

Table 5.4-1: LRS Bus CCSDS Format

Word	Bits	Value	Description
0	15-13	0	Version
0	12	0	Type
0	11	1	Secondary Header Flag
0	10-0	Note 1	Application Process ID
1	15-14	0-3	Sequence Flags: 0 = Continuation segment (Burst Data Packets, only) 1 = First segment (Burst Data Packets, only) 2 = Last segment (Burst Data Packets, only) 3 = Unsegmented
1	13-0	0-16383	Packet Sequence Count
2	15-0	--	Length of Data Zone (total number of bytes - 1)
3	15	0	Data Zone: Time Tag
3	14-0	--	Data Zone: Time Tag in CCSDS day segmented time code format
4-6	15-0	--	Data Zone: Time Tag in CCSDS day segmented time code format
7	15	0/1	Data Zone: Quick Look Flag (0 = no, 1 = yes)
7	14-8	0	Data Zone: Quick Look Flag (not used)
7	7-0	0	Data Zone: Not used
8-n	--	--	Data Zone: $40 \leq n \leq 3848$

Note 1: The APIDs for LRS bus CCSDS packets are [Ref. GLIS 7.1.3.1.2]:

Science CCSDS Packet	192
Engineering CCSDS Packet	193
Test CCSDS Packet	194
Burst Data Packet	195
Table Packet	196

5.5 Science Data Format

Science Data, as defined by the MOPITT Instrument, includes the information from the IR detector array (i.e., "stare" and "burst" data). The Science Data format is described in Appendix B [Ref. ICS 4.4.4.5, 4.4.4.6, 4.4.4.7, 4.4.4.10, 5.1.1.1, 5.1.9.2].

5.6 Science Data Formatting

The ICM is polled by the Spacecraft at least once every 2 seconds and not more often than once every 20 ms for Science Data. Since the instrument scan time is 0.45 seconds per stare, buffering must be provided by the ICM for the data collected from at least 5 stares. All Science and Engineering Data gathered are sent in separate CCSDS packets for Science and Engineering Data.

The MIL-STD-1553B Low Rate Science Data bus interface requires that the Science Data be prepared and packaged for transmission before the Spacecraft SFE poll message is received by the ICM.

Science Data is sent by sending multiple transmissions messages, in blocks of 32 words, on the MIL-STD-1553B sub-addresses 10-25. The sub-addresses "wrap-around" at 25 back to 10.

5.6.1 Data Collection Timing

The synchronization of the instrument with the signal processing, LMC, PMC and choppers is accomplished by the ICM timing control circuitry. The following is a baseline description for ICM software design.

The MOPITT Instrument will be synchronized with a master clock that synchronizes scan mirror movement and channel data collection. The scan mirror typically makes 29 stares per scan, which corresponds to 88 km. (4*22 km.) of ground travel (4 pixels at 22 km by 22 km square). At a ground track rate of about 6.76 km/sec, this is equivalent to 450 ms./stare. The cycle time for channel data collection is 50 ms for stepping the mirrors and 400 ms for a stare. Each stare will consist of 4 rotations of an LMC at 4 sectors/rotation for a total of 16 sectors, and typically 32 half cycles (or sectors) of a PMC.

The ICM computer will maintain an instrument clock at 1 KHz. This clock is used to time the event queue. The instrument scanning and science data collection use the event queue for synchronizing to the 50 ms step and 400 ms stare cycles.

The synchronization of the choppers to the PMC, LMC, and SPMs are done by hardware in the ICM's Timing Control Unit (TCU).

5.6.2 Signal Processing Data Stream

The following table summarizes the science data sent from the signal processing sub-system to the ICM computer [Ref. MIS Table 3.1.1-2].

Table 5.6-1: Science Data Compression

Channel	Device, Gas Sensor	Samples per Pixel per stare per Chopper Open or Closed	Total Samples 4 Pixels per Chopper Open or Closed	Compressed Data Samples, per Pixel (Chopper Open & Closed)	
				Sum	Delta
1	LMC CO, 4.617 μ m	16	64	8 * 24 bit	12 * 16 bit
2	LMC CO, 2.334 μ m	16	64	8 * 24 bit	12 * 16 bit
3	PMC CO, 4.617 μ m	32	128	4 * 24 bit	-
4	LMC CH ₄ , 2.258 μ m	16	64	8 * 24 bit	12 * 16 bit
5	LMC CO, 4.617 μ m	16	64	8 * 24 bit	12 * 16 bit
6	LMC CO, 2.334 μ m	16	64	8 * 24 bit	12 * 16 bit
7	PMC CO, 4.617 μ m	32	128	4 * 24 bit	-
8	LMC CH ₄ , 2.258 μ m	16	64	8 * 24 bit	12 * 16 bit

5.6.3 Instrument Data Stream

The MOPITT Instrument data is packaged into a stream of formatted data object. Each data object will describe a specific type of data.

Since sums are maintained to greater than 16 bits, (32 bits internally), a 16 bit word value is too small for the data. In order to conserve bit usage, the values are returned in a 24 bit value. However, since the "C++" programming language does not support 24 bit integers, the 32 bit values are packed into an array of 3 unsigned chars with the most significant byte of the 24 bit value placed in the least significant byte of the array, index[0] (big endian). Similarly, the least significant byte of the 24 bit value is placed in the most significant byte of the array, index[2]. The bytes are ordered with the most significant byte first in the data stream.

5.6.3.1 Channel Data Object

The data for an optical channel is collected for a stare period into a "channel data object". Channel data is sent even if the channel is waiting for its mirror to stabilize or is disabled. The header for each channel data object indicates the mirror status and position. Even though channel pairs share a mirror they are treated independently for the purposes of data collection. Pixel data is always grouped into 4 pixels per channel and all data is collected on a 4 pixel basis.

5.7 Engineering Data Format

Engineering Data consists of such information as temperature and pressure readings, which are used by the scientists to calibrate the received Science Data. Appendix C describes the format of the Engineering Data [Ref. ICS 5.1.1.1, 5.1.8.2].

5.8 LRS Bus Test Packet

1. The MOPITT Instrument is required to generate and transmit, on command, a continuous sequence containing a single test packet repeated [Ref. GLIS 7.1.4.1.1].
2. The Test CCSDS packet shall have the "TYPE" field set to 1. The header bit sequence shall not be repeated within the data zone of the packet [Ref. GLIS 7.1.4.1.2].
3. The Test packet data zone must be of a predefined bit pattern and the length shall be the same as a typical science data packet [Ref. GLIS 7.1.4.1.3].
4. The test packet must have its own unique APID [Ref. GLIS 7.1.4.3.1].
5. The Appendix E of this document specifies the format for the Low Rate Science Data Bus Test Packet [Ref. ICS 4.1.22.1, GLIS 7.1.4.3.2].
6. The Test packet quick look flag shall be set or reset upon command [Ref. GLIS 7.1.5].

5.9 LRS Bus Burst Packet

1. Burst mode science data is sent in multiple LRS packets. A unique APID identifies burst science packets on the LRS bus. Each burst science data packet contains a burst header that contains burst science data parameters and sequence number in addition to a chunk of burst science data.

5.10 LRS Bus Table Packet

Table packets contain a copy of all internal tables. Refer to Section 6 for more information.

5.11 Telemetry Sampling Rates

The Housekeeping Telemetry and Critical Health and Safety Telemetry points need to be sampled at periodic intervals. Table 5.11-1 shows the sampling rates for all telemetry points [Ref. ICS 4.4.3.7, 5.1.2.3, GHS 7.3.3.4].

Table 5.10-1: Telemetry Sampling Rates

Sampling Rate (Major Cycles)	Data Type	Description
1/8	H/K Telemetry	Motor Voltage Monitor Points
1/8	H/K Telemetry	Motor Current Monitor Points
1/8	H/K Telemetry	Device Status
1/8	H/K Telemetry	Heater Temperature Monitor
1/8	Engineering Data	Science temperature, pressure points
1/8	H/K Telemetry	All other Housekeeping Telemetry points

5.12 MIL-STD-1553B Telemetry Bus Schedule

The C&T bus data is packaged and sent according to the bus schedule shown in Table 5.12-1 [Ref. ICS 5.1.3.1, GLIS 7.3.3.7].

Table 5.11-1: Telemetry Bus Schedule

First Cycle (Major Cycle Number)	Frequency (1/n Major Cycles)	Telemetry Type
0	1	Critical Health and Safety Telemetry
0	8	Housekeeping Telemetry - Block 1
8	8	Housekeeping Telemetry - Block 2
16	8	Housekeeping Telemetry - Block 3
24	8	Housekeeping Telemetry - Block 4
32	8	Housekeeping Telemetry - Block 5
40	8	Housekeeping Telemetry - Block 6
48	8	Housekeeping Telemetry - Block 7
56	8	Housekeeping Telemetry - Block 8

5.13 Telemetry Names

Each Telemetry point has an associated name. The telemetry names are listed in Appendix A.

5.14 Byte Orientation

The 80x186 series of micro-processors arrange data in a "little endian" manner, i.e., the least significant byte of a word is stored beginning with the lowest memory address. The ground station equipment is set up to handle data in a "big endian" manner, i.e., the most significant byte of a word is stored beginning with the lowest memory address.

The ICM reverses the bytes in a word for all memory loads and dumps (excluding tables). Tables are word aligned and are not byte reversed by the ICM when loading and dumping.

6. TABLES

The MOPITT Instrument uses a variety of internal tables for such activities as specifying scan sequences, temperature limits, etc. This section documents the table types, numbers and formats for all internal MOPITT Instrument tables. The table CCSDS packet on the LRS bus contains a copy of all internal table contents.

Note that all tables are an even number of bytes in size, i.e., they are word aligned.

6.1 MOPITT Tables

The tables which are present in the MOPITT Instrument are summarized in Table 6.1-1. The following subsections explain each table in more detail.

Table 6.1-1: MOPITT Tables

MOPITT Table Sizes (all sizes in words):				
TABLE MNEMONIC	TABLE NUMBER	SIZE	TABLE TYPE	TYPE NUMBER
=====	=====	=====	=====	=====
TN_NULL	0	0	TT_NULL	0
TN_INDEX	1	105	--	--
TN_ACTIVE	2	26	--	--
TN_STATUS	3	92	--	--
TN_STATISTICS	4	57	--	--
TN_LOADDUMP	5	20	--	--
TN_DEVICE	6	42	--	--
TN_RAM_MASK_A	7	33	TT_RAM_MASK	1
TN_RAM_MASK_B	8	33	TT_RAM_MASK	1
TN_CONFIG_A	9	13	TT_CONFIG	2
TN_CONFIG_B	10	13	TT_CONFIG	2
TN_ENG_TELEM_A	11	58	TT_ENG_TELEM	3
TN_ENG_TELEM_B	12	58	TT_ENG_TELEM	3
TN_SCHED_A	13	13	TT_SCHED	4
TN_SCHED_B	14	13	TT_SCHED	4
TN_LIMITS_A	15	100	TT_LIMITS	5
TN_LIMITS_B	16	100	TT_LIMITS	5
TN_SCAN_A	17	128	TT_SCAN	6
TN_SCAN_B	18	128	TT_SCAN	6
TN_COOLER_A	19	768	TT_COOLER	7
TN_COOLER_B	20	768	TT_COOLER	7
TN_TCU_A	21	26	TT_TCU	8
TN_TCU_B	22	26	TT_TCU	8
TN_SPM1_A	23	8	TT_SPM1	9
TN_SPM1_B	24	8	TT_SPM1	9
TN_SPM2_A	25	8	TT_SPM2	10
TN_SPM2_B	26	8	TT_SPM2	10
TN_HEATER_A	27	14	TT_HEATER	11
TN_HEATER_B	28	14	TT_HEATER	11
TN_PMC_A	29	3	TT_PMC	12
TN_PMC_B	30	3	TT_PMC	12
TN_COOLER_REPORT	31	77	--	--
TN_COOLER_SHOW	32	187	--	--
TN_COOLER_ATEM	33	4	--	--
TN_COOLER_CAMP	34	19	--	--

6.1.1 *TN_NULL - Null Table*

Description: This is the Null Table number. The null table number is reserved and is not used.

Format: None.

Usage Notes: This table is not used.

6.1.2 *TN_INDEX - Index Table*

Description: The Index Table is comprised of entries with table information. This table is dynamic and is built by the ICM during initialization. The addresses of all tables, their sizes, and table access restrictions are stored in the Index Table.

Format:	Word	Bits	Value	Description
	0	15 - 0	--	Table Address (relative to 80C186 segment DS)
	1	15 - 0	--	Table Size
	2	15 - 0	--	Table Flags:
				bit 0 = Valid (0=no, 1=yes)
				bit 1 = Protected (0=no, 1=yes)
				bit 2 = Programmable (0=no, 1=yes)

The above words constitute a table entry. Each table in the ICM has its own table entry; thus, the above format is repeated for each ICM table in the Index Table. The Table Number corresponds to the table entry number in the Index Table, e.g., table entry 5 is the TN_STATUS table. All unused table entries are set to zero.

Usage Notes: This table is used by the ICM to access other tables. During normal instrument operation, this table should not be changed as it may be disruptive to instrument operation.

6.1.3 *TN_ACTIVE - Active Table*

Description: The Active Table is used by the ICM to indicate the currently active table for tables belonging to a table type.

Format:	Word	Bits	Value	Description
	0	15 - 8	--	Alternate Table Number
	0	7 - 0	--	Primary Table Number
	1	15 - 1	0	Not used
	1	0	0/1	Active Table (0=primary, 1=alternate)

The above words constitute the table entry for the Active Table. There is one table entry for each TT_x table type, with the exception of TT_NULL. The TT_NULL type is not used. The default Active Table is stored in EEPROM and is loaded by the ICM software during initialization.

Usage Notes: The SELECT_TABLE command can be used to change the Active Table selection for an entry. The default Active Table can also be updated in EEPROM by programming the EEPROM.

6.1.4 TN_STATUS - ICM Status Table

Description: The ICM Status Table contains the ICM run time parameters such as memory management variables. This table is always in use by the ICM and should only be changed in contingency situations.

Format:	Word	Bits	Value	Description
	0 - 32	15 - 0	0/1	RAM Status - Bad blocks (0=good, 1=bad)
	33 - 65	15 - 0	0/1	RAM Status - Blocks used (0=free, 1=used)
	66	15 - 0	--	System RAM, heap base
	67	15 - 0	--	System RAM, heap top
	68	15 - 0	--	RAM, far heap base
	69	15 - 0	--	RAM, far heap top
	70	15 - 0	--	System RAM, base block #
	71	15 - 0	--	System RAM, small block #
	72	15 - 0	--	System RAM, first free byte in small block
	73	15 - 0	--	System RAM, last free byte+1 in small block
	74	15 - 0	--	C&T RAM, base block #
	75	15 - 0	--	C&T RAM, small block #
	76	15 - 0	--	C&T RAM, first free byte in small block
	77	15 - 0	--	C&T RAM, last free byte+1 in small block
	78	15 - 0	--	LRS RAM, base block #
	79	15 - 0	--	LRS RAM, small block #
	80	15 - 0	--	LRS RAM, first free byte in small block
	81	15 - 0	--	LRS RAM, last free byte+1 in small block

82	15 - 0	--	Starting block number of data segment
83	15 - 0	--	Number of blocks in data segment
84	15 - 0	--	Starting block number of stack segment
85	15 - 0	--	Number of blocks in stack segment
86	15 - 0	--	Starting block number of code segment in RAM
87	15 - 0	--	Number of blocks in code segment
88	15 - 0	--	Boot EEPROM bank CRC
89	15 - 0	--	Spare EEPROM bank CRC
90	15 - 0	--	Boot Status (this word returned in H/K Telemetry)
91	15 - 0	--	Data segment of EEPROM code

Usage Notes: This table can be dumped to find unused RAM blocks during contingency situations.

6.1.5 *TN_STATISTICS - Statistics Table*

Description: The Statistics Table contains statistics on ICM operation such as communications errors, software errors, system, number of events since reset, etc.

Format:	Word	Bits	Value	Description
	0	15 - 0	--	Main Event Queue Counter
	1	15 - 0	--	Seconds Event Queue Counter
	2	15 - 0	--	Major Cycle Event Counter
	3	15 - 0	--	Scan Event Counter
	4	15 - 0	--	Command Counter
	5	15 - 0	--	Idle Counter
	6	15 - 0	--	Diagnostic Port Receive Errors
	7	15 - 0	--	Cooler Port Receive Errors
	8	15 - 0	--	Cooler Port Transmit Errors
	9	15 - 0	--	Last Major/Minor Cycle of H/K Telemetry sent
	10	15 - 0	--	Last Major/Minor Cycle of H&S Telemetry sent
	11	15 - 0	--	# Raw SPM1 Data Words Transferred
	12	15 - 0	--	# Raw SPM2 Data Words Transferred
	13	15 - 0	--	# H/K Telemetry gather events
	14	15 - 0	--	C&T bus RT High Priority Interrupts
	15	15 - 0	--	C&T bus RT Message Errors
	16	15 - 0	--	C&T bus RT Retransmissions
	17	15 - 0	--	C&T bus RT Valid Messages
	18	15 - 0	--	C&T bus Out of Free Messages
	19	15 - 0	--	C&T bus Messages Queued
	20	15 - 0	--	C&T bus Refresh Telemetry
	21	15 - 0	--	LRS bus RT High Priority Interrupts
	22	15 - 0	--	LRS bus RT Message Errors
	23	15 - 0	--	LRS bus RT Valid Messages
	24	15 - 0	--	LRS bus RT Interrupts Serviced
	25	15 - 0	--	LRS bus RT Out of Free Packets

26	15 - 0	--	LRS bus RT Packets Reserved
27	15 - 0	--	LRS bus RT Interrupts Expected
28	15 - 0	--	LRS bus RT Packets Made Pending
29	15 - 0	--	LRS bus RT Service Request Bit Set
30	15 - 0	--	LRS bus CCSDS Science Packet Sequence Count
31	15 - 0	--	LRS bus CCSDS Engineering Packet Sequence Count
32	15 - 0	--	LRS bus CCSDS Test Packet Sequence Count
33	15 - 0	--	LRS bus CCSDS Burst Packet Sequence Count
34	15 - 0	--	LRS bus CCSDS Table Packet Sequence Count
35	15 - 0	--	Number of Messages from Cooler
36	15 - 0	--	# SPM 1 Communication Errors
37	15 - 0	--	# SPM 2 Communication Errors
38	15 - 0	--	# PCDM Communication Errors
39	15 - 0	--	# SCDM Communication Errors
40	15 - 0	--	# PLDM Communication Errors
41	15 - 0	--	# TCMM Communication Errors
42	15 - 0	--	# Ticks Added to Clock
43	15 - 0	--	# Ticks Subtracted from Clock
44	15 - 0	--	# times Major/Minor cycle counter jumped
45	15 - 0	--	Delta for last jump
46	15 - 0	--	# missing Sync-With-Data-Word messages
47	15 - 0	--	Major/minor cycle of last scan
48	15 - 0	--	Time to process science data
49	15 - 0	--	# bad blocks found by background RAM test
50	15 - 0	--	Last bad block found
51	15 - 0	--	# calls to dummy free() function
52	15 - 0	--	# times EEPROM busy writing
53	15 - 0	--	# memory allocation errors
54	15 - 0	--	# times bad argument passed to function
55	15 - 0	--	Current device index number
56	15 - 0	--	# of NMIs (Non Maskable Interrupts)

Usage Notes: Dump this table periodically to check on the health of the ICM and system.

6.1.6 TN_LOADDUMP - Memory Load/Dump Table

Description: The Memory Load/Dump Table is used by the ICM to maintain the state of a memory load or dump operation.

Format:	<u>Word</u>	<u>Bits</u>	<u>Value</u>	<u>Description</u>
	0	15 - 8	0x80	Command Group
	0	7 - 0	0x10/0x11	DUMP_INITIATE/MLOAD_INITIATE command
	1	15 - 8	0/1	Type (0=table, 1=memory)
	1	7 - 0	--	Table Number
	2	15 - 0	--	Start Segment (hex)
	3	15 - 0	--	Start Offset (hex)
	4	15 - 0	--	Number of Words (MSW)
	5	15 - 0	--	Number of Words (LSW)
	6	15 - 0	--	Not used
	7	15 - 0	--	Expected CRC-16 value
	8	15 - 0	--	Actual CRC-16 value
	9 - 10	15 - 0	--	Far pointer to destination
	11 - 12	15 - 0	--	Far pointer to source
	13	15 - 0	--	Near pointer to table upload buffer
	14 - 15	15 - 0	--	Far pointer to Load Start Address
	16 - 17	15 - 0	--	Number of words to load/dump
	18 - 19	15 - 0	--	Number of words left to load/dump

Usage Notes: Table is provided for debugging purposes. Under normal operation, manual adjustment to the table is not required. Loads and Dumps are initiated via MLOAD_INITIATE and DUMP_INITIATE commands, respectively.

6.1.7 TN_DEVICE - Device Pointer Table

Description: The Device Pointer Table is an array of pointers to all device objects. The table is indexed by the Device Number. See Device Numbers, next section, for more details. Unused entries in the table are set to zero.

Format:	<u>Word</u>	<u>Bits</u>	<u>Value</u>	<u>Description</u>
	0 - 41	15 - 0	--	Near pointer to a device object

Usage Notes: This table is created by the ICM on initialization. Manual manipulation of this table is not recommended in normal operation.

6.1.8 *TN_RAM_MASK_A, TN_RAM_MASK_B - Bad Block Table*

Description: The Bad Block Table is a bit string used to exclude any RAM blocks from usage. This table is stored in EEPROM and the ICM performs a logical OR on this table and the results of the startup RAM test to produce the RAM bad block status array. Any bit marked with 1 indicates the corresponding memory block is bad and the ICM will not use that block.

Format:

Word	Bits	Value	Description
0 - 31	15 - 0	--	Bit markers (0=good, 1=bad)
32	15 - 0	--	Unused

To calculate the word and bit offset for a memory block, use these formulas:

$$\text{Block \#} = (\text{integer})(\text{Absolute Address}) / 512$$

$$\text{Word \#} = (\text{Block \#}) / 16$$

$$\text{Bit \#} = (\text{Block \#}) \% 16 \quad (\text{where "\%"} \text{ is the modulus operator})$$

Usage Notes: This table can be modified by memory load and programming into EEPROM. Use this table to exclude any RAM areas from ICM usage.

6.1.9 *TN_CONFIG_A, TN_CONFIG_B - ICM Configuration Table*

Description: The ICM Configuration Table contains the default ICM settings. These settings determine such things as whether FDIR routines are executed or not after a CPU reset.

Format:

Word	Bits	Value	Description
0	15 - 0	--	ICM Control Port bit image
1	15	0/1	Science CCSDS Packet Quick Look Flag
1	14	0/1	Engineering CCSDS Packet Quick Look Flag
1	13	0/1	Table CCSDS Packet Quick Look Flag
1	12	0/1	Test CCSDS Packet Quick Look Flag
1	8-11	0	spare
1	7	0/1	Science CCSDS Packet
1	6	0/1	Engineering CCSDS Packet
1	5	0/1	Table CCSDS Packet
1	4	0/1	Test CCSDS Packet
1	2-3	0	spare
1	1	0/1	H/K Telemetry (Eng. CCSDS Packet)
1	0	0/1	Ancillary Data (Eng. CCSDS Packet)

2	15 - 5	0	Not used
2	4	0/1	Boot to Safe Mode transition on SEU reset; default = YES
2	3	0/1	Obsolete was: Cooler On in Safe Mode; default = NO
2	2	0/1	TMF Bus Selection; default = 0
2	1	0/1	Auto Safe Mode Entry, default = ON
2	0	0/1	FDIR, default = OFF
3	15 - 0	--	Serial Interface maximum retry count (0=no retries)
4	15 - 0	--	Serial Interface maximum timeout loop count
5	15 - 0	--	Scale factor for 24 bit LMC sum Science Data
6	15 - 0	--	Scale factor for 24 bit PMC sum Science Data
7	15 - 0	--	Scale factor for 24 bit delta Science Data
8	15 - 0	--	Scale factor for 16 bit delta Science Data
9	15 - 0	--	Scan Mirror 1 max nadir check (0=disable check)
10	15 - 0	--	Scan Mirror 2 max nadir check (0=disable check)
11	15 - 0	--	Scan Mirror 3 max nadir check (0=disable check)
12	15 - 0	--	Scan Mirror 4 max nadir check (0=disable check)

Usage Notes: The FDIR setting can be changed by using the DISABLE_FDIR and ENABLE_FDIR commands. The Auto Safe Mode Entry setting can be changed by using the DISABLE_SAFE and ENABLE_SAFE commands. The TMF Bus Selection can be changed by using the SET_FREQ command.. The LRS Bus CCSDS packet settings can be changed by using TURN_OFF_SCI_DAT and TURN_ON_SCI_DAT commands.

6.1.10 *TN_ENG_TELEM_A, TN_ENG_TELEM_B - Engineering Data to H/K Telemetry Copy Table*

Description: This table is used to indicate which words from the Engineering Data to copy to block 7 of the H/K Telemetry.

Format:

<u>Word</u>	<u>Bits</u>	<u>Value</u>	<u>Description</u>
0	15 - 8	3 - 31	Destination (H/K Telemetry block 7 word offset)
0	7 - 0	0/1	Copy (0=no, 1=yes)
1	15 - 0	--	Source (Engineering Data word offset)
2 - 57	--	--	Repeat of word 0 and 1 definitions

Usage Notes: This table can be changed by table load via the LOAD_INITIATE command. The command, SELECT_TABLE, can be used to select the primary or alternate table.

6.1.11 *TN_SCHED_A, TN_SCHED_B - C&T Bus Telemetry Schedule Table*

Description: This table specifies the minor cycle in which telemetry will be sent/collected by the Spacecraft to/from the C&T bus for the MOPITT Instrument.

Format:

<u>Word</u>	<u>Bits</u>	<u>Value</u>	<u>Description</u>
0	15 - 0	0 - 127	Minor cycle of IMOK from Spacecraft
1	15 - 0	0 - 127	Minor cycle of Time Code message from Spacecraft
2	15 - 0	0 - 127	Minor cycle of Ancillary Data message from Spacecraft
3	15 - 0	0 - 127	Minor cycle of H&S Telemetry collection
4	15 - 0	0 - 127	Minor cycle of H/K Telemetry collection
5 - 8	15 - 0	0 - 127	Minor cycles of Sync-With-Data word message
9	15 - 0	0 - 127	Minor cycle to start gathering H&S Telemetry
10	15 - 0	0 - 127	Minor cycle to start gathering H/K Telemetry
11	15 - 0	0 - 127	Minor cycle to start gathering Engineering Telemetry
12	15 - 0	0 - 127	Minor cycles to trigger the H/K telemetry software event

Usage Notes: This table can be changed by table load via the MLOAD_INITIATE command. The command, SELECT_TABLE, can be used to select the primary or alternate table.

6.1.12 *TN_LIMITS_A, TN_LIMITS_B - Limits Table*

Description: The Limits Table defines limits for voltage, current, and temperature points. The ICM periodically reads the current, voltage, and temperature points and compares these points to the limits defined in this table.

Voltage and current telemetry values are compared once every 8 C&T bus major cycles. Two limits may be defined for currents and voltages: yellow hi and red hi. If a device reaches the yellow hi limit for more than 3 consecutive readings, the ICM will attempt to turn off the device. If a device reaches the red hi limit for more than 3 consecutive readings, the ICM will set the BS_FATAL flag in the H&S Telemetry and wait for TMON action to shut the instrument off.

Temperature of heater sensors are compared once every 8 C&T bus major cycles. Each heater and each detector power control is associated with one or more sensors. The worst sensor reading for a heater is used for the heater temperature (i.e., red is worse than yellow). Four limits may be defined for heaters: red hi, red low, yellow hi, and yellow low. In all cases, only over temperature limits are defined, however since some sensor readouts have a negative slope, the sensor value limit may either be "hi" or "low" limit. The ICM will turn off a heater if the yellow limit is reached for more than 3 consecutive readings (approx. 25 seconds). The ICM will set the BS_FATAL flag in the H&S Telemetry if the red limit is reached for more than 3 consecutive readings. The BS_FATAL flag will signal the TMON to shut the instrument off.

PMC amplitude settings are only allowed to increase to full running stroke if sieve temperature is within the specified yellow limits window. In this case both the high and low limits are used.

On a detected Dewar over temperature condition, the detectors for the respective SPM are turned off.

The limits table is defined as:

/*+Data:

- * limitsTable - Limits Table

- *

- * Synopsis:

- * LimitTableEntry limitsTable[]

- *

- * Description:

- * TN_LIMITS_x: This table contains the temperature, voltage and current, and dewar limits.

- *

- * The format of the limits are:

- *

- * {red hi, yellow hi, yellow low, red low, valid flag}

- *

- * Note:

- * All temp data is assumed to be 14 bit unipolar, limits values are 16 bit signed ints.

- * 0x3fff - highest telemetry value

- * 0x0000 - lowest telemetry value

- *

- * for no limit triggers use:

- * 0x7fff for a max hi value - no limit

- * 0xffff for a max low value - no limit

- */


```
LimitTableEntry limitsTable[] = {  
    //      {red hi, yel hi, yel lo, red lo, valid},  
    // nest heater limits  
    {0x3692, 0x3491, 0xffff, 0xffff, 1}, // LM_ENG_DETECTOR1_4,  
    {0x3692, 0x3491, 0xffff, 0xffff, 1}, // LM_ENG_DETECTOR5_8,  
  
    // cal source heaters  
    {0x7fff, 0x7fff, 0x09c8, 0x059d, 1}, // LM_ENG_CAL1,  
    {0x7fff, 0x7fff, 0x09c8, 0x059d, 1}, // LM_ENG_CAL2,  
    {0x7fff, 0x7fff, 0x09c8, 0x059d, 1}, // LM_ENG_CAL3,  
    {0x7fff, 0x7fff, 0x09c8, 0x059d, 1}, // LM_ENG_CAL4,  
  
    // sieve 1-4 heater  
    {0x7fff, 0x7fff, 0x1f6c, 0x1a0c, 1}, // LM_ENG_SIEVE1,  
    {0x7fff, 0x7fff, 0x1f6c, 0x1a0c, 1}, // LM_ENG_SIEVE2,  
    {0x7fff, 0x7fff, 0x1f6c, 0x1a0c, 1}, // LM_ENG_SIEVE3,  
    {0x7fff, 0x7fff, 0x1f6c, 0x1a0c, 1}, // LM_ENG_SIEVE4,  
  
    // PMC current  
    {0x7fff, 0x3091, 0xffff, 0xffff, 1}, // LM_PMC1_CURRENT  
    {0x7fff, 0x3091, 0xffff, 0xffff, 1}, // LM_PMC2_CURRENT  
  
    // PMC amplitude  
    {0x7fff, 0x2fcb, 0x2933, 0xffff, 1}, // LM_PMC1_AMP  
    {0x7fff, 0x3556, 0x331d, 0xffff, 1}, // LM_PMC2_AMP  
  
    // dewar limits  
    {0x3692, 0x3491, 0xffff, 0xffff, 1}, // LM_ENG_DETECTOR1_4,  
    {0x3692, 0x3491, 0xffff, 0xffff, 1}, // LM_ENG_DETECTOR5_8,  
  
    // voltage monitoring  
    {0x3ff1, 0x7fff, 0xffff, 0xffff, 1}, // LM_HTR_REF_HI  
    {0x3f8c, 0x7fff, 0xffff, 0xffff, 1}, // LM_PMC1_MOTOR  
    {0x7fff, 0x7fff, 0xffff, 0x239d, 1}, // LM_PCDM_REF28  
    {0x7fff, 0x7fff, 0xffff, 0x2118, 1}, // LM_PCDM_REF14  
};
```

6.1.13 *TN_SCAN_A, TN_SCAN_B - Scan Table*

Description: The Scan Table defines the scan sequence for the Instrument when in Science Mode. The Scan Table contains MOPITT Scan Language (MSL) instructions which specify the sequence of how to step the mirrors, start a stare, and how long to wait.

Format:

Word	Bits	Value	Description
0 - 127	15 - 0	--	MSL Instructions

Usage Notes: The alternate Scan Table can be selected by using the SELECT_TABLE command.

6.1.14 *TN_COOLER_A, TN_COOLER_B - Cooler Initialization Table*

Description: The Cooler Initialization Table contains the command strings for the Stirling Cycle Coolers. String 0 from this table is sent to the coolers when the Instrument transitions to Safe Mode from Boot Mode or when the PERFORM_DEV_INIT command is received for the cooler device. Any of the command strings can be sent to the coolers via the SELECT_COOL_CMD command.

MOPITT Cooler Table Initialization Strings

MOPITT contains six predefined strings used in cooler operations. A description of the contents is shown below:

```
// P-DECS mode
// [0] - COOLER_INIT_STRING, Boot->Safe
// P-DECS, Temp control mode
"vcm 0 mode 0 tsrc 0 ttemf 3639 " // init string
"wmin -718 0 wmin -740 2 wmax 719 0 wmax 741 2 "
"dgain 0 0 dgain 0 1 dgain 0 2 dgain 0 3 "
"dshif 30 0 dshif 27 1 dshif 30 2 dshif 27 3 "
"amp 698 0 amp 722 2\r",
```

Format:

Word	Bit	Hex	Value
0	15-7	0x76	('v')
0	7-0	0x63	('c')
1	15-7	0x6d	('m')
1	7-0	0x20	(SPACE)
2	15-7	0x30	('0')

2	7-0	0x20	(SPACE)
3	15-7	0x6d	('m')
3	7-0	0x6f	('o')
4	15-7	0x64	('d')
4	7-0	0x65	('e')
5	15-7	0x20	(SPACE)
5	7-0	0x30	('0')
6	15-7	0x20	(SPACE)
6	7-0	0x74	('t')
7	15-7	0x73	('s')
7	7-0	0x72	('r')
8	15-7	0x63	('c')
8	7-0	0x20	(SPACE)
9	15-7	0x30	('0')
9	7-0	0x20	(SPACE)
10	15-7	0x74	('t')
10	7-0	0x74	('t')
11	15-7	0x65	('e')
11	7-0	0x6d	('m')
12	15-7	0x66	('f')
12	7-0	0x20	(SPACE)
13	15-7	0x33	('3')
13	7-0	0x36	('6')
14	15-7	0x33	('3')
14	7-0	0x39	('9')
15	15-7	0x20	(SPACE)
15	7-0	0x77	('w')
16	15-7	0x6d	('m')
16	7-0	0x69	('i')
17	15-7	0x6e	('n')
17	7-0	0x20	(SPACE)
18	15-7	0x45	('5')
18	7-0	0x37	('7')
19	15-7	0x31	('1')
19	7-0	0x38	('8')
20	15-7	0x20	(SPACE)
20	7-0	0x30	('0')
21	15-7	0x20	(SPACE)
21	7-0	0x77	('w')
22	5-7	0x6d	('m')

22	7-0	0x69	('i')
23	15-7	0x6e	('n')
23	7-0	0x20	(SPACE)
24	15-7	0x45	('·')
24	7-0	0x37	('7')
25	15-7	0x34	('4')
25	7-0	0x30	('0')
26	15-7	0x2d	(SPACE)
26	7-0	0x32	('2')
27	15-7	0x20	(SPACE)
27	7-0	0x77	('w')
28	15-7	0x6d	('m')
28	7-0	0x61	('a')
29	15-7	0x78	('x')
29	7-0	0x20	(SPACE)
30	15-7	0x37	('7')
30	7-0	0x31	('1')
31	15-7	0x39	('9')
31	7-0	0x20	(SPACE)
32	15-7	0x30	('0')
32	7-0	0x20	(SPACE)
33	15-7	0x77	('w')
33	7-0	0x6d	('m')
34	15-7	0x61	('a')
34	7-0	0x78	('x')
35	15-7	0x20	(SPACE)
35	7-0	0x37	('7')
36	15-7	0x34	('4')
36	7-0	0x31	('1')
37	15-7	0x20	(SPACE)
37	7-0	0x32	('2')
38	15-7	0x20	(SPACE)
38	7-0	0x64	('d')
39	15-7	0x67	('g')
39	7-0	0x61	('a')
40	15-7	0x69	('i')
40	7-0	0x6e	('n')
41	15-7	0x20	(SPACE)
41	7-0	0x30	('0')
42	15-7	0x20	(SPACE)

42	7-0	0x30	('0')
43	15-7	0x20	(SPACE)
43	7-0	0x64	('d')
44	15-7	0x67	('g')
44	7-0	0x61	('a')
45	15-7	0x69	('i')
45	7-0	0x6e	('n')
46	15-7	0x20	(SPACE)
46	7-0	0x30	('0')
47	15-7	0x20	(SPACE)
47	7-0	0x31	('1')
48	15-7	0x20	(SPACE)
48	7-0	0x64	('d')
49	15-7	0x67	('g')
49	7-0	0x61	('a')
50	15-7	0x69	('i')
50	7-0	0x6e	('n')
51	15-7	0x20	(SPACE)
51	7-0	0x30	('0')
52	15-7	0x20	(SPACE)
52	7-0	0x32	('2')
53	15-7	0x20	(SPACE)
53	7-0	0x64	('d')
54	15-7	0x67	('g')
54	7-0	0x61	('a')
55	15-7	0x69	('i')
55	7-0	0x6e	('n')
56	15-7	0x20	(SPACE)
56	7-0	0x30	('0')
57	15-7	0x20	(SPACE)
57	7-0	0x33	('3')
58	15-7	0x20	(SPACE)
58	7-0	0x64	('d')
59	15-7	0x73	('s')
59	7-0	0x68	('h')
60	15-7	0x69	('i')
60	7-0	0x66	('f')
61	15-7	0x20	(SPACE)
61	7-0	0x33	('3')

62	15-7	0x30	('0')
62	7-0	0x20	(SPACE)
63	15-7	0x30	('0')
63	7-0	0x20	(SPACE)
64	15-7	0x64	('d')
64	7-0	0x73	('s')
65	15-7	0x68	('h')
65	7-0	0x69	('i')
66	15-7	0x66	('f')
66	7-0	0x20	(SPACE)
67	15-7	0x32	('2')
67	7-0	0x37	('7')
68	15-7	0x20	(SPACE)
68	7-0	0x31	('1')
69	15-7	0x20	(SPACE)
69	7-0	0x64	('d')
70	15-7	0x73	('s')
70	7-0	0x68	('h')
71	15-7	0x69	('i')
71	7-0	0x66	('f')
72	15-7	0x20	(SPACE)
72	7-0	0x33	('3')
73	15-7	0x30	('0')
73	7-0	0x20	(SPACE)
74	15-7	0x32	('2')
74	7-0	0x20	(SPACE)
75	15-7	0x64	('d')
75	7-0	0x73	('s')
76	15-7	0x68	('h')
76	7-0	0x69	('i')
77	15-7	0x66	('f')
77	7-0	0x20	(SPACE)
78	15-7	0x32	('2')
78	7-0	0x37	('7')
79	15-7	0x20	(SPACE)

79	7-0	0x33	('3')
80	15-7	0x20	(SPACE)
80	7-0	0x61	('a')
81	15-7	0x6d	('m')
81	7-0	0x70	('p')
82	15-7	0x20	(SPACE)
82	7-0	0x36	('6')
83	15-7	0x39	('9')
83	7-0	0x38	('8')
84	15-7	0x20	(SPACE)
84	7-0	0x30	('0')
85	15-7	0x20	(SPACE)
85	7-0	0x61	('a')
86	15-7	0x6d	('m')
86	7-0	0x70	('p')
87	15-7	0x20	(SPACE)
87	7-0	0x37	('7')
88	15-7	0x32	('2')
88	7-0	0x32	('2')
89	15-7	0x20	(SPACE)
89	7-0	0x32	('2')
90	15-7	0x0d	(CR)
90	7-0	0x00	(null)
91-127	15-0	0x0000	(null, null)

// [1] - COOLER_START_STRING, Safe->Standby

"mode 1 vcm 1\r", // turn it on

Format:	Word	Bit	Hex	Value
	128	15-7	0x6d	('m')
	128	7-0	0x6f	('o')
	129	15-7	0x64	('d')
	129	7-0	0x65	('e')
	130	15-7	0x20	(SPACE)
	130	7-0	0x31	('1')
	131	15-7	0x20	(SPACE)

```

131 7-0 0x76 ('v')
132 15-7 0x63 ('c')
132 7-0 0x6d ('m')
133 15-7 0x20 (SPACE)
133 7-0 0x31 ('1')
134 15-7 0x0d (CR)
134 7-0 0x00 (null)
135-255 15-0 0x0000 (null, null)

```

// [2] - COOLER_STOP_STRING, ->Safe

"vcm 0 mode 0\r",

Format:	Word	Bit	Hex	Value
	256	15-7	0x76	('v')
	256	7-0	0x63	('c')
	257	15-7	0x6d	('m')
	257	7-0	0x20	(SPACE)
	258	15-7	0x30	('0')
	258	7-0	0x20	(SPACE)
	259	15-7	0x6d	('m')
	259	7-0	0x6f	('o')
	260	15-7	0x64	('d')
	260	7-0	0x65	('e')
	261	15-7	0x20	(SPACE)
	261	7-0	0x30	('0')
	262	15-7	0x0d	(CR)
	262	7-0	0x00	(null)
	263-383	15-0	0x0000	(null, null)

// [3] - On - Normal fixed stroke

"amp 698 0 amp 722 2 mode 2 vcm 1\r",

Format:	Word	Bit	Hex	Value
	384	15-7	0x61	('a')
	384	7-0	0x6d	('m')
	385	15-7	0x70	('p')
	385	7-0	0x20	(SPACE)
	386	15-7	0x36	('6')
	386	7-0	0x39	('9')
	387	15-7	0x38	('8')


```

387  7-0  0x20  (SPACE)
388  15-7 0x30  ('0')
388  7-0  0x20  (SPACE)
389  15-7 0x61  ('a')
389  7-0  0x6d  ('m')
390  15-7 0x70  ('p')
390  7-0  0x20  (SPACE)
391  15-7 0x37  ('7')
391  7-0  0x32  ('2')
392  15-7 0x32  ('2')
392  7-0  0x20  (SPACE)
393  15-7 0x32  ('2')
393  7-0  0x20  (SPACE)
394  15-7 0x6d  ('m')
394  7-0  0x6f  ('o')
395  15-7 0x64  ('d')
395  7-0  0x65  ('e')
396  15-7 0x20  (SPACE)
396  7-0  0x32  ('2')
397  15-7 0x20  (SPACE)
397  7-0  0x76  ('v')
398  15-7 0x63  ('c')
398  7-0  0x6d  ('m')
399  15-7 0x20  (SPACE)
399  7-0  0x31  ('1')
400  15-7 0x0d  (CR)
400  7-0  0x00  (null)
401-511 15-0 0x0000 (null, null)

```

// [4] - 0n - Max fixed stroke

"amp 716 0 amp 740 2 mode 2 vcm 1v",

Format:	Word	Bit	Hex	Value
	512	15-7	0x61	('a')
	512	7-0	0x6d	('m')
	513	15-7	0x70	('p')
	513	7-0	0x20	(SPACE)
	514	15-7	0x37	('7')
	514	7-0	0x31	('1')
	515	15-7	0x36	('6')
	515	7-0	0x20	(SPACE)

```

516 15-7 0x30 ('0')
516 7-0 0x20 (SPACE)
517 15-7 0x61 ('a')
517 7-0 0x6d ('m')
518 15-7 0x70 ('p')
518 7-0 0x20 (SPACE)
519 15-7 0x37 ('7')
519 7-0 0x34 ('4')
520 15-7 0x30 ('0')
520 7-0 0x20 (SPACE)
521 15-7 0x32 ('2')
521 7-0 0x20 (SPACE)
522 15-7 0x6d ('m')
522 7-0 0x6f ('o')
523 15-7 0x64 ('d')
523 7-0 0x65 ('e')
524 15-7 0x20 (SPACE)
524 7-0 0x32 ('2')
525 15-7 0x20 (SPACE)
525 7-0 0x76 ('v')
526 15-7 0x63 ('c')
526 7-0 0x6d ('m')
527 15-7 0x20 (SPACE)
527 7-0 0x31 ('1')
528 15-7 0x0d (CR)
528 7-0 0x00 (null)
529-639 15-0 0x0000 (null, null)

```

```
// [5] - COOLER_SPARE_STRING
"V",
```

```

Format: Word  Bit  Hex  Value
        640  15-7  0x00  (null)
        640  7-0   0x0d  (CR)
       1-767 15-0  0x0000 (null, null)

```

Usage Notes: This table can be updated by using the table load command, LOAD_INITIATE. The PERFORM_DEV_INIT command can be used to update the Coolers with the table parameters. The alternate table can be selected using the SELECT_TABLE command.

6.1.15 *TN_TCU_A, TN_TCU_B - TCU Initialization Table*

Description: The TCU Initialization Table contains the initialization parameters for the Timing Control Unit (TCU). The parameters are written to the TCU when the Instrument changes from Safe to Standby Mode.

Format:	<u>Word</u>	<u>Bits</u>	<u>Value</u>	<u>Description</u>
	0	15 - 0	--	Chopper 1 Divider
	1	15 - 0	--	Chopper 1 Frequency Delay
	2	15 - 0	--	Chopper 2 Divider
	3	15 - 0	--	Chopper 2 Frequency Delay
	4	15 - 0	--	Chopper 3 Divider
	5	15 - 0	--	Chopper 3 Frequency Delay
	6	15 - 0	--	Chopper 4 Divider
	7	15 - 0	--	Chopper 4 Frequency Delay
	8	15 - 0	--	LMC 1 Rotation Divider
	9	15 - 0	--	LMC 1 Sector Divider
	10	15 - 0	--	LMC 1 Clock Delay
	11	15 - 0	--	LMC 2 Rotation Divider
	12	15 - 0	--	LMC 2 Sector Divider
	13	15 - 0	--	LMC 2 Clock Delay
	14	15 - 0	--	LMC 3 Rotation Divider
	15	15 - 0	--	LMC 3 Sector Divider
	16	15 - 0	--	LMC 3 Clock Delay
	17	15 - 0	--	LMC 4 Rotation Divider
	18	15 - 0	--	LMC 4 Sector Divider
	19	15 - 0	--	LMC 4 Clock Delay
	20	15 - 0	--	PMC 1 Frequency Divider
	21	15 - 0	--	PMC 1 Reference Delay
	22	15 - 0	--	PMC 2 Frequency Divider
	23	15 - 0	--	PMC 2 Reference Delay
	24	15 - 0	--	Chopper 1/2 Cmd PPO
	25	15 - 0	--	Chopper 3/4 Cmd PPO

Usage Notes: The TCU has a device number which can be used in conjunction with the PERFORM_DEV_INIT command and this table to re-initialize the TCU (except in instrument Boot Mode).

6.1.16 *TN_SPM1_A, TN_SPM1_B, TN_SPM2_A, TN_SPM2_B - SPM Initialization Table*

Description: The SPM Initialization Table contains the default initialization parameters for the SPMs. There is a separate table for each SPM. The SPM Initialization Table parameters are written to the SPM when the Instrument changes from Safe Mode to Standby Mode and also when the PERFORM_DEV_INIT command is issued for the specific SPM device.

SPM 1 processes input from Chopper 1 and 2, LMC 1 and 2, and PMC 1. SPM 2 processes input from Chopper 3 and 4, LMC 3 and 4, and PMC 2.

Format:

<u>Word</u>	<u>Bits</u>	<u>Value</u>	<u>Description</u>
0	15 - 8	--	# Groups of 4 samples to process for Chopper 1 or 3 open state
0	7 - 0	--	# Groups of 4 samples to blank for Chopper 1 or 3 open state
1	15 - 8	--	# Groups of 4 samples to process for Chopper 1 or 3 closed state
1	7 - 0	--	# Groups of 4 samples to blank for Chopper 1 or 3 closed state
2	15 - 8	--	# Groups of 4 samples to process for Chopper 2 or 4 open state
2	7 - 0	--	# Groups of 4 samples to blank for Chopper 2 or 4 open state
3	15 - 8	--	# Groups of 4 samples to process for Chopper 2 or 4 closed state
3	7 - 0	--	# Groups of 4 samples to blank for Chopper 2 or 4 closed state
4	15 - 8	--	# Chopper Cycles to process for each LMC 1 or 3 sector
4	7 - 0	--	# Chopper Cycles to blank for each LMC 1 or 3 sector
5	15 - 8	--	# Chopper Cycles to process for each LMC 2 or 4 sector
5	7 - 0	--	# Chopper Cycles to blank for each LMC 2 or 4 sector
6	15 - 8	--	# LMC 1 or 3 sectors to process for each stare
6	7 - 0	--	# Chopper Cycles to process for each PMC sector
7	15 - 8	--	# PMC sectors to process for each stare
7	7 - 0	--	# LMC 2 or 4 sectors to process for each stare

Usage Notes: This table can be updated by using the table load command, MLOAD_INITIATE. The PERFORM_DEV_INIT command can be used to update the SPM with the table parameters. The alternate table can be selected using the SELECT_TABLE command.

6.1.17 TN_HEATER_A, TN_HEATER_B - Heater Set Point Table

Description: The Heater Set Point Table contains the default heater set point values. The table parameters are written to the TCMM when the Instrument changes from Safe Mode to Standby Mode or when the PERFORM_DEV_INIT command is issued.

Format:

<u>Word</u>	<u>Bits</u>	<u>Value</u>	<u>Description</u>
0	15 - 8	0	Not used
0	7 - 0	0 - 255	Detector nest 1 heater, normal setting
1	15 - 8	0	Not used
1	7 - 0	0 - 255	Detector nest 2 heater, normal setting
2 - 5	15 - 0	0	Not used
6	15 - 8	0	Not used
6	7 - 0	0 - 255	Calibration Source 1 setting
7	15 - 8	0	Not used
7	7 - 0	0 - 255	Calibration Source 2 setting
8	15 - 8	0	Not used
8	7 - 0	0 - 255	Calibration Source 3 setting
9	15 - 8	0	Not used
9	7 - 0	0 - 255	Calibration Source 4 setting
10	15 - 8	0 - 255	Sieve 1 heater, fine setting
10	7 - 0	0 - 255	Sieve 1 heater, coarse setting
11	15 - 8	0 - 255	Sieve 2 heater, fine setting
11	7 - 0	0 - 255	Sieve 2 heater, coarse setting
12	15 - 8	0 - 255	Sieve 3 heater, fine setting
12	7 - 0	0 - 255	Sieve 3 heater, coarse setting
13	15 - 8	0 - 255	Sieve 4 heater, fine setting
13	7 - 0	0 - 255	Sieve 4 heater, coarse setting

Usage Notes: The heater settings can be changed by using the SET_HEATER command. Note that the SET_HEATER command also changes the active table values. To load new table values, use the table load command, MLOAD_INITIATE. The alternate table can be selected using the SELECT_TABLE command.

6.1.18 TN_COOLER_REPORT - Cooler Report Table

Description: The Cooler Report Table contains the data from the Cooler REPORT command. The REPORT command causes the CDE (Cooler Drive Electronics) to send back 154 bytes of ASCII data. The ICM converts the Cooler Report Table from ASCII to hex and sends this down in the H/K Telemetry. The Cooler Report Table is updated periodically at a rate of about once every 10 seconds [Ref. ICS 4.4.2.4].

Format:

Word	Bits	Value	Description
0 - 76	15 - 0	--	ASCII data

Usage Notes: As the contents of this table is also converted to hex and sent down in the H/K Telemetry, it is not anticipated that frequent dumping of this table will be required. Thus, dumping this table is provided as a debugging feature to be used in contingency situations.

Telemetry: SR_COMP_X_VIB, SR_COMP_Y_VIB, SR_DISP_X_VIB, SR_DISP_Y_VIB, SR_COMP_Z_VIB, SR_DISP_Z_VIB, SR_COMP_A_POS, SR_COMP_B_POS, SR_DISP_A_POS, SR_DISP_B_POS, IR_COMP_A_MOTOR, IR_COMP_B_MOTOR, IR_DISP_A_MOTOR, IR_DISP_B_MOTOR, VR_M12VDC, VR_M15VDC, TR_COOL_CDE_1, TR_COOL_CDE_2, TR_COOL_CDE_3, TR_COOL_DISP1, TR_COOL_DISP2, VR_P15VDC, VR_P12VDC, VR_P5VDC, TR_COLD_TIP1_W, TR_TEMP_DIODE_RW, TR_COLD_TIP2_W, TR_COLD_TIP1_N, TR_TEMP_DIODE_RN

6.1.19 TN_COOLER_SHOW - Cooler Show Table

Description: The Cooler Show Table contains the data from the Cooler SHOW command. The SHOW command causes the CDE (Cooler Drive Electronics) to send back 373 bytes of ASCII data. The Cooler Show Table is updated periodically at a rate of about once every 10 seconds [Ref. ICS 4.4.2.4].

Format:

Word	Bits	Value	Description
0 - 187	15 - 0	--	ASCII data

Usage Notes: The Cooler Show Table shows cooler settings. This table can be viewed by dumping it via the DUMP_INITIATE command.

Telemetry: SS_DEV_COOLMODE, SS_DEV_COOLVMODE, NR_COOL_DGAIN0, NR_COOL_DGAIN1, NR_COOL_DGAIN2, NR_COOL_DGAIN3, NR_COOL_DSHIF0, NR_COOL_DSHIF1, NR_COOL_DSHIF2, NR_COOL_DSHIF3, NR_COOL_MIN0, NR_COOL_MIN1, NR_COOL_MIN2, NR_COOL_MIN3, NR_COOL_MAX0, NR_COOL_MAX1, NR_COOL_MAX2, NR_COOL_MAX3

6.1.20 TN_COOLER_ATEM - Cooler Atem Table

Description: The Cooler Atem Table contains the data from the Cooler ATEM command. The ATEM command causes the cooler to send back the current temperature reading from the selected diode specified by the Cooler TSRC command. The table is 8 bytes long and the data is in ASCII format. The ICM converts the temperature value in the table from ASCII to hex and sends this down in the H/K Telemetry. The Cooler Atem Table is updated periodically at a rate of about once every 10 seconds [Ref. ICS 4.4.2.4].

MOPITT Cooler ATEM Strings

The ASCII strings contained in the TN_COOLER_ATEM tables are reported to the ground packed in Little Endian format. To print out the strings properly, they must be first byte swapped by ground software.

Format:	Word	Bit	Value	Description
	0-3	15-0	--	ASCII data

Usage Notes: As the relevant data from this command is already converted to hex and sent down in the H/K Telemetry, dumping of this table is not normally required. For debugging purposes, this table can be dumped using the DUMP_INITIATE command.

Telemetry: TR_COOLER_ATEM

6.1.21 TN_COOLER_CAMP - Cooler Camp Table

Description: The Cooler CAMP Table contains the data from the Cooler CAMP command. The CAMP command causes the cooler to send back the current amplitudes for the displacer and compressors. The table is 38 bytes long and the data is in ASCII format. The ICM sends this down in the Table Packet. The Cooler Camp Table is updated periodically at a rate of about once every 10 seconds [Ref. ICS 4.4.2.4].

MOPITT Cooler Camp Strings

The ASCII strings contained in the TN_COOLER_CAMP tables are reported to the ground packed in Little Endian format. To print out the strings properly, they must be first byte swapped by ground software.

Format:	Word	Bit	Value	Description
	0-18	15-0	--	ASCII data

Usage Notes: This table can be dumped via the DUMP_DATA command when required.

7. DEVICE COMMAND AND TELEMETRY

The following sections describe the low level interface command and telemetry to/from the ICM devices.

7.1 Device Numbers

All hardware devices on the MOPITT instrument are assigned the Device Numbers as shown in Table 7.1-1. The Device Number is used to identify the device in many ICM commands (e.g., SET_DEVICE, PERFORM_DEV_INIT, etc.)

Table 7.1-1: Device Numbers

Number	Device Name	Number	Device Name
0	Not used	25	Scan Mirror 2
1	Detector Nest 1 Heater	26	Scan Mirror 3
2	Detector Nest 2 Heater	27	Scan Mirror 4
3-6	Not used	28	Chopper 1
7	Calibration Source 1 Heater	29	Chopper 2
8	Calibration Source 2 Heater	30	Chopper 3
9	Calibration Source 3 Heater	31	Chopper 4
10	Calibration Source 4 Heater	32	Pressure Modulation Cell 1
11	Molecular Sieve 1 Heater	33	Pressure Modulation Cell 2
12	Molecular Sieve 2 Heater	34	Stirling Cycle Coolers
13	Molecular Sieve 3 Heater	35	Signal Processing Module 1
14	Molecular Sieve 4 Heater	36	Signal Processing Module 2
15-19	Not used	37	Thermal Monitoring (TCMM)
20	Length Modulation Cell 1	38	Thermal Monitoring (PCDM)
21	Length Modulation Cell 2	39	Timing Control Unit (TCU)
22	Length Modulation Cell 3	40	Earth Port Cover
23	Length Modulation Cell 4	41	Space Port Cover
24	Scan Mirror 1		

7.2 Device States

All devices (except the port covers and latches) must be enabled before device control can take effect. Basically, there are two methods of control for a device: autonomous and manual (i.e., ground command). Autonomous control is via ICM procedures, such as the scan procedure. Manual control is via ground commands and effectively takes the device "offline".

For autonomous control, the Disabled and Normal State settings are used. For manual control, the Maintenance State setting is used. Placing a device in the Failed State will exclude that device from any manual or autonomous access (including device status queries).

The Device States are assigned the values shown in Table 7.2-1.

Table 7.2-1: Device States

Value	Device State
0	Disabled
1	Normal
2	Maintenance
3	Failed

7.3 Device Status

All devices (except port covers and latches) have a software generated Device Status, which reflects the current status of the device. The allowable Device Status are shown in Table 7.3-1.

The Unknown Status is used to indicate that the device status is not known, which occurs when communications to the device is lost. The Not Operational status indicates that the device is not enabled or running. The Operational Status indicates the device is enabled or running. The Fault Status indicates that device has encountered an unrecoverable failure (such as an over current, over voltage, or temperature out of limits condition).

The Fault status is latched if the device is in Normal State. Changing the device State to Disabled or Maintenance will reset the Fault Status.

Table 7.3-1: Device Status

Value	Device Status
0	Unknown
1	Not Operational
2	Operational
3	Fault

7.4 Device Port Addresses

The devices on the ICM are accessed via memory I/O address locations. The 80C186 Peripheral Chip Select lines will be programmed upon ICM initialization to the values shown in Table 7.4-1.

Table 7.4-1: Peripheral Chip Select Addresses

Peripheral Chip Select (Offset from Base)	Purpose	Notes
PCS~0 (0x0400)	Various miscellaneous ports	even addresses only (see table, below)
PCS~1 (0x0480)	Timing Control ports	even addresses only (see table, below)
PCS~2 (0x0500)	Command and Telemetry RT	18 ports, even addresses only
PCS~3 (0x0580)	Low Rate Science RT	18 ports, even addresses only

The Miscellaneous ports in the table below are relative to PCS~0 and the Timing Control ports are relative to absolute address PCS~1. Table 7.4-2 shows the addresses of the Miscellaneous Ports and the Timing Control Ports relative to PCS~0 and PCS~1, respectively.

Table 7.4-2: Miscellaneous and Timing Control Ports

Port Name	Port Description	Address (Offset)	I/O
Miscellaneous ICM Ports (Relative to PCS~0)			
spm1_txd_data	SPM1 transmit data word	0x0000	O
spm1_rxd_data	SPM1 receive data word	0x0000	I
spm2_txd_data	SPM2 transmit data word	0x0002	O
spm2_rxd_data	SPM2 receive data word	0x0002	I
strth_txd_data	PCDM transmit data word	0x0004	O
strth_rxd_data	PCDM receive data word	0x0004	I
chop/mir_txd_data	SCDM transmit data word	0x0006	O
chop/mir_rxd_data	SCDM receive data word	0x0006	I
plmc_txd_data	PLDM transmit data word	0x0008	O
plmc_rxd_data	PLDM receive data word	0x0008	I
tcmm_txd_data	TCMM transmit data word	0x000a	O

Port Name	Port Description	Address (Offset)	I/O
tcmm_rxd_data	TCMM receive data word	0x000a	I
buffer_full_status	Transmitter Receiver Buffer Full Status Port (single word interfaces)	0x000c	I
scc_txd_data	Cooler transmit data (lower 8 bits)	0x0010	O
scc_rxd_data	Cooler receive data (lower 8 bits)	0x0010	I
scc_uart_ctrl	Cooler UART Control Register	0x0012	O
scc_uart_stat	Cooler UART Status Register	0x0012	I
diag_txd_data	Diagnostic transmit data (lower 8 bits)	0x0014	O
diag_rxd_data	Diagnostic receive data (lower 8 bits)	0x0014	I
diag_uart_ctrl	Diagnostic UART Control Register	0x0016	O
diag_uart_stat	Diagnostic UART Status Register	0x0016	I
led_diag_port	LED Status Port (Only on prototype board)	0x0018	O
general_control	ICM Control Port	0x001a	O
wd_kick	Watchdog Kick Port	0x001c	O
tmf_int_ack	TMF Interrupt Acknowledge	0x001e	O
spm1_rxd_data_sci	SPM 1 science return data word	0x0020	I
spm2_rxd_data_sci	SPM 2 science return data word	0x0022	I
general_status	Miscellaneous Status Bits	0x0024	I
spm_rev_port_reset	SPM Science Receiver Reset	0x0026	I
safe_on	Safe Mode On (to BDU)	0x0028	O
safe_off	Safe Mode Off (to BDU)	0x002e	O
survival_on	Survival Mode On (to BDU)	0x002c	O
Survival_off	Survival Mode Off (to BDU)	0x002e	O
Timing Control Ports (Relative to PCS-1)			
Optical Channels 1 and 2			
div_chop_freq_a12	Chopper 1 Clock Divide Value	0x0000	O
div_lmc_freq_b12	LMC 1 Rotation Clock Divide Value	0x0002	O
div_lmcsct_freq_c12	LMC 1 Sector Clock Divide Value	0x0004	O

Port Name	Port Description	Address (Offset)	I/O
del_lmc_sect_f12	LMC 1 Clock Delay Value	0x0006	O
del_chop_freq_e12	Chopper 1 Frequency Delay Value	0x0008	O
Optical Channels 3 and 4			
div_chop_freq_a34	Chopper 2 Clock Divide Value	0x000a	O
div_lmc_freq_b34	LMC 2 Rotation Clock Divide Value	0x000c	O
div_lmcscct_freq_c34	LMC 2 Sector Clock Divide Value	0x000e	O
del_lmc_sect_f34	LMC 2 Clock Delay Value	0x0010	O
div_pmc_freq_d34	PMC 1 Frequency Divide Value	0x0012	O
del_chop_freq_e34	Chopper 2 Frequency Delay Value	0x0014	O
tcu1_initialize	TCU 1 Initialize port	0x0016	O
chop12_cmd_ppo	Chopper 1&2 Command/PPO Select	0x0018	O
pmc1_ref_delay	PMC 1 reference clock delay	0x001a	O
Optical Channels 5 and 6			
div_chop_freq_a56	Chopper 3 Clock Divide Value	0x0020	O
div_lmc_freq_b56	LMC 3 Rotation Clock Divide Value	0x0022	O
div_lmcscct_freq_c56	LMC 3 Sector Clock Divide Value	0x0024	O
del_lmc_sect_f56	LMC 3 Clock Delay Value	0x0026	O
del_chop_freq_e56	Chopper 3 Frequency Delay Value	0x0028	O
Optical Channels 7 and 8			
div_chop_freq_a78	Chopper 4 Clock Divide Value	0x002a	O
div_lmc_freq_b78	LMC 4 Rotation Clock Divide Value	0x002c	O
div_lmcscct_freq_c78	LMC 4 Sector Clock Divide Value	0x002e	O
del_lmc_sect_f78	LMC 4 Clock Delay Value	0x0030	O
div_pmc_freq_d78	PMC 2 Frequency Divide Value	0x0032	O
del_chop_freq_e78	Chopper 4 Frequency Delay Value	0x0034	O
tcu2_initialize	TCU 2 Initialize port	0x0036	O
chop34_cmd_ppo	Chopper 3&4 Command/PPO Select	0x0038	O
pmc2_ref_delay	PMC 2 reference clock delay	0x003a	O

The individual bits of the receive/transmit buffer full status register (0x000c) are assigned as outlined in Table 7.4-3, below. A '1' level on a bit indicates the buffer is full; while a '0' indicates empty.

Table 7.4-3: ICM Transmitter/Receiver Buffer Full Flag Status Port

Bit	Applicable Device Interface
Transmit Buffer Full Flags	
0	Signal Processing Module 1
1	Signal Processing Module 2
2	Port Cover Driver Module (Port Covers & Latches)
3	Chopper and Scan Mirror Driver Module
4	Length and Pressure Modulated Cell Driver Module
5	Thermal Control and Monitoring Module
6	not assigned
7	not assigned
Receive Buffer Full Flags	
8	Signal Processing Module 1
9	Signal Processing Module 2
10	Port Cover Driver Module (Port Covers & Latches)
11	Chopper and Scan Mirror Driver Module
12	Length and Pressure Modulated Cell Driver Module
13	Thermal Control and Monitoring Module
14	not assigned
15	not assigned

The bit allocations for the Miscellaneous Status Register (0x0024) is shown in Table 7.4-4.

Table 7.4-4: ICM Miscellaneous Status Register

Bit	Bit Definition
0	1= Watchdog reset occurred
1	1= Power On reset occurred
2	0 = Prime ICM 1= Redundant ICM
3	0= TMF bus A selected 1= TMF bus B selected
4	1= Safe Mode
5	1= Survival Mode
6	0= Boot EEPROM 0 selected 1= Boot EEPROM 1 selected
7 - 15	Not used

The bit allocations for the Control Port is shown in Table 7.4-5.

Table 7.4-5: ICM Control Port

Bit	Bit Definition
0	0 = Disable Timing Control Master Clock 1 = Enable Timing Control Master Clock
1	0 = Select TMF Bus A 1 = Select TMF Bus B
2	0 = Normal RAM Bank Configuration 1 = Swap RAM Banks MCS0 and MCS1
3 - 7	Not used

Bit	Bit Definition
8 - 11	Diagnostic Signal Select for TCU 1: 0 = LMC 1 sector count, LSB 1 = LMC 1 sector count, MSB 2 = Chopper 1 reference clock 3 = LMC 1 reference clock 4 = LMC 2 sector count, LSB 5 = LMC 2 sector count, MSB 6 = Chopper 2 reference clock 7 = LMC 2 reference clock 8 = PMC 1 cycle clock 9 = PMC 1 reference clock 10 = Diagnostic input signal 11 - 15 = not used
12 - 15	Diagnostic Signal Select for TCU 2: 0 = LMC 3 sector count, LSB 1 = LMC 3 sector count, MSB 2 = Chopper 3 reference clock 3 = LMC 3 reference clock 4 = LMC 4 sector count, LSB 5 = LMC 4 sector count, MSB 6 = Chopper 4 reference clock 7 = LMC 4 reference clock 8 = PMC 2 cycle clock 9 = PMC 2 reference clock 10 = Diagnostic input signal 11 - 15 = not used

7.5 Device Interfaces

The ICM communicates with the devices via serial interfaces. There are 7 serial interfaces used for command and telemetry: SPM1, SPM2, PCDM, PLDM, SCDM, TCMM and Cooler. The Cooler interface is a 9600 baud serial interface using an ASCII protocol. All the other interfaces are single word interfaces, where a command is 16 bits and the return status/telemetry is also 16 bits. The SPM interfaces also have a separate serial interface for the return science data.

The following sections describe the command and telemetry for each of the interfaces.

7.6 PLDM Command and Telemetry (PMC/LMC)

7.6.1 *Command Word:*

The command word is received by the PLDM via the RS-422 serial bus as a 16 bit word. The command word contains the following bits:

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	T	Address	Command					Amplitude (PMC only)							

Bits	Name	Description																																		
0-7	Amplitude	PMC Amplitude for "Set Amplitude" command. This field is zero for all other commands.																																		
8-11	Command	<table><tr><td><u>For LMC</u></td><td><u>For PMC</u></td></tr><tr><td>0 = Report status</td><td>0 = Reports status</td></tr><tr><td>1 = Reset</td><td>1 = Reset</td></tr><tr><td>2 = Enable</td><td>2 = Enable</td></tr><tr><td>3 = Disable</td><td>3 = Disable</td></tr><tr><td>4 = Enter Launch Mode</td><td>4 = External Command Frequency</td></tr><tr><td>5 - 9 = reserved</td><td>5 = Obsolete, was Free Run</td></tr><tr><td>10 = Measure Current</td><td>6 = Set Amplitude</td></tr><tr><td>11 = Measure Voltage</td><td>7 = Report Amplitude/Phase Error</td></tr><tr><td>12 = Report Telemetry</td><td>8 = Obsolete, was Measure Frequency</td></tr><tr><td>13 - 14 = reserved</td><td>9 = Obsolete, was Report frequency</td></tr><tr><td>15 = Interface Test</td><td>10 = Measure Current</td></tr><tr><td></td><td>11 = Measure Voltage</td></tr><tr><td></td><td>12 = Report Measured Current/Voltage</td></tr><tr><td></td><td>13 = Measure Phase Error</td></tr><tr><td></td><td>14 = Measure PPO Amplitude</td></tr><tr><td></td><td>15 = Interface Test</td></tr></table>	<u>For LMC</u>	<u>For PMC</u>	0 = Report status	0 = Reports status	1 = Reset	1 = Reset	2 = Enable	2 = Enable	3 = Disable	3 = Disable	4 = Enter Launch Mode	4 = External Command Frequency	5 - 9 = reserved	5 = Obsolete, was Free Run	10 = Measure Current	6 = Set Amplitude	11 = Measure Voltage	7 = Report Amplitude/Phase Error	12 = Report Telemetry	8 = Obsolete, was Measure Frequency	13 - 14 = reserved	9 = Obsolete, was Report frequency	15 = Interface Test	10 = Measure Current		11 = Measure Voltage		12 = Report Measured Current/Voltage		13 = Measure Phase Error		14 = Measure PPO Amplitude		15 = Interface Test
<u>For LMC</u>	<u>For PMC</u>																																			
0 = Report status	0 = Reports status																																			
1 = Reset	1 = Reset																																			
2 = Enable	2 = Enable																																			
3 = Disable	3 = Disable																																			
4 = Enter Launch Mode	4 = External Command Frequency																																			
5 - 9 = reserved	5 = Obsolete, was Free Run																																			
10 = Measure Current	6 = Set Amplitude																																			
11 = Measure Voltage	7 = Report Amplitude/Phase Error																																			
12 = Report Telemetry	8 = Obsolete, was Measure Frequency																																			
13 - 14 = reserved	9 = Obsolete, was Report frequency																																			
15 = Interface Test	10 = Measure Current																																			
	11 = Measure Voltage																																			
	12 = Report Measured Current/Voltage																																			
	13 = Measure Phase Error																																			
	14 = Measure PPO Amplitude																																			
	15 = Interface Test																																			
12-13	Address	0 = LMC/PMC 1/Interface Test 1 = LMC/PMC 2 2 = LMC 3 3 = LMC 4																																		
14	T	Type: 0 = LMC/Interface Test 1 = PMC																																		
15	Reserved	Reserved for future expansion, should always be 0.																																		

Notes: Control bits remain latched until the next valid control command sequence.

7.6.2 Status/Telemetry Words:

All commands sent to the PLDM return a status or telemetry word. The Interface Test returns a word with a fixed bit pattern. The return status or telemetry types for each command is shown in the following table:

Type	Command	Status or Telemetry Word Type
LMC/PMC	Report Status	Status Word
LMC/PMC	Reset	Status Word
LMC/PMC	Enable	Status Word
LMC/PMC	Disable	Status Word
LMC/PMC	Measure Current	Status Word
LMC/PMC	Measure Voltage	Status Word
LMC/PMC	Report Telemetry, Report Measured Current/Voltage, Report Measured Amplitude	Telemetry Word
LMC	Enter Launch Mode	Status Word
PMC	External Command Frequency	Status Word
PMC	Free Run	Status Word
PMC	Set Amplitude	Status Word
PMC	Measure PPO Amplitude	Status Word
PMC	Measure Demand Amplitude	Status Word
PMC	Report frequency	Telemetry Word
--	Interface Test	0x36E1

LMC Status Word:

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0	0	0	0	0	0	LM	LS	En

Bits	Name	Description
0	En	Enable/Disable: 0 = disabled 1 = enabled
1	LS	Lock State: 0 = phase locked 1 = not phase locked
2	LM	Launch Mode: 0 = off 1 = on

PMC Status Word:

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

Bits	Name	Description
0	En	Enable/Disable: 0 = disabled 1 = enabled
1	X	Don't care (could be 0 or 1).

Telemetry Word (LMC and PMC):

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

Interface Test Return Word:

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

Hex value: 0x36e1

7.6.3 PLDM Operation

The External Command Frequency command should be issued as the first command in the initialization process.

Each LMC's Enter Launch mode is reset by a power off/on sequence to the PLDM.

Measure current/voltage commands require approximately 8 microseconds for mux settling before the data is available. Data is read using the Report commands. There is only a single A/D and telemetry latch for use by all LMC and PMC devices. Read Voltage/Current commands must be paired with a Report command.

Transition from Instrument Safe mode to Standby mode will:

- enable each LMC, PMC

Transition from Instrument Science or Standby mode to Safe mode will:

- disable each LMC, PMC

The measure pressure procedure requires the following:

5 Hz sweep about a center frequency, with 1/2 Hz steps (11 steps total)

PMC frequency is calculated by the following formula:

$$\text{PMC frequency} = 2.55\text{e}6 / (256 * (\text{div} + 1))$$

where: div is the TCU divide value for the PMC

7.7 SCDM Command and Telemetry (Scan Mirror and Chopper)

7.7.1 Command Word:

The command word is received by the SCDM via the RS-422 serial bus as a 16 bit word. The command word contains the following bits:

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	T	Address	Command				Relative Position								

Bits	Name	Description																																
0-7	Relative Position	Relative position in steps for "Goto Position" command (Scan Mirrors, only). This byte is zero for all other commands.																																
8-11	Command	<table><thead><tr><th><u>For Choppers</u></th><th><u>For Scan Mirrors</u></th></tr></thead><tbody><tr><td>0 = Report status</td><td>0 = Report status</td></tr><tr><td>1 = Reset</td><td>1 = reserved (was reset absolute position counter)</td></tr><tr><td>2 = Enable</td><td>2 = Enable</td></tr><tr><td>3 = Disable</td><td>3 = Disable</td></tr><tr><td>4 = Enter Launch Mode</td><td>4 = Set Direction Counter Clockwise</td></tr><tr><td>5-9 = reserved</td><td>5 = Set Direction Clockwise</td></tr><tr><td>10 = Measure Current</td><td>6 = Set Between Detent Step</td></tr><tr><td>11 = Measure Voltage</td><td>7 = Set On Detent Step (baseline)</td></tr><tr><td>12 = Report Telemetry</td><td>8 = Goto Position</td></tr><tr><td>13-14 = reserved</td><td>9 = reserved (was Report Position)</td></tr><tr><td>15 = Interface Test</td><td>10 = Measure Current</td></tr><tr><td></td><td>11 = Measure Voltage</td></tr><tr><td></td><td>12 = Report Telemetry</td></tr><tr><td></td><td>13-14 = reserved</td></tr><tr><td></td><td>15 = Interface Test</td></tr></tbody></table>	<u>For Choppers</u>	<u>For Scan Mirrors</u>	0 = Report status	0 = Report status	1 = Reset	1 = reserved (was reset absolute position counter)	2 = Enable	2 = Enable	3 = Disable	3 = Disable	4 = Enter Launch Mode	4 = Set Direction Counter Clockwise	5-9 = reserved	5 = Set Direction Clockwise	10 = Measure Current	6 = Set Between Detent Step	11 = Measure Voltage	7 = Set On Detent Step (baseline)	12 = Report Telemetry	8 = Goto Position	13-14 = reserved	9 = reserved (was Report Position)	15 = Interface Test	10 = Measure Current		11 = Measure Voltage		12 = Report Telemetry		13-14 = reserved		15 = Interface Test
<u>For Choppers</u>	<u>For Scan Mirrors</u>																																	
0 = Report status	0 = Report status																																	
1 = Reset	1 = reserved (was reset absolute position counter)																																	
2 = Enable	2 = Enable																																	
3 = Disable	3 = Disable																																	
4 = Enter Launch Mode	4 = Set Direction Counter Clockwise																																	
5-9 = reserved	5 = Set Direction Clockwise																																	
10 = Measure Current	6 = Set Between Detent Step																																	
11 = Measure Voltage	7 = Set On Detent Step (baseline)																																	
12 = Report Telemetry	8 = Goto Position																																	
13-14 = reserved	9 = reserved (was Report Position)																																	
15 = Interface Test	10 = Measure Current																																	
	11 = Measure Voltage																																	
	12 = Report Telemetry																																	
	13-14 = reserved																																	
	15 = Interface Test																																	
12-13	Address	0 = Chopper/Scan Mirror 1/Interface Test 1 = Chopper/Scan Mirror 2 2 = Chopper/Scan Mirror 3 3 = Chopper/Scan Mirror 4																																
14	T	Type: 0 = Scan Mirror/Interface Test 1 = Chopper																																
15	Reserved	Reserved for future expansion, should always be 0.																																

Notes: Control bits remain latched until the next valid control command sequence.

7.7.2 Status/Telemetry Words:

All commands sent to the SCDM return a status or telemetry word. The Scan Mirrors and Choppers each have their own status word format (i.e., not combined). The returned status or telemetry type for each command is shown in the following table:

Type	Command	Status or Telemetry Word Type
Scan Mirror/ Chopper	Report Status	Status Word
Chopper	Reset status latches	Status Word
Scan Mirror/ Chopper	Enable	Status Word
Scan Mirror/ Chopper	Disable	Status Word
Chopper	Enter Launch Mode	Status Word
Scan Mirror	Set Direction Clockwise	Status Word
Scan Mirror	Set Direction Counter Clockwise	Status Word
Scan Mirror	Set On Detent Step	Status Word
Scan Mirror	Set Between Detent Step	Status Word
Scan Mirror	Goto Position	Status Word
Scan Mirror	Report Position	Status Word
Scan Mirror/ Chopper	Measure Current	Status Word
Scan Mirror/ Chopper	Measure Voltage	Status Word
Scan Mirror/ Chopper	Report Telemetry	Current/Voltage Telemetry Word
--	Interface Test	0x59D2

Scan Mirror Status Word:

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0	Step	Nadir	CW	CCW	0	Mode	Dir	En

Bits	Name	Description			
0	En	Enable/Disable: 0 = Disabled 1 = Enabled			
1	Dir	Direction: 0 = Clockwise 1 = Counter Clockwise			
2	Mode	Step Mode: 0 = On Detent Step 1 = Between Detent Step			
3	unused	always 0			
4 - 6	CW, CCW Nadir	Nadir - detector 2, Nadir position detector			
		CW - detector 1, Clockwise			
		CCW - detector 0, Counter-clockwise			
		Nadir	CW	CCW	Position
		bit6	bit5	bit4	

		0	0	0	Unknown
		0	0	1	Unknown
		0	1	0	Unknown
		0	1	1	Deep Space (-50)
		1	0	0	Cal Source (100)
		1	0	1	CCW view (-1....-14)
		1	1	0	CW view (+1....+14)
1	1	1	Nadir (0)		
Note: Bits 4 & 5 are reversed for scan mirror 1					
7	Step	Scan mirror stepping (0 = off, 1 = on)			

Chopper Status Word:

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0	0	0	0	0	0	S2	S1	S0

Bits	Name	Description
0	S0	Enable/Disable: 0 = enabled 1 = disabled
1	S1	Lock State: 0 = not locked 1 = locked
2	S2	Launch Mode: 0 = on 1 = off
3	unused	always 0

Current/Voltage Telemetry Word:

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	A/D Reading													

Interface Test Return Word:

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

Hex Value: 0x59d2

7.7.3 SCDM Operation

Each chopper's Enter Launch mode is reset by a power off/on sequence to the SCDM.

Measure current/voltage commands require approximately 8 microseconds for mux settling before the data is available. Data is read using the Report Telemetry command. There is only a single A/D and telemetry latch for use by all chopper and mirror devices. Read Voltage/Current commands must be paired with a Report Telemetry command.

Transition from Instrument Safe mode to Standby mode will:

- enable each chopper

- initialize each mirror

Transition from Instrument Science or Standby mode to Safe mode will:

- disable each chopper
- park each mirror

Software maintains a position variable for each mirror. The variable is nominally in the range 0 to 199, with the value at Nadir of zero. The scan mirror initialization procedure determines the actual mirror position and resets the position variable. The software maintains the mirror position variable while commanding relative position stepping. This is done as an open loop control, with absolute position verified at specific mirror positions using the encoder feedback information. The scan mirrors are parked in all Instrument modes except Standby and Science mode.

The scan mirror initialization sequence is as follows:

- enable the scan mirror
- rotate 400 degrees to verify functionality of the encoders
- if an error is detected set the mirror to Failed state, if possible determine mirror position otherwise assume the mirror was originally in the Cal Source position.
- position to Nadir, deep space port and then to the Cal Source position.
- mirror may now be used for scanning

Each scan mirrors is parked by :

- move the scan mirror to the Cal Source position
- disabling the scan mirror

The mirror step rate is approximately 5 ms. per step (200Hz +/- 5Hz).

The On Detent mode is the baseline for mirror calibration and flight operation. Between Detent mode requires recalibration and current setting adjustments for proper operation.

Scan mirror direction or rotation is referenced with respect to the Spacecraft axes. Clockwise (CW) and counterclockwise (CCW) are referenced by viewing the MOPITT instrument from the scan mirror to the dewar, looking in the positive X direction. Thus, scan mirror motors are viewed from the encoder side.

7.8 PCDM Command and Telemetry (Port Covers and Heaters)

7.8.1 Command Word:

The command word is received by the PCDM via the RS-422 serial bus as a 16 bit word. The command word contains the following bits:

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Command				T	Parameter			Data Field							

Note: the T bit (bit 11) = the type of port cover (0 = Earth Port, 1 = Space Port)

Description	Command	Notes	
Report Status	0x0	No other actions.	
Set Heater (survival)	0x1	Parameter: 000 = off , 001 = on	
†Read Telemetry	0x2	<u>Earth View (T bit = 0)</u> Parameter: 000 = motor temperature 001 = bearing temperature 010 = latch temperature 011 = baffle temperature 100 = +28V reference 101 = +13.7V reference 110 = +5V reference 111 = N/A	<u>Space View (T bit = 1)</u> Parameter: 000 = motor temperature 001 = bearing temperature 010 = latch temperature 011 = baffle temperature 100 = reference high 101 = reference low 110 = N/A 111 = N/A
‡Set Latch	0x3	Parameter: 000 = off , 001 = on Resets Arm Critical to initial state.	
Arm Critical	0x4	Initiates 15 minute timer. Command is independent of port. Prerequisite for Set Latch, Step Cover, and Limit Switch Override commands.	

Description	Command	Notes
‡Step Cover (direction, n)	0x5	Earth Port Space Port Parameter: 000 = open Parameter: 000 = close 001 = close 001 = open Data: value * 256 steps (for value: 00 = FF-1) Resets Arm Critical to initial state.
Reset	0x6	Acts similar to a "power on" reset
‡Limit Switch Override	0x7	Parameter: 000 = off, 001 = on. Overrides Limit Switch. Resets Arm Critical to initial state.
Interface Test	0xF	Test Pattern.

Notes: Control bits remain latched until the next valid control command sequence.

- | | |
|---|--|
| † | This command must be sent twice (the first time allows the Mux to settle; the second time receives valid telemetry). |
| ‡ | This command must be preceded by an Arm Critical command, otherwise no action is taken. |

7.8.2 Status/Telemetry Words:

All commands sent to the PCDM return a status or telemetry word. The Interface Test returns a word with a fixed bit pattern. The return status or telemetry types for each command is shown in the following table:

Type	Command	Status or Telemetry Word Type
PCDM	Report Status	Status Word
PCDM	Set Heater	Status Word
PCDM	Read Telemetry	Telemetry Word
PCDM	Set Latch	Status Word
PCDM	Arm Critical	Status Word
PCDM	Step Cover	Status Word
PCDM	Reset	Status Word
PCDM	Limit Switch Override	Status Word
PCDM	Interface Test	0x6AB4

Status Word:

Each port cover returns a status word of the format shown below.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0						LC	Arm	LSO	LE	ME	Dir	HE	LL	LS	DO

Bit Field	Definition	Notes
0	DO - Door Open Encoder: 0 = door open 1 = door not open	Signal comes directly from encoder.
1	LS - Latch Status: 0 = Latch not open 1 = Latch open	Indicates that limit switch has opened (de-bounced).
2	LL - Latch Limit Switch: 0 = closed 1 = open	Signal comes directly from limit switch.
3	HE - Heater Enable Status 0 = Heater disabled 1 = Heater enabled	Commanded state.

Bit Field	Definition	Notes
4	Dir - Direction Status:EP: 1 = open, 0 = close SP: 0 = open, 1 = close	Commanded direction.
5	ME - Motor Enable Status 0 = Motor disabled 1 = Motor enabled	Indicates that motor is stepping.
6	LE - Latch Enable Status: 0 = Latch power disabled 1 = Latch power enabled	Indicates that power is being applied to latch.
7	LSO - LSO Status: 0 = override off 1 = override on	Indicates the Limit Switch has been overridden.
8	Arm - Arm Status 0 = not armed 1 = armed	Indicates that arm operation was successful.
9	LC - Latch Command Status 0 = Latch not commanded open 1 = Latch commanded open	Indicates the current latch command status.
10 - 15	Unused: All zeros	

Telemetry Word:

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	A/D Reading													

Interface Test Return Word:

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

Hex Value: 0x6AB4

7.8.3 PCDM Operation

The port covers must be armed before the Set Latch, Step Cover, or Limit Switch Override command can be executed. The execution of one of these commands will cause the armed condition to be reset. Thus, each one of these commands must be preceded by an Arm Critical command.

The Armed Critical command will arm both port covers (space and earth).

A hardware timeout of 15 minutes is set on the Arm Critical command. If the armed condition is not removed by executing a Set Latch, Step Cover, or Limit Switch Override command within 15 minutes, the armed condition will automatically be reset.

The Reset command acts as a "power on" reset; all latches, heaters, and motors (for both Earth and Space port covers) will be disabled (turned off).

The Reset command can be executed by writing 0x6 and is independent of the T bit setting.

The Read Telemetry command must be issued twice (with at least 2 ms between commands). This must be done to allow the multiplexer to settle. Thus, the first reading is discarded and the second reading is the valid reading.

The Step Cover command takes on the following format: 0x5XYY, where X is the direction of the motor and YY (hex) is the data value provided to the motor. A data value of YY = 00 is defined as YY = 100, that is, the motor will turn for a full count (equivalent to giving it a data value of FF) plus 1.

Nominal door movement (disregarding clutch slippage) in Degrees is = Command Value (decimal) x 256 x 1.8 / 300.

7.9 SPM Command and Telemetry (Signal Processing Module 1 & 2)

The command and telemetry interface for SPM 1 and SPM 2 are separate and identical. Each SPM is accessed by the ICM through a separate port address. SPM 1 handles choppers 1 & 2, LMC 1 & 2, and PMC 1. SPM 2 handles choppers 3 & 4, LMC 3 & 4, and PMC 2. This section describes the commands and status/telemetry for SPM 1 but the information is also applicable for SPM 2.

SPM data is returned on a separate interface and is not described in this section.

NOTE: Detectors are numbered 1 to 8, with detectors 1 to 4 controlled by SPM 1 and detectors 5 to 8 controlled by SPM 2.

7.9.1 Command Word:

The command word is received by SPM1 (and similarly for SPM2) via the RS-422 serial bus as a 16 bit word. The command word contains the following bits:

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Command				Parameter				Data							

Bits	Name	Description
0-7	Data	Data to write for the following commands: Set Parameter = 0 - 255 Arm Burst = aabbcccc, where aa = channel 0 - 3, bb = pixel 0 - 3, cccc = duration 0 - 15 The first letter "a" is the most significant bit (bit 7) and the last "c" is the least significant bit (bit 0). The "duration" specifies how many samples to send back for the burst. Each sample is the sum of 8 A/D samples, divided by 4. The number of samples is given by: samples = duration * 1024 This field is zero for all other commands.

Bits	Name	Description
8-11	Parameter	Parameter to select for the following commands: - Set Parameter = 0 - 15 - Read Parameter = 0 - 15 - Enable A/D Power = 0 - 1 - Disable A/D Power = 0 - 1 - Disable Fuse = 0 - 3 - Enable Fuse = 0 - 3 - Disable Detector Power = 0 - 3 - Enable Detector Power = 0 - 3 Parameters are defined as follows for Set Parameter and Read Parameter commands: 0 = # groups of 4 samples to blank for Chopper 1 open state 1 = # groups of 4 samples to process for Chopper 1 open state 2 = # groups of 4 samples to blank for Chopper 1 closed state 3 = # groups of 4 samples to process for Chopper 1 closed state 4 = # groups of 4 samples to blank for Chopper 2 open state 5 = # groups of 4 samples to process for Chopper 2 open state 6 = # groups of 4 samples to blank for Chopper 2 closed state 7 = # groups of 4 samples to process for Chopper 2 closed state 8 = # chopper cycles to blank for each LMC 1 sector 9 = # chopper cycles to process for each LMC 1 sector 10 = # chopper cycles to blank for each LMC 2 sector 11 = # chopper cycles to process for each LMC 2 sector 12 = # chopper cycles to process for each PMC 1 sector 13 = # LMC 1 sectors to process for each stare 14 = # LMC 2 sectors to process for each stare 15 = # PMC 1 sectors to process for each stare NOTE: Once parameters are set, they are latched and not cleared until the SPM is powered down. Parameters are defined as follows for the Enable A/D Power and Disable A/D Power commands: 0 = A/Ds for detectors 1 and 2 1 = A/Ds for detectors 3 and 4

Bits	Name	Description
		Parameters are defined as follows for Disable Fuse, Enable Fuse, Disable Detector Power, and Enable Detector Power commands: 0 = Detector 1 1 = Detector 2 2 = Detector 3 3 = Detector 4 This field is zero for all other commands.
12-15	Command	0 = Report Status 1 = Set Parameter 2 = Read Parameter 3 = Arm Burst 4 = Trigger Burst 5 = Start Stare 6 = Enable A/D Power (Note 1) 7 = Disable A/D Power 8 = Disable Fuse 9 = Enable Fuse 10 = Disable Detector Power 11 = Enable Detector Power (Note 1) 12 = select A/B clock, bit 8 = 0 - A clock, 1 - B clock 13 = Reserved 14 = Reset (only affects Arm Burst, Trigger Burst, Start Stare) 15 = Interface Test Note 1: Detector and A/D powers default to off on SPM power up. Fuses default to on. Detector power for each detector must be individually enabled by the Enable Detector Power command. A/D power must be enabled by Enable A/D Power command.

Notes: Control bits remain latched until the next valid control command sequence.

7.9.2 Status/Telemetry Words:

All commands sent to the SPM return a status or telemetry word. The Interface Test returns a word with a fixed bit pattern. The return status or telemetry types for each command is shown in the following table:

Type	Command	Status or Telemetry Word Type
SPM	Report Status	Status Word
SPM	Set Parameter	Status Word
SPM	Read Parameter	Telemetry Word
SPM	Arm Burst	Status Word
SPM	Trigger Burst	Status Word
SPM	Start Stare	Status Word
SPM	Enable A/D Power	Status Word
SPM	Disable A/D Power	Status Word
SPM	Disable Fuse	Status Word
SPM	Enable Fuse	Status Word
SPM	Disable Detector Power	Status Word
SPM	Enable Detector Power	Status Word
SPM	Reset	Status Word
—	Interface Test	0x9C78 (SPM 1) 0xA31E (SPM 2)

Status Word:

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	AD34	AD12	D4	D3	D2	D1	F4	F3	F2	F1	P1	L2	L1	BA

Bits	Name	Description
0	BA	Burst Active (0=idle, 1=active)
1	L1	LMC1 channel processing (0=off, 1=on)
2	L2	LMC2 channel processing (0=off, 1=on)

Bits	Name	Description
3	P1	PMC1 channel processing (0=off, 1=on)
4	F1	Fuse Status, Detector 1 (0 = disabled, 1 = enabled)
5	F2	Fuse Status, Detector 2 (0 = disabled, 1 = enabled)
6	F3	Fuse Status, Detector 3 (0 = disabled, 1 = enabled)
7	F4	Fuse Status, Detector 4 (0 = disabled, 1 = enabled)
8	D1	Detector 1 power status (0 = off, 1 = on)
9	D2	Detector 2 power status (0 = off, 1 = on)
10	D3	Detector 3 power status (0 = off, 1 = on)
11	D4	Detector 4 power status (0 = off, 1 = on)
12	AD12	A/D power status for detectors 1 and 2 (0 = off, 1 = on)
13	AD34	A/D power status for detectors 3 and 4 (0 = off, 1 = on)
14	--	Not used.
15	--	Not used.

Telemetry Word:

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Burst Pixel	Burst Channel	Burst Duration	Data												

Interface Test Return Word for SPM1:

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

Hex Value: 0x9C78

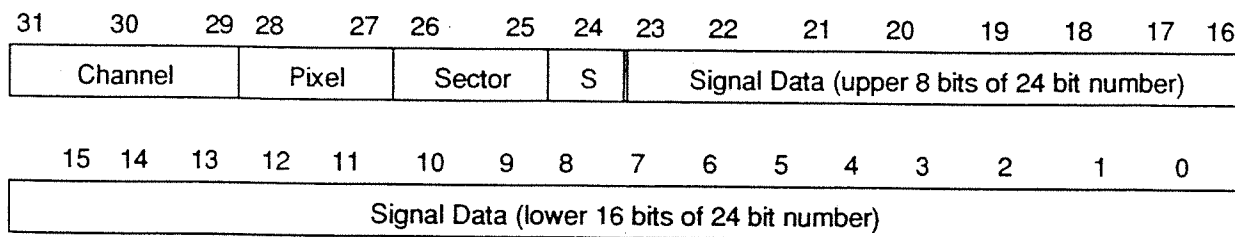
Interface Test Return Word for SPM2:

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

Hex Value: 0xA31E

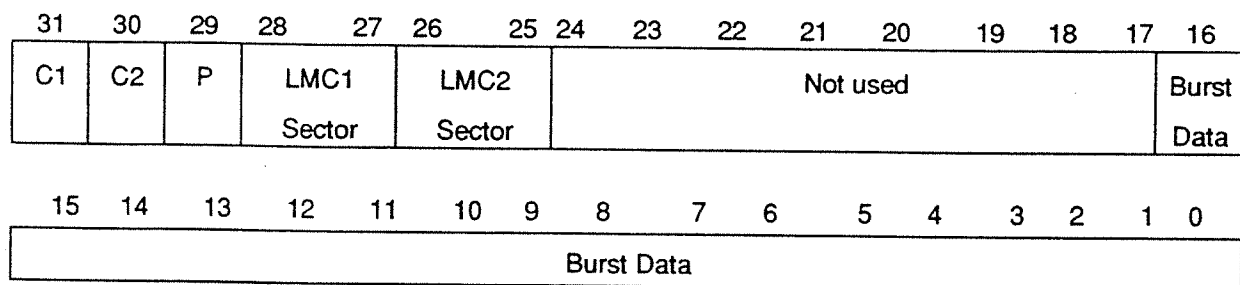
7.9.3 SPM Data Return Interface

The SPMs return data from the detectors on the SPM Data Return Interface. The format of the data is as follows for science stare data:



NOTE: "S" (bit 24) indicates chopper open/closed, with 0=closed, 1=open

The format for burst science data is:



NOTE: "C1 and C2" (bit 31 and 30) indicates chopper 1 and 2, respectively, open/closed state, with 0=closed, 1=open. "P" is the PMC sector number. "LMC1" and "LMC2" are "LMC3" and "LMC4", respectively, when using channels 4 or higher.

7.9.4 SPM Operation

The SPM is used for science data collection. It is operational during science mode and when burst data is collected.

7.9.4.1 Detector Power

Turn on in STANDBY and SCIENCE modes.

Interlocked with temp based on table driven telemetry point and value.

There is a problem with surge power when the SPM turns on detector power. In order to prevent a false tripping of the detector power fuse the following sequence is performed every time the detector power is turned on for each detector:

1. Save fuse state, disable fuse
2. Turn on detector power
3. Wait at least 5 ms.
4. Enable fuse if it was previously enabled

7.9.4.2 *SPM and Cooler Interlock*

To prevent physical damage, the detectors are only powered when the coolers are operating and the detectors are below a temperature limit value. This requires active monitoring of a temperature telemetry point associated with each detector. Detector power is turned off when the temperature limit is exceeded. Detector power is turned on only when the temperature point is below the limit and the detectors have been commanded to be on. The temperature limit value and associated temperature point address are maintained in the temperature limits table for each detector.

7.9.4.3 *Detector Fuses*

Must disable fuse prior to turning on detector and restore previous state >5ms after turn on of detector.

Detector Fuse trip point is 18.3 +/- 0.5 mA.

7.9.4.4 *A/D Power*

Off in standby, on in science. During science, turned off for 8 ms (and 12 ms) when mirror stepping starts. Forced on 50ms prior to burst mode initiation, then turned off again. Note, manual turn on should not be done on orbit since could get latchup.

Software turns on the two banks (ie Chan 1/2 and Chan 3/4) with a delay between of 4 ms in order to reduce the peak surge current caused by charging up capacitors on the analog boards.

In order reduce the possibility of damage to the A/Ds due to internal latchup when the A/D are powered, the A/D power is cycled at least once per second. This is done during science stares and science burst data collection.

During science mode the A/D power is cycled as follows:

1. Perform stare
2. At end of stare, turn off A/D power
3. Wait 10 ms.
4. Turn on A/D power

During a burst data collection A/D power is cycled as follows:

1. Turn on A/D power
2. Wait 50 ms.
3. Perform burst data collection
4. At end of burst, turn off A/D power

A/D power is off except when in SCIENCE mode or during burst data collection.

Do not manually turn on when in orbit since a latchup may occur.

7.9.4.5 *SPM Reset Command*

The SPM reset command is sent to the SPM at the beginning of the SPM initialization procedure. It is also sent before and after collecting burst data.

The Reset command does not affect power, fuse, or parameter settings. It resets the processing state.

7.9.4.6 *Clock Input A/B Selection*

On power up the SPM defaults to A side clock input. In order to select B side, a command is issued upon boot to safe transition. If the instrument is operating on Side B, the SPM will ignore all commands until B side clock select command is received.

The first command sent to the SPM on initialization must select A/B clock to be the same as the active ICM, A or B.

7.9.4.7 Processing Parameters

The SPM processes data based on reference timing signals provided by the TCU. The SPM processing parameters are loaded from a table upon initialization of the SPM. The table may be changed with an upload of a new table. Individual values may also be changed while the Instrument is in SCIENCE or STANDBY modes.

Use table upload and SPM dev_init command to reload parameters during fine tuning. Can be done from standby or science.

7.9.4.8 Burst/Stare Mode (Stare, Reset, Arm, Trig, Reset, Stare)

Reset command should be issued both before and after a burst command.

7.10 TCMM Command and Telemetry (Thermal Control and Monitoring Module)

7.10.1 Command Word:

The command word is received by TCMM via the RS-422 serial bus as a 16 bit word. The command word contains the following bits:

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Command				Parameter				Data							

Bits	Name	Description
0-7	Data	Data to write for the following commands: Set Heater = 0 - 255 Set Heater Fine = 0 - 255 Read = 0 - 63 For Set Heater and Set Heater Fine commands, the value is the desired heater setting. For the Read command, the following applies: Heater voltage: 0 = VR_SIEVE_1, Sieve 1 1 = VR_SIEVE_2, Sieve 2 2 = VR_SIEVE_3, Sieve 3 3 = VR_SIEVE_4, Sieve 4 4 = VR_HTR_NEST1, Detector Nest 1 5 = VR_HTR_NEST2, Detector Nest 2 6 = VR_CAL_1, Calibration Source 1 7 = VR_CAL_2, Calibration Source 2 8 = VR_CAL_3, Calibration Source 3 9 = VR_CAL_4, Calibration Source 4 10 = VR_HTR_REF_HI, High Reference 11 = VR_HTR_REF_LO, Low Reference 12 - 63 = Not used

Bits	Name	Description
		Diodes: 0 = TR_ENG_DETECTOR1, Detector 1 1 = TR_ENG_DETECTOR2, Detector 2 2 = TR_ENG_DETECTOR5, Detector 5 3 = TR_ENG_DETECTOR6, Detector 6 4 = TR_ENG_CFILTER3, Cold Filter 3 5 = TR_ENG_CFILTER7, Cold Filter 7 6 = TR_ENG_DIODE1_HI, Diode Reference High, bank 1 7 = TR_ENG_DIODE1_LO, Diode Reference Low, bank 1 8 = TR_ENG_DETECTOR3, Detector 3 9 = TR_ENG_DETECTOR4, Detector 4 10 = TR_ENG_DETECTOR7, Detector 7 11 = TR_ENG_DETECTOR8, Detector 8 12 = TR_ENG_CFILTER1, Cold Filter 1 13 = TR_ENG_CFILTER5, Cold Filter 5 14 = TR_ENG_DIODE2_HI, Diode Reference High, bank 2 15 = TR_ENG_DIODE2_LO, Diode Reference Low, bank 2 16 - 63 = Not used

Bits	Name	Description
		Thermistors: 0 = TR_COOL_COMP1, Cooler Compressor 1 1 = TR_LMC1_MTR, LMC Motor 1 2 = TR_SCAN1_MTR, Scan Motor 1 3 = TR_CHOP1_MTR, Chopper Motor 1 4 = TR_ENG_LMC1, LMC Gas 1 5 = TR_ENG_PMC1, PMC Gas 1 6 = TR_ENG_CHOP1, Chopper 1 (shroud) 7 = TR_ENG_OPT2_1, Optical chassis 2, point 1 8 = TR_ENG_OPT1_1, Optical chassis 1, point 1 9 = TR_ENG_SCAN1, Mirror 1 10 = TR_SPM1, SPM 1 11 = TR_BPLT_3, Baseplate, point 3, by the ICM 12 = TR_TCMMA_1, PRT Board A 13 = TR_ENG_PRESS1, Pressure sensor 1 (temperature) 14 = TR_THERM1_HI, TR_ENG_THERM1_HI, Thermistor High Reference, bank 1 15 = TR_THERM1_LO, TR_ENG_THERM1_LO, Thermistor Low Reference, bank 1

Bits	Name	Description
		16 = TR_COOL_COMP2, Cooler Compressor 2
		17 = TR_LMC2_MTR, LMC Motor 2
		18 = TR_SCAN2_MTR, Scan Motor 2
		19 = TR_CHOP2_MTR, Chopper Motor 2
		20 = TR_ENG_LMC2, LMC Gas 2
		21 = TR_ENG_PMC1, PMC Gas 2
		22 = TR_ENG_CHOP2, Chopper 2 (shroud)
		23 = TR_ENG_OPT2_2, Optical chassis 2, point 2
		24 = TR_ENG_OPT1_2, Optical chassis 1, point 2
		25 = TR_ENG_SCAN2, Mirror 2
		26 = TR_SPM2, SPM 2
		27 = TR_PSM, PSM
		28 = TR_TCMMA_2, PRT Board B
		29 = TR_ENG_PRESS2, Pressure sensor 2 (temperature)
		30 = TR_THERM2_HI, TR_ENG_THERM2_HI, Thermistor High Reference, bank 2
		31 = TR_THERM2_LO, TR_ENG_THERM2_LO, Thermistor Low Reference, bank 2

Bits	Name	Description
		32 = TR_PMC1_MTR, PMC Motor 1
		33 = TR_LMC3_MTR, LMC Motor 3
		34 = TR_SCAN3_MTR, Scan Motor 3
		35 = TR_CHOP3_MTR, Chopper Motor 3
		36 = TR_ENG_LMC3, LMC Gas 3
		37 = TR_ENG_CHOP3, Chopper 3 (shroud)
		38 = TR_ENG_OPT2_3, Optical chassis 2, point 3
		39 = TR_ENG_OPT1_3, Optical chassis 1, point 3
		40 = TR_ENG_SCAN3, Scan Mirror 3
		41 = TR_BPLT_1, Baseplate, point 1, by scan mirror 2
		42 = TR_TCM MB_1, Thermistor Board
		43 = TR_ENG_PRESS3, Pressure sensor 3 (temperature)
		44 = TR_SPARE_1, Spare 1
		45 = TR_SPARE_2, Spare 2
		46 = TR_THERM3_HI, TR_ENG_THERM3_HI, Thermistor High Reference, bank 3
		47 = TR_THERM3_LO, TR_ENG_THERM3_LO, Thermistor Low Reference, bank 3

Bits	Name	Description
		48 = TR_PMC2_MTR, PMC Motor 2 49 = TR_LMC4_MTR, LMC Motor 4 50 = TR_SCAN4_MTR, Scan Motor 4 51 = TR_CHOP4_MTR, Chopper Motor 4 52 = TR_ENG_LMC4, LMC Gas 4 53 = TR_ENG_CHOP4, Chopper 4 (shroud) 54 = TR_ENG_OPT2_4, Optical chassis 2, point 4 55 = TR_ENG_OPT1_4, Optical chassis 1, point 4 56 = TR_ENG_SCAN4, Scan Mirror 4 57 = TR_BPLT_2, Baseplate, point 2, by SPM1 58 = TR_TCMMB_2, Pressure Sensor Board 59 = TR_ENG_PRESS4, Pressure sensor 4 (temperature) 60 = TR_SPARE_3, Spare 3 61 = Not used 62 = TR_THERM4_HI, TR_ENG_THERM4_HI, Thermistor High Reference, bank 4 63 = TR_THERM4_LO, TR_ENG_THERM4_LO, Thermistor Low Reference, bank 4 PRT: 0 = TS_ENG_CAL1_1, Calibration Source 1, point 1 1 = TS_ENG_CAL1_1RH, Calibration Source 1, point 1, High Ref. 2 = TS_ENG_CAL1_1RL, Calibration Source 1, point 1, Low Ref. 3 = TS_ENG_CAL1_2, Calibration Source 1, point 2 4 = TS_ENG_CAL1_2RH, Calibration Source 1, point 2, High Ref. 5 = TS_ENG_CAL1_2RL, Calibration Source 1, point 2, Low Ref. 6 = TS_ENG_CAL2_1, Calibration Source 2, point 1 7 = TS_ENG_CAL2_1RH, Calibration Source 2, point 1, High Ref. 8 = TS_ENG_CAL2_1RL, Calibration Source 2, point 1, Low Ref. 9 = TS_ENG_CAL2_2, Calibration Source 2, point 2 10 = TS_ENG_CAL2_2RH, Calibration Source 2, point 2, High Ref. 11 = TS_ENG_CAL2_2RL, Calibration Source 2, point 2, Low Ref. 12 = TS_ENG_CAL3_1, Calibration Source 3, point 1 13 = TS_ENG_CAL3_1RH, Calibration Source 3, point 1, High Ref. 14 = TS_ENG_CAL3_1RL, Calibration Source 3, point 1, Low Ref. 15 = Not Used

Bits	Name	Description
		16 = TS_ENG_CAL3_2, Calibration Source 3, point 2 17 = TS_ENG_CAL3_2RH, Calibration Source 3, point 2, High Ref. 18 = TS_ENG_CAL3_2RL, Calibration Source 3, point 2, Low Ref. 19 = TS_ENG_CAL4_1, Calibration Source 4, point 1 20 = TS_ENG_CAL4_1RH, Calibration Source 4, point 1, High Ref. 21 = TS_ENG_CAL4_1RL, Calibration Source 4, point 1, Low Ref. 22 = TS_ENG_CAL4_2, Calibration Source 4, point 2 23 = TS_ENG_CAL4_2RH, Calibration Source 4, point 2, High Ref. 24 = TS_ENG_CAL4_2RL, Calibration Source 4, point 2, Low Ref. 25 = TS_ENG_SIEVE1, Sieve 1 26 = TS_ENG_SIEVE1_RH, Sieve 1 High Reference 27 = TS_ENG_SIEVE1_RL, Sieve 1 Low Reference 28 = TS_ENG_SIEVE2, Sieve 2 29 = TS_ENG_SIEVE2_RH, Sieve 2 High Reference 30 = TS_ENG_SIEVE2_RL, Sieve 2 Low Reference 31 = Not used 32 = TS_ENG_SIEVE3, Sieve 3 33 = TS_ENG_SIEVE3_RH, Sieve 3 High Reference 34 = TS_ENG_SIEVE3_RL, Sieve 3 Low Reference 35 = TS_ENG_SIEVE4, Sieve 4 36 = TS_ENG_SIEVE4_RH, Sieve 4 High Reference 37 = TS_ENG_SIEVE4_RL, Sieve 4 Low Reference 38 - 63 = Not used

Bits	Name	Description
		Pressure: 0 = VR_ENG_PRESS1, Pressure 1 1 = VR_ENG_PRESS1_RH, High Reference 1 2 = VR_ENG_PRESS1_RL, Low Reference 1 3 = Not used 4 = VR_ENG_PRESS2, Pressure 2 5 = VR_ENG_PRESS2_RH, High Reference 2 6 = VR_ENG_PRESS2_RL, Low Reference 2 7 = Not used 8 = VR_ENG_PRESS3, Pressure 3 9 = VR_ENG_PRESS3_RH, High Reference 3 10 = VR_ENG_PRESS3_RL, Low Reference 3 11 = Not used 12 = VR_ENG_PRESS4, Pressure 4 13 = VR_ENG_PRESS4_RH, High Reference 4 14 = VR_ENG_PRESS4_RL, Low Reference 4 15 - 63 = Not used This field is zero for all other commands.

Bits	Name	Description
8-11	Parameter	Parameter to select for the following commands: Disable Heater, Enable Heater, Enable Fuse and Disable Fuse commands: 0 = Sieve 1 1 = Sieve 2 2 = Sieve 3 3 = Sieve 4 4 = Detector Nest 1 5 = Detector Nest 2 6 - 15 = Not used Set Heater command: 0 = Sieve 1 1 = Sieve 2 2 = Sieve 3 3 = Sieve 4 4 = Detector Nest 1 5 = Detector Nest 2 6 = Calibration Source 1 7 = Calibration Source 2 8 = Calibration Source 3 9 = Calibration Source 4 10 - 15 = Not used Set Heater Fine command: 0 = Sieve 1 1 = Sieve 2 2 = Sieve 3 3 = Sieve 4 4 - 15 = Not used

Bits	Name	Description
		Read: 0 = Heater Voltage 1 = Diode 2 = Thermistor 3 = PRT Coarse 4 = PRT Fine 5 = Pressure 6-15 = not used Diode Bias On and Diode Bias Off commands: 0 = Bank 1 1 = Bank 2 2 - 15 = Not used This field is zero for all other commands.
12-15	Command	0 = Report Status 1 = Disable Heater 2 = Enable Heater 3 = Set Heater 4 = Set Heater Fine 5 = Read 6 = Diode Bias On 7 = Diode Bias Off 8 - 12 = Reserved 13 = Enable Fuse 14 = Disable Fuse 15 = Interface Test

Notes: Control bits remain latched until the next valid control command sequence.

7.10.2 Status/Telemetry Words:

All commands sent to the TCMM return a status or telemetry word. The Interface Test returns a word with a fixed bit pattern. The return status or telemetry types for each command is shown in the following table:

Type	Command	Status or Telemetry Word Type
TCMM	Report Status	Status Word
TCMM	Disable Heater	Status Word
TCMM	Enable Heater	Status Word
TCMM	Set Heater	Status Word
TCMM	Set Heater Fine	Status Word
TCMM	Read	Telemetry Word
TCMM	Diode Bias On	Status Word
TCMM	Diode Bias Off	Status Word
TCMM	Enable Fuse	Status Word
TCMM	Disable Fuse	Status Word
--	Interface Test	0xC52D

Status Word:

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	S13	S12	S11	S10	S9	S8	S7	S6	S5	S4	S3	S2	S1	S0

Bits	Name	Description
0	S0	Sieve 1 heater status (0 = disabled, 1 = enabled)
1	S1	Sieve 2 heater status (0 = disabled, 1 = enabled)
2	S2	Sieve 3 heater status (0 = disabled, 1 = enabled)
3	S3	Sieve 4 heater status (0 = disabled, 1 = enabled)
4	S4	Detector Nest 1 heater status (0 = disabled, 1 = enabled)
5	S5	Detector Nest 2 heater status (0 = disabled, 1 = enabled)
6	S6	Diode Bank 1 status (0 = off, 1 = on)

Bits	Name	Description
7	S7	Diode Bank 2 status (0 = off, 1 = on)
8	S8	Fuse Status, Sieve 1 Heater (0 = disabled, 1 = enabled)
9	S9	Fuse Status, Sieve 2 Heater (0 = disabled, 1 = enabled)
10	S10	Fuse Status, Sieve 3 Heater (0 = disabled, 1 = enabled)
11	S11	Fuse Status, Sieve 4 Heater (0 = disabled, 1 = enabled)
12	S12	Fuse Status, Detector Nest 1 Heater (0 = disabled, 1 = enabled)
13	S13	Fuse Status, Detector Nest 2 Heater (0 = disabled, 1 = enabled)

NOTE: The heater status (disabled/enabled) indicates the actual enable state of the heater, taking into account the fuse and enable settings, but not the heater set point value. To determine heater on/off status, the heater voltage must be queried.

Telemetry Word:

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

Interface Test Return Word:

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

7.10.3 TCMM Operation

7.10.3.1 Heaters

Heater settings are table driven and initialized on transition to Standby Mode.

Heaters are disabled and set to zero setting on transition to Safe Mode or in event of over temperature detected. Calibration source heaters have no enable/disable command so they are only set to zero.

Heater power up state is disabled and set to zero with fuses enabled.

A hardware timeout of 4-6 min. disables heaters and sets them to zero setting. Any TCMM command will reset the timer to zero.

7.10.3.2 *Sieve Heaters*

Coarse Set is baselined for operation, Fine Set is for contingency if needed to correct small orbital variations.

Fuse trip disables the heater and is indicated in the status.

Heater setting is cleared to zero and held at zero whenever the heater is disabled.

7.10.3.3 *Nest Heaters*

Coarse Set only.

Fuse trip disables the heater and is indicated in the status.

Heater setting is cleared to zero and held at zero whenever the heater is disabled.

7.10.3.4 *Cal. Heaters*

Coarse Set only.

No enable/disable or fuse.

In order to reduce peak power requirements, there may be operational limits on number of heaters on versus the heater settings.

7.10.3.5 *Readouts in General*

Two read commands must be issued consecutively with a minimum 2ms. between each. The first read selects the sensor, the second takes an accurate reading after the mux and following circuitry has settled.

The mux setting is only affected by the Read command so other commands (such as heater control, interface test, etc) may occur between the two consecutive read commands.

7.10.3.6 *Heater Voltage Readout*

Ref Hi = 14V rail

Rel Lo = 0V

7.10.3.7 Diode Readout

The baseline for Diode Bias On/Off is that it be left On at all times. Power up condition is Off.

There are separate references for each of the 2 banks of sensors. There will be individual calibration curves for each diode sensor.

7.10.3.8 Thermistor Readout

There are separate references for each of the 4 banks of sensors. Most sensors are 30 kOhm thermistors. Pressure sensor thermistors are 2500 Ohm nominal.

A generic conversion curve will be used for the 30 kOhm thermistors. Pressure sensor thermistors will be individually calibrated.

7.10.3.9 PRT Readout

There are individual references for each sensor and they are read out for each of Coarse and Fine readouts.

Individual calibrated for Coarse/Fine readout, prime/redundant readout and under ambient and hot TCMM temperature.

7.10.3.10 Pressure Readout

There are individual references for each sensor.

Individual calibrated for prime/redundant readout and under ambient and hot TCMM temperature.

7.11 Cooler Command and Telemetry

Cooler command and telemetry is contained in the document, Telemetry Interface Design, ICD/MOP/113362/001/LMS.

7.11.1 Cooler Operation

Cooler commands are listed below with specific information for the MOPITT instrument.

mode <n>

0 = Off, 1 = On Temp Ctrl, 2 = On Fixed Stroke

Power on default is mode 0, coolers disabled.

ICM will NOT turn on coolers automatically when transitioning from Safe to Standby. Coolers will be commanded on by specific C&T command.

Ground system software will check Cooler parameters: dgain, dshif, wmin, and wmax prior to commanding coolers on.

ICM will turn off cooler when transitioning from Science or Standby to Safe.

ICM will initialize coolers upon the Boot to Safe mode transition. The normal initialization string will turn off the coolers. If a problem such as SEUs cause frequent re-boots, the initialization string could be changed to leave the coolers on.

The cooler initialization is done on the transition from Boot to Safe. In the event of a re-boot, the coolers will remain in their previous operating mode until that initialization is done. The Boot to Safe occurs automatically for a watchdog (SEU).

Temperature control mode will maintain the fixed initial delta between cooler A and cooler B strokes. If stroke limits are reached, the strokes are maintained at the stroke limits.

On cool down, the temperature control integrator does saturate, causing the stroke delta to be zero once the strokes come below the stroke limits and temperature regulation begins.

Operation in fixed stroke mode for approximately 5 minutes, followed by switching back to temp control mode will reset the integrator and re-establish a stroke delta.

As a result, optimal cool down sequence is to cool under fixed stroke (at stroke limit), then once slightly below target temperature, switch to temp control mode.

vcm <n>

0 = No-DECS, 1 = P-DECS, 2 = A-DECS

Power on default parameters are configured for A-DECS and vcm 2. Note that prior to issuing a "mode" command, a "vcm 0" command should be issued.

Since we are operating in P-DECS, parameters are reloaded as part of the initialization string.

Some sort of bias drift was observed when the CDE was left in its power on state for several minutes (see NCR/MOP/5127/308). As a result, a vcm 0 mode 0 is sent as part of the ICM boot process to avoid this problem.

Operation of P-DECS with A-DECS parameters is stable but does not provide proper performance. Operation of A-DECS with P-DECS parameters is unstable and may damage the coolers.

When operating in A-DECS, the A-DECS algorithm operates on Compressor B and Displacer B, and the P-DECS algorithm operates on Compressor A and Displacer A.

It has been found that the A-DECS configuration is not fully stable in the instrument structure. It is possible that this could be rectified by reducing the decs gain of compressor B with command dgain 3 2, but close monitoring of coolers is required.

temf <n>

Sets cold tip target temperature. Range is 42.9 K to 88.7 K, based on MOPITT diode curves, for <n> of 0 thru 4096.

Power on default is <n> = 3278, which is a diode voltage of 0.9797 V, which is 79.5 K.

Our normal operating point is 84.4 K (cold tip 1) which is a diode voltage of 0.9689 V which is <n> = 3639

The maximum setting of "temf 4096" gives a voltage of 0.9552 V which is 88.7 K.

setP <n>, setI <n>, setD <n>, ilim <n>

These are the temperature control loop PID parameters.

Power on defaults should not be changed and are: setP 32767, setI 1024, setD 512, ilim 3000

bias <a><c>, amp <a><c>

Stroke Parameters. The "bias" settings affect all modes and should always be zero. The "amp" settings are used in fixed stroke operation (mode 2). The amplitude delta between cooler A and cooler B is maintained while under temperature control (mode 1).

The amplitude of the waveform driving the coolers is ramped up or down slowly (approx 20 seconds) upon mode change.

The amp parameters are updated by temp control mode, but not by DECS operation. Therefore they must be re-initialized if running fixed stroke after temperature control mode.

The power on defaults of these parameters allow the coolers to be operated fixed stroke without any parameter changes. They correspond to 96 K cold tip at 780 mW performance with reasonable PDECS vibration cancellation.

The power on default strokes (zero to peak) are:

CompA 5.322 mm, DispA 2.695 mm, CompB 5.615 mm, DispB 2.998 mm

Power on defaults are: bias 0 0, bias 0 1, bias 0 2, bias 0 3,

amp 545 0, amp 276 1, amp 575 2, amp 307 3

wmin <a><c>, wmax <a><c>

This command sets the stroke limits. Each value is the zero to peak excursion.

Power on default will limit system power to about 90 W, which is 30 W on CompA and 24 W on CompB. Peak current under this operation is 6.5 A. Performance is limited to about 80 K cold tip at 780 mW load.

During normal operation, the stroke limits will be decreased on compressor A in order to balance cooling capacity and vibration during cool down. See initialization string.

It is intended that wmin and wmax never be increased beyond their power on defaults.

The power on default stroke limits are:

CompA +/-7.227 mm, DispA +/-2.998 mm, CompB +/-7.227 mm, DispB +/-2.998 mm

Power up defaults are: wmin -740 0, wmin -307 1, wmin -740 2, wmin -307 3,

wmax 741 0, wmax 308 1, wmax 741 2, wmax 308 3

phase <a><c>

Sets phase offsets for each motor.

The CDE requires up to 3 seconds to process each command. Other commands issued after the carriage return will be rejected while it is processing. Commands following phase <a><c> in the same string (prior to carriage return) will be processed.

The phase settings are for 56.0 degrees between each compressor and displacer, providing optimal cooling efficiency. These settings should not be changed.

Power up defaults are: phase 0 0, phase 4003 1, phase 0 2, phase 4003 3.

tsrc <n>

Control temp diode select. Dewar 2 is <n>=2, Dewar 1 is <n> = 0.

Power on default is Dewar 2.

Dewar 1 will normally be control since that dewar runs warmer than dewar 2.

spc <n>

Set cooler drive frequency.

The CDE requires up to 3 seconds to process this command. Other commands issued after the carriage return will be rejected while it is processing. Commands following spc <n> in the same string (prior to carriage return) will be processed.

This would only be adjusted if a resonance interaction problem occurred.

Power on default is 43.96 Hz which is: spc 241

dgain <g><c>, dshif <s><c>, dbisc1 <n>

These are the DECS parameters.

Power on defaults are configured for A-DECS. Parameters must be updated before operating in P-DECS.

Operation of P-DECS with A-DECS parameters is stable but does not provide proper performance. Operation of A-DECS with P-DECS parameters is unstable and may damage the coolers.

A-DECS parameters are: dbisc1 7642, dgain 1 0, dgain 1 1, dgain 2 2, dgain 5 3,
dshif 27 0, dshif 30 1, dshif 26 2, dshif 26 3

P-DECS parameters are: dbisc1 7642, dgain 0 0, dgain 0 1, dgain 0 2, dgain 0 3,
dshif 30 0, dshif 27 1, dshif 30 2, dshif 27 3

Note that A-DECS operation has been shown to be somewhat unstable when operating within the instrument structure.

The best option for improving A-DECS stability would be change to "dgain 3 2" but this would also reduce the already limited effectiveness of the vibration cancellation.

mon

This command invokes the test monitor, which stops the watchdog from being kicked, which causes a CPU Reset with 3 seconds. This could be used as a Reset command.

Prior to the Reset occurring, the monitor would accept monitor commands but these are all upper case so normal operating commands would not be accepted.

camp

This command retrieves amplitude settings. Note that amplitude settings are updated by the CDE when in temperature control mode.

This command is not required since the same data is available in the 'show' command.

The CDE will not accept new command strings until the telemetry has been sent.

atem

This command retrieves the temperature reading from the sensor diode selected by the tsr command.

While in temperature control mode, the returned temperature is processed as a 200 point average with electronics temperature compensation performed (also based on a 200 point average). In other modes, the value returned is uncompensated and unaveraged.

The raw unprocessed data is also available in the 'report' command.

The CDE will not accept new command strings until the telemetry has been sent.

show

This command retrieves all parameter and mode settings.

The CDE will not accept new command strings until the telemetry has been sent.

report

This command retrieves all measured telemetry values.

The CDE will not accept new command strings until the telemetry has been sent.

General

Verify key parameter settings (dgain, dshif, wmin, wmax) from the 'show' command prior to enabling the coolers (mode 1 or mode 2). These are included in C&T telemetry.

Parameter defaults are initialized at power up and not re-initialized unless power is cycled or CDE reset with "mon" command.

Each command string is verified by parity bits, and by command echo.

Cooler commands are case sensitive.

Invalid command strings are ignored.

Cooler strings are limited to 512 characters by the CDE, and to 256 characters by the ICM.

Parameters and optional settings listed here were determined by Lockheed Martin MSATC. Parameter adjustments not detailed here should not be made without their consultation.

Engineering unit calibrations should be sufficiently similar to HTSSE that those number can be used. There has been no change in the form of the equations (see Telemetry Interface Document).

Cooler A is Dewar 2, Cooler B is Dewar 1.

Accelerometer and motor current telemetry should be monitored by ground software and the coolers shut down if increased levels are observed since this may indicate a drive instability has developed.

Command Strings for A-DECS, Temp Control Operation (not in Software).

String 0 is Initialization, String 1 is Turn On, String 2 is Turn Off

- 0) vcm 0 mode 0 ttemf 3639 tsrc 0 wmin -716 0 wmin -740 2 wmax 717 0 wmax 741 2
dgain 1 0 dgain 1 1 dgain 2 2 dgain 5 3 dshif 27 0 dshif 30 1 dshif 26 2 dshif 26 3
- 1) mode 1 vcm 2
- 2) vcm 0 mode 0

Command Strings for A-DECS, Fixed Stroke Operation (not in Software).

String 0 is Initialization, String 1 is Turn On, String 2 is Turn Off

- 0) vcm 0 mode 0 wmin -716 0 wmin -740 2 wmax 717 0 wmax 741 2 amp 698 0 amp
722 2 dgain 1 0 dgain 1 1 dgain 2 2 dgain 5 3 dshif 27 0 dshif 30 1 dshif 26 2 dshif
26 3
- 1) mode 2 vcm 2
- 2) vcm 0 mode 0

Command Strings for P-DECS, Temp Control and Fixed Stroke Operation (Software Table).

String 0 is Initialization, String 1 is Turn On Temp Ctrl, String 2 is Turn Off, String 3 is Turn On Fixed Stroke Nominal, String 4 is Turn On Fixed Stroke Limit.

- 0) vcm 0 mode 0 tsrc 0 ttemf 3639 wmin -718 0 wmin -740 2 wmax 719 0 wmax 741 2
dgain 0 0 dgain 0 1 dgain 0 2 dgain 0 3 dshif 30 0 dshif 27 1 dshif 30 2 dshif 27 3
amp 698 0 amp 722 2
- 1) mode 1 vcm 1
- 2) vcm 0 mode 0
- 3) amp 698 0 amp 722 2 mode 2 vcm 1
- 4) amp 716 0 amp 740 2 mode 2 vcm 1

7.12 Serial Diagnostic Interface Telemetry

Obsoleted.

8. TRACEABILITY TO PARENT'S DESIGN

Table 8-1 shows the traceability of the requirements in the parent documents to the corresponding section in this document.

Table 8—1: Traceability Matrix

<u>PARENT DOC.</u>	<u>THIS DOCUMENT SECTION AND TITLE</u>
GIIS 6.1.2.4.1	4.2.6 SYNC_WITH_DATA - Synchronize with Data Word
GIIS 6.1.2.4.1.1	4.2.6 SYNC_WITH_DATA - Synchronize with Data Word
GIIS 6.1.2.4.1.2	4.2.6 SYNC_WITH_DATA - Synchronize with Data Word
GIIS 6.1.2.4.1.3	4.2.6 SYNC_WITH_DATA - Synchronize with Data Word
GIIS 6.1.2.4.1.4	4.2.6 SYNC_WITH_DATA - Synchronize with Data Word
GIIS 6.1.2.4.1.6	5.1.1 Instrument Telemetry Requirements
GIIS 6.1.2.4.6.1	4.3.4 ANCILLARY_DATA - Ancillary Data
GIIS 6.1.2.4.6.1	4.3.5 IMOK - SCC "I'm OK" Indication
GIIS 6.1.2.4.6.1	4.3.6 TIME_CODE - Time Code Data
GIIS 6.1.2.4.6.1	4.3.7 SET_SAFE_MODE - Spacecraft Safe Mode Command
GIIS 6.1.3.1.1	4.1.4 Command Requirements
GIIS 6.1.3.1.2	4.1.5 Command Requirements
GIIS 6.1.3.1.3	4.3.7 SET_SAFE_MODE - Spacecraft Safe Mode Command
GIIS 6.1.3.1.4	4.3.5 IMOK - SCC "I'm OK" Indication
GIIS 6.1.3.3	4.3.2 LOAD_DATA - Memory Load Data
GIIS 6.1.3.4	4.3.3 DUMP_DATA - Memory Dump Data
GIIS 6.1.3.5.1	4.3.4 ANCILLARY_DATA - Ancillary Data
GIIS 6.1.3.5.2	4.3.4 ANCILLARY_DATA - Ancillary Data
GIIS 6.1.3.6.1	4.3.6 TIME_CODE - Time Code Data
GIIS 6.1.3.6.2	4.3.6 TIME_CODE - Time Code Data
GIIS 6.1.3.6.3	4.3.6 TIME_CODE - Time Code Data
GIIS 6.2.1	4.3.6 TIME_CODE - Time Code Data
GIIS 6.2.2	4.3.6 TIME_CODE - Time Code Data
GIIS 6.3.5.4	4.2.11 TRANS_VECTOR - Transmit Vector Word
GIIS 7.1.3.1.2	5.4 LRS Bus CCSDS Format
GIIS 7.1.4.1.1	5.8.1 LRS Bus Test Packet
GIIS 7.1.4.1.2	5.8.2 LRS Bus Test Packet
GIIS 7.1.4.1.3	5.8.3 LRS Bus Test Packet
GIIS 7.1.4.3.1	5.8.4 LRS Bus Test Packet
GIIS 7.1.4.3.2	5.8.5 LRS Bus Test Packet
GIIS 7.1.5	5.8.6 LRS Bus Test Packet
GIIS 7.2.2.2	4.6.1 Stored Commands
GIIS 7.2.2.2.2.1	4.6.3 Stored Commands
GIIS 7.2.2.2.2.2	4.6.4 Stored Commands
GIIS 7.2.2.2.2.3	4.6.4 Stored Commands
GIIS 7.2.2.2.2.4	4.6.4 Stored Commands
GIIS 7.2.2.3	4.7 Telemetry Monitor
GIIS 7.2.2.3.2	4.7 Telemetry Monitor
GIIS 7.2.2.3.4	4.4.17 SELECT_SURVIVAL - Enter Survival Mode
GIIS 7.2.2.3.4	4.6.6 SC_SURVIVAL_MODE

GIIS	7.2.4.1	4.1.1	Command Requirements
GIIS	7.2.5	4.1.2	Command Requirements
GIIS	7.2.5	4.1.3	Command Requirements
GIIS	7.2.5	4.1.6.1.1	Multifunction Commands
GIIS	7.2.5.1	4.1.2	Command Requirements
GIIS	7.2.5.2	4.1.3	Command Requirements
GIIS	7.2.5.3	4.1.6.1.1	Multifunction Commands
GIIS	7.3.2.3.2	5.1.3	Instrument Telemetry Requirements
GIIS	7.3.2.3.3	5.1.4	Instrument Telemetry Requirements
GIIS	7.3.3.3	5.2	Critical Health and Safety Telemetry Format
GIIS	7.3.3.3	5.3	Housekeeping Telemetry Format
GIIS	7.3.3.4	5.9	Telemetry Sampling Rates
GIIS	7.3.3.5	5.3	Housekeeping Telemetry Format
GIIS	7.3.3.6	4.7.2	Telemetry Monitor
GIIS	7.3.3.7	5.10	MIL
GIIS	7.3.4.7	5.1.2	Instrument Telemetry Requirements
GIIS	7.3.4.8	5.1.2	Instrument Telemetry Requirements
GIIS	7.5.1.2	4.1.6	Command Requirements
GIIS	7.5.2.3	4.3.7	SET_SAFE_MODE - Spacecraft Safe Mode Command
GIIS	7.5.2.3	4.4.14	SELECT_SAFE - Enter Safe Mode
GIIS	7.5.2.3	4.4.17	SELECT_SURVIVAL - Enter Survival Mode
ICS	4.1.15.1	4	MOPITT INSTRUMENT COMMANDS
ICS	4.1.15.2.2	4.2.1	INHIBIT_TFB - Inhibit Terminal Flag Bit
ICS	4.1.15.2.2	4.2.10	TRANS_STATUS - Transmit Status Word
ICS	4.1.15.2.2	4.2.11	TRANS_VECTOR - Transmit Vector Word
ICS	4.1.15.2.2	4.2.2	INIT_SELF_TEST - Initiate Remote Terminal Controller BIT Routine
ICS	4.1.15.2.2	4.2.3	OVERRIDE_TRANS - Override Transmitter Shutdown
ICS	4.1.15.2.2	4.2.4	RESET_RT - Reset Remote Terminal
ICS	4.1.15.2.2	4.2.5	SYNC_WITHOUT_DATA - Synchronize Without Data Word
ICS	4.1.15.2.2	4.2.6	SYNC_WITH_DATA - Synchronize with Data Word
ICS	4.1.15.2.2	4.2.7	TRANS_BIT - Transmit BIT Word
ICS	4.1.15.2.2	4.2.8	TRANS_LAST - Transmit Last Command
ICS	4.1.15.2.2	4.2.9	TRANS_SHUTDOWN - Transmitter Shutdown
ICS	4.1.18.1	4.3	Spacecraft Commands
ICS	4.1.18.1	4.3.1	Instrument Commands (sub
ICS	4.1.18.1	4.3.10	CRITICAL_TELEM - Critical Health and Safety Telemetry Transfer
ICS	4.1.18.1	4.3.11	SCIENCE_DATA - MOPITT Science Data Telemetry
ICS	4.1.18.1	4.3.2	LOAD_DATA - Memory Load Data
ICS	4.1.18.1	4.3.3	DUMP_DATA - Memory Dump Data
ICS	4.1.18.1	4.3.4	ANCILLARY_DATA - Ancillary Data
ICS	4.1.18.1	4.3.5	IMOK - SCC "I'm OK" Indication
ICS	4.1.18.1	4.3.6	TIME_CODE - Time Code Data
ICS	4.1.18.1	4.3.7	SET_SAFE_MODE - Spacecraft Safe Mode Command
ICS	4.1.18.1	4.3.8	LOOP_BACK - MIL
ICS	4.1.18.1	4.3.9	HOUSE_TELEM - Housekeeping Telemetry
ICS	4.1.18.2	4.3	Spacecraft Commands
ICS	4.1.18.3	4.3	Spacecraft Commands
ICS	4.1.19.1	4.5.15	MLOAD_INITIATE WITH
ICS	4.1.19.1	4.5.7	DUMP_INITIATE WITH
ICS	4.1.19.2	4.3.2	LOAD_DATA - Memory Load Data

ICS	4.1.19.2	4.3.3	DUMP_DATA - Memory Dump Data
ICS	4.1.19.3	4.5.15	MLOAD_INITIATE WITH
ICS	4.1.19.3	4.5.7	DUMP_INITIATE WITH
ICS	4.1.19.4	4.5.19	RESET_DUMP - Abort Memory Dump Operation
ICS	4.1.19.4	4.5.20	RESET_LOAD - Abort Memory Load Operation
ICS	4.1.19.6	4.5.16	PASS_COMMAND WITH
ICS	4.1.19.6	4.5.17	PASS_DATA WITH
ICS	4.1.19.7	4.5.14	GET_DATA WITH
ICS	4.1.19.8	4.5.12	ENABLE_MAINCMDS
ICS	4.1.20.2	4.5.7	DUMP_INITIATE WITH
ICS	4.1.22.1	4.5.27	TURN_ON_SCI_DAT WITH
ICS	4.1.22.1	5.8.5	LRS Bus Test Packet
ICS	4.1.7.10	4.5.25	TURN_OFF_SCI_DAT WITH
ICS	4.1.7.10	4.5.27	TURN_ON_SCI_DAT WITH
ICS	4.1.7.3	4.2.11	TRANS_VECTOR - Transmit Vector Word
ICS	4.1.7.4	5.4	LRS Bus CCSDS Format
ICS	4.2.2	4.5.23	SET_FREQ TO
ICS	4.4.10.2	4.4.20	SET_HEATER WITH
ICS	4.4.2.2	4.4.19	SET_DEVICE WITH
ICS	4.4.2.3	4.4.10	PERFORM_DEV_INIT
ICS	4.4.2.4	6.1.18	TN_COOLER_REPORT
ICS	4.4.2.4	6.1.19	TN_COOLER_SHOW
ICS	4.4.2.4	6.1.20	TN_COOLER_ATEM
ICS	4.4.2.4	6.1.21	TN_COOLER_CAMP
ICS	4.4.3.2	4.4.19	SET_DEVICE WITH
ICS	4.4.3.3	4.4.20	SET_HEATER WITH
ICS	4.4.3.7	5.9	Telemetry Sampling Rates
ICS	4.4.4.10	5.5	Science Data Format
ICS	4.4.4.3	4.4.10	PERFORM_DEV_INIT
ICS	4.4.4.4	4.4.19	SET_DEVICE WITH
ICS	4.4.4.4	4.5.1	DISABLE_DETECTOR WITH
ICS	4.4.4.4	4.5.8	ENABLE_DETECTOR WITH
ICS	4.4.4.5	5.5	Science Data Format
ICS	4.4.4.6	5.5	Science Data Format
ICS	4.4.4.7	5.5	Science Data Format
ICS	4.4.5.3	4.4.19	SET_DEVICE WITH
ICS	4.4.5.4	4.4.10	PERFORM_DEV_INIT
ICS	4.4.5.4	4.5.21	SELECT_PMC_FREQ WITH
ICS	4.4.6.3	4.4.19	SET_DEVICE WITH
ICS	4.4.6.4	4.4.13	SELECT_LAUNCH - Enter Launch Mode
ICS	4.4.7.3	4.4.19	SET_DEVICE WITH
ICS	4.4.7.4	4.4.13	SELECT_LAUNCH - Enter Launch Mode
ICS	4.4.8.3	4.4.5	MOVE_MIRROR WITH
ICS	4.4.8.4	4.4.19	SET_DEVICE WITH
ICS	4.4.9.2	4.4.1	CLOSE_COVER_1 - Close the Earth View Port Cover
ICS	4.4.9.2	4.4.8	OPEN_LATCH_1 - Unlatch the Earth View Port Cover
ICS	4.4.9.2	4.4.9	OPEN_LATCH_2 - Unlatch the Space View Port Cover
ICS	4.4.9.3	4.4.2	CLOSE_COVER_2 - Close the Space View Port Cover
ICS	4.4.9.3	4.4.6	OPEN_COVER_1 - Open the Earth View Port Cover
ICS	4.4.9.3	4.4.7	OPEN_COVER_2 - Open the Space View Port Cover

ICS	5.1.1.1	5.2	Critical Health and Safety Telemetry Format
ICS	5.1.1.1	5.3	Housekeeping Telemetry Format
ICS	5.1.1.1	5.5	Science Data Format
ICS	5.1.1.1	5.7	Engineering Data Format
ICS	5.1.11.10.3.2	4.4.15	SELECT_SCIENCE - Enter Science Mode
ICS	5.1.11.5.2.2	4.4.13	SELECT_LAUNCH - Enter Launch Mode
ICS	5.1.11.6.3.3	4.4.17	SELECT_SURVIVAL - Enter Survival Mode
ICS	5.1.11.8.3.5	4.5.13	ENABLE_SAFE - Enable Safe Mode Timeout
ICS	5.1.11.8.3.5	4.5.6	DISABLE_SAFE - Disable Safe Mode Timeout
ICS	5.1.11.9.3.2	4.4.16	SELECT_STANDBY - Enter Standby Mode
ICS	5.1.13.2	4.4.10	PERFORM_DEV_INIT
ICS	5.1.14.2.6	4.4.19	SET_DEVICE WITH
ICS	5.1.16.6	4.5.18	PASS_MSL WITH
ICS	5.1.17.1	4.4.22	TURN_ON_BURST WITH
ICS	5.1.2.2	5.3	Housekeeping Telemetry Format
ICS	5.1.2.3	5.9	Telemetry Sampling Rates
ICS	5.1.2.4	5.3	Housekeeping Telemetry Format
ICS	5.1.2.4	5.4	LRS Bus CCSDS Format
ICS	5.1.3.1	5.10	MIL
ICS	5.1.3.2	4.5.22	SELECT_TABLE WITH
ICS	5.1.6.1	5.2	Critical Health and Safety Telemetry Format
ICS	5.1.6.3	5.2	Critical Health and Safety Telemetry Format
ICS	5.1.7.1	5.3	Housekeeping Telemetry Format
ICS	5.1.7.2	5.3	Housekeeping Telemetry Format
ICS	5.1.8.2	5.7	Engineering Data Format
ICS	5.1.9.2	5.5	Science Data Format
ICS	5.3.1	4.4.3	DISABLE_COVERS - Disable the Port Covers from Operation
ICS	5.3.1	4.4.4	ENABLE_COVERS - Enable the Port Covers for Operation
ICS	5.3.5	4.5.12	ENABLE_MAINCMDS
ICS	5.3.5	4.5.2	DISABLE_EE_BURN - Disable EEPROM Program Commands
ICS	5.3.5	4.5.24	TURN_OFF_EE_BURN - Abort EEPROM Program Procedure
ICS	5.3.5	4.5.4	DISABLE_MAINCMDS
ICS	5.3.5	4.5.9	ENABLE_EE_BURN - Enable EEPROM Program Commands
ICS	5.5.14.4.3	4.5.10	ENABLE_FDIR - Enable Instrument FDIR
ICS	5.5.14.4.3	4.5.3	DISABLE_FDIR - Disable Instrument FDIR
ICS	5.5.17.1	4.5.26	TURN_ON_EE_BURN WITH
ICS	5.5.5.4	5.3	Housekeeping Telemetry Format
MIS	Table 3.1.1-2	5.6.2	Signal Processing Data Stream

9. ABBREVIATIONS AND ACRONYMS

The following abbreviations and acronyms have been employed in this document.

AIT	Assembly, Integration and Test
ANSI	American National Standards Institute
BC	1553B Bus Controller (Spacecraft Control Computer)
BDU	Bus Data Unit
BIT	Built-in Test
C&T	Command and Telemetry
CDE	Cooler Drive Electronics
CDR	Critical Design Review
COTS	Commercial off the shelf
CPU	Central Processing Unit
CRC	Cyclic Redundancy Check
CSA	Canadian Space Agency
CTIU	Command and Telemetry Interface Unit
DC	Direct Current
EOS	Earth Observing System
FDIR	Failure Detection, Isolation and Recovery
GIIS	EOS General Instrument Interface Specification
GSE	Ground Station Equipment
H/K	Housekeeping
H&S	Critical Health and Safety
Hz	Hertz
ICM	Instrument Controller Module
IV&V	Independent Verification and Validation
LMC	Length Modulated Cell
MIL-STD	Military Standard
MOPITT	Measurement Of Pollution in The Troposphere
N/A	Not applicable
PCDM	Port Cover Driver Module

PLDM	PMC/LMC Driver Module
PMC	Pressure Modulated Cell
PROM	Programmable Read Only Memory
RAM	Random Access Memory
RT	1553B Remote Terminal (MOPITT Instrument)
SCC	Spacecraft Control Computer
SCDM	Scan Mirror/Chopper Driver Module
SEU	Single Event Upset
SFE	Science Formatting Equipment
SPM	Signal Processing Module
T/R	Transmit/Receive
TBA	To Be Approved
TBC	To Be Confirmed
TBD	To Be Determined
TBE	To Be Evaluated
TCMM -	Thermal Control and Monitoring Module

10. GLOSSARY

For terms not appearing in this glossary, refer to the "IEEE Standard Glossary of Software Engineering Terms."

Check Out - Routines that perform specific test to verify the functionality of a system devices and interfaces. The routines are usually executed upon power on as part of the device or interface initialization or as part of the device or interface maintenance functions. They are used to detect device or interface failures. These routines are part of the fault detection, isolation and recovery (FDIR) routines.

Endian - Refers to the ordering of bytes in a word. When the least significant byte of a word is the lowest addressed byte within that word, then this is called "Little Endian" byte order. When the least significant byte of a word is the highest addressed byte within that word, then this is called "Big Endian" byte order.

Firmware - Hardware that contains a computer program and data that cannot be changed in its user environment. The computer programs and data contained in the firmware are classified as software; the circuitry containing the computer program and data is classified as hardware.

Life Cycle (software) - The period of time that starts when a software product is conceived and ends when the software is no longer available for use. The software life cycle traditionally has eight phases: Concept and Initiation; Requirements; Architectural Design; Detailed Design; Implementation/Coordination; Integration and Tests; Acceptance and Delivery; and Sustaining Engineering and Operations. This example is referred to as the waterfall life cycle.

Self Test - Routines that perform specific test to verify the functionality of a microprocessor, RAM memory, Prom memory or support device. The routines are usually executed upon power on (power on self test - POST). They are used to detect computer system failures with possible adaptation to avoid failures. These routines are part of the fault detection, isolation, and recovery (FDIR) routines.

Single Event Upset Protection - software used to detect and recover from single event upsets. Software can not prevent single event upsets, but it can help protect the instrument from faulty operation once a single event upset is detected.

Software - Programs, procedures, rules, and any associated documentation and data pertaining to the operation of a computer system, including programs and data contained in firmware.

Software, Flight - Software and firmware executing within the instrument when the instrument is in flight (excludes test software that exists and is executed within the instrument only during ground testing). This includes flight self-test software.

Software, GSE - Software used in checkout of the instrument prior to flight; software to command the instrument, software to input and process the instrument telemetry and science data; software to produce simulated data for instrument elements not able to produce data; software to produce sample inputs to the Instrument Flight Software.

Software, Development - Includes software such as editors, compilers, computer-aided software engineering (CASE) tools, operating systems, etc., which is typically COTS.

Software, Engineering Analysis - Produced as part of the requirements and/or design process of an instrument (will not be used in the instrument, the ground support system, or the ground test system). It may be used to generate data to compare instrument test data during development of the instrument. Engineering Analysis Software includes prototypes.

11. NOTES

11.1 Scan Procedure

The typical scan procedure will comprise of a continuous series of 29 stares. Each stare is a 50 ms period of mirror positioning and settling, followed by a 400 ms data collection period, for a total of 450 ms. The mirrors are stepped in a way that results in an interlaced scan.

The scan mirrors are controlled by stepping motors associated with each scan mirror. The scan mirror may be positioned in ± 1.8 (360 degrees/200 steps) degree increments. The zero position is in the Nadir direction, pointing directly to the ground (Spacecraft Z direction). A positive mirror step from Nadir is to the Spacecraft +Y direction, to the right for an observer facing forward with feet pointing to the ground.

A scan swath containing 29 views (29 stares) starts at the Nadir position and contains the following stepping sequence:

<u>Step</u>	<u>Action</u>
1.	position mirror to point to Nadir (directly down)
2.	stare
3.	+2 steps, stare; repeat 7 times (+ = look east, - = look west)
4.	-1 step, stare
5.	-2 steps, stare; repeat 13 times
6.	-1 step, stare
7.	+2 steps, stare; repeat 6 times
8.	repeat from step 1 for next swath

To provide a space reference roughly every two minutes and a calibration source reference roughly every ten minutes the scan swath is repeated 10 times followed by a calibration cycle. The calibration cycle consists of a space view and every fifth time, an additional calibration source view.

The default scan and calibration cycle is:

```

  forever {
    4 loops of {
      10 swaths
      space view (5 stares)
    }
    10 swaths
    space view (5 stares)
    claibration view (20 stares)
  }

```

APPENDIX A

MOPITT INSTRUMENT DATA FORMATS