Voyager Support

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This is a continuation of the Deep Space Network Report on Tracking and Data Acquisition for Project Voyager. This report covers the period from May 1978 through December 1978.

I. Voyager Operation

A. Status

Both spacecraft are approaching their encounter with Jupiter. In mid-December Voyager 1 was approximately 80 days and 78 million kilometers (49 million miles) from Jupiter. It was traveling at a heliocentric velocity of 14 kilometers per second, with one-way communication time of 33 minutes, 51 seconds with Earth being 609 million kilometers (378 million miles) away.

Voyager 2 has 146 million kilometers (91 million miles) to go in the next seven months before its encounter. One-way light time was 31 minutes, 10 seconds, while its heliocentric velocity is 12.6 kilometers per second.

Workaround procedures have been developed and tested to compensate for some of the spacecraft problems. As of the end of December the probability of the project meeting its mission objectives at Jupiter Encounter is very high.

B. Spacecraft Problems

1. Spacecraft 31

a. Plasma main detector. The loss of sensitivity has been diagnosed and simulated in the laboratory. The problem was an open circuit in the feedback loop of an amplifier driving the buckout grid of the forward detector cluster. A procedure of temperature cycling was started and the instrument recovered completely on DOY 138.

b. Scan platform pointing. Continued slewing tests have not resulted in any difficulties as encountered in February 1978, and constraints on the scan platform slewing envelope were removed. The suspected cause was debris in the gears, which has now been apparently crushed and no further difficulty has been detected.

2. Spacecraft 32

a. Photopolarimeter filter wheel/analyzer wheel. The specific reason for the problem has not been determined; however, an operation sequence has been developed so that the desired position can be attained.

b. RCVR loss. Remains same – Receiver 1 failed. Receiver 2 is being used, although the tracking loop capacitor has failed. Special procedures are being utilized for tracking operations.

C. Spacecraft Special Events

Superior conjunction on both spacecraft occurred during July. Spacecraft 31 entered Sun-Earth-Probe (SEP) angle of 5 degrees inbound on 6 July and SEP angle of 5 degrees outbound on 21 July – the minimum SEP angle was 0.75 degree. S-band AGC and SNR degradations were observed and correlated with the degradations recorded during the Mariner '69 conjunction.

Spacecraft 32 entered SEP angle of 5 degrees inbound on 9 July and SEP angle of 5 degrees outbound on 23 July. The minimum SEP angle was 2 degrees. The S-band AGC and SNR degradations correlated with degradation recorded during spacecraft 31 conjunction.

II. DSN Operations

A. Command System Update

The complexity of the Voyager Mission and the effort to reduce the actual real-time operation of the commanding effort placed a requirement on the DSN to revise its command system. The change at the DSSs to separate Command and Telemetry computers and the change of the MCCC from the IBM 360/75 computer to the Modcomp mini-computers (Mark III System) allowed a complete change in concept.

1. Telemetry and Command Processor (Replaced). Under the operation with the DSS Telemetry and Command Processor (TCP) and the MCCC 360/75 computers, only 24 commands could be stored at the station in four command modules, each with six commands in queue. During operation, after one module's commands were transmitted, another module was promoted in the stack; then the empty module could be refilled. This procedure required constant operator attention and intervention during long command loads.

2. Command Processor Assembly (New). The TCPs were replaced by a Command Processor Assembly (CPA) and a Telemetry Processor Assembly (TPA) as separate computers. The CPA was provided with the capabilities of the TCP with an alternate capability (store-and-forward mode) of storage space for eight files, each file capable of 256 elements (commands) for a total storage of 2048 commands. This total capacity can be used at any one time, or any part of it could be used, resulting in a greater flexibility in the command system operation. Likewise, the command files could be assigned a transmit time to be consistent with a command window or at any opportune time during a spacecraft tracking pass by the Voyager Project. Likewise, all checks for errors, computer handshaking, status reporting, etc., were expanded to provide a complete, more or less automatic, command system.

B. Telemetry System Update

Concurrent with the Command System change, the Telemetry System was also changed. Again, the DSS was provided with a separate telemetry computer as was the MCCC. In preparation for the Voyager encounters, a capability was also provided at the 64-meter and 34-meter stations to interface with wideband data lines to support the data rates expected from the spacecraft. DSSs 14 and 63 were provided with the capability to return, in real-time, all of the high rate telemetry up to and including the 115.2-kb/s Imaging and General Science data. DSSs 12 and 43 were provided with the capability to return in real-time all of the high rate data up to and including the 44.8-kb/s Imaging and Playback data.

The limitation of the real-time capability at DSS 12 and especially at DSS 43 for high rate telemetry data return made it mandatory that a strategy be developed to return high rate telemetry data received at the higher data rates in near real-time. The procedure developed was to record the higher rate telemetry data and, after one tape was completed, start the replay of the data from one TPA over the 56-kb/s line at line rate while continuing to record on the other TPA. Since this method requires a longer transmission time as compared to receive time, the replay would continue post-pass into the next tracking period, regardless of Project. To implement this requirement required negotiation and understanding with the Pioneer Venus and Viking Projects.

C. CMD and TLM Capability Testing

As the Command and Telemetry capabilities became available for testing in July, a series of Operational Verification Tests (OVTs) was conducted during July and August to provide training to the stations and Operation Control Team and to validate the capability. DSS 12 was not tested at this time; rather the station was tested in November after the update from a 26-meter to 34-meter station with S/X-band capability. These same capabilities were tested with Project and MCCC through the use of Ground Data System (GDS) tests during July through November, including all stations at different times. Included in the GDS tests were updates of software that corrected anomalies or provided additional capabilities in the DSN, MCCC or Project software as well as the conversion of the MCCC to the Mark III Data System. The tests had varying degrees of success, mainly due to problems with the Simulation Conversion Assembly (SCA) in generating the higher data rates and the interfacing of new systems. However, the test sequence was successful overall and the capabilities verified for encounter support. In total there were 26 Operational Verification Tests scheduled, each being approximately of 8 hours duration and supported by a minimum of 13 DSN personnel. This effort required 208 station hours and some 2700 manhours to complete the task.

D. DSS 12 Upgrade

DSS 12 was decommitted from Project support in June 1978. The station was converted from a 26-meter antenna/S-band station to a 34-meter antenna/S- and X-band station during the period June through September 1978. Subsystem and system tests were conducted at the station, by station and implementation personnel, during October 1978, with the station being available for DSN testing, training and demonstrating tracking capability during November. This required a program for all station personnel to become familiar with the new capability; therefore, support periods were scheduled so that each crew was exercised at least twice. The DSN activities included 11 OVTs, conducted by the Network Operations Project Engineers (NOPEs), each approximately 8 hours in duration and supported by a minimum 13 DSN operational personnel. This program required 88 station hours and 1144 manhours. Tracking demonstration passes included both spacecraft, on one pass each, and was of approximately 12 hours duration each. The subsystem/system testing took a week longer than scheduled, but the DSN activities schedule was condensed and the station was verified for operational support on schedule.

The verification of the new support systems and stations cited above required that GDS tests be conducted at various phases of system implementation. To validate, the updates required 35 GDS tests overall and 53 individual station tests. Each test required approximately 8 hours of station time and support by an average of 13 operations personnel. This resulted in expenditure of 424 station hours and approximately 5500 DSN manhours in addition to the MCCC/Project support manhours involved.

E. Special Tests

During November, the DSN participated with the project in exercising the Mission Operations Control Team (MOCT) anomaly detection and problem resolution capabilities. Anomalies, such as antenna offset, radio receiver anomaly, weather anomaly, were induced into the system and emergency or contingency plans were implemented.

F. Radio Science

A new digital Radio Science (RS) subsystem has been implemented at the 64-meter subnet to replace the analog method of recording radio science data. This new RS subsystem was implemented in different phases as new equipment became available. Basically, the system has a narrowband (prime) and wideband (back-up) capability.

The phase 1 subsystem implemented at DSSs 14 and 43 (until the narrowband multi-mission receiver becomes available) utilizes an S- and X-band open-loop receiver (OLR) (for narrowband) with the following filter bandwidth selection:

	S-Band	X-Band
(a)	1 kHz	3 kHz
(b)	2 kHz	7.5 kHz
(c)	5 kHz	15 kHz
(d)	10 kHz	30 kHz

The OLR output is fed to the Occultation Data Assembly (ODA) subsystem (A/D converters and mod comp computer) for digital tape recording at sample rates of 2K, 5K, 10K and 20K samples/s.

The wideband back-up system utilizes a wideband (1 MHz) multi-mission receiver which is recorded on a Digital Recording Assembly (DRA) in the megabit range.

To facilitate on-site observations of the digital recordings (since the data are usually mailed to JPL for data reduction) a new Spectrum Signal Indicator (SSI) subsystem is used to verify proper operation of the system during recording.

The ODA receives Radio Science predicts from JPL to drive the narrowband OLR programmable local oscillator to maintain the spacecraft downlink signal within the desired OLR filter bandwidth. These predicts are a series of linear ramps which profile the anticipated doppler signature from the spacecraft.

The DSS 63 RS subsystem (Phase 2) basically uses the same system described above except the wideband system uses the 300-kHz output of the OLR and the narrowband system uses the new narrowband MMR (7 filters, S- and X-band). The new narrowband Multi-Mission Receiver (MMR) will be available at DSS 14 for Voyager 2 encounter.

G. Meteorological Monitor Assembly Data

In the continuing effort to provide calibration data for the tracking system, in both the S- and X-band frequencies, the implementation of a meteorological atmospheric sampling capability was effected at the 64-meter stations. The primary data provided are temperature, barometric pressure, dew point, water vapor partial pressure, precipitation, precipitation rate, diurnal Faraday rotation, Faraday rotation angle, satellite azimuth, satellite elevation, solar insolation, microwave polarization angle, ellipticity and microwave mode. The initial capability was provided by an HP9821A calculator recording data on a seven-track recorder. The collected data were transmitted to JPL once a week, utilizing the station Digital Instrumentation System (DIS). An IDR was made from the received data and turned over to the Tracking System Analytical Calibration (TSAC) operation for further processing. The processed data would then be available for Navigational Orbit Determination operations.

Upgrade of the initial system will be to provide for nine-track recorders instead of the seven-track recorders. This will bring the facility in line with other station recorders and the normal interface with the station CMF for data transmission. This upgrade is presently being implemented.

H. Station Antenna Arraying

During the Jupiter Near Encounter Phase of the Voyager 2 Mission, DSSs 12 and 14 will be arrayed to demonstrate the antenna array configuration. This configuration will be required for the Saturn Encounter Phase of the Voyager Mission at all three complexes. The main objective for antenna arraying is to provide an effective signal increase of approximately 1.2 dB on the X-band signal during Saturn Encounter.

At present, the antenna arraying is in the testing phase and is being readied for the configuration demonstration at DSSs 12 and 14. The arraying consists of both DSSs 12 and 14 tracking the spacecraft simultaneously, with the telemetry data microwaved from DSS 12 to DSS 14. At DSS 14 the signal from DSS 12 is input to the real-time signal combiner with the signal from DSS 14, and the combined output is transmitted to JPL.

I. Range Accuracy

The precision of the Planetary Ranging Assembly (PRA) range data was questionable since adequate capabilities to verify the accuracy were not readily available. The decision was made to install the MU2 ranging system at the DSS 42/43 conjoint station and conduct tests that would allow data comparison.

The MU2 equipment was shipped to DSS 42/43 and installed in October 1978. Data gathering passes were authorized and the data evaluated. Reports in December 1978 indicated that the MU2's higher code frequency (1 MHz) and filtering had dramatically reduced residual scatter. Preliminary results indicate a 3-fold increase in range precision (from approximately 6 meters to approximately 2 meters). The MU2 continued to be used for tests during December, and plans included utilizing the equipment for investigation of a inter-station range bias problem.

J. Signal Enhancement

During the Encounter Phase, it is necessary that maximum antenna gain be available. To optimize the antenna gain it is necessary to refocus the subreflector whenever the antenna elevation is below 40 degrees elevation. Three focus settings (10, 30 and 50 degrees) are used and are elevation dependent. The X-band Subreflector Refocusing Assembly required calibration every four months. Settings established during the calibrations are used on a daily basis or as required to optimize antenna gain. When refocusing, the stations extract the elevation angle from the DSN predicts and performs the refocusing.

The subreflector refocusing tests conducted with DSS 14 on 1 December were very successful and showed that there is no effect on radio metric or radio science data during refocusing periods.

K. Roll Turn Test

On Day 363, a negative 360-degree roll turn with spacecraft 31 was successfully supported at DSS 63. The objective of the test was to determine the offset between the HGA electrical boresight with that of the turn axis. Preliminary analysis of the data provided by DSS 63 indicated an offset of 0.15 to 0.2 degree exists (which is within the design tolerance).

III. DSN Support Assessment

As an indication of the high level support provided by the DSN Tracking Stations and the Network Operations Control Team, from 20 November through 31 December 1978 there were 170 scheduled Voyager tracks. The average track was between 8-1/2 and 9 hours long, resulting in approximately 1488 tracking hours for the time period. Of these tracks, 111 or 65 percent were trouble free. Of the 59 remaining passes that had problems, 12 passes concerned a CPA alarm that caused no loss of data. This essentially meant that 123 or 72 percent of the passes were trouble free as concerns data loss. Of the 47 remaining tracks, the problems on 8 passes were the result of communication problems, primarily High Speed or Wideband Data Line outages. The 39 remaining passes resulted in non-receipt of 23 hours, 27 minutes of data in real-time. Five hours, 8 minutes of this data was radio metric or ranging data and non-recoverable; the remaining 18 hours, 19 minutes of telemetry data and the non-receipt caused by the communication problems was recoverable, requiring only data recall from the stations to complete the required data records. Overall, 98.3 percent of the data was received in real-time, with only 0.3 percent of the radio metric/ranging data being non-recoverable and all of the telemetry data recoverable.

These 170 scheduled tracks required a minimum of 13 DSN personnel throughout the system per pass for support. Since each track averaged 8.75 hours in length and 13 support personnel, a total of 19,338 manhours were expended for the period. Considering the non-receipt in real-time of 23.45 hours

(23 hours, 27 minutes) of data, for the 19,338 manhours, a 0.12 percent error or non-receipt rate results. Likewise, the 23.45 hours of data non-receipt for 1488 tracking hours results in a 1.58 percent non-real-time data reception due to equipment problems. The 5.133 hours (5 hours, 8 minutes) of radio metric data loss in the 1488 tracking hours equals 0.34 percent of non-recoverable data due to mis-configuration or human problem. Further, the 5.133 hours of data loss for 19,338 manhours expended is a 0.026 percent error rate. This error rate is considered negligible in relationship to the number of tasks performed, i.e., computer loading, knob turning, computer instruction inputs, interpretation of required configuration, scheduling codes, short turnarounds, etc., to complete a tracking pass.

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