Helios Mission Support

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Operating beyond its 18-month design lifetime, the Helios-1 spacecraft continues to gather valuable scientific data. Having achieved its fourth perihelion, the Helios-1 spacecraft is being closely followed by Helios-2, as the latter emerges from a lengthy solar conjunction period, in which considerable scientific data were collected on Experiments 11 and 12 (Celestial Mechanics and Faraday Rotation). The scientific opportunities to compare the data from the two Helios spacecraft continue to add to man's knowledge of the sun's influence upon the inner solar system.

I. Introduction

This is the twelfth article in a series that discusses Helios-1 and -2 mission support. The previous article (Ref. 1) reported on a Helios-1 spacecraft power anomaly, Helios-2 occultation, STDN–DSN telemetry cross-support engineering-level tests, tracking coverage and DSN performance. This article covers the Helios-1 third solar occultation and fourth perihelion. A Helios-2 spacecraft emergency and third solar conjunction (occultation) are also discussed. Additional topics include STDN–DSN telemetry and command cross-support, Ground Data System tests, tracking coverage, plus DSN system performance for August and September 1976.

II. Mission Operations and Status

A. Helios-1 Operations

The Helios-1 spacecraft occulted the sun for a third time on September 23, 1976. The spacecraft was transmitting on traveling-wave tube amplifier 2 (TWTA-2), high-power mode, and stored experiment data on-board the spacecraft for memory readout later at a higher bit rate. As the probe cleared the "blackout" region, heading towards its fourth perihelion, the spacecraft team commanded TWTA-2 to medium power. The medium power mode was selected to reduce the risk of excessive traveling-wave tube (TWT) assembly temperature as the spacecraft approached the sun.

At 1907 GMT on Tuesday, October 5, 1976, the Helios-1 spacecraft successfully passed its fourth perihelion at a minimum distance of 0.309 AU (approximately 45 million km) from the sun. The maximum solar impact was equal to 10.445 solar constants. The overall performance of the spacecraft and its 10 scientific instruments, which had exceeded the design lifetime of 18 months, was excellent. All 10 experiments were fully configured for prime mission mode and delivering valuable science data.

Several members of the scientific team observed the perihelion passage from the German Space Operations Center (GSOC). The scientists are finding Helios-1 perihelion data very interesting since it provides a second unique opportunity of comparing measurements with Helios-2 (presently approaching its second perihelion, which is centered around October 20, 1976).

B. Helios-2 Operations

At 17:44:52 GMT on September 4, 1976, after transmission of a "ranging-on" command (at 1715 GMT), the downlink of the Helios-2 spacecraft was lost. This occurred during pass number 234 over DSS 11 (Goldstone). The failure was observed while attempting to acquire the ranging signal. Several commands were transmitted altering the spacecraft's RF configuration in an attempt to restore the downlink. This eventually resulted in reestablishing the Helios-2 spacecraft's downlink, but near threshold. To learn if the low signal was due to DSS 11 or the spacecraft, the services of DSS 42 (Australia) were attained from a scheduled Viking pass. DSS 42 was brought up as a Helios "follow-on" pass after DSS 11's loss of signal. Subsequent troubleshooting (altering the spacecraft configuration by commands) over DSS 42 tentatively restored the downlink signal at 1938 GMT in the following configuration: TWTA-1, high power, driver 1, and noncoherent mode. A spacecraft emergency was declared at 2254 GMT. After reconfiguring the spacecraft in the combination of TWTA-1, medium power, driver 1, coherent and medium-gain antenna, the DSS 42 receiver obtained lock. Switching to the spacecraft's high-gain antenna (HGA) resulted in a solid receiver and telemetry lock at 0121 GMT, September 5. The spacecraft configuration and health were verified, and the spacecraft emergency terminated at 0500 GMT on September 5.

After a few days in which to analyze the spacecraft anomaly, it was theorized that the loss of downlink was probably caused as a result of two commands: (1) ranging-on, and (2) TWTA-2 medium power. Pending further investigations it was recommended to (1) avoid ranging commands until after the second perihelion, and (2) stay on TWTA-1 in the medium-power mode.

Helios-2 experienced its third "blackout" (solar occultation) period during September 20–29, centered on September 26, 1976. All scientific data were read into memory on-board the spacecraft and later read-out when higher bit rates were available.

The Helios-2 spacecraft will pass its second perihelion around October 20, 1976. The results of this perihelion will be covered in the next progress report.

C. STDN–DSN Engineering Test and Support

Encouraged by the DSN engineering tests regarding STDN real-time telemetry and command cross-support completed during May–June 1976 (Refs. 1 and 2), the U. S. Helios Project Manager requested support for Helios-1 and -2 by the STDN Goldstone Station (GDS). This cross-support was requested for the October perihelions of Helios-1 and -2, thence continuing until November 15, when STDN GDS will temporarily be de-committed from all flight support for a scheduled equipment modification program.

Before the STDN–DSN real-time Helios cross-support could be considered operational, the link between STDN GDS and the DSN Goldstone inter-site microwave system needed more permanency. The interface installed for the engineering tests in June was a one-way temporary coaxial cable.

After considering available options, it was decided that the most suitable and economical method of providing a full duplex interconnection between STDN GDS and DSS 11 was to reestablish the old Project Apollo microwave link between STDN GDS and DSS 14. There it could join the DSN Goldstone inter-site microwave system. The Apollo-era equipment was reinstalled and successfully tested by September 30, 1976.

The plan was to first send real-time spacecraft telemetry over the newly established microwave link (Fig. 1) from STDN GDS to DSS 11 (via DSS 14 and GCF 10, both at Goldstone) where it would be processed by the back-up TCP string and sent to JPL. The uplink-lock and command tests would be conducted a week later followed by a telemetry and command demonstration pass. Upon successful completion of this demonstration pass, the STDN–DSN Helios cross-support configuration would be committed for operational support.

The first real-time Helios spacecraft telemetry was processed over the new STDN–DSN configuration (see Figs. 1 through 3) on October 1, 1976, during a demonstration pass. Data from two other STDN–DSN Helios cross-support passes were accumulated on October 15 and 16. The results are shown in Table 1.

The STDN–DSN Helios command configuration was successfully tested during the week of October 11, 1976. Several spacecraft uplink acquisitions and commanding sequences were conducted for STDN (GDS) operator training during this week. With the successful STDN–DSN Helios Telemetry and Command cross-support demonstration track performed on October 18, 1976, the STDN–DSN cross-support configuration was declared operational for Helios Project support.

Although the data from this cross-support configuration were degraded (approximately 3.5 dB) when compared to a DSN 26-meter station, the data received from Helios at perihelion and distances less than 1 AU are excellent.

D. Ground Data System Tests

1. High-Speed Data Line Change to 7.2 kb/s. The Deep Space Network (DSN) plans to convert all high-speed data terminals to 7.2 kb/s on December 1, 1976. This conversion will standardize DSN high-speed data line rates with NASA Communications (NASCOM) standards. On September 27, 1976, during Helios-1 pass 658 over DSS 12 (Goldstone), a special Ground Communications Facility (GCF) test was performed to verify that the DSN GCF conversion to a 7.2-kb/s high-speed data line (HSDL) rate was compatible with mission-dependent Mission Control and Computing Center (MCCC) software programs and hardware. The test consisted of sending parallel data streams on standard 4.8-kb/s HSDL and the new 7.2-kb/s HSDL to MCCC for Model 360-75 computer processing (monitor and tracking data were not tested at this time). Although one command anomaly did occur, there were no problems attributable to the 7.2-kb/s interface during the test. The planned changeover to the 7.2-kb/s HSD system on December 1, 1976 should be essentially "invisible" to the MCCC data system and to DSN–MCCC operations.

2. New Telemetry Capability at the German Weilheim Station. In April 1976, the German Helios Project Office received word that their request to modify the Telecommand Station at Weilheim to include a telemetry data receiving capability had been approved. Conversion was planned for late 1976 (Ref. 2). By August the conversion was progressing quite satisfactorily. The telemetry receiving equipment had been transported from the 100-meter Effelsberg Station to Weilheim. After internal (German) engineering tests were completed, internetwork interface tracking validation tests were scheduled involving Weilheim and DSS 62 (Spain). The DSN supported two of these tests—the first on September 13 and the second on September 17, 1976. These tests were highly successful, and the Weilheim Telemetry/Command Station (67/68) became operational on September 20, 1976.

E. Actual Coverage Versus Scheduled Coverage

This report covers tracking activities for a 63-day period from August 9 through October 10, 1976. Operations for this period include Helios-1 cruise, solar occultation, and fourth perihelion. Helios-2, still in solar conjunction phase, occulted the sun for the third time. Total tracks for both spacecraft were 101 for a total of 862.7 hours. Although this represents only 82 percent of the passes taken last period, there were 61 more hours of coverage. The Helios spacecraft received 41.4 percent of the DSN tracking time allotted to both Pioneer and Helios, after Viking requirements were satisfied. Helios-1 was tracked 50 times for a total of 441.4 hours; Helios-2 was tracked 51 times for 421.6 hours. The average pass time was 8.8 hours for Helios-1 and 8.2 hours for Helios-2. This compares with the last report period of 7.03 and 5.5 hours, respectively. Only 25 hours of 64-meter subnet support was allocated for the Helios spacecraft during this period due to Viking support requirements. As the Helios-1 and -2 spacecraft trajectories approach Earth, only the 26-meter subnet will be required for tracking, with the exception of ranging at DSS 14. DSN tracking support is expected to continue at its present level throughout the next report period.

III. DSN System Performance

A. Command System

The Helios extended mission command activity continued at a low level during August and September for both spacecraft. A total of 2461 commands were radiated to both Helios-1 and -2 spacecraft. This compares to 2910 commands radiated during the last reporting period. This low activity is due to two reasons: (1) the Helios-2 spacecraft spent the greater portion of this time in solar conjunction (sun–Earth–probe (SEP) angle less than 5 degrees), and (2) heavy Viking activities resulting in relatively few tracks for Helios. The cumulative command totals through September are 40,792 for Helios-1 and 14,345 for Helios-2.

There were three command system aborts during August and September—all with Helios-1. Two of the aborts were caused by DSS transmitter failures and the third by a fault in a DSS Command Modulator Assembly (CMA). Helios-2 experienced no command aborts. The cumulative command system abort count was raised to 13 for Helios-1 and remained at 3 for Helios-2.

Total command system downtime for the months of August and September rose to 12 hours and 50 minutes (almost twice the figure for the previous 2 months). Approximately one-half (5.3 hours) of the reported downtime for this period was caused by one failure at DSS 44 (a faulty circuit breaker). Of the 10 failures recorded, 5 were transmitter associated.

B. Tracking System

As the Helios spacecraft speed toward their even-numbered (in-bound) perihelions, their velocity with respect to Earth causes a negative doppler shift which exceeds the capability of the standard doppler extractor. To compensate for this condition, an additional 1-megahertz bias is added to the standard doppler bias at the 26-meter stations for a total bias of 2 megahertz. (Stations with Block IV receivers (64-meter) are able to select a minus 1-MHz bias.) The bias shift is required to avoid ambiguous doppler counts when the negative doppler approaches or exceeds the amount of positive doppler fixed bias.

The Network Operations Analysis Group (Tracking) computes the dates to add this special bias into the systems for each spacecraft. This doppler "offset" bias will be required for Helios-1 from September 29 through October 26 and for Helios-2 from October 6 through November 7, 1976.

Also affected are the transmit and receive frequencies at the Helios-supporting DSN stations. Because of this negative doppler frequency, a ground station must transmit at a lower than normal frequency and receive a higher than normal frequency to maintain relative constant frequencies at the spacecraft receiver. On September 23 the DSN stations supporting Helios-1 began operating 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 will continue until November 2, 1976. Helios-2 VCO change to 14-b and 16-a for transmit and receive, respectively, will be required between September 27 and November 14, 1976. The times to switch to these frequencies are computed by the Network Operations Analysis Group.

The Helios-1 spacecraft's ranging transponder began to operate once more on July 14, 1976, when its temperature again came within operable limits (Ref. 3). Good ranging points are now possible with Helios-1 until about October 20 when it is predicted that the temperature of the ranging unit will again slip into the non-operational range (5°C to 18°C).

Ranging with the Helios-2 spacecraft has not been attempted since the spacecraft emergency on September 4, 1976. Because a ranging command was thought to be partially to blame for the loss of spacecraft downlink, it was agreed that ranging would not be tried again with Helios-2 until after the second perihelion on October 17, 1976, when better link conditions would exist.

C. Telemetry System

During the Helios-1 and -2 superior conjunction periods, two types of data have been routinely collected for internal DSN use. The first type of data consists of hourly readings from the system-noise-temperature (SNT) recordings. The second type was spectral broadening test data. These data are being used to expand a data base that will be used later to improve telemetry predict values at small SEP angles.

Telemetry support for Project Helios has been rather routine—broken only with special downlink signal predictions for the STDN–DSN cross-support configuration. DSN telemetry predicts have been within 0.6 dB in automatic gain control (AGC) and 0.8 dB in signal-to-noise ratio (SNR) for Helios-1. Helios-2 figures are not so readily computed since tracking has been minimal during this period, caused by extremely small SEP angles.

IV. Conclusions

Emerging from a relatively quiet cruise phase, the Helios-2 spacecraft experienced its third solar occultation on September 23, 1976. Spacecraft ranging was again possible as the spacecraft ranging assembly temperature rose above 18 degrees Celsius. On October 5, 1976, the Helios-1 spacecraft passed within 0.309 AU (approximately 45 million km) of the sun as its instruments recorded the fourth perihelion. The spacecraft's health is good as it continues its trajectory which will bring it closer to Earth.

Overcoming a spacecraft emergency on September 4, 1976, the Helios-2 spacecraft passed its third solar occultation on September 26, 1976. Owing to the nature of the spacecraft emergency, the spacecraft team is cautiously delaying, until after the second perihelion (October 20, 1976), any further attempt at spacecraft ranging.

The awaited decision confirming STDN–DSN Helios cross-support for Project Helios came in mid-September 1976. An STDN–DSN Helios cross-support configuration was verified and placed into operation on October 18, 1976. This telemetry and command configuration utilizes the facilities shown in Figs. 1 through 3.

The DSN is continuing plans to convert to the 7.2-kb/s high-speed data terminals. One of the tests performed to verify hardware/software compatibility was run during Helios-1 pass 658 in September. All equipment performed well.

The German Helios command station at Weilheim was modified to include telemetry and command capabilities (telemetry added) and began operations on September 20, 1976. The German Effelsberg 100-meter radio telescope is no longer supporting Helios.

The Helios-1 and -2 spacecraft tracking activities remained at about the same level as in the previous period. This was primarily because the Helios-2 spacecraft remained in solar conjunction for most of this time period. Tracking coverage should increase during the next period owing to both spacecraft passing perihelion and approaching closer to Earth.

Although the number of commands sent to the Helios spacecraft decreased, there were three command system aborts during this report period (all on Helios-passes). Except for transmit and receive frequency changes and added doppler bias to compensate for the high doppler rate at this point in the trajectories of the spacecraft, the performance of the Telemetry and Tracking Systems remained fairly routine.

Acknowledgments

The authors wish to thank the following members of the Network Operations Analysis Group for their contribution of periodic Network Performance Reports.

Tracking:	A. L. Berman, R. S. Schlaifer, L. Bright
Command:	R. Gillette, W. L. Tucker
Telemetry:	R. Allis, H. G. Lemasters
Monitor and RFI:	P. Low, C. Lunde

References

1. Goodwin, P. S., Meeks, W. G., and Morris, R. E., "Helios Mission Support," in *The Deep Space Network Progress Report 42-35*, pp. 24–27, Jet Propulsion Laboratory, Pasadena, Calif., Oct. 15, 1976.
2. Goodwin, P. S., Meeks, W. G., and Morris, R. E., "Helios Mission Support," in *The Deep Space Network Progress Report 42-34*, pp. 21–26, Jet Propulsion Laboratory, Pasadena, Calif., Aug. 15, 1976.
3. Goodwin, P. S., Meeks, W. G., and Morris, R. E., "Helios Mission Support," in *The Deep Space Network Progress Report 42-33*, pp. 26–31, Jet Propulsion Laboratory, Pasadena, Calif., June 15, 1976.

Table 1. STDN—DSN Helios cross-support engineering test results

Day of year (1976)	Bit rate	Predicted (DSN), dB	STDN		DSN vs STDN	
			Block III, dB	MFR, dB	Block III difference, dB	MFR difference, dB
275 (Oct 1)	32	9.8	6.2	4.8	3.6	5.0
	64	8.5	4.0	2.6	4.5	5.9
289 & 290 (Oct 15, 16)	128	8.1	5.3	N/A	2.8	N/A

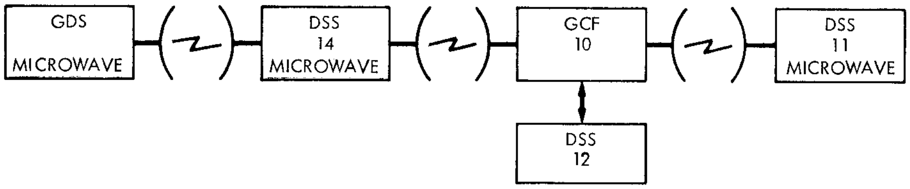

Fig. 1. STDN (GDS)-DSS microwave configuration

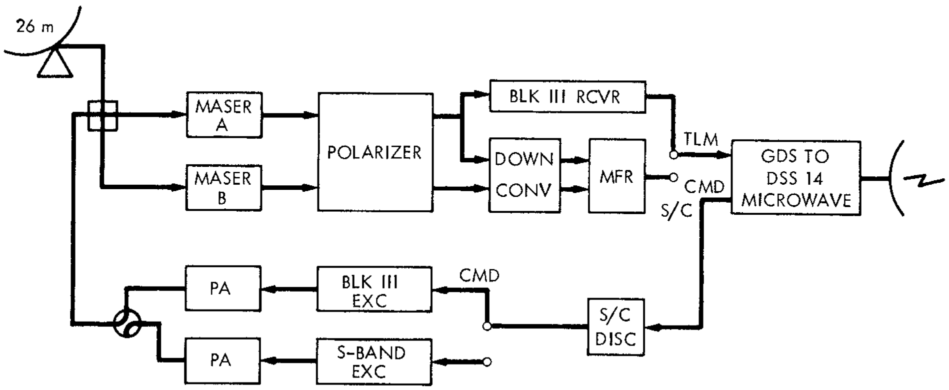

Fig. 2. STDN (GDS) cross-support configuration

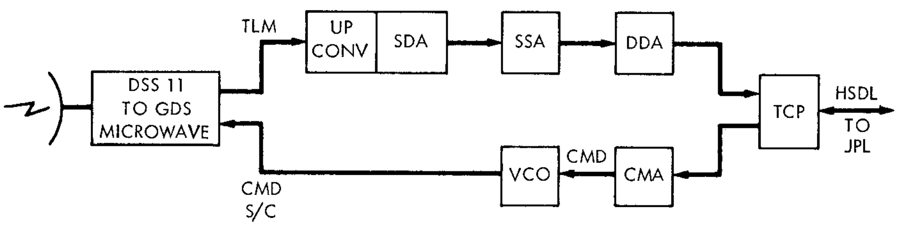

Fig. 3. DSS cross-support configuration