Helios Mission Support

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The second Helios spacecraft was successfully launched on January 15, 1976. The trajectory will allow inspection of the solar atmosphere at an unprecedented 0.29 astronomical units (AU) distance from the Sun during the Helios-2 perihelion in April 1976. Such a close solar approach will greatly enhance man's knowledge of the inner part of our solar system. This article reports on the prelaunch and launch activities through the first six days of the Helios-2 mission, as well as cruise status of the Helios-1 spacecraft.

I. Introduction

This is the eighth article in a series that discusses Helios-1 and -2 mission support. The previous article (Ref. 1) reported on Helios-1 cruise operation between the second perihelion and second aphelion, the traveling-wave tube (TWT) spacecraft anomaly, and Helios-B test and training results. This article covers Helios-B prelaunch and launch activities, Helios-1 cruise status, Helios Deep Space Network (DSN)-Spaceflight Tracking and Data Network (STDN) cross-support and DSN systems performance.

II. Mission Operations and Status

A. Helios-B Test and Training

1. DSN tests. Prior to the last Mission Operations System (MOS) test, a DSN Configuration Verification Test (CVT) was performed with each DSN 26-meter station scheduled to support Helios B in order to verify the Network launch configuration. Each CVT was designed to simulate those station activities expected during the first day's coverage of Helios B. The CVTs were scheduled so that each station could maintain its verified Helios-B launch configuration after the completion of the test.

Initial acquisition was simulated at DSS 42 and DSS 44 in Australia. Nominal spacecraft and silent spacecraft acquisition cases were conducted with excellent results from all operational facilities and personnel.

Step II maneuver procedures were practiced with DSS 11 and DSS 12 at Goldstone, since this maneuver is planned during the first pass. All test objectives were met, and the test sequence was completed, free of problems.

Cruise operational procedures were emphasized during the CVT at DSS 61 in Spain. Some contingency procedures, such as manual commanding and an analog tape playback, were included in the CVT. All facets of the test went smoothly, and, upon completion, the station was placed under modified configuration control.

The CVTs brought to a close DSN Helios-B testing. All that remained was the final Operational Readiness Test (ORT) and launch. Subsequent DSN performance during the ORT and the launch phase seem to verify the soundness of the DSN test and training philosophy for Helios B. The plan was for minimal testing of day-to-day Helios operations while concentrating on Helios-B unique operational requirements.

2. Mission Operations System (MOS) tests. To verify the readiness of all systems for mission operations in preparation for the launch of Helios B, an Operational Readiness Test (ORT) was conducted on January 12, 1976. STDN (MIL-71), DSS 42, DSS 44, DSS 61, DSS 11, and DSS 12 participated in this exercise. Viewperiods were simulated so as to allow the launch phase and Step II maneuver to be accomplished in a 12-hour test period. The Helios Math Model was used to simulate the spacecraft from prelaunch through the Step II maneuver. The Mission Control and Computing Center's flight support IBM-360 computer was used to process telemetry, tracking, monitor, and command data, plus the attitude determination programs, providing a realistic atmosphere for the test.

Although a few anomalies occurred during the test, none was serious enough to stop or delay the test. The test was successful, meeting its objectives, demonstrating all systems readiness to support the Helios-B launch.

B. Helios-B Near-Earth Operations

1. Launch operations. Helios-B launch preparations for a January 15, 1976 liftoff were initiated with the Deep Space Station prelaunch countdowns. Prime Helios-B stations participating in the first pass countdown were the DSN portion of the Spacecraft Compatibility-Monitor Station, Cape Canaveral (STDN (MIL-71)), DSSs 42 and 44 in Australia, DSS 61 in Spain, and DSSs 11 and 12 at Goldstone.

The Helios-B spacecraft was successfully launched on schedule at 05:34:00.36 GMT on January 15, 1976. All Titan-Centaur-Delta launch vehicle stages performed nominally. Data were received from the various down-range, Near-Earth Phase Network (NEPN) stations, and the spacecraft was injected into the desired orbit around the Sun with a preliminary perihelion distance of 0.29 astronomical units (AU) and an orbit period of 185 days. Immediately after solar orbit injection, the Helios-B mission was redesignated Helios 2.

Primary control of Helios-2 post-launch and mission activities resides at the German Space Operations Center (GSOC). The spacecraft team was located at GSOC with a backup team at JPL. Because the launch phase and attitude maneuver computer programs, generated for Helios 1, were available at JPL, the spacecraft attitude and navigation teams were located at JPL for the first weeks of the Helios-2 mission. The interface with STDN (MIL-71) for launch and the down-range stations was handled by the Chief of Mission Operations Support (CMOS). This function was previously handled by the DSN Operations Control Team (OCT).

The German Space Operations Center (GSOC) systems performed very well during the entire launch phase as did the Deep Space Network (DSN) and all other systems at JPL.

2. DSN initial acquisition. DSN initial acquisition by DSSs 42 and 44 in Canberra, Australia, occurred at 06:24 GMT on January 15, 1976. DSS 42 provided the prime source of data with DSS 44 in the role of a redundant backup.

At initial acquisition, the Helios-2 spacecraft transmitted via its low-gain antenna system. This antenna system consists of a linearly polarized dipole element at the top of the spacecraft and a circularly polarized horn antenna at the bottom. The spacecraft radiation pattern boundary between the top dipole antenna and the bottom circular horn antenna element of this omni-antenna system creates an interference region. Approximately five minutes after initial acquisition, the Helios-2 spacecraft aspect angle was such that this interference region was experienced for about three minutes. During the Helios-1 launch phase, this region was predicted to be much longer (approximately 8 minutes) and caused concern as to the quality of telemetry data while in this region. However, during the actual flight of Helios 1 (Ref. 2), the signal degradation caused by this interference region proved to be much less than feared. During the Helios-2 flight, the downlink signal degradation was hardly noticeable at the ground stations.

The establishment of the spacecraft's command uplink followed the end of the interference region. The first of two spacecraft attitude maneuvers was performed during the DSS 42 pass.

3. Step I maneuver. The Step I maneuver orients the Helios spacecraft such that its solar panels are evenly illuminated by the Sun, with the spacecraft's spin axis lying essentially in the plane of the ecliptic, i.e., the plane of its injection. This maneuver is required for both electrical power and thermal control. This Helios-2 maneuver was executed completely as planned, and without incident.

4. Near-Earth experiments turn-on. Following the Step I maneuver, turn-on of the Near-Earth experiments was executed. During this instrument turn-on and science experiment antennae deployment, the spacecraft telemetry indicated that the cover for Experiment 10 (Micrometeoroid Detector and Analyzer) failed to jettison. However, after careful analysis of other spacecraft instruments, and thermal and attitude parameters, the Project concluded that there is a high probability that the cover did indeed jettison and that the telemetry indicator was faulty. Experiment 10 seems to be functioning normally for this portion of the mission. The data will continue to get careful scrutiny from the Helios spacecraft team as the mission progresses. Spacecraft experiment calibration and memory readouts continued through the first Madrid (DSS 61) pass.

5. Step II maneuver. With the Helios-2 spacecraft's first rise over Goldstone, preparation was started for the Step II maneuver. The spacecraft telemetry format was switched from science to engineering data so that more spacecraft parameters could be monitored during the maneuver.

Commands were sent to the Helios-2 spacecraft to calibrate the attitude control gas jets in preparation for the Step II maneuver. This calibration allows more precise control over the spacecraft during the maneuver sequence.

Commands were initiated to pitch the spacecraft such that the antenna mast moved toward the south pole of the ecliptic. This is a deliberate change from Helios 1 in order to provide zodiacal light experiment coverage in the northern ecliptic hemisphere.* Helios 1 will continue to provide zodiacal light sensing in the southern ecliptic hemisphere during its remaining lifetime.

During the Step II maneuver, the spacecraft's attitude is also monitored in the radio metric data as spin modulation on the doppler frequency. As the pitch angle increases, so does the spin modulation. As the spacecraft's attitude is changed, the aspect angle between the DSS and the spacecraft changes, and again the antenna interference region is encountered. To traverse this interference region, two Deep Space Stations (DSSs 11 and 12) were configured to receive linear signals polarized 90 degrees apart. DSS 12 was configured for horizontal antenna polarization with DSS 11 configured for vertical antenna polarization. Telemetry from both stations was supplied via high-speed data lines to the Mission Control and Computing Center (MCCC) at JPL. Telemetry from DSS 12 was selected during the first half of the Step II maneuver, and as the signal level decreased from DSS 12 an increase in DSS 11's signal level followed. When the signal at DSS 11 surpassed that of DSS 12, then DSS 11's telemetry was processed. The degradation of the signal was not severe, so the interference region was traversed without difficulty. Midway through the Step II maneuver, the spacecraft's transmitter was switched to the medium-gain antenna supplying a 6-dB increase in signal level.

During this period, spacecraft temperatures were running low, reaching so-called "soft limits" at various points. This was due to a Project decision to remain in the TWT medium-power mode during this period. To avoid any further decrease of temperatures (caused by gas supply usage), the Project decided to delay the spin-up maneuver.

At the end of the Step II maneuver, the spacecraft had been positioned with the antenna mast aligned toward the south pole of the ecliptic. The medium-gain antenna pattern was close to its peak value, and only minor corrections would be required. Several small trim maneuvers were completed during Goldstone passes 3 and 4 in order to bring the zodiacal light experiment, E-9, into its required attitude to acquire reference stars. Ranging was turned on during the fourth Australian pass. Three good ranging measurements were obtained. The spacecraft spin rate was then stabilized at 60.591 rev/min.

With the completion of the Step II maneuver, the Helios-2 spacecraft had achieved its final orientation, which will be maintained throughout the life of the mission.

C. Helios-1 and -2 Cruise Operations

1. Helios 1. The Helios-1 spacecraft arrived at its second aphelion Christmas Day, December 25, 1975. After 380 days in space, the spacecraft had completed its second orbit around the Sun and was on its way for another. All systems were performing well, but that was not to last.

* The zodiacal light experiment's sensors view the region opposite that of the spacecraft's antenna mast assembly.

On January 28, 1976, while attempting a range measurement over DSS 42 (Australia), the spacecraft's ranging system failed to respond. First thoughts were that perhaps not enough time had been taken in calibrating the DSS ranging equipment because of a "load and go" countdown before the pass. However, on a Viking spacecraft pass following that Helios-1 pass, DSS 42's ranging equipment performed perfectly. Subsequent ranging attempts with the Helios-1 spacecraft have failed to give results. The Helios Project was notified of the problem, and the Project is keeping a very close check on the spacecraft to provide analysis of the failure. Other than the ranging problem, the Helios-1 spacecraft's experiments are performing well, and the spacecraft is in excellent health.

2. Helios 2. After six days of initial operation, the Helios-2 spacecraft is now in its cruise phase. All spacecraft systems have been checked out and are providing excellent data. Good downlink power levels and stable spacecraft temperatures prevail. All booms, extendable antennae, and the high-gain antenna (HGA) have been successfully deployed or pointed, and are working as planned. The Helios-2 mission is now well on its way with an expected perihelion of 0.29 AU on April 17, 1976.

On January 30, 1976, the GSOC Helios-2 backup spacecraft team terminated activities at JPL and departed for Germany. According to plan, support by the JPL MOS organization was reduced to the level required for cruise phase. Phase I of the Helios-2 mission has been successfully completed.

D. Spaceflight Tracking and Data Network (STDN) Cross-Support

On January 15, STDN cross-support for the Helios Mission became operational. This cross-support plan is for the STDN stations (Goldstone and Madrid) to track the Helios-1 and -2 spacecraft and provide analog recordings of telemetry data. These recordings are to be shipped to the STDN (MIL-71) station at Merritt Island, Florida, where they will be played through the DSN telemetry equipment and converted to digital recordings which will subsequently be replayed to JPL via NASCOM high-speed data lines (HSDL). At JPL, the telemetry data will be merged into the Helios Master Data Record (MDR) and shipped to the Project in the normal manner, via existing interfaces. This STDN cross-support provides Helios-1 spacecraft telemetry data that would otherwise be lost because the DSN is scheduled to support other spacecraft, e.g., Helios 2. Approximately 4 passes per week of at least 4 hours each are presently being scheduled at STDN Madrid Station on days when no Helios-1 DSN coverage is scheduled at zero degrees longitude. As of February 16, 15 passes have been recorded by the STDN-Madrid station. The STDN-Goldstone station is presently down for equipment update and is scheduled to become operational and provide Helios support after March 1, 1976.

The timing interface problem reported in the last DSN Progress Report was corrected by the Modified Time Code Translator shipped from JPL to STDN (MIL-71). Several playbacks of the Digital Original Data Record (DODR) produced at STDN (MIL-71) and sent via HSDL to the JPL MCCC have now been made with good results. Blocks of time have been scheduled each week for these playbacks.

The DSN-STDN Interface Agreement regarding cross-support for Project Helios is now in publication and will be ready for review on March 1, 1976. The purpose of this document is to establish the necessary interfaces and operations plans to provide tracking of the Helios-1 and -2 spacecraft by the Spaceflight Tracking and Data Network (STDN) and analog recording of Helios telemetry data.

Figure 1 depicts the milestones associated with the DSN-STDN cross-support effort.

E. Actual Tracking Coverage Versus Scheduled Coverage

This report covers a 55-day period for Helios-1 tracking coverage, from December 12, 1975 through February 5, 1976, and a 21-day period for Helios-2 tracking coverage, from January 15 through February 5, 1976.

Helios-1 extended mission coverage allocated during this period was 28 percent of the total passes possible. Helios-1 spacecraft received 77 tracking passes and 427 hours of tracking coverage. This is the second reporting period to show a decline in the number of Helios-1 passes, the number of hours tracked, and the percentage of coverage supported. The average pass duration dropped from 7.0 to 5.5 hours. This drop was mainly due to split-pass coverage caused by heavy network activity for other spacecraft and their overlapping viewperiods. During this reporting period, Helios 1 was close to the Earth and could be supported by a 26-meter subnet at high data rates. For this reason, the 64-meter subnet only supported 148.5 hours, a decrease of 81 percent from the last reporting period.

Although declines are shown in most phases of actual coverage of Helios 1, it must be remembered that during the last 21 days of this reporting period Helios 2 was receiving 24 hours a day coverage and most of GSOC's attention. In addition to this, GSOC can receive data from only one Helios spacecraft at a time.

Helios-2 tracking coverage consists of 68 passes, equalling 817.5 hours. The average pass time was 12 hours. This represents 100 percent coverage by the DSN during this period.

Tracking coverage should pick up from this low point for Helios 1, as the third perihelion will occur during the next reporting period. Scheduled coverage for Helios 2 should remain at 24 hours per day until first occultation.

III. DSN System Performance for Helios

A. Command System

With the launch of another Helios spacecraft, a sharp increase in total Helios commands transmitted in December and January was evident. During December, the Helios-1 spacecraft made its first close approach to Earth since launch. A total of 2433 spacecraft commands was transmitted to Helios 1 in December alone. With the launch of Helios B (now identified as Helios 2), tracking opportunities and spacecraft interest shifted to the new flight spacecraft. Many commands are necessary to check out the spacecraft, ready the on-board instruments, adjust the attitude, and in general ready the spacecraft for cruise operations. During the remaining 16 days of January 1976, 2610 spacecraft commands were transmitted. An overall total of 6049 Helios commands were transmitted during the months of December 1975 and January 1976. This was 1380 more than the last period. The cumulative totals at the end of January are: 26,740 commands for Helios 1, and 2610 commands for Helios 2.

One command system abort occurred with Helios 1 on pass 373 over DSS 11 (Goldstone). A command aborted when the Station Monitor & Control Subsystem (DMC) tuned the exciter off the Track Synthesizer Frequency (TSF). The exciter was manually tuned back to the TSF but not before one command abort had occurred. The cumulative total for the Helios-1 Command System aborts was increased to 6, with the System and Project abort total at 14 since the spacecraft launch. No command aborts have been experienced with the Helios-2 spacecraft.

Command System downtime due to equipment problems during this reporting period was 5.06 hours. Only 0.3 hours were lost due to high-speed data line outages. These figures are for both Helios-1 and Helios-2 spacecraft; although the total downtime reflects an increase from last period, considering both spacecraft the increase is not significant.

B. Tracking System

During this reporting period, two significant ranging anomalies occurred. The first discrepancy was observed on December 12, 1975 while ranging over DSS 42 with Helios 1. When checking the point-to-point consistency of range acquisitions, an unusual pattern was observed in the output of the psuedo-Differenced Range Versus Integrated Doppler (DRVID) program. It was found that periodically one acquisition would differ from the next by approximately 2048 range units. Four other occurrences of this problem have been recorded at different tracking stations. Investigation revealed that each track during which the problem occurred had been preceded by a "load and go" countdown. At this writing, the problem is thought to be procedural in nature, since a similar problem had been observed during Planetary Ranging Assembly testing when the phase relationships were not properly set between the receivers and the Range Demodulator Assembly. Further investigation is underway.

The second ranging problem came to light on January 28, 1976, when the Helios-1 spacecraft failed to respond to a range acquisition over DSS 42. Later attempts have also met with similar results. The Project was informed and is closely monitoring spacecraft conditions to gain insight into the cause.

C. Telemetry System

Other than the normal weekly telemetry predicts of signal level and signal-to-noise ratio (SNR), no direct support for Helios 1 was required during the first part of this reporting period. With the discovery of a possible Helios-1 spacecraft ranging problem, there has been an extra awareness placed on Helios-1 telemetry by the Helios Project. Certain engineering parameters are being studied by GSOC and compared with the post-analysis of the TWTA 1 failure. To date, none of these data points has repeated itself.

A "load and go" station countdown prepass concept has been initiated in the Network on a trial basis. Although this increases available tracking time, it is causing an increase in the number of out-of-limits residuals. There were nine instances reported for Helios 1 in December alone.

All other projects experienced similar increases. The Data Decoder Assembly again leads the list of telemetry discrepancy reports with 3 of the 6 during Helios tracks.

Several special Telemetry System Analysis Reports were written by the Telemetry Analysis Group. Among them was a Solar Conjunction Report, based on data obtained from the Helios 1 and Pioneer projects. This report provides a cross-correlation on the bit error rate (BER), signal-to-noise ratio (SNR) and system temperature versus the Sun-Earth-probe (SEP) angle.

IV. Conclusions

The Helios-2 spacecraft has been successfully launched and properly oriented for its mission in space. This achievement culminates the year-long effort between NASA and the Federal Republic of West Germany to place into orbit about the Sun a second Helios spacecraft to further man's knowledge about our solar system.

Helios 2 will travel three million kilometers closer to the Sun than did Helios 1. The orientation of the Helios-2 spacecraft complements that of Helios 1, such that data from both spacecraft may be correlated to prove or disprove theories about the solar system.

Initial control of the spacecraft after being placed into orbit by the Titan-Centaur TE-364-3 launch vehicle was initiated from the German Space Operations Center (GSOC). All JPL-GSOC systems performed as expected and the spacecraft was placed into a 185.67-day-period orbit. The spacecraft will come within 0.29 astronomical units (AU) of the Sun during its perihelion in mid-April 1976. Its inclination to the plane of the ecliptic is 0.0575 degrees.

The DSN will provide continuous coverage of the Helios-2 spacecraft through the first occultation in mid-May 1976. Spaceflight Tracking and Data Network-Deep Space Network cross-support of the Helios spacecraft has been negotiated, and an interface document has been written. This STDN-DSN cross-support is designed to recover data that would otherwise be lost, and will aid in filling the gaps caused by lack of DSN resources to provide continuous coverage of all in-flight spacecraft.

Acknowledgments

The authors wish to thank the following members of the Network Operations Analysis Group for their contribution of periodic Network Performance Reports: R. Gillette, W. Tucker, and R. Frampton (Command); R. Allis and J. Hendricks (Telemetry); and A. Berman, L. Bright, R. Scharfer, and G. Spradlin (Tracking).

References

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EVENT	1975			1976				DATE
	O	N	D	J	F	M	A	
STDN (MIL-71) RECORDING TEST	▲							OCT. 3, 1975
STDN-GOLDSTONE ENGINEERING TRACK	▲▲							OCT. 16, 21, 1975
STDN-MADRID ENGINEERING TRACK		▲▲						NOV. 8, 17, 1975
STDN (MIL-71) DATA CONVERSION AND PLAYBACK			▲					DEC. 19, 1975
MCCC DATA EVALUATION				▲				JAN. 6, 1976
DEMONSTRATION PASS				▲				JAN. 9, 1976
INTERIM INTERFACE DOCUMENTATION				▲				JAN. 15, 1976
CONDITIONAL TRANSFER TO OPERATIONS				▲				JAN. 15, 1976
FINAL TRANSFER TO OPERATIONS						△		MAR. 15, 1976

Fig. 1. Overall schedule for STDN cross-support