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Manned Space Flight: Apollo

Apollo is the third step in NASA's manned space flight program. Its goals:

* To land American explorers on the moon and bring them safely back to earth.

* To establish the technology required to meet other National interests in space.

* To achieve for the United States pre-eminence in space.

Apollo was preceded by Project Mercury which pioneered the technology and man's capabilities for manned space flight and by Gemini which significantly extended the technology and experience gained through Mercury. Both Mercury and Gemini were programs in which astronauts test piloted spacecraft which were largely experimental. Apollo, on the other hand, calls for an operational spacecraft capable of carrying astronauts safely to and from another body in the solar system.

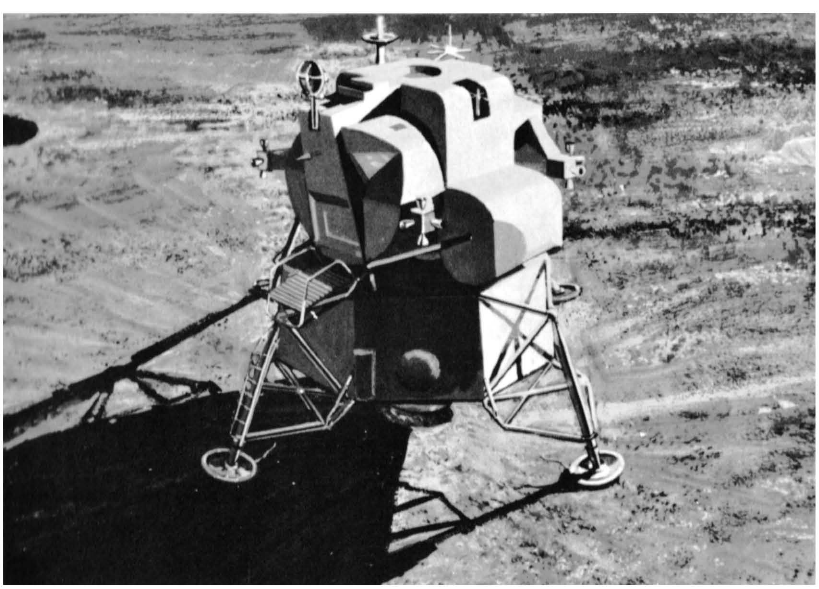
LUNAR ORBIT RENDEZVOUS

Three methods were considered to accomplish the manned lunar landing mission. They were: 1) direct flight of a full-size spaceship from the earth to the moon and back, 2) launching two separate sections of a spaceship from earth into orbit, joining them together, and sending them as a single spacecraft to land on and take off from the moon; and 3) launching the whole spacecraft from earth to lunar orbit and landing a section of the craft on the moon while the other part waits in orbit for the landing craft to return.

The third method, called lunar orbit rendezvous, was chosen after careful study. This method reduced significantly the rocket power required for landing on and taking off from the moon. Moreover, a craft using the earth-orbital rendezvous method (2) would weigh more than twice as much as the one using the lunar-orbit rendezvous method, mainly because of additional fuel.

APOLLO SPACECRAFT

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



Lunar Module of Apollo spacecraft, piloted by two astronauts, moments after touchdown on the moon.

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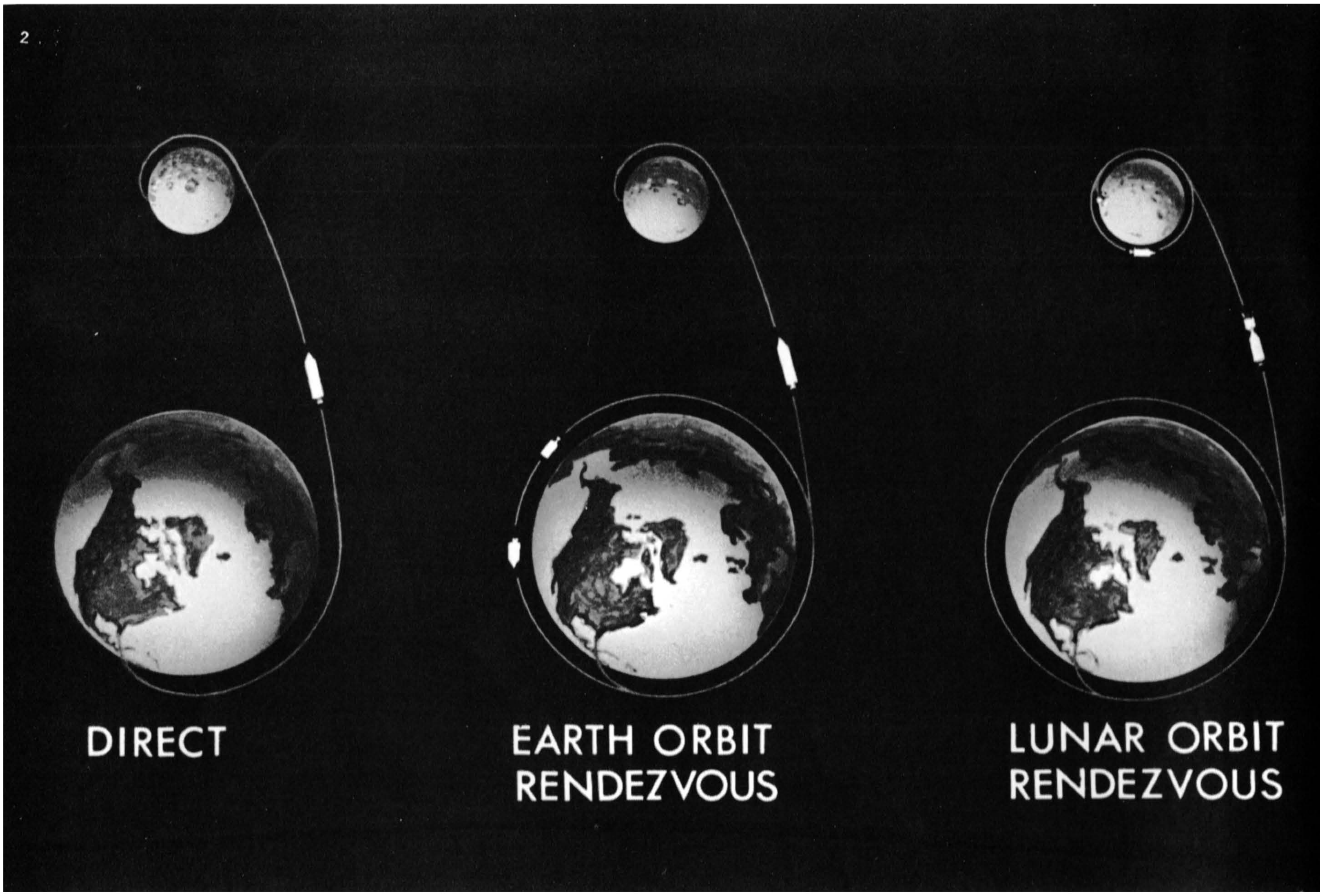

COMMAND MODULE

The Command Module (CM) is the only module which will return to earth from the lunar mission. It contains the crew's living compartment and all the controls for the various in-flight maneuvers. Similar in shape to a cone, this module has a bottom width of 13.8 feet and stands about 12 feet high. It consists of two shells: a pressurized inner crew compartment and an outer heat shield. Launch weight is about 12,000 pounds. More elaborately equipped for human comfort than either the Mercury or Gemini spacecraft, the Apollo CM contains a pilot cockpit for three astronauts. It has two side windows, a crew hatch window, and two rendezvous windows which face toward the nose of the CM.

The Apollo Environment Control System (ECS) is similar to that of the Gemini spacecraft. It supplies pure oxygen in the cabin at 5 psi (pounds per square inch), a temperature of approximately 75° with a humidity index between 40% and 70%.

LAUNCH ESCAPE SYSTEM

On top of the Command Module at launch is the Launch Escape System (LES) tower, with rocket motors similar to those used on the Mercury escape system. The LES is 33 feet tall and weighs about 8,200 pounds. With this tower and motors, the launch pad Apollo spacecraft (without its booster) has a total height of 82 feet. It is almost as tall as the combined Mercury-Atlas vehicle that placed John Glenn in orbit on America's first manned orbital flight in 1962.

The LES is designed to separate the command module from the rest of the launch vehicle should an emergency occur on the launch pad or shortly after lift-off. The system rockets the command module a safe distance away from the launch vehicle and to an altitude high enough for parachutes in the module to function for descent to earth. The LES is jettisoned about 35 seconds after ignition of the launch vehicle's second stage.

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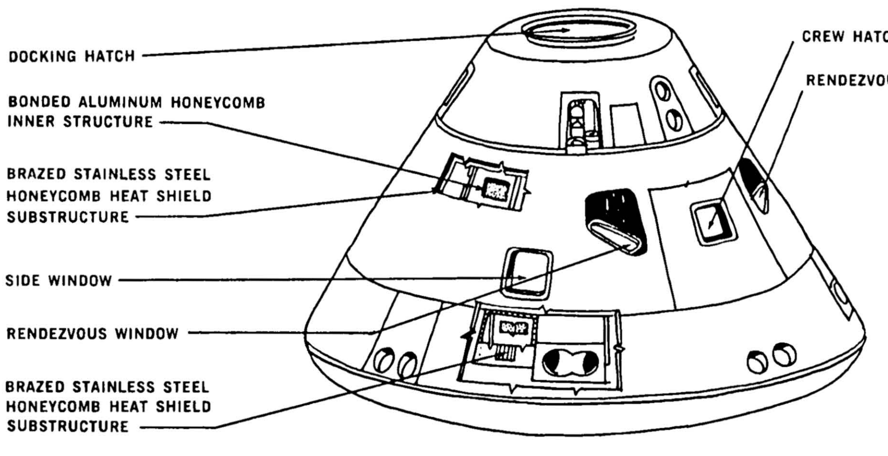

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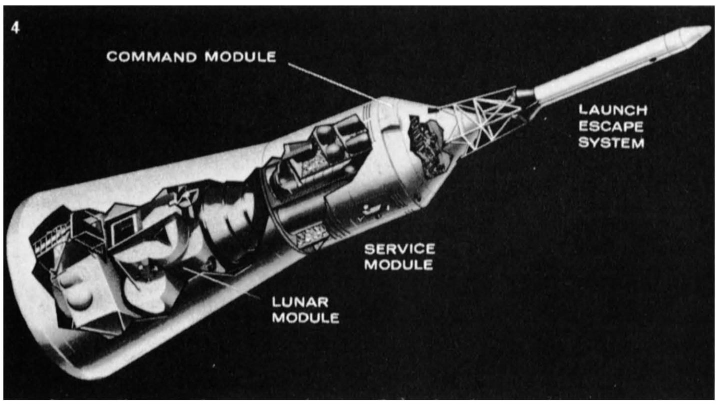


2 Techniques considered for the lunar landing mission.
3 Apollo Command Module.
4 Apollo spacecraft.

SERVICE MODULE

Beneath the Command Module at launch is the Service Module, a cylindrical unit 12.8 feet in diameter and 22 feet tall, weighing 55,000 pounds. It contains the spacecraft's electrical power supply equipment and its primary propulsion system, which produces 22,000 pounds of thrust. This stop-and-restart engine will be used for several important maneuvers while the spacecraft is moon-bound. It will also be used to slow the spacecraft to go into lunar orbit, to make midcourse corrections while earth-bound.

Having fulfilled all these functions during the round trip, the Service Module will be jettisoned prior to the Command Module's reentry into the earth's atmosphere.

ADAPTER

Under the Service Module, at launch, is the adapter section which connects the Apollo spacecraft to the third stage of the Saturn V launch vehicle and serves as the housing for the Lunar Module (LM), the lunar landing vehicle.

The adapter section is a fairing 28 feet tall. It is 12.8 feet in diameter at the top to match the width of the Apollo spacecraft. At the bottom it flares out to a diameter of 22 feet in order to match the width of the Saturn V booster's third stage (S-IVB). Weight of the adapter section is about 4,000 pounds.

LUNAR MODULE

The Lunar Module (LM), which weighs approximately 35,000 pounds, is the flight unit that will detach from the orbiting Command and Service Modules and descend to the moon's surface with two of the three astronauts aboard. Called the "bug" because of its appearance, it has two windows that will serve as "eyes" for the landing maneuvers, a tubular "mouth" for entry and exit, and four spidery "legs" for steady support after lunar touchdown.

The LM has its own complete guidance, propulsion, computer, control, communications, and environmental control systems, all with at least one and sometimes two backup systems. These precautions are necessary because landing on the moon will be the lunar mission's most critical phase.

The LM's descent propulsion system has a throttle control—its rocket engine's thrust power can be varied from low to high (1,050 pounds to 10,500 pounds) in order to control the lunar touchdown flight with great precision. The pilots will use this engine to provide braking thrust for the moon landing.

The final descent can be slowed to 3 mph at an altitude of 15 feet, but if the LM should drop at twice this speed, its four jointed steel-truss legs can absorb the landing shock without harm to the craft or crew. The legs are also designed to land on slopes up to 12 degrees in slant, or to retain balance if one or two legs sink into a layer of dust as much as 12 inches deep.

The LM is a two-stage vehicle. The bottom stage contains the rocket engine and legs for lunar landing. For the return trip, this stage also serves as the "launch platform" for the upper stage, which includes the cabin for the astronauts and the ascent engine. The ascent engine propels the upper stage from the lunar surface for rendezvous and docking with the CSM (combined Command and Service Modules) which had remained in lunar orbit.

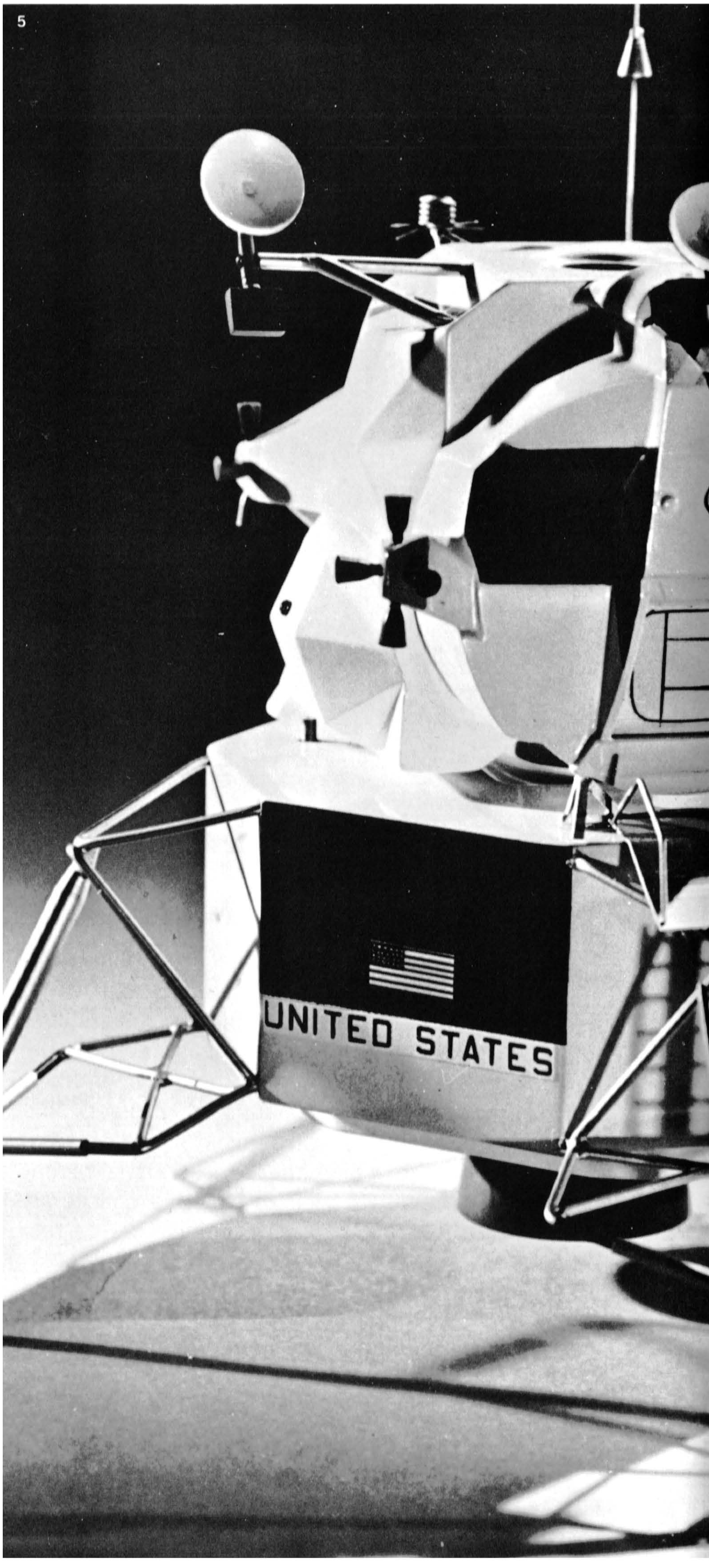
GUIDANCE AND NAVIGATION

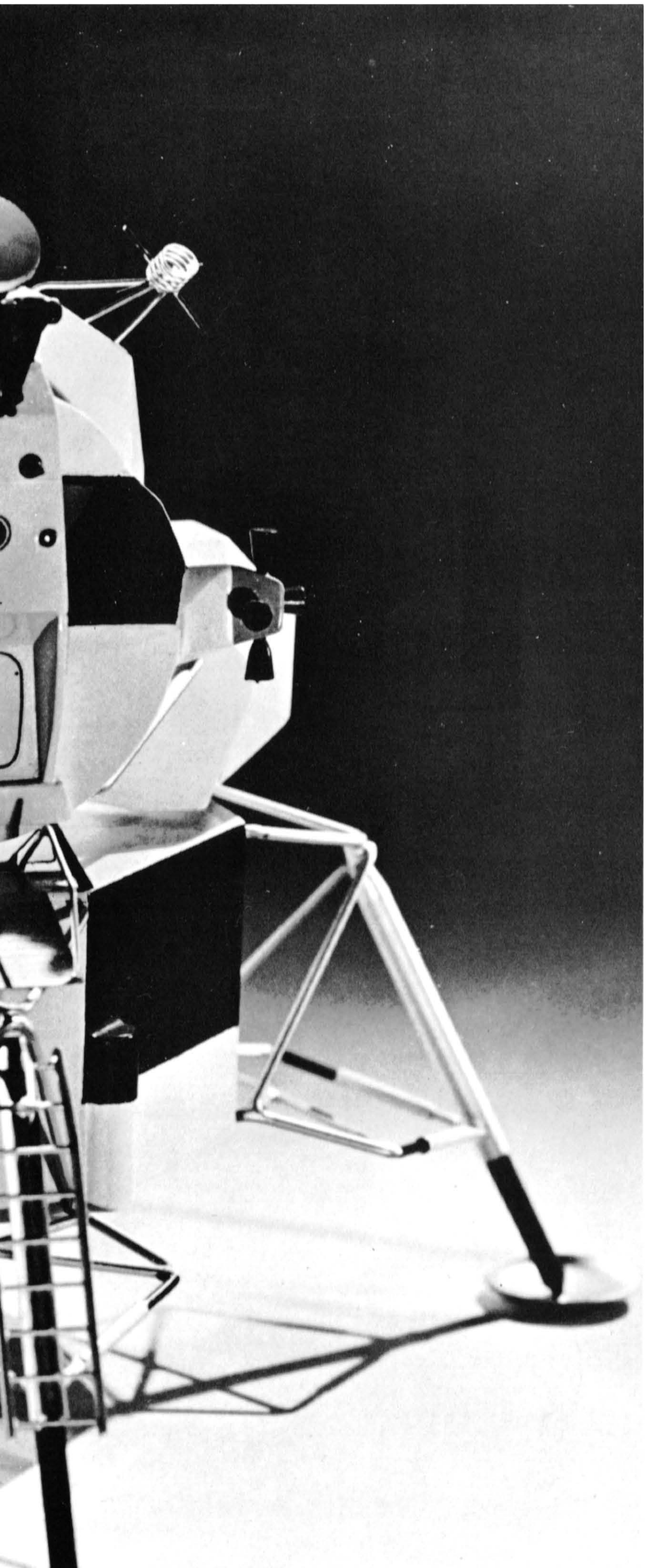
The Apollo space navigation system includes two relatively conventional units—inertial guidance platform and flight pattern computer. A third unit is an optical space sextant with which the astronauts will take sightings of the earth, moon, and reference stars to check out their position before each maneuver.

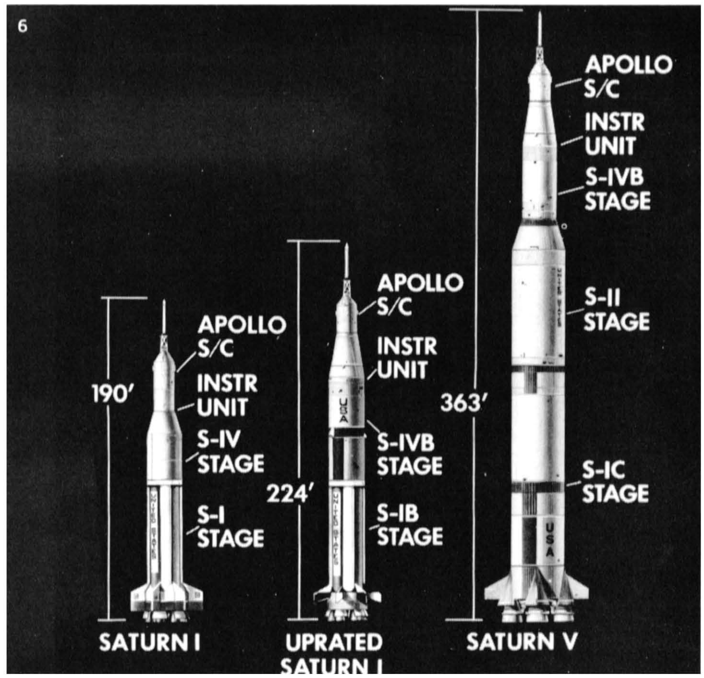
ASTRONAUT WARDROBE

The Apollo crewmen will have a changeable wardrobe for wear at different times. On the trip, two of the men (in rotation with the third) may relax in their "constant wear garment," a two-piece, close-fitting garment which covers all the body except the head and hands.

The third man will be in the Apollo space suit, with "accordion" joints (bellows principle) for flexible ease in walking, bending, or moving his limbs, and a helmet that has a pivoted visor for



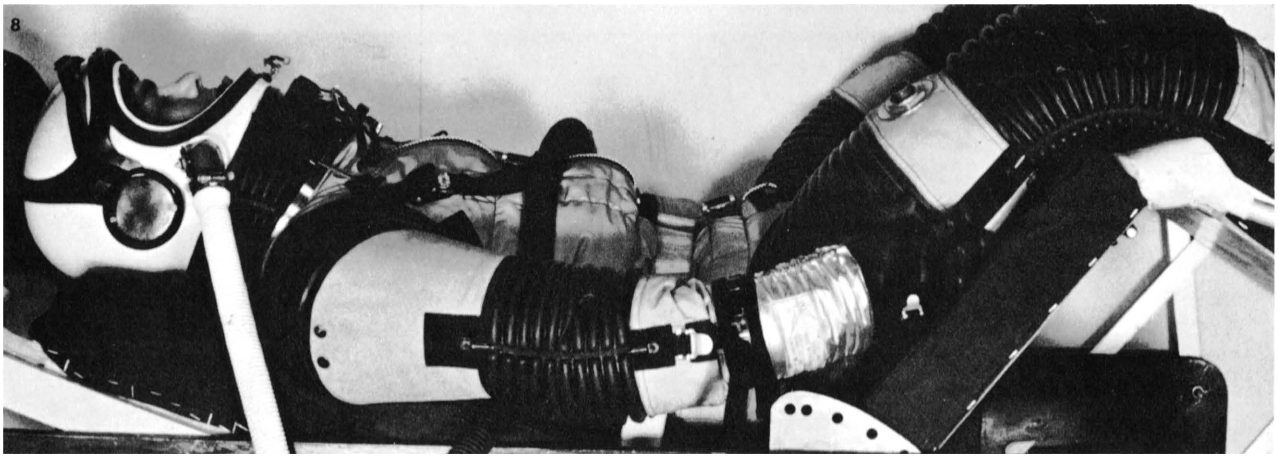




5 Model of Apollo Lunar Module.
6 The Apollo launch vehicles. (see text page 7)

7

7 Wearing an Apollo pressure suit and buoyed by apparatus that cancels out five-sixths of his weight, an engineer carries out an experiment in a simulated lunar crater.



8 Test of Apollo pressure suit.

quick closing and sealing.

The same type of space suit will be worn by the two LM astronauts who explore the moon. Underneath the pressure suit will be a special undergarment interwoven with a fine network of water-circulating tubes to carry away body heat. Covering the entire space suit will be a "thermal garment," or a white coverall with hood, to protect the astronaut from blistering sunshine on the airless moon. Finally, a "meteoroid cape" on his back will protect him from micrometeoroid dust which may rain down on the moon at high speed. Meteoroids that would penetrate the cape are calculated to be rare.

An important unit of the Apollo space suit system is the strap-on backpack for lunar exploration which includes a 4-hour oxygen supply, two-way radio, heat-dumping radiator, and dosimeter (radiation gauge). Partial radiation protection is built into the space suit fabric.

LAUNCH VEHICLES

The Apollo launch vehicles are the Saturn I, Uprated Saturn I, and the Saturn V.

(1) 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 RP-1 (refined kerosene) and LOX (liquid oxygen). Its second stage (S-IV) had six RL-10-A3 engines burning liquid hydrogen and LOX, producing 90,000 pounds total thrust. With a diameter of 21.5 feet and standing 125 feet tall (without spacecraft), this two-stage vehicle delivered a payload of 22,000 pounds into low earth orbit.

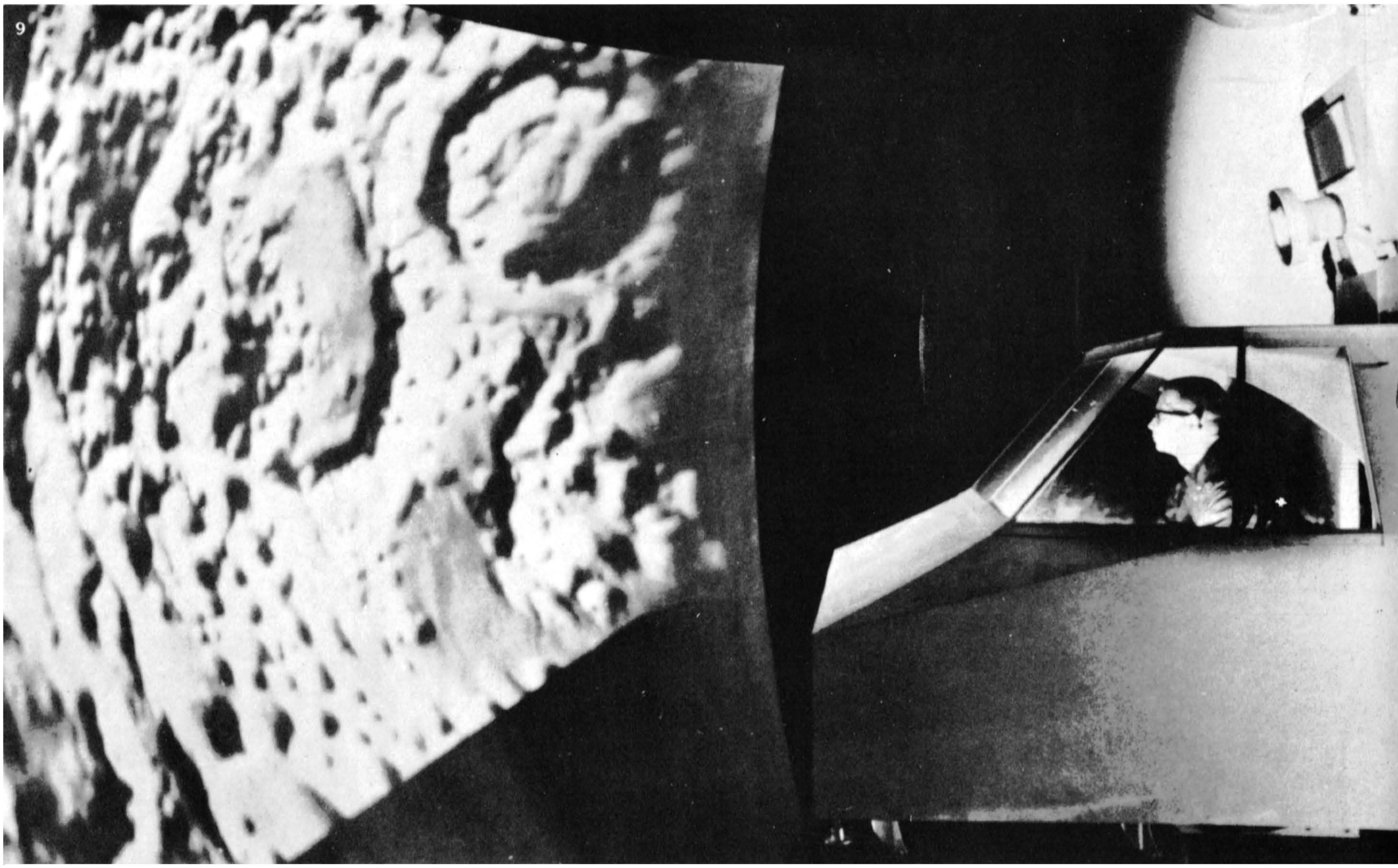
The Saturn I has placed the Command and Service Modules of the Apollo spacecraft into orbit in unmanned test flights and has been used to launch the Pegasus micrometeoroid technology satellites. The Saturn I program was completed in 1965 with ten successes in as many launches.

(2) The Uprated Saturn I has an improved version of the Saturn I first stage and a new and more powerful second stage—the S-IVB. The Uprated Saturn I is designed to launch the first manned Apollo flights into earth orbit.

The second stage (S-IVB) has one J-2 engine which burns liquid hydrogen and LOX and produces 200,000 pounds thrust. Low earth-orbit payload for the Uprated Saturn I is 40,000 pounds.

(3) The Saturn V is a vehicle of gigantic size and power. The first stage (S-IC) has a diameter of 33 feet and is powered by a cluster of five F-1 engines, each developing 1.5 million pounds of thrust, for a total of 7.5 million pounds.

The Saturn V second stage (S-II) has a cluster



9 Space flight simulator, with image of the moon on left, shows what man can and cannot do in controlling spacecraft during actual missions.

10 An Apollo-Saturn V test vehicle.

of five J-2 engines that furnish a total of 1 million pounds of thrust. The Saturn V's third stage (S-IVB) is identical with the Uprated Saturn I's second stage and produces 200,000 pounds of thrust.

This immense three-stage booster is 281 feet tall. The entire Apollo-Saturn V assembly will stand 365 feet high at the launch pad and will weigh 6 million pounds fueled before a moon flight. It will furnish the power to boost the Apollo Command, Service, and Lunar Modules into both manned earth orbital and lunar flights.

The mighty Saturn V launch vehicle will be able to launch 140 tons into a low earth orbit at a speed of 5 miles per second (mps), and accelerate 47.5 tons of payload to an escape velocity of 7 mps. This means that both the Apollo spacecraft and the Saturn V third stage will go into parking orbit, after which the S-IVB will re-ignite and add speed of 2 mps to send the spacecraft on its way to the moon.

UNMANNED MOON EXPLORATION

Three manned spacecraft programs are contributing to planning for manned landings by providing close-range pictures and other information about the moon. The first of these was Ranger, completed in 1965, which telecast close-ups of selected lunar areas before crashing as intended on the moon.

Another spacecraft is Lunar Orbiter which takes sharp close-range photographs of extensive areas from relatively low orbits around the moon. The photographs are being used primarily to select sites for manned landings. In a closely coordinated effort, Surveyor spacecraft are soft-landed on the moon to transmit pictures and other information about the lunar surface in their vicinity. These are coordinated with the broader overhead views provided by Lunar Orbiters.


USA

TRAINING

Astronaut training for the Apollo program includes the "basic space training" of the Mercury and Gemini programs along with the new Apollo specialties which are added from time to time, among them:

* "Moon Trips" in trainers that provide a realistic simulation of travel through space, descent to the moon, and return to earth.

* "Lunar Obstacle Course," a 328-foot-wide simulation of the moon's rugged surface, complete with craters up to 50 feet wide and 15 feet deep, large boulders, a dust layer, and fissures over which to jump. A suspension harness reduces an astronaut's weight to the moon's value (1/6th earth weight).

* "Space Suit Workouts," during which astronauts wear experimental Apollo pressure garments to practice walking, bending, opening of visor, and other operations.

MOON FLIGHT TRACKING SYSTEM

A network of tracking stations around the world was established for Project Mercury, augmented for Gemini, and redesigned and rebuilt for Apollo.

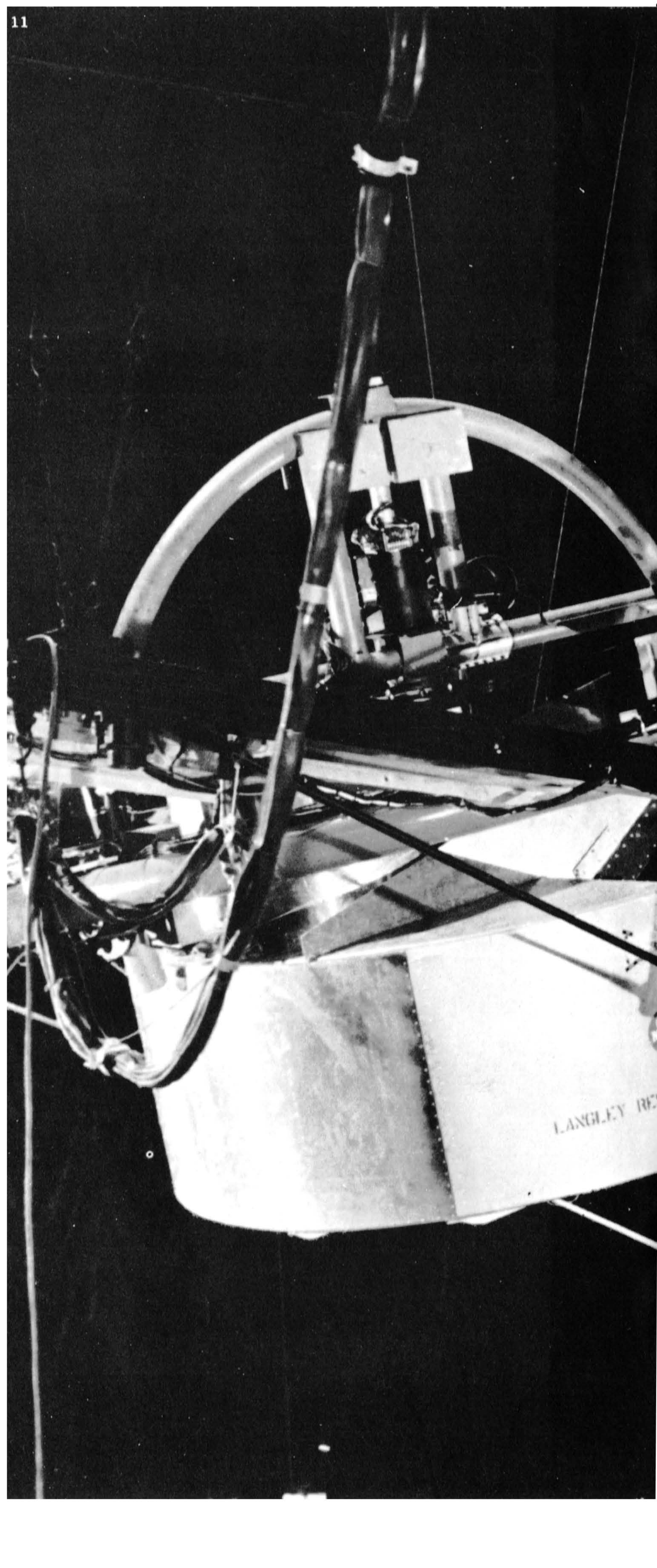
One group of network stations will follow the Apollo spacecraft at launch, during earth orbit, and again at the end of the flight after the moon trip is finished.

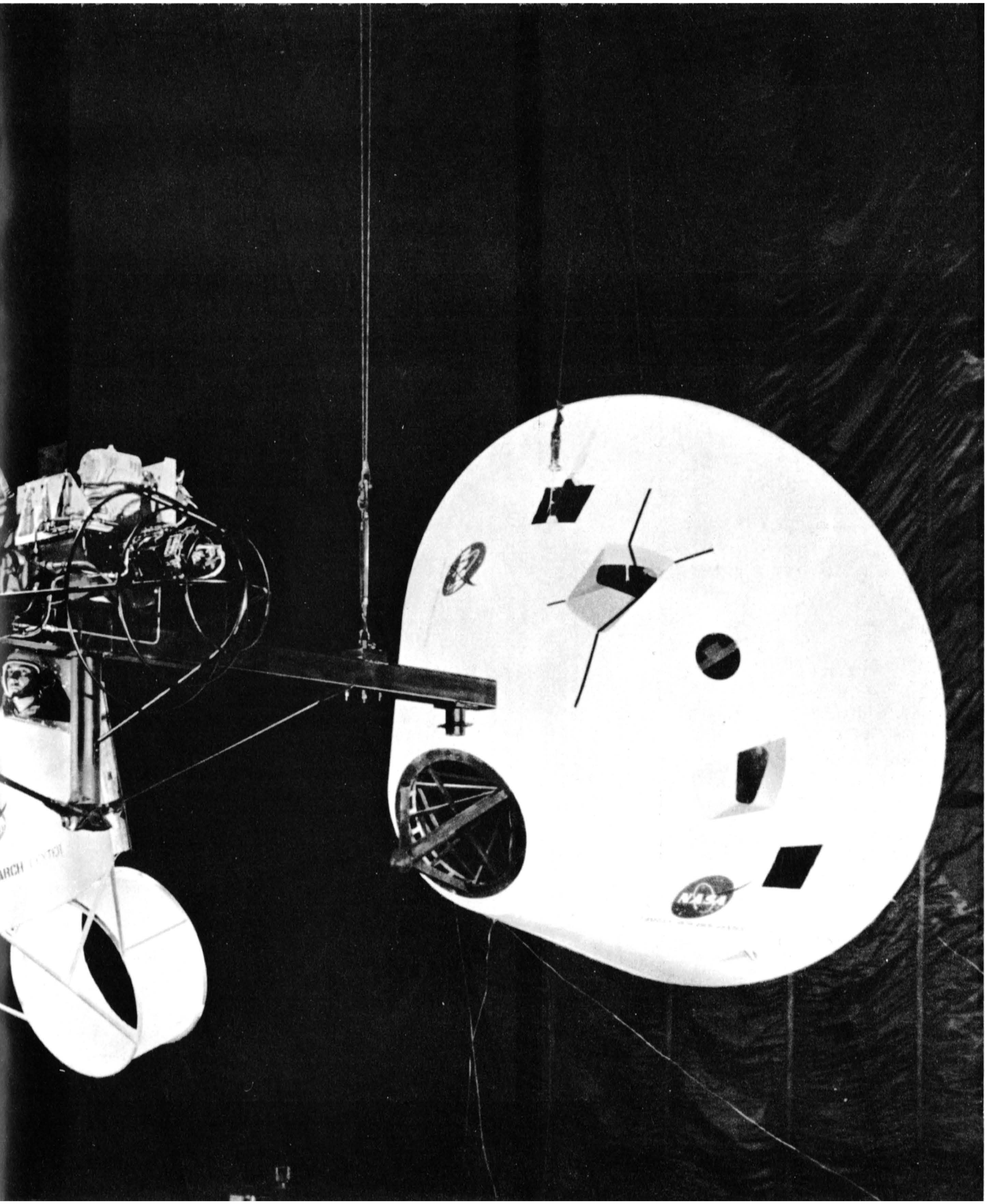
As the spacecraft leaves earth orbit and starts toward the moon, it passes from range of these stations. Tracking then switches to a second group of stations whose powerful transmitters and sensitive receivers are dependable for communications at great distance.

These stations have huge 85-foot diameter dish-shaped antennas and are similar in appearance to those which communicate with spacecraft, such as Mariner, millions of miles away in the vicinity of Mars or Venus or orbiting the sun.

Located at Goldstone, California; Madrid, Spain; and Canberra, Australia, they stand approximately one-third of the earth's circumference (120°) apart. As the rotating earth cut offs one station's direct line of contact with the spacecraft on its way to the moon or back, the next station rises above the horizon and takes over.

When the returning Apollo, speeding toward earth at 25,000 mph, enters the range of the earth-orbital tracking chain, these stations go into operation again and monitor the vital reentry and recovery.





11 Rendezvous docking simulator enables astronauts to practice the last 200 feet of lunar orbit rendezvous and docking.

Sequence of major events in Apollo lunar landing mission.

FLIGHT TO THE MOON

The first U.S. manned flight to the moon will take place sometime before the end of this decade. The mission will begin with launch of the 365-foot Apollo-Saturn V vehicle. The first and second stages will be jettisoned after burning all their propellants, but the third stage will burn only enough to place itself and the three-module Apollo spacecraft in "parking" orbit about 100 miles high.

Later, when the lunar "launch window" (best period of time for takeoff) is open, the third stage will refire and add enough speed for the Apollo spacecraft to escape from earth orbit.

On the way to the moon, the crew will reorient the combined Command and Service Modules (CSM) and dock (link-up) the nose of the Command Module with the nose of the Lunar Module (LM). The CSM then extracts the LM from the adapter section and the third stage of the launch vehicle.

Mid-course maneuvers may be made if the lunar trajectory, or flight path, requires adjustment. The maneuvers are accomplished by firing the Service Module's 22,000-pound-thrust rocket engine.

By about 54 hours after launch, earth's gravity will have slowed the spacecraft gradually from about 25,000 mph to about 2,500 mph. When it enters the area where the moon's gravitational field is dominant, the spacecraft will be accelerated toward the moon.

About 64 hours after launch, the spacecraft will near the moon at a speed of about 5,200 mph and the astronauts will apply the retro power of the Service Module propulsion system for about 6 minutes to slow the spacecraft down to about 3,600 mph. This will cause the craft to swing into a lunar orbit about 80 miles high. For the lunar landing, two men will transfer into the LM.

After about 68 hours of mission time, the LM will separate from the CSM with a difference in velocity of about 3 mph and will move away about 735 feet. The descent engine will then put the LM into a transfer orbit at a velocity of 3,500 mph. The LM will coast until an altitude of about 49,500 feet is reached; then powered descent will begin. Powered descent will take the LM to the hover altitude of 200 feet, where either a manual or automatic hover-to-touchdown procedure will be initiated. In either method, the engine will be cut off at LM altitude of about 15 feet, giving the LM a lunar impact speed of about 3 mph.

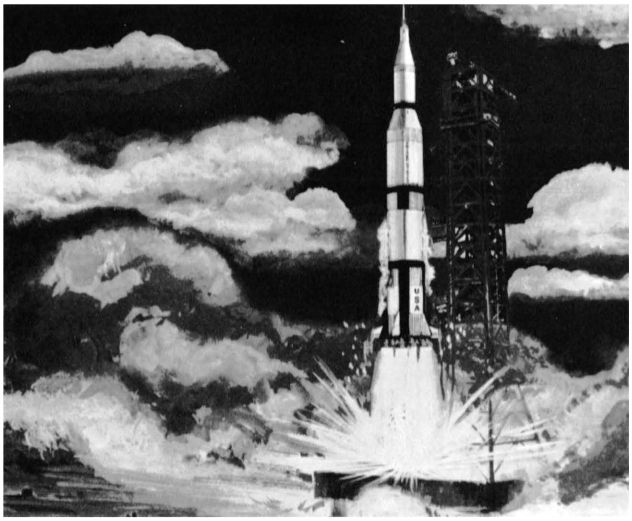
ASTRONAUT EXPERIMENTS ON THE MOON

Plans call for the astronauts to stay on the moon about 18 hours. Of this time, they will work on experiments for two separate 3-hour periods, in between which they will have about 6 hours of sleep. The remaining time will be spent on such matters as equipment checks, meals, making ready for experiments, post-landing inspection, and preparation for take-off.

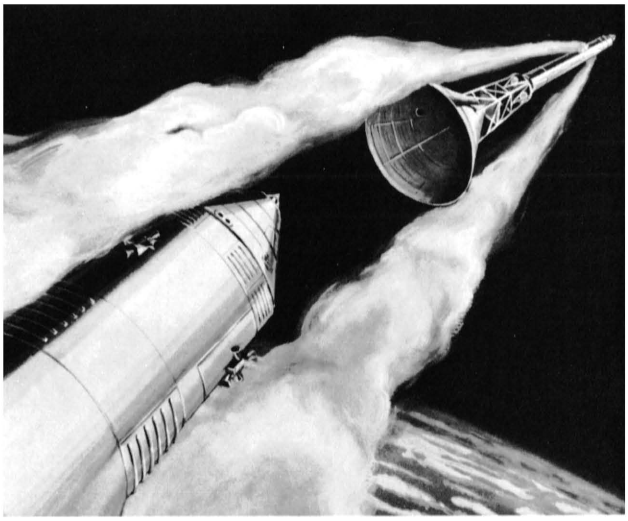
The most important parts of the astronauts' duties are their radioed descriptions, photographs, and direct telecasts of the moon and the 60 pounds of assorted rock samples they are to bring home in vacuum-sealed containers. In addition, the astronauts are to set up a group of Lunar Surface Experiments which will continue to radio their information to earth for as long as a year. The experiments are designed to report on such scientific phenomena as temperature changes, radiation levels, moonquakes, and micrometeoroids (tiny particles of matter in space).

RETURN FLIGHT TO THE EARTH

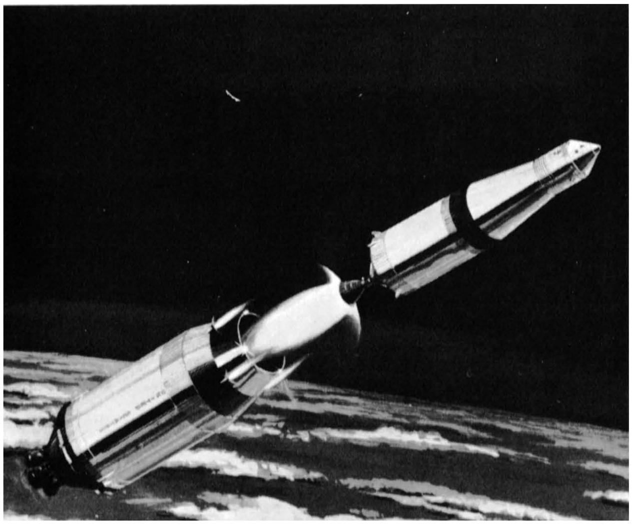
When the time arrives for leaving the moon's surface and joining the orbiting CSM, the lower stage of the LM will be used as a launching pad and left behind on the moon.



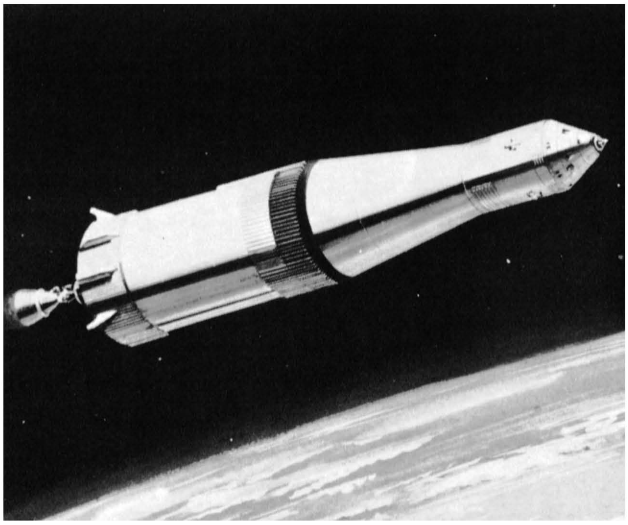
1 Lift Off.



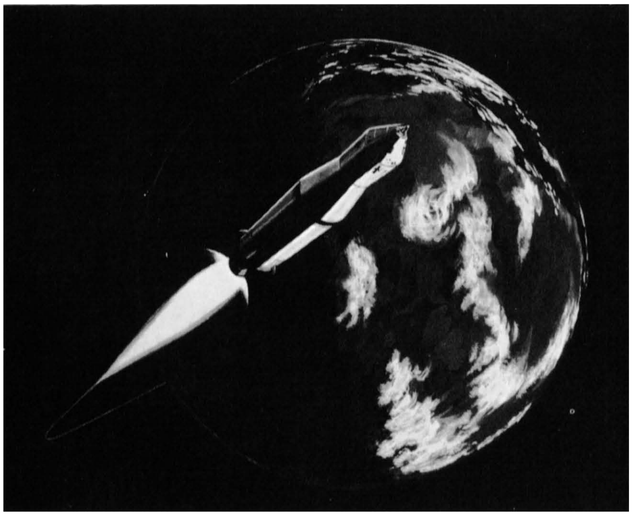
2 Jettison Launch Escape System



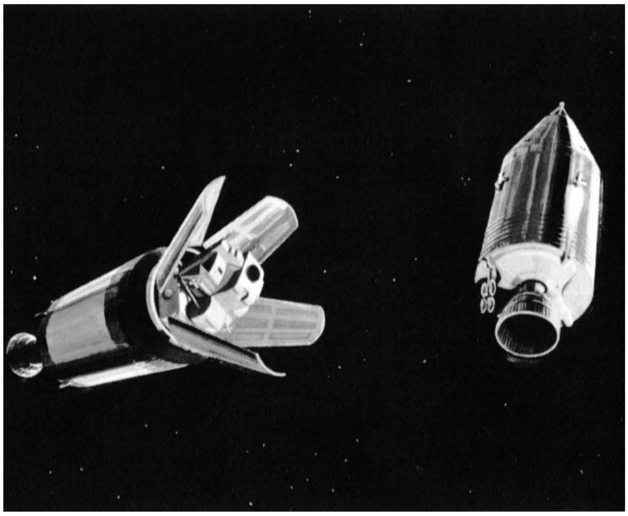
3 S-II Stage Separation, S-IVB Stage Thrusting.



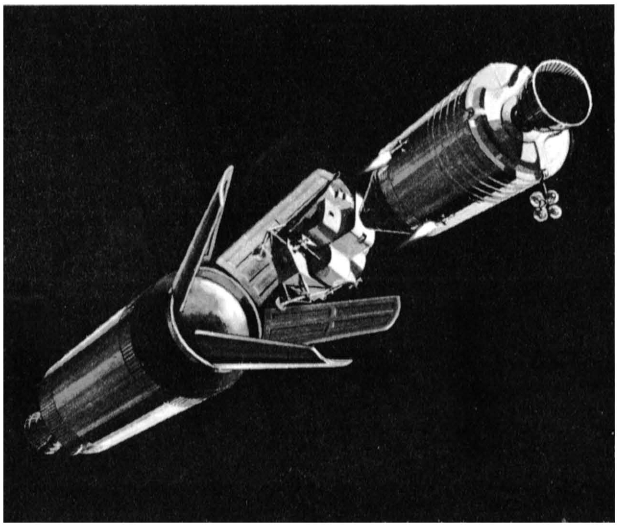
4 Earth Orbit Insertion of the S-IVB Stage and Spacecraft



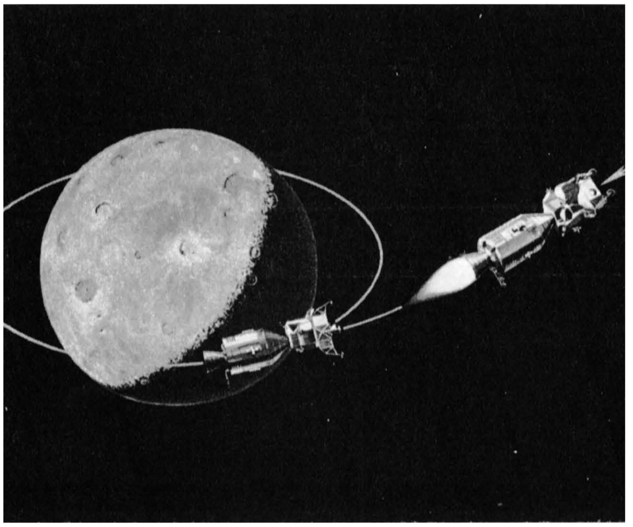
5 Translunar Injection.



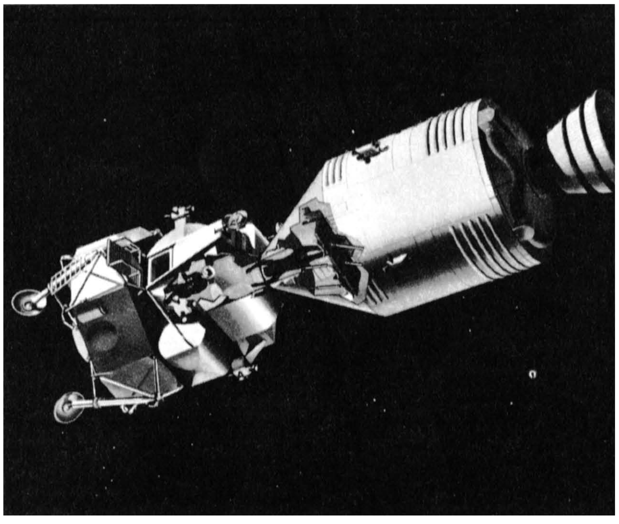
6 Turnaround of CSM.



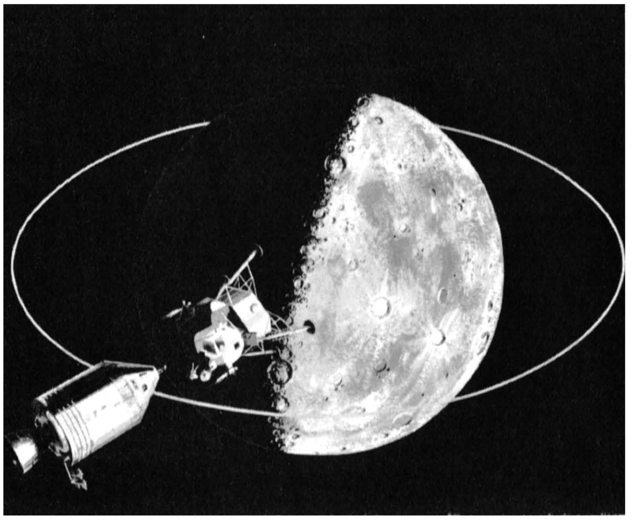
7 Docking and Separation of Spacecraft From S-IVB



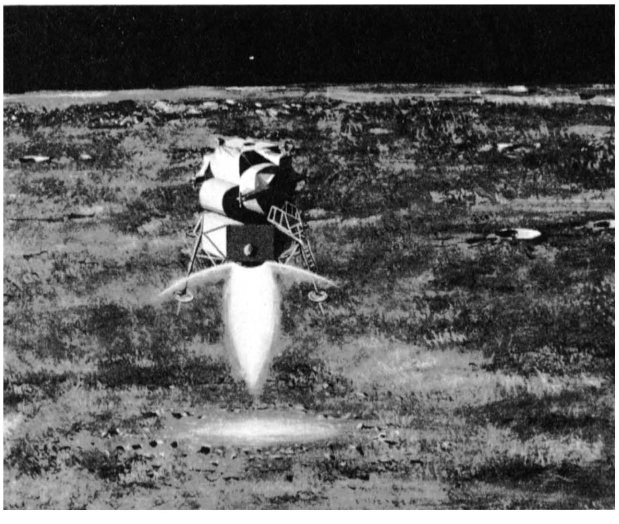
8 Lunar Orbit Insertion



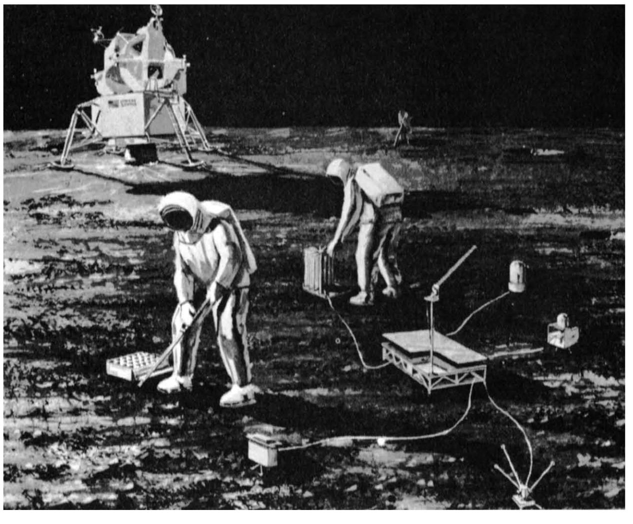
9 Transfer to LM



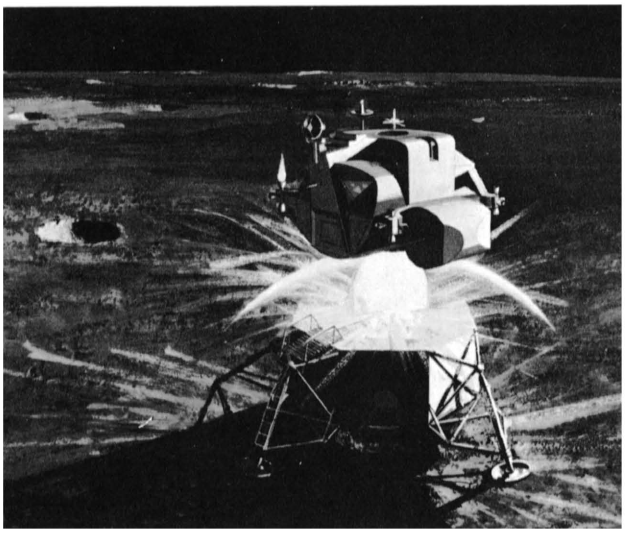
10 LM Separation



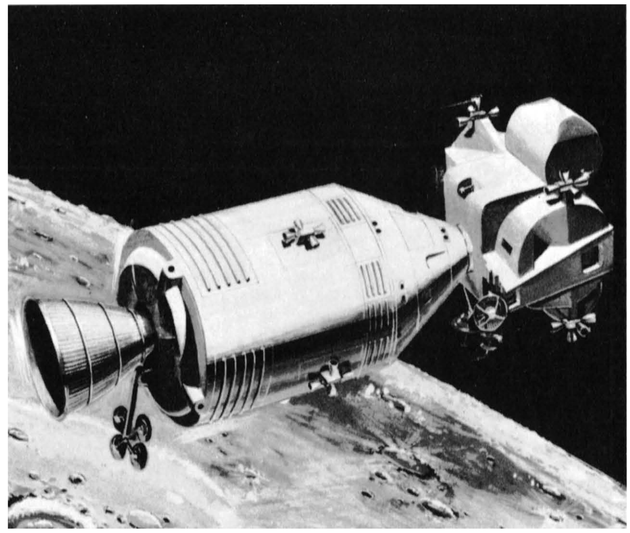
11 Final Descent



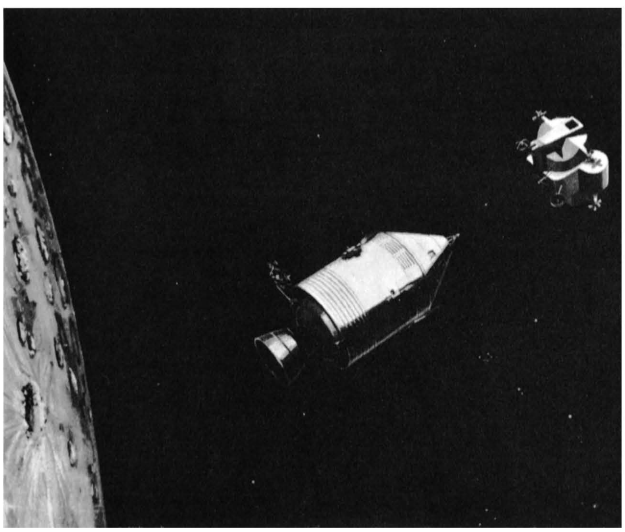
12 Exploration of Lunar Surface



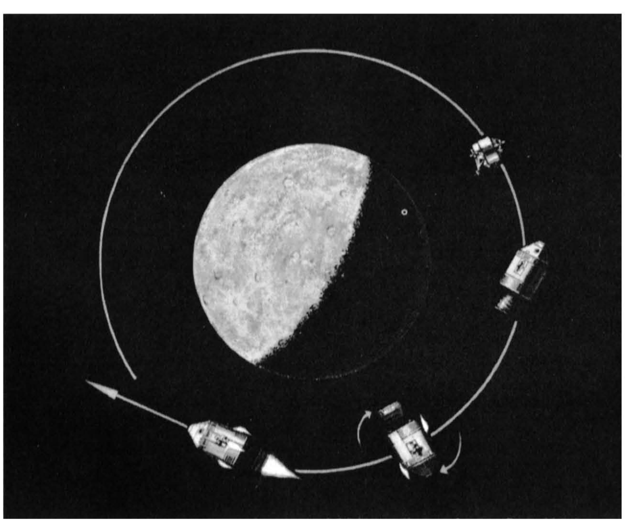
13 Ascent Stage Liftoff



14 LM Ascent—CSM Docked



15 LM Jettison



16 Transearth Injection

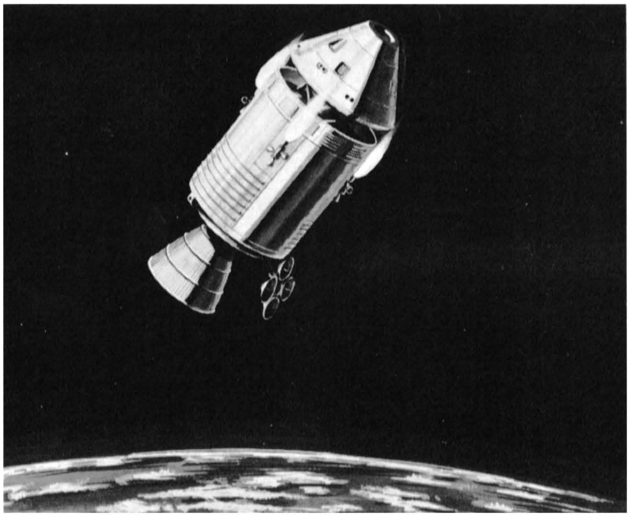
With launch timed for rendezvous with the orbiting CSM, the LM ascent stage will ascend to an altitude of 80 miles and dock with the CSM. After the two astronauts have transferred to the CSM, the LM will be jettisoned and left in moon orbit. The Service Module's rocket engine will be ignited to build up lunar escape velocity of 5,460 mph. About 29,000 miles outward, the spacecraft will reach the point where the earth's gravitational influence becomes dominant. Then, subject to the earth's pull, the CSM will return at ever-increasing speed until it reaches the same velocity at which the spacecraft left earth—about 25,000 mph.

After using its propulsion for final course corrections, the Service Module will be jettisoned, leaving the Command Module to plunge into the earth's atmosphere.

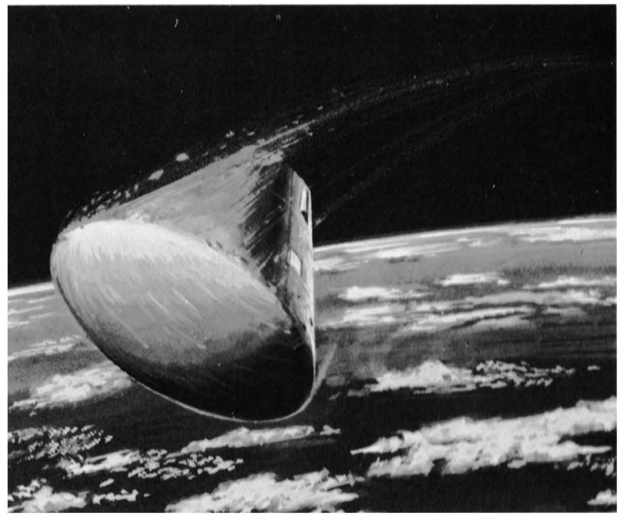
At the velocity of 25,000 mph, reentry will be trickier for the Apollo spacecraft than it was for the Gemini or Mercury spacecraft. The Command Module must enter the top of the earth's atmosphere and transfer into an earthbound ballistic path. The safe "reentry corridor" will be only 40 miles wide, while the angle of attack (slant toward earth horizontal) must be kept between 5½° to 7½°.

Apollo's reentry temperature will be about 5,000°F. As in Mercury and Gemini, the heat shield will protect the crew as air resistance rapidly cuts velocity to a safe point for parachute deployment and landing.

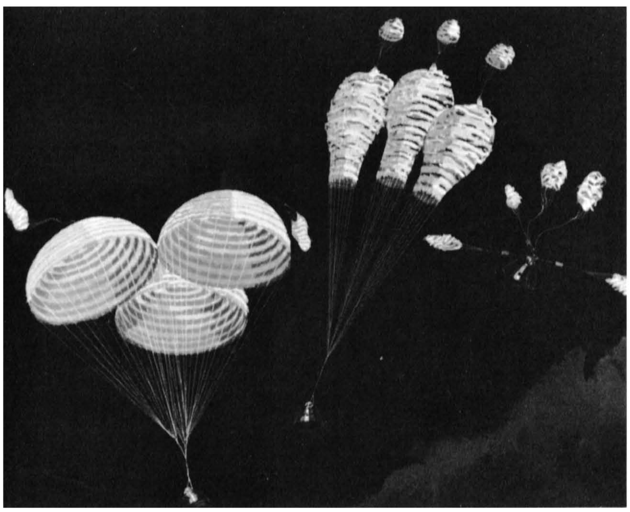
From earth launch to earth touchdown, the total moon trip time will be approximately 198 hours, or about 8 days.



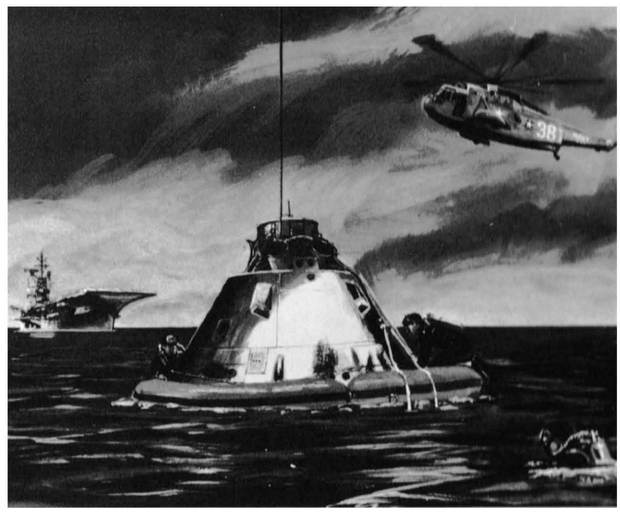
17 CM.SM Separation



18 Entry into Earth Atmosphere



19 Main Parachute Deployment



20 Spacecraft Recovery

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