Voyager Support

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This is a continuation of the Deep Space Network report on tracking and data acquisition for the Voyager project. This report covers the post-encounter period for Voyager 1 and the encounter period for Voyager 2, from April 1979 through July 1979.

I. Voyager Operation – Status

A. Voyager 1

Voyager 1 completed the post-encounter activities on 9 April 1979. During the remainder of the reporting period the activities were kept at a low level so that the majority of the support facilities could be committed to the preparation and support of the Voyager 2 encounter.

B. Voyager 2

Voyager 2 made its closest approach to Jupiter and its largest satellites on the afternoon of 9 July 1979. This event, like that of Voyager 1, was preceded by the observatory phase from 24 April through 23 May, and far-encounter phases from 23 May through 7 July 1979. A movie phase was completed during 27 to 29 May. After completion of the close-encounter phase the activities moved to the post-encounter activities which extend to 28 August 1979. Solar conjunction activities were observed by both spacecraft during the period 8 through 29 August 1979.

II. DSN Operations

A. Quick Turn Around

The period from January through August 1979, was the first time in the history of the DSN that it was required to support two projects, both in their prime mission phase, with the same priority on commitment of the tracking facilities. These two projects were Voyager and Pioneer Venus. The past philosophy of providing tracking coverage to an encountering spacecraft and exclude tracking of any other spacecraft for a period of time had to be abandoned and a new philosophy adapted. This new philosophy included the tracking of at least two projects by a DSN station and providing maximum tracking time per spacecraft. To accomplish these objectives, the "quick turnaround" was devised for the 64–m network along with a new plan for station maintenance.

The basic premise of the new philosophy was that the involved Network Operations Project Engineers (NOPEs) establish guidelines pertaining to the configurations and levels of support to be used during the various phases of their mission. Each level of support corresponds to mission phase criticality and the extent to which a station must be calibrated/tested prior to tracking support. Four levels of support were defined:

(1) Critical redundant support

(2) Critical nonredundant support

(3) Normal support

(4) Minimum (load and go) support.

The time required to perform the pretrack preparation (PTP) depends on the configurations and the level of support required. The time includes time for station reconfiguration, but not time for normal housekeeping chores.

For the 64–m stations with S- and X-band downlinks, high rate telemetry streams and ranging for Voyager, the typical PTP times prior to quick turnaround averaged:

	Level 4	Level 3	Level 2	Level 1
VGR	1.5 h	3.5 h	6-8 h	8-10 h
PNV	1.0 h	3.0 h	6-8 h	8-10 h

NOTE: Radio Science Occultation Data Assembly (ODA) PTP time is not included in the Level 3 and 4 times.

Utilizing the normal PTP times as a starting point, the strategy utilized under the new philosophy essentially provides for: (1) performing the PTP at one time for both spacecraft; (2) reducing the time between tracks to a minimum; and, (3) performing posttrack activities for both spacecraft at one time.

The basis strategy under this new philosophy can then be broken down for the station considering two spacecraft support by specified time periods. (View periods for the 64–m network allow PNV tracking followed by Voyager tracking.)

A	B	C	D	E	F
0 . .	3 . . 6 . . 9	. .	12 . . 15 . . 18	. .	21 . . 24

A = PTP (TLM and CMD for both S/C) = 2 hours, 20 minutes.

B = Tracking PNV S/C ≅ 8 hours

C = Turnaround VGR S/C = 30 minutes

D = Tracking VGR S/C ≅ 8 hours

E = Posttrack activities for PNV and VGR ≅ 1 hour 30 minutes

F = Station maintenance ≅ 4 hours.

(Approximately 30 minutes are added to Period A when Radio Science equipment is required.)

Period A includes the following activities:

(1) RF calibrations on S- and X-bands

(2) Ranging calibrations for Voyager (when required)

(3) Telemetry and command strings for Voyager

(4) Telemetry and command strings for PNV

(5) Command data transfer for PNV.

Period C (quick turnaround) includes:

(1) Loss of signal on PNV

(2) Reconfiguring the front end equipment for Voyager

(3) Mounting of new tapes

(4) Resetting command suppression

(5) Command data transfer on String #2 while antenna moving in AZ

(6) Continue antenna to point for acquisition of signal (AOS) of Voyager

(7) After AOS, reinitialization of telemetry and command string for Voyager.

Period E (posttrack activities) requires:

(1) Ranging calibration for Voyager

(2) Recalls for PNV and Voyager

(3) Playback high rate telemetry for Voyager

(4) Providing data package for both projects.

After some "implementation pains" at the stations, the concept was implemented and successfully used for support during this critical period. Maximum tracking time was provided for each project so that prime requirements were fully satisfied. Additionally, this new philosophy increased the station's overall utilization percentage for flight projects.

B. Level 3 Implementation

The period from January through July 1979 included the encounter periods for both Voyager spacecraft. Concurrently, the implementation of new capabilities had to be considered. Background work which did not affect configuration requirements was authorized throughout the period; however, each item was very carefully scrutinized to assess the impact. The period between mid-March and the latter part of June was authorized for implementations that changed software and/or configurations by adding capabilities or correcting known anomalies. These Voyager encounter tasks/Phase III were all completed on time and included:

(1) Metric data assembly software patch to correct halts and other anomalies

(2) Meteorological monitor assembly clock and sensor failure alarm corrections

(3) Occultation data assembly POCA truncation problem correction

(4) Installing a remote interim spectral signal indicator for the project and the DSN

(5) Installing a 168 kbit wide-band data line to DSS 43

(6) Installing a real-time signal combiner system at DSS 14 for antenna array between DSS 12 and 14.

(7) Completing a Radio Science open-loop recording wide-band data capability at DSS 14

(8) Providing tracking-radio science

(9) CPA-CMA noise elimination fix

(10) Providing a multi-mission receiver (MMR II B) at DSS 14.

As stated, these implementations were completed after the Voyager 1 closest encounter and were used to support the Voyager 2 closest encounter.

C. Real-Time Video

A request was made by DSS 14 to check the feasibility of providing the station with the processed video data from the real-time data stream during the encounter period. The station received comments from the Operations Chief of Trakon on the quality of the pictures as displayed in the Space Flight Operation Facility (SFOF), but could not make a correlation with only the operational indications of the Telemetry Processing Assembly. In addition, it was felt that it would be a morale factor for the station to observe a portion of the product of its efforts.

Several alternatives were investigated, including amateur radio facilities that produce video tapes. In the course of the process, Robot Corporation of San Diego volunteered to provide slow scan equipment, free of charge, for JPL and Goldstone with display capability at Goldstone. The interface was completed with the Mission Control and Computing Facilities at JPL and implementation of equipment at Goldstone prior to the closest approach of Voyager 2. The system worked very well and station personnel were able to view the encounter pictures along with the Network Operations Control Team in near-real-time. Presently, we are investigating the possibility of providing this capability permanently to Goldstone, as well as to other DSN facilities.

D. Backup to the Real-Time Monitors (RTM)

The number of Modcomp computers provided to the DSN for Real-Time Monitor (RTM) activities at JPL did not allow for backup or spare equipment. Since the test and training (T&T) RTM was not being utilized to any extent during the encounter period, it became a candidate to fill the void.

The different systems' software was successfully tried and tested in the T&T RTM. Likewise, provisions were made whereby the T&T RTM could be interfaced with the real-time systems as a substitute for another RTM.

The T&T RTM was declared capable, but not committed, as backup to any system RTM. This additional capability was maintained during the encounter period, but never required.

E. DSS 12/14 Arraying

The arraying of DSS 12 and DSS 14 antennas provide the real-time combiner with the dual input of the telemetry stream, thus improving the acquired composite signal, which required special procedures as well as equipment.

It was determined during preliminary testing that the desired results could only be obtained from an effective basic telemetry string, operating at maximum efficiency. Therefore, it was determined that the stations should count down both telemetry strings and determine which had the better performance. The high performance string was then used for the data which was, in turn, used as the input to the real-time combiner.

Likewise, DSS 14 was required to count down the real-time combiner along with other station equipment. It was determined that nominal time for station PTP was two hours for DSS 12 and three hours for DSS 14. This type of schedule was maintained for pre-closest encounter day, with the pretrack preparation time being doubled on closest encounter.

DSS 12 and 14 supported the encounter by arraying from 3 July through 9 July and again on 11 July. The average X-band telemetry signal gain from this operation for the period was 1.1 dB + 0.2 dB (which was the anticipated signal gain).

F. Io Torus

An additional radio science experiment was confirmed in May 1979 for the Voyager 2 near encounter. The experiment was to evaluate plasma density during occultation by the Io torus. The experiment required simultaneous tracking of both Voyager spacecraft from 9 July through 11 July. The basic requirement for the experiment was:

(1) Voyager 1: Continuous track, acquire high-rate Doppler (S/X-band) and range data;

(2) Voyager 2: Continuous track, acquire high-rate Doppler (S/X-band) and open-loop receiver recording.

This experiment represented an added requirement at DSS 43 and 63 as DSS 14 already had occultation requirements that were not changed. To ensure this requirement could be satisfied, a series of tests were conducted during June 1979, to exercise the Radio Science subsystem at DSS 43 and DSS 63. Testing at DSS 14 had already been scheduled as part of the radio science implementation sequence.

Since the observations of the Io torus were characterized by narrow data spectra and small orbit uncertainties, it was advantageous to use very narrow open-loop filter bandwidths. The test plan utilized 1.0 kHz/3.0 kHz filter pairs for S/X-band. Recording periods were scheduled when the spacecraft was two-way noncoherent. Special radio science predicts for Voyager 2 were provided the 64–m stations. The Doppler sample rate was set to one per second for the first 15 minutes of the recording period. The SSI was used to monitor and ensure that signals were within loop receiver bandpass.

After four hours of recording, DSS 43/63 configured for ODA/ODR replay. The replay consisted of sampling the first 15 minutes of the first tape recorded: IDRs were made of the data and evaluated. The ODA/ODR tapes were shipped to JPL for final processing.

G. DSS 43 Multiple Wide-Band Data Line

During the Voyager 1 Jupiter encounter, a multiple wide-band data line (MWBDL), capable of transmitting data rates above 44.8 kbit in real-time was not available from DSS 43. The capability was available from DSS 14 and DSS 63. This configuration required that when DSS 43 was tracking and therefore receiving high-rate data, a special data replay strategy had to be implemented (Ref. 1).

A MWBDL capability was planned from Australia to Goddard for shuttle operation, so it was proposed to advance the date of implementation to cover the Voyager 2 Jupiter encounter beginning with the movie phase on 27 May 1979. The implementation was pushed and the capability made available for operations, on a best-effort basis, on that date for the movie. A considerable number of problems were experienced during the testing phase and a major effort was expended to solve the problems. The last real problems were experienced on 28 June. The period following through closest encounter was practically problem-free with very few error blocks being received.

A limitation of the system was the capability of Goddard and JPL to handle either, but not both, DSS 43 and DSS 63 data at the same time. Since the DSS 43 view period overlapped the DSS 63 view period, it became necessary to specify the time at which Goddard would switch from providing DSS 43 data to providing DSS 63 data. By advising the switch time beforehand and monitoring the switchover, the data interruption was only a matter of seconds.

This capability greatly reduced the data replay requirement for IDR production. Instead of having to recall all high-rate data (above 44.8 kbit/s) from DSS 43, it was only necessary to recall the portion of data lost due to the switchover interruption, assuming no other problems occurred during a pass. Approximately 851 IDRs were produced for the first 15 days of July, all being on time, with no backlog being experienced. For the entire encounter period only 12 minutes of data were actually lost (nonrecoverable from DODR) when the antenna at DSS 43 drove off point due to a hardware problem.

H. Radio Science

About 22 hours after the closest approach to Jupiter by Voyager 2, the spacecraft was occulted by the planet. This occultation lasted about 1.8 hours and data acquisition during this period was a key objective of the Radio Science experiment. A special sequence and acquisition of special data types required by the experiment involved activities at the three DSN stations at Goldstone, as well as special configuration of Voyager 2.

DSS 14 was the prime station for occultation data acquisition with DSS 11. Likewise, during Voyager 2 occultation tracking, DSS 12 tracked Voyager 1 to provide necessary calibrations of the Voyager 1 and 2 ray paths and to allow for solar plasma and the Earth's ionosphere. The data from DSS 12 was applied to the Voyager 2 data to enhance the overall data quality.

Special configuration was required at DSS 14 to support this activity. Real-time bandwidth reduction for the prime open-loop data was performed by the Occultation Data Assembly (ODA) using predicts generated and transmitted from JPL. The detection bandwidths were 5.0 kHz at S-band and 15.0 kHz at X-band and resulted in a recording rate of 320 kbits/s. Also, redundant S-band and X-band receivers were operated without bandwidth reduction to provide backup capability for the instrumentation supporting prime occultation data acquisition. The signals from the backup receiver was digitized in real-time and recorded on the digital recording assembly (DRA) with effective filter bandwidths of about 300 kHz at S-band and 1.7 MHz at X-band. Nonreal-time processing of the DRA tapes can be performed at CTA-21, if required.

Closed-loop data acquisition was performed using the Block IV multimission receivers at DSS 14 and Block III receivers were used at DSS 11 and 12. High-rate Doppler was required at all three stations with the highest rate being 10 samples per second.

The maximum refractive loss expected as the Voyager 2 signal passed through the Jovian atmosphere was to be about 24 dB. However, it was anticipated that the closed loop receivers would remain in lock throughout the occultation period and that the SSI signal-to-noise ratio (SNR) would be adequate to provide good visibility of the open-loop received signal.

Figure 1 shows the actual and anticipated S-band signal profile.

(1) The refractive signal loss in dB is shown on the left side.

(2) The S-band downlink (ground received) signal is shown on the right side.

(3) The RCVR-3 SNR is given for the W-10 Hz bandwidth.

(4) The ODA SSI SNR is given for the 5 kHz bandwidth.

(5) The DRA SSI SNR is given for the 50 kHz bandwidth. If the 300 kHz bandwidth is used, the SNR will be about 8 dB less.

Figure 2 shows the actual and anticipated X-band signal profile.

(1) The refractive signal loss in dB is shown on the left side.

(2) The S-band downlink (ground received) signal is shown on the right side.

(3) The RCVR-4 SNR is given for the W-30 Hz bandwidth.

(4) The ODA SSI SNR is given for the 20 kHz bandwidth.

(5) The DRA SSI SNR is given for the 50 kHz bandwidth.

The figures show the correct ODA SSI and DRA SSI SNRs for the DSS 14 (800 line) display. The displays at JPL are 400 line; therefore, the SNR will be 3 dB less than shown in the figures. Also, establishing the true noise floor can easily be another 3 dB error source at JPL.

During the geometric Earth occultation it was found that the S/X-band signal profile dropped about 14 dB lower than anticipated and that the closed loop receiver lock was lost during the occult period. The best estimate of the signal during this period is -170 dBm for X-band and -178 dBm for S-band. X-band was out of lock approximately 50 percent of the time due to signal fading and S-band approximately 90 percent of the time due to threshold condition. Figures 1 and 2 reflect the estimated actual signal profile during the occultation period.

A tracking system graphic display capability was provided for the monitoring of pseudo-residual and tracking system noise during the occultation period. Terminal equipment was installed in the Network Analysis Team (NAT) tracking area and in the project Radio Science area. The primary display was a volatile digital TV, with a hard copy capability in NAT track. The system was controlled by NAT track in the fulfillment of their primary task; however, project requirements were accepted and honored whenever possible. Coördination was maintained between project and NAT track over the normal voice circuit.

Likewise, remote Spectral Signal Indicator (SSI) displays were slaved to the DSS 14 open-loop receivers and installed in the NAT track area and in the project Radio Science area. Using this display, both project and NAT could monitor the station activity during occultation and correlate with other data available.

Reference

1. For detail see J. E. Allen and H. E. Nance, "Voyager Support," *The Deep Space Network Progress Report 42-51*, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, March and April, 1979.

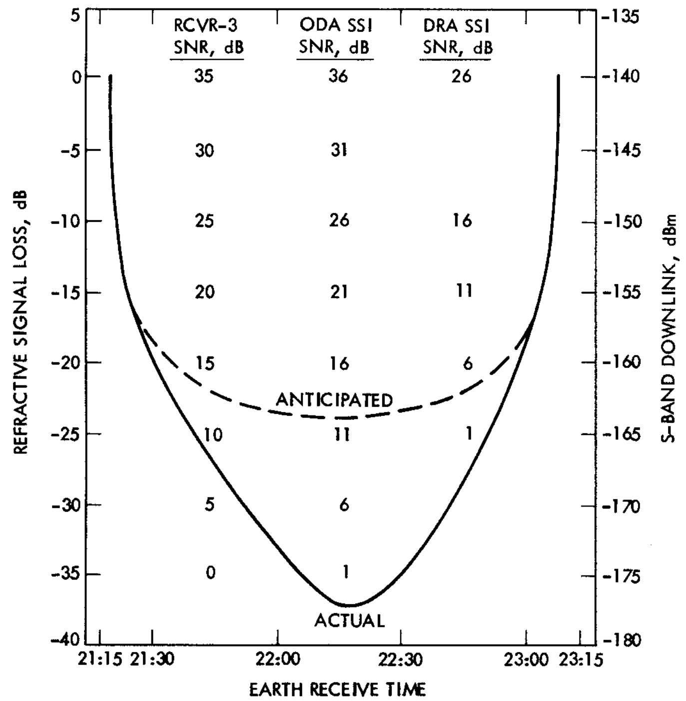

Fig. 1. Actual and anticipated S-band signal profile during Jupiter occultation (July 10, 1979)

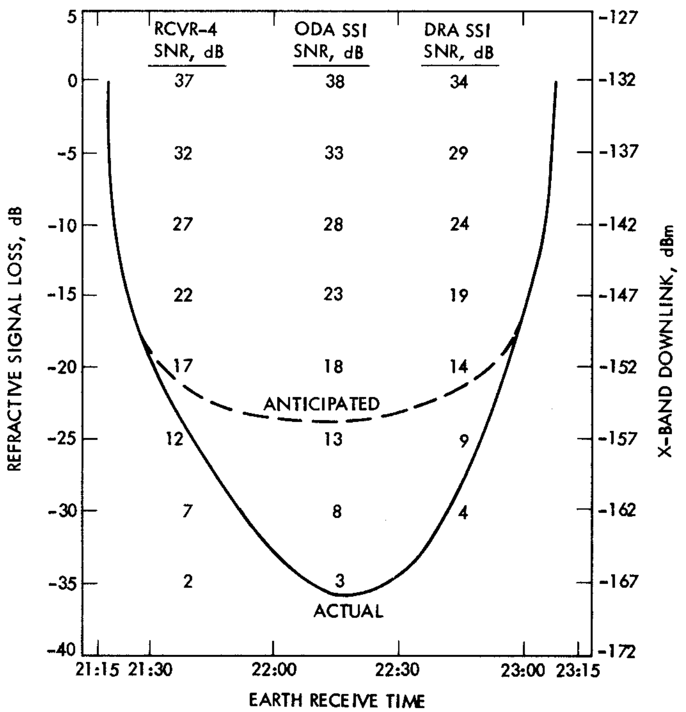

Fig. 2. Actual and anticipated X-band signal profile during Jupiter occultation (July 10, 1979)