DSN Support of the Mariner Mars 1971 Extended Mission

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DSN Operations

Each mission supported by the Deep Space Network is unique. Operations planning normally covers the standard mission only and does not include extended mission operations. This article describes the innovations that had to be made to support this portion of the Mariner Mars 1971 mission.

I. Definition of Extended Mission

The extended Mariner Mars 1971 (MM'71) mission began on February 12, 1972, 90 days after Mariner 9 was inserted into Mars orbit. A revision of the Support Instrumentation Requirements Document (SIRD) and corresponding NASA Support Plan (NSP) was necessary to cover commitments and requirements for the extended mission.

II. Establishment of Extended Mission Requirements

A. Time Period

The SIRD established the period for the extended mission as "Mariner 9 orbit insertion + 90 days to orbit insertion + 365 days." The extended mission of MM'71 was unique in that this was the first Mariner to orbit a planet, and although all nominal mission data taking capabilities remained, the data return capabilities were decreased because of spacecraft antenna pointing and the extreme spacecraft–Earth range.

B. Objectives

Because of the long orbit time of the standard mission and the solar geometry, it was possible to extend the nominal mission and formulate objectives unique to the extended mission. Table 1 (Ref. 1) lists these objectives and the experiments which would achieve them. The NSP indicated that only Deep Space Station (DSS) 14 would be able to support the major portion of the extended mission because of telecommunications constraints. Since DSS 14 was the only 64-m-diameter antenna station available, a loss of this station for any reason meant that all objectives might not be met.

C. Unsupported Requirements

DSS 14 could not give all of the requested coverage because of commitments to other projects. One-way doppler occultation data requirements could not be met for the same reason. Planetary ranging data would be provided at DSS 14 only, using R&D equipment. This configuration would not provide the requested real-time data, but would provide nonreal-time data in the form of punched paper tapes. In addition, all of the original standard mission unsupported requirements remained unsupported in the extended mission.

III. Extended Mission Profile

The extended mission began with no change in the operating mode. DSSs 12, 14, 41, and 62 continued their support 7 days per week. Mapping of the Martian surface continued, and as telecommunications performance degraded, selected features of Mars were re-examined. Table 2 (Ref. 1) lists key milestones and events during the extended mission. By mid-March, RF downlink threshold was reached for the 26-m DSSs, following which they were used only sporadically for uplink purposes. For the remainder of the mission, DSS 14's coverage varied between three and six passes per week.

IV. DSN Support

The innovations required during the extended mission were numerous. Most were needed to correct problems as they occurred in real time. The more significant ones are discussed below.

A. Block Decoder Assembly Threshold

By mid-February, a decrease in telecommunications capability was being observed as a result of the mispointing of the high-gain antenna in position 2 and the increasing range of Mars. The first innovation involved the lowering of the block decoder assembly (BDA) threshold from +2.5 to 0.0 dB signal-to-noise ratio (SNR). This effectively lowered the point at which the BDA would go into an automatic restart, permitting the Project to process pictures at SNRs lower than 2.5 dB. Higher science data rates could then be maintained for longer periods of time and more pictures received per pass, with some degradation in picture quality. This telemetry and command processor (TCP) software option was to remain in effect through the end of the mission.

B. Uplink Tuning

Instances of loss of uplink lock were observed during the latter part of February. The losses occurred during the tuning of the station transmitter exciters. The tuning rates being used at the time were the ones determined during spacecraft compatibility tests conducted before launch. Since station transfers were being performed near periapsis, at times of maximum doppler rate and offset, it was concluded that the standard tuning rate of 15 Hz/min for spacecraft signal levels of −139 to −145 dBm could no longer be used. The tuning rate was lowered on March 1 to 10 Hz/min, and no further anomalies occurred.

C. SDA Bandwidth Settings

The table defining the bandwidth setting for the receiver/subcarrier demodulator assembly was revised for the extended mission. The table covered the various telemetry modes, bit rates, and parts of orbit expected during the extended mission. By periodically zeroing the static error of the phase-locked loops (approximately every 2 h), the telemetry degradation was minimized. A graph was also supplied for members of the Network Analysis Team which defined the optimum SDA bandwidth setting for engineering data for S-band doppler vs. engineering SNR. This allowed the option of changing the bandwidth to cope with real-time conditions.

D. Picture Reception Operations

By mid-March, threshold for 2-kbps data had been reached and a series of high-gain antenna maneuvers had begun. These maneuvers increased the data rate to 8 kbps. For each of the maneuvers, DSS 14 configured for a listen-only mode. In this mode, the diplexer was bypassed and overall system temperature improved. Since DSS 14 could not provide an uplink in this mode, DSS 11 or 12 was called upon to provide an uplink to the spacecraft for the purpose of commanding and also to permit DSS 14 to receive three-way doppler occultation data.

E. Blind Commanding

Blind commanding was introduced during the period of solar occultation when leakage of spacecraft attitude control gas had been observed. DSSs 41, 51, and 62 provided the blind commanding support with the transmission of a series of DC-32s. The DC-32s set a flag in the spacecraft computer and enabled a sequence which conserved gas during the solar occultations. For days on which the DC-32s could be transmitted, 2.81 kg/m^2 of gas would be used per day. Without these commands (no

DSN support), the use rate increased to 12.66 kg/m^2 per day. The commanding was considered blind in that engineering threshold had been reached for the 26-m DSSs, and these stations could not see the results of their commanding effort.

F. Third-Order Tracking Loop Filter

By the end of April, the Block III DSIF receiver had been pushed to the limit of its tracking capability by doppler rates of 25 Hz/s and doppler acceleration rates as high as 0.16 Hz/s. At this point, a third-order loop filter was introduced (Ref. 2). Tests conducted at Compatibility Test Area (CTA) 21 demonstrated a capability of tracking doppler rates in excess of 1000 Hz/s and doppler acceleration as high as 3.8 Hz/s. Installation of the filter in receiver 1 at DSS 14 substantiated the CTA 21 tests. The third-order loop coped with all doppler conditions through the end of the mission.

G. Recording of Occultation Data

As the received signal level approached −164.0 dBm in June, the point of exit occultation could no longer be determined at DSS 14. A procedure was developed whereby the analog recordings of occultation data made at DSS 14 could be sent to CTA 21 and time of exit determined to within less than 1 s. The procedure was unique in that the tapes were played in a reverse direction to determine the point at which the signals disappeared. Determination of this time allowed the occultation experimenters to begin the processing of the prime digital tapes at the exact time of exit and save valuable computer processing time.

H. DSS 14 Antenna Azimuth Bearing

The hydrostatic bearing of the DSS 14 antenna, which had shown signs of degradation in film height as early as December 1971, reached a critical point in June. The final week of July was devoted to a complete regrouting and shimming operation of the degraded area, thereby increasing the possibility of continued antenna operation to the end of the mission. Much needed 400-kW transmitter maintenance was also performed during this period.

I. Coordination of Ranging Operations

A special Mu ranging voice coordination net was established prior to the beginning of the relativity experiment. This separate voice net, which connected the Mu ranging operator at DSS 14 to the ranging advisers located at JPL, was used for technical coordination, exchange of technical information, and the operation of the R&D ranging equipment. The net was used for a 2-month period centered around superior conjunction.

J. Use of Programmed Local Oscillator and 3-Hz Tracking Loop

As superior conjunction neared, excessive solar activity and spectrum broadening were making it difficult to maintain receiver lock. A mixer unit was installed in receiver 2 at DSS 14 which allowed this receiver to be used with a programmed local oscillator (PLO). A 3-Hz tracking loop filter was introduced at the same time. The R&D XDS 930 computer, which had previously been used for Mu ranging, was the input source for the mixer module. Superior conjunction occurred a week after the PLO configuration was first used, and valuable ranging data were obtained on that date.

K. Spacecraft Engineering Test Support

DSS 14 was instrumental in the accomplishment of a series of "end-of-mission" engineering tests. Radio-Frequency Subsystem (RFS) and Flight Command Subsystem (FCS) threshold tests were conducted, and an uplink comparison test was performed. These tests required a precise calibration of the transmitter output power level. Special procedures and operations had to be performed for each of these tests.

V. Summary

The extended mission was completely successful. All of the original objectives were met. The amount of occultation data received was more than doubled during the extended mission. The technique of pointing the high-gain antenna permitted 8-kbps data to be received during the entire extended mission. One hundred percent of the planet was mapped, and selected areas were monitored as possible Viking landing sites. Mariner 9 completed 259 days of extended mission operations and doubled the length of the mission.

Extended missions are seldom planned in advance, and the ability to overcome problems in a relatively short time is extremely important. During the MM'71 extended mission, the DSN demonstrated the ability to react to real-time situations and provide support under adverse conditions.

The extended mission not only enhanced the success of the Mariner 1971 Project but, because of the Mars dust storm during the early portion of the mission, actually became a vital part of the Project itself.

References

1. Textor, G. P., "Mariner Mars 1971 Mission Support," in *The Deep Space Network Progress Report*, Technical Report 32-1526, Vol. IX, pp. 35–37, Jet Propulsion Laboratory, Pasadena, Calif., June 15, 1972.

2. Crow, R. B., "S-Band Receiver Third-Order Loop Demonstration," in *The Deep Space Network Progress Report,* Technical Report 32-1526, Vol X, pp. 168–171, Jet Propulsion Laboratory, Pasadena, Calif., Aug. 15, 1972.

Table 1. Extended mission objectives

Objective	Experiment
Acquire special data	Solar conjunction [S-band, Celestial Mechanics Experiment (CME)]
	High-latitude coverage [TV, Infrared Interferometer Spectrometer (IRIS), Infrared Radiometer (IRR), Ultraviolet Spectrometer (UVS)]
Acquire long-time base data (>90 days)	Meteorology (TV, IRIS, IRR, UVS)
	Celestial Mechanics
Acquire data supplemental to 90-day observations	Repeated spot coverage of areas of interest (TV, IRIS, IRR, UVS)
	Monitor Viking landing sites (TV, IRIS, IRR, UVS)
	Earth occultation (S-band)
	Cooling data (IRR)

Table 2. Extended mission events (Ref. 1)

Event	Date, 1972
Start extended mission	Feb. 12
Complete pre-solar occultation science-taking sequences	Mar. 27
Start solar occultations	Apr. 1
Start orbit edge-on celestial mechanics mass concentration (mascon) period	Apr. 22
Start S-band occultations of polar regions	May 6
Complete orbit edge-on period	June 1
End solar occultations	June 4
Start weekly cycle of high-gain antenna maneuvers with one or two playbacks per week	June 5
End Earth occultations	June 24
Start solar conjunction period (relativity)	Aug. 19
Solar conjunction	Sept. 7
Complete solar conjunction period	Oct. 18
Complete extended mission	Approx. Mar. 1, 1973