# DSN Command System Mark IV-85

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*Modification of the currently operational DSN Command System Mark III-80 in 1982 consisted of upgrading Command System monitoring functions in the Network Operations Control Center. DSN Command System Mark IV-85 functional design is described for the Mark IV-A Network, which is planned for 1984-1985 implementation.*

## I. Present System

The Mark III-80 configuration of the DSN Command System, which was described in Ref. 1, is the currently operational configuration. To provide computer-controlled prepass data transfer and validation tests and revised displays, Network Operations Control Center (NOCC) Command Subsystem software modifications were completed in May 1982 as part of a general upgrade of the Network Operations Control Area (NOCA) to reduce operations costs.

## II. Mark IV-85 System

### A. Mark IVA Network Implementation

The Mark IVA Network implementation, to be completed in 1985, will provide one Signal Processing Center (SPC) at each of the three Deep Space Communication Complexes (Goldstone, California; Canberra, Australia; and Madrid, Spain). The Ground Communications Facility (GCF) will provide communications between JPL and each SPC. The Networks Consolidation Program (Ref. 2) provides for the Mark IVA Network to support high-apogee earth-orbital missions in addition to the deep space missions.

Figure 1 is a block diagram of the DSN Command System Mark IV-85, as previously described in Ref. 3. Each Deep Space Communications Complex (DSCC) will have a 64-meter antenna with deep space uplink, a 34-meter antenna with both deep space and earth orbiter uplinks, and a 9-meter antenna with earth orbiter uplink. (The Goldstone and Canberra complexes will each have an additional 34-meter antenna for downlink only.)

During the past year the Mark IVA Network implementation schedule has been modified to provide earlier completion at the Canberra complex. Additional support requirements have enlarged the mission set. The Command System performance requirements, functional description, and subsystems configurations, however, are the same as presented in Ref. 3.

DSCC Command Subsystem prototype testing and software design are progressing on schedule. A contract for fabrication of the 16 new command modulator assemblies was awarded in June 1982.

### B. Implementation Schedule

The Mark IVA Network implementation plan calls for an interim configuration to be installed at all three complexes in early 1984, and a final configuration at Goldstone by February 1985, Canberra by May 1985, and Madrid by August 1985. The interim configuration will include new command equipment for support of high earth orbit and deep space missions, while retaining portions of the present Mark III configuration. The final configuration at each complex will include the 9-meter antenna and associated front end equipment, at least three strings of DSCC command subsystem equipment, and the new DSCC Monitor and Control Subsystem, as shown in Fig. 1.

### C. Mission Set

The Mark IVA Network baseline requirements have been extended to provide capabilities to support all of the flight missions listed below:

(1) Current deep space missions:

   (a) Pioneers 6 through 12

   (b) Viking Lander

   (c) Helios

   (d) Voyagers 1 and 2

(2) Planned deep missions:

   (a) Galileo

   (b) International Solar Polar Mission (ISPM)

   (c) Giotto (backup support)

(3) Current high elliptical earth orbital missions:

   (a) International Sun-Earth Explorer No. 3 (ISEE-3)

(4) Future high elliptical earth orbital missions:

   (a) Active Magnetospheric Particle Tracking Explorer (AMPTE); 3 spacecraft

   (b) Origin of the Plasma in the Earth's Neighborhood (OPEN); 4 spacecraft

(5) Other earth orbiter missions:

   (a) TDRS (launch and emergency support)

   (b) Space Telescope (emergency support)

   (c) GOES G, H, I (backup support)

### D. Performance Requirements

Support of the Mark IVA mission set will require Command System performance characteristics compatible with the NASA standard transponders, which are to be used on future spacecraft, and also compatible with current inflight spacecraft and certain planned spacecraft that do not use the standard transponder. Some of the required capabilities are listed below:

(1) Data rates. Data rates from 1 to 2000 bits/sec will be provided.

(2) Subcarrier frequencies. Sine-wave and square-wave subcarriers will be generated at frequencies of 100 Hz to 16 kHz.

(3) Subcarrier data modulation. Selection will be provided for phase-shift-keyed (PSK) or frequency-shift-keyed (FSK) modulation of the subcarrier by the pulse-code-modulated (PCM) command symbol stream. An option for amplitude modulation (AM) of the FSK subcarrier will also be provided.

(4) Carrier modulation. The command-modulated subcarrier will be phase-modulated on an S-band carrier for radiation to the spacecraft. Control of modulation index angle will be provided over a range from 0.1 to 1.8 radians.

(5) Carrier frequencies. Generation of the uplink carrier at S-band frequencies assigned for deep space missions will be provided at the 64- and 34-meter antennas. S-band frequencies assigned for earth orbit missions will be provided at the 34- and 9-meter antennas.

## III. System Functional Description

As discussed in Ref. 4, many of the spacecraft supported by the DSN have onboard storage and sequencing capabilities that permit command sequences to be sent well in advance of the actions to be taken by the spacecraft. Thus, fewer direct action (real-time) commands are needed. Ground system capabilities providing massive storage of spacecraft commands, multimission operating functions, and standardized protocol were incorporated in the DSN Command System in 1978 (Ref. 5). These capabilities will be continued in the Mark IV-85 system configuration.

### A. Operational Functions

End-to-End spacecraft command operations are represented functionally in Fig. 2. Command sequences for one or more spacecraft are generated and stored at a Mission Operations Center (MOC). Commands for a particular spacecraft are selected from the command files, formatted into messages, and stored for transmittal to a specified link of a DSCC. Command data are extracted from the message received and are stored and queued until radiated. Finally, the commands arrive at the spacecraft and are either executed immediately or stored onboard for later execution.

The functions of the DSN Command System in this process include the following:

(1) Establishing the DSCC configuration for the specified spacecraft.

(2) Receiving and storing command data at the DSCC.

(3) Queuing command data to be radiated to the spacecraft.

(4) Radiating the command data to the spacecraft.

(5) Monitoring and reporting system status and events.

## B. Operational Procedure

On-site configuration inputs to the DSCC Command (DCD) Subsystem specify the flight project name and the spacecraft identification number. These inputs cause the Command Processor Assembly (CPA) software to transfer a specified configuration and standards and limits table from disk storage to memory, and to configure the DCD Subsystem according to the table. Changes may later be made by messages from NOCC via the GCF (or by keyboard entries at the Link Monitor and Control Console, in an emergency).

Prior to the beginning of the scheduled spacecraft track, the control of the DSCC command functions is transferred to the NOCC. Configuration standards and alarm/abort limits can be updated by GCF transmission of messages from the NOCC Command Subsystem (NCD) real-time monitor processor. The standards and limits are derived from files compiled in the NOCC Support Subsystem. Spacecraft-dependent parameters, such as symbol period, subcarrier frequency, alarm limits, and abort limits, are established via these messages. After the proper configuration standards and limits have been established, test commands are transmitted through the system to ensure that the system can accept spacecraft commands via GCF, temporarily store the commands, and confirm radiation. During this test the transmitter output is radiated into a dummy load. After the Network Operations Control Team (NOCT) has established that the system is operating properly, the station operator switches the transmitter to space radiation, and the NOCT transfers command data control to the flight project's MOC for loading of actual spacecraft command sequences to be radiated to the spacecraft during the track period.

At the time for radiation of each command element, the subsystem advances to the active mode (see Fig. 3 for description of the various modes) and command data are transferred to the Command Modulator Assembly (CMA) for immediate radiation via the Receiver-Exciter, Transmitter, Microwave, and Antenna Subsystems.

## C. Command Data Handling

The DCD Subsystem design allows mission operations to prepare large files of spacecraft commands in advance and then to forward several files to the DSCC link at the beginning of a spacecraft track. The design also provides real-time system status monitoring and control. For protection of data integrity, every message block to or from the CPA contains a block check sum, in addition to the GCF error detection provisions.

**1. Command files.** Each file may consist of up to 256 high-speed data blocks. The content of each data block is a file element. The first block in a file contains the header element and each subsequent block contains a command element. Each command element may consist of up to 800 bits of spacecraft command data. Up to 8 files for a given mission can be stored by the CPA. Thus the available storage is over 1.6 million command bits.

The header element contains file identification information, file processing instructions, and a file checksum. The file processing instructions include optional file radiation open and close window times, and an optional file bit 1 radiation time. File open and close window times specify the time interval during which command elements in the file may begin radiation (i.e., a mission sequence may demand that specific commands not be sent before or after a certain time). The bit 1 radiation time allows the project to specify the exact time at which the file is to begin radiation to the spacecraft. The file checksum is created at the time of file generation and is passed intact to the CPA. It adds reliability to insure that no data were dropped or altered in the transfer from one facility to another. (This is in addition to the previously mentioned block checksums.)

The command elements each contain command bits, file identification, element number, element size, and an optional "delay time" (interval from start of previous element). If delay time is not specified, the element will start radiating immediately after the end of the previous element.

**2. Receiving and storing command data at a DSCC.** Normally, the files of commands to be radiated to the spacecraft will be sent from the MOC to the specified DSCC link at the beginning of a spacecraft track period. However, files may be sent to the DSCC link at any time during the spacecraft track period. The first step in receiving and storing command data at a DSCC is the process of opening a file area on the CPA disk. The MOC accomplishes this by sending a header element, which serves as a *file-open* directive. After the CPA acknowledges receipt of the header element, the MOC sends the remainder of the file (up to 255 command elements) and follows it with a *file-close* directive. The CPA acknowledges the file-close instruction and indicates whether the file loading was successful or unsuccessful. If the file loading was unsuccessful, the acknowledge message contains the reason for the failure and from what point in the file the command elements are to be transmitted. When the file is successfully closed, the MOC may proceed to send additional files, up to a total of eight.

3. **Queuing the command data for radiation.** After the files are stored at the CPA, the MOC then sends a *file-attach* directive for each of up to five file names to be placed in the radiation *queue*. The Mission Control Team determines in which order the files are to be attached. The order in which the file-attach directives are received at the CPA determines the sequence in which the files will be radiated: that is, first attached, first to radiate to the spacecraft.

4. **Command radiation to the spacecraft.** The first command element in the top (prime) file in the queue begins radiation to the spacecraft immediately after attachment or as soon as all optional file instructions (such as bit 1 radiation time) are satisfied. The prime file status is defined to be *active* when the first command element begins radiation. Upon completion of radiation of the first command element, the second command element begins radiation either immediately or when the optional *delay time* has been satisfied. The process continues until all command elements in the file have been radiated. After the first file completes radiation, the second file in the queue automatically becomes the prime file and the command radiation process is repeated. After the second file completes radiation, the third file becomes prime, etc. This process is repeated until all files in the queue are exhausted. The MOC can attach new files to the queue whenever space is available.

Confirmations of prime-file command-element radiations are reported in *event messages* to the MOC and NOCC once per minute, or after five elements have been radiated, whichever occurs first. If a command element is aborted, or if an alarm occurs, an event message is sent immediately.

5. **Additional data processing.** The foregoing descriptions of the DSCC functions of storing the command files, attaching the files to the queue, and radiating the commands to the spacecraft assume nominal (standard) operation. Additional data processing functions are provided for worst-case conditions of non-nominal operations and failure recovery. Control of these functions is normally exercised remotely from the MOC. However, emergency control is also available at the Link Monitor and Control Console.

*a. File erase.* A file can be deleted from storage at the CPA by means of a *file erase* directive, if the file is not attached to the radiation queue.

*b. Clearing the queue.* As previously stated, the order of file radiation to the spacecraft is dependent on the order of files in the queue. To rearrange the order, a *clear-queue* directive must be sent, followed by file-attach directives in the desired order.

*c. Suspend radiation.* If the Mission Control Team desires to stop command radiation, a *suspend* message can be sent to the CPA. This message stops command radiation to the spacecraft upon completion of the current element. The file status then changes from active to suspended.

*d. Resume command radiation.* To restart radiation of a suspended file (either suspended intentionally or from an abort), a message can be sent to *resume* radiation *at* any specified unradiated element in the file. The suspend and resume-at directives can be used for skipping elements of the prime file, if desired.

*e. Command abort.* As each command bit is radiated to the spacecraft, numerous checks are made to insure validity of the command data. If a failure is detected during the radiation, the command element is automatically aborted, the prime file status is changed from active to suspended, and radiation is terminated until a resume directive is received.

In addition to the automatic abort function there is provision for the MOC to send an *abort and suspend* directive to terminate command radiation immediately without waiting for completion of an element.

*f. Close window time override.* If a close-window time is specified in a file header element, and the Mission Operations Team later decides to extend the permissible time for radiation of that file, an *override* message can be sent (after the file becomes prime) which instructs the CPA to ignore the close window time.

## D. Data Records

All message blocks received by the CPA and all blocks sent from the CPA will be logged at the DSCC on the Original Data Record (ODR). In addition, the CPA has the capability to record a temporary ODR on disk if the ODR is disabled.

Message blocks from all complexes are recorded at the GCF central communications terminal (CCT). Command system message blocks from a Mission Operation Center to a DSCC are also recorded at the CCT.

The DSCC original data records and the CCT recording provide information for fault isolation in case problems occur in the Command System operation.

## IV. Subsystems Configurations for Mark IV-85 System

Planned modifications and reconfiguration of subsystems for the DSN Command System Mark IV-85 (and Mark IV-84) are summarized below.

### A. Antenna Mechanical Subsystem

At Canberra and Madrid all antennas will be located in the vicinity of the SPC. At Goldstone, the 64-meter antenna and the 9-meter antenna will be located near the SPC. The Goldstone 34-meter transmit-receive antenna will remain at the present DSS 12 (Echo Station) site, but control will reside at the SPC.

### B. Antenna Microwave Subsystem

For the 9-meter antenna, the microwave subsystem will provide uplink signal feed at S-band frequencies assigned for earth orbital missions (2025-2110 MHz). For one 34-meter antenna at each complex, the microwave subsystem will be required to handle S-band uplinks over the range of earth orbital and deep space missions (2025-2120 MHz). For the 64-meter antenna the microwave subsystem uplink capability will be unchanged (S-band 2110-2120 MHz).

The 9-meter and 34-meter antenna microwave subsystems provide selection of right or left circular polarization. The 64-meter antenna microwave subsystem provides selection of linear polarization or right or left circular polarization.

### C. Transmitter Subsystem

The 9-meter antenna will have a 10-kW transmitter operating in the earth orbital mission S-band frequency range. A 34-meter antenna will have a 20-kW transmitter operating over the range of earth orbital and deep space mission S-band frequencies. The 64-meter antenna will have 20-kW and 100-kW transmitters for the deep space mission S-band frequency range, as now.

### D. Receiver-Exciter Subsystem

An S-band exciter for the earth orbital frequency range will be provided for each 9-meter antenna. The DSN exciter for the 34-meter antenna will be upgraded to cover earth orbital and deep space mission S-band frequencies. The present DSN S-band exciter will be retained in the 64-meter antenna link.

Functions of the exciter include receiving the command-modulated subcarrier signal from the DSCC Command (DCD) Subsystem, phase-modulating that signal on the uplink carrier, returning a demodulated signal to the DCD subsystem for confirmation, and sending modulation on or off indications to the DCD subsystem.

### E. DSCC Command Subsystem

In the final Mark IVA Network configuration (in 1985), the DCD Subsystem in the SPC at each complex will be implemented as shown in Fig. 1. A new Command Switch Assembly (CSA) will permit any of the exciters to be connected to any of the Command Modulator Assemblies (CMA) under control of the Complex Monitor and Control console. New CMAs will be implemented to accommodate the Mark IVA mission support requirements. The CPAs will use existing Modcomp II-25 computers with core memory increased to maximum capacity. CPA software will be upgraded to satisfy new mission support requirements, to modify the CMA interface functions, and to provide required functions for interfacing with the new DSCC Monitor and Control Subsystems.

### F. DSCC Monitor and Control Subsystem

New equipment will be implemented for the DSCC Monitor and Control Subsystem (DMC) at each complex in the final Mark IVA Network configuration. Assignment of command equipment (antenna, transmitter, exciter, and command modulator-processor combinations) to a given "link," for each scheduled spacecraft pass or for a scheduled test, will be accomplished by the DMC along with telemetry and tracking equipment assignments. Prepass countdown will be controlled by inputs at the Link Monitor and Control Console.

The DMC will receive antenna pointing and uplink frequency predictions and will relay them to the appropriate subsystems. The DMC will send link status information to the CPA, and the CPA will send Command Subsystem status information to the DMC for link console displays and for incorporation into the monitor data that the DMC sends to the NOCC.

In the interim configuration, the Monitor and Control Subsystem will be limited to the existing Data System Terminal (DST) and Digital Information Subsystem (DIS) functions.

### G. GCF Subsystems

In the final Mark IVA Network configuration, the GCF Digital Communication (GDC) Subsystem will replace the present GCF High Speed Data and GCF Wideband Data Subsystems. Command data blocks will be communicated at a line rate of 56 kb/s, instead of the present 7.2 kb/s rate, between the Central Communications Terminal at JPL and the Area Routing Assembly at each DSCC.

At the Goldstone DSCC the GCF Intersite Analog Communications Subsystem will communicate the CMA output signal from the SPC to the DSS 12 exciter and the confirmation signal from the exciter to the SPC.

### H. NOCC Command Subsystem

The NOCC Command Subsystem (NCD) Real-Time Monitor (RTM) software will be upgraded to accommodate new destination codes, spacecraft identifiers, standards and limits tables and test command tables for the interim and final configurations. The NOCC Support Subsystem will be expanded to provide capability for Command System performance records and analysis and additional capacity for test command tables.

## References


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2. Yeater, M. L., and Herrman, D. T., "Networks Consolidation Program," in *The Telecommunications and Data Acquisition Progress Report 42-65,* pp. 19-24, Jet Propulsion Laboratory, Pasadena, Calif., Oct. 15, 1981.
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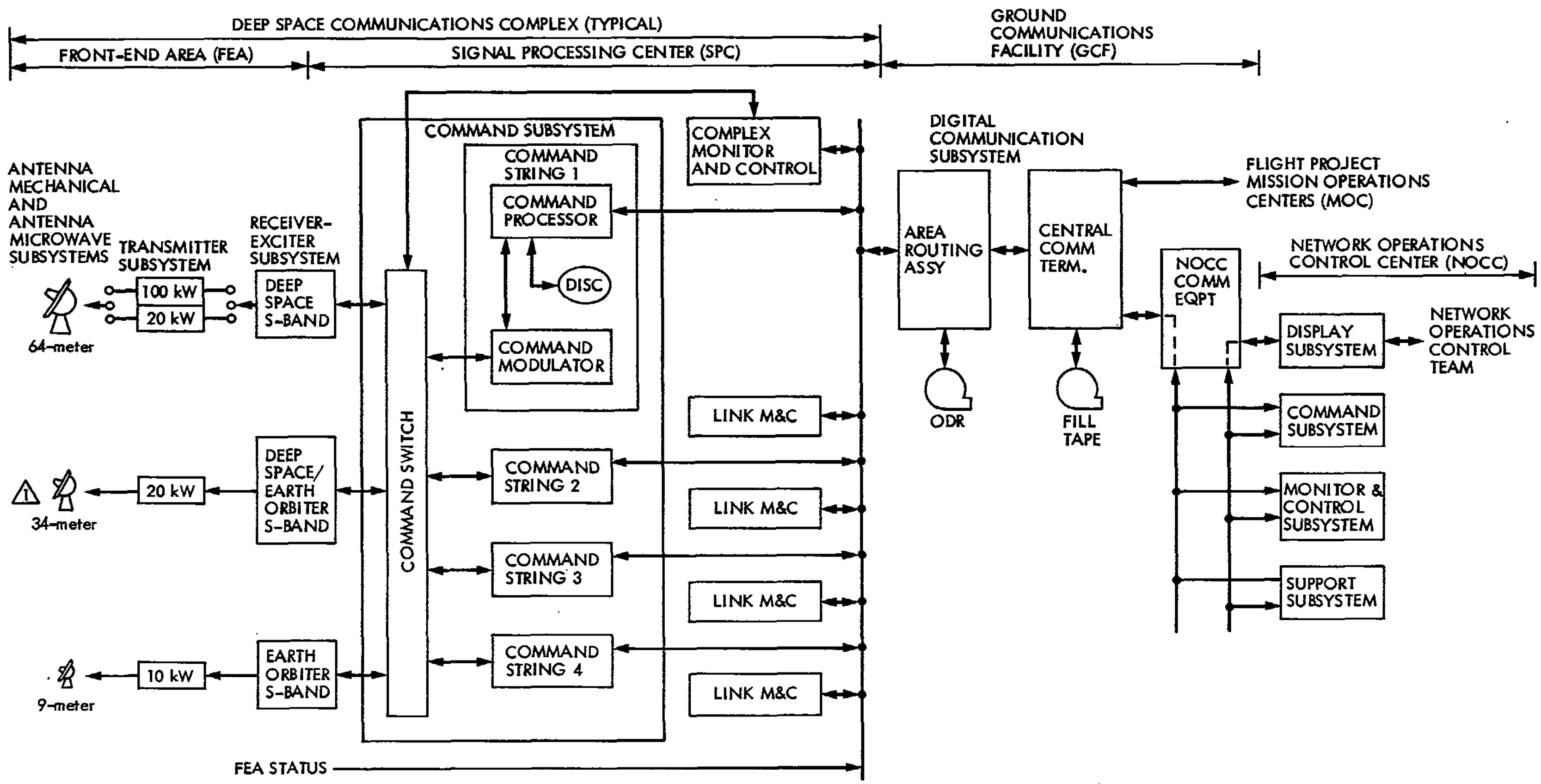
5. Thorman, H. C., "DSN Command System Mark III-78," in *The Deep Space Network Progress Report 42-49,* pp. 11-18, Jet Propulsion Laboratory, Pasadena, Calif., Feb. 15, 1979.




NOTE ⚠ AT GOLDSTONE DSCC THE SIGNALS TO/FROM FEA 12 FROM/TO SPC 10 COMMAND SWITCH ARE VIA GCF INTERSITE COMMUNICATION

**Fig. 1. DSN Command Subsystem Mark IV-85 block diagram**

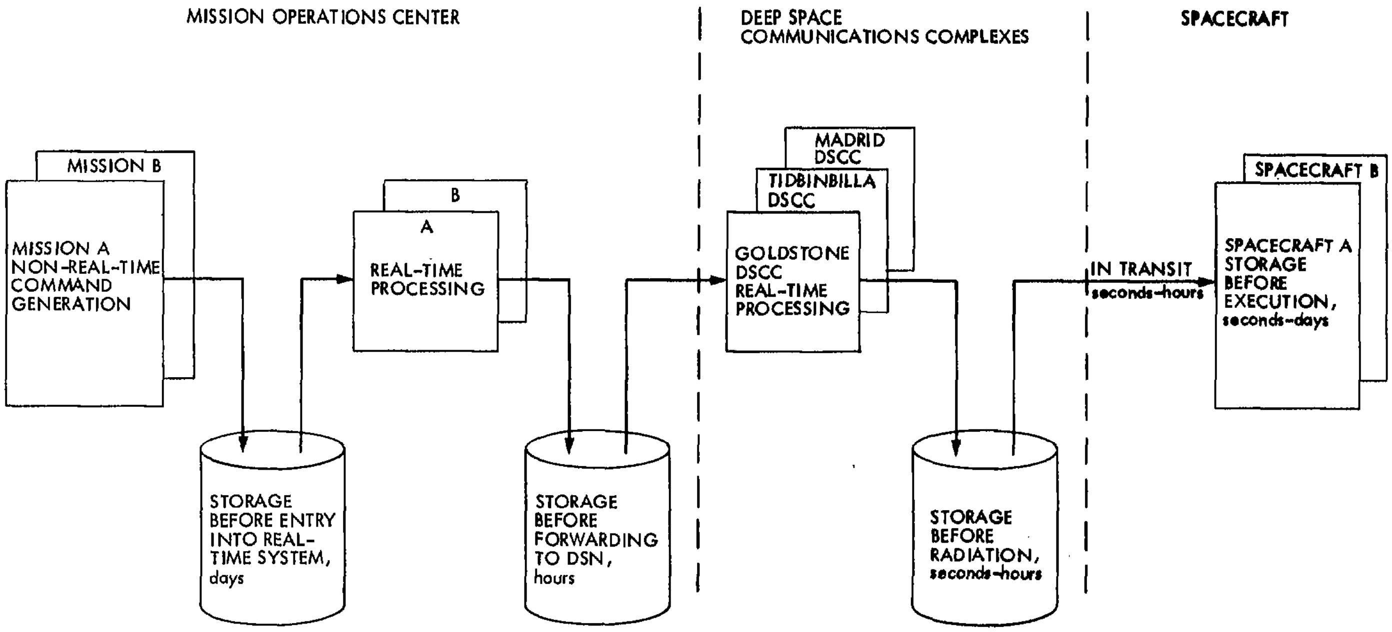
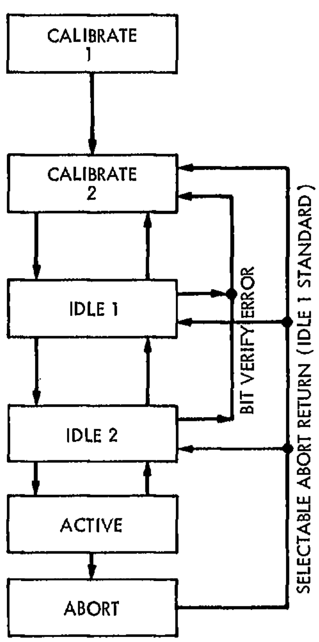



**Fig. 2. End-to-end command data flow—typical storage times**




| SUBSYSTEM MODE | PRIME PURPOSE | DATA ACCEPTED VIA HIGH SPEED | COMMENTS |
|---|---|---|---|
| CALIBRATE 1 | ALLOWS DSS OPS PERSONNEL TO PERFORM INITIALIZATION TASKS | CONFIGURATION, STANDARDS AND LIMITS, MODE CONTROL, RECALL | UPON RECEIPT OF A STANDARDS AND LIMITS AND CONFIGURATION HSD BLOCK, THE CALIBRATE 2 MODE WILL BE ENTERED |
| CALIBRATE 2 | STANDARD MODE FOR UPDATING STANDARDS AND LIMITS AND CONFIGURATION DATA VIA HIGH SPEED PRIOR TO SPACECRAFT ACQUISITION | CONFIGURATION, STANDARDS AND LIMITS, MODE CONTROL, RECALL | MULTIMISSION STANDARD PROCEDURES SHOULD STATE THAT THIS MODE IS TO BE ENTERED FOR CHANGING SUBCARRIER FREQUENCY, BIT RATE |
| IDLE 1 | SAFE MODE - CANNOT COMMAND. PROVISION FOR IDLE/ACQUISITION SEQUENCE. ALLOWS CONFIGURATION AND STANDARDS AND LIMITS TO BE CHANGED | CONFIGURATION, STANDARDS AND LIMITS, MODE CONTROL, RECALL | ALL STANDARDS AND LIMITS AND CONFIGURATION DATA PARAMETERS WILL TAKE IMMEDIATE EFFECT IN THIS MODE |
| IDLE 2 | ALLOWS ENTRY INTO ACTIVE MODE. PROVIDES IDLE/ACQUISITION SEQUENCE DURING COMMAND PERIODS | RECALL AND MODE CONTROL DATA ONLY | MODE CONTROL DATA CONTAINED IN THE COMMAND ELEMENT BLOCK |
| ACTIVE | COMMAND TRANSMISSION | RECALL AND MODE CONTROL DATA ONLY | |
| ABORT | PROVIDES ABORT INSTRUCTION TO CMA | RECALL AND MODE CONTROL DATA ONLY | |

NOTES: 1. COMMAND DATA MESSAGES WILL BE ACCEPTED IN ALL MODES
2. ALARM MESSAGES/ALARM DATA WILL BE TRANSMITTED TO THE MOC IN ALL MODES EXCEPT ABORT

**Fig. 3. DSCC Command Subsystem modes**