Helios Mission Support

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The first of two Helios spacecraft, built by West Germany, was successfully launched from Cape Kennedy on December 10, 1974 and is now enroute to an unprecedented 0.31-astronomical unit (AU) perihelion in mid-March 1975. This article describes the DSN support starting with the prelaunch activities and carrying through the first three critical days of the mission.

I. Introduction

The previous article (Ref. 1) discussed the results of the Helios prototype model spacecraft compatibility testing that was conducted at Cape Canaveral, Florida, utilizing the Spaceflight Tracking and Data Network (STDN) (MIL-71) facility. This article covers the compatibility testing of the flight spacecraft (F-1) and its subsequent launch on December 10, 1974 from Cape Canaveral, the initial DSN acquisition of the flight spacecraft over Australia, and the DSN support during the Step I and II maneuvers that occurred during the first three days of the mission.

II. Prelaunch Activities

A. Flight Model (F-1) Compatibility Testing

The Helios-A flight model spacecraft (F-1) arrived at Cape Canaveral on September 22, 1974 and was transported to Hangar AO, where it was assembled for testing of its compatibility with the DSN. Compatibility tests using the STDN (MIL-71) facility commenced on October 25, 1974 and continued for 68 hours. With only one minor exception, these tests showed that the F-1 model spacecraft either duplicated or exceeded the performance characteristics demonstrated by the prototype model spacecraft during the latter's compatibility tests in July/August 1974 (Ref. 1). The minor exception was that the F-1 spacecraft transponder has a range code polarity inverted from that measured with the prototype model spacecraft—however, this difference is not significant since the DSN Tracking System is capable of supporting either a normal or an inverted range code. The Helios flight model compatibility tests also demonstrated that the DSN's corrective steps to overcome the difficulties detected during the prototype compatibility tests at Cape Canaveral were successful. The overall success of the Helios flight model spacecraft/DSN compatibility test effort gave reassurance that Helios-A could achieve its December launch opportunity.

B. Initial Acquisition Backup by DSS 44

With Pioneer 11 Jupiter encounter operations occurring very close to the contemplated December 8, 1974 launch of Helios-A, the DSN became concerned about providing redundancy within Australia to perform the initial acquisition of the Helios spacecraft. Prior planning had assumed that the Australian 64-meter station (DSS 43) could be employed in case of an emergency to provide backup support to DSS 42 during the initial acquisition. However, Pioneer Jupiter encounter requirements dictated that DSS 43 be exclusively devoted to the Pioneer Project—hence, there would be no backup to DSS 42. While no backup Australian station had been committed to the Helios Project, the DSN realized the importance of an early initial acquisition in order to perform the Step I maneuver and, therefore, took steps to see whether or not the scheduled conversion of the STDN Honeysuckle Creek facility to a DSN station (DSS 44) could be accelerated sufficiently to provide an "engineering level" support during the first pass over Australia. A teletype message presenting this proposal was sent to the Honeysuckle Creek facility on November 4, 1974. The station responded that they would give it their best effort and appreciated the DSN's offer of assistance. While a considerable amount of the necessary equipment was already located on site at Honeysuckle Creek, much remained to be done to implement the hardware and to debug the special computer software programs which were dictated by the Honeysuckle X-Y antenna mount. In addition, it was desirable to arrange for the loan of an STDN acquisition aid antenna from the Goddard Space Flight Center and to remount this antenna on the quadripod of the X-Y antenna. Completion of the implementation, plus at least a minimum amount of operator training, was desired prior to the Helios Operational Readiness Test (ORT) scheduled for December 5, 1974. All of this was very successfully accomplished—which is certainly a tribute to the personnel at DSS 44. While many of these station personnel had prior tracking experience during the Apollo Program, few, if any, had prior experience with the DSN or its procedures. Therefore, their efforts are doubly appreciated.

C. Helios Operational Readiness Test

The Helios-A Operational Readiness Test (ORT) was conducted on December 5, 1974 with the DSN configured as it would be on launch day—including all backup DSSs. This was the first (and only) exercise of the newly implemented DSS 44 in a Helios Project test. (Prior training had been on a *DSN internal* basis.) During the ORT, simulated failures at DSS 42 (Tidbinbilla, the Australian prime station) were exercised with DSS 44 assuming responsibility for the "failed" function at DSS 42. This included a simulated 100% failure at DSS 42. DSS 44 performed well under all simulated conditions. The ORT also simulated the Step I maneuver and science turn-on sequence over Australia, the near-Earth science return over Madrid, and a Step II maneuver sequence over Goldstone using DSS 12 as the prime facility and DSS 11 in a hot backup capacity. All DSN facilities performed well during the ORT. This fact, plus a favorable Mission Readiness Review held at Cape Canaveral on December 6, culminated in the Project Managers' decision to attempt a launch of Helios-A on December 8, 1974.

III. Launch Activity

A. December 8, 1974 Countdown

Preparations were commenced to launch Helios-A on December 8, 1974 with the opening of a 42-minute daily launch window at 07:16 GMT. During the minus count, all supporting DSN facilities began their pre-track calibration sequences. Besides STDN (MIL-71), DSSs 42 and 44 in Australia, DSS 62 in Madrid, and DSSs 11 and 12 at Goldstone were involved in this first-pass countdown procedure. At $T-10$ minutes in the countdown sequence, which was at the point of a built-in hold, a launch vehicle telemetry readout from the Centaur liquid hydrogen engine caused some concern. The $T-10$-minute hold extended into the opening of the launch window, but the Centaur telemetry problem was not resolved. The hold continued until approximately 20 minutes prior to the 07:58 GMT close of the daily window on December 8, at which time it was decided by the Project Managers to "scrub" the launch attempt for that day. Shortly thereafter, the Project Managers made a decision to reschedule the next launch attempt for December 10, 1974 in order to avoid unfavorable weather forecast for December 9, as well as to provide time to thoroughly diagnose the problem within the Centaur stage of the launch vehicle.

B. December 10, 1974 Launch of Helios-A

The launch countdown of Helios-A resumed on December 10, 1974 towards a targeted opening of the 42-minute daily window at 07:11 GMT. Again, the DSN stations at all three longitudes participated in the minus count by performing their pre-pass calibrations and dataflow tests. This time the launch vehicle proceeded through the $T-$ 10-minute built-in hold and continued satisfactorily right up to the opening of daily launch window. Helios-A lifted off the pad at Cape Canaveral at 07:11:01.5 (hours:minutes:seconds) GMT with all subsequent launch vehicle events occurring on schedule. Early radar tracking from the Eastern Test Range Radar Stations indicated that the trajectory was entirely nominal. This fact, plus confirmation from the down-range telemetry stations that the

Helios spacecraft transmitter signal was "on the air" gave confidence that a nominal initial acquisition procedure could be employed by the Australian DSSs upon spacecraft rise.

C. DSN Initial Acquisition

Following a perfect launch trajectory, Helios-A spacecraft was acquired by the Australian DSSs at 07:57:33 GMT with DSS 42 providing the prime source of data and DSS 44 acting as a hot, redundant backup. During this time, the spacecraft's attitude was such that its signal as received by the Australian DSSs was being transmitted by the dipole (top) element of the omni-directional antenna (see Fig. 2, Ref. 2). However, as the spacecraft gained altitude during its trajectory over Australia, the aspect angle changed such that the DSS reception would be via the (bottom) circularly polarized horn element of the omni-directional antenna system. The spacecraft radiation pattern boundary between the top dipole antenna and the bottom circular horn antenna element of the omni-antenna system created an interference region. This was of concern to both the Project and the DSN with respect to whether successful telemetry reception could be achieved during the transition. However, during flight, the signal degradation caused by this interference region proved to be less than had been feared. Once the spacecraft's trajectory had carried the aspect angle past the interference region, commands were sent by DSS 42 to initiate the Step I maneuver sequence.

IV. Early Mission Support

A. Step I Maneuver

The Step I maneuver orients the spacecraft such that its solar panels are uniformly illuminated by the Sun, but with the spacecraft's spin axis still 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.

At the completion of the Step I maneuver, the spacecraft was still rotating at its 92.8-rev/min velocity imparted during its spin-up prior to injection. The next sequence was to deploy the magnetometer booms (Fig. 2, Ref. 2)—a process that caused the spacecraft's rotational rate to decrease to less than 55 rev/min. Following the magnetometer boom deployment, the radiowave experiment antenna booms (located at 90 degrees to the magnetometer booms) were also commanded deployed. Early telemetry analysis indicated that one of the antenna booms did not deploy fully; however, the Helios Project decided to defer investigation of this possibility until the spacecraft had achieved its cruise phase configuration. With boom and antenna deployment completed, and the spacecraft still lying in the plane of the ecliptic, the next mission sequence over Australia was to initiate selected on-board science experiments in order to measure the solar wind bow wave that surrounds Earth. This was also successfully accomplished over Australia.

B. Near-Earth Science Return

Following science instrument activation, DSS 42/44 in Australia and DSS 62 in Madrid, Spain, processed the cislunar science telemetry desired by the Project. DSS 62 performed very well during this first pass over Madrid, during which the Helios Project began preparations for the Step II maneuver following the subsequent Goldstone rise.

C. Step II Maneuver Sequences

Following Helios-A spacecraft first rise at Goldstone, the spacecraft telemetry format was changed from science to engineering data in preparation for the Step II maneuver. At this time, the spacecraft was well past lunar distance so the near-Earth science had been accomplished. The first series of Step II maneuver commands caused the spacecraft to yaw within the plane of the ecliptic to calibrate the thrust of the cold gas attitude control nozzles. After this was accomplished, commands were sent to pitch the spacecraft such that the antenna mast began to move towards the North Pole of the ecliptic. During the early portion of the Step II maneuver pitch commands, the spacecraft attitude was such that DSS reception was via the off-axis horn antenna out of the bottom of the spacecraft. As the pitch angle increased, so did the spin modulation on the doppler frequency increase—thereby giving an indication of spacecraft attitude in the tracking data. The spin modulation doppler signal was usable up to the point where the interference region was being traversed. To traverse the interference region (a feat requiring numerous commands), the Helios Project, in cooperation with the DSN, requested horizontal (ecliptic-plane) polarization at DSS 12 and vertical (perpendicular) polarization at DSS 11, with both stations supplying spacecraft telemetry via high-speed data lines to the Mission Control and Computing Center in Pasadena. This technique enabled DSS 12 to communicate with the spacecraft via the horn antenna while DSS 11 was communicating via the spacecraft's omni-dipole antenna. The point of equal signal strength reception between DSS 11 and DSS 12 represented emergence from the interference region. Since the degradation of the signal was not as severe as had been feared, the interference region was traversed with a telemetry margin of +10 dB at a 128-

bit/s engineering data rate. Following emergence from the interference region, DSS 12 was switched to vertical polarization, and the spacecraft downlink was switched from the omni-antenna system to the medium-gain antenna system so the Goldstone DSS's received signal strength (AGC) readings would indicate the commanded traverse of the side lobe pattern of the spacecraft's medium-gain antenna (Fig. 2, Ref. 2) and also indicate when the peak of the main lobe of this antenna had been located. By the end of the first Goldstone pass, the spacecraft attitude was such that the medium-gain antenna pattern was very close to its peak value—indicating a nearly 90-degree orientation of the spacecraft with respect to the plane of the ecliptic. By this time the Helios Project's prime Mission Operations Support Team had been up nearly 24 hours (since many had participated in the prelaunch activities), so the reactivation of the on-board science instruments was deferred to the second Goldstone pass. Further Step II maneuver orientations were consequently deferred to the third Goldstone pass, during which time the exact center of the main lobe of the spacecraft medium-gain antenna was accurately measured and the spacecraft's attitude accordingly determined. Prior to this, during second-pass activity, the spacecraft spin rate was increased to nearly 60 rev/min—though not exactly 60 rev/min per the experimenters' real-time request. With both the spacecraft's spin rate and attitude in the cruise mode, the last engineering sequence of this series was to position the spacecraft's high-gain antenna (Fig. 2, Ref. 2) such that it was directed towards Earth. This was accomplished by commanding various phase adjustments to the despin velocity until the main lobe of the high-gain antenna had been determined through DSS receiver signal strength measurements. This completed the intense post-launch Helios activity, and the mission settled down to its primary objective of achieving science return enroute to its perihelion passage of the Sun.

V. Conclusions

With the successful launch and orientation of the spacecraft, Helios-A has now been officially renamed Helios-1. This feat was the culmination of approximately 10 years of effort on the part of both NASA and the Federal Republic of (West) Germany. The DSN is pleased to be a part of this effort.

Helios-1 is now on a trajectory that will carry it to a 0.31-astronomical unit (AU) perihelion in mid-March 1975. Its orbital period is 190 days, and its inclination to the plane of the ecliptic is 0.016 degrees. Since Helios does not have course correction capability, achievement of the above targeted orbital parameters was accomplished by the Titan–Centaur–TE-364-4 launch vehicle using the Centaur guidance system.

Future DSN support of Helios-1 will continue to provide continuous coverage throughout the primary mission, with special emphasis on the first perihelion passage and subsequent solar occultation. Following that, the DSN will provide scheduled support through the lifetime of Helios-1. In addition, both Project and DSN activities are now starting preparations to launch Helios-B in approximately one year.

References

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2. Goodwin, P. S., "Helios Mission Support," in *The Deep Space Network Progress Report*, Technical Report 32-1526, Vol. II, p. 22, Jet Propulsion Laboratory, Pasadena, Calif., Apr. 15, 1971.