II. THE APOLLO 9 MISSION

A. Mission Description

Apollo 9 was the third manned Apollo mission and the second manned mission flown aboard the three-stage Saturn V launch vehicle. With astronauts James A. McDivitt (spacecraft commander), David R. Scott (command module pilot), and Russell L. Schweickart (lunar module pilot), Apollo 9 was placed in a 10-day earth orbit with the primary objective of checking out the lunar module prior to undertaking an actual lunar mission.

On March 3, 1969, at 16:00:01.07 GMT, Apollo 9 was launched on an azimuth of 72° from Pad 39-A at Cape Kennedy. The S-IVB third stage successfully inserted the spacecraft into a 190-km circular earth orbit. The Command Service Module (CSM) separated from the S-IVB third-stage booster at 02:43 GET and withdrew at a rate of 30.48 cm/s to a distance of approximately 12 m. At this distance the velocity of the CSM was nulled, and the CSM pitched 180 deg and returned to successfully dock with the Lunar Module (LM) which was still attached to the third stage. Subsequently, the LM attachment bolts were released, and a 3-s Service Module Reaction Control System (SMRCS) burn separated the CSM/LM from the third stage. The third stage J-2 engine was later restarted and the burn lasted 4 min. Passivation of the S-IVB commenced with the residual propellants being propulsively vented to place it in an earth escape trajectory and into solar orbit.

The docked CSM/LM remained in earth orbit while numerous checkouts were made on the CSM and especially the LM spacecraft. A 110-s SPS burn at 22:13 GET placed the CSM/LM in a 353 × 209-km orbit. At 25:17 GET, this orbit was changed to 501 × 212 km by a 277-s SPS burn.

One of the highlights of the Apollo 9 mission was to be a 2-h Extravehicular Astronaut (EVA) activity to be performed by Schweickart, the Lunar Module Pilot (LMP). Because of an earlier illness experienced by the LMP, the EVA activities were revised to 1-h and restricted to an egress through the forward hatch to the "golden slipper" foot restraints on the LM "front porch" to photograph various components of the two spacecraft. EVA activities began at 72:55 GET and were terminated at 73:50 GET. EVA activities were followed at 74:57 GET until 75:13 GET by a live TV transmission from inside the LM while it was over the United States.

On March 7, at 92:39 GET, undocking of the CSM from the LM occurred, and the CSM RCS placed the CSM in a circular orbit of 240 km. This was followed by a LM Descent Propulsion System (DPS) burn, placing the LM in a 266 × 218 km orbit. Approximately an hour and a half later, the LM descent engine was ignited, simulating an lunar Descent Orbit Insertion (DOI) burn, which placed the LM in a 264 × 261-km orbit. After jettisoning the LM descent stage, propulsive maneuvers were performed with the LM Ascent Propulsion System (APS) prior to a successful rendezvous and docking with the CSM at 98:57 GET. After successfully docking, the LM crew returned to the CSM and, at 101:30 GET, the LM ascent stage was jettisoned. Twenty-two minutes later, a APS burn-to-depletion command was initiated from MCC-H. The remainder of the mission was spent by the three-man crew doing multispectral terrain photography for earth resources studies, spacecraft systems exercises, etc.

The Apollo 9 mission was originally scheduled for 150 revolutions around the earth, but because of bad weather conditions and an unfavorable sea state in the planned western Atlantic recovery area, the mission was extended for an additional revolution in order to place the point of impact in a more favorable sea. At 240:36 GET (March 13, 1969, 16:31 GMT), the Service Propulsion System (SPS) deorbit burn occurred over Hawaii on the 151st revolution. Approximately 5 minutes later, the CM separated from the Service Module (SM) to start the reentry sequence. Splashdown occurred at 17:00 GMT, 23.14° N, 68.00° W, and approximately 4.83 km north of the recovery ship USS Guadalcanal. The Apollo 9 mission was successfully concluded when the astronauts were landed safely aboard the recovery ship.

B. Requirements for DSN Support of Apollo 9

Other than the countdown and launch-phase support provided the Apollo project by the Spacecraft Monitoring Station at Cape Kennedy, the DSN is not committed to support Apollo earth-orbital missions. However, in the case of Apollo 9, the Manned Spacecraft Center placed a requirement on the MSFN, operated by the Goddard Space Flight Center, to have the MSFN Wing at Tidbinbilla, Australia participate in Apollo 9 during the rendezvous portion of the mission, which was planned for revolutions 58 through 61. The two spacecraft would be separated sufficiently to be outside the beamwidth of the MSFN Honeysuckle Creek (Canberra, Australia) Apollo prime 26-m antenna station.

The initial requirement was for both radio metric data and telemetry voice data from either the command service module or the lunar module, as circumstances dictated during the mission. Both the MSFN and the DSN expressed concern in their ability to meet this requirement due to two problem areas that had been experienced on the previous missions, especially Apollo 8. These were:

(1) The Apollo spacecraft angular tracking rates in earth orbit exceeded the DSN stations' capability to track (i.e., rates in excess of 0.85 deg/s).

(2) The strong signal strength received on an 26-m antenna from a spacecraft in earth orbit overloaded the receiver front end and created an instability in the angle channels when in the auto-track mode.

In the weeks preceding Apollo 9 launch, numerous techniques were proposed to overcome these limitations provided certain compromises could be made with respect to either the emphasis upon the radio metric data or the emphasis upon the telemetry voice portion of the requirement. After careful consideration, the Manned Spacecraft Center selected the technique proposed by the

Tidbinbilla station. This technique was to use the acquisition aid antenna for the entire pass, using a computer program drive mode with boresight offsets.

The station would acquire the spacecraft on the horizon with the boresight of the acquisition aid antenna leading the spacecraft by one-half the beamwidth (or about 9 deg), and the antenna would be programmed to keep this boresight offset as the spacecraft rose on the station's horizon until the spacecraft angular rates exceeded the mechanical limitation of the antenna (0.85 deg/s), at which time the spacecraft would advance into the acquisition beamwidth at a differential rate between the actual spacecraft velocity and the mechanical velocity limit of the antenna servo. Tracking would be continued until the spacecraft disappeared out of the acquisition antenna's beamwidth, thereby obtaining the largest possible percentage coverage during the pass.

The preflight expectation was that the rates would be such that the antenna would not be able to catch up with the spacecraft before its set on the outgoing station horizon. While this technique would invalidate the angular radio metric data, the critical factor of the other data was such that this technique would be satisfactory. This technique simultaneously optimized the angular-rate problem while reducing the tendency for receiver front-end saturation because of the lower gain of the acquisition antenna compared to that of the 26-m antenna. It had the further advantage that the modifications were all procedural and that no hardware changes would be required to implement the plan. As noted in Section C, below, the technique proved to be 100% successful with horizon-to-horizon tracks being obtained by the Tidbinbilla/MSFN Wing on revolutions 58 through 61.

C. DSN Mission Support

1. Spacecraft Monitoring Station Support. The DSN Spacecraft Monitoring Station supported the Apollo 9 prelaunch and launch activities in a manner identical with the support previously provided for Apollos 4 through 8. The station was reconfigured in a manner identical to that of the Apollo 4 mission, i.e., the CSM S-band downlink was received at the Spacecraft Monitoring Station, and the detected phase-modulated telemetry baseband was relayed to the MSFN Merritt Island Station (MILA) for processing. This arrangement provides backup during the launch in case the MSFN MILA station experiences signal-level difficulties due to either multipath propagation phenomena or flame attenuation phenomena from liftoff to loss-of-signal at the horizon.

Activities commenced at the Spacecraft Monitoring Station on February 12, 1969 with the countdown demonstration test from 17:00 to 24:00 GMT. During this test, telemetry was processed from the receiver to the MSFN MILA station and five photographs were taken of the received spectrum. During February, the station also participated in the Mariner Mars 1969 spacecraft F prelaunch and launch activities. The next Apollo activity occurred on February 18 when the Spacecraft Monitoring Station participated in a second countdown demonstration test (wet) from 11:00 until 20:40 GMT. The telemetry output was processed to the MSFN MILA station and photographs were obtained of the received spectrum.

The Spacecraft Monitoring Station participated in the third countdown demonstration test (dry) on February 19 from 11:20 until 17:51 GMT, with the same data being provided as for the February 18 test. On February 25 and 26, the station completed the DSN-specified Apollo configuration verification test, and the results were sent to the appropriate project engineers. On March 3, the station participated in the Apollo 9 terminal countdown and launch, from 04:00 to 16:08 GMT. The telemetry output of the receiver and spectral analyses plus 31 photographs of the received spectrum were provided to the MSFN MILA station. The received signal strengths at the station from launch to loss-of-signal at horizon are shown in Table 1. No anomalies were experienced during this entire period.

2. Tidbinbilla/MSFN Wing Support. Premission activities at Tidbinbilla/MSFN wing started on February 11 with a computer and data flow test. Additional computer and data flow tests, antenna position programmer drive tests, and acquisition antenna angle calibrations were interspersed between Pioneer IX tracks up to Apollo 9 launch. After Apollo 9 launch, the Tidbinbilla station continued to support Pioneer IX in the DSN configuration, except that the station did track Apollo 9 in revolutions 13, 14, and 15 in the MSFN configuration to evaluate the various tracking options. A decision was made to use the station configuration described in Section B, above. Both revolutions 14 and 15 produced rates of the order of 1 deg/s, which the station successfully tracked-thereby proving the technique to be practicable for use during revolutions 58 through 61. Tidbinbilla resumed Pioneer IX support in the DSN configuration up to the time it became necessary to perform a class A countdown prior to revolution 58.

To support the rendezvous portion of Apollo 9 (revolutions 59 through 61), the Tidbinbilla/MSFN wing was configured as shown in Table 2. The acquisition-of-signal and loss-of-signal times are shown in Table 3, along with the servo mode for each of the revolutions.

a. Revolution 58. Since the maximum elevation angle of the spacecraft with respect to the station was expected to be only 13 deg, no hour-angle offsets were included in the program drive for this pass. The actual maximum antenna tracking rates were 0.7 deg/s in hour angle, and 0.2 deg/s in declination. The CSM and LM were not separated during this pass. The CSM was acquired at a signal level of -132 dBmW, rising to a maximum of -105 dBmW. The LM signal-level maximum was -108 dBmW. Several losses of lock were experienced due to the rolling motion of the spacecraft, but these were momentary. There were no station anomalies during revolution 58.

b. Revolution 59. Since a maximum elevation angle of 30 deg was anticipated for revolution 59, an initial hour-angle offset of 9 deg was set into the antenna position programmer. The CSM was acquired at a signal level of -135 dBmW, rising to a maximum of -94 dBmW. The CSM and LM were separated for this pass. The maximum signal received from the LM was -124 dBmW. The servo-mode control changes for this revolution are shown in Table 3. The boresight offsets and the angular rates experienced during revolution 59 are shown as a function of time in Fig. 3. A change in CSM omniantennas resulted in a receiver loss-of-lock for a period of 8 s during this revolution. No ground equipment anomalies were noted for this pass.

c. Revolution 60. A transmitter water-load interlock trip, which could not be reset, occurred at 15 min prior to spacecraft rise. At 5 min prior to spacecraft rise, the battle-short override was applied and the station was green for acquisition at spacecraft rise. The initial programmer hour-angle offset was 8 deg for this revolution since a maximum elevation angle of angle of 30 deg was anticipated. Due to spacecraft attitude and omnidirectional antenna changes, there were several periods of receiver loss-of-lock during revolution 60. Table 3 shows the servo-mode control change times, and Fig. 4 depicts the performance of the tracking system as a function of time during revolution 60. Except as noted above, there were no other anomalies during this revolution.

d. Revolution 61. Since the maximum elevation angle anticipated for revolution 61 was only 10 deg, no hour-angle offsets were inserted for this pass. During the pass, a real-time request was made to change the station configuration to have system 3, receiver 6 connected to the main 26-m antenna via maser 1. This was accomplished and a corresponding CSM signal-level increase from -103 to -76 dBmW resulted. One anomaly occurred 10 min before spacecraft rise when the transmitter power amplifier beam voltage overload tripped; this was reset and no further difficulties were experienced.

The spacecraft coverage provided by the Tidbinbilla/MSFN wing during revolutions 58 through 61 is depicted in Fig. 5. The periods of good and bad data are shown. The station was released from further Apollo support on March 7 at 17:38 GMT, and the station was reconfigured and participated in the next Pioneer 9 tracking in the DSN configuration.

3. Conclusion. The Apollo 9 mission was completely successful in every respect, thereby paving the way for further evaluation of the LM in orbit about the moon on the Apollo 10 mission. While the DSN/MSFN wing support requirements for Apollo 9 were considerably less than those for Apollo 8, because Apollo 9 was an earth-orbital type mission, Apollo 9 did present a very interesting challenge to the Tidbinbilla station to operate in a mode that was not contemplated when the facility was designed. The high degree of success attained during the rendezvous phase of Apollo 9 points up the importance of the human resources of the MSFN and DSN.

Table 1. Spacecraft monitoring station time vs signal level for Apollo 9 launch (March 3, 1969)

GMT, h:m:s	Receiver 1 automatic gain control, dBmW	GMT, h:m:s	Receiver 1 automatic gain control, dBmW	GMT, h:m:s	Receiver 1 automatic gain control, dBmW
16:00:00	69.5	16:03:00	128.6	16:06:00	124.8
:10	67.9	:10	119.3	:10	117.7
:20	73.2	:20	116.7	:20	136.0
:30	97.6	:30	116.9	:30	140.0
:40	91.5	:40	98.4	:40	144.3
:50	88.6	:50	100.3	:50	134.3
16:01:00	81.8	16:04:00	102.7	16:07:00	144.8
:10	89.4	:10	101.5	:10	134.9
:20	85.5	:20	100.7	:20	132.4
:30	91.0	:30	100.6	:30	131.8
:40	96.7	:40	101.0	:40	132.0
:50	100.0	:50	102.0	:50	129.7
16:02:00	102.4	16:05:00	105.2	16:08:00	130.7
:10	145.6	:10	105.4	:10	131.0
:20	128.1	:20	107.3	:20	131.0
:30	102.0	:30	109.6	:30	130.7
:40	101.0	:40	125.5	:40	132.2
:50	117.6	:50	128.4	:52	Out of lock

[a]The automatic gain control values were recorded at a standard 50-Hz 2-B_{LO} receiver bandwidth.

Table 2. Ground receiver configuration, Tidbinbilla/MSFN wing

System	Receiver	Spacecraft telemetry
3	5	Command/service module phase-modulated
	6	Command/service module phase-modulated
4	7	Lunar module phase-modulated
	8	Command/service module frequency-modulated

[a]Systems 1 and 2 (receivers 1 through 4) refer to MSFN *Apollo* prime station, while systems 3 and 4 (receivers 5 through 8) refer to DSN/MSFN-wing station.

Table 3. Tracking event times, Tidbinbilla/MSFN wing

Revolution	Tracking mode	Acquisition-of-signal time[b]	Select-manual-velocity time	Select-program time	Loss-of-signal time[b]	Transmitter-on time	Transmitter-off time
58	3-way	11:58:08	—	—	12:02:43	—	—
59	2-way	13:31:44	13:34:21	13:35:48	13:37:04	13:30:59	13:40:00
60	2-way	15:05:37	15:07:59	15:09:28	15:10:27	15:04:29	15:14:30
61	2-way	16:39:34	—	—	16:44:14	16:39:59	16:47:00

[a]All times quoted are GMT, h:m:s.

[b]Acquisition-of-signal and loss-of-signal times are defined as horizon times given in 29-point predict messages.