Apollo Mission Support

R. B. Hartley
TDA Planning Office

The support provided by the DSN to the Spaceflight Tracking and Data Network during the Apollo 17 mission is described. Support was provided by three 26-m-diameter antenna deep space stations, the 64-m-diameter antenna Mars Deep Space Station (DSS 14), the Ground Communications Facility, and the Mission Control and Computing Center. Premission and mission activities of the DSN are discussed, and the mission is described.

I. Introduction

The DSN support provided to the Spaceflight Tracking and Data Network (STDN) has been described in Refs. 1 through 4 and earlier issues of the JPL Space Programs Summary, Vol. II series. This article describes the support provided for the Apollo 17 (AS 512) mission, the sixth manned lunar landing and the third of the "J" type missions devoted primarily to scientific objectives.

II. Mission Description

Apollo 17, the tenth manned Apollo spacecraft flown above the three-stage Saturn V launch vehicle carried astronauts Eugene A. Cernan, Commander (CDR), Ronald E. Evans, Command Module Pilot (CMP), and Harrison H. Schmitt, a geologist by profession, Lunar Module Pilot (LMP). The mission goal was exploration of the area around the Taurus Mountains and Littrow Crater with the aim of filling in gaps in current knowledge of the moon and its history.

Launch from Cape Kennedy Pad 39A occurred at 5:33:00.83 GMT on December 7, 1972 at a launch azimuth of 92.0 deg. A countdown hold of 2 h 40 min was required when the launch auto-sequencer failed to pressurize a third stage LOX tank, and then failed to recognize that the launch controllers had manually pressurized the tank after observing the discrepancy. The sequencer was reprogrammed to overlook the one countdown step, and the countdown proceeded normally. This was the first Apollo program launch hold for technical reasons (Apollo 14 was held for weather). The launch was the first Apollo launch to occur at night. The geometry of the Sun and moon constrain a launch to one or two days in any month to allow acceptable Sun lighting angles at the landing site during touchdown. During December, the geometry was such that a daylight launch would have required the spacecraft to spend many hours in the shadow of the Earth, causing an unacceptable amount of spacecraft cooling. The trajectory of the night launch avoided this long duration in the shadow.

Due to the unusual launch time, translunar injection (TLI) occurred over the Atlantic Ocean in the beginning of the third revolution in Earth parking orbit (the customary TLI occurs over the Pacific Ocean in the second orbit). A 5-min 46-s burn of the S-IVB engine placed the spacecraft on a translunar trajectory. Following TLI, the Command Service Module (CSM) separated from the booster and docked with the unattended Lunar Module (LM). During docking, three of the docking latches did not lock. The crew manually recocked and fired two of the problem latches and they seized properly, completing an adequate docking. The CSM extracted the LM from the S-IVB, and the S-IVB was directed by ground command to crash on the moon in a seismic experiment involving the seismometers left there by the Apollo 12, 14, 15, and 16 missions. The S-IVB impacted the moon at 20:32:43 GMT on December 10 at lunar coordinates 4° 12′ S, 12° 18′ W, approximately 160 km northwest of the planned site.

Midcourse correction 1 was deleted due to the accuracy of the TLI maneuvers. Midcourse correction 2 was a short 1.7 s burn of the Service Propulsion System (SPS) for a velocity change of 3.0 m/s (9.9 ft/s) and a trim of 0.2 m/s (0.7 ft/s) with the Reaction Control System (RCS). Midcourse corrections 3 and 4 were not required.

At 22:33 GMT on December 9, the ground elapsed time (GET) clocks were advanced from 65:00 GET to 67:40 GET to compensate for the 2-h 40-min delay in the launch. This time clock change, together with a faster translunar trajectory, timed to speed up moon arrival by 2 h 40 min, put the mission back onto the original GMT/GET schedule. After this change, all mission events occurred within minutes of the premission plan. Table 1 reflects both the GET times and the actual elapsed times (AET) of each event.

Several minor problems occurred during translunar cruise. Several erroneous master alarms were observed in the spacecraft. The master alarm system warns the astronauts when some measurement in the spacecraft is found to be reaching an unusual value, but the master alarm was sounding without reason. The alarm was bypassed during sleep periods to avoid unnecessarily waking the astronauts. On December 9, mission control found it impossible to wake the astronauts, and they overslept more than an hour. As usual, only one astronaut (the CMP) was sleeping with his headset on, and the headset inadvertently fell off, leaving the crew out of contact with mission control. In such a circumstance, Houston normally sends a master alarm command to the spacecraft, setting off the warning signals. Since the master alarm was disabled, the crew could not be reached, causing some concern at mission control; without a master alarm, the crew might have slept through a spacecraft emergency. Other problems included a pressure oscillation in a hydrogen tank and several losses of communication; a 3-min dropout at 60:55 GET caused by a ground problem at the Ascension STDN site; a 9-min dropout at 86:08 GET caused by a maser failure at the Madrid STDN site, and a 4-min delay in acquisition due to an antenna pointing problem at the Goldstone STDN site during the first lunar revolution, resulting in a rapid handover to DSS 11.

Shortly before entering lunar orbit, the astronauts jettisoned a door covering the Scientific Instruments Module (SIM) of the Service Module. The SIM bay carries scientific instruments for observation of the moon from lunar orbit.

A successful lunar orbit insertion (LOI) burn of 6 min 33 s, for a velocity change of 911.32 m/s (2989.9 ft/s), put the spacecraft into a 315.4 × 97.2 km (170.3 × 52.5 nmi) orbit. Two orbits later, a descent orbit insertion (DOI) burn of 22 s for a velocity change of 60.41 m/s (198.2 ft/s) lowered the orbit to 109.5 × 27.6 km (59.1 × 14.9 nmi).

During lunar orbit 12, the CSM and LM separated, with astronauts Cernan and Schmitt in the LM preparing for descent to the lunar surface on orbit 13. A LM-only descent orbit burn (DOI-2) at 18:55:42 on December 11 placed the LM into a 110.4 × 11.5 km (59.6 × 6.2 nmi) orbit. Landing occurred at 19:54:59 GMT on December 11 at lunar coordinates 20° 9′ 50.5″ N and 30° 46′ 19.3″ E, approximately 369 m east of the planned landing site. After a short eating period, the astronauts began extravehicular activity 1 (EVA1), during which they deployed the lunar rover, set up the Apollo Lunar Surface Experiments Package (ALSEP) and activated the ALSEP transmitters. The ALSEP signals were received at Goldstone at 2:53:32 GMT on December 12, at a signal level of −133 dBm on a 26-m-diameter antenna. Several 9-m (30-ft) stations later reported signal fluctuations of ±1 dB with a period of approximately 45 s and an average level of −137 dBm. Shortly after deployment of the rover, the CDR inadvertently knocked the right rear fender extension off. A temporary fix was attempted using tape, but the extension fell off again during the one short traverse of the first extravehicular activity (EVA1), resulting in the astronauts and rover being covered with considerable dust. The EVA ended after 7 h 12 min.

After a sleep period, the crew began the second EVA. Prior to starting the traverse, the crew replaced the rover fender extension with a set of four plastic maps taped together and held in position with a clamp from a portable utility lamp in the LM. The fix worked perfectly and alleviated the dust problem. The crew visited four sites, obtaining photographs and samples and deploying three explosive charges to be detonated by timers after liftoff as part of seismic studies. During this traverse, the LMP noticed an orange-colored material that may provide evidence of recent volcanic activity on the moon and could be the youngest lunar material ever brought back to Earth. EVA2 lasted 7 h 38 min, the longest EVA of the Apollo program.

Following another sleep period, EVA3 was begun. Five sites were visited and one explosive charge was deployed. The LMP attempted unsuccessfully to repair the Lunar Surface Gravimeter (part of ALSEP), which had not been working since deployment. The third EVA was 7 h 16 min long. At the end of this EVA, the crew had explored the surface for a total of 22 h 6 min and had driven the rover 32.0 km (19.9 mi) at speeds up to 17.8 kph (11.1 mph), all three figures setting records for the Apollo program. Other records broken were the amount of rocks and soil collected: 117 kg (258 lb) and the time spent on the moon: 74 h 59 min. Approximately 2120 photographs were taken during the EVAs.

Following EVA 3 and an 8-h sleep period, the LM blasted off the lunar surface to rejoin the orbiting CSM. The liftoff was observed on Earth via the television camera on the rover. This camera continued to provide television views of the moon until its temperature control unit failed at 08:13 GMT on December 16. It had been expected to last until battery depletion on approximately December 25. Rendezvous and docking were also televised, the first use of the CSM television camera on Apollo 17. The crew transferred the samples and exposed film to the CSM, then jettisoned the LM for its deorbit and subsequent crash on the moon. The crash occurred at 6:50:19 on December 15 at 19° 54′ N and 30° 30′ E. The event was observed by the seismometers from Apollos 12, 14, 15 and 16, and by the four geophones of the Apollo 17 ALSEP.

The CSM remained in lunar orbit for another 40 h conducting orbital science. On this flight, however, there was no Particle and Fields Subsatellite, as its space was given over to a lunar sounder experiment. Also there was not enough time in the mission plan for a Bistatic Radar Experiment. Trans-Earth injection (TEI) was initiated at 23:35:09 GMT on December 16 with an SPS burn of 144.9 s for a velocity change of 928.51 m/s (3046.3 ft/s). The TEI maneuver was very accurate, and midcourse corrections 5 and 6 were not needed. The CMP conducted an EVA on December 17 to retrieve exposed film and other scientific materials from the SIM bay. Apollo 17 landed at 19:24:59 GMT December 19 at 17° 52′ S and 166° 8′ W, approximately 630 km (340 nmi) southeast of Pago Pago.

III. Requirements for DSN Support

A. DSN 26-m-Diameter Antenna Stations

As was done with previous Apollo missions, DSSs 11, 42, and 61 were committed to support Apollo 17 under direct STDN/Manned Spacecraft Center (MSC) control. Their responsibilities included two-way tracking of the CSM, LM, S-IVB, and the rover's lunar communications relay unit (LCRU), which transmits on a frequency of 2265.5 MHz and receives on the LM uplink frequency. Scheduling authority for these stations was retained by the DSN for the entire mission, since the DSN has complete maintenance and operations responsibilities.

B. DSN 64-m-Diameter Antenna Stations

The Mars station, DSS 14, was required to receive voice, telemetry, biomedical, and television data and to relay the data to the Goldstone prime STDN station (GDS). No uplink was required. DSS 14 was also required to receive 15-min television transmissions from the LCRU approximately once each day from LM liftoff through December 25. Contrary to previous missions, there were no requirements for Bistatic Radar reception or for precision doppler recording at DSS 14.

Several months before launch, NASA questioned the DSN as to whether DSS 43, the 64-m-diameter antenna station under construction in Australia, could be committed for Apollo use to avoid the need for the Parkes, Australia, 64-m-diameter radio-astronomy antenna. Since the operational date of DSS 43 was not until mid-1973, committed support was impossible. Nevertheless, the station did track on an uncommitted basis as backup to Parkes, and the acquired data were used.

IV. DSN Premission Preparations and Testing

A. DSN 26-m-Diameter Antenna Stations

A light level of testing was conducted continuously from Apollo 16 to Apollo 17. As the testing pace increased in late November 1972, a few problems surfaced. DSS 11 experienced a transmitter tripoff due to a primary ac overcurrent sensing. Because of several similar problems in the past at DSS 11, considerable attention was focused upon the problem, which turned out to be nothing more than a chafed high-voltage cable. DSS 11 was found to have a doppler problem on December 6 during an STDN test. The problem was traced to a modified doppler detector that had been installed at STDN request. With the original detector returned to service, the problem disappeared. DSS 11 also experienced a pump failure on heat exchanger No. 2, and the pump was replaced. DSSs 11, 42, and 61 were placed on mission status by the STDN on December 1.

B. DSS 14

DSS 14 conducted the normal premission tests as shown in Table 2. In addition, since DSS 14 experienced overloading during Apollo 16 when trying to receive a weak LM signal in the presence of a strong CSM television signal, a 20-dB attenuator was added after the Mod III maser. This configuration was then tested, even though the Mod III maser was only to be used as backup to the (polarization diversity S-band) (PDS) maser.

V. DSN Operations During Mission

A. 26-m-Diameter Antenna Stations

DSSs 11, 42, and 61 successfully supported all phases of the Apollo 17 mission. The problems experienced are noted in Table 3.

B. DSS 14

Nine Apollo passes were tracked, as shown in Table 3. The station had originally been scheduled for short LCRU tracks through December 25, but, as mentioned earlier, the LCRU ceased to operate on December 16.

DSS 14 experienced a pointing problem on the first pass. The antenna was pointed manually from 18:40 to 19:09 GMT because the station was unable to process the 29-point acquisition message. The problem was apparently caused by a bad punch point at the start of the acquisition message tape. Normal tracking was again interrupted at 20:57 due to a bad sample on the drive tape. A new drive tape was prepared from the same acquisition message, and normal tracking operations resumed at 21:26 GMT.

Beginning at 17:00 on December 8, problems were experienced with the Mod III maser. The maser was out of service three times until it was reliably back in service at 16:30 on December 10. Since the Mod III maser is only used for backup on Apollo, its problems did not affect Apollo support.

C. Ground Communications Facility Participation

The Ground Communications Facility (GCF) provided voice, teletype, and high-speed data circuits to support the DSN Apollo operations. In addition, JPL acts as the West Coast switching center for the NASA Communications Network and handles many non-DSN circuits, including video channels, in support of Apollo. There were no known GCF anomalies.

D. Mission Control and Computing Center Participation

The Mission Control and Computing Center (MCCC) areas and equipment used for the Apollo 17 mission included the Operations Area, the Network Analysis Area, the Mariner computer terminal area, and the Univac 1108 and 360/75 computers. The MCCC support was limited to backup predict generation for DSS 14 (and DSS 43), and some off-line monitoring in the operations areas.

References

1. Hartley, R. B., "Apollo Mission Support," in *The Deep Space Network*, Space Programs Summary 37-64, Vol. II, pp. 7–11. Jet Propulsion Laboratory, Pasadena, Calif., Aug. 31, 1970.

2. Hartley, R. B., "Apollo Mission Support," in *The Deep Space Network Progress Report*, Technical Report 32-1526, Vol. II, pp. 33–41. Jet Propulsion Laboratory, Pasadena, Calif., Apr. 15, 1971.

3. Hartley, R. B., "Apollo Mission Support," in *The Deep Space Network Progress Report*, Technical Report 32-1526, Vol. V, pp. 29–38. Jet Propulsion Laboratory, Pasadena, Calif., Oct. 15, 1971.

4. Hartley, R. B., "Apollo Mission Support," in *The Deep Space Network Progress Report*, Technical Report 32-1526, Vol. X, pp. 41–48. Jet Propulsion Laboratory, Pasadena, Calif., Aug. 15, 1972.

Table 1. Apollo 17 sequence of major events

Event	GET, h:min:s	AET, h:min:s	Date/GMT, h:min:s
Launch	0:00:00	0:00:00	12– 7/05:33:01
Insertion	0:11:47	0:11:47	12– 7/05:44:48
TLI ignition	3:12:35	3:12:35	12– 7/08:45:36
TLI cutoff	3:18:21	3:18:21	12– 7/08:51:22
Transposition/ docking	3:43:00	3:43:00	12– 7/09:16:01
CSM/LM eject	4:45:00	4:45:00	12– 7/10:18:01
S4B evasive maneuver[a]	5:30:00	5:30:00	12– 7/11:03:01
S4B first midcourse[a]	6:36:00	6:36:00	12– 7/12:09:01
First midcourse (deleted)			
Second midcourse	35:29:59	35:29:59	12– 8/17:03:00
LM communication test begin	41:16:00	41:16:00	12– 8/22:49:01
LM communication test end	41:59:00	41:59:00	12– 8/23:32:01
LM communication test begin	60:12:00	60:12:00	12– 9/17:45:01
LM communication test end	60:26:00	60:26:00	12– 9/17:59:01
Third midcourse (deleted)			
Fourth midcourse (deleted)			
SIM door jettison	84:12:00	81:32:00	12–10/15:05:01
CSM first occultation	88:43:22	86:03:22	12–10/19:36:23
LOI	88:54:21	86:14:21	12–10/19:47:22
S4B impact	89:39:42	86:59:42	12–10/20:32:43
DOI	93:11:00	90:31:00	12–11/00:04:01
Separation	110:27:55	107:47:55	12–11/17:20:56
CSM circularization	111:57:28	109:17:28	12–11/18:50:29
DOI-2	112:02:41	109:22:41	12–11/18:55:42
PDI	112:49:53	110:09:53	12–11/19:42:54
Touchdown	113:01:58	110:21:58	12–11/19:54:59
EVA 1 begin	117:01:36	114:21:36	12–11/23:54:37
ALSEP activated	120:00:31	117:20:31	12–12/02:53:32
EVA 1 end	124:13:47	121:33:47	12–12/07:06:48
EVA 2 begin	140:34:49	137:54:49	12–12/23:27:50
EVA 2 end	148:12:10	145:32:10	12–13/07:05:11
EVA 3 begin	163:32:35	160:52:35	12–13/22:25:36
EVA 3 end	170:48:06	168:08:06	12–14/05:41:07
Lunar orbit plane change	182:33:53	179:53:53	12–14/17:26:54
LM ascent	188:01:36	185:21:36	12–14/22:54:37
CSM/LM docking	190:17:03	187:37:03	12–15/01:10:04
LM jettison	193:58:35	191:18:35	12–15/04:51:36
LM deorbit	195:38:13	192:58:13	12–15/06:31:14
LM crash	195:57:18	193:17:18	12–15/06:50:19
TEI	236:42:08	234:02:08	12–16/23:35:09
Fifth midcourse (deleted)			
CSM EVA begin	257:34:24	254:54:24	12–17/20:27:25
CSM EVA end	258:41:42	256:01:42	12–17/21:34:43
Sixth midcourse (deleted)			
Seventh midcourse[a]	301:18:00	298:38:00	12–19/16:11:01
CM/SM separation	304:03:48	301:23:48	12–19/18:56:49
Entry interface	304:18:41	301:38:41	12–19/19:11:42
Splashdown	304:31:58	301:51:58	12–19/19:24:59

[a]Time approximate.

Table 2. DSS 14 tests

Date	Test
Nov. 8, 1972	Support constraint testing
Nov. 15, 1972	Configuration verification test
Dec. 1, 1972	Apollo 17 OVT
Dec. 2, 1972	24-h interface test with GDS

Table 3. Apollo 16 tracking

Date/GMT, h:min	Problems
DSS 11	
Dec 7/18:31 – 03:47	100-channel event recorder inoperative 23:52 – 01:57
Dec 8/18:40 – 04:20	None
Dec 9/18:45 – 04:42	None
Dec 10/18:42 – 05:11	Declination angle DATEX jumping intermittently 00:42 – 01:20. No data loss
Dec 11/19:26 – 06:12	None
Dec 12/19:43 – 06:10	None
Dec 13/20:33 – 07:52	None
Dec 14/20:49 – 08:48	None
Dec 15/21:15 – 09:19	None
Dec 16/22:04 – 10:03	None
Dec 17/22:26 – 10:13	None
Dec 18/22:36 – 10:23	Antenna drives off in both axes (06:31 – 06:40) due to bad interpolation on predict
DSS 14	
Dec 7/19:04 – 03:25	Problem with 29-point acquisition message 18:40 – 19:09 and 20:57 – 21:26. Cut new tape from same message. Antenna stowed 22:35 – 23:35 due to high winds
Dec 9/18:53 – 03:00	Backup Mod III maser red 9/1500 – 10/0200
Dec 10/18:52 – 03:27	Lost 20 min of 1-s doppler data due to punch being on 60-s rate
Dec 11/19:29 – 05:37	None
Dec 12/19:43 – 06:36	None
Dec 13/20:11 – 07:43	None
Dec 14/20:41 – 08:49	None
Dec 15/21:17 – 03:28	None
Dec 16/22:39 – 04:30	None

Date/GMT, h:min	Problems
DSS 42	
Dec 7/23:09 – 11:53	None
Dec 8/23:39 – 12:03	None
Dec 9/23:53 – 12:05	None
Dec 11/00:27 – 12:21	None
Dec 12/01:22 – 12:50	None
Dec 13/01:57 – 13:22	None
Dec 14/03:05 – 13:56	None
Dec 15/04:26 – 14:26	None
Dec 16/06:10 – 15:09	None
Dec 17/06:18 – 15:17	None
Dec 18/06:34 – 15:02	None
Dec 19/07:22 – 13:54	None
DSS 61	
Dec 7/10:43 – 19:06	None
Dec 8/11:24 – 20:18	None
Dec 9/11:28 – 20:35	None
Dec 10/11:26 – 20:33	None
Dec 11/11:52 – 21:37	None
Dec 12/11:54 – 22:22	None
Dec 13/12:56 – 23:52	None
Dec 14/12:48 – 00:59	None
Dec 15/13:22 – 01:30	None
Dec 16/14:06 – 03:09	None
Dec 17/14:13 – 03:16	None
Dec 18/13:59 – 03:31	None
Dec 19/16:38 – 19:23	None