Helios Mission Support

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Having successfully passed its first aphelion, the Helios-1 spacecraft is in excellent health and is preparing to enter its second solar occultation on its way to the second perihelion. DSN activities in support of Helios-B testing are increasing, with the results covered in this article.

I. Introduction

This is the fifth article in a series that discusses the Helios-1 flight support provided by the Deep Space Network (DSN). The previous article (Ref. 1) reported on the results of Helios-1 superior conjunction passage and initial Helios-B planning activities. This article covers that period between the first and second superior conjunctions in Helios-1 mission operations. Also included are Helios-1 tracking coverage and system performance as well as results of initial Helios-B testing.

II. Mission Status and Operations

A. Helios-1 Intraconjunction Operations

The Helios-1 mission has now progressed well into Phase III, which started with the entrance into the first superior conjunction in April 1975. Helios 1 is rapidly approaching its second superior conjunction on August 31, 1975. The intraconjunction activities have been, as expected (Ref. 1), relatively quiescent.

As Helios 1 approached an intraconjunction Sun–Earth–probe (SEP) angle of 7.4 degrees on July 26, 1975, the solar corona effects upon the telemetry and tracking data diminished. With near-normal data for the first time in several months, it appears that the Helios-1 spacecraft is in excellent condition for its second perihelion.

The second perihelion period will start September 9, 1975, and extend through October 3, 1975, with closest approach occurring on September 21. This perihelion represents an additional opportunity for the Helios science team to gather data which will enhance primary mission objectives.

The first day of the 25-day perihelion period (September 9) is also the last day of the second superior conjunction. Primary support for superior conjunction will be provided by the 64-meter antenna station at Goldstone, Calif. (DSS 14). Near-continuous coverage during the second perihelion operations will be provided by two complete subnets—one 64-meter and one 26-meter.

Inasmuch as Helios 1 is returning to its first closest approach to Earth, a large negative doppler shift which exceeds the capability of the standard doppler extractor will occur during the second perihelion. To compensate for this condition, 1 megahertz has been added to the standard doppler bias for a total of 2 megahertz. Testing is currently in progress.

On September 3, the deep space stations supporting Helios 1 will begin to operate on voltage-controlled oscillator (VCO) transmit S-band channel 20-b and receive S-band channel 22-a as opposed to channels 21-a and 21-b, which are normally used.

This change in frequency is required to compensate for the resultant perihelion doppler shift in both the transmit and receive frequencies. This doppler shift will be observed throughout most of September and October.

Helios-1 operational support is expected to decrease somewhat as Helios-B and other network facility commitments increase in the immediate future.

B. Helios-B Test and Training

The test and training for Helios B will follow essentially the same basic outline as that of Helios 1, except on an abbreviated scale. Only the Helios-B 26-meter subnet will be tested prior to launch. The 64-meter stations will perform a demonstration pass prior to assuming their active participation after launch.

1. Simulation System Tests. Helios-B testing will utilize the modified Helios-A mathematical model representation of the Helios-B spacecraft. No changes are anticipated to the Helios-A model subsystem subroutines. Minor changes have been made, however, to the executive subroutines to allow interface with the Mission Control and Computing Center (MCCC) multimission simulation software.

Several "in-core" data routing tests were conducted with the Helios mathematical model. The objectives were to test the hardware and software integration, the interface, and to retrain the Helios simulation engineers. After these tests, the first long-loop demonstration was a test with the JPL Compatibility Test Area (CTA 21), conducted on July 22, 1975. Although a portion of the test sequence was skipped due to lack of time, all test objectives were met. This test provided acceptance of the Simulation Data System/Mathematical Model for Ground Data System/Mission Operations System test and training support.

Other Simulation System tests are planned for the Helios 26-meter stations in September. These tests will verify long-loop operations of each deep space station (DSS) Simulation System with the mathematical model.

2. Ground Data System Tests. Five U.S. Ground Data System tests are planned for Helios B in August and September. They are designed to exercise those functions required of the Ground Data System that are not normally exercised in the daily tracking of Helios 1, but are necessary for the early operational phases of Helios B.

Two tests have been conducted to date: one with CTA 21 and another with DSS 61 (Madrid, Spain). The test with CTA 21 was generally successful.

The second test with DSS 61 (Madrid) was also successful. This exercise was performed simultaneously with a Helios-1 spacecraft track, providing the Mission Control and Computing Center with computer loading data.

3. DSN Test and Training. The DSN test and training effort started with the transmission of the Helios-B on-site Operator Training Plan and Sequence of Events to all Helios supporting stations. These on-site training exercises are designed to prepare the DSS operators in the use of hardware, software, and procedures required for Helios-B configuration and support.

With the daily tracking of the Helios-1 spacecraft, most Helios operations procedures are practiced on each track. The DSN Operations Verification Tests (OVTs) are designed to utilize the Helios-1 spacecraft telemetry and command systems to practice those operational requirements infrequently used in day-to-day operations, such as manual mode commanding and analog tape playback. Three tests were conducted with two stations at Goldstone, Calif. (DSSs 11 and 12) and one station in Australia (DSS 44). Manual mode commanding and analog tape playback were practiced as well as normal Helios-1 spacecraft support activities. All test objectives were met during each test.

The Helios-B Performance Demonstration Tests and spacecraft end-to-end testing with the spacecraft, the Spacecraft Tracking and Data System, the Mission Control and Computing Center, and the German Control Center are presently scheduled for October 1975.

4. Mission Operations System Testing and Training. Mission Operations System training and tests are scheduled to begin in October, with DSN support required in November. Training at JPL will be minimal because, unlike Helios 1, Helios-B launch and Phase I operations are to be controlled from the German Space and Operations Center (GSOC). A backup Spacecraft Operations Team will be located at JPL during this time in the event of an emergency. The prime team for spacecraft attitude control operations will be located at JPL. The Project–DSN interface remains the same as for Helios-1 operations.

C. Actual Tracking Coverage Versus Scheduled Coverage

This portion of the report covers Helios-1 tracking coverage provided by the DSN from June 13 through August 14, 1975. During this time, the Helios-1 spacecraft was traversing from its first superior conjunction and approaching its second.

The Helios-1 tracking schedule called for only 36 tracks within this section of its trajectory. The total tracks available during this 63-day period were 189. Of these, the DSN supported Helios with 71% of the total available—135 tracks. The long-range scheduling forecast had requested four 64-meter tracks per week. The actual 64-meter coverage was slightly less than the forecast, but when the additional 26-meter tracks were provided, the weekly average was 15 passes per week.

The total Helios-1 tracking coverage support provided by the DSN was 1071 hours. The coverage provided by the 64-meter subnet accounted for 24.3% of this total. The average Helios-1 track was 7 hours and 56 minutes from acquisition-of-signal to loss-of-signal. The increase in coverage for Helios 1 is attributed to the redefinition of priorities by NASA Headquarters, which gives Helios-1 the same priority as Pioneers 10 and 11.

III. DSN System Performance for Helios

A. Command System

The DSN command activity in support of Helios 1 during June and July 1975 totaled 1803 transmitted commands. The cumulative total since launch is 15,283 commands. Command activity in June, due to the distance from Earth, was low; but as Helios 1 closed this distance, spacecraft scientific experiment interest again increased, resulting in an increase in the number of commands transmitted in July.

Lost command capability throughout the network decreased during this period (6.5 hours) from that experienced during the last reporting period (9 hours). Approximately 85% was attributable to DSS 14 (Goldstone); however, because of the great distance, this station accounted for a large percentage of the total tracking time during this interval. Two Command System aborts occurred during this period—one at DSS 11 (Goldstone) in June and one at DSS 43 (Australia) in July. One Project abort (a command disabled during transmission) was optioned in June at DSS 61 (Madrid).

Heavy Viking 1975 testing activity made its impact felt on the DSN during this period and probably contributed to three procedural errors affecting the Helios-1 command operations. Two procedural errors at DSS 14 (Goldstone) and one at DSS 42 (Australia) accounted for approximately two hours of Command System outage in the month of July.

B. Tracking System

The DSN Tracking System performance during this reporting period was very satisfactory. As Helios 1 completed its first superior conjunction in late June, the doppler noise, which had increased as the Sun–Earth–probe (SEP) angle decreased, began to slowly decrease again and ultimately leveled out well within the nominal range. The SEP angle increased to 7.4 degrees on July 26 before it started decreasing again as the spacecraft started toward its second superior conjunction on August 31.

It was this brief interlude in the Helios-1 trajectory which allowed the first normal doppler noise data measurements to be made since the SEP angle decreased to 5 degrees on April 7, 1975. The doppler noise, as expected, slowly started to increase as the SEP angle decreased. Figure 1 depicts the expected doppler noise from day of year (DOY) 212 (July 31, 1975) through DOY 256 (September 12, 1975); this covers the second superior conjunction period. There were no significant Discrepancy Reports during this reporting period.

C. Telemetry System

The Helios-1 Telemetry System performance, which has followed the predicted performance curves except during superior conjunction, has now returned to within the nominal predicted values. Following superior conjunction, the signal level residuals and the signal-to-noise ratio residuals were out of tolerance. The downlink telemetry performance improved markedly as the SEP angle increased and the solar effects diminished.

While there were no significant Helios-1 telemetry Discrepancy Reports, there were several isolated reports of signal level and signal-to-noise ratio residuals being out of tolerance. Prior to superior conjunction, there were two categories of failures being reported via the Discrepancy

Reporting System, which were contributing to approximately 50% of all telemetry failures. These were the Data Decoder Assembly, and the Automatic Total Recall System II failures. During June and July, no failures of Automatic Total Recall System II were reported, but Data Decoder Assembly failures continued to account for 25% of all telemetry failures.

Procedural errors increased to 21% of the total Discrepancy Reports as the Viking 1975 test and training effort made its impact fully felt on the operational elements of the DSN. As Helios-B test and training activities increase over the ensuing months, adding to the highly active operational commitments of the DSN, procedural reliability will be an important operational element to monitor, along with the current hardware and software systems required for Helios operations.

IV. Conclusions

With Helios 1 traversing its farthest distance from Earth and the Sun, preparations for a second superior conjunction and a second perihelion are underway. Renewed interest in the region of space in close proximity to the Sun awaits Helios-1 scientific instrument data readout and analysis. The passive experiments (Faraday rotation and celestial mechanics) will be of major importance during the superior conjunction, with the active experiments spotlighted during the second perihelion. Helios-B testing activities will increase as the DSN makes preparation for support of another Helios spacecraft, to be launched in early December 1975.

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Reference

1. Goodwin, P. S., et al., "Helios Mission Support," in *The Deep Space Network Progress Report 42-28*, pp. 23–28, Jet Propulsion Laboratory, Pasadena, Calif., Aug. 15, 1975.

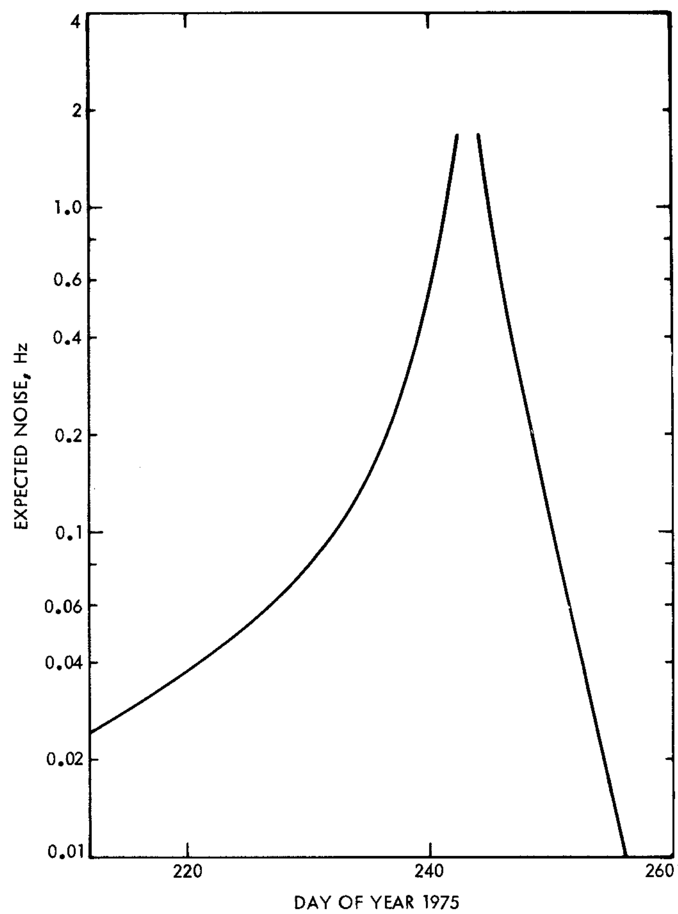

Fig. 1. Helios-1 doppler noise (expected) vs day of year