MSC-04768

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 15 MISSION
5-DAY REPORT

FACILITY FORM 602

N71-37427
(ACCESSION NUMBER)
46
(PAGES)
TMX-67381
(... OR AD NUMBER)

(THRU)
G3
(CODE)
30
(CATEGORY)

DISTRIBUTION AND REFERENCING

This paper is not suitable for general distribution or referencing. It may be referenced only in other working correspondence and documents by participating organizations.

MANNED SPACECRAFT CENTER
HOUSTON, TEXAS
AUGUST 1971

MSC-04768

APOLLO 15 MISSION

5-DAY REPORT

PREPARED BY

Mission Evaluation Team

APPROVED BY

James A. McDivitt

James A. McDivitt
Colonel, USAF
Manager, Apollo Spacecraft Program

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MANNED SPACECRAFT CENTER

HOUSTON, TEXAS

August 1971

PREFACE

This report is based on an evaluation of preliminary data, and the stated values are subject to change in the Mission Report. Unless otherwise stated, all times are referenced to range zero, the integral second before lift-off; range zero was 13:34:00 G.m.t., July 26, 1971. All distances quoted in miles are nautical miles.

SUMMARY

The successful Apollo 15 mission, the first of three flights in the J series of Apollo missions, was launched from Kennedy Space Center, Florida at 9:34:00 a.m. e.d.t. (13:34:00 G.m.t.) on July 26, 1971. The spacecraft was manned by Colonel David R. Scott, Commander; Major Alfred J. Worden, Command Module Pilot; and Lt. Colonel James B. Irwin, Lunar Module Pilot. The spacecraft/S-IVB combination was inserted into a parking orbit of 91.5 by 92.5 miles for systems checkout and preparation for translunar injection, which was initiated about 2 3/4 hours after lift-off.

Shortly after the command and service module separated from the S-IVB, the color television camera was activated to observe docking with the lunar module, and separation of the combined spacecraft from the S-IVB. The crew observed the venting of the S-IVB tanks which was followed by the auxiliary propulsion system firing which targeted the S-IVB to a lunar impact. During the separation phase, a shorted condition in the control circuit to bank A of the service propulsion system occurred, requiring bank A to be used in the manual mode for the lunar orbit insertion and transearth injection firings. The first midcourse correction was performed at about 28 3/4 hours with a velocity change of 5.3 ft/sec, and the second midcourse correction of 5.4 ft/sec was performed at about 73 1/2 hours.

The service propulsion system was fired for 398.4 seconds during the lunar orbit insertion maneuver at about 78 1/2 hours, inserting the spacecraft into a lunar orbit 170.1 by 57.7 miles. The impact of the S-IVB stage at about 79 1/2 hours was recorded by the Apollo 12 and 14 siesmometers, and was about 79 miles from the preselected point, and approximately 100 miles east/northeast of the Apollo 14 landing site. The descent orbit insertion maneuver was performed at about 82 1/2 hours. Some 13 hours later, a 3.2 ft/sec trim maneuver was required to raise the periline altitude. The spacecraft were separated at about 100 3/4 hours, after which a 68.3 ft/sec circularization maneuver was performed using the service propulsion system.

The 741-second powered descent initiation maneuver was performed at 104:30:09 and the lunar module landed in the Hadley Rille region of the moon at 104:42:30. At lunar touchdown, the low-level propellant light illuminated, indicating a total hover time of 111 seconds remaining. The best estimate of the landing location is 26 degrees 6 minutes 10 seconds north latitude and 3 degrees 38 minutes 55 seconds east longitude on the Rima Hadley Lunar Photomap, First Edition, April 1970.

About two hours after landing, the Commander performed a 33-minute standup extravehicular activity by extending his upper body through the top hatch. From this position, he described and photographed the surrounding lunar terrain.

The first lunar extravehicular activity began at 119:39:10. The crew egressed, activated the television camera, made relevant comments, and quickly became acclimated to the lunar environment. The lunar rover vehicle, Apollo lunar surface experiments package, and related gear were unstowed. Some difficulty was experienced in detaching the rover from the lunar module. Checkout of the rover disclosed that there were no voltage or current readouts on battery 2 and that there was no front-wheel steering capability. After verifying that all other rover systems were operative and that adequate vehicle control could be ..intained with rear wheel steering, the crew proceeded to explore the lunar surface. The first traverse was made by passing close to Nameless, Qua nt, Pooh and Canyon Craters on the way to the first stop at Elbow Crater. An enthusiastic crew provided a colorful commentary on the lunar features as they were observed and as samples were obtained and documented. Hadley Rille and St. George Crater were covered in exacting detail. The return traverse was made using the lunar rover vehicle navigation system, which provided accurate vectoring to the lunar module landing site. After returning to partially unload and to retrieve additional gear, the crew drove to the selected Apollo lunar surface experiments package deployment site, approximately 360 feet west/northwest of the lunar module. The Apollo lunar surface experiments package was deployed and two drilling operations were partially performed. The lunar surface was more difficult to drill than expected. Duration of the first lunar surface extravehicular activity was 6 hours and 32 minutes.

The second traverse began at about 142 1/4 hours and after recycling rover switches and circuit breakers, the rover front wheel steering was restored. This traverse was east of the first, but also in a southerly direction. Passing in sight of Index, Arbeit, Crescent, Dune, and Spur Craters, the crew stopped in the sampling area. The return traverse closely followed the outbound route. The drilling was completed, and the second of two probes was emplaced while the nearby area was photographed. Returning to the lunar module, the United States flag was errected, and samples were stowed. This traverse lasted approximately 7 1/4 hours and communications were satisfactory despite the fact that Lunar Module Pilot had operated with a broken antenna blade, which was repaired with tape prior to the extravehicular activity.

The third day of lunar exploration was cut short in order to rest the crew and to meet the lift-off timeline. A curtailed traverse was made to pick up the deep core samples, visit Scarp and Rim Craters and investigate the region named The Terrace. The traverse was roughly west in direction from the landing site. More samples were obtained and trouble was experienced with the 16- and 70-mm cameras. On return, the rover was parked at a vantage point to allow television coverage of lift-off. During the three extravehicular periods totaling 19 hours 46 minutes and 12 seconds of lunar exploration, approximately 171 pounds of lunar material were collected for return to earth. Audio transmissions were good, but an increasing problem with a slipping clutch on the television camera prevented television tracking of lunar module ascent. Dust and high sun angles caused some heat management problems with the communications equipment, and television picture quality was degraded; however, the crew dusted the space radiators and camera lens, and this restored near nominal operation.

After 66 hours 54 minutes and 53 seconds on the lunar surface, the ascent stage lifted off the lunar surface at 171:37:23 and attained a 42.5 by 9.0 mile orbit. From this orbit, the crew performed a nominal lunar-module-active rendezvous, and docking was completed at about 173-1/2 hours.

During the lunar stay, the command and service modules had orbited the moon 34 times and functioned as a scientific satellite. The lunar module was jettisioned one revolution later than planned because of difficulty with the tunnel venting or sealing. Jettisoning occurred at about 179 1/2 hours, and the lunar module deorbit maneuver was initiated about 1 1/2 hours later. Lunar module impact occurred at 181:29:36 at 26 degrees 21 minutes north latitude and 0 degrees 15 minutes east longitude, about 12 miles from the planned impact point and about 50 miles west of the Apollo 15 landing site. Impact was recorded by the Apollo 12, 14, and 15 seismic stations.

The laser altimeter malfunctioned after 24 lunar revolutions and could not be restored to an operative condition. The lunar surface television camera which had provided good coverage of lift-off, was cycled on again at about 211 1/4 hours and operated normally for about 13 minutes before the downlink signal was abruptly lost. All efforts have failed to restore video transmission. The subsatellite was deployed at about 222 1/2 hours. All systems are operating and the subsatellite orbit is approximately 76.3 by 55.1 miles. The lunar orbital phase of the Apollo 15 mission was terminated by the transearth injection maneuver at 223:48:45.

The transearth coast extravehicular activity began at about 242 hours. Television coverage was provided while the Command Module Pilot retrieved film cassettes and examined the scientific instrumentation module for any abnormalities. The extravehicular activities lasted approximately 38 minutes which was about 20 minutes shorter than planned.

The only midcourse correction of the transearth phase was performed at the seventh midcourse correction opportunity. The maneuver was 24.2 seconds in duration and provided a velocity of 5.6 ft/sec. The entry flight path angle, as a result, was reduced to a nominal minus 6.51 degrees. The command module was separated from the service module 15 minutes prior to entry interface at 400 000 feet. The entry was nominal and the spacecraft was observed on the main parachutes. Later, one of the three main parachutes collapsed, but a safe landing was made at 295:11:53. The landing coordinates, determined by the onboard computer, were 26 degrees 7 minutes 48 seconds north latitude, and 158 degrees 7 minutes 12 seconds west longitude, about 1 mile from the planned landing point. The crew were brought onboard the recovery ship by helicopter about 39 minutes after landing. The Apollo 15 mission was successfully concluded with the placing of the command module onboard the recovery ship about 1 1/2 hours after landing.

The Apollo 15 mission accomplished all of its objectives and provided the scientific community with a wealth of data about the moon and its characteristics.

LUNAR SURFACE SCIENCE

The Apollo lunar surface experiments and associated equipment were deployed on the lunar surface and all experiments are operating satisfactorily. The Apollo lunar surface experiment package consists of a radioisotope thermoelectric generator power source, six scientific experiments, and a central station. Figure 1 shows the arrangement of the experiments on the lunar surface after deployment.

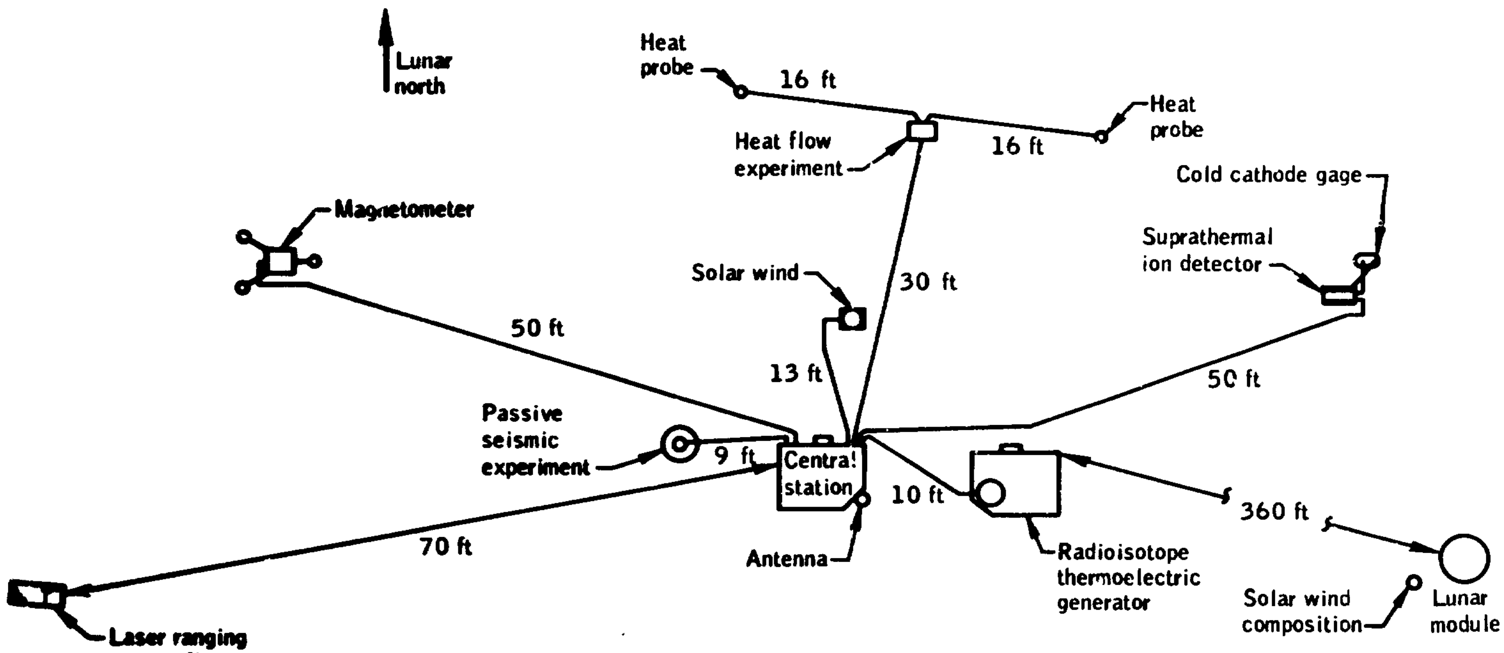
CENTRAL STATION

The central station was deployed 360 feet west of the lunar module. When antenna alignment was completed, the received signal strength was slightly higher than the predicted nominal value. The power output of the radioisotope thermoelectric generator was also above nominal, and stabilized at 74 watts. The 18-hour event timer which backs up the command functions is operating on schedule. The dust, thermal, and radiation engineering measurement is showing nominal outputs on all sensors, and indicated no thermal degradation attributable to dust from the ascent stage lift-off.

PASSIVE SEISMIC EXPERIMENT

The passive seismic experiment was deployed approximately 9 feet west of the central station and all elements have operated normally since activation.

Seismic signals generated by the lunar rover vehicle during the second and third extravehicular traverses vary smoothly in amplitude according to the distance between the vehicle and the seismic sensors. Other astronaut activities, as well as signals from the lunar module ascent, were also recorded at the new station. Signals from the impact of the lunar module ascent stage were recorded at all three stations (Apollo 12, 14, and 15). These recordings at the Apollo 12 and 14 stations are by far the most distant for any impact at a known location, and demonstrate that many previously recorded natural events must have occurred at great distances from these stations. A comparison of recordings made at the widely separated stations show significant differences which will help to clarify wave propagation phenomena and should yield more precise locations of moonquakes.



Note: The solar wind composition experiment was located about 50 feet from the Lunar Module.

Figure 1.- Apollo lunar surface experiment deployment.

S-IVB impact signals which were recorded strongly at the Apollo 12 and 14 stations, show the same prolonged character as observed from previous impacts. These signals, however, traveled with higher velocity than those previously observed at shorter ranges.

SUPRATHERMAL ION DETECTOR EXPERIMENT

The suprathermal ion detector experiment was deployed approximately 50 feet east-northeast of the central station and is operating normally. The instrument was first turned on at 1943 G.m.t. on July 31, 1971, and returned a good data stream with very low background rates. The instrument was commanded on and recorded ions from lunar module venting prior to the last two extravehicular activity periods and from lunar module ascent. The instrument has been reconfigured to allow outgassing of the electronics package and, thereby, reduce the susceptibility to arcing. The suprathermal ion detector experiment will be commanded on just prior to lunar sunset.

COLD CATHODE GAGE EXPERIMENT

The cold cathode gage experiment was deployed about 1 foot northeast of the suprathermal ion detector experiment and is operating properly. The experiment was initially turned on at 1943 G.m.t. on July 31, 1971. The cold cathode gage was commanded on to record the effects of the following events:

a. Lunar module venting prior to the second and third extravehicular activity periods;

b. Lunar module venting for equipment jettisoning;

c. Ascent stage lift-off;

d. Ascent stage impact.

The instrument was commanded to STANDBY shortly after lunar module impact to allow outgassing of the gage until shortly before lunar sunset.

LUNAR SURFACE MAGNETOMETER

The lunar surface magnetometer was properly deployed 50 feet west-northwest of the central station. The instrument has operated as planned since it was initially turned on, and is measuring the steady and time-varying magnetic fields. This is the first time that induced lunar magnetic fields have been measured simultaneously from two magnetometer stations (Apollo 12 and 15) separated by 1188 kilometers.

HEAT FLOW EXPERIMENT

The heat flow experiment electronics package was deployed approximately 30 feet north of the central station. The experiment was scheduled for deployment during the first extravehicular activity, but because of an unexpectedly slow rate of penetration of the drill, only the first probe could be emplaced at that time. The first probe is in a hole approximately 5 1/2 feet deep, with the top of the probe approximately 1 1/2 feet beneath the surface. The second hole was completed to a depth of approximately 5 3/4 feet during the second extravehicular activity. The top of the probe is almost at the surface because of an undetermined obstruction but the experiment is performing well and all temperature sensors are returning data. The transient disturbances to the lunar temperatures, caused by the emplacement of the probes and drillstems, are decaying and the temperatures are returning to equilibrium values.

SOLAR WIND SPECTROMETER EXPERIMENT

The solar wind spectrometer was deployed 13 feet north of the central station. The instrument was initially turned on at 1937 G.m.t. on July 31, 1971. After activation, the experiment recorded normal engineering and background data for 46 1/2 hours before the dust covers were removed. After the dust covers were removed, it recorded normal magnetospheric-plasma data for 53 hours until the final crossing into the magnetotail.

LUNAR GRAVITY MEASUREMENT

Lunar module accelerometer data during lunar stay was limited to 20 minutes because of power constraints. This short time decreases the confidence in the accuracy of the observed data.

APOLLO LUNAR SURFACE DRILL

The Apollo lunar surface drill was used to drill three holes in the lunar surface - two for emplacement of heat flow probes and one to obtain a core sample.

The heat flow probe holes were drilled first with the drill operational time required to drill the first hole being approximately 80 seconds. Hard material was encountered at a depth of approximately 5 feet and this slowed the drill penetration rate. Time constraints necessitated termination of drilling the first hole at a depth of about 5 1/2 feet. The normal procedure of releasing the drill head from the bore stems was hampered by the bore stem turning freely with the drill head. A contingency method of holding the bore stem with a wrench was used to release the drill head. In drilling the second hole, drilling slowed to a near stop at about 3 feet. Because of time constraints, the second hole was completed during the second extravehicular activity to the same approximate depth as the first hole. The drilling time for the second hole was about 230 seconds.

The hole for the core sample was drilled to the required depth of 93 inches in about 150 seconds. Removal of the core stem, drill head, and treadle was accomplished by the crewmen lifting upward. The power head treadle, and upper three core stem sections were separated with some difficulty. The remaining three sections could not be separated and have been returned in one piece.

LASER RANGING RETRO-REFLECTOR

The Apollo 15 reflector was deployed approximately 70 feet west of the central station. To permit the use of smaller earth-based telescopes, the Apollo 15 reflector has three hundred reflectors as opposed to the 100 reflectors of the laser ranging retro-reflectors deployed during Apollo 11 and Apollo 14. A good quality signal has been received on earth.

SOLAR WIND COMPOSITION EXPERIMENT

The solar wind experiment was deployed near the end of the first extravehicular activity and was exposed to the lunar environment for 41 hours and 8 minutes. Deployment was accomplished with no difficulty approximately 50 feet west of the lunar module. During retrieval, the foil failed to roll up mechanically and was rolled up manually by the crew.

LUNAR GEOLOGY INVESTIGATION

The surface in the vicinity of the landing site is undulating and highly cratered. It was described by the crew as being similar in appearance to the Apollo 14 site. The Apennine Mountains are steep but rounded. Rock fragments at the landing site are more abundant than along the front.

Photography

An estimated 1243 photographs were taken with the lunar surface cameras which includes approximately 368 color frames using the 60-mm lens, 540 black-and white frames using the 60-mm lens, and 335 black-and-white frames using the 500-mm lens. The photographic coverage at the landing site will greatly enhance the scientific return of the mission.

Samples

Samples were taken from the Apennine front, the rim of Hadley Rille including the first sample chipped from bedrock on the lunar surface, the mare, and from a probable ray. The five core-tube samples and the drilled deep-core sample should provide much information on the stratigraphy of the regolith and the site. Approximately 171 pounds of lunar material were collected. The sample return containers were difficult to close, causing the handles to be bent on container number 2.

SOIL MECHANICS EXPERIMENT

Activities for the soil mechanics experiment were at Station 8 (the Apollo lunar surface experiments package site) at the end of the second extravehicular activity. The Lunar Module Pilot excavated a soil mechanics trench, exposing a vertical face to a depth of more than 1 foot without apparent difficulty. The exposed vertical face consisted of a fine-grained, cohesive gray material with small white fragments and larger fragments of glass without visual evidence of stratification. This task was followed by six of the seven planned measurements, using the self-recording penetrometer which performed satisfactorily. These consisted of four cone penetration resistance tests and two plate load tests. Time was not available for detailed photographic documentation of these activities. Data from these tests are expected to provide quantitative information on the physical properties of the lunar surface material at the trench site, and on the uppermost part of a very resistant layer encountered at that depth.

The soil conditions encountered during the three extravehicular activities were variable. In the immediate vicinity of the lunar module there was a soft layer, about 6 inches deep, consisting of fine-grained and relatively loose material having a powdery appearance. At the Apollo lunar surface experiments package site, a hard layer at a depth of about 1 foot was penetrated by both the drill core, the soil mechanics trench, and the self-recording penetrometer. Local variations in soil cohension were observed on the slopes of St. George Crater, although no appreciable variations in the granularity of the material were noted. At the steep slopes of the Apennine front, the material is, in general, light gray, very fine grained, relatively soft, and moderately cohesive with local variations in cohesiveness, granularity, and stratigraphy.

INFLIGHT SCIENCE

All planned experiment and photographic activities during translunar flight, lunar orbit, and transearth flight were completed. The bulk of the equipment, including the subsatellite, were housed in a bay of the service module. The experiments operated or were deployed from this bay after the removal of the panel.

GAMMA RAY EXPERIMENT

The gamma ray experiment operation of about 132 hours was acceptable during the mission. A drift in instrument gain was noted early in the mission, but this stabilized within the adjustment range of the gainstep switch. Boom operation was nominal.

Scientifically, the level of continuum data observed is close to that predicted from the Ranger and Luna 10 data, but a full understanding will require a detailed analysis. Peaks due to potassium, uranium, and thorium in the moon, and some others due to cosmic ray effects can be seen. The level of activity and concentration has not been defined. The data does indicate that the high level of radioactivity observed at Fra Mauro on the Apollo 14 mission is not typical of the lunar highlands.

Both gamma ray astronomy and background data were obtained during the transearth phase. Following the first boom extension during transearth coast, anomalous data was transmitted for almost 24 hours. The difficulty cleared and the system operated normally after the transearth coast extravehicular activity.

X-RAY EXPERIMENT

The more than 100 hours of X-ray experiment operation was nominal durin the mission.

A large amount of good scientific data were received and portions have been reduced, which has allowed some preliminary interpretations. These data show the predicted distinctive difference in aluminum levels between the highlands and mare regions.

ALPHA PARTICLE SPECTROMETER

The alpha particle spectrometer operated for 123 hours and performed satisfactorily during the lunar orbital portion of the mission.

The background, primarily due to cosmic ray interactions, was higher by a factor greater than two.

There is no evidence of radon emanation from the moon in a preliminary evaluation of the data. However, during the final analysis of the data, where optimum filtering techniques can be applied to reduce background and data from successive orbits may be superimposed, it should be possible to locate the areas of high concentration.

MASS SPECTROMETER

The mass spectrometer provided good quality data throughout the mission. A problem associated with the boom reduced the total amount of data obtained. The boom problem is discussed in the mechanical portion of the command and service module performance section of this report. In addition to the 33 hours of prime data and 7 hours of background data obtained in lunar orbit, an additional 49 hours of supplemental data were obtained during transearth coast.

Variations in peaks were shown by the large number of mass spectra in the lunar orbit data obtained. A statistical analysis is required to determine the natural constituents of the lunar atmosphere and their abundances. Preliminary indications are that the atmosphere is very rarified and may well be below theoretical predictions.

A short, but intense burst of several gases was observed near the center of the backside of the moon. This burst may have been related to a lunar surface venting event or a sudden gas burst from the command and service modules. The dominant constituent in the gas burst was carbon dioxide. However, carbon dioxide has been observed all along the orbit and further analysis of this event is required to understand its significance.

During transearth coast, the residual gas levels around the instrument decreased considerably compared to those in lunar orbit.

S-BAND EXPERIMENT

The S-band transponder experiment was accomplished through S-band Doppler tracking of the command and service modules and lunar module using the spacecraft S-band systems. High quality data were obtained. Preliminary analysis shows many detailed features about the mascons (gravitational anomalies) in Serenitatis, Crisium and Smythii. Their acceleration profiles are different than the Nectaris profile obtained on Apollo 14, implying that not all mascons have the same shape or density characteristics.

SUBSATELLITE

The subsatellite was deployed into a 76.3- by 55.1-mile orbit with an inclination of minus 28.7 degrees. All uplink commands were checked and are operating normally.

Subsatellite Magnetometer

The magnetometer is operating as planned. All operational modes were checked and the inflight calibration sequence was performed. The data storage unit is operating as predicted, obtaining backside magnetic field measurements. The sensor temperature has stabilized between 67 degrees F at sunrise and 73 degrees F at sunset. This is within the design operational range.

Subsatellite S-Band Transponder

The S-band transponder has provided satisfactory data on each tracking revolution.

Subsatellite Particle Experiment

The electrostatic analyzer high voltage was turned on and all five analyzers performed normally. In some of the orbits following activation, the magnetotail plasma sheet was entered by the moon and low energy electrons were immediately detected. Complex electron shadows were also observed.

The solid-state detector telescope performed satisfactorily with protons of 35 000 to 100 000 electron volts being observed in the magnetotail, particularly near magnetic boundaries. Detector temperatures have stabilized between 50 and 55 degrees F.

BISTATIC RADAR EXPERIMENT

The bistatic radar experiment was conducted using the onboard command and service modules S-band and VHF communications systems. Two dual-frequency passes were conducted on lunar revolutions 17 and 28. In the dual-frequency mode, the S-band high gain antenna and the VHF omnidirectional antenna were used. The S-band data were received by the 210-foot antenna at Goldstone, and the VHF data by the 150-foot antenna at Stanford University. During the crew sleep cycle on August 2, a VHF-only bistatic radar experiment, was conducted for approximately ten hours.

The experiment results will require considerable processing of the received signals. From a scan of the data, the potential for determination of the bulk dielectric constant and near surface roughness along the spacecraft track looks good. However, data from the seventeenth lunar revolution are marginal and probably unusable because of an improper spacecraft attitude resulting in an incorrect pointing of the VHF and high gain antennas. This condition was corrected prior to the twenty-eighth revolution.

ULTRAVIOLET PHOTOGRAPHY

The ultraviolet photography experiment was conducted using a still camera with a 105-mm ultraviolet transmitting lens and three filters. Photographs were taken from earth orbit, translunar coast, lunar orbit, and transearth coast. A portion of the photographs taken in lunar orbit were of the lunar surface. The photographs obtained will be used in the determination of ultraviolet emission from the earth's atmosphere. Such studies, coupled with knowledge of meteorological conditions at the time of photography, will aid in the interpretation of ultraviolet observations of other planets, primarily Venus and Mars.

PANORAMIC CAMERA

Telemetry indicates that good quality photographs were obtained of all critical areas. Telemetry from the first camera pass on the fourth revolution indicated that the velocity/altitude sensor was operating improperly. When the sensor is off-scale, it automatically resets to a nominal 60 mile altitude. For the remainder of the mission, the sensor oscillated between off-scale high and nominal. However, it is expected that 80 percent of the photography will be good.

MAPPING CAMERA AND LASER ALTIMETER

Mapping camera operation was nominal throughout the mission with the exception of a problem with the deployment mechanism. The deployment mechanism exhibited slow response throughout the mission. The deploy and retract times were two to three times greater than the preflight baseline. At final retraction (prior to the transearth extravehicular activity), the mechanism failed to completely retract.

The laser altimeter operates primarily in support of the mapping camera, and lunar figure studies, but its measurements are also used in support of many inflight experiments. Altimeter operations were nominal through revolution 24. On revolution 27, some altitude words were clearly in error and this situation became progressively worse. The mapping camera and altimeter were left extended, but not operative, for the dark-side pass on revolutions 36 and 37 to lower the temperature. On revolution 38, the altimeter had failed completely. However, the altimeter was operated on all light-side mapping camera passes. On the sixty-third revolution, an attempt was made to revive the altimeter by a switch operation routine, but it was not successful.

LUNAR SURFACE PHOTOGRAPHY

Lunar surface photography from the command module provided oblique photography of special targets using the Hasselblad camera with the 80-mm and 250-mm lenses and both black-and-white and color film. The targets varied from coverage of areas not photographed by the service module cameras to targets which require obliquity to produce the desired detail. Two out of 24 targets were deleted because of the delay in lunar module jettison and the subsequent extension of the sleep cycle. Of the other 22 targets acquired, good photography was obtained of the prime sites. In addition, near-terminator photography using high speed black-and-white film was obtained. One target of the ten was deleted because of the delay in lunar module jettison. All photography of the lunar surface in earthshine was completed as planned.

VISUAL OBSERVATIONS FROM LUNAR ORBIT

The objective of visual observations from lunar orbit was implemented for the first time on Apollo 15. The Command Module Pilot was asked to make and record his observations of lunar features in specific regions.

The emphasis was on characteristics that are difficult to record, but can be delineated by the eye, such as subtle color differences. All scheduled observations were accomplished and the information was relayed to the ground.

GEGENSCHEIN FROM LUNAR OBIT

The three sequences of photographs using the 35-mm camera with the 55-mm lens were completed.

EXTRAVEHICULAR ACTIVITIES

Five extravehicular activities, with a total time of 19 hours 46 minutes 12 seconds, were performed by the crew of Apollo 15. The first was conducted from the lunar module soon after the lunar landing; the next three were made on the lunar surface; and the fifth was accomplished in space during the transearth coast phase. The routes taken during the three lunar surface traverses are shown in figure 2.

STANDUP EXTRAVEHICULAR ACTIVITY

The Commander initiated the first extravehicular period approximately two hours after successfully landing on the lunar surface. The Commander partially exited the lunar module by standing on the ascent engine cover after the overhead hatch was opened. From this vantage point, the Commander observed recognizable geographic features such as: Pluton, Icarus, Chain, St. George, Window, and Spur Craters. The sun compass, with the aid of an overlay map, was used to determine the lunar module location. Bearings were taken on Icarus Crater, Bennett Peak, and Hadley Delta. Local lunar terrain was photographed. The extravehicular activity was terminated after 33 minutes of exposure to the lunar environment.

FIRST LUNAR SURFACE EXTRAVEHICULAR ACTIVITY

The Commander egressed from the lunar module, deployed the modular equipment stowage assembly and activated the television camera, which provided coverage of his subsequent descent to the surface. The observations included a glass ball near the lunar module, and the slight crumpling of the descent engine bell as a result of contact with the rim of a small crater at landing. Also, the six-inch deep imprint of the forward footpad was noted. The rover and all other appropriate gear were unstowed, accompanied by remarks describing the difficulty encountered in removing the tape from the modular equipment stowage assembly and the deployment problems with the rover. The rover was checked out and given a trial run, after which it was loaded with equipment including the television camera and associated communications equipment.

The first manned vehicle usage for lunar exploration was initiated at about 121 3/4 hours. A southwest heading was selected toward Nameless Crater and Hadley Rille. Speeds up to 12 kilometers per hour were attained and dust from the rover's wheels caused no visibility problems. However, the crew commented that a high degree of visual acuity was required in steering the rover to avoid local obstructions such as rocks, humps, and

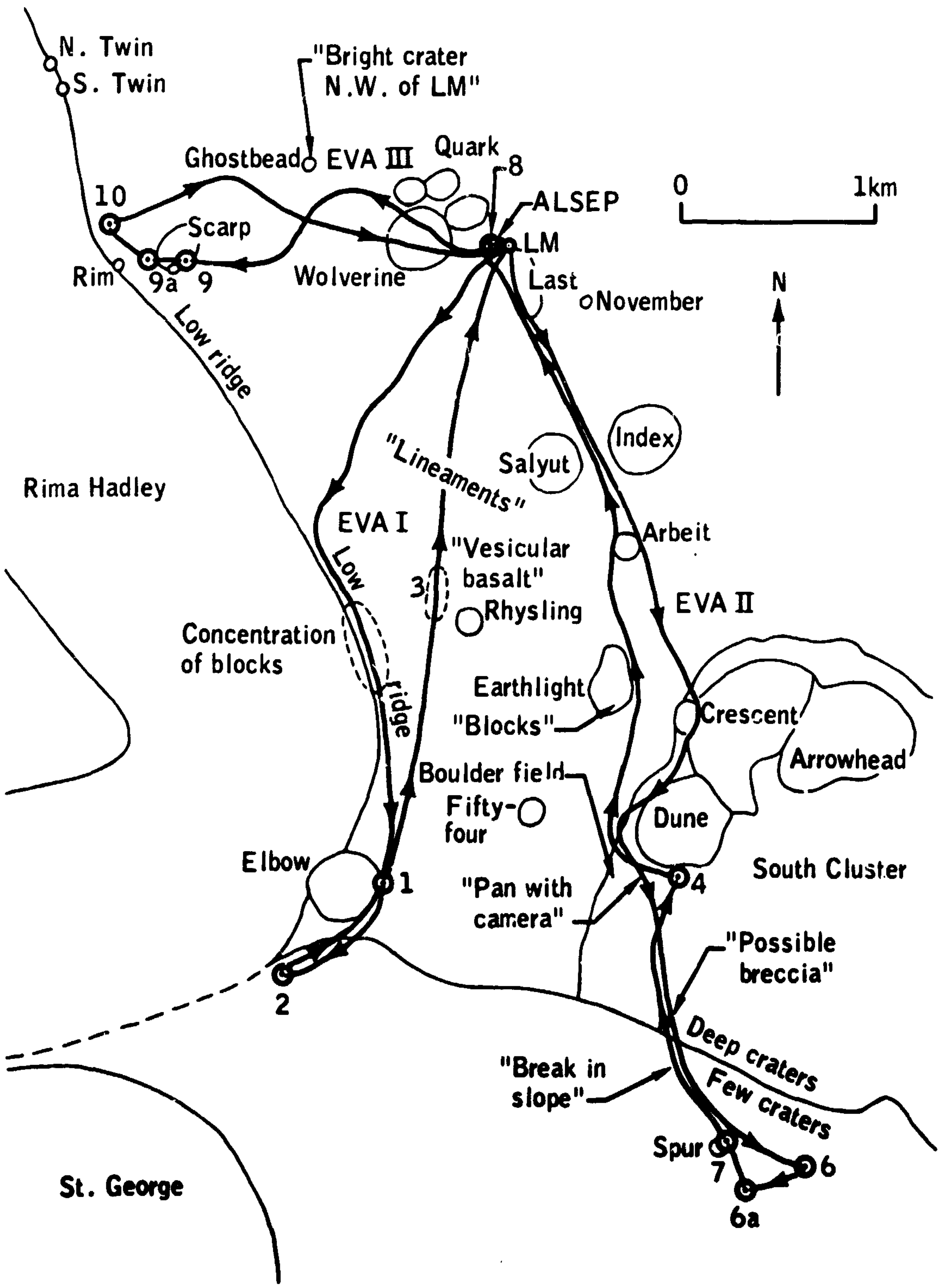


Figure 2.- Extravehicular activity traverses.

deep depressions. Zero-phase visibility presented the same problem that has been noted by other crews. The rille was reached about 19 minutes after departure from the landing site. Large blocks were also observed at the base of St. George Crater. Many interesting craters were passed and some appeared to be surrounded by fresh ejecta. One five-foot rock was mentioned and much evidence of glass content was also noted. The lunar module was not visible from the terminal stop near St. George Crater, and after obtaining documented samples, the return trip to the lunar module was begun using the rover navigation system for guidance. Upon returning to the lunar module, the Apollo lunar surface experiments package was moved to the selected site and deployed. The crew experienced some difficulty with the Boyd bolts, suprathermal ion detector experiment cables, and the lunar drill. As a result of these difficulties, the crew was behind the timeline. The first extravehicular activity was terminated after about 6 1/2 hours, because consumable oxygen was approaching the lower limit on the Commander's extravehicular mobility unit.

SECOND LUNAR SURFACE EXTRAVEHICULAR ACTIVITY

The second extravehicular activity featured two outbound and two inbound stops. While driving near Dune Crater, a fresh crater and the lightest albedo yet seen was observed. Three horizontal lines or benches were described as being near the base of Hadley and had the appearance of high water marks. Four small craters were described as being distributed linearly on the slope of Hadley Delta and a large block was identified and estimated to be about 3 kilometers away. Spur Crater was recognized and while there were surface rocks, no fragments, other than those around Spur Ccrater appeared to be ejecta from local craters. Intricate patterned samples which were joined as if glued together were obtained. The soil was found to be very powdery and many rocks had a consistent coloration because of a powdery covering.

Many interesting items were discussed and photographed, including an irregular shaped rock which had skipped about one foot from the point of impact. Also, a rock track having an arc which curved in an uphill direction was noted. As in all lengthy stops, television coverage was obtained of the trenching and sample collection in the Spur Crater region. One sample was particularly interesting because of its apparent green coloration. Another sample was found which appeared to be all glass.

On the return traverse, more samples and rocks were collected and the crew was told that the Apollo lunar surface experiments package station was tracking the rover into the lunar module landing area. The Commander commented on a malfunction experienced with his camera. At the Apollo lunar surface experiments package site, the Commander again experienced some delay from continuing problems with the lunar surface drill and the total deep drilling operation was again suspended. The American flag was deployed and the second lunar surface extravehicular activity ended after about 7 1/4 hours.

THIRD LUNAR SURFACE EXTRAVEHICULAR ACTIVITY

The third day of lunar exploration began later than planned as a result of allowing the crew to obtain additional rest. Because of this delay, coupled with a constraining lift-off time commitment, and time delays at the Apollo lunar surface experiments package area, the traverse to the region of Pluton Crater was deleted. The first of four stops was made at the core sample and Apollo lunar surface experiments package sites to recover core samples and take photographs. Two sections of the deep core sample tube were disengaged after about 1/2 hour of effort was expended. The remaining four sections were left on the surface for later retrieval and the crew started the rover toward Scarp Crater. More camera problems were encountered along the way, this time with the Lunar Module Pilot's camera. Another glass object was seen and described as a two-inch black spherule of glass. As the crew proceeded west toward Bennett Peak, they commented about the number of depressions, some of which were avoided and some of which they drove through. The Lunar Module Pilot saw and named a large crater, Wolverine.

Several large blocks were encountered, described, and photographed as the crew approached Scarp Crater, where the far side of the rille could be seen. Much fresh debris and an ejecta blanket were also observed. The Commander photographically panned the area from the rim of Scarp Crater and commented that his boots sank to a depth of about four inches in the soft rim material. More samples were extracted from this area including another glass ball. A third stop was made on the terrace near Rim crater. Here another extensive and detailed verbal description of the rille was made by the Commander. The Lunar Module Pilot obtained samples while the Commander photographed the features he had described. An area was sampled where the Commander thought that he was assured of obtaining bedrock specimens. Several core samples were taken and much use was made of the hammer in sinking the core tube. A final outgoing stop was made north of Rim Crater. Returning by way of the north rim of Scarp Crater, the crew again observed that the rover navigation system indication of lunar module position coincided with their visual observation from afar. The drill site was reached and the deep core samples were retrieved. The rover was positioned for lift-off television coverage and samples were stowed in the lunar module. Duration of the third lunar surface extravehicular activity was about five hours and total time on the lunar surface for the three extravehicular activities was about 19 3/4 hours.

TRANSEARTH EXTRAVEHICULAR ACTIVITY

The transearth coast phase of the Apollo 15 mission was highlighted by television coverage of the Command Module Pilot's extravehicular activity. The period covered approximately 38 minutes and during this time three excursions were made to the scientific instrument module bay area. The Command Module Pilot first recovered the cassettes for the panoramic and mapping cameras, and each retrieval required a separate trip. He observed and described the condition of the equipment in the bay as he removed the cassettes. The last excursion was made to reverify the condition of the experiments and to assure that no detail had been overlooked in the earlier observations.

EXTRAVEHICULAR SYSTEMS PERFORMANCE

EXTRAVEHICULAR MOBILITY UNIT

First Extravehicular Activity

Checkout of the Commander's portable life support system prior to the first extravehicular activity was normal. Portable life support system start-up for the Lunar Module Pilot was normal until the feedwater was turned on. The feedwater pressure increased faster and higher than expected and a warning tone was actuated. No flag was actuated initially, but a vent flow flag was actuated a short time later during troubleshooting. The trouble was traced to a gas bubble trapped in the feedwater bladder during charging. The gas bubble caused high feedwater pressure which eventually decayed as water was used from the bladder. Until the feedwater pressure had decayed to the suit pressure level, the condensate stowage volume was blocked by the bladder. This resulted in the water separator becoming saturated and allowing droplets of water to be carried over to the fan. This reduces fan speed slightly, thereby causing the vent flow flag. Data confirmed the presence of current spikes which are a characteristic of water droplets hitting the fan.

Throughout the first extravehicular activity, the extravehicular mobility units maintained crew comfort as required at all times. The feedwater was depleted in the primary tank of both the Commander and Lunar Module Pilot during the first extravehicular activity, and the auxiliary tank activation and sublimator repressurization were normal. The extravehicular activity duration was constrained by the Commander's oxygen quantity. The total extravehicular activity time was approximately 6 hours 33 minutes (from 3.5-psia cabin pressure during depressurization to 3.5-psia cabin pressure during repressurization). During the extravehicular activity, the sublimator gas-outlet temperature on the Commander's extravehicular mobility unit ran slightly higher than expected. A comparative analysis of all extravehicular mobility unit parameters indicates the condition was most likely due to the cooling water flow rate being on the low side of normal. Analysis also suggests a slightly higher oxygen leak rate from the Commander's suit than the nominal calculated.

Second Extravehicular Activity

Preparations for the second extravehicular activity were interrupted when it was discovered that the Lunar Module Pilot's portable life support system was recharged with water while it was at a 30-degree tilt from the vertical. This condition probably caused the gas bubble experienced on the first extravehicular activity. The crew was requested to vent and recharge the portable life support system.

The communications check at the beginning of the second extravehicular activity was initially unsuccessful for the Lunar Module Pilot. At this time, the Commander reported that the Lunar Module Pilot antenna was broken off and that it had been nicked before the first extravehicular activity. The crewmen taped the antenna to the oxygen purge system in the stowed configuration and the communication check was successfully completed.

The feedwater was depleted in the primary tank of both the Commander and the Lunar Module Pilot during the second extravehicular activity, and the auxiliary tank activation and sublimator restart were normal. Based on data analysis after the extravehicular activity, the oxygen leak rates were estimated at 0.018-pound per hour for the Lunar Module Pilot and 0.028-pound per hour for the Commander. The second extravehicular activity duration was 7 hours 12 minutes 14 seconds.

Third Extravehicular Activity

During portable life support system activation, the sublimator outlet gas temperature and feedwater pressure on the Lunar Module Pilot's extravehicular mobility unit were both reading lower than expected. At lunar module depressurization, these parameters began an upward trend which led to normal readings by the time the Lunar Module Pilot reached the lunar surface. Both extravehicular mobility units functioned normally throughout the third extravehicular activity.

The third extravehicular activity was terminated at 168 hours 8 minutes 4 seconds, after a duration of 4 hours 49 minutes 50 seconds. Using the Commander's average extravehicular activity work rate, approximately 1 hour, 50 minutes of oxygen remained at the completion of the period. The oxygen leak rate from the Commander's extravehicular mobility unit appears to have increased slightly during the third extravehicular activity. The oxygen leak rate and from the Lunar Module Pilot's extravehicular mobility unit was nominal.

LUNAR COMMUNICATIONS RELAY UNIT AND GROUND COMMANDED TELEVISION ASSEMBLY

The lunar communications relay unit operated normally during all lunar surface extravehicular activities. The quality of voice and data were good during all three extravehicular activities.

The lunar rover vehicle in-motion communications were satisfactory except that not pointing the low-gain antenna to the vertical position at one time resulted in noisy downlink voice when the lunar rover vehicle was parked on a steep slope during the second extravehicular activity.

The fixed-site television operation of the lunar rover vehicle was satisfactory except for a minor problem with high gain antenna pointing using the optical sight.

The ground-commanded television assembly operated successfully during the three extravehicular activity periods and provided coverage of the lunar lift-off. Good quality video signals were received while the camera was operating with the lunar module and the lunar communications relay unit. The elevation clutch began to slip during the second extravehicular activity period and the performance of the elevation mechanism deteriorated during the rest of the mission. The crew repeatedly assisted in returning the system to an operative pitch angle.

Lunar dust on the camera lens caused a halo effect and additional reflections from sun glints. Improvement in picture quality was restored after the crew brushed the lens.

The camera was activated 40 hours after lunar lift-off. After about 13 minutes of satisfactory operation, signals from the lunar communications relay unit were lost and all attempts to reactivate this system have failed.

LUNAR ROVER VEHICLE

The crew was very pleased with the rover performance and especially with the speed and hill climbing capability. The lunar rover vehicle suspension was softer than anticipated and resulted in much more bouncing than had been experienced during training.

All aspects of deployment were normal except that both of the walking hinge latches were found unlatched during the pre-deployment inspection and were reset. Also, the deployment saddle and the velcro seat tie down were difficult to release.

During checkout, the ampere-hour integrators were initially reading 105 ampere-hours, then 110 and 115 ampere-hours approximately 50 minutes later, instead of 121 ampere-hours. Battery 2 instrumentation showed zero volts and amperes.

The front wheels did not initially respond to steering commands. The Commander changed busses and observed the ampere meter closely for indications that power was being applied to the front wheels in response to steering commands. No response was seen. He also tried to manually force the front wheels to turn, again with no response. Consequently, all steering was accomplished by the rear wheels during the first traverse. Little difficulty was experienced, except the crew noted that the tendency to slip sideways on turns was aggravated by the lack of front wheel steering.

During checkout of the second extravehicular activity the crew cycled the steering power switches and circuit breaker, and found that the front wheel steering was normal. After starting the second traverse, the Commander tried driving with front wheel steering only. He soon returned to dual steering for the remainder of the traverses because the rear wheels seemed to drift excessively.

The lunar rover vehicle used less power than predicted. Consumption predictions were based on worst case surface roughness and soil composition. Based on the ampere meter readings, which were correlated with the change in the ampere-hour meter, the total power consumption was estimated to be 52 ampere-hours of the 242 ampere-hours available. Except for the ampere-hour integrator reading, the electrical power system operation was normal.

The navigation system operation was normal. The odometer showed a total distance traveled of 27.9 kilometers. Map distance is estimated to be approximately 25.3 kilometers. The average speed was 9.2 kilometers per hr. The navigation system had a 1 degree per hr gyro drift rate and 0.1 kilometer distance error, both of which are within the predicted values; however, the crew thought that the lunar rover vehicle navigation system indicated the lunar module position accurately.

The lunar rover vehicle battery temperatures were approximately 20 degrees higher than expected when the lunar rover vehicle was deployed and they continued to read higher than predicted but acceptable. The battery covers which control temperature appeared to have operated properly.

The crew station was satisfactory except for a problem with the seat belts. The prelaunch belt adjustment was too short for the lunar surface operation; also, the Commander's seat belt hook would catch on the electrical connector on the console post.

COMMAND AND SERVICE MODULE PERFORMANCE

MECHANICAL

The mechanical systems performance was nominal except for the boom deploy/retract mechanism for the mass spectrometer experiment located in the scientific instrument module bay of the service module. The 25-foot long boom was cycled in and out about 11 times. On five of these cycles, the boom did not fully retract. The retract mechanism stalled and the talkback indicator went from barberpole to half barberpole. Electrical current data and crew comments indicated that the boom was retracting to within 2 inches of the fully retracted position. This was confirmed by the Command Module Pilot during his extravehicular activity. The cycles when it did not retract were associated with a cold soak of the scientific instrument module. The boom was subsequently retracted fully after a warm up period and the boom was fully retracted on the last cycle before command module/service module separation.

Visual observations of the initial portions of descent confirmed three fully deployed main parachutes; however, subsequent visual observations following spacecraft descent through a cloud layer, one main parachute had collapsed. It appeared that the spacecraft had a relatively flat landing, and the spacecraft remained in upright (stable I) attitude. Consequently the uprighting bags were not deployed. A single parachute was recovered, but it was not the parachute that had collapsed.

COMMUNICATIONS

The command and service module communications which encompasses voice, uplink command, manned spaceflight network tracking, operations data, television, and very high frequency ranging were nominal throughout the mission. The high gain antenna performance was satisfactory in all modes of operation.

GUIDANCE AND CONTROL

Guidance, navigation, and control systems performance was nominal. During the launch phase as well as the translunar injection maneuver, the primary guidance system provided adequate display information to monitor the Saturn instrument unit performance. Both the primary and back-up con-

Seven of the eight service propulsion system maneuvers during the flight were under control of the primary guidance system. The first midcourse correction, which was also a service propulsion test firing, was performed under manual control by the crew. Performance was nominal despite the need for a procedural change to compensate for an electrical-short condition in one of the service propulsion system control circuits.

The command module was controlled by the primary system during entry and was guided to a landing at 26 degrees 7 minutes 48 seconds north latitude and 158 degrees 7 minutes 12 seconds west longitude, as indicated by the onboard computer.

SERVICE PROPULSION SYSTEM

Service propulsion system performance was normal during the eight firings, which had a total of 590 seconds of firing time. Propellant management resulted in an indicated propellant unbalance of only 25 pounds at the end of the transearth injection maneuver.

A short which developed in the ignition control circuitry, was isolated to the downstream side of the bank A solenoid valve. The problem required a revision to the ignition procedures for the lunar orbit insertion and transearth injection maneuvers. Automatic ignition was accomplished using bank B valves, then bank A valves were opened at ignition plus 5 seconds. Bank A valves were then manually shut down prior to normal shutdown, thus allowing an automatic shutdown on bank B. The remainder of the maneuvers were accommplished on bank B in the automatic mode.

REACTION CONTROL SYSTEM

Performance of the reaction control systems was nominal. Telemetry parameters were nominal with the exception of the service module quad A fuel manifold pressure which periodically oscillated between 175 and 190 psia. The quad A helium and oxidizer manifold pressures verified proper system operation and showed the oscillations were associated with the fuel manifold instrumentation.

Uncommanded isolation valve closures, as observed in previous flights, again occurred during this flight. In all occurrences, the valves were recycled open, as indicated by a gray flag on the talkback indicators, without incident. The crew reported that the quad B secondary valves indicator had cycled closed sometime during launch. This indicator again cycled closed at S-IVB separation. The quad D primary and secondary valve indicators were reported to be indicating closed sometime prior to 1 1/2 hours. The quad D valve indicators also went to the closed position during S-IVB separation. During scientific instrument module door jettison, the quad B primary valves indicator went closed, indicating that at least one of the two valves was shocked closed during this operation. The valves were recycled to open.

FUEL CELLS AND CRYOGENICS

Fuel cell performance was normal throughout the mission. The fuel cells provided 653 kilowatt hours of energy at an average bus voltage of 28.8 volts and a current average of 76.8 amperes. The fuel cells consumed 462 pounds of oxygen and 58.2 pounds of hydrogen while producing 520.2 pounds of water.

Cryogenic hydrogen and oxygen system performance was normal. Lift-off quantities were 952 pounds of oxygen and 80.3 pounds of hydrogen; quantities remaining at command and service module separation were 389.0 pounds of oxygen and 22.1 pounds of hydrogen.

BATTERIES

The batteries performed within expected limits. Total battery capacity in batteries A, B, and C was maintained above the 97-ampere-hour minimum throughout the mission by charging. Batteries A and B were placed on the main buses to support the fuel cells during launch, all service propulsion system maneuvers, and once for the terminal phase initiation backup maneuver, had it been required. Batteries A, B, and C provided power for entry, expending an estimated total of 30 ampere hours at landing at a maximum current of 81 amperes. The batteries were essentially fully charged just prior to entry, and had more than 100 ampere hours remaining for postlanding usage.

The pyrotechnic batteries performed required functions. The auxiliary battery maintained nominal open circuit voltages throughout the mission.

INSTRUMENTATION

The instrumentation performed normally with three exceptions. The service module reaction control system quad A fuel manifold pressure measurement was intermittently noisy (about 4 percent). Also, the central timing equipment timer was reset at 97 hours 53 minutes. The correct time was inserted via updata link, and it continued to operate properly throughout the flight. Indications are that the first 20 feet of tape on the data recorder reproducer became degraded after about 100 dumps. This portion of the tape was not utilized for the remainder of the flight.

CONTROLS AND DISPLAYS

The service propulsion system thrust light was noted to be illuminated shortly after launch. Tapping panel 1 near the thrust toggle switches caused the light to go on or off. Subsequent testing indicates that an intermittent ground exists in thrust switch A. The service propulsion system contains a discussion of this anomaly.

At approximately 33 3/4 hours, dc bus B and ac bus 2 undervoltage alarms occurred. The integral lighting circuit breaker was found open. The loss of this circuit was not essential to the mission, so the breaker was not touched.

At approximately 81 1/2 hours, the battery relay bus measurement read 13.66 volts and should have read 32 volts. Movement of the panel 101 systems test meter switch caused the reading to be normal.

The mission timer on panel 2 stopped at about 125 hours. The timer was restarted and operated properly for the remainder of the mission.

ENVIRONMENTAL CONTROL SYSTEM

The command and service module environmental control system performed satisfactorily throughout the mission with several discrepancies from planned operation.

A leak developed in the water chlorination injection port on two occasions. The first occurred at approximately 61 hours, during the chlorination procedure. The leak was stopped by the crew tightening the septum gland retention nut. The second leak occurred approximately 140 hours later and was easily corrected using the same procedure.

During preparation for lunar module housekeeping, difficulty was experienced in reading the onboard lunar module/command module differential pressure gage. This necessitated additional venting to assure the proper oxygen concentration in the lunar module.

Difficulty was encountered with tunnel venting operations during the hatch integrity test in preparation for lunar module jettison. The crew reported that after a successful hatch integrity check, the differential pressure decrease between the command module cabin and the tunnel, indicating the possibility of a command module hatch leak. The tunnel was again vented, and hatch seal integrity was demonstrated for a 10-minute period. However, the decision was made to inspect the lunar module and command module hatch seals. No evidence of contamination was found. The hatches were reinstalled and a successful hatch integrity test was performed.

During the lunar module jettison operations, the crew had difficulty in obtaining an acceptable suit circuit integrity check. The crew reported that they installed the liquid cooling garment plug in the Commander's suit, and then an acceptable suit check was obtained. Because of the initial difficulty with the hatch integrity check, the suit integrity was broken, and the suit check had to be repeated. The subsequent check was again unsatisfactory. The crew adjusted a glove connection and repeated the suit test with satisfactory results.

The transearth extravehicular activity was performed with all extravehicular activity equipment and environmental control system parameters normal. The extravehicular activity lasted 38 minutes and 12 seconds.

The potable water tank quantity began to decrease at approximately 277 hours and failed to fill automatically after each crew use. All fuel cell water flowed into the waste water tank until it began to be used for evaporative cooling during entry preparations.

LUNAR MODULE PERFORMANCE

THERMAL

The lunar module flight values of all thermal measurements were close to the preflight thermal predictions.

COMMUNICATIONS

Transmissions from the S-band steerable antenna were lost for about 6 minutes, apparently because of vehicle blockage during a yaw maneuver after undocking. Voice and data transmission were nominal during descent to the lunar surface, lunar stay, and ascent through rendezvous. However, the lunar module did not receive VHF transmissions from the command and service module during the descent phase. The checklist erroneously configured the VHF communications system of the command and service module to transmit on channel A and the lunar module to receive on channel B. Otherwise, the VHF communications were entirely normal between the lunar module/command and service module and lunar module/extravehicular communications system.

RADAR

The landing radar acquisition of slant range and velocity was normal. The acquired slant range of 42 000 feet increased to about 50 000 feet in approximately 10 seconds. The indication of range increase may have been caused by blockage from a lunar mountain at initial acquisition. Velocity was acquired at an altitude of approximately 39 000 feet above the local lunar terrain. Landing radar outputs were perturbed as expected by moving dust and debris at an altitude of about 30 feet.

Rendezvous radar tracking operation was nominal. Initial acquisition occurred at a range of approximately 109 miles and tracking was continuous until loss of signal when the vehicles went behind the moon. From reacquisition of the telemetry signal through rendezvous, the tracking was continuous and proper range-scale-factor changes were observed.

ELECTRICAL POWER

All lunar module batteries performed satisfactorily. The descent batteries delivered 1479 ampere hours out of a rated capacity of 2075 ampere hours. The ascent batteries, delivered 385 ampere hours from a 592-ampere hour capacity through lunar module undocking prior to the deorbit maneuver. The main dc bus minimum voltage was 28.9 volts and the maximum observed current was 74 amperes during power descent.

DESCENT PROPULSION SYSTEM

Transmitted data indicates that the descent propulsion system operated properly during powered descent to the lunar landing. The firing time for powered descent was 741 seconds. The minimum quantity remaining in any tank at landing was 5.6 percent. Postlanding venting of the propellant tanks was nominal. The skirt of the engine was buckled by contact with the rim of a crater during landing. The low-level propellant light illuminated at lunar touchdown, indicating a total hover time of 111 seconds remaining.

ASCENT PROPULSION SYSTEM

The ascent engine firing time was 433.6 seconds. Terminal phase initiation was performed behind the moon and the predicted firing time was 2.6 seconds. All ascent propulsion system parameters indicated a nominal lunar ascent engine firing.

REACTION CONTROL SYSTEM

Management of the reaction control system provided lower than preflight predicted propellant usage. Actual propellant remaining at lunar module jettison was 68 percent for system A and 63 percent for system B, compared with the prediction of 55.5 percent for both systems.

GUIDANCE AND CONTROL SYSTEM

Both the primary and abort guidance systems provided satisfactory guidance, navigation, and control throughout the mission. Spacecraft-attitude data on the lunar surface landing showed the lunar module to be pitched up 6.9 degrees, rolled left 8.6 degrees, and yawed right 17.4 degrees.

One abort guidance system inflight calibration and two lunar surface calibrations were performed with good results.

Powered ascent and all direct ascent rendezvous firings were successfully targeted and executed on time, resulting in residual velocities within expected deviations. The abort guidance system insertion residual velocities were trimmed. An abort guidance system caution and warning indication was observed after lunar orbital insertion, however, system performance during and after the caution and warning indication appears to be nominal. All abort guidance system and primary guidance and navigation system solutions throughout rendezvous agreed.

ENVIRONMENTAL CONTROL

System operation and component functioning was nominal with some minor discrepancies. The urine receptacle was allowed to remain in the open position for about 7 hours, resulting in the loss of about 8 pounds of descent stage oxygen before the valve was reclosed. Speed of the water separator 1 decreased below the caution and warning level of 800 rpm, causing a master alarm.

After the first extravehicular activity, a broken bacteria filter disconnect fitting on the water gun allowed the spillage of about 30 pounds (earth weight) of water into the cabin. The water was removed by partially filling two used portable life support system lithium-hydroxide containers (which were later jettisoned) and by dumping the remainder through the urine receptacle. Fluctuations in the glycol pump 1 differential pressure were noted. Glycol pump 2 was selected for about 8 minutes and operation was normal. Glycol pump 1 was reselected at this time and pump operation was normal for the rest of the mission.

The expected cabin leakage, based on preflight data, was 0.042-pound per hour. The flight leakage rate was about 0.03-pound per hour. The cabin temperature was maintained at approximately 65 degrees F during the lunar stay.

CONTROLS AND DISPLAYS

The crew reported during housekeeping that about 70 percent of the glass was missing from the range/range rate tapemeter face. Special ground tests conducted to establish that the range indicator would function without a hermetic seal and without endangering the crew indicated that the instrument was satisfactory for flight usage. The range indicator and all other controls and displays performed satisfactorily during the mission.

TRAJECTORY

The sequence of events and summary of spacecraft maneuvers performed during this mission are shown in tables I and II, respectively.

The translunar injection maneuver was nominal after two S-IVB instrumentation unit navigation updates were performed. The initial tracking showed a perilune of 1[illegible] miles compared with the targeted 79 miles. The first midcourse correction maneuver to reduce the perilune altitude was performed in conjunction with a service propulsion system firing test. The firing was accurate and less than a one-second firing was later required to achieve the desired altitude.

The lunar orbit insertion maneuver was executed as targeted, but the targeted vector was incorrect and this necessitated a small plane change during the descent orbit insertion maneuver. The spacecraft was placed into a 58.5 by 9.6 mile orbit; however, the decay rate was more than anticipated and a trim maneuver was performed to restore the desired orbital conditions for lunar descent.

The S-IVB impacted the lunar surface at 1 degree 21 minutes south and 11 degrees 48 minutes west. This point was about 79 miles from the prelaunch target point.

After undocking and separation in lunar orbit, the command and service module performed a circularization maneuver to place the spacecraft in a 64.7 by 53.7 mile orbit. The lunar module then executed the powered descent initiation maneuver and landed near its target in the vicinity of Hadley Rille. The crew made six landing point redesignations during the descent phase. The best estimate of the landing location (fig. 3) is 26 degrees 6 minutes 10 seconds north latitude and 3 degrees 38 minutes 55 seconds east longitude on the Rima Hadley Lunar Photomap, First Edition, April 1970.

In preparation for lunar orbit rendezvous, the command and service module performed a plane change maneuver to place the command and service module and lunar module in the same plane at orbital insertion. After 66 hours 54 minutes 53 seconds on the lunar surface, the ascent stage lifted off and was inserted into a 42.5 by 9.0 mile orbit. The lunar-module-active direct rendezvous procedure was used and docking occurred approximately one hour and fifty-eight minutes after ascent. The lunar module ascent stage was jettisoned from the command and service module and after a deorbit maneuver, impacted the lunar surface at 26 degrees 21 minutes 43 seconds north and 0 degree 15 minutes 12 seconds east. This impact point was 12.4 miles from the prelaunch target point.

TABLE I.- SEQUENCE OF EVENTS

Events	Elapsed time Hr:min:sec
Lift-off (Range zero = 207:13:34:00 G.m.t.)	00:00:00.6
Earth orbit insertion	00:11:44
Translunar injection maneuver	02:50:03
S-IVB/command module separation	03:22:27
Translunar docking	03:33:50
Spacecraft ejection	04:18:01
Service propulsion system firing test/first midcourse correction	28:40:30
Second midcourse correction	73:31:14
Scientific instrument module door jettison	74:06:48
Lunar orbit insertion	78:31:47
S-IVB lunar impact	79:24:42
Descent orbit insertion	82:39:48
Descent orbit insertion trim firing	95:56:43
Lunar module undocking and separation	100:39:30
Circularization maneuver	101:38:59
Powered descent initiation	104:30:09
Lunar landing	104:42:30
Start standup extravehicular activity	106:42:49
End standup extravehicular activity	107:15:56
Start first extravehicular activity	119:39:10
Apollo lunar surface experiment package first data	125:34:30
End first extravehicular activity	126:11:59
Start second extravehicular activity	142:14:48
End second extravehicular activity	149:27:02
Start third extravehicular activity	163:18:14
Plane change	165:08:32
End third extravehicular activity	168:08:04
Lunar ascent	171:37:23
Terminal phase initiation	172:29:39
Terminal phase finalization	173:11:12
Docking	173:35:47
Lunar module jettision	179:30:14
Lunar module deorbit maneuver	181:04:19
Lunar module lunar impact	181:29:36
Shaping maneuver	221:20:48
Subsatellite launch	222:39:19
Transearth injection	223:48:45
Start transearth extravehicular activity	241:57:57
End transearth extravehicular activity	242:36:09
Third midcourse correction	291:56:49
Command module/service module separation	294:43:55
Entry interface (400 000 feet)	294:58:55
Begin blackout	294:59:13
End blackout	295:02:31
Drogue deployment	295:06:46
Landing	295:11:53

TABLE II.- MANEUVER SUMMARY

Maneuver	System	Firing time, sec	Velocity change, ft/sec	Resultant orbit	
				Apocynthion, miles	Pericynthion, miles
Translunar injection	S-IVB	350.8	10 414.7		
First midcourse correction (Service propulsion test firing)	Service propulsion	0.7	5.3		
Second midcourse correction	Service propulsion	0.9	5.4		
Lunar orbit insertion	Service propulsion	398.4	3000.1	170.1	57.7
Descent orbit insertion	Service propulsion	24.5	213.4	58.5	9.6
Descent orbit insertion trim	Service module reaction control	21.2	3.2	59.9	9.6
Lunar module separation	Service module reaction control	7.2	1.1	60.9	9.0
Lunar orbit circularization	Service propulsion	2.7	68.3	64.7	53.7
Powered descent initiation	Descent propulsion	741.0	6694.0		
Plane change	Service propulsion	18.1	330.6	64.5	53.6
Ascent	Ascent propulsion	431.0	6059.0	42.5	9.0
Terminal phase initiation	Ascent propulsion	2.6	72.7	64.4	38.7
Final separation	Service module reaction control	12.6	2.0	66.2	52.6
Lunar module deorbit	Lunar module reaction control	83.0	200.3		
Orbital shaping	Service propulsion	3.4	66.4	76.0	54.3
Transearth injection	Service propulsion	141.2	3047.0		
Third midcourse correction	Service module reaction control	24.2	5.6		

Figure 3.- Preliminary landing location.

The command and service modules performed an orbital shaping maneuver at 221:20:48 in preparation for deploying the subsatellite. The maneuver was 3.4 seconds in duration with a resulting velocity change of 66.4 ft/sec. This maneuver was required to adjust the orbital altitude and orientation so that the subsatellite would have a minimum orbital lifetime of one year. About one lunar revolution later, the 141.2-second transearth injection maneuver was performed. The velocity change during the maneuver was 3047 ft/sec.

The third midcourse correction was performed at the seventh midcourse correction opportunity during the transearth phase. The 24.2-second maneuver provided a velocity of 5.6 ft/sec. As a result, the entry flight path angle was reduced to an acceptable -6.51 degrees.

The service module was jettisoned at 294:43:55 and entry interface (400 000-foot altitude) occurred at 294:58:55. This interface occurred about 1160 miles from the landing point. After a nominal entry, the spacecraft landed in the Pacific Ocean, at 158 degrees 7 minutes 12 seconds west longitude and 26 degrees 7 minutes 48 seconds north latitude, about 1 mile from the planned landing point. These coordinates were determined from the onboard computer.

BIOMEDICAL

The Apollo 15 crew remained in good health and reported no medication requirements during the flight; however, the crew reported after landing that they had taken aspirin on several occasions.

All three crewmen slept well during translunar and transearth coast. The Command Module Pilot's sleep during solo operations was also adequate; however, no more than a total of 12 hours of sleep were obtained by the Commander and Lunar Module Pilot during the 67-hour lunar stay.

This was the first mission on which sponge/pellet electrodes were used. The data obtained with these new electrodes was good. After lift-off, however, the impedance pneumograms on all three crewmen showed large baseline shifts and then became unreadable. The signals were restored by removing and reapplying the electrodes.

The Commander's personal radiation dosimeter failed prior to 39 hours. In order to have functional dosimeters on both extravehicular crewmen during surface operations, the Commander and the Command Module Pilot exchanged dosimeters prior to the lunar module intravehicular transfer. The total inflight radiation dose received by the crew was well within expected limits.

The light flash experiment was accomplished by all crewmen during translunar and transearth coast. The Lunar Module Pilot also made observations while in the lunar module on the lunar surface and again in the command module during one lunar orbit. All crewmen reported seeing numerous light flashes in their eyes at these times. Most of the light flashes were bright point sources of light and a few were streaks of light.

The average Btu's per hour for the three lunar surface extravehicular activities varied between 930 and 1200. The metabolic rates observed during these extravehicular activities were generally higher than predicted.

MISSION SUPPORT PERFORMANCE

FLIGHT CONTROL

Flight control operations during the Apollo 15 mission were satisfactory.

At about 3 hours 35 minutes, the crew noted that the service propulsion system thrust light on the entry monitor system was on. The crew was requested to pull both pilot valve circuit breakers to prevent an inadvertent service propulsion system ignition. There was concern over this condition because of possible loss of one bank of ball valves if a short existed upstream of the pilot solenoid valve.

A test firing of the service propulsion system was conducted prior to the nominal second midcourse correction time and verified both banks of ball valves were operative. Procedures were subsequently developed to control all service propulsion system maneuvers. When the entry monitor system was not required, the crew was requested to remove the power to the entry monitor system.

During the first intravehicular transfer to the lunar module, the crew observed that the glass cover was broken on the range/range rate tapemeter. Ground tests verified that the tapemeter would operate properly. A technique was developed to use the abort guidance system for displaying raw landing radar altitude data should the tape meter and primary guidance and navigation system fail.

NETWORK

Requirements placed upon ground instrumentation system were the largest and most demanding of any previous mission. The support during the mission was satisfactory. No significant Mission Control Center or Manned Spaceflight Network problems developed that hampered mission support.

During the first period of scientific instrument module film advancement activity, the ground station had a problem in locking onto the FM subcarrier. This was determined to be a site procedural problem. All sites were briefed on the problem and no subsequent troubles were encountered.

RECOVERY

The Apollo 15 spacecraft landed 1.1 mile from the target and 5.3 miles from the primary recovery ship, USS Okinawa. The landing point was 26 degrees 7 minutes 30 seconds north latitude and 158 degrees 9 minutes west longitude as determined by the primary recovery ship. Recovery occurred at 26 degrees 7 minutes north latitude and 158 degrees 10 minutes 12 seconds west longitude. The onboard computer coordinates of the landing point are 26 degrees 7 minutes 48 seconds north latitude and 158 degrees 7 minutes 12 seconds west longitude.

The command module remained in the stable I position after landing. There were light seas and winds in the recovery area. The helicopter crew were able to retrieve one of the main parachutes and the apex cover.

The following table lists the significant recovery events:

Events	G.m.t., Hr.min	G.e.t., Hr:min
Radar contact by USS Okinawa	2037	295:03
Electronic contact by aircraft	2038	295:04
Visual contact by aircraft	2041	295:07
Visual contact by USS Okinawa	2043	295:09
Voice contact by aircraft	2043	295:09
Command module landing	2046	295:12
Flotation collar installed	2100	295:26
Command module hatch open	2111	295:37
Crew egress to raft	2112	295:38
Crew aboard helicopter	2120	295:46
Crew aboard Okinawa	2125	295:51
Command module aboard Okinawa	2220	296:46