Cluster2 FGM

User's Manual
Appendix A

Software Requirements Document

IC/CLUSTER/DOC/SRD Issue 3 Rev. 5th July 2000

This document constitutes the Software Requirements Document (SRD) for the Cluster2 FGM DPU software and has been prepared in accordance with the Software Quality Assurance plan (CI IC/CLUSTER/SQAP).

Documentation Control:

Changes between issues marked with a vertical line in the margin.
Deleted text marked with strike through.
Added text marked with underline.

Issue 1
Defines EM Code
Revision 3:
Code draft 1 written to this spec. & deviations / non-conformances listed in IC/CLUSTER/NONCON
Code draft 2 written to this spec. & deviations / non-conformances listed in IC/CLUSTER/NONCON2

Issue 2
Defines FM Code
Revision 0:
All sections revised
RIDs 1 to 44 ex. 32
Revision 1:
RIDS 32,45,46,47,48,49
Change to HK allocation.
boot procedure
ADC error routine
MSA handling
Bus configuration
Rev 2
RIDS 50to 51
Rev 3:
RIDS 52 to TBD
Changes to sampling lead to different numbers of vectors in TM options.
Change to layout of instrument status word and error word.
Definition of calibration and DPU test modes.
New HK parameters: bad data and wrong number of vectors acquired.
Rev 4:
RIDs 51,67,74,75,76,77,78
MSA update
TM options 6,7,8,9
Re-definition ML2 counter
Change format of variance in auxiliary data
Change to error word: addition of parameter count exceeded
MSA filtering telecommand added
MSA "un-trigger" parameter to command
Rev 5:
RIDs 79 to 114

Issue 3
Necessary code modifications due to re-design of processor card:
RAM-Check block increased to 2k due to doubling of SRAM to 32k
PROMs are disabled, not turned-off.
DPUID values are updated.
New function of ZEF2CALS and ZEF2CAMS.
Rev 1:
Event recognition is disabled by default.

Requirement D1 (ticks of sync60 between vectors) is clarified.
Description of sumchecks in code patch header is clarified.
Rev:2
Only unfiltered data to the MSA.
Revised MSA header contents.
MSA words in Option A changed to 126
MSA words in Option F changed to 1778
Code Patch error flag asserted for two resets.
No filtered data to the MSA. MSA filtering command removed.
Event is located at one-third position in MSA data block.
Timeout for startup words is 4 seconds.
Default location of keyhole is Reg. 0 on active INT.
Autoranging disabled for five samples after uprange executed.
Rev:3
Extended mode requirements included
Rev:4
Constraint on data field of CALs/CAMs/CILs/CIMs ML2 commands.
DPU2 has a different order of interface/bus check during boot up to DPU1.
Rev 5 More detail given on the structure of the Bx variance data

Chapter 1 Scope and Introduction

1.1 Scope

The SRD constitutes a formal part of the FGM DPU software quality assurance plan (CI IC/CLUSTER/SQAP). The scope of this document is to define the complete set of software requirements as an input to the Architecture Design and Detailed Design Phases.

Applicable Documents:

1.	IC/CLUSTER/SQAP	Cluster FGM Software Quality Assurance Plan
2.	IC/FGM/INT	FGM Interface Specification
3.	ESA PSS-05-0	ESA Software Engineering Standards
4.	CL-EST-RS-0002/EID A	EID Part A / ESA
5.	Event Recognition Algorithms	H Luhr / Private Communication
6.	Cluster Magnetometer Data Filtering System Report / ICSTM	
7.	EID Part B	ICSTM / ESA
8.	IC/CLUSTER/AIT/AIT_TC	ICSTM / Telecommand definition
9.	IC/CLUSTER/AIT/PARAM	ICSTM / Housekeeping Parameter definition

1.2 Introduction

This document will not include any hardware specific requirements except by reference to applicable documents. The SRD will address three main issues:

Software Functionality
Inputs (telecommands)
Outputs (telemetry)

All software requirements are grouped and numbered in order to facilitate tracing through subsequent implementation and test. Requirements are identified by a letter denoting requirement type and a number and are enclosed in square brackets thus:

[B20] type boot, number 20.

Notes:

i) The convention of naming Bit zero as most significant bit will be used throughout.

Chapter 2 Software Requirements and Functionality

2.1 Boot Procedure

During the boot the DPU will:

Retrieve the result of the built in test on the processor and place it in a memory location to be defined in the software documentation [B1]. If the built in test indicates an error then the DPU Fault flag in the housekeeping error word shall be set.[B2].

Determine active interface by reading a "start-up" word and its inverse from ML2 and identifying it in the housekeeping [B3]. If no start-up word pair is seen on either interface, then the DPU will choose an interface arbitrarily.

Perform a RAM check to determine invalid RAM addresses . If any are found, the RAM Check Error condition is set in the housekeeping error word.[B4]. In addition, the routine shall map the 32k of DPU RAM to a single 16 bit word (default all bits set) to be held in a defined location, such that if at least one address in each 2k RAM block is faulty then the corresponding bit is cleared in the word.

Load code from ROM to RAM and disable the ROM [B5].

Perform automatic testing and configuration of hardware, "Auto-boot", if indicated by the start-up word [B6]. This involves testing the MSA over the chosen bus. During an auto-boot, an ADC shall be powered but not tested.

Accept and recognise a manual configuration, "Manual Boot", loaded by telecommand, if indicated by the start-up word [B7].

During auto startup only, the processor should set the active interface to its power-on configuration, then set the inactive interface to its power on configuration but with the SYNC_60 output disabled. The DPU shall then enable the RESET on the active interface, and then enable the IEL on interface 1. [B8]

The active interface sensor control register shall have FLIP=OFF, CAL=OFF, RANGE=7 and sensor control output enabled [B9].

The DPU shall boot as a result of receiving instructions for MANUAL boot or AUTO boot . In the event that neither automatic or manual boot is detected 4 seconds after DPU power on, the instrument shall AUTO boot into operation [B10].

The first startup word correctly interpreted at the interface shall determine the type of boot in the event that a second is not forthcoming. After the timeout period the instrument shall boot according to the first startup word. [B11].

The order of routing bus/interface check during boot up for DPU1 is INT1 RB1
INT2 RB1
INT2 RB2
INT1 RB2
The order is reversed on DPU2 (on units F8, F9 and F1 only). [B12].

2.2 Error Handling

Error conditions will be signalled by setting flags in an Error Word in the housekeeping channel. The following Error Conditions shall be tested for:

[E1] RAM Check Failure:
During the experiment boot procedure, the DPU will execute a read/write check on the DPU RAM. In the event that any addresses in the RAM space are faulty, this error condition will be set and the appropriate bit in the error word will be continuously asserted. The boot procedure will not be aborted.

ADC Fault:
Three ADC failure conditions are identified: ADC Reset, ADC Time-out and Bus Acknowledge failure. If either ADC is powered when an ADC error occurs, then any powered ADCs are turned off. After a delay, the duration of which shall be in the DDD, those originally powered ADCs shall be powered on again. [E2]
[E12] It shall be possible to disable the routine for ADC error checking and handling with a single code patch. This code patch shall be defined in the DDD.

[E3] MSA Fault:
Set when no Bus Acknowledge is returned by the (powered)MSA. The DPU software shall only check the interface that the DPU has been commanded to use, to determine whether the MSA is powered.

[E4] Sum Check Failure:
This error condition is set when the sum check of code fails during normal operation. The sum check of code will be performed continuously during operation of the instrument in science modes. No other action will be taken.

[E5] Interface Fault:
Set when no Bus Acknowledge is returned by the interface. Also set in the event of read/write contention on register 0. The result will be either failure to read from or failure to write to register 0. No other action will be taken. This error is not tested for on every access to the interface, however the frequency shall be at least once per reset and will be documented in the DDD.

[E6] DPU Fault:
At each reset the DPU will examine its fault register and if any bits are set then this error condition will be set. No other action will be taken.

[E7] Code Patch Fail:
Set after code patch sum check failure or timeout. See sec. 2.6 Code Patch.

[E8] Parameter Count Overflow:
Set when the parameter byte count exceeds 127.

[E9] IEL Fault:
The IEL stack is full.

[E10] No RESET or HF Clock:
Set when the DPU fails to see either a RESET pulse or HF Clock signal at the active interface.

[E11] Corrupt Science data:
This flag is asserted for two resets after:
1. Any ADC fault.
2. Telemetry option change.

[E12]: Incorrect number of vectors sampled:

If the correct number of samples between two reset pulses is not attained, this flag is set in the HK for the following format.

[E13]: No start-up words detected:
Set in the event that no start-up word pair is detected at either interface, implying that the instrument has auto-booted on an arbitrary interface (see also [B3]).

2.3 General Requirements

[G1]:
The default mode of operation shall be transmission of science data. (Option # C)

[G2]:
Operations such as calibration, memory dump etc. shall be specifically requested by telecommand. On returning from such a procedure, the instrument shall revert to its configuration immediately prior to the procedure call.

[G3]:
The default primary sensor is the outboard sensor. The default secondary sensor is the inboard sensor. This configuration may be changed by telecommand.

[G4]:
Science data shall be filtered by default. Filtering may be disabled by telecommand.

[G5]:
The event recognition software shall be disabled as default.

2.4 Data Gathering and Filtering

[D1]:
Vector acquisitions at the primary sensor shall be at equally spaced time intervals, corresponding to 1188 ticks of the SYNC COUNT register between vectors (equivalent to 297 periods of the SYNC_60 clock).

[D3]:
Vector acquisitions at the secondary sensor shall be at equally spaced time intervals. The time interval is chosen to generate enough vectors to make up the number required for the chosen telemetry option.

[D4]:
Data from the primary sensor shall be available to be placed in the telemetry stream as raw data or as filtered data.

[D5]:
Data from the secondary sensor shall be available to be placed in the telemetry stream as raw data only.

[D6]:
Raw (unfiltered) science data from the primary sensor shall consist of equally spaced vectors from the acquired data.

[D7]:
Filtered data shall be obtained by passing all acquired data from the primary sensor through a Gaussian digital filter.

2.5 MSA Operation

[M1]:
Only unfiltered vectors may be stored in the MSA.

[M9]:
The storage rate shall be an integer division of the acquisition rate.

[M2]:
Each stored block of vectors shall have associated with it the following auxiliary data:

0x1234	Synchronisation word
0x5678	Synchronisation word
0x9ABC	Synchronisation word
0xDEF0	Synchronisation word
RESCNT	Number of reset pulses recorded since DPU boot
RESCLK	Reset Count (HFCLK at last Reset)
HFCLK	Instantaneous value of HFCLK
SUNCLK	Time of last Sun Pulse
SWSTAT	Software Status word
TMSTAT	Telemetry Status word

[M3]:
The data format for MSA vectors shall be as follows:

15 bits X component
1 bit range (msb)
15 bits Y component
1 bit range
15 bits Z component
1 bit range (lsb)
(48 bits total)

MSA vectors shall therefore obey word boundaries in the MSA address space and also in the science telemetry.

[M4]:
The data block frozen in the MSA shall consist of one-third pre-event data and one-third post-event data.

[M8]:
Between blocks of auxiliary data there shall be vectors gathered within the corresponding period. The length of the vector data blocks shall be fixed. Any spare memory space at the end of the block shall be a fixed value detailed in the DDD. This value shall be distinguished from vectors in that it would indicate a range of zero.

[M11]:
The IEL trigger bit is to be set in the IEL word following the trigger.

[M10]:
A single event shall occupy the entire MSA space. Data in the MSA is to be frozen around the *first* firing of the event trigger algorithm. No action is to be taken on subsequent triggers until the entire event has been downloaded from the MSA.

2.6 Code Patch

The instrument shall have a code patch facility defined as follows :

[P1]:
Code patch will be signalled by ML2 telecommand and subsequent ML2 words will contain the following data:

New Code Sumcheck.
Sumcheck of patch (from start address though to last word of patch inclusive)
Start address
Length (words) of code (not including sum checks etc.)
Code

[P2]
In the event of sumcheck failure upon receipt, the CODE PATCH FAIL error condition is set for two reset periods, and the patch is rejected.

The code patch procedure is as follows:
The routine to be patched is sent as a number of 64 word (max) individual code patches each of which is individually sum-checked on receipt [P3]. The new 'total code sumcheck' is sent as a code patch of length one word. The pointer to the new routine is then similarly uplinked into the table in memory which holds the pointers to routines [P4].

[P5]
The code patch facility shall incorporate a time-out facility which will abandon the code patch after 16 resets in the event that expected data is not forthcoming. The CODE PATCH FAIL error condition shall be set for two reset periods.

[P6]
Sumcheck is defined as 16 bit addition (no carry) of the included data, from the lowest address first to the highest address, inclusive.

2.7 Memory Dump

[N1]:
The start address and length of the memory dump shall be part of the parameter block.
The start address shall be address 1 of the parameter block and the length in words shall be address 2 of the parameter block. At the next reset, the science telemetry will be replaced with the appropriate memory dump followed by a sum check (16 bit addition) of the data sent .

2.8 Event Recognition

[V1]:
Input from the Co-I team at T. U. Braunschweig shall be applied (Document 5).

[V2]:
The following parameters (reference Document 5) shall be calculated and compared with associated threshold values which are held in the parameter block (location to be defined in the DDD):

Varx Variance of X

Bx	Offset Corrected X
B2	Offset Corrected Magnitude squared
BL2	Offset Corrected Angular Change squared
BYZ2	Offset Corrected Spin Plane Magnitude squared

[V3]:
Two event criteria held in the parameter block (location to be defined in the DDD), shall specify which of the threshold values associated with the above parameters are required to be exceeded in order that an event is indicated. The criteria shall comprise an AND_WORD and an OR_WORD; the calculation applied to these words in order to signal an event shall be:

```
if (( AND_WORD && PARAMS_WORD ) || ( OR_WORD || PARAMS_WORD ))
then SET_TRIGGER
```

[V4]:
If an event is indicated then this fact shall be communicated to the MSA handling software and the IEL service routine.

[V5]:
The threshold values and event criterion shall be held as part of the parameter block.

2.9 IEL

[I1]:
Data shall be supplied to the IEL as defined in the EID part B section 3.4 (document 7).

[I2]:
The timing of vectors transmitted by the IEL with respect to acquisition shall be defined in the DD phase.

[I3]:
Transmission of data to the IEL shall be suspended whilst the "Corrupt data" error flag is asserted.

2.10 Calibration Sequences

Calibration sequence #1:
[C1]:
A telecommand will initiate a sequence in which the CAL control to the primary sensor is switched ON and OFF 512 times with a 50% duty cycle. The frequency of the oscillation should be one half of the Nyquist frequency of the current primary science output.
[C2]:
The phase relationship between the output of the vectors to the telemetry and the switching of the CAL signal must be fixed and clearly stated in the DDD.
[C3]:
The calibration sequence always terminates with CAL OFF.

Calibration sequence #2:
[C4]:
As sequence #1 except that sequence #2 acts on the FLIP and executes 512 cycles with a 50% duty cycle at a frequency of one half Hz., i.e. FLIP once per second.
[C5]:
Sequence always terminates with FLIP OFF.

[C6]:
Calibration sequence #0:
Sequence 0 is a NULL sequence, which acts as a stop instruction for all the other calibration sequences. If no other sequence is running when sequence 0 command is received, the state of the FLIP and CAL control lines in not changed.
[C7]:
Calibration sequences are independent, i.e. it is possible to run sequence #1 and sequence #2 at the same time. This would be indicated in the housekeeping as calibration sequence #3.

[C8]:
The CAL sequence number is reflected in the housekeeping in any RESET period during which the CAL sequence is running, and zero otherwise.

Actions such as inhibiting the IEL during calibration are operational constraints.

2.11 DPU Test Sequences

[U1]:
Test Sequence #0:
Restore telemetry to normal (previous) state if DPU test is in operation, otherwise do nothing.

[U2]:
Test Sequence #1, #2 , #3:
Take all X (Test Sequence #1) Y (#2) or Z (#3) components of the field at the sample frequency and write it to the telemetry stream in the format normally used for X, Y & Z. The range will be that belonging to the first vector of the three.

[U3]:
Test Sequence #4:
Selects the IEL test pattern defined in document reference EMIEL.DOC

[U4]:
An "invalid vector" must follow the last valid vector in a given format.

2.12 Extended Mode

[E1]:
Vector acquisitions at the primary sensor shall be at spin synchronised almost equal intervals, corresponding to n ticks of the HF clock where n is equal to the difference between consecutive sun clock readings divided by 512.

[E2]:
Data from the primary sensor shall be available to be placed in the telemetry stream and MSA as spin synchronised with one averaged vector per spin being stored as outlined in EXTEND.DOC.

[E3]:
No data is taken from the secondary sensor in extended mode. As a precaution it should be commanded into range 7 prior to entering this mode.

[E4]:
Autoranging of the primary sensor is enabled.

[E5]:
The instrument is commanded into extended mode via modification of an entry in the parameter table and exited through the receipt of **any** ML2 command.

[E6]:
The first word of the telemetry science packet should be 0000E.

[E7]:
The data format is four words per spin
x component 16 bits
y component 16 bits
z component 16 bits
16 bit sensor ID, 3 bit range, 12 bit reset count.

[E8]:
The reset count will increment by one every 16 reset periods (82.4seconds).

Chapter 3 Telemetry Format

Housekeeping and Science telemetry will be provided by the FGM instrument.
This chapter provides a description of the telemetry requirements.

3.1 Science Telemetry

Science data will comprise timing information and 45 bit vectors from primary (usually outboard) and secondary (usually inboard) sensors, plus auxiliary data and vectors from the MSA. Table (i) below gives FGM telemetry resources in the spacecraft normal and burst modes .

Table (i) Science Telemetry

Mode	Bits per Reset (words)	Bits per second
NM1	6240 (390)	1211
NM2	6240 (390)	1211
NM3	6240 (390)	1211
BM1	17856 (1116)	3466
BM2	6944 (434)	1348
BM3	28768(1798)	5584

A maximum of 16 "options" are identified for filling the telemetry resources. Each option is constrained to one or more spacecraft telemetry modes. Table (ii) gives the contents of each option . The telemetry option number is reported in the housekeeping and the first word of each science data packet.

Options 0x0A, 0x0B, and 0x0C shall be duplicated as option 0x02, 0x03, and 0x04 respectively, the difference being that when operating in 0x04 and with event recognition enabled, if an event is triggered and MSA data becomes available, then the instrument shall auto-switch to option 0x02 thus allowing the MSA data to be down-linked [S34]. When the MSA is empty, the instrument shall auto-switch back to option 0x04 [S35].

FGM Telemetry Option Number (hex)	**Available in OBDH Mode**	**Primary Vectors per Reset**	**Secondary Vectors per Reset**	**MSA Words per Reset**	**Comment / Requirement**
2	NM1, NM2, NM3 or BM2	81 (13)	6 (185)	126	Auto-switching mode [S32]
3	NM1, NM2, NM3 or BM2	95(11)	37(29)	0	Auto-Switching mode [S36]
4	NM1, NM2, NM3 or BM2	116(9)	16(67)	0	Auto-switching mode [S33]
A	NM1, NM2, NM3 or BM2	81(13)	6(185)	126	Normal Data [S27]

B	NM1, NM2, NM3 or BM2	95(11)	37(29)	0	Normal Data[S28]
C	NM1, NM2, NM3 or BM2	116(9)	16(67)	0	Normal Data[S29]
D	BM1	348(3)	41(26)	0	Burst Data[S30]
F	BM3	0	0	1778	MSA Dump [S31]

Table (ii). Eight options for Allocation of the FGM Experiment Format

() indicates the decimation level, based upon sampling at intervals of 297 ticks of the sync_60 clock. The detailed description of contents and layout for each telemetry option is given in Appendix A .

[S15]:
Data within a format shall be supplied to the OBDH in the following sequence:

Auxiliary Data (always supplied)
primary sensor vectors (always supplied except during MSA dump)
secondary sensor vectors (always supplied except during MSA dump)
MSA vectors (if applicable)

Auxiliary data, primary, and secondary vectors shall always be supplied by the instrument except during:

Memory dump
Code patch

[S16]:
There is spare capacity in the science telemetry equivalent to 1 vector. This shall allow for the periodic acquisition of an additional vector in a reset resulting in an additional vector for downlink.

[S17]:
Unused telemetry space shall have all bits set to zero, signaling "not valid field data".

[S11]:
All vectors acquired during a reset period shall be stored in DPU memory, sorted, and downlinked during the following telemetry format with timing information.

3.1.1 Auxiliary Data

Auxiliary Data shall comprise the telemetry status word, timing information and the variance of the field [S3].

[S23]
The first word of the science telemetry shall be bits 4 to 15 of the housekeeping instrument status word and bits 12 to 15 of the housekeeping error word inserted as bit 0 to 3. This word shall be known as the telemetry status word.

Within each telemetry format, 6 words are used to record timing information, and these words will be the first six after the telemetry status word. The sequence is as follows:
[S24]

Reset count. (HF Clock at RESET pulse)
Previous sun count (HF Clock at SRP)
Most recent sun count
Time of first primary sensor vector after reset (HF Clock at acquisition).
Time of first secondary sensor vector after reset (HF Clock at acquisition).
Count of resets since DPU boot.

The next word contains is made up as follows

Bit 00	Primary sensor is OB (bit set)/ IB (bit clear)
Bit 01	Secondary sensor is OB (bit set)/ IB (bit clear)
Bit 02	Filtering of science data is enable (bit set)/ disabled (bit clear)
Bit 03	OB CAL is on (bit set)/off (bit clear)
Bit 04	IB CAL is on (bit set)/ off (bit clear)
Bit 05	OB FLIP is on (bit set)/ off (bit clear)
Bit 06	IB FLIP is on (bit set)/ off (bit clear)
Bit 07	Not used
Bits 8-15	Holds the vector number at which the first variance calculation of the current reset has begun

The next nine words of the format shall contain the variance of the field [S25]. The total length of the auxiliary data is therefore 17 words or 272 bits.

3.1.2 Format of Vectors

Vector format is defined as follows:[S22]
One vector consists of a 45 bit sequence. Components will be supplied in the order X Y Z in the sensor co-ordinate system. Each component is 14 bits of 2's complement.

bits 0-13	X component most significant 14 bits
bit 14	Range MSB
bits 15-28	Y component most significant 14 bits
bit 29	Range bit 1
bits 30-43	Z component most significant 14 bits
bit 44	Range LSB

The three bit range code is reported as follows:
[S21]

Range Code	Range	Comment
111	-65536 to +65528 nT	
110	-16384 to 16382 nT	
101	-4096 to +4095.5 nT	
100	-1024 to +1023.9 nT	
011	-256 to +255.97 nT	
010	-64 to +63.992 nT	
001	-16 to +15.998 nT	Commandable but cannot autorange to
000	not used	Signifies "Not valid field data"

3.2 Housekeeping Telemetry

FGM housekeeping allocation is 15 words per reset. This will comprise (in the given order): [S5]

Parameter	Length (bits)
Error Parameter	16 bits
+12V line	10 bits
-12V line	10 bits
PSU Temp	10 bits
(spare)	2 bits
+5V line	10 bits
(spare)	2 bits
DPU Identifier	4 bits
Resets since boot	16 bits
Software Status	16 bits
Hardware status	16 bits
Instrument Status	16 bits
Telecommand count	16 bits
Primary sensor vector	32 bits
Secondary snsr. vector	32 bits
Key Hole Word	16 bits
Memory Monitor	16 bits
Total	240 bits

Analogue Parameters

Experiment voltages (+/- 12V, +5V) and PSU temperature are sampled at the ADC and truncated to 10 most significant bits for transmission. [S7]

Memory Monitor

The SEU Memory Monitor shall run in the top 512 words (0x3E00 to 0x3FFF) testing one word per science acquisition. The housekeeping shall report:

bits 0 to 6 Count of bad addresses in the last reset period
bits 7 to 15 Last encountered bad address (minus 0x3E00).

[S20]

Count of Resets

A 16 bit counter of the number of reset pulses since the DPU was booted [S6]. This will roll-over every 94 hours (approx.)

Software Status

The following software functions are enabled/true, if the given bit of this parameter is set
[S19]

bit 00 Primary sensor is outboard (bit set) / inboard (bit clear)

bit 01	Secondary sensor is outboard (bit set) / inboard (bit clear)
bit 02	SEU Monitor enabled (bit set) / disabled (bit clear)
bit 03	Booted AUTO (bit set) / booted MANUAL (bit clear)
bit 04	Filtering of science data enabled (bit set) / disabled (bit clear)
bit 05	Primary Autoranging enabled (bit set) / disabled (bit clear)
bit 06	Event triggered during previous reset (bit set) / no event (bit clear)
bit 07	Secondary Autoranging enabled (bit set) / disabled (bit clear)
bit 08	Booted on primary bus (bit set) / redundant bus (bit clear)
bit 09	Event recognition enabled (bit set) / disabled (bit clear)
bit 10	Interface 1 IEL Fast Clock enabled (bit set) / disabled (bit clear)
bit 11	Interface 2 IEL Fast Clock enabled (bit set) / disabled (bit clear)
bit 12	OB CAL on (bit set) / off (bit clear)
bit 13	IB CAL on (bit set) / off (bit clear).
bit 14	OB FLIP on (bit set) / off (bit clear).
bit 15	IB FLIP on (bit set) / off (bit clear).

Hardware Status

Contains the value read from the interface ASIC register 0 (hardware control register that the instrument has been commanded to use), plus the interface power status [S8] (bit set implies power on / output enabled)

bit 00	interface 1 power
bit 01	interface 2 power
bit 02	OB enable
bit 03	IB enable
bit 04	IEL enable
bit 05	sync 60 kHz. enable
bit 06	DPU 1 and DPU 2 Reset enable
bit 07	TM data enable
bit 08	ADC 2 power
bit 09	ADC 1 power
bit 10	MSA power
bit 11	interface power
bit 12	dpu 2 power
bit 13	dpu 1 power
bit 14	dpu 2 reset
bit 15	dpu 1 reset

Instrument Status

[S9]
Gives the status of science telemetry and instrument configuration.

bit 00	CONFIG_INT_MSB instruction received during last reset period
bit 01	CONFIG_INT_LSB instruction received during last reset period
bit 02	CONFIG_ADC_MSB instruction received during last reset period
bit 03	CONFIG_ADC_LSB instruction received during last reset period
bits 04 to 06	DPU Test Sequence number
bit 07	MSA data is filtered (bit set) / unfiltered (bit clear)
bits 08 & 09	Calibration Sequence number
bit 10	Memory Dump in-progress flag

bit 11	Code patch in-progress flag
bits 12 to 15	Telemetry option*

*Telemetry option flag.
This 4 bit data field defines which one of the 16 available telemetry options is currently selected. The choice of telemetry option is constrained by the OBDH mode. The telemetry options are numbered from zero to 0x0F

Telecommand count
[S10]
The FGM shall receive no more than 255 ML2 telecommands in any one reset period. (This is also an experiment operations constraint). The number of ML2 telecommands received since the processor was booted shall be reported in bits 8 to 15 of the Telecommand Count word. The counter shall roll-over to zero after 255.

Bit 0 set shall indicate the parameter block base address has been updated. Bits 1 to 7 shall contain a count of the total number of Parameter Byte Update commands received since the base address was last updated. The number of bytes sent between base updates shall therefore be limited to 127.

Primary Sensor Vector

The vector shall be the most recently acquired primary sensor vector. The coding is as follows:
[S12]

8 bits X component
8 bits Y component
8 bits Z component
5 bits unused
3 bits range

Secondary Sensor Vector

The vector shall be the most recently acquired secondary sensor vector. The coding is as follows:
[S13]

8 bits X component
8 bits Y component
8 bits Z component
5 bits unused
3 bits range

Key Hole Word

This word shall contain the data pointed to by the address in location zero of the parameter table. Its default position is that of a variable which contains the value of the register 0 of the active interface ASIC. [S15]

DPU identification

This four bit data field shall contain a code which uniquely identifies the DPU card which is in use.
[S17]

DPU Card	Code
EM DPU 1 (primary DPU)	0x1
EM DPU2 (redundant DPU)	0x2
F6 DPU 1 (primary DPU)	0x3
F6 DPU2 (redundant DPU)	0x4
F7 DPU 1 (primary DPU)	0x5
F7 DPU2 (redundant DPU)	0x6
F8 DPU 1 (primary DPU)	0x7
F8 DPU2 (redundant DPU)	0x8
F9 DPU 1 (primary DPU)	0x9
F9 DPU2 (redundant DPU)	0x0A
F1 DPU1 (primary DPU)	0x0B
F1 DPU2 (redundant DPU)	0x0C

Error Parameter

This parameter contains flags which are set in the event of any of the following error conditions: [S14]

bit 00	Parameter Count Overflow
bit 01	Interface Fault
bit 02	RAM Check Failure occurred during boot
bit 03	MSA Fault
bit 04	ADC Fail (Reset)
bit 05	ADC Fail (Timeout)
bit 06	ADC Fail (Bus ACK)
bit 07	Startup word not recognised during boot
bit 08	Reset Pulse not detected / No HFClock.

bit 09	Code Patch Fail
bit 10	DPU Fault
bit 11	IEL Fail (stack full)
bit 12	Sum Check of Code Failure
bit 13	not used
bit 14	Incorrect number of vectors sampled during the last reset period.
bit 15	Warning of possibly corrupt science data

See also section 2.2 (Error Handling).

The error word will be reset to zero after transmission.

Table (iii) gives the location of each parameter within the housekeeping format
[S18]

Table (iii) Housekeeping Format

Content	Start Bit	End Bit	Length
Error	0	15	16
+12V	16	25	10
-12V	26	35	10
PSU Temp	36	45	10
spare	46	47	2
+5V	48	57	10
spare	58	59	2
DPU ID	60	63	4
Reset Counter	64	79	16
s/w status	80	95	16
h/w status	96	111	16
Instrument status	112	127	16
TC Counter	128	143	16
Primary X	144	151	8
Primary Y	152	159	8
Primary Z	160	167	8
spare	168	172	5
Primary Range	173	175	3
Secondary X	176	183	8
Secondary Y	184	191	8
Secondary Z	192	199	8
spare	200	204	5
Secondary Range	205	207	3
Key-hole word	208	223	16
SEU Monitor	224	239	16

Document 9 (IC/CLUSTER/AIT/PARAM) defines the complete naming and extraction process for input to the AIT database.

Chapter 4 Telecommand Set

4.1 FGM Command Set

This section lists the command set available on the FGM instrument by name, destination (ML1 or ML2), description and value. Full details of telecommands may be found in documentation on the AIT database, reference IC\CLUSTER\AIT\AIT_TC.XLS.

4.2 ML1 Telecommands

ML1 commands control the on/off and enable/disable status of FGM hardware. Execution of these commands will be verified by observing data in the housekeeping channel. The complete list of ML1 telecommands is given in the list below. Each command is self contained within a single 16 bit word.

The telecommand name is the given name of the telecommand as used in the AIT database and is coded as follows:

Name: αβγδεζηθ
Where:
α = 'Z' (for telecommand)
β = 'E' (for experiment)
γ = 'F' (For FGM)
δ = '1' for ML1, or '2' for ML2
εζη = Text label
θ = 'N' for on, 'F' for off, 'D' for disable, 'E' for enable or 'S' for select

ML1 Telecommand List:

Name	Short Description	Long Description	Value (hex)
ZEF1DP1N	DPU1_ON	dpu 1 power on	0300
ZEF1DP2N	DPU2_ON	dpu 2 power on	0C00
ZEF1DP1F	DPU1_OFF	dpu 1 power off	0200
ZEF1DP2F	DPU2_OFF	dpu 2 power off	0800
ZEF1RESE	RESET_ENABLE	enable dpu reset	8030
ZEF1RESD	RESET_DISABLE	disable dpu reset	8020
ZEF1D1RN	DPU1_RESET_ON	dpu 1 reset high	0030
ZEF1D1RF	DPU1_RESET_OFF	dpu 1 reset low	0020
ZEF1D2RN	DPU2_RESET_ON	dpu 2 reset high	00C0
ZEF1D2RF	DPU2_RESET_OFF	dpu 2 reset low	0080
ZEF1AD1N	ADC1_ON	adc 1 power on	4C00
ZEF1AD2N	ADC2_ON	adc 2 power on	7000
ZEF1AD1F	ADC1_OFF	adc 1 power off	4800
ZEF1AD2F	ADC2_OFF	adc 2 power off	6000
ZEF1MSAN	MSA_ON	msa power on	4300
ZEF1MSAF	MSA_OFF	msa power off	4200
ZEF1OBSE	OB_ENABLE	enable control outboard sensor	B000
ZEF1IBSE	IB_ENABLE	enable control inboard sensor	8C00
ZEF1OBSD	OB_DISABLE	disable control outboard sensor	A000
ZEF1IBSD	IB_DISABLE	disable control inboard sensor	8800

ZEF1IELE	IEL_ENABLE	enable iel	8300
ZEF1IELD	IEL_DISABLE	disable iel	8200
ZEF1DR0S	DUMP_REG0	send ASIC reg.0 to HK	E000
ZEF1MSCS	ML2_STK_CLR	clear ML2 stack	C020
ZEF1INTN	INT_ON	power on other interface	3000
ZEF1INTF	INT_OFF	power off other interface	2000

There shall be a special ML1 telecommand for which all bits are configurable at send time and this telecommand shall be used for contingency purposes only:

ZEF1MLTS	DATAML1	uplink of 16 bit word	configurable at send time.

4.3 ML2 Telecommands

ML2 commands control execution of the DPU code. ML2 telecommands are read by the DPU in near real-time and take effect at the next reset pulse [T2]. The DPU shall buffer up to 255 ML2 telecommands received between resets [T3]. ML2 telecommands are of five types:

Boot telecommands consist of the special bit patterns and their bitwise inverse for which the DPU searches at the interfaces when the instrument is booted.

Hardware Control Commands instruct the DPU to execute ASIC related procedures which are not visible to the ML1 memory load register, e.g. sensor cal/flip etc.

Instrument Function Commands switch the instrument between its major modes of operation, e.g. science telemetry modes, test, calibrate etc.

Software Control Commands with 4 bit Data Field enable/disable/control on-board software functions. The data field is supplied at send time.

Software Control Commands with 8 bit Data Field contain a data field which is supplied at telecommand send time.

The coding of the 16 bit value of the telecommand is as follows:

Value = wxyz(hex)

Where:
wx specifies the unique telecommands number.
yz contains data field if defined.

ML2 Telecommand List:

Boot Telecommands
[T4]
These telecommands have no data field

Name	**Short Description**	**Long Description**	**Value (hex)**

ZEF2ATTS	AUTO	perform auto configuration	0002
ZEF2ATCS	AUTO_INVERTED	perform auto configuration	FFFD
ZEF2MNTS	MANUAL	telecommand configuration	0001
ZEF2MNCS	MANUAL_INVERTED	telecommand configuration	FFFE

Hardware Control Commands
[T5]
These commands have a 4 bit data field.

Name	Short Description	Long Description	Value (hex)
ZEF2I1FN	INT1_IEL_FAST_ON	INT 1 IEL Fast, ON/OFF	101z ON:z=1 OFF:z=0
ZEF2I2FN	INT2_IEL_FAST_ON	INT2 IEL Fast ON/OFF	102z ON:z=1 OFF:z=0
ZEF2PCLN	PRIMARY_CAL_ON	Primary Sensor Cal ON/OFF	104z ON:z=1 OFF:z=0
ZEF2SCLN	SECOND_CAL_ON	Secondary Sensor Cal ON/OFF	108z ON:z=1 OFF:z=0
ZEF2PFLN	PRIMARY_FLIP_ON	Primary Sensor Flip ON/OFF	110z ON:z=1 OFF:z=0
ZEF2SFLN	SECOND_FLIP_ON	Secondary Sensor Flip ON/OFF	120z ON:z=1 OFF:z=0
ZEF2PRNS	PRIM_RANGE	Primary Range Select	410z Auto Rng: z=0 Range 1:z=1 Range 2:z=2 Range 3:z=3 Range 4:z=4 Range 5:z=5 Range 6:z=6 Range 7:z=7
ZEF2SRNS	SEC_RANGE	Secondary Range Select	420z Auto Rng: z=0 Range 1:z=1 Range 2:z=2 Range 3:z=3 Range 4:z=4 Range 5:z=5 Range 6:z=6 Range 7:z=7

Instrument Function Commands (with 4 bit data field)
[T6]
These telecommands have a four bit data field which is used to select one of 16 options.

Name	Short Description	Long Description	Value (hex)
ZEF2TMMS	TM_SELECT	Telemetry Option Select z =Telemetry option #	201z
ZEF2TSTS	TEST_SELECT	DPU Test Mode Select z =Test option #	210z
ZEF2CLBS	CALIBRATE	Select Instrument Calibrate z= Calibrate program #	202z

Instrument Function Commands (with no Data Field)

These telecommands select FGM functions which run to completion, the instrument then reverts to its previous state.

Name	Short Description	Long Description	Value (hex)
ZEF2PATS	CODE_PATCH	Select Code Patch	2040
ZEF2DMPS	MEMORY_DUMP	Select Memory Dump	2080

Software Control Commands with 4 bit data field
[T8]

Name	Short Description	Long Description	Value (hex)
ZEF2SEUN	SEU_CONTROL	SEU Monitor ON/OFF	400z ON:z=1 OFF:z=0
ZEF2FILN	FILTER_CONTROL	Science Filtering ON/OFF	401z ON:z=1 OFF:z=0
ZEF2ENTN	EVENT_CONTROL	Event Recognition ON/OFF	402z ON:z=1 OFF:z=0
ZEF2POBS	PRIM_OB	Primary Sensor is OB/IB	440z OB:z=1 IB:z=0
ZEF2SOBS	SEC_OB	Secondary Sensor is OB/IB	480z OB:z=1 IB:z=0
ZEF2TRGS	MSA_TRIGGER	Select MSA Trigger	220z z=0: Trigger MSA z=1: Un-trigger MSA

Software Control Commands with 8 bit Data Field
[T9]

Name	Short Description	Long Description	Value (hex)
ZEF2CIMS	CFG_INT_MSB	int. config. word most sig. byte	80yz*
ZEF2CILS	CFG_INT_LSB	int. config. word least sig. byte	81yz*
ZEF2CAMS	CFG_ADC_MSB	adc config. word most sig. byte	82yz*
ZEF2CALS	CFG_ADC_LSB	bus config. word least sig. byte	83yz*
ZEF2PBAS	PARAM_BASE	Parameter base address send yz defines offset in words from parameter base address	84yz

ZEF2PBYS	PARAM_BYTE	Parameter byte send yz gives byte to be poked at current address	85yz

*The commands CFG_INT_LSB/MSB and CFG_ADC_LSB/MSB perform detailed configuration of FGM hardware. These functions require a 16 bit data word, which is uplinked as most significant byte (bits 0-7) and least significant byte (bits 8-15) separately. Only data fields 0x0000 or 0xFFFF are allowed

For CFG_INT_MSB and CFG_INT_LSB, the 16 bit word is defined as follows:

Data Field Value	Function
0x0000	Interface I/O Requests to INT2
0xFFFF	Interface I/O Requests to INT1

Hence a data field of 0x0000 will direct all
interface I/O requests to interface 2.
Status registers for SC, HK and ML2 are also similarly directed.
Also enables / disables the appropriate sync 60 to the sensors.

The command CFG_ADC configures the ADC/BUS combination in a similar manner:

Data Field Value	Function
0x0000	ADC I/O Requests to ADC2 over BUS2
0xFFFF	ADC I/O Requests to ADC1 over BUS1

There shall be a special ML2 telecommand in which all 16 bits are configurable. This shall be used for the uplinking of data during code patch operations:

ZEF2MLTS	DATAML2	uplink of 16 bit data word	wxyz

4.4 Defaults

The following software functions are to be taken as the default setting after dpu boot:

[D1]
Normal mode telemetry (option C) is the default instrument function.
[D2]
Vector filtering is enabled.
[D3]
Event recognition is disabled
[D4]
Autoranging is enabled. The autoranging is disabled for 5 vector samples after an uprange has occurred.
[D5]
Primary sensor is outboard.
[D6]
Secondary sensor is inboard.
[D7]

All interface services routed through the same interface (chosen at boot)
[D8]
All bus services routed through the same bus (chosen at boot)
[D9]
All ADC services from the same ADC (chosen at boot)

The following hardware functions are to be taken as the default setting after dpu boot:

[D10]
All hardware control functions enabled
[D11]
IEL speed is fast on interface 2 and slow on interface 1

4.5 Data Fields

4.5.1 Setting Parameters for The Event Detection Algorithm

Parameters for event recognition algorithms are to be held in the parameter block, locations to be defined in the DDD.

Appendix A

A.1 Introduction

The FGM Experiment format is a telemetry unit containing all science data sent from the instrument during a spacecraft telemetry format. 16 possible of "Options" are defined for filling the Experiment Format; selection of Option is indicated to the instrument by telecommand, though choice of Option is constrained by the spacecraft telemetry mode.

For each option, the following tables give the bitwise layout of the FGM Experiment Format. Experiment data types are as follows:

- Auxiliary Data
  Includes in the following order:

  Telemetry Status word (16 bits)
  Timing Information (96 bits)
  Variance (160 bits)
  _____
  Total 272 bits.

- Variance.
  Variance of the field data (10 x 16 bits)

- MSA data.
  Data dumped from the MSA.

- Primary Sensor Vectors
  45 bit coded blocks

- Secondary Vectors
  45 bit coded blocks.

- Unused telemetry space is indicated.

Bit zero of the format is the most significant bit. Data is transmitted from the instrument as 16 bit words. In the case of bytewise transmission of data (i.e. telemetry packets), the most significant byte is transmitted first.

A.1.1 Option # 0x0A & Option #0x02

Available in modes NM1, NM2, NM3 & BM2

Data Type	Start Bit	End Bit	Length
Auxiliary	0	271	272
Primary Vectors	272	3916	3645
Unused	3917	3919	3
Secondary Vectors	3920	4189	270
Unused	4190	4191	2
MSA	4192	6239	2048

A.1.2 Option # 0x0B & Option #0x03

Available in modes NM1, NM2, NM3 & BM2

Data Type	Start Bit	End Bit	Length
Auxiliary	0	271	272
Primary Vectors	272	4546	4275
Unused	4547	4559	13
Secondary Vectors	4560	6224	1665
Unused	6225	6239	15

A.1.3 Option # 0x0C & Option #0x04

Available in modes NM1, NM2, NM3 & BM2

Data Type	Start Bit	End Bit	Length
Auxiliary	0	271	272
Primary Vectors	272	5491	5220
Unused	5492	5503	12
Secondary Vectors	5504	6223	720
Unused	6224	6239	16

A.1.4 Option # 0x0D

Available in mode BM1 only

Data Type	Start Bit	End Bit	Length
Auxiliary	0	271	272
Primary Vectors	272	15931	15660
Unused	15932	15935	4
Secondary Vectors	15936	17780	1845
Unused	17781	17855	75

A.1.5 Option #0x0F

Available in Mode BM3

Data Type	Start Bit	End Bit	Length
Auxiliary	0	271	272
MSA	272	28767	28496