 000 pounds total thrust. The diameter of the Saturn I was 21.5 feet, and its height (without spacecraft) was 125 feet. The two-stage vehicle delivered a payload of 22 000 pounds into low earth orbit. It placed a boilerplate Apollo CM into earth orbit in unmanned test flights and was used to launch the Pegasus micrometeoroid technology satellites. The Saturn I program was completed in 1965 with 10 successes in as many launches.

Saturn IB

The Saturn IB launch vehicle is an improved version of the Saturn I first stage with a more powerful second stage, the S-IVB. A Saturn IB launched the first manned Apollo spacecraft (Apollo 7) into earth orbit. It also will be used in the Skylab Program. The second stage of the Saturn IB consists of one J-2 engine, which burns liquid hydrogen and lox and produces about 230 000 pounds thrust. The low-earth-orbit payload for the Saturn IB is 40 000 pounds.

Saturn V

The first stage (S-IC) of the Saturn V launch vehicle is 33 feet in diameter and is powered by a cluster of five F-1 engines, each of which develops 1.5 million pounds of thrust. The second stage (S-II) is a cluster of five J-2 engines that generates a total of approximately 1.15 million pounds of thrust. The third stage (S-IVB) is identical with the Saturn IB second stage. The three-stage booster is 281 feet tall. The entire Apollo/Saturn V assembly is 363 feet high at the launch pad and weighs 6 million pounds when fueled for a lunar mission. The Saturn V booster can launch 140 tons into low earth orbit and accelerate a 47.5-ton payload to earth escape velocity. On a lunar mission, both the Apollo spacecraft and the Saturn V third stage go into an earth parking orbit, after which the third stage is reignited to send the spacecraft on its way to the moon.

APOLLO TRACKING NETWORK

A network of tracking stations around the world maintains voice and telemetry communications with the spacecraft. One group of stations follows the spacecraft at launch, during earth orbit, and again at the end of the mission. As the spacecraft leaves earth orbit and starts toward the moon, it passes from the range of these stations. Tracking then switches to a second group of stations whose powerful transmitters and sensitive receivers are designed for communications at great distances. These stations are located at Goldstone, California; Madrid, Spain; and Canberra, Australia. The three stations are approximately one-third of the earth circumference (120°) apart. As the rotating earth cuts off one station's direct line of contact with the spacecraft, the next station rises over the horizon and takes over.

APOLLO SCIENCE PROGRAM

Lunar Surface Science

In addition to returning lunar rocks and soil to earth for detailed study by scientists throughout the world, Apollo astronauts deploy an Apollo Lunar Surface Experiment Package (ALSEP) at each landing site. The ALSEP system is designed to return scientific data to earth for at least a year after each landing. The data obtained by the instruments provide the scientific community with knowledge of the lunar environment, particularly in the areas of geology, geophysics, geochemistry, and particles and fields. Areas of particular scientific interest include (1) measurement of natural lunar seismology, (2) properties of the lunar interior, (3) properties of the lunar material at shallow depths, (4) chemical sorting of lunar mantle material, (5) thermal insulating properties of the lunar surface, (6) measurement of lunar dust, (7) interaction of the solar wind and the moon, (8) measurement of the lunar magnetic field and of temporal variations in the field at the lunar surface, (9) composition of the lunar atmosphere, (10) lunar ionosphere positive-ion detection, (11) lunar atmospheric pressure, and (12) laser ranging using a retroreflector.

Lunar-Orbit Science

Lunar-orbit science experiments have been added to study deep space and the surface of the moon by photography and sensor techniques. The experiments include a subsatellite which will be placed in lunar orbit during two of the Apollo missions to investigate the formation and the dynamics of the earth magnetosphere and the boundary layer of the solar wind as it flows over the moon. The scientific equipment will be carried in a bay of the SM and will require extravehicular activity to retrieve film.

APOLLO MANNED MISSION EMBLEMS

APOLLO 7

APOLLO 8

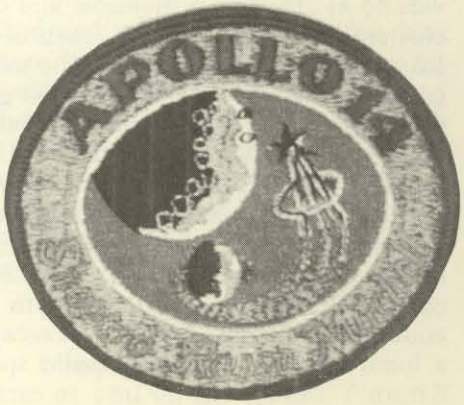
APOLLO 9

APOLLO 10

APOLLO 11

APOLLO 12

APOLLO 13



APOLLO 14

NASA — MSC

NASA FACTS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MANNED SPACECRAFT CENTER

PUBLIC AFFAIRS OFFICE

Houston, Texas

APOLLO 17 PREFLIGHT SUMMARY

A combination mountain highland and valley lowland region designated Taurus-Littrow is the landing site for Apollo 17, the sixth and final Apollo lunar landing mission. The flight currently is planned for December 1972.

Taurus-Littrow is about 20 degrees north and 30 degrees east of the center of the Moon as viewed from Earth. The site is named for the Taurus Mountains and the crater Littrow. Both lie to the north of the landing point.

Exploration of the site is expected to answer questions about (1) the early crust of the Moon, (2) large early impacts, and (3) young volcanic rock.

The current model shows a complex Moon about 4-½ billion years old which was subjected to intense cratering. Apollo 14 and 15 data show that one of the last large basins, Imbrium, was formed by an impact 3.9 billion years ago.

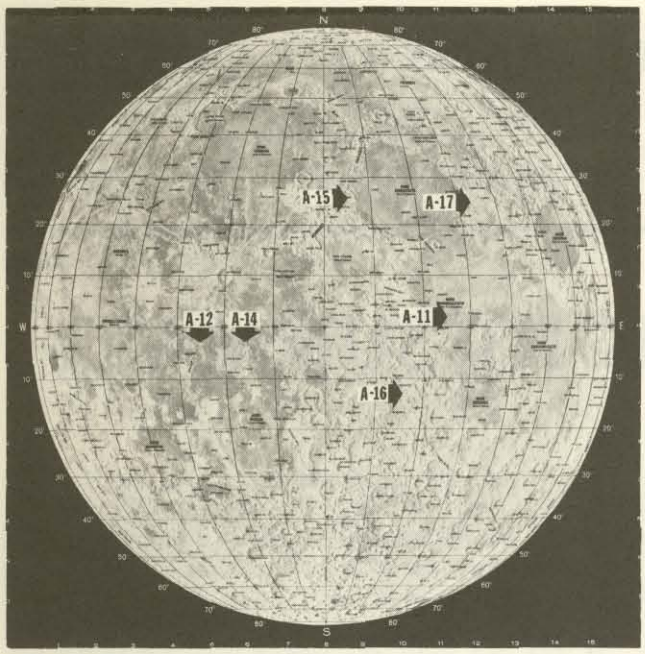
It was not until the period from 3.2 to 3.7 billion years ago, however, that the great basins, formed during the intense cratering phase, became flooded by molten lavas originating in the lunar interior.

One of the key questions remaining is to understand what happened in the period between 3.7 and 4.5 billion years. Similarly, it is important to understand whether or not the Moon has been thermally inactive for the last 3.2 billion years.

Gene Cernan
Apollo 17 Commander

Harrison Schmitt
Lunar Module Pilot

Ron Evans
Command Module Pilot



The Apollo 17 landing site is located in the northeast as viewed from Earth and is about equidistant from the Apollo 11 and 15 sites.

Taurus-Littrow is situated just beyond the southeast edge of Mare Serenitatis, one of the largest lunar mascons. Steepsided mountains of light-colored highlands dominate the terrain and are expected to provide samples older in age and different in composition from those returned from the Mare Imbrium basin on Apollo flights 14 and 15.

Nature has already helped in the sampling, as one of the sample sites is a rock slide which contains the debris which has fallen into the valley from high up on a 7000-foot mountain.

The targeted landing point itself will be on the other prime sampling objective, which is the very dark non-mare material filling the valleys between the mountains.

On occasion, the dark material is found in small troughs on the mountainsides, indicating that it once thinly covered the mountains but has eroded off the steep slopes. This observation, plus the presence of volcanic-looking cinder cones, first reported by Apollo 15 Command Module Pilot Al Worden, indicates to lunar scientists that the dark material is an explosively produced volcanic ash.

The apparently low crater density in the area covered by the dark material also leads geologists to believe it to be among the youngest lunar volcanics. The explosive nature of the volcanism indicates a relatively high content of volatiles or gases, both of which have been exceedingly rare in all lunar samples seen thus far.

If the Moon, as the preferred models indicate, has indeed cooled from the outside in, these youngest lunar volcanics should be derived from the greatest depths and may give the first good samples of the deep lunar interior.

The astronauts will use the Lunar Roving Vehicle to transport them to locations determined prior to the mission and to other points they might select during their exploration. Contingency walking traverses also will be planned to accomplish as many of the scientific objectives as possible.

The astronauts will deploy an advanced Apollo Lunar Surface Experiments Package (ALSEP) containing a Heat Flow Experiment similar to that deployed on Apollo 14 and planned for Apollo 17, as well as four new experiments.

In addition, two new surface traverse experiments, not powered by the ALSEP Central Station, will be deployed. These new experiments represent second generation scientific approaches to difficult lunar problems.

Three of the six new experiments represent new or improved geophysical techniques of exploring the hidden subsurface properties of the Moon:

(1) The Traverse Gravimeter will measure variations in subsurface structure and furnish data on such problems as whether the mountains have deep roots or are merely deposits on a uniform subsurface;

(2) The Seismic Profiling; and

(3) Surface Electrical Properties. Investigations will measure the physical properties of the lunar interior down to about a kilometer in depth, and will indicate subsurface electrical and mechanical properties, the extent of subsurface layering and the degree of energy scattering at the landing site. Underground water, should it exist, also will be detectable.

A new ALSEP experiment, the Tidal Gravimeter, to study both the response of the Moon to the Earth's tidal pull and its response to gravity waves, should they exist in space, will be a fundamental contribution to astrophysics.

Two other new experiments also will be part of the ALSEP. A mass spectrometer will measure the constituents of the lunar atmosphere — the findings of which may be correlated with the mass spectrometers carried previously in lunar orbit; a lunar ejecta and meteorites experiment will determine the frequency and energy of the small meteorites and their ejecta which constantly impact and modify the Moon.

Three new experiments are added to the Apollo 17 orbital science payload. These replace the geochemical

As the Apollo 17 spacecraft approaches the target, it will pass between several noteworthy craters — Vitruvius at the upper right corner, and Littrow and Littrow A at extreme left center.

investigations and the mass spectrometer. Apollo 17 will be the third mission to carry a large set of orbital sensors in the Service Module. However, three new experiments are under development and production to replace the mass spectrometer, Alpha, x-ray and gamma experiments, as well as the subsatellite carried on Apollo 15 and planned for Apollo 16.

The first of these, a Lunar Sounder, is a pulsed radar sounder and has the potential for identifying electrical properties and layering of the lunar crust overflown by the spacecraft.

The Lunar Sounder will provide the opportunity to study detailed physical properties of the Moon up to depths of 1-½ kilometers, and if it exists, to aid in the location of subsurface water.

The second, the Infrared Scanning Radiometer,

will provide, for the first time, a high resolution thermal map of portions of the Moon.

Thirdly, a Far Ultraviolet Spectrometer will measure the compositional and density variation of the lunar atmosphere. Since this experiment has the capability of measuring these variations as a function of atmosphere height, it will greatly extend the knowledge of the lunar atmosphere that was gained through the use of the original mass spectrometers on Apollo flights 15 and 16.

The Scientific Instrument Module (SIM) camera system flown successfully on Apollo 15, and planned for Apollo 16, will be carried on Apollo 17. This system contains the 24-inch Panoramic Camera, a 3-inch Mapping Camera, and a Laser Altimeter. The Apollo 17 ground track will permit some new areas of the Moon to be investigated and photographed.

In addition, where Apollo 17 overflies areas covered by previous missions, the difference in Sun angle will provide the photo-geologists with photographs of lunar features at new illuminations.

Apollo 17 will be commanded by Navy Capt. Eugene A. Cernan with Navy Cmdr. Ronald E. Evans, Command Module Pilot, and Dr. Harrison H. Schmitt, civilian scientist-astronaut, Lunar Module Pilot.

Apollo 17 lunar astronauts Schmitt, left, and Cernan train at a site near Boulder City, Nevada, that approximates what they will encounter on the Moon. All lunar landing crews underwent similar field excursions to prepare themselves for their moonwalks.

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NASA FACTS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MANNED SPACECRAFT CENTER

PUBLIC AFFAIRS OFFICE

Houston, Texas

SKYLAB

MANNED ORBITAL SCIENTIFIC SPACE STATION

Skylab is the name of an experimental space station program of the National Aeronautics and Space Administration (NASA). An extension of the manned Mercury-Gemini-Apollo space programs, the Skylab Program will make extensive use of the hardware and technological base developed during those previous missions.

The Skylab Program is designed to expand our knowledge of manned earth-orbital operations and to accomplish carefully selected scientific, technological, and medical investigations.

The success of the Skylab Program is essential not only in achieving sound decisions on the content and configuration of future space vehicles, but in gaining the confidence and support needed for later, more advanced programs.

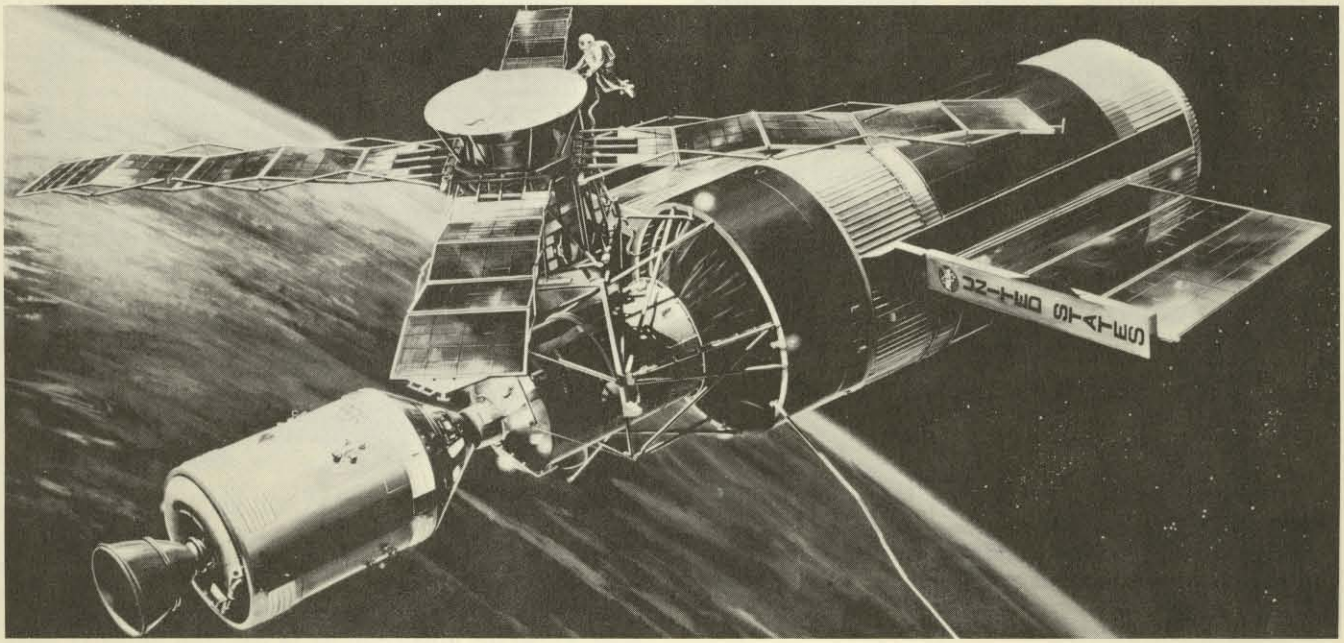
Three groups of experiments are of particular importance: an Earth Resources Experiment Package designed for investigating and application of remote sensing of the earth resources, a series of medical experiments associated with the careful extension of man's living and working in space for longer periods of time, and several high-resolution astronomical experiments for studying the sun at short wavelengths not observable from the earth.

The Skylab Program, scheduled to begin late in 1972, will consist of several low earth-orbital missions — approximately 235 nautical miles altitude — using the payload of the Saturn V and Saturn IB launch vehicles. The series of missions will begin with the orbital insertion of an unmanned Saturn workshop (SWS). Each subsequent launch will provide a manned command and service module (CSM) that will rendezvous and dock with the SWS. Because of the unique design, which incorporates the huge third stage of the Saturn V launch vehicle and provides an orbital facility equal in volume to a medium-sized home, the program is expected to provide the United States with the capability to develop and maintain permanent space stations that will be of increasing benefit to mankind.

The goal of the Skylab Program is the accomplishment of four basic objectives.

1. Scientific investigations in earth orbit. — These investigations are designed to take advantage of space operations to learn more about the universe, the space environment, the phenomena that exist in the solar system, and the manner in which these phenomena influence our earth environment.

2. Applications in earth orbit. — Applications experiments include the development and evaluation of efficient techniques using man for sensor operation, discrimination, data selection and evaluation, control, maintenance and repair, assembly and setup, and mobility. These experiments include studies in meteorology, earth resources, and communications. The



proper relationship between manned and unmanned applications operations will be examined.

3. Long-duration space flights of men and systems. — The unique capabilities of man as a participant in space flight activities will be exploited in the Skylab Program. Techniques are being developed for measuring the life-support systems and subsystems of space vehicles. Man's psychological responses and aptitudes in space will be evaluated and his postmission readaptation to the terrestrial environment will be analyzed as a function of progressively longer missions. Some of the major medical areas that will be studied include nutritional and musculoskeletal functions, cardiovascular function, hematology and immunology, neurophysiology, pulmonary function, and metabolism.

4. Effective and economical development of future space programs. — The Skylab missions will give man the capability to operate in space for increasingly longer periods of time. The technology developed will provide the basis for the design and development of future long-duration space stations. In addition, manned operational requirements for future extended planetary exploration will be further defined.

PROGRAM RESPONSIBILITY

The Skylab Program Office in the Office of Manned Space Flight, NASA Headquarters, Washington, D. C., has the responsibility for directing, integrating, and evaluating all phases of the program. Direction of the program is implemented by the Skylab office at each responsible NASA center. The responsibilities of the three major centers are as follows:

Manned Spacecraft Center, Houston, Texas —

- Development of the modified CSM
- Development of the spacecraft launch adapter for manned missions
- Development of assigned experiments, crew systems, medical equipment, food, and other crew-support items
- Integration of experiments carried in the CSM; stowage and return of experiment data and designated hardware from orbit
- Mission analysis, including mission-requirements development, detailed mission planning, and preflight preparations
- Flightcrew selection and training
- Mission control, flight operations, and recovery activities
- Mission evaluation

Marshall Space Flight Center, Huntsville, Alabama —

- Development of all Saturn workshop hardware elements
- Development of assigned experiment-support hardware; integration of assigned experiments and support systems
- Overall systems engineering and integration for each flight
- Flight evaluation
- Saturn IB and Saturn V launch vehicles

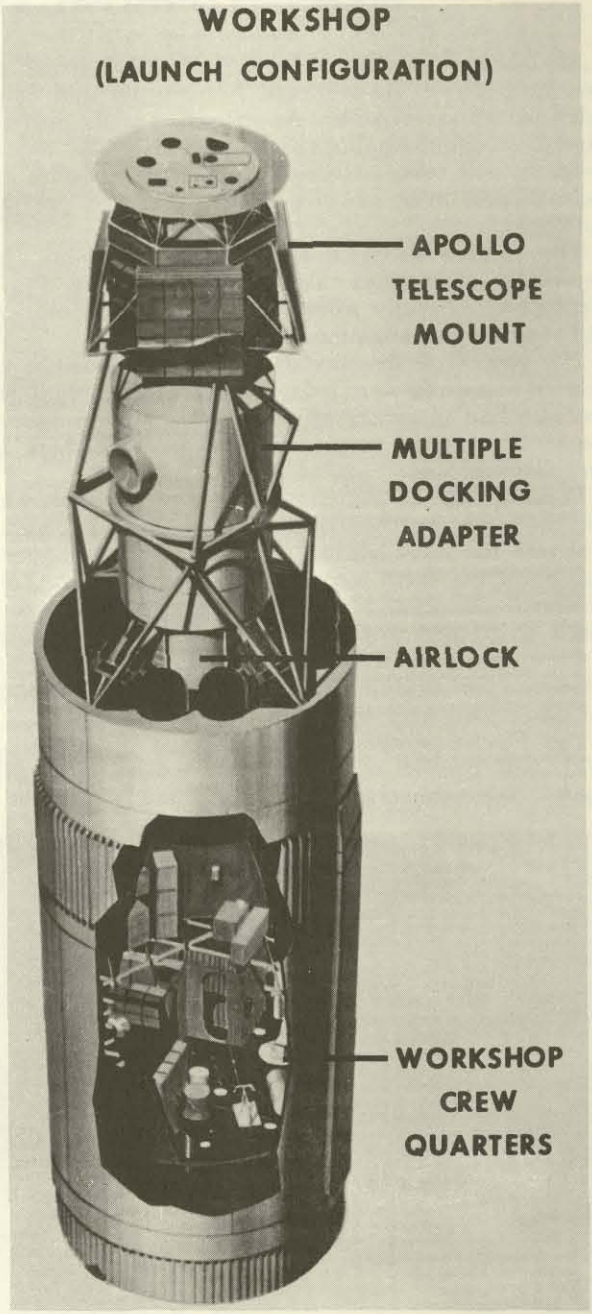
John F. Kennedy Space Center, Florida —

- Launch facilities for Skylab flights
- Preparations and implementation of prelaunch checkout procedures
- Launch operations

SKYLAB CLUSTER

The Skylab orbital cluster will consist of an SWS and a docked Apollo CSM. The SWS will be composed of an S-IVB stage modified into an orbital workshop (OWS), an airlock module (AM), a multiple docking adapter (MDA), an instrument unit, an Apollo telescope mount (ATM), and an ATM deployment assembly. The SWS will be launched by a two-stage Saturn V rocket.

In orbit, the Skylab cluster will be 118 feet long and will weigh 181,300 pounds. The total work area of the OWS, AM, MDA and CSM will be 12,763 cubic feet.



The ATM, AM, and MDA will be the only new major components of the cluster; the other components will consist of standard Apollo hardware converted for Skylab use.

The AM, a 5.5-foot-diameter circular tunnel, will be attached to the upper surface of the tank formerly used

for liquid hydrogen storage in the third stage (S-IVB) of the Saturn V launch vehicle. The AM will provide a passageway for the astronauts to enter and exit the main workshop area. Capable of being depressurized, the AM will be used by astronauts whose work entails extravehicular activity. The majority of the workshop systems and controls will be located in the AM.

The MDA, when attached to the AM, will provide the docking ports for the CSM and the crew. The adapter, 10 feet in diameter and 17 feet long, will contain the Earth Resources Experiment package and the ATM film vault.

The SWS, including the ATM, will be completely outfitted before launch. The workshop will have 10,644 cubic feet of interior space, sufficient for kitchen, bath, and workroom facilities to support a crew of three men for one 28-day period and two 56-day periods. Certain experiments and the necessary experiment-support equipment will be installed in the OWS, which will be maintained in a dormant state during unmanned periods, then reactivated for use by a later crew.

The instrument unit, which will provide guidance and sequencing functions, will be used during launch and the first 7.5 hours of orbital operations. The unit will also be used during the initial deployment of the ATM and the solar arrays of the OWS and the ATM.

The ATM will be essentially a manned solar observatory that can be aimed with pinpoint accuracy. The structure and behavior of the sun, particularly during periods of solar-flare activity, will be observed, monitored, and recorded in the ATM. Astronauts equipped with extravehicular equipment will exit the AM to install and retrieve film from the ATM cameras.

LAUNCH VEHICLES

The Saturn V launch vehicle used to place the SWS in orbit will consist of two stages, the S-IC and the S-II. The total weight of the Saturn V and the SWS at lift-off will be approximately 6.2 million pounds. At launch, the entire vehicle will be 333 feet high.

A Saturn IB launch vehicle will place the CSM into orbit for rendezvousing and docking with the SWS. The Saturn IB, a two-stage vehicle — the S-IB and the S-IVB — with the CSM will have a combined lift-off weight of 1,3 million pounds. The height of the S-IB will be 223 feet at launch.

MISSION SEQUENCE

In the flight sequence, the fully outfitted but unmanned SWS and attached ATM will be launched into a 235-nautical-mile circular orbit by the two-stage Saturn V launch vehicle. The ATM will be deployed and the OWS will be pressurized to 5 psia with an oxygen-nitrogen mixture, so that the crew can enter immediately after the CSM is docked.

Then, 24 hours later, an S-IB launch vehicle will place the CSM and the three-man crew into an intermediate 81- by 120-nautical-mile orbit. The crew will rendezvous with SWS (using the CSM service propulsion system to attain the required 235-nautical-mile orbit) and then dock to a port of the MDA.

The crew will enter and completely activate the OWS, which will be their home and work area for the next 28 days. During the remainder of the mission, the experiment program (scientific, biomedical, technological, earth resources, and crew operations) will be conducted. Emphasis will be placed on the medical experiments and evaluation of the habitabilty of the SWS. The ATM experiments will be conducted and satisfactory operation of the experiments will be verified. The Earth Resources Experiment Package will be operated to a limited degree.

On the 26th day, the crew will exit the AM, retrieve exposed ATM film, and reload the cameras. Near the end of the 28-day mission, the crew will prepare the SWS for orbital storage, a dormant period scheduled to last 2 months until another crew visits the Skylab.

The CSM and crew will deorbit and make an ocean landing on the 28th day of the mission.

The second manned flight of the Skylab Program will be similar to the first, except that the open-ended mission may be extended to 56 days. Greater emphasis will be placed on the solar-astronomy experiments and on the Earth Resources Experiment Package during the second manned mission. A third crew of astronauts is scheduled to revisit the Skylab 1 month after the end of the second mission. On the third visit, 56 days long, the earth-resources, medical, and ATM experiments will be emphasized. Science, technology, and crew operations will be investigated on all three missions.

EXPERIMENTS

The inflight experiments, grouped into six major areas, will be performed in the OWS, the AM, or MDA. The categories of experiments are as folows.

- Solar astronomy — The scientific experiments that comprise the ATM payload are the largest, most complex experiments ever designed for performing solar research from an orbital spacecraft. Special emphasis will be placed on observations that cannot be made by astronomers on earth because of spectral absorption by the atmosphere.
- Science — The 17 scientific experiments are designed to study geophysics, the physics of the upper atmosphere, the physics of the interplanetary medium, solar studies supplementing ATM data, and galactic and intergalactic astronomy.
- Biomedicine — The 15 inflight and postflight biomedical experiments are planned to determine the effects of long-duration space flight on the crew. The major areas of interest are nutritional and musculoskeletal functions, cardiovascular function, hematology and immunology, neurophysiology, pulmonary function, and metabolism.
- Technology — The three technological experiments are designed to make use of the orbital environment to study space effects on various scientific phenomena and industrial arts.
- Earth resources — The five experiments are planned to investigate practical applications of remote sensing of the earth resources and environment. During the research, the quality of earth-resources data taken through the atmosphere will be analyzed, and the data and possible applications will be examined. A multispectral photographic facility, an infrared spectrometer, a 10-band multispectral scanner, a microwave radiometer-scatterometer-altimeter, and an L-band radiometer will comprise the equipment used in the investigations.
- Crew operations — These experiments are planned to evaluate and demonstrate engineering developments and hardware designed to facilitate the functioning of the crew in the space enviroment.

SKYLAB EXPERIMENTS

TITLE	COGNIZANT AGENCY(a)	INVESTIGATOR AND AFFILIATION(b)	MISSIONS		
			1	2	3
White-light coronagraph	MSFC	Dr. Gordon Newkirk, High Altitude Obs.	X	X	X
X-ray spectographic telescope	MSFC	Dr. M. Zombeck, American Science and Engineering	X	X	X
uv scanning polychromator spectroheliometer	MSFC	Dr. Edward Reeves, Harvard College Obs.	X	X	X
Dual X-ray telescope	MSFC	Mr. James Milligan	X	X	X
Extreme uv coronal spectroheliograph	MSFC	Mr. J. D. Purcell, Naval Research Lab.	X	X	X
Extreme uv spectrograph	MSFC	Mr. J. D. Purcell, Naval Research Lab.	X	X	X
Nuclear emulsion	MSFC	Dr. M. M. Shapiro, Naval Research Lab.	X		
uv stellar astronomy	MSC	Dr. K. G. Henize and Dr. James Wray, Northwestern Univ.	X	X	
X-ray uv solar photography	MSC	Dr. R. Tousey, Naval Research Lab.	X		
Potato respiration	MSC	Dr. B. W. Pince, Space Defense Corp.			X
uv airglow horizon photography	MSC	Dr. D. Packer, Naval Research Lab.		X	
Gegenschein zodiacal light	MSFC	Dr. J. Weinberg, Dudley Obs.		X	
Particle collection	MSC	Dr. C. L. Hemmenway, Dudley Obs.	X	X	
Galactic X-ray mapping	MSFC	Dr. W. Kraushaar, Univ. of Wisconsin		X	
Multispectral photographic facility	MSC	Mr. A. L. Grandfield	X	X	X
Infrared spectrometer	MSC	Dr. T. Barnett	X	X	X
10-band multispectral scanner	MSC	Dr. C. L. Korb	X	X	X
Microwave scatterometer	MSC	Mr. D. Evans	X	X	X
Radiation in spacecraft	MSC	Capt. M. F. Schneider, USAF	X		
Expandable airlock technology	MSFC	Mr. F. W. Forbes, USAF Wright-Patterson Air Force Base (AFB)	X	X	
Thermal control coatings	MSFC	Mr. Carl Boebel, USAF Wright-Patterson AFB	X	X	
Material processing in space	MSFC	Mr. P. G. Parks	X		
Effects of zero-g on human cells	MSC	Dr. P. O. Montgomery, Dallas County Hospital	X		
Circadian rhythm, pocket mice	ARC	Dr. C. S. Pittendrigh, Princeton Univ.		X	
Circadian rhythm, vinegar gnat	ARC	Dr. C. S. Pittendrigh, Princeton Univ.		X	
Crew vehicle disturbances	LaRC	Mr. B. A. Conway		X	
Precision optical tracking	MSFC	Mr. John Gould	X	X	X
Coronagraph contamination measurement	MSC	Dr. G. P. Bonner		X	
Contamination measurement	MSFC	Dr. J. Muscari, Martin Marietta Corp.	X		
Zero-g flammability	MSFC	Mr. Howard Kimzey		X	
Gravity substitute workbench	MSFC	Mr. J. Rendall	X		
Extravehicular- and intravehicular-activity hardware evaluation	MSC	Mr. John Jackson	X	X	
Astronaut-maneuvering equipment	MSC	Maj. C. E. Whitsett, USAF		X	
Foot-controlled maneuvering unit	LaRC	Mr. D. E. Hewes		X	
Mineral balance	MSC	Dr. G. D. Whedon, National Institute of Health	X	X	X
Bone densitometry	MSC	Dr. Pauline Mack, Texas Women's Univ.	X	X	X
Bioassay of body fluids	MSC	Dr. C. Leach	X	X	X
Specimen mass measurement	MSC	Col. John Ord, USAF, Brooks AFB	X	X	X
Lower-body negative pressure	MSC	Col. John Ord, USAF, Brooks AFB	X	X	X
Inflight lower-body negative pressure	MSC	Dr. R. J. Johnson	X	X	X
Vectorcardiogram	MSC	Capt. Newton W. Allebach, USN, Bureau of Medicine and Surgery	X	X	X
Cytogenetic studies of blood	MSC	Dr. M. Shaw, Univ. of Texas Medical Center	X	X	X
Man's immunity in vitro aspects	MSC	Dr. Stephen Ritzman, Shriners' Burn Institute	X	X	X
Blood volume and red-cell life span	MSC	Dr. Phillip Johnson, Baylor Univ.	X	X	X
Red-blood-cell metabolism	MSC	Mr. Charles Mengel, Univ. of Missouri	X	X	X
Human vestibular function	MSC	Dr. Ashton Graybiel, Naval Aviation Medical Institute	X	X	
Time and motion study	MSC	Dr. J. F. Kubis, Fordham Univ.	X	X	X
Metabolic activity	MSC	Mr. Edware Michel	X	X	X
Body-mass measurement	MSC	Col. John Ord, USAF, Brooks AFB	X	X	X
Thermal control coatings	MSFC	Mr. E. C. McKannon	X		
Inflight aerosol analysis	MSFC	Dr. W. Leavitt	X	X	X

(a) MSFC, Marshall Space Flight Center; MSC, Manned Spacecraft Center; ARC, Ames Research Center; and LaRC, Langley Research Center.

(b) If different from cognizant agency.

NASA FACTS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MANNED SPACECRAFT CENTER

PUBLIC AFFAIRS OFFICE

Houston, Texas

MISSION CONTROL CENTER

"Houston, Tranquility Base here. The Eagle has landed."

Those words, of course, came from the first men on the Moon. They were broadcast to the entire world, but the call sign "Houston" to which the message was addressed designates the control center for United States manned space flight.

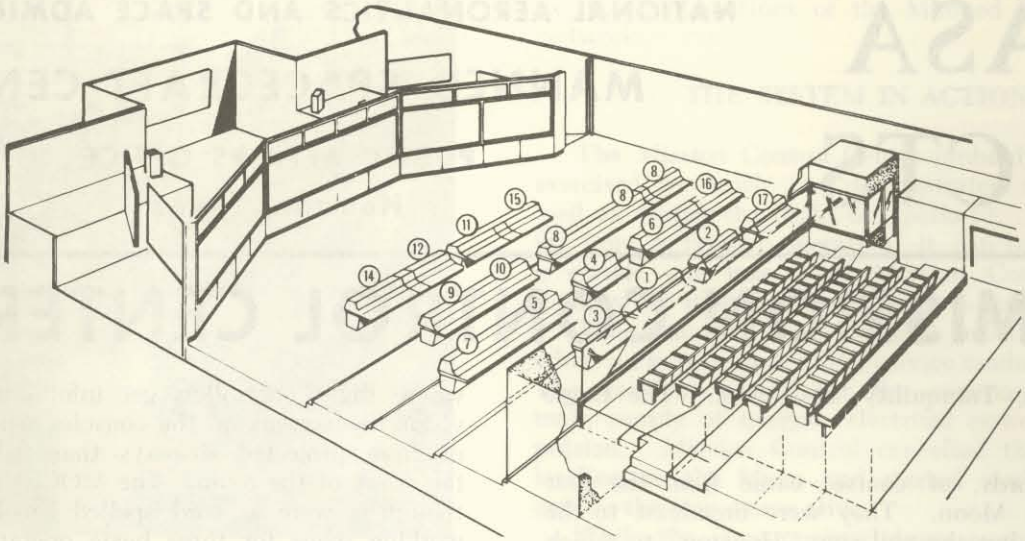
Mission Control Center is a three-story building at the NASA Manned Spacecraft Center. In it is some of the most sophisticated communication, computer, data reduction, and data display equipment available. Operating it – 24 hours a day during manned space flights – are hundreds of engineers and technicians with a wide scope of specialized skills. And from it come the decisions that can mean mission success or failure.

Focal point of the Mission Control Center is the Mission Operations Control Room (MOCR) where flight controllers get information from television-like screens on the consoles where they work, or from projected displays that fill the wall at the front of the room. The MOCR (pronounced as though it were a word spelled "moker") provides working space for three basic operating groups of flight controllers: mission command and control, systems operations, and flight dynamics.

Mission command and control positions are: the mission director, who is responsible for overall mission conduct; flight operations director, representing Manned Spacecraft Center management; flight director, who is responsible for operational decisions and actions in the MOCR; and the assistant flight director.

Others in the command and control group are: the flight activities officer, who develops and coordinates the flight plan; the Department of Defense (DOD) representative coordinates and directs DOD

Mission Control Center, in the center of the picture, is also the center of attention during manned space flights, when it hums with activity 24 hours a day. The Mission Operations Control Room is located in the windowless west wing of the three-story building.



This layout of a Mission Operations Control Room shows the visual display wall, the flight control consoles, and the viewing area for official observers. Console assignments vary landing mission would be: (1) the Flight Operations Director; (2) Mission Director; (3) Public Affairs Officer; (4) Flight Director; (5) Assistant Flight Director; (6) Flight Activities Officer; (7) Communication Systems Engineer, and Operations and Procedures Officer; (8) Vehicle Systems Engineer (two for the command module, two for the lunar module); (9) Flight Surgeon; (10) Spacecraft Communicator; (11) Flight Dynamics Officer; (12) Retrofire Officer; (14) Booster Systems Engineer; (15) Guidance Officer; (16) Network Controller, and (17) Department of Defense Representative.

mission support; the network controller is responsible to the flight director for Mission Control Center and for operations relating to the Manned Space Flight Network; the surgeon monitors the crew's medical condition; the spacecraft communicator, referred to as "Capcom" (from early manned flight, when Mercury was called a capsule rather than a spacecraft), is the voice contact with the crew; the experiments officer coordinates mission experiments activity; and the public affairs officer reports mission events to the public.

The systems operations group monitors data on the spacecraft and the launch vehicle and, when necessary, suggest ways to repair or circumvent malfunctioning equipment. The group includes an environmental, electrical, and communications engineer for each spacecraft and a guidance, navigation, and control engineer for each. Other positions are booster systems engineers, communications engineer, and operations and procedures officer.

In the flight dynamics grouping are the flight dynamics officer (FIDO), who monitors and plans spacecraft maneuvers, the guidance officer (GUIDO), who keeps spacecraft guidance systems updated with current flight information, and the retrofire office, who plans deorbit maneuvers for earth orbital flights, or calculates reentry trajectories for return from deep space.

THE SUPPORTING CAST

Mission Control Center contains two identical MOCRs, one on the second floor and one on the third. Either can be used for mission control, or they can be used simultaneously to control separate flights. At times, one team of flight controllers has conducted an actual flight while a second team is going through a make-believe mission to prepare for a future operation.

But the MOCR occupies only a relatively small portion of the Mission Control Center. Each operating group is assigned a nearby staff support room where data on the mission are monitored and analyzed in detail. Other support areas within the facility include the Spacecraft meteorological Room, the Spacecraft Planning and Analysis (SPAN) Room, the Recovery Operations Control Room, and the Lunar Surface Experiment Package Support Room.

On the first floor of the Mission Control Center are the communications, command, and telemetry system for processing data from the Manned Space Flight Network stations, and the real-time computer complex, which converts the flight data into the visual displays used by the flight controllers in the MOCR.

Mission Control Center is supported by an emergency power building which houses generators and air conditioning equipment for use if regular power fails. In the event of some unforeseeable but catastrophic failure that prevents the Houston control center from continuing its support of the flight, an emergency facility at the Goddard Space Flight Center in Greenbelt, Maryland, is activated. The emergency center is a stripped-down model of the one in Houston, incorporating just enough equipment to let the controllers support the flight to its conclusion.

One of the most interesting of the MOCR support facilities is the display/control system, which uses the front wall of the room as a projection screen for displays ranging from plotting charts that show the spacecraft's location, to actual television pictures

such as the scenes from the Moon's surface. Other display units built into the wall show such things as elapsed time after launch, or time remaining before a maneuver or other event.

The information displayed, and on which the flight controllers base many of their decisions or recommendations, can be telemetry and tracking data relayed from Manned Space Flight Network stations and processed through the real-time computer complex, or it might be information – predicted time of upcoming events, for instance – derived through the computer, or even stored reference data based on simulated flights conducted as practice for the actual mission.

The consoles at which the flight controllers work in the MOCR, and those in many of the support rooms, include one or more TV screens and the necessary switches to let the controller view a data display on a number of different channels. He may view the same display being shown on the large projection screens on the front wall, or he can "call up" data he is especially interested in just by changing channels. A library of prepared reference data is available to display static information, while digital-to-television display generators provide dynamic, or constantly changing, data.

The view from the Flight Director's position takes in the other control consoles, as well as the visual displays on the front wall. The picture of two astronauts is coming live from the Moon and is beamed onto a special screen (right projection screen in the diagram below).

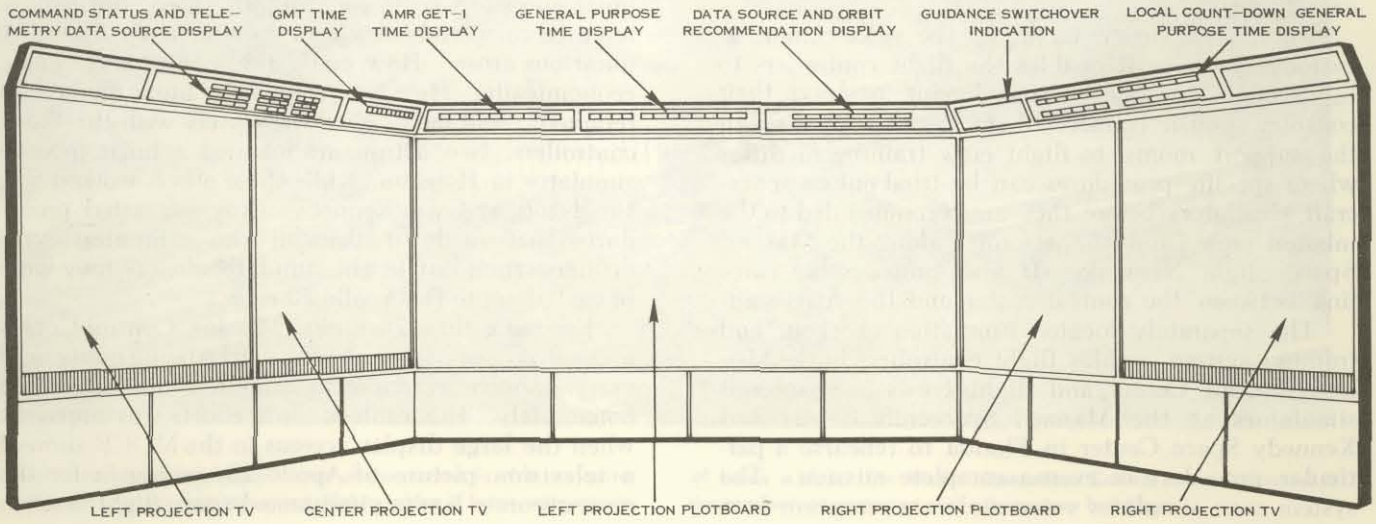
BEHIND THE SCENES

The Mission Operations Control Room, with its rows of consoles and its large display screens, is a familiar sight to many television viewers around the world, for a view of the busy MOCR during peak-interest periods of United States manned space flights has become almost a standard scene in video coverage of the mission.

But other equally busy areas of the Mission Control Center are just as important to the success of the flight. One such area is the communications, command, and telemetry system (CCATS) on the first floor. The CCATS processes incoming digital data and distributes it on a real-time basis to the facilities associated with the MOCR and support room displays. The system also handles the digital command signals to the spacecraft – the up-data link which lets Mission Control do such things as keep the spacecraft guidance computer's facts and figures up to date.

The real-time computer complex (RTCC), also on the first floor, processes incoming tracking and telemetry data and compares actual mission conditions with predetermined parameters – simply, it compares what is happening with what should be happening. Often, it does not even bother displaying the information unless something is going wrong. As the system evaluates factors such as spacecraft position and velocity, it also computes what maneuvers should be made to correct any shortcomings.

The RTCC, as its name implies, computes and evaluates on a real-time basis: through the high-speed electronic data from the worldwide network of tracking stations, the real-time computer complex



One of many unseen and unsung support areas of Mission Control Center, this is the television color converter that turns video signals from the Moon into the color picture seen on home sets around the world.

"sees" what is happening at almost the instant it happens; its computations are fast enough to correct a situation as it develops. Using this same data, the RTCC also predicts where the spacecraft will be at any given time in the flight.

Further, the computers are used to give acquisition information that helps the tracking stations point their antennas at the spacecraft. And the RTCC is used to monitor and evaluate telemetry information from the spacecraft to be sure that personnel and equipment are performing normally.

Of the five primary computers in the real-time computer complex, two are used to support one MOCR and two the other, where a second live mission can be controlled or a simulated flight conducted to train additional teams of flight controllers. The fifth serves as a backup for any of the first four, or it can be used separately to help develop and perfect the many computer programs used in each flight.

Another important facility is the voice communications system. It enables the flight controllers to talk to one another without having to leave their consoles, and it connects them to the specialists in the support rooms, to flight crew training facilities where specific procedures can be tried out on spacecraft simulators before they are recommended to the mission crew, and to personnel along the Manned Space Flight Network. It also provides the voice link between the control center and the spacecraft.

The separately located simulation checkout and training system enables flight controllers in the Mission Control Center and flight crews in spacecraft simulators at the Manned Spacecraft Center and Kennedy Space Center in Florida to rehearse a particular procedure or even a complete mission. The system even simulates voice and data reception from the far-flung stations of the Manned Space Flight Network.

THE SYSTEM IN ACTION

The Mission Control Center probably never was exercised so much nor demonstrated its value so well as during the flight of Apollo 13. While being far from a typical operation, it can be considered a classic one insofar as Mission Control Center doing what it was designed to do – and then some.

The spacecraft was 200,000 miles from Earth when an oxygen tank in the service module exploded. The accident wiped out the command module's main supply of oxygen, electrical power, and propulsion. Mission Control cancelled the scheduled landing on the Moon and started working toward getting the crew home alive.

While the crew powered-down as many systems as possible and took up residence in the attached lunar module, Mission Control mobilized all its available personnel, as well as those of the companies that built the spacecraft. They went to work to determine how best to make a "lifeboat" of the lunar module, a spacecraft with its own power and oxygen supply but not designed to reenter the Earth's atmosphere.

Maneuvers to put Apollo 13 on the proper path back home were computed and simulated on the ground. Since the lunar module engine was to do the thrusting, its burn had to be tailored to a greater mass and different center of gravity than that for which the system was designed.

Computation of available consumables – oxygen, electricity, and water (for cooling electronic equipment rather than for drinking) – pointed up the desirability of another maneuver that would shorten the time of return. The computers and the simulators were exercised again to demonstrate that the lunar module engine could, in fact, stand up under the additional strain.

Now the crew was on its way back. But the strange spacecraft – the dead service module, the powered-down command module, and the two-man lunar module accommodating all three crewmen – required completely new course correction data. Other questions arose. How could the maneuvers be done economically? How long should the lunar module be retained? And more. Working closely with the flight controllers, two astronauts manned a lunar module simulator in Houston, while three others worked two simulators at Cape Kennedy. Any suggested procedures that made it through the computers were further wrung out in the simulators before they were passed along to the Apollo 13 crew.

For more than 70 hours, Mission Control Center and all its supporting forces used all ingenuity and every resource available to bring the three spacemen home safely. The result of those efforts was apparent when the large display screens in the MOCR showed a television picture of Apollo 13 coming in for the most accurate landing in manned space flight history.

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NASA FACTS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MANNED SPACECRAFT CENTER

PUBLIC AFFAIRS OFFICE

Houston, Texas

SPACE BENEFITS

IN THE BEGINNING . . .

Galileo's observations of the Moon through a telescope in 1609 provided our first accurate picture of the Moon as a planet with mountains, valleys, and plains. Before Galileo reported his observations, scientists, including Aristotle, Copernicus, and Ptolemy, had developed only vague and inaccurate concepts of the Moon. With little more than the naked eye and a scientist's intuition as a basis for lunar studies, these earlier scientists depicted the Moon as a smooth crystalline sphere or as a lantern-like body lighted by internal fires which showed through openings in its surface.

For 300 years after Galileo and his contemporaries opened the door for modern lunar studies, our knowledge of the Moon grew only gradually as scientists obtained bigger and better telescopes.

Not until 1959, when the Soviet Union's Luna 3 first photographed the side of the Moon facing away from Earth, did we discover that this side of the Moon, never before seen by men, was strikingly different from the side of the Moon which always faces Earth. The large, dark-colored, circular basins which dominate the near side of the Moon are very rare on the far side of the Moon, which appears much rougher and generally lighter than the lunar near side.

The unmanned Orbiter satellites, which photographed potential landing sites for Apollo missions, exhibited unexpected orbital variations when flying around the Moon. Scientists attributed these changes in orbit to dense pockets of material on the Moon and to irregularities in the Moon's shape which exerted differing gravitational pull on the spacecraft, causing it to speed up and slow down at various places over the lunar surface. Subsequent studies have shown these curious gravitational variations are related to the large circular mare basins which predominate on the front side of the Moon.

Discovery of these large collections of dense materials, called mass concentrations or "mascons," raised many new questions and posed some difficult problems for scientists attempting to explain the formation of the Moon and the nature of its interior. Did the Moon have a crust like the Earth's? they wanted to know. And, it so, how thick would such a crust have to be and how could it be formed to support the mascons?

NEW ANSWERS

This was only one of many unanswered questions about the Moon at the time Neil Armstrong and Edwin Aldrin landed their spacecraft "Eagle" in the Sea of Tranquility in July 1969.

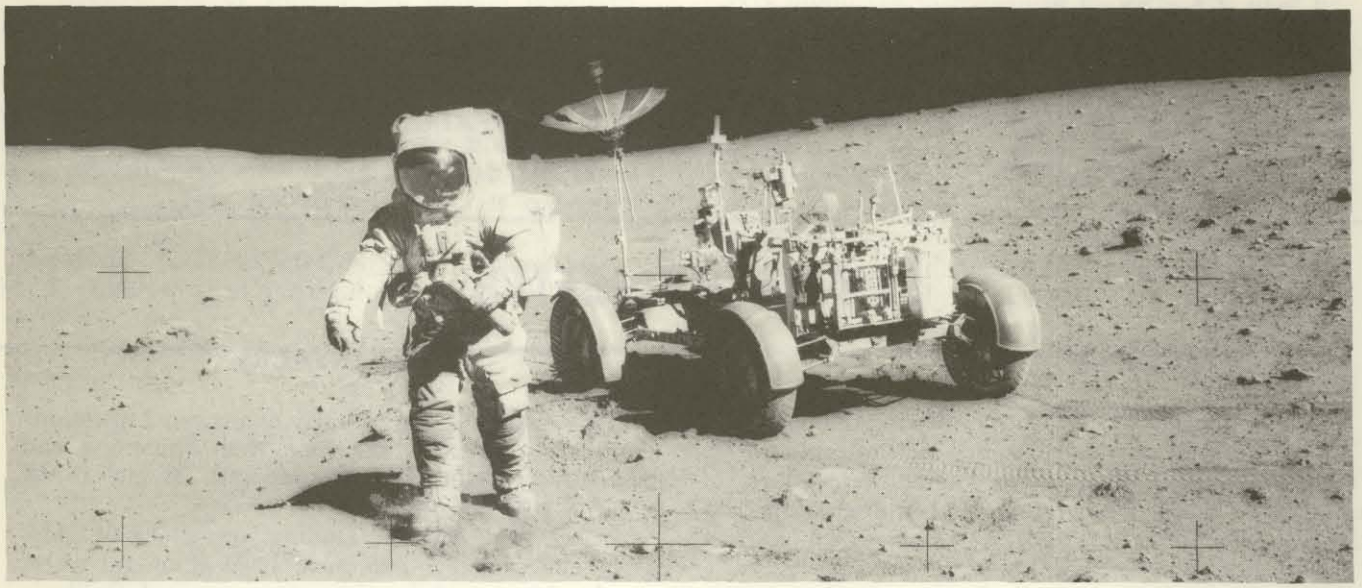
Before the Apollo 11 landing, one group of scientists believed there had once been abundant water on the Moon. Like the astronomers of Galileo's time who named the dark areas on the front side of the Moon mare (the Latin word for sea), this group believed that the flat lunar maria represented the accumulation of sediments brought into the mare basins by running water and that these basins were once seas or lakes. This same group thought that sinuous rilles that appear as canyons on the lunar surface represented stream channels along which water had flowed.

Another group suggested that the mare areas of the Moon were filled by volcanic processes and consisted largely of lava flows.

There was also much speculation before the Apollo 11 landing whether volcanic processes or meteorite impacts were the major process forming its cratered surface.

Not only were the origins of the maria and of lunar craters in debate, but also the age of different areas on the surface. Some scientists believed the

The scientific equipment set up on the Moon, and the rocks and soil brought back from it, will help man learn more about Earth — what it has been, what it is, and what it might become.



Surface transportation, such as the electric lunar rover, extends the capability for scientific investigation of the Moon. The Apollo 15 crew covered about 17 miles in 3 days and came home with about 170 pounds of samples.

Moon was a primitive body which had changed little since it formed some 4.6 billion years ago. Others believed the Moon had a more active earth-like history and speculated that features such as the maria were formed relatively recently – a few hundred million years ago rather than several billion years ago.

And, of course, fundamental to all these debates and still not answered is the question, how and where did the Moon form?

LUNAR SCIENCE

From samples of the Moon returned by Apollo astronauts, from instruments they set up on the lunar surface, and from experiments they conducted in lunar orbit, scientists are assembling the framework of new theories which can answer these questions about the Moon and which eventually will tell us much about our own planet.

Looking at the Moon from Earth on a clear night, one sees a large, dark-colored circular area which dominates the upper left quadrant of the lunar disc. This feature, known to scientists as Mare Imbrium – the Sea of Rains – was formed early in the Moon's history when an asteroid-size body about 100 kilometers or 60 miles in diameter crashed into the Moon with an explosion that lifted material from deep beneath the lunar surface and scattered it over much of the lunar front side. Much later the crater left by the explosion was filled with lava, giving it its oceanlike appearance.

Mare Imbrium is a most important feature in understanding lunar history because its formulation affected such a large part of the lunar surface. By studying samples returned from the Moon, scientists have determined not only that the mare basin was formed by a collision with an asteroid and that the crater was filled with lava and not ocean sediments, but they have also determined that the collision occurred about 4 billion years ago or about half a billion years earlier than any known geologic event on Earth. The lunar material where the crater was formed is obviously even older and may, in part, date back to the formation of the Moon and the planets of our solar system.

Many other lunar features are covered by rays and blankets of material thrown out of the Imbrium basin and thus contain rocks that are also older than 4 billion years.

MOON CHRONOLOGY

By dating this one major feature, scientists are able to piece together relative and absolute ages for many other lunar features, and a chronology of major events on the Moon is gradually taking shape.

A network of scientific stations set up on the Moon by Apollo astronauts has detected quakes or movement about 700 kilometers (more than 400 miles) beneath the lunar surface – as deep or deeper than quakes which occur on Earth. The stresses which cause quakes can accumulate only in rigid structures. Thus, scientists believe the Moon has a crust and rigid mantle as thick or thicker than Earth's. Furthermore, the size and pattern of certain small lunar quakes suggest they are caused by stresses associated with planetary interiors where there are significant temperature differences rather than with a cold, dead planet.

Despite these apparent similarities of the Moon and Earth, Apollo lunar orbital experiments, coupled with laboratory studies of samples, suggest that the Moon may not have formed from the same chemical building blocks as Earth or the rest of the solar system.

Other studies of lunar minerals show that there was little or no water present when the rocks crystallized and that Moon rocks have not been exposed to water since the time of their formation.

The apparent total absence of water, the very low carbon content of lunar materials, and the absence of organic compounds are convincing evidence that life never began to evolve on the moon.

MORE QUESTIONS

Though our knowledge of the Moon, and consequently our knowledge of planets in general, has increased immensely as a result of Apollo exploration, many important questions about the Moon have yet to be answered.

Why are most of the lunar mare on the side facing Earth? What was the source of the heat which appears to have melted much of the lunar surface? And when did the surface cool to form the crust which is still evident in the lunar highlands or mountain areas? What is the internal composition and structure of the Moon? And is there water vapor — a common gas in the interior of planets — deep beneath the surface of the Moon?

The geologic record once contained in Earth's crust has been largely worn away by the effects of our planet's atmosphere, and we know little of Earth's surface history beyond about 3.5 billion years ago. The Moon, by comparison, has almost no atmosphere and its surface features erode very slowly. As a result, rocks barely an arm's length beneath the lunar surface remain relatively unchanged for 100 million years; while on Earth in this same period of time, water, ice, and wind will wear down an entire mountain range and begin to deposit it as sediment at the bottom of the sea.

The Moon, perhaps more than any other body in the solar system, can be a Rosetta stone for interpreting the early history of our Sun and its planets. Scientists can read in the Moon's rocks and soil, records etched by high-speed particles emitted by the Sun when it was still a young star. They can view this record as it changed over the eons, showing how the Sun developed and released its life-giving energy. Our growing knowledge of the Moon's surface and its early formation will allow us to infer things about the structure and history of our own planet's crust, from which we draw nearly all the resources that support human life and progress.

SCIENCE BONANZA

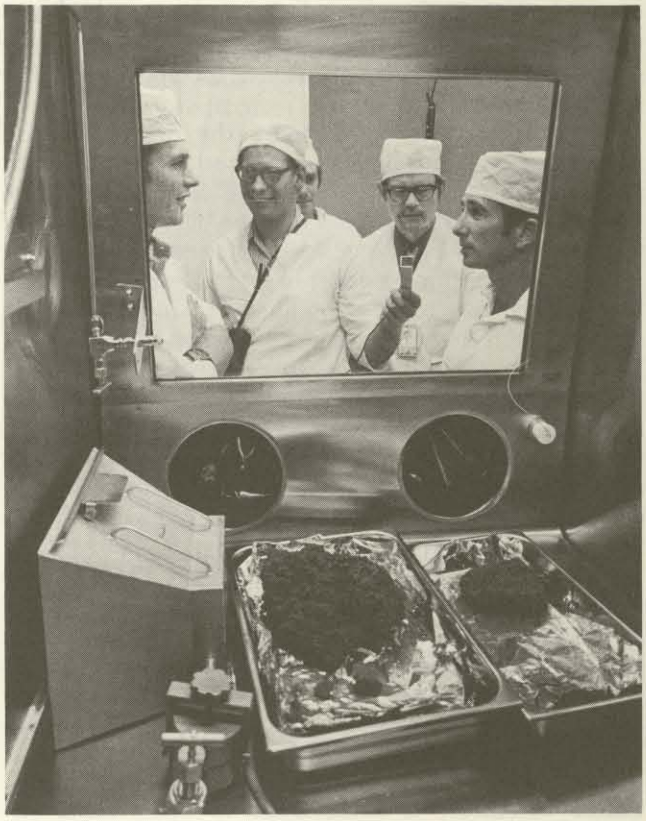
Of the six lunar landing missions which make up the Apollo program, the final three flights offer by far the greatest potential for scientific return. The first of these second generation Apollo missions, Apollo 15, showed that with a lunar car to give them mobility, with improved spacecraft and life support systems to double their time on the lunar surface, and with the base of knowledge provided by previous missions, astronauts could achieve scientific results on a single mission equivalent to three previous missions combined. The remaining Apollo missions are thus the most important of the program and the most likely to provide answers to some of our remaining questions about the Moon, the Earth, and the solar system.

Our knowledge of Earth has advanced steadily over the past three or four hundred years, whereas our knowledge of the Moon and of the early history of the solar system has moved forward with two great bursts of learning associated with the development of the telescope in the early 1600's and with the development of space technology in our own time. Though the final achievements of Apollo lunar exploration remain to be seen, we can be sure from the scientific results already obtained that future generations will remember our generation as the one that first understood the early history of the solar system.

PRACTICAL BENEFITS

While it is not always clear at first just what the full results and practical benefits of new knowledge and exploration will be, history can provide some interesting clues.

Early experiments with electricity, nuclear energy, automobiles, airplanes, and rockets were generally considered novel and interesting but of little practical



The lunar samples — rocks and soil from on and under the Moon's surface — hold clues to the formation of our solar system. Scientists the world over are taking part in the effort to find those clues.

Space technology is being applied to Earth needs, such as finding and keeping track of pollution sources. The area pictured is a part of the Houston Ship Channel, but airplanes and satellites can monitor any area in the world.

value at the time they were performed. Daniel Webster complained that the great American West encompassed in the Louisiana Purchase was a howling wilderness Americans could never occupy. The purchase of Alaska from Russia at a cost of $7 million was derided at the time as "Seward's Folly." And the electric motor, which has revolutionized our society, found little practical use for 100 years after it was invented.

It is interesting to compare the delayed payoff from these previous investments and enterprises with the almost immediate returns we have gotten from the space program and with the clear promise of future benefits which space activities offer.

Communications satellites have already more than repaid the cost of developing and launching them and, in fact, have become commercially profitable. This new benefit from the space program is obvious to TV viewers. The Olympics were first televised internationally in 1968 from Tokyo and were viewed instantaneously by U.S. audiences. The largest audience in world history — over half a billion people, one-sixth of the world's population — saw man's first steps on the Moon.

In 1960, you could not send live TV across the Atlantic; by 1965, it was possible but expensive; by 1969, as a result of the space program, the quality had been improved and the cost reduced to one-fifth of the 1965 rate.

At present, communications satellites are used largely for transoceanic traffic, providing economical links across the Atlantic, Pacific, and Indian Oceans. Before satellites, a West Coast-to-Japan cable circuit cost $15,000 per month; today the Communications Satellite Corporation offers the same service at a charge of $4,000 per month.

It is becoming apparent that satellites will soon handle domestic communications as well as transoceanic traffic. In 1960, there were fewer than 75 million phones in America. We now have about 120 million. In 1960, Americans made about 18 billion calls; this year, we will make about 200 billion. We are rapidly reaching the point where cables will not be able to handle the entire communications load in this country.

LOWER COSTS

The recent decision by the Federal Communications Commision to entertain suggestions for a U.S. domestic satellite system opens a whole range of potential new services, including low-cost message, data, and television transmissions coast-to-coast — and anywhere in between. The feasibility of using satellites to supplement and, in some cases, to replace cables and micro-wave circuits for domestic communications has been well demonstrated; and the response from industry to the Federal Communications Commission invitation shows that satellites have great potential for national as well as international communications.

Weather satellites have yielded almost immediate practical returns from our investment in space research and now provide constant daily information to the U.S. Weather Bureau. Tiros III gave advance information on Hurricane Carla which resulted in the greatest mass evacuation ever to take place in the United States. Over 350,000 people moved from the path of the storm. **There is no way to determine how many lives were saved.**

The continual improvement in techniques of interpreting data from this type of satellite and the improvements in the satellite itself offer the possibility of accurate forecasting of weather over vast regions. An accurate 5-day forecast of weather conditions over the United States alone would provide an estimated annual savings of $6.75 billion when applied to agriculture, lumber business, surface transportation, retail marketing, and water resources management. This savings alone would be more than any single year's cost of the total nation space program.

GREATER SAVINGS

Weather satellites survey the ice fields of the Gulf of St. Lawrence with an estimated savings to the United States and Canada of $1.7 million each year by more accurately predicting the opening of shipping on the Great Lakes.

Space observation of weather patterns on a global scale offers the only hope of understanding weather movement, global temperature, and global wind patterns which is necessary for long-range forecasts.

The National Academy of Sciences-National Research Council has estimated that accurate long-range forecasts would lead to savings of at least $70 million annually from flood and storm damage; $1 billion a year to the construction industry, $500

million a year to fuel and electric power industries, $500 million a year to fruit and vegetable producers, and $450 million annually to livestock producers.

Although national pride, international goodwill, and a nation's prestige cannot be measured in dollars and cents, these are real and tangible benefits resulting from the space program.

The Associated Press recently reported that a survey of high school student leaders in the United States showed this country's landing on the Moon was one of things of which students were most proud.

In 1960, a worldwide poll showed the majority of the world believing that the dominant force in international affairs would be the Soviet Union. In 1970, after the Apollo 11 landing on the Moon, the same survey indicated the majority of the world's people believed that the United States was and would continue to be the most powerful and influential country in world affairs.

STABILIZING FORCE

Former NASA Administrator Thomas O. Paine described space as a major "stabilizing force in world affairs," which he said has given both America and the Soviet Union a unique opportunity to demonstrate before the entire world their national will, the strength of their institutions, the quality of their people, and the vision of their leaders.

In a hearing before U.S. Senate's Committe on Aeronautical and Space Sciences, the State Department's U. Alexis Johnson cited as examples of internation cooperation fostered by the space program the Treaty on Outer Space, which, among other things, states that no nation can claim sovereignty to outer space and forbids the stationing of nuclear weapons on celestial bodies or in space; and an Agreement on Rescue and Return of Astronauts.

More than 50 countries benefit from the automatic picture-taking systems on U.S. weather satellites, which allow them to view daily weather patterns over their own territory. Teams of scientists in 39 institutions, representing 14 foreign countries, have received samples of lunar rock and soil collected by U.S. astronauts. At the same time, the United States and the Soviet Union have exchanged lunar samples and have conducted a series of meetings aimed at developing compatible spacecraft docking equipment so that U.S. and Soviet spacecraft can link up in space in a future joint manned mission.

MORE ECONOMY

Much of the potential use of space as a new resouce to benefit man depends, of course, on the cost of transporting man and his machines into space In 1958, the first U.S. satellite, Explorer I, cost more than $100,000 a pound to place in orbit. When we use the largest present launch vehicles, the cost now is less than $1,000 a pound. But we can do much better than that.

The United States has developed more than 20 different launch vehicles for manned and unmanned space programs. Each has required development cost, special support equipment, separate production facilities, and specially trained ground personnel, all for one launch in which the vehicle – successful or not – is destroyed.

As a result of our experience with manned and unmanned programs, space technology has advanced to the point where it is possible to return entire space vehicles from orbit and use them again. NASA and industry teams have begun design and development work on a new generation launch vehicle and spacecraft called the Space Shuttle, which will not be discarded after a single flight but will be flown many times during its 10-year lifetime. This versatile vehicle, which combines the features of both airplanes and rockets, will be designed to carry men and supplies and unmanned spacecraft into orbit. It will be piloted like a commercial airliner and will land on conventional type runways, avoiding the cost or recovery at sea; and it should reduce space flight costs to about one-tenth their present level.

The reduction of operating costs is only part of the savings to be realized. The major part of total space program costs, about 80 percent, is reflected in the efforts required to develop and test payloads. The Space Shuttle, revolutionizing our whole approach to placing payloads in space, will provide such important economic dividends as:

1. Drastic reduction of payload development costs;
2. Less risk of failure in placing payloads in orbit; and
3. A capability for routine, economical operations in space.

High altitude and orbital photography of farmlands and watersheds is being applied to programs to preserve and improve the Earth's resources. This photo, taken on black and white film through a green filter, shows the mouth of the Colorado River as it looks from 140 miles overhead.

More accurate, longer-range weather tracking and forecasting is one of the benefits of the space program. Quicker detection of weather systems, such as Hurricane Gladys, can help save lives and property.

Ecomonies also are anticipated in the use of the Space Shuttle as a "test bed" for instrument development. Spacecraft found inoperable or erratic upon deployment could be returned to the launch site for further work before final placement into orbit. Thus, the operation of the Shuttle should virtually eliminate the risk of total failure in spacecraft operations.

INCREASED BENEFITS

As space flight becomes more economical and as it becomes easier for men and machines to operate in space, the potential uses and benefits of this new environment are almost unlimited. The immediate and substantial returns from communications and weather satellites demonstrate the value of space to man, and similar gains are waiting to be achieved in numerous other areas.

Potentially, the most useful of all the applications of space flight is to observe and measure the resources of Earth, to help manage them properly, and to deal with the problems of the environment. As with weather satellites and communications satellites, the value of space to Earth resources studies is the ability it gives man to view his planet from a perspective other than standing on its surface or looking down on it from only a few thousand feet in the air.

Every object on Earth, its subsurface strata, its asmosphere, and its oceans reflect distinctive electromagnetic characteristics which can be detected from a distance by specialized sensors. Vegetation has a different and recognizable reflective "signature" from water or bare earth. And a diseased crop will appear different from a healthy crop.

Coupling this knowledge with the synoptic view of earth which space provides will allow us to capitalize on our previous investments in space in a practical and immediate way.

As an example of how this new space tool can be used, it is possible to detect, measure, and map water pollution, detect and determine the size of oil slicks at sea, and monitor worldwide air pollution. Off the coast of Iceland, airborne infrared sensors located the Gulf Stream, which meanders a considerable distance. This could enable fishermen to continue hauling in good catches.

POLLUTION CONTROL

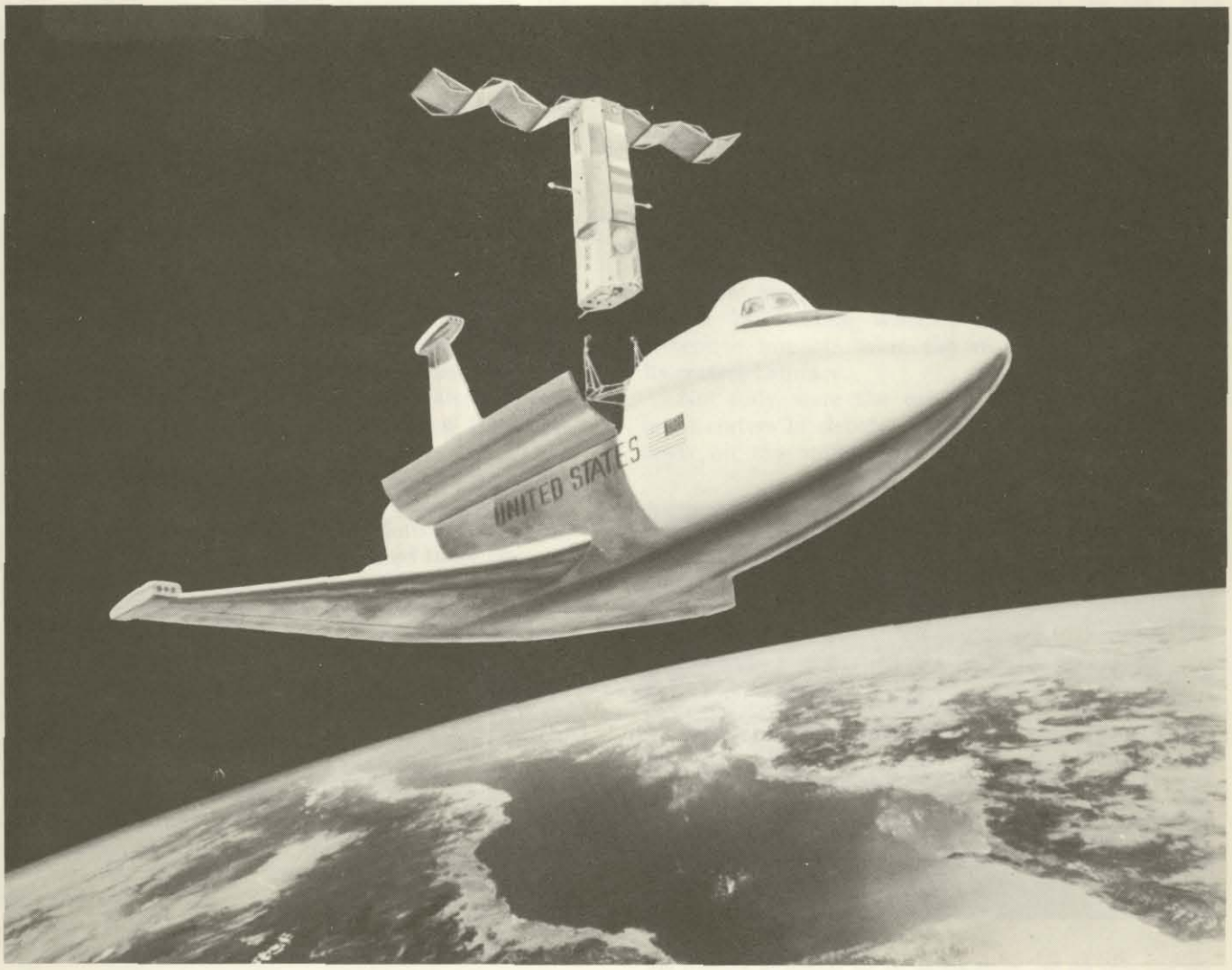
It is significant that a sudden worldwide interest in controlling pollution and protecting Earth's environment has appeared just as we are developing the means to assess and monitor earth's ecology on a global scale. For ecologists agree that only by dealing with the problem on a worldwide basis will we be able to save our oceans and atmosphere from being destroyed by pollution.

Infrared scanners, for example, can detect thermal pollution in water — both day and night. Conventional photographs from space can show discoloration and patterns in bodies of water for tracking and controlling pollutants. Other sensors can monitor the atmosphere to get the information on large regional distributions and cross-country movements of polluted air to help determine the sources of pollution and its extent.

By providing improved cropland surveys, space sensing could aid both the farmer and the ecology. Crop diseases and insect infestations often begin in a localized area, perhaps within a single field and then spread to the rest of the crop. It is common practice today for farmers to protect crops through large-scale preventive application of pesticides, which all too often are washed off the fields by rainfall and into streams, lakes, and oceans where they endanger wildlife and eventually work back in the food chain to man himself. But, if crop disease could be detected early, before it had spread to an entire field or crop, the farmer could apply only that pesticide needed to control the specific disease or infestation and only at the location where it was required. And both the farmer and the ecology would benefit.

UNLIMITED POTENTIAL

Seldom has a national investment yielded quicker or more substantial returns, offered clearer potential



The Space Shuttle is designed to make working in space easier and more economical. The spacecraft will fly many times, not just once, and can be used for many purposes — launching or retrieving unmanned satellites, for instance.

benefits for the future, or stimulated more effective and creative use of human and natural resources than has the space program.

The dividends from our investment in space have continued even as we made major reductions in the money and manpower committed to space research and exploration, prompting a European finance minister to estimate that each dollar the U.S. invested in space research over the past 10 years is returning $4 today.

Speaking to the United Nations Conference on the Exploration and Peaceful Use of Outer Space in Vienna recently, an Italian delegate noted that, "very often, the expenditures borne by the most advanced countries for space activity are criticized as luxury in the face of the pressing needs of large sectors of mankind. But satellite educational transmissions would almost magically close a circuit through which money spent for the most sophisticated technology returns manifold benefits to a large number of less privileged peoples." And he said, "There can be no more dramatic confirmation of the sometimes obscured truth that technological progress assures the progress of all humankind."

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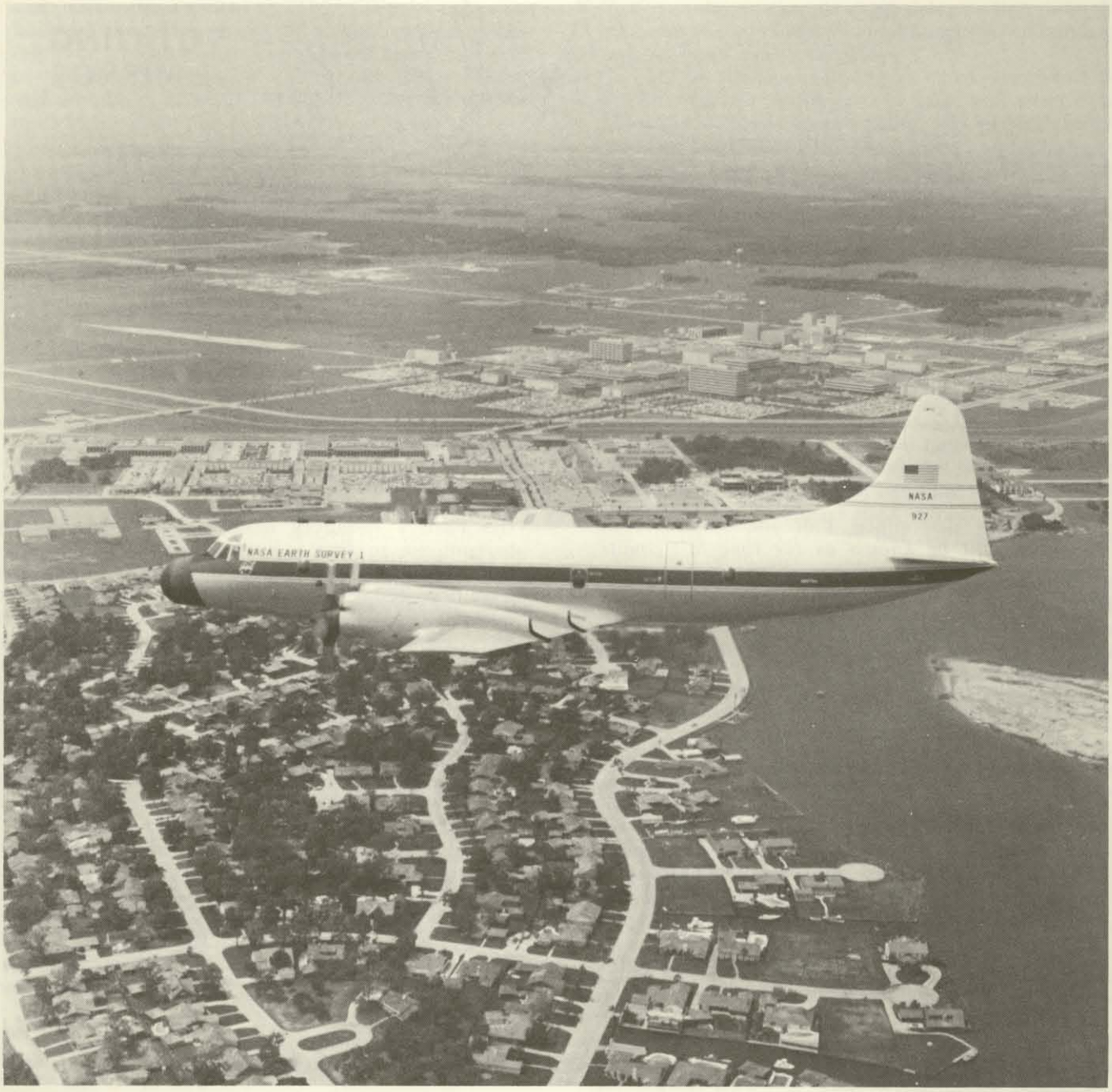
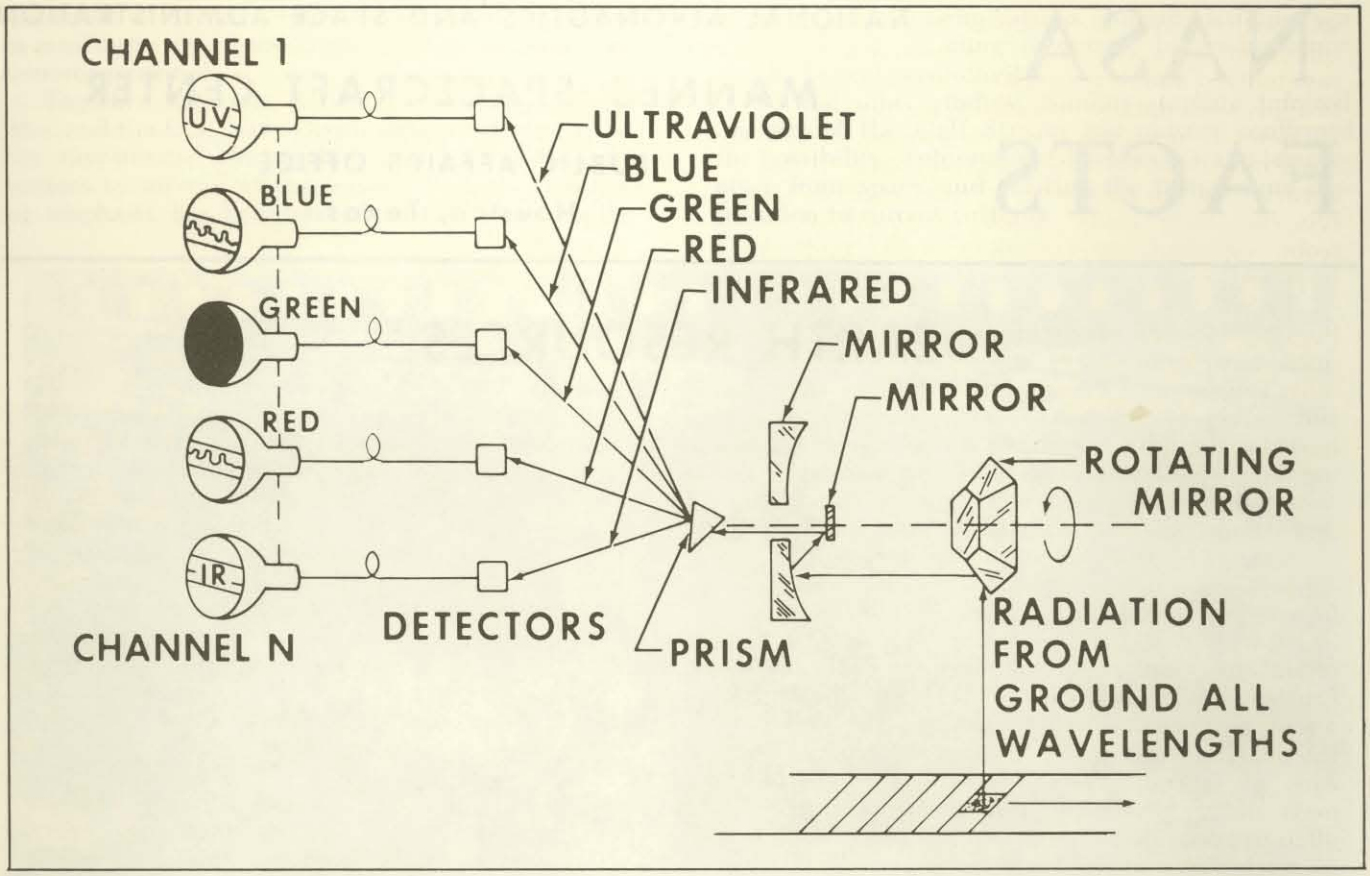
NASA FACTS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
PUBLIC AFFAIRS OFFICE
Houston, Texas

EARTH RESOURCES



Specially equipped aircraft play a big role in NASA's Earth Resources Survey Program, bringing back photographs and data to augment that provided from ground and space missions. The Manned Spacecraft Center is in the background.



A multispectral television camera system aboard the Earth Resources Technology Satellite will record the planet's color "signature," from which ground-based technicians can identify and analyze the world's vast collection of forests, crops, bodies of water, and geological and mineralogical points of interest.

"We are determined that the decade of the seventies will be known as the time this country regained a productive harmony between man and nature."

President Richard M. Nixon, January 1, 1970.

Sophocles found the Earth "rugged" and "all nourishing." Centuries later Shakespeare called it a "goodly frame."

But now many persons fear, like the Director of the Harvard Center for Population Studies, that the "21st century may witness a world of half-starved, depressed human masses, gasping for air, short of sweet water, struggling to avoid one another, living at a degraded subsistence level . . . ."

Space flight has shown not only how beautiful and small the Earth is but also how similar it is to a spaceship. Both are closed ecological systems in which diligent housekeeping is necessary. Can the "cloud-streaked blue spaceship" that we have found ourselves in be kept habitable for more ages, for more people?

Space technology promises help in gathering information about Earth resources that man will need to live decently on this planet.

The population and the per capita demands on the Earth's resources have risen and seem likely to continue to soar. By the year 2000, it is estimated that the world's population will be over 6 billion; today it stands at about 3 billion. So one challenge that faces mankind within the next 30 years is to double the entire food production capability that has been achieved since time began.

Space programs such as Nimbus, Gemini, and Apollo show that certain phenomena related to Earth can be better understood when viewed from a great distance. For the first time, man has the ability of surveying (remote sensing) large sections of the Earth and its environment within a very limited time frame.

Earth resources are defined here as those naturally occurring materials, such as mineral deposits, timberlands, crops and fresh water, and cultural resources which are of value to mankind. Comprehensive study of the Earth's surface from the ground, the air, and space is a complex problem which requires application of many different disciplines and technologies.

NASA's role in the Earth Observation Program is the research and development required to build, launch, and evaluate the operational prototype of the spacecraft for conducting resource and environmental inventories. NASA works directly with other agencies at the Federal, State, Regional, and local levels

and with individual scientists to determine the requirement for such surveys, to develop measurement capabilities and the complete information systems to apply such data to operational problems.

Research programs involving ground, aircraft, and space measurements have been conducted with various agencies for the past several years. Significant progress has been made in the advancement of the technology and understanding of the problems to be solved.

NASA has conducted, since 1966, an Earth Resources Survey Program – a program in which instrumented aircraft fly multidiscipline missions for other Government Agencies, as well as for individual and university scientists. This program forms the basis for the advancement of technology and gathering data which will be used aboard spacecraft and/or satellite platforms. Photography from Gemini and Apollo missions has made important contributions to the Earth Resources Survey Program.

The next major advance will come when Earth Resources Technology Satellites (ERTS) are launched in 1972 and 1973. This satellite observes the Earth repeatedly, covering every point, each 18 days. Further, ERTS satellites will observe Earth in different portions of the spectrum – the visible and the near infrared. By looking at the same object in each of several "color bands," it is possible to make direct identifications of surface materials and often to assess their condition.

Such observations as these are necessary to understand large-scale problems in hydrology, geology, and geography; to conduct agricultural surveys, inventories of forest lands, and wide-scale monitoring of the vigor of plant growth; to study coastal zone dynamics and provide a basis for the effective management of these resources.

ERTS concepts were tested in the Apollo 9 mission of March 1969. One experiment, SO 65, used four cameras that took simultaneous pictures in the green, red, and near infrared bands of the spectrum. The fourth camera used color infrared film to simulate a combination of the three separate color bands.

Evaluation of the SO 65 data forms part of the basis for the selection for the ERTS bands. ERTS will use a system of three television cameras and a four-channel multispectral point scanner to acquire the resource data. This information will be sent to ground stations by radio link and will make it possible to obtain repetitive coverage over long periods of time.

Another system to collect data on Earth resources is the scientific package for Skylab, a long duration manned orbital mission. Skylab's Earth Resources Experiment Package (EREP) will provide quantitative analysis of resources by investigating the visible, infrared, and microwave spectral regions multiple-sensing techniques.

Examples of how these data can be used in various resources disciplines follow.

Agriculture

It is especially helpful to observe croplands sequentially from spacecraft or satellite because of the dramatic changes that occur in them. The managers of cultivated vegetational resources need to know such things about the foods and fibers growing in the world's major agricultural basins as: (1) the type of crop in each field, (2) the size of the field, (3) the vigor of the crop, (4) the identity of any damaging agents, and (5) the probable yield per unit of the area.

Both agriculturists and wildland managers also find it helpful to know for each area such terrain characteristics as the slope, aspect and soil depth, texture, chemical composition, moisture content, and susceptibility to erosion. Conservation requires also that men know the state of deterioration brought about by overgrazing, overcropping, repeated burning, erosion, or mineral depletion.

Remote sensing, through manned spacecraft or satellite, together with ground data, will make contributions towards meeting the current and future needs for crop information. Such spacecraft equipped with multiband sensors, offer the potential of providing macroscopic surveys of the earth on a synoptic basis and entailed observations of selected areas.

Cartography

At present, vast areas of the world are without meaningful map coverage and certain remote areas, such as Antarctica, are largely unsurveyed. Plainly, a program to hasten the acquisition of knowledge of the land surface, indeed of the entire Earth, should be a high priority undertaking. Primitive people began to draw maps of their parts of the Earth before they learned to write, and often excelled as cartographers. Aerial photography and electronic surveying have increased the accuracy of many maps and charts in this century but have not sufficed to keep them up to date.

The value of using orbital-height photographs in cartographic programs has already been demonstrated. The Gemini VII flight was particularly successful in obtaining good photographs from a height of 165 miles above Cape Kennedy area. The photographs contain a startling clarity of imagery, and the density and planimetric detail compares favorably with what is shown on the quarter-million-scale map of the area. Many major cultural changes can be identified, indicating that orbital-height photographs can be used for some types of map revisions.

Forestry

Like mountains and seas, the Earth's billions of acres of woodland are a storehouse of raw materials – so big that its size affects the weather. Birds, beasts, and men have long depended on forests for shelter, and wood product industries are a major segment of the American economy.

The most pressing need in forestry is a worldwide inventory to round our knowledge concerning (1) forest location and distribution (mapping), (2) tree size, (3) tree quantity, (4) tree growth rate, and (5) site quality. To meet this need, remote sensing methods, in conjunction with other infor-

mation, have begun to be employed in the U.S. and in other parts of the world.

Color infrared aircraft photography has shown promise in locating insect- or disease-damaged trees before such damage is visible to the eye. This is possible because the infrared rays penetrate the leaves, and the internal cells of the leaves on the unhealthy trees cease to reflect such waves sooner than the surface cells stop reflecting the wavelengths utilized by the eye.

Thermal infrared imagery has also been shown to be useful in the detection of forest fires. In some parts of the world, fires seem to have affected the vegetation as much as the climate and soil.

Geography

Geography once meant literally "to write about the Earth." Geographers complain now that scientists in related disciplines have left them very little to write about. We still rely upon the geographer, however, to bring each scientist's findings about the Earth into proper regional and global perspective.

Fundamentally, geography deals with the location, arrangement, and association of such factors as environmental conditions, Earth features, resources, population, and the human interaction with these factors. The availability of imagery and other forms of data from sensors in aircraft, manned spacecraft, and unmanned satellites greatly expands the horizons and techniques for geographical research and the portrayal of thematic maps.

When the objective, as in geographic studies, is to determine changes in the human use of the Earth in large areas, data acquired from space is useful in conjunction with conventional aircraft and ground survey data.

Hydrology

Hydrologists emphasize that water has become the most limiting and valuable resource in some parts of the world. Rapidly receding water tables suggest that in many areas inadequate fresh-water suppliers may soon limit food production and even human occupancy.

Remote sensing data with other data can significantly advance the investigation of many hydrological engineering problems. For example, infrared instruments that record thermal radiation from land and water surfaces were flown in an aircraft over the coastline of Jamaica, where underground springs discharge fresh ground water into the ocean.

The light and dark contrasts of the images showed the cool fresh water as it entered the ocean and mixed with warm salt water. Fresh water is a precious commodity in Jamaica and, by pinpointing the areas of these springs, the water prospector's drilling can be restricted to the areas most likely to produce fresh water.

Intrusion of salt water into fresh water streams is another example which can be examined by Earth observation. For many purposes, such as the protection of municipal water supplies, we must know the shape, size, and position of the salt-water intrusion.

The conventional method of plotting salt-water intrusion of this type is manual sampling and plotting, which is slow and tedious. In contrast to the conventional method, the salt-water intrusion (wedge) in an estuary in Massachusetts was readily defined by infrared imagery obtained from an aircraft because the temperature of the ocean water differed from that of the river water.

Pollution Control

Water pollution and the concentration of chemical and biological constituents of water are commonly measured by sampling procedures or by continuously recording monitors. For a better definition of the effect of pollutants in a water body, we must know the distribution of those pollutants and the hydrodynamics of the water body.

Geology

Twentieth century geologists urgently need more knowledge on both a regional and global basis about the extent and location of mineral and petroleum deposits. Men have used more of these "nonrenewable" resources in the last three decades than in all of the previous years since the dawn of civilization, and proven reserves of several such resources are liable to be exhausted within the next 20 years.

Some estimates show that fuel and mineral consumption in the next 30 years will triple the consumption of all of recorded history. Geophysical prospecting can be greatly aided by survey information from satellite-borne sensors which can permit the geoscientist to observe the whole, then focus on specific targets of interest.

For example, an entire mountain range may be seen to include a series of folded rocks, and in the series of folds may be seen an anticline or dome that is a potential oil producer.

One promising geologic tool for developing synoptic terrain maps is the side-looking radar which is able to provide sharp definition of valleys, slopes, ridges, and other topographic features.

One of the major efforts today is the search for heavy metals that are in short supply, and some of the work NASA's Earth Resources has done has been concentrated in the mining districts of Nevada. Airborne sensors have detected geologic features associated with known deposits of importance, and these features can then be investigated in more detail on the ground. Radar images revealed a series of northeast-trending faults that had not been detected by earlier field mapping or aerial photographs of a Nevada mine.

Management and Conservation of Public Lands

We must also consider our public lands, national parks, forests, and the seas around us as priceless natural resources.

Beyond their value as a resource base for the future, these public lands even now yield a sub-

Photographs from high in the atmosphere or from space, like this orbital view of the Galveston Island-Houston area, already have improved the maps of the world.

stantial income to the nation from oil, gas, forest products, and recreation. Moreover, about 7 million head of livestock and 3 million big-game animals depend on the public lands for all or part of their year-long needs.

The proper maintenance and preservation of our national parks must be based upon a fund of knowledge about their physical and biological components and the influence, particularly the adverse ones, which affect them. The sound principles of ecological engineering require us to obtain timely and reliable information on the distribution, health, and vigor of vegetation within the parks, measurements of snow accumulation and glacier growth; retreat, and movement; and an analysis of natural hazards that may be present, such as potential earthquakes and volcanic eruptions.

The results of surveys already conducted by NASA, in conjunction with the U.S. Geological Survey, have been very encouraging and suggest as promising the use of satellite and manned spacecraft surveying techniques in conjunction with existing data-gathering systems in our national parks.

Oceanography

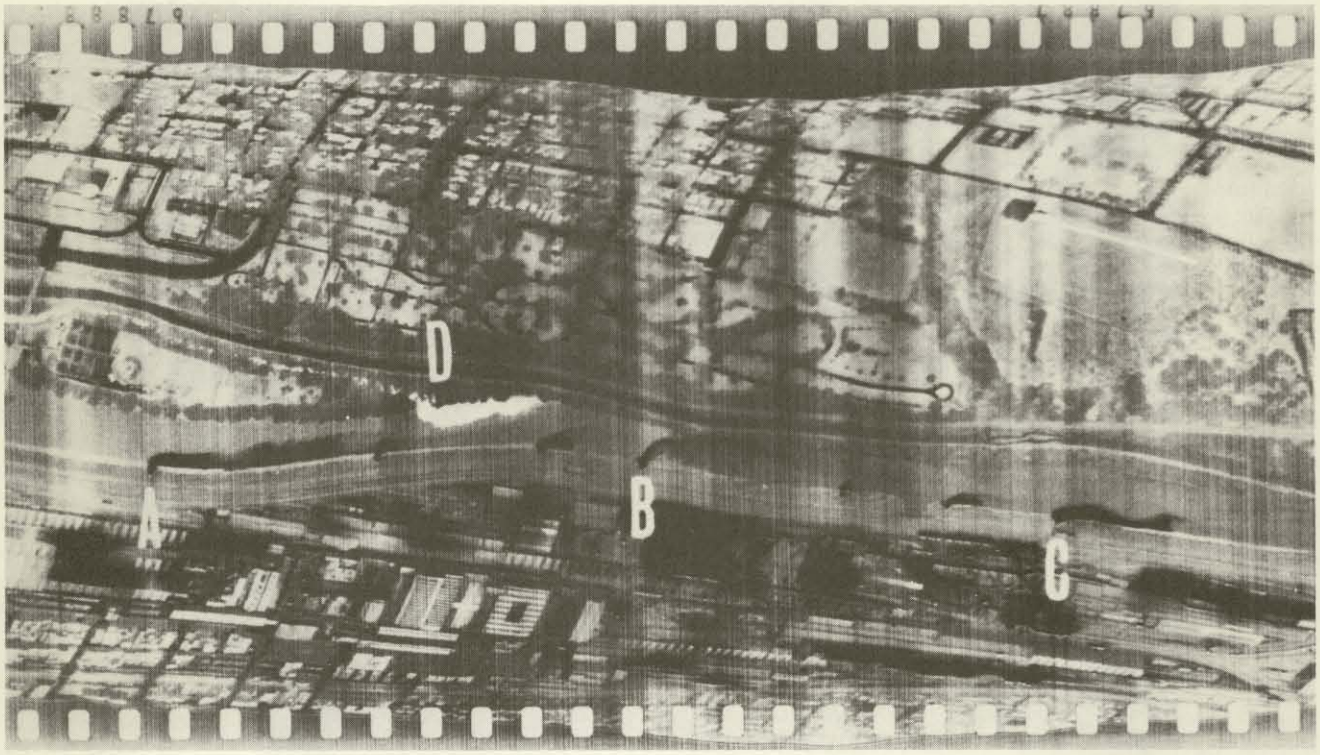
Oceanographers remind us that the greatest and least-tapped natural resource of the Earth is the ocean. It is important not only as a rich source of minerals and food but also because its effect on climate can govern the habitability of much of the land surface of the world, and because oceanographic features determine the safety with which men can travel on the surface of three-fourths of the globe. Better oceanographic inventories of many kinds are needed.

Approximately 70 percent of the earth's surface is covered with water, much of it not practically accessible for broad surveillance by conventional methods. Remote sensing, especially that in manned

spacecraft or satellites, offers significant opportunities in man's quest for knowledge of the oceans and their resource potential.

Together with the Bureau of Commercial Fisheries and the U.S. Navy Oceanographic Office, NASA has investigated the application of remote-sensing systems to surveys of our ocean resources. Particular emphasis has been placed on the determination of ocean surface temperatures, current patterns, sea state, sea ice, shoaling processes, bioluminescence and biological productivity.

In the other studies, Nimbus satellite infrared imagery of the Gulf Stream has already confirmed the possibility of observing differences in water temperature from space and relating the temperature distribution to current patterns.



Infrared imagery techniques record temperature variations, such as between the liquid wastes being discharged along the banks, and the water of the river. Such aerial observation enables the identification of pollution sources as well as the study of how the discharges affect the river.

President Richard M. Nixon in a message to Congress, February 11, 1970, stated

"Like those in the last century who tilled a plot of land to exhaustion and then on to another, we in this century have too casually and too long abused our natural environment. The time has come when we can wait no longer to repair the damage already done and to establish a new criteria to guide us in the future.

"While adopting laws prohibiting injury to persons or property, we have freely allowed injury to our surroundings. Conditioned by an expanding frontier, we came only lately to a recognition of how precious and how vulnerable our resources of land, water, and air really are."

NASA — MSC — Coml., Houston, Texas

MSC-04264

NASA FACTS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MANNED SPACECRAFT CENTER

PUBLIC AFFAIRS OFFICE

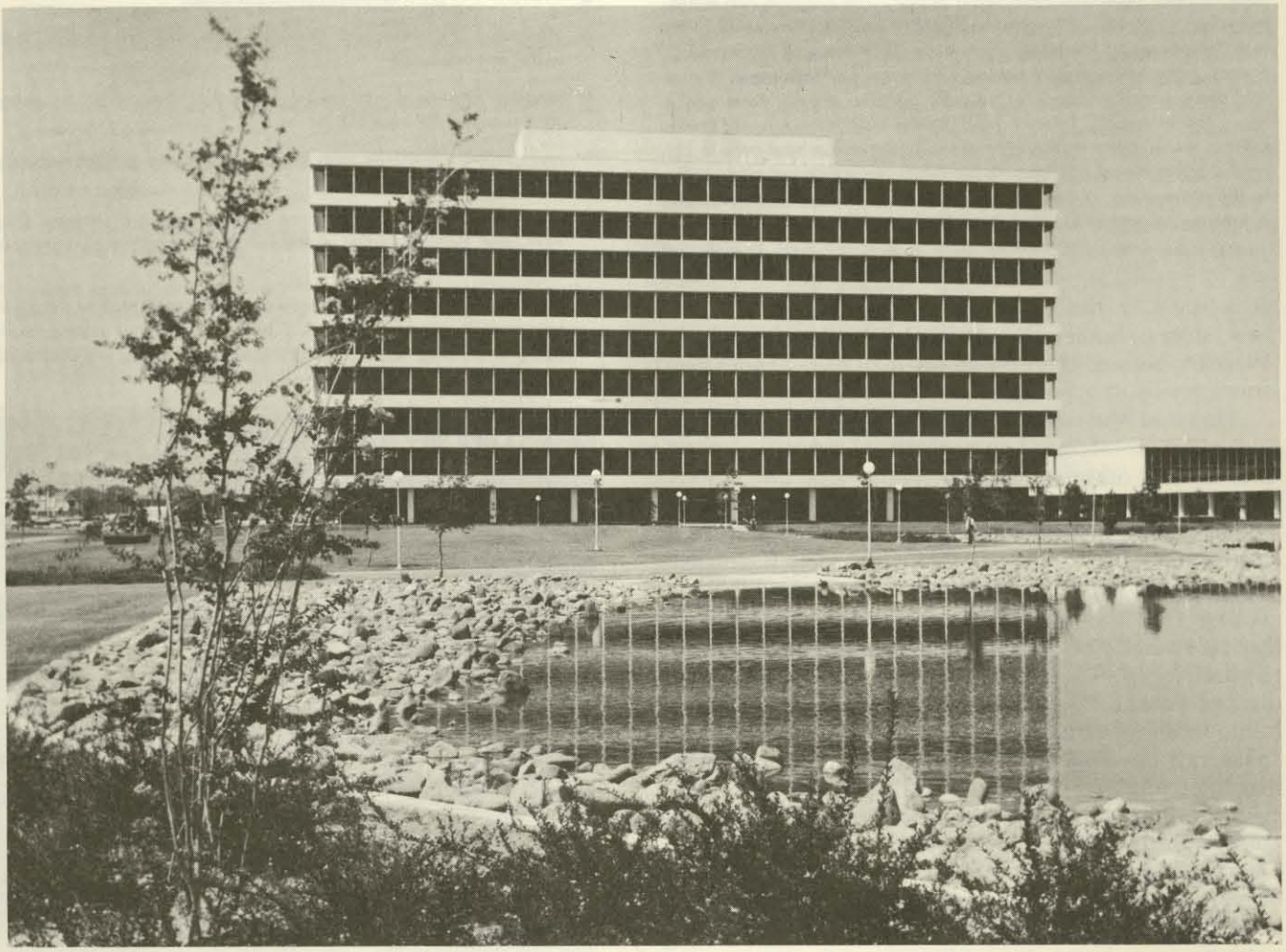
Houston, Texas

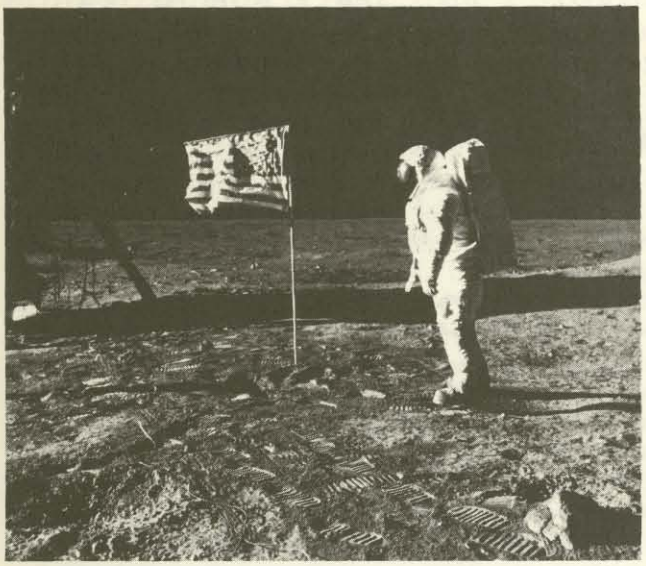
MANNED SPACECRAFT CENTER

The NASA Manned Spacecraft Center (MSC) opened for business at its 1620-acre site 25 miles southeast of downtown Houston in September 1963. The Center's responsibilities include: design, development, and testing of the spacecraft and associated systems for manned flight; selection and training the astronauts; planning and conducting the manned missions; and extensive participation in the medical, engineering, and scientific experiments that are helping man understand and improve his environment.

Although a manned space flight starts at a launch pad a thousand miles away from MSC and ends on the deck of a ship even more distant, the MSC Mission Control Center is the astronauts' link with Earth from lift-off to splashdown. The space crew's return to MSC completes a cycle begun months earlier. Mission planning and preparation involves several thousand MSC personnel, elements of NASA headquarters and other centers, and employees of American industry throughout the nation.

The MSC employs some 4,000 engineers, technicians, scientists, secretaries, mathematicians, managers, clerks, photographers, writers, instructors, administrators, and . . . astronauts. Another 7,000 contractor personnel work at or near the Center to help test spacecraft systems, work out computer programs, or just keep the Center running smoothly. The total combined payroll adds more than $150 million a year to the Houston area economy. Much of





The July 20, 1969, Moon landing and the safe return to Earth of the Apollo 11 crew signified the successful accomplishment of a goal set 8 years earlier. But the initial lunar landing, and those that followed, are just the obvious fruits of a nationwide mobilization without precedent. Historically, the most rapid technological advances are forced by war; peacetime benefits from the new technologies generally develop more slowly and, at times, unpredictably. When President Kennedy called for a national effort to land an American on the Moon before the end of the '60s, he mobilized the country's talent and purpose as they never had been, short of war. The program cost Americans less than $20 billion up to that first landing; they spent more than four times as much on liquor, better than twice as much on cigarettes, more on parimutual betting, and more on foreign travel during the same period. Tangible "spinoff" benefits already form a long list. The intangible interest from Apollo dollars is America's self-esteem, its prestige in the eyes of the world, and a new path to improved international relations. But probably the greatest of all benefits is the stimulation of basic research and technological development already being applied to help solve problems on Earth.

it is spent in the Clear Lake business community — new stores, homes, hotels, and schools where, only 10 years before, there were open pastures and a few small towns.

Houston was chosen as site of the MSC after an investigation of many prospective locations around the United States. The selection was announced in September 1961. Personnel began moving to offices in Houston from Langley Field, Virginia during October 1961. MSC construction started in April 1962.

The facilities were designed and built to house the wide variety of technical and scientific disciplines required for MSC's mission. MSC was organizationally divided into several directorates, where each directorate was responsible for a specific function — spacecraft development, astronaut training, or space flight planning, for example. The system is flexible, and the directorates are frequently realigned to keep pace with the changing directions and dimensions of manned space flight. Some of the original MSC directorates have reorganized, merged, or split into separate groups; new directorates are created as needed.

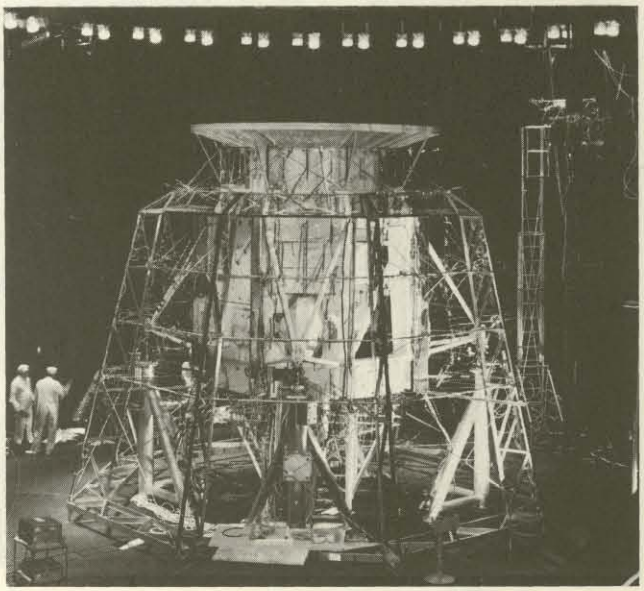
The MSC program offices direct or coordinate the efforts required locally, elsewhere within NASA, or by the industrial contractors to fulfill the MSC's specific program responsibilities. The Skylab Program Office, for instance, deals with such MSC Skylab tasks as development of a modified Apollo command/service module spacecraft and of crew-support items, mission planning and evaluation, and selection and training of flight crews.

Directorates and program offices are responsible to the Center Director who, in turn, is responsible to the Office of Manned Space Flight at NASA Headquarters in Washington, D.C.

The Center is situated near Clear Lake on a 1620-acre site, much of it donated to NASA by Rice University. It is made up of about 100 different buildings of sizes and uses that range from

The broad field of developing and analyzing spacecraft systems, the materials and techniques that go into them, and the equipment and methods of testing them — tasks of the Engineering and Development Directorate at MSC — accounts for many of the new and improved products that make everyday living easier, better, or safer:

- **cookware that goes from freezer to oven without cracking and which can be cleaned easily;**
- **pressure-sensitive fasteners and closures;**
- **fire-retarding paint and flameproof materials;**
- **electronics for radio and television sets that are smaller, work better and last longer;**
- **tungsten fiber-reinforced nickel superalloy four times as strong as previous nickel-base alloys;**
- **more reliable batteries with longer lifetime and greater rechargeability;**
- **new thermosetting polyurethane plastics that are stronger than ever, and better molding processes that strengthen conventional plastics; and**
- **a shock absorber capable of softening a 60 mph shock to the equivalent of 5 miles an hour, and better methods of sealing, packaging, inspecting, testing, designing, measuring, and manufacturing items equally at home in space or on Earth.**



the nine story Project Management Building to the tiny traffic-control booths at each entrance. While many of the Center's structures are devoted to office space, others are uniquely designed to accomplish special tasks. Some are open to the public for self-guided walking tours, and others can be seen on specially arranged guided tours.

The building probably most familiar to the public is Building 30 Mission Control. TV networks around the world show the activity in Mission Control several times during each manned flight — the flight controllers at rows of consoles, studying the data that helps them make mission decisions.

But Building 30 contains much more than just the Mission Operations Control Room (MOCR). It actually contains two identical MOCRs, one on the second floor and one on the third, which can be used simultaneously to control two missions or to practice procedures for a future flight while the current flight goes on.

The Medical Research and Operations Directorate at the Manned Spacecraft Center is responsible not only for helping man to stay alive, healthy and active in space, but also to help find how the knowledge from space flight can help man on Earth. Many hospitals and specialized medical facilities already use space-age products:

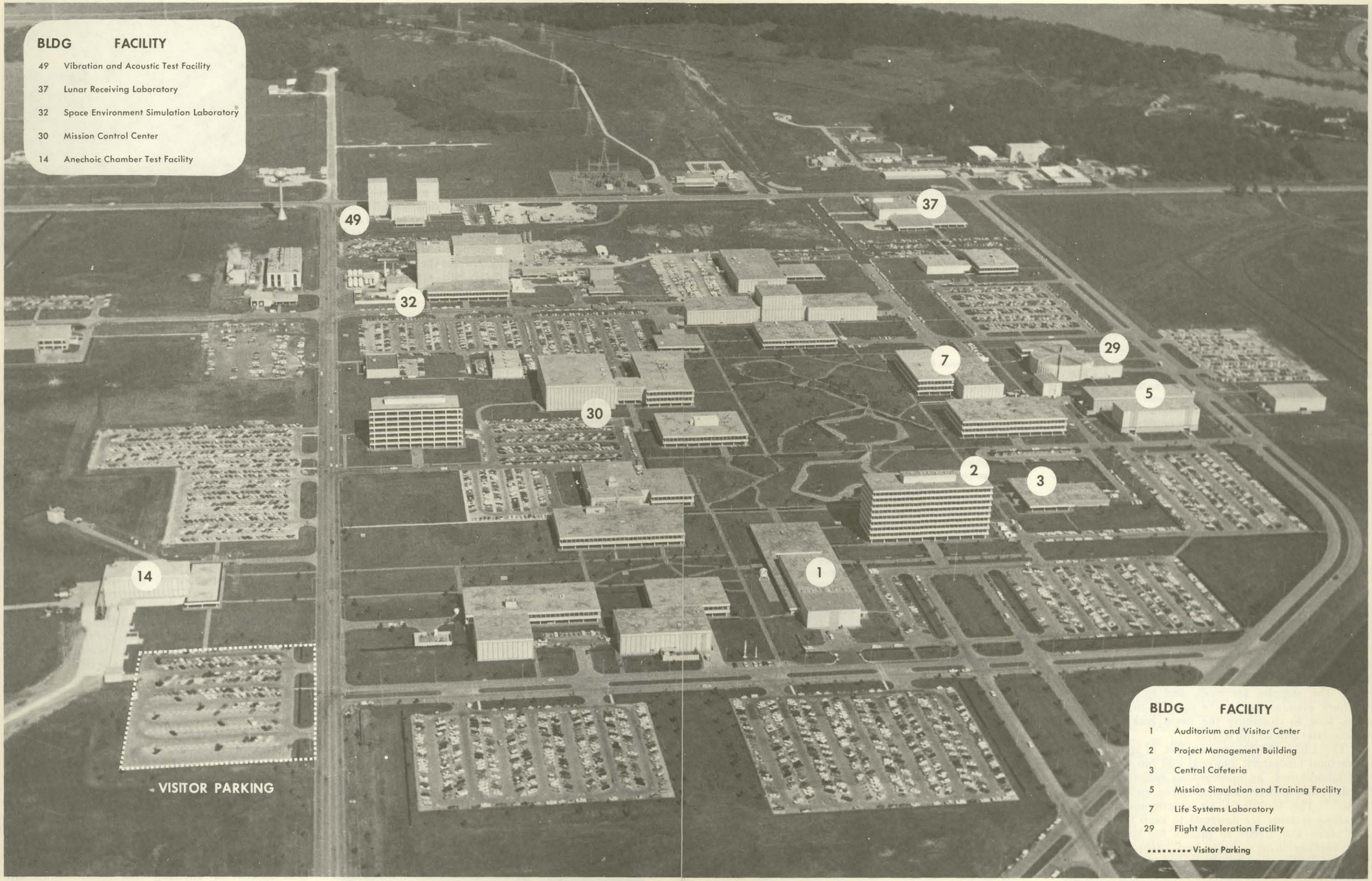
- **blood pressure or heart monitoring sensors so small they can be inserted by a hypodermic needle rather than surgery;**
- **contamination control procedures to keep operating and recovery rooms infection-free;**
- **remote monitoring equipment that lets one nurse keep a continual check on 64 patients at once;**
- **equipment to send an electrocardiograph by radio or telephone from the accident or illness site;**
- **a motorized wheelchair that is controlled by only the eye movements of a paralysis victim;**
- **a lunar gravity simulator used to train Apollo crews, modified to help rehabilitate handicapped or bedridden patients;**
- **transducers used to measure spacecraft splashdown impact incorporated into a device for precision fitting of artificial limbs; and**
- **many more products are still being developed.**

The view of Earth from space is not only spectacular, but informative. Photographs such as this one from Apollo 9 can help survey the natural resources of the world. Work being done by MSC and other NASA centers may help establish more efficient management and use of Earth's commodities. Projects involving unmanned and manned spacecraft, as well as specially equipped airplanes, have already shown the value of remote sensing — observation and measurement from a distance. Coupled with ground data, remote sensing will help maintain an up-to-the-minute picture of the world's farmlands and forests; identify areas of availability, pollution, or waste of Earth's dwindling fresh water supply; globally prospect for new deposits of minerals and petroleum, resources which are now threatened with depletion; and survey the oceans that cover 70 percent of the globe to determine how best to benefit from this source of untapped wealth. Observation from space, being perfected and extended in NASA's Earth Resources Survey Program, has proven most beneficial so far in the science of weather forecasting. Satellite tracking of the 1969 killer hurricane Camille prompted early evacuation of 70,000 people from the area of predicted impact; many of the 324 dead or missing had stayed behind in spite of the warnings.

On the first floor of the windowless Mission Operations half of the building house the computers, processors, control panels, tape recorders, test boards, wiring, displays, controls, and distribution equipment needed to support the activity on the second and third floors. The second half of the first floor, the more conventional-looking Operations Support wing, contains mostly office space.

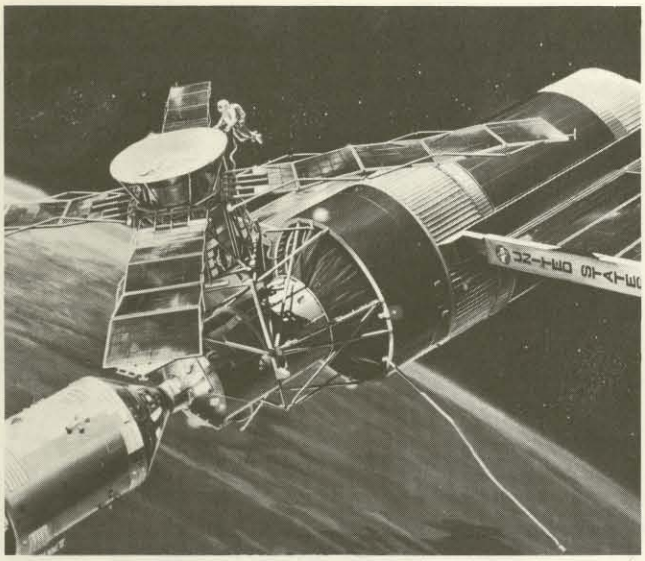
Through space-age electronics, a doctor in Houston can monitor a heartbeat a quarter-million miles away. A systems engineer can tell whether life-sustaining oxygen is flowing at the right rate, or if a switch is in the proper position. And a man can sit in his own home and marvel at the communications systems that bring mankind closer together.

If Building 30 is the center of attraction during a space flight, its postmission counterpart is Building 37, the Lunar Receiving Laboratory (LRL). One original basic purpose of the LRL was to keep crew, spacecraft and samples in quarantine on their return from the moon, while doctors, technicians, and scientists looked for anything that could contaminate



BLDG	FACILITY
49	Vibration and Acoustic Test Facility
37	Lunar Receiving Laboratory
32	Space Environment Simulation Laboratory
30	Mission Control Center
14	Anechoic Chamber Test Facility

BLDG	FACILITY
1	Auditorium and Visitor Center
2	Project Management Building
3	Central Cafeteria
5	Mission Simulation and Training Facility
7	Life Systems Laboratory
29	Flight Acceleration Facility
.....	Visitor Parking



Two manned space programs, one active and one in the study stage, represent some of the planning for logical steps beyond current capability. Skylab is the active program, and Space Shuttle is the program under study. Skylab, perhaps a forerunner of large permanent space stations, is a workshop from which long-term scientific experiments can be conducted. The lab and living quarters are in the empty third stage of a Saturn V rocket, which is equal in volume to a three-bedroom house. The lab will be boosted into a 260-mile earth orbit. Three-man crews will spend 28 to 56 days in the lab studying ways of checking Earth's resources, making astronomical observations not possible from the ground, and seeing how the human body reacts to the increase in flight duration. Space Shuttle is the reusable launch vehicle and spacecraft needed to reap the benefits of space more economically — both launcher and spacecraft would make airplane-like landings. Some anticipated Shuttle missions are: in-flight repair and maintenance of orbiting satellites; and the launching of new satellites. The Shuttle will be used to carry nonastronaut scientists up to Skylab where they will carry out experiments in space. With NASA and Russia studying compatible docking facilities on Skylab, and several nations ready to put technical skills and money into Shuttle, international harmony in space is growing.

Earth — lunar bacteria, for example, that might be immune to any known treatment.

But careful analysis of man and materials from the first lunar landings turned up nothing alarming, and the other activities of the LRL are beginning to be more publicized. These further purposes of the LRL are to preserve and protect the lunar samples, to perform investigation that must be done while the samples are fresh, and to make a preliminary examination of the samples to help determine how to distribute the moon rocks and dust to scientists around the world.

The LRL's 83,000 square feet of space include a vacuum laboratory, physical and bio-science sample laboratories, an underground radiation-counting facility, and medical, administrative, and lab-support areas. The building's air circulation and waste handling systems are designed to keep the laboratories clean and sterile to protect the lunar samples from contaminating or being contaminated.

Many of the special facilities of MSC are designed to help determine that spacecraft systems and materials can stand up against the rigors of space flight. One such is the Space Environment Simulation Laboratory, Building 32. It contains two vacuum chambers, one 120 feet high by 65 feet in diameter and the other 43 feet high by 35 feet in diameter. A complete spacecraft or individual components can be subjected not only to a space-like vacuum, but to temperature extremes from 280° F below to 260° F above zero. Near by, in the Building 49 Vibration and Acoustic Test Facility, space hardware is buffeted by equipment which simulates the shakes and sounds the spacecraft will experience in flight. In contrast, complete silence is found in the Anechoic Chamber Test Facility, Building 14, where foam-covered walls, floor, and ceiling soak up stray signals during spacecraft communication system tests.

Just as unique are some of the specialized facilities used to test and train the men who fly the spacecraft.

The Flight Acceleration Facility, in Building 29, is another area open to the public as part of the MSC self-guided tour. A 50-foot centrifuge with a 12-foot-round gondola at the end spins up to

The scene in Mission Control is a familiar one to TV audiences around the world. What is not shown is the preparation for a space flight — the months of planning and analysis, programming, and practice by Flight Operations Directorate personnel and the thousands of other NASA, Department of Defense, and contractor personnel who support each flight. When Neil Armstrong reported his "giant leap for mankind" to Mission Control, his words went around the world through facilities set up by 2,000 newsmen gathered at the Manned Spacecraft Center to follow the historic flight. The technology which let Mission Control see Armstrong's image and hear his words, check his heartbeat and respiration rate, keep tabs on fellow Moon explorer Edwin Aldrin, and monitor the status of the lunar module "Eagle" as well, is proving beneficial on Earth. Right now, the capability to monitor remote functions and events is helping many hospitals run more efficiently. Tomorrow's applications may not yet have been thought of. Nuclear Physicist Dr. Edward Teller once remarked "When Columbus took off, the purpose was to improve trade relations with China. That problem has not been solved to this very day, but just look at the byproducts." The byproducts of space flight are just beginning to emerge.

impose g-forces even greater than those experienced by the astronauts during launch or reentry. The facility also is used to help develop equipment that will survive the acceleration stresses of space flight.

Most of the time spent in training an astronaut for a specific mission is logged in simulators — training devices that duplicate spacecraft equipment and control panels, or even the entire spacecraft cabin. The most sophisticated of these, called "mission simulators," include projections onto screens where the spacecraft windows would be. The scenes are those the crew will see during the real mission. These trainers in the Mission Simulation and Training Facility can be tied in with the Mission Control communication system so that crews and flight controllers can practice the entire mission many times before the actual flight.

Other specialized facilities at the Center include a photography processing laboratory, a technical services shop, printing plant, cafeterias, fire department, dispensary, and a Visitor Orientation Center that houses spacecraft which have flown in three American manned space programs — Mercury, Gemini, and Apollo.

MSC's Flight Crew Operations Directorate includes some of the best known people in the world, but the astronauts' jobs are not necessarily filled with glamour and adventure. Like the personnel who work with them, the astronauts put in a full 5-day workweek — and then some — to make manned space flight efficient, safe, and productive. A flight crew spends a year or more in preparation for a mission. Training devices such as the mission simulator are so realistic that many astronauts say the weightlessness of space is the only difference between the practice flights and the actual one. Similar equipment is being used to train airline pilots, and an automobile simulator gives driving trainees a sense of assurance and safety before they actually take to the highway. Other items developed for crew training or for space flight also find application to nonspace activity. Fireproof material used in the spacesuits is worn by firefighters, while full-protection garments, including a breathing system, let the fireman walk right into the flames. Lightweight, flexible insulation that protects spacemen from extreme heat and cold is featured as new outdoor wear and an emergency rescue blanket. Space food research is being turned toward easy-to-fix and more nutritious food for the home.

The Lunar Receiving Laboratory, an element of the Science and Applications Directorate, is NASA's cataloging and distribution point for the samples Apollo astronauts bring back from the Moon. One of many lunar sample tests conducted to date indicates that moondust may be a sort of super fertilizer, containing elements that help Earth plants grow bigger faster. Techniques used within the directorate to increase the detail and clarity of Lunar Orbiter photographs of the Moon have proven useful in enhancing X-ray pictures of humans. The picture's composition is broken down electronically, then put through a computer to clean up and sharpen the image. This technique significantly increases the capability of X-ray examination of deep, inaccessible areas of the body. The scientific activity within NASA carries over into the community. Between 1965 and 1971, NASA awarded grants and research contracts for 1,640 programs to 223 universities and colleges in all 50 states and the District of Columbia. Of the money spent on the space program in the decade 1959-1969, nearly $3 billion went to schools. A NASA grant to the National Academy of Sciences helped set up the Lunar Science Institute next door to the Manned Spacecraft Center. MSC works closely with the Institute and its owner, Rice University.

The MSC also maintains airplanes for astronaut training, research programs, and administrative travel at nearby Ellington Air Force Base, and it operates the White Sands Test Facility in New Mexico.

MSC PROGRAM MANAGEMENT

One important function of the National Aeronautics and Space Administration is management. By the time NASA began the second 10 years of its existence, it had conducted manned and unmanned space programs involving some 20,000 contractors from American industry, and — at the peak period of the mid-1960's — 420,000 employees, 35,700 of them working for NASA, and federal funds of about $40 billion.

Hundreds of contractor companies helped build the space program. These companies are located throughout the United States and range in size from small several-man shops to corporations employing tens of thousands of people. The task of

managing these efforts — bringing everything together in the proper place at the right time with confidence it will work as planned — is monumental.

The MSC's largest contribution to program management is in the design and construction of manned spacecraft. Apollo is an example of the job's scope: the command module, which carries the astronauts to the Moon and then back to Earth, is manufactured in California; the lunar module, which makes the actual Moon landing, is built on Long Island, New York; the guidance and navigation hardware contractor for both spacecraft is located in the Midwest. Several hundred additional subcontractors and suppliers have important inputs to the program.

MSC overcomes the distance problem by assigning resident managers to the spacecraft contractors' plants where they work closely with the development, manufacturing, and testing activities. Regular reviews and progress reports go into status charts which show whether all phases of the program are moving smoothly ahead. Program management defines and controls the many interfaces between systems to assure compatibility of crew, spacecraft, and launch vehicle; and it establishes quality control and reliability standards, along with the appropriate checkout and test procedures.

Similar management functions are performed by NASA centers responsible for other aspects of the program — the launch vehicle at Marshall in Huntsville, Alabama; tracking and communication systems at Goddard in Greenbelt, Maryland; and launch facilities at Kennedy in Florida. The total effort is coordinated by NASA Headquarters to a precise schedule with rigid standards. Yet, it is flexible enough to take advantage of new technology or to bounce back from failures.

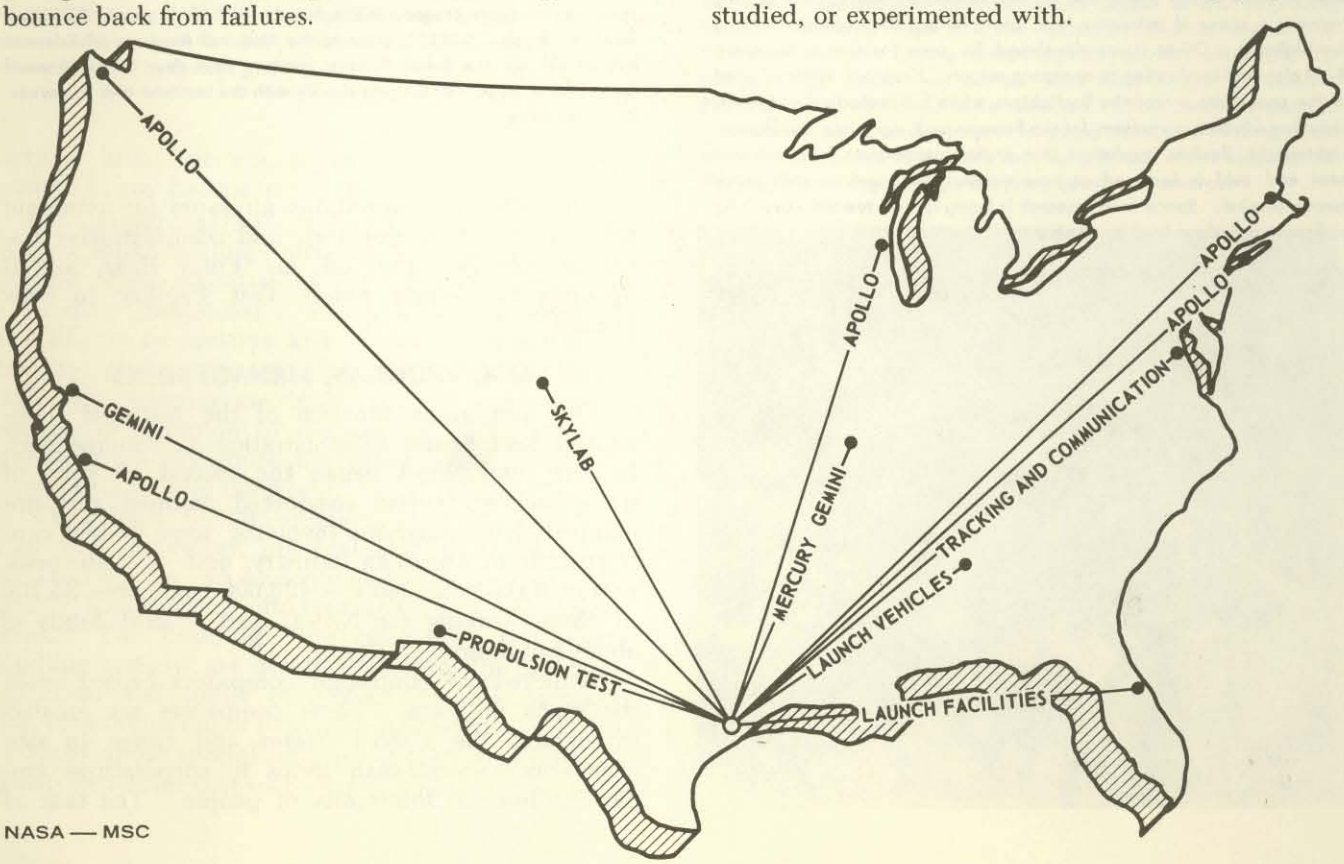
The success of NASA's management techniques was confirmed July 20, 1969, when Apollo 11 Commander Neil Armstrong announced "The Eagle has landed!"

Eight years earlier, when President Kennedy was preparing to declare the lunar landing as a national goal to be accomplished within the decade, NASA management estimated that it could be done, and done at a cost of "$20 to $40 billion." After Apollo 11 and follow-on Moon landings with increasingly extensive exploration, the final cost of the Apollo Program is pegged at about $25 billion.

The management techniques which enabled the National Aeronautics and Space Administration to fulfill such an ambitious commitment — plans for the lunar landing were presented publicly before any human had flown in space — are being applied to help solve some of the growing problems of America's large cities. The City of Los Angeles was among the first, using NASA-perfected procurement and source-evaluation procedures to start updating the city's overworked police, fire, and ambulance services.

An increasing number of businesses, big and small, are taking advantage of NASA-sponsored data banks, which are another spinoff benefit from management's in-depth documentation of the space program. The data centers are located at several universities around the country. They stock nearly a million documents on technical research and development. A subscribing business can get a computer search that will turn out condensations of every technical report ever recorded on the subject in question.

Meanwhile, other beneficial uses of these management techniques and tools are being proposed, studied, or experimented with.



NASA — MSC

We're Scared.

Scared of a man running for President who wants us wiped out. He voted against the SST, the Lockheed Assistance Loan, The ABM Missile Protection System, and vows to wipe out our B-1 Defense Bomber and the 50,000 jobs from our Space Shuttle Program... and God knows what else.

Many of us are Democrats—but we now support President Nixon. Please join us. VOTE for President Nixon and Help Us Save Our Jobs (and the Economy of California).

Thank You.

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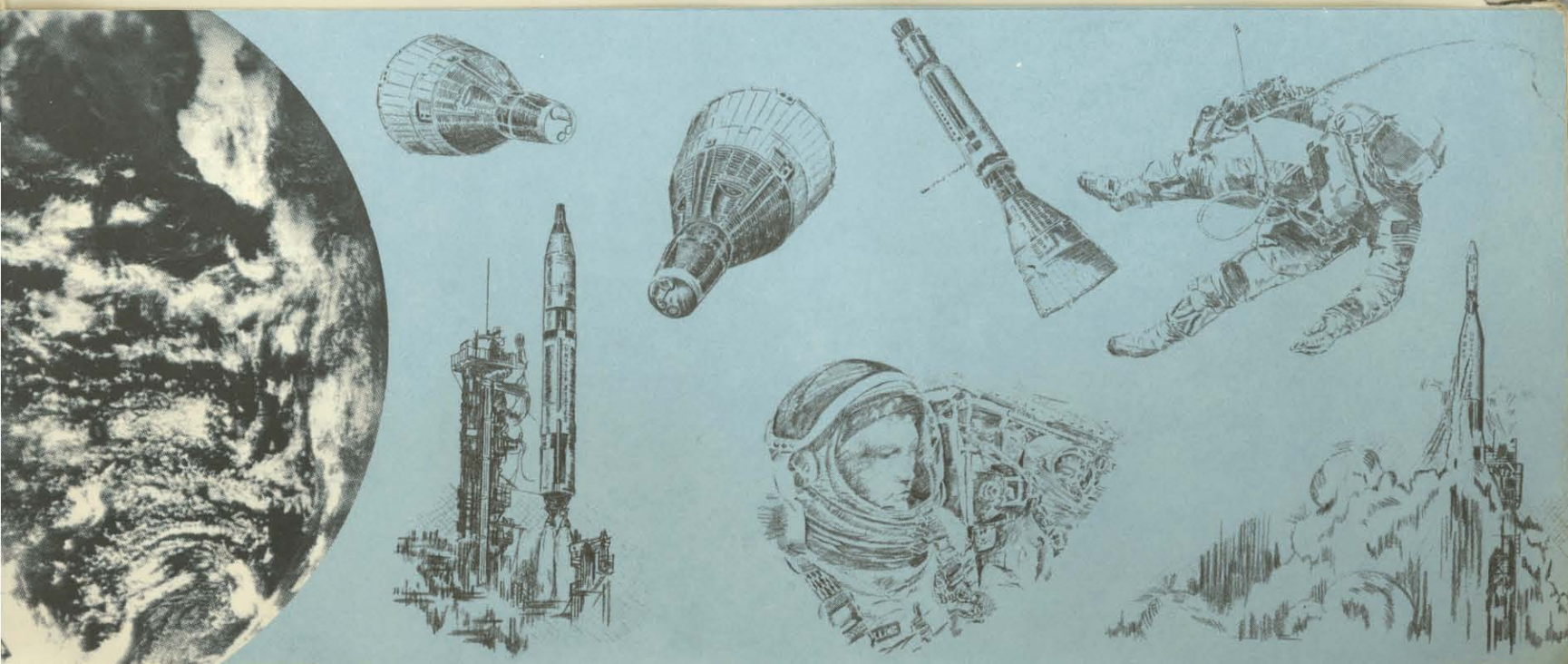
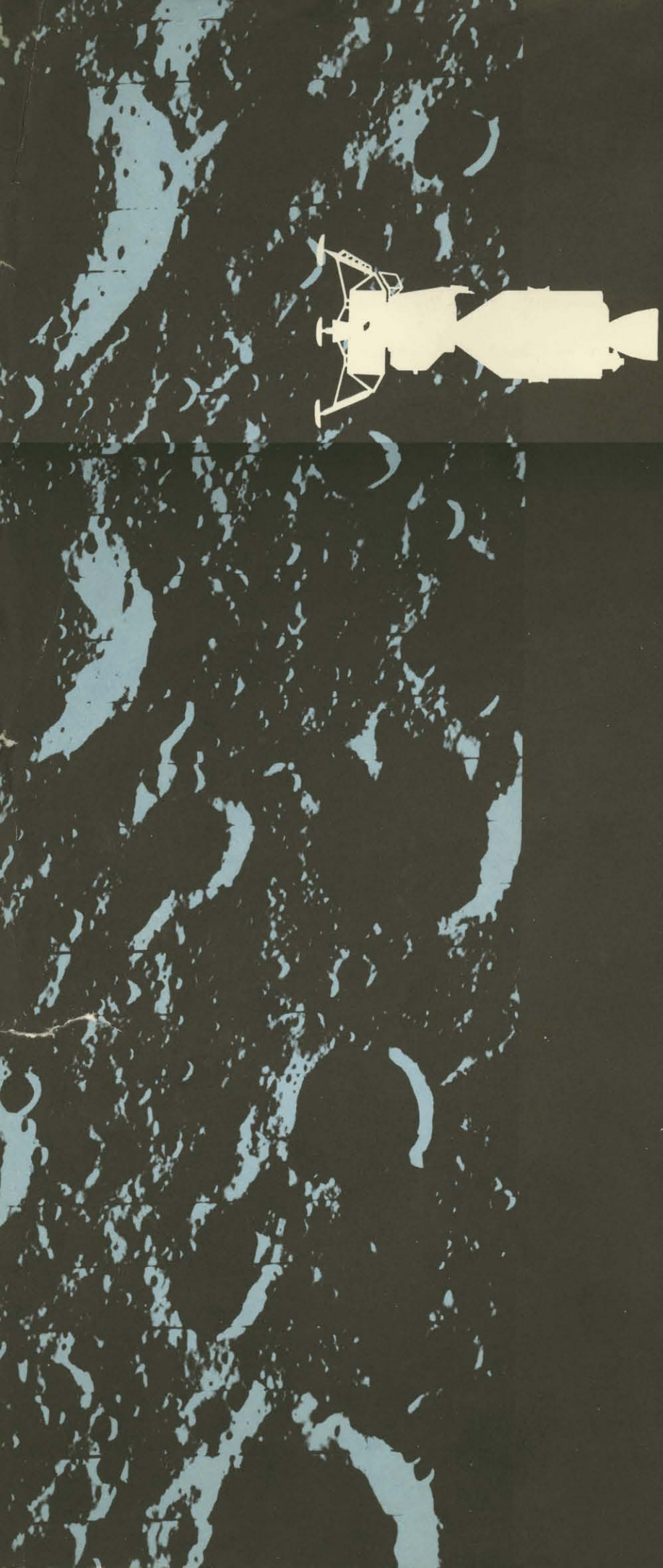
GEMINI CHRONOLOGY

MISSION	CREW	DATE(S)	DURATION (HRS:MIN:SEC)	REVOLUTIONS	OBJECTIVES
Gemini I	- -	April 8, 1964	3 revs	Reentered rev 64	Demonstrate SC structure, GLV systems performance.
Gemini II	- -	Jan. 19, 1965	18:16	Suborbital	Demonstrate SC systems performance.
Gemini III	Grissom-Young	Mar. 23, 1965	4:52:31	3	Manned qualification of Gemini SC.
Gemini IV	McDivitt-White	June 3-7, 1965	97:56:12	62	Demonstrate SC systems and crew capability for four days; demonstrate EVA.
Gemini V	Cooper-Conrad	Aug. 21-29, 1965	190:55:14	120	Demonstrate long-duration flight, rendezvous radar and rendezvous maneuvers.
Gemini VII	Borman-Lovell	Dec. 4-18, 1965	330:35:01	206	2-week duration, shirt-sleeve environment, rendezvous vehicle for Gemini VI, controlled reentry.
Gemini VI	Schirra-Stafford	Dec. 15-16, 1965	25:51:24	16	On-time launch procedures, closed-loop rendezvous, station keep with SC VII.
Gemini VIII	Armstrong-Scott	Mar. 16, 1966	10:41:26	7	Demonstrated rendezvous and docking with Agena, multiple Agena restart in orbit, controlled landing, emergency recovery (mission terminated early because of control system electrical short).
Gemini IX	Stafford-Cernan	June 3-6, 1966	72:20:50	45	Demonstrate three rendezvous techniques, EVA with detailed work tasks, precision landing (0.38 nm from planned landing point).
Gemini X	Young-Collins	July 18-21, 1966	70:46:39	43	Dual rendezvous using Agena propulsion for docked maneuvers, retrieval of experiment package from Agena during EVA; demonstrated feasibility of using onboard navigation for rendezvous.
Gemini XI	Conrad-Gordon	Sept. 12-15, 1966	71:17:08	44	First-orbit rendezvous and docking with Agena, 741 nm apogee using Agena propulsion, 161 minutes total EVA, tether exercise, automatic reentry.
Gemini XII	Lovell-Aldrin	Nov. 11-15, 1966	94:34:31	59	Three EVAs, gravity-gradient tether exercise, rendezvous and docking with Agena, rendezvous with solar eclipse.