Helios Mission Support

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The Helios-A spacecraft is now less than 6 months from launch. DSN activity is shifting from implementation to operational preparations. There have been, however, three significant recent developments which bear discussion: (1) the final selection of the targeted perihelion distance for the Helios-A mission has been established as 0.31 AU; (2) the Helios-A launch trajectory has been changed from a direct-ascent mode to a parking-orbit mode; and (3) the prototype model spacecraft has successfully passed compatibility testing with the DSN. The significance to the Tracking and Data System of each of these developments is discussed.

I. Introduction

With the Helios-A launch now scheduled for the latter part of October 1974, there have been several changes or refinements to the mission plan in addition to what has been previously reported in prior volumes of this report. Of particular interest to the reader will be the following topics: the targeted perihelion distance now being set at 0.31 astronomical units (AU); the use of a parking-orbit launch trajectory; and the results of the compatibility test program between the DSN and the prototype model Helios spacecraft. Each of these is discussed further in the paragraphs that follow.

II. The 0.31-AU Perihelion

Figures 3 and 4 of Ref. 1 depicted typical Helios trajectories for a July 1974 launch, with 0.25- and 0.30-AU perihelions, respectively. Figure 1 herein depicts a similar fixed Earth-Sun-line plot of the Helios-A trajectory for a September/October 1974 launch and a 0.31-AU perihelion. The principal effect of the combined launch date (September/October vs July 1974) and 0.31-AU perihelion is that the upper loop of Fig. 1 does not achieve a total (geometric) Sun occultation as the spacecraft is viewed from Earth. However, little if any scientific value has been lost by this effect since the Helios-A spacecraft will now have a considerably longer dwell-time in very close proximity to the Sun when expressed in terms of look angle from the Earth. This will permit many weeks of Faraday rotation measurements to determine the influence of the Sun's corona upon the propagation characteristics of the radio signal transmitted from the spacecraft to the DSN. This feature of the new trajectory, plus the fact that the spacecraft is expected to enter into a total occultation starting a little after 270 days from launch, provides scientific data at least equally important to that which had been previously planned. The change in perihelion and launch date, therefore, is not considered by the Helios Project to have impacted the expected scientific return from the Helios-A Mission.

III. Parking Orbit

Approximately six months prior to the planned Helios-A launch, NASA and the German Ministry for Research and Technology (Der Bundesministerium fuer Forschung und Technologie, BMFT) mutually agreed to alter the planned launch trajectory for Helios-A from a direct-ascent mode to a parking-orbit mode. The motivation for this change was the February 1974 partial success/failure of the Titan-Centaur proof-test flight, denoted TC-1, during which the Centaur stage failed to achieve full ignition. Since this launch vehicle will also be used for the future NASA Viking and Mariner Jupiter-Saturn missions, as well as for the Helios-B mission—all of which will use parking-orbit launch trajectories—there was a strong desire to prove out as early as possible the Centaur restart capabilities, especially after a long-duration coast period in the parking orbit. Further, a parking-orbit trajectory for Helios-A would permit the extension of the launch opportunity to the end of January 1975 as opposed to mid-December for the direct-ascent mode. These and other factors, when considered in total, resulted in the aforementioned decision. Admittedly time was short, but it was still possible to modify both the Centaur stage and the near-Earth phase Tracking and Data System support prior to the scheduled Helios-A launch.

From Fig. 1 it can be seen that the Helios-A spacecraft will depart the vicinity of Earth in the late afternoon hours of the day. Using a direct-ascent launch trajectory mode, such a departure could be achieved with a noon or afternoon launch from Cape Canaveral. However, to achieve the same injection conditions with a parking-orbit launch trajectory it is necessary to advance the launch time into the very early morning hours—i.e., before sunrise. These features are depicted in Fig. 2. Though not drawn accurately to scale, Fig. 2 also shows that the parking-orbit mode launch trajectory will have a lower perigee altitude than the formerly planned direct-ascent mode. There is, therefore, an infinitesimal increase in the aphelion distance at injection of the spacecraft.

From a Tracking and Data System viewpoint, the change to a parking-orbit launch trajectory has its greatest impact on the plan for the near-Earth phase support (i.e., number of supporting stations) and to a lesser extent on the Deep Space Network (which must now switch its initial acquisition from the Madrid facilities to the Australian facilities).

Figure 3 depicts the Earth-track of the Helios-A parking-orbit launch trajectory for the opening (Case I) and closing (Case II) of the Helios-A launch opportunity. It is obvious from this figure that more near-Earth phase network facilities—land-based stations, tracking ship, and aircraft—will be required to support critical launch-phase events than would have been necessary for a direct-ascent mission (see Ref. 1, Fig. 1) whose spacecraft injection would have occurred just after first rise at the Madrid Deep Space Station. At this writing, the near-Earth phase network support plan is still being revised; however, it does appear that there will be sufficient resources available to provide support during the critical launch-phase mission events.

With respect to the DSN, the first-order impact was the shift of the initial postinjection acquisition station location from the Madrid Deep Space Station to the Canberra, Australia, Deep Space Station. This could be done since the Canberra station (DSS 42) is already equipped with an acquisition-aid antenna system—hence no new implementation was required at that facility.

There are, however, two important aspects to performing an initial acquisition at Australia: first, the initial spacecraft rise at Canberra occurs approximately 1 hour after launch as opposed to 15 to 30 minutes for the direct-ascent acquisition at Madrid; second, the length of time the spacecraft is in view during the first pass over Australia is much shorter than it would have been over the Madrid DSS using a direct-ascent launch trajectory. The Australian view-period is shortest for the early portion of the launch opportunity and gradually lengthens towards the end. The primary tasks for the Canberra DSS will be to perform the initial acquisition and provide for an early checkout of the spacecraft conditions. Once this is accomplished, the Canberra and Madrid DSSs will share the responsibility (depending upon launch date) of individually or jointly supporting the Step I maneuver and subsequent near-Earth science instrument turn-on (see Ref. 1). This level of activity is sufficiently high that there is not enough time remaining during the first Madrid DSS pass to initiate and complete the Step II maneuver, which is to be performed after the spacecraft passes lunar distance from Earth. The latter task is sufficiently time-consuming that it is reserved for the first Goldstone pass—with a possibility of performing the final trim of the Step II maneuver during the second Goldstone pass. However, the delay in the rise time for Goldstone due to the parking-orbit mode also means that the spacecraft will be farther from Earth at the initiation of the Step II maneuver. The increased space loss due to this increased distance amounts to approximately 4 dB, which is not available in the telecommunications link design margins and must therefore be compensated by the use of the 64-meter antenna instead of 26-meter antennas at Goldstone.

The previous direct-ascent mode Step II maneuver support plan called for the Goldstone 26-meter DSSs to be equipped with a fixed linear polarizer to support the first part of the Step II maneuver with the polarizer in the plane of the ecliptic and then to switch to the polarization being normal to the plane of the ecliptic at a prescribed point during the maneuver. However, the Goldstone 64-meter station (DSS 14) has a continuously variable linear polarizer as opposed to a fixed polarizer. After considerable study, it was mutually decided between the DSN and the Helios Project not to attempt to continuously track the polarization of the incoming signal during the Step II maneuver but rather to emulate the plan previously developed for the 26-meter stations. The main reason for this is that the spacecraft omniantenna radiation pattern had not been measured for linear polarization reception at angles other than 0 and 90 degrees with respect to the spin axis, and further, there was insufficient time or resources to accomplish such measurements prior to launch. While it might be possible to achieve a small increase in performance by continuously tracking this changing polarization, the concurrent unknown risks were considered to be too high in relationship to the potential gains. Further, calculations show that there is sufficient margin to accomplish the Step II maneuver using the Goldstone 64-meter antenna in conjunction with the polarization step-changing techniques developed for the 26-meter stations.

Once the Step II course and fine maneuver adjustments are completed, which should be by the end of the second Goldstone pass, the DSN support of the Helios-A parking-orbit mission closely approximates that which had been previously planned for the direct-ascent mission—i.e., as depicted in Fig. 1. The impact of the change to a parking-orbit mission is therefore confined to the first few days after launch.

IV. DSN/Helios Prototype Model Compatibility Tests

The Helios prototype model spacecraft arrived at the Jet Propulsion Laboratory in late April 1974 for a series of environmental and ground system compatibility tests. Formal compatibility testing with the DSN Compatibility Test Area (CTA 21) occurred between 17 and 31 May 1974. Prior to that time, the spacecraft underwent thermal/vacuum testing in the JPL 25-foot-diameter space simulator chamber. Alerted by the fact that telemetry system incompatibilities had been discovered during compatibility tests in Germany using the Weilheim station and the upgraded engineering model spacecraft, the DSN arranged for some "quick look" telemetry system gross tests while the prototype spacecraft was still in the thermal/vacuum chamber at JPL. These "quick look" telemetry checks disclosed problems in addition to the inverted tail (synchronization word) discovered during the German compatibility tests. The additional telemetry problems were traced to a specification ambiguity regarding the sequence of transmitting the two components of the Helios convolutional code.

Technically speaking, the spacecraft and DSN telemetry systems were incompatible. Since it was obviously too late in the spacecraft manufacturing cycle to introduce modifications to that design, remedies were sought within the DSN. Fortunately, the software sequential decoding scheme employed by the DSN for convolutionally encoded telemetry streams was sufficiently well modularized to allow temporary instructions (i.e., patches) to be inserted into the software. These "patches" were developed and tested using the prototype spacecraft while it was still in the thermal/vacuum chamber. Compatibility testing with the DSN was therefore able to commence on schedule on May 17. The ensuing formal compatibility tests with the DSN disclosed no further incompatibilities, and in fact pointed out that the Helios spacecraft transponder design was very well executed—especially with respect to the stability of the ranging delay through the transponder. The success of the prototype compatibility tests is doubly significant when one considers the fact that the Helios transponder was developed in Germany without benefit of frequent interfacing with the DSN. The discrepancies noted during the April 1972 compatibility tests using the engineering model transponder and the DSN facility at Cape Kennedy (DSS 71) had been corrected by a complete redesign of the spacecraft transponder receiver portion with only a subsequent spot check of the receiver at CTA 21. The Helios Project is certainly to be commended for these efforts.

While the prototype spacecraft/CTA 21 compatibility tests are considered completely successful, the coded telemetry *technical* incompatibility mentioned above requires further DSN effort. The DSN's software sequential decoding package developed for Helios (known as Model B) had been distributed and tested within the Network prior to the discovery of the aforementioned incompatibility. Either this software had to be changed or new software introduced into the Network, tested, and subsequent operator training accomplished prior to the start of Mission Operations System training for the Helios-A launch.

Since a Model C version of the DSN software was nearing completion to support both Helios and Viking, it was decided to make the modifications required for the Helios telemetry in the Model C software package rather than to attempt to upgrade the Model B software in the field. Since the Model C version would also require Network testing and training, the Network test/training recycle time could be shortened by using the latter of the two approaches. Therefore, it is now planned to support the Helios-A launch and premission training using the Model C telemetry software in the Network.

The net result of the *technical* telemetry incompatibility is a one-month delay in DSN readiness to support the Helios premission training. However, this one-month delay could be absorbed in the schedule without significant overall impact.

V. Conclusions

Despite the unexpected circumstances that led to these near-last-minute changes to the DSN support plans for Helios-A, the DSN has put into effect modifications that will permit the Helios-A mission to be supported without a slip in launch date. This fact, plus the overall success of the compatibility test plan with the prototype spacecraft, leads the DSN to be optimistic about its role in the support of the Helios-A mission.

References

1. Goodwin, P. S., "Helios Mission Support," in *The Deep Space Network Progress Report*, Technical Report 32-1526, Vol. III, pp. 20–28, Jet Propulsion Laboratory, Pasadena, Calif., June 15, 1971.

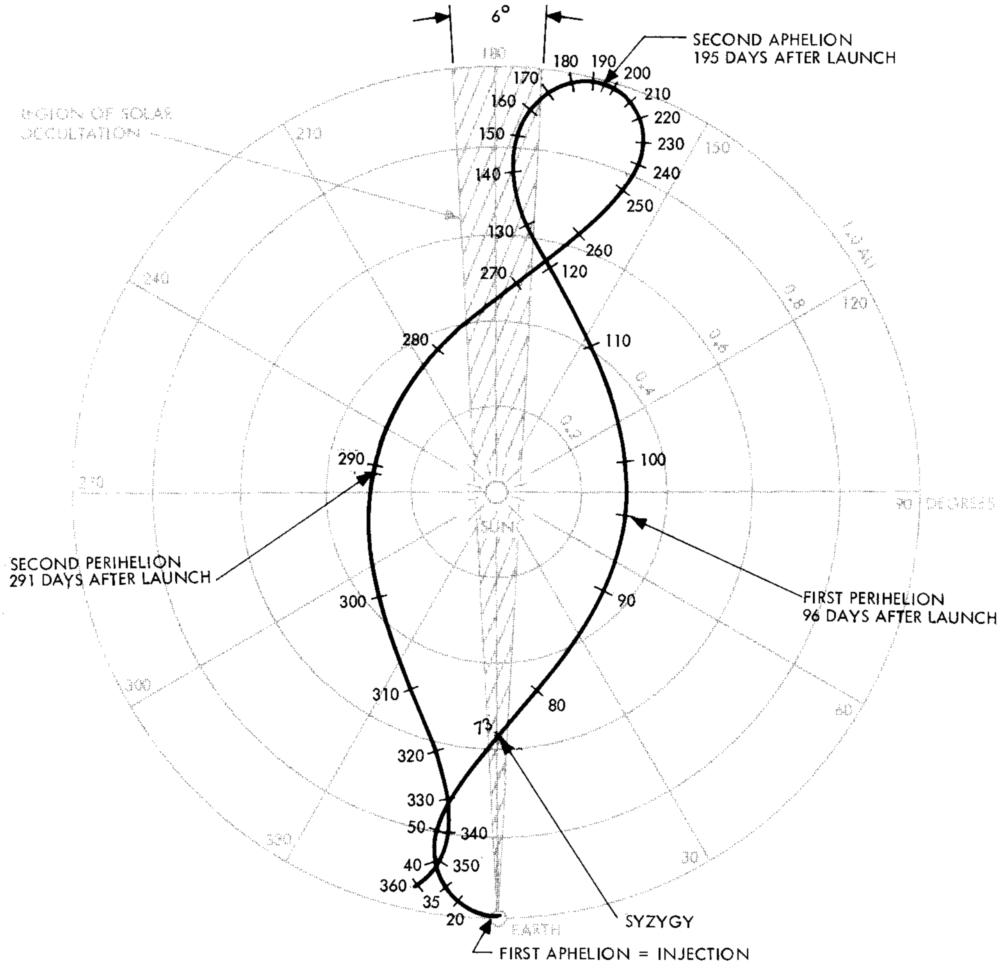


Fig. 1. Fixed Earth-Sun-line plot of Helios-A trajectory, 0.31-AU perihelion, September/October 1974 launch

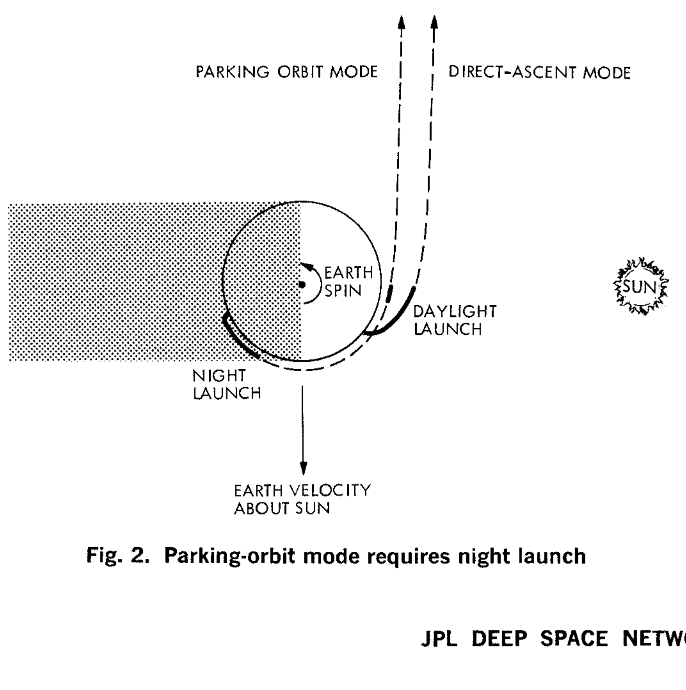
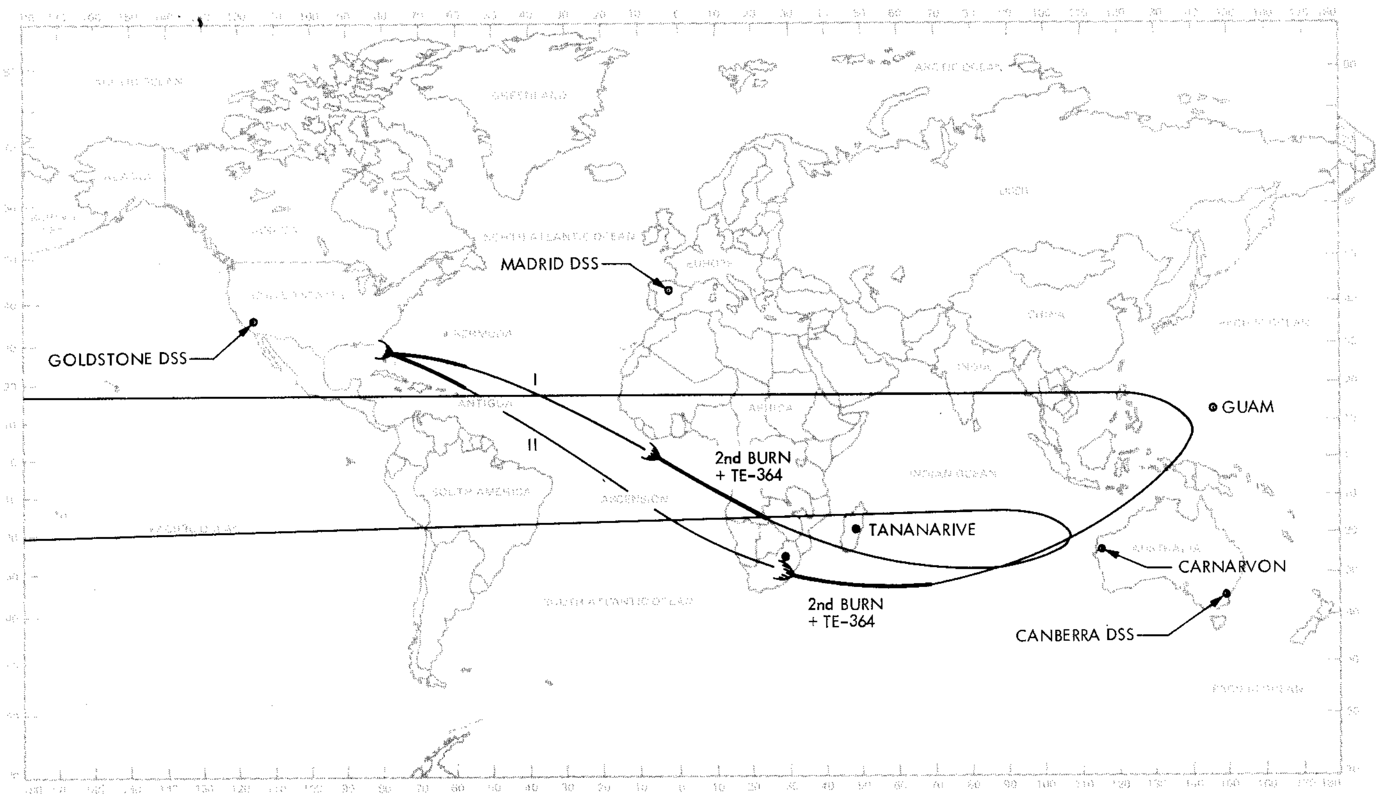


Fig. 2. Parking-orbit mode requires night launch



CASE I =	SHORT COAST (14 min) FLIGHT AZIMUTH = 95.2° OCT 16, 1974 CASE (OPENING)
CASE II =	LONG COAST (25 min) FLIGHT AZIMUTH = 108° JAN 15, 1975 CASE (CLOSING)

Fig. 3. Typical Helios-A parking orbit trajectories