MATRA MARCONI SPACE

ANCHORAGE ROAD, PORTSMOUTH,
PO3 5PU, ENGLAND

MICROWAVE HUMIDITY SOUNDER (MHS)

TM-TC AND SCIENCE DATA FORMAT DIRECTORY MHS-TN-JA063-MMP

(4)

MHS TM-TC & Science Data Format

RESPONSIBLE ENGINEER						
PRODUCT ASSURANCE						
PROJECT MANAGER						
CUSTOMER						
ISSUE	3	4	5			
SRB/CCB DATE	Jun 99	Jul 99	Jan 2000			
PROJECT MHS		SHEET 1 OF 92 SHEETS		NUMBER 3175-JA063-TNO		

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CHANGE RECORD

CHANGE NUMBER	CLASS	CHANGE DETAILS	ISSUE
3175-00084	-	First Issue	A
3175-00264	II	Major Update following Instrument and Equipment PDRs (including reordering and renumber of sections)	B
3175-00515	II	Update prior to HW/SW Integration	C
3175-00672	II	Features required for Scan Control Tests added (non-incorporated EO)	D
3175-01132	II	Update following EM formal HW/SW Integration Tests (includes C to D non-inc. EO changes)	1
3175-01362	II	TLT values (sheets 63-70) updated iaw fax MHS-MMS-FX-0167-97. Resultant repagination of sheets 63 onwards. Section E4: Clarification of quiet period applicability.	2
3175- 01842	II	Memory addresses provided for Software Tables (Appendices A..D)	3
3175-01871	II	Correction of typographical errors on sheets 61 and 81	4
3175-	***II***	***Correction of ICT5,6 default values (p62)*** ***Correction of TLT86,89,93,95 default values and correction of equivalent engineering values (pp76,77)***	***5***

Changes are shown in ***bold italics*** and side-lined

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1.0 SCOPE

This document describes the contents and format of all the command, telemetry and data transferred between the instrument and the platform.

It also describes all of the MHS Instrument Internal Commands and Internal Telemetry used to control the total instrument.

2.0 DOCUMENTS AND ABBREVIATIONS

2.1 Applicable Documents

AD1	PSS-04-106 Iss 1, Jan 88	ESA Packet Telemetry Standard
AD2	PSS-04-107 Issue 2, Apr 92	ESA Packet Telecommand Standard

2.2 Reference Documents

RD1	MHS-ES-XA001-MMP	MHS Electronics Equipment Hardware Specification (EE Spec)
RD2	MHS-RE-30003-MMP	MHS Instrument On-board Software User Requirements Document (MINOS URD)
RD3	CCSDS 701.0-P-1	Advanced Orbiting Systems, Networks and Data Links
RD4	GSFC-S-480-72 July 1993	Command/Telemetry Bus General Specification
RD5	GSFC-S-480-73 July 1993	Low Rate Data Bus General Specification
RD6	MHS-TN-JA137-MMP	MHS Housekeeping Telemetry Conversion to Engineering Units

2.3 Abbreviations and Acronyms

AD	Applicable Document
ADC	Analogue to Digital Converter
AMSU	Advanced Microwave Sounding Unit
CCSDS	Consultative Committee on Space Data Systems
CPU	Central Processing Unit
EDAC	Error Detection and Correction
EE	Electronics Equipment
EEPROM	Electrically Erasable PROM
ESA	European Space Agency
EUMETSAT	European Meteorological Satellite Consortium
FDM	Flywheel Drive Mechanism
HK	Housekeeping
HOOD	Hierarchical Object Oriented Design
METOP	Polar Orbiting Meteorological Satellite Series
MHS	Microwave Humidity Sounder
MINOS	MHS Instrument On-board Software
MMS	Matra Marconi Space
MMU	Memory Management Unit
NOAA	National Oceanic and Atmospheric Administration
OBCT	On-board Calibration Target
PIE	Processor and Interface Electronics
PROM	Programmable Read Only Memory
PSE	Power Supply Electronics
PSS	Procedures, Specifications and Standards
QA	Quality Assurance
RAM	Random Access Memory
RD	Reference Document
RDM	Reflector Drive Mechanism
RF	Radio Frequency
RIN	Requirement Identification Number
SCE	Scan Control Electronics
SDA	Scan Drive Amplifier
SDE	Software Development Environment
SLC	Software Life Cycle
SPE	Signal Processing Electronics
SRD	System Requirements Document
SW	Software
TBA	To Be Agreed
TBC	To Be Confirmed
TBD	To Be Defined
TC	Telecommand
TM	Telemetry
UR/R	User Requirements Review
URD	User Requirements Document

2.4 Data notations and numeric data significance

THROUGHOUT THIS DOCUMENT BIT 0 IS ALWAYS THE MSB OF THE DATA ENTITY. IN GENERAL, THE HIGHER THE BIT NUMBER, THE LOWER THE BIT SIGNIFICANCE.

MSB							LSB
bit 0	bit 1	bit 2	bit 3	bit 4	bit 5	bit6	bit 7

The same convention applies to other data entities, eg. octets, bytes, words, blocks (ie. octet 0 is the most significant, if octets 0..n represent a single data entity).

The most significant bit (or data entity) is transferred first on the communication medium.

These conventions are used to be consistent with ESA and CCSDS standards.

3.0 INTRODUCTION

3.1 External Instrument Interfaces

The MHS Instrument has two MIL-STD-1553B interfaces with the platform, used as follows:-

- Command/Telemetry Bus
- Science Data Bus

The Command/Telemetry Bus is used for general instrument command and control, and for essential health monitoring telemetry. The bus functions as a remote terminal and will return packets only in response to a request (one for each packet). The following packets are transferred on this bus:-

- Command Packets (Platform -> MHS Instrument)
- Housekeeping Telemetry Packet (MHS Instrument -> Platform)
- Test Data Packet (MHS Instrument -> Platform)
- Memory Dump Packet (MHS Instrument -> Platform)

The contents and format of these packets are described in Section 4.2.

The Science Data Bus is used primarily to return the radiometer scene data during Scan Mode and Fixed View Mode to the platform. The bus is also used to return diagnostic data incorporated in the data packets. The bus functions as a remote terminal and will return packets only in response to a request (one for each packet). The following packets are transferred on this bus:-

- Command Packets (Platform -> MHS Instrument)
- Science Data Packet (MHS Instrument -> Platform)
- Extended Test Data Packet (MHS Instrument -> Platform)
- Extended Memory Dump Packet (MHS Instrument -> Platform)

The contents and format of these packets are described in Section 4.3.

All packets follow a common CCSDS format, which requires certain specified headers and common fields. These common aspects of all the packets listed above are described in Section 4.1, and sections 4.2 and 4.3 will afterwards describe the features particular to the individual busses.

3.2 Internal Interfaces

The internal interfaces connect the Electronics Equipment to the other internal MHS equipments and to other peripheral equipments included as part of the Electronics Equipment. The MHS Instrument has the following internal telemetry monitoring types:-

- Thermistor Telemetry
- High Precision Temperature Telemetry (PRTs)
- Analogue Telemetry (voltage and current monitoring)
- Switch Status Telemetry (relay status)
- Bi-level telemetry

Section 5.0 gives a complete list of individual inputs for each of these telemetry interface types. The list also gives the channel number required to access the separate telemetry values. This channel number will be included as a parameter by one of the Command/Telemetry Bus Command Packets that reads telemetry values.

The MHS Instrument has the following internal telecommand interfaces:-

- High Level Commands (latching relay control)
- Steady State Commands

Section 6.0 gives a complete list of individual outputs for each of these command interface types and a cross-reference to the internal telemetry list for the telemetry input used for command verification. The list also gives the channel number required to drive the separate command values. This channel number will be included as a parameter by one of the Command/Telemetry Bus Command Packets that outputs telecommands.

4.0 PLATFORM INTERFACE PACKETS

4.1 Packet Formats

All packets transmitted over either of the platform interfaces must conform to the CCSDS format specified in the CCSDS standard (RD3) and identified separately for each of the MHS Instrument 1553B busses in the Command/Telemetry Bus General Specification and the Low Rate Data Bus General Specification, RD4 and RD5 respectively. Some of the requirements of these documents are summarised in Appendix E, in addition to some specific points for the MHS application.

All requirements of this section are applicable to all message types described in sections 4.2 and 4.3 of this document. The overall structure of a CCSDS message is as shown in figure 4.1-1.

Primary Header Field	Source Data Field	Packet Error Control
3 words 6 octets	variable	1 word 2 octets

Figure 4.1-1 CCSDS Packet Format

The application message level protocol is contained in the Source Data Field. This is specific to the application and the bus involved, and will be expanded upon in sections 4.2 and 4.3 of this document. Although this field is variable in length, the overall packet length is entered into one of the fields of the fixed length Primary Header Field (see the following section).

- The Primary Header Field is described in section 4.1.1.
- The Source Data Field is described in section 4.1.2.
- The Packet Error Control Field is described in section 4.1.3.

4.1.1 Primary Header Field

All Primary Header Fields for all of the MHS message set will conform to the general format as shown in Figure 4.1.1-1.

Subfield Name	Size (Octets)
Packet ID Field	2
Packet Sequence Control	2
Packet Length Field	2

Figure 4.1.1-1 Primary Header Format

4.1.1.1 Packet ID Field

The Packet ID Field will follow the format shown in figure 4.1.1.1-1.

Bit Position	Subfield Name	Set to	Code
0..2	Version	'Version 1'	000
3	Type	'TM' or 'TC'	0 = TM packets 1 = TC packets
4	Secondary Header Flag	'Header present'	1
5..15	Application process ID	'MHS'	022 hex for all models

Figure 4.1.1.1-1 Packet ID Field Format

The Version, the Secondary Header Flag and the Application Process ID will be constant for all MHS packet types. The type will obviously change between received telecommands and generated telemetry.

4.1.1.2 Packet Sequence Control Field

The Packet Sequence Control Field will follow the format shown in figure 4.1.1-2.

Bit Position	Subfield name	Set to	Code
0..1	Segment Flags	'Stand-alone'	11
2..15	Source Sequence Count	incremented for each packet	modulo-n count

Figure 4.1.1.2-1 Packet Sequence Control Format

The segment flags are used to show the relation of the current packet to other packets. Segmented Telemetry packets are forbidden in the system. Telecommand segmentation is permitted, but none of the proposed telecommand types will fit into this category. This code will therefore remain constant for all MHS packets.

Source Sequence Count is a method of counting the number of packets generated on the bus by the application. The significant parameter is a sequential count of the Packet Sequence Control Fields. This field will start with a value of 16#0000# and increment to 16#3FFF#. At this point it will roll-over and continue again from 16#0000#. The counts for the Command and Telemetry Bus and for the Science Data Bus will be independent. The count will re-start from 0 after power-on. Note that the count is a count of packets transferred on the bus, and not packets generated. For example, the same telemetry packet may be collected twice by the platform, and the time code and data content of the two packets will be identical, but the sequence count will not.

At power-on initialisation, an 'initialisation packet' is generated on the Command/Telemetry Bus. This packet will always have a zero packet sequence count, irrespective of the number of times it is transferred, until the MINOS is fully initialised.

Two source sequence counts will be maintained on each bus: one for command packets, the second for telemetry packets. A 'missing' count on an command packet does not necessarily constitute an error condition, as the command could be declared invalid by the hardware, and might never appear at the software level. The error handling procedures of the platform are not to constrain the MINOS.

4.1.1.3 Packet Length Field

The Packet Length Field will contain a 16-bit data word which represents the remaining length in octets of the packet. The data word will contain the size of the combination of the source data field and the packet error control field, minus 1.

All MHS command packets on both the Command/Telemetry and Science Data Buses are the same length.

4.1.2 Source Data Field

The Source Data field is the region that contains the application message. There is a further CCSDS field, the Secondary Header, which is used to contain a time code. The time code shall indicate the time corresponding to the start of Earth Scan of the scan revolution for which the data applies. The optional CCSDS preamble field, which includes the epoch (ie the event at which t=0), is not included. The implied epoch is midnight, January 1, 1958. This time will be extracted from the on-board clock maintained by the MINOS. It will be the responsibility of the ground control to upload an absolute time. In general this will be a time value that will become valid at the next occurrence of the 8SP clock.

Source Data Field	
Subfield Name	Size (octets)
Secondary Header	6
Source Data	Variable

Figure 4.1.2-1 Source Data Field Format

Secondary Header		
Subfield Name	Size (octets)	Description
Coarse Time Code	4	1 LSB = 1 second
Fine Time Code	2	1 LSB = 2^{-16} seconds

Figure 4.1.2-1 Secondary Header Field Format

The coarse time code will contain a count of the number of seconds elapsed since the epoch, and the fine time shall contain the fractions of seconds since the last increment of the coarse field.

The Source Data itself is defined by the application, and by the bus. The range of formats of this field forms the basis of sections 4.2 and 4.3 of this document.

4.1.3 Packet Error Control Field

Consists of a vertical parity checksum calculated by performing an exclusive-OR on all other octet pairs that constitute the packet.

4.2 Command and Telemetry Bus

4.2.1 Command Packet

The Command Types are shown in Figure 4.2.1-1. All commands are the same length equal to that of the longest command (Load Memory); unused octets are an undefined state.

Command Type	Total Command Packet Length (octets)	Source Data Field Length (octets)	Number of parameters (octets)	Command Code (hex)	Parameters
Set Mode	28	14	2	CC	1) Mode; 2) Submode
Switch Command	28	14	2	3C	1) Switch Channel Number; 2) Command Level
Read Telemetry	28	14	2	36	1) Channel Number
Request HK TLM Packet	28	14	2	C3	1) Relative Datation
Set Fixed View Position	28	14	4	66	1) Pointing Angle
Fixed View Step	28	14	2	6C	1) Step size; 2) Step direction
Load Memory	28	14	14	33	1) Start address; 2) Data; 3) Checksum
Set Time Code	28	14	8	69	1) Coarse time; 2) Fine time
Load Table Data	28	14	10	63	1) Table reference; 2) Data reference; 3) Data
Request Memory Data Packet	28	14	4	39	1) Start address

Figure 4.2.1-1 Command Types

The validity of commands in the different Instrument modes of operation are given in Figure 4.2.1-2.

	Power-on	Warm-up	Standby	Scan	Fixed View	Self-test	Safeing	Fault
Set Mode	Y	Y	Y	Y	Y	Y	N	Y
Switch Command	Y	Y	Y	N	N	N	N	Y
Read Telemetry	Y	Y	Y	N	N	N	N	Y
Request HK TLM Packet	Y	Y	Y	Y	Y	Y	Y	Y
Set Fixed View Position	N	N	Y	N	Y	Y	N	N
Fixed View Step	N	N	N	N	Y	Y	N	N
Load Memory	Y	Y	Y	N	N	N	N	Y
Set Time Code	Y	Y	Y	N	N	N	N	N
Load Table Data	Y	Y	Y	Y	Y	Y	N	Y
Request Memory Data Packet	Y	Y	Y	N	N	N	N	Y

Figure 4.2.1-2 Command Validity versus Mode

4.2.1.1 Set Mode Command

Octet 1:	Command Code	8 bits
Octet 2:	Mode Field	4 bits
	Submode Field	4 bits
Octets 3..14:	Spares	12 x 8 bits

The spare octets will be set to undefined values.

MSB							LSB
Command Code							
Mode Code				Submode code			

Figure 4.2.1.1-1 Set Mode Command Format

The Command Code is a fixed value of CC hex.

Mode Field	Code
Power-on	0000
Warm-up	0001
Standby	0010
Scan	0011
Fixed View	0100
Self-test	0101
Safeing	0110
unused	0111
unused	1000.. 1110
Reserved	1111

Figure 4.2.1.1-2 Mode Parameter Definition

The Submode Code is only used for Self-test Mode (otherwise the field has undefined contents), to identify the type of self-test routine to be performed. The Submode Code format is as follows:-

bit 4	bit 5	bit 6	bit 7
Repeat bit	Self-test code		

Repeat bit = 0: Self-Test is performed once.
One complete set of test data is generated.
Automatic return to calling mode after one Scan Period.

Repeat bit = 1: Self-Test is repeated until telecommanded to the calling mode.

Self-Test Code	Self-Test Name
0	PIE Functions
1	Fixed Pattern
2	Watchdog
3	Motor
4	PRT Calibration
5..7	Unused

Figure 4.2.1.1-3 Self-test Code Parameter Definition

4.2.1.2 Switch Command

Octet 1:	Command Code	8 bits
Octet 2:	Switch Channel Type/ Level/ Number	8 bits
Octets 3..14:	Spares	12 x 8 bits

The spare octets will be set to undefined values.

MSB							LSB
Command Code							
Type		Switch Channel Number					

Figure 4.2.1.2-1 Switch Command Format

The Command Code is a fixed value of 3C hex.

The Type corresponds to the command channel number prefix (see figures 6.1-1, 6.2-1, 6.3-1) as follows:-

Type = 00 not used
Type = 01 High Level commands (eg pulsed relay commands)
Commands 1:n (see figure 6.1-1) where n is the
Switch Channel Number (max capability of 64).

For Type = 10 and 11 the command format is:-

MSB							LSB
Command Code							
	Type	Level	Switch Channel Number				

Type = 10 'Steady state' commands (eg FET control)
Commands 2:n (see figure 6.2-1)
Level = 0 = Switch OFF; Level = 1 = Switch ON

Type = 11 'BIM register' commands (for SCE, SPE functions)
Commands 3 : n (see figure 6.3-1)
Level = 0 = clear register bit
Level = 1 = set register bit

4.2.1.3 Read Telemetry

Octet 1:	Command Code	8 bits
Octet 2:	Telemetry Channel Number	5 bits
	Telemetry Channel Type	3 bits
Octets 3..14:	Spares	12 x 8 bits

The spare octets will be set to undefined values.

MSB							LSB
Command Code							
Type			Telemetry Channel Number				

Figure 4.2.1.3-1 Read Telemetry Command Format

The Command Code is a fixed value of 36 hex.

The Type corresponds to the Telemetry Channel Number prefix (see Figures 5.1-1, 5.1-2, 5.1-3, 5.2-1 and 5.3-1). The Telemetry Channel Number corresponds to those listed in the afore mentioned tables.

Note: The Read Telemetry command is not available for Type = 6 (ie. PRT data, channels 6:1 to 6:8).

4.2.1.4 Request HK Telemetry Packet

Octet 1:	Command Code	8 bits
Octet 2:	Packet Relative Datation	2 bits
	Unused	6 bits
Octets 3..14:	Spares	12 x 8 bits

The spare octets will be set to undefined values.

MSB							LSB
Command Code							
Unused (undefined)						Packet Relative Datation	

Figure 4.2.1.4-1 Request HK Telemetry Packet Command Format

The Command Code is a fixed value of C3 hex.

The Packet Relative Datation is used to indicate which packet is requested. A new packet is generated each Scan Period (8/3 seconds) and the instrument stores the three most recent packets generated. When a new Scan Period starts (ie. start of Earth View, synchronised to 8SP on every third Scan Period) a completed new packet is available. This packet becomes the 'most recent' packet for the duration of the next scan period, and older packets move down the buffer. This process occurs irrespective of whether packets are requested and/or collected or not. This feature allows the platform to recover packets which are up to 8 seconds old, in the event of error handling or timing constriants of the data collection process in the platform.

By default, if this command is in any way corrupted, then it will return the most recent data available, whether or not it has already been extracted.

Datation Field	Code
Most Recent Packet	00
Next-most recent packet	01
Next-next most recent packet	10
Unused	11

If this command is sent in one of the self test modes then a Test Data Packet will be returned. The Datation parameter will have the same meaning in this case.

4.2.1.5 Set Fixed View Position

Octet 1:	Command Code	8 bits
Octet 2:	Unused	8 bits
Octet 3:	Pointing Position MS Byte	8 bits
Octet 4:	Pointing Position LS Byte	8 bits
Octets 5..14:	Spares	10 x 8 bits

The spare octets will be set to undefined values.

MSB							LSB
Command Code							
Unused							
Pointing Angle MS Byte							
Pointing Angle LS Byte							

Figure 4.2.1.5-1 Set Fixed View Position Command Format

The Command Code is a fixed value of 66 hex.

The pointing angle is an absolute position, measured in degrees where 1 LSB = 0.01 degrees. Angles greater than 359.99° are interpreted as modulo 360.

4.2.1.6 Fixed View Step

Octet 1:	Command Code	8 bits
Octet 2:	Step Direction	1 bit
	Step Size	7 bits
Octets 3..14:	Spares	12 x 8 bits

The spare octets will be set to undefined values.

MSB							LSB
Command Code							
Step Dir.	Step Size						

Figure 4.2.1.6-1 Fixed View Step Command Format

The Command Code is a fixed value of 6C hex.

Step Direction=0 : indicates forwards (ie. direction of rotation for nominal Scan Mode Profile).
Step Direction=1 : indicates backwards

The Step Size is a relative step, measured in degrees, from the current pointing position.

Step Size 1LSB = 1/9 degrees (ie 1/10th of a pixel).

4.2.1.7 Load Memory

Octet 1:	Command Code		8 bits
Octet 2:	Start Address (MS Byte)		8 bits
Octet 3:	Start Address		8 bits
Octet 4:	Start Address (LS Byte)		8 bits
Octet 5:	Data Word 1	(MS Byte)	8 bits
Octet 6:	Data Word 1	(LS Byte)	8 bits
Octet 7:	Data Word 2	(MS Byte)	8 bits
Octet 8:	Data Word 2	(LS Byte)	8 bits
Octet 9:	Data Word 3	(MS Byte)	8 bits
Octet 10:	Data Word 3	(LS Byte)	8 bits
Octet 11:	Data Word 4	(MS Byte)	8 bits
Octet 12:	Data Word 4	(LS Byte)	8 bits
Octet 13:	Checksum	(MS Byte)	8 bits
Octet 14:	Checksum	(LS Byte)	8 bits

MSB							LSB
Command Code							
Start Address MS Byte							
Start Address							
Start Address LS Byte							
Data Word 1 MS Byte							
Data Word 1 LS Byte							
Data Word 2 MS Byte							
Data Word 2 LS Byte							
Data Word 3 MS Byte							
Data Word 3 LS Byte							
Data Word 4 MS Byte							
Data Word 4 LS Byte							
Checksum MS Byte							
Checksum LS Byte							

Figure 4.2.1.7-1 Load Memory Command Format

The Command Code is a fixed value of 33 hex.

The block start address is a 24-bit address passed in as parameter.

The Data Words will be written to memory in consecutive locations.

The Checksum will be the exclusive-OR of all the other octet pairs (ie. Command/unused octet pair to Data Word 4 octet pair).

4.2.1.8 Set Time Code

Octet 1:	Command Code	8 bits
Octet 2:	Unused (undefined)	8 bits
Octet 3:	Coarse Time (MS Byte)	8 bits
Octet 4:	Coarse Time	8 bits
Octet 5:	Coarse Time	8 bits
Octet 6:	Coarse Time (LS Byte)	8 bits
Octet 7:	Fine Time (MS Byte)	8 bits
Octet 8:	Fine Time (LS Byte)	8 bits
Octets 9..14:	Spares	6 x 8 bits

The spare octets will be set to undefined values.

MSB							LSB
Command Code							
Unused (undefined)							
Coarse Time (MS Byte)							
Coarse Time							
Coarse Time							
Coarse Time (LS Byte)							
Fine Time (MS Byte)							
Fine Time (LS Byte)							

Figure 4.2.1.8-1 Set Time Code Command Format

The Command Code is a fixed value of 69 hex.

Octets 3 .. 6 : Coarse Time 32 bits (LSB=1 second)
Octets 5,6 : Fine Time 16 bits (LSB=2^{-16} seconds)

Instrument time is set to the defined value at the next 8SP event.

4.2.1.9 Load Table Data

Octet 1:	Command Code	8 bits
Octet 2:	Unused (undefined)	4 bits
	Table Reference	4 bits
Octet 3:	Unused (undefined)	4 bits
	Data Reference (MS Nibble)	4 bits
Octet 4:	Data Reference (LS Byte)	8 bits
Octet 5:	Data Byte 1	8 bits
Octet 6:	Data Byte 2	8 bits
Octet 7:	Data Byte 3	8 bits
Octet 8:	Data Byte 4	8 bits
Octet 9:	Checksum (MS Byte)	8 bits
Octet 10:	Checksum (LS Byte)	8 bits
Octets 11..14:	Spares	4 x 8 bits

The spare octets will be set to undefined values.

MSB							LSB
Command Code							
Unused (undefined)				Table Reference			
Unused (undefined)				Data Reference			
Data Reference							
Data Word 1							
Data Word 2							
Data Word 3							
Data Word 4							
Checksum MS Byte							
Checksum LS Byte							

Figure 4.2.1.9-1 Load Table Data Command Format

The Command Code is a fixed value of 63 hex.

The Table Reference is a code which points to one of the internally implemented databases:

Code	Database Table
0000	Instrument Configuration Table
0001	Telemetry Limits Table
0010	Scan Control Table
0011	DC Offsets Table
0100 .. 1111	Unused

The Data Reference is a pointer value from 0 .. 4095. It is used to select the required entry in the table.

The data tables implemented are described in appendices A, B, C & D.

The Checksum will be the exclusive-OR of all other octet pairs (ie. Command Code/Table Ref octet pair to Data Word 3/4 octet pair).

4.2.1.10 Request Memory Data Packet

The instrument will place the contents of the 4 16 bit memory locations defined by the Start Address into the output buffer ready for collection by the platform.

Octet 1:	Command Code	8 bits
Octet 2:	Start Address (MS Byte)	8 bit
Octet 3:	Start Address	8 bits
Octet 4:	Start Address (LS Byte)	8 bits
Octets 5..14:	Spares	10 x 8 bits

The spare octets will be set to undefined values.

MSB							LSB
Command Code							
Start Address MS Byte							
Start Address							
Start Address LS Byte							

Figure 4.2.1.10-1 Request Memory Data Packet Command Format

The Command Code is a fixed value of 39 hex.

The block start address is a 24 bit address passed in as parameter.

Note that if a Request Memory Data Packet is received, then the current HK Telemetry packet will be abandoned. A Memory Data Packet will be generated and connected to the output buffers.

4.2.2 Telemetry Packets

The Telemetry Packet Types are shown in Figure 4.2.2-1

Telemetry Packet Type	Total Packet Length (octets)
Housekeeping Telemetry	30
Memory Data	26
Test Data Packet Types 0..4	30

Figure 4.2.1-1 Telemetry Packet Types

Telemetry packets fit into the general CCSDS format described in section 4.1. The detailed structure of the Source Data field is given in the following sections.

4.2.2.1 Housekeeping (HK) Telemetry Packet

Housekeeping Telemetry Packets contain the following fields:

Field Name	Size (Octets)
Mode and Subcommutation Code	1
Telecommand Acknowledgement and Fault Code	5
Switch Status	3
Temperature Data	4
Current/Power Consumption Data	3
Total Data Field Length	16

Figure 4.2.2.1-1 Housekeeping Telemetry Packet Format

The following definitions of the HK Telemetry Packet apply for all modes of operation. However, during initialisation (entry to Power-on Mode following application of power) one or more 'empty' packets may be generated, until initialisation is complete. An 'empty' packet shall have a valid Primary and Secondary Header (except packet sequence count and timecode will be zero, irrespective of the number of packets generated), a valid Mode Code (Power-on), and a valid Packet Error Control field, and all other fields will be set to zero.

The Mode and Sub-commutation Code format is as shown in Figure 4.2.2.1-2.

MSB							LSB
Mode Code				PIE ID	Sub-commutation Code		

Figure 4.2.2.1-2 Mode and Sub-Commutation Field

Mode Field	Code
Power-on	0000
Warm-up	0001
Standby	0010
Scan	0011
Fixed View	0100
Self-test	0101
Safeing	0110
Fault	0111
Unused	1000 .. 1110
Memory Data Packet ID	1111

Figure 4.2.2.1-3 Mode Parameter Definition

The Mode Code identifies the current operating mode, as shown in Figure 4.2.2.1-3. The Mode Code is changed following successful completion of a mode transition, except for transitions to Fault Mode when the Mode Code is changed as soon as the fault is detected.

The Mode Code implies the type of packet. All mode codes except 0101 and 1111 imply that the packet is a HK Telemetry Packet. Code 0101 implies a Test Packet, and Code 1111 implies a Memory Data Packet.

The PIE identify bit indicates which PIE is active.

0: PIE A
1: PIE B

The subcommutation Code indicates which set of thermistor telemetry data is included in this packet, as defined in Figures 5.2-1 and 5.4-1. The subcommutation Code is incremented each time a HK Telemetry Packet is sent.

The TC Acknowledgment and Fault Code field is shown in Figure 4.2.2.1-4. The Fault Code is latched on entry to Fault Mode and reset on exit from Fault Mode.

MSB							LSB
TC Clean	TC Conforms	TC Recognised	TC Legal	FDM Motor Current Trip Status	TC Application ID		
TC Application ID							
TC Packet Sequence							
TC Packet Sequence						TC Received Count	
Current Monitor Fault	Thermistor Monitor Fault	Switch Fault	Processor Fault	RDM Motor Current Trip Status	DC Offset Error	Scan Control Error	REF ck Error

Figure 4.2.2.1-4 Telecommand Acknowledgement and Fault Code Field

The 'TC Clean Flag' will be set to a '1' if a parity or a checksum error is not found in the received packet.

The 'TC Conforms Flag' will be set to a '1' if the header of the received command conforms to the CCSDS format.

The 'TC Recognised Flag' will be set to a '1' if the received command is a recognised MHS command of the correct format.

The 'TC Legal Flag' will be set to a '1' if the received command is legal for execution in the current MHS operating mode.

The 'TC Application Process ID' is taken from the Packet ID field of the primary header of the received Serial Command.

'FDM Motor Current Trip Status' : see RDM Motor Current Trip Status below.

The 'TC Packet Sequence Count' is the Source Sequence Count taken from the Packet Sequence Control field of the primary header of the received Serial Command (see figure 4.1.1.2-1).

All of the above fields (except FDM Motor current Trip Status) will be set when a Serial Command (received on the Cmd/Tlm Bus) is processed. If a second Serial Command is received in the period of the same Housekeeping Telemetry packet, then no field will be overwritten. The second (and subsequent commands) will be acknowledged ONLY in the TC Received Count.

The 'TC Received Count' is the count of all valid (ie. accepted for execution) Serial Commands received since the last Housekeeping Telemetry packet was transmitted. This count is limited to three, ie it will not roll over.

The TC Acknowledgement field in the HK Telemetry Packet which is transmitted on the Cmd/Tlm Bus is used to acknowledge commands received on the Cmd/Tlm Bus only. Commands received on the Science Data Bus (see section 4.3.1) are acknowledged in the TC Acknowledgement field of the Full HK Telemetry Field which is included in packets transmitted on the Science Data Bus.

Housekeeping Telemetry Packets will be generated internally at the same rate as a frame of telemetry is collected. Results from the frame collection will also be included in the packet.

The 'Current Monitor Fault' bit will be set to a '1' when any of the PSU Current monitor parameters exceeds its expected limits.

The 'Thermistor Monitor Fault' bit will be set to a '1' when any of the Thermistor temperature monitor parameters listed in section 5.2 is outside of its expected limits. For Housekeeping telemetry, this flag will be set if it is one of the four multiplexed values that are in error; if a value is outside limits, but not included in the packet, then this bit will not be set. For Science Data packets (see section 4.3.2.1), all temperature values are included in all packets, so this bit will be set whenever any value is outside expected limits.

The 'Switch Fault' bit will be set to a '1' when a switch status telemetry parameter does not agree with its last commanded state, or a PROM board switch error has occurred.

The 'Processor Fault' bit will be set to a '1' after a processor internal fault has occurred (overflow, illegal address, BIT failure).

The 'RDM (or FDM) Motor Current Trip Status' will be set to a '1' when the instantaneous current in the respective motor has exceeded a preset level, resulting in the disabling of the respective motor drive circuit. These bits correspond to the inverse of the Telemetry Channels 3:12 and 3:13 (see Figure 5.1-3).

The 'DC Offset Error' bit will be set to a '1' when any of the channel calibration targets readings indicate a change in the DC offset is required (see DC offset Algorithm, Appendix B, RD2). This bit will be set only in Scan Mode when the calibration targets are sampled.

The 'Scan Control Error' bit will be set to a '1' if the measured mid-pixel position of the reflector during Earth, Space or OBCT views is outside the limits for the Scan Mode profile, or the reflector position is outside the limits of the requested position for Fixed View Mode, or the position acquisition initialisation has failed.

The 'REF CK Error' bit will be set if the Scan Control Clock stops as a result of the platform Reference Clock (1.048576 MHz) stopping.

The Switch Status field gives the latest values of all Contact Parameters acquired from the Internal Telemetry interface. The format of this field is:

MSB							LSB
1:8	1:7	1:6	1:5	1:4	1:3	1:2	1:1
PROM	2:4	2:3	2:2	2:1	1:11	1:10	1:9
3:11	3:10	3:9	3:8	3:7	3:6	3:5	3:4

Figure 4.2.2.1-5 Switch Status Field

The channel number codes of the telemetry parameters are cross referenced to the actual parameter in Figure 5.1-1 later in this document.

Notes

- Telemetry channels 3:1, 3:2 and 3:3 are not reported in the HK Telemetry Packet but appear in the Signal Processing Status Field (SPE MUX CODE) of the Science Data Packet.
- Telemetry Channels 3:12 and 3:13 are not reported in this field but appear in the Telecommand Acknowledgement and Fault Code Field of the HK Telemetry Packet (called RDM and FDM Motor Current Trip Status)
- PROM : set when a PROM segment switch has failed ON.

The Temperature Data Field of each packet will contain four thermistor telemetry channel parameters. Each packet will contain a pre-defined sub-commutated group of values, from either the normal instrument monitors (8-bit), or from the precision temperature (OBCT) monitors (12-bit). In the case of the high precision temperature telemetry, the data is truncated to an 8-bit resolution.

The Current/Power Consumption Data Field is a processed subset of the internal PSU Current analogue telemetry defined in figure 5.3-1. The field conforms to figure 4.2.2.1-6.

MSB							LSB
5V Secondary Current							
Receiver Global Secondary Power							
Total Motor Current							

Figure 4.2.2.1-6 Current and Power Consumption Data Field

The 5V Secondary Current is given by the EE + SM current, read as a single telemetry parameter.

The Receiver Global Secondary Power is given by:

Power = 8.44x(Rx +8V current) + 15x(Rx +15V current) + 15x(Rx -15V current)

where
current is in amps.
power is in watts (1LSB = 0.2W)

Refer to RD6 for conversion of the above current telemetries into amps.

The Total Motor Current is given by:

Total = RDM Motor Current + FDM Motor Current

The result of the addition of the two 8 bit motor current telemetries shall be divided by two and truncated to reconstitute an 8 bit parameter.

4.2.2.2 Memory Data Packet

Memory Data Packets contain the following fields:

Octet 1:	Packet ID/PIE ID	8 bits
Octet 2:	Start Address (MS Byte)	8 bits
Octet 3:	Start Address	8 bits
Octet 4:	Start Address (LS Byte)	8 bits
Octet 5:	Data Word 1 (MS Byte)	8 bits
Octet 6:	Data Word 1 (LS Byte)	8 bits
Octet 7:	Data Word 2 (MS Byte)	8 bits
Octet 8:	Data Word 2 (LS Byte)	8 bits
Octet 9:	Data Word 3 (MS Byte)	8 bits
Octet 10:	Data Word 3 (LS Byte)	8 bits
Octet 11:	Data Word 4 (MS Byte)	8 bits
Octet 12:	Data Word 4 (LS Byte)	8 bits

MSB							LSB
Memory Packet ID = 1111				PIE ID	unused (undefined)		
Start Address MS Byte							
Start Address							
Start Address LS Byte							
Data Word 1 MS Byte							
Data Word 1 LS Byte							
Data Word 2 MS Byte							
Data Word 2 LS Byte							
Data Word 3 MS Byte							
Data Word 3 LS Byte							
Data Word 4 MS Byte							
Data Word 4 LS Byte							

Figure 4.2.2.2-1 Memory Data Packet Format

The Memory Packet ID is in the position of the Mode Code in HK Telemetry Packets and Test Data Packets. Mode Code = 1111 is a reserved code, so that this uniquely identifies a packet as a Memory Data Packet.

The block start address is the 24-bit address of the returned data block.

The Data Words will be sequentially read from memory in consecutive locations starting from the start address.

4.2.2.3 Test Data Packet

Test Data Packets are only produced in Self-test Mode and the format depends on the type of Self-test routine selected. The general format of Test Packets is as follows (excluding headers and checksum):

Field Name	Length (octets)
Mode and Self-test Code	1
Test Data Field	15
Total Data Field Length	16

The Mode and Self-test Code field format is as follows:

MSB							LSB
Mode Code				PIE ID	Self-Test Code		

The Mode Code is always set to 0101 for Self-test Mode and uniquely identifies the packet as a Test Packet.

The PIE ID identifies which PIE is active (0=PIE A, 1=PIE B).

Self-test Code identifies the specific format of the Test Data Field.

(i) For Self Test Code = 0 (PIE Functions Test) the format is as follows:

Octet 1 bit 0 (MSB):	Memory Test	Done(1)/Not Done(0)
Octet 1 bit 1 :	Processor Test	Done(1)/Not Done(0)
Octet 1 bit 2 :	Switch TMTC Test	Done(1)/Not Done(0)
Octet 1 bit 3 :	Memory Test	Pass(1)/Fail(0)
Octet 1 bit 4 :	Processor Test	Pass(1)/Fail(0)
Octet 1 bit 5 :	Switch TMTC Test	Pass(1)/Fail(0)
Octet 1 bits 6,7:	unused, set to zero.	

Octets 2,3,4 :	Memory Test: Start Address of area tested : 17 bits
Octets 5,6,7 :	Memory Test: End Address of area tested : 17 bits
Octets 8,9:	Memory Test: Number of errors : 16 bits

If the ICT test parameters define a large block of memory to be tested, the block is divided into sub-blocks. Each sub-block is tested in a single Scan Period and the results reported in a single Test Packet. The Start and End address refer to the sub-block, and the pass/fail and error fields refer to the current sub-block only.

Octet 10 bit 0 (MSB):	Processor test : EDAC test Pass(1)/Fail(0)
Octet 10 bit 1:	Processor test : CPU test Pass(1)/Fail(0)
Octet 10 bit 2:	Processor test : Reset Source : HW_Reset(1)/Other(0)
Octet 10 bit 3:	Processor test : PCC test Pass(1)/Fail(0)
Octet 10 bit 4:	Processor test : BIC test Pass(1)/Fail(0)
Octet 10 bits 5..7:	unused, set to zero

Octet 11 :	Switch TMTC Channels 1..8 Pass(1)/Fail(0)
Octet 12 :	Switch TMTC Channels 9..16 Pass(1)/Fail(0)
Octet 13 :	Switch TMTC Channels 17..20 Pass(1)/Fail(0); 4 LSBs unused: set to 0.
Octet 14 :	Unused. Set to zero.
Octet 15 :	Unused. Set to zero.

(ii) For Self Test Code = 1 (Fixed Pattern Test) the format is as follows:

Octets 1..15 : 55 hex nominally, but can be modified by changing parameter 7:3 of the ICT (Appendix A).

(iii) For Self Test Code = 2 (Watchdog Test) the format is as follows:

No Packets are generated in this self-test. The test is 'terminal' for the software, and causes an Instrument re-initialisation.

(iv) For Self Test Code = 3 (Motor Test) the format is as follows:

If position data stored:
Octets 1,2: Sample 1 position data (16 bits)
Octets 3,14: Samples 2..7 position data (16 bits)
Octet 15 : Test Identification Word, see octet 1247 of Motor Self-test Extended Test Data packet.

If current demand data stored:
Octet 1 : Sample 1 current demand data (8 bits)
Octets 2..14 : Sample 2..14 current demand data (8 bits)
Octet 15 : Test Identification Word, see octet 1247 of Motor Self-test Extended Test Data packet.

(v) For Self Test Code = 4 (PRT Calibration Test) the format is as follows:

Octets 1,2 : PRT 1 sample 120
Octets 3,4 : PRT 2 sample 120
Octets 5,6 : PRT 3 sample 120
Octets 7,8 : PRT 4 sample 120
Octets 9,10 : PRT 5 sample 120
Octets 11,12 : Calibration channel 1
Octets 13,14 : Calibration channel 2
Octet 15 : spare; set to zero

(vi) Self Test Code = 5: test undefined.

(vii) Self Test Code = 6: test undefined

(viii) Self Test Code = 7: test undefined

4.3 Science Data Bus

4.3.1 Command Packets

The Command Types are shown in Figure 4.3.1-1. Both commands are the same length. Unused octets are an undefined state.

Command Type	Total Command Packet Length (octets)	Source Data Field Length (octets)	Number of parameters (octets)	Command Code (hex)	Parameters
Request Science Data Packet	28	14	2	C3	1) Datation
Request Extended Memory Data Packet	28	14	2	39	1) Start Address

Figure 4.3.1-1 Science Data Bus Command Types

The validity of commands in the different Instrument modes of operation are given in Figure 4.3.1-2.

	Power-on	Warm-up	Standby	Scan	Fixed View	Self-test	Safeing	Fault
Request Science Data Packet	Y	Y	Y	Y	Y	Y	Y	Y
Request Extended Memory Data Packet	Y	Y	Y	N	N	N	N	Y

Figure 4.3.1-2 Science Data Bus Command Validity versus Mode

d to explain
Data Bus

4.3.1.1 Request Science Data Packet

Octet 1:	Command Code	8 bits
Octet 2:	Packet Relative Datation	2 bits
	Unused (undefined)	6 bits
Octets 3..14:	Spares	12 x 8 bits

The spare octets will be set to undefined values.

MSB							LSB
Command Code							
Unused (undefined)						Packet Relative Datation	

Figure 4.3.1.1-1 Request Science Data Packet Command Format

The Command Code is a fixed value of C3 hex.

The Packet Relative Datation is used to indicate which packet is requested. A new packet is generated each Scan Period (8/3 seconds) and the instrument stores the three most recent packets generated. When a new Scan Period starts (ie. start of Earth View, synchronised to 8SP on every third Scan Period) a completed new packet is available. This packet becomes the 'most recent' packet for the duration of the next scan period, and older packets move down the buffer. This process occurs irrespective of whether packets are requested and/or collected or not. This feature allows the platform to recover packets which are up to 8 seconds old, in the event of error handling or timing constraints of the data collection process in the platform.

By default, if this command is in any way corrupted, then it will return the most recent data available, whether or not it has already been extracted.

Datation Field	Code
Most Recent Packet	00
Next-most recent packet	01
Next-next most recent packet	10
Unused	11

If this command is sent in one of the self-test modes then an Extended Test Data Packet will be returned. The Datation parameter will have the same meaning in this case.

4.3.1.2 Request Extended Memory Data Packet

The instrument will place the contents of the 512 16 bit memory locations defined by the Start Address into the output buffer ready for collection by the platform.

Octet 1:	Command Code	8 bits
Octet 2:	Start Address (MS Byte)	8 bits
Octet 3:	Start Address	8 bits
Octet 4:	Start Address (LS Byte)	8 bits
Octets 5..14:	Spares	10 x 8 bits

The spare octets will be set to undefined values.

MSB							LSB
Command Code							
Start Address MS Byte							
Start Address							
Start Address LS Byte							

Figure 4.3.1.2-1 Request Extended Memory Data Packet Command Format

The Command Code is a fixed value of 39 hex.

The block start address is a 24-bit address passed as a parameter.

4.3.2 Telemetry Packets

The following telemetry packet types are generated on the Science Data Bus:-

Packet Type	Total Packet Length (octets)
Science Data Packet	1300
Extended Memory Data Packet (EMDP)	1042
Extended Test Data Packet (ETDP)	1300

The packets have CCSDS format (ie. a primary header, secondary header and checksum) as described in section 4.1. The detailed structure of the Source Data field is given in the following sections.

4.3.2.1 Science Data Packet

Science Data Packets contain the following fields:

Field Name	Size (Octets)
Full Housekeeping Data	39
Status Word	1
Signal Processing Status	9
Pixel Data	1176
OBCT Temperature Data	16
Spares	45

Figure 4.3.2.1-1 Science Data Packet Format

The format of the 'Full Housekeeping Data' field is described at the end of this section.

In modes which do not generate Science Data (ie. all modes except Scan Mode and Fixed View Mode), an 'Empty Science Data Packet' is generated, in which the remaining fields of the Science Data Packet are undefined.

The format of the spares field is unallocated at present. All octets will be set to '00'.

The format of the Status Word is shown in Figure 4.3.2.1-2.

MSB							LSB
DC Offset Valid	Scan Control Valid	Profile		Unused			

Figure 4.3.2.1-2 Status Word Field

The 'DC Offset Valid' bit is set to a '1' when all channels calibration targets readings lie within acceptable limits, as determined by the DC Offset Algorithm (see RD2, Appendix B). This bit will be set only in Scan Mode when the calibration targets are sampled.

The 'Scan Control Valid' bit is set to a '1' if all mid-pixel positions of the reflector during Earth, Space and OBCT views are within the limits for the Scan Mode profile, or within the limits of the requested position in Fixed View Mode. This bit will be set only in Scan Mode or Fixed View Mode.

The 'Profile' code is set to:

00 : Profile 0
01 : Profile 1
10 : Profile 2
11 : No Profile calculated (profile will be manually loaded/modified)

It is intended that Profile 0 will define the Nominal Scan Mode Profile with nominal Space View position. Profiles 1 and 2 will nominally be used for the alternate Space view positions. However, any profile can be reprogrammed to another position versus time profile by reloading the Scan Control Table profile parameters (see appendix C)

The format of the Signal Processing Status field is shown in Figure 4.3.2.1-3.

MSB							LSB
Channel H1 DC Offset Word							
Channel H2 DC Offset Word							
Channel H3 DC Offset Word							
Channel H4 DC Offset Word							
Channel H5 DC Offset Word							
H1 VALID	H2 VALID	H3 VALID	H4 VALID	H5 VALID	SPE MUX CODE		
H1 GAIN			H2 GAIN			UNUSED	
H3 GAIN			H4 GAIN			UNUSED	
H5 GAIN			UNUSED			UNUSED	

Figure 4.3.2.1-3 Signal Processing Status Field

The 'Valid' bit is set to a '1' when all samples of this channel for this scan revolution lie within the ADC dynamic range.

H1..H5 are the 5 input channels from the Receiver. The Electronics Equipment has 6 signal processing channels, SPE1..SPE6. In the nominal configuration, the Receiver channel is connected to the corresponding EE channel eg H1 to SPE1, and SPE6 is unused.

The SPE Mux Code is used to identify which Receiver channel, if any, is connected to the EE redundant channel, as shown in Figure 4.3.2.1-4.

SPE MUX Code	Configuration
000	H1 to SPE 6
001	H2 to SPE 6
010	H3 to SPE 6
011	SPE 6 not used
100	H4 to SPE 6
101	H5 to SPE6
110	SPE6 not used
111	SPE6 not used

Figure 4.3.2.1-4 SPE MUX Code Subfield format

The H1...H5 Gain Fields identify the gain settings of the Receiver video output channels as in Figure 4.3.2.1-5.

Gain Code	Gain
000	0 dB
001	1 dB
010	2 dB
011	3 dB
1xx	not used

Figure 4.3.2.1-5 Receiver Gains Sub Field

The Science Data field can be separated into Earth, Space and OBCT View Data fields, which all follow a common format. They are differentiated only by the source of the data that is written to them. The fields are arranged as:

Field name	Number of Pixel subfields
Earth	90
Space	4
OBCT	4

Figure 4.3.2.1-6 Science Data Field Format

In Fixed View Mode, the Science Data Packet is the same format as Scan Mode, but the concept of Earth, Space and OBCT pixels does not apply. All 98 pixels are for the fixed view position. The (90 + 4 + 4) pixels are however collected with the same timing as though Scan Mode were performed.

Each of the Pixel sub-fields contain a position and five pixel values. The format of a Pixel Subfield is shown in figure 4.3.2.1-7.

MSB							LSB
Mid-pixel Position MS Byte							
Mid-pixel Position LS Byte							
Channel H1 Data MS Byte							
Channel H1 Data LS Byte							
Channel H2 Data MS Byte							
Channel H2 Data LS Byte							
Channel H3 Data MS Byte							
Channel H3 Data LS Byte							
Channel H4 Data MS Byte							
Channel H4 Data LS Byte							
Channel H5 Data MS Byte							
Channel H5 Data LS Byte							

Figure 4.3.2.1-7 Pixel Subfield Format

The 'Mid-pixel position' data is the angular position of the Reflector at the mid-point of the pixel integration period.

$$1\ \text{LSB} = \frac{7.2}{1024} = 7.03125 \times 10^{-3}\ \text{degrees}$$

The OBCT Temperature Data field contains the On-Board Calibration Target high precision temperature parameters as listed in figure 5.4-1. The format of this block is given in figure 4.3.2.1-8.

MSB							LSB
Unused				On-Board Target Temperature 1			
On-Board Target Temperature 1 (PRT1)							
Unused				On-Board Target Temperature 2			
On-Board Target Temperature 2 (PRT 2)							
Unused				On-Board Target Temperature 3			
On-Board Target Temperature 3 (PRT 3)							
Unused				On-Board Target Temperature 4			
On-Board Target Temperature 4 (PRT 4)							
Unused				On-Board Target Temperature 5			
On-Board Target Temperature 5 (PRT 5)							
Unused				Calibration Channel 1			
Calibration Channel 1 (PRT CAL 1: 118Ω)							
Unused				Calibration Channel 2			
Calibration Channel 2 (PRT CAL 2: 95.3Ω)							
Unused				Calibration Channel 3			
Calibration Channel 3 (PRT CAL 3: 80.6Ω)							

Figure 4.3.2.1-8 OBCT Subfield Format

The full Housekeeping Telemetry Data blocks contain the following fields:

Field Name	Size (Octets)
Mode and Subcommutation Code	1
Telecommand Acknowledgement and Fault Code	5
Switch Status	3
Temperature Data	24
Raw Current Consumption Data	6

Figure 4.3.2.1-9 Full Housekeeping Telemetry Data Block

The Mode and Sub-Commutation field is as shown previously in figures 4.2.2.1-2 and 4.2.2.1-3. The Sub-Commutation code is not significant for the Science Data packet as all telemetry is returned.

As with other packets, the Mode Code identifies the packet as either a Science Data Packet (Scan and Fixed View Modes), an Extended Test Packet (self-test mode), an Extended Memory Data Packet (Mode Code = '1111') or an Empty Science Data Packet (all other Modes).

The Telecommand Acknowledgement and Fault Code Field is as shown in figure 4.2.2.1-4. Note that the Telecommand Acknowledgement field of Science Data packets provides acknowledgement of commands received on the Science Data Bus. (Commands on the Command/telemetry Bus are acknowledged in HK Telemetry Packets.)

The Switch Status field follows the format as described in figure 4.2.2.1-5. The same data is used in the construction of this field.

The Temperature Data Field of each packet will contain all twenty-four thermistor telemetry channel parameters, instead of the multiplexed four of the Housekeeping telemetry packet. The OBCT temperatures are not contained here, as all such values are allocated a separate field in the Science Data Bus.

The Raw Current Consumption Data Field is the internal PSU Current analogue telemetry as defined in figure 5.3-1. The field is as shown in figure 4.3.2.1-10.

MSB							LSB
+5V Secondary Current							
+8V Receiver Current							
+15V Receiver Current							
-15V Receiver Current							
RDM Motor Current							
FDM Motor Current							

Figure 4.3.2.1-10 Raw Current Consumption Data Field Format

4.3.2.2 Extended Memory Data Packet (EMDP)

Extended Memory Data Packets contain the following fields:

Octet 1:	Packet ID/PIE ID	8 bits
Octet 2:	Start Address (MS Byte)	8 bits
Octet 3:	Start Address	8 bits
Octet 4:	Start Address (LS Byte)	8 bits
Octet 5:	Data Word 1 (MS Byte)	8 bits
Octet 6:	Data Word 1 (LS Byte)	8 bits
Octet 7:	Data Word 2 (MS Byte)	8 bits
Octet 8:	Data Word 2 (LS Byte)	8 bits
	.	
	.	
	.	
	.	
Octet 1025:	Data Word 511 (MS Byte)	8 bits
Octet 1026:	Data Word 511 (LS Byte)	8 bits
Octet 1027:	Data Word 512 (MS Byte)	8 bits
Octet 1028:	Data Word 512 (LS Byte)	8 bits

MSB							LSB
Memory Packet ID = 1111				PIE ID	unused (undefined)		
Start Address MS Byte							
Start Address							
Start Address LS Byte							
Data Word 1 MS Byte							
Data Word 1 LS Byte							
Data Word 2 MS Byte							
Data Word 2 LS Byte							
. . . . .							
Data Word 511 MS Byte							
Data Word 511 LS Byte							
Data Word 512 MS Byte							
Data Word 512 LS Byte							

Figure 4.3.2.2-1 Extended Memory Data Packet Format

The Memory Packet ID is in the position of the Mode Code in Science Data Packets and Extended Test Data Packets. Mode Code = 1111 is a reserved code, so that this uniquely identifies a packet as an Extended Memory Data Packet.

The block start address is the 24-bit address of the returned data block.

The 512 Data Words will be sequentially read from memory in consecutive locations starting from the start address.

4.3.2.3 Extended Test Data Packet (ETDP)

Extended Test Data Packets are only produced in Self-test Mode and the format depends on the type of Self-test routine selected. The general format of Extended Test Packets is as follows (excluding headers and checksum):

Field Name	Length (octets)
Mode Code/PIE ID/Self-Test Code	1
Unused (set to zero)	38
Extended Test Data Field	1247

The Mode Code, PIE ID and Self-test Code Field is as defined for the Test Packet (Section 4.2.2.3).

The Extended Test Data Field formats are as follows:

(i) For Self Test Code = 0 (PIE Functions Test) the format is as follows:

Octets 1..15:	PIE Functions Test Data Field (same as Test Data Packet).
Octets 16,17,18:	Memory Test: Error address 1
Octets 19,20,21:	Memory Test: Error Address 2
Octets 22..1215:	Memory Test: Error Addresses 3..400
Octets 1216..1247:	Spares, set to zero.

(ii) For Self Test Code = 1 (Fixed Pattern Test) the format is as follows:

Octets 1..1247 :	55 hex, but can be modified by changing parameter 7:3 of the ICT (Appendix A)

(iii) For Self Test Code = 2 (Watchdog Test) the format is as follows:

No Packets are generated in this self-test. The test is 'terminal' for the software, and causes an Instrument re-initialisation.

(iv) For Self Test Code = 3 (Motor Test) the format is as follows:

If position data stored:

Octet 1,2 :	Sample 1 position data (16 bits) for defined period (see below)
Octets 3..1246 :	Samples 2..623 position data for defined period
Octet 1247:	Test Identification word : see below.

623 samples are collected, starting at the COUNT value defined in the ICT (see Appendix A). COUNT = 0..1151; COUNT = 0 corresponds to start of Earth Scan period.

If current demand data stored:

Octet 1 :	Sample 1 (COUNT=0) current demand data (8 bits)
Octets 2..1152 :	Sample 2..1152 (COUNT=1..1151) current demand data (8 bits)
Octets 1153..1184 :	RDM current telemetry samples 1 to 32 (8 bits).
Octets 1185..1216 :	FDM current telemetry samples 1 to 32 (8 bits).
Octets 1217..1246 :	spare, set to zero.
Octet 1247:	Test Identification word : see below.

Octet 1247 : Test Identification Word:-

1 (MSB)	2	3	4	5	6	7	8 (LSB)
data_type	data_precision	motor	Profile_type	Profile		start_block	

data_type	0 : current demand data
	1 : position data
data_precision	N/A when data_type = current demand data
	0 : 16 bit precision
	1 : pseudo 18 bit precision
motor	0 : FDM
	1 : RDM
profile_type	as defined in ICT:
	0 : Profile Table
	1 : Constant Velocity / Fixed View
profile	as defined by SCT
	00..10 : Profiles 0,1,2
	11 : Manually loaded profile
start_block	Special case start_count values:
	00 : start count = 0 (ie. samples 1..623 = start of Earth View)
	01 : start count = 97 (ie. samples 98..720 = end of Earth View)
	10 : start count = 529 (ie. samples 530..1152 = end of Earth View + transitions)
	11 : start count not any of the above (defined by ICT)

(v) For Self Test Code = 4 (PRT Calibration Test) the format is as follows:

Octet 1,2	PRT 1 sample 1 (12 bits)
Octet 3,4	PRT 1 sample 2 (12 bits)
Octets 5..240	PRT 1 samples 3..120
Octets 241..480	PRT 2 samples 1..120
Octets 481..720	PRT 3 samples 1..120
Octets 721..960	PRT 4 samples 1..120
Octets 961..1200	PRT 5 samples 1..120
Octets 1201,1202	Calibration channel 1
Octets 1203,1204	Calibration channel 2
Octets 1205,1206	Calibration channel 3
Octets 1207..1247	Spares, set to zeros.

(vi) Self Test Code = 5: test undefined.

(vii) Self Test Code = 6: test undefined

(viii) Self Test Code = 7: test undefined

5.0 INTERNAL TELEMETRY

5.1 Switch Status Telemetry

Figures 5.1-1, 5.1-2 and 5.1-3 list the Switch Status Telemetry, which consists of Switch Closure (HL Commands verification), Bilevel Status (Steady State Commands verification) and BIM Register (BIM Register Commands verification) channels respectively.

MHS Channel Number	Parameter Name	Status	Tlm Source
1:1	Receiver Channel H1 On/Off	0=Off	Rx
1:2	Receiver Channel H1 Local Oscillator A/B selected	0=A	Rx
1:3	Receiver Channel H2 On/Off	0=Off	Rx
1:4	Receiver Channel H2 Local Oscillator A/B selected	0=A	Rx
1:5	Receiver Channels H3/H4 Frontend On/Off	0=Off	Rx
1:6	Receiver Channel H3/H4 Local Oscillator A/B selected	0=A	Rx
1:7	Receiver Channel H3 Backend On/Off	0=Off	Rx
1:8	Receiver Channel H4 Backend On/Off	0=Off	Rx
1:9	Receiver Channel H5 On/Off	0=Off	Rx
1:10	Receiver Channel H5 Local Oscillator A/B selected	0=A	Rx
1:11	RX CV On/Off	0=Off	EE

Figure 5.1-1 Switch Closure Telemetry Channels

MHS Channel Number	Parameter Name	Status	Tlm Source
2:1	Receiver Operational Heaters On/Off	0=Off	EE
2:2	Scan Mechanism Operational Heaters On/Off	0=Off	EE
2:3	Auxiliary Operational Heaters On/Off	0=Off	EE
2:4	Signal Processing Electronics/Scan Control Electronics On/Off	0=Off	EE

Figure 5.1-2 Bilevel Status Telemetry Channels

MHS Channel Number	Parameter Name	Status	Telemetry Source
3:1	SPE MUX CODE*	MSB	
3:2	SPE MUX CODE*		
3:3	SPE MUX CODE*	LSB	
3:4	RDM Zero Position Sensors A/B selected	0=A	EE
3:5	FDM Zero Position Sensors A/B selected	0=A	EE
3:6	RDM Motor Sensors A/B selected	0=A	EE
3:7	FDM Motor Sensors A/B selected	0=A	EE
3:8	RDM Motor Supply On/Off	0=Off	EE
3:9	FDM Motor Supply On/Off	0=Off	EE
3:10	RDM Motor Current Trip Enable/Disable Status	0=enabled	EE
3:11	FDM Motor Current Trip Enable/Disable Status	0=enabled	EE
3:12	RDM Motor Current Trip Status	0=trip detected	EE
3:13	FDM Motor Current Trip Status	0=trip detected	EE

* SPE MUX CODE
000=H1 connected to SPE6
001=H2 connected to SPE6
010=H3 connected to SPE6
011=SPE6 not used
100=H4 connected to SPE6
101=H5 connected to SPE6
110=SPE6 not used
111=SPE6 not used

Figure 5.1-3 BIM Register Telemetry Channels

5.2 Thermistor Telemetry

Figure 5.2-1 lists the thermistor telemetry channels for general monitoring of the temperature of instrument hardware.

MHS Channel Number	Telemetry Name	Source	Sub-commutation Code	Acquisition Time (note 1)
4:1	LO H1 Temperature (QBS1)	Rx	1	669
4:2	LO H2 Temperature (QBS2)	Rx	1	671
4:3	LO H3/4 Temperature (QBS3/4)	Rx	1	674
4:4	LO H5 Temperature (QBS5)	Rx	1	675
4:5	Mixer/LNA/Multiplexer H1 Temperature (DC1)	Rx	2	677
4:6	Mixer/LNA/Multiplexer H2 Temperature (DC2)	Rx	2	679
4:7	Mixer/LNA/Multiplexer H3/4 Temperature (DC3/4)	Rx	2	685
4:8	Mixer/LNA/Multiplexer H5 Temperature (DC5)	Rx	2	687
4:9	Quasi-optics Baseplate Temperature No.1 (Dichroic D1(A) or Polarisor(B))	Rx	3	690
4:10	Quasi-optics Baseplate Temperature No.2 (Dichroic D2(A) or Mirror(B))	Rx	3	691
4:11	IF Baseplate Temperature No.1 (Top connector cavity)	Rx	3	693
4:12	IF Baseplate Temperature No.2 (Relay Board)	Rx	3	695
4:13	Scan Mech. Core Temperature	SM	4	698
4:14	Scan Mech. HousingTemperature	SM	4	699
4:15	RDM SSHM Temperature	SM	4	701
4:16	FDM SSHM Temperature	SM	4	703
4:17	Structure 1 Temperature (-A edge, next to baseplate cutout)	Baseplate	5	706
4:18	Structure 2 Temperature (+A edge, inbetween Rx and SM)	Baseplate	5	707
4:19	Structure 3 Temperature (-V edge, inbetween EE and SM)	Baseplate	5	709
4:20	Processor Module Temperature	EE	6	711
4:21	Main DC/DC Converter Module Temperature	EE	6	714
4:22	SCE RDM Module temp	EE	6	722
4:23	SCE FDM Module temp	EE	6	724
4:24	RF DC/DC converter Module temp	EE	5	726

Figure 5.2-1 Thermistor Telemetry List

Note : Subcommutation code 7 is also used, see Table 5.4-1.
Note 1 : Acquisition Time is the time interval (in software real-time slots) between the start of the scan period and the acquisition of the telemetry channel. The absolute time at which a parameter is acquired is given by T = Packet Time Code + (Acquisition Time x 1/432).

The temperature telemetry monitoring and automatic mode switching based on temperature functions are described in Appendix B.

Refer to RD6 in order to convert the digital codes into engineering units, ie. temperature.

5.3 Analogue Telemetry

Figure 5.3-1 lists the analogue telemetry channels for the monitoring of current consumption.

MHS Channel Number	Command Name	Source	Acquisition Time (note 1)
5:1	RDM Motor Current	EE	728
5:2	FDM Motor Current	EE	730
5:3	EE+SM +5v current	EE	732
5:4	Receiver +8V current	EE	734
5:5	Receiver +15V current	EE	736
5:6	Receiver -15V current	EE	738

Figure 5.3-1 Analogue Telemetry List

Note: not all of these parameters are copied directly into the HK Telemetry Packet. Some are combined as described in section 4.2.2.1.

Note 1 : Acquisition Time is the time interval (in software real-time slots) between the start of the scan period and the acquisition of the telemetry channel. The absolute time at which a parameter is acquired is given by T = Packet Time Code + (Acquisition Time x 1/432).

Note: for current telemetry monitoring function, refer to Appendix B.

Refer toRD6 in order to convert the digital codes into engineering units, ie. current.

5.4 High Precision Temperature Telemetry (PRTs)

The high-precision temperature values are used to accurately monitor the On-Board Calibration Target. The values that are sub-commutated into the Housekeeping Telemetry packets are truncated to 8-bits, but the full 12-bit range is included in the Science Data packets. Figure 5.4-1 lists the PRT temperature telemetry channels.

MHS Channel Number	Parameter Name	Source	Sub-commutation Code	Acquisition Time (note 1)
6:1	PRT 1	OBCT	-	133
6:2	PRT 2	OBCT	7	263
6:3	PRT 3	OBCT	7	394
6:4	PRT 4	OBCT	7	523
6:5	PRT 5	OBCT	7	653
6:6	PRT CAL 1 (118Ω)	EE	-	860
6:7	PRT CAL 2 (95.3Ω)	EE	-	983
6:8	PRT CAL 3 (80.6Ω)	EE	-	1113

Figure 5.4-1 High Precision Temperature Telemetry

Note 1 : Acquisition Time is the time interval (in software real-time slots) between the start of the scan period and the acquisition of the telemetry channel. The absolute time at which a parameter is acquired is given by T = Packet Time Code + (Acquisition Time x 1/432).

Refer to RD6 in order to convert the digital codes into engineering units, ie. temperature.

6.0 INTERNAL COMMANDS

6.1 High Level Commands

Figure 6.1-1 lists the High Level Command channels (typically used for the control of latching relays).

MHS Channel Number	Command Name	Destination
1:1	H1 ON	Rx
1:2	H1 OFF	Rx
1:3	H1 Select LO A	Rx
1:4	H1 Select LO B	Rx
1:5	H2 ON	Rx
1:6	H2 OFF	Rx
1:7	H2 Select LO A	Rx
1:8	H2 Select LO B	Rx
1:9	H3/4 Frontend ON	Rx
1:10	H3/4 Frontend OFF	Rx
1:11	H3/4 Select LO A	Rx
1:12	H3/4 Select LO B	Rx
1:13	H3 Backend ON	Rx
1:14	H3 Backend OFF	Rx
1:15	H4 Backend ON	Rx
1:16	H4 Backend OFF	Rx
1:17	H5 ON	Rx
1:18	H5 OFF	Rx
1:19	H5 Select LO A	Rx
1:20	H5 Select LO B	Rx
1:21	RFCV ON	EE
1:22	RFCV OFF	EE
1:23	H1 Gain Reset	Rx
1:24	H1 Gain 1dB	Rx
1:25	H1 Gain 2dB	Rx
1:26	H2 Gain Reset	Rx
1:27	H2 Gain 1dB	Rx
1:28	H2 Gain 2dB	Rx
1:29	H3 Gain Reset	Rx
1:30	H3 Gain 1dB	Rx
1:31	H3 Gain 2dB	Rx
1:32	H4 Gain Reset	Rx
1:33	H4 Gain 1dB	Rx
1:34	H4 Gain 2dB	Rx
1:35	H5 Gain Reset	Rx
1:36	H5 Gain 1dB	Rx
1:37	H5 Gain 2dB	Rx

Figure 6.1-1 HL Command List

Channels 1 to 22 are self-explanatory ON/OFF and select A/B commands.

The 2 LSBs of the Gain Code (see Figure 4.3.2.1-5) report the position of latching relays which control the Receiver Channel Gain. The relay positions are controlled by the high level commands such that:-

- The 'Reset' command clears both bits of the gain code.
- The '1dB' command sets the LSB of the gain code.
- The '2dB' command sets the MSB of the gain code.

Often it will be possible to change to the desired gain with a single command, based upon the existing gain code. However, it is recommended that the Reset command is used to ensure the relays are in a known starting position. The following sequences will guarantee a given gain:-

- To set gain to 0dB: issue 'Reset'
- To set gain to 1dB: issue 'Reset' then '1dB'
- To set gain to 2dB: issue 'Reset' then '2dB'
- To set gain to 3dB: issue '1dB' and '2dB' (any order, 'Reset' is not necessary).

MHS Command Channel Number	Switch Status Telemetry Verification	Current Consumption Telemetry Verification
1:1	1:1	5:4,5:5,5:6
1:2	1:1	5:4,5:5,5:6
1:3	1:2	5:4
1:4	1:2	5:4
1:5	1:3	5:4,5:5,5:6
1:6	1:3	5:4,5:5,5:6
1:7	1:4	5:4
1:8	1:4	5:4
1:9	1:5	5:4
1:10	1:5	5:4
1:11	1:6	5:4
1:12	1:6	5:4
1:13	1:7	5:5,5:6
1:14	1:7	5:5,5:6
1:15	1:8	5:5,5:6
1:16	1:8	5:5,5:6
1:17	1:9	5:4,5:5,5:6
1:18	1:9	5:4,5:5,5:6
1:19	1:10	5:4
1:20	1:10	5:4
1:21	1:11	5:4,5:5,5:6
1:22	1:11	5:4,5:5,5:6
1:23-1:37	see note	N/A

Figure 6.1-2 HL Command Verification

Note: for current consumption telemetry verification, refer to Appendix B.

Note: gain verification is achieved via the 'Gain Code' in the Science Data Packet and by the 'DC Offset Error' flag in the Fault Code of the HK Telemetry Packet. The MINOS checks the dynamic range of the radiometric data and sets the flag in the Fault Code if the gain needs changing.

6.2 Steady State Commands

Figure 6.2-1 lists the steady state commands for the control of steady state switches (typically power FETs).

MHS Channel Number	Command Name	Command Levels	Destin-ation
2:1	Receiver Operational Heaters ON/OFF	0=Off	EE
2:2	SM Operational Heaters ON/OFF	0=Off	EE
2:3	Aux Operational Heaters ON/OFF	0=Off	EE
2:4	SPE/SCE ON/OFF	0=Off	EE

Figure 6.2-1 Steady State Command List

MHS Command Channel Number	Switch Status Telemetry Verification	Current Consumption Telemetry Verification
2:1	2:1	N/A
2:2	2:2	N/A
2:3	2:3	N/A
2:4	2:4	5:3

Figure 6.2-1 Steady State Command Verification

Note: for monitoring of current telemetry, in response to switch status changes, refer to Appendix B.

6.3 BIM Register Commands

Figure 6.3-1 lists the switch commands which are implemented within the EE using the Inter-Module Bus (BIM).

MHS Channel Number	Command Name	Command Level
3:1	SPE Mux Code	MSB
3:2	SPE Mux Code	
3:3	SPE Mux Code	LSB
3:4	Select RDM Zero Position Sensors A/B	0=A
3:5	Select FDM Zero Position Sensors A/B	0=A
3:6	Select RDM Motor Sensors A/B	0=A
3:7	Select FDM Motor Sensors A/B	0=A
3:8	RDM Motor Supply ON/OFF	0=Off
3:9	FDM Motor Supply ON/OFF	0=Off
3:10	RDM Motor Current Trip enable/disable	0=enabled
3:11	FDM Motor Current Trip enable/disable	0=enabled

Figure 6.3-1 BIM Register Command List

The meaning of 3:1 to 3:3 is the same as that given in Figure 5.1-3.

MHS Command Channel Number	Switch Status Telemetry Verification	Current Consumption Telemetry Verification
3:1	3:1	N/A
3:2	3:2	N/A
3:3	3:3	N/A
3:4	3:4	N/A
3:5	3:5	N/A
3:6	3:6	N/A
3:7	3:7	N/A
3:8	3:8	5:1
3:9	3:9	5:2
3:10	3:10	N/A
3:11	3:11	N/A

Figure 6.3-1 BIM Register Command Verification

Note: for monitoring of current telemetry in response to switch status changes, refer to Appendix B.

APPENDIX A : INSTRUMENT CONFIGURATION TABLE (ICT)

The ICT defines parameters related to the ON/OFF and redundancy configuration of the Instrument. It also defines parameters used by the Self-Test modes.

Table Reference = 0

Data Ref	Octet	Parameter Name	Definition	Default (in PROM)		Verification (read memory)	
				Value (hex)	Value (Engineering)	Address (hex)	Format
0	1	Mode Change Control	00 hex = manual FF hex = auto	00	Manual	14FDF (MS)	8 bit integer
	2	Operational Heater Control	00 hex = manual FF hex = auto	00	Manual	14FDF (LS)	8 bit integer
	3	DC Offset Control	00 hex = manual FF hex = auto	00	Manual	14FE0 (MS)	8 bit integer
	4	Telemetry Checking Control	bit 0 (MSB) : Thermistor checking bit 1 : Switch status checking bit 2 : Current Tlm checking bits 3..7(LSB) : unused 0 = checking OFF 1 = checking ON	E0	All Tlm checking on	14FE0 (LS)	8 bit flags
1	1	HL Commands 1	1:1 (MSB) to 1:8 (LSB)	AA	H1 & H2 on LO A	14FE1 (MS)	8 bit flags
	2	HL Commands 2	1:9 (MSB) to 1:16 (LSB)	AA	H3 & H4 on LO A	14FE1 (LS)	8 bit flags
	3	HL Commands 3	1:17 (MSB) to 1:24 (LSB)	AA	H5 on, LO A, RFCV On, H1 Gain =0dB	14FE2 (MS)	8 bit flags
	4	HL Commands 4	1:25 (MSB) to 1:32 (LSB)	49	H2, H3, H4 Gains = 0dB	14FE2 (LS)	8 bit flags
2	1	HL Commands 5	1:33 (MSB) to 1:37 (3 LSBs unused)	20	H5 Gain = 0dB	14FE3 (MS)	8 bit flags
	2	Rx Heater Redundancy Selection	bit 0 (MSB) = 0 : use Rx Op Htrs bit 0 = 1 : use Aux Op Htrs bits 1 to 15 : unused	00	Use Rx Heaters	14FE3 (LS)	8 bit flags
	3	unused	-	00	N/A	14FE4 (MS)	N/A

Data Ref	Octet	Parameter Name	Definition	Default (in PROM)		Verification (read memory)	
	4	unused	-	00	N/A	14FE4 (LS)	N/A
3	1	BIM Commands 1	3:1 (MSB) to 3:8 (LSB)	E1	SPE nominal RDM motor on, sensors side A	14FE5 (MS)	8 bit flags
	2	BIM commands 2	3:9 (MSB) to 3:11 (5 LSBs not used)	80	FDM motor on Sensors side A	14FE5 (LS)	8 bit flags
	3	unused	-	00	N/A	14FE6 (MS)	N/A
	4	unused	-	00	N/A	14FE6 (LS)	N/A
4	1	PIE Memory Test	00 hex = do test FF hex = do not do test	00	Do test	14FE7 (MS)	8 bit integer
	2	PIE Processor Test	00 hex = do test FF hex = do not do test	00	Do test	14FE7 (LS)	8 bit integer
	3	PIE TMTC Test	00 hex = do test FF hex = do not do test	00	Do test	14FE8 (MS)	8 bit integer
	4	unused	-	00	N/A	14FE8 (LS)	N/A
5	1	Memory Self Test	Start Address (A23..16)	***01***	***Start address = 013004*** ***(Scan Profile Table)***	14FE9 (MS)	24 bit integer
	2	Memory Self Test	Start Address (A15..8)	***30***		14FE9 (LS)	
	3	Memory Self Test	Start Address (A7..0)	***04***		14FEA (MS)	
	4	Memory Self Test	End Address (A23..16)	01	***End Address = 014683***	14FEA (LS)	24 bit integer
6	1	Memory Self Test	End Address (A15..8)	***46***		14FEB (MS)	
	2	Memory Self Test	End Address (A7..0)	***83***		14FEB (LS)	
	3	Memory Self Test	Test Pattern (MS)	AA	Test Pattern = AAAA	14FEC (MS)	16 bit integer
	4	Memory Self Test	Test Pattern (LS)	AA		14FEC (LS)	
7	1	Memory Self Test	No. of errors (MS)	00	No of errors =1	14FED (MS)	16 bit integer
	2	Memory Self Test	No. of errors (LS)	01		14FED (LS)	
	3	Fixed Pattern Self Test	Data Pattern	55	Test Pattern = 55	14FEE (MS)	8 bit integer
	4	unused	-	00	N/A	14FEE (LS)	N/A

Data Ref	Octet	Parameter Name	Definition	Default (in PROM)		Verification (read memory)	
8	1	Motor Test	bit 0 (MSB): RDM drive enable (1) / disable (0) bit 1: FDM drive enable (1) / disable (0) bit 2: Store RDM (1) / FDM (0) data bit 3: Store position (1) / current demand (0) data bit 4: algorithm type: 0 = scan algorithm 1 = see bit 6 bit 5 : Position Data Precision 0 = 16 bit precision 1 = pseudo 18 bit precision bit 6 : only applies if bit 4 is set 0 = constant vel. algorithm 1 = fixed view algorithm bit 7 : unused	F0	RDM Enabled FDM Enabled Store RDM Data Store Position Data Scan Algorithm 16 bit precision	14FEF (MS)	8 bit flags
	2	Motor Test	Start COUNT (MS)	00	Start Count = 0	14FEF (LS)	16 bit integer
	3	Motor Test	Start COUNT (LS)	00		14FF0 (MS)	
	4	Motor Test	Constant velocity value 1 LSB = 5°/sec	0C	60 deg/sec	14FF0 (LS)	8 bit integer

APPENDIX B : TELEMETRY LIMITS TABLE (TLT)

The TLT defines limits against which telemetry channels are compared as part of the normal health monitoring of the Instrument. It also defines parameters which control the automatic mode switching functions (if enabled) and automatic heater control (if enabled).

Monitoring is performed on thermistor telemetry, current telemetry and switch status telemetry. The TLT defines the limits for thermistor and current telemetries.

Two levels of limits are defined. Firstly, 'warning' limits are levels which represent the expected worst case boundaries for each telemetry channel. If a channel goes outside of the warning limits, an error flag is raised in the Fault Code field of the HK Telemetry Packet, and the Instrument continues to operate in the same mode. Secondly, 'fault' limits are levels which represent the extreme values for which safe operation of the Instrument can continue. If a channel goes outside the fault limits, an error flag is raised in the Fault Code field of the HK Telemetry Packet and the instrument switches to Fault Mode. In Fault Mode, the necessary actions are taken to minimise the risk of damage to the instrument.

An upper level and a lower level are defined for both warning limits and fault limits, and for both temperature and current telemetry. The actions taken for exceeding either the upper or lower limit on either type of telemetry are the same. (Note: for thermistors, the upper limit defines the upper resistance threshold, which corresponds to the lower temperature threshold. This is because the thermistors have a negative temperature coefficient and the telemetry value is proportional to thermistor resistance.)

The warning and/or fault limit monitoring can be effectively 'disabled' by setting the upper and lower limits to FSR and zero respectively. In addition, parameter 0:4 of the ICT (Appendix A) allows global enabling/disabling of monitoring on each type of telemetry.

The TLT also defines temperature levels at which automatic mode transitions (if enabled by ICT parameter 0:1) occur. Levels are given for each temperature channel, and for the Power-on to Warm-up transition (tr1) and Warm-up to Standby transition (tr2). When all temperature telemetry channels exceed the given levels, the Instrument automatically switches to the next mode. In addition, timeout durations are given for each automatic transition. If the timeout period is exceeded then the Instrument automatically switches mode, irrespective of the telemetry values.

Automatic control of the Operational Heaters is achieved (when enabled by ICT parameter 0:2) using the upper and lower warning temperature limits. If any temperature of an equipment falls below the lower warning level then the corresponding heater is switched on. If any temperature of an equipment rises above the upper warning level then the corresponding heater is switched off. If one channel of an equipment is above the upper limit, and another channel of the same equipment is below the lower limit, then no action is taken (a fault flag will have been raised and the ground must take any appropriate action).

Note: no limit monitoring or automatic mode changes are based on the OBCT temperatures. These telemetry channels are only used for scientific data analysis.

Telemetry Limits Table (TLT)

Table Ref: 1

All temperature and current parameters are digital codes (ie. not engineering units) which correspond directly to the digital telemetry code as reported in the telemetry data in the HK Telemetry Packet and Science Data Packet.

NOTE: The 'high' limit refers to the upper limit of resistance of the thermistor, which corresponds to the lower temperature limit. (Thermistors have negative temperature coefficient.)

Refer to more notes at end of table.

Data Ref	Octet	Name (see notes at end of table)	Default (in PROM)		Verification (read memory)	
			Value (hex)	Value (Engineering)	Address (hex)	Format
0	1	Unused	N/A	N/A	N/A	N/A
	2	Unused	N/A	N/A	N/A	N/A
	3	Unused	N/A	N/A	N/A	N/A
	4	Unused	N/A	N/A	N/A	N/A
1	1	T1_m1_fault_high	FE	-35.5°C	10500 (MS)	8 bit integer
	2	T1_m1_warn_high	FD	-33.4°C	10500 (LS)	8 bit integer
	3	T1_m1_warn_low	42	+55°C	10501 (MS)	8 bit integer
	4	T1_m1_fault_low	3A	+60°C	10501 (LS)	8 bit integer
2	1	T2_m1_fault_high	FE	-35.5°C	10502 (MS)	8 bit integer
	2	T2_m1_warn_high	FD	-33.4°C	10502 (LS)	8 bit integer
	3	T2_m1_warn_low	42	+55°C	10503 (MS)	8 bit integer
	4	T2_m1_fault_low	3A	+60°C	10503 (LS)	8 bit integer
3	1	T3_m1_fault_high	FE	-35.5°C	10504 (MS)	8 bit integer
	2	T3_m1_warn_high	FD	-33.4°C	10504 (LS)	8 bit integer
	3	T3_m1_warn_low	42	+55°C	10505 (MS)	8 bit integer
	4	T3_m1_fault_low	3A	+60°C	10505(LS)	8 bit integer
4	1	T4_m1_fault_high	FE	-35.5°C	10506 (MS)	8 bit integer
	2	T4_m1_warn_high	FD	-33.4°C	10506 (LS)	8 bit integer
	3	T4_m1_warn_low	42	+55°C	10507 (MS)	8 bit integer
	4	T4_m1_fault_low	3A	+60°C	10507 (LS)	8 bit integer

Data Ref	Octet	Name (see notes at end of table)	Default (in PROM)		Verification (read memory)	
5	1	T5_m1_fault_high	FE	-35.5°C	10508 (MS)	8 bit integer
	2	T5_m1_warn_high	FD	-33.4°C	10508 (LS)	8 bit integer
	3	T5_m1_warn_low	42	+55°C	10509 (MS)	8 bit integer
	4	T5_m1_fault_low	3A	+60°C	10509 (LS)	8 bit integer
6	1	T6_m1_fault_high	FE	-35.5°C	1050A (MS)	8 bit integer
	2	T6_m1_warn_high	FD	-33.4°C	1050A (LS)	8 bit integer
	3	T6_m1_warn_low	42	+55°C	1050B (MS)	8 bit integer
	4	T6_m1_fault_low	3A	+60°C	1050B (LS)	8 bit integer
7	1	T7_m1_fault_high	FE	-35.5°C	1050C (MS)	8 bit integer
	2	T7_m1_warn_high	FD	-33.4°C	1050C (LS)	8 bit integer
	3	T7_m1_warn_low	42	+55°C	1050D (MS)	8 bit integer
	4	T7_m1_fault_low	3A	+60°C	1050D (LS)	8 bit integer
8	1	T8_m1_fault_high	FE	-35.5°C	1050E (MS)	8 bit integer
	2	T8_m1_warn_high	FD	-33.4°C	1050E (LS)	8 bit integer
	3	T8_m1_warn_low	42	+55°C	1050F (MS)	8 bit integer
	4	T8_m1_fault_low	3A	+60°C	1050F (LS)	8 bit integer
9	1	T9_m1_fault_high	FE	-35.5°C	10510 (MS)	8 bit integer
	2	T9_m1_warn_high	FD	-33.4°C	10510 (LS)	8 bit integer
	3	T9_m1_warn_low	42	+55°C	10511 (MS)	8 bit integer
	4	T9_m1_fault_low	3A	+60°C	10511 (LS)	8 bit integer
10	1	T10_m1_fault_high	FE	-35.5°C	10512 (MS)	8 bit integer
	2	T10_m1_warn_high	FD	-33.4°C	10512 (LS)	8 bit integer
	3	T10_m1_warn_low	42	+55°C	10513 (MS)	8 bit integer
	4	T10_m1_fault_low	3A	+60°C	10513 (LS)	8 bit integer
11	1	T11_m1_fault_high	FE	-35.5°C	10514 (MS)	8 bit integer
	2	T11_m1_warn_high	FD	-33.4°C	10514 (LS)	8 bit integer
	3	T11_m1_warn_low	42	+55°C	10515 (MS)	8 bit integer
	4	T11_m1_fault_low	3A	+60°C	10515 (LS)	8 bit integer
12	1	T12_m1_fault_high	FE	-35.5°C	10516 (MS)	8 bit integer
	2	T12_m1_warn_high	FD	-33.4°C	10516 (LS)	8 bit integer
	3	T12_m1_warn_low	42	+55°C	10517 (MS)	8 bit integer
	4	T12_m1_fault_low	3A	+60°C	10517 (LS)	8 bit integer
13	1	T13_m1_fault_high	FE	-35.5°C	10518 (MS)	8 bit integer

Data Ref	Octet	Name (see notes at end of table)	Default (in PROM)		Verification (read memory)	
	2	T13_m1_warn_high	FD	-33.4°C	10518 (LS)	8 bit integer
	3	T13_m1_warn_low	55	+45°C	10519 (MS)	8 bit integer
	4	T13_m1_fault_low	4B	+50°C	10519 (LS)	8 bit integer
14	1	T14_m1_fault_high	FE	-35.5°C	1051A (MS)	8 bit integer
	2	T14_m1_warn_high	FD	-33.4°C	1051A (LS)	8 bit integer
	3	T14_m1_warn_low	55	+45°C	1051B (MS)	8 bit integer
	4	T14_m1_fault_low	4B	+50°C	1051B (LS)	8 bit integer
15	1	T15_m1_fault_high	FE	-35.5°C	1051C (MS)	8 bit integer
	2	T15_m1_warn_high	FD	-33.4°C	1051C (LS)	8 bit integer
	3	T15_m1_warn_low	55	+45°C	1051D (MS)	8 bit integer
	4	T15_m1_fault_low	4B	+50°C	1051D (LS)	8 bit integer
16	1	T16_m1_fault_high	FE	-35.5°C	1051E (MS)	8 bit integer
	2	T16_m1_warn_high	FD	-33.4°C	1051E (LS)	8 bit integer
	3	T16_m1_warn_low	55	+45°C	1051F (MS)	8 bit integer
	4	T16_m1_fault_low	4B	+50°C	1051F (LS)	8 bit integer
17	1	T17_m1_fault_high	FE	-35.5°C	10520 (MS)	8 bit integer
	2	T17_m1_warn_high	FD	-33.4°C	10520 (LS)	8 bit integer
	3	T17_m1_warn_low	42	+55°C	10521 (MS)	8 bit integer
	4	T17_m1_fault_low	3A	+60°C	10521 (LS)	8 bit integer
18	1	T18_m1_fault_high	FE	-35.5°C	10522 (MS)	8 bit integer
	2	T18_m1_warn_high	FD	-33.4°C	10522 (LS)	8 bit integer
	3	T18_m1_warn_low	42	+55°C	10523 (MS)	8 bit integer
	4	T18_m1_fault_low	3A	+60°C	10523 (LS)	8 bit integer
19	1	T19_m1_fault_high	FE	-35.5°C	10524 (MS)	8 bit integer
	2	T19_m1_warn_high	FD	-33.4°C	10524 (LS)	8 bit integer
	3	T19_m1_warn_low	42	+55°C	10525 (MS)	8 bit integer
	4	T19_m1_fault_low	3A	+60°C	10525 (LS)	8 bit integer
20	1	T20_m1_fault_high	F6	-25°C	10526 (MS)	8 bit integer
	2	T20_m1_warn_high	EC	-20°C	10526 (LS)	8 bit integer
	3	T20_m1_warn_low	33	+65°C	10527 (MS)	8 bit integer
	4	T20_m1_fault_low	28	+75°C	10527 (LS)	8 bit integer
21	1	T21_m1_fault_high	F6	-25°C	10528 (MS)	8 bit integer
	2	T21_m1_warn_high	EC	-20°C	10528 (LS)	8 bit integer

Data Ref	Octet	Name (see notes at end of table)	Default (in PROM)		Verification (read memory)	
	3	T21_m1_warn_low	30	+67°C	10529 (MS)	8 bit integer
	4	T21_m1_fault_low	25	+77°C	10529 (LS)	8 bit integer
22	1	T22_m1_fault_high	F6	-25°C	1052A (MS)	8 bit integer
	2	T22_m1_warn_high	EC	-20°C	1052A (LS)	8 bit integer
	3	T22_m1_warn_low	31	+66°C	1052B (MS)	8 bit integer
	4	T22_m1_fault_low	26	+76°C	1052B (LS)	8 bit integer
23	1	T23_m1_fault_high	F6	-25°C	1052C (MS)	8 bit integer
	2	T23_m1_warn_high	EC	-20°C	1052C (LS)	8 bit integer
	3	T23_m1_warn_low	31	+66°C	1052D (MS)	8 bit integer
	4	T23_m1_fault_low	26	+76°C	1052D (LS)	8 bit integer
24	1	T24_m1_fault_high	F6	-25°C	1052E (MS)	8 bit integer
	2	T24_m1_warn_high	EC	-20°C	1052E (LS)	8 bit integer
	3	T24_m1_warn_low	3E	+57°C	1052F (MS)	8 bit integer
	4	T24_m1_fault_low	30	+67°C	1052F (LS)	8 bit integer
25	1	T1_m2_fault_high	F6	-25°C	10530 (MS)	8 bit integer
	2	T1_m2_warn_high	EC	-20°C	10530 (LS)	8 bit integer
	3	T1_m2_warn_low	55	+45°C	10531 (MS)	8 bit integer
	4	T1_m2_fault_low	4B	+50°C	10531 (LS)	8 bit integer
26	1	T2_m2_fault_high	F6	-25°C	10532 (MS)	8 bit integer
	2	T2_m2_warn_high	EC	-20°C	10532 (LS)	8 bit integer
	3	T2_m2_warn_low	55	+45°C	10533 (MS)	8 bit integer
	4	T2_m2_fault_low	4B	+50°C	10533 (LS)	8 bit integer
27	1	T3_m2_fault_high	F6	-25°C	10534 (MS)	8 bit integer
	2	T3_m2_warn_high	EC	-20°C	10534 (LS)	8 bit integer
	3	T3_m2_warn_low	55	+45°C	10535 (MS)	8 bit integer
	4	T3_m2_fault_low	4B	+50°C	10535 (LS)	8 bit integer
28	1	T4_m2_fault_high	F6	-25°C	10536 (MS)	8 bit integer
	2	T4_m2_warn_high	EC	-20°C	10536 (LS)	8 bit integer
	3	T4_m2_warn_low	55	+45°C	10537 (MS)	8 bit integer
	4	T4_m2_fault_low	4B	+50°C	10537 (LS)	8 bit integer
29	1	T5_m2_fault_high	F6	-25°C	10538 (MS)	8 bit integer
	2	T5_m2_warn_high	EC	-20°C	10538 (LS)	8 bit integer
	3	T5_m2_warn_low	55	+45°C	10539 (MS)	8 bit integer

Data Ref	Octet	Name (see notes at end of table)	Default (in PROM)		Verification (read memory)	
	4	T5_m2_fault_low	4B	+50°C	10539 (LS)	8 bit integer
30	1	T6_m2_fault_high	F6	-25°C	1053A (MS)	8 bit integer
	2	T6_m2_warn_high	EC	-20°C	1053A (LS)	8 bit integer
	3	T6_m2_warn_low	55	+45°C	1053B (MS)	8 bit integer
	4	T6_m2_fault_low	4B	+50°C	1053B (LS)	8 bit integer
31	1	T7_m2_fault_high	F6	-25°C	1053C (MS)	8 bit integer
	2	T7_m2_warn_high	EC	-20°C	1053C (LS)	8 bit integer
	3	T7_m2_warn_low	55	+45°C	1053D (MS)	8 bit integer
	4	T7_m2_fault_low	4B	+50°C	1053D (LS)	8 bit integer
32	1	T8_m2_fault_high	F6	-25°C	1053E (MS)	8 bit integer
	2	T8_m2_warn_high	EC	-20°C	1053E (LS)	8 bit integer
	3	T8_m2_warn_low	55	+45°C	1053F (MS)	8 bit integer
	4	T8_m2_fault_low	4B	+50°C	1053F (LS)	8 bit integer
33	1	T9_m2_fault_high	F6	-25°C	10540 (MS)	8 bit integer
	2	T9_m2_warn_high	EC	-20°C	10540 (LS)	8 bit integer
	3	T9_m2_warn_low	55	+45°C	10541 (MS)	8 bit integer
	4	T9_m2_fault_low	4B	+50°C	10541 (LS)	8 bit integer
34	1	T10_m2_fault_high	F6	-25°C	10542 (MS)	8 bit integer
	2	T10_m2_warn_high	EC	-20°C	10542 (LS)	8 bit integer
	3	T10_m2_warn_low	55	+45°C	10543 (MS)	8 bit integer
	4	T10_m2_fault_low	4B	+50°C	10543 (LS)	8 bit integer
35	1	T11_m2_fault_high	F6	-25°C	10544 (MS)	8 bit integer
	2	T11_m2_warn_high	EC	-20°C	10544 (LS)	8 bit integer
	3	T11_m2_warn_low	55	+45°C	10545 (MS)	8 bit integer
	4	T11_m2_fault_low	4B	+50°C	10545 (LS)	8 bit integer
36	1	T12_m2_fault_high	F6	-25°C	10546 (MS)	8 bit integer
	2	T12_m2_warn_high	EC	-20°C	10546 (LS)	8 bit integer
	3	T12_m2_warn_low	55	+45°C	10547 (MS)	8 bit integer
	4	T12_m2_fault_low	4B	+50°C	10547 (LS)	8 bit integer
37	1	T13_m2_fault_high	FE	-40°C	10548 (MS)	8 bit integer
	2	T13_m2_warn_high	FD	-35°C	10548 (LS)	8 bit integer
	3	T13_m2_warn_low	55	+45°C	10549 (MS)	8 bit integer
	4	T13_m2_fault_low	4B	+50°C	10549 (LS)	8 bit integer

Data Ref	Octet	Name (see notes at end of table)	Default (in PROM)		Verification (read memory)	
38	1	T14_m2_fault_high	FE	-40°C	1054A (MS)	8 bit integer
	2	T14_m2_warn_high	FD	-35°C	1054A (LS)	8 bit integer
	3	T14_m2_warn_low	55	+45°C	1054B (MS)	8 bit integer
	4	T14_m2_fault_low	4B	+50°C	1054B (LS)	8 bit integer
39	1	T15_m2_fault_high	FE	-40°C	1054C (MS)	8 bit integer
	2	T15_m2_warn_high	FD	-35°C	1054C (LS)	8 bit integer
	3	T15_m2_warn_low	55	+45°C	1054D (MS)	8 bit integer
	4	T15_m2_fault_low	4B	+50°C	1054D (LS)	8 bit integer
40	1	T16_m2_fault_high	FE	-40°C	1054E (MS)	8 bit integer
	2	T16_m2_warn_high	FD	-35°C	1054E (LS)	8 bit integer
	3	T16_m2_warn_low	55	+45°C	1054F (MS)	8 bit integer
	4	T16_m2_fault_low	4B	+50°C	1054F (LS)	8 bit integer
41	1	T17_m2_fault_high	FE	-40°C	10550 (MS)	8 bit integer
	2	T17_m2_warn_high	FD	-35°C	10550 (LS)	8 bit integer
	3	T17_m2_warn_low	42	+55°C	10551 (MS)	8 bit integer
	4	T17_m2_fault_low	3A	+60°C	10551 (LS)	8 bit integer
42	1	T18_m2_fault_high	FE	-40°C	10552 (MS)	8 bit integer
	2	T18_m2_warn_high	FD	-35°C	10552 (LS)	8 bit integer
	3	T18_m2_warn_low	42	+55°C	10553 (MS)	8 bit integer
	4	T18_m2_fault_low	3A	+60°C	10553 (LS)	8 bit integer
43	1	T19_m2_fault_high	FE	-40°C	10554 (MS)	8 bit integer
	2	T19_m2_warn_high	FD	-35°C	10554 (LS)	8 bit integer
	3	T19_m2_warn_low	42	+55°C	10555 (MS)	8 bit integer
	4	T19_m2_fault_low	3A	+60°C	10555 (LS)	8 bit integer
44	1	T20_m2_fault_high	F6	-25°C	10556 (MS)	8 bit integer
	2	T20_m2_warn_high	EC	-20°C	10556 (LS)	8 bit integer
	3	T20_m2_warn_low	33	+65°C	10557 (MS)	8 bit integer
	4	T20_m2_fault_low	28	+75°C	10557 (LS)	8 bit integer
45	1	T21_m2_fault_high	F6	-25°C	10558 (MS)	8 bit integer
	2	T21_m2_warn_high	EC	-20°C	10558 (LS)	8 bit integer
	3	T21_m2_warn_low	30	+67°C	10559 (MS)	8 bit integer
	4	T21_m2_fault_low	25	+77°C	10559 (LS)	8 bit integer
46	1	T22_m2_fault_high	F6	-25°C	1055A (MS)	8 bit integer

Data Ref	Octet	Name (see notes at end of table)	Default (in PROM)		Verification (read memory)	
	2	T22_m2_warn_high	EC	-20°C	1055A (LS)	8 bit integer
	3	T22_m2_warn_low	31	+66°C	1055B (MS)	8 bit integer
	4	T22_m2_fault_low	26	+76°C	1055B (LS)	8 bit integer
47	1	T23_m2_fault_high	F6	-25°C	1055C (MS)	8 bit integer
	2	T23_m2_warn_high	EC	-20°C	1055C (LS)	8 bit integer
	3	T23_m2_warn_low	31	+66°C	1055D (MS)	8 bit integer
	4	T23_m2_fault_low	26	+76°C	1055D (LS)	8 bit integer
48	1	T24_m2_fault_high	F6	-25°C	1055E (MS)	8 bit integer
	2	T24_m2_warn_high	EC	-20°C	1055E (LS)	8 bit integer
	3	T24_m2_warn_low	3E	+57°C	1055F (MS)	8 bit integer
	4	T24_m2_fault_low	30	+67°C	1055F (LS)	8 bit integer
49	1	T1_m3_fault_high	AD	+10°C	10560 (MS)	8 bit integer
	2	T1_m3_warn_high	A1	+15°C	10560 (LS)	8 bit integer
	3	T1_m3_warn_low	6C	+35°C	10561 (MS)	8 bit integer
	4	T1_m3_fault_low	60	+40°C	10561 (LS)	8 bit integer
50	1	T2_m3_fault_high	AD	+10°C	10562 (MS)	8 bit integer
	2	T2_m3_warn_high	A1	+15°C	10562 (LS)	8 bit integer
	3	T2_m3_warn_low	6C	+35°C	10563 (MS)	8 bit integer
	4	T2_m3_fault_low	60	+40°C	10563 (LS)	8 bit integer
51	1	T3_m3_fault_high	AD	+10°C	10564 (MS)	8 bit integer
	2	T3_m3_warn_high	A1	+15°C	10564 (LS)	8 bit integer
	3	T3_m3_warn_low	6C	+35°C	10565 (MS)	8 bit integer
	4	T3_m3_fault_low	60	+40°C	10565 (LS)	8 bit integer
52	1	T4_m3_fault_high	AD	+10°C	10566 (MS)	8 bit integer
	2	T4_m3_warn_high	A1	+15°C	10566 (LS)	8 bit integer
	3	T4_m3_warn_low	6C	+35°C	10567 (MS)	8 bit integer
	4	T4_m3_fault_low	60	+40°C	10567 (LS)	8 bit integer
53	1	T5_m3_fault_high	AD	+10°C	10568 (MS)	8 bit integer
	2	T5_m3_warn_high	A1	+15°C	10568 (LS)	8 bit integer
	3	T5_m3_warn_low	6C	+35°C	10569 (MS)	8 bit integer
	4	T5_m3_fault_low	60	+40°C	10569 (LS)	8 bit integer
54	1	T6_m3_fault_high	AD	+10°C	1056A (MS)	8 bit integer
	2	T6_m3_warn_high	A1	+15°C	1056A (LS)	8 bit integer

Data Ref	Octet	Name (see notes at end of table)	Default (in PROM)		Verification (read memory)	
	3	T6_m3_warn_low	6C	+35°C	1056B (MS)	8 bit integer
	4	T6_m3_fault_low	60	+40°C	1056B (LS)	8 bit integer
55	1	T7_m3_fault_high	AD	+10°C	1056C (MS)	8 bit integer
	2	T7_m3_warn_high	A1	+15°C	1056C (LS)	8 bit integer
	3	T7_m3_warn_low	6C	+35°C	1056D (MS)	8 bit integer
	4	T7_m3_fault_low	60	+40°C	1056D (LS)	8 bit integer
56	1	T8_m3_fault_high	AD	+10°C	1056E (MS)	8 bit integer
	2	T8_m3_warn_high	A1	+15°C	1056E (LS)	8 bit integer
	3	T8_m3_warn_low	6C	+35°C	1056F (MS)	8 bit integer
	4	T8_m3_fault_low	60	+40°C	1056F (LS)	8 bit integer
57	1	T9_m3_fault_high	AD	+10°C	10570 (MS)	8 bit integer
	2	T9_m3_warn_high	A1	+15°C	10570 (LS)	8 bit integer
	3	T9_m3_warn_low	6C	+35°C	10571 (MS)	8 bit integer
	4	T9_m3_fault_low	60	+40°C	10571 (LS)	8 bit integer
58	1	T10_m3_fault_high	AD	+10°C	10572 (MS)	8 bit integer
	2	T10_m3_warn_high	A1	+15°C	10572 (LS)	8 bit integer
	3	T10_m3_warn_low	6C	+35°C	10573 (MS)	8 bit integer
	4	T10_m3_fault_low	60	+40°C	10573 (LS)	8 bit integer
59	1	T11_m3_fault_high	AD	+10°C	10574 (MS)	8 bit integer
	2	T11_m3_warn_high	A1	+15°C	10574 (LS)	8 bit integer
	3	T11_m3_warn_low	6C	+35°C	10575 (MS)	8 bit integer
	4	T11_m3_fault_low	60	+40°C	10575 (LS)	8 bit integer
60	1	T12_m3_fault_high	AD	+10°C	10576 (MS)	8 bit integer
	2	T12_m3_warn_high	A1	+15°C	10576 (LS)	8 bit integer
	3	T12_m3_warn_low	6C	+35°C	10577 (MS)	8 bit integer
	4	T12_m3_fault_low	60	+40°C	10577 (LS)	8 bit integer
61	1	T13_m3_fault_high	DF	-10°C	10578 (MS)	8 bit integer
	2	T13_m3_warn_high	D3	-5°C	10578 (LS)	8 bit integer
	3	T13_m3_warn_low	55	+45°C	10579 (MS)	8 bit integer
	4	T13_m3_fault_low	4B	+50°C	10579 (LS)	8 bit integer
62	1	T14_m3_fault_high	DF	-10°C	1057A (MS)	8 bit integer
	2	T14_m3_warn_high	D3	-5°C	1057A (LS)	8 bit integer
	3	T14_m3_warn_low	55	+45°C	1057B (MS)	8 bit integer

Data Ref	Octet	Name (see notes at end of table)	Default (in PROM)		Verification (read memory)	
	4	T14_m3_fault_low	4B	+50°C	1057B (LS)	8 bit integer
63	1	T15_m3_fault_high	DF	-10°C	1057C (MS)	8 bit integer
	2	T15_m3_warn_high	D3	-5°C	1057C (LS)	8 bit integer
	3	T15_m3_warn_low	55	+45°C	1057D (MS)	8 bit integer
	4	T15_m3_fault_low	4B	+50°C	1057D (LS)	8 bit integer
64	1	T16_m3_fault_high	DF	-10°C	1057E (MS)	8 bit integer
	2	T16_m3_warn_high	D3	-5°C	1057E (LS)	8 bit integer
	3	T16_m3_warn_low	55	+45°C	1057F (MS)	8 bit integer
	4	T16_m3_fault_low	4B	+50°C	1057F (LS)	8 bit integer
65	1	T17_m3_fault_high	FA	-30°C	10580 (MS)	8 bit integer
	2	T17_m3_warn_high	F6	-25°C	10580 (LS)	8 bit integer
	3	T17_m3_warn_low	6C	+35°C	10581 (MS)	8 bit integer
	4	T17_m3_fault_low	60	+40°C	10581 (LS)	8 bit integer
66	1	T18_m3_fault_high	FA	-30°C	10582 (MS)	8 bit integer
	2	T18_m3_warn_high	F6	-25°C	10582 (LS)	8 bit integer
	3	T18_m3_warn_low	6C	+35°C	10583 (MS)	8 bit integer
	4	T18_m3_fault_low	60	+40°C	10583 (LS)	8 bit integer
67	1	T19_m3_fault_high	FA	-30°C	10584 (MS)	8 bit integer
	2	T19_m3_warn_high	F6	-25°C	10584 (LS)	8 bit integer
	3	T19_m3_warn_low	6C	+35°C	10585 (MS)	8 bit integer
	4	T19_m3_fault_low	60	+40°C	10585 (LS)	8 bit integer
68	1	T20_m3_fault_high	E0	-10°C	10586 (MS)	8 bit integer
	2	T20_m3_warn_high	D3	-5°C	10586 (LS)	8 bit integer
	3	T20_m3_warn_low	33	+65°C	10587 (MS)	8 bit integer
	4	T20_m3_fault_low	28	+75°C	10587 (LS)	8 bit integer
69	1	T21_m3_fault_high	E0	-10°C	10588 (MS)	8 bit integer
	2	T21_m3_warn_high	D3	-5°C	10588 (LS)	8 bit integer
	3	T21_m3_warn_low	30	+67°C	10589 (MS)	8 bit integer
	4	T21_m3_fault_low	25	+77°C	10589 (LS)	8 bit integer
70	1	T22_m3_fault_high	E0	-10°C	1058A (MS)	8 bit integer
	2	T22_m3_warn_high	D3	-5°C	1058A (LS)	8 bit integer
	3	T22_m3_warn_low	31	+66°C	1058B (MS)	8 bit integer
	4	T22_m3_fault_low	26	+76°C	1058B (LS)	8 bit integer

Data Ref	Octet	Name (see notes at end of table)	Default (in PROM)		Verification (read memory)	
71	1	T23_m3_fault_high	E0	-10°C	1058C (MS)	8 bit integer
	2	T23_m3_warn_high	D3	-5°C	1058C (LS)	8 bit integer
	3	T23_m3_warn_low	31	+66°C	1058D (MS)	8 bit integer
	4	T23_m3_fault_low	26	+76°C	1058D (LS)	8 bit integer
72	1	T24_m3_fault_high	E0	-10°C	1058E (MS)	8 bit integer
	2	T24_m3_warn_high	D3	-5°C	1058E (LS)	8 bit integer
	3	T24_m3_warn_low	3E	+57°C	1058F (MS)	8 bit integer
	4	T24_m3_fault_low	30	+67°C	1058F (LS)	8 bit integer
73	1	T1_tr1	EC	-20°C	10590 (MS)	8 bit integer
	2	T2_tr1	EC	-20°C	10593 (LS)	8 bit integer
	3	T3_tr1	EC	-20°C	10596 (MS)	8 bit integer
	4	T4_tr1	EC	-20°C	10599 (LS)	8 bit integer
74	1	T5_tr1	EC	-20°C	1059C (MS)	8 bit integer
	2	T6_tr1	EC	-20°C	1059F (LS)	8 bit integer
	3	T7_tr1	EC	-20°C	105A2 (MS)	8 bit integer
	4	T8_tr1	EC	-20°C	105A5 (LS)	8 bit integer
75	1	T9_tr1	EC	-20°C	105A8 (MS)	8 bit integer
	2	T10_tr1	EC	-20°C	105AB (LS)	8 bit integer
	3	T11_tr1	EC	-20°C	105AE (MS)	8 bit integer
	4	T12_tr1	EC	-20°C	105B1 (LS)	8 bit integer
76	1	T13_tr1	FD	-35°C	105B4 (MS)	8 bit integer
	2	T14_tr1	FD	-35°C	105B7 (LS)	8 bit integer
	3	T15_tr1	FD	-35°C	105BA (MS)	8 bit integer
	4	T16_tr1	FD	-35°C	105BD (LS)	8 bit integer
77	1	T17_tr1	FD	-35°C	105C0 (MS)	8 bit integer
	2	T18_tr1	FD	-35°C	105C3 (LS)	8 bit integer
	3	T19_tr1	FD	-35°C	105C6 (MS)	8 bit integer
	4	T20_tr1	EC	-20°C	105C9 (LS)	8 bit integer
78	1	T21_tr1	EC	-20°C	105CC (MS)	8 bit integer
	2	T22_tr1	EC	-20°C	105CF (LS)	8 bit integer
	3	T23_tr1	EC	-20°C	105D2 (MS)	8 bit integer
	4	T24_tr1	EC	-20°C	105D5 (LS)	8 bit integer
79	1	T1_tr2	A0	+15°C	10591 (MS)	8 bit integer

Data Ref	Octet	Name (see notes at end of table)	Default (in PROM)		Verification (read memory)	
	2	T2_tr2	A0	+15°C	10594 (LS)	8 bit integer
	3	T3_tr2	A0	+15°C	10597 (MS)	8 bit integer
	4	T4_tr2	A0	+15°C	1059A (LS)	8 bit integer
80	1	T5_tr2	A0	+15°C	1059D (MS)	8 bit integer
	2	T6_tr2	A0	+15°C	105A0 (LS)	8 bit integer
	3	T7_tr2	A0	+15°C	105A3 (MS)	8 bit integer
	4	T8_tr2	A0	+15°C	105A6 (LS)	8 bit integer
81	1	T9_tr2	A0	+15°C	105A9 (MS)	8 bit integer
	2	T10_tr2	A0	+15°C	105AC (LS)	8 bit integer
	3	T11_tr2	A0	+15°C	105AF (MS)	8 bit integer
	4	T12_tr2	A0	+15°C	105B2 (LS)	8 bit integer
82	1	T13_tr2	D3	-5°C	105B5 (MS)	8 bit integer
	2	T14_tr2	D3	-5°C	105B8 (LS)	8 bit integer
	3	T15_tr2	D3	-5°C	105BB (MS)	8 bit integer
	4	T16_tr2	D3	-5°C	105BE (LS)	8 bit integer
83	1	T17_tr2	F6	-25°C	105C1 (MS)	8 bit integer
	2	T18_tr2	F6	-25°C	105C4 (LS)	8 bit integer
	3	T19_tr2	F6	-25°C	105C7 (MS)	8 bit integer
	4	T20_tr2	D3	-5°C	105CA (LS)	8 bit integer
84	1	T21_tr2	D3	-5°C	105CD (MS)	8 bit integer
	2	T22_tr2	D3	-5°C	105D0 (LS)	8 bit integer
	3	T23_tr2	D3	-5°C	105D3 (MS)	8 bit integer
	4	T24_tr2	D3	-5°C	105D6 (LS)	8 bit integer
85	1	time_tr1 (MS)	00	120 seconds	10627 (MS)	16 bit integer
	2	time_tr1 (LS)	78		10627 (LS)	
	3	time_tr2 (MS)	00	120 seconds	10628 (MS)	16 bit integer
	4	time_tr2 (LS)	78		10628 (LS)	
86	1	RDM1_fault_high	***18***	***165mA***	104E4 (MS)	8 bit integer
	2	RDM1_warn_high	***10***	***110mA***	104E4 (LS)	8 bit integer
	3	RDM1_warn_low	00	0mA	104E5 (MS)	8 bit integer
	4	RDM1_fault_low	00	0mA	104E5 (LS)	8 bit integer
87	1	RDM2_fault_high	16	***152mA***	104E6 (MS)	8 bit integer
	2	RDM2_warn_high	0E	***96mA***	104E6 (LS)	8 bit integer
	3	RDM2_warn_low	00	0mA	104E7 (MS)	8 bit integer

Data Ref	Octet	Name (see notes at end of table)	Default (in PROM)		Verification (read memory)	
	4	RDM2_fault_low	00	0mA	104E7 (LS)	8 bit integer
88	1	RDM3_fault_high	74	***799mA***	104E8 (MS)	8 bit integer
	2	RDM3_warn_high	70	***771mA***	104E8 (LS)	8 bit integer
	3	RDM3_warn_low	52	***565mA***	104E9 (MS)	8 bit integer
	4	RDM3_fault_low	4D	***530mA***	104E9 (LS)	8 bit integer
89	1	FDM1_fault_high	***18***	***165mA***	10EEA (MS)	8 bit integer
	2	FDM1_warn_high	***10***	***110mA***	104EA (LS)	8 bit integer
	3	FDM1_warn_low	00	0mA	104EB (MS)	8 bit integer
	4	FDM1_fault_low	00	0mA	104EB (LS)	8 bit integer
90	1	FDM2_fault_high	16	***152mA***	104EC (MS)	8 bit integer
	2	FDM2_warn_high	0E	***96mA***	104EC (LS)	8 bit integer
	3	FDM2_warn_low	00	0mA	104ED (MS)	8 bit integer
	4	FDM2_fault_low	00	0mA	104ED (LS)	8 bit integer
91	1	FDM3_fault_high	74	***799mA***	104EE (MS)	8 bit integer
	2	FDM3_warn_high	70	***771mA***	104EE (LS)	8 bit integer
	3	FDM3_warn_low	52	***565mA***	104EF (MS)	8 bit integer
	4	FDM3_fault_low	4D	***530mA***	104EF (LS)	8 bit integer
92	1	EE1_fault_high	2E	***773mA***	104F0 (MS)	8 bit integer
	2	EE1_warn_high	2A	***706mA***	104F0 (LS)	8 bit integer
	3	EE1_warn_low	22	***572mA***	104F1 (MS)	8 bit integer
	4	EE1_fault_low	1E	***504mA***	104F1 (LS)	8 bit integer
93	1	EE2_fault_high	47	***1194mA***	104F2 (MS)	8 bit integer
	2	EE2_warn_high	41	***1093mA***	104F2 (LS)	8 bit integer
	3	EE2_warn_low	***2A***	***706mA***	104F3 (MS)	8 bit integer
	4	EE2_fault_low	***25***	***622mA***	104F3 (LS)	8 bit integer
94	1	Rx8_off_fault_high	1B	***595mA***	104F4 (MS)	8 bit integer
	2	Rx8_off_warn_high	10	***352mA***	104F4 (LS)	8 bit integer
	3	Rx8_off_warn_low	00	0mA	104F5 (MS)	8 bit integer
	4	Rx8_off_fault_low	00	0mA	104F5 (LS)	8 bit integer
95	1	Rx8_on_fault_high	55	***1874mA***	104F6 (MS)	8 bit integer
	2	Rx8_on_warn_high	53	***1830mA***	104F6 (LS)	8 bit integer
	3	Rx8_on_warn_low	***30***	***1058mA***	104F7 (MS)	8 bit integer
	4	Rx8_on_fault_low	00	0mA	104F7 (LS)	8 bit integer
96	1	Rxp15_off_fault_high	20	***258mA***	104F8 (MS)	8 bit integer
	2	Rxp15_off_warn_high	14	***161mA***	104F8 (LS)	8 bit integer

Data Ref	Octet	Name (see notes at end of table)	Default (in PROM)		Verification (read memory)	
	3	Rxp15_off_warn_low	00	0mA	104F9 (MS)	8 bit integer
	4	Rxp15_off_fault_low	00	0mA	104F9 (LS)	8 bit integer
97	1	Rxp15_on_fault_high	7B	***992mA***	104FA (MS)	8 bit integer
	2	Rxp15_on_warn_high	73	***927mA***	104FA (LS)	8 bit integer
	3	Rxp15_on_warn_low	5B	***734mA***	104FB (MS)	8 bit integer
	4	Rxp15_on_fault_low	00	0mA	104FB (LS)	8 bit integer
98	1	Rxm15_off_fault_high	25	***70mA***	104FC (MS)	8 bit integer
	2	Rxm15_off_warn_high	1A	***49mA***	104FC (LS)	8 bit integer
	3	Rxm15_off_warn_low	00	0mA	104FD (MS)	8 bit integer
	4	Rxm15_off_fault_low	00	0mA	104FD (LS)	8 bit integer
99	1	Rxm15_on_fault_high	7F	***239mA***	104FE (MS)	8 bit integer
	2	Rxm15_on_warn_high	67	***194mA***	104FE (LS)	8 bit integer
	3	Rxm15_on_warn_low	4C	***143mA***	104FF (MS)	8 bit integer
	4	Rxm15_on_fault_low	00	0mA	104FF (LS)	8 bit integer

Refer to RD6 for conversion between hex and engineering units (eg mA, °C)

Notes:

1. Thermistor telemetry

Tn : Thermistor Channel n
low / high : low limit, high limit (corresponds to the thermistor resistance, therefore the low limit corresponds to high temperature, and the high limit corresponds to low temperature).
warn / fault : warning limit (set Fault Bit), fault limit (switch to Fault Mode)

Automatic heater control shall use the warning low and high limits as the switching points for the operational heaters:
Warning_low = high temperature threshold = heater switch off point
Warning_high = low temperature threshold = heater switch on point

m1/m2/m3 : mode dependency :-

Mode	applicable limits
Power-on	m1
Warm-up	m2
Standby	m3
Scan	m3
Fixed View	m3
Safeing	telemetry checking not required - automatically goes to Power-On Mode
Fault	telemetry checking not performed (Fault bits indicate the fault which caused the transition to Fault Mode)
Self-Test	limits same as calling mode

tr1/tr2 : mode transition dependency (for automatic mode transitions):-

tr1 : Power-on to Warm-up
tr2 : Warm-up to Standby
time defined in integer seconds.

2. Current Telemetry

The limits are mode dependent.

Mode	RDM Motor (5:1)	FDM Motor (5:2)	EE 5V (5:3)	RX +8V (5:4)	Rx +15V (5:5)	Rx -15V (5:6)
Power-on 1 (SPE/SCE OFF)	RDM1	FDM1	EE1	Rx8_off	Rxp15_off	Rxm15_off
Power-on 2 (SPE/SCE ON)	RDM1	FDM1	EE2	Rx8_off	Rxp15_off	Rxm15_off
Warm-up	RDM1	FDM1	EE2	Rx8_on	RXp15_on	Rxm15_on
Standby	RDM2	FDM2	EE2	Rx8_on	RXp15_on	Rxm15_on
Scan	RDM3	FDM3	EE2	Rx8_on	RXp15_on	Rxm15_on
Fixed View	RDM3	FDM3	EE2	Rx8_on	RXp15_on	Rxm15_on
Safeing	n/a	n/a	n/a	n/a	n/a	n/a
Fault	n/a	n/a	n/a	n/a	n/a	n/a
Self_Test (except motor)	same as calling mode					
Motor Self-Test	RDM3	FDM3	same as calling mode			

APPENDIX C : SCAN CONTROL TABLE (SCT)

The SCT defines parameters which are used by the Scan Control functions. It defines parameters such as:-

- Characterisation parameters for the Motors, Scan Drive Amplifiers, Inductosyn measurement system, Reflector/shroud/flywheel, etc.
- Algorithm gain parameters
- Profile definition parameters
- Initialisation parameters
- Performance monitoring parameters

Many parameters use 1750 floating point notation. Refer to the end of the table for the definition of this number notation.

Scan Control Table (SCT)

Table Ref = 2

Data Ref	Octet	Parameter Name	Definition	Default (in PROM)		Verification (read memory)	
				Value (hex)	Value (Engineering)	Address (hex)	Format
0	1	RDM SDA max demand code (RDM_DIG_C_MAX)	FF=DAC full scale	F0	240 decimal	109BA	32 bit FP
	2	FDM SDA max demand code (FDM_DIG_C_MAX)	FF=DAC full scale	F3	243 decimal	109CC	32 bit FP
	3	Cog/Ripple torque compensation enable/disable	bit 1 (MSB): 0 = cogging torque disabled 1 = cogging torque enabled bit 2 : 0 = ripple torque disabled 1 = ripple torque enabled bits 3..8(LSB) : unused	80	cogging enabled, ripple disabled	Bit 1 – 10861 Bit 2 – 108CD	16 bit Boolean 16 bit Boolean (0000 = disabled) (0001 = enabled)
	4	Delay parameter	0..7: 0 = no delay; 7=max delay.	00	Delay = 0	10864	32 bit FP
1	1	Earth Scan position error tolerance	1 LSB = 0.01° (therefore full scale = 2.55°)	0A	0.10°	108D0	32 bit FP
	2	Calibration targets position error tolerance	1 LSB = 0.01° (therefore full scale = 2.55°)	3C	0.6°	108CE	32 bit FP
	3	Fixed View position error tolerance	1 LSB = 0.01° (therefore full scale = 2.55°)	3C	0.6°	10895	32 bit FP
	4	unused	N/A	00	N/A	N/A	N/A
2	1	Position measurement initialisation velocity	1 LSB = 5°/second	0C	60°/s	108AF	32 bit FP
	2	unused	N/A	00	N/A	N/A	N/A
	3	unused	N/A	00	N/A	N/A	N/A
	4	unused	N/A	00	N/A	N/A	N/A
3	1	Profile	00 = Profile 0 01 = Profile 1 02 = Profile 2 03 = Manual Profile	00	Profile 0	13003	8 bit integer
	2	unused	N/A	00	N/A	N/A	N/A
	3	unused	N/A	00	N/A	N/A	N/A
	4	unused	N/A	00	N/A	N/A	N/A

Data Ref	Octet	Parameter Name	Definition	Default (in PROM)		Verification (read memory)	
4	1..4	RDM_MOI	RDM moment of inertia (kg.m^2)	4B 87 BE FA	9.22e-3	108B7	32 bit FP
5	1..4	RDM_K_motor	motor constant (N.m/Amp)	72 4D D3 00	0.893	1089F	32 bit FP
6	1..4	RDM_SDA_k0	amplifier offset (LSBs)	00 00 00 00	0.0	109BC	32 bit FP
7	1..4	RDM_SDA_k1	amplifier gain (LSBs per Amp)	60 94 7B 08	193.16	109BE	32 bit FP
8	1..4	RDM_Ind_A	Inductosyn correction, amplitude (°)	00 00 00 00	0.0	108A3	32 bit FP
9	1..4	RDM_Ind_N	Inductosyn correction, frequency (cycles/rev)	64 00 00 06	50.0	108B3	32 bit FP
10	1..4	RDM_Ind_θ	Inductosyn correction, phase (°)	00 00 00 00	0.0	108B5	32 bit FP
11	1..4	RDM_Ind_offset_A	Inductosyn correction, zero position A offset (°)	00 00 00 00	0.0	109C0	32 bit FP
12	1..4	RDM_cog_A1	Cogging torque correction 1, amplitude (N.m)	51 EB 85 FB	0.02	10899	32 bit FP
13	1..4	RDM_cog_N1	Cogging torque correction 1, frequency (cycles/rev)	4E 00 00 08	156.0	1089B	32 bit FP
14	1..4	RDM_cog_θ1	Cogging torque correction 1, phase (°)	00 00 00 00	0.0	1089D	32 bit FP
15	1..4	RDM_ripple_A	Ripple torque correction, amplitude (N.m)	77 5F 70 00	0.9326	108BB	32 bit FP
16	1..4	unused	N/A	00 00 00 00	N/A	N/A	N/A
17	1..4	unused	N/A	00 00 00 00	N/A	N/A	N/A
18	1..4	RDM_ripple_θ	Ripple torque correction, phase (°)	00 00 00 00	0.0	108BF	32 bit FP
19	1..4	RDM_Scan_kp	Scan Mode proportional term gain (N.m/°)	5D 6A 16 FF	0.3649	108B9	32 bit FP
20	1..4	RDM_Scan_ki	Scan Mode integral term gain (N.m/(°.s))	4B 9D B2 03	4.726	108B1	32 bit FP
21	1..4	RDM_Scan_kv	Scan Mode derivative term gain (N.m/(°/s))	6B B9 8C FA	0.01315	108A1	32 bit FP
22	1..4	RDM_Scan_k	Scan Mode global gain	40 00 00 01	1.0	108A5	32 bit FP
23	1..4	RDM_FV_kp	Fixed View Mode proportional term gain (N.m/°)	77 65 FE FF	0.4664	108AD	32 bit FP
24	1..4	unused	N/A	00 00 00 00	N/A	N/A	N/A
25	1..4	RDM_FV_kv	Fixed View Mode derivative term gain (N.m/(°/s))	6B B9 8C FA	0.01315	108A7	32 bit FP
26	1..4	RDM_FV_k	Fixed View Mode global gain	40 00 00 01	1.0	108A9	32 bit FP
27	1..4	FDM_MOI	FDM moment of inertia (kg.m^2)	48 D3 AE FA	8.89e-3	10885	32 bit FP
28	1..4	FDM_K_motor	motor constant (N.m/Amp)	70 E5 60 00	0.882	1086F	32 bit FP
29	1..4	FDM_SDA_k0	amplifier offset (LSBs)	00 00 00 00	0.0	109CE	32 bit FP
30	1..4	FDM_SDA_k1	amplifier gain (LSBs per Amp)	60 94 7B 08	193.16	109D0	32 bit FP
31	1..4	FDM_Ind_A	Inductosyn correction, amplitude (°)	00 00 00 00	0.0	10873	32 bit FP
32	1..4	FDM_Ind_N	Inductosyn correction, frequency (cycles/rev)	64 00 00 06	50.0	10881	32 bit FP
33	1..4	FDM_Ind_θ	Inductosyn correction, phase (°)	00 00 00 00	0.0	10883	32 bit FP
34	1..4	unused	N/A	00 00 00 00	N/A	N/A	N/A
35	1..4	FDM_cog_A	Cogging torque correction, amplitude (N.m)	00 00 00 00	0.0	10869	32 bit FP
36	1..4	FDM_cog_N	Cogging torque correction, frequency (cycles/rev)	00 00 00 00	0.0	1086B	32 bit FP
37	1..4	FDM_cog_θ	Cogging torque correction, phase (°)	00 00 00 00	0.0	1086D	32 bit FP
38	1..4	FDM_ripple_A	Ripple torque correction, amplitude (N.m)	77 5F 70 00	0.9326	10889	32 bit FP
39	1..4	unused	N/A	00 00 00 00	N/A	N/A	N/A
40	1..4	unused	N/A	00 00 00 00	N/A	N/A	N/A
41	1..4	FDM_ripple_θ	Ripple torque correction, phase (°)	00 00 00 00	0.0	1088D	32 bit FP

Data Ref	Octet	Parameter Name	Definition	Default (in PROM)		Verification (read memory)	
42	1..4	FDM_Scan_kp	Scan Mode proportional term gain (N.m/°)	63 46 DC FF	0.3878	10887	32 bit FP
43	1..4	unused	N/A	00 00 00 00	N/A	N/A	N/A
44	1..4	FDM_Scan_kv	Scan Mode derivative term gain (N.m/(°/s))	4A 0E 41 FA	0.009040	10871	32 bit FP
45	1..4	FDM_Scan_k	Scan Mode global gain	40 00 00 01	1.0	10875	32 bit FP
46	1..4	FDM_FV_kp	Fixed View Mode proportional term gain (N.m/°)	73 1F 8A FF	0.4497	1087F	32 bit FP
47	1..4	unused	N/A	00 00 00 00	N/A	N/A	N/A
48	1..4	FDM_FV_kv	Fixed View Mode derivative term gain (N.m/(°/s))	67 DF E3 FA	0.01268	10877	32 bit FP
49	1..4	FDM_FV_k	Fixed View Mode global gain	40 00 00 01	1.0	1087B	32 bit FP
50	1..4	alpha	Ratio of inertia : RDM/FDM	40 00 00 01	1.0	10897	32 bit FP
51	1..4	gamma1	Profile 0 calculation: acceleration 1 (°/s/s)	4A 79 9A 0D	4766.4000008	14F8D	32 bit FP
52	1..4	gamma2	Profile 0 calculation: acceleration 2 (°/s/s)	50 56 BA 0D	5141.6816329	14F8F	32 bit FP
53	1..4	gamma3	Profile 0 calculation: acceleration 3 (°/s/s)	4D 7E CC 0D	4959.6990058	14F91	32 bit FP
54	1..4	speed	Profile 0 calculation: scan velocity (°/s)	78 00 00 06	60.0°/s	14F93	32 bit FP
55	1,2	c1	Profile 0 calculation: phase 1 end: (COUNTs)	02 D0	720 (note 1)	14F84	16 bit integer
	3,4	c2	Profile 0 calculation: phase 2 end: (COUNTs)	02 E8	744	14F85	16 bit integer
56	1,2	c3	Profile 0 calculation: phase 3 end: (COUNTs)	03 00	768 (note 1)	14F86	16 bit integer
	3,4	c4	Profile 0 calculation: phase 4 end: (COUNTs)	03 20	800 (note 1)	14F87	16 bit integer
57	1,2	c5	Profile 0 calculation: phase 5 end: (COUNTs)	03 58	856	14F88	16 bit integer
	3,4	c6	Profile 0 calculation: phase 6 end: (COUNTs)	03 90	912 (note 1)	14F89	16 bit integer
58	1,2	c7	Profile 0 calculation: phase 7 end: (COUNTs)	03 B0	944 (note 1)	14F8A	16 bit integer
	3,4	c8	Profile 0 calculation: phase 8 end: (COUNTs)	03 ED	1005	14F8B	16 bit integer
59	1,2	c9	Profile 0 calculation: phase 9 end: (COUNTs)	04 2A	1066	14F8C	16 bit integer
	3,4	unused	N/A	00 00 00 00	N/A	N/A	N/A
60	1..4	gamma1	Profile 1 calculation: acceleration 1 (°/s/s)	52 F1 AA 0D	5308.4160032	14F9E	32 bit FP
61	1..4	gamma2	Profile 1 calculation: acceleration 2 (°/s/s)	48 AF 1B 0D	4651.7760000	14FA0	32 bit FP
62	1..4	gamma3	Profile 1 calculation: acceleration 3 (°/s/s)	4D 7E CC 0D	4959.6990058	14FA2	32 bit FP
63	1..4	speed	Profile 1 calculation: scan velocity (°/s)	78 00 00 06	60.0°/s	14FA4	32 bit FP
64	1,2	c1	Profile 1 calculation: phase 1 end: (COUNTs)	02 D0	720 (note 1)	14F95	16 bit integer
	3,4	c2	Profile 1 calculation: phase 2 end: (COUNTs)	02 E4	740	14F96	16 bit integer
65	1,2	c3	Profile 1 calculation: phase 3 end: (COUNTs)	02 F8	760 (note 1)	14F97	16 bit integer
	3,4	c4	Profile 1 calculation: phase 4 end: (COUNTs)	03 18	792 (note 1)	14F98	16 bit integer
66	1,2	c5	Profile 1 calculation: phase 5 end: (COUNTs)	03 54	852	14F99	16 bit integer
	3,4	c6	Profile 1 calculation: phase 6 end: (COUNTs)	03 90	912 (note 1)	14F9A	16 bit integer
67	1,2	c7	Profile 1 calculation: phase 7 end: (COUNTs)	03 B0	944 (note 1)	14F9B	16 bit integer
	3,4	c8	Profile 1 calculation: phase 8 end: (COUNTs)	03 ED	1005	14F9C	16 bit integer
68	1,2	c9	Profile 1 calculation: phase 9 end: (COUNTs)	04 2A	1066	14F9D	16 bit integer
	3,4	unused	N/A	00 00 00 00	N/A	N/A	N/A
69	1..4	gamma1	Profile 2 calculation: acceleration 1 (°/s/s)	43 1D 42 0D	4295.3142852	14FAF	32 bit FP

Data Ref	Octet	Parameter Name	Definition	Default (in PROM)		Verification (read memory)	
70	1..4	gamma2	Profile 2 calculation: acceleration 2 (°/s/s)	59 94 4C 0D	5733.0745568	14FB1	32 bit FP
71	1..4	gamma3	Profile 2 calculation: acceleration 3 (°/s/s)	4D 7E CC 0D	4959.6990058	14FB3	32 bit FP
72	1..4	speed	Profile 2 calculation: scan velocity (°/s)	78 00 00 06	60.0°/s	14FB5	32 bit FP
73	1,2	c1	Profile 2 calculation: phase 1 end: (COUNTs)	02 D0	720 (note 1)	14FA6	16 bit integer
	3,4	c2	Profile 2 calculation: phase 2 end: (COUNTs)	02 EC	748	14FA7	16 bit integer
74	1,2	c3	Profile 2 calculation: phase 3 end: (COUNTs)	03 08	776 (note 1)	14FA8	16 bit integer
	3,4	c4	Profile 2 calculation: phase 4 end: (COUNTs)	03 28	808 (note 1)	14FA9	16 bit integer
75	1,2	c5	Profile 2 calculation: phase 5 end: (COUNTs)	03 5C	860	14FAA	16 bit integer
	3,4	c6	Profile 2 calculation: phase 6 end: (COUNTs)	03 90	912 (note 1)	14FAB	16 bit integer
76	1,2	c7	Profile 2 calculation: phase 7 end: (COUNTs)	03 B0	944 (note 1)	14FAC	16 bit integer
	3,4	c8	Profile 2 calculation: phase 8 end: (COUNTs)	03 ED	1005	14FAD	16 bit integer
77	1,2	c9	Profile 2 calculation: phase 9 end: (COUNTs)	04 2A	1066	14FAE	16 bit integer
	3,4	unused	N/A	00 00 00 00	N/A	N/A	N/A
78	1,2	Start_integration	Scan Mode integral term start updates 0..1151 (counts)	00 00	0 (= Earth View start)	108D2	16 bit integer
	3,3	Stop_integration	Scan Mode integral term stop updates 0,,1151 (counts)	02 D0	720 (= Earth View end)	10866	16 bit integer
79	1..4	Epsilon_max	Error constant for limiting Fixed View torque (°) (=Vmax * RDM_FV_kv / RDM_FV_kp)	5A 39 58 02	2.8195	10867	32 bit FP
80	1..4	RDM_vel_kv	RDM constant velocity alg. derivative gain (N.m/(°/s))	6B B9 8C FA	0.01315	108C7	32 bit FP
81	1..4	RDM_vel_k	RDM constant velocity alg. global gain	40 00 00 01	1.0	108C9	32 bit FP
82	1..4	FDM_vel_kv	FDM constant velocity alg. derivative gain (N.m/(°/s))	67 DF E3 FA	0.01268	1088F	32 bit FP
83	1..4	FDM_vel_k	FDM constant velocity alg. global gain	40 00 00 01	1.0	10891	32 bit FP
84	1..4	RDM_Ind_offset_B	Inductosyn correction, zero position B offset (°)	5A 00 00 08	180.0	109C2	32 bit FP
85	1..4	RDM_vel_kp	RDM constant vel. alg. proportional term (N.m/°)	77 65 FE FF	0.4664	108CB	32 bit FP
86	1..4	FDM_vel_kp	FDM constant vel. alg. proportional term (N.m/°)	73 1F 8A FF	0.4497	10893	32 bit FP
87	1..4	RDM_scan_epsilon0	RDM scan algorithm initial control error (°)	00 00 00 00	0.0	108C1	32 bit FP
88	1..4	RDM_scan_i0	RDM scan algorithm initial integral term (°.s)	00 00 00 00	0.0	108C3	32 bit FP
89	1..4	RDM_scan_d0	RDM scan algorithm initial derivative term (°/s)	00 00 00 00	0.0	108C5	32 bit FP
90	1..4	RDM_cog_A2	Cogging torque correction 2, amplitude (N.m)	00 00 00 00	0.0	108D7	32 bit FP
91	1..4	RDM_cog_N2	Cogging torque correction 2, frequency (cycles/rev)	00 00 00 00	0.0	108DF	32 bit FP
92	1..4	RDM_cog_θ2	Cogging torque correction 2, phase (°)	00 00 00 00	0.0	108E7	32 bit FP
93	1..4	RDM_cog_A3	Cogging torque correction 3, amplitude (N.m)	00 00 00 00	0.0	108D9	32 bit FP
94	1..4	RDM_cog_N3	Cogging torque correction 3, frequency (cycles/rev)	00 00 00 00	0.0	108E1	32 bit FP
95	1..4	RDM_cog_θ3	Cogging torque correction 3, phase (°)	00 00 00 00	0.0	108E9	32 bit FP
96	1..4	RDM_cog_A4	Cogging torque correction 4, amplitude (N.m)	00 00 00 00	0.0	108DB	32 bit FP
97	1..4	RDM_cog_N4	Cogging torque correction 4, frequency (cycles/rev)	00 00 00 00	0.0	108E3	32 bit FP
98	1..4	RDM_cog_θ4	Cogging torque correction 4, phase (°)	00 00 00 00	0.0	108EB	32 bit FP
99	1..4	RDM_cog_A5	Cogging torque correction 5, amplitude (N.m)	00 00 00 00	0.0	108DD	32 bit FP
100	1..4	RDM_cog_N5	Cogging torque correction 5, frequency (cycles/rev)	00 00 00 00	0.0	108E5	32 bit FP

Data Ref	Octet	Parameter Name	Definition	Default (in PROM)		Verification (read memory)	
101	1..4	RDM_cog_θ5	Cogging torque correction 5, phase (°)	00 00 00 00	0.0	108ED	32 bit FP

Note 1 : these values must be divisible by 8 so that the pixel acquisition system is synchronised to the Scan Control.

Where 4 bytes (ie. 1..4) are assigned to a parameter, these use the 1750 standard precision floating point representation (32 bit), with the following format:-

SCT Table reference	Octet 1	Octet 2	Octet 3	Octet 4
Memory Read	Address (MS)	Address (LS)	Address +1 (MS)	Address + 1 (LS)
Floating Point notation	24 bit mantissa			8 bit exponent

Mantissa = fractional two's complement - normalised
Exponent = two's complement.

APPENDIX D: DC OFFSETS TABLE (DOT)

The DOT defines parameters which are used by the Science Data acquisition system, related to maintaining the Rx input signals within the ADC dynamic range.

Table Ref: 3

Data Ref	Octet	Parameter Name	Definition	Default (in PROM)		Verification (read memory)	
				Value (hex)	Value (Engineering)	Memory Address (hex)	Format
0	1	Channel H1 DC Offset	FF = 10V	5A	3.5V	10810 (LS)	8 bit integer
	2	Channel H2 DC Offset	FF = 10V	D1	8.2V	10811 (LS)	8 bit integer
	3	Channel H3 DC Offset	FF = 10V	AB	6.7V	10812 (LS)	8 bit integer
	4	Channel H4 DC Offset	FF = 10V	BA	7.3V	10813 (LS)	8 bit integer
1	1	Channel H5 DC Offset	FF = 10V	AE	6.8V	10814 (LS)	8 bit integer
	2	SPE Channel Gain	1 LSB = 0.05	85	Gain = 6.65	107E6	32 bit FP
	3,4	Ideal calibration mid-point	FFF0 = fullscale	732C	45% of Full Scale	107E5	16 bit integer
2	1,2	Upper Deadband	FFF0 = fullscale	F324	95% of Full Scale	107E1	16 bit integer
	3,4	Lower Deadband	FFF0 = fullscale	0CCC	5% of Full Scale	107E2	16 bit integer
3	1,2	Max Dynamic Range	FFF0 = fullscale	E658	90% of Full Scale	107E3	16 bit integer
	3,4	Min Dynamic Range	FFF0 = fullscale	BFF4	75% of Full Scale	107E4	16 bit integer

APPENDIX E : 1553 PROTOCOL

This section describes specific points on the use of the MIL-STD 1553 Protocol for the MHS application.

E.1 Remote Terminal (RT) Addresses

The MHS RT addresses are set using 'programming connectors' mounted on the Electronics Equipment (refer to EICD for how to programme these connectors). The addresses are set as follows:-

Command/Telemetry Bus	16 decimal (applicable to all models)
Science Data Bus	7 decimal (applicable to models)

These addresses apply for both bus redundancies A and B (both buses go to a common RT) and for MHS redundancies A and B (ie. PIE A and PIE B, cold redundancy ensures only one RT can respond at any one time).

E.2 Transfer mechanism

MHS Application Telecommands can be divided into two categories:

Instrument commands : these are 'true' telecommands in the sense that they either instruct the Instrument to perform some function, or pass data to the Instrument, eg. Change Mode, Switch Command, Load Table Data

Packet Requests: these commands instruct the Instrument to place data in the output buffer so that it can be collected by the platform, eg. Request HK TLM Packet, Request Extended Memory Data Packet.

Instrument commands can be sent to the Instrument at any time, given the timing restrictions given in section E4.

The mechanism for collecting a packet from the Instrument is as follows:

- Issue a Packet Request (BC to RT transfer)
- Poll the Service Request Bit (SRQ) of the RT. The Instrument sets this to zero when a Packet Request is received and sets it to one when a complete and valid packet is in the output buffer. The platform can poll the SRQ by issuing 'Transmit Vector Word' Mode Commands.
- When the SRQ indicates the packet is ready, the platform initiates an RT to BC transfer to collect the data.

Data is transferred on the 1553 bus using a sub-address mechanism. Packets are divided into blocks of 32 words and each block stored in the output buffer with a unique sub-address. A separate 1553 message is then used to transfer each sub-address block.

All MHS command packets are short enough to fit into one sub-address. The same sub-address will be used for all commands, namely sub-address 1.

All telemetry packets on the Command/Telemetry bus are also short enough to fit into one sub-address. Again, sub-address 1 will be used for all packets on this bus.

Telemetry packets on the Science Data Bus are longer than one sub-address block. These packets will be transferred using multiple sub-addresses from 1 to N as necessary. All packets types can be transferred in less than 30 sub-addresses, so a mechanism for re-loading the buffer part way through a packet is not required.

Note that subaddresses 0 and 31 are reserved for 'Mode Commands' (see below), and subaddress 30 is reserved for the 'Data Wrap-around Test' (see below).

E.3 Mode Commands

In addition to the MHS Application commands and telemetry, 1553 'Mode Commands' are transmitted on both buses, according to RD4 and RD5. (Note: do not confuse these Mode Commands with the MHS Application command 'Change Mode'.) These messages are ignored by the MHS application software and have no affect on the operating state of the Instrument. They are not acknowledged in any way by the TC Acknowledgement Field.

- 'Broadcast with Data Word', followed by 'Transmit Status' : once every second
- 'Initiate RT Self-test', followed 100ms later by 'Transmit BIT Word' : once every 8 seconds
- Data Wrap-Around Test (BC to RT, followed by RT to BC, using sub-address 30) : once every 8 seconds

E.4 Timing restrictions

The following restrictions are placed on the platform regarding command timing:

- 1553 Mode Commands must be transmitted at least 10ms after MHS Application Commands, otherwise there is a risk that the Mode Command will overwrite the Application Command in the buffer.

- MHS Application Commands (ie. Instrument commands and Packet Requests, as defined in E.2) shall be followed by a 'quiet period' in which no further commands of any type shall be sent to the instrument. This is to allow adequate time for the Instrument to respond and schedule execution of the command. If commands are received during the quiet period then they may overwrite a previous command which will result in that command being ignored. The durations of the 'quiet periods' are dependent on the type of command and the current mode of operation of the instrument, as shown in the table below:

	POWER-ON WARM-UP FAULT (ie. when no scan control performed)	STANDBY (scan control performed, no performance required)	SCAN FIXED VIEW (full scan performance required)	SAFEING
CMD/TLM BUS:-				
Request HK TLM Packet	0.1	0.1	0.1	0.1
Request Memory Data Packet	0.1	0.1	x	x
Set Mode	when mode change completed, as indicated by TLM			x
Switch Command	0.1	0.1	x	x
Read Telemetry	0.1	0.1	x	x
Set Fixed View Position	x	0.1	when step completed, as indicated by TLM/SCI DATA	x
Fixed View Step	x	x		x
Load Memory	0.1	0.1	x	x
Set Time Code	0.1	0.1	x	x
Load Table Data	0.1	0.1	0.1	x
SCIENCE DATA BUS:-				
Request Science Data Pkt	0.1	0.1	0.1	0.1
Request Ext Memory Pkt	0.1	0.1	x	x

times in seconds
x = command not legal in this mode
For Self-test Modes : the timing requirements are the same as the calling mode (provided the command is valid).

However, it is recommended that the platform does not issue more than one Instrument Command (as defined in E.2), in addition to a Packet Request, per 8/3 period. If this is done, the recovered packet will give full acknowledgement of the Instrument Command in the TC Acknowledgement Field, and the TC Count Field will be set to 2 (ie. one Instrument Command + one Packet Request). If more than one Instrument Command is sent, only the first will be acknowledged (all valid commands are however executed). If no Instrument Command is sent, then the Packet Request command will be acknowledged in the TC Acknowledgement Field.

E.5 Redundancy

The Instrument will accept commands on either bus at any time. Message responses are provided on the same bus as the command, as required by the 1553 standard.

E.6 Status and BIT words format and usage

Status Word :

The format and usage of the Status Word are defined by the 1553 standard. However, the use of some bits are optional and others may have specific meanings defined by the application. The format and the MHS usage is as follows:-

bit	Name	1553 Standard	MHS usage
0 (MSB)	RT Address A4 (MSB)	address of RT which transmitted this status word	as per standard
1	RT Address A3		
2	RT Address A2		
3	RT Address A1		
4	RT Address A0 (LSB)		
5	Message Error (ME)	1 = error in one or more data words of the message	See notes below.
6	Instrumentation	Optional : can be used to distinguish between command and status words.	Not used. Always zero.
7	Service Request (SRQ)	Optional : allows the RT to signal to the BC that a specific action is required.	Used to indicate a packet is ready for collection. See section E2.
8	Reserved	Set to zero.	Set to zero.
9	Reserved		
10	Reserved		
11	Broadcast Command Received	1 = preceding command was a broadcast command.	as per standard
12	Busy	Optional : 1 = RT cannot respond to command	Implemented. See notes below.
13	Subsystem Flag (SSF)	Optional : 1 = flag a fault condition in the subsystem.	Implemented in hardware but not used in the MHS application. Always zero.
14	Dynamic Bus Control Acceptance (DBC)	1 = RT has accepted to become the bus controller.	Implemented in hardware but will never be used in the MHS application. Always zero.
15 (LSB)	Terminal Flag (TF)	Optional : 1 = error in the RT.	Implemented. See notes below.

Notes:

- The Status Word refers to the message to which it forms part of. Only the 'Transmit Status Word' and 'Transmit Last Command' messages do not change the Status Word; all other messages reset the Status Word (as defined by 1553 standard).

- Message Error (ME): Set if a command is 'illegal' at 1553 protocol level, or if the number of words received is not correct.. For the case of illegal commands, each type of 1553 command (eg. receive, transmit, transmit status word, initiate self-test, etc.) is initialised by the application as legal or illegal at power-on initialisation. If an illegal command is received at any time, the status word is returned with the ME bit set. Note this 1553 level 'legalisation' is different to the application level legalisation which refers to the legality of MHS application commands for each MHS mode of operation.

- Busy Bit: For 'Transmit' commands (MHS output, ie. packet collection) it will never be set. For 'Receive' commands (MIU input, ie. commanding) it is set if the RT cannot access the buffer because the MHS application is using it. This may occur when the SREQ bit is polled after requesting a packet (using 'Transmit Vector Word' command), but once the SREQ bit is set, the MHS processor will have finished loading the buffer so the BUSY bit will not be set. Provided the minimum inter-command times are respected (see section E4), the MHS

processor will not be using the RT buffer when an MHS Application Command is received, so the BUSY bit should never be set.

- Terminal Flag (TF): Set if LP, BUSYAPP, TTOFLG or MEMERR set (Refer to BIT Word). If TF is set, the state of bits 10 to 1 (0=LSB) of the Status Word is irrelevant.

BIT Word:

The format and usage of the BIT Word is as follows:

bit	Name	Usage
0 (MSB)	unused	always zero.
1	MEMERR	Set if an error when the during RT access to 1553 buffer memory, see notes below.
2	TTO0	Transmission time-out activation on bus A
3	TTO1	Transmission time-out activation on bus B
4	TFINH	Inhibition of Terminal Flag bit.
5	unused	always zero
6		
7		
8		
9	HIWRD	Number of words in the received message was higher than expected.
10	LOWRD	Number of words in the received message was lower than expected.
11	UNDCMD	Undefined command received.
12	T/R_ILL	The T/R bit is illegal in the received Mode Command.
13	LP	Loop-test failure indicator
14	BUSYAP	Same as Status Word BUSY bit
15 (LSB)	TTOFLG	= 1 if TTO0 or TTO1 is set.

Notes:

- The BIT Word is updated each time a valid command addressing the RT is received, except for 'Transmit Status Word', 'Transmit Last Command' and 'Transmit BIT Word' commands (as defined by 1553 standard).

- MEMERR

Can be set by:-

  - Timeout

  Set if a timeout occurs when the RT accesses the buffer memory.

  - EDAC double error

  Set if an EDAC double error detected whilst accessing the buffer memory which supports the RT. If this occurs before sending the Status Word then the Status Word is transmitted with the TF bit set and the rest of the message aborted. Otherwise it completes transmission of the current word and then aborts the message.

  - MEMERRB

  A hardware pin which is permanently inactive in the MHS configuration.

- TTO0/TTO1

Set if a transmission takes greater than 800μs (longest possible message is one full subaddress = 32 words x 20 bit periods x 1μs = 640μs). TTO0 is for Bus A, TTO1 is for Bus B. This bit is only applicable to RT-BC transfers.

- LP (loop test)

When the RT is transmitting (for all types of message), the signals on the bus are monitored using the active receiver channel of the RT, and the RT compares the received data with the transmitted data. Any difference will cause the message to be aborted (after the current word), and the LP flag is set.