Mariner 10 Mission Support

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This report covers the period from April 15, 1974 through October 15, 1974. April 15, 1974 marked the end of the Mariner Venus/Mercury 1973 Project and the beginning of the Mariner 10 Extended Mission Project. The Extended Mission Project was formally approved to include a Sun-side second encounter of Mercury and an understanding that every reasonable effort would be made to preserve the possibility of achieving a dark-side third encounter of Mercury in March 1975. In addition to the Mercury second encounter (Mercury II), DSN support during this report period included other major events, such as superior conjunction and two trajectory correction maneuvers. This article also summarizes the special antenna arraying experiment that the DSN conducted to enhance the video data quality at Mercury II.

I. Planning Activities

Only after completion of the primary mission in early April 1974 was any significant Project or DSN attention given to extended mission planning. This late start, combined with the number of required critical events and the occurrence of additional spacecraft problems, placed a heavy load on DSN planners during the short six-month interval between Mercury first and second encounters. Detailed planning was, however, satisfactorily accomplished in advance of each major event, which included the following: (1) trajectory correction maneuver (TCM) 4, (2) cruise support, (3) superior conjunction radio science, (4) TCM 5, and (5) Mercury second encounter.

A. Documentation

During April 1974, the Mariner 10 Extended Mission Project Support Instrumentation Requirements Document (SIRD) was prepared and approved by JPL. In response to this SIRD, the NASA Support Plan (NSP) was prepared and approved by JPL in June 1974. These documents covered requirements and commitments only through Mercury second encounter. Updates of these documents will be required for activities beyond October 15, 1975. The Network Operations Plan for Mariner Venus/Mercury 1973 was revised to incorporate new configurations and capabilities described in this article.

B. TCM 4

First priority was given to supporting the Project in planning for TCM 4. The primary concern in the DSN was in arranging for required 64-meter DSS support once the date and time of TCM 4 were fixed. The Project had many factors to consider: spacecraft constraints, science return, encounter aim point, and third Mercury encounter, before finalizing the TCM design. On April 26, 1974, the DSN supported a special spacecraft gyro test conducted to determine if the roll axis oscillation would occur with the solar panels and the scan platform set in the planned maneuver configuration. No oscillations resulted. Also, spacecraft propulsion subsystem thermal constraints precluded one engine burn of the required duration; therefore, the maneuver was planned to be conducted in two parts. It was pointed out that real-time telemetry data would not be possible during the TCM unless the spacecraft high-gain antenna was adjusted to point at Earth. However, the Project opted to give up these data in order to maintain the high-gain antenna in the April 26, 1974 test configuration during the actual TCM. These data would be recorded on the spacecraft recorder for post-TCM playback.

C. Cruise Support Plan

The Mariner Venus/Mercury 1973 primary mission had enjoyed essentially continuous tracking coverage from November 3, 1973 through April 15, 1974, via a combination of the 26- and 64-meter deep space stations. This level of support could not be continued throughout the extended mission due to the higher priorities of other flight projects and DSN implementation requirements. Basically, the plan was for Mariner 10 to receive approximately two-thirds continuous coverage by a combination of full or partial passes each day. The daily coverage gap would normally occur over the Australian longitude since each of these stations was planned to be down for upgrade and repair, in a serial manner, throughout the extended mission. Therefore, it was plannned that the Mariner 10 spacecraft would record non-imaging science data during coverage gaps and then play back these data via a 7.35-kbps dump during the next scheduled 64-meter pass.

During the very first such coverage gap on April 16, 1974, analog-to-digital converter number two in the spacecraft flight data subsystem apparently failed, causing a loss of 50 of the 134 analog engineering measurements. This spacecraft failure, unlike some others, had no direct effect on the DSN. It did, however, raise some concerns regarding continuation of the partial coverage plan, but circumstances dictated a continuation in this mode. Unfortunately, the spacecraft was not long in putting an end to the record–playback plan.

On August 14, 1974, the spacecraft recorder was to serve as the data source for a ground telemetry test; however, no tape start occurred. It appeared that the recorder tape was stuck in the parking window and could not be freed. Trouble shooting continued through August 19. Some tape movement was achieved, but it then apparently became permanently jammed. The recorder was declared inoperable and tuned off on August 21, 1974. This, of course, meant complete loss of data during DSN coverage gaps. Of more concern, however, was the increased potential for loss of critical event data even while tracking due to inadequate telecommunications link performance (e.g., during TCMs) or failures at the deep space stations. As a result of this loss, the DSN gave added attention to redundant configurations and backup recordings to assure recovery of data on Earth.

D. Superior Conjunction Support Plans

Mariner 10 superior conjunction activities occurred during the period May 24–June 21, 1974. Recovery of dual-frequency S/X-band doppler, range, and open-loop receiver data types was required. In addition, it was desired that calibration tracks be provided beyond the stated interval. Since Mariner 10 provided the first opportunity for spacecraft dual-frequency analysis of solar corona and gravity effects, the DSN gave considerable emphasis to arranging proper support at DSS 14. Originally, DSS 14's Block IV S/X-band receiver was scheduled for removal and rework in preparation for Viking test support in mid-June 1974 following superior conjunction on June 6, 1974. The expanded observation period required negotiation of the removal date and was subsequently set for July 1, 1974. Support of the special Block IV receiver trouble-shooting team was planned to continue in effect until July 1, 1974.

E. TCM 5

In parallel with superior conjunction activities, the DSN assisted the Project in planning support for TCM 5. The TCM was planned to occur on July 2, 1974 over DSS 14, preceded by a gyro roll test on June 24, 1974. To avoid possible impact on DSS 14's support of the TCM, removal of the Block IV receiver was negotiated to occur on July 5 rather than July 1, 1974 as previously planned.

F. Mercury Second Encounter Support Planning

Following the Project's decision in May 1974 regarding the second encounter aim point, detailed encounter support plans were able to rapidly progress. Initially, the second encounter differed in two significant ways from the first encounter: (1) the second encounter would be a Sun-side pass having no solar or Earth occultations with emphasis on additional TV coverage of Mercury; and (2) the Earth–spacecraft distance would be greater than that at first encounter, resulting in a 1-dB lower signal level in the telecommunications link.

The aim-point difference in fact made second encounter planning easier for the DSN than that for first encounter since there were no occurrences of radio science occultation and rapid signal reacquisition requirements. The spacecraft could be continuously tracked near the planet in a listen-only mode. However, the lower signal level due to the increased distance posed some critical questions and support considerations. Would real-time 117-kbps video still be possible at Mercury II? Or would the reduced rate of 22 kbps be necessary to stay above the maximum allowable bit error rate of one in thirty? Could some improvement in the DSN deep space stations be implemented to regain the "lost" dB?

Telecommunications link analyses indicated that the bit error rate would be, at best, one in twenty and somewhat worse during much of the encounter pass at the 117-kbps rate. It appeared as if TV experimenters had a choice between a large number of TV frames of poor quality or a small number of high quality.

In June 1974, engineers of the DSN Communications Systems Research Section proposed that DSS antenna-arraying and signal-combining techniques might be employed to gain 0.6 to 0.7 dB. The feasibility of this approach was pursued in a number of meetings, and the decision was made to implement an arrayed antenna capability for Mercury second encounter. It was understood that data via this source would be provided on an engineering experiment basis in parallel with the standard configuration at DSS 14. The implementation of this capability is further discussed in Section III of this report.

Tests were planned which would evaluate the array performance using actual spacecraft data during far-encounter TV sequences. The Project would decide between the standard configuration and the array on the basis of these tests. Theoretically, the arraying gain was expected to produce a bit error rate of between one in thirty and one in fifty over most of the Goldstone near-encounter passes. If achievable, this would exceed minimum requirements and provide picture quality nearly equal to that of the first encounter. This would represent a significant increase in TV science data return; consequently, priority attention was given to the experiment.

The subsequent failure of the spacecraft tape recorder in August 1974 added a significant third difference to Mercury II. There would be no preservation of high-quality TV frames on board for later playback; only what was recorded on the ground in real time would be available to experimenters. The optional record–playback mode was no longer available, and this added more importance to the arraying implementation.

DSS 43 support was also employed as a part of the second encounter TV data acquisition plan. To provide for reasonable data quality, the low-noise ultra cone was retained at DSS 43 through second encounter.

II. Program Control

The DSN continued to provide monthly inputs to the Project Management Report throughout this period. With the decision to implement the antenna arraying capability, the DSN held weekly status meetings to review progress. These meetings continued until encounter. A DSN encounter readiness review was conducted on September 6, 1974, and all action items were closed prior to encounter.

III. Implementation Activities

Very little implementation activity was anticipated between Mercury first and second encounters. However, this proved to be a busy period, primarily as a result of antenna arraying and the possibility of real-time 117-kbps video data.

To provide tracking coverage flexibility in the Spain longitude, DSS 61 was, for the first time, configured and checked for Mariner 10 support. This also gave access to DSS 61's 20-kW transmitter for commanding during spacecraft loss-of-Canopus emergencies.

The 230-kbps super group communications service between DSS 14 and JPL was reinstalled and checked for encounter support. The service had been removed in the belief that real-time 117 kbps would not be possible during the second encounter. The 28.5-kbps wideband communications service to the overseas 64-meter stations was reactivated after being down in cruise for cost avoidance reasons. The DSS 14-to-JPL 28.5-kbps circuit had been converted to 50 kbps in preparation for Viking test support.

Improvements were made in DSS 14's backup antenna cone-maser performance by relocation of the maser nearer the feed horn in the cone. This provided an acceptable backup to DSS 14's standard cone-maser in the event of failure. Special configurations were implemented at DSSs 14 and 43 for analog recording of integral values of video data bits at the symbol synchronizer assembly output for possible post-encounter processing and enhancement.

The proposed antenna array and signal combining experiment was successfully implemented at Goldstone and tested for encounter support. Tests with the spacecraft demonstrated achievement of the expected 0.6–0.7-dB improvement, and the decision was made to use this configuration for real-time handling of encounter data. The key characteristics of the array experiment are given in Table 1 and Fig. 1. It should be noted that DSS 13, which is not normally a flight support station, was employed as one of the arrayed stations to take advantage of its lower system temperature.

Table 1. Goldstone antenna arraying experiment key characteristics and comments

Three-station array, two 26-meter and one 64-meter, DSSs 12, 13, and 14, all listen-only.
DSS 12 and 13 receiver baseband output microwaved to DSS 14 for arraying experiment.
DSS 14 receiver 1 output to DSS 14 string alpha for normal 117-kbps processing recording.
DSS 14 receiver 2 baseband output microwaved to Goldstone area comm terminal and looped back to DSS 14 via microwave to induce signal delay nearly equivalent to DSSs 12 and 13.
Signal combiner device located in DSS 14 at microwave interface. Receives parallel input from microwave of DSS 12, 13 and 14 baseband signal.
Signal combiner correlated and phased signals providing a combined output to the DSS 14 SDA-string beta for processing, real-time transmission to JPL, and recording.
DSS 14 string alpha did a little better than expected on the non-arrayed data.
DSS 14 string beta performed a little worse than expected on the arrayed data.
String beta appeared to be about ½ dB down from alpha. Arraying was hard-wired into beta; a switch would have been ideal but no time to implement. Even so, arraying gave 0.3 to 0.4 dB better performance. Had arraying been on alpha, the expected 0.8-dB gain would have been realized or exceeded.
Signal combiner worked well, no difficulties.
Promised and delivered pictures at BER of ≤ 3 in 100 for 2½ hours near encounter.
Low-rate data (2450 bps) microwaved from DSS 14 to DSS 12 for processing and transmission to JPL.

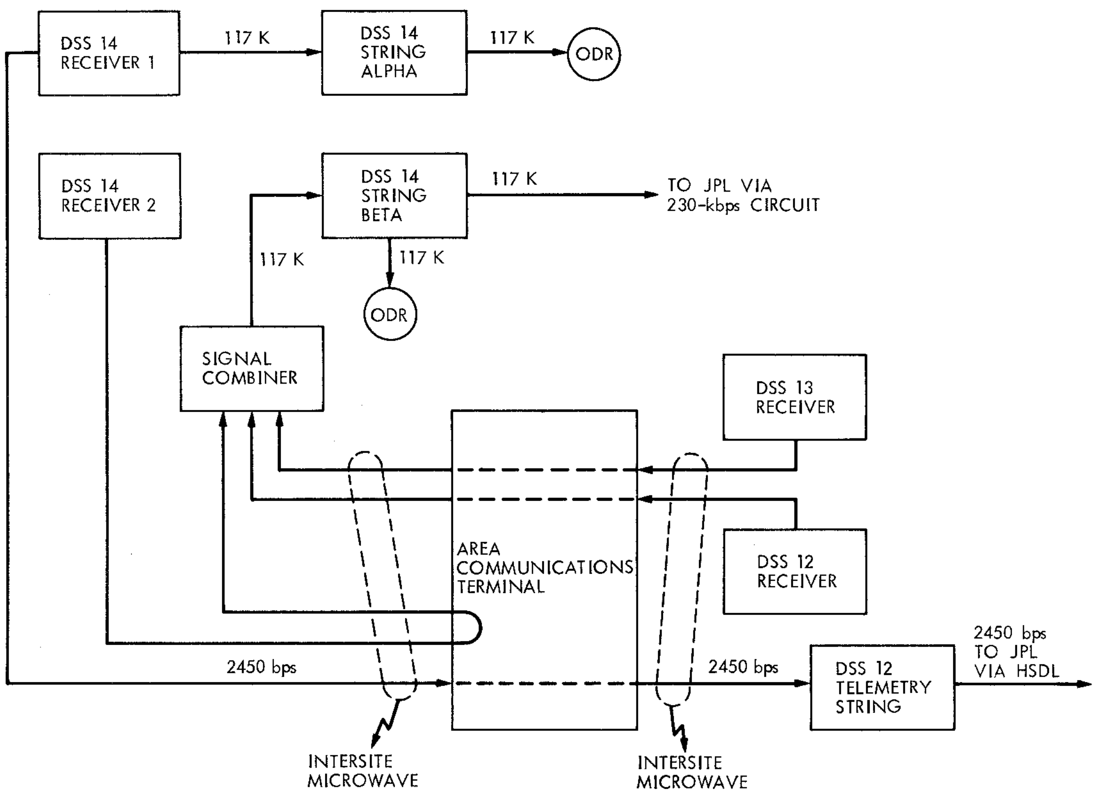

Fig. 1. Goldstone antenna array experiment configuration for Mariner 10