Pioneer 10 and 11 Mission Support

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The functional requirements, detailed design, and implementation of the Direct Interface between the Deep Space Network and the Pioneer Project are described.

I. Introduction

The existing Ground Data System used to support the Pioneer 10 and 11 missions was described in a previous Progress Report article (Ref. 1). The block diagram contained in the referenced article is repeated here as Fig. 1. An additional unique aspect of the Pioneer 10 and 11 missions is that they are the first unmanned missions supported by the Jet Propulsion Laboratory which have involved a Remote Control Center. The Ground Data System as it exists involves three major elements which are separated geographically. The first element is the Deep Space Stations which are located around the world, the second is the Mission Control and Computing Center and Network Operations located at the Jet Propulsion Laboratory, and the final element is the Pioneer Mission Operations Control Center located at the Ames Research Center (ARC). As was described in more detail in the referenced article, the data flow from the Pioneer Mission Operations Control Center (PMOCC) passes from the Ames Research Center via high-speed data line to the Computer System located at the Jet Propulsion Laboratory where extensive processing takes place, and then the data flows on to the Deep Space Stations (DSSs). Recognizing the complexity of the Ground Data System as it currently exists, ARC initiated an activity to implement a Direct Interface between the Pioneer Mission Operations Control Center and the Deep Space Stations. Over the past several months, representatives of the Deep Space Network and the Pioneer Project Office have jointly formulated a detailed technical plan for the implementation of such a Direct Interface. The technical plan has been completed and has undergone a formal review and acceptance by DSN Management and Pioneer Project Office Management.

The basic objective in implementing the Direct Interface is to simplify the Ground Data System for Pioneer Operations by eliminating Pioneer telemetry and command processing in the 360/75 computers of the Mission Control and Computing Center located at the Jet Propulsion Laboratory and interfacing the Pioneer Mission Operations Control Center at ARC directly with the DSS. This simplification of the Ground Data System should reduce the complexity of operational interfaces and should improve reliability since a major element, with its independent mean time between failure and

mean time to recover, is no longer in series with the data flow. The direct mode will also reduce the interaction between Pioneer Project and other in-flight missions since only the radio metric data processing for Pioneer will remain in the multimission co-resident 360/75 environment.

II. Design Guidelines

The following general requirements were used in formulating the detailed design of the Direct Interface.

In the direct mode and during the implementation period, Pioneer 10 and 11 operations should not be degraded. Because of the time scale of the planned implementation, it was decided that the Pioneer 11 Jupiter encounter should not be supported in the direct interface mode, but rather in the same fashion that the Pioneer 10 Jupiter encounter was supported.

Simplicity of the resulting interface was a primary concern. For this reason, the development of additional interactive computer-to-computer interfaces between ARC and the Deep Space Stations was avoided. In particular, the automatic telemetry recall system will not be implemented in the Direct Interface. It was also a design objective that both the Pioneer Project and the DSN should be able to self-test that they have met the agreed-upon interface prior to calling upon each other to test across that interface.

In order for the implementation of the Direct Interface to be cost-effective, it was deemed necessary to develop an implementation schedule which matched the implementation schedule of the Network Control System. This was so that when the Pioneer processing was no longer necessary in the 360/75 for Pioneer Project purposes, it would also no longer be necessary for DSN Network Operations Control purposes.

The DSN is ordinarily responsible for the quality of the data at the point they are delivered to a Mission Operations Control Center. However, in the case of the Pioneer Mission Operations Control Center located at ARC, there is no DSN equipment nor personnel at the ARC end of the high-speed data system to monitor the quality of the incoming data. For this reason, it was agreed that the Pioneer Project would be responsible for assessing the quality in realtime of the data flowing into the PMOCC.

III. Detailed Design

The functional block diagram for the telemetry and command portion of the Direct Interface Ground Data System is shown in Fig. 2. The Telemetry System involves the implementation in the realtime Sigma 5 system at ARC of additional realtime analysis functions and a logging function for the purpose of producing data records.

The interface for producing the Master Data Record for the Telemetry System will eventually be the Intermediate Data Record (IDR), which will be produced in the Network Control Data Processing Center from the GCF log tape. The IDR will be shipped from JPL to ARC and undergo processing in an off-line Sigma 5 computer in order to produce the Master Data Records and the resulting Experimenter Data Records. The GCF log and IDR will not be a Network Control System capability until December of 1975. In the time frame prior to when the IDR is available, the Telemetry Master Data Record will be produced by the PMOCC using a limited selected recall directly from the Deep Space Stations. This recall will ordinarily be performed during the one-hour post-pass. In order to determine the required recall, there will be realtime accountability software implemented in the Sigma 5 which will produce a summary of missing data upon request. From that summary of missing telemetry data, an operator at ARC will be able to select by computer input a subset of data gaps that should be recalled. A message will then automatically be produced by the Sigma 5 and transmitted over the high-speed data line to a line printer at the Deep Space Stations to list for the station operator the outages that should be recalled from the Digital Original Data Records. No implementation was required by the Deep Space Network for this system of doing telemetry data recalls since the message produced by the Sigma 5 will be compatible with the DSS capability of receiving text messages from the Network Control System.

The Command System is being implemented in a PDP-11 computer at ARC. The Direct Interface will utilize the Mark III-74 Telemetry and Command Processor software known as the Command Redesign. The command message construction, verification, and high-speed block formatting functions will be performed by the PDP-11 computer system. Response message blocks returning from the Deep Space Station will be routed to the PDP-11 for verification, and to the Sigma 5 system for post-transmission processing. Mode change and recall request messages will be generated by the PDP-11 computer. Initialization of the Command System will take place from the Network Control System, although backup

initialization can be accomplished at the DSS in the event of an NCS failure. In order for the NCS to have access to the Command System at the DSS over the same single high-speed data line which interfaces with the PMOCC, a special piece of hardware was developed at JPL. This equipment, known as a Filler Multiplexer, detects filler blocks in the data flowing from the PMOCC and replaces the detected filler blocks with high-speed data blocks from the Network Control System.

There will be three Filler Multiplexers implemented for the Direct Interface, two of them on line and the third functioning as a spare. When station handovers require a third high-speed data line into the PMOCC, the spare Filler Multiplexer will be utilized if available. Special procedures will be required in the event that a third Filler Multiplexer is not available when a handover between stations occurs on one Pioneer spacecraft while another Pioneer spacecraft is being tracked.

The Command MDR will be produced in the Pioneer Mission Operations Control Center, utilizing the same log tape function which will be used for Telemetry Data Records. Ordinarily any missing command messages will be provided by Network Operations Control via voice or written message provided to the Pioneer Mission Operations Control Center.

It was decided that at least in the initial implementation there would be no requirement at ARC to process the monitor data which are present on the in-bound high-speed data line. In the existing Ground Data System, the sequence of events generated at JPL is reformatted in the 360/75 into a high-speed data message which is compatible with existing ARC software. For the Direct Interface, it was necessary to implement in the Sigma 5 realtime system a capability to receive Xerox Data System 6-bit binary coded data, which is the same system used for transmitting text data from the Network Control System to the DSS.

The flow of radio metric data for navigation purposes is unchanged in the Direct Interface and is pictured in Fig. 3. The only difference between the Tracking System end-to-end in the Direct Interface and in the existing Ground Data System is the addition of the off-line Network Control System for the purposes of DSN operations control and the deletion of DSN operations control functions from the 360/75 realtime system. The Pioneer Project Office will look to their existing contract with Division 39 for monitoring any changes to the Tracking System functions in the 360/75.

It was mentioned above that the Direct Interface will utilize the Mark III-74 Telemetry and Command Processor software. The advantages of using this new software in the Direct Interface are that Pioneer Mission Operations will then be utilizing the same new generation of multimission software which will be used for all other missions without the Mission Control and Computing Center having to implement this capability for Pioneer in the 360/75. The disadvantage of using the new software is that, when the direct mode is utilized between the Ames Research Center and the DSS, the Command and Telemetry formats will not be compatible with the existing 360/75 realtime system. This meant that it was not possible to phase the implementation by a gradual buildup of capability, such as implementing the Command System first, then the Telemetry Realtime System, and then the Telemetry MDR. Instead, the Direct Interface must go into operation with the full required capability at one time. Because of this, it was decided to phase the implementation by spacecraft, placing Pioneer 10 operation in the direct mode first prior to Pioneer 11 Jupiter encounter and adding Pioneer 11 to the Direct Interface immediately after Jupiter encounter.

IV. Implementation Status

The implementation of the Direct Interface involves principally software development at ARC but is dependent on the implementation of the Network Control System by the DSN. ARC software development is at the current time on or ahead of schedule. Extensive testing has been in progress on the command portion of the Direct Interface. End-to-end testing of the command portion of the Direct Interface has utilized special configurations at the Deep Space Stations during actual Pioneer 10 and 11 tracking passes. This testing has involved using one Telemetry and Command Processor at the DSS to support the existing Ground Data System configuration with MCCC, and a second Telemetry and Command Processor with the Mark III-74 software configured so as to prevent commands from the second Telemetry and Command Processor from being radiated to the spacecraft. In this way, the testing has been accomplished without requiring additional Deep Space Network resources and without interrupting the ongoing realtime operations on the Pioneer 10 and 11 missions. Essentially all of the test and training for the Direct Interface will be accomplished in this same fashion.

The current plans are leading to having the Direct Interface operational for Pioneer 10 on September 1, 1974 and on Pioneer 11 on January 15, 1975. The opera-

tional date for Pioneer 10 is a compromise between avoiding the Pioneer 11 Jupiter encounter time frame and waiting for the Network Control System to be fully operational. As a result, Pioneer 10 in the direct mode will be utilizing the Block I NCS for two months until the Block II NCS becomes operational on November 1, 1974. Final acceptance testing of the direct mode will take place during the month of August concurrent with extensive activity in preparation for the Helios launch and the Pioneer 11 Jupiter encounter. This scheduling was deemed necessary because postponing the implementation of the Direct Interface to after the Pioneer 11 Jupiter encounter would have placed it on top of the Helios first perihelion, which is in January and February of 1975. Pushing it beyond the Helios first perihelion would have placed it on top of the heavy Viking preparation activity which gets into full swing at that time.

All testing accomplished to date has been highly successful, and no serious difficulty with the implementation has been uncovered. It is anticipated that the most difficult part of the interface to develop will be that portion associated with Telemetry Data Records. Previous experience with developing Telemetry Data Record interfaces on both Pioneer and other missions has shown that a fair amount of operational resources are consumed before the data record production becomes routine. A principal design aspect in the Direct Interface, which it is hoped will alleviate some of these previous problems with data record production, is that the accountability which will take place in the Sigma 5 will be by high-speed data block number rather than by data time. This is the same concept that will be utilized in the design of the NCS GCF log capability. One of the main time-consuming problems in data record production in the past has been the determination of what data should be recalled and what data are available for recall. Using high-speed data block serial number instead of data time should be a better indication that the data are actually available on the Digital Original Data Record at the DSS.

V. Summary

The design of the Direct Interface between the DSN and the Pioneer Project has been completed, and the implementation is well underway. No significant problems have yet been uncovered in the interface implementation and the Direct Interface should eventually provide a simplified and more reliable Ground Data System and operational interfaces for the Pioneer missions.

Reference

1. Miller, R. B., "Pioneer 10 and 11 Mission Support," in *The Deep Space Network Progress Report*, Technical Report 32-1526, Vol. XVIII, pp. 16–19, Jet Propulsion Laboratory, Pasadena, Calif., Dec. 15, 1973.

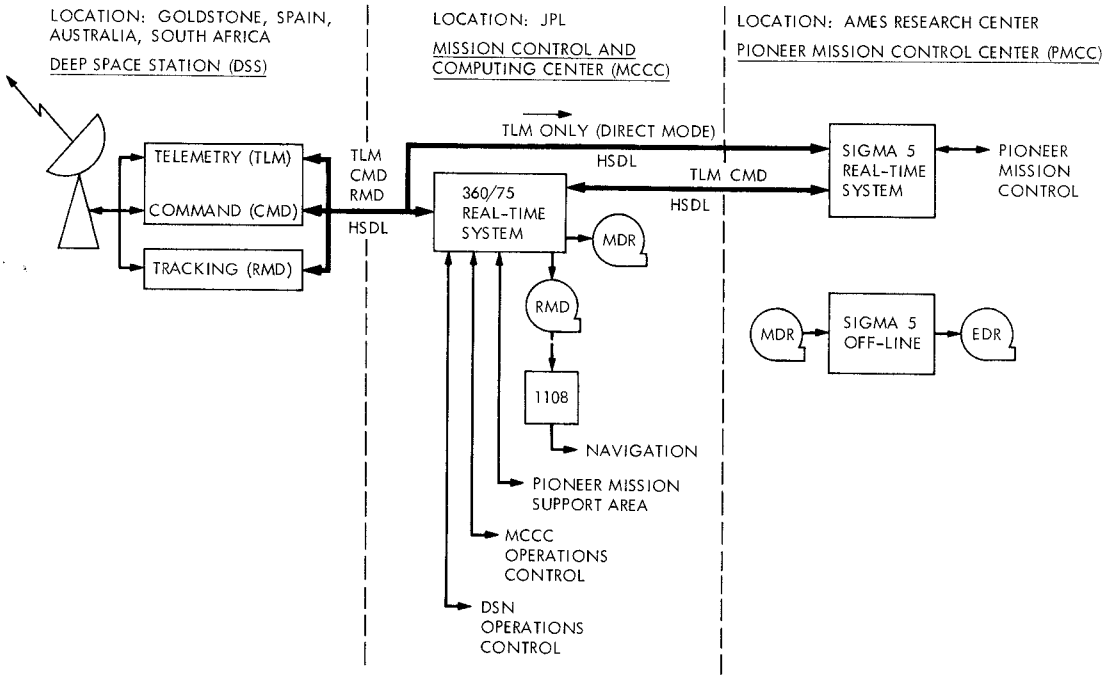

Fig. 1. Existing Pioneer 10 and 11 Ground Data System configuration

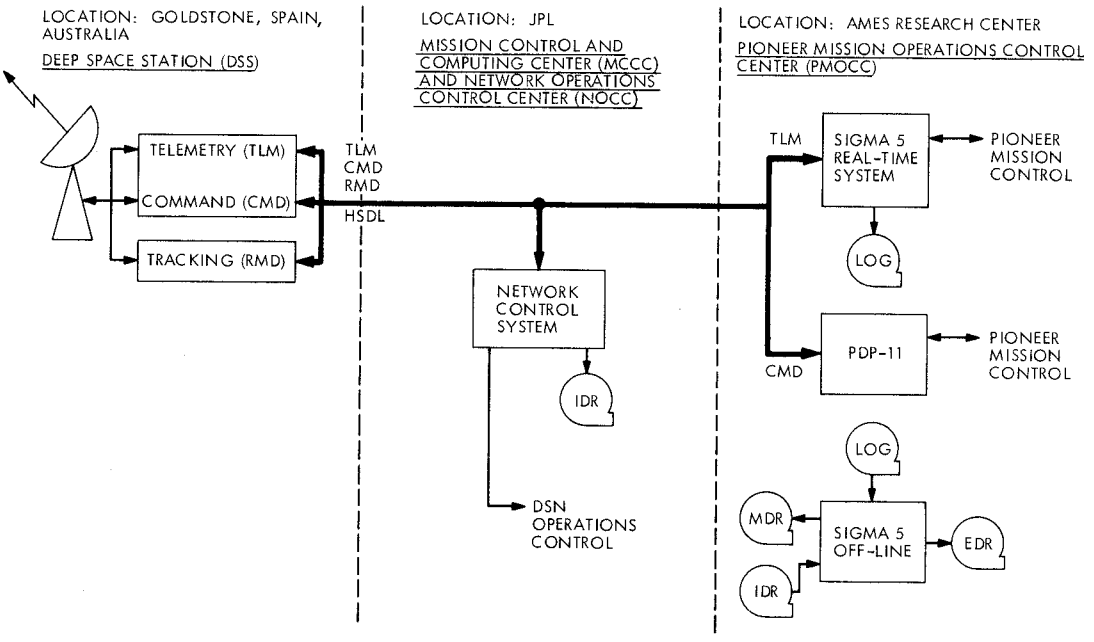

Fig. 2. Pioneer 10 and 11 Direct Interface Ground Data System configuration for Telemetry and Command

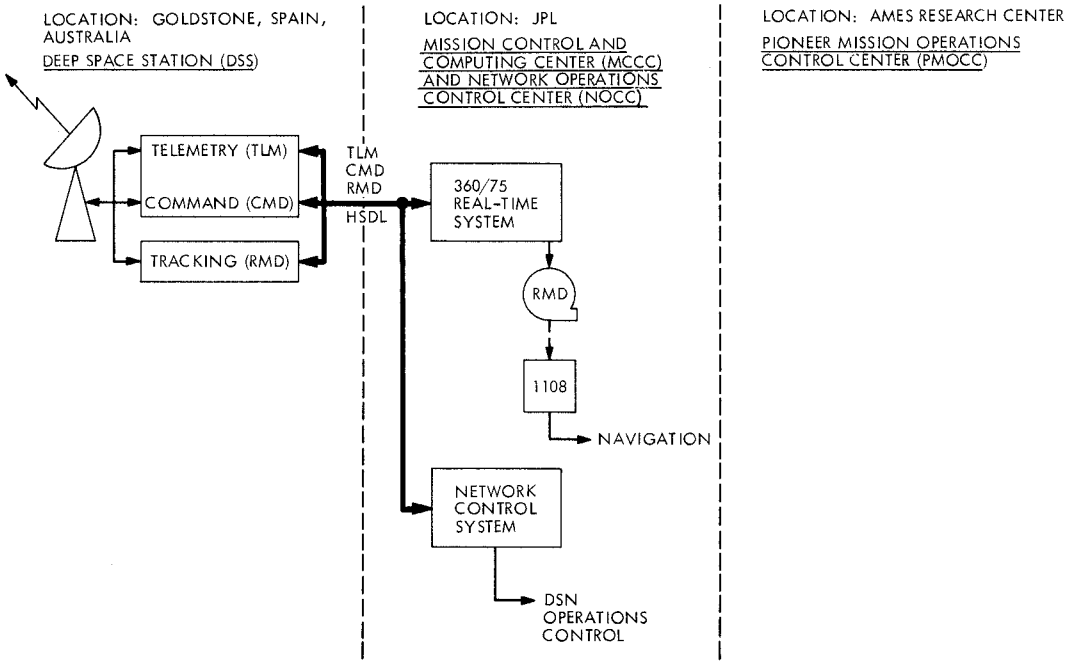

Fig. 3. Pioneer 10 and 11 Direct Interface Ground Data System configuration for radio metric data