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DSN Support of Mars Observer

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TDA Mission Support and DSN Operations

This article provides a summary of the DSN prelaunch, launch and cruise support of Mars Observer through Trajectory Correction Maneuver 2 (TCM-2) on February 8, 1993. This summary includes planning, implementation, testing, DSN special configurations and DSN operational problems, and successes and challenges to date.

I. Introduction

The Mars Observer Project was originally planned as the first of the Observer series with a launch in August 1990. The primary purpose of the mission is to gather scientific information in orbit around Mars for one Mars year (687 days). Several factors dictated by budget constraints mandated that the launch be replanned to September 1992. This mission was directed to use Consultative Committee on Space Data Systems (CCSDS) data standards which played a significant role in the final Multimission Operations Systems Office (MOSO) and DSN configurations selected for this mission.

The spacecraft was built by GE Astro, East Windsor, New Jersey and required an overview function which had DSN participation. This spacecraft has an X-band 7164.624229-MHz uplink and an X-band downlink at two frequencies: 8417.716050 (coherent or auxiliary oscillator) or 8423.148147 (ultrastable oscillator). The spacecraft has a high-gain antenna, one low-gain transmit antenna and two low-gain receive antennas. All antennas are right-hand circular polarized.

II. Prelaunch Planning and Implementation

For several years the DSN worked in partnership with the Project to determine the specific DSN stations and

configurations which would best serve the mission objectives. The 34-m High Efficiency subnet, the newest of the DSN subnets, was selected to provide daily X-band uplink and downlink communications with the spacecraft. This DSN subnet provides telemetry at data rates from 10 bps through 85.3 kbps, commanding at data rates from 7.8 through 500 bps, radio metric data (two-way Doppler, ranging and VLBI), radio science, and DSN monitor data to the Project. The 70-m subnet also provides periodic VLBI and real-time high-rate telemetry support. These requirements were documented in the Mars Observer Support Instrumentation Requirements Document (SIRD) and a NASA Support Plan developed to meet these requirements.

The joint DSN/MOSO/Project plan for Mars Observer data developed into a real-time data flow of all DSN data types via the Advanced Multimission Operations System (AMMOS) to the Project Data Base. The exception is the radio metric data, which is routed via the DSN Multimission Navigation team for preprocessing before routing to the Project in near-real time.

The DSN implementation improvements for Mars Observer at launch were part of significant electronics upgrades (new computers, software and hardware) at the DSN complexes, Network Operations Control Center, and Ground Communications Facility. The DSN improve-

ments included several specific capabilities for Mars Observer. These improvements included (1) Standard Format Data Unit (SFDU) headers for all data types except command, (2) Reed-Solomon decoders at each complex, and (3) X-band acquisition aid at Canberra. The X-band acquisition aid in particular was required to provide a ± 2.4 deg beamwidth capability to ensure the first DSN initial acquisition at X-band. The 34-m high-efficiency (HEF) antenna has a pencil beam (± 0.0375 deg) at X-band. Therefore, the X-band acquisition aid was mounted on the 26-m antenna where angle information was transferred to the 34-m antenna to ensure timely spacecraft acquisition. All these upgrades were completed and thoroughly tested before launch.

III. DSN Compatibility Testing

The DSN conducted a comprehensive and intensive series of tests with the spacecraft telecommunications panel and associated equipment in April 1991. These two weeks of testing included telemetry, command, radio metric and radio science configurations required for the Mars Observer.

There were five anomalies found which are listed in Table 1. Anomalies 1-3 presented configurations which, while not desirable, were acceptable to the DSN. At the end of this testing, the spacecraft telecommunications system to the level it was tested was declared compatible with the DSN.

The DSN performed another 40-hour intensive set of compatibility tests with the final spacecraft at the Kennedy Space Center (KSC) launch site in July 1992. Four additional anomalies were identified and are listed in Table 2. The KSC testing was the first end-to-end command testing with the spacecraft.

IV. Prelaunch Testing

The DSN Network Operations Project Engineer (NOPE) conducted approximately 60 Mission Readiness Tests with the complexes. This large number of tests was partially required because of late changes to DSN and MOSO launch software.

A significant effort was also spent on planning, testing and documenting the DSN acquisition plan for Mars Observer. This was necessitated by the requirement that the DSN initially acquire the spacecraft at the X-band frequency. The launch vehicle and related interfaces were also new.

The launch vehicle was a Titan III/Transfer Orbit Stage (TOS). Interfaces were established with the launch vehicle to obtain prelaunch trajectory information, launch vehicle Mark Events and Titan and TOS state vectors. The DSN initial acquisition plan documented the nominal acquisition strategy and the planned use of the Mark Events, trajectory information and state vectors for nominal and non-nominal trajectories as well as spacecraft anomalies.

V. Launch and DSN Initial Acquisition Phase

The Mars Observer spacecraft was successfully launched on September 25, 1992, thirty-five minutes into the window at 17:05 UTC. The Titan Mark Events were passed over the net and indicated nominal performance. The Titan Operations Control Center at Cape Canaveral Air Force Station (CCAFS) provided the parking orbit state vector as planned, about 10 minutes after launch. The only significant problem in the launch phase was the loss of the TOS S-band (2272.5 MHz) transmitter, which was identified by the Advanced Range Instrumented Aircraft (ARIA) and confirmed by Dakar and Johannesburg.

The loss of the TOS transmitter caused all the TOS Mark Events not to be provided. The DSN was well informed of the probable reason for no TOS data and stayed with the DSN nominal acquisition plan. The TOS Project Operations Control Center (POCC) at KSC provided the DSN with a state vector based on the actual Titan parking orbit and planned TOS burn at launch plus 33 min. This vector was used by the DSN to generate updated predicts for the Canberra stations.

The DSN Canberra 26-m station had planned to track the TOS S-band (2272.5-MHz) downlink starting at station horizon break (approximately launch plus 49 min). Because of the TOS transmitter being off, there was no signal for Canberra to track.

The DSN 34-m HEF and 26-m stations acquired the X-band (8417.716-MHz) spacecraft downlink within 40 sec of the planned turn-on time of launch plus 84.7 min.

The Canberra tracking of the Mars Observer launch was excellent with all data provided to the Project. The quick acquisition of the spacecraft X-band signal by the Canberra 26- and 34-m antennas during initial contact with the spacecraft was much appreciated by the Project. This acquisition helped quickly relieve the tension from not having any TOS performance data and allowed the Project to quickly evaluate the spacecraft.

The DSN support of the launch countdown, launch, initial acquisition and first pass by Canberra was nearly flawless with no problems identified. The DSN met or exceeded all Project requirements, including the spacecraft 2-kbps data flow from a Payload Data Formatter (PDF) at Canberra to Building AO at Cape Canaveral Air Force Station.

VI. Early Cruise Through TCM-2

The 34-m HEF subnet provided continuous tracking from launch through 30 days on October 24, 1992. Trajectory Correction Maneuver 1 (TCM-1) and spacecraft checkout were accomplished during this period.

The DSN was unable to symbol synchronize and convolutionally decode the TOS telemetry data played back from the spacecraft twice over Madrid and Canberra shortly after entering cruise. The TOS telemetry playback was tried a third time, on October 7, over Canberra and the DSN was able to convolutionally decode and frame sync the data. Both digital and analog tapes of the TOS data were expedited to the TOS Project. The DSN Compatibility Test station within the Merritt Island Launch Area (MILA) complex at KSC played back the TOS analog tape to the TOS POCC at KSC with the same configuration used prelaunch to expedite TOS analysis.

Later DSN analysis indicates that the TOS testing and Network Operations Plan were flawed, leading to the stations' using the wrong Maximum Likelihood Convolutional Decoder (MCD) connection vector configuration during the first two tape-recorder playbacks of TOS data. The MCD connection vector required was Ground Spaceflight Tracking and Data Network ("GSTDN") versus "DSN."

The DSN real-time data delivered over the first 30 days to Mars Observer well exceeded the 97.5 percent required by the Project.

Since November 1992, the DSN tracking has been reduced to one or two 34-m HEF passes per day except for the continuous coverage period around a Flight Software Load centered on January 7-8 and TCM-2 on February 8, 1993. Again the DSN has generally provided good tracking, telemetry and command data exceeding the 97.5-percent requirement.

Several configuration problems have arisen at Madrid during the Mars Observer cruise period. Most of one pass was lost when two Telemetry Processor Assemblies

(TPA's) were configured and concurrently transmitting; another time they were left circular polarization (LCP) instead of right circular polarization (RCP); another time a whole pass was lost for unexplained reasons. Also, scheduling and spacecraft sequencing problems were encountered due to the Madrid strike.

One significant problem with the Mars Observer Camera (MOC) telemetry data has been identified however. The end-to-end spacecraft and ground system is losing a few telemetry data blocks each day which are periodically scattered through the tracking pass. A gap in telemetry data of even one block will cause up to 128 lines of an MOC image to be lost. Depending on the data compression scheme, even more lines could be lost.

A Mars Observer telemetry data loss team was formed and determined that the data abnormalities were one of two types: (1) Unexplained data corruption errors of downlink signal and (2) dropped blocks from the station telemetry system to the MOSO Telemetry Input Subsystem (TIS). Much analysis indicated that the Goldstone uplink was being periodically shifted in phase by a defective Frequency and Timing Subsystem feed. This problem was corrected and the unexplained errors were reduced dramatically but were not completely eliminated. The tiger team is continuing its investigation of this problem.

The dropped blocks between the station telemetry system and the MOSO TIS were identified as three problems associated with the Station Communications Processor (SCP), NASCOM circuits and the SFOC Gateway (DSN) to GCF Interface (MOSO). The Space Flight Operations Center (SFOC) Gateway to Ground Communications Facility (GCF) Interface accounted for the largest amount of numerical blocks lost. Action is currently under way to improve this real-time data flow throughput. TCM-2 was supported without incident by the DSN.

VII. Future Tracking

The plan that has been adopted is for the DSN to continue to track the spacecraft at a one- to two-pass per day rate during the outer cruise mode until July 24, 1993, when continuous 34-m HEF coverage will begin. DSN continuous 34-m HEF coverage will be required through Mars Orbit Insertion (MOI) on August 24, 1993, and will continue until start of the mapping phase on November 22, 1993. The rest of the prime mission is planned to be generally supported by the DSN at a one-to-two 34-m HEF pass per day level until February 2, 1996.

Table 1. Anomalies discovered in testing the spacecraft telecommunications panel.

No.	Anomaly	Characterization/status
1.	Subcarrier harmonics feed-through at -35 dB down from subcarrier in four configurations of the Mars Observer Transponder (MOT).	Verified to occur in Cross-Strapping Unit (XSU) configurations: MOT 1-XSU side 1, MOT 1-XSU side 2 cross-strapped, MOT 2-XSU side 2, MOT 2-XSU side 1 cross-strapped. Demonstrated to be caused by signal leakage by the MOT telemetry on-off relay.
2.	Subcarrier harmonics at all the same amplitude.	Testing indicates 320-kHz subcarrier squarewave distorted at MOT input. Distortion is being caused by overshoot on the squarewave in an XSU amplifier.
3.	Ranging signal feed through on downlink.	Ranging signal is on downlink whenever ranging modulation is on uplink. Signal is being coupled through the MOT ranging modulation on-off relay at ≈ 30 dBc. DSN can lock up ranging with spacecraft ranging switch either in the on or off position.
4.	1.024-MHz signal on downlink all the time about 30 dB down from carrier.	Signal present in all cross-strap configurations and all downlink configurations. The 1.024-MHz signal appeared to be coming from the XSU, but the exact route transferred as downlink modulation was not determined. This anomaly was later fixed by GE Astro and verified by the DSN.
5.	The spacecraft convolutional encoder had a Goddard Space Flight Center (GSFC) connection vector convention instead of the JPL (DSN) standard convention.	The DSN could not lock up the MCD in the planned configuration. The DSN reconfigured the MCD to the GSFC connection vector mode and successfully decoded the data. The DSN agreed to support Mars Observer in this mode.

Table 2. Anomalies discovered in compatibility tests with final spacecraft.

No.	Anomaly	Characterization/status
1.	Spurious signals (≈ -35 dBc) appeared approximately 20 kHz and 12.5 kHz from downlink carrier.	These spurs were thought to be intermodulation products between frequency sources. While not desirable, these were acceptable to the DSN and Radio Science personnel because of their distance from the carrier.
2.	At high signal levels the end-to-end command system could not reliably send and validate long strings of commands to the spacecraft.	The spacecraft configuration is for both MOT/Command Demodulation unit (CDU) strings to be active all the time. The problem was identified as the lower signal level CDU occasionally locking first even when deliberately set for the wrong command data rate. This problem was solved by setting the low signal CDU to 7.8125 bits/sec and offsetting the subcarrier by 2 Hz to 16,002 Hz, therefore locking out this CDU.
3.	The safe mode operation of the spacecraft (7.8125 b/sec in both CDU's) and the 16,000-Hz subcarrier would not reliably send and validate commands.	Limited testing of commanding with ten-sec instead of six-sec spacing indicated 100 percent of commands received.
4.	Long strings of commands radiated by AMMOS at 125 Hz could not be reliably radiated by the DSN.	It was determined that the DSN Command Processor Assembly (CPA) has a limitation which will not reliably radiate long strings of commands in the Mars Observer configuration if closer than 4 to 5 sec. The Project is to transmit commands with 10-sec spacing until new DSN command system software is delivered in June 1993.