

MISSIONS

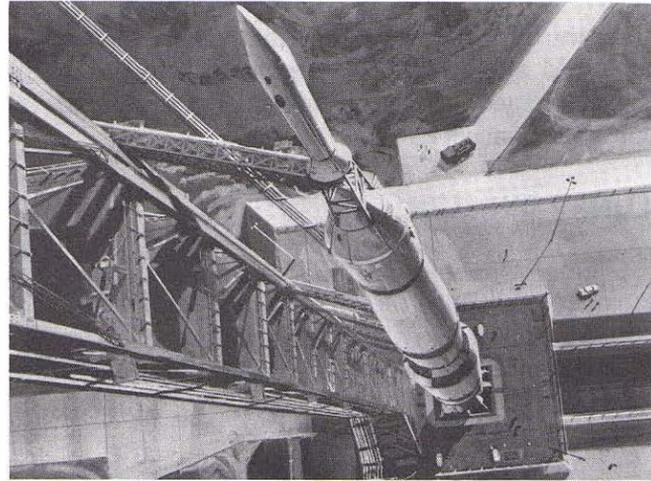
Apollo missions fall into two categories: earth-orbital and lunar. Earth-orbital and lunar-orbital missions are part of the flight-testing program to test the spacecraft, the launch vehicles, launch and communications equipment and procedures, and crew operations. The lunar mission calls for the landing of two American astronauts on the moon, exploration of the moon, and return to earth.

EARTH-ORBITAL MISSIONS

NASA's schedule of Apollo development missions is a flexible one that progresses logically toward accomplishing a lunar landing mission. The flight test program consists of unmanned flights, manned flights in earth orbit, a lunar orbital flight, and, finally, the lunar landing flight. Alternative flight plans are prepared for use in the event contingencies arise.

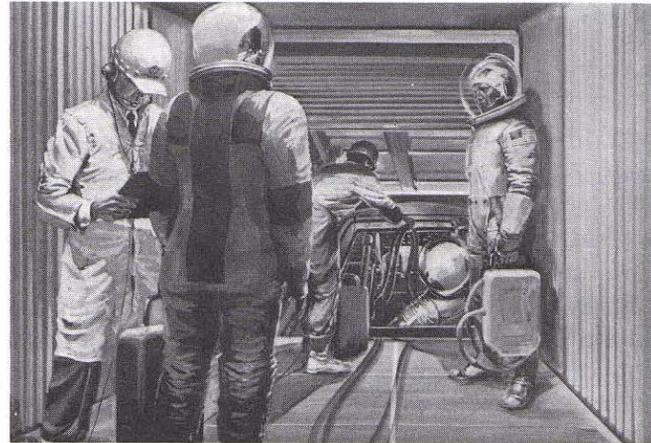
Previous flight tests of the Apollo command, service, and lunar modules--all unmanned--have been successful. CSM tests were aimed primarily at the operation of its subsystems and of man-rating the subsystems (certifying for manned space flight). Particularly important were tests of the heat shield and command module structure, which survived such rigorous conditions as the 5,000-degree heat during atmospheric entry from a lunar mission. The spacecraft's compatibility with the Saturn launch vehicles has been demonstrated.

Primary objective of the manned missions is to determine the proficiency of the crew in the



P-13

Apollo and Saturn are checked out before launch



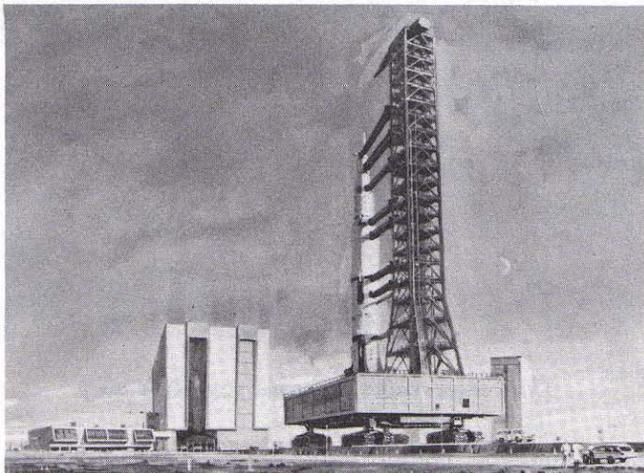
P-14

Three astronauts enter the command module

complex tasks required during the lunar missions and to test the operation of the manned space flight network, the communications link that will be used during the lunar mission. Crew tasks to be evaluated are those required for navigation, transposition and docking, rendezvous and docking, major propulsion maneuvers, entry, and recovery.

The first manned mission is designed to test the adequacy and overall performance of all CSM subsystems, including its life support and environmental control subsystems, over a substantial period. In the first mission, only the command and service modules will be launched with a Saturn IB.

The second manned flight, designated Apollo 8, calls for low earth-orbital checkout of the spacecraft



P-12

Mobile launcher carries space vehicle to launching pad

and upper portion of the Saturn V launch vehicle. The flight will be in some senses an expansion of the Apollo 7 mission. No lunar module will be flown.

The third manned earth-orbital mission will involve the CSM and LM and is designed to demonstrate the combined operation for the first time of the complete spacecraft.

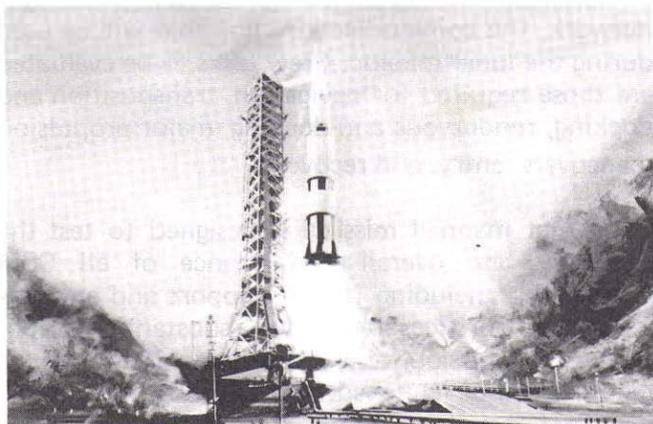
LUNAR MISSION

A lunar mission will mark the first time that astronauts will not be within minutes of earth. The landing mission will be a milestone in man's history--the first time man will set foot on another celestial body.

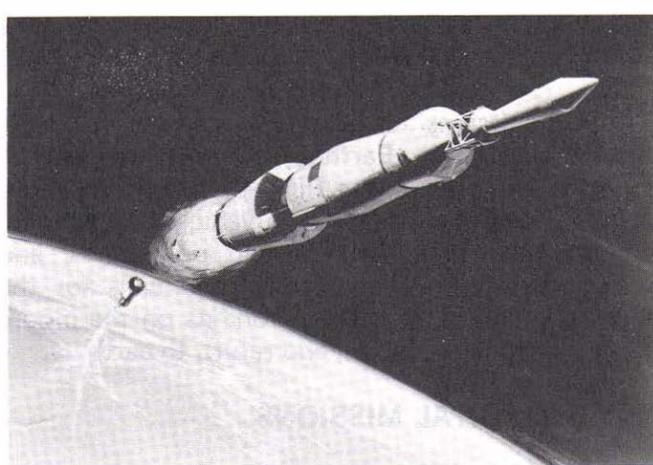
For planning purposes, the lunar mission is divided into phases. To gain an understanding of how the mission will be accomplished, each of these phases, with the exception of pre-launch and post-landing, is described.

EARTH ASCENT

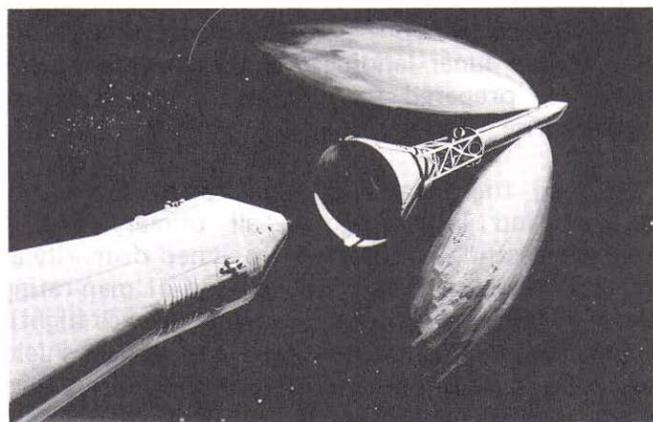
At liftoff, the Saturn V's first stage, developing over 7-1/2 million pounds of thrust from its five F-1 engines, lifts the 6.4 million-pound space vehicle off the pad and boosts it on its way. The first stage burns for about 2-1/2 minutes and reaches a velocity of about 5400 miles per hour and an altitude of about 40 miles. After the F-1 engines cut off, retrorockets on the first stage fire to achieve separation from the second stage. Four seconds later, the second stage's five J-2 engines ignite to boost the third stage and spacecraft to an altitude of approximately 114 statute miles. During its approximately 6 minutes of firing, the second



P-15 *First stage lifts huge space vehicle off pad*



P-16 *Second stage ignites after first stage falls away*



P-17 *Launch escape assembly is jettisoned*



P-18 *Third stage ignites as second stage falls away*

stage increases velocity to about 15,000 miles per hour. When its engines cut off, the second stage is jettisoned.

The third stage's single J-2 engine ignites at separation and burns for about 2 minutes to increase speed to about 16,500 miles an hour and put it and the Apollo spacecraft into a near-circular earth orbit at about 115 statute miles.

During ascent, the crew monitors the launch vehicle displays to be prepared for an abort, if necessary; relays information about boost and the spacecraft to the ground; and monitors critical subsystem displays.

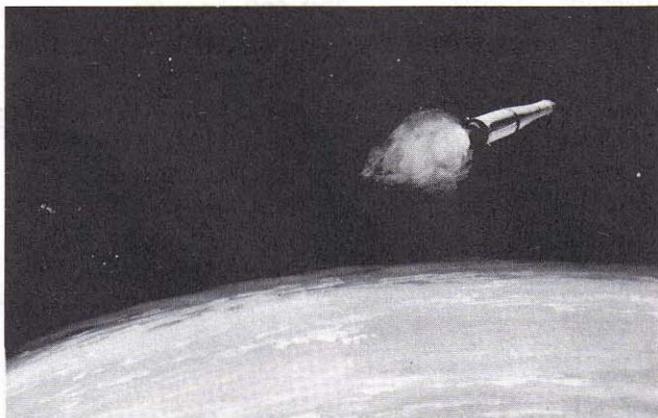
EARTH PARKING ORBIT

The spacecraft is inserted into an earth parking orbit to permit checkout of subsystems before it is committed to lunar flight, and to allow for more than one opportunity for translunar injection (instead of a single one in a direct launch).

The mission allows the spacecraft, with the third stage attached, to orbit the earth up to three times (for 4-1/2 hours) before injection into translunar flight. Because injection is desirable as soon as possible after checkout, the translunar injection maneuver probably will be performed during the second orbit. To inject the spacecraft into translunar flight, the crew reignites the third-stage engine.

TRANSLUNAR INJECTION

The translunar injection parameters are computed with the guidance system in the Saturn V's third-stage instrumentation unit. Thus, the third stage is commanded to fire at the proper moment and for the precise length of time necessary to put the spacecraft into a trajectory toward the moon.



P-19

Third stage fires again for translunar injection

This trajectory is nominally one that provides a "free return" to earth; that is, if for any reason the spacecraft is not inserted into an orbit around the moon, the spacecraft will return to earth.

The third-stage engine burns for about 5-1/2 minutes and cuts off at an altitude of about 190 miles and at a velocity of about 24,300 statute miles an hour.

During the engine thrusting, the crewmen remain in their couches and monitor the main display console.

INITIAL TRANSLUNAR COAST

The manned space flight network tracks the spacecraft for about 10 minutes after third-stage engine cutoff to determine whether to proceed with transposition and docking. During the same period, the third stage maneuvers the spacecraft to the attitude programmed for the transposition, docking, and LM-withdrawal maneuvers.

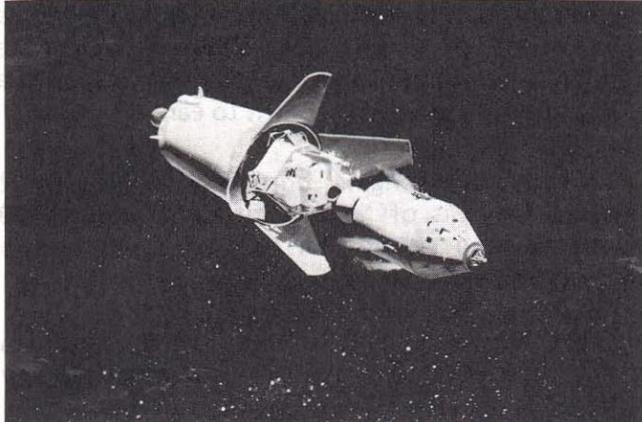
The crewmen position their couches to see out of the docking windows. The commander begins the transposition and docking maneuver by firing the service module reaction control engines. A signal is sent almost simultaneously to deploy and jettison the SLA panels, separate the CSM from the SLA, and deploy the CSM's high-gain antenna. The lunar module remains attached to the adapter.

The commander stops the CSM 50 to 75 feet away from the third stage, turns 180 degrees with a pitch maneuver so the docking windows are facing the LM, rolls the CSM for proper alignment with the LM, closes with the LM, and docks.

After the CSM and LM have docked, the pressure between the CM and the LM is equalized and the CM forward hatch is removed. A check is made to determine that all docking latches are engaged, the CSM-LM electrical umbilicals are connected, and the CM forward hatch is reinstalled. The LM's four connections to the SLA are severed by small explosive charges, and the spacecraft is separated from the SLA and third stage by spring thrusters.

TRANSLUNAR COAST

Now the long journey to the moon begins. It has been three to six hours since liftoff from Kennedy Space Center, depending on the number of earth



P-20

SLA panels jettison and the CSM pulls away

parking orbits, and the crew settles down for the 2-1/2- to 3-1/2-day flight.

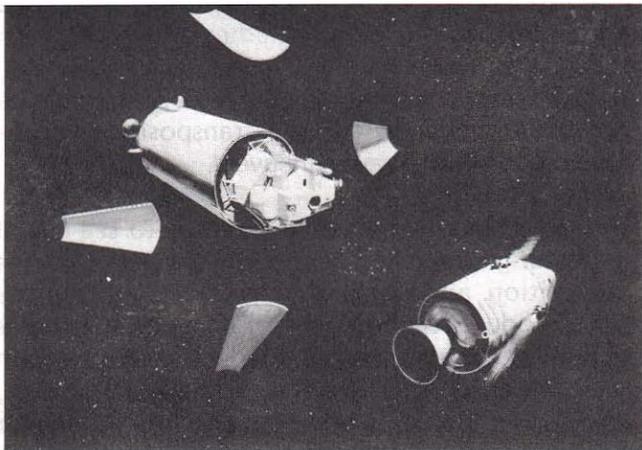
In this phase of the flight, the spacecraft is coasting. At the time of injection into the translunar trajectory, the spacecraft is traveling almost 24,300 miles per hour with respect to the earth. It begins slowing almost immediately because of the pull of earth's gravity. The speed drops until the spacecraft enters the moon's sphere of influence where it again increases due to the moon's gravitational pull.

Shortly after the coast period begins, the spacecraft is oriented for navigation sightings of stars and earth landmarks. The spacecraft is then put into a slow roll (about 2 revolutions an hour) to provide uniform solar heating. This thermal control rolling is stopped for inertial measurement unit alignment and for course corrections.

If tracking from the ground indicates a course correction is needed during the translunar coast, the correction is made with the service propulsion engine when a large change is indicated or with the SM reaction control engines when the change required is small.

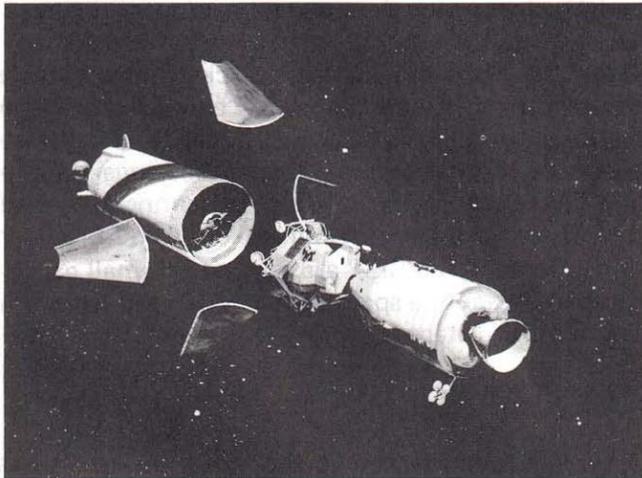
The crew has a number of subsystem duties. Electrical power and environmental control subsystem status checks are conducted. The service propulsion and SM reaction control subsystems are checked. Hydrogen and oxygen purges of the fuel cells are conducted, the lithium hydroxide canisters exchanged and communication with the ground is maintained.

The three astronauts eat in shifts but sleep at the same time. The ground monitors the spacecraft performance continuously and can awaken the crew. Biomedical data is sent to the ground continuously.



P-21

Commander turns CSM around for docking maneuver



P-22

After docking, spring thrusters separate two craft



P-23

Engine retro-fires to put spacecraft in lunar orbit

LUNAR ORBIT INSERTION

Insertion of the spacecraft into lunar orbit is essentially a braking maneuver in which the spacecraft is transferred from the ellipse of the lunar approach to an orbit around the moon.

The insertion maneuver involves the longest firing of the service propulsion engine and results in a reduction in the craft's velocity with respect to the moon from about 5600 to 3600 miles per hour. The insertion may be a two-stage firing of the service propulsion engine, the first to put the CSM in an elliptical orbit of approximately 70-by-195 statute miles and the second to put the CSM in a circular orbit of about 70 miles. The precise timing of the firing and the exact length of the burn or burns are determined by the Mission Control Center in Houston and are programmed into the CM computer, which automatically fires the engine.

During the firing the spacecraft is out of communication with the ground since it will be passing behind the moon. Communications, which require line-of-sight to earth, are lost for about 45 minutes on each 2-hour lunar orbit.

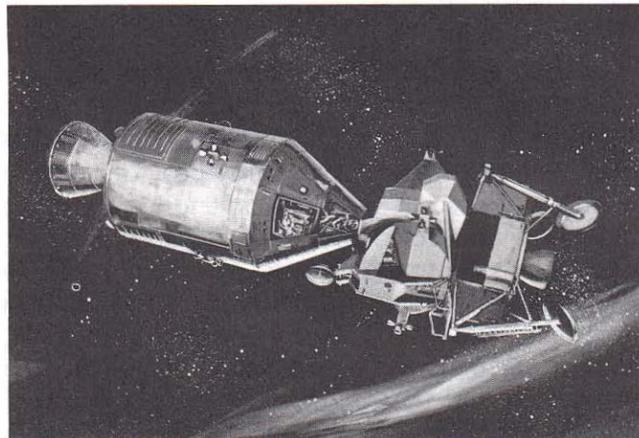
During the maneuver, the crew monitors the display of the velocity change required, the digital event timer, the flight director attitude indicators, and subsystem status displays.

LUNAR ORBIT COAST

The docked CSM and LM orbit the moon until the LM is checked out for descent to the lunar surface. During this time coarse and fine alignments are made of the CSM inertial measurement unit, as is a series of sightings of landmarks on the lunar surface. These operations, each involving changes in spacecraft attitude, are compared with tracking data from the manned space flight network to determine the spacecraft's precise location in orbit with respect to the landing site on the moon.

The CM-LM tunnel and the LM are pressurized, and the CM hatch, the probe, and drogue are removed. The LM hatch is opened to clear the way into the LM. First to transfer to the LM is the LM pilot, who activates the LM's environmental control, electrical power and communications subsystems.

After the commander has transferred to the LM, he and the LM pilot perform a lengthy series of checks

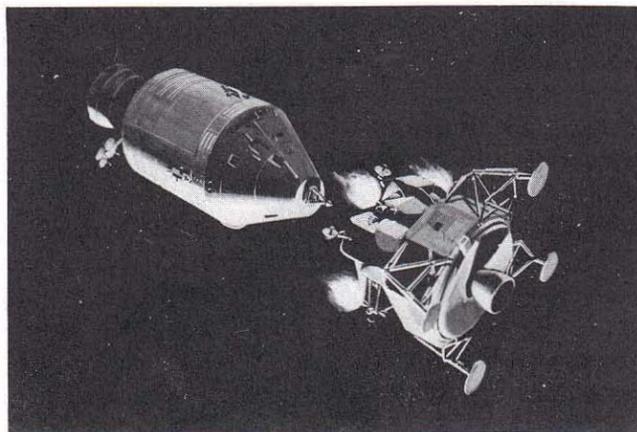


P-24

Two crewmen transfer to LM to prepare for separation

of the LM subsystems. While they do this, the CM pilot is performing another series of alignments and landmark sightings. The CM controls the attitude of the spacecraft during the lunar orbits and during the coarse alignments of the LM inertial measurement unit. (The fine aligning of the LM inertial measurement unit is done after the CSM and LM have separated.)

The probe and drogue are installed, the 12 docking latches are unlatched, the LM hatch is closed, the CM hatch is installed, the LM landing gear is deployed, and guidance computations are made in the final minutes before separation. Then the CM pilot activates the probe extend/release switch which undocks the LM from the CSM. The LM reaction control system moves the LM away from the CSM a short distance and is oriented so the CM pilot can inspect the LM landing gear. The LM's reaction control system then fires again to separate further the LM and CSM.



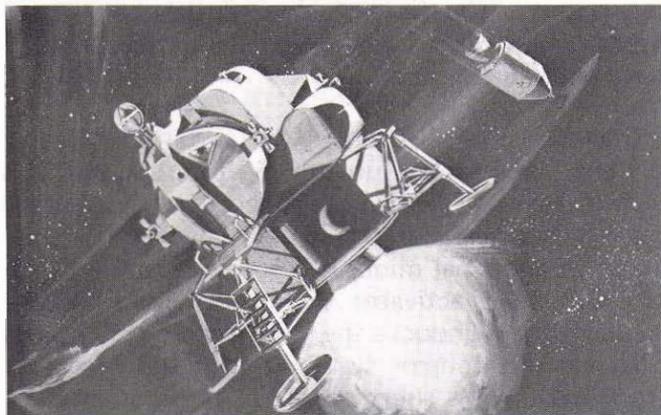
P-25

LM with two men separates from CSM

CSM LUNAR ORBIT

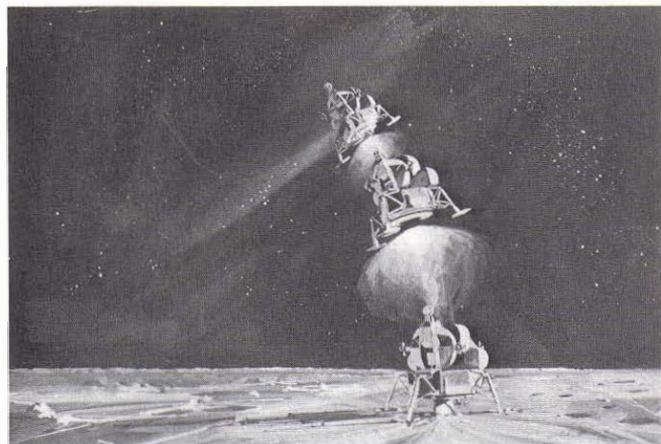
The CSM remains in the 70-mile lunar orbit for about a day and a half, until the LM returns from its moon landing. The CM pilot has many duties during this time and is particularly busy during two periods: LM descent to the moon and LM ascent to rendezvous and docking. His principal jobs during these periods are to monitor the performance of the LM (requiring changes in CSM attitude to keep it in sight), communicate with the LM and with earth, and activate or operate equipment to aid in both the landing and the rendezvous and docking procedures. The CM pilot will have a period to sleep while the LM is on the lunar surface.

After separation, the CSM and LM pass behind the moon, and communications with earth are cut off. During this period, the LM telemeters its data to the CSM, where it is stored and relayed to earth after the CSM emerges from behind the moon.



P-26

LM descends and CSM stays in orbit



P-27

LM's descent engine fires as craft comes in for landing

LM DESCENT

The descent to the moon takes an hour of complex maneuvering that taxes the skills of the astronauts and the capabilities of the lunar module.

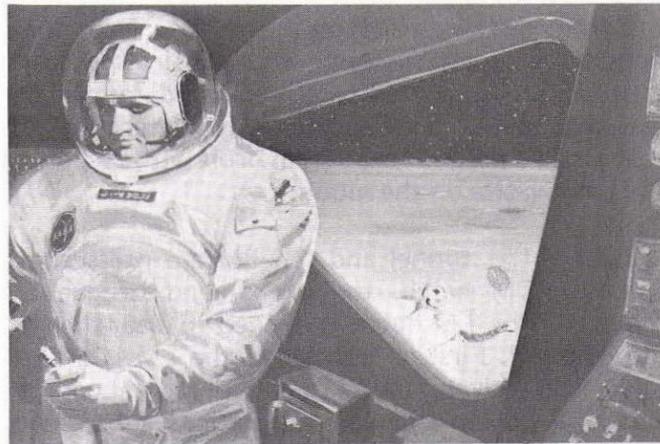
Briefly, the descent will follow this course. The LM fires its descent engine to put it into an elliptical orbit that reaches from about 70 miles to within 50,000 feet of the moon's surface. Near the 50,000 foot altitude at a preselected surface range from the landing site, the engine is fired again in a braking maneuver to reduce the module's speed.

The LM's two-man crew is busy with position and velocity checks, subsystem checks, landing radar test, attitude maneuvering, and preparation of the LM computer or the braking maneuver.

The final approach begins at approximately 9000 feet altitude with a maneuver to bring the landing site into the view of the LM crew. The firing is controlled automatically until the craft reaches an altitude of about 500 feet. When the commander takes over, the LM is pitched at an angle which permits the crewmen to assess the landing site. At about 65 feet altitude, the LM is re-oriented and descends vertically to the surface at about 3 feet per second. The commander shuts off the descent engine as soon as the landing gear touches the moon.

LUNAR STAY

It will be about 4-1/2 hours after landing before the first American steps foot on the moon. Upon landing, the commander and LM pilot first spend

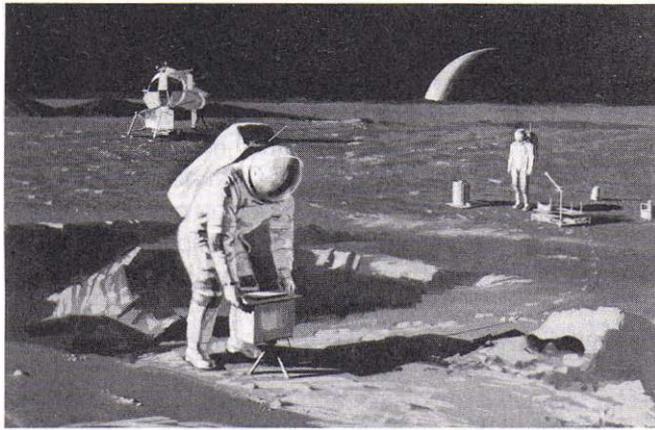


P-28

One astronaut checks LM, other stays inside at first

LM ASCENT

Ascent of the LM from the moon and rendezvous and docking with the orbiting CSM takes three hours.



P-29 *Two astronauts set up scientific equipment on moon*

about two hours checking out the LM ascent stage. Any remaining propellant for the descent engine is vented and the inertial measurement unit is aligned and placed in standby operation. It takes 2 hours for the extravehicular mobility units to be checked out and prepared for use.

Finally, the LM cabin is depressurized, and one of the LM crewmen emerges from the lunar module, descends its ladder, and walks on the moon. He remains alone on the lunar surface for about 20 minutes while he gathers a sample of surface material and transfers it to the crewman in the ascent stage, who has been recording this activity on still and motion picture film.

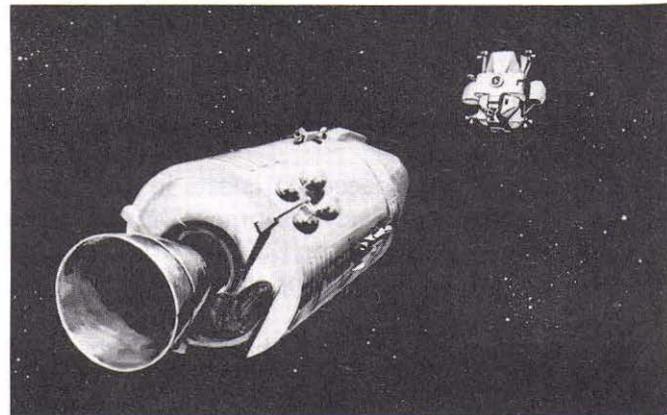
Following a period of equipment transfer between the astronaut in LM cabin, and the astronaut on the lunar surface, the second crewman descends to the surface and the two inspect the LM to determine the effects of the lunar touchdown on the vehicle. The rest of the time in the first surface excursion is consumed by erecting the S-band surface antenna, collecting a preliminary set of geological samples, and making a TV scan of the landing site.

A second lunar exploration period lasts about three hours, with both astronauts on the surface. They have many tasks to perform, including sample collections, photography, exploration of the lunar surface up to about a quarter-mile from the LM, and erection of a station that will continue to send scientific data to earth after the astronauts leave.

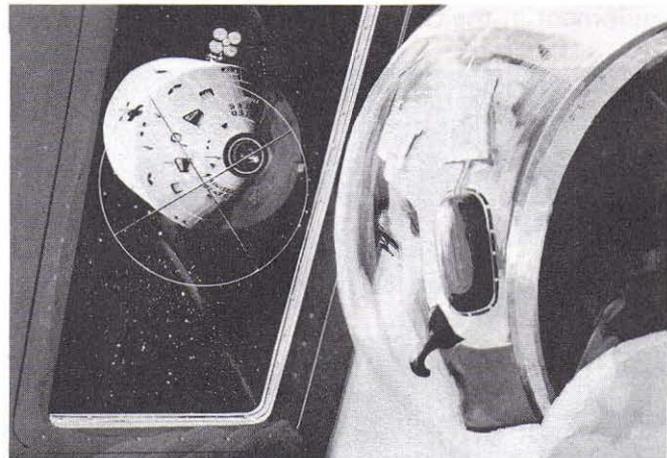
Between the two exploratory periods, the astronauts will have a sleep period. Then, after about 24 to 26 hours on the moon, the astronauts prepare for their return to the CSM.



P-30 *Astronaut fires ascent stage engine to leave moon*



P-31 *LM's ascent stage in rendezvous with orbiting CSM*



P-32 *Commander in LM guides craft to docking with CSM*

When the ascent engine ignites, the ascent stage of the LM separates from the descent stage, using the latter as a launching platform. The engine boosts the ascent stage off the moon into an elliptical orbit of an estimated 60,000 feet by about 11.4 by 34.5 miles.

The next maneuver places the LM in a circular orbit which has a constant altitude distance from that of the CSM. When the LM's orbit is in the proper phase with the CSM orbit, the LM reaction control engines are fired to raise the LM orbit to that of the CSM, about 70 miles. During these maneuvers the CM pilot tracks the LM.

The LM takes about 30 minutes to intercept the CSM, during which course corrections are made with the reaction control engines. The firings are controlled by the LM computer on the basis of data supplied by the ground. The LM closes on the CSM through a series of short reaction control engine firings. The commander takes over control of the LM and maneuvers it with short bursts of the reaction control engines to a docking with the CSM.

LUNAR ORBIT COAST

After docking, the spacecraft coasts in lunar orbit while the crew transfers equipment and samples into the CSM, returns to the CSM, jettisons the LM ascent stage, and prepares for transearth injection.

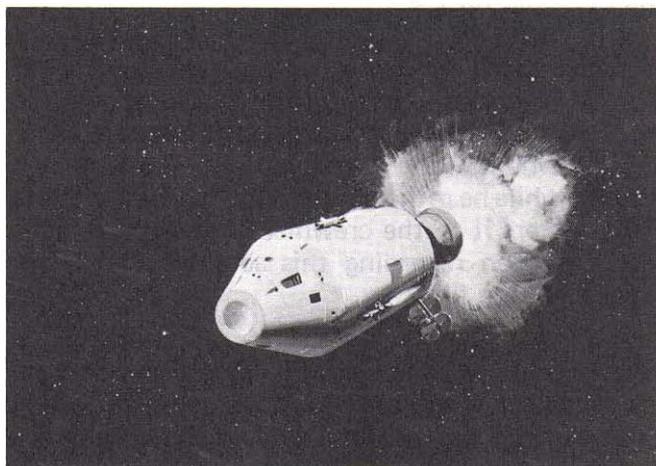
The LM crew opens the LM hatch after the CSM and LM pressures have been equalized and the CM pilot removes the CM tunnel hatch. The drogue and probe are removed and stowed in the LM. Lunar samples, film, and equipment to be returned to earth are transferred from the LM to the CM; equipment in the CM that is no longer needed is put

into the LM and the LM hatch is closed, the CM hatch is replaced, and the seal checked.

The LM is jettisoned by firing small charges around the CM docking ring. The entire docking mechanism separates from the CM and remains with the LM ascent stage. The SM reaction control engines are fired in a short burst to assure separation and to put the CSM into the lead in the orbit.

TRANSEARTH INJECTION

The service propulsion engine injects the CSM into a trajectory for return to earth. The engine fires for about 2-1/2 minutes to increase the spacecraft's velocity relative to the moon from about 3600 to nearly 5500 miles per hour. This maneuver takes place behind the moon, out of communications with earth. Communication is regained about 20 minutes after the engine has cut off.



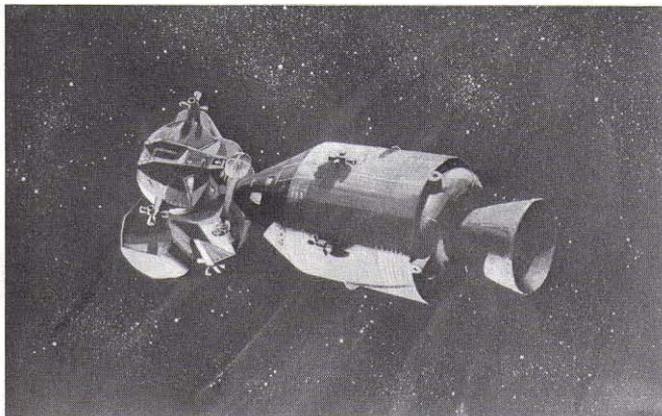
P-34

After jettisoning LM, the CSM heads for earth

TRANSEARTH COAST

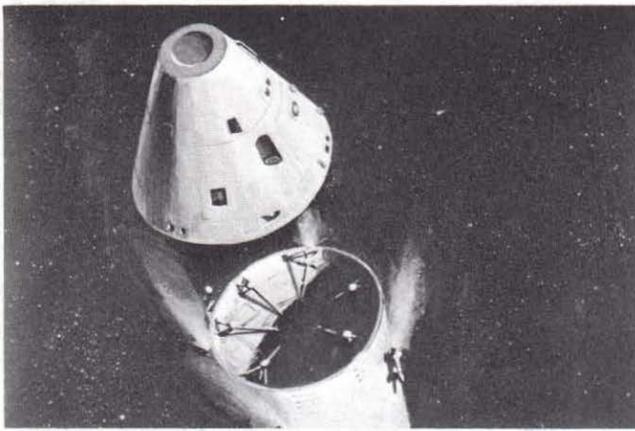
The trip from lunar orbit back to the earth's atmosphere could be the longest phase of the mission, lasting anywhere from 80 to 110 hours. The spacecraft's velocity on the coast back gradually decreases because of the moon's gravitational pull and then increases again when the spacecraft comes into the earth's sphere of influence. When the spacecraft enters the atmosphere, its velocity has increased to about 25,000 miles per hour.

Crew duties during the homeward coast are similar to those of the outbound journey. The spacecraft is again in a slow roll for thermal control. Crewmen make any necessary course corrections, maneuver

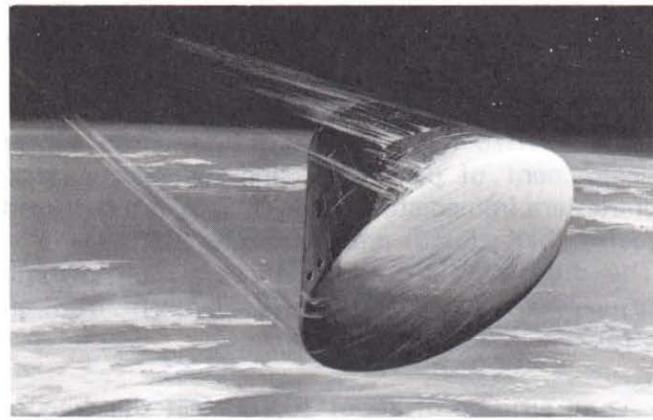


P-33

Astronauts return to CM, prepare to jettison LM



P-35 *Shortly before entry, the CM separates from SM*



P-37 *Aft heat shield chars to absorb 5,000-degree heat*

the spacecraft for inertial measurement unit alignments and regularly check subsystems.

About three and a half hours before entry, the CSM is rotated and held in an attitude that puts the forward heat shield of the CM in shadow. This cooling of the shield lasts for about an hour and a half, after which the attitude must be changed for the final course correction.

Shortly before entry into the earth's atmosphere, the service module is jettisoned. The CM and SM are separated by small explosive devices in the SM. The SM reaction control engines fire simultaneously to increase separation and assure that the two modules will not collide.

ENTRY

The desired entry conditions include the arrival of the CSM at a particular point above earth at a

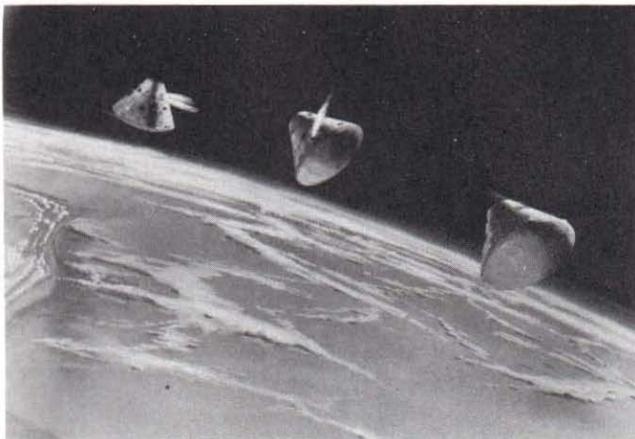
particular time and with a proper flight path angle, neither too steep nor too shallow.

Entry is considered to begin at an altitude of about 400,000 feet, when the CM begins to meet the resistance of the atmosphere. At this point the CM is traveling about 24,500 miles an hour, and the heat generated on its plunge through the atmosphere may reach 5000 degrees Fahrenheit on the blunt aft heat shield.

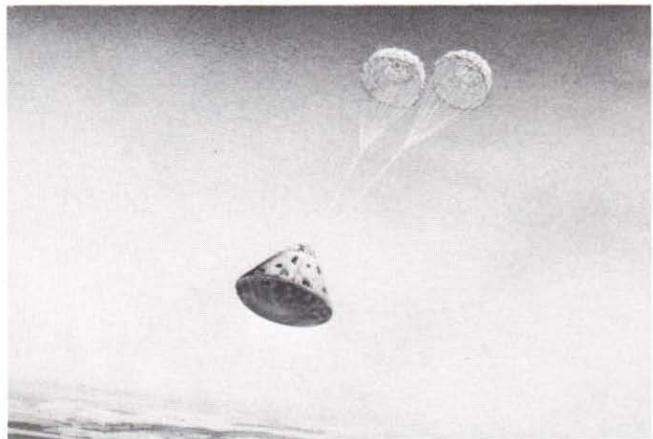
But despite the heat generated on the outside of the CM, its cabin will remain at 80 degrees. The maximum gravitational forces felt by the astronauts will be a little over 5 G's.

LANDING

The landing is controlled automatically by the earth landing subsystem, although the crew has



P-36 *CM is oriented blunt end forward for entry*

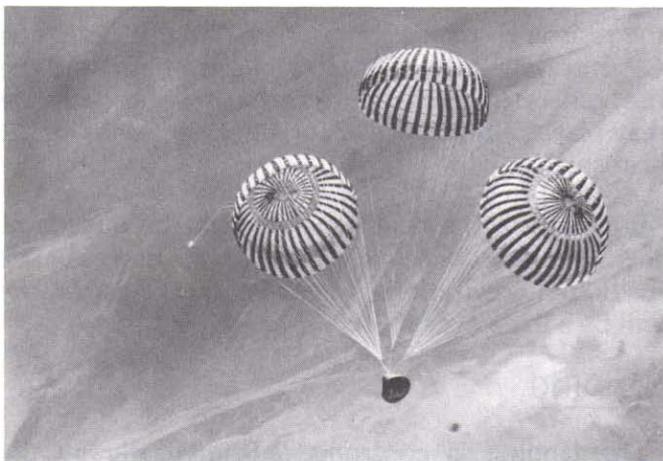


P-38 *Drogue chutes open to provide initial slowing*

backup controls. At about 24,000 feet, a barometric switch closes to start the subsystem in operation.

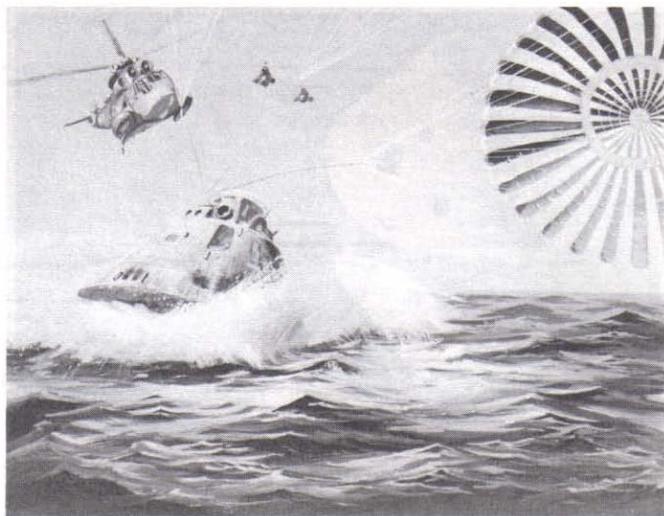
The forward heat shield is jettisoned to permit deployment of parachutes, and the drogue parachutes are immediately released. They are deployed reefed (half closed) and open after a few seconds. The drogues orient the CM for main parachute deployment and reduce the CM's speed from an estimated 325 to 125 miles an hour.

At an altitude of about 10,700 feet the drogues are disconnected and the pilot parachutes are deployed. They pull out the main parachutes. The main parachutes are double reefed, which means they open in two stages. They further slow the CM, and final descent and splashdown is made at about 22 miles an hour.



P-39

CM drifts gently to splashdown on main chutes



P-40

Recovery helicopters move in as CM floats in water

As soon as the main parachutes are disreefed, the crewmen start burning the remaining reaction control propellant, activate the VHF recovery beacon, adjust their couches for landing, and purge the propellant lines. Final descent on the main parachutes takes about 5 minutes.

In addition to the recovery beacon deployed by the crew, two VHF antennas are deployed automatically shortly after the main parachutes are deployed. These provide voice communication with the recovery forces. The recovery beacon transmits a continuous signal.

The main parachutes are released by the crew at splashdown and postlanding ventilation is turned on.