Helios Mission Support

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Project Helios is a joint space endeavor between the United States and West Germany. Its objective is to place two unmanned spacecraft into heliocentric orbits whose perihelion distance will come closer to the sun than any previously or presently planned Free-World deep space undertaking. The West German government is designing and fabricating the spacecraft and will conduct mission operations. NASA will provide the launch vehicle, the launch facilities, and the major portion of the tracking and data acquisition with respect to this program. The launch of the first spacecraft is planned for mid-1974 and the second in late 1975.

To ensure proper technical coordination between the activities in West Germany and in the United States, the International Agreement provides for semiannual Helios Joint Working Group Meetings for the exchange of information and for the proper coordination of the activities leading toward launch and subsequent Mission Operations. This article reports the highlights, with respect to the DSN, of the subjects discussed during the Seventh Helios Joint Working Group Meeting which was held at Porz-Wahn (near Bonn), West Germany, October 25 to 31, 1972.

I. Introduction

The International Agreement between the United States of America and the Federal Republic of West Germany, which formally established Project Helios, specified that the two countries should meet on a semiannual basis to coordinate the technical activities associated with their respective responsibilities regarding this project. These sessions, which are known as Helios Joint Working Group (HJWG) Meetings, are organized as shown in Fig. 1 of Ref. 1, and are held alternately between the United States and West Germany. The seventh such meeting was conducted in Porz-Wahn (near the capitol city Bonn), West Germany, October 25–31, 1972. The previous article in this series (Ref. 2) depicted the significant DSN activities leading to the 7th HJWG Meeting. This article treats the Tracking and Data System highlights that occurred during the 7th HJWG Meeting. Further details of these (as well as other) activities may be found in the official minutes (Ref. 3).

II. TDS Highlights of the 7th HJWG Meeting

At the time of the 7th HJWG Meeting, the Helios Project was approximately 20 months away from its scheduled launch date for the first flight spacecraft. The fundamental design of the spacecraft had been completed and an engineering model of the spacecraft and its associated ground support equipment had been constructed and was undergoing extensive testing. Consequently, the discussion emphasis at the 7th HJWG Meeting was shifting from spacecraft-oriented topics to mission design and operations topics. In addition, the scope of the technical discussions had already transcended the conceptual stage and was now focused upon the detailed definition and understanding of the working interfaces between the various elements of the project. Because of these factors, both the quantity and variety of the agenda topics became too numerous to be efficiently handled during the formal five-day meeting period. As a result, a large portion of the list of TDS agenda topics was shifted to Special Splinter Session Meetings—some of which, due to time limitations, had to be scheduled for the days immediately following the concluding General Session of the 7th HJWG Meeting. Further, many of the agenda topics required participation by representatives from more than two of the formally constituted subgroups. However, for convenience of presentation in this article, the topics are grouped under the headings deemed most appropriate to the subject matter.

A. TDS Subgroup Activities

1. Initial DSN Acquisition. As a prelude to the discussions (reported below) regarding the possible "blind acquisition" of the Helios spacecraft, it was necessary to thoroughly understand the procedures and techniques associated with a standard or nominal DSN initial acquisition of the Helios spacecraft after launch. In this regard, certain key factors had been established during the proceedings of the 6th HJWG Meeting (Ref. 4), namely, the selected trajectory would have a 926 km (500 nmi) perigee altitude and would be restricted to the southern launch corridor (Ref. 5, p. 26, Fig. 1). The combination of these two factors greatly reduces the angle and doppler tracking rates associated with the DSN initial acquisition to the point that both are now within standard DSN station capabilities. Consequently, the remaining uncertainties were associated with the interferometer region of the spacecraft's low-gain antenna system (Ref. 1), and the dispersion uncertainties in the injection point due to the TE-364-4 last-stage solid-rocket motor burn. The latter had been studied in detail prior to the meeting (Ref. 2) with the result that the estimate for a successful DSN initial acquisition would be greater than 0.9 (90%) in the nominal case. Further, this probability would occur in a time period (measured in minutes) closely following spacecraft rise at the initial acquisition stations, which are DSS 61 in Madrid, Spain and/or DSS 51 in Johannesburg, South Africa.

2. Review of the Helios Preliminary NASA Support Plan. As mentioned in the previous article (Ref. 2), the Helios preliminary NASA Support Plan (NSP) was distributed for review and comment in September 1972. During the 7th HJWG Meeting, the Helios Ground and Operations System (HGOS) (Fig. 1 of Ref. 1) reported that their review of the preliminary NSP had disclosed no significant incompatibilities. Their comments pertained either to the clarity of certain portions of the text material or to the desire for additional detail regarding certain planned capabilities in support of Helios. These comments were accepted by the DSN for inclusion in the final NSP. It was mutually agreed that these HGOS comments would not necessitate the issuance of change pages to the preliminary NSP.

3. Definition of MDR Content and Format. The definition of the content and format for the various Master Data Records (MDRs) required for the production of the Helios Experimenter Data Records (EDRs) has been an iterative process over the last several Helios Joint Working Group Meetings. During the 7th HJWG Meeting, this process culminated in the selection of a final format for the telemetry MDR and the near-final agreement upon the format for the Command MDR. In addition, considerable progress was made toward definitizing the Orbit MDR. The major remaining effort concerns the attitude MDR, which, in turn, is dependent upon the outcome of on-going discussions regarding the techniques for attitude determination (see "Special Splinter Meeting Topics," *Subsection E*).

4. German/U.S. Network Operations Interface. In a Splinter session, Operations representatives from the DSN and the German Network developed a mutually acceptable Helios Network Operations Management Plan which defines the areas of responsibility, the operating interfaces for inter-Network coordination, as well as the scope and responsibility for documenting Network Operations procedures. By mutual agreement between the TDS and the Mission Analysis and Operations (MA&O) Subgroup Chairmen, this Helios Network Operations Management Plan will be included as a section within the HGOS/JPL Interface Management Plan, mentioned in *Section II-C-1.*

B. TDS/Spacecraft Joint Session

As mentioned in the opening remarks to this section, the Helios spacecraft design has completed its development phase and is heavily involved in the testing and performance evaluation phase of the Engineering Model spacecraft. However, this does not imply a cessation of design effort, but rather it implies that future design effort would be directed toward either overcoming design deficiencies or making significant contributions toward meeting mission objectives. In either event, proposed design changes must be weighed very carefully against their impact upon both schedule and cost limitations. The latter, in effect, creates an atmosphere wherein only the most critical proposed design changes receive project approval. This reality permeated the following discussions:

1. Telecommunications Link Analysis. In September 1972, the Helios Project Office issued an update to their Telecommunications Link Design Document. In the time available prior to the 7th HJWG Meeting, the DSN carefully reviewed each link analysis covering the multitude of operating modes permitted by the Helios spacecraft radio system. By necessity, this review concentrated upon the validation of the various DSN performance parameters assumed in the link calculations, with secondary emphasis being placed upon the techniques and/or assumptions used in conjunction with the spacecraft parameters. During the 7th HJWG Meeting, the DSN reported that its review of the Helios Telecommunications Link Design had *not* disclosed any errors in computation nor any serious errors of omission regarding unidentified losses within the link. It was noted, however, that the September 1972 revision still contained certain assumptions—i.e., design or specification values were employed for those spacecraft parameters for which actual test data are not yet available. This situation is significant because several of the Helios telecommunications links have experienced an erosion of performance margin to the point where any further decrease in performance can begin to jeopardize the accomplishment of mission objectives as they relate to obtaining useable data over those links.

2. DSN Telemetry Performance for Helios. Related to the foregoing activity are the parameters assumed for the performance of the DSN Telemetry System while sequentially decoding the Helios convolutionally encoded telemetry. Since the Data Decoder Assembly (DDA) to be used in support of Helios is still under development by the DSN, it has been necessary to estimate its future performance. The estimates employed in the September 1972 issue of the Helios Telecommunications Link Design were based upon approximately one month of post-launch data obtained from the Pioneer 10 spacecraft, which also uses convolutionally encoded telemetry. However, the Pioneer 10 telemetry frame length is much shorter than the 1152 bits/frame employed for Helios. Therefore, to further refine the estimate of DSN Telemetry System performance for Helios, the DSN performed a computer simulation based upon the Pioneer 10 telemetry performance data but converted to the Helios frame length. This computer simulation was compared to theoretical analyses performed by both JPL and the Helios DFVLR[1] facility. The result was an updated performance estimate for Helios (see Fig. 1) which was presented during the 7th HJWG Meeting. Further updates to this estimate are anticipated as DSN telemetry performance test data become available.

3. Solar Occultation (Blackout). As noted in Ref. 5, p. 28, the Helios trajectory is such that the spacecraft is occulted by the sun several times. These occultations create a radio signal "blackout." The blackout region or angle as viewed from Earth is larger than that dictated by the physical size of the sun, because the solar corona distorts the radio signal in such a manner as to make it more difficult to receive. In addition, the temperature of the sun causes an increase in radio system noise as an antenna looks closer and closer towards the sun. The combination of these two effects increases both the apparent blackout angle and the amount of time the spacecraft must endure without communications from Earth. Because of the latter, it is highly desirable to be able to accurately predict this blackout angle. Unfortunately, this presents a difficult problem since both of the aforementioned effects are dependent upon the level of solar activity which can vary from day to day as well as year to year. Nonetheless, some data are available from near-solar occultations by Pioneer and Mariner spacecraft, and these data have been provided to the Helios Project. During the 7th HJWG Meeting, it was decided that the Helios Project would use these data to develop an assumed model for the telecommunications link performance vs angle from the sun, and that a special meeting would be held at JPL in December 1972 to review and critique this Project-developed model.

[1]Deutsche Forschungs und Versuchsanstalt fuer Luft-Und Raumfahrt (German Research and Experimental Institution for Aerospace) at Oberpfaffenhofen, West Germany.

4. Helios/DSN Compatibility Test Plan and Schedule. The DSN/Helios Spacecraft Compatibility Test Plan and Schedule has been discussed from various aspects in previous articles (Refs. 6 to 12). The original plan/schedule as shown in Fig. 3 of Ref. 6 has remained valid in concept even though specific dates and locations have changed slightly from those forecast. The Engineering Model (EM) compatibility tests were conducted in April of 1972 as originally scheduled; however, the test location was transferred from the Compatibility Test Area at JPL, Pasadena (CTA 21) to DSS 71 at Cape Kennedy, Florida. The Test Plan and the Test Results of the EM compatibility test effort are described in Refs. 9, 10, 11, and 12. The prototype compatibility tests are still planned to be conducted at CTA 21; however, the dates have changed from October–November 1973 to February–March 1974. Under the new schedule, compatibility tests with the German Network will be conducted in Germany prior to the shipment of the Prototype to JPL for thermal vacuum chamber and CTA 21 tests, with subsequent reshipment of the Prototype back to Cape Kennedy (as opposed to Germany) where the Prototype can act as a backup to the Flight Spacecraft. The plans for the Flight Model Spacecraft (F-1) remain unchanged from those depicted in Fig. 3 of Ref. 6.

5. Spacecraft Compatibility Test Tapes. As noted in Ref. 10, the EM compatibility tests did not include the spacecraft data-handling equipment portion of the spacecraft radio system. This fact, together with the now delayed arrival of the Prototype Spacecraft, places the first opportunity for Spacecraft/Ground Data System (GDS) compatibility and data-flow testing only four months prior to scheduled launch. Should a serious incompatibility be discovered at this late date prior to launch, the launch schedule could be jeopardized. To reduce the impact of such a possibility, it was decided during the 7th HJWG Meeting to utilize spacecraft Test Tapes obtained during spacecraft checkout with its Ground Support Equipment in Germany in order to replay actual recorded spacecraft telemetry data through the DSN, etc., prior to the arrival of the Prototype for CTA 21 compatibility testing. While it is recognized that such Test Tapes have limitations (i.e., they are not command-responsive, the data are corrupted by tape recorder wow and flutter, etc.), they do permit a significant amount of testing within the Ground Data System in preparation for the Prototype compatibility tests. Consequently such Test Tapes serve as a stepping-stone toward the final demonstration of Ground Data System compatibility/readiness. A preliminary study regarding the possible use of such tapes indicated that compatible playback tape machines were available at JPL; therefore, the DSN accepted an action item to define the tape format and content needed by the DSN in order to accomplish the intended use for these spacecraft Test Tapes.

C. TDS/Mission Analysis and Operations Joint Session

As mentioned above, the Helios Joint Working Group emphasis had shifted by the time of the seventh meeting from Spacecraft Design to the Flight Mission Design. This does not imply that a considerable amount of mission planning had not been accomplished prior to the seventh meeting; it was merely the total emphasis that had shifted. For example, a considerable portion of the Mission Analysis and Operations (MA&O) agenda topics—particularly those with other Subgroups—concerned the detailed, step-by-step operational procedures that would be used during the execution of the mission. The TDS contributed to this effort in two ways: first, the TDS has a representative as a permanent member of the MA&O Subgroup; and second, the TDS Subgroup meets jointly with the MA&O Subgroup at each HJWG meeting to assist in mission planning.

Further, as mission planners, the MA&O Subgroup has a strong interest in all of the subject matter being reported in this article; therefore, the author does not intend to imply that the MA&O participation in the 7th HJWG Meeting was limited to the few topics listed below.

1. Helios Ground and Operations System/JPL Interface Management Plan. By intent, a significant portion of the MA&O Subgroup membership is composed of personnel from the West German Helios Ground and Operations System (HGOS)—(Fig. 1 of Ref. 1). Further, it is evident that the HGOS has a significant operational interface with the JPL Helios support organization (Figs. 2, 3). Therefore, activity was initiated during the 6th HJWG Meeting to develop a HGOS/JPL Interface Management Plan. Considerable progress was made in the interval between that meeting and the 7th HJWG Meeting with the result that near-final agreement was reached upon its contents. At the present time, the final changes/corrections are being incorporated into the manuscript. After proper approval, the plan will be published as a project document. Its contents are shown in Table 1.

2. Ground Data System Test Plan. The TDS Subgroup had long recognized the need to demonstrate compatibility between the various elements of the total Ground Data System (GDS) (Fig. 2) prior to the initiation of Mission Operations Training by the HGOS personnel. Portions of the total Ground Data System will be tested, both within the U.S. and within Germany, during the spacecraft compatibility tests mentioned in *Paragraph II-B-4*. However, due to the different operational readiness dates for the German, DSN, and Near-Earth Phase Networks (NEPN), the total world-wide Helios Ground Data System could not be demonstrated simultaneously until after the arrival of the Flight (F-1) Spacecraft at Cape Kennedy, Fla. However, significant subdivisions of the total GDS could and should be demonstrated prior to this time. During the 7th HJWG Meeting, the TDS and MA&O Subgroups agreed to develop a coordinated plan leading up to the final total Ground Data System demonstration prior to launch. The JPL effort will be coordinated by the Helios representative from the JPL Flight Project's Operations Support Coordination Office (Fig. 3). This plan is expected to be presented at the 8th HJWG Meeting.

*3. **DSN Command System Redesign.*** During the prelaunch compatibility testing of the Pioneer 10 spacecraft, it became evident that the DSSs' Telemetry and Command Processor (TCP) had become overloaded with ever-increasing project requirements during its lifetime. At the time of Pioneer 10 compatibility testing, the TCP could just handle the Pioneer telemetry and command requirements. Since the Helios telemetry frame length is much longer and commands are sent at 8 symbols-per-second (sps) as opposed to 1 sps for Pioneer, it became evident that a TCP software redesign would be necessary to support Helios. One of the steps currently being taken to reduce total project loading on the TCP is to reapportion the Command System workload between the TCP and the Mission Control and Computing Center (MCCC) 360-75 computers. One of the features of the Pioneer 10 era TCP software design was the ability or flexibility that would permit a project to remotely rearrange or manipulate the Command sequence or "stack" in residence within the station's TCP. This flexibility required a considerable amount of TCP on-site processing. In the new Command System design, such manipulation is done in the MCCC 360-75 computer with only the resultant "command stack" being sent via high-speed data lines to the station's TCP. Considerable TCP processing time has therefore been eliminated without sacrificing the basic Command System flexibility concept. The redesign, however, did affect the operational procedures to be used and the bit-by-bit definition of the high-speed data blocks being used to transfer commands from the MCCC 360-75 to the DSS TCP. These changes were points of discussion during the 7th HJWG Meeting. At the present time, the HGOS organization is reviewing these changes in preparation for a new agreement on the command system interface.

*4. **DSN Experience With the Blind Acquisition of Pioneer 7 Spacecraft.*** As mentioned in *Paragraph II-B-3*, the Helios mission sequence designers are concerned with the ability of the DSN to reacquire the spacecraft signal after the spacecraft emerges from a long-duration solar occultation or blackout. To illustrate the type of techniques that can be employed, the DSN related a recent experience regarding tracking the Pioneer 7 spacecraft.

Because Pioneer 7 was in its Extended Mission Phase, the DSN had not been scheduled to track the spacecraft between July 25 and August 6, 1972. At the latter date, the DSN attempted to locate the Pioneer 7 spacecraft at its predicted frequency without initial success. The condition of the spacecraft, therefore, became unknown. On the assumption that the spacecraft was still transmitting but not on its predicted frequency, a DSN receiver search was made to no avail. Something had therefore happened to the downlink. Commands were then transmitted, using the nominal or predicted uplink frequency, to reinstate the downlink. At that time, Pioneer 7 was 312.2 million km from Earth, which required a round-trip light time of 34.7 min. When this time passed without a successful reacquisition of the downlink, the DSN and the Pioneer Project jointly planned an uplink frequency sweep with simultaneous transmission of commands to the spacecraft. The strategy was to sweep from the predicted uplink frequency in a direction which the spacecraft receiver's frequency would have drifted had the spacecraft temperature decreased because the transmitter had been accidentally turned off. On the third attempt, more than three hours later, the downlink was successfully reestablished. Subsequent telemetry analysis indicated that a spacecraft under voltage protection circuit had actuated to turn off the traveling-wave tube (TWT) RF power amplifier and the science instruments. As a result, the spacecraft receiver had dropped from a temperature of 14.2 to $-13.6°C$. The latter temperature was below the calibrated range of spacecraft receiver rest frequencies; therefore, in developing the transmitter sweep frequency strategy, project personnel had had to estimate the frequency necessary to reestablish the uplink and to command the spacecraft on.

This experience had two major points of significance for Helios. First, assuming a noncatastrophic loss of downlink signal, the DSN can employ operational techniques in an attempt to reestablish communication with the spacecraft; second, it is very important for the project to preflight calibrate the spacecraft receiver's rest frequency over temperature ranges beyond those expected during normal mission operations.

5. DSN Operational Constraints to Mission Design. Due to the nature of station hardware/software design, the DSN does impose certain operational constraints upon mission sequence design. In general, these constraints are not serious, but certainly need to be understood when developing detailed mission sequence procedures. Among others, the following two constraints were noted:

a. Telemetry. The Helios spacecraft has a number of telemetry bit rates available for transmission of data to Earth (Ref. 6). These bit rates change in steps of two, namely, 8, 16, 32, 64 . . . 2048 bps. When the data are convolutionally encoded, each bit becomes two symbols (8 bps becomes 16 sps), with the result that the symbol rates are 16, 32, 64, 128 . . . 4096 sps.

When these symbol streams are received at the DSS, the station's Telemetry System must synchronize to the incoming serial bit stream. This is done in the Symbol Synchronizer Assembly (SSA) which also must be set up or "initialized" in multiples of two centered around the expected downlink symbol rate. Therefore, whenever a Helios telemetry bit rate mode change is commanded, the DSS Telemetry System must be re-initialized at the new symbol rate. Re-initialization can result in the loss of several telemetry frames. This factor should be considered in mission planning, i.e., it is desirable to command telemetry bit rate changes mostly during periods of quiescent spacecraft activity in order to minimize the impact of the lost data.

b. Command. The Helios spacecraft has two command uplink subcarrier frequencies (Refs. 1, 6, and 7). Whenever it is desired to change from one command subcarrier frequency to the other—as for example, during the Step II maneuver (Ref. 5)—it is necessary to interrupt the command modulation and/or the transmission of the command idle sequence (Ref. 7), as well as to switch the actual subcarrier frequencies that are being modulated onto the uplink carrier. This procedure requires the re-initialization of the DSS Command System which can occupy a time period of one to five minutes, depending upon circumstances.

From the above-cited examples, it can be seen that the normal operation of the DSN does place certain constraints upon the mission sequence design. However, if these are properly recognized during mission planning they should have no impact upon mission success.

D. TDS/Experiments Joint Meeting

The major interface between the TDS Subgroup and the Experiments Subgroup lies in the content, structure, and detailed definition of the EDRs to be delivered by the Helios Ground Data System (GDS) to each experimenter. In gross terms, this interface is defined in the project Support Instrumentation Requirements Document (SIRD) and in the responses provided by the NASA Support Plan (NSP) and by the German Support Plan. However, these documents do not define the detailed structure of these EDRs. Further, many of the specifications that do appear in the SIRD and its supporting documents are the direct result of experimenters' requirements. It is a trite truism to say that Experimenters and Ground Data System personnel live and think in different worlds. A good example of this truism is given in the following, which in itself justifies the need for continued TDS/experimenter discussions during the HJWG meetings.

1. Telemetry Master Data Record/Experiment Data Record Completeness Criteria. The Helios SIRD contains a specification that the Telemetry Experiment Data Record (EDR) shall have a bit error rate (BER) no greater than 10^{-5}. This is a very stringent specification and is one of the reasons the Helios Project selected convolutional coding for its telemetry. However, coding alone will not achieve a BER this low; each telemetry mode must contain additional signal margin in its telecommunications link analysis. Further, a BER specification does not apply to lost telemetry frames (e.g., signal dropouts, etc.) so additional completeness criteria are needed. All of these subjects have been repeatedly discussed during previous HJWG meetings; however, the words used by the respective parties were not fully understood by the other. During the 7th HJWG Meeting at least one area of misunderstanding was finally described in words understood by both Subgroups. It relates to both the BER and the completeness criteria:

In the transmission of telemetry data from the DSN stations to the Mission Control and Computing Center (MCCC), (where the data are logged onto the Master Data Record) telephone-type voice/data circuits known as High-Speed Data Lines (HSDLs) are used. These circuits are subject to bursts of noise which in turn obliterate small blocks or chunks of the data being transmitted over the circuit. These noise bursts are random in the sense that they can occur at any time in an unpredictable manner. Prior to the 7th HJWG Meeting, the experimenters had interpreted the word "random" to mean that the noise was more or less uniform—i.e., that it would affect all data bits being transmitted over the circuit more or less uniformly. Because some experimenters' data are subcommutated within the Helios telemetry frame, those experimenters in particular were alarmed at the discovery that a given HSDL noise burst could obliterate their entire data word. Further, this data word might not be repeated in another measurement until the next Main Frame (one Helios Main Frame is composed of 72 regular 1152 bit Helios frames). The experimenters' concern was even further aggravated by the realization that the mere act of repeating the data transmission from the station would not guarantee that another noise burst would not occur to again affect his data. Unfortunately, this situation can occur in the practical world even though at the same time the Helios Ground Data System is averaging less than 10^{-5} BER and has met a 95–98% completeness criteria. Obviously, the experimenters were not prepared to make an on-the-spot evaluation of the impact of this realization. Nonetheless, it was at least opportune that this realization occurred some 20 months prior to launch —as opposed to after launch, as it did in the case of at least one prior project.

2. Data Records for Experiments 11 and 12. Helios has ten major on-board scientific experiments plus two ground-based, passive experiments (Table 2). The latter are Experiments 11 (Celestial Mechanics) and 12 (Faraday Rotation) whose primary data are not contained in the Helios telemetry stream, but rather from measurements taken at the DSN stations. For Experiment 11, the primary data types are doppler and planetary ranging, which are contained in the DSN Tracking System MDR. For Experiment 12, Faraday Rotation, the primary data are recordings of the polarization angle of the incoming Helios carrier signal as received by the DSN 64-m-diam stations. Since neither of these data types fit conveniently into the EDR format structure negotiated with the Experimenters Subgroup for Experiments 1 through 10, action items were jointly assigned to these experimenters and the TDS Subgroup to develop an MDR/EDR Plan specific to Experiments 11 and 12 for presentation at the 8th HJWG Meeting.

3. Use of Mu Ranging. The Celestial Mechanics Experiment (No. 11) uses DSN doppler and range data to precisely measure the influence of the sun's gravity upon the Helios trajectory and the propagation of its radio signal. These influences are greatest when the spacecraft is near perihelion and near solar occultation, respectively; however, to completely measure the effect and to get reference points, data are also needed regarding the trajectory well before and after perihelion and occultation passage. During this total time period, the range from Earth to the spacecraft can vary anywhere from 0.6 to 2.0 AU (Ref. 5). Therefore, the DSN Planetary Ranging System must be employed. During the development of the Helios spacecraft, the DSN contemplated employing a "continuous spectrum" (Tau) type of planetary ranging system during the Helios era. However, during the course of this development, flight projects in general expressed an interest in the DSN "discrete spectrum" (Mu) planetary ranging technique, with the result that in July 1972 the DSN made a formal decision to implement both types of planetary ranging systems for operational use in the Helios era. It will now be possible for Helios to use either type of planetary ranging system, with the only constraint being that the project would have to select one or the other ranging system types prior to the beginning of any particular DSN 64-m station pass (planetary ranging is not presently planned for implementation into the DSN 26-m networks). The significance to Helios of this decision is that the *discrete spectrum* (or Mu) Planetary Ranging System permits either or both: (1) less power to be used in the ranging sidebands, or (2) a shorter range code acquisition time (time consumed in making a ranging measurement)—depending upon the project tradeoffs involved.

As mentioned in the discussions regarding link analysis, the Helios telemetry margins, particularly at 2.0 AU, had degraded during the evolution of the spacecraft radio system design. As a result, use of the Tau Planetary Ranging System at 2.0 AU would force a reduction in spacecraft telemetry bit rate when the turnaround ranging mode was activated. In contrast, the use of the Mu Planetary Ranging System under these circumstances could be designed to have only slight effect upon the telemetry data return at 2 AU. A special 7th HJWG Splinter Session investigated this situation in detail and recommended that the planetary ranging modulation index used by the spacecraft be changed from its prior value of 45- to 24-deg phase modulation. This new value should enhance science data return at 2.0 AU, yet still provide capability for Tau Planetary Ranging to a distance of 1.6 AU together with Mu Planetary Ranging capability all the way to 2.0 AU. The latter situation turned out to be completely acceptable to the Experiment 11 representative.

E. Special Splinter Meeting Topics

As mentioned earlier in this article, the 7th HJWG Meeting agenda contained a large number of splinter topics due to the level of detail needed to complete the various interfaces. While this situation prevailed throughout all Subgroup agendas, it was particularly true for the TDS Subgroup where the number of splinter topics exceeded the number of general session agenda items. Space does not permit the inclusion of even a majority of these topics in this article; therefore, only a few having the greatest significance to the TDS Subgroup activities will be reported in the paragraphs that follow.

*1. **Blind Acquisition.*** Just prior to the 6th HJWG Meeting, it was discovered that a possibility exists that the Helios spacecraft might not be transmitting a downlink signal at the time of the initial DSN acquisition. This situation could occur if an unpredicted spacecraft power system overload occurred during launch, which in turn could cause a protective circuit to shut down a number of instruments including the transmitter. Therefore, during the 6th HJWG Meeting, a special study team was constituted to investigate this potential problem in detail and to present their findings at the 7th HJWG Meeting. The DSN participated in this effort both prior to and during the 7th HJWG Meeting. In performing their study, the Team had to make certain key assumptions: the spacecraft failure was not catastrophic; the 926 km (500-nmi) perigee altitude (lofted) trajectory would be employed; the Low-Gain Antenna (LGA or omni) pattern nulls would not exceed 5 db; the Near-Earth Phase Network (NEPN) could provide pointing information to the DSN based on launch vehicle tracking data; and that the DSN initial acquisition station would have an Acquisition Aid Antenna. Of the foregoing, the assumption of -5 dB antenna nulls seemed to be questionable, with the feeling that -40 dB would be a better number. While the DSN agreed to recalculate their predictions based on the -40 dB null criterion, the team concluded that the controlling factor in a successful blind acquisition is the perigee altitude. Altitudes significantly lower than 926 km (500 nmi) would both increase the time required and lower the probability of successfully entering a blind command into the spacecraft to reactivate the downlink. For evaluation purposes, the original assumptions produced the conclusion that the DSN would have a high probability (e.g., 0.9) of successfully establishing communications with the spacecraft by Launch $+1$ hour. The significant change with respect to a standard initial acquisition (*Paragraph II-A-1*) is, therefore, the time required after spacecraft rise at the initial station for two-way communication to be established.

*2. **Step II Attitude Determination.*** A topic of continuing discussion during the past several HJWG Meetings has been techniques for the determination of spacecraft attitude during the Step II maneuver sequence. It has been relatively well understood that the Medium-Gain Antenna (MGA or pancake antenna) pattern characteristics would be used during the final portion of the Step II maneuver to ascertain that the spin axis is pointing to the pole of the ecliptic. This is to be done by monitoring the received signal strength (AGC) at the DSN station. During the 7th HJWG Meeting, it was concluded that the SIRD requirement for sampling DSN AGC values could be reduced from 10/s to 1/s without impacting the Project's ability to perform this maneuver. Since the higher AGC sampling rate would require special implementation within the DSN, it was concluded that the SIRD requirement should be revised to the lower sampling rate to avoid unnecessary cost within the network.

Prior to the 7th HJWG Meeting, there had been concern regarding the initial phases of the Step II maneuver. This regards the determination of whether the spacecraft would start to precess toward the north or toward the south ecliptic pole. While a successful mission could be accomplished with the spin axis oriented toward either pole, the north pole was desired. However, once the precession had gone more than a limited number of degrees, there was insufficient attitude gas reserve to reverse the direction toward the other ecliptic pole. During the 7th HJWG Meeting, it was ascertained that the spin modulation due to the offset of the bottom horn antenna (LGA) would cause a doppler modulation which, in turn, could provide information regarding the direction of orientation—i.e., whether it was precessing toward the north or south ecliptic pole. However, to use this information, it would be necessary to sample the doppler at a rate of 10/s, which is faster than the presently committed DSN maximum sample rate of 1/s. The DSN is contemplating an added capability at selected stations to accommodate 10/s doppler sampling—which if implemented could support Helios, providing this higher rate became a SIRD requirement.

*3. **Coded vs Uncoded Telemetry at Launch.*** As mentioned in the previous article (Ref. 1), a major agenda point for the 7th HJWG Meeting was a joint session recommendation regarding whether Helios should be launched in the coded or the uncoded telemetry mode. As might be expected, there were reasonably strong arguments presented in favor of each side of the question. From the DSN viewpoint, either mode could be supported during the initial DSN acquisition, but with the understanding that the coded mode would take slightly longer to process at the station, since telemetry frame synchronization must take place prior to the data being decoded and processed for transmission to the MCCC. The latter proved not to be a compelling argument, but since the Helios Ground Support Equipment (Helios Test Set–(HTS)) was presently structured only to handle telemetry in the coded mode, the MA&O Subgroup submitted its recommendation that Helios be launched in the coded telemetry mode.

4. Automatic vs Commanded Transponder Coherent Operation. The current design of the Helios spacecraft requires that the transponder be commanded into the coherent mode of operation as opposed to having this function performed automatically upon receipt of an up-link by the spacecraft. Reference 6, p. 23, describes the rationale for the commanded approach. During the 6th HJWG Meeting, an action item was assigned to the DSN to evaluate the operational impact of each approach upon the network as it might relate to Helios mission design. This evaluation was completed, and it was reported during the 7th HJWG Meeting that the commanded technique would not present any significant constraints to network operations over the use of an automatic technique for initiating coherent transponder operation. The project is, therefore, free to select whichever technique best satisfies its mission objectives and/or mission sequence design.

5. Other Topics. There were numerous other topics resolved during the 7th HJWG Meeting—these may be found in the formal minutes (Ref. 3). In addition, there were several on-going topics that were discussed as part of other agenda items. One example of the latter concerns the Low-Gain Antenna (LGA) pattern which was mentioned in relation to several of the agenda topics discussed in this article. There is an obvious need for an early definition of this pattern, particularly with respect to the interferometer region between the dipole and horn antenna elements (Ref. 1)—but, unfortunately, such data are difficult to obtain via Earth-based measurements. Discussions regarding this subject are, therefore, iterative in nature and may be expected to continue through the next several HJWG meetings.

III. Conclusions

This article has treated some of the more significant highlights with respect to the DSN/TDS activity during the 7th HJWG Meeting. The next (8th) Helios Joint Working Group Meeting, is presently scheduled for May 9 through 15, 1973, at Cape Kennedy, Fla. and will emphasize the launch operations aspect of the Helios preparations. In the meantime, the next article in this series will discuss the results of Helios Project technical discussions that were held at JPL during December 1972.

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11. Goodwin, P. S., "Helios Mission Support," Technical Report 32-1526, Vol. IX, pp. 33–34. Jet Propulsion Laboratory, Pasadena, Calif., June 15, 1972.
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Table 1. HGOS/JPL interface management plan contents

I.	Introduction
II.	Project Management
III.	Project Phases
IV.	Joint Management Policies and Requirements
V.	Task Breakdown and Responsibility Assignment

Table 2. Helios experiments

No.	Experiment	Scientific affiliation
1	Plasma Detectors	
	(A) Proton and Alpha Detector High Angular Resolution	Max Planck Institut fur Extraterrestrische Physik, Garching
	(B) Proton and Alpha Detector Faraday Cup	Ames Research Center
	(C) Electron Detector	
2	Flux-Gate Magnetometer	Tu Braunschweig Institut fur Giophysik und Meteorologie
3	Flux-Gate Magnetometer	Goddard Space Flight Center University of Rome
4	Search-Coil Magnetometer	Tu Braunschweig Institut fur Giophysik und Meteorologie
		Institut fur Nachrichtentechnik
5	(A) Solar Wind Plasma Wave Experiment	University of Iowa University of Minnesota
	(B) Radio Wave Experiment	Goddard Space Flight Center
6	Cosmic Ray Experiment 1 Mev to 1 Gev	University Kiel
7	Cosmic Ray Experiment	
	(A) High Energy Telescope	Goddard Space Flight Center
	(B) Medium Energy Telescope	
	(C) Low Energy Telescope	University of Adelaide
	(D) X-Ray Detector	
8	Electron Detector	Max Planck Institut fur Aeronomie, Lindau/Harz
9	Zodiacal Light Photometer	Landessternwarte Heidelberg
10	Micrometeoroid Detector and Analyzer	Max Planck Institut fur Kernphysik, Heidelberg
11	Celestial Mechanics	Jet Propulsion Laboratory University of Hamburg
12[a]	Faraday Rotation	Jet Propulsion Laboratory

[a]Pending final intergovernmental approval.

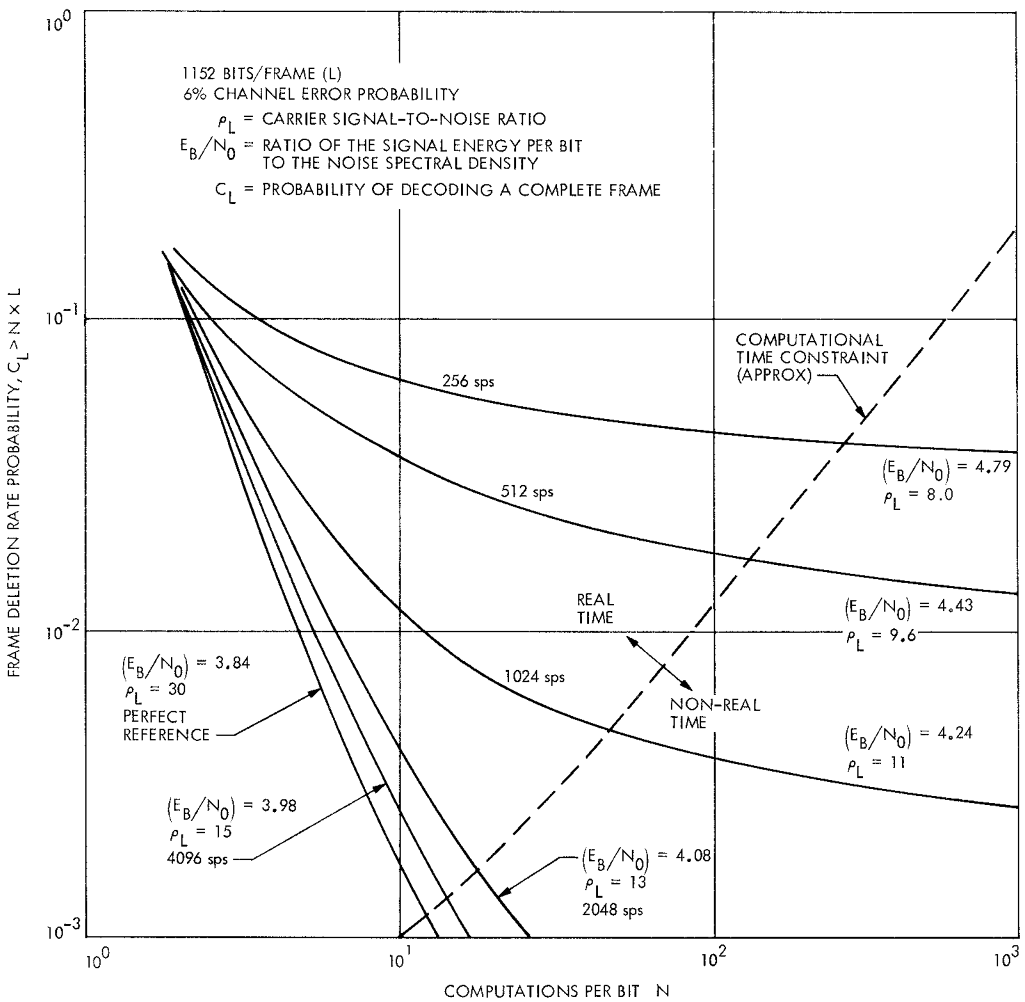

Fig. 1. DSN October 1972 estimate for Helios coded telemetry performance

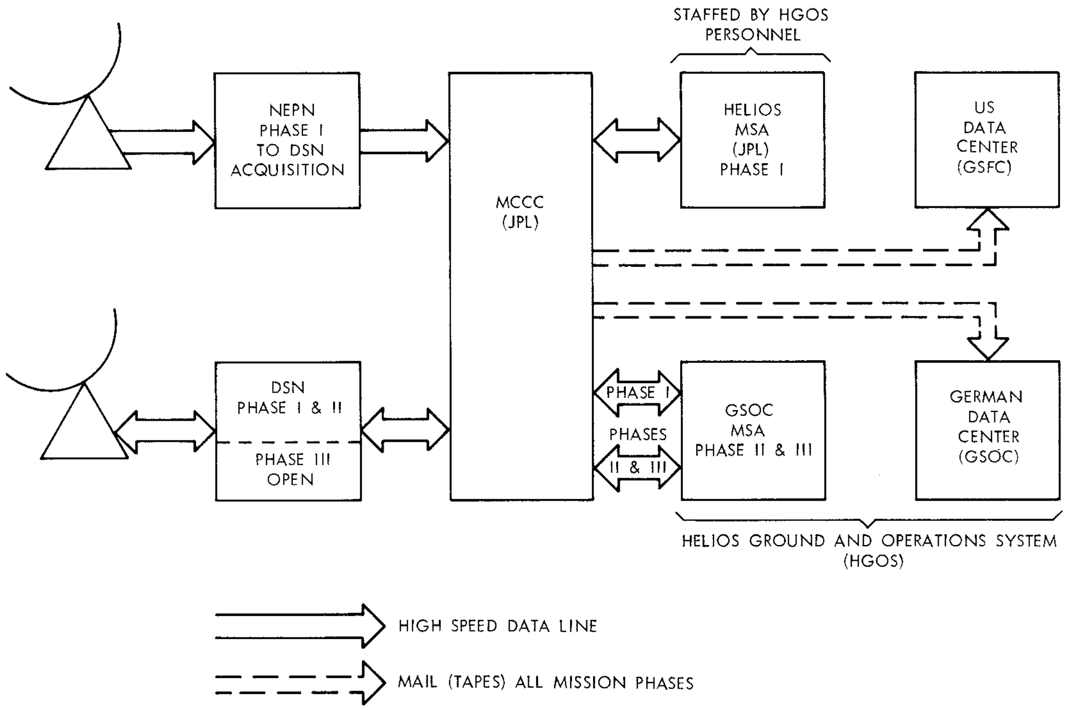

Fig. 2. NASA-TDS Helios data flow

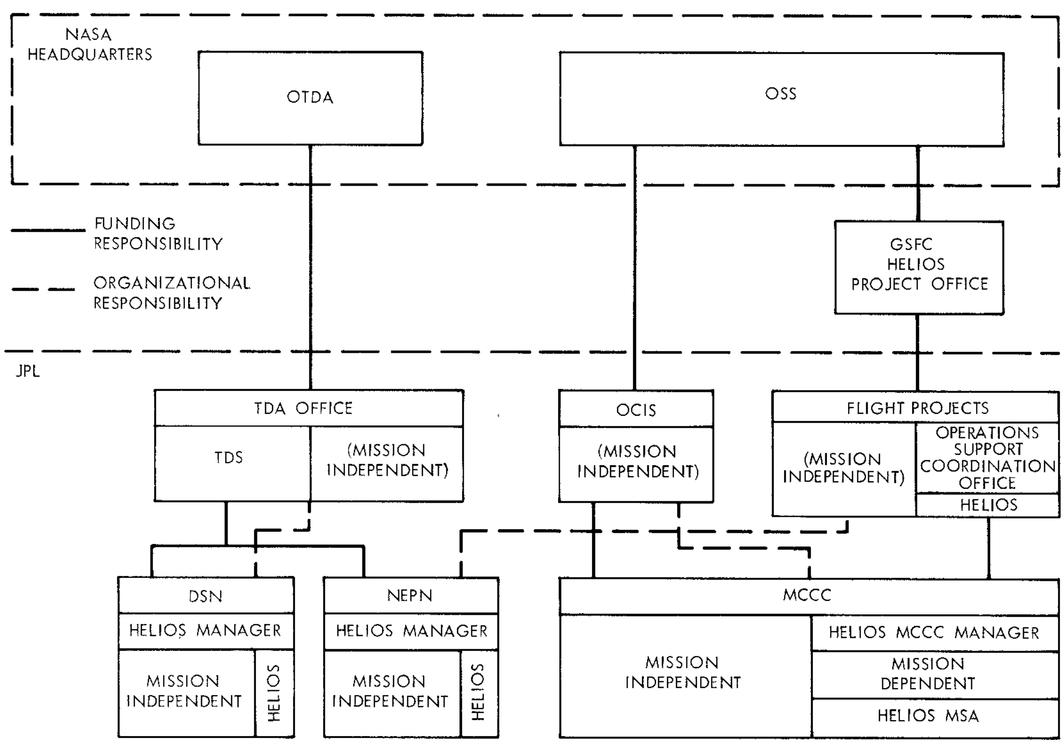

Fig. 3. JPL Helios support functional relationships