# Helios Mission Support

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*The Helios-1 spacecraft has completed its dual superior conjunctions and second perihelion passage of the Sun and is rapidly approaching its second aphelion, near the Earth's heliocentric trajectory. Valuable scientific data were obtained during these two important events. Helios-B testing activities are proceeding according to schedule, with test results reported in this article.*

## I. Introduction

This is the sixth article in a series that discusses the Helios-1 flight support provided by the DSN. The previous article (Ref. 1) reported on that mission period between the first and second superior conjunctions of the Helios-1 spacecraft and initial Helios-B test and training results. This article covers the Helios-1 second superior conjunction and second perihelion operations. Additionally, DSN tracking coverage and systems performance are discussed, as well as the Helios-B test and training activity.

## II. Mission Status and Operations

### A. Helios-1 Second Superior Conjunction

The second Helios-1 superior conjunction occurred on August 31, 1975, and lasted for only 16 days. The superior conjunction period is determined by the amount of time which is necessary for the spacecraft trajectory to cross from occultation entry minus 3 degrees, through solar conjunction to exit plus 3 degrees, within the ecliptic plane. The second superior conjunction was relatively short as compared to the first, which took 56 days to traverse this "blackout" region. The second blackout period started on August 22 and extended through September 6, 1975. The spacecraft was configured for blackout two days earlier than planned when unexpected solar interference was encountered at a Sun–Earth–probe (SEP) angle of 3.65 degrees. A detailed spacecraft analysis was initiated by the German Control Center (GCC) when the spacecraft's downlink signal-to-noise ratio was unexpectedly degraded by 2 dB. The analysis revealed that the degraded performance could be attributed only to solar interference, which was much more intense than anticipated. During the time in which the spacecraft was configured for blackout operation, the Goldstone 64-meter station (DSS 14) was denoted the prime station for support of radio metric and polarimetry data. In addition to project requirements, the DSN Tracking and Telemetry Analysis Groups continued their own parallel studies of the observed radio metric and spectral broadening effects resulting from the varied solar phenomena.

### B. Helios-1 Second Perihelion

The second perihelion phase started four days after the termination of the second superior conjunction. The second Helios-1 perihelion occurred at 12:16 GMT (05:16 PDT) on September 21, 1975. The perihelion phase includes perihelion plus and minus 12 days while the probe gathers its objective data within the environs of our solar sphere. DSN support provided during the second perihelion was not continuous, as during the first perihelion, but the tracking coverage was substantial. The Goldstone 64-meter station did provide daily coverage during September; the Madrid 64-meter station, which was scheduled for the first time for Helios-1 support, covered six tracking passes at their longitude during the September portion of the second perihelion phase. DSN 26-meter station support was scheduled to complete the coverage requirements when their services were not committed to flight projects with higher priority than Helios 1.

The overall performance of the spacecraft's subsystems and science instruments during perihelion was excellent. At second perihelion the minimum distance to the Sun was 0.309 AU (46.2885 million km), and the distance to the Earth was 1.01 AU. As expected, the probe encountered slightly higher temperatures during the second perihelion. The increased temperatures were caused by the gradual degradation of the spacecraft skin due to the high-radiation environment.

### C. Post-Perihelion Performance and Operations

A problem was observed on October 10, 1975, within the spacecraft's ranging subsystem. The anomaly occurred during a ranging pass over DSS 14 and was subsequently verified by the Australian and Madrid 64-meter stations. The anomaly is manifested by an apparent absence of ranging modulation on the downlink carrier when all other correlated spacecraft ranging functions appear normal. Subsequent to the Network verification, a special ranging test was conducted on October 18, 1975 at DSS 14. The uplink was modulated with a 500-kHz signal while a downlink spectrum analysis was performed to determine if the 500-kHz modulation was detectable. This test revealed that the modulation and a harmonic at a 1.5-MHz interval was present but markedly degraded. The ranging anomaly analysis continues under project and DSN investigation.

### D. Tracking Coverage

The DSN is investigating the possibility of obtaining support for the Helios Mission from the Spaceflight Tracking and Data Network (STDN). This cross support is desirable for all parties: the DSN is committed to an exceedingly demanding flight support program; STDN has available resources to provide support through the projected Helios mission lifetime; and the Helios project would receive data that would otherwise be lost. The present prospects for STDN cross support for Helios tracking coverage rose substantially with the completion of two STDN Helios data acquisition tests. The tests were conducted at Goldstone utilizing DSS 12 and the STDN–Apollo 26-meter station to determine the respective performance differences between an STDN 26-meter station and a standard 26-meter DSN station. Analysis of the real-time telemetry performance, coupled with non-real-time data retrieval from STDN analog tapes at the Merritt Island Compatibility Test Area (STDN (MIL 71)) will then provide long-range cross-support projection for Helios coverages. STDN (MIL 71), the only location where STDN–DSN systems are co-located, will become the focal point of the cross-support system. The STDN analog recordings will be converted to DSN digital recordings and merged into the Master Data Record at JPL via the high-speed data lines from STDN (MIL 71). While confidence of success remains high, a functional cost-effective operational system has yet to be completely demonstrated. Test completion is expected in mid-November 1975.

### E. Actual Tracking Coverage Versus Scheduled Coverage

This report covers Helios-1 tracking coverage provided by the DSN from August 15 through October 16, 1975. Spacecraft operations during this time period included both the *second superior conjunction* and *second perihelion*.

The revised DSN long-range Helios-1 forecast had requested 101 tracking passes within this time frame. This requested coverage had projected continuous coverage throughout the second perihelion period. Due to higher priority commitments to other flight projects, continuous coverage for Helios 1 was not available. Nevertheless, DSN operations supported 122 Helios-1 tracking passes during this reporting period of 62 days, in which a total of 186 tracks were available. The total requested support equalled 54% of the available tracks with 66% actually supported, for a total of 927.2 hours of coverage. Total support during this period had a slight drop from the last period, but there was a 16-day blackout period where only DSS 14 was required to provide 14 days of coverage. The average pass duration changed little and was 7.6 hours long. Support during perihelion increased from 61 to 71%

of available tracks, excluding any mission support provided by the German network during perihelion. The DSN 64-meter stations supported for 626.1 hours out of the total 927.2 hours of coverage. In summary, the total Helios-1 DSN tracking coverage provided to the project continues to fulfill the total requested project tracking coverage requirements.

## III. Helios-B Test and Training Status

The Helios-B mission has been delayed from its December 8, 1975 launch to a date between January 15 and February 7, 1976. The delay resulted from fire damage to the launch pad ground support equipment during launch of the Viking 2 spacecraft.

The test and training activities in preparation for Helios-B launch and flight support have been progressing according to schedule. Simulation System, Ground Data System, and Operations Verification tests were completed in September. Initial Acquisition and Step II Maneuver tests are scheduled for late October and early November. The Mission Operations System Tests began in mid-October.

### A. Simulation System Tests

Simulation System testing was conducted with all 26-meter stations scheduled to support Helios B. These tests verified correct long-loop operation of the Helios system while also providing operator training. This system was used to support the Mission Operations System tests.

### B. Ground Data System Tests

Two Ground Data System (GDS) tests were conducted during September, prior to joining the German network in the U.S.–German Performance Demonstration Test on September 28, 1975. The objectives of the latter test were to verify the performance of the Helios GDS Telemetry, Command, and Monitor System functions and to verify the system interfaces between the Jet Propulsion Laboratory and the German Control Center (GCC), while the respective Control Centers were operating in their normal multimission environments. All test objectives were met; therefore, the U.S.–German Combined System Test, which had similar objectives, was cancelled. The Ground Data System was declared ready to support the Mission Operations System tests.

### C. DSN Test and Training

The 26-meter stations completed their Operation's Verification tests for Helios B in early September with the last three tests being performed with DSS 42, 61, and 62. These tests were conducted during Helios-1 spacecraft tracks and were designed to test only those operational requirements infrequently used in day-to-day operations, such as manual mode commanding and analog tape playback. All three tests were successfully completed, reinforcing the Helios-B test and training philosophy of minimizing redundant testing and concentrating on Helios-B unique operational requirements.

Special DSN tests, concerning critical portions of the mission (Initial Acquisition and Step II Maneuver), were begun in mid-October, and will continue through mid-November. Approximately six each of these tests are planned, four in October with the remaining in November. As of this writing three Initial Acquisition tests have been conducted with DSS 42/44. All have been completed satisfactorily with only minor discrepancies. The two recent Viking launches have added a measure of confidence and experience to the operational crews.

Step II Maneuver Tests are planned for the first half of November with DSSs 11 and 12. Each station is scheduled to perform three Step II Maneuver Tests.

In the interest of reducing the number of test conflicts between Helios B and various flight projects, and because of the excellent results of testing thus far, the DSN Helios-B Performance Demonstration Tests were cancelled. DSN Configuration Verification Tests have been scheduled for late December. The Helios-B Spacecraft End-to-End Test (spacecraft–STDN (MIL 71)–JPL–German Control Center) is now due to be performed the first week of November.

### D. Mission Operations System Test and Training

Mission Operations System (MOS) tests and training began on October 21 with a Helios-B launch exercise. This test, conducted from the German Control Center, was successfully completed while simulating the Initial Acquisition at DSS 42. The backup Spacecraft Operations Team and Attitude Control Team, located at JPL, also participated in these tests. Two other MOS tests, Step II Maneuver, and Post Step II Maneuver plus Experiment Turn-On, were scheduled during the month of October. Both tests employed computer simulation of the Deep Space Stations. Actual DSN support of MOS testing is scheduled to begin in mid-November and continue until launch.

## IV. DSN System Performance for Helios

### A. Command System

The DSN command activity for Helios 1 sharply increased over the last period because of increased command requirements during the perihelion period. During August and September 1975, the DSN transmitted 3349 commands to Helios 1; in the prior period only 1803 commands were transmitted. The DSN cumulative total now stands at 18,632 commands transmitted with an attendant abort total of 11. The DSN Command System experienced one abort for a cumulative total of 3 aborts. Project aborts also increased by 1, to a total of 8 project aborts.

The DSN abort occurred at DSS 42 in Australia and was caused by a GMT timing problem in the Telemetry and Command Processor. The correction for this anomaly was to reseat the logic cards within the time display buffer of the computer.

The command capability lost throughout the DSN decreased in proportion to total support and was 5.85 hours. The 64-meter and 26-meter station contributions were also representative of their respective support. Additionally, 57 minutes of command capability were lost due to overseas high-speed data line outages. In total, 11 incidents resulted in 6.8 hours of lost command capability to the Helios Project, with the longest outage being 70 minutes and the average outage equal to 37 minutes.

### B. Tracking System

The performance of the DSN Tracking System during superior conjunction and perihelion continued to more than satisfactorily fulfill all DSN and Helios Project requirements. One significant Discrepancy Report was submitted on a DSS 42/43 planetary ranging subsystem problem. Fortunately, it was a timing interface problem, and it has been determined that the ranging data will eventually be recoverable when an appropriate timing bias is applied to the data reduction process.

Superior conjunctions always reflect the importance of radio metric data, and extensive analysis of these data was performed by both the Project Scientists and the DSN Tracking Analysis Group. Following considerable work, the DSN Tracking Analysis Group has developed an improved model of the effects of Sun–Earth–spacecraft geometry upon doppler noise. This model is now being used and was compared to an extensive set of historical values of doppler noise. Very good correlation has been obtained using this model, and its results will be reported in greater detail in a separate report initiated by the DSN Tracking Analysis Group.

A special 2-MHz doppler bias capability was implemented to insure quality doppler data during the second Helios-1 perihelion. Due to the Sun–Earth–probe geometry during this perihelion, the Earth-received doppler is shifted in a negative direction outside the normal operating range of the Tracking System. Selected DSN stations received the modified doppler configuration for operational support from September 11 to October 11, 1975. Additionally, the stations had to compensate for the excessive doppler effects in the uplink and downlink communication signal by switching from the standard S-band channel 21 frequency. The doppler effect resulted in a receive frequency within the channel 22 range, while the transmitter frequency dropped to a channel 20 frequency. This operational mode existed from September 3 to October 24, 1975. These special modes operated flawlessly during this important stage of the mission.

### C. Telemetry System

The analysis of the Telemetry System performance during August and September was accomplished in two parts. All solar conjunction data analysis is viewed as extraordinary data and is outside the normal range of performance analysis. Therefore, a special data analysis and report was undertaken by the DSN Telemetry Analysis Group.

All other Helios-1 telecommunication link performance data during this period revealed the following trends. Preceding entry into superior conjunction, both the downlink signal level and the signal-to-noise ratio departed from established trends and had degraded performance curves earlier than expected. Following superior conjunction, the degradations returned to their normal trends. The average signal level differential for actual-versus-predicted performance is near zero dB, while the actual-versus-predicted signal-to-noise ratio average is –0.5 dB. There were no significant discrepancy reports during this period. A problem area which has been corrected concerned numerous Discrepancy Reports on erroneous signal level calibration curves; most of the errors were operator procedural errors. The DSN Telemetry Analysis Group is also supporting the on-going analysis of the aforementioned spacecraft ranging problem.

## V. Conclusions

The Helios-1 spacecraft has now completed its second superior conjunction and second perihelion of the Sun. As the spacecraft enters its second aphelion, making its closest approach to the Earth, all experiments except spacecraft ranging remain active. During the second superior conjunction and second perihelion, data from both passive and active spacecraft subsystems and ground experiment instruments again contributed to an increased and much-valued second opportunity for the Helios Project scientists to collect collaborating solar data.

The preparations for Helios-B launch and flight support (now scheduled for late January 1976) have increased during this report period and are presently progressing smoothly. Special tests conducted between the DSN and the Spaceflight Tracking and Data Network seem promising as a possible alternative for providing future Helios telemetry coverage.

As other flight project support activities increase, DSN coverage of the Helios-1 spacecraft is likely to decrease from previous levels.

## Acknowledgment

The authors wish to thank the following persons from the Network Operations Analyst Group, for their contribution of Periodic Network Performance Reports: Command—R. Frampton, B. Hoffman, and W. Tucker; Telemetry—J. Henricks and C. Lunde; Tracking—R. Schlaifer.

## Reference

1. Goodwin, P. S., et al., "Helios Mission Support," in *The Deep Space Network Progress Report 42-29*, pp. 15–19, Jet Propulsion Laboratory, Pasadena, Calif., Oct. 15, 1975.