DSS Command System Redesign

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The existing Deep Space Station (DSS) Command System cannot meet project requirements through the Viking era (1975). The DSS Command System redesign, described herein, will be used to support Mission Command requirements through 1975. Major areas of redesign include command stack capacity and allocation of command stack manipulating functions from the DSS computer to the Mission Control and Computing Center. This article describes the system configuration and the functional operation of the redesign.

I. Introduction

The Deep Space Station (DSS) Command System redesign was initiated on September 1, 1972. The primary reason for the redesign effort is that the existing command software system is no longer capable of supporting project requirements through the Viking era (1975). The Telemetry and Command Processor (TCP) at the DSS has reached its limits of capability, in both processing cycle time and storage capacity, when telemetry and command functions must be performed simultaneously.

The primary objective of the command redesign is to develop new TCP command software that will operate with existing DSS equipment to satisfy project command requirements (such as command rates higher than 1 symbol/s) through the Viking era. In order to accomplish this, two major areas, command stack manipulation and command storage, in the existing TCP command software require redesign. The result of the redesign was to (1) reallocate the command stack manipulation (stack sorting, merging, and searching) control logic from TCP to the Mission Control and Computing Center (MCCC) and (2) limit the command storage to four High-Speed Data (HSD) blocks of 6–71 bit command elements each for remote-controlled operation and one HSD block for manual commanding.

The command software redesign reduced TCP command activity loading as well as TCP input HSD processing because of decreased HSD loading. Thus, the implementation of this new command software will permit the DSS Command System to operate at 8 symbols/s simultaneously with telemetry processing.

The following describes the DSS equipment configuration for command and the detailed functional operation of the new TCP command software. [After the command software is developed, it will be integrated into the Telemetry and Command Data Handling Subsystem (TCD) Multiple Mission Software.]

II. System Configuration

The purpose of the command software is to provide uplink communication capability to spacecraft. The command software, which is located in the TCP computer, utilizes the Command Modulator Assembly (CMA) as its connection to the Exciter/Transmitter Subsystem. The primary method of operation is the automatic mode, in which the TCP receives command inputs from the HSD lines; the second method of operation is the manual mode, in which the TCP receives local command inputs from the DSS typewriter and/or paper tape reader. In both modes, the TCP logs information on a magnetic tape [called the Original Data Record (ODR)], displays status information at the DSS through the Station Monitor [called the Digital Instrumentation Subsystem (DIS)] or teletype output printer, and receives time from the Frequency and Timing Subsystem (FTS) for time tag of command events. Figure 1 shows the DSS system configuration for command, and the following sections describe the functions of the components.

A. Control Center

Any control center can interrogate the TCP at any time by sending HSD blocks requesting information to the TCP. Configuration tables, standards and limits tables, and mode control and command stack modules and status can be obtained. In either the automatic or manual mode, the TCP will address and transmit HSD blocks describing events that are asynchronous to other HSD communications to one control center, called the control source.

B. Typewriter/Paper Tape Reader

The typewriter and paper tape reader are input devices used to perform software initialization and to control the command software in the manual mode.

C. FTS Inputs

The FTS timing interrupts and GMT time information are utilized by the command software to time-tag transmission of the first bit of a command element and HSD outbound messages, and to time initiation of transmission of timed command elements. In addition, command partial status periodic messages are generated for display in the DIS.

D. ODR Output

All input HSD blocks to the TCP are logged on the ODR, as are all acknowledge blocks. All HSD block images constructed in response to typewriter input are logged on the ODR regardless of HSD communications to the control center.

E. DIS Output

The DIS displays information generated by the command software on the station line printer. If the DIS is inoperable, information will be displayed on a teletype output printer. The information displayed includes display requests, command partial status messages, and command event messages.

F. CMA

The CMA accepts configuration, frequency, symbol rate, and command data from the TCP for different CMA operations as controlled by the command software. CMA status information is fed back to the TCP to allow checks to be made by the software.

G. Analog Tape

Modulated subcarrier output from the CMA is recorded on analog tape for post-operation analysis.

H. Exciter/Transmitter

Modulated subcarrier output from the CMA is input to the exciter/transmitter subsystem for signal amplification, carrier modulation, and transmission to the spacecraft.

III. Functional Operations

A. TCP/CMA Modes of Operation

The CMA, under the control of the command program, operates in various modes:

Cal-1 (Calibrate-1) – the DSS operator establishes CMA signal modulation attenuation settings.

Cal-2 (Calibrate-2) – the CMA is operating according to project specific frequency-modulation method and symbol rate, but no modulated output is transmitted to the exciter/transmitter subsystem.

IDLE-1 – a project Idle word is continuously transmitted.

IDLE-2 – a second project Idle word is continuously transmitted.

ACTIVE – project command bits are transmitted.

ABORT – command bits are no longer transmitted because of command check failures.

Figure 2 shows the relationship between each mode and the sequence of events leading to the entry and exit of the mode.

B. Initialization

During the initialization process, type-ins are made by DSS operator through the typewriter. The type-ins [Command Station-Spacecraft (CSS)] identify the DSS, computer string, spacecraft, and destination code for outbound HSD blocks. The modulation attenuation for the CMA is also established. The operator then types in CRUN to terminate the initialization process, and the command program subsequently enters formal Cal-1 mode. At this point, the program operates in either the automatic or the manual mode, depending upon the key setting of the station manager's console.

C. Automatic Mode

In the formal Cal-1 mode, the program is ready to accept all HSD blocks consisting of configuration and standards and limits tables. When it has rceived both of these tables, the program enters Cal-2. From Cal-2, the mode changes are under the control of the mode enable/disable flags of the mode control portion of the command block.

From Cal-2, the program goes to Idle-1 when that flag is enabled, and from Idle-1 to Idle-2 when the Idle-2 flag is enabled. The transfer from Idle-2 to Active occurs only when the Active flag is enabled and transmission of a command element is started. The transfer to Abort is made when an Abort directive is received, when an Abort limit is reached and the Abort-override flag is not set, when a watchdog timer (computer overload condition) occurs, or when a manual button is started.

Mode regressions also occur. From the Abort mode, return to the Cal-2, Idle-1, or Idle-2, depending on the Abort return code, occurs after the Abort duration has expired. Active regresses to Idle-2 when a command element confirms and no other command elements exist in the stack, or the next command element is timed. Idle-2 to Idle-1 and Idle-1 to Cal-2 regressions occur when the Idle-2 and Idle-1 flags are disabled (the program being in that particular mode), respectively. In the redesign, bit verification is performed on the Idle word sequence; if the Abort-override flag is not set and a bit error occurs, the program reverts to Cal-2. The return from the Abort mode plus the bit error regressions disable all mode flags higher than Cal-2. Once the program is past Cal-2, only mode control and command blocks are accepted. That is, it is necessary to revert to Cal-2 for program reconfiguration.

The Network Control System (NCS) can establish a lockout condition in which normal HSD blocks from NCS would be rejected. NCS should establish lockout after configuring the TCP to prevent interference of NCS with project commands through MCCC.

D. Command Stack Loading and Logic

Figure 3 shows the command stack and manual buffer structure. The command stack consists of four modules of six elements (71 bits per element) each, plus the extent which specifies how many modules have data in them. The loading of command stack modules is accomplished by way of HSD blocks from a control center. Recalls of the contents of any stack module can be made by HSD blocks. Only element 1 of the prime module is eligible for transmission. When transmission of the element begins, it is transferred to the active register; the remaining elements of the prime module are then pushed up one, and element 6 is filled with zeros. If element 1 of the prime module is empty (all command elements are transmitted), the extent is reduced by 1, and if the results are positive, the modules are promoted by being pushed up one and radiation of commands until the extent reaches 0.

Synchronization with a control center is based on the extent, and for the prime module references, also on the count of elements. An input module from a control center is marked as to which stack module it replaces, and also carries the expected TCP extent and a new TCP extent, plus the expected TCP count.

Synchronization is achieved by comparing the expected TCP extent against the actual and, for prime module references, the expected count against the actual. If the comparison is nonequal, the control center does not know the current TCP situation, so the module is rejected, and the resulting HSD block notifies the control center of the actual TCP extent and count. If a module is accepted, it replaces the indicated stack module and the new extent replaces the actual extent. Note that the stack will be empty if the new extent is zero.

E. Manual Mode

Manual mode operation is, in the main, similar to automatic. Direct type-ins exist to take the TCP from Cal-1 to Cal-2 and any other mode. One type-in, CIN, exists to put the TCP back into the dormant pre-initialization stage.

All manual mode commands in Cal-1, except for the manual buffer updating and display requests, result in HSD block images which flow through the system as formal HSD blocks, are logged on the ODR, and generate an Acknowledge response. These blocks are identified as manually generated.

F. Manual Buffer

A manual buffer is exactly the same size as a stack module (six elements of 71 bits each). The manual buffer is independent of the stack. In the automatic mode, a specially earmarked module can be sent to fill the manual buffer. The contents of the manual buffer can be recalled by the HSD block. Manual entry of the command elements into the manual buffer is accomplished through type-ins. Other type-ins are used to send the whole manual buffer to the stack as a module, or to send one command element to the stack in a partially filled module. Once a command element enters the stack module, the transmission of a command is the same as described above.

IV. Summary

The implementation of the command software as described will meet project requirements through the Viking era. The following outlines the performance characteristics of the redesigned system:

(1) Command storage

Command stack: 4 modules × 6 elements/module × 71 bits/element

Manual buffer: 6 elements × 71 bits/element

The factor most limiting the capacity of command storage is that the command software shares the TCP computer with the telemetry processor.

(2) HSD input block rate: maximum of 1 block/5 s

The rate is limited by the time-consuming routine required to process input blocks. Additional time is also required in the command stack synchronization process between a control center computer and the TCP computer.

(3) CMA operations monitoring

Bit-by-bit check is performed for each command bit. Other checks, such as frequency, symbol rate, and data quality are performed once per word.

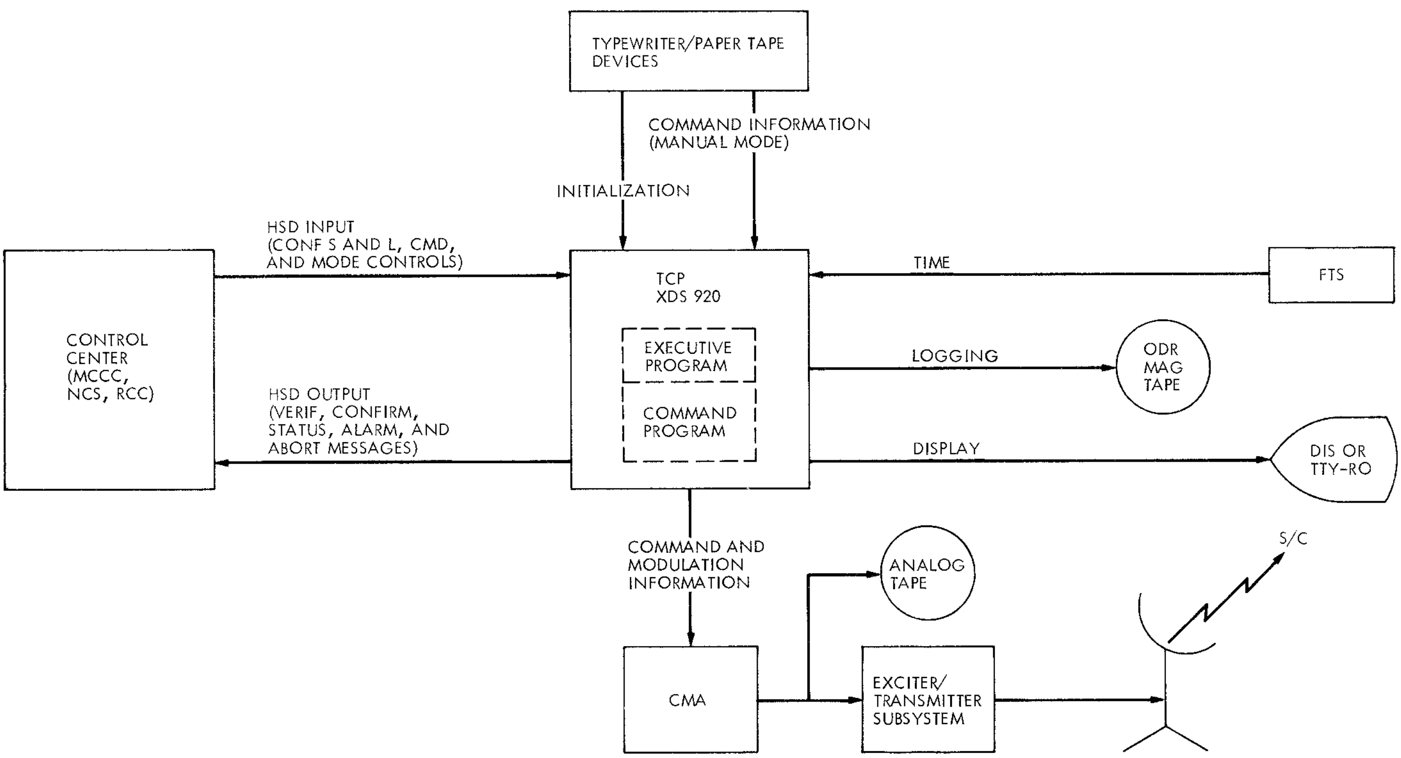

Fig. 1. DSS command configuration

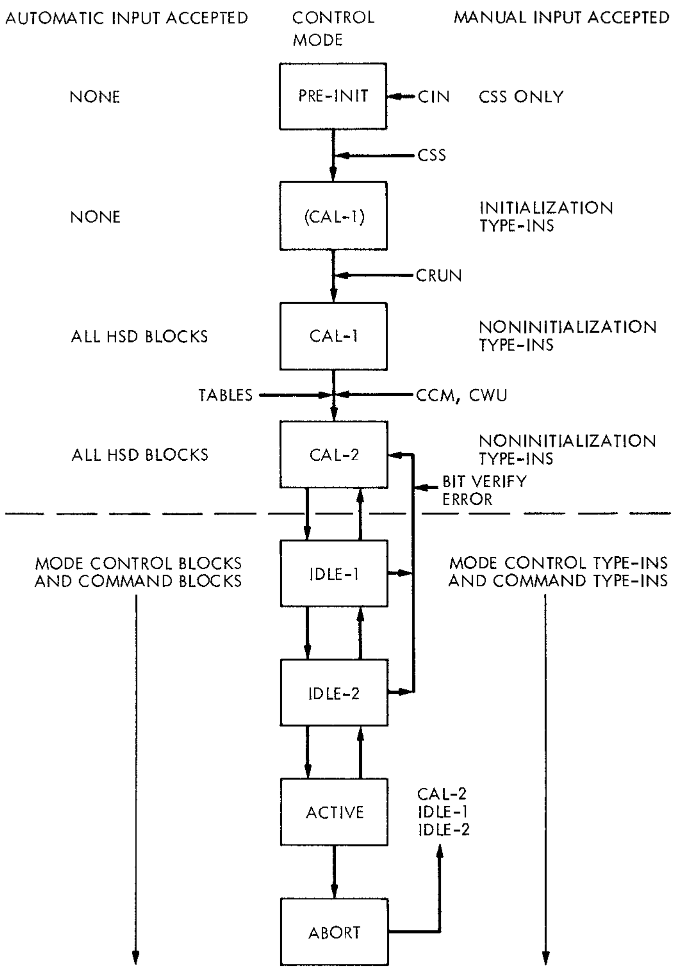

Fig. 2. Mode relationships

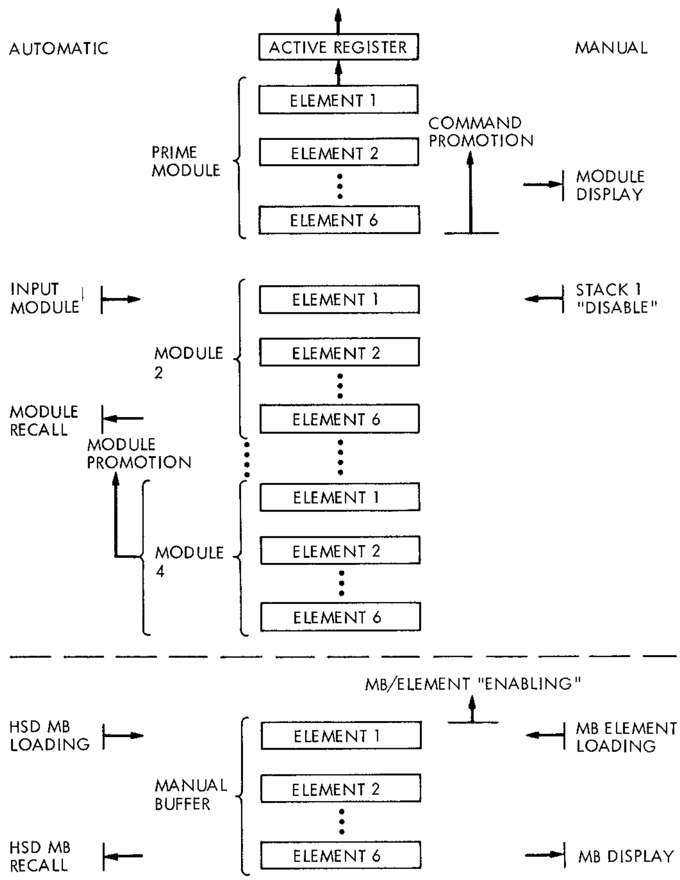

Fig. 3. Command data update/recall diagram