APOLLO 10

The Fourth Mission:
Testing the LM in Lunar Orbit
18 May–26 May 1969

Background

Apollo 10 was a Type F mission, a piloted lunar module demonstration in lunar orbit, the dress rehearsal for the first piloted landing on the Moon. It was also the first time all members of a three-person crew had previously flown in space.

The primary objectives were:

- to demonstrate crew, space vehicle, and mission support facilities performance during a piloted lunar mission with command and service modules and lunar module; and

- to evaluate lunar module performance in the cislunar and lunar environment.

The mission events simulated those for a lunar landing mission. In addition, visual observations and stereoscopic strip photography of Apollo Landing Site 2 (first planned lunar landing site) would be attempted.

The crew members were Colonel Thomas Patten Stafford (USAF), commander; Commander John Watts Young (USN), command module pilot; and Commander Eugene Andrew "Gene" Cernan (USN), lunar module pilot.

Selected as an astronaut in 1962, Stafford was making his third spaceflight. He had been pilot of Gemini 6-A and command pilot of Gemini 9-A. Born 17 September 1930 in Weatherford, Oklahoma, Stafford was 38 years old at the time of the Apollo 10 mission. He received a B.S. from the U.S. Naval Academy in 1952. His backup was Colonel Leroy Gordon Cooper, Jr. (USAF).

Young was also making his third spaceflight, having been pilot on Gemini 3 and command pilot of Gemini 10. Born 24 September 1930 in San Francisco, California, Young was 38 years old at the time of the Apollo 10 mission. Young received a B.S. in aeronautical engineering from the Georgia Institute of Technology in 1952, and was selected as an astronaut in 1962. His backup was Lt. Colonel Donn Fulton Eisele [EYES-lee} (USAF).

Cernan had been pilot of Gemini 9-A. Born 14 March 1934 in Chicago, Illinois, he was 35 years old at the time of the Apollo 10 mission. Cernan received a B.S. in electrical engineering from Purdue University in 1956 and an M.S. in aeronautical engineering from the U.S. Naval Postgraduate School in 1963, and was selected as an astronaut in 1963. His backup was Commander Edgar Dean Mitchell (USN).

The capsule communicators (CAPCOMs) were Major Charles Moss Duke, Jr. (USAF), Major Joe Henry Engle (USAF), Major Jack Robert Lousma (USMC), and Lt. Commander Bruce McCandless, II (USN). The support crew consisted of Engle, Lt. Col. James Benson Irwin (USAF), and Duke. The flight directors were Glynn S. Lunney and Gerald D. Griffin (first shift), Milton L. Windler (second shift), and M. P. "Pete" Frank (third shift).

The Apollo 10 launch vehicle was a Saturn V, designated SA-505. The mission also carried the designation Eastern Test Range #920. The CSM was designated CSM-106, and had the call-sign "Charlie Brown." The lunar module was designated LM-4, and had the call-sign "Snoopy." The call-signs were taken from the popular comic strip Peanuts©[1] by Charles L. Schultz. For this mission, Snoopy the Beagle exchanged his traditional World War I flying ace goggles and scarf for a space helmet. At the Manned Spacecraft Center, Snoopy was the symbol of quality performance.

Launch Preparations

The terminal countdown was picked up at 01:00:00 GMT on 17 May 1969 and proceeded with no unscheduled holds. The primary LOX replenish pump failed to start at T-8 hours due to a blown fuse in the pump motor starter circuit. Troubleshooting and fuse replacement delayed LOX loading by 50 minutes but it was completed by T-4 hours 22 minutes. The lost time was made up during the scheduled 1-hour hold at T-3 hours 30 minutes.

A high pressure cell in the Atlantic Ocean off the New England coast caused southeasterly surface winds and brought moisture into the Cape Canaveral area, which contributed to overcast conditions. At launch time, cumulus clouds covered 40 percent of the sky (base 2,200 feet), altocumulus covered 20 percent (base 11,000 feet), and cirrus covered 100 percent (base not recorded); the temperature was 80.1° F; the relative humidity was 75 percent; and the barometric pressure was 14.779 lb/in^2. The winds, as measured by the anemometer on the light pole 60.0 feet above ground at the launch site, measured 19.0 knots at 142° from true north.

Ascent Phase

Apollo 10 was launched from Kennedy Space Center Launch Complex 39, Pad B, at a Range Zero time of 16:49:00 GMT (12:49:00 p.m. EDT) on 18 May 1969, and was the first piloted launch from this pad. The launch window extended to 21:09 GMT to take advantage of a sun elevation angle on the lunar surface of 11°.

Between 000:00:13.05 and 000:00:32.3, the vehicle rolled from a launch pad azimuth of 90° to a flight azimuth of 72.028°. The S-IC engine shut down at 000:02:41.63, followed by S-IC/S-II separation, and S-II engine ignition. The S-II engine shut down at 000:09:12.64 followed by separation from the S-IVB, which ignited at 000:09:16.81. The first S-IVB engine cutoff occurred at 000:11:43.76, with deviations from the planned trajectory of only -0.23 ft/sec in velocity and only -0.08 n mi in altitude.

The S-IC stage impacted the Atlantic Ocean at 000:08:59.12 at latitude 30.188° north and longitude 74.207° west, 348.80 n mi from the launch site. The S-II stage impacted the Atlantic Ocean at 000:20:17.89 at latitude 31.522° north and longitude 34.512° west, 2,389.29 n mi from the launch site.

The maximum wind conditions encountered during ascent were 82.6 knots at 270° from true north at 46,520 feet, with a maximum wind shear of 0.0203 sec^{-1} at 50,200 feet.

Parking orbit conditions at insertion, 000:11:53.76 (S-IVB cutoff plus 10 seconds to account for engine tailoff and other transient effects), showed an apogee and perigee of 100.32 by 99.71 n mi, an inclination of 32.546°, a period of 88.20 minutes, and a velocity of 25,567.88 ft/sec. The apogee and perigee were based upon a spherical Earth with a radius of 3,443.934 n mi.

The international designation for the CSM upon achieving orbit was 1969-043A and the S-IVB was designated 1969-043B. After undocking at the Moon, the LM would be designated 1969-018C.

Earth Orbit Phase

After inflight systems checks, the 343.08-second translunar injection maneuver (second S-IVB firing) was performed at 002:33:27.52. The S-IVB engine shut down at 2:39:10.58 and translunar injection occurred ten seconds later, after 1.5 Earth orbits lasting 2 hours 27 minutes 16.82 seconds, at a velocity of 35,562.96 ft/sec.

Translunar Phase

At 003:02:42.4, the CSM was separated from the S-IVB stage. It was transposed and then docked with the LM at 003:17:36.0. The docked spacecraft were ejected at 003:56:25.7 and a separation maneuver was performed at 004:39:09.8. The sequence was televised to Earth starting at 003:06:00 for 22 minutes and from 003:56:00 for 13 minutes 25 seconds. Additional television broadcasts during translunar coast included:

Television Transmissions—Translunar Coast

Start GET	Duration (mm:ss)	Subject
005:06:34	13:15	View of Earth and spacecraft interior
007:11:27	24:00	View of Earth and spacecraft interior
027:00:48	27:43	View of Earth and spacecraft interior
048:00:51	14:39	View of Earth and spacecraft interior (recorded)
048:24:00	03:51	View of Earth and spacecraft interior (recorded)
049:54:00	04:49	View of Earth
053:35:30	25:00	View of Earth and spacecraft interior
072:37:26	17:16	View of Earth and spacecraft interior

A ground command for propulsive venting of residual propellants targeted the S-IVB to go past the Moon. The closest approach of the S-IVB to the Moon was 1,680 n mi, at 078:51:03.6 on May 21 at 23:40 GMT. The trajectory after passing from the lunar sphere of influence resulted in a solar orbit with an aphelion and perihelion of 82.160 million by 73.330 million n mi, an inclination of 23.46, and a period of 344.88 days.

A preplanned, 7.1-second, midcourse correction of 49.2 ft/sec was executed at 026:32:56.8 and adjusted the trajectory to coincide with a July lunar landing trajectory. The maneuver was so accurate that two additional planned midcourse corrections were canceled. The passive thermal control technique was employed to maintain desired spacecraft temperatures throughout the translunar coast except when a specific attitude was required.

At 075:55:54.0, at an altitude of 95.1 n mi above the Moon, the service propulsion engine was fired for 356.1 seconds to insert the spacecraft into a lunar orbit of 170.0 by 60.2 n mi. The translunar coast had lasted 73 hours 22 minutes 29.5 seconds.

Lunar Orbit Phase

After two revolutions of tracking and ground updates, a 13.9-second maneuver was performed at 080:25:08.1 to circularize the orbit at 61.0 by 59.2 n mi.

A 29-minute 9-second scheduled color television transmission of the lunar surface was conducted at 080:44:40, with the crew describing the lunar features below them. The picture quality of lunar scenes was excellent.

The lunar module pilot entered the LM at 081:55 for two hours of “housekeeping” activities and some LM communications tests. The tests were terminated following the LM relay communications tests due to time limitations. Results were excellent, and the remaining tests were conducted later in the mission.

At 095:02, the commander and lunar module pilot entered to activate LM systems and discovered that the LM had moved 3.5 degrees out of line with the CM. The crew feared that separating the two spacecraft might shear off some of the latching pins, possibly preventing redocking. But mission control reported that as long as the misalignment was less than six degrees, there would be no problem. Undocking occurred at 098:29:20 and was televised for 20 minutes 10 seconds starting at 098:13:00. During this period, the LM landing gear were deployed and all LM systems checked out.

A 8.3-second CSM reaction control system maneuver at 098:47:17.4 separated the CSM to about 30 feet from the LM.

The CSM was in an orbit of 62.9 by 57.7 n mi at the time. Stationkeeping was initiated at this point while the command module pilot visually inspected the LM. The CSM reaction control system was then used to perform the separation maneuver directed radially downward toward the Moon's center. This maneuver provided a separation at descent orbit insertion of about 2 n mi from the LM.

Following stationkeeping, a 27.4-second LM descent propulsion system burn at 099:46:01.6 inserted the LM into a descent orbit of 60.9 by 8.5 n mi so that the resulting lowest point in the orbit occurred about 15° from lunar landing site 2.

Numerous photographs of the lunar surface were taken. Some camera malfunctions were reported and although some communications difficulties were experienced, the crew provided a continuous commentary of their observations. An hour later, the LM made a low-level pass over Apollo landing site 2. The pass was highlighted by a test of the landing radar, visual observation of lunar lighting, stereoscopic strip photography, and execution of the phasing maneuver using the descent engine. The lowest measured point in the trajectory was 47,400 feet (7.8 n mi) above the lunar surface at 100:41:43.

The second LM maneuver, a 39.95-second descent propulsion system phasing burn at 100:58:25.93, established a lead angle equivalent to that which would occur at powered ascent cutoff during a lunar landing, and put the LM into an orbit of 190.1 by 12.1 n mi.

At 102:44:49, during preparations for rendezvous with the CSM, the LM started to wallow off slowly in yaw, and then stopped. At 102:45:12, it started a rapid roll accompanied by small pitch and yaw rates. The ascent stage was then separated from the descent stage at 102:45:16.9 at an altitude of 31.4 n mi and the motion was stopped eight seconds later. A 15.55-second firing of the ascent engine at 102:55:02.13 placed the ascent stage into an orbit of 46.5 by 11.0 n mi. The descent stage went into lunar orbit.

Analysis revealed that the cause of the anomalous motion was human error. Inadvertently, the control mode of the LM abort guidance system was returned to AUTO rather than being left in the ATTITUDE HOLD mode for staging. In AUTO, the abort guidance system drove the LM to acquire the CSM which was not in accordance with the planned attitude timeline. The commander took over manual control to reestablish the proper attitude.

At the orbital low point, the insertion maneuver was performed on time using the LM ascent propulsion system. This burn established the equivalent of the standard LM insertion orbit of a lunar landing mission (45 x 11.2 n mi). The LM coasted in that orbit for about one hour. The terminal maneuver occurred at about the midpoint of darkness, and braking during the terminal phase finalization was performed manually as planned.

The rendezvous simulated one that would follow a normal ascent from the lunar surface. It started with a 27.3-second LM coelliptic sequence initiation maneuver at 103:45:55.3, which placed the spacecraft into an orbit of 48.7 by 40.7 n mi. This was followed by a 1.65-second constant differential height maneuver at 104:43:53.28 which raised the perigee to 42.1 n mi. The 16.50-second terminal phase initiation maneuver at 105:22:55.58 then raised the orbit to 58.3 by 46.8 n mi. Docking was complete at 106:22:02 at an altitude of 54.7 n mi after 8 hours 10 minutes 5 seconds of lunar flight.

Once docked, the LM crew transferred the exposed film packets to the CM. The LM ascent stage was jettisoned at 108:24:36. A 6.5-second separation maneuver at 108:43:23.3 raised the LM orbit to 64.0 by 56.3 n mi. This was followed at 108:52:05.5 (about one revolution after jettison) by a 249.0-second remote control firing to depletion of the ascent engine. This burn, commanded as planned, utilized the LM ascent engine arming assembly and was targeted to place the LM into a solar orbit. Communications were maintained until LM ascent stage battery depletion at about 120:00. The ascent stage batteries lasted about 12 hours after LM jettison.

Prior to transearth injection, views of the lunar surface and spacecraft interior were transmitted to Earth for 24 minutes 12 seconds starting at 132:07:12.

After a rest period, the crew conducted landmark tracking and photography exercises. During the remaining lunar orbital period or operation, 18 landmark sightings, and extensive stereo and oblique photographs were taken. Two scheduled TV periods were deleted because of crew fatigue.

Transearth injection was achieved at 137:39:13.7 at a velocity of 8,987.2 ft/sec, following a 164.8-second engine firing at 56.5 n mi altitude. The spacecraft had been in lunar orbit for 31 lunar orbits lasting 61 hours 37 minutes 23.6 seconds.

Transearth Phase

Transearth activities included a number of star-Earth horizon navigation sightings and the CSM S-band high gain reflectivity test which was conducted at 168:00. The passive thermal control technique and the navigation procedures used on the translunar portion of the mission were also used during the return trip.

The only midcourse correction required was a 6.7-second, 2.2 ft/sec, maneuver at 188:49:58.0, three hours before CM/SM separation.

Six television transmissions were made on the return trip and were broadcast to Earth. The duration of the transmissions and the subjects were as follows:

Television Transmissions—Return Trip

Start GET	Duration (mm:ss)	Subject
137:50:51	43:03	View of Moon after transearth injection
139:30:16	06:55	View of Moon after transearth injection
147:23:00	11:25	View of receding Moon and spacecraft interior
152:29:19	29:05	View of Earth, Moon, and spacecraft interior
173:27:17	10:22	View of Earth and spacecraft interior
186:51:49	11:53	View of Earth and spacecraft interior

The service module was jettisoned at 191:33:26, and the CM entry followed a normal profile. The command module reentered Earth's atmosphere (400,000 feet altitude) at 191:48:54.5 at a velocity of 36,314 ft/sec, following a transearth coast of 54 hours 3 minutes 40.9 seconds[2]. The service module impacted the Pacific Ocean at a point estimated to be latitude 19.4° south and longitude 173.37° west.

Recovery

The parachute system effected a soft splashdown of the CM in the Pacific Ocean at 16:52:23 GMT (12:52:23 p.m. EDT) on 26 May. Mission duration was 192:03:23. The impact point was about 1.3 n mi from the target point and 2.9 n mi from the recovery ship U.S.S. Princeton. The splashdown site was estimated to be latitude 15.07° south and longitude 164.65° west.

After splashdown, the CM assumed an apex-up flotation attitude. The crew was retrieved by helicopter and was aboard the recovery ship 39 minutes after splashdown. The CM was recovered 57 minutes later. The estimated CM weight at splashdown was 10,901 pounds, and the estimated distance traveled for the mission was 721,250 n mi.

At CM retrieval, the weather recorded onboard the Princeton showed 10 percent cloud cover at 2,000 feet and 20 percent at 7000 feet; visibility 10 n mi; wind speed five knots from 100° true north; air temperature unknown; water temperature 85° F; with waves to three feet.

The CM was offloaded from the Princeton on 31 May at Ford Island, Hawaii, and the Landing Safing Team began the evaluation and deactivation procedures at 18:00 GMT. Deactivation was completed at 05:56 GMT on 3 June. The CM was flown to Long Beach, California, where it arrived at 10:15 GMT on 4 June. It was trucked the same day to the North American Rockwell Space Division facility in Downey, California, for postflight analysis.

All systems in the CSM and the LM were managed very well. Although some problems occurred, most were minor and none caused a constraint to completion of mission objectives. Valuable data concerning lunar gravitation were obtained during the 61 hours in lunar orbit.

Spacecraft systems performance was satisfactory, and all mission objectives were accomplished. All detailed test objectives were satisfied with the exception of the LM steerable antenna and relay modes for voice and telemetry communications.

Conclusions

The Apollo 10 mission provided the concluding data and final environmental evaluation to proceed with a lunar landing. The following conclusions were made from an analysis of post-mission data:

1. The systems in the command and service modules and lunar module were operational for a piloted lunar landing.
2. The crew activity timeline, in those areas consistent with the lunar landing profile, demonstrated that critical crew tasks associated with lunar module checkout, initial descent, and rendezvous were both feasible and practical without unreasonable crew workload.
3. The lunar module S-band communications capability using either the steerable or the omni-directional antenna was satisfactory at lunar distances.
4. The operating capability of the landing radar in the lunar environment during a descent propulsion firing was satisfactorily demonstrated for the altitudes experienced.
5. The range capability of the lunar module rendezvous radar was demonstrated in the lunar environment with excellent results. Used for the first time, VHF ranging information from the CM provided consistent correlation with radar range and range-rate data.
6. The lunar module abort guidance system capability to control an ascent propulsion system maneuver and to guide the spacecraft during rendezvous was demonstrated.
7. The capability of the Mission Control Center and the Manned Space Flight Network to control and monitor two vehicles at lunar distance during both descent and rendezvous operations was proven adequate for a lunar landing.
8. The lunar potential model was significantly improved over that of Apollo 8, and the orbit determination and prediction procedures proved remarkably more precise for both spacecraft in lunar orbit. After a combined analysis of Apollo 8 and 10 trajectory reconstructions, the lunar potential model was expected to be entirely adequate for support of lunar descent and ascent.

[1] Copyright United Features Syndicate.
[2] The Guinness Book Of World Records states that Apollo 10 holds the record for the fastest a human has ever traveled: 24,791 st mi per hour at 400,000 feet altitude (entry) on 26 May 1969. However, the Apollo 10 mission report states the maximum speed at entry was 36,397 feet per second, or 24,816 st mi per hour.

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