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Technical Memorandum 33-752

Volume III

Tracking and Data Systems Support for the Helios Project

DSN Support of Project Helios May 1976 Through June 1977

JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA

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Tracking and Data Systems Support for the Helios Project

DSN Support of Project Helios May 1976 Through June 1977

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PREFACE

The work described in this report was performed by the engineering and operations personnel of the Tracking and Data Acquisition organizations of the Jet Propulsion Laboratory. This is the third in a series of engineering reports describing the continuing support provided to the Helios Project.

This report describes the support provided for the Helios-1 spacecraft from third perihelion in April and May 1976 through its entry into its fourth superior conjunction passage in May 1977. Also described is the support provided for the Helios-2 spacecraft from entry into its first superior conjunction passage in May 1976 through to its second superior conjunction passage in May 1977.

This is the last volume in this series of reports. Further reports on support for the Helios Project will be contained in the bimonthly Deep Space Network Progress Report. At the conclusion of Helios Project support, articles on this subject that appeared in the Progress Report will be bound and published as an anthology.

ACKNOWLEDGEMENT

The authors express their gratitude to the many JPL contributors whose skills in management, planning, and operation have contributed so significantly to the success of the Helios Project.

Further, the authors express their thanks for and acknowledge the contributions of Ants Kutzer of the German Society for Space Research and Gilbert W. Ousley of the Goddard Space Flight Center in providing the interface and coordination between our two countries.

Finally, and perhaps most important, the authors wish to recognize the very meaningful contributions of the NASA Headquarters team: the Office of Space Science (OSS) for its program direction to Project Helios and the Office of Tracking and Data Acquisition (OTDA) for continued foresight in providing the network facilities required to support such projects as Helios.

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ABSTRACT

This volume of Technical Memorandum 33-752 describes the Deep Space Network's support of the extended missions of Helios-1 and Helios-2 during the interval from May 1976 through June 1977. Spacecraft extended mission coverage does not generally carry a high priority, but Helios has been fortunate in that a combination of separated viewperiods and unique utilization of the STDN Goldstone antenna have provided a considerable amount of additional science data return — particularly at key times such a perihelion and/or solar occultation.

I. INTRODUCTION

A. PURPOSE

The purpose of this report is to provide a continuing historical account of the DSN operational support supplied to the Helios Project. This volume covers the period May 1976 through June 1977. Prior activities are contained in Volumes I and II of Technical Memorandum 33-752.

B. SCOPE

This report discusses the DSN operational support during Mission Phase III of both the Helios-1 and Helios-2 spacecraft.

C. HISTORICAL RECAP

1. Helios-1

Launched on 10 December 1974, Helios-1, which was the first spacecraft to traverse the unexplored region of the inner solar system, reached its closest approach to the Sun, a distance of 0.3095 astronomical unit (AU), on 15 March 1975. Mission Phase III (Extended Mission) began on 13 April 1975 as the Helios-1 spacecraft entered its first superior conjunction (see Volume I of this Technical Memorandum). From April 1975 until May 1976 Helios-1 successfully completed:

(1) First solar occultation (superior conjunction), 31 August 1975.
(2) Second perihelion, 21 September 1975.
(3) Second inferior conjunction, 14 March 1976.
(4) Third perihelion, 29 March 1976.

DSN support of these events was discussed in Volume II of this Technical Memorandum.

2. Helios-2

Launched on 15 January 1976, Helios-2 became the second spacecraft to explore the inner solar system. Owing to the success of Helios-1 in withstanding the high temperatures at a perihelion of 0.3095 AU, the target perihelion for Helios-2 was set at 0.29 AU. On 18 April 1976 the Helios-2 spacecraft reached its closest approach to the Sun, a distance of 0.29 AU, nearly three million kilometers (approximately 2 million miles) closer than Helios-1. Mission Phase III (Extended Mission) began on 4 May 1976 as Helios-2 entered its first superior conjunction. From launch in January until May 1976, Helios-2 successfully completed the following:

(1) First inferior conjunction, 24 March 1976.
(2) First perihelion, 18 April 1976.

DSN support of these events was discussed in Volume II of this Technical Memorandum.

II. DSN ENGINEERING SUPPORT

A. GERMAN DEEP SPACE NETWORK

As mentioned in Volume II, Technical Memorandum 33-752, the Max Planck Institute (German) had intended to discontinue support of the Helios Project with its 100-meter antenna in mid-September 1976, owing to heavy radio astronomy commitments. Arrangements were then made between NASA and the German Space Operations Center (GSOC) for NASA to loan the required equipment to provide the German Telecommand Station (GTS) at Weilheim with a receive capability, and the equipment was shipped in December 1975 and January 1976.

In April 1976, the German Ministry decided instead to approve a request of the German Helios Project Office to modify the Telecommand Station at Weilheim using the Helios telemetry receiving equipment previously supplied to the 100-meter Effelsberg station. Conversion of GTS into a 2-way station was planned, with a completion date in early September to allow support of the Helios-2 third occulation in late September 1976. Following the second occultation in early July 1976, the Effelsberg telemetry receiving equipment was disconnected and transported to Weilheim. Following GTS installation and engineering tests, two internetwork interface tracking validation tests were conducted.

These tests, involving the upgraded Weilheim station and DSS 62, were conducted on 13 September and 17 September 1976 and were highly successful. As a result, the Weilheim station was declared operational on 20 September 1976 — five days before the Helios-2 third occultation. The NASA loaned equipment was therefore not needed for Helios support, and, by interim agreement, was placed in safe storage by Weilheim personnel.

B. STDN REAL-TIME CROSS SUPPORT

The DSN engineering tests of STDN real-time telemetry and command cross-support for Helios began in April and were successfully completed in June 1976. The concept of utilizing interstation microwave links to send Helios-modulated subcarriers (both telemetry and command) between the STDN receiver-transmitter and a DSN telemetry-command data processing computer was demonstrated using live tracks of the Helios-1 spacecraft.

The last two tests were conducted on 17 and 25 June 1976 between the STDN-Goldstone and DSS 12, and demonstrated that it was possible to obtain 64 bits/s coded telemetry data from Helios with a usable signal-to-noise ratio (SNR) of 3 to 4 dB at a 2-AU range from Earth.

The U. S. Helios Project Manager, encouraged by the DSN engineering tests regarding STDN real-time telemetry and command cross-support, requested the STDN-Goldstone Station (GDS) for support of Helios-1 and -2 spacecraft. This cross-support was requested for the October perihelions of Helios-1 and -2, thence continuing until November 15, when the STDN would temporarily be decommited from all flight support for a scheduled equipment modification program.

Before the STDN-DSN real-time Helios cross-support could be considered operational, a permanent link between STDN-GDS and the DSN Goldstone intersite microwave system was needed. The interface installed for the earlier engineering tests in June had been a temporary coaxial cable.

After considering available options, it was decided that the most suitable and economical method of providing a full duplex interconnection between STDN-GDS and DSS 11 was to reestablish the old Project Apollo microwave link between STDN-GDS and DSS 14. There it could join the DSN Goldstone intersite microwave system. The Apollo-era equipment was reinstalled and successfully tested by September 30, 1976.

The plan was to first send real-time spacecraft telemetry over the newly established microwave link from STDN-GDS to DSS 11 (via DSS 14) (Fig. 1) where it would be processed and sent to JPL. The uplink-lock and command tests would be conducted a week later, followed by a Telemetry and Command demonstration pass. Upon successful completion of this demonstration pass, the STDN-DSN Helios cross-support configuration would be committed for operational support.

The first real-time Helios spacecraft telemetry was processed over the new STDN-DSN configuration (Figs 1, 2, and 3) on October 1, 1976, during a demonstration pass. Data from two other STDN-DSN Helios cross-support passes were accumulated on 15 and 16 October. The results are shown in Table 1.

The STDN-DSN Helios command configuration was successfully tested during the week of October 11, 1976. Several spacecraft uplink acquisitions and commanding sequences were conducted for STDN-GDS operator training during that week. With the successful STDN-DSN Helios Telemetry and Command cross-support demonstration track performed on October 18, 1976, the STDN-DSN cross-support configuration was declared operational for Helios Project support.[1]

On 15 November 1976 STDS-GDS cross-support was terminated on schedule so that the station could undergo extensive reconfiguration. Although the cross-support period was short, STDN-GDS successfully tracked Helios-1 11 times and Helios-2 five times.

The STDN-DSN cross-support for Helios was reactivated on 1 March 1977 with a demonstration track using the reconfigured STDN station (Fig. 4) and DSS 12 (Fig. 5) at Goldstone. Helios-2 was tracked by the STDN antenna and the received downlink signal successfully microwaved to DSS 14, which in turn relayed the signal to DSS 12 (Fig. 6). At DSS 12 the signal was processed through the station's backup telemetry string and the data were transmitted to JPL and Germany via high-speed data line. Commanding was accomplished in the reverse order. It is interesting to note that during this period DSS 12 was tracking Helios-1 and processing data on its prime telemetry and command system. The main problem encountered in the demonstration track was the initial poor signal quality being received at DSS 12 from STDN. After system

[1]Although the data from this cross-support configuration were degraded (3.5 dB) when compared to a DSN 26-meter station, the data received from Helios at perihelion and distances less than 1 AU were excellent.

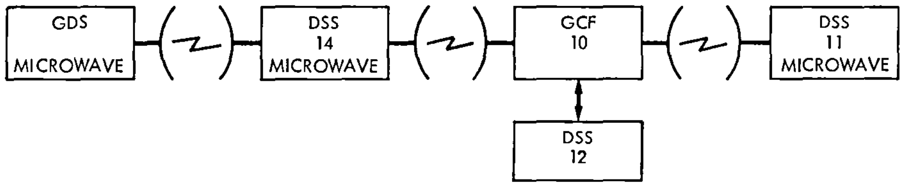

Fig. 1. STDN (GDS)-DSS microwave configuration

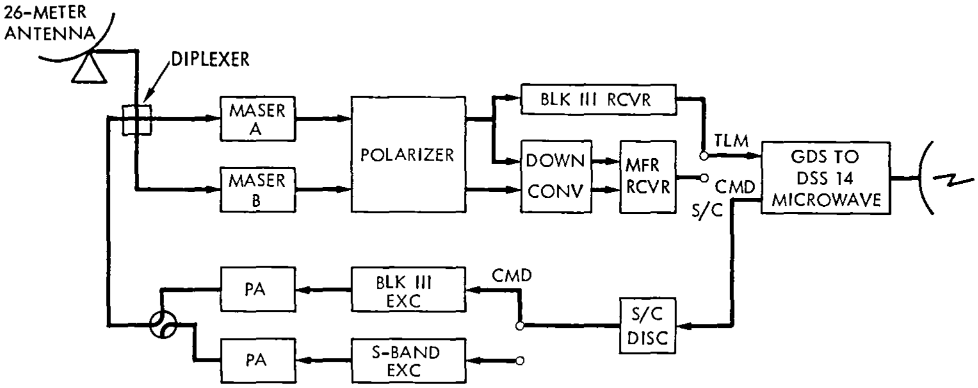

Fig. 2 STDN (GDS) cross-support configuration

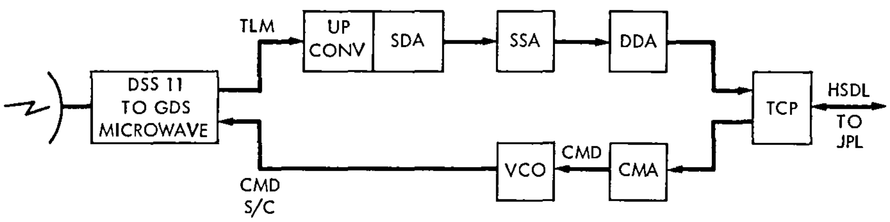

Fig. 3 DSS cross-support configuration

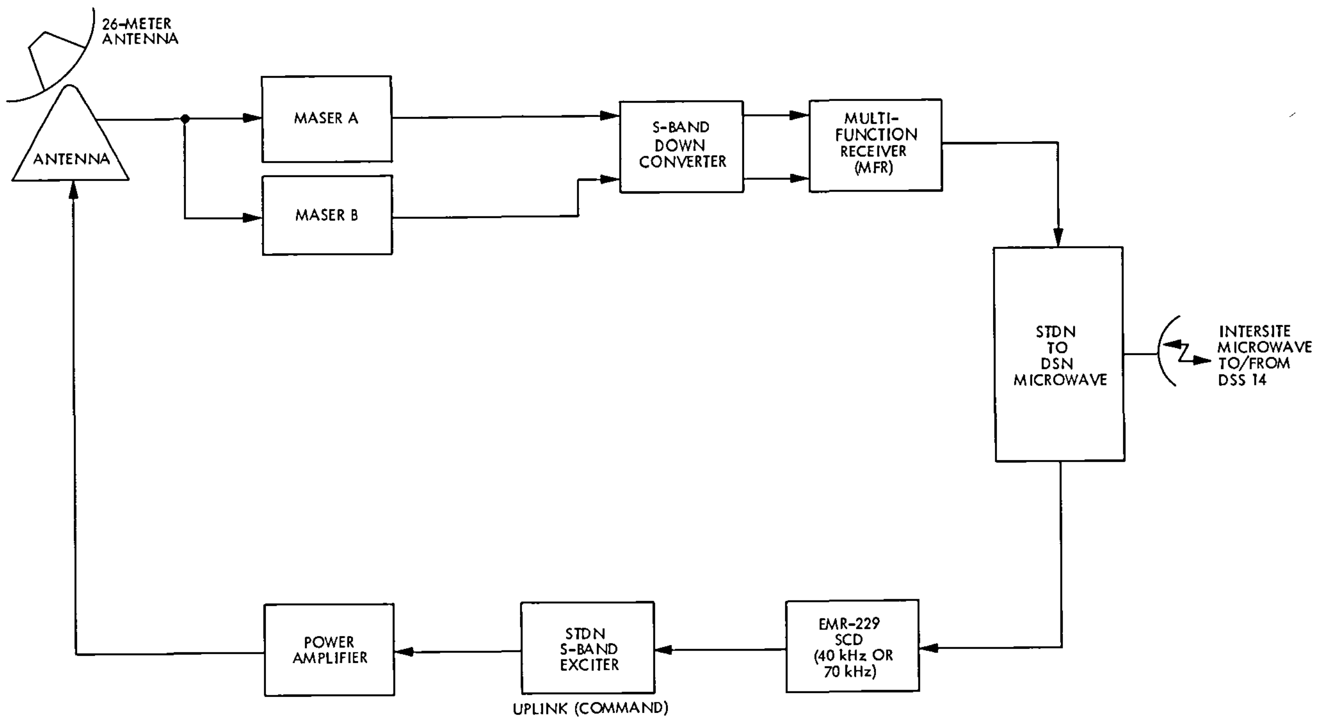

Fig. 4. STDN Helios cross-support configuration

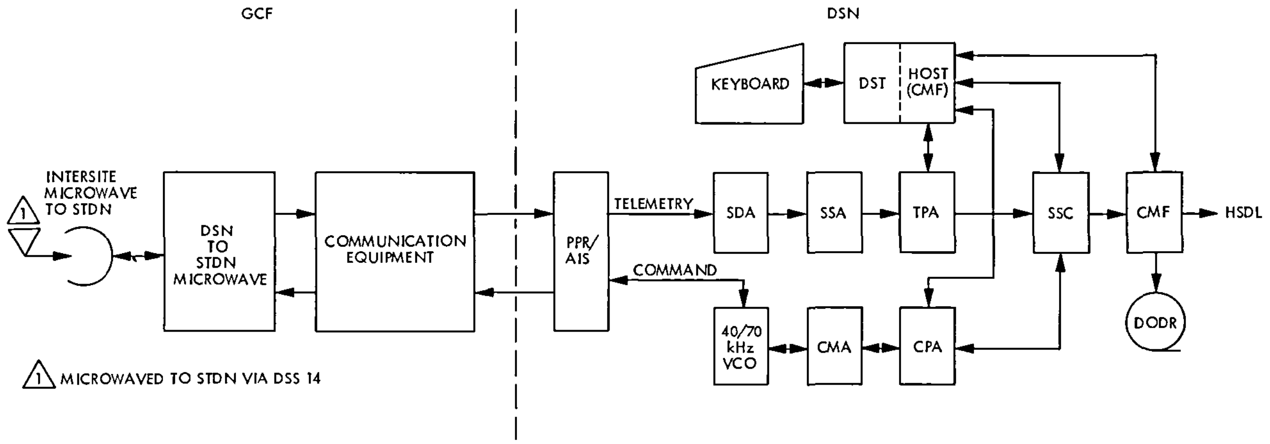

Fig. 5. DSN DSS 12 Helios cross-support configuration

Table 1. STDN-DSN Helios cross-support engineering test results

Bit rate, bits/s	1 October, signal-to-noise ratio, dB				
		STDN		DSN vs STDN	
	Predicted (DSN)	Block III receiver	MFR receiver	Block III difference	MFR difference
32	9.8	6.2	4.8	3.6	5.0
64	8.5	4.0	2.6	4.5	5.9
	15 and 16 October, signal-to-noise ratio, dB				
128	8.1	5.3	N/A	2.8	N/A

troubleshooting it was found that the STDN receiver was not functioning properly. Having four multifunction receivers (MFR) available, each was brought into operation until the most efficient was found. After that was accomplished, DSS 12 established a solid lock on the STDN data, and the track proceeded without incident. On 4 March 1977 the same activity was performed using DSS 11 (Fig. 7) and, except for a few minor operator errors, the system functioned well. Both demonstration tracks were considered successful and the system was declared functionally operational.

C. DSN MARK III-77 DATA SYSTEM

The DSN Mark III-77 Data System (MDS) shown in Fig. 8 established a standardized, simple, and easily managed interface with flight projects, including Mission Control and Computer Center (MCCC) multimission flight support. A key factor in the MDS was the development of a Network Control System using separate hardware from that used by flight projects and the introduction of such new technology as (1) multistation radio metric data type using interferometric principles, (2) network automation leading to lower operating cost, and (3) global wideband data lines for real-time transmission of spacecraft video information.

Figures 9 and 10 are block diagrams of MDS configured 26- and 64-meter DSN stations.

In December 1976, implementation of the new DSN Mark III Data System was completed at DSS 12 (Fig. 9). On 21 December, the first of a series of Helios demonstration tracks was performed to exercise the equipment and provide operator training. Although this first demonstration track did not meet with complete success because of minor hardware and software problems, it did provide valuable operator training.

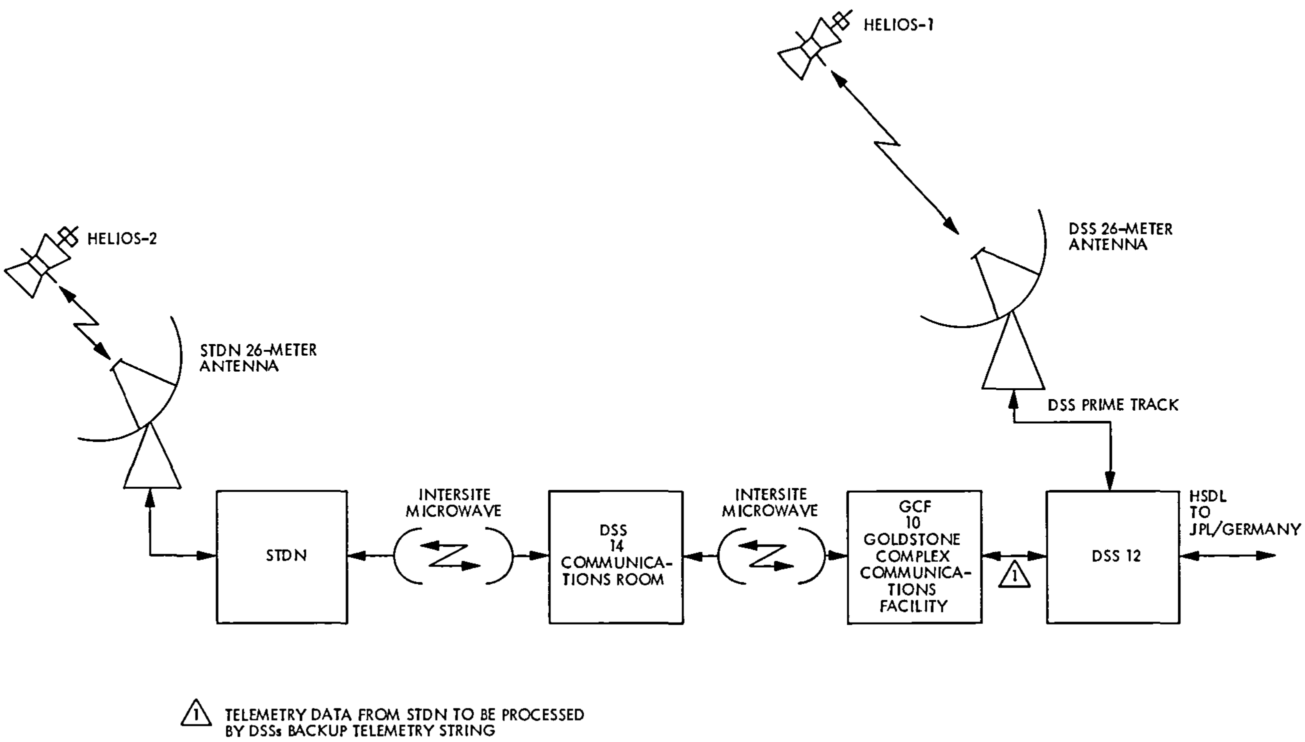

Fig. 6. Goldstone STDN-DSN cross-support configuration on 1 March 1977

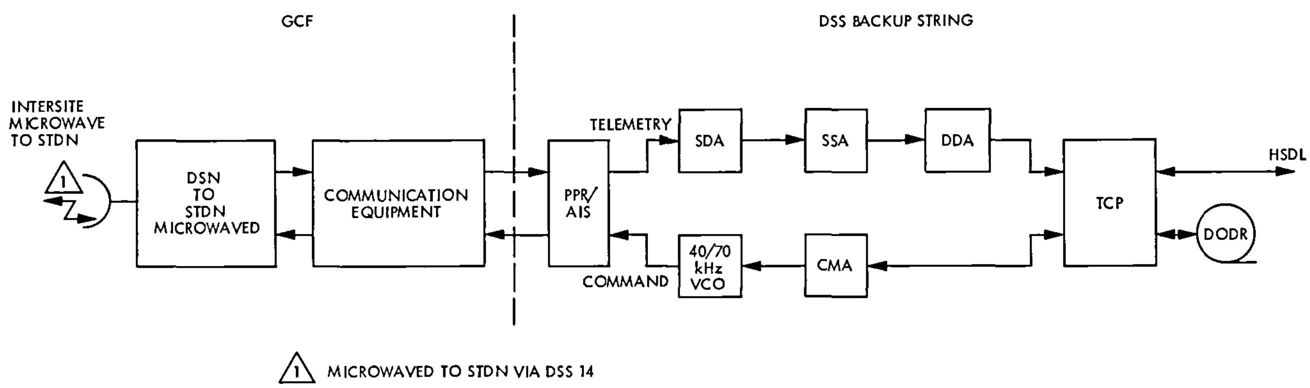

Fig. 7. DSN DSS 11 cross-support configuration

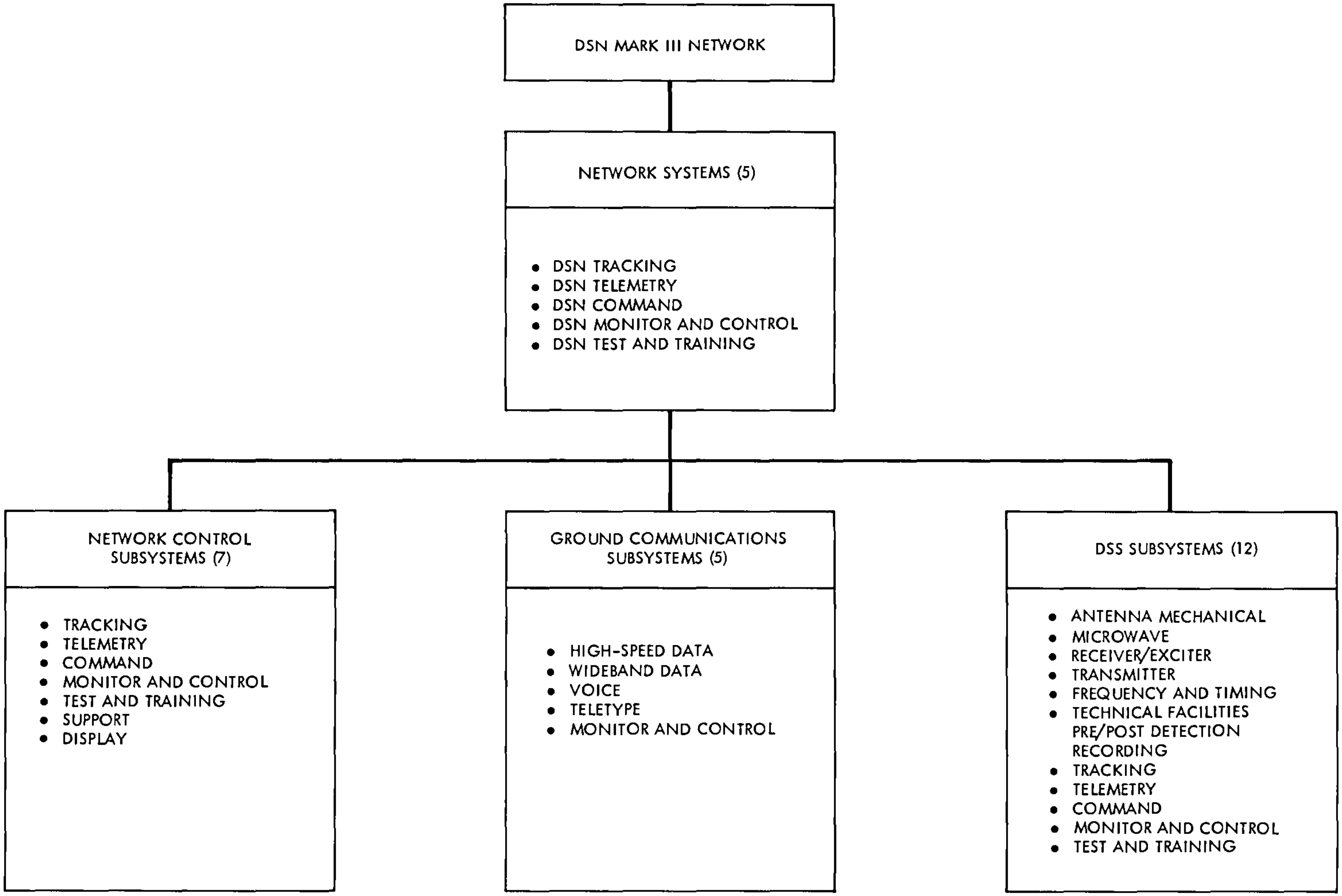

Fig. 8. DSN Mark III-77 Systems and Subsystems

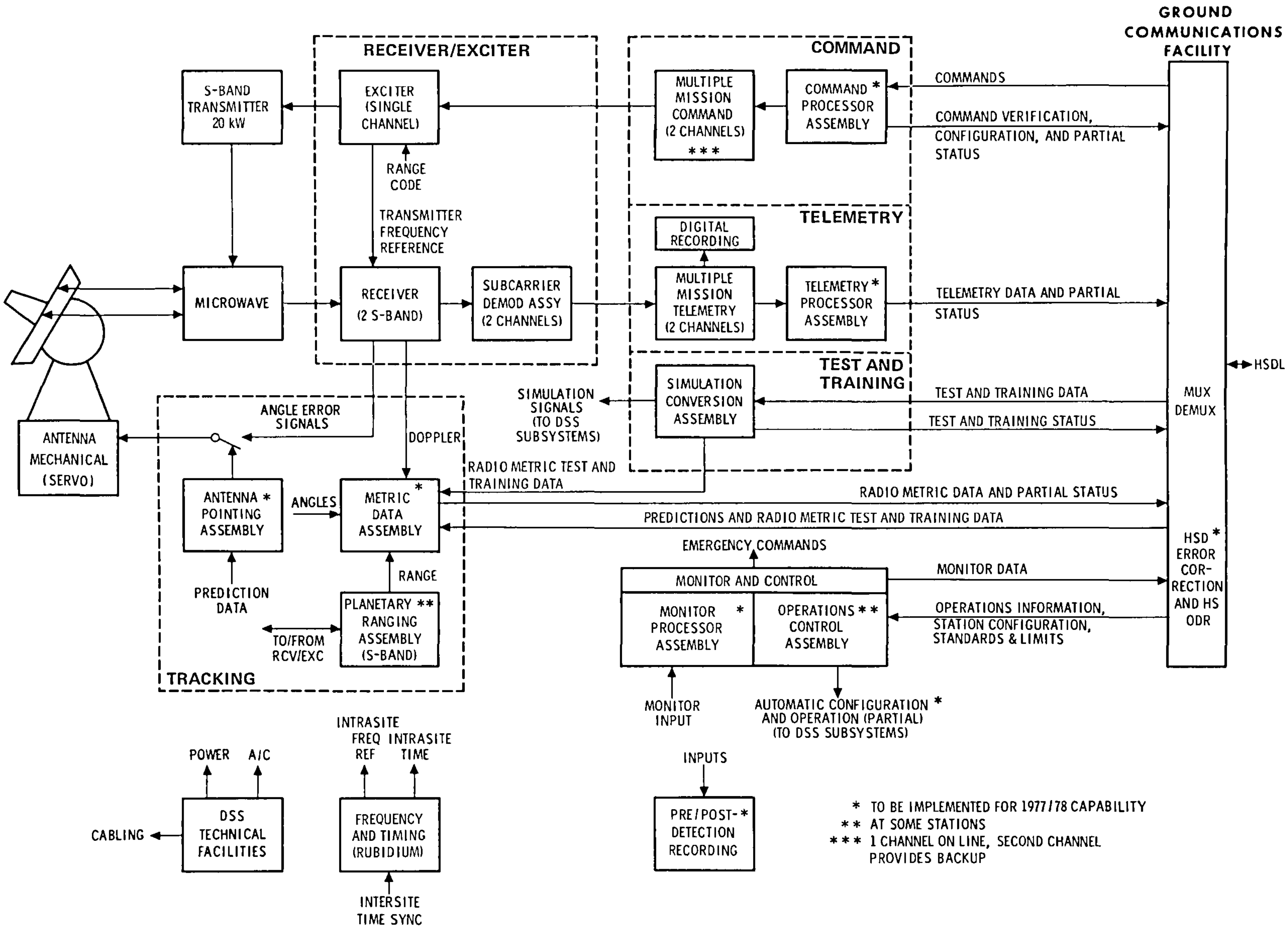

Fig. 9. DSN Mark III-77 Data System block diagram for a typical 26-meter DSS (1977)

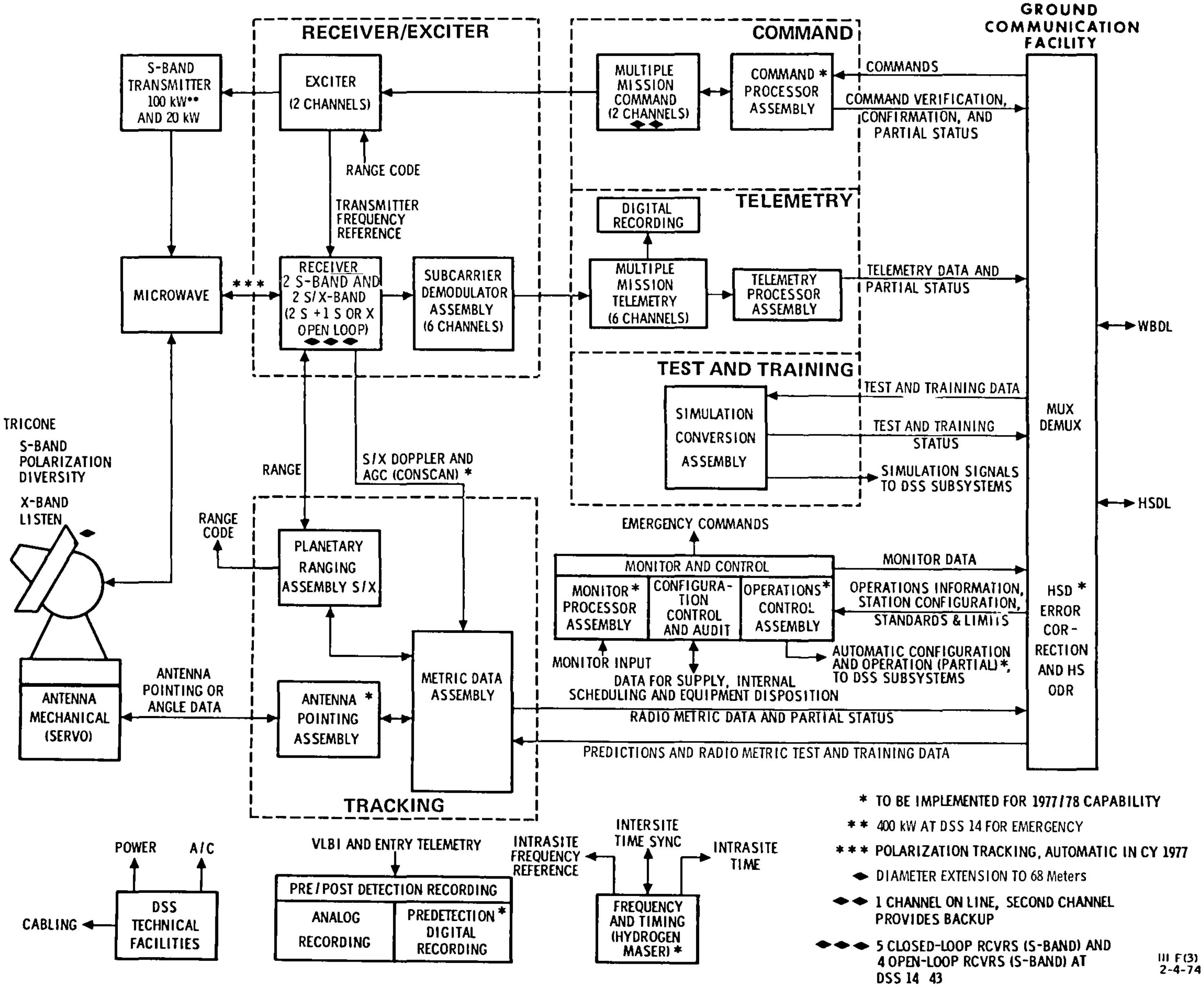

Fig. 10. DSN Mark III-77 Data System block diagram for a typical 64-meter DSS (1977)

During the month of January 1977, 10 demonstration tracks were performed, and, as a result of the overall successful performance, DSS 12 was declared operational for Helios Project support.

Implementation was completed at DSS 62 in late January and the first demonstration track was performed on 12 February 1977. The station acquired the Helios-1 downlink signal at approximately 14:00 GMT and tracked the spacecraft until 22:30 GMT. This first demonstration track was very successful with two data rate changes and commanding being performed without any major problems. After a series of successful demonstration tracks, DSS 62 was declared operational for Helios support on 1 March 1977.

The DSN Mark III Data System implementation was completed at DSS 44 in late February 1977 and was declared operational on 22 March 1977 after a series of successful demonstration tracks.

With three DSN 26-meter stations (DSSs 12, 44, 62) updated with the Mark III Data System (Fig. 10) the task shifted to updating the 64-meter station (DSS 14) at Goldstone.

On 16 April 1977, DSS 14 ceased all mission support operations to undergo implementation of the DSN Mark III-77 Data System. The MDS implementation was completed on 24 June 1977, and the station crews began their test and training activities prior to returning to operational status for Helios and other flight project support. The first of a series of Helios demonstration tracks was conducted on 25 June 1977.

D. NASCOM-GCF CONVERSION

To standardize the DSN high-speed data rates with those used by NASA Communications (NASCOM), plans were made by the DSN in late 1975 to convert the Ground Communications Facility (GCF) High-Speed Data Subsystem (GHS) to operate at a line rate of 7200 bits/s instead of 4800 bits/s.

In May and June 1976, engineering tests were conducted at the DSN Compatibility Test Area (CTA-21) at JPL (Ref. 1). Analysis of the test results indicated that a data rate of 7200 bits/s had no adverse effect on the processing of telemetry, command, radio metric, monitor, or operations control data by a DSN deep space station. On the basis of these test results, plans were made to convert from 4800 to 7200 bits/s throughout the DSN by December 1976.

On 27 September 1976, with DSS 12 tracking Helios-1, a special GCF test was performed to verify that the new 7200-bits/s data rate was compatible with mission-dependent software and hardware. Results of this test indicated that the conversion from 4800 to 7200 bits/s would be "invisible" to the DSN-Helios operations. By the end of December 1976, the NASCOM-GCF conversion was complete throughout the DSN.

Evaluation of this new 7200-bits/s high-speed data configuration indicated that, for the first time, the DSN was capable of receiving, processing, and forwarding to GSOC, in real-time, Helios spacecraft telemetry data at 4096 bits/s. To validate this capability, a 4-hour operational test was successfully conducted on 16 January 1977 with DSS 12 tracking the Helios-2 spacecraft, which had been commanded to transmit 4096-bits/s telemetry for the first time during its mission.

III. HELIOS MISSION SUPPORT

A. HELIOS-1 OPERATIONS

1. General

Having successfully completed its third perihelion on 29 March 1976 (Volume II of this Technical Memorandum), the Helios-1 spacecraft continued on its trajectory in a cruise mode and DSN tracking operations became low-keyed.

2. Spacecraft Emergency

On 22 June 1976, at 03·45 GMT, DSS 44 noticed that the telemetry downlink signal from Helios-1 was beginning to degrade, and at 04:13 GMT the station dropped lock completely. Following a quick verification of proper station configuration for Helios-1, the DSN negotiated with the Viking Project for a short-term use of DSS 42, which was actively tracking the Viking 2 spacecraft at the time. With the approval of the Viking Project, DSS 42 was reconfigured for Helios-1 support. From 05:05 to 05:35 GMT, DSS 42 attempted unsuccessfully to acquire the Helios-1 downlink. The search was terminated at 05:35 and DSS 42 reconfigured for Viking 2 support.

In the meantime, a telemetry data recall was being conducted at MCCC in Pasadena, California. The recalled data indicated that the spacecraft power had dropped from +26.98 volts to +23.56 volts just prior to DSS 44 dropping lock. This information was passed to DSN and Project personnel at the German Space Operations Center (GSOC) in Oberpfaffenhofen near Munich, West Germany. GSOC requested that the 100-meter Effelsberg station (GES) be configured for Helios-1 support.[2] At 06:54 GMT the station came on-point (a point in space over the horizon where the spacecraft was predicted to be for acquisition) but failed to detect any downlink signal. After conducting an unsuccessful search, the Effelsberg station informed GSOC of the situation. A preliminary analysis by GSOC indicated that when the spacecraft available power threshold was reached, a decreasing regulator input voltage automatically caused a switch to a backup regulator, dropping a nonessential bus and causing the high-gain antenna (HGA) to change its pointing angle. Working on this hypothesis, GSOC requested the German telecommand station (GTS) to command the Helios-1 to switch to the medium-gain antenna (MGA). At 10·53 GMT the 100-meter German Effelsberg station acquired the Helios-1 downlink signal and determined the spacecraft status to be:

(1) 8 bits/s, coded data.

(2) No. 2 power regulator on.

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[2]At that time, the German Deep Space Network consisted of two stations: a German telecommand station (GTS) at Weilheim, and a receiving station, the 100-m German Effelsberg Station (GES), near Bonn.

(3) All experiments turned off.

(4) HGA pointing away from Earth.

(5) Regulator power output 146 W (down from 206 W).

Because the Helios-1 spacecraft was close to its third aphelion (1 AU from the Sun) at the time of acquisition by Effelsberg, a group of onboard heaters with a power consumption of approximately 34 W had automatically turned on.

GSOC then requested that GTS command the spacecraft back to HGA, the data rate to 64 bits/s, and the total spacecraft power consumption limited to 200 W maximum. Because the spacecraft heaters could not be commanded off due to the spacecraft design characteristics, their power consumption along with that required for essential equipments resulted in only three experiments (Nos. 1, 2, and 8 described in Volumes I and II of this series) being turned on again as the spacecraft temperatures increased and the heaters automatically turned off.

Once again in cruise mode, the Helios-1 spacecraft continued on towards its third aphelion and occultation (Figure 11).

3. Fourth Perihelion

The Helios-1 spacecraft occulted the Sun for a third time on September 23, 1976. The spacecraft was transmitting on TWTA-2, high-power mode, and experiment data onboard the spacecraft was stored for memory readout later at a higher bit rate. As the spacecraft cleared the "blackout" region, heading toward its fourth perihelion, the spacecraft team commanded the TWTA-2 to medium power. The medium power mode was selected to reduce the risk of excessive TWT assembly temperature as the spacecraft approached the Sun.

At 19:07 GMT on 7 October 1976, the Helios-1 spacecraft successfully passed its fourth perihelion (Fig. 11) at a minimum distance of 0.309 AU (approximately 45 million km) from the Sun. Telemetry data received at STDN-Goldstone indicated that at perihelion the bit rate was 64 bits/s AGC was -153.3 dB and SNR was 4.5 dB. The maximum solar impact was equal to 11.44 solar constants. The overall performance of the spacecraft and its 10 scientific instruments, which had exceeded the design lifetime of 18 months, was excellent. All 10 experiments were fully configured for prime mission mode and delivering valuable science data.

Data received at STDN-Goldstone were transmitted via the new microwave link to DSS 14 and then via the Ground Communication Facility (GCF) microwave system to DSS 11, where the data were processed and transmitted to the Mission Control and Computing Center (MCCC) at JPL via high-speed data lines (HSDL). From MCCC the data were transmitted via NASCOM HSDL to the German Space Operations Center (GSOC) in Oberpfaffenhofen, West Germany.

Several members of the Scientific Team observed the perihelion passage from the German Space Operations Center (GSOC) and found the data very interesting because it provided a second unique opportunity for comparing measurements with the Helios-2 after its second perihelion.

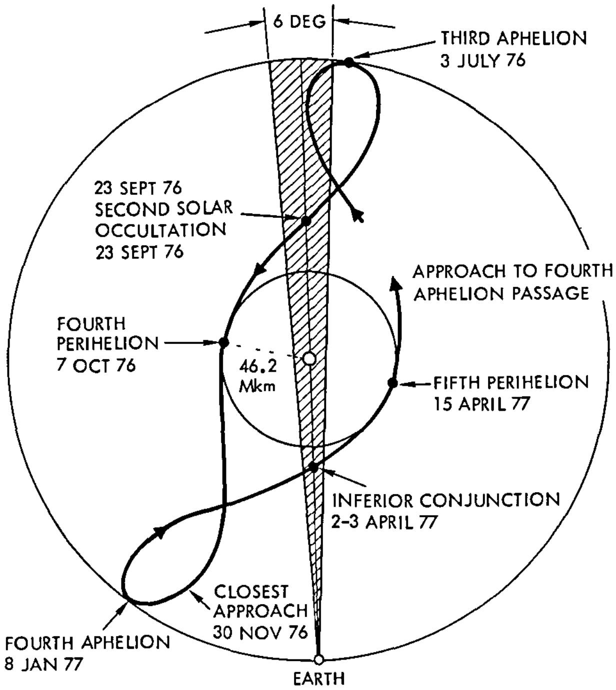

Fig. 11. Helios-1 superior and inferior conjunction passage

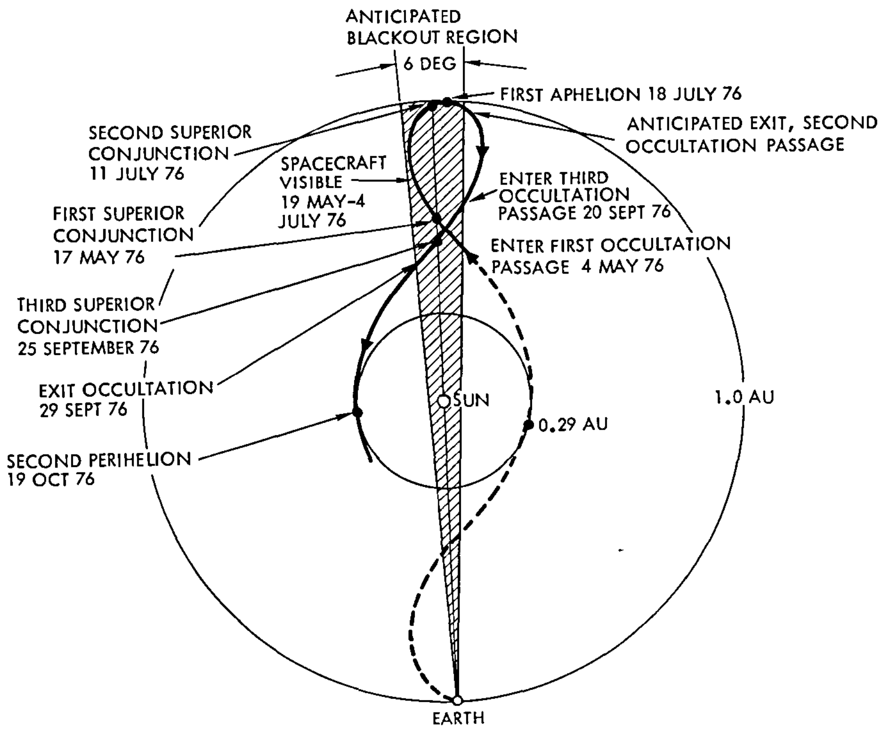

Fig. 12. Helios-2 superior conjunction passage

4. Third Inferior Conjunction Passage

Having completed its fourth perihelion passage, the Helios-1 spacecraft continued on in the cruise mode. Helios-1 perigee (closest approach to Earth) occurred on 30 November 1976, at a distance of approximately 52 million km from Earth. The spacecraft then continued along its trajectory towards its fourth aphelion, which occurred on 8 January 1977 (see Fig. 11).

On 30 March 1977, the spacecraft began its inferior conjunction passage which lasted until 9 April 1977. DSN coverage was provided by DSS 14 (Goldstone, California), DSS 42 (Canberra, Australia), and DSS 63 (Madrid, Spain). On 2 April, DSS 42 tracked the spacecraft to a Sun-Earth-probe (SEP) angle of 0.7734 deg, where a communications grayout occurred. On 3 April, DSS 63 acquired the spacecraft as it exited the grayout at an SEP angle of 0.4049 deg. DSS 14, after taking over the handover from DSS 63, tracked the spacecraft until 17:16 GMT, when the downlink signal was suddenly lost. As a result, a spacecraft emergency was declared and a contingency plan placed in operation. The contingency plan, prepared in case of a TWT failure, consisted of commanding the spacecraft into a noncoherent mode, Driver 1, and the TWT to medium-power configuration. DSS 14 was then able to reacquire the spacecraft downlink signal. However, there were no telemetry data present. After commanding the spacecraft to change to a bit rate of 1024 bits/s, telemetry data became available.

Analysis of the spacecraft data revealed no anomaly with the TWT as had been thought, so it was assumed that a random signal spike had caused a regulator switch to put the spacecraft in the silent mode.

5. Fifth Perihelion Passage

On 13 April 1977, DSS 44 reported that at 22:31 GMT the Helios-1 had reached its fifth perihelion. The spacecraft was 46,298,579 km from the Sun, 128,425,887 km from Earth, traveling at a velocity of 66.0456 km/s, and transmitting at a data rate of 256 bits/s. With all systems and experiments functioning normally, the spacecraft continued on its trajectory towards its fourth superior conjunction passage.

B. HELIOS-2 OPERATIONS

1. General

Having successfully completed its first perihelion passage in April 1976, the Helios-2 spacecraft entered its first superior conjunction passage on 4 May 1976 (Sun-Earth-probe (SEP) angle 5.11 deg), thereby completing its Mission Phase II (primary mission) and beginning Mission Phase III (extended mission). Whereas the Helios-1 spacecraft experienced one solar occultation during its first superior conjunction passage, the Helios-2 spacecraft experienced three solar occultations (Fig. 12). Because this superior conjunction passage would last from 4 May to 5 October 1976, the DSN engineers hoped that the following two questions would be answered:

(1) What would be the increase in the system noise temperature that could be expected due to the small Sun-Earth-probe (SEP) angles, and how would it compare with past conjunctions?

(2) To what extent would the station's receiver automatic gain control (AGC) and signal-to-noise ratio (SNR) be affected by the small SEP angles; how well could this be predicted, and what RF and Subcarrier Demodulator Assembly (SDA) bandwidths would be best for minimizing degradation?

From 4 May until 6 October 1976, the SEP angle remained at less than 5 deg and was a period of extreme interest to the Celestial Mechanics and Faraday Rotation Experimenters (Experiment Nos. 11 and 12 described in Volumes I and II of this series), as well as to the DSN and the Helios radio science team. Therefore, plans that had been prepared in advance to gather special spacecraft telemetry and DSN performance data pertinent to these experiments were initiated, as were the special operational plans prepared by the radio science team to assemble and analyze the spacecraft data relative to these two experiments.

2. First Solar Occultation

On 14 May 1976, the German 100-meter receiving station reported that due to equipment problems they had lost the downlink carrier at 11:40 GMT with the spacecraft at an SEP angle of 0.625 deg. At 11:45 GMT, DSS 14 reported that they had lost downlink with the spacecraft at an SEP angle of 0.586 deg.

The occultation or blackout period lasted until 19 May, when DSS 14 reported that at 00:30 GMT they had acquired the downlink signal at an SEP angle of 0.59 deg. The German 100-meter receiving station at Effelsberg, West Germany, reported that they had acquired the downlink signal at an SEP angle of 0.71 deg.

Data gathered by the spacecraft during the period of blackout was stored in memory banks and transmitted at 8 bits/s during subsequent passes over the German 100-meter receiving station.

3. Second Solar Occultation

The Helios-2 second solar occultation or blackout was entered on 4 July 1976, when the German 100-meter receiving station at Effelsberg reported the SNR at 0.9 dBm and the AGC at -157 dBm; they had lost the downlink signal at 16:00 GMT and at an SEP angle of 0.88 deg. This blackout period lasted until 08:00 GMT 16 July, when the German Effelsberg station reported that the downlink signal had been acquired at an SEP angle of 0.64 deg. Again, all data gathered by the spacecraft during this period was stored in memory banks, but transmission of this stored data had to wait until the SEP angle became greater than 5 deg and higher telemetry data rates (64 bits/s) were possible.

On 18 July 1976 at 22:00 GMT, Helios-2 reached its first aphelion (Fig. 12). The temperatures were:

(1) -61.11° for precession thruster.

(2) -5 to -12° for central compartment.

(3) -49.39° for the average solar array.

All onboard experiments were functioning normally as the Helios-2 spacecraft reached aphelion after traveling a radial distance of two AU from Earth.

4. Spacecraft Emergency

Having completed two solar occultations, the Helios-2 spacecraft continued on its trajectory towards its third solar occultation. All spacecraft systems and DSN systems were functioning normally until 4 September 1976, when at 17:15 GMT the downlink was lost following the transmission of a ranging command from DSS 11. For approximately two hours DSS 11 transmitted various spacecraft configuration commands without success until 19:28 GMT, when the downlink was reacquired with the spacecraft in the traveling wave tube amplifier 1 (TWTA1), driver 1, high-power, noncoherent configuration. Because of the previous difficulties with the TWT-1, high-power configuration, it was decided that a more stable configuration was needed. All subsequent configurations were unsuccessful, and at 22:54 GMT a spacecraft emergency was declared and temporary support provided by DSS 42 at 00:12 GMT, 5 September 1976. DSS 42 commanded the spacecraft to TWT-1, medium power, driver 1, coherent, and MGA configuration, resulting in a strong downlink signal being acquired at 00:42 GMT. The spacecraft was then successfully commanded from the MGA to the HGA, resulting in a solid receiver and telemetry downlink signal lock by DSS 11 at 01:21 GMT. At 01:24 GMT, DSS 11 lost the downlink signal as the spacecraft disappeared over the horizon and automatically reverted to the noncoherent mode, medium power, and TWTA-1. Thus, with the spacecraft again functioning normally, the emergency was terminated at 05:00 GMT.

Based on the findings of the early analysis of the problem, it was decided that the spacecraft would remain in the above configuration for the upcoming third solar occultation. In addition, all further ranging attempts were cancelled until the final results of the investigation were known. The decision was based on the fact that on 2 September (two days prior to loss of the downlink) a ranging command was transmitted to and accepted by the spacecraft, but all subsequent commands had to be repeated, demonstrating that the command link was marginal when ranging modulation was applied from a DSN 26-meter (20-kW) antenna. The analysis indicated that it was possible that a failure in the command decoder had caused an improper spacecraft switching to occur, i.e., an unrequested command to be exercised.

Based on this analysis, the U.S. Helios Project Manager requested the use of a 64-meter antenna with a 100-kW command uplink capability for the third blackout period (20 through 29 September 1976).

5. Third Solar Occultation

The third solar occultation occurred at 03:07 GMT on 20 September 1976, as DSS 44 tracked the spacecraft until the SEP angle decreased to 1.8 deg and a telecommunications blackout occurred. This blackout lasted until 29 September 1976, when DSS 14 acquired the spacecraft at 23:59 GMT. At the time of acquisition, the SEP angle was 2.08 deg. As the SEP angle increased, so did the telemetry data bit rate as shown in Fig. 13. On 8 October 1976, the spacecraft was commanded for a memory readout of all stored data taken during this third solar conjunction passage.

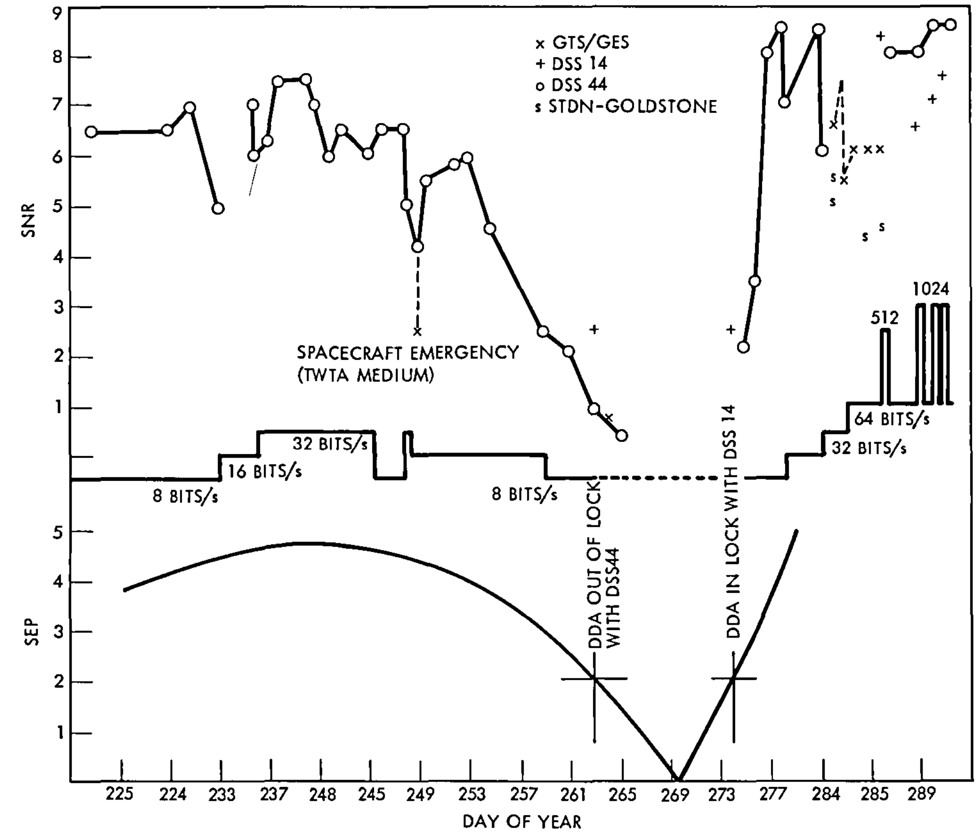

Fig. 13. Bit rate-SNR profile (courtesy GSOC)

6. Second Perihelion

The second perihelion passage for Helios-2 covered a time period from 7 October through 31 October 1976. Perihelion occurred 278 days after launch, 19 October 1976 at 18:08 GMT. At that point the spacecraft was at a minimum distance of 0.29 AU (approximately 43.4 million km) from the sun. Solar impact was equal to 11.876 solar constants.

Owing to higher priorities of another project (GEOS), real-time coverage of perihelion could not be provided by either the upgraded German station at Weilheim or by the DSN. The first data from the Helios-2 spacecraft were received by the STDS-Goldstone station approximately two hours after perihelion and indicated that the spacecraft was in the medium power mode (TWT-1) high-gain antenna, driver 1, and regulator 2 configuration. The downlink parameters were a bit rate of 128 bits/s and a SNR of 1.5 dB.

Data received at STDN-Goldstone were transmitted via the new microwave link to DSS 14 and then via the Ground Communication Facility (GCF) microwave system to DSS 11, where the data were processed and transmitted to the Mission Control and Computing Center (MCCC) at JPL via high-speed data lines (HSDL). From MCCC the data were transmitted via NASCOM HSDL to the German Space Operations Center (GSOC) in Oberpfaffenhofen, West Germany.

7. Second Inferior Conjunction Passage

Having successfully completed its second perihelion, the Helios-2 spacecraft continued along its trajectory toward its second and third inferior conjunction passage in mid-November 1976.

After extensive analysis of the 4 September ranging problems, the German Project Manager stated that the TWT 2 was not to be used in either the high- or medium-power mode for the balance of the Helios-2 mission and that ranging commands were not to be attempted until directed otherwise.

The DSN continued to monitor the performance of the spacecraft until it entered an inferior conjunction grayout period on 18 November 1976 (Fig. 14). The grayout period began at an SEP angle of 0.4 deg, lasted for approximately 26 hours, and ended at an SEP angle of 0.7 deg.

On 1 January 1977, the Helios-2 spacecraft again passed between the Earth and Sun, but this time its trajectory path was from west-to-east whereas its path on 18 November 1976 had been east-to-west. DSS 42 tracked the spacecraft until grayout occurred at an SEP angle of 0.38 deg and ended at an SEP angle of 0.46 deg.

Helios-2 first perigee occurred on 4 January 1977 and was the closest approach to Earth (4 million km) made by either Helios spacecraft.

DSS 12 was tracking the Helios-2 on 7 January 1977 when at 08:36 GMT the station reported that the coherent downlink signal had been lost. Attempts to reacquire the spacecraft on Receiver 1 (hard-wired to the medium-gain antenna) were unsuccessful. Downlink was acquired after commanding the spacecraft to Receiver 2 and to the noncoherent mode. The telemetry data received from the spacecraft indicated everything was normal except that Receiver 1 was out of lock, its limiter showed zero voltage and its AGC showed a -206 dB.

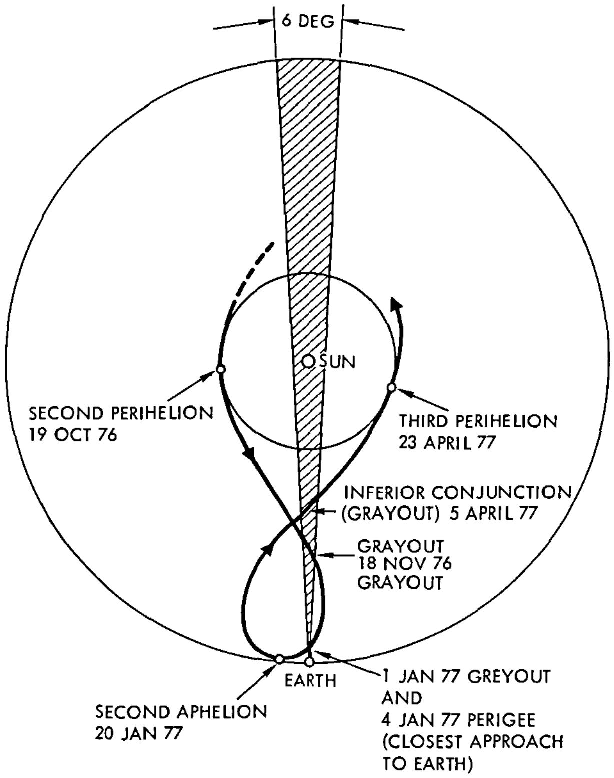

Fig. 14. Helios-2 second-to-third perihelion trajectory

The German Weilheim station acquired the spacecraft at 11·10 GMT and also attempted, unsuccessfully, to turn on Receiver 1. It was then decided that Receiver 2 (hard-wired to the low-gain antenna) would be used for all commanding. The use of Receiver 2 meant the loss of 9 dB in the uplink performance (due to differences in the spacecraft's antenna gain), no ranging channel capability, and the command subcarrier frequency had to be changed from 512 to 448 Hz.

On 20 January 1977 at 16:00 GMT, Helios-2 reached its second aphelion. Approximately three hours later, at 19:45 GMT, data from the spacecraft were received by DSS 12 that indicated that all experiments were on, that the configuration was medium-power mode, high-gain antenna, and the data rate was 2048 bits/s.

Having completed two orbits about the Sun at second aphelion, the Helios-2 continued along its trajectory toward its fourth inferior conjunction grayout and its third perihelion.

The spacecraft entered its fourth inferior conjunction passage on 29 March 1977. Grayout occurred on 3 April as DSS 12 tracked the spacecraft to an SEP angle of 0.7148 deg. DSS 63 picked up the spacecraft as it exited from grayout at an SEP angle of 0.3534.

8. Third Perihelion Passage

Upon exiting from the inferior conjunction passage on 11 April 1977, the Helios-2 spacecraft began its third perihelion passage, which lasted until 5 May. On 23 April 1977, at 13:03 GMT, DSS 63 reported receiving data at a bit rate of 2048 bits/s and that the spacecraft was 43,489,693 km from the Sun, 149,935,731 km from Earth, and proceeding at a velocity of 68,636 km/s. All spacecraft systems and experiments were functioning normally.

On 4 May, the DSN was informed by the German Helios Space Flight Operations Manager that the 20-kW transmitter power from the 26-meter stations would be insufficient for commanding the spacecraft after 8 May as the design threshold of 141.5 dB for Receiver 2 had already been reached. As a result, commanding would have to be performed by the 64-meter station during the upcoming superior conjunction passage.

9. Second Superior Conjunction Passage

Helios-2 entered its second superior conjunction passage on 10 May 1977. This passage (Fig. 15), which was to last until mid-October 1977, was of great scientific interest to the Solar Wind and Faraday Rotation experimenters. For the Faraday Rotation experiment this was the last opportunity to observe the phenomenon of the spacecraft relatively motionless for an extended period of time. For the Solar Wind experimenters this would be the first opportunity to obtain direct solar wind velocity measurements throughout the solar wind acceleration region of the solar atmosphere.

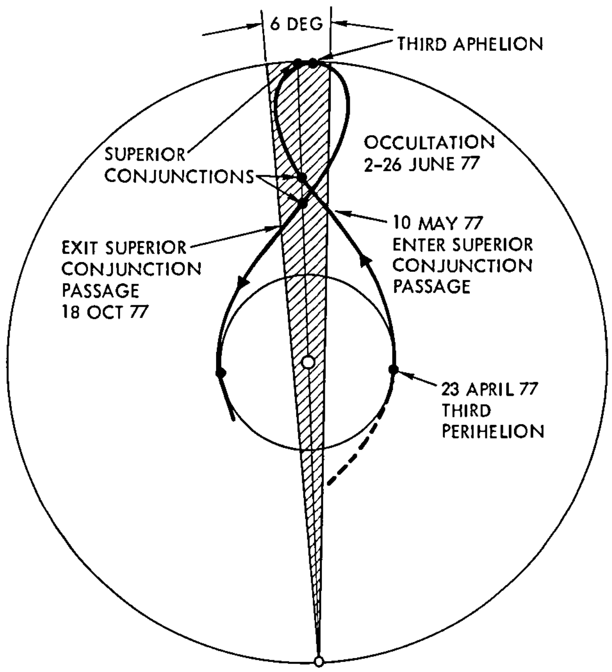

Fig. 15. Helios-2 second superior conjunction passage

IV. CONCLUSION

This volume of Technical Memorandum 33-752 has described the Deep Space Network's support of the extended missions of Helios-1 and Helios-2 during the interval from May 1976 through June 1977. Overall, the support was routine except for a couple of spacecraft emergencies, which were overcome in a relatively short period of time. Spacecraft extended mission coverage does not generally carry a high priority, but Helios has been fortunate in that a combination of separated viewperiods and unique utilization of the STDN Goldstone antenna have provided a considerable amount of additional science data return — particularly at key times such a perihelion and/or solar occultation.

REFERENCE

1. Thorman, H.C., "Evaluation of DSN Data Processing with 7200-b/s GCF High-Speed Data Interfaces," in the Deep Space Network Progress Report 42-37, pp 132-135. Jet Propulsion Laboratory, Pasadena, Calif., Feb. 15, 1977.

GLOSSARY

AGC	automatic gain control
AU	astronomical unit
BER	bit error rate
bits/s	bits per second
CMA	Command Modulator Assembly
CMF	Communications Monitor and Formatter Assembly
CPA	Command Processor Assembly
DDA	Data Decoder Assembly
DODR	Digital Original Data Record
DST	Data System Terminal Assembly
GCC	German Control Center
GCF	Ground Communications Facility
GES	German Effelsberg Station
GSOC	German Space Operations Center
GTS	German Telecommand Station
HGA	high-gain antenna
HSD	high-speed data
HSDL	high-speed data line
LCP	left circular polarization
MCCC	Mission Control and Computing Center
MDR	Master Data Record
MDS	Mark III Data System
MFR	multifrequency receiver
MGA	medium-gain antenna
NASCOM	NASA Communications Network
ODR	Original Data Record

RCP	right circular polarization
S/C	spacecraft
SCA	Simulation Conversion Assembly
SDA	Subcarrier Demodulator Assembly
SEP	Sun-Earth-probe (angle)
SNR	signal-to-noise ratio
SNT	system noise temperature
SSA	Symbol Synchronizer Assembly
SSC	Star Switch Controller
STDN	Spaceflight Tracking and Data Network
STDN-GDS	Spaceflight Tracking and Data Network — Goldstone Station
SWE	Solar Wind Experiment
TCP	Telemetry and Command Processor Assembly
TPA	Telemetry Processor Assembly
TTY	teletype
TWT	traveling-wave tube
TWTA	traveling-wave tube amplifier

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