

Helios Mission Support

P. S. Goodwin
DSN Systems Engineering Office

W. G. Meeks
Network Operations Office

Helios-A, the cooperative U.S./West German space flight, is now successfully enroute to its 0.31-astronomical unit (AU) perihelion passage of the Sun in mid-March 1975. This article describes the DSN performance to date, along with a few minor problem areas that have developed but do not jeopardize mission objectives.

I. Introduction

The previous article (Ref. 1) discussed the successful launch of Helios-1 (previously denoted Helios-A) on December 10, 1974, and the support provided by the DSN through the completion of the critical Step II maneuver sequence of the spacecraft which oriented its spin axis towards the ecliptic pole. The final sequence of the Step II maneuver oriented the spacecraft's despun high-gain antenna (HGA) towards Earth. Early science instrument telemetry data indicated a possible problem with one of the experiment packages; however, that article closed before the extent of the problem was fully diagnosed.

II. Mission Status and Operations

A. Scientific Data Versus Spacecraft High-Gain Antenna Operation

With a successful conclusion to the critical Step I and II spacecraft maneuver sequences and the subsequent orientation of its high-gain antenna, the equally critical

checkout of the scientific experiment package was initiated by the Flight Team and Project Scientists. Ten mutually complementary experiments are carried by Helios-1. These experiments are designed to achieve, as a package, the science portion of the Helios mission. The experiment package checkout using the spacecraft high-gain antenna proceeded nominally through the first four experiments. Experiment 5 (the Plasma and Radio Wave Experiment) telemetry data contained an excessive level of noise. The experimenter, Dr. Gurnett of the University of Iowa, requested that the spacecraft's operational antenna be switched to the medium-gain antenna to isolate the noise source. This request was honored, but on a later pass over Deep Space Station (DSS) 42. After the initial delay caused by the Experiment 5 anomaly, final verification and configuration of the scientific experiment data package continued using the spacecraft high-gain antenna.

With the exception of Experiment 5, the checkout and analysis of the scientific experiments established the

integrity of the package. At this juncture, Experiment 5 underwent intensive analysis. The experimenter recommended spacecraft medium-gain antenna operations which would result in substantially lower, and therefore unacceptable, spacecraft telemetry data rates during the early phase of the mission. Thus, the high-gain antenna mode was selected, at the expense of Experiment 5 data, to allow operation at a higher data rate using the 26-meter deep space stations.

As Mission Operations Phase I came to a close in early January 1975, noise on Experiment 1 telemetry data was detected. Analysis of Experiment 1 (the Plasma Detectors Experiment by Dr. Rosenbauer of the Max Planck Institute) telemetry data revealed that noise generated during high-gain antenna mode operation was also affecting its data. With Experiment 5 data being essentially worthless and an important part of Experiment 1 data being lost due to high-gain antenna operation, the consensus was to increase operations on the spacecraft medium-gain antenna by using the 64-meter deep space stations.

This mutual German-NASA decision was made to maximize scientific data return of the total scientific experiment package. Medium-gain antenna operations required schedule reallocation of the 64-meter stations at Goldstone and Australia, in conjunction with the 100-meter German Effelsberg station, to maximize scientific data return during January and February, when only DSN 26-meter station support had been originally scheduled. To minimize the amount of switching between high-gain and medium-gain antenna modes, a Helios antenna switching plan was implemented.

This plan, which was agreed upon by both Flight Operations and Project Scientists, resulted in maximum medium-gain antenna operations by providing extended coverage by the large aperture antennas. The defined tracking schedule in this plan required 14 switching operations during the period January 30 to February 28, 1975, for a total of 28 switches between medium-gain and high-gain antenna modes. The DSN 26-meter stations did provide support during several of the extended medium-gain antenna mode operations, but usually only provided scheduled coverage during spacecraft high-gain antenna operating modes, which enabled maximum telemetry data rate.

The first Helios perihelion occurs March 15, 1975 with the attendant critical period coverage; the total Helios

perihelion period is March 3 through March 27, 1975. During Helios perihelion coverage, when the large aperture antennas provide almost total coverage, the plan is to operate in the medium-gain antenna mode during one pass every other day.

B. Mission Phase I/II Handover

Mission Phase I was defined as that time period wherein Mission Operations were conducted by the German Operations Team, but from the JPL Mission Support Area (MSA). It encompassed pre-launch operations activities, launch, Step I and II maneuvers, and subsequent operations up to four weeks following launch—at which time Mission Operations personnel were transferred to the German Space and Operations Center (GSOC) at Oberpfaffenhofen, West Germany. Mission Phase II is defined as that time period starting with the completion of Phase I and continuing through the spacecraft entry into first solar occultation.

Transfer of Mission Control Area responsibility from JPL to GSOC was accomplished, as planned, on January 10, 1975 at 1400 GMT. Two of the three German Flight Operations Teams departed JPL on January 7, 1975 for the GSOC. To provide for a smooth handover, one operations team remained at JPL until January 14, 1975. A DSN Operations representative also accompanied the German Flight Operations Teams to GSOC to provide real-time interface and problem analysis pertaining to DSN Operations support.

Data comparison between JPL and GSOC real-time computer programs showed full agreement regarding Helios flight data. Calibration and limit values were adjusted, where needed. GSOC successfully recorded and processed data from the Effelsberg station while in a multimission configuration with West Germany's AEROS-B and Symphonie Projects, which were active simultaneously with Helios-1.

Mission control responsibility had been with the German Flight Operations Teams at JPL since the successful launch of the Helios spacecraft on December 10, 1974; however, the German Space Operations Center had actively participated since the initial spacecraft acquisition over DSS 42 (Australia). The German Effelsberg Station (GES) first tracked the spacecraft on December 13, 1974, and the German Telecommand Station (GTS) first transmitted to the spacecraft on December 15, 1974.

The continuity of mission operations during this handover verified the soundness of the Mission Phase I/II

handover plan. Interface problems and/or questions that arose were addressed as they happened by those cognizant personnel involved. Internetwork operating procedures are continuing to be refined to further enhance mission operations.

C. Operational Interface Change

With the departure of the German Flight Operations Teams, the JPL Helios mission support at JPL consisted only of the remaining JPL Mission Operations Support (MOS) teams. This JPL staffing remained at the Phase I level of support until February 1, 1975, 1530 GMT. At that time, a new operational support mode was implemented.

The new operational mode for Mission Phase II involves a German/JPL real-time voice interface between the German Network Operations Control Chief (NOCC) and the DSN Operations Chief (OPSCHIEF)/Mission Control and Computing Center Operations Controller (MCCC OPSCON), rather than via the JPL Chief of Mission Operations Support (CMOS) which was the case for Phase I. The CMOS and the JPL Command Operator will continue to support all critical Phase II operations on a shift-by-shift basis, as appropriately scheduled in advance; otherwise, support will be on a call-up basis. Within three hours of a request by GSOC to the DSN OPSCHIEF/MCCC OPSCON, preparations for commanding in the backup mode (command initiated from JPL) will commence. This applies 24 hours a day, 7 days a week, throughout the remainder of the mission.

During all noncritical periods, including periods of commanding in the backup mode, the operational interface with JPL exists through the DSN OPSCHIEF and MCCC OPSCON. All MCCC-related coordination is handled by the OPSCON. DSN-related (including DSN Ground Communications Facility (GCF)) coordination is handled by the OPSCHIEF.

The "CMOS Call-Up" has been exercised only once since February 1, 1975. On February 4, 1975, at 2025 GMT, GSOC requested backup mode commanding from JPL because of an inoperative computer at the German Center. Within 10 minutes, the first of 9 backup commands was sent and verified. Backup command support was successful and terminated at 2225 GMT, when control was transferred back to GSOC.

The present operational mode, with its critical-period coverage and call-up provision, has proven capable of providing adequate support for the Helios-1 Mission Phases II and III. Future adjustments to this coverage, if

required, will be negotiated between JPL and GSOC Mission Operations.

D. Scheduled Versus Actual Coverage

From Helios-1 launch until February 13, 1975, a total of 199 station tracks of the requested 202 tracks have been completed. Only seven 64-meter station tracks (DSS 14) were originally requested by the long-range schedule. However, the problems encountered with Experiments 1 and 5, plus a downlink signal level anomaly, caused real-time schedule changes. This involved successful negotiations with other projects to secure additional 64-meter coverage substantially greater than the original requirement for investigation of these problems. Multiple-mission tracking and Helios Project data requirements have necessitated schedule changes that have caused Helios to lose three complete passes, one over Australia and two at Goldstone. Considering the varied spacecraft tracking requirements of the DSN and similar viewperiods between Helios and Pioneer, spacecraft coverage has been very good to date.

Helios-1 will be entering a critical perihelion mission period during mid-March 1975. DSN resources will be extremely scarce because of the Mariner 10 and Pioneer Projects' critical activities also planned for mid-March. A Network Allocation Plan has been formulated by all affected projects to meet multiproject requirements. Results will be covered in the next report.

E. Helios Downlink Signal Level Variation

DSS 62 (Spain) reported on January 8, 1975 that since Helios-1 had been switched back to high-gain antenna mode on December 20, 1974, random transient phenomena had been observed on the system noise temperature chart recordings. These transients, which were noted as small but sudden changes in system temperature, could be detected in both two-way (one station) and three-way (two station) tracking configurations. This observation eliminated the possibility that the noise was being generated by the station transmitter. Occasional variations of 1 to 2 dB in the downlink signal level had also been detected.

The variation in the received signal level was one aspect of the anomaly that was not as readily observable as was the system temperature chart recording. This is due to the sample rate of the station monitoring device, the Digital Instrumentation Subsystem (DIS), and the DSS receivers being configured in narrow AGC bandwidths. The DIS algorithm uses several points to calculate the receiver AGC. With the receivers in the narrow bandwidth position, a smoothing action resulted in the

observed downlink signal level fluctuations. Therefore, only the occasional large variations of 1 to 2 dB were observable.

As a result of their astute observations, DSS 62 (Spain) initiated a thorough investigation of the Helios downlink signal during pass 27 on January 5, 1975. The variations in the downlink signal level were directly correlated to the transients on the system noise temperature chart recording during this test, but no definite trend or periodicity of the variations could be established.

The Helios downlink investigation was expanded by the DSN throughout the 26-meter network that was supporting Helios. The analysis efforts were concentrated at DSS 12 (Goldstone). DSS 62's initial experiences were duplicated at DSS 12 on passes 32 through 35. No attempt was made to isolate the problem within the spacecraft during the DSN investigation, inasmuch as it was a Helios Project responsibility. The investigation provided detailed information on the characteristics of the shape, duration, and recovery time of the variations. This phenomenon has only been observed with data associated with spacecraft high-gain antenna operation. One typical 3-1/2-hour period that was analyzed had 22 randomly occurring variations. The magnitude of the majority of these variations was 0.3 to 0.6 dB, with an average duration of approximately 5 seconds; but some had a magnitude of as much as 2 dB. The DSN has provided the above information to the German Operations Team, and is continuing to assist and provide support to GSOC, as required, in their efforts to isolate and correct the variations in Helios-1 downlink transmission.

F. Telecommunication Constraints Caused by Grayout/Blackout

The Helios orbit, relative to the Sun-Earth line, at various times during the mission crosses either in front of or behind the Sun. As the spacecraft approaches the Sun-Earth line, telecommunication is disrupted, either by solar-generated noise or by total occultation of the spacecraft, thus causing a grayout or a blackout, respectively. The critical angular range is expected to be plus and minus 3 degrees around the Sun-Earth line.

The first grayout has occurred and data are being compiled for analysis. Results should be available for the next DSN Progress Report. DSS 62 (Spain) first observed the grayout effects during pass 70, February 17, 1975. The grayout period lasted through pass 72, and again DSS 62 was tracking the spacecraft as it exited the region of solar grayout. The most severe solar effects were observed by DSS 62 and DSS 12 (Goldstone) during pass 71, February

18, 1975. The receiver out-of-lock times were so extensive that no useful telemetry data were observable.

III. DSN System Performance for Helios

A. Telemetry System

The Helios Telemetry System performance analysis has shown that a constant improvement in the Helios telecommunications link performance versus predicted performance has occurred. This improvement has been noted in the actual residual calculations of the downlink signal level and signal-to-noise ratio (SNR). The improvement of telecommunications link performance is still being analyzed and has not yet been satisfactorily explained. Link analysis of actual performance has resulted in minor changes to the predicted pre-flight nominal predictions. These parameter adjustments are incorporated into the DSN Link Analysis and Prediction (computer) Program (LAPP) for refinements to the telemetry predictions for real-time operations.

The investigation of the aforementioned variations in the downlink signal level was one area of major analysis activities during this reporting period. Other significant analytical studies were made on the Helios telemetry threshold and the Helios performance at solar conjunction. Both of these studies will be relevant for Helios perihelion which occurs March 15, 1975. The only Helios telemetry discrepancy reports opened during this period concerned anomalous SNR residuals and were not considered significant.

B. Tracking System

The DSN Tracking System performance for Helios-1 from launch through January 31, 1975 has been nominal. Predicted spacecraft frequencies, both transmitted and received, have been extremely accurate and reliable. Trend analysis of 160 Helios tracks indicates the doppler noise for Helios-1 averaged 0.003 Hz, which is well within specification. The two-way doppler residual averaged -0.1 Hz, indicating a high reliability in the Helios Project-supplied ephemeris tapes. Several tracking discrepancy reports were opened during this period but none was considered significant.

C. Command System

During the months of December 1974 and January 1975, 6890 commands were transmitted to the Helios spacecraft. No DSN Command System aborts occurred; however, two Project command aborts have happened. A system abort is an abort due to a Command System

failure. A Project abort is a command aborted by Project, i.e., disabled while being transmitted.

Although minor command equipment anomalies have occurred throughout the network, they have caused no significant impact to the Helios Project's Command System performance.

IV. Conclusions

The Helios-1 spacecraft has now passed in front of the Sun (first syzygy) enroute to an 0.31-AU perihelion passage, which will be well into the unexplored region of the solar system inside the orbit of the planet Mercury. DSN coverage support to date has not been completely as

planned before launch, due to both spacecraft anomalies and schedule difficulties with other flight project support; however, mission objectives have not been jeopardized. The scheduling difficulties are expected to increase during March 1975, especially with respect to 64-meter station coverage, due to a severe peaking of flight project activity: Mariner 10 will re-encounter the planet Mercury a day after the Helios-1 perihelion point, and Viking pre-launch implementation within the DSN will necessitate some selected station downtime. The impact on Helios-1 will be a lower science telemetry bit rate return when coverage is provided by 26-meter DSSs instead of 64-meter DSSs. Nonetheless, near-continuous coverage of the Helios-1 perihelion region is still planned for this important mission event.

Reference

1. Goodwin, P. S., "Helios Mission Support," in *The Deep Space Network Progress Report 42-25*, pp. 43-46, Jet Propulsion Laboratory, Pasadena, Calif., Feb. 15, 1975.