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EARTH OBSERVING SYSTEM (EOS) COMMON SPACECRAFT PROGRAM INTERFACE CONTROL DOCUMENT

BETWEEN THE EOS PM-1 SPACECRAFT
AND THE
EOS GROUND SYSTEM

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FIGURES

TABLES

SECTION 1. INTRODUCTION

1.1 PURPOSE

This Interface Control Document (ICD) defines and controls the communications data format interface between the EOS PM-1 Spacecraft and the EOS Ground System. This ICD documents the data formats for the EOS PM-1 Spacecraft and the on-board instruments, flight software command and telemetry formats under ground system control, and any command constraints that are imposed on the ground system by the spacecraft subsystems or the instruments.

This ICD does not cover the RF interface other than that presented herein. For additional RF information, reference the Radio Frequency Interface Control Document between EOS PM-1 Spacecraft (SC) and Spaceflight Tracking and Data Network (STDN), and the Radio Frequency Interface Control Document between EOS PM-1 Spacecraft and the EOS Polar Ground Station (EPGS) or Wallops Orbital Tracking Station (WOTS or WPS), reference section 2.2.1, documents 10 and 11.

This document does not cover implementation or operational procedures other than that defined herein. For additional implementation information, reference section 2.2.2, document 1.

This ICD does not provide detailed command and telemetry lists for the Spacecraft. The command and telemetry lists shall be contained in the PM-1 Command Allocation and PM-1 Telemetry Allocation Documents, reference section 2.2.2, documents 9 and 10..

When the term "shall" is used in this document, it is referring to a requirement on the Spacecraft or the Ground System, while the term "will" refers to descriptive material. Interface format requirements are traced to the General Interface Requirements Document (GIRD), reference section 2.1.1, document 1, the General Instrument Interface Specification (GIIS), reference section 2.1.1, document 2; EOS Common Spacecraft Specification, reference section 2.1.1, document 3, and the EOS PM-1 Contract End Item (CEI) Specification reference section 2.1.2, document 1.

The Spacecraft to Ground System End-to-End test shall verify requirements contained within this ICD.

1.2 INTERFACE IDENTIFICATION

Figure 1.2-1 depicts the EOS PM-1 connectivity.

The interface formats are consistent with the requirement of the Consultative Committee for Space Data Systems (CCSDS) standards. However, further definition may be required to establish relationships (if any) between CCSDS and EOSDIS Backbone Network (EBnet) data formats. This document is structured to identify EOS PM-1 selected options and requirements.

The spacecraft communications links are S-band and X-band. Commands are via S-band only. Command and Telemetry links may be active simultaneously. The data format will be Non-Return to Zero-Level (NRZ-L). The data formats described herein are valid for all science phases and Spacecraft states.

The S-band section of the Communications Subsystem provides primary telemetry and command (T&C) service to and from EPGS. The STDN Space Network (SN) provides primary tracking, SC clock correlation and support for special and emergency operations. In addition, the STDN Ground Network (GN) and Wallops Orbital Tracking Station (WOTS) provides back-up S-band support.

The X-band section of the Communication Subsystem provides the science and engineering data downlink for the EOS PM-1 common spacecraft. Three modes of operation are provided:

1) In the Direct Playback (DP) mode stored science and engineering data is transmitted, at 150 Mbps, to the two northern latitude EPGS playback stations (Alaska and Norway);
2) In the Direct Broadcast (DB) mode all real-time science and engineering data is broadcast, at 15 Mbps, to any receiving station with line of sight view provided that the SC is not configured for DP to EPGS; and,
3) In Direct Downlink (DD) mode all real-time science and engineering data is transmitted, (at 15 Mbps) to the playback station.

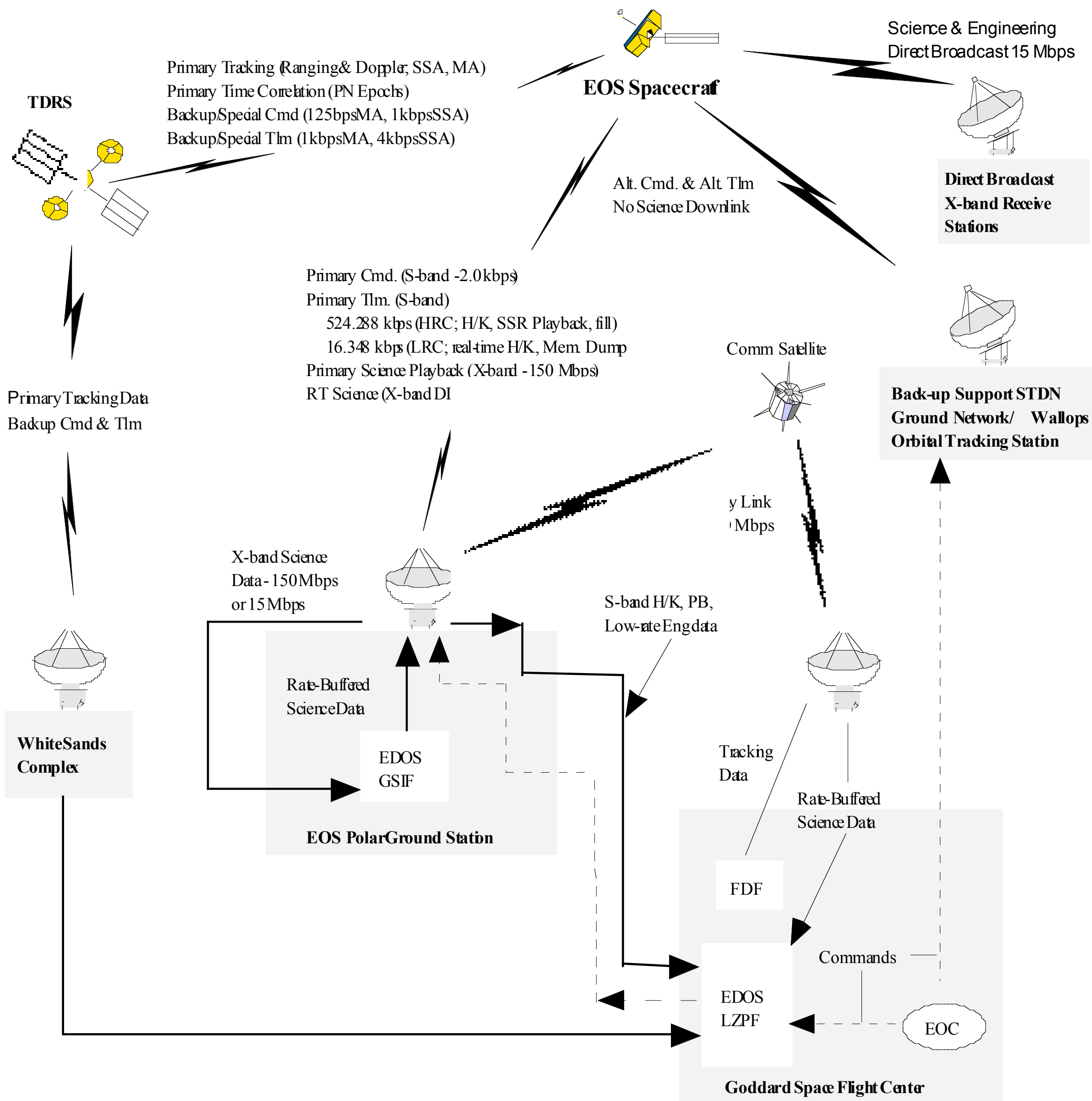


Figure 1.2-1. EOS PM-1 Connectivity

SECTION 2. DOCUMENTS

2.1 APPLICABLE DOCUMENTS

The following documents of the exact issue shown form a part of this ICD to extent specified herein. If no revision or date is specified, the latest issue of the applicable document shall apply. In the event of conflict between this ICD and the documents listed below, the documents below shall govern.

2.1.1 Government Documents

1. GSFC 422-11-12-01 General Interface Requirements Document (GIRD) for the EOS Common Spacecraft/Instruments, January 1994.
2. GSFC 420-03-02 General Instrument Interface Specification
3. GSFC 422-13-11-01 EOS Common Spacecraft Specification, August 1994.

2.1.2 Contractor Documents

1. SY1-0029 EOS Common Spacecraft Contract End Item (CEI) Specification.
2. D26468 EOS PM-1 Spacecraft Time Management

2.2 REFERENCE DOCUMENTS

The following documents are used for reference purposes only. These documents do not form a part of this ICD and are not controlled by their reference herein. In the event of a conflict between this ICD and documents listed below, this ICD shall govern.

2.2.1 Government Documents

1. CCSDS 101.0-B-3 Recommendation For Space Data Systems Standards; Telemetry Channel Coding, May 1992.
2. CCSDS 102.0-B-3 Recommendation For Space Data Systems Standards; Packet Telemetry, November 1992.
3. CCSDS 201.0-B-2 Recommendation For Space Data Systems Standards; Telecommand, Part 1, Channel Service, November 1995.
4. CCSDS 202.0-B-2 Recommendation For Space Data Systems Standards; Telecommand, Part 2, Data Routing Service, November 1992.
5. CCSDS 202.1-B-1 Recommendation For Space Data Systems Standards; Telecommand, Part 2.1, Command Operation Procedures, October 1991.
6. CCSDS 203.0-B-1 Recommendation For Space Data Systems Standards; Telecommand, Part 3, Data Management Service, January 1987.

7.	CCSDS 301.0-B-2	Recommendation For Space Data Systems Standards; Time Code Formats, Issue 2, April 1990.
8.	CCSDS 701.0-B-2	Recommendation For Space Data Systems Standards; Advanced Orbiting Systems, Networks and Data Links, Architectural Specification, November 1992.
9.	530-SNUG	Space Network (SN) User's Guide, Rev. 7, November 1995.
10.	450-RFICD-EOS PM-1/STDN	Radio Frequency Interface Control Document between EOS PM-1 Spacecraft and Spaceflight Tracking and Data Network (STDN).
11.	450-RFICD-EOS PM-1/EPGS/WPS	Radio Frequency Interface Control Document between EOS PM-1 Spacecraft and the EOS Polar Ground Stations (EPGS) and the Wallops Orbital Tracking Station (WPS).
12.	530-UGD-GN	Ground Network (GN) Users Guide, June 1993.
13.	531-TR-001	Users Spacecraft Clock Calibration System (USCCS) User's Guide, October 1991, NASA GSFC, Greenbelt, Maryland

2.2.2 Contractor Documents

1.	D22257	Spacecraft Operations Requirements Document (SORD), Revision A, July 22, 1997.
2.	D24843	Interface Control Document for the Atmospheric Infrared Spectrometer, (AIRS),
3.	D24844	Interface Control Document for the Advanced Microwave Sounding Unit 1, (AMSU-A1),
4.	D24845	Interface Control Document for the Advanced Microwave Sounding Unit 2, (AMSU-A2),
5.	D24846	Interface Control Document for the Clouds and Earths' Radiant Energy System, (CERES), Original, September 22, 1997.
6.	D24847	Interface Control Document for the Moderate Resolution Imaging Spectroradiometer, (MODIS), Original, July 07, 1997.
7.	D24848	Interface Control Document for the Advanced Microwave Scanning Radiometer, (AMSR)
8.	D24849	Interface Control Document for the Humidity Sounder of Brazil, (HSB)
9.	D25099	PM-1 Command Allocation Document
10.	D25100	PM-1 Telemetry Allocation Document
11.	SS6-0165	EOS PM-1 Spacecraft Communications Subsystem Specification
12.	SS6-0164	EOS PM-1 Spacecraft Command and Data Handling Subsystem Requirements Specification
13.	ES-SDA-001	EOS PM-1 Spacecraft Flight Software Requirements Specification

14. EQ4 -4951 EOS Common Spacecraft Equipment Specification for Formatter-Multiplexer/Solid State Recorder Unit (FMU/SSR)

15. EQ 4-4957 EOS PM-1 Spacecraft Equipment Specification for Transponder Interface Electronics

2.2.3 Other Documents

1. 34111515SRS Software Requirements Specification for the Earth Observing System Common Processors Startup ROM (SUROM), Computer Software Configuration Item (CSCI), Rev. A, Honeywell Inc., Feb. 19, 1998

2. 151840 MODIS Command, Telemetry, Science and Engineering Description, Santa Barbara Remote Sensing, May 1997.

SECTION 3. OVERVIEW

This section provides an overview of the PM-1 Spacecraft command and telemetry links as defined in Section 1.2 and the on-board Time Management system. The PM-1 Spacecraft C&DH subsystem components are shown in Figure 3-1.

3.1 SC CONTROLLERS

There are 4 controllers on the PM-1 spacecraft. Each controller is internally redundant and each controller has two processors that are redundant. One of the processors is designated as the on-line processor. It has control of that controllers secondary data bus. The other controller is off-line and it may be powered on (the CTC) or off (the PC, GN&C, and ISC). The Spacecraft controllers collect the engineering data, build the data packets for unpacketized data, and transmit data to the Transponder Interface Electronics (TIE), via the Primary Data Bus. The packets are also routed to the Solid State Recorder (SSR), via the Formatter/Multiplexer Unit (FMU), for formatting, storage, and playback. The TIE routes the engineering data packets to the FMU SSR for high rate S-band playback storage and to the S-band transponder for downlink to the ground. Science and engineering data are collected/formatted by the FMU and stored in the SSR for later playback or real-time broadcast to the ground. The sizes of the PM-1 Spacecraft controllers are defined in Table 3.1-1.

Table 3.1-1. Controller Sizes

Controller	Size
Command and Telemetry	768K Words of RAM 512K Words of EEPROM 16K Words of Prom 8K Words of I/O RAM
Instrument Support	256 Words of RAM 16K Words of Prom 8K Words of I/O RAM
GN&C	256K Words of RAM 16K Words of Prom 8K Words of I/O RAM
Power	256K Words of RAM 16K Words of Prom 8K Words of I/O RAM

3.2 COMMAND DESCRIPTION

Command data structures and associated format requirements and description are in Section 5.

3.2.1 Uplink Data Rates

The PM-1 Spacecraft Bus receives command data in accordance with the rates (which includes all CCSDS overhead) shown in Table 3.2.1-1.

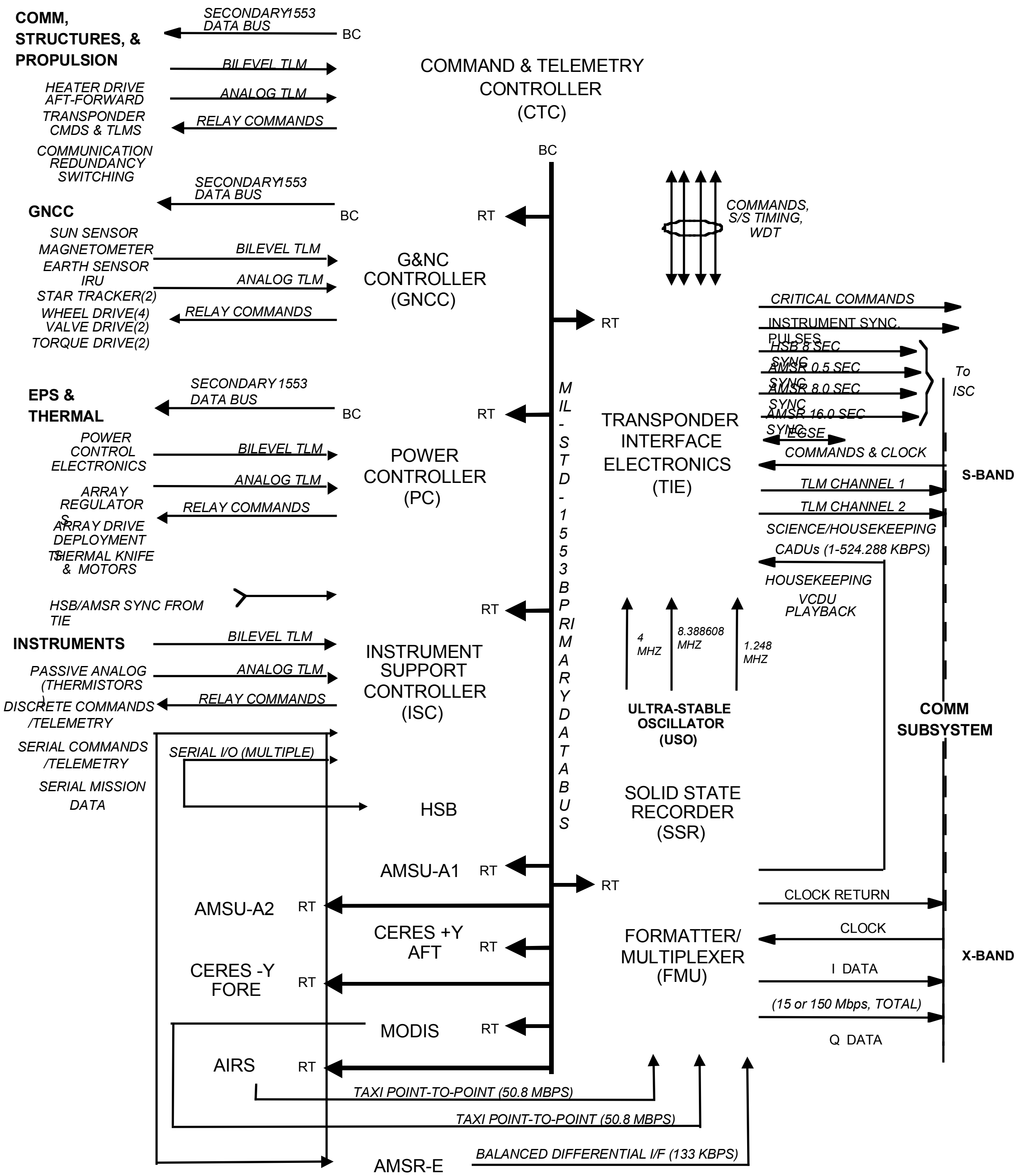


Figure 3-1. PM-1 C&DH Subsystem

Table 3.2.1-1. Command Links

External Interface	Spacecraft Omni Antenna[1]	Data Rate (bps)	Usage
TDRSS SSA	Zenith	1000	Command and Tracking
TDRSS SSA	Zenith	500	Command and Tracking
TDRSS SSA	Zenith	250	Command and Tracking
TDRSS SSA	Zenith	125	Command and Tracking
TDRSS MA	Zenith	125	Command and Tracking
GN & EPGS	Nadir	2000	Command and Emergency[2]

Note 1: For command and receive links Zenith and Omni antennae are coupled together.
Note 2: Only Doppler tracking is available through the ground station. Ranging is not available.

3.3 TELEMETRY DATA RATES

S-band engineering and X-band science data structures and associated format requirements are in Section 6. The return links are shown in Table 3.3-1.

The required science data formats for the instruments are specified in Section 2.1.1, documents 1 & 2. For more detailed format information refer to the specific instrument ICD, reference section 2.2.2, documents 2 -8.

In the STDN mode, S-band will utilize two simultaneous telemetry channels for direct downlink to the EPGS. The High Rate Channel (HRC) will carry the stored data at 524288 bits per second (bps). The Low Rate Channel (LRC) will carry the real-time data at 16384 bps.

For TDRS links, the I and Q channels will each have identical data. S-band downlink rates using TDRS will be 1024 bps or 4096 bps.

The Spacecraft can transmit simultaneously S-band engineering data and X-band science data transfers, but does not support simultaneous X-band DP and DB.

3.4 TIME MANAGEMENT

The ground portion of the EOS/PM-1 Spacecraft Time Management System uses the NASA User Spacecraft Clock Calibration System (USCCS) technique which is based on the TDRSS range epochs and the EOC Spacecraft Time Management Software (ESTMS). Reference Section 2.2.1, document 13.

The SC Time Management function maintains SC/GIRD time in CCSDS Unsegmented Time Code (CUC) format, (reference Figure 6.3.1-1), for use by the spacecraft and GIRD compliant instruments. The Time Management function also maintains time in the CCSDS Day Segmented Time Code (CDS), (reference Figure 6.4.7-1), for use by the GIIS compliant instruments (i.e., CERES and MODIS).

The TIE provides master clocks for Spacecraft/GIRD Time and GIIS Time. The Spacecraft/GIRD master clock is maintained as a 64-bit counter with a resolution of 476.8 ns. The GIIS Time master clock is maintained in the CDS format with a resolution of 1 μsec. The Flight Software Time Management function provides for adjustments to the master clocks, but does not provide for initialization of the master clocks. The ground has the capability to initialize the master clocks on the online and off-line TIE via direct commands to the TIE.

3.4.1 GIRD Clock Implementation:

GIRD time code data is in the CCSDS Unsegmented Time Code (CUC) format which is derived from the 64-bit spacecraft time (GIRD time-of-day master clock in the TIE). The lower 32 bit of the master clock is implemented in hardware design with 32-bit adder for time adjustment, and upper 32 bit is implemented in TIE firmware (in a memory location). The carry-over from the addition of a time delta to the lower 32 bit counter does not cause the upper 32 bit (stored in memory) to be incremented. The upper 32 bit is always jam loaded with correct time for time adjustment and update.

3.4.2 GIIS Clock Implementation:

GIIS time code data is in the CCSDS Day Segmented (CDS) time code format. It consists of μsec segment counter, msec segment counter and day segment counter. The μsec segment counter and the msec segment counter are implemented with the hardware design in the Time and Frequency Slice (TFS), and the day segment counter is implemented in TIE firmware (in a memory location).

The μsec segment counter ranges from 0 to 999. The μsec segment counter rollover increments the msec segment counter by one. The msec segment counter ranges from 0 to 86,399,999 (0 to 86,400,999 and 86,398,999 for leap seconds correction). The msec segment counter rollover increments the day segment in the TIE firmware.

The μsec segment counter provides an adder which allows user to add time delta of +1 to +499 for time forward and -1 to -500 for time backward. Negative time delta value are derived from (1000 - $|t_\Delta|$), where $|t_\Delta|$ is absolute time delta. Adjustment takes place at the next counter rollover following the adjustment command. Negative adjustment inhibits increment of the msec segment counter. The μsec segment counter ignores time delta values other than [0 to 999].

The msec segment counter provides a parallel fast forward counter which allows the user to advance the msec segment counter forward. Allow 22 seconds for the fast forward operation and 22,000 msec shall be added to the time delta value. For example, 27,400-time delta shall be provided to the fast forward counter for 5400-msec time delta adjustment.

3.4.3 Time Correlation Telemetry

Time correlation data will be available to the ground within a telemetry packet. The time correlation telemetry packet will contain:

- GIRD & GIIS "ARM" time;
- GIRD & GIIS "EPOCH" time;

- Virtual Channel Sequence Count number (mod 16) which "ARM the EPOCH registers in the TIE.

Table 3.3-1. Telemetry Downlink

Return Link Service	Spacecraft Antenna	Downlink Rate		Usage
		I	**Q**	
Direct Playback (DP)	X-Band	75 Mbps	75 Mbps	Stored data (science and engineering) to EPGS . Effective Rate = 150 Mbps
Direct Broadcast (DB)	X-Band	7.5 Mbps	7.5 Mbps	All real-time data (science and engineering) to Direct Broadcast ground stations. Effective Rate = 15 Mbps
Direct Downlink (DD)	X-Band	7.5 Mbps	7.5 Mbps	All real-time data (science and Engineering) to EPGS Effective Rate = 15 Mbps
TDRSS MA	S-Band Zenith Omni	1.024 kbps	1.024 kbps	Selected real-time data (engineering or diagnostic) or processor data dump. Data Identical and synchronous on I & Q channels.
TDRSS SSAR	S-band Zenith Omni	4.096 kbps	4.096 kbps	Selected real-time data (engineering or diagnostic) or processor data dump. Data Identical and synchronous on I & Q channels.
TDRSS SSAR	S-band Zenith Omni	1.024 kbps	1.024 kbps	Selected real-time data (engineering or diagnostic) or processor data dump. Data Identical and synchronous on I & Q channels
		LRC	**HRC**	
EPGS/STDN/ WOTS S-Band	S-Band Nadir Omni	16.384 kbps	524.288 kbps	LRC = Real-time Engineering Data HRC = Stored Engineering or Processor Data Dump

SECTION 4. SYSTEM ARCHITECTURES

EOS PM-1 SC requirements, SC states, and subsystem operating modes may be found in the Contract End Item Specification, reference section 2.1.2, document 1, and the respective subsystem specifications.

RF interfaces shall be as defined in the Radio Frequency Interface Control Document between the EOS PM-1 Spacecraft and the Spaceflight Tracking and Data Network (STDN), and between the EOS PM-1 Spacecraft and the EOS Polar Ground Station (EPGS) /WPS reference section 2.2.1, documents 10 & 11.

Command and Data Handling (C&DH) interfaces and SC timing control interfaces shall be as defined in section 2.2.2, document 12.

Operational requirements for the SC, subsystem, and ground operations are as defined in section 2.2.2, document 1.

Flight Software requirements and description are defined in Section 2.2.2, document 13.

SECTION 5. UPLINK COMMAND DATA TRANSFER FORMATS

This section details the requirements for the uplink command data transfer formats and structures.

Additional information regarding the CCSDS formats may be found in Section 2.2.1 documents 1 - 8.

Additional SC Flight Software detail and content may be found in Section 2.2.2, document 13.

Additional SUROM information, command format and content may be found in Section 2.2.2, document 13 and Section 2.2.3, document 1.

For Instrument format and content, Reference Section 2.2.2, documents 2-8, (Instrument specific) and Section 2.2.3, document 2 (MODIS specific).

For additional information regarding the CCSDS Time Management formats and detail, Reference Section 2.2.1, document 7. For additional information regarding the SC Time Management formats and detail, Reference Section 2.1.2, document 2.

5.1 GENERAL COMMAND CHANNEL STRUCTURE AND PROCESSING

Command messages contain user data formatted per user specification and are contained within the telecommand data packet. The command packet is described later in this section. Commands shall be compatible with the Forward Link Service which uses the format recommended by the Consultative Committee for Space Data Systems (CCSDS).

The Command Processing function within the on-board CTC provides for the reception, decoding, distribution and execution of commands received from the ground or from on-board Stored Command Sequences (SCS). Commands received from the ground are in the form of CCSDS Telecommand Packets and commands received from the SCSs are in their raw form.

Ground commands are transmitted, via S-band, to the spacecraft in Command Link Transmission Units (CLTUs). Embedded in the CLTU are 64-bit codeblocks. The Codeblock Processor within the Transponder Interface Electronics (TIE) is responsible for processing the CLTU and validating each of the embedded codeblocks. TIE critical commands are transferred via Type "BD" Transfer Frames to the TIE Relay Slice for processing. Prior to passing the codeblocks to the online CTC, via the LSIO I/F, the TIE replaces the embedded Error Control bits with a control code. The control code designates whether the codeblock is the first one in the CLTU following the Start Sequence that does not contain a TIE Critical Command, or if the codeblock is a continuation of the current CLTU.

The CTC will initially execute from the Start-Up ROM (SUROM) during power-up/reset. If EEPROM FSW autoload is not selected, SUROM FW goes into command and telemetry loop waiting for SUROM commands from the ground. If selected for EEPROM FSW autoload, SUROM FW loads the FSW image to the CTC. When completed, SUROM transfers control to the FSW. The CTC will now accept SC normal commands and SUROM commands

The Flight Software (FSW) within the online CTC assembles the codeblocks into Transfer Frames. The Transfer Frames are validated using the Frame Acceptance and Reporting

Mechanism-1 (FARM-1) protocol, which is the receiving end of the Command Operation Procedure-1 (COP-1) protocol as defined by the Consultative Committee for Space Data Systems (CCSDS). The FARM-1 protocol accepts or rejects the Transfer Frames based on 3 predetermined states and 11 defined event conditions.

SC normal commands, designated by VCID 0 or 1, are sent directly to the command-processing portion of the CTC. CTC specific commands are processed within the CTC. The online CTC assembles valid Transfer Frames into CCSDS Telecommand Packets. The online CTC processes the packets based on the APID contained in the packet header. When the APID indicates a destination that supports CCSDS Telecommand Packets, the packet is routed to its intended destination for further processing. This includes Telecommand Packets destined for any of the spacecraft controllers (GNCC, PC, and ISC) and the AIRS, AMSU-A1, AMSU-A2, HSB, and CERES+Y Aft, CERES-Y Fore instruments. RT commands on the primary data bus, (i.e., commands designated for the off-line CTC, PC, GNCC, or the ISC controllers), are transferred from the CTC to the RT as a normal SC command via the Primary Data Bus. RT SUROM commands are transferred from the CTC to the RTs' SUROM processing via SC Type 1 and Type 2 commands. Non-packetized commands, (i.e., TIE, FMU/SSR, and the MODIS instrument), the command data is extracted from the packet and routed to its intended destination for further processing. Finally, when the APID indicates that the online CTC is the destination, the command data is extracted from the packet and processed accordingly. Figure 5.1-1 depicts the SC command flow. The two SC command pathways (Normal and Critical) are shown in Figure 5.1-2.

The uplink command data transfer format shall comply with the format recommended by the CCSDS. Figure 5.1-3 shows the PM-1 application of the CCSDS Telecommand (TC) protocol layers and the associated data structures. Figure 5.1-3 starts with the CLTU and Codeblock and removes the various CCSDS required format structures as the data moves to the next higher CCSDS TC protocol layer.

By CCSDS convention all fields which are not used in the CCSDS standard data structures and all fields marked spare or reserved are filled with zeroes.

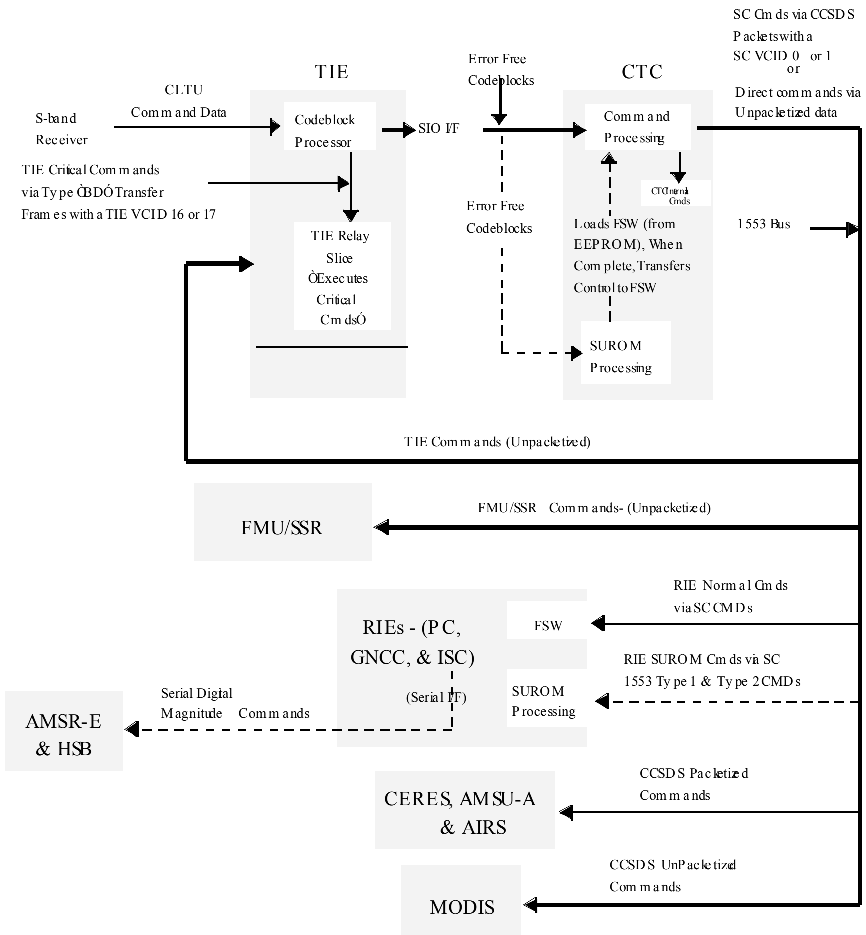


Figure 5.1-1. SC Command Flow

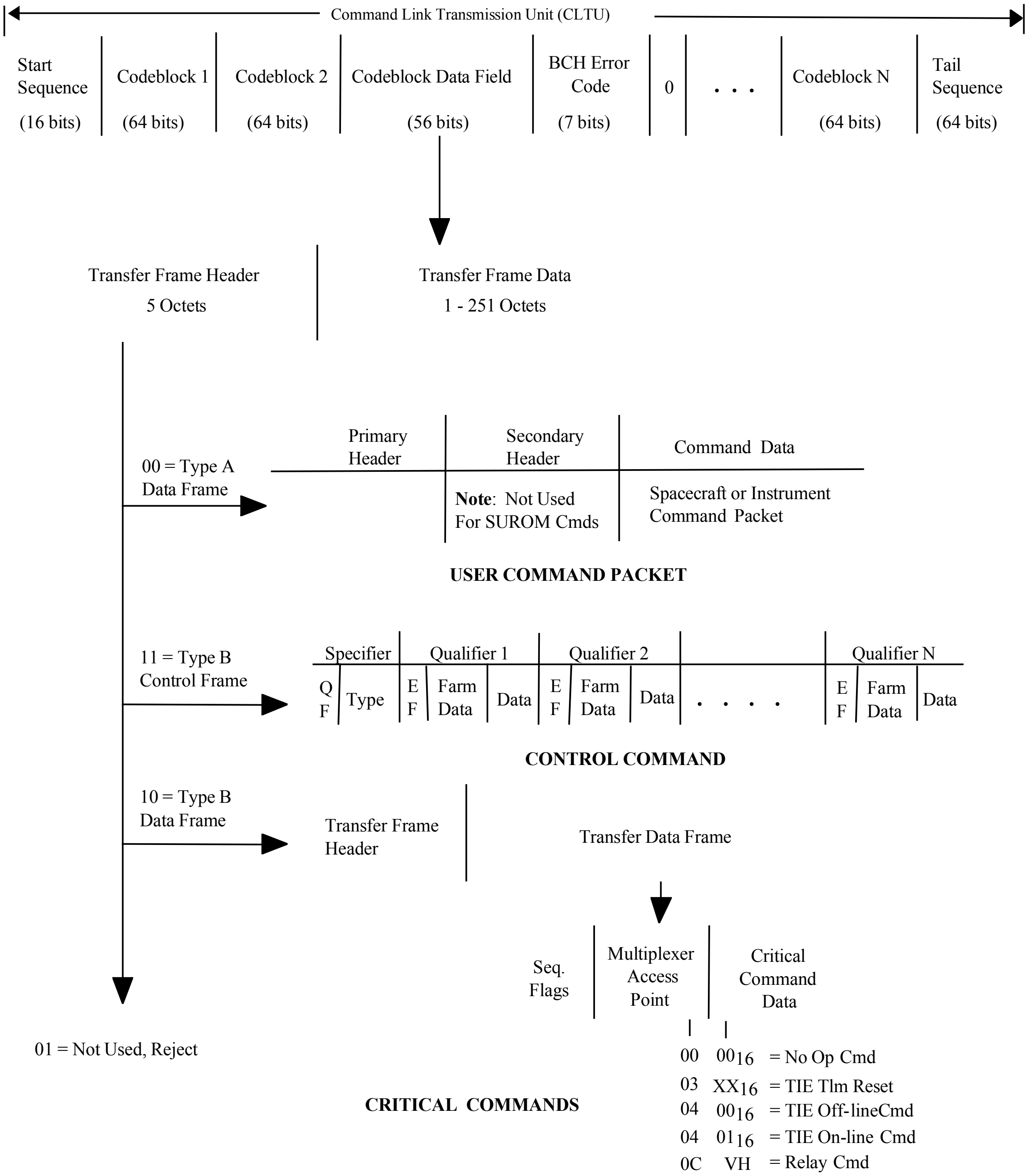


Figure 5.1-2. SC Command Pathways

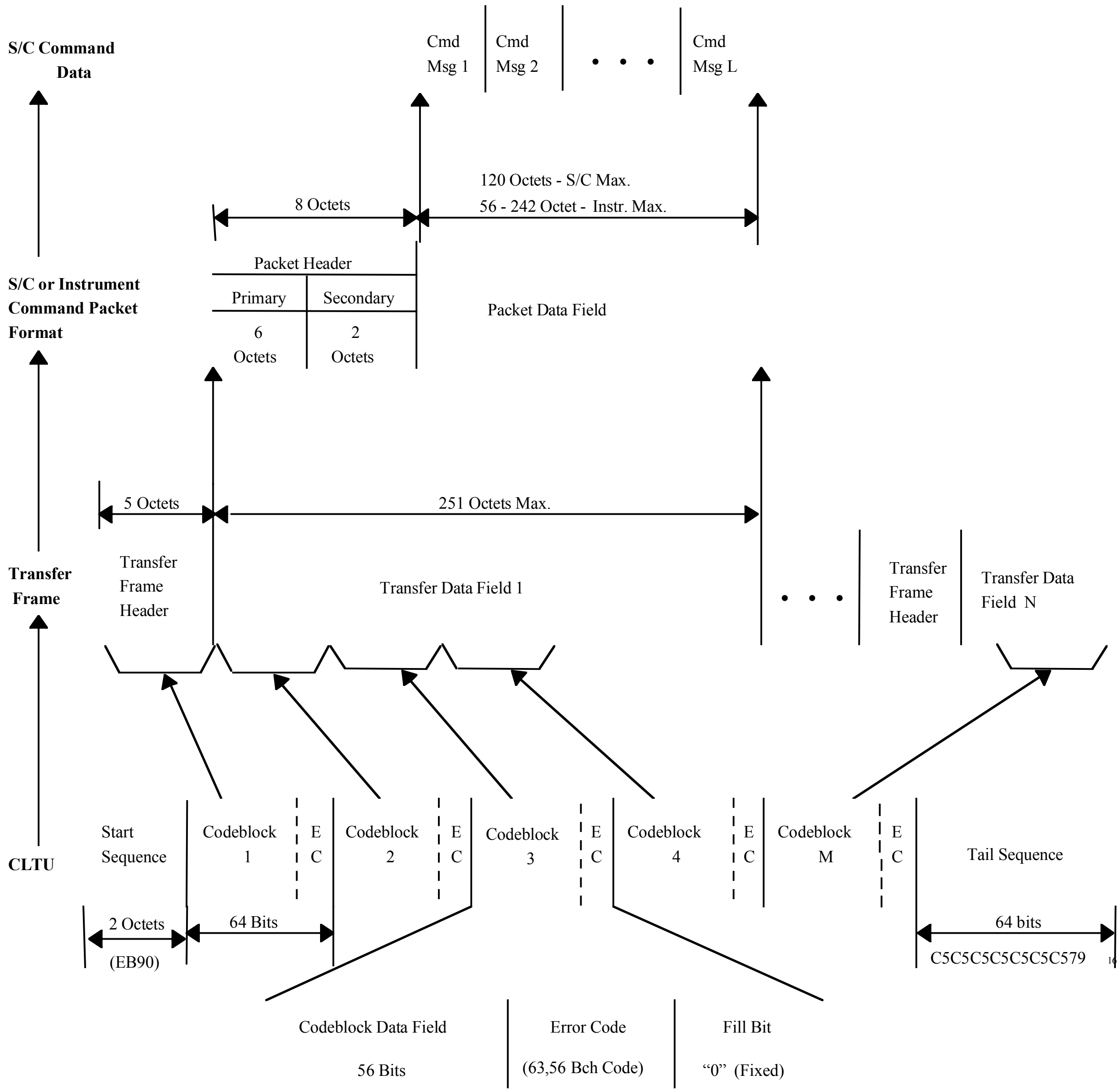


Figure 5.1-3. SC Command Data Structure

5.1.1 Command Link Transmission Unit

Ground commands are transmitted to the PM-1 SC in the form of CLTUs, defined in Figure 5.1.1.3-1.

5.1.1.1 RF Acquisition Lock

An acquisition sequence as defined by the CCSDS is a specific high transition density bit pattern transmitted to permit the receiving end to acquire symbol synchronization. To ensure that RF lock is attained with the PM-1 SC receiver, an acquisition sequence shall be appended to each

CLTUs' start sequence (EB90), prior to forwarding the command on to the SC. The PM-1 acquisition shall have the following characteristics:

Pattern shall be alternating ones (1's) or zeros (0's), starting with a one,
The pattern shall be a minimum of 128 bits in length; and
No idle pattern is required following the tail sequence of an CLTU. However, the ground may use an idle pattern if desired with no impact to the SC.

The detection of the symbol synchronization by a transponder detect lock = true. Whenever the symbol synchronization is dropped, the acquisition sequence shall be transmitted again if re-acquisition is desired.

5.1.1.2 TIE Receiver Lock

The TIE only processes valid codeblocks. To ensure that all commands sent are received and processed the ground shall send a CLTU containing a critical NOP command, defined in Figure 5.1.1.2-1 prior to sending a CLTU. The TIE to select a receiver such that subsequent CLTUs would be accepted without the incidence of Receiver switchover would use NOP CLTUs. The NOP Codeblock is processed and increments the TIE Critical command counter (mod 8). The count will be and included in telemetry.

Start Sequence	Critical NOP Codeblock	Tail Sequence

Where:

Start Sequence = 16 bit, $EB90_{16}$
Critical NOP Codeblock (if TIE A on-line) = 209A 4006 00C000 $9E_{16}$ or
(if TIE B on-line) = 209A 4406 00C000 22_{16}
Tail Sequence = 64 bit, C5C5 C5C5 C5C5 $C579_{16}$

Figure 5.1.1.2-1. NOP Codeblock Format

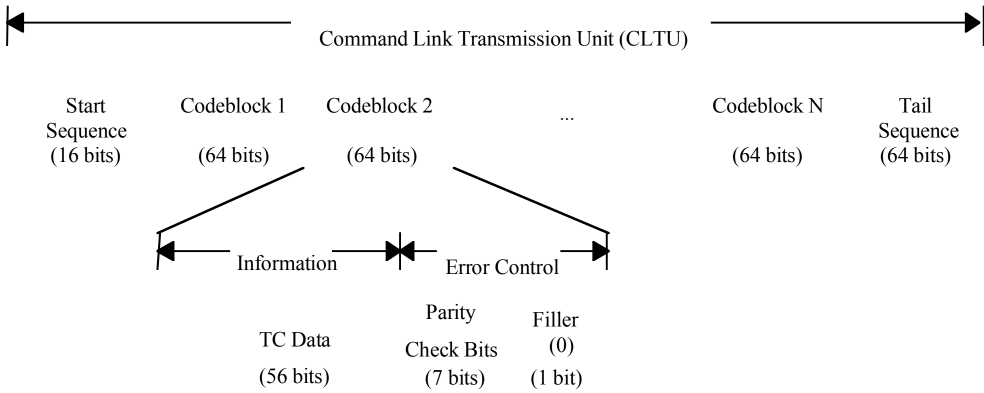
Therefore, for the PM-1 SC each CLTU shall be formatted as shown in Figure 5.1.1.2-2.

RF Acq. Seq.	Start Sequence	Critical NOP Codeblock	Tail Sequence	SC CLTU
128 bits	16 bits	64 bits	64 bits	

Figure 5.1.1.2-2. SC CLTU Sequence Pattern

5.1.1.3 SC CLTU Format

The CLTU will consist of a 16 bit Start Sequence, N Codeblocks, and a 64 Bit Tail Sequence. A codeblock consists of 56 bits of data, 7-check bits (which allow double bit errors to be detected) and a single fill bit as defined in Figure 5.1.1.3-1.



Command Link Transmission Unit:

1. Start Sequence: $EB90_{16}$
2. Tail Sequence: C5C5 C5C5 C5C5 $C579_{16}$

Codeblock:

1. Information: Contains up to 56 bits of telecommand data. When the telecommand data does not fit exactly within an integral number of Codeblocks, the last octet(s) of the last Codeblock in the CLTU may contain fill bits. The fill bits are a sequene of alternating ones and zeroes, starting with a zero (i.e., 55_{16})
2. Error Control: These bits are processed by the TIE and are used to validate the Codeblocks contained within the CLTU. The Parity Check Bits are based on a BCH code. The filler is always zero. The TIE replaces these bits with the following Control Codes before passing the Codeblock on to the online CTC for further processing:
   a. 54_{16} when the Codeblock is the first one following the Start Sequence that does not contain a TIE Critical Command
   b. AB_{16} when the Codeblock is a continuation of the current CLTU.

Figure 5.1.1.3-1. CLTU Format

5.1.2 Transponder Interface Electronics Commanding

The TIE is responsible for processing the CLTU and validating each of the embedded codeblocks. TIE critical commands, (i.e., those transfer frames with a VCID of 16 or 17), are transferred to the TIE Relay Slice for processing. The TIE replaces the embedded Error Control bits with a control code designating whether the codeblock is the first one in the CLTU following the Start Sequence that does not contain a TIE Critical Command, or if the codeblock is a continuation of the current CLTU.

5.1.2.1 TIE Commands

Each TIE, in either active or standby operational state, can receive commands from the ground.

There are two modes of commands for the TIE: 1) Critical or Configuration commands and 2) Normal commands. These are described below.

5.1.2.1.1 TIE Critical Commands

TIE critical commands are embedded in the Transfer Frame and are designated a critical command when the Transfer Frame header VCID field contains a 16 or a 17. and will be acted upon internal to the TIE. The TIE supports the reception and execution of 3 types of critical transfer frames as shown in Figure 5.1.2.1.1-1. Each transfer frame shall contain only one of the following critical commands:

1) Non-Operation commands
2) TIE Configuration Commands
3) Critical Relay Commands are those commands that control specific functions within the SC on-board controllers.

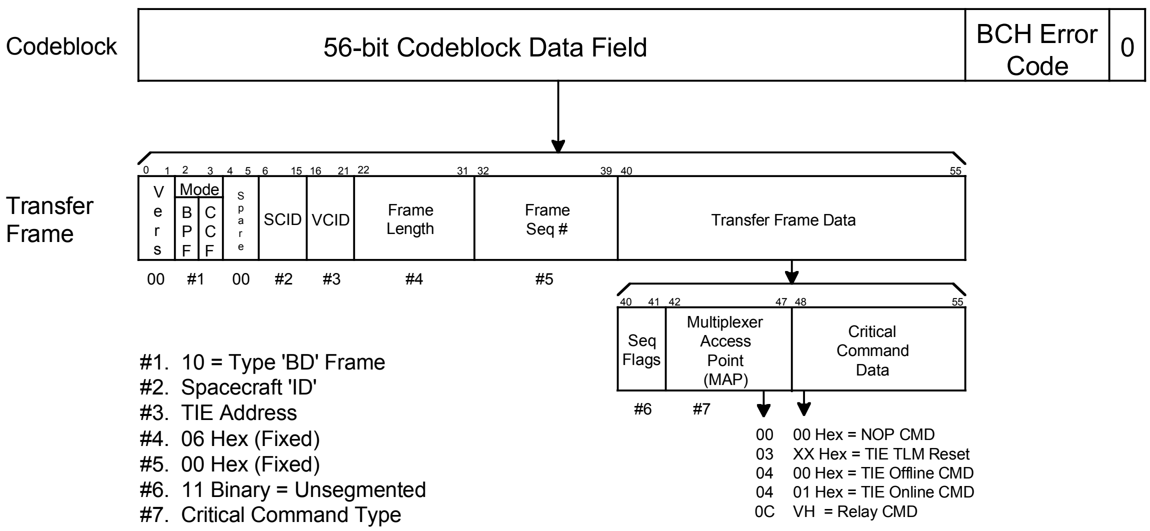


Figure 5.1.2.1.1-1. TIE Critical Command Format

5.1.2.1.1.1 Non-Operation Commands

The TIE shall provide the capability to perform Non-Operation (NOP) commands as shown in Figure 5.1.2.1.1-1. The NOP shall not result in a change to the SC function or configuration.

5.1.1.1.1.2 TIE Configuration Commands

There are three types of configuration commands:

a). TIE Disable is that command that results in the on-line (command executing side) TIE to go off-line and the off-line TIE to come on-line.
b). TIE Enable is that command that results in the off-line TIE to come on-line.
c). TIE Reset is that command that forces the TIEs' Telemetry Processor MicroController to re-start from a Zero state, all activity prior to the Reset command will be lost as the TIE is re-initialized.

5.1.1.1.1.3 TIE Critical Relay Commands

Critical Relay Commands are those commands that control specific functions within the SC on-board controllers. A total of 64 different relay commands are required to control all 32 relays. The particular relay to be commanded is addressed via the value of the V and H bits of the critical transfer frame critical command data field. TIE Critical Relay Commands shall be addressed as shown in Figure 5.1.2.1.1-1.

5.1.2.1.2 TIE Normal Command Structures

TIE normal commands are those commands with a VCID address not equal to 16 or 17. The codeblocks are passed through the TIE to the CTC that converts them into directives for execution by the various SC functions. The TIE is capable of executing various types of directives. Examples of TIE directives include: adjusting the TIE master clock, changing VCDU fill patterns, other telemetry system parameters. A TIE directive shall consist of a destination, a descriptor and 1 or more data words. The TIE "generic" directive format is shown in Figure 5.1.2.1.2-1.

	15 – 13	12 – 8	7 – 4	3 – 0
Header 1	Cmd Destination	Unused	Data Word Count	Unused

	15 – 0
Header 2	Destination Physical Address
Data 1	Data
• • •	
Data 16	Data

Figure 5.1.2.1.2-1. TIE Primary Data Bus Command Format

5.1.2.1.3 TIE Command Rate Constraints

The maximum command rate to the TIE is one command per 125msec. The actual command rate can vary based on processing time for individual TIE commands, however, the TIE will reject a new command if the previous command has not finished processing.

5.1.3 SUROM Commanding

SUROM software is entered from processor power-up or a reset. The SUROM software checks an external signal to determine whether to perform a cold start or warm start. If the signal indicates a cold start, SUROM software performs memory initialization. If the signal indicates a warm start, SUROM software performs memory initialization only to pages used by the SUROM software and disables the secondary 1553 chip. The SUROM software will then verify processor health and perform processor and IO initialization. The primary health tests are run to verify the health of the processor. The IO devices (SIO and Primary Data Bus) will be initialized. When SUROM software has completed its initialization and test, an external auto load signal is read. If the signal indicates auto load, it will check for the Random Access Memory (RAM) Test flag. If the flag is true, it will perform RAM test. EEPROM is then moved to memory and control is transferred to flight software. If the signal indicates no auto load, it checks the EEPROM physical memory location for the autoload flag. If the flag is true, it will check the physical memory location for the RAM Test flag. If the flag is true, it will perform RAM test. It then performs autoload and transfers control to the flight software. If the flag indicates no autoload, SUROM waits for commands to be received via the Primary Data Bus or SIO interface. Telemetry data will be presented to the SIO and Primary Data Bus interfaces for continuous transmission as detailed in Section 6.

The SUROM provides processing for the following commands:

- Load SRAM
- Run Secondary Tests
- Jump to Application
- Load SRAM from EEPROM
- SRAM Dump
- Load EEPROM
- EEPROM Dump

The SUROM Command Structure is shown in Figure 5.1.3-1.

5.1.3.1 SUROM Command Packet

SUROM commands are CCSDS packetized by the ground system prior to sending to the SC as shown in Figure 5.1.3.1-1. The SUROM packet size is 126 octets. When the CTC Flight Software (FSW) is running, non-CTC SUROM commands can be routed to the respective controllers via the primary data bus. SC Type I and Type II commands are used for sending commands to the non-CTC controllers that are in SUROM mode.

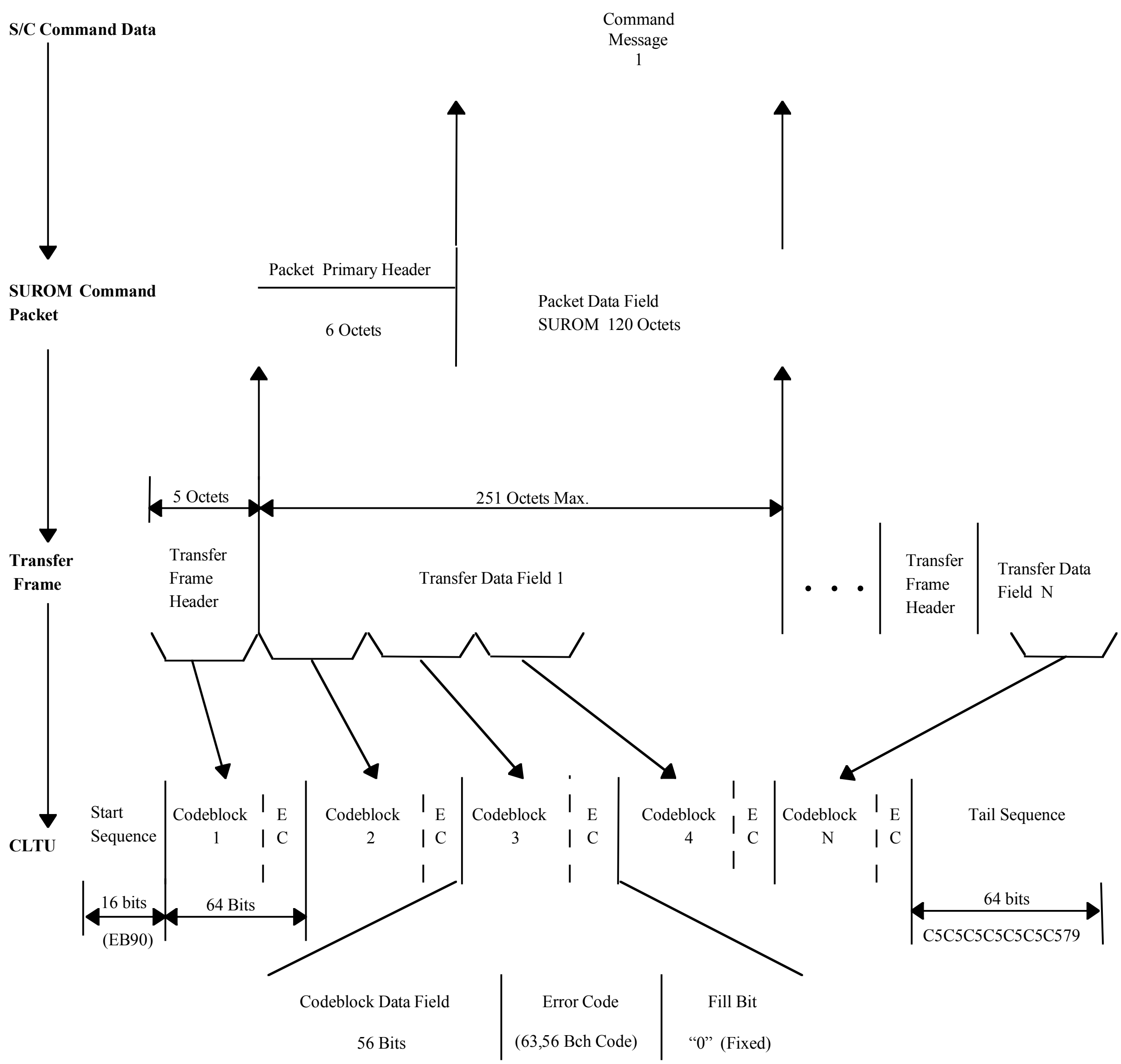


Figure 5.1.3-1. SUROM Command Structure

Packet Identification				Packet Seq Control		Packet Length	SUROM Data Zone
Version #	Type	Sec Header Flag	APID	Seq Flag	Packet Seq Count		SUROM Command Data
3 bits	1 bit	1 bit	11 bits	2 bits	14 bits	16 bits	16 - 960 bits

Notes:
1. Version #: 000
2. Type: 1 (TC Packet)
3. Secondary Header Flag: 0, No secondary header present
4. APID: 463 - Identifies the packet as a SUROM packet
5. Sequence Flag: 11 (Unsegmented)
6. Packet Sequence Count: Not used
7. Packet Length: Total number of Octets in the data zone minus one. Valid range is 1 - 119 Octets.
8. Secondary Header: N/A for SUROM
9. SUROM Data Field: Contains up to 120 Octets (60 16-bit words). Bits are left justified.

Figure 5.1.3.1-1. SUROM TC Packet Format

5.1.3.1.1 Commands - LSIO Interface

The TIE receives LSIO data in CCSDS format. The TIE routs SUROM commands to the CTC via the LSIO. The format of the LSIO commands defined in Figure 5.1.3.1.1-1 is presented with the CCSDS formatting removed.

MSB	0 – 11	12 – 15
1	ppp	Cmd1
2	offset	
3	word_cnt	
4	checksum	
5	data_word (1)	
	•	
	•	
	•	
word_cnt+4	data_word (word_cnt)	

Cmd1 = Command 1 Load SRAM = 1

Ppp = physical page which specifies where data is to be loaded
Offset = starting location offset from physical page (≤4095)
word_cnt = number of data words in this command (≤4096)
checksum = checksum of words 5 through word_cnt+4
data_word 16-bit data words

Note: If word_cnt and offset cause data_word(s) to exceed the number of words in the specified ppp, the command will be rejected and notification of error placed in telemetry.

Figure 5.1.3.1.1-1. SUROM LSIO Interface Command Formats

MSB	0 … 11	12 … 15
1	000	Cmd2

Cmd2 Command 2 Run Secondary Tests = 2

MSB	0 … 11	12 … 15
1	opr	Cmd3
2	Ipr	

Cmd3 Command 3 Jump to Application = 3
Opr operand page register 0 value group 0
ipr instruction page register 0 value group 0

MSB	0 … 11	12 … 15
1	ppp	Cmd4
2	offset	
3	Retries	

Cmd4 Cmd 04 Load SRAM from EEPROM = 4
ppp physical page load map resides in
offset offset from 0 load map starts
retries number of times to attempt load

MSB	0 … 11	12 … 15
1	ppp	Cmd5
2	Offset	

Cmd5 Command 5 Memory Dump = 5
ppp physical page to start dump
offset starting location offset from physical page ($\leq$4095)
Note: If offset causes the 32-word dump to exceed the number of words in the specified ppp, the additional words shall be taken from the next sequential physical page.

MSB	0 … 11	12 … 15
1	ppp	Cmd6
2	offset	
3	word_cnt	
4	checksum	
5	data_word (1)	
	•	
	•	
	•	
word_cnt+4	data_word (word_cnt)	

Cmd6 Command 6 Load EEPROM = 6
ppp physical page which specifies where data is to be loaded
offset starting location offset from physical page ($\leq$4095)
word_cnt number of data words in this command ($\leq$4096)
checksum checksum of words 5 through word_cnt+4
data_word 16-bit data words
Note: If word_cnt and offset cause data_word(s) to exceed the number of words in the specified ppp, the command will be rejected and notification of error placed in telemetry.

Figure 5.1.3.1.1-1. SUROM LSIO Interface Command Formats (Cont'd)

MSB	0 11	12 15
1	ppp	Cmd7
2	Offset	

Cmd7 **Command 7 EEPROM Dump = 7**
ppp physical page to start dump
offset starting location offset from physical page (≤4095)

Note:
If offset causes the 32-word dump to exceed the number of words in the specified ppp, the additional words shall be taken from the next sequential physical page.

Figure 5.1.3.1.1-1. SUROM LSIO Interface Command Formats (Cont'd)

5.1.3.1.2 SUROM Primary Data Bus Command Formats - Generic

The generic SUROM command data structure sent via the Primary Data Bus interface is shown in Figure 5.1.3.1.2-1 and defined in subsequent paragraphs. Each SUROM command (subaddress 1) may contain from one to five (1-5), command words inclusive. The "Load SRAM and Load EEPROM" SUROM command data structure sent via the Primary Data Bus interface is comprised of the data structure shown in Figure 5.1.3.1.2-1 and followed by up to 32 16-bit words (subaddress 2) of data as shown in Figure 5.1.3.1.2-2.

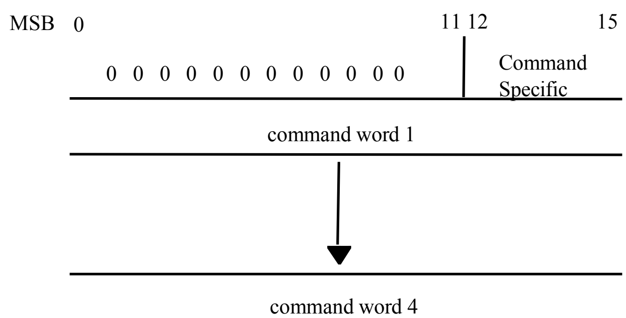


Figure 5.1.3.1.2-1. SUROM Command Format - Generic

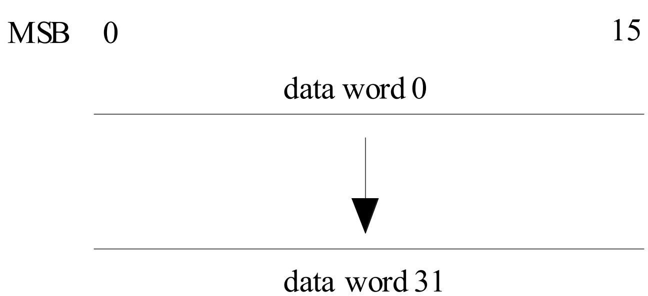


Figure 5.1.3.1.2-2. SUROM Command Data Format - Generic

5.1.3.1.3 SUROM Commands - Primary Data Bus (1553B) Interface

The SUROM Primary Data Bus commands are defined in Figure 5.1.3.1.3-1.

MSB	0 … 15
0	Cmd1
1	ppp
2	offset
3	word_cnt
4	Checksum

Subaddress 1

Cmd1	**Command 01 Load SRAM = 1**
ppp	physical page which specifies where data is to be loaded
offset	starting location offset from physical page (≤4095)
word_cnt	number of data words in this command (≤4096)
checksum	checksum of all data words received in subaddress 2

MSB	0 … 15
0	data_word 0
	•
	•
	•
31	data_word 31

Subaddress 2

Cmd1 Command 01 Load SRAM = 1 (Cont'd)

Note:
If word_cnt and offset cause data_word(s) to exceed the number of words in the specified ppp, the command will be rejected and notification of error placed in telemetry.

MSB	0 … 15
0	Cmd2

Cmd2 Command 2 Run Secondary Tests = 2

MSB	0 … 15
0	Cmd3
1	opr
2	Ipr

Cmd3	**Command 3 Jump to Application = 3**
opr	operand page register 0 value group 0
ipr	instruction page register 0 value group 0

Figure 5.1.3.1.3-1. SUROM Commands – Primary Data Bus I/F

MSB	0 15
0	Cmd4
1	ppp
2	offset
3	Retries

Cmd4 Command 4 Load SRAM from EEPROM = 4
ppp physical page load map resides in
offset offset from 0 load map starts
retries number of times to attempt load

MSB	0 15
0	Cmd5
1	ppp
2	Offset

Cmd5 Command 5 Memory Dump = 5
ppp physical page to start dump
offset starting location offset from physical page (≤4095)

Note:
If offset causes the 32-word dump to exceed the number of words in the specified ppp, the additional words shall be taken from the next sequential physical page.

MSB	0 15
0	Cmd6
1	ppp
2	offset
3	word_cnt
4	Checksum

Subaddress 1

Cmd6 Command 06 Load EEPROM = 6
ppp physical page which specifies where data is to be loaded
offset starting location offset from physical page (≤4095)
word_cnt number of data words in this command (≤4096)
checksum checksum of all data words received in subaddress 2

MSB	0 15
0	data_word 0
	•
	•
	•
31	data_word 31

Subaddress 2

Cmd6 Command 06 Load EEPROM = 6 (Cont'd)

Note:
If word_cnt and offset cause data_word(s) to exceed the number of words in the specified ppp, the command will be rejected and notification of error placed in telemetry.

Figure 5.1.3.1.3-1. SUROM Commands – Primary Data Bus I/F (Cont'd)

MSB	0 15
0	Cmd7
1	ppp
2	Offset

Cmd7 **Command 7 Memory Dump = 7**
ppp physical page to start dump
offset starting location offset from physical page (≤4095)
Note:
If offset causes the 32 word dump to exceed the number of words in the specified ppp, the additional words shall be taken from the next sequential physical page.

Figure 5.1.3.1.3-1. SUROM Commands – Primary Data Bus I/F (Cont'd)

5.1.3.1.4 SUROM FW Start-up Control

SUROM FW start-up is controlled by setting the discrete signals to the CTC by TIE critical commands prior CTC power-up or reset. The following lists the SUROM operations based on the setting of these discrete signals

1. Input Discrete 5 determines if an automatic load of SRAM from EEPROM should occur. If discrete 5 is off, load SRAM with the contents of EEPROM.
2. Input Discrete 3 determines warm start or cold starts initialization. If discrete 3 is off, execute a cold start initialization. If it is on, execute a warm start initialization.

5.1.4 Flight Software Commanding

The online CTC assembles valid Transfer Frames into CCSDS Telecommand Packets. The Transfer Layer will utilize the Command Operations Procedure (COP)-1. There are three types of transfer frames utilized by the PM-1 spacecraft; (1) Type-AD frame which is data, (2) Type-BC frame which only contains Transfer Layer control commands, and (3) Type-BD which is data. Type AC is not used on the PM-1 spacecraft. The maximum PM-1 TF length is 256 octets, including the frame header (5 octets).

The transfer frame is the data structure that is uplinked to the receiving end of the layer on the Spacecraft. It contains 2 major fields: the frame header and the frame data field as shown in Figure 5.1.4-1. The maximum TF length is 256 octets, including the frame header (5 octets).

The subsequent paragraphs describe the SC implementation of the Transfer Frame.

5.1.4.1 Transfer Frame Format and Content

The SC Transfer Frame format and content is defined in. Figure 5.1.4.1-1.

Frame Header (40 bits)								Frame Data (up to 2008 bits)
Version #	Mode		Spare	SCID	VCID	Frame Length	Frame Seq. Count	
	BPF	CCF						
2 bits	1 bit	1 bit	2 bits	10 bits	6 bits	10 bits	8 bits	up to 2008 bits

Notes:
1. Version #: 00
2. ByPass Flag: this field controls whether or not the frame acceptance tests of FARM-1 are applied to the Transfer Frame. A value of "0" indicates a Type-A Transfer Frame subject to all of the frame acceptance tests of FARM-1. A value of "1" indicates a Type-B Transfer Frame which bypasses all of the frame acceptance tests of FARM-1.
3. Control Command Flag: This field indicates if the Transfer Frame contains a FARM-1 control command or telecommand data. A value of "0" indicates the Frame Data field contains telecommand data ("D" mode). A value of "1" indicates the Frame Data Field contains a FARM-1 control command ("C" mode).
4. Spare: 00
5. SCID: $9A_{16}$ (PM-1 Spacecraft).
6. VCID: 00_{16} = Spacecraft, 01_{16} = Instrument
7. Frame Length: Total number of octets in the TF minus1. The valid range is 5 - 255, inclusive
8. Frame Seq. Number: Up-counting, modulo-256 counter. Maintained separately for each VC.
9. Frame Data: Contains up to 251 Octets of TC data or a FARM-1 control command.

Figure 5.1.4.1-1. PM-1 SC Transfer Frame Format

5.1.4.2 Transfer Frame Control Commands

If the transfer frame contains a Control Command (Mode = 00) then a check shall be made to verify that the control command is either:

UNLOCK: The UNLOCK Control Command consists of a single octet containing "all Zeros".

SET V(R): The SET V(R) Control Command consists of three octets with the following values: "82"$_{16}$; "00"$_{16}$; and "00_{16}-FF"$_{16}$, where the third octet contains the value for V(R), the Receiver Frame Sequence Number.

If not, then the transfer frame shall be rejected. Only one control command is allowed for each transfer frame, i.e., sending both set V(R) and unlock control commands, requires two separate transfer frames.

5.1.5 Frame Acceptance and Reporting Mechanism-1

The SC shall comply with the Frame Acceptance and Reporting Mechanism (FARM) –1 protocol. All valid Type AD, BC, and BD transfer frames shall be subjected to the FARM-1 protocol. The FARM-1 protocol accepts or rejects the Transfer Frames based on 3 predetermined states and 11 defined event conditions as defined in Tables 5.1.5-1 and 5.1.5-2. A FARM-1 Command Link Control Word (CLCW) shall be maintained for each virtual channel. The CLCW is defined in Figure 5.1.6.1-1.

Table 5.1.5-1. FARM-1 Operating States

State	Definition	Wait Flag	Lockout Flag
S1 (Open)	Normal state for accepting in-sequence Transfer Frames.	0	0
S2 (Wait)	Wait condition has been activated. This occurs when the FARM-1 protocol machine receives a Type-AD frame and cannot pass it on to the next higher layer (due to no buffer being available).	1	0
S3 (Lockout)	Lockout condition has been activated. This occurs when the FARM-1 protocol machine receives a frame with a sequence number outside the Sliding Window.	0	1

Table 5.1.5-2. FARM-1 Events

Event Condition	Definition
E1	Valid Type-AD frame arrives, N(S) = V(R), and a buffer is available for this frame.
E2	Valid Type-AD frame arrives, N(S) = V(R), and no buffer is available for this frame.
E3	Valid Type-AD frame arrives and N(S) is inside the positive part of the sliding window (i.e., V(R) < N(S) < (V(R) + PW - 1)). Refer to Figure 5.1.3.1-1 for more details.
E4	Valid Type-AD frame arrives and N(S) is inside the negative part of the sliding window (i.e., (V(R) - N(W)) < N(S) < V(R)). Refer to Figure 5.1.3.1-1 for more details.
E5	Valid Type-AD frame arrives and N(S) is outside the sliding window (i.e., N(S) > (V(R) + PW - 1) and N(S) < (V(R) - NW)). Refer to Figure 5.1.3.1-1 for more details.
E6	Valid Type-BD frame arrives.

Event Condition	Definition
E7	Valid 'Unlock' Type-BC frame arrives.
E8	Valid 'Set V(R)' Type-BC frame arrives.
E9	Invalid frame arrives
E10	Buffer release signal
E11	CLCW report time.

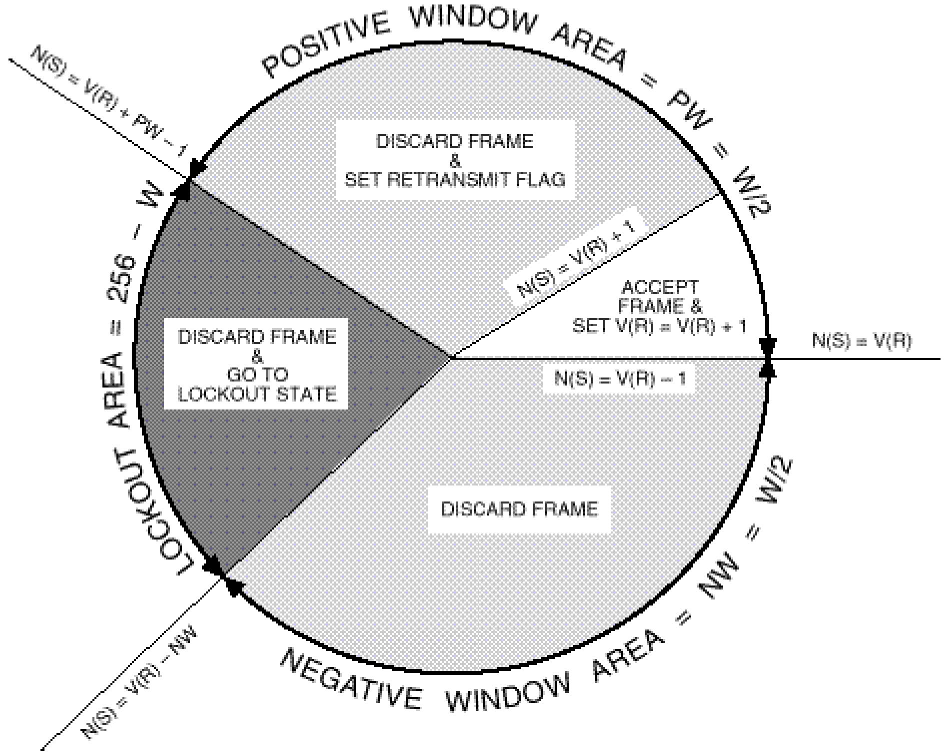
Notes:

1. Type AD Frame: The TF data field contains TC data. This type of frame is subject to acceptance check under control of the FARM.
2. Type BC Frame: The TF data field contains FARM Control Commands. This type of frame bypasses the acceptance checks under control of the FARM.
3. Type BD Frame: The TF data field contains TC data. This type of frame bypasses the acceptance checks under control of the FARM.
4. N(S): Frame Sequence Number contained in the TF header
5. V(R): Receiver Frame Sequence Number. Contains the value of N(S) expected to be seen in the next Type AD frame on the corresponding virtual channel.
6. PW: FARM Positive Window Width. Refer to Figure 5.1.5.1-1 for more detail.
7. NW: FARM Negative Window Width. Refer to Figure 5.1.5.1-1 for more detail.
8. V(R): New Receiver Frame Sequence Number. This is the value received in a 'Set V(R)' control command
9. CLCW: FARM-1 Command Link Control Word. The format of the CLCW is shown in Figure 5.1.6.1-1.

5.1.5.1 FARM-1 Sliding Window

The spacecraft FARM sliding window will be as depicted in Figure 5.1.5.1-1. The spacecraft FARM sliding window variables will be as follows:

Total Width = 100 ("64"$_{16}$)
Positive Part = TW/2 = 50 ("32"$_{16}$)
Negative Part = TW/2 = 50 ("32"$_{16}$)



Where:
W = FARM Sliding Window Width. Defines the range of N(S) without lockout occurring
PW = FARM Positive Window Width. Positive window starts at V(R) and extends PW frames in the positive direction.
NW = FARM Negative Window Width. Negative window starts at V(R)-1 and extends NW frames in the negative direction.
V(R) = Receiver Frame Sequence Number
V'(R) = New Receiver Frame Sequence Number
N(S) = Frame Sequence Number contained in the Transfer Frame header.

Figure 5.1.5.1-1. FARM-1 Sliding Window

5.1.6 Command Receipt Verification

5.1.6.1 Command Link Control Word

The 4 octet CLCW data structure (shown in Figure 5.1.6.1-1) shall be used to report the status of the FARM from the command link. The CLCW shall be updated for a given Virtual Channel (VC) when a Transfer Frame for that VC is processed. CLCWs are downlinked with every other CADU alternating between Spacecraft VCIDs 0 and 1.

5.1.7 PM-1 SC TC PACKET FORMAT

PM-1 SC or Instrument commands are embedded within the Application Data field of the CCSDS telecommand packet and is shown in Figure 5.1.7-1.

By CCSDS convention all fields which are not used in the CCSDS standard data structures and all fields marked spare or reserved are filled with zeroes.

5.1.7.1 APID

The APIDs uniquely identifies the data destination of the PM-1 Spacecraft Forward Link and are summarized in Table 5.1.7.1-1.

5.1.7.2 Spacecraft Commands

Primary data bus commands are destined for either the Spacecraft bus or instruments. An individual command data structure shall be the same whether the command is issued by the ground or by the on-board computer.

The spacecraft command data structure is shown in Figure 5.1.7.2-1 and defined in subsequent paragraphs. Each SC command message contains a 5-bit header and either a 27 or a 43-bit command field.

Ctrl Word Type	Version	Status	COP In Effect	VCID	Spare
1 bit	2 bits	3 bits	2 bits	6 bits	2 bits

No RF Avail	No Bit Lock	Flags: Lock-out	Flags: Wait	Flags: Re-xmt	FARM-B Counter	Spare	Report Value
1 bit	1 bit	1 bit	1 bit	1 bit	2 bits	1 bit	8 bits

Notes:

1. Control Word Type: 0 (Operation Control Field contains a CLCW)
2. Version: 00 (Version-1 CLCW)
3. Status: Provides additional status for the FARM-1 protocol machine. This field is mission specific and is not part of the COP-1 protocol. It is defined as follows:

000 = No fault detected	001 = Illegal SCID
010 = Incorrect frame length	011 = Illegal Type-BC frame
100 = Illegal frame type (Type-AC)	101 = Unused
110 = Illegal VCID	111 = Unused

4. COP In Effect: 01 (COP-1)
5. VCID: Identifies which virtual channel this CLCW is for. Only two virtual channels are processed: 00_{16} = Spacecraft, 01_{16} = Instrument.

   NOTE: VCID channels do not apply to the TIE critical commands. TIE critical commands are Type BD frames and they by-pass FARM.
6. Spare: These bits are not used and shall always be set to zero.
7. No RF Available: Provides the "ready" status of the RF equipment in the physical data channel. The valid settings are defined as follows: 0 = Physical channel is available, 1 = Physical channel is not available. This field shall always be set to zero (TBR).
8. No Bit Lock: Indicates if bit synchronization has been acheived. This field is optional and mission specific and shall always be set to zero.
9. Lockout: Contains a copy of the Lockout Flag used by the FARM-1 protocol machine.
10. Wait: Contains a copy of the Wait Flag used by the FARM-1 protocol machine.
11. Retransmit: Contains a copy of the Retransmit Flag used by the FARM-1 protocol machine.
12. FARM-B Counter: Contains the 2 LSBs of the FARM-B Counter used by the FARM-1 protocol machine.
13. Spare: This bit is not used and shall always be set to zero.
14. Report Value: Contains the value of N(R), the current observed value of the FARM's Next Expected Frame Sequence Number.

Figure 5.1.6.1-1. CLCW Structure

Primary Header 48 bits							Data Zone up to 976 bits	
Packet Identification				Packet Seq Control		Packet Length	Secondary Header	Command Data
Version #	Type	SHF	APID	Seq Flag	Packet Seq Count			
3 bits	1 bit	1 bit	11 bits	2 bits	14 bits	16 bits	16 bits	up to 960 bits

Notes:

1. Version #: 000
2. Type: 1 (Telecommand Packet)
3. Secondary Header Flag: 1
4. APID: Identifies the packet as either a Spacecraft Command Packet, Spacecraft Memory Load Packet, TIE Command Packet, FMU Command Packet, or SUROM Command Packet (CTC Only). The APIDs assigned to each packet type for the forward link can be found in Table 5.1.7.1-1.
5. Sequence Flag: 11 (unsegmented)
6. Packet Sequence Count: Monotonically increasing number.
7. Packet Length: Total number of octets in the data zone minus one. The valid range is as follows:

Spacecraft Command Packets	5 - 121
Spacecraft Memory Load Packets	11 -121
TIE Command Packets	7 - 31
FMU Command Packets	3 - 11

8. Secondary Header (bit 0 is the MSB)
   a. Bit zero shall be set to zero to indicate this is a non-CCSDS defined Secondary Header
   b. For Spacecraft Command Packets:
      1. Bits 1 through 7 are not used and are always zero.
      2. Bits 8 through 15 contain the Command Count indicating the number of commands that are embedded in the packet. The valid range is 1-30.
   c. For Spacecraft Memory Load Packets:
      1. Bits 1 through 13 are not used and are always zero.
      2. Bits 14 through 15 contain the Memory Load Sequence Flags indicating which part of the memory load is embedded in the packet. The valid range is '00'-'11', defined as follows: 00 = Continuation, 01 = First Component, 10 = Last Component, and 11 = Standalone.
   d. For all other packets:
      1. Bits 1 through 15 are not used and are always zero.
9. Command Data: For Spacecraft Command Packets, contains spacecraft commands, formatted as shown in Table 5.1.7.2.1-1. For Spacecraft Memory Load Packets, contains portions of the Memory Load Buffer, formatted as shown in Figure 5.1.7.2.2-1 . For SC TIE and FMU/ SSR packets, contains the command data to send to the destination, as-is.

Figure 5.1.7-1. PM-1 Spacecraft TC Packet Format

Table 5.1.7.1-1. Forward Link VCID/APID Assignments

Source	Destination	Packet Size (Octets)	$VCID_{10}$	$APID_{10}$	Description
EOC	SC Instrument Support Controller (ISC)	128	0	449	ISC Command
EOC	SC ISC	128	0	450	ISC Memory Load
EOC	SC ISC	64	0	451 - 452	Reserved
EOC	SC Power Controller (PC)	128	0	453	PC Command
EOC	SC PC	128	0	454	PC Memory Load
EOC	SC PC	64	0	455 - 456	PC Reserved
EOC	SC Guidance, Navigation, and Control Controller (GNCC)	128	0	457	GNCC Command
EOC	SC GNCC	128	0	458	GNCC Memory Load
EOC	SC GNCC	64	0	459 - 460	GNCC Reserved
EOC	SC Command and Telemetry Controller (CTC) - (On-Line)	128	0	461	CTC (On-Line) Command
EOC	SC CTC - (On-Line)	128	0	462	CTC (On-Line) Memory Load
EOC	SC CTC - On-line SUROM	64	0	463	CTC On-Line SUROM
EOC	SC CTC Backup Controller - Off-line	128	0	464	CTC (Off-line) Command
EOC	SC CTC Backup Controller - Off-line	128	0	465	CTC (Off-line) Memory Load
EOC	SC CTC - Off-line	64	0	466	CTC Off-line Reserved
EOC	Transponder Interface Electronics (TIE) - “A Side”	128	16 (x’10)	N/A	TIE “A” Critical Command
EOC	TIE - “B Side”	128	17 (x’11)	N/A	TIE “B” Critical Command
EOC	TIE - On-line	128	0	467	TIE (On-line) Command
EOC	TIE	128	0	468	TIE - Reserved
EOC	Formatter Multiplexer Unit (FMU)	128	0	469	FMU (On-line) Command
EOC	FMU	128	0	470	FMU - Reserved
EOC/IST	CERES +Y Aft Instrument	250	1	128	Long Command Packet Transfer Memory Loads and Table Updates

Table 5.1.7.1-1. Forward Link VCID/APID Assignments (Cont'd)

Source	Destination	Packet Size (Octets)	$VCID_{10}$	$APID_{10}$	Description
EOC/IST	CERES +Y Aft Instrument	12	1	129	Short Command Packet Transfer
EOC/IST	CERES -Y Fore Instrument	250	1	170	Load Command Packet Transfer Memory Loads and Table Updates
EOC/IST	CERES -Y Fore Instrument	12	1	171	Short Command Packet Transfer
EOC/IST	MODIS	72	1	110	Instrument Command
EOC/IST	MODIS	72	1	111	Load Data
EOC/IST	MODIS	8	1	112	Safe Mode Command
EOC/IST	AIRS	64	1	385	AIRS Command
EOC/IST	AIRS	10	1	386	Soft Reset
EOC/IST	AMSU-A1	12	1	272	AMSU-A1 - Command
EOC/IST	AMSU-A2	12	1	304	AMSU-A2 - Command
EOC/IST	AMSR-E	16	1	240	Serial Digital Magnitude Commands
EOC/IST	HSB	8	1	322	Level Discrete Commands

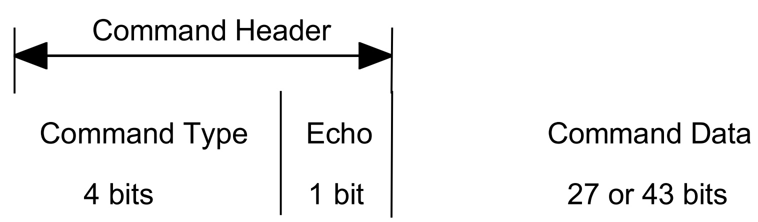


Figure 5.1.7.2-1. Spacecraft Command Structure- Generic

5.1.7.2.1 Command Formats

The spacecraft command formats are defined in Table 5.1.7.2.1-1.

Table 5.1.7.2.1-1. SC Command Message Formats

(4)	(1)	(4)	(23)	(16)
0 0 0 0	**E**	**Spare**	**Write Address**	**Memory Write Data**

Notes: **Single Command Write (48 bits)**

Write Address specifies where in RAM the 'Memory Write Data' is written. The valid range is as follows: CTC RAM: 100000_{16} - $1BFFFF_{16}$

GNCC, PC, and ISC RAM: 100000_{16} - $13FFFF_{16}$

(4)	(1)	(4)	(23)	(8)	(8)
0 0 0 1	**E**	**Spare**	**Write Address**	**Value**	**Mask**

Notes: **Write Most Significant Half (48 bits)**

Write Address specifies where in RAM the 'Value' is written. The valid range is as follows:
CTC RAM: 100000_{16} - $1BFFFF_{16}$,

GNCC, PC, and ISC RAM: 100000_{16} - $13FFFF_{16}$.

Mask contains the bit mask used when writing the 'Value' to memory. The valid range is 00_{16} - FF_{16}.

(4)	(1)	(4)	(23)	(8)	(8)
0 0 1 0	**E**	**Spare**	**Write Address**	**Value**	**Mask**

Notes: **Write Least Significant Half (48 bits)**

Write Address specifies where in RAM the 'Value' is written to. The valid range is as follows:
CTC RAM: 100000_{16} - $1BFFFF_{16}$,

GNCC, PC, and ISC RAM: 100000_{16} - $13FFFF_{16}$.

Mask contains the bit mask used when writing the 'Value' to memory. The valid range is 00_{16} - FF_{16}.

(4)	(1)	(9)	(2)	(16)
0 0 1 1	**E**	**SCS Id**	**Action**	**Repeat Count**

Notes: **Stored Command Sequence (32 bits)**

SCS ID specifies which SCS to perform the 'Action' on. The valid range is as follows:
ISC: 0 - 128,
CTC, GNCC, and PC: 0 - 159.

Action contains one of the following:

0 = Terminate, 1 = Activate, 2 = Suspend, 3 = Resume.

Repeat Count specifies how many times to repeat the SCS before terminating. This field is only applicable when the 'Action' is Activate. The valid range is -1 - 256, where -1 indicates to repeat forever (until terminated).

Table 5.1.7.2.1-1. SC Command Message Formats (Cont'd)

(4)	(1)	(12)	(1)	(3)	(5)	(3)	(3)
0 1 0 0	**E**	**Spare**	**Slice**	**Pulse Width**	**Relay Slice Number**	**V**	**H**

Notes: **Relay Matrix Control (32 bits)**

Slice contains one of the following:

0 = I/O Controller Slice, 1 = Instrument Serial I/O Slice (ISC only).

Pulse Width specifies the relay command execution time where 0 = 4msec; 1 = 8msec; 2 = 16msec; 3 = 32msec; 4 = 64msec; 5 = 128msec; 6 = 256msec; and 7 = 512msec.

Relay Slice Number specifies which relay slice is being commanded.

V and H specify the vertical and horizontal position, respectively, of the relay command on the relay matrix.

The complete list of relay assignments, indicating their respective Pulse Widths, Relay Slice Numbers, and V and H locations, can be found in the Command Allocation Document (D25099).

(4)	(1)	(9)	(2)	(16)
0 1 0 1	**E**	**Spare**	**Channel**	**Serial Data**

Notes: **Serial I/O** (32 bits)

This command is only applicable to the CTC and is used for commanding the Ultra Stable Oscillators (USOs).

Channel indicates which serial channel the Serial Data is for. In this case, the Channel identifies which USO is being commanded.

Serial Data contains the 16 bits of data to transmit over the serial channel. In this case, Serial Data contains the frequency correction for the USO being commanded.

Table 5.1.7.2.1-1. SC Command Message Formats (Cont'd)

(4)	(1)	(8)	(2)	(1)	(5)	(1)	(5)	(5)
1 0 0 0	**E**	**Spare**	**Seq Flag**	**Bus Select**	**RT Address**	**T/R**	**Sub-address**	**Word Count or Mode Code**

Notes: 1553B Type 1 (32 bits)

This command is the first part of a primary data bus message sent from the ground. It contains the control information required to transfer the message on the bus to its intended destination.

Sequence Flag contains one of the following: 0 = Continuation, 1 = First Component, 2 = Last Component, 3 = Standalone. For this command type, only First Component and Standalone are considered valid.

Bus Selection indicates if the message will be transferred over the C&T Bus (i.e., primary data bus) or the controller's secondary bus. The valid range is as follows: 0 = Primary data bus (CTC only), 1 = secondary bus.

RT Address specifies which Remote Terminal the message is for.

Transmit/Receive specifies if the RT is transmitting or receiving data. For non mode code messages, this bit must be set to 'Receive'. The valid range is as follows: 0 = Receive, 1 = Transmit.

Subaddress specifies the subaddress to use when transferring the message to the Remote Terminal.

When the specified 'Subaddress' is zero or 31, the last field contains the 'Mode Code'. Otherwise, the last field contains the 'Word Count'.

(4)	(1)	(8)	(2)	(1)	(16)
1 0 0 1	**E**	**Spare**	**Seq Flag**	**0**	**1553B Data**

Notes: **1553B Type 2** (32 bits)

This command is the continuation of a primary data bus message sent from the ground. It contains part of the data that will comprise the message transferred on the bus to its intended destination. There may be up to 32 1553B Type 2 Commands following a 1553B Type 1 Command.

Sequence Flag contains one of the following: 0 = Continuation, 1 = First Component, 2 = Last Component, 3 = Standalone. For this command type, only Continuation and Last Component are considered valid.

1553B Data contains 16 bits of data to be included in the message.

5.1.7.2.1.1 Command Echo

The command echo field is 1 bit in length and shall be set to either 1 when a command is to echoed back to the ground or 0 (zero) when no echo is required. Each spacecraft controller processes its command and if the command echo bit is set and the format table has been collecting the data, the command is inserted into the telemetry stream for transmission to the ground.

5.1.7.2.2 SC Memory Loads

The Memory Load function allows the ground to modify the memory contents of the controllers while the flight software is running. It can be used for both database and code updates, to modify RAM, and to reload EEPROM (on the C&T Controllers only). The Memory Load Buffer is filled by the Command Processing function from the memory load packet received from the ground. The format of the memory load buffer is shown in Figure 5.1.7.2.2-1.

5.1.7.2.3 Stored Command Sequences

The Stored Command Processing function, within the CTC, processes repeatable blocks of one or more flight software commands, which simplifies issuing commands from the ground or flight software. These blocks consist of Stored Command Sequences (SCSs) and Predefined Command Scripts (PCSs). The Ground Segment via memory loads can reprogram SCSs and PCSs.

An SCS is composed of spacecraft commands, remote unit commands (e.g., instrument commands), and control commands. PCSs are blocks of commands that can be activated by an SCS and can only contain spacecraft commands and remote unit commands. Spacecraft commands and remote unit commands are routed to the Command Processing function where they are interpreted as if they came from the ground. Control commands regulate the execution of an SCS by issuing delays, waiting on event or time triggers, executing PCSs, performing conditional branches, or suspending the SCS.

An SCS can be in either the Active, Inactive, or Suspended state. The flight software processes an active SCS every minor cycle. The flight software does not process an inactive SCS. A suspended SCS is one that is temporarily inactive until it is activated, terminated, suspended, or resumed via ground command. SCS state transitions are shown in Table 5.1.7.2.3-1. When an SCS is activated, it can be repeated a specified number of times or repeated forever. There are over 100 SCSs allocated per spacecraft controller. However on the CTC, GNCC and PC controllers, only 10 SCSs may be active on each controller at any one time. The ISC can have 40 SCSs active at any one time.

The flight software keeps track of which commands in the SCS or PCS have been processed. Each SCS has an associated step number which is set and updated by control commands in the SCS. The status of each SCS is available for inclusion in the spacecraft telemetry stream and subsequent reporting to the ground.

5.1.7.2.3.1 Stored Command Formats

The format of the stored commands is shown in Figure 5.1.7.2.3.1-1.

Word	Bit 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	XF	Block Count (J)				Word Count (M)										
2	Block 1 Physical Address (7 MSBs)							Block 1 Word Count (N)								
3	Block 1 Physical Address (16 LSBs)															
4	Block 1 Data Word 1															
• •	• •															
N+3	Block 1 Data Word N															
• •	• •															
M-J-2	Block J Physical Address (7 MSBs)							Block J Word Count (L)								
M-J-1	Block J Physical Address (16 LSBs)															
M-J	Block J Data Word 1															
• •	• •															
M-1	Block J Data Word L															
M	Checksum															

Notes:

1. XF (Checksum Regions Affected Flag): Indicates if the memory load will affect a region of memory that is checksummed in the background. The valid range is 0 - 1, where 0 = False and 1 = True.
2. Block Count: Number of data blocks contained in the Memory Load Buffer. The valid range is 1 - 12.
3. Word Count: Total number of words contained in the Memory Load Buffer (including the Checksum). The valid range is 5 - 512, where the minimum value represents a memory load of a single data block containing a single word.
4. Checksum: Contains the arithmetic checksum for the entire Memory Load Buffer. The valid range is 0000_{16} - $FFFF_{16}$.
5. For each block:
   a. Physical Address: The physical address of where the data block will be loaded. The valid range is as follows:
      CTC RAM: 100000_{16}-$1BFFFF_{16}$
      CTC EEPROM: 200000_{16} - $27FFFF_{16}$
      PC, GNCC, and ISC RAM: 100000_{16} - $13FFFF_{16}$
   b. Word Count: The number of words contained in the data block. The valid range is 1 – 508.

Figure 5.1.7.2.2-1. Memory Load Buffer

Table 5.1.7.2.3-1. SCS State Transitions

SCS State	Command			
	Activate	**Terminate**	**Suspend**	**Resume**
Active	X	Inactive	Suspended	X
Inactive	Active	X	X	X
Suspended	X	Inactive	X	Active
X = Request ignored.				

(4)	(12)	(48)
0000	0000 0000 0000	Spacecraft command

Note: **Spacecraft**

1. Spacecraft command. Commands are left justified and appended with trailing zeros when less than 48 bits in length and is stored in the SCS Command Buffer.

(4)	(24)	(20)	(16)
0001	0000 0000 0000 0000 0000 0000	Delay Value (in minor cycles)	0000 0000 0000 0000

Note: **Relative Delay**

1. Delay value specifies how many minor cycles Stored Command Processing function should delay the execution of the SCS. SCS processing the SCS for the number of minor cycles specified.

(4)	(12)	(32)	(16)
0010	0000 0000 0000	Time Value (in seconds since Epoch)	0000 0000 0000 0000

Note: **Absolute Time Delay**

1. Time Value specifies the time when Stored Command Processing function should continue the execution of the SCS. SCS processing stops processing the SCS until the specified time is reached.

(4)	(2)	(3)	(23)	(16)	(16)
0011	Glitch Filter	Event Operator	Physical Address of Event Trigger variable	Value to compare against the Event Trigger	Event Mask

Note: **Event Trigger**

1. Glitch Filter specifies the number of consecutive minor cycles to delay while the event condition is true before continuing the execution of SCS.

2. Event Operator contains one of the followings:

0 = Equal To (=), 1 = Less Than (<), 2 = Greater Than (>),

4 = Not Equal To (/=), 5 = Greater Than or Equal To(≥), 6 = Less Than or Equal to (≤)

3. Physical address specifies where in RAM the comparison data is located.

4. Value to compare specifies the value to compare against RAM though the actual mask.

5. Mask contains the bit mask used when comparing the value against RAM.

Figure 5.1.7.2.3.1-1. Stored Command Format

(4)	(60)
0100	0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000
Note: **Suspend SCS** 1. The SCS is suspended until "resume SCS" command is received.	

(4)	(12)	(16)	(32)
0101	0000 0000 0000	New step value	0000 0000 0000 0000 0000 0000 0000 0000
Note: **Set Step** 1. SCS processing continues from the step specified by New Step Value			

(4)	(5)	(23)	(16)	(16)
0110	00000	Physical Address of Predefined Command Script	Number of commands to process	0000 0000 0000 0000
Note: **Predefined Command Script** 1. Physical address specifies where in RAM the predefined command script is located. 2. Number of commands specifies how many stored commands to process in the predefined command script.				

(4)	(1)	(3)	(8)	(1)	(8)	(23)	(16)
0111	By-pass	Condition Operator	Mask	Mask High/Low	New Step Value	Physical Address of a condition variable	Value to compare against the condition variable

Note: **Conditional Go To**

1. Bypass specifies whether, or not, the masking should be bypassed. The valid range is as follows:

0 = No Bypass, 1 = Bypass If Bypass bit is clear, 8 MSB/LSB of a word at the specified address is compared with the specified value through mask if High/Low is zero/one. If Bypass bit is set, a word at the specified address is compared with the specified value.

2. Condition Operator contains one of the followings:

0 = Equal To (=), 1 = Less Than (<), 2 = Greater Than (>),

4 = Not Equal To (/=), 5 = Greater Than or Equal To(>=), 6 = Less Than or Equal to (<=)

3. Mask contains the bit mask used when comparing the value against RAM. When Bypass flag is set, the specified mask is ignored; otherwise, padding zeros to 8-bit mask specified generates the actual 16-bit mask. If Mask High/Low flag is set, the specified mask is place in MSH of the actual mask, and vice versa.

4. Mask High/Low specifies whether the masking should be applied to MSH or LSH when Bypass flag is set: The valid range is as follows:

0 = Mask Low, 1 = Mask High

5. New Step Value specifies the step where Stored Command Processing function continues execution of the SCS. The valid range is 0 - 255. Jumping to a step greater than 255 can be achieved by jumping to some step which contains "Set Step" to the desired step.

6. Physical Address specifies where in RAM the comparison data is located.

7. Value to compare specifies the value to compare against RAM though the actual mask.

Figure 5.1.7.2.3.1-1. Stored Command Format (Cont'd)

(4)	(3)	(3)	(2)	(4)	(48)
1000	Unused	Byte Count	Seg	Unit ID	Command Data
Note: **Remote Unit**					

1. Unused: 000
2. Byte Count indicates the number of command octets present in the Command Data field, (up to 6).
3. Segment: 00 = First, 01 = Continuation, 10 = Last, 11 = Unsegmented
4. Unit ID: 0 =AIRS; 1 = AMSR; 2 = AMSU-A1; 3 = AMSU-A2; 4 = CERES +Y; 5 = CERES -Y; 6 = HSB; 7 = MODIS; 8 = Online TIE; 9 = Off-line TIE; 10 = Online FMU; 11 = Off-line FMU; 12 = GNCC; 13 = PC; 14 = ISC; 15 = Unused

The "Remote Unit" Stored Command is only applicable on the CTC and ISC. On all other controllers, this command is ignored. Furthermore, all Unit IDs are valid on CTC. On ISC, only the instrument Unit IDs (0-7) are valid.

5. Command Data contains up to 48 bits of command data. The data is left justified and appended with trailing zeros when less than 47 bits in length.

(4)	(60)
1110	0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000
Note: **NOP** SCS performs no task for NOP command	

(4)	(60)
1111	0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000
Note: **SCS End** SCS processing terminated if Active.	

Figure 5.1.7.2.3.1-1. Stored Command Format (Cont'd)

5.1.8 Formatter-Multiplexer Unit

The FMU provides the interface to the X-band modulator for data downlink and is the primary interface to the SSR for generic recording and playback of data via the Primary Data Bus . The FMU supports CCSDS packets for storage on the SSR, but the FMU does not depacketize commands or packetize telemetry. The FMU provides State of Health Telemetry at predefined intervals and Diagnostic Telemetry as needed.

5.1.8.1 FMU/SSR Command Structures

CCSDS TC commands destined for the FMU are depacketized by the CTC. Commands are sent to the FMU one command at a time in its entirety (i.e., no partial commands) and are from one to five 16-bit words long. If the number of words sent to the FMU does not match the number of words required by the command (as determined by the command's opcode), the FMU will reject the command. The FMU/SSR generic command structure will be as shown in Figure 5.1.8.1-1.

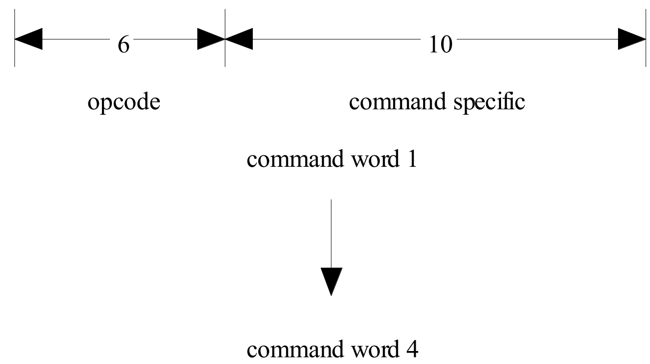


Figure 5.1.8.1-1. Generic FMU Command Structure

5.1.9 Clock Maintenance

The ground system shall comply with the requirements found in section 2.1.2, document 2.

The Ground System provides ground commands for performing SC clock maintenance. Clock maintenance includes:

Clock Initialization: Power on sequence
Time adjustment: Keep all clocks within required tolerance (± 10 msec)
USO frequency Adjustment: Minimize frequencies drift rate such that time adjustments are infrequent
Leap Second Adjustment: Required to specify the difference between UTC time and TAI time
Resynchronization: Required whenever the FSW and Hardware are out of sync.

5.1.9.1 Clock Accuracy

The Ground System maintains the accuracy of both GIRD time and GIIS time correlation to within the required limit of the correct time by tracking and monitoring the spacecraft time.

5.1.9.1.1 GIRD Time Code Data Accuracy

During the normal mode of operation (SC Science state), the ground shall maintain GIRD Time Code Data Accuracy to within ± 10 ms of correct TAI time.

5.1.9.1.2 GIIS Time Code Data Accuracy

During the normal mode of operation (SC Science state), the ground shall maintain GIIS Time Code Data Accuracy to within ± 10 ms of correct UTC time.

5.1.9.2 Clock Initialization

During initialization of the master clocks on both the online and off-line TIE, the ground via a direct command to the TIE (i.e., jam loading) provides the entire clock adjustment. The flight software and the ground ignore errors (e.g., minor cycle overrun) resulting from initialization of the master clock for Spacecraft Time.

The Ground System shall initiate the master clock on both TIEs' via SC 1553 Type 1 and Type 2 commands, reference Table 5.1.7.2.1-1.

5.1.9.2.1 GIRD Clock Initialization

The GIRD CUC clock initialization command can be performed by sending multi-word TIE commands, via the primary data bus to the appropriate TIE RT, subaddress 2. The GIRD clock in the TIE is 64 bits. The least significant portion of this clock is contained in a hardware clock processor, the most significant portion is contained in data memory. and should conform to the following as shown in Figure 5.1.9.2.1-1. The GIRD Time Adjustment is 32 bits and uses two registers. Both registers must be written to and the MSW of the LSH shall be written to first. The format is shown in Figure 5.1.9.2.1-1.

<u>LSH:</u> (MSW)

Word 1: Command Word	
Command Destination	0100_{16}, I/O port write
Unused	set all bits to 0
Data Word Count - 1	0001_{16}. (ie; 2 words)
Unused	set all bits to 0
Word 2: Destination Address	$FFB5_{16}$ (Time adjust MSW address)
Word 3: Data word 1	(Most significant word of LSH time adjustment)

<u>LSH:</u> (LSW)

Word 1: Command Word	
Command Destination	0100_{16}, I/O port write
Unused	set all bits to 0
Data Word Count - 1	0001_{16}. (ie; 2 words)
Unused	set all bits to 0
Word 2: Destination Address	$FFB4_{16}$ (Time adjust LSW address)
Word 3: Data word 1	(Least significant word of LSH time adjustment)

MSH:

Word 1: Command Word	
Command Destination	4_{16}, data memory write
Unused	set all bits to 0
Data Word Count (- 1)	0101_{16}. (ie; 6 (-1) words)
Unused	set all bits to 0
Word 2: Destination Address	0200_{16} (Time adjust MSW address)
Word 3: Data word 1	(LSW of MSH time adjustment)
Word 4: Data word 2	(MSW of MSH time adjustment)
Word 5: Data word 3 (same as data word 1)	(LSW of MSH time adjustment)
Word 6: Data word 4 (same as data word 2)	(MSW of MSH time adjustment)
Word 7: Data word 5 (same as data word 1)	(LSW of MSH time adjustment)
Word 8: Data word 6 (same as data word 2)	(MSW of MSH time adjustment)

Figure 5.1.9.2.1-1. GIRD Clock Initiation Format

5.1.9.2.1.1 GIRD Time Initialization Constraints

1) Time initialization is only allowed when the spacecraft is in the Standby state.
2) The ground system shall send no clock initialization command to the TIE when the GIRD time is in between 32 seconds before the LSH of the time-of-day (TOD) counter rollover to the time immediately after the LSH of the TOD rollover. This prevents the MSH of the TOD counter from missing its time increment.

5.1.9.2.2 GIIS Clock Initialization

The CDS clock is a 16-bit counter contained within the TIE. GIIS time initialization consists of sending adjustment commands to respective time segments of the CDS time format. Each segment should be commanded separately as shown in Figure 5.1.9.2.2-1.

uS of mS Adjustment:

Performed by sending a single-word command conforming to the following:

Word 1: Command Word	
Command Destination	4_{16}, I/O port write
Unused	set all bits to 0
Data Word Count - 1	0000_{16}. (ie; 1 words)
Unused	set all bits to 0
Word 2: Destination Address	$A009_{16}$ (us of mS address)
Word 3: Data word 1	(uS of mS time adjustment data)

<u>mS of Day Adjustment: (32-bits, 2 words)</u>

Performed by sending a multi-word command conforming to the following:

Word 1: Command Word	
Command Destination	4_{16}, I/O port write
Unused	set all bits to 0
Data Word Count - 1	0001_{16}. (ie; 2 words)
Unused	set all bits to 0
Word 2: Destination Address	$A00A_{16}$ (ms of Day address)
Word 3: Data word 1	(LSW of mS of Day time adjustment data)
Word 3: Data word 2	(MSW of mS of Day time adjustment data)

<u>Day Adjustment:</u>

Performed by sending a multi-word command conforming to the following:

Word 1: Command Word	
Command Destination	0010_{16}, data memory write
Unused	set all bits to 0
Data Word Count (- 1)	0101_{16}. (ie; 6 (-1) words)
Unused	set all bits to 0
Word 2: Destination Address	0206_{16} (Time adjust LSW address)
Word 3: Data word 1	16-bit Day Adjustment
Word 4: Data word 2	16-bit Day Adjustment
Word 5: Data word 3 (same as data word 1)	16-bit Day Adjustment

Figure 5.1.9.2.2-1. CDS Clock Adjustment Format

5.1.9.3 Minor Time Adjustment

In the normal mode of operation (SC Science State), the ground maintains the onboard clocks to within $\pm$ 10 msec of correct time. When the master clocks on the TIE drift more than a predefined number of milliseconds (say 8 msec) from the TAI time reference, the ground sends a time adjustment command to the spacecraft.

5.1.9.3.1 GIRD Time Adjustment

The GIRD minor time adjustment is sent to the SC via a SCW. It contains the GIRD time adjustment and the time delta to be adjusted. The time delta is 16 bit in length, expressed in binary number, and has no sign bit. The bit weight of the GIRD time adjustment LSB value is 4.76837158e-7 seconds.

5.1.9.3.1.1 GIRD Time Adjustment Constraints

A block period is utilized to avoid errors in time adjustment. The ground shall send an absolute time stored command for GIRD time adjustment so that no GIRD time adjustment command is sent from 32 seconds before counter rollover to 976.5625 μsec after rollover.

5.1.9.3.2 GIIS Time Adjustment

.The GIIS minor time adjustment is sent to the SC via a SCW. It contains the GIIS time adjustment and the time delta to be adjusted. The time delta is 16 bit in length, expressed in binary and contains a sign bit. The bit weight of the GIIS time adjustment LSB value is 1 μsec as defined in Table 5.1.9.3.2-1.

Table 5.1.9.3.2-2. Bit Weights of GIIS Time Delta Data Word

Bit No.	Bit Weight (in μsec)
(LSB) 0	1
1	2
2	4
3	8
4	16
5	32
6	64
7	128
8	256
9	512
10	1024
11	2048
12	4096
13	8192
14	16384
(MSB) 15	Sign Bit (1 = negative value 0 = positive value)

5.1.9.4 USO Frequency Adjustment Command

USO frequency adjustment is for controlling the clock drift with respect to the ground time reference. The Ground System shall send an USO frequency drift correction via a SC SIO command, reference Table 5.1.7.2.1-1. To keep reference time to within limit of correct time, a 16-bit frequency adjustment value shall be made to the to the 8.388 MHz and 4.000 MHz Ultra Stable Oscillator (USO). The format for the USO Frequency Drift Command is shown in Figure 5.1.9.3-1.

Frequency correction command words shall be 16 bits in length. Bit 0 shall be the MSB and the leading bit that is shifted into the USOs first. Bit 15 shall be the LSB and bits 14 and 15 shall be set to zero (0). The bit weighting for serial correction commands shall be as documented in the CAD, reference section 2.2.2, document 9.

0 MSB	1	2	3	4	5	6	7	8	9	10	11	12	13	14 0	15 LSB 0

Figure 5.1.9.3-1. USO Frequency Adjustment Command Word Format

5.1.9.5 Leap Second Adjustment

5.1.9.5.1 GIRD Leap Second Adjustment

The ground is responsible for maintaining the leap seconds value in the mission constants database and activating the leap second adjustment command. The EOS ground system shall send to the spacecraft a memory load containing the new leap second value. This will be written to EEPROM. The leap seconds correction command shall be in a Stored Command Sequence to delay execution of the leap second adjustment until midnight according to the GIRD clock. The SCS will contain a SC SCW command to copy the leap seconds over to the GIRD time code.

5.1.9.5.2 GIIS Leap Second Adjustment

The GIIS Leap Second Adjustment is made according to Table 5.1.9.5.2-1

Table 5.1.9.5.2-1. GIIS Leap Second Adjustment Format

Word 1: Command Word	
Command Destination	0100_{16}, I/O port write
Unused	set all bits to 0
Data Word Count - 1	0000_{16}. (ie; 1 words)
Unused	set all bits to 0
Word 2: Destination Address	$A00F_{16}$ (us of mS address)
Word 3: Data word 1	0001_{16} for negative leap second 0002_{16} for positive leap second

5.1.9.6 Time Re-Synchronization Commands

The FSW on all controllers contain a minor cycle counter (modulo 4096) from which all modulo counters are derived. When the FSW starts up, the minor cycle counter is reset (to zero) and the FSW waits for the occurrence of the first one hertz pulse to occur before beginning task execution. By doing so, the modulo counters are synchronized to the one hertz pulse from the TIE (i.e., the modulo 8 counter is zero whenever the one hertz pulse occurs). To keep all controllers synchronized, the CTC transmits its copy of the minor cycle count to the PC, GNCC, and ISC. During a switchover from the on-line to off-line TIE, the one hertz pulse may not be synchronized with the FSW and the SC will remain in current state.

The ground will issue a SC single command write following a switchover, or when any out-of-synch condition occurs, to resynchronize the FSW with the TIE one second pulse.

5.2 PM-1 INSTRUMENTS

The following sections describe the command formats and constraints applicable to the instruments on-board the EOS PM-1 spacecraft.

5.2.1 PM-1 Instrument TC Packet Format

The instrument TC packet is shown in Figure 5.2.1-1. The instrument TC packet length, including primary and secondary headers, is 64 octets. The exception is CERES which has a short packet length of 64 octets and a long packet length of 250 octets.

Primary Header							Data Zone	
48 bits							up to 464/1952 bits	
Packet Identification				Packet Seq Control		Packet Length	Secondary Header	Instrument Command
Version #	Type	Sec Header Flag	Appl Proc Id	Seq Flag	Packet Seq Count			
3 bits	1 bit	1 bit	11 bits	2 bits	14 bits	16 bits	16 bits	up to 448/1936 bits

Notes:

1. Version #: 000
2. Type: 1
3. Secondary Header Flag: 1
4. Application Process ID: Identifies which instrument the telecommand packet is for. The APIDs assigned to each instrument for the forward link can be found in Table 5.1.5.1-1.
5. Sequence Flag: 11 (unsegmented)
6. Packet Sequence Count: Monotonically increasing number.
7. Packet Length: Total number of octets in the packet minus one. The valid range is 3 - 57, except for CERES Long Command Packets, in which case the valid range is 3 - 243.
8. Secondary Header (bit 0 is the MSB)
   a. Bit zero shall be set to zero to indicate this is a non-CCSDS defined Secondary Header
   b. Bits 1 through 7 are the Function Code and shall always be set to zero
   c. Bits 8 through 15 shall contain the Arithmetic Checksum for the packet. It is the receiving instrument's responsibility to validate the checksum.
9. Instrument Command: Contains the commands or load data to be processed by the instrument. The amount of data contained in this field varies by instrument.

Figure 5.2.1-1. Instrument Telecommand Packet Format

5.2.1.1 Instrument Data Field

The instrument command field shall be an even number of octets not to exceed 56 octets. The exception, CERES long packet data field shall be 242 octets.

5.3 AIRS

AIRS instrument command and memory loads comply with the Instrument TC packet defined in Figure 5.2.1-1. AIRS TC packets are fixed length of 64 Octets (56 Octet instrument command field). The Soft Reset Command is an exception, reference paragraph 5.3.2.

5.3.1 AIRS Instrument Command Field

The AIRS command field contains the AIRS Data Load Command defined in Figure 5.3.1-1. The first word of all AIRS instrument command fields will contain a command ID. When the AIRS command is less than 448 bits in size, the remaining bits will be filled with zeros.

Command ID				Table Offset	Size	Data
Cmd Type	Tag Type	Group	Cmd			
2 bits	3bits	3bits	8 bits	16 bits	16 bits	Up to 400 bits

Notes:
1. Command Type: 10 (data load command)
2. Tag Type: 001 (immediate execution)
3. Group: 010
4. Command:
   - 42_{16} = Scan Profile Table
   - $A2_{16}$ = Data Collection/Packetization Table
   - 12_{16} = Subsample Integration Time Table
   - 52_{16} = Detector Gain/Circumvention Level Table
5. Table Offset:
   For the first data load command for a given table, this field is set to zero. For subsequent data load commands for a given table, this field is set to the number of octets of data that have previously been sent to the instrument during current table load.
6. Size:
   Indicates the number of 16-bit data words (1 - 25) contained in the data field.
7. Data: Contains up to 25 16-bit words.

Figure 5.3.1-1. AIRS Data Load Command

5.3.2 AIRS Reset Command

The AIRS Soft Reset command is used to reset the AIRS instrument. It is CCSDS packetized when sent from the ground. The SC depacketizes the command and sends a single 16-bit word to the instrument. The command word contains a code indicating whether a soft reset or hard reset of the instrument is to be performed. When the code for a soft reset is received, the AIRS instrument software reinitializes itself. When the code for a hard reset is received, the entire AIRS instrument is reset (hardware and software).

The instrument ignores all other codes. Table 5.3.2-1 defines the available command codes for the AIRS Instrument Reset command.

Table 5.3.2-1. AIRS Reset Command Codes

Code	Definition
1	Soft Reset
2	Hard Reset

5.3.3 AIRS Command Constraints

1. There shall be no more than 3 commands contained in each command packet.
2. Memory Load commands shall not contain more than 25 data words.
3. Minimum spacing between commands shall be 375 msec.
4. The spacecraft and instrument shall comply with the command constraints specified in GIRD paragraphs 6.5.6.5.1 through 6.5.6.5.6.

5.4 AMSU-A1

5.4.1 AMSU-A1 Instrument Commands

AMSU-A1 instrument command and memory loads comply with the Instrument TC packet defined in Figure 5.2.1-1. AMSU-A1 TC packets are fixed length of 12 Octets (4 Octet instrument command field).

5.4.1.1 AMSU-A1 Instrument Data Field

AMSU-A1 commands contain 2 16-bit words. The first word of all TC instrument data fields will contain a command ID; the second word is the mask. Command data field format is shown in Table 5.4.1.1-1.

Table 5.4.1.1-1. AMSU-A1 Command Format

Word 1 - Command Bits															
msb															**lsb**
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Word 2 - Mask Bits															
msb															**lsb**
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

5.4.1.2 AMSU-A1 Reset Command

AMSU-A1 is not required to support soft reset commands. A re-initialization sequence has to be commanded from the ground to properly assess AMSU-A1 configuration and initiate a re-configuration of commands.

5.4.1.3 AMSU-A1 Command Constraints

Minimum spacing between commands shall be 16 secs.

5.5 AMSU-A2

5.5.1 AMSU-A2 Instrument Commands

AMSU-A2 instrument command and memory loads comply with the Instrument TC packet defined in Figure 5.2.1-1. AMSU-A2 TC packets are fixed length of 12 Octets (4 Octet instrument command field) and has the same formatting, content, and constraints as AMSU-A1, reference paragraphs 5.4.1.1 through 5.4.1.3.

5.6 AMSR-E

Commands sent by the EOS ground system that are destined for the AMSR-E instrument are embedded within the instrument command field of the Instrument TC packet defined in Figure 5.2.1-1. AMSR-E TC packets are fixed length of 64 Octets (56 Octet instrument command field). The ISC depacketizes the CCSDS TC packet prior to forwarding the commands on to AMSR-E.

5.6.1 AMSR-E Commands

The AMSR-E commands consist of Serial Digital Magnitude (SDM) or Discrete (DS) commands.

5.6.1.1 AMSR-E SDM Command Formats

The AMSR-E SDM command format is defined in Table 5.6.1.1-1.

Table 5.6.1.1-1. AMSR-E Serial Digital Command Format

Command Bits															
msb															**lsb**
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

5.6.1.2 AMSR-E Discrete Commands

The discrete commands consist of high-level pulse commands. The high level, 32 millisecond pulse width commands are sent to AMSR-E via the SC Relay Matrix Control command, reference Figure 5.1.7.2.1-1.

5.6.2 AMSR-E Command Constraints

a. The minimum spacing between SDM commands shall be greater than 125 msec.
b. The minimum spacing between DS commands shall be greater than 125 msec.
c. There shall be a maximum of 5 commands (at 16 bits per command) per packet.

5.7 CERES INSTRUMENTS

The CERES system aboard the PM-1 spacecraft consists of two instruments designated CERES +Y Aft and CERES -Y Fore and shall be treated as one system. The Primary Data Bus interface is used for commanding both instruments. CERES instruments support Version 1 CCSDS packets for commands; however, the time tag is CDS time vs CUC time.

5.7.1 CERES Instrument Commands

There are two types of CERES commands; short commands that are 12 octets in size (4 octet command data field) and long command which are 250 octets in size (242 octet command data field. Short commands are used to control all instrument functions and to initiatesizeution of instrument sequences. Long commands are used to perform memory loads of code or instrument unique parameters, load elevation gimbal scan profiles, and load instrument sequences. The CERES TC packet complies with Figure 5.3.1-1.

5.7.1.1 CERES Command Constraints

The following command constraints shall be maintained for CERES commands:

a. Lock and key commands shall be used for any critical functions.
b. No toggle or step commands shall be used for normal operational commands.
c. Command counter is kept, only 1 command is echoed in the housekeeping packet.
d. Any commandable bi-state condition (ON/OFF, OPEN/CLOSE) within a command packet shall be implemented using two bits, one of each state.
e. Only 1 command may be in one short command packet.
f. The minimum spacing between CERES short or long commands shall be greater than 500 msec.

5.8 MODIS INSTRUMENT

5.8.1 MODIS Command Message Formats

Commands sent by the EOS ground system that are destined for the MODIS instrument are embedded within the instrument command field of the Instrument TC packet defined in Figure 5.2.1-1. MODIS does not support CCSDS commands to it. The ISC depacketizes the CCSDS TC packet prior to forwarding the commands on to MODIS.

MODIS commands are one, two, six, or eight 16-bit words. Multiple commands can be sent to MODIS in a single message transfer with a maximum command transfer size of 32 16-bit words. MODIS uses the CRC checksum only for memory loads and memory dumps.

Figure 5.8.1-1 depicts the "generic" MODIS command structure including those for memory loads and memory dumps

MSB 0 4	5 7	LSB 8 15
Operation Code	Cmd Word Count	Command Parameters
Parameters (Optional)		
Parameters (Optional)		

Figure 5.8.1-1. MODIS Generic Bus Command Structure

5.8.1.2 MODIS Command Constraints

The following MODIS command constraints apply:

1. The minimum spacing between MODIS commands shall be greater than 250 msec.
2. The minimum spacing between MODIS Memory Load Data shall be greater than 500 msec.
3. The minimum spacing between MODIS Safe Mode Command shall be greater than 1.0 sec.
4. Commands must be sent to MODIS in their entirety, (no partial commands)
5. Maximum command transfer size is thirty-two 16 bit words.

5.9 HSB

There are two types of commands that will be provided to the spacecraft. These are Level Discrete and Pulse Discrete commands. HSB instrument does not utilize checksum.

5.9.1 HSB Instrument Command Message Formats

The pulse discrete commands are 64 millisecond pulse width commands and are sent to the SC via SC 0100, Relay Matrix Control, reference Figure 5.1.7.2.1-1.

The level discrete commands destined for the HSB instrument are embedded within the instrument command field of the Instrument TC packet defined in Figure 5.2.1-1.

5.9.2 HSB Command Timing

The HSB command spacing for the level discrete commands will be 8/3 seconds.

5.9.3 HSB Memory Loads

HSB does not require memory loads.

5.9.4 HSB Command Constraints

The ground system shall place no more than 1 16-bit command in the HSB instrument command data field separated by 8/3 seconds minimum.

SECTION 6. TELEMETRY DATA FORMATS

6.1 TELEMETRY FORMATS

This section will describe the Telemetry Data Message Format and Content to be sent from the PM-1 spacecraft (SC) to EOS Ground Systems.

For additional information on the CCSDS Telemetry definition, reference section 2.2.1, documents 1, 2, and 8.

For additional information on SC telemetry format and content, telemetry format tables, SC telemetry process reference section 2.2.2, documents 13.

For additional SUROM telemetry detail, reference section 2.2.3, document 1.

6.2 GENERAL TELEMETRY STRUCTURE AND PROCESSING

The general downlink structure for the Housekeeping (H/K) telemetry, diagnostic telemetry, and science data is the Channel Access Data Unit (CADU) and the basic unit of SC or Instrument telemetry shall be the CCSDS Path Protocol Data Unit as specified in Section 2.2.1, document 8.

The following is a brief overview of the SC telemetry process.

6.2.1 S-band Real-time Downlink

Instrument and Spacecraft H/K packets are transmitted, via 1553B bus, to the TIE. Selected set of packets are formatted into CCSDS interleave depth 1 VCDUs and subsequently CADUs for real-time transmission, via S-band, at 1.024 kbps or 4.096 kbps to TDRSS, or 16.384 kbps directly to the ground stations. A fill VCDU is transmitted to keep the link to ground active when no packets are available for transmission to the ground. The spacecraft outputs continuous fill CADUs, if a real-time CADU is not available for the return link. The S-band low rate CADU is 256 octets in length. The application of the CCSDS protocol for the S-band standard telemetry CADU is shown in Figure 6.2.1-1.

6.2.2 X-band Real-time Downlink

The X-band section of the PM-1 SC communications provides two modes of real-time transmission.

a. In the Direct Broadcast (DB) mode, high-rate instrument science data is transmitted to the FMU via high speed Transparent Asynchronous Transmitter/Receiver Interface (TAXI) bus (from AIRS and CERES) and a balanced differential serial/digital data interface (AMSR-E). The FMU formats the data into M_PDUs, processes the M_PDUs, formats VCDUs, generates Reed Solomon code, adds the 32-bit sync code, and generates CADUs. The CADU is sent to the X-band communication equipment for high-rate transmission at 15 Mbps to the ground broadcast receiving system, or to the SSR for storage and playback.

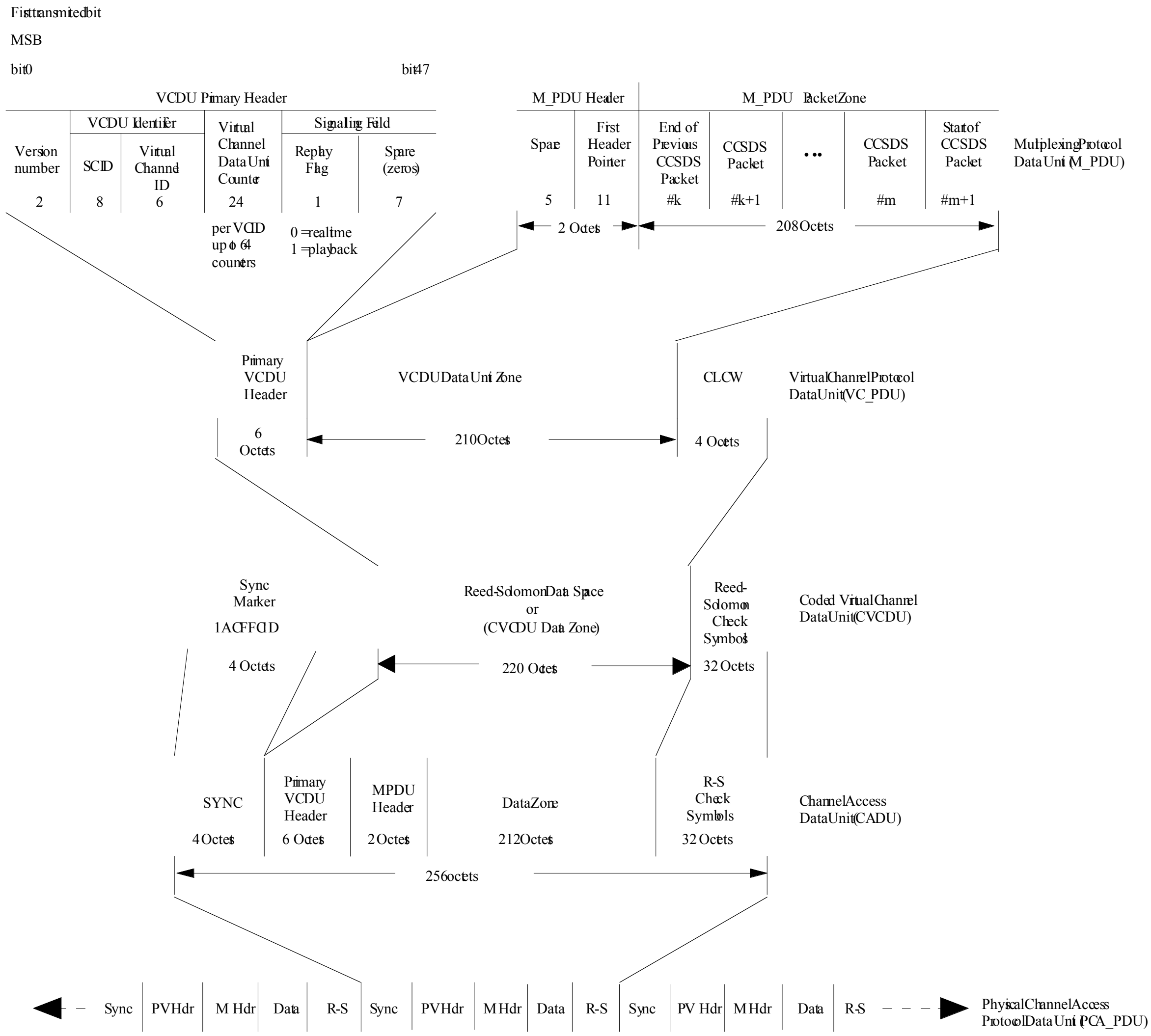


Figure 6.2.1-1. PM-1 S-band CADU

b. In the Direct Downlink (DD) mode, low rate science data is transferred to the FMU via RT to RT transfer. The FMU formats the data in the same manner as the high rate science data. Selected real-time high-rate and low-rate science data are transmitted to the EOSDIS ground stations at 15 Mbps.

The X-band CADU is identical for both H/K and science data. The Virtual Channel Identifier distinguishes the CADU as either a H/K or a science CADU. The X-band CADU utilizes interleave depth 4, the packet length is 1024 octets. The application of the CCSDS protocol for the high-rate X-band CADU is shown in Figure 6.2.2-1.

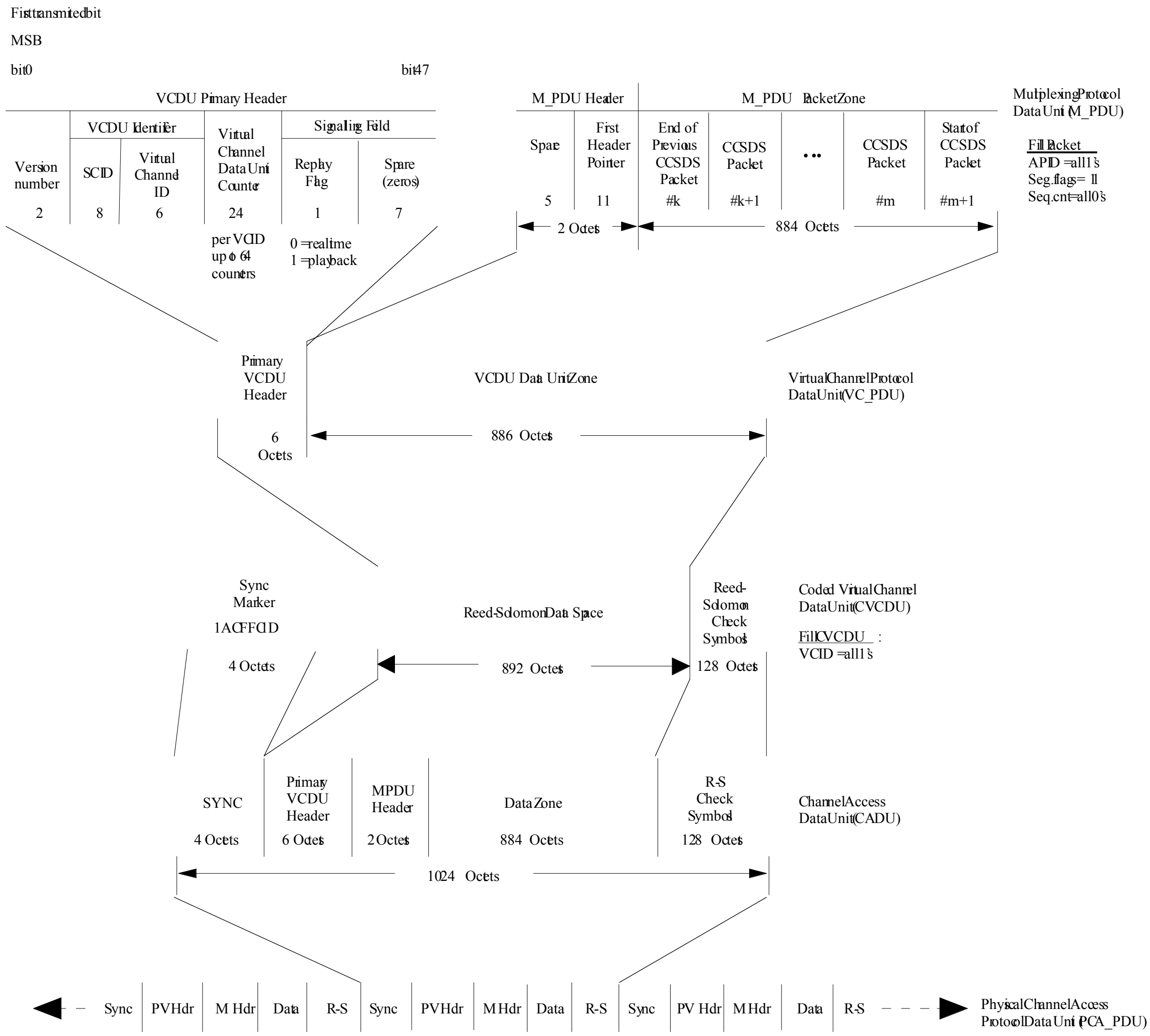


Figure 6.2.2-1. X-band CADU for Science and Housekeeping Data

6.2.3 S-band and X-band Storage

Packetized H/K data destined for storage is processed by the TIE into VCDUs. The CTC routes the data from the TIE to the FMU via an RT-to-RT transfer on the Primary Data Bus. The FMU sends the VCDUs to the SSR where they are stored in Bypass mode to a specific H/K storage partition.

a. On playback request, the FMU/SSR retrieves VCDUs from the H/K storage partition. The VCDUs are passed on to the TIE which Reed-Solomon (R-S) encodes it to create a Coded Virtual Channel Data Unit (CVCDU). The FMU/SSR forms the CVCDU into a Channel Access Data Unit (CADU), and finally convolutionally encodes the CADU as it is passed on to the S-band Transponder where it is downlinked to the ground at 524.288 kbps, simultaneously with the 16.384 kbps real-time H/K data.

b. Additionally, all H/K packets that are sent to the FMU, are formatted into R-S interleave depth 4 CADUs, and passed on to the SSR for storage. Upon playback request, the CADUs are retrieved from the SSR and passed on (with Science data) to the X-band transponder for DP to the EPGS at 150 Mbps.

6.3 PM-1 SPACECRAFT TELEMETRY

The PM-1 Spacecraft telemetry consists of health and status telemetry and memory dump data. Raw spacecraft data is encapsulated into CCSDS version 1 packets. Each telemetry packet has an associated telemetry Packet List (Figure 6.3-1) and telemetry Format table (Figure 6.3-2) that determines the contents of the data portion of the packet. A standard telemetry format table contains up to 128 entries. Table 6.3-1 defines the standard telemetry format table fields. Figure 6.3-3 defines the Telemetry Access Types. Packet size will include the CCSDS headers. Each packet's telemetry format table is loadable from the ground and includes the packet's APID as well as a memory dump indicator. The length of the telemetry packet and the rate of telemetry packet generation are controlled via an active packet list on each controller. The active packet list is loadable from the ground and includes the packet's internal identifier (not APID). The spacecraft supports a maximum of 16 packets per controller. Each packet may be up to 256 octets in size with the actual packet size being determined by the corresponding telemetry format table. There are up to 4 packet lists per controller and each packet list can select from any of the 16 format tables per CTC (on-line and off-line), PC, and ISC. The GNCC has 20 format tables and 5 packet lists to accommodate the Ground Based Attitude Determination (GBAD) packets. However, only one packet list on each of the four controllers is active at any given time and is selectable via ground command. The ground system may change the entries in any of the telemetry format tables and packet lists via memory loads.

6.3.1 Spacecraft Bus Housekeeping Telemetry Packet Format

The PM-1 SC Bus H/K telemetry packet consists of two major components; the Primary Header and the Data Zone as defined in Figure 6.3.1-1.

6.3.1.1 Primary Header

All PM-1 telemetry packets comply with CCSDS recommendation.

6.3.1.1.1 APIDS

Table 6.3.1.1.1-1 lists the APID assignments for the S-band downlink. Table 6.3.1.1.1-2 lists the APID assignments for the X-band downlink.

		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Pkt	**0**	Format Table Number																Pkt # 0
List	**1**	Sample Period																
# 0	**2**	Slot Number																
…		. . . . . .																
		Format Table Number																Pkt # 15
# 3		Sample Period																
	191	Slot Number																
Pkt	**192**	Format Table Number																Pkt # 0
List		Sample Period																
# 4		Slot Number																
(GNCC Only)		. . . . . .																
		Format Table Number																Pkt # 19
		Sample Period																
	251	Slot Number																

Figure 6.3.1. Telemetry Packet List

		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
fmt_tbl number 0 ::: 15	**0**	mdf	spare		number of entry (*)													
	1	spare					APID											
	2	access type (*)									start addr msb (*)							entry #1
	3	start addr lsb (*)																
	4	access type (*)									start addr msb (*)							entry #2
	5	start addr lsb (*)																
		...																
		access type (*)									start addr msb (*)							entry #128
	4127	start addr lsb (*)																
fmt_tbl number 16 ::: 19 (GNCC only)	**4128**	mdf	spare		number of entry (*)													
		spare					APID											
		access type (*)									start addr msb (*)							entry #1
		start addr lsb (*)																
		access type (*)									start addr msb (*)							entry #2
		start addr lsb (*)																
		...																
		access type (*)									start addr msb (*)							entry #128
	5159	start addr lsb (*)																

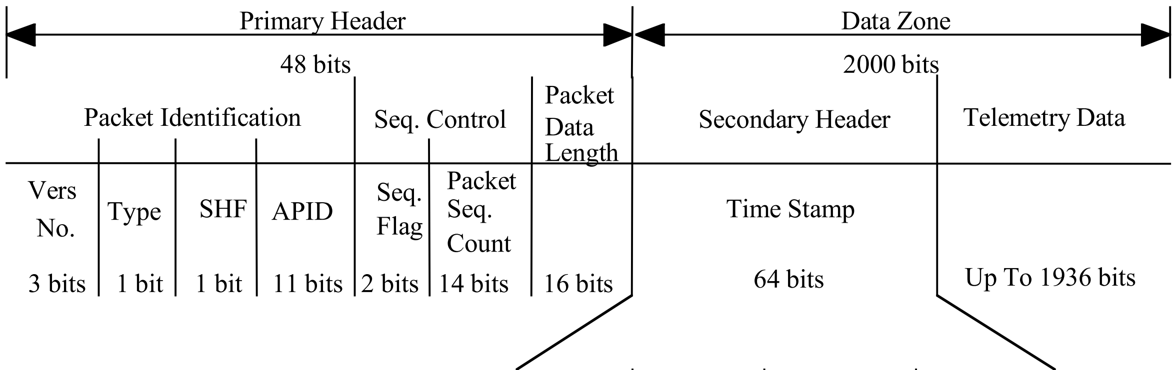
Figure 6.3-2. Packet Format Tables for Standard Telemetry

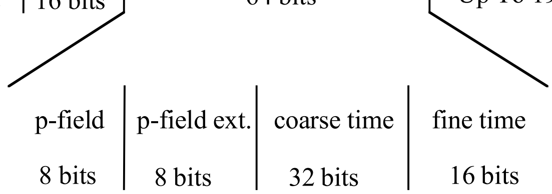
Table 6.3-1. PM-1 Standard Telemetry Format Table Fields Defined

Field	**Description**
Memory Dump Flag	Indicates whether the Telemetry Format Table is a standard format table or a memory dump format table. The valid range is 0 - 1. 0 = Standard 1 = Memory Dump
Application Process ID	Contains the packet's APID. The defined range per controller is allocated in Table 6.3.1.1.1-1
Memory Dump Requests Region Start Address	Contains the region requests for memory dumps. Contains the starting physical address of the memory dump region. This field is only applicable to memory dump format tables. The valid range is as follows: CTC RAM: 100000H - 1BFFFFH CTC EEPROM: 200000H - 27FFFFH PC, GNCC, and ISC RAM: 100000H - 13FFFFH
Region Word Count	Contains the number of words to dump from the memory dump region. This field is only applicable to memory dump format tables. The valid range is 1 - 512.
Standard Telemetry Requests	Contains the data requests for collecting spacecraft telemetry data. This field is only applicable to standard format tables.
Data Address	This sub-field contains the physical address of the data to be read. The valid range is as follows: CTC RAM: 100000H - 1BFFFFH PC, GNCC, and ISC RAM: 100000H - 13FFFFH
Access Type	This sub-field defines the number of octets to read from the specified Data Address. The valid range is 0 - 8. 0 = MSH 1 = LSH 2 = 16-bit Wd 3 = 2 16-bit Wds 4 = 16-bit Float 5 = 24-bit Float 6 = 32-bit Float 7 = 40-bit Float 8 = 48-bit Float

Access Type	Words to Retrieve	Processing	Bytes to Output
MSH	1	Extract the 8 MSBs	1
LSH	1	Extract the 8 LSBs	1
16-bit wd	1	None	2
2 16-bit wds	2	None	4
16-bit float	2	Byte 1: 8 MSBs of word 1 (8 MSBs of mantissa) Byte 2: 8 LSBs of word 2 (exponent)	2
24-bit float	2	Bytes 1-2: word 1 (16 MSBs of mantissa) Byte 3: 8 LSBs of word 2 (exponent)	3
32-bit float	2	None	4
40-bit float	3	Bytes 1-4: words 1-2 (24 MSBs of mantissa and entire exponent) Byte 5: 8 msbs of word 3 (next 8 MSBS of mantissa)	5
48-bit float	3	None	6

Figure 6.3.3. Telemetry Access Types





Notes:
1. Version # = 000
2. Type = 0
3. Secondary Header Flag = 1
4 APID = Allocated in Tables 6.3.1.1.1-1 and -2
5. Sequence Flag = 11 (Unsegmented)
6. Packet Sequence Count = Monotonically increasing number. The Sequence Count of the first packet following a controller power-up shall be zero (0).
7. Packet Data Length = Total number of octets in the Data Zone minus 1.
8. Secondary Header: Contains the time that the telemetry data in the packet was collected. The time tag shall be in CCSDS Unsegmented time code (CUC) where:
    p-field - bit 0 =1 = second octet is present
        bits 1-3 = 001= Epoch Time = Jan. 1, 1958
        bits 4-5 = 11= 4 octets coarse time present
        bits 6-7 = 10 = 2 octets fine time present
    p-field extension - bit 0 = 0 = No extension is present
        bits 1-7 = Leap Seconds, Range = 0 - 127 seconds
    T-field, Coarse time - bits 0-31 = No. of secs. since Jan. 1, 1958, Range 0 - 4,294,967,295
    T-field, Fine time - bits 0-15 = Sub-seconds, Range: 0-65,535, Units 15.258 microsecs.
9. Telemetry Data Field: Contains up to 242 octets of data. When an odd number of data octets have been collected, a single fill octet of all zeros shall be appended tothe data to force the packet to end on a 16-bit boundary.

Figure 6.3.1-1. Spacecraft Telemetry Packet Format

Table 6.3.1.1.1-1. Telemetry Downlink VCID/APID Assignments – S-band

Down-Link Rate	Operations State	Packet Size (incl. Hdrs) (Octets)	$VCID_{10}$	$APID_{10}$	Contents
16.384 kbps	S-band - Normal Operation	160 - 256	2	484 - 486	SC ISC “A” SUROM
16.384 kbps	S-band - Normal Operation	160 - 256	2	487 - 489	SC ISC “B” SUROM
16.384 kbps	S-band - Normal Operation	160 - 256	2	490 - 492	SC PC “A” SUROM
16.384 kbps	S-band - Normal Operation	160 - 256	2	493 - 495	SC PC “B” SUROM
16.384 kbps	S-band - Normal Operation	160 - 256	2	496 - 498	SC GNCC “A” SUROM
16.384 kbps	S-band - Normal Operation	160 - 256	2	499 - 501	SC GNCC “B” SUROM
16.384 kbps	S-band - Normal Operation	160 - 256	2	502 - 504	SC CTC “A” SUROM
16.384 kbps	S-band - Normal Operation	160 - 256	2	505 - 507	SC CTC “B” SUROM
16.384 kbps	S-band - Normal Operation	15 - 256	2	508 - 662	SC ISC
16.384 kbps	S-band - Normal Operation	15 - 256	2	663 - 817	SC PC
16.384 kbps	S-band - Normal Operation	15 - 256	2	818 - 956	SC GNCC
16.384 kbps	S-band - Normal Operation	15 - 256	2	973 - 1127	SC CTC (On-line)
16.384 kbps	S-band - Normal Operation	15 - 256	2	1128 - 1147	SC CTC (Off-line)
16.384 kbps	S-band - Normal Operation	15 - 38	2	1148 - 1153	TIE
16.384 kbps	S-band - Normal Operation	79	2	113	MODIS Dump Data
16.384 kbps	S-band - Normal Operation	79	2	114	MODIS Low Rate Engineering Data
16.384 kbps	S-band - Normal Operation	271	2	140	CERES +Y Aft Low Rate Engineering Data
16.384 kbps	S-band - Normal Operation	271	2	156	CERES -Y Fore Low Rate Engineering Data

Table 6.3.1.1.1-1. Telemetry Downlink VCID/APID Assignments – S-band (Cont'd)

Down-Link Rate	Operations State	Packet Size (incl. Hdrs) (Octets)	$VCID_{10}$	$APID_{10}$	Contents
16.384 kbps	S-band - Normal Operation	127	2	220	AMSR-E Low Rate Engineering Data
16.384 kbps	S-band - Normal Operation	162	2	264	AMSU-A1 Low Rate Engineering Data - No Mode
16.384 kbps	S-band - Normal Operation	162	2	265	AMSU-A1 Low Rate Engineering Data - Full Scan Mode
16.384 kbps	S-band - Normal Operation	162	2	266	AMSU-A1 Low Rate Engineering Data - Staring Mode
16.384 kbps	S-band - Normal Operation	88	2	296	AMSU-A2 Low Rate Engineering Data - No Mode
16.384 kbps	S-band - Normal Operation	88	2	297	AMSU-A2 Low Rate Engineering Data - Full Scan Mode
16.384 kbps	S-band - Normal Operation	88	2	298	AMSU-A2 Low Rate Engineering Data - Staring Mode
16.384 kbps	S-band - Normal Operation	67	2	340	HSB Low Rate Engineering Data
16.384 kbps	S-band - Normal Operation	256	2	394	AIRS Standard low-rate 1553B engineering data Packet #1
16.384 kbps	S-band - Normal Operation	256	2	395	AIRS Standard low-rate 1553B engineering data Packet #2
16.384 kbps	S-band - Normal Operation	256	2	396	AIRS Flexible low-rate 1553B engineering data - Packet # 1
16.384 kbps	S-band - Normal Operation	256	2	397	AIRS Flexible low-rate 1553B engineering data - Packet # 2
4.096 kbps	S-band - TDRSS SSA Mode	As Above	2	See Contents	Selected subset of 16.384 kbps data
1.024 kbps	S-band - TDRSS MA/SSA Mode	As Above	2	See Contents	Selected subset of 16.384 kbps data
524.288 kbps	S-band - Normal Operation - Playback	As Above	1	See Contents	Same APIDs as 16.384 kbps, different downlink rate

Table 6.3.1.1.1-2. Telemetry Downlink VCID/APID Assignments – X-band

Down-Link Rate	Operations State	Packet Size (incl. Hdrs) (Octets)	$VCID_{10}$	$APID_{10}$	Contents
150 Mbps[1]	X-band Playback	Same packet size as Low-Rate H/K Tlm	3	957 - 972	Ground Based Attitude Determination (GBAD)
150/15/15[2] Mbps	X-band - Instrument Science & H/K + S-band H/K Playback	Same packet size as Low-Rate H/K Tlm	5	See Contents	Summation of all Instrument Science & H/K APIDs. It also includes the S-band H/K .
CERES +Y Aft INSTRUMENT					
150/15/15[2] Mbps	X-band	6982	10	141	Science Data
150/15/15[2] Mbps	X-band	6982	10	142	Calibration Data
150/15/15[2] Mbps	X-band	6982	10	143	Diagnostic Data
150/15/15[2] Mbps	X-band	6982	10	144	Fixed Pattern
CERES-Y Fore INSTRUMENT					
150/15/15[2] Mbps	X-band	6982	15	157	Science Data
150/15/15[2] Mbps	X-band	6982	15	158	Calibration Data
150/15/15[2] Mbps	X-band	6982	15	159	Diagnostic Data
150/15/15[2] Mbps	X-band	6982	15	160	Fixed Pattern
AMSU-A1 INSTRUMENT					
150/15/15[2] Mbps	X-band	162	20	257	No Mode

Table 6.3.1.1.1-2. Telemetry Downlink VCID/APID Assignments – X-band (Cont'd)

Down-Link Rate	Operations State	Packet Size (incl. Hdrs) (Octets)	$VCID_{10}$	$APID_{10}$	Contents
150/15/ 15^2 Mbps	X-band	704	20	259	Packet 1 - Staring Mode - NADIR, Warm Calibration, Cold Calibration
150/15/ 15^2 Mbps	X-band	492	20	260	Packet 2 - Staring Mode - NADIR, Warm Calibration, Cold Calibration
150/15/ 15^2 Mbps	X-band	704	20	261	Packet 1 - Full Scan Mode
150/15/ 15^2 Mbps	X-band	612	20	262	Packet 2 - Full Scan Mode
AMSU-A2 INSTRUMENT					
150/15/ 15^2 Mbps	X-band	88	25	288	No Mode
150/15/ 15^2 Mbps	X-band	326	25	289	Staring Mode
150/15/ 15^2 Mbps	X-band	350	25	290	Full Scan Mode
MODIS INSTRUMENT					
150/15/ 15^2 Mbps	X-band	642	30	64	Science/Day/Long
150/15/ 15^2 Mbps	X-band	276	30	64	Science/Night/Short
150/15/ 15^2 Mbps	X-band	642	30	64	Engineering Data
150/15/ 15^2 Mbps	X-band	642	30	127	Memory Dump or Test Data
AIRS INSTRUMENT					
150/15/ 15^2 Mbps	X-band	4286	35	404	Science Data - 90 scene footprint packets per scan cycle

Table 6.3.1.1.1-2. Telemetry Downlink VCID/APID Assignments – X-band (Cont'd)

Down-Link Rate	Operations State	Packet Size (incl. Hdrs) (Octets)	$VCID_{10}$	$APID_{10}$	Contents
150/15/15[2] Mbps	X-band	4286	35	405	Calibration Data - 4 space look calibration packets per cycle
150/15/15[2] Mbps	X-band	4286	35	406	Calibration Data - 1 radiometric calibration packet per cycle
150/15/15[2] Mbps	X-band	4286	35	407	Calibration Data - 1 combined (Spectral +Vis/NIR) calibration packets per scan/orbit
150/15/15[2] Mbps	X-band	4286	35	414	Standard High Rate Engineering Data Packet 1
150/15/15[2] Mbps	X-band	4286	35	415	Standard High Rate Engineering Data Packet 2
150/15/15[2] Mbps	X-band	4286	35	416	Flexible High Rate Engineering Data Packet 1
150/15/15[2] Mbps	X-band	4286	35	417	Flexible High Rate Engineering Data Packet 2
150/15/15[2] Mbps	X-band	4286	35	418, 419	Not used - Reserved
AMSR-E INSTRUMENT					
150/15/15[2] Mbps	X-band	1024	40	192	Science Data
HSB INSTRUMENT					
150/15/15[2] Mbps	X-band	665	45	342	Science Data

Notes:

1) GBAD packet may be commanded to Direct Downlink or Direct Broadcast mode at 15 Mbps

2) 150 Mbps = Direct Playback of all stored science and engineering data to direct playback ground stations, but not simultaneously with either direct downlink or direct broadcast.

15 Mbps = Direct Broadcast of real-time spacecraft bus engineering data and instrument science and engineering data to direct broadcast ground stations.

15 Mbps = Direct Downlink of selected science and engineering data in real-time to the direct playback ground stations, but not simultaneously with direct playback.

6.3.2 SC Memory Dump

The Memory Dump function provides a method for the ground to dump selected regions of any prime or redundant C&DH controllers memory while the flight software is running. A standard telemetry format table, Figure 6.3.2-1, will contain a memory dump flag, a physical address and a word count indicating the location of the region of memory and the number of words to be dumped. Memory dumps are enabled/disabled via ground commands. Memory dumps are automatically disabled when all the regions specified in the memory dump format table have been dumped**.**

<table>
<tr><th></th><th></th><th>0</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>10</th><th>11</th><th>12</th><th>13</th><th>14</th><th>15</th><th></th></tr>
<tr><td rowspan="9">fmt_tbl
number
0
:::
15</td><td>0</td><td>mdf</td><td colspan="2">spare</td><td colspan="13">number of entry (*)</td><td></td></tr>
<tr><td>1</td><td colspan="5">spare</td><td colspan="11">APID</td><td></td></tr>
<tr><td>2</td><td colspan="9">M words</td><td colspan="7">start addr msb (*)</td><td rowspan="2">entry
#1</td></tr>
<tr><td>3</td><td colspan="16">start addr lsb (*)</td></tr>
<tr><td>4</td><td colspan="9">M words</td><td colspan="7">start addr msb (*)</td><td rowspan="2">entry
#2</td></tr>
<tr><td>5</td><td colspan="16">start addr lsb (*)</td></tr>
<tr><td></td><td colspan="16">...
...</td><td></td></tr>
<tr><td></td><td colspan="9">M words</td><td colspan="7">start addr msb (*)</td><td rowspan="2">entry
#128</td></tr>
<tr><td>4127</td><td colspan="16">start addr lsb (*)</td></tr>
<tr><td rowspan="9">fmt_tbl
number
16
:::
19
(GNCC
only)</td><td>4128</td><td>mdf</td><td colspan="2">spare</td><td colspan="13">number of entry (*)</td><td></td></tr>
<tr><td></td><td colspan="5">spare</td><td colspan="11">APID</td><td></td></tr>
<tr><td></td><td colspan="9">M words</td><td colspan="7">start addr msb (*)</td><td rowspan="2">entry
#1</td></tr>
<tr><td></td><td colspan="16">start addr lsb (*)</td></tr>
<tr><td></td><td colspan="9">M words</td><td colspan="7">start addr msb (*)</td><td rowspan="2">entry
#2</td></tr>
<tr><td></td><td colspan="16">start addr lsb (*)</td></tr>
<tr><td></td><td colspan="16">...
...</td><td></td></tr>
<tr><td></td><td colspan="9">M words</td><td colspan="7">start addr msb (*)</td><td rowspan="2">entry
#128</td></tr>
<tr><td>5159</td><td colspan="16">start addr lsb (*)</td></tr>
</table>

Figure 6.3.2-1. Packet Format Tables for Memory Dump Telemetry

6.3.2.1 SC Memory Dump Packet Format

The PM-1 SC Memory Dump Packet is shown in Figure 6.3.2.1-1. All the regions specified by the memory dump format table will be contained in several consecutive packets per APID. All packets, except for the last one for a region, will be 256 octets in length. The last packet will contain the data required to complete the dump. Each packet of a memory dump contains the starting address of the data contained in the packet.

Primary Header (48 bits)							Data Zone (up to 2000 bits)		
Packet Identification				Packet Seq Control		Packet Data Length	Secondary Header	Start Address	Dump Data
Version #	Type	Sec Header Flag	APID	Seq Flag	Packet Seq Count				
3 bits	1 bit	1 bit	11 bits	2 bits	14 bits	16 bits	64 bits	32 bits	up to 1904 bits

Notes:

1. Version #: 000
2. Type: 0
3. Secondary Header Flag: 1
4. APID: Defined range per controller as allocated in Table 6.3.1.1.1-1 and -2.
5. Sequence Flag: 11 (unsegmented)
6. Packet Sequence Count: Monotonically increasing number. The Sequence Count of the first packet following a controller power-up shall be zero (0).
7. Packet Data Length: Number of octets in the Data Zone minus 1.
8. Secondary Header: Contains the data time tag. The time tag shall represent the time that the dump data in the packet was collected. The time tag shall comply with the CCSDS Unsegmented Time Code (CUC).
9. Start Address: Contains the starting physical address of the data in the Dump Data field.
10. Dump Data Field: Contains up to 119 16-bit words. For a given memory dump region, each packet, except the last one, shall contain 119 16-bit words. The last packet shall only contain the remaining data from the dump region.

FIGURE 6.3.2.1-1. PM-1 SC Bus Memory Dump Packet Format

6.3.3 Multiplexing Protocol Data Unit (M_PDU)

The TIE and the FMU shall generate Multiplexer Protocol Data Units (M_PDUs). Packet lengths are variable and can be longer or shorter than the CADU data field, allowing multiple packets per CADU or multiple CADUs per packet. The M_PDU data structure is used to locate the start of a packet in the CADU and allows the insertion of variable length packets into fixed length CADUs.

The M_PDU consists of a Packet Zone in which the CCSDS packets are compiled and a header that points to the first Packet Primary Header in the Packet Zone. The length of the M_PDU is fixed based on the Virtual Channel.

The S-band M_PDU is shown in Figure 6.2.1-1, the X-band M_PDU is shown in Figure 6.2.2-1.

6.3.3.1 M_PDU Header

The M_PDU header contains a 5-bit spare field and an 11-bit First Header Pointer.

6.3.3.1.1 Spare Bits

The first five bits of the M_PDU header are unassigned and shall be set to "00000"".

6.3.3.1.2 First Header Pointer

Variable length packets shall be multiplexed into the VCDU via the use of an M_PDU. The last 11 bits of the M_PDU header shall provide a binary count, ""P"" (modulo 2048), which when incremented by 1, shall point to the first byte of the first complete packet header in the MPDU.

Per CCSDS, the count "P" is required to be expressed as:

P = (Number of the octet) - 1

The M_PDU first header pointer shall be set to all 'ones' (1s) if no packet header resides within the M_PDU. If the first header in the M_PDU is a partial header (packet header split between two M_PDUs), it shall be ignored, and the first header shall be the next header resident in the M_PDU.

6.3.3.1.3 M_PDU Packet Zone

Packets of data shall be placed end-to-end in the Packet Zone. The beginning of the Packet Zone is not necessarily the beginning of a packet, since it will often be a continuation from a packet from the previous M_PDU.

6.3.3.2 Fill Packets

Fill packets may be used as required to limit the data storage time on board, or to complete an M_PDU data zone. A fill packet is identified by its APID field (all 1's), Packet Sequence Count (all 0's), and its data field must contain a minimum of 1 byte of fill data (all 0's).

6.3.3.2.1 S-band M_PDU Fill Packets

The TIE will not generate fill packets.

6.3.3.2.2 X-band M_PDU Fill Packets

The SC FMU/SSR shall create a fill packet to complete the MPDU data zone. The format for the FMU/SSR Fill Packet shall be as shown in Figure 6.3.3.2.2-1.

Primary Header							Packet Data Field
Packet Identification				Seq Control		Packet Data Length	Data Zone
Version	Type	Sec. Hdr Flag	APID	Seq. Flag	Packet Seq. Count		User Data Field
3 bits	1 bit	1 bit	11 bits	2 bits	14 bits	16 bits	

Note:
1. Version # = 000
2. Type = 0 (Telemetry Packet)
3. Secondary Header Flag = 0
4. APID = 11111111111 (Fill Packet)
5. Sequence Flag = 11 (Unsegmented)
6. Packet Sequence Count = 00000000000000 (Along with APID, indicates Fill Packet.
7. Packet Data Length = Number of octets in Data Zone minus 1.
8. Packet Data Field = Contains a minimum of 1 byte of fill data. Fill data = all 0's.

FIGURE 6.3.3.2.2-1. PM-1 SC FMU/SSR Fill Packet

6.3.4 Coded Virtual Channel Data Unit

Section 5 of the CCSDS 701.0-B-2 describes the Virtual Channel Data Unit Format. The following is the PM-1 spacecraft implementation. A CVCDU consists of a CVCDU primary header, a CVCDU Data Unit Zone, and a block of Reed-Solomon check symbols.

The Coded Virtual Channel Data Unit (CVCDU) structure for S-band telemetry (H/K telemetry, low-rate science, and diagnostic/dump) data is shown in Figure 6.2.1-1. The X-band CVCDU is shown in Figure 6.2.2-1. The S-band telemetry CVCDU has the four octet CLCW, the X-band CVCDU does not.

6.3.4.1 CVCDU Primary Header

The PM-1 SC CVCDU Primary Header is shown in Figure 6.3.4.1-1.

First transmited bit MSB 0 — bit 47

VCDU Primary Header					
Version	VCDU Identifier		VCDU Counter	Signalling Field	
	SCID	VCID		Replay Flag	Spare (zeros)
2	8	6	24	1	7

Note:
1. Version # = 01 (CCSDS VCDU)
2. SCID = $9A_{16}$
3. VCID = Reference Table 6.3.1.1.1-1 and -2.
4. VCDU Counter = Sequential Count of the total number of VCDUs which have been transmitted on each of the Virtual Channels.
5. Replay Flag = 0 = Data transmitted in real-time; 1 = Playback & Science data.
6. Spare = All 0's

Figure 6.3.4.1-1. PM-1 CVCDU Primary Header

6.3.4.2 CVCDU Data Unit Zone

The CVCDU Data Unit Zone contains the M_PDU. The length of the S-band data unit zone shall be 220 octets and the length of the X-band data unit zone shall be 892 octets.

6.3.4.2.1 Operational Control Field

The 4 octet Operational Control Field shall be used for the CLCW. The CLCW (reference this ICD, section 5.1.2.1) is only utilized with the S-band downlink.

6.3.4.2.2 Command Link Control Word

For each open virtual channel, (i.e., VCID 0 and 1, if not in lockout or in wait state), there will be an assigned CLCW.

6.3.4.2.3 Reed-Solomon Check Symbols

The Reed-Solomon Check Symbols are the final bits in the CVCDU and are generated according to CCSDS 101.0-B-3, Recommendation For Space Data Systems Standards; Telemetry Channel Coding. There shall be 32 check symbols for every 223 symbols of preceding data in the CVCDU. For the X-band data (interleave depth = 4), there are 128 octets of check symbols and for the S-band telemetry data, (interleave depth = 1), there are 32 octets of check symbols.

6.3.5 Channel Access Data Unit

A fixed 32 bit pattern sync pattern represented in hexadecimal notation as: lACFFClD, shall be added to the front of each VCDU to create a Channel Access Data Unit (CADU).

6.3.5.1 Fill CADUs - S-band

The spacecraft outputs continuous data CADUs. If a CADU is not available for the return link, the FMU/SSR and the TIE will generate and transmit fill CADUs. The TIE generates and transmits fill CADUs in both STDN and TDRSS modes. The VCDU Decommutation Function (ground system) for the Fill Removal Function shall recognize "Fill"" VCDUs by their unique VCID value and discard them.

6.3.5.1.1 STDN Format - LRC

In STDN Mode, when no real-time data is available at VCDU release time, the TIE I-Channel (LRC for Transponder Channel 1) interface will generate a "Fill" VCDU as shown in Figure 6.3.5.1.1-1.

Sync	Vers	SCID	VCID	Seq. Count	Replay	Spare	VCDU Data Zone Fill Pattern	Reed-Solomon Check Symbols
"1ACFFC1D" h	"01" B	"9A" h	"3F" h	Monotonically Increasing to 2^{24}	"0" b	"0" h	214 Octets = "11" h	32 Octets

Figure 6.3.5.1.1-1. "Fill" CADU - STDN Mode - LRC

6.3.5.1.2 STDN Format - HRC

In STDN Mode, when no real-time data is available at VCDU release time, the TIE Q-Channel (HRC for Transponder Channel 2) interface will generate a "Fill" VCDU as shown in Figure 6.3.5.1.2-1

Sync	Vers	SCID	VCID	Seq. Count	Replay	Spare	VCDU Data Zone Fill Pattern	Reed-Solomon Check Symbols
"1ACFFC1D" $_{16}$	"01" $_2$	"9A" $_{16}$	"3F" $_{16}$	Monotonically Increasing to 2^{24}	"0" $_2$	"0" $_{16}$	214 Octets = "A5" $_{16}$	32 Octets

Figure 6.3.5.1.2-1. "Fill" CADU - STDN Mode - HRC

6.3.5.1.3 TDRSS Format

In TDRSS Mode, when no real-time data is available at VCDU release time, the TIE I-Channel (Transponder Channel 1) interface and the TIE Q-Channel (Transponder Channel 2) will generate a "Fill" VCDU as shown in Figure 6.3.5.1.2-1.

6.3.5.1.4 FMU/SSR (X-band) Fill CADU

The FMU/SSR shall provide fill CADUs as required to maintain a constant flow of CADU sync headers and data transitions to facilitate maintenance of modulator link synchronization.

The VCDU fill pattern will be "7878"$_{16}$ and distributed bit wise starting with "Q" so that,

I channel: 11 00 11 00 …..
Q channel: 01 10 01 10…..

The FMU/SSR CADU is shown in Figure 6.3.5.1.4-1.

Sync	Vers	SCID	VCID	Seq. Count	Replay	Spare	VCDU Data Zone Fill Pattern	Reed-Solomon Check Symbols
"1ACFFC1D$_{16}$"	"01"$_2$	"9A"$_{16}$	"3F"$_{16}$	Always "0"	"0"$_2$	"0"$_{16}$	886 Octets = "7878"$_{16}$	128 Octets

Figure 6.3.5.1.4-1. X-band Fill CADU

6.3.6 Bit Transition Generation

To ensure adequate bit transition density when the PCA_PDU is modulated directly onto the space channel, a random sequence will be exclusive ORed with each bit of the CADU, exclusive of the Synchronization Marker. The random sequence shall be generated using the following polynomial: $h(x) = x^8 + x^7 + x^5 + x^3 + 1$.

For the S-band links, data is received by the SC S-band transponder from the C&DH Subsystem in NRZ-L format with a capability of being randomized within the TIE. The randomizer is commandable on or off.

6.3.7 SUROM Telemetry

In order for the SUROM to provide the same telemetry service regardless of the interface (LSIO or 1553B) through which the commands are received, telemetry are output simultaneously to the LSIO and 1553B.

6.3.7.1 SUROM LSIO Telemetry Format

SUROM provides Version-1 CCSDS packets to the TIE via LSIO. SUROM also provides Version-1 CCSDS packets to the TIE via 1553B. The format for the SUROM Version-1 CCSDS packet will be the same for both the LSIO and Primary Data Bus as shown in Figure 6.3.7.1-1.

Primary Header (6 Octets)							Data Zone (Variable)
Packet Identification				Seq. Control		Packet Length	Data Field
Version #	Type	SHF	APID	Seq. Flag	Packet Seq. Count		
3 bits	1 bit	1 bit	11 bits	2 bits	14 bits	16 bits	Up To 1232 bits

Note:
1. Version # = 000
2. Type = 0
3. Secondary Header Flag = 0 (No Secondary Header Present).
4. APID = Allocated in Table 6.3.1.1.1-1 and -2.
5. Sequence Flag = 11 (Unsegmented)
6. Sequence Count = 00000000000000.
7. Packet Length = Number of octets in the Data Zone minus1
8. Data Field = SUROM = Min. 154 octets; Max of 250 octets
   TIE = Min 1 octet; Max of 32 octets.

Figure 6.3.7.1-1. SUROM/TIE Telemetry Packet

6.3.7.2 SUROM SOH Telemetry

SUROM SOH packets are fixed length 69 words including memory dump telemetry. SUROM SOH telemetry defines the condition of each processor and is downlinked continuously at 1 second intervals and every time a ground command is executed, SUROM telemetry is updated.

For detailed description of SUROM telemetry, reference Section 2.2.3, document 1.

6.3.7.3 SRAM Memory Dump

Upon receipt of the Memory Dump command, 32 words of SRAM as defined by the physical page and offset will be placed in the SUROM telemetry from word 32 through word 63.

6.3.7.4 EEPROM Memory Dump

Upon receipt of the EEPROM dump command, 32 words of EEPROM as defined by the physical page and offset will be placed in the SUROM telemetry from word 32 through word 63.

6.3.8 TIE Status Packet

The TIE internally generates a configuration and status packet as defined in Figure 6.3.7.1-1. TIE configuration and status packet shall be generated once per second, referenced to the CUC Time of Day Clock one-second tick. The TIE telemetry packet size will be a fixed 38 octets. The fixed packet length will be 31 octets. The TIE packet does not use the Secondary Header Field.

6.3.8.1 TIE Data Field

The TIE packet data field will contain a fixed 32 octets of configuration and status data as shown in Figure 6.3.8.1-1.

Word	MSB	LSB
Word 1	Bilevel Word 1	
Word 2	Bilevel Word 2	
Word 3	Relay Word 1	
Word 4	Relay Word 2	
Word 5	Critical Transfer Frame Count	Accepted Codeblock Count
Word 6	Fixed at ‘0’s	TIE Enable Status
Word 7	I Channel Configuration	
Word 8	I Channel Rate Setting (Most Significant Word)	
Word 9	I Channel Rate Setting (Least Significant Word)	
Word 10	Q Channel Configuration	
Word 11	Q Channel Rate Setting (Most Significant Word)	
Word 12	Q Channel Rate Setting (Least Significant Word)	
Word 13	1553B BCRT Control Register	
Word 14	1553B BCRT Status Register	
Word 15	1553B BCRT RT Address Register	
Word 16	TIE Firmware Processing Error Status	

Figure 6.3.8.1-1. TIE Data Field Format

6.3.9 Ground Based Attitude Determination

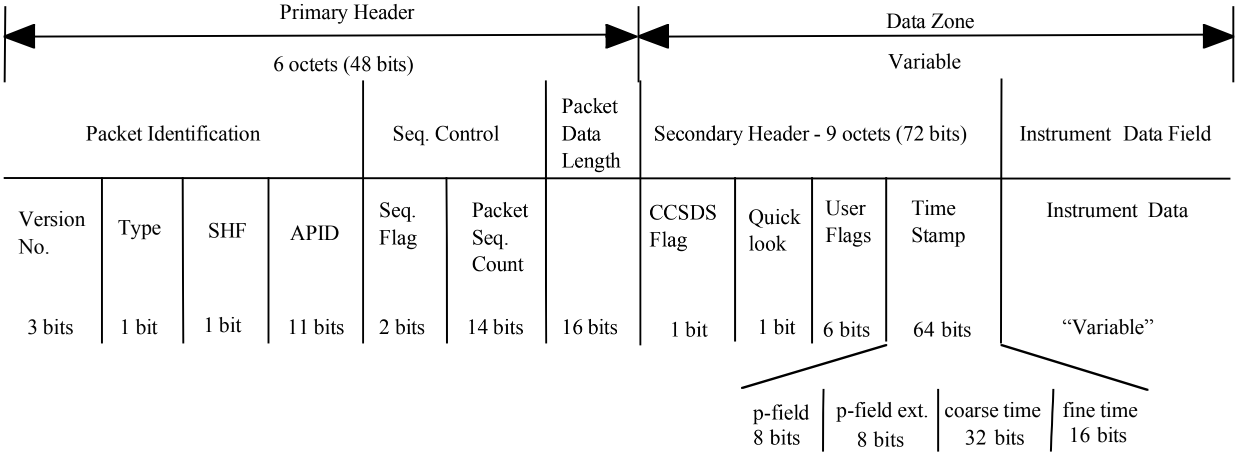
GBAD data is generated internal to the GNCC controller and can be used by the ground system analysts to access the on-board attitude determination processing performance and provide high accuracy attitude fixes prior to entering the on-board Star ID acquisition logic. The GBAD data is separate from standard H/K telemetry. An extra four format tables and 1 additional packet list have been allocated to the GNCC controller to perform this option. The GBAD data is placed into the data zone of a spacecraft packet shown in Figure 6.3.1-1, sent via the Primary Data Bus to the FMU/SSR, encased in an X-band CADU and is playbacked to the ground system at 150 Mbps. The GBAD data packet can be commanded to be routed to the DD or DB mode.

6.4 PM-1 SPACECRAFT INSTRUMENTS

The PM-1 spacecraft carries a contingent of 8 instruments; Advanced Microwave Scanning Radiometer, (AMSR); Advanced Microwave Sounding Unit-A (AMSU-A1 and A2); Atmospheric Infrared Sounder (AIRS); Clouds and the Earth''s Radiant Energy System, (CERES +Y Aft, -Y Fore); Humidity Sounder of Brazil, (HSB); and the Moderate Resolution Imaging Spectrometer (MODIS). The following describes the instrument telemetry formats.

6.4.1 GIRD Instrument Telemetry Format

The Instrument GIRD format is shown in Figure 6.4.1-1. The difference between the instrument and the SC GIRD packets resides in the format of the secondary header. The SC secondary header has 8 octets of CUC time, while the instrument packet contains 1 octet of CCSDS Flag fields followed by 8 octets of CUC time. The SC GIRD packet is defined in paragraphs 6.3 to 6.3.2. The instrument secondary header is defined in Figure 6.4.1-1.



Note:
1. Version # = 000
2. Type = 0
3. Secondary Header Flag = 1
4. APID = Defined per Table 6.3.1.1.1-1 and -2.
5. Sequence Count = 11 (Unsegmented)
6. Packet Sequence Count = Monotonically increasing number.
7. Packet Data Length = Number of octets in the Data Zone minus1.
   - AIRS = 4279 octets - H/R Science and Engineering Data; 249 octets - L/R Engineering Data
   - AMSR-E = 120 octets L/R Engineering Data; 1017 octets Science Data
   - AMSU-A1 = 155 octets L/R Eng. & Science (No mode); 697 octets- (Pkt 1 "All" Science); 605 (Pkt 2 Full Scan); 485 octets (Packet 2 Science Data)
   - AMSU-A2 = 81 octets-L/R Eng. & No mode science data; 343 octets (Full Scan Science); 319 octets -(Staring mode science)
   - HSB = 6o octets (Eng. Data); 658 octets (Science Data)
   - MODIS = 72 octets (Eng. Data)
8. Secondary Header:
   - CCSDS Flag = 1
   - Quick Look Flag = 0 = QL Processing Not Required; 1 = QL Processing Required.
   - User Flags = Reserved for future instrument use.
   - Time Stamp = Expressed in CCSDS Unsegmented Time Code (CUC) where:
     - p-field = Bit 0 = second octet is present
       - Bits 1-3 = 001 = Epoch Time = Jan. 1, 1958
       - Bits 4-5 = 11 = 4 Octets Coarse Time Present
       - Bit 6-7 = 10 = 2 Octets Fine Time Present
     - p-field Extension = Bit 0 = 0 = No extension present
       - Bits 1-7 = Numbe r of seconds to convert TAI to UTC.
     - T-field, Coarse = Bits 0-31 = Number of seconds since Jan. 1, 1958
     - T-field, Fine = Bits 0-15 = Sub-seconds time (LSB = 15.2 microseconds)

9 Instrument Data Field:
   - AIRS = 241 octets - L/R Engineering Packet; 4271 octets = H/R Science & Engineering Packet (Size includes 16-bit Checksum)
   - AMSR-E = 112 octets = L/R Engineering Packet; 1009 octets = Science Data Packet (No Checksum Utilized)
   - AMSU-A1 = 147 octets L/R Eng. & Science (No mode); 689 octets (All Science); 587 octets (Full Scan); 477 octets (Pkt 2, Staring Modes) (Size includes 16-bit Checksum)
   - AMSU-A2 = 73 octets L/R eng. and Science data; 335 octets (Full Scan Science); 311 octets (Staring Mode Science) (Size includes 16-bit Checksum)
   - HSB = 52 octets (Eng. Data); 650 octets (Science Data) (No Checksum Utilized)
   - MODIS = 64 octets (No Checksum Utilized)

Figure 6.4.1-1. GIRD Instrument Telemetry Packet

6.4.2 AIRS

The Spacecraft-to-AIRS interface consists of a Primary Data Bus, high-rate science link, and point-to-point analog channels. The Primary Data Bus interface is used for commanding the instrument and collecting low rate engineering data from it. The high-rate science link (TAXI interface) provides a direct serial interface to the FMU for recording high rate science data on the SSR. As a GIRD compliant instrument, AIRS supports version 1 CCSDS packets for commands, memory and data loads, time code data, low rate engineering data, and high rate science data. The telemetry packet format is the same for AIRS engineering data, science data, and high-rate engineering data as shown and defined in Figure 6.4.1-1. The AIRS low-rate engineering packets are 249 octets in length, the high-rate science and engineering data packets are 4279 octets in length.

6.4.2.1 Engineering Data Packet

The C&T outputs 2 Engineering CCSDS telemetry packets. The spacecraft CTC is responsible for transferring the data over the Primary Data Bus. The C&T output is continuous whenever the AIRS instrument is powered on.

6.4.2.2 High-Rate Data Link Packet

The HRDL outputs 98 CCSDS telemetry packets each scan, 96 packets are Science packets and 2 are Engineering packets. The HRDL output is continuous whenever the AIRS instrument is powered on.

The AIRS instrument will begin operation with two standard packets. The first packet is the nominal (default) engineering data packet, and the second packet contains memory or buffer status. The content of the engineering data within the first packet can be modified by command from the ground. The modified engineering packets are called flexible packets because their content is flexible depending on the ground command. Each flexible packet has its own APID.

6.4.3 AMSR-E

The Spacecraft-to-AMSR-E interface consists of dedicated serial digital channels and point-to-point high-level pulses, analog channels, and bi-levels. The serial digital channels are used for commanding the instrument, providing it with spacecraft time, and collecting housekeeping data and low rate science data from it. The serial digital interface for collecting low rate science data provides a direct link to the FMU/SSR for real-time X-band DB and for storage for recording low rate science data. The AMSR-E instrument supports version 1 CCSDS packets for low rate science data only. All other data to and from the instrument is not in the form of CCSDS packets.

Engineering data collected by the instrument is transmitted over the serial digital interface to the ISC. The ISC generates the CCSDS packet and inserts the AMSR-E data directly into the data zone. The CTC ships the packet over the Primary Data bus to the TIE for transmission to the ground, in real-time, via the S-band Transponder or to the FMU/SSR for storage and subsequent playback via X-band.

6.4.3.1 AMSR-E Engineering Packet

The AMSR-E low-rate engineering packet complies with Figure 6.4.1-1 with the exception of the Secondary Header field. The secondary header is defined in the following paragraph.

6.4.3.1.1 AMSR-E Engineering Packet Secondary Header

The following is AMSR-E usage of the Packet secondary header. The first octet is defined as:

Bit 0 = 0 to designate a non-CCSDS secondary header
Bit 1 = 0 Quick Look processing not required.
Bits 2-7 = Represent Minor Frames and are defined as:

Minor Frames	1–8	are set to 000001
	9-16	are set to 000010
	17-24	are set to 000011
	25-32	are set to 000100

6.4.3.1.5 AMSR-E Engineering Packet Data Field

The AMSR-E engineering packet instrument data field contains eight minor frames formatted as shown in Figure 6.4.3.1.5-1, each consisting of 14 8-bit words. The active bi-level data byte format is shown in Figure 6.4.3.1.5-2.

6.4.3.1.6 AMSR-E Engineering Packet Fill Data

The unused octets in each engineering minor frame shall be filled with all ones (1's) to maintain constant data sets of 14 octets.

6.4.3.2 AMSR-E Science Data

The AMSR-E instrument science data packet is compliant with the version 1 CCSDS packet shown in Figure 6.4.1-1, with the following exceptions:

6.4.3.2.1 Science Packet Sequence Control

The AMSR-E Science Packet Sequence Field is utilized as follows:

Sequence Flag (Bits 0-1) = 01 = Packet 1; Ancillary Data
= 00 = Packets 2 - 15; Observation / Calibration Data
= 10 = Packet 16; Spare

Packet Sequence Count 14 bits = Science Data Packet sequence starts with 0000h and continues until 3FFFh per packet

MSB				LSB
Serial Digital Telemetry	Active Bilevel Data Word	Passive Bilevel Data Word	Active Analog Data Word	Passive Analog Data Word
80 bits	8 bits	8 bits	8 bits	8 bits

Notes:
1. Serial Digital Telemetry: Read from the Serial Digital Telemetry interface when 10 bytes of data are available. Otherwise, 10 bytes of fill data (00H) will be placed here.
2. Active Bilevel Data Word: Formatted as shown in Figure 6.4.3.1.5-2.
3. Passive Bilevel Data Word: The 8 LSBs of the raw passive bilevel value will be placed here.
4. Active Analog Data Word: ADE A, ADE B, and MWA motor currents and motor speeds. The 8 MSBs of the 12-bit raw analog value will be placed here. The data placed in this field will be in accordance with the following table:

Minor Frame	Data
1, 9, 17, 25	ADE A Motor Current
2, 10, 18, 26	ADE A Speed
3, 11, 19, 27	ADE B Motor Current
4, 12, 20, 28	ADE B Speed
5, 13, 21, 29	MWA Motor Current
6, 14, 22, 30	MWA Speed
7, 8, 15, 16	Fill Pattern (00H)
23, 24, 31, 32	Fill Pattern (00H)

5. Passive Analog Data Word: SPC A and SPC B temperatures. The 8 MSBs of the 12-bit raw analog value is placed here. The data placed in this field will be in accordance with the following table:

Minor Frame	Data
1, 9, 17, 25	SPC A Temperature
2, 10, 18, 26	SPC B Temperature
3, 11, 19, 27	Fill Pattern (00H)
4, 12, 20, 28	Fill Pattern (00H)
5, 13, 21, 29	Fill Pattern (00H)
6, 14, 22, 30	Fill Pattern (00H)
7, 8, 15, 16	Fill Pattern (00H)
23, 24, 31, 32	Fill Pattern (00H)

Figure 6.4.3.1.5-1. AMSR-E Engineering Data Minor Frame Format

MSB		LSB
Unused	SPC A Power Status	SPC B Power Status
6 bits	1 bit	1 bit

Notes:
1. Unused: Will always be set to zero.
2. SPC A Power Status: On/Off status for SPC A.
3. SPC B Power Status: On/Off status for SPC B.

Figure 6.4.3.1.5-2. AMSR-E Active Bi-level Data Byte Format

6.4.3.2.1 Instrument Data Field

The first 8 bits of AMSR-E instrument science data will be “dummy data”, defined as all zeroes.

6.4.4 AMSU-A1

The Spacecraft-to-AMSU-A1 interface consists of a Primary Data Bus and point-to-point analog channel. The Primary Data Bus interface is used for commanding the instrument and collecting low rate engineering data and low-rate science data from it. The AMSU-A1 instrument supports version 1 CCSDS packets for commands, time code data, low rate engineering data, and low rate science data.

6.4.4.1 AMSU-A1 Telemetry Packet

The AMSU-A1 telemetry packet is the same for low-rate engineering and low-rate science data as shown in Figure 6.4.1-1.

6.4.5 AMSU-A2

The Spacecraft-to-AMSU-A2 interface consists of a Primary Data Bus and point-to-point analog channel. The Primary Data Bus interface is used for commanding the instrument and collecting low rate engineering data and low rate science data from it. The AMSU-A2 instrument supports version 1 CCSDS packets for commands, time code data, low rate engineering data, and low rate science data.

6.4.5.1 AMSU-A2 Telemetry Packet

The AMSU-A2 telemetry packet is the same for low-rate engineering and low-rate science data as shown in Figure 6.4.1-1. The difference between the AMSU-A1 and AMSU-A2 is the length of the instrument data zone.

6.4.6 HSB

HSB H/K telemetry data is sent to the SC over a dedicated serial digital interface and is not CCSDS packetized. HSB H/K data shall be part of the Science Data and consists of 26, 16-bit words. The serial digital channel is used for collecting housekeeping data and low rate science data from it.

The SC will combine 13 minor frames of HSB science data into a single segmented CCSDS packet. A major frame of science data will be distributed over 6 consecutive packets.

6.4.6.1 HSB Telemetry Packet

The SC ISC packetizes the HSB low-rate engineering and science data by inserting it, as it is, into the GIRD packet shown and defined in Figure 6.4.1-1. The following paragraphs define those GIRD packet fields that are specific to the HSB instrument.

6.4.6.1.1 HSB Sequence Flags

HSB uses the sequence flag field of the Instrument packet to designate which half of the instrument scan data is contained in the packet. The sequence flags are set as follows:

01 = For the First Packet
10 = For the Second Packet

6.4.6.1.2 HSB Time Tag - Engineering Packet

The last 64 bits of the HSB Engineering Packet and Science Data Packet secondary header will contain the time tag. The time tag shall represent the time HSB begins outputting data for its current scan cycle. The first pair of packets will have a time tag representing the time tag at the 8.0 second boundary plus 123.1 msec. The second and third pair of packets will have time tags that are 2.6 and 5.2 seconds later, respectively.

6.4.6.1.3 HSB Instrument Data Field

The HSB Engineering data field contains a single 26 word minor frame of H/K data, 16-bits wide.

The instrument Science packet data field contains 26 minor frames of science data each containing 25, 16-bit words.

6.4.7 GIIS Telemetry Packet

The PM-1 instruments, MODIS and CERES utilize the GIIS Telemetry Packet for their science data. The main difference between the GIIS and the GIRD packet is in the secondary header. In the GIIS packet, the first 64 bits of the Secondary Header is the Time Stamp expressed in CCSDS Day Segmented Time Code. The remaining 8 bits are the CCSDS User Flags. Figure 6.4.7-1 defines format and content of the GIIS packet.

Data Zone
"Variable"

CCSDS PRIMARY HEADER 48 bits							CCSDS SECONDARY HEADER 72 bits				DATA FIELD	CHECKSUM
Vers	Type	SHF	APID	Seq flag	Pkt Seq Count	Pkt Data Length	Spacecraft Time - day count, coarse time, fine time	CCSDS Flag	Quick Look Flag	User Flag	Instrument Science Data	
3	1	1	11	2	14	16	16, 32, 16	1	1	6	"Variable"	Up To 12 bits

Note:
1. Version # = 000
2. Type = 0 = Tlm. Pkt.; 1 = Test Packet (MODIS)
3. SHF = 1
4. APID = Allocated in Table 6.3.1.1.1-1 and -2.
5. Sequence flag = 11
6. Sequence Count = Monotonically increasing number starting with 0 for the first telemetry packet after power on.
7. Packet Data Length = Number of octets in the Data Zone minus 1.
   MODIS = 635 octets (Science/Day/Long packet); 269 octets (Science/Night/Short)
   CERES = 249 octets (Engineering); 6987 octets (Science)
8. Time Stamp = CCSDS Day Segmented Time Code. Reference Section 2.2.1, document 7.
9. Quick Look = 0 , Quick-look processing not required; 1 = Quick Look Processing Required.
10. User Flags = Reserved for Instrument Usage
12. Data Field = MODIS = 627 octets (Science/Day/Long Pkt or Engineering Data) ; 261 octets (Science/Night/Short (includes 12 fill bits) also Includes 12 bits checksum.
    CERES = 241 octets (Engineering) ; 6979 octets (Science Data) (CERES does not use checksum bits)

Figure 6.4.7-1. GIIS Telemetry Packet

6.4.8 MODIS

The Spacecraft-to-MODIS interface consists of a Primary Data bus, high-rate science link, point-to-point relay drive commands, and point-to-point analog and bilevel telemetry channels. The Primary Data Bus is used for commanding the instrument and collecting low rate housekeeping data from it. It is not GIRD compliant and does not support CCSDS packets for its engineering data.

6.4.8.1 MODIS H/K Data

The ISC is responsible for providing the Spacecraft-to-MODIS unique interface capability. This includes collection and packetization of MODIS housekeeping data and dump data and providing synchronization information to MODIS (e.g., major and minor cycle counts, spacecraft heartbeat). Housekeeping data is not CCSDS packetized and is 32 16-bit words long. The SC ISC packetizes the MODIS engineering data, as received, into the GIRD packet data zone as shown in Figure 6.4.1-1. MODIS does not use Checksum for its low-rate engineering data.

6.4.8.1.1 MODIS H/K Data Frame

The MODIS H/K Data Frame Format and data collection times is shown in Figure 6.4.8.1.1-1.

Words 01 - 20	1 second data
Words 21 - 28	8 second data
Words 29 -32	64 second data

Figure 6.4.8.1.1-1. MODIS Data Frame Format

6.4.8.2 MODIS Science Data

MODIS also has a serial link to the FMU/SSR for high rate science data. The science data is CCSDS packetized in GIIS format shown in Figure 6.4.7-1. MODIS collects data in both Day Mode and Night Mode. When in Day Mode, two science packets are required for one frame of formatted data, whereas in Night Mode only one science packet is required. MODIS uses Checksum for its science data.

6.4.8.2.1 MODIS Fill Data

The instrument data field of the MODIS night packet contains 2040 bits of data and 12 bits of fill, (all zeroes).

6.4.8.3 MODIS Test Packet

When the MODIS sends a test packet, the MODIS packet headers will contain the normal header data except APID 127 will replace the normal APID 064. The header sequence count will change to count the number of Test Packets. MODIS will continue in Test mode until commanded back to normal operation.

6.4.9 CERES

The Spacecraft-to-CERES interface consists of a Primary Data Bus, a high-level pulse for reset, and point-to-point analog channels. The Primary Data Bus interface is used for collecting housekeeping data and low rate science data from the CERES. However, they are only partially GIRD compliant. The time distribution, housekeeping data packetization, and science data packetization of CERES are in accordance with the GIIS. The Spacecraft accepts the CERES

GIIS H/K packets and inserts them directly into a GIRD packet for downlink to the ground station.

6.4.9.1 CERES +Y Aft and -Y Fore Telemetry

CERES packetizes its housekeeping data in accordance with Figure 6.4.8-1. The PM-1 SC packetizes the CERES packets as GIRD compliant by inserting the CERES packet as it is into the GIRD packet data zone, Figure 6.4.1-1. The total H/K packet size that is downlinked to the ground is 264 octets, (i.e., 256 octet CERES H/K packet + 9 octet GIRD Secondary header minus 1).

6.4.9.2 CERES Low-rate Science Data

The CERES instrument will provide unsegmented CCSDS GIIS packets, Figure 6.4.7-1, for the low rate science data. The instrument will format the low rate science data into seven data blocks of 1024 octets in length, except for the last one, whose length shall be 850 octets. The Data Blocks are defined in subsequent paragraphs. The CCSDS header will be located at the beginning of the first data block only. CERES does not use checksum.

6.4.9.2.1 CERES Science Data Block 1

CERES Data Block 1 will contain 15 octets of GIIS Header data, and 1009 octets of instrument data as shown in the following diagram:

GIIS Headers – 15 octets
CERES Science Data – 1009 octets

6.4.9.2.2 CERES Science Data Blocks 2 through 6

Each of the next 5 blocks of CERES science data blocks contains 1024 Octets (total of 5120 octets) of data with no primary or secondary header data.

6.4.9.2.3 CERES Science Data Packet 7

The last CERES science data block will contain 850 Octets of data with no primary or secondary header data.

6.4.10 Packet Assembly

The EOS ground segment will reassemble the CERES data packet and provide a single unsegmented packet to the Langley Research Center.

APPENDIX A GLOSSARY

Application Process Identifier (APID): An 11-bit field within the Primary Header of a Version-l CCSDS Packet, which identifies a particular User Application within a local naming domain.

Application Services: Upper layer communications services provided to interactive space science applications such as file transfers, electronic messages, database queries, etc.

Asynchronous: A data transfer technique that does not preserve precise timing or structural relationships between the transmitted signal and the transfer mechanism.

CCSDS Packet: A variable length delimited data unit whose structure and header information is specified by the CCSDS.

Channel Access Data Unit: A protocol data unit within the Virtual Channel Access sublayer of the Space Link Subnet. A CADU consists of a VCDU or a CVCDU that has been prefixed and delimited by a Synchronization Mark.

Coded Virtual Channel Data Unit: A Virtual Channel Data Unit to which a block of error correcting Reed-Solomon check symbols has been appended.

Command and Data Handling Subsystem (C&DHS): Includes the Command and Telemetry Controller (CTC) which is configured as the master controller for the subsystem. Three (3) remote controllers provide dedicated support for other spacecraft subsystems and the science instruments. These remote controllers are identified as the Guidance and Navigation Control Controller (GNCC), the Power Controller (PC) and the Instrument Support Controller (ISC). The CTC and each of the three remote controllers contain a MIL-STD-1750A processor that supports the on-board Flight Software (FSW) to execute the command and telemetry processing functions provided by the C&DHS.

Additionally, the C&DHS includes a Transponder Interface Electronics (TIE) unit which interfaces with the COMM subsystem S-band transponder for receipt of commands from the ground and the transfer of telemetry to the ground. C&DHS data formatting and storage functions are provided by the Formatter Multiplexer Unit/Solid State Recorder (FMU/SSR) unit. The FMU/SSR also provides an interface to the COMM subsystem.

X-band modulator for the transmission of high rate science data or stored data to the EOS Ground Stations.

C&DHS Command: This is a command which a C&DHS component accepts, decodes and executes.

C&DHS Critical Commands: These are commands which the TIE receives from the ground and distributes to the addressed user directly without adherence to the standard CCSDS command processing protocols used by the CTC for normal command distribution.

C&DHS Provided Services: The C&DHS provides the distribution of all commands (normal and critical) received from the ground or from on-board Stored Command Sequences (SCSs) to the addressed user. The subsystem provides the memory to store the SCSs and the capability to load this memory or modify the SCSs by ground operations. The C&DHS collects telemetry from all the spacecraft subsystems and science instruments on a pre-defined schedule as determined by ground operations. The subsystem then formats the collected telemetry data according to CCSDS protocols for transmission to the ground or for on-board data storage. Additionally, the C&DHS provides all the timing and data synchronization services required by the spacecraft subsystems and sciences instruments.

Command: A signal or message (series of symbols) when received will cause a predetermined response such as (a) enabling/disabling an autonomous function by the TIE firmware or (b) hardware responding to a signal sent to an active analog interface by the BC.

Command Data Transfer: This is data transfer from a ground controller or from the CTC-based FSWS. It contains 1553B message to be delivered to some Spacecraft equipment. The message content could be a command, a memory load, a table load, etc.

C&DHS Fault Management: The C&DHS, with its FSW, provides the necessary fault management capability to autonomously place the spacecraft (subsystems and science instruments) into a safe state or survival state in the event of on-board anomalies.. The subsystem provides necessary fault knowledge to the ground and the capability for the ground to command the spacecraft back to normal operations.

Data Acquisition: Data acquisition monitors of the forward link bit stream received from the S-band transponder after RF-bit and bit lock are asserted and looks for the synchronization marked in the Command Link Transfer Unit (CLTU).

Distribution: The active TIE distributes command messages on the 1553 bus either for delivery to another Spacecraft element or to itself for execution based on RT address in the 1553 command word. After gathering and formatting telemetry, the active TIE also distributes telemetry based on resident algorithms to various destinations such as the S-band transponders or hardlines or CTC-based FSWS.

Grade of Service: A selectable method of data transmission service within the Space Link Subnet (SLS).

Grade-2 Service: A Space Link Subnet data transmission service whereby user data are delivered through the SLS possibly incomplete (i.e., with omissions), possibly with duplications caused by onboard storage and retrieval, but with a very high probability of being error free.

Ground Network: The around data distribution part of the CCSDS Principal Networks

Header: A standard label that identifies a standard data communications structure.

Idle: A mechanism for maintaining synchronous data transmission, in the event that no user data are available, by inserting "fill" data.

Layer: A functional organization whereby a complex distributed system may be broken into relatively simple modules of service.

Multiplexing Protocol Data Unit: The protocol data unit of the Multiplexing Function of the Space Link Subnet, having the format of a header followed by a fixed length block of data that contains a piece of a contiguous string of concatenated CCSDS Packets.

Octet: An eight-bit word.

Packet: A variable length, delimited data structure consisting of a set of higher layer user data that are encapsulated within standard header information. (Note: the term "packet" is used generically in this Recommendation, while the term "Packet" refers to the Version-l CCSDS Packet.)

Packet Channel: A mechanism used by the Multiplexing Function to allow multiple users to share one Virtual Channel.

Packet Channel ID: The identifier for a Packet Channel, mechanized using the APID field of a CCSDS Packet.

Packet Service: A service option within the CCSDS Path service, whereby users create the CCSDS Packets that support the Path protocol.

Physical Channel: The space/space or space/ground transmission medium.

Physical Channel Layer: The bottom layer of the Space Link Subnetwork.

Reed-Solomon: A high-performance block-oriented outer coding technique which provides powerful collection capability; named after its inventors, Reed and Solomon.

Secondary Header: An optional field within a Version-l CCSDS Packet, into which supplementary information (e.g., a Time Code) may be placed to facilitate value-added network service.

Service: A standard capability that is offered within a network layer.

Spacecraft Equipment: This is defined to be Spacecraft subsystems and instruments.

Telemetry: A term used to characterize the generation of more or less continuous and predictable sets of space mission measurement data at data rates and volumes which may be extremely high, and which have a large interaction with overall communications resources.

Uplink Command Data Transfer: This is issued by the ground controller and transmitted to the satellite. It may contain commands, memory loads, table loads, etc.

Validated Commands: Command data transfers which have been successfully received over a communication link within the total communication path between the source and destination. Only validated command data transfers can be delivered to the designated recipient.

Virtual Channel: A mechanism whereby a single Physical Channel may be shared by different types of users by creating multiple apparently parallel “virtual” paths through the channel.

Virtual Channel Access Service: A cross-supported Space Link Subnetwork service which exposes the Virtual Channel Access sublayer to users.

Virtual Channel Data Unit: The protocol data unit of the Virtual Channel Access sublayer of the Space Link Subnet, consisting of a fixed length CCSDS data structure which is used bidirectionally on space channels within Advanced Orbiting Systems to implement an OSI Layer 2 protocol.

APPENDIX B. ACRONYMS

ACE	Attitude Control Electronics
AIRS	Atmospheric Infrared Sounder
AMSR	Advanced Microwave Scanning Radiometer
AMSU-A	Advanced Microwave Sounding Unit-A
APID	Application Process Identifier
BC	Bus Controller
BCH	Bose-Chaudhuri-Hocquenghem
bps	bits per second
CADU	Channel Access Data Unit
CCSDS	Consultative Committee for Space Data Systems
C&DHS	Command and Data Handling System
CEI	Contract End Item
CERES	Clouds and the Earth's Radiant Energy System
CLCW	Command Link Control Word
CLTU	Command Link Transmission Unit
CMD	Command
COMM	Communications
COP	Command Operations Procedure
CTC	Command and Telemetry Controller
CUC	CCSDS Unsegmented Time Code
CVCDU	Coded Virtual Channel Data Unit
C&DH	Command and Data Handling
C&T	Command and Telemetry
DB	Direct Broadcast
DD	Direct Downlink
DP	Direct Playback
DS	Discrete
ECF	Error Control Field
EDOS	EOS Data Operations System,
EOC	EOS Operations Center
EOS	Earth Observing System
EOSDIS	Earth Observing System Data Interface System

EPGS	EOS Polar Ground Stations
ESTMS	EOC Spacecraft Time Management Software
FARM	Frame Acceptance Reporting Mechanism
FDF	Flight Dynamics Facility
FMU	Formatter/Multiplexer Unit
FOP	Frame Operation Procedure
fp	Floating Point
FSW	Flight Software
GIRD	General Interface Requirements Document
GN	Ground Network
GN&C	Guidance, Navigation, and Control
GPSR	Global Positioning Satellite Receiver
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
HDR	Header
HRC	High Rate Channel
HSB	Humidity Sounder of Brazil
H/K	Housekeeping
ICD	Interface Control Document
ID	Identifier/Identification
ISC	Instrument Support Controller
kbps	Kilobits per second
LRC	Low Rate Channel
LSB	Least Significant Bit
LSH	Least Significant Half
LSW	Least Significant Word
LSIO	Low Speed Serial Input/Output
LV	Launch Vehicle
M_PDU	Multiplexed Protocol Data Unit
MAP	Multiplexer Access Point
Mbps	Megabits Per Second

MODIS	Moderate Resolution Imaging Spectrometer
MSB	Most Significant Bit
MSH	Most Significant Half
MSW	Most Significant Word
NA	Not Applicable
NASA	National Aeronautics and Space Administration
NOP	No Operation
NRZ-L	Non-Return to Zero-Level
OCF	Operational Control Field
PCD	Payload Correction Data
PLOP	Physical Layer Operation Procedure
PN	Psuedorandom Noise
QPSK	Quadrature Phase Shift Keying
RF	Radio Frequency
R-S	Reed-Solomon
RT	Remote Terminal
SC	Spacecraft
SCID	Spacecraft Identifier
SCS	Stored Command Sequences
SDM	Serial Digital Magnitude
SMA	S-band Multiple Access
SPC	Serial Processor Control
SPS	Serial Processor Sensor
SSA	S-band Single Access
SSR	Solid State Recorder
STDN	Spaceflight Tracking and Data Network
TAI	International Atomic Time
TAXI	Transparent Asynchronous Transmitter/Receiver Interface
TBD	To Be Determined
TBR	To Be Reviewed
TBS	To Be Supplied
TC	Telecommand

TDRS	Tracking and Data Relay Satellite
TDRSS	Tracking and Data Relay Satellite System
TIE	Transponder Interface Electronics
TLM	Telemetry
USCCS	User Spacecraft Clock Calibration System
UTC	Universal Time Coordinated
VCID	Virtual Channel Identifier
VCDU	Virtual Channel Data Unit
WOTS	Wallops Orbital Tracking Station