Helios Mission Support

P. S. Goodwin
DSN Systems Engineering Office

W. G. Meeks and S. E. Reed
Network Operations Office

The successful flight of the Helios-1 spacecraft continues. It has emerged from its first solar occultation and has reached aphelion at its maximum distance from Earth. Valuable scientific data were obtained during entry and exit from this solar occultation, and preparations are underway for the second solar occultation which will occur during mid-summer. Preparations are also underway for the launch of Helios-B in December 1975.

I. Introduction

This is the fourth article in a series that discusses the Helios-1 flight support provided by the DSN. The previous article (Ref. 1) reported the results of Helios-1 inferior conjunction and perihelion operations. Helios-1 superior conjunction and initial Helios-B planning were also discussed. This article covers the Helios-1 superior conjunction passage and the initial plans for a second superior conjunction in August 1975. Additionally, DSN tracking coverage and system performance are covered as well as current Helios-B DSN Operations planning. The Helios-B DSN Test and Training schedule has been submitted in preparation for launch in December 1975.

II. Mission Status and Operations

A. Helios-1 Superior Conjunction

The Helios-1 Mission Phase II ended and Phase III commenced as the spacecraft's trajectory reached a Sun–Earth–probe (SEP) angle of 3 degrees on April 13, 1975. The first Helios superior conjunction was not completed until June 8, 1975. As the SEP angle diminished to 0.43 degrees on May 6, the degradation of the telemetry data increased until a total telemetry blackout was observed. Telemetry blackout occurred at the 26-meter stations on April 25, and telemetry data were not recoverable again until May 23. Due to a greater antenna gain factor, telemetry blackout at the 64-meter stations was not as severe as at the 26-meter stations; therefore, the total 64-meter station blackout lasted only from May 2 through May 15, 1975.

The Helios superior conjunctions are highly unusual as compared to those of previous spacecraft, which were more nearly polar conjunctions. The unique Helios trajectory (Fig. 1) has an orbital eccentricity of 0.016 degrees and offers the Helios Radio Science Team their first opportunity to measure solar and corona effects upon the radio-frequency (RF) line, which is within the plane of the ecliptic during a superior conjunction.

The Faraday rotation experiment, which is one of the passive radio science experiments for Helios, exhibited an unexpected magnitude during superior conjunction. This phenomenon affected the polarization of the RF link more than had been anticipated and invalidated the DSN's polarization predicts near the station's local meridian. A special polarizer configuration and procedure were implemented at DSS 14 (64-meter station at Goldstone, California) to permit the auto-polarizer to track the received RF signal completely through 360 degrees. This procedure, along with a polarization boresite calibration procedure, removed a potential 180-degree ambiguity in the Faraday rotation data. It is understandable that stations not equipped with remotely controlled polarizers encountered more difficulty maintaining a correct polarizer setting. Fortunately, biases to correct the polarization predicts could be obtained from the stations with auto-polarizers.

The celestial mechanics experiment, the second passive radio science experiment, was supported with the Planetary Ranging Assembly at DSS 14. Additionally, the experiment was supported by the MU II Sequential Ranging equipment. This equipment was designed to support the Mariner Venus/Mercury 1973 radio science experiments (Ref. 2). The experimenter is currently attempting to correlate the planetary ranging and MU II ranging data. Continued investigation of celestial mechanics will be supported during the next Helios-1 superior conjunction.

Helios-1 will enter its second superior conjunction period on August 20, 1975. The second superior conjunction, which occurs at 1.6 AU from Earth, will result in a total occultation on August 31, 1975. The second Helios-1 superior conjunction will be supported by the DSN at a level equal to that of the first solar occultation. Telemetry data may be degraded somewhat during the interval between the first and second occultations due to the relatively small SEP angle throughout this period. The Helios-1 second superior conjunction and second perihelion phase will almost overlap each other. The second occultation period will end on September 6, and Perihelion II will start on September 9, 1975. DSN planning for the second perihelion has started, with 64-meter antenna support for the second perihelion requested from September 9 through October 4, 1975.

B. Helios-B Planning

The 11th Helios Joint Working Group Meeting was held in Munich, West Germany, from May 20 through 22, 1975. This meeting was to formally consummate the ongoing Helios-B planning. The Helios-B spacecraft will be launched from Cape Canaveral, with the window opening on December 8, 1975. The planned trajectory will place the spacecraft in a solar orbit with a perihelion distance of 0.29 AU. The Helios-B launch profile will be similar to that of Helios-1, with initial acquisition over DSS 42/44 in Australia.

The entire Helios-B scientific mission will, in fact, closely parallel that of Helios-1, and it is anticipated that Helios-B will provide the project scientists with three perihelion crossings during its planned mission. Mission operations, however, will be markedly different during launch and Phase I operations. Unlike Helios-1, Helios-B launch and Phase I operations will be controlled from the German Space and Operations Center (GSOC) and not from the Jet Propulsion Laboratory. This will be a new launch configuration and another first in the field of outer space exploration and cooperation. This launch configuration for Helios-B is only one indication of the ever-increasing ability of GSOC. In preparation for an unforeseen emergency, a backup Spacecraft Operations Team will be located at JPL during Helios-B launch and Phase I activities. All Helios-B attitude and orbit determination functions will be accomplished by teams located at JPL. The DSN will continue to provide tracking support over Australia and Goldstone while the German stations will be prime in the zero-longitude area.

Helios-B test and training will start in early August with the DSN Operational Verification Tests and terminate in early December with the Mission Operations System Operational Readiness Tests one week prior to launch. Intervening Simulation System and Ground Data System tests will be performed in September. DSN Performance Demonstration Tests and Helios-B end-to-end testing, from the spacecraft through the STDN (MIL 71) station at Merritt Island, Florida, will be performed in October 1975. In early November, DSN launch and Step II Maneuver Operational Verification Tests will be conducted. DSN Helios-B test and training will be concluded in late November with the Configuration Verification Tests.

C. Actual Tracking Coverage Versus Scheduled Coverage

This report covers Helios-1 tracking coverage which was provided by the DSN from April 15 through June 12, 1975. With Helios Phase III operations commencing at the start of superior conjunction on April 13, there were substantially fewer tracks supported by the DSN during this period than during the two previous reporting periods. There were only 79 tracks supported by the DSN, while theoretically 177 tracks were available. This was primarily due to the telemetry data blackout caused by solar effects when the Earth–spacecraft line is near the Sun.

Prior to Helios-1 launch, 82 tracks had been forecast in the long-range schedule for this time period, but the long-range forecast had provided less coverage than desired at the entry and exit of solar conjunction, and more than was required during the telemetry blackout phase. To rectify this and to obtain a more operationally desirable superior conjunction tracking schedule, the tracks during solar blackout were negotiated away to other projects in return for tracks that would fulfill the Helios requirements. The actual coverage provided by the DSN during this period more than satisfied Project requirements.

III. DSN System Performance for Helios

A. Command System

The DSN command activity in support of Helios-1 during April and May 1975 totaled only 977 transmitted commands. The cumulative total since launch is 13,480 commands. The significant reduction in command activity during April– May is the result of entering into mission Phase III operations on April 13, 1975. Mission Phase I and II command activities had produced a level of activity which resulted in an approximate average of 100 commands per day being transmitted to the spacecraft.

Even though overall command activity was at a lower level during this period, the total number of command system anomalies did not decrease in proportion to the total activity. During the April–May time period, there was only one Command System abort and this was due to a Block IV receiver/exciter problem at DSS 14. The cause was an erroneous exciter/ transmitter off alarm, and was corrected by cycling the auto/manual strobe switches.

Lost command capability throughout the network increased from 7 hours during the previous reporting period to over 9 hours for this period. More than 50% of this lost time is directly attributed to antenna failures at Goldstone, California, and Canberra, Australia. The remaining 50% is split relatively evenly between computer software problems and transmitter/exciter hardware problems.

While there was an apparent drop in the performance of the Command System, it should be noted that the Helios spacecraft was in a relatively quiescent state as it traversed the blackout region of its first superior conjunction; therefore, little or no impact was observable as a result of the loss of command capabilities. Indeed, to date the total percentage of commands transmitted by the DSN versus the total number of commands aborted (6, which includes Project aborts) gives the DSN a Command System performance achievement rate of 99.99956%.

B. Tracking System

The DSN Tracking System performance was excellent during this period while fulfilling all of the Helios Project requirements for radio metric data during the first Helios superior conjunction. With the exception of the early launch phase, which was a very short period of time, the present superior conjunction phases of the Helios mission represent the next highest period of activity for radio metric data.

The DSN continued to provide support for both of the passive radio metric experiments, Faraday rotation and celestial mechanics, while gathering specific quantities of radio metric data for analysis. The small Sun–Earth–probe angle has caused the doppler noise to remain at a higher than normal level. Due to Helios proximity to the Sun, the doppler noise will continue at a level which is substantially higher than is normal for other operational missions. Figure 2 is a plot of the expected doppler noise from June 15 through August 10, 1975. Figures 3 and 4 are plots of Helios doppler noise versus Earth–Sun–probe and Sun–Earth–probe angles, respectively, as Helios entered its first superior conjunction. It is felt that data derived from plots versus Sun–Earth–probe angle may reveal patterns caused by station antenna structure, and plots versus Earth–Sun–probe angle may reveal patterns caused by solar plasma. A detailed study is planned, and a better model for these effects is expected to be forthcoming from this study.

There were no significant Helios Tracking System discrepancy reports during this period.

C. Telemetry System

The Helios Telemetry System Performance Analysis during superior conjunction, which was from April 13 to June 25, 1975, inclusive, will be the subject of a separate DSN Progress Report. Inasmuch as these data were not within the normal analysis range, due to solar effects during solar conjunction, a special analysis will be performed. A Helios Telemetry Report covering the Helios superior conjunction is planned.

During this reporting period, there were no significant discrepancy reports. All telemetry data analyzed prior to superior conjunction were nominal and within the predicted DSN Telemetry System specifications.

IV. Conclusions

Phase III marked the start of Helios-1 first superior conjunction, and, within a few days after a successful superior conjunction passage, Helios-1 reached its first aphelion. The passive experiments (Faraday rotation and celestial mechanics) were the prime scientific experiments under observation during the initial portion of Phase III operations. Phase III operations also resulted in a marked reduction of flight support for Helios-1. However, flight support will increase somewhat when the second superior conjunction and perihelion occur in the late summer of 1975. Helios-B activities will increase as the DSN prepares for a launch in early December.

References

1. Goodwin, P. S., Meeks, W. G., and Reed, S. E., "Helios Mission Support," in *The Deep Space Network Progress Report 42-27*, pp. 36–40, Jet Propulsion Laboratory, Pasadena, Calif., June 15, 1975.
2. Martin, W. L., "System Performance of the Dual-Channel MU II Sequential Ranging," in *The Deep Space Network Progress Report 42-26*, pp. 54–68, Jet Propulsion Laboratory, Pasadena, Calif., Apr. 15, 1975.

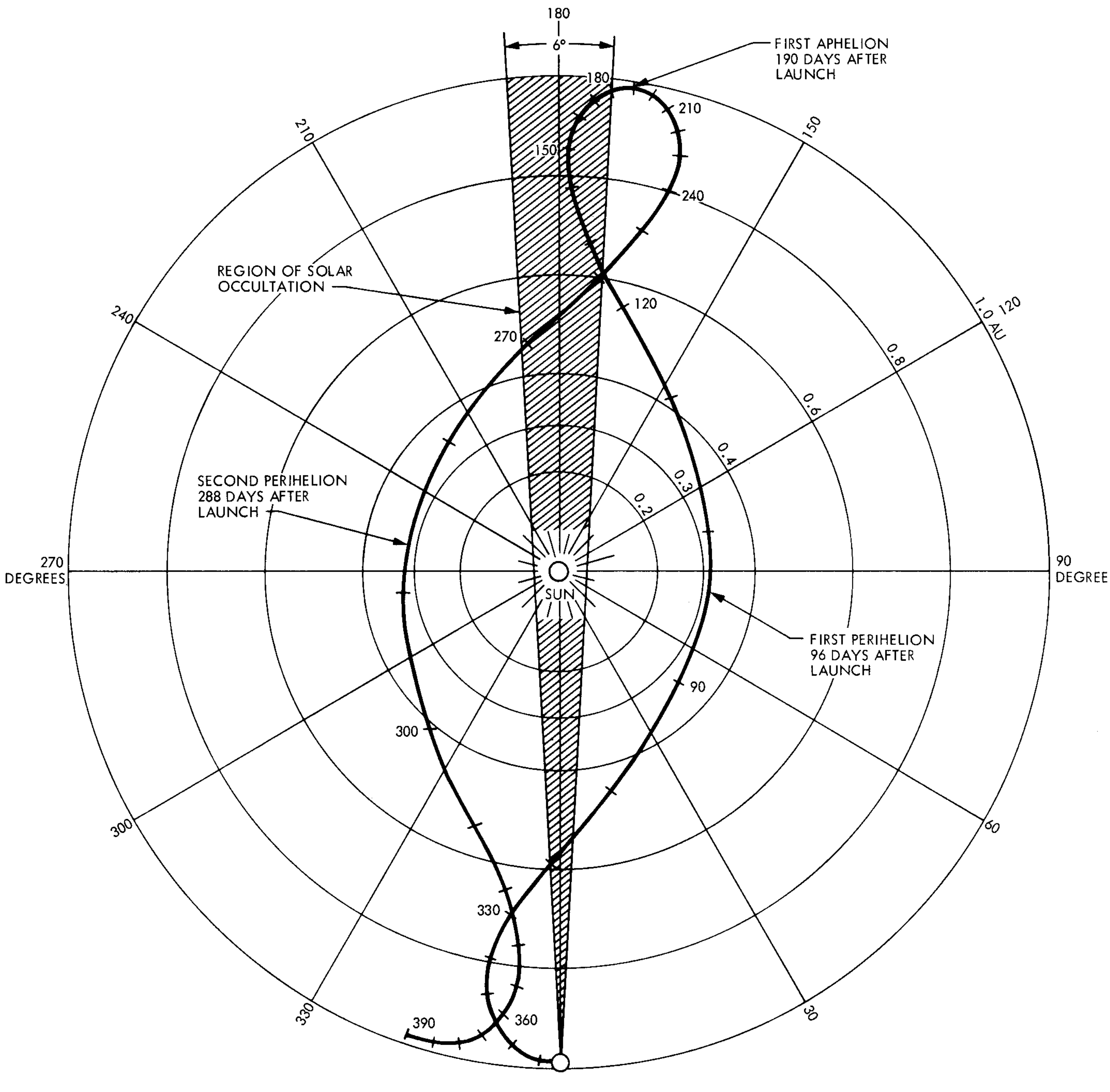

Fig. 1. Helios-1 0.31 AU perihelion trajectory

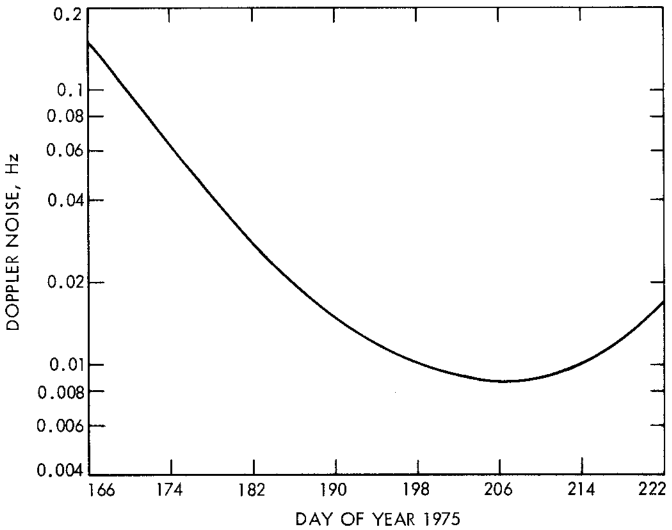

Fig. 2. Helios-1 estimated doppler noise

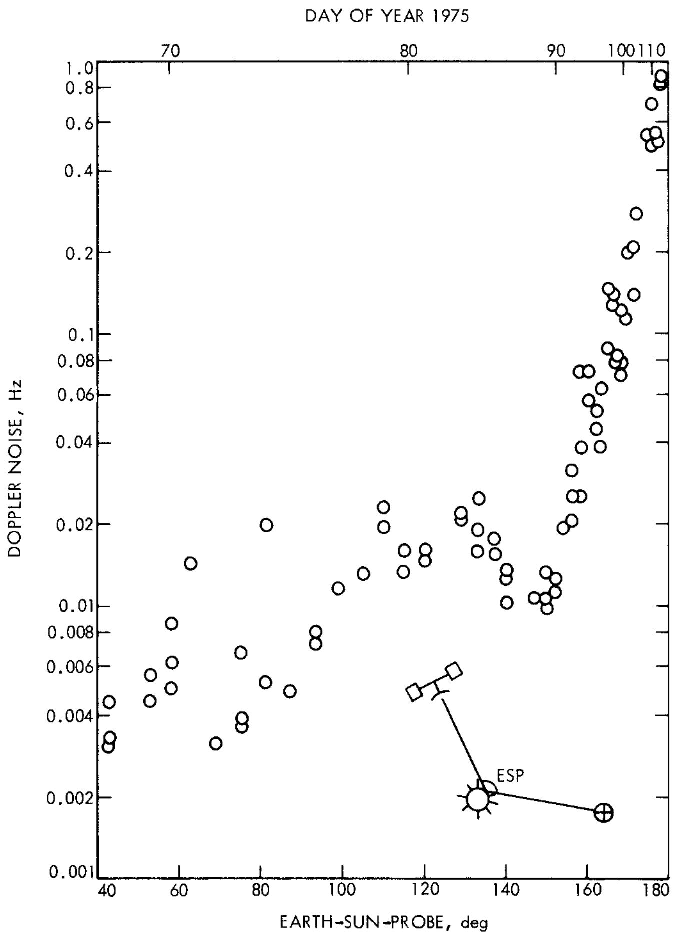

Fig. 3. Helios-1 doppler noise vs Earth-Sun-probe angle

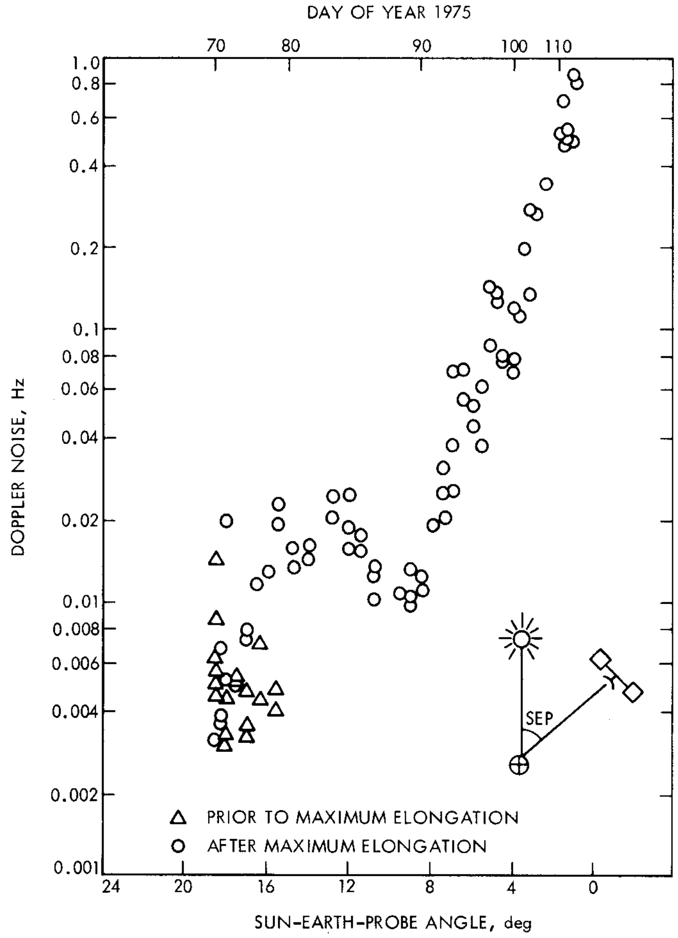

Fig. 4. Helios-1 doppler noise vs Sun-Earth-probe angle