XMM OPTICAL MONITOR

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XMM-OM USER MANUAL (EM)

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1. Introduction

1.1 Purpose and Scope

This manual gives an overview of the XMM Optical Monitor (OM) and acts as an explanatory supplement to the Integrated Functional Test Procedure. It is limited in scope to the Engineering Model.

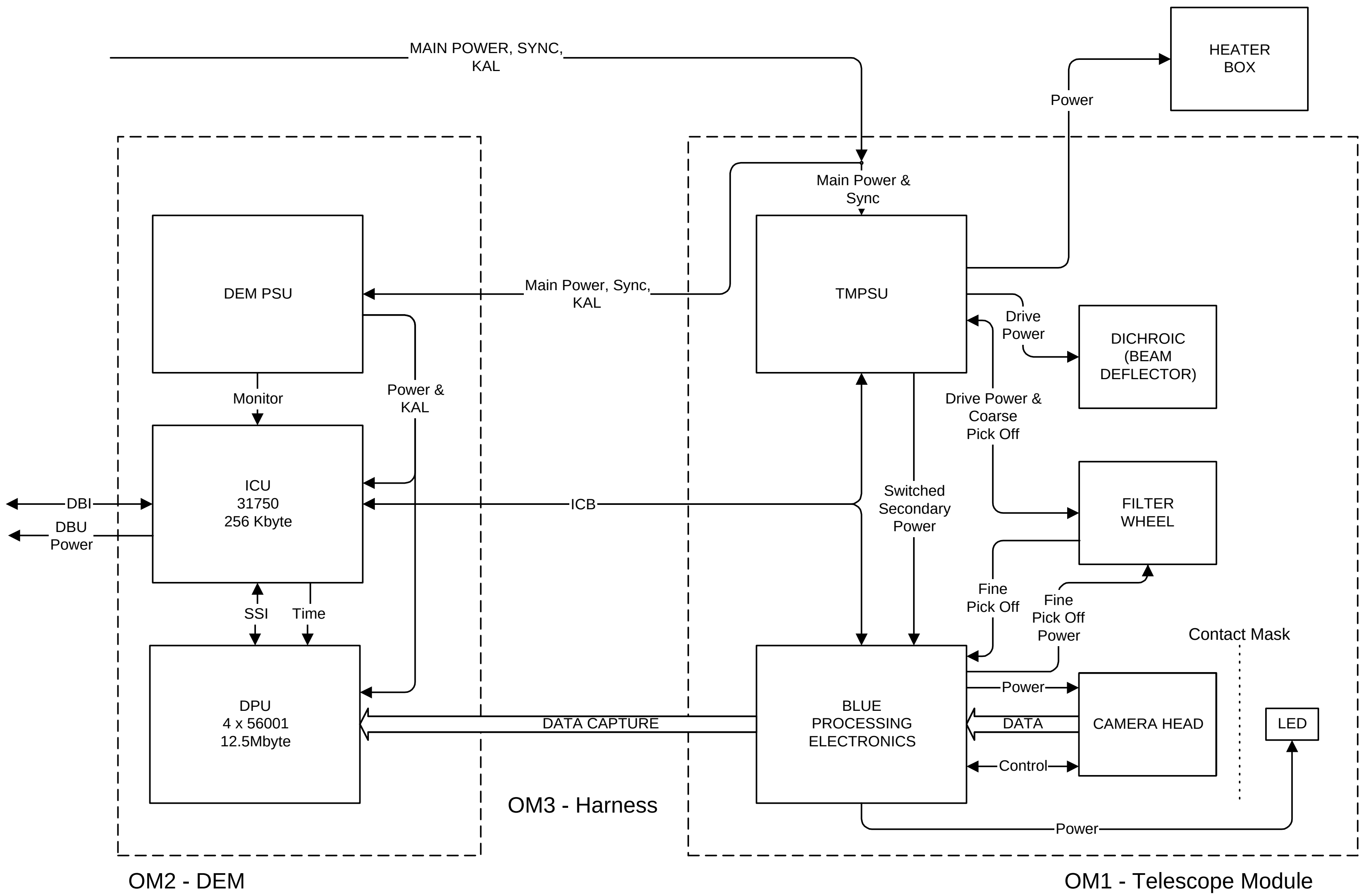
1.2 Applicable Documents

APP-1	Packet Structure Definition	RS-PX-0032
APP-2	XMM Operations Interface Requirements	RS-PX-0028
APP-3	ICU-DPU Protocol Definitions	XMM-OM/MSSL/SP/0014
APP-4	Telecommand & Telemetry Specification	XMM-OM/MSSL/SP/0061
APP-5	User Requirements Specification	XMM-OM/MSSL/SP/0030
APP-6	XMM-OM Bootstrap Specification	XMM-OM/MSSL/SP/0153
APP-7	XMM-OM EM Integrated Functional Test Procedure	XMM-OM/MSSL/SP/0146

1.3 Terms and Abbreviations

ADC	Analogue to Digital Conversion
APID	Application Identifier
BCH	Blue Camera Head (synonym for Detector Camera Head)
BPE	Blue Processing Electronics (synonym for Detector Processing Electronics)
CCD	Charge Coupled Device
CRC	Cyclic Redundancy Code
DEM	Digital Electronics Module.
DMA	Direct Memory Access
DPU	Digital Processing Unit
DSP	Digital Signal Processor
EM	Engineering Model
FID	Function Identifier
FM	Flight Model
ICB	Instrument Control Bus
ISR	Interrupt Service Routine
KAL	Keep Alive Power
LSB	Least Significant Bit
MACSbus	Modular Attitude Control System bus
MFN	Master Function Number
MID	Memory Identifier
MSB	Most Significant Bit
N/A	Not Applicable
OM	Optical Monitor
OMIF	OM Interface card
OM1	Synonym for the Telescope Module
OM2	Synonym for the Digital Electronics Module
PSD	Packet Structure Document
PREF	Parameter Reference
RBI	Remote Bus Interface
S/C	Spacecraft
SCI	Serial Communications Interface
SIBA	Spacecraft Interface Bus Adapter
SID	Structure Identifier
SSI	Serial Synchronous Interface
TBC	To Be Confirmed
TBD	To Be Defined
TBI	To Be Implemented
TC	Telecommand Packet
TID	Task Identifier
TM	Telemetry Packet
TM	Telescope Module
TMPSU	Telescope Module Power Supply Unit
TPN	Telemetry Packet Number
VBWL	Variable Block Word Length
XMM	X-ray Multi Mirror

XMM-OM Engineering Model Block Diagram



2. Overview

2.1 XMM Mission

The X-ray Multi-Mirror Mission (XMM) is an ESA spacecraft mission aimed at performing detailed imaging spectro-photometry of a wide variety of x-ray sources.

It is designed to be a long duration (~10 years) observatory type mission, open to the astronomical community.

It is planned be launched at the end of the century (~1999), placed into a 48 hour highly eccentric inclined orbit and have continuous ground station contact.

The payload is designed to be a mutually complementary package composed of 3 instruments as follows :-

EPIC - **E**uropean **P**hoton **I**maging **C**amera
RGS - **R**eflection **G**rating **S**pectrometer
OM - **O**ptical **M**onitor

2.2 OM Experiment

2.2.1 Science

The OM (Optical Monitor) experiment is designed to provide optical coverage of astronomical sources simultaneously with the x-ray coverage provided by the EPIC and RGS instruments.

- Onboard optical observations remove the need for simultaneous ground based observations which are difficult to organise, expensive and frequently fail due to bad observing conditions. There is also the added difficulty of correlating ground event times with those from the spacecraft. Furthermore, a spaceborn optical monitor allows extension of the wavelength range into the UV.
- Such simultaneous optical and x-ray information about astronomical x-ray sources is very important to understanding these objects and in particular provides :-
- Optical variability measurements simultaneously with x-ray measurements.
- Astrometry. (e.g. Identification of optical counterparts)
- Broad band colours/ low resolution spectroscopy.
- Improved spacecraft attitude reconstruction for the x-ray observations.
- Simultaneous correlation of optical & x-ray events/periods.
- Optical measurements extending into the UV. (The Hubble telescope is the only other way to provide this information but will be too heavily subscribed to perform this function for the XMM mission routinely.)
- Ratio of optical to x-ray flux. (Important for cosmological studies of quasars and galaxies).
- Studies of optical objects which may have no x-ray counterparts. (Serendipitous data which may be used for e.g. astero-seismology and micro-variability which may provide insight into the internal structure of such objects.)

2.2.2 Scope of Engineering Model

The engineering model (EM) is electrically and functionally representative of the flight model (FM) unit.
It consists of only a prime channel. The unit is suitable for EMC tests but not thermal vacuum or vibration tests. It does not contain any optical element, telescope, baffle or intensifier. There is also no high voltage unit and thus no high voltage control and monitoring.

2.2.3 Architecture Overview

The OM Engineering (EM) instrument is composed of 3 units as follows:

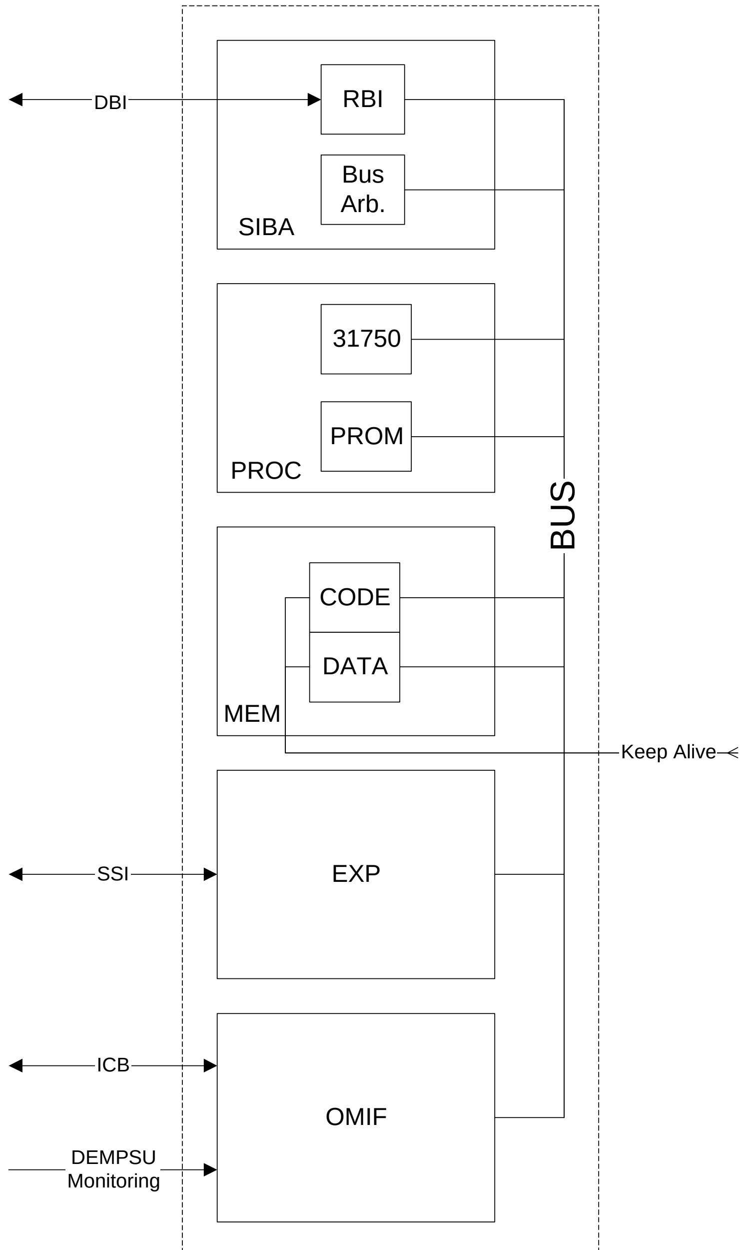
- TELESCOPE MODULE (TM)- OM1 - containing
  - A beam deflector and filter wheel (without elements).
  - External to OM1, a heater box is provided to simulate the heaters that will be present on the flight model (FM).
  - A detector processing electronics and camera head, but without an optical system or intensifier (and therefore no high voltage control and monitoring). A contact mask, illuminated by an LED, substitutes for the star field. The contact mask consists of a diagonal cross of holes approximately 1 CCD pixel in size.
  - A TM Power Supply - the TMPSU - see OM3 description for more information.

- DIGITAL ELECTRONICS MODULE (DEM) - OM2 - containing the
  - Digital Processing Unit (DPU). It performs basic science data reception and processing including image accumulation.
  - Instrument Control Unit (ICU). The ICU provides the basic instrument control function, housekeeping monitoring and code up-link for both itself and the DPU. DPU processed data is passed to the Instrument Control Unit (ICU) processor for reformatting into packets prior to being passed to the spacecraft OBDH system.
  - SSI Interface. The DPU and ICU communicate via a full duplex Serial Synchronous Interface (SSI).
  - DBI. The interface from the ICU to the spacecraft for data downlink and command up-link will be carried by a digital bus interface (DBI). The ICU supports a telemetry rate of up to 8 kbps and a telecommand rate of 2 kbps.
  - DEM Power Supply. This provides the conditioned power for the ICU and DPU in the DEM. It provides latchup protection.

- INTERCONNECTING HARNESS MODULE - OM3
  - This harness carries power, synchronisation information, keep-alive line and an Instrument Control Bus (ICB) between the Telescope Module and the Digital Electronics Module. The ICB is used by the ICU to control and monitor the detector, mechanisms and heaters via the TMPSU. It is based on the MACS-bus standard.

2.2.4 ICU

This consists of 5 cards:-



SIBA — The Spacecraft Interface Bus Adapter card. Contains the RBI chip and bus arbitrator. The RBI provides
- interfaces to the spacecraft to provide DMA of telemetry and telecommand packets
- input of spacecraft time
- time signals to be forwarded to the DPU.
- The watchdog

PROC — The processor card - contains
- a 31750 processor
- PROMs - 16K 16 bit words

MEM — The memory card
- 64k 16 bit words of code
- 64k 16 bit words of data.

EXP — The expansion card - Contains the Synchronous Serial Interface (SSI) control circuitry- the DPU communication path.

OMIF — The OM Interface card.- contains
- ICB interface circuitry
- DEMPSU monitoring circuitry

2.2.5 DPU

The DPU is a hybrid local/shared memory multiple processor computer. It shares the DEM with the ICU and DEMPSU.

Four Digital Signal Processor (DSP) cards access a global memory in series via a global bus, with access to the bus managed by an arbiter card. Each processor is granted access to the bus once per millisecond. Each DSP also has local memory. Each DSP is assigned specific tasks

White	• Overall Management of the Other Processors via the Serial Command Interface (SCI) • ICU communication • Initial field acquisition • Spacecraft drift tracking.
Blue 1 and 2	Data collection and initial processing (e.g. tracking frame image accumulation)
Red	Shift and Add Calculation (i.e. summation of image corrected for drift)

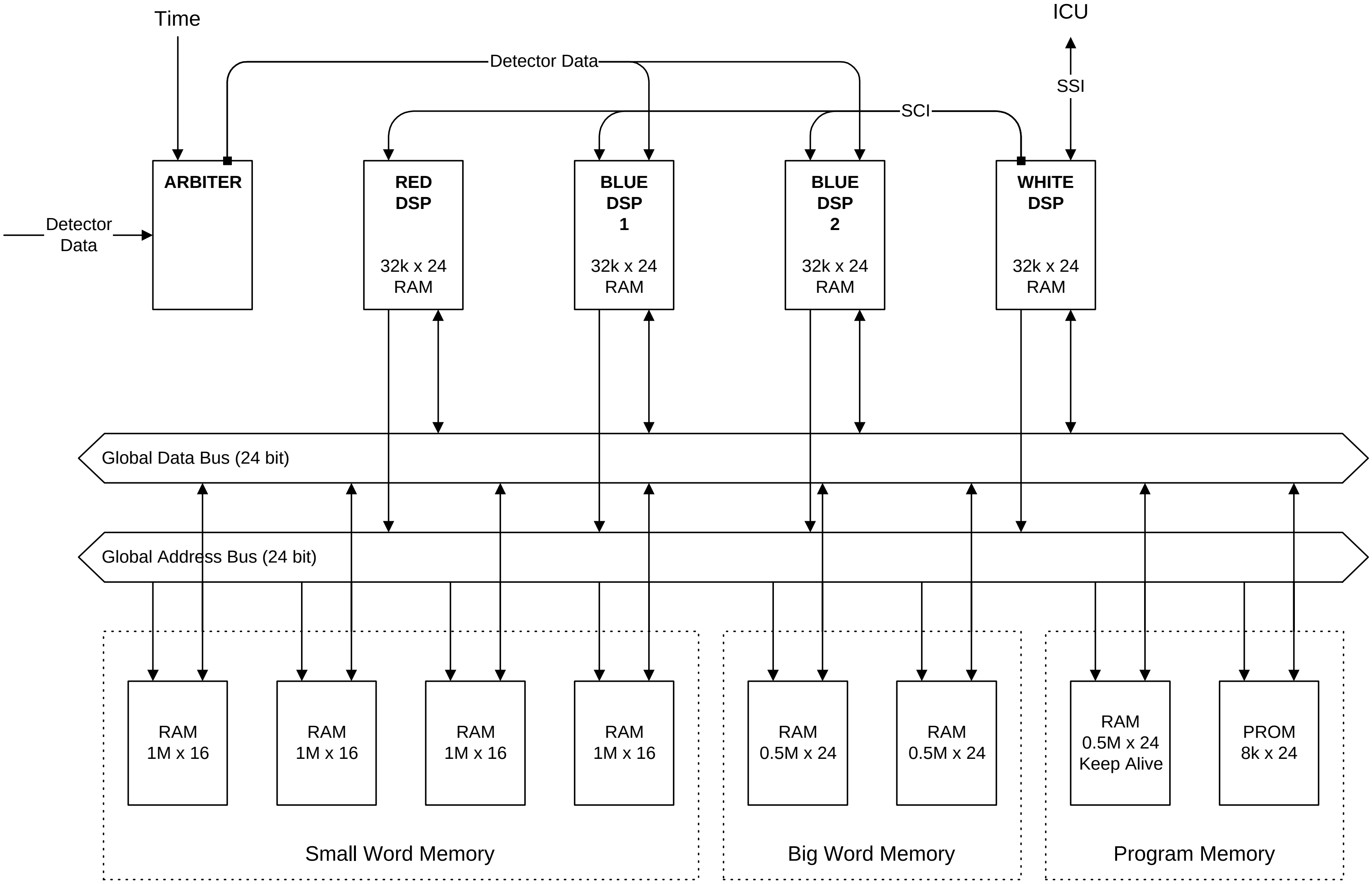
The global memory consists of 12.5 Mbytes of memory, divided into:-

Small Word Memory	4 Mwords of 16 bit words RAM. Used to store a tracking frame and full frame applications
Big Word Memory	1 Mwords of 24 bit words RAM. Stores accumulated images.
Program Memory	0.5 Mwords of 24 bit RAM and 8k 26 bit words of PROM.

Each DSP card has its own local memory (32k by 24 bit words) which can only be accessed by that DSP.

A block diagram illustrating the above is given overleaf.

DPU Block Diagram



2.2.6 Detector System

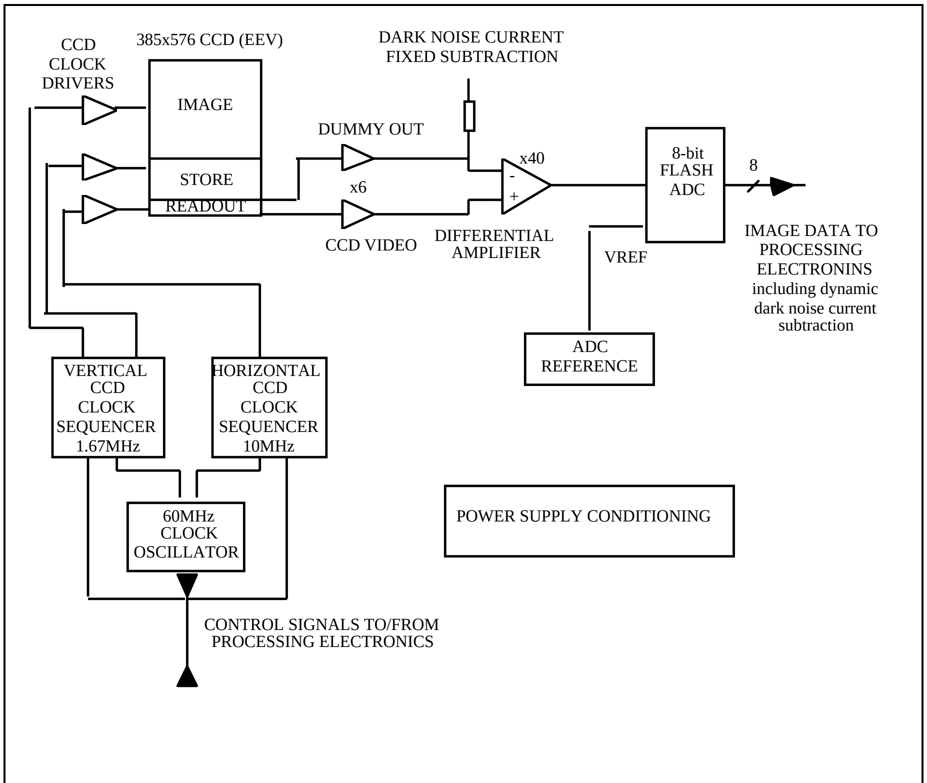
2.2.6.1 Camera Head

The sensor in the Camera Head (BCH) is an EEV CCD-02-06 which is a frame transfer device running with a vertical clock rate of 1.67 MHz and a horizontal readout rate of 10 MHz. The CCD is of well proven design and is used in many monochrome commercial and scientific TV applications. The dummy output from the CCD is subtracted from the video signal to reduce the level of saturation of the final video amplifier stage. The main cause of this is clock feed-through in the CCD wiring and the reset spike. The diagram below shows the functional blocks of the camera.

The CCD outputs are directly buffered with wide bandwidth emitter followers. The pre-amps are set at a gain of 4, and the differential amplifier at 10, giving a combined gain of 40. Because of the high read out rate, the video signal has settled to only approximately 75% of its final value at the instant of the ADC sample strobe. The gain is therefore slightly higher than that deduced from the CCD manufacturer's published data.

The horizontal clock sequencers and ADC sample strobe are derived from a highly stable ECL sequencer circuit based around a twisted ring counter. This, together with a fast horizontal driver circuit design, guarantees minimum timing jitter and hence low systematic noise as required for centroiding the image to 1/8th x 1/8th of a pixel.

Under control from the Blue Processing Electronics (BPE), the camera is capable of reading out of a number of windows in the CCD image in rapid succession, or full 256 x 256 pixel frames. The integration time is typically 12 ms.



Block Diagram of Blue Camera Head Electronics

2.2.6.2 Detector Processing Electronics

2.2.6.2.1 General

The principal features of the detector processing electronics are:

- Generation of the Detector Head clock sequences to operate the CCD in a frame transfer mode
- Specification of the area (windows) of CCD to be read out.
- Event Detection.
- Event Centroiding.
- Engineering Data.
- Construction and transmission of data to the DPU.
- ICB interface for control of the above.

N.B. The detector processing electronics is often referred to as the Blue Processing Electronics (BPE). This refers to an earlier design which included an additional detector more sensitive to the red end of the spectrum. The two detectors were labelled ‘blue’ and ‘red’.

A block diagram of the detector electronics is given overleaf.

2.2.6.2.2 Window Bitmap RAM

Before the detector processing electronics may be used, the window bitmap RAM must be loaded. The RAM is 64k by 4 bits. The information loaded will cause only those CCD pixels within the desired windows to be readout i.e. a clocking sequence is generated for the desired camera format.

For every location on the CCD, there is a location in RAM. During a row readout, the corresponding RAM contents are interpreted as a window ID. An ID in the range 1 to 15 is a valid window ID and the corresponding pixel *pair* is readout, whereas a value of 0 means that it is not in any window and will not be readout. By loading up the RAM accordingly, the detector area can be thus divided up into a collection of windows of varying size. **Note** that windows must start on an *even* number in X and an *odd* number in Y.

For each *pair* of CCD rows, there is a location in the RAM that will contain a ‘row action code’. This will specify what to do with the row *pair* as a whole. The values and meanings are

0 Perform vertical transfer only, i.e. no horizontal readout. This is used for skipping unwanted rows
2 Readout the row, ignoring window IDs, thus dumping unwanted charge build-up.
3 Readout the row, taking note of window Ids and transmitting the event data to the DPU.
8 Complete horizontal readout and skip to the start of frame transfer i.e. skip to end.

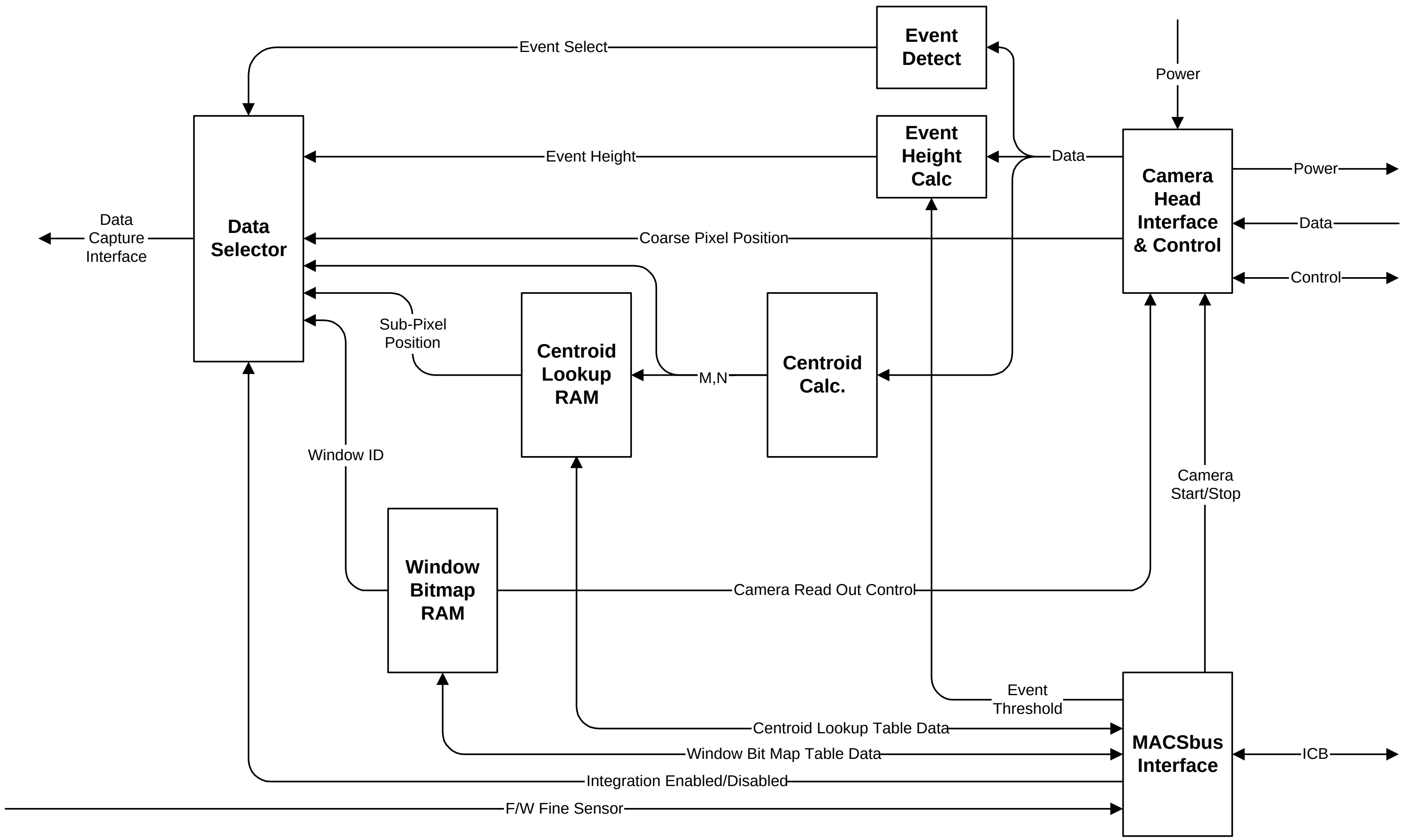
The table is loaded from the ICU via the ICB.

2.2.6.2.3 Centroid Lookup RAM

Centroiding is the process of locating the position of an event to an accuracy greater than that of a CCD pixel. For each event and in both the x and y axes, the processing electronics produces two 8 bit numbers, labelled **m** and **n**. The division **m/n** is the fractional position within a CCD pixel of the event. The range is divided into 8 bins, otherwise known as sub-pixels. Rather than performing this calculation, there are two (64k by 4 bit) tables containing all possible results of the division. The **m** and **n** are combined into a single 16 bit address which is used to lookup the result. The result is in the range 0-7.

Preparing the table contents requires two sets of 9 ‘channel boundary’ values giving the edges of the sub-pixels in both x and y. They are in the range -1.00 to 1.00. These values are multiplied by 1000 for up-link purposes. The tables are loaded from the ICU via the ICB.

DETECTOR PROCESSING ELECTRONICS



2.2.6.2.4 Output Data Formats

The output of the processing electronics to the DPU is a series of 24 bit words, one per event processed. The format of the word is determined by the data acquisition mode set via the ICB and is detailed in the figure overleaf. There are 4 scientific modes (numbered 0 to 3) and effectively 2 engineering modes (numbered 4 to 7).

The scientific modes provide event positions in the form of the x and y CCD pixel number, the sub-pixel number in x and y and the window ID of the window in which they occurred. There are 2 full frame modes where the window ID is replaced by the most significant bits of the x and y CCD pixel counters, thus giving 16 tiles covering the full detector area.

The engineering modes provide information for setting up and checking the detector. Modes 4 or 5 capture centroiding information in the form of events in which the x and y co-ordinates are replaced with the **m** and **n** values. The two 256 by 256 ‘pseudo images’ thus formed can be used to calculate a new sub-pixel channel boundaries from which the centroid lookup table can be reloaded. Note that a) modes 4 and 5 are equivalent and both formats are transmitted at once b) the first X M/N event for each frame is not transmitted. Modes 6 or 7 gives event height leading to a 1D image i.e. a histogram. They also produce event energy records in which the energy value is set to zero, due to this feature being removed from the design. Therefore, all records of this format should be ignored. Note that mode 6 and 7 are equivalent and both formats are transmitted at once.

In addition, there are two words of all zeros, the ‘frame tags’, transmitted at the start of each frame. These are used for frame counting and timing purposes. This feature is enabled via the ICB. It should be disabled for engineering modes.

For the full frame modes only, windows should be defined so that the full detector area is covered, even though the window ID in bits 4 through 1 does not appear in the data. Instead, the high order bits of the CCD pixel co-ordinates are inserted. Because the DPU will regard these as a window ID, it is thus possible to have an apparent window ID of zero (which is impossible for the windowed modes).

For engineering modes, windows of any ID should be defined to cover the area of the detector from which information is required. The DPU will again regard bits 4 through 1 as a window ID.

A height threshold, set via the ICB, is used to select valid events. This value should be set low (~8) for engineering data so as to obtain a full pulse height distribution. Otherwise a value ~30 should be used.

When, as a result of an ICB command, an integration is enabled, data is sent on to the DPU at the start of the next frame.

Detector Data Transmission Formats

Science or Engineering	Detector Mode	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
Science	0	0	YC 6-0							y 2	y 1	XC 6-0							x 2	x 1	ID				P	Low Resolution, Windowed
Science	1	0	0	YC 5-0						y 2	y 1	0	XC 5-0						x 2	x 1	YC 7	YC 6	XC 7	XC 6	P	Low Resolution, Full Frame
Science	2	0	YC 5-0						y 2	y 1	y 0	XC 5-0						x 3	x 2	x 1	ID				P	High Resolution, Windowed
Science	3	0	YC 5-0						y 2	y 1	y 0	XC 5-0						x 3	x 2	x 1	YC 7	YC 6	XC 7	XC 6	P	High Resolution, Full Frame
Engineering	4	0	0	M value								0	N Value								0	0	0	1	P	Engineering, X M/N Data
Engineering	5	0	0	M value								0	N Value								0	0	1	0	P	Engineering, Y M/N Data
Engineering	6	0	0									0	Event Height								0	0	0	1	P	Engineering, Event Height
Engineering	7	0	0									0	0								0	0	1	0	P	Engineering, Event Energy (contains no meaningful data)

P = Parity (Odd)
XC = X Pixel Co-ordinate
YC = Y Pixel Co-ordinate
x = X Sub-Pixel Bit
y = Y Sub-Pixel Bit
ID = Window ID

2.2.7 Mechanisms

2.2.7.1 Filter Wheel

Eleven optical elements are placed at equal angles around the filter wheel. For the EM, these positions are vacant. The wheel is driven by a pinion on a 4-phase stepper motor shaft, with a gear ratio of 11 to 1. Thus one revolution of the motor, which requires 200 steps, moves the wheel from one optical element to another and 2200 steps will completely rotate the filter wheel.

The wheel position will normally be determined in open loop mode by step counting from a known datum position, specifically when the blank is placed centrally in the beam. Two position sensors are provided to relocate the datum position, should it be lost and to verify the wheel position during and after every rotation. This system also confirms that the centre of any optical element has been found, although the element is not identified. A reflective infra-red *coarse* position sensor is fitted to the wheel which gives a true output when the blank is within about $\pm 15°$ of its correct position. A further infra-red *fine* position sensor, this time used in transmissive mode, is fitted to the rear end of the motor. An occulting disk with a small aperture, through which the sensor looks, is fitted to the rear extension of the motor shaft. It is aligned such that the element will be in its correct position when the fine sensor gives a true reading *and* the first phase is energised. **Note** - for the EM only, the *3rd* phase is used for alignment.

The LED that illuminates the *coarse* sensor is powered directly from the TMPSU. However, the *fine* sensor LED is powered and sensed, via the detector electronics, which is dependent on the switched secondary power being enabled. This does not occur until the OM is in operational mode. Therefore, it is not possible to obtain full control of the filter wheel until that time. It should also be noted that, for the EM, there is no system to control the current and therefore the brightness, of the fine sensor LED.

2.2.7.2 Dichroic

The dichroic contains a mirror placed at 45° in the path of the incoming beam. The purpose of the mechanism in the FM is to steer the reflected light beam from one of two redundant detector systems to the other. It will be rotated from one position to the other by pulse counting. The final step will drive the rotor to its stop where it will be held by a magnetic detent. The dichroic has to rotate 180° between the stops and is driven by a 4 step per revolution motor geared at 14.5:1. Therefore the motor needs to be driven up to 29 steps from one position to the other. One further step in each direction means that the rotor is driven hard onto its stop. Thus the total number of steps required is 31. As there is no harm in overdriving the system against this stop, the motor is always driven the maximum number of steps required in the specified direction. The drive frequency is 2 Hz.

2.2.8 Heater Box

This simulates the four instrument heaters, which on the FM will be as follows:

HTR1	Main Interface
HTR2	Forward Tube
HTR3	Metering Rods Focusing
HTR4	Secondary Mirror Focusing

HTR1 and HTR2 will be used in the FM in an closed loop fashion to maintain the interface temperature within tight limits (TBC). For the EM, they are used in a open loop manner.

HTR3 and HTR4 will be used in the FM to compensate for any focus shift that occurs after launch.

2.3 Software

2.3.1 Operational Modes

For the **EM** model, the Safe, Idle, Engineering and Science modes proposed for the FM (App-5) are combined into one Operational Mode and Initial mode is renamed Basic. Some modes have sub-modes. An outline of the function of each mode is given below. The characteristics, inter-relationship and required transitions between the modes are given in more detail in the diagram and table overleaf.

2.3.1.1 Off

ICU is not powered. The Bootstrap Init mode is entered autonomously after power on.

2.3.1.2 Bootstrap Init

The ICU is powered and

- performs a reset of interfaces
- copies required ROM to RAM
- initialises the software,
- sets high voltage ports to zero,
- turns off the secondary power
- resets the DPU
- moves the filter wheel close to the blank position (i.e. such that the coarse sensor is seen).

The software then autonomously enters the Bootstrap Reset mode.

2.3.1.3 Bootstrap Reset

The ICU is powered. The configuration is in a known state.

If entry to Bootstrap Init was from being powered on or as a result of a Cold Start Instruction to RBI, the ICU autonomously enters Basic Mode.

Otherwise, the transition to Basic Mode only occurs after receipt of the Start Instruction to RBI.

2.3.1.4 Basic

This is the first point at which telecommanding and telemetry are possible. It is possible to move to ICU operational mode from here. However, before that is possible, the ICU operational code must have been uplinked since the last cycling of the Keep Alive Power.

2.3.1.5 ICU Operational

This is the first point at which it is possible to command and receive telemetry from the DPU. Before a transition to Full Operational is possible, the DPU Operational must have been uplinked since the last cycling of the Keep Alive Power.

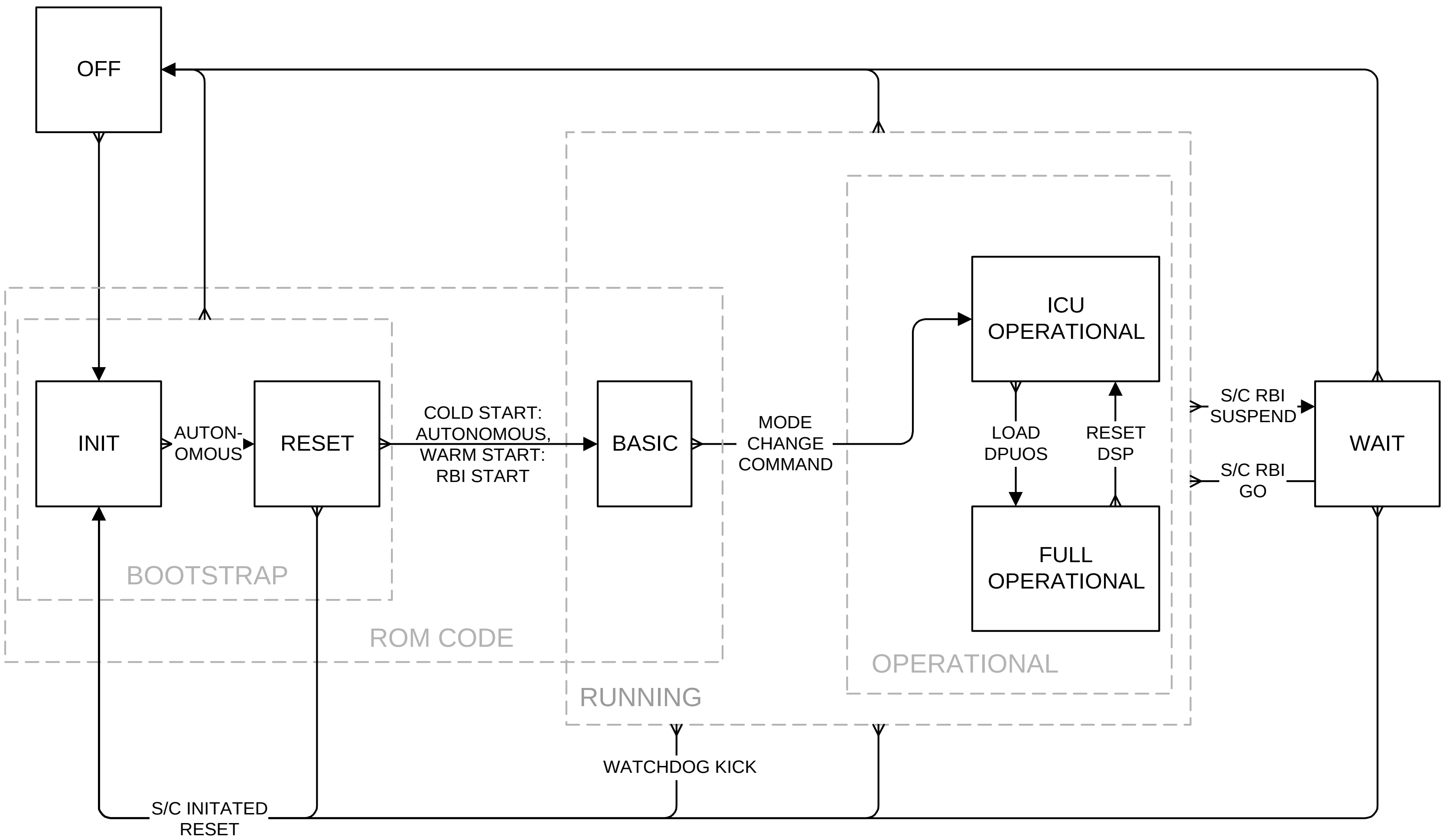
2.3.1.6 Full Operational

The OM is fully operational.

2.3.1.7 Wait State

The OM is powered but the ICU processor is in a halt state. It is possible to perform low-level memory dumps from and patches to the ICU. TM and TC Packets are not processed.

OM EM MODE TRANSITIONS



EM Model Mode Characteristics

<table>
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<tr><th>ICU</th><th>FULL</th></tr>
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<tr><td colspan="2">Illuminating LED</td><td>Off</td><td>Unchanged</td><td>Off</td><td>Off</td><td colspan="2">On</td><td>Unchanged</td></tr>
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</table>

2.3.2 ICU

2.3.2.1 Overview

The overall instrument function is provided by the instrument controller. Its main software functions are as follows:-

- Configuring the instrument.
- Monitoring for breakdown/failure conditions (and safing if required - not supported for EM).
- Controlling and monitoring status of, the detector, the telescope power supply and the DPU
- Incorporating new or modified code modules for itself or the DPU
- Collecting and telemetering. instrument housekeeping and engineering packets.
- Accepting, reformatting into packets and telemetering science data from the DPU
- Interfacing with the OBDH for data and commands.
- Monitoring and controlling the thermal environment.

The ICU software consists of 3 programs :-

BOOTSTRAP	This resides in ROM and is copied into RAM for execution. The bootstrap software is described in APP-6. It is responsible for bringing up the ICU in a known safe state after turn on or spacecraft initiated reset, for either a cold or warm start. It also copies the basic state software from ROM to RAM.
BASIC	This resides in ROM and is copied into RAM for execution. Basic will be responsible for loading the uplinked ICU operational mode code into RAM, housekeeping and basic thermal control.
OPERATIONAL	This is uplinked and will reside in RAM. Operational provides the full functionality of the ICU. It also allows up-linking of the DPU DPUOS code to provide full OM functionality (see the DPU software illustrations below for more information).

The diagrams overleaf illustrate the control and data flows between the main software components for both basic and operational code. A brief explanation of each component is also given.

2.3.2.2 Main Software Components

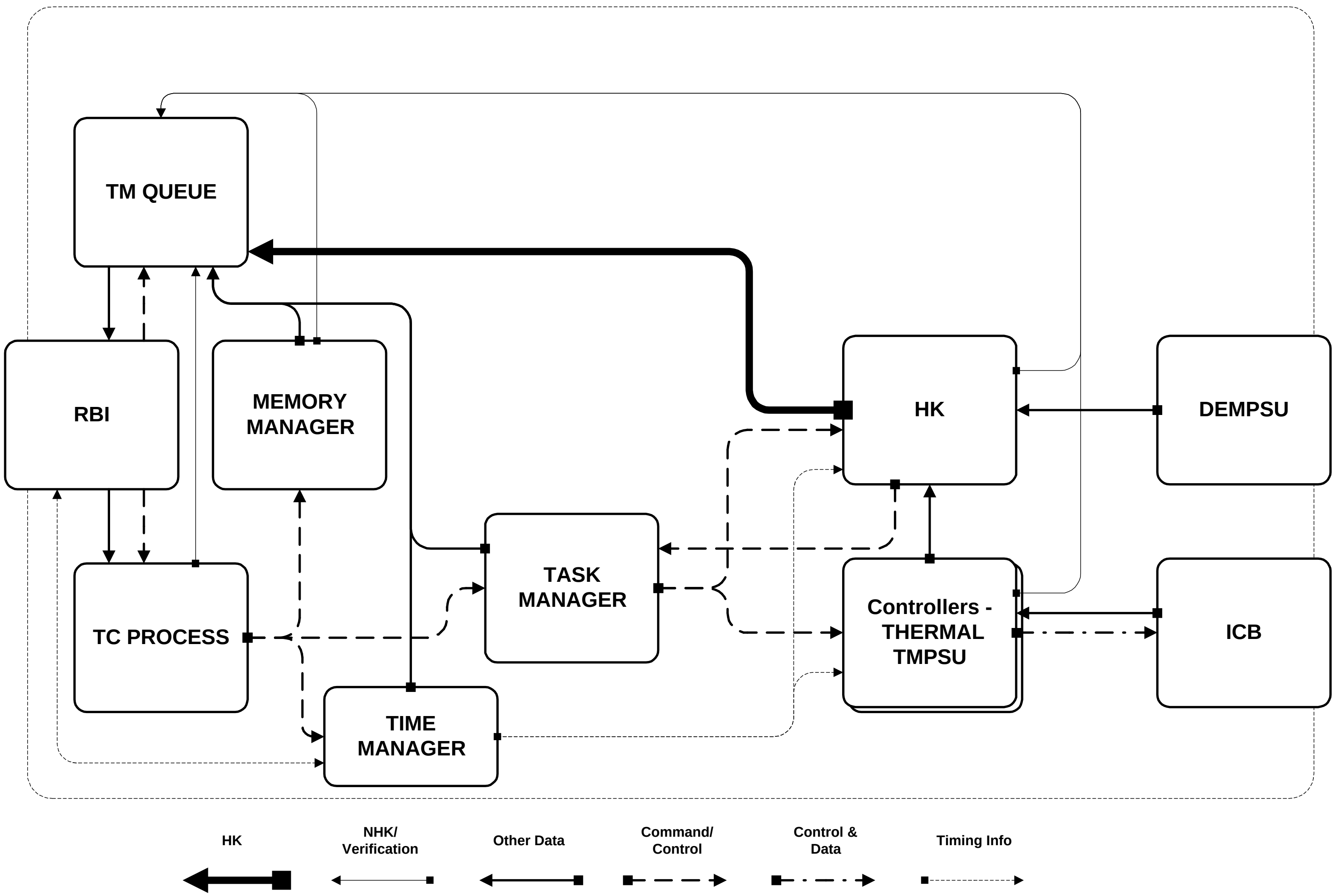
DEMPSU	Obtains HK from DEM Power Supply
DETECTOR	Control and monitor detector.
DPU	Configure and control DPU modes. Control data taking from DPU and send to TM QUEUE. Take science data from the DPU, Monitors DPU heartbeats
HK	Collect and pass HK packets to the TM QUEUE
ICB	Controls dataflow to/from the instrument subsystems using the ICB interface.
MECHANISMS	Control & monitor mechanisms (filter wheels, dichroic).
MEMORY MANAGER	Supports memory uplink and downlink and memory checksum calculations.
RBI	Provides routines to support the RBI chip - supply appropriate interrupts to the TC and TM queues, watchdog facility and time.
SSI	Passes control and data info to the DPU using the SSI interface. Obtains info from the DPU using the SSI interface.
TASK MANAGER	Implements the task management packet requests Implements mode change requests from spacecraft or HK.
TC PROCESS	Obtains telecommand packets from the telecommand queue. Verifies, acknowledges and routes telecommand packets - the ‘main’ program
THERMAL	Provide thermal control (basic control only for EM).
TIME MANAGER	Implements the Time management packet requests (verification and synchronisation). Provide time stamps for packets.
TM QUEUE	Provide ability to control and queue telemetry packets for downlink.

2.3.2.3 Principle Memory Areas

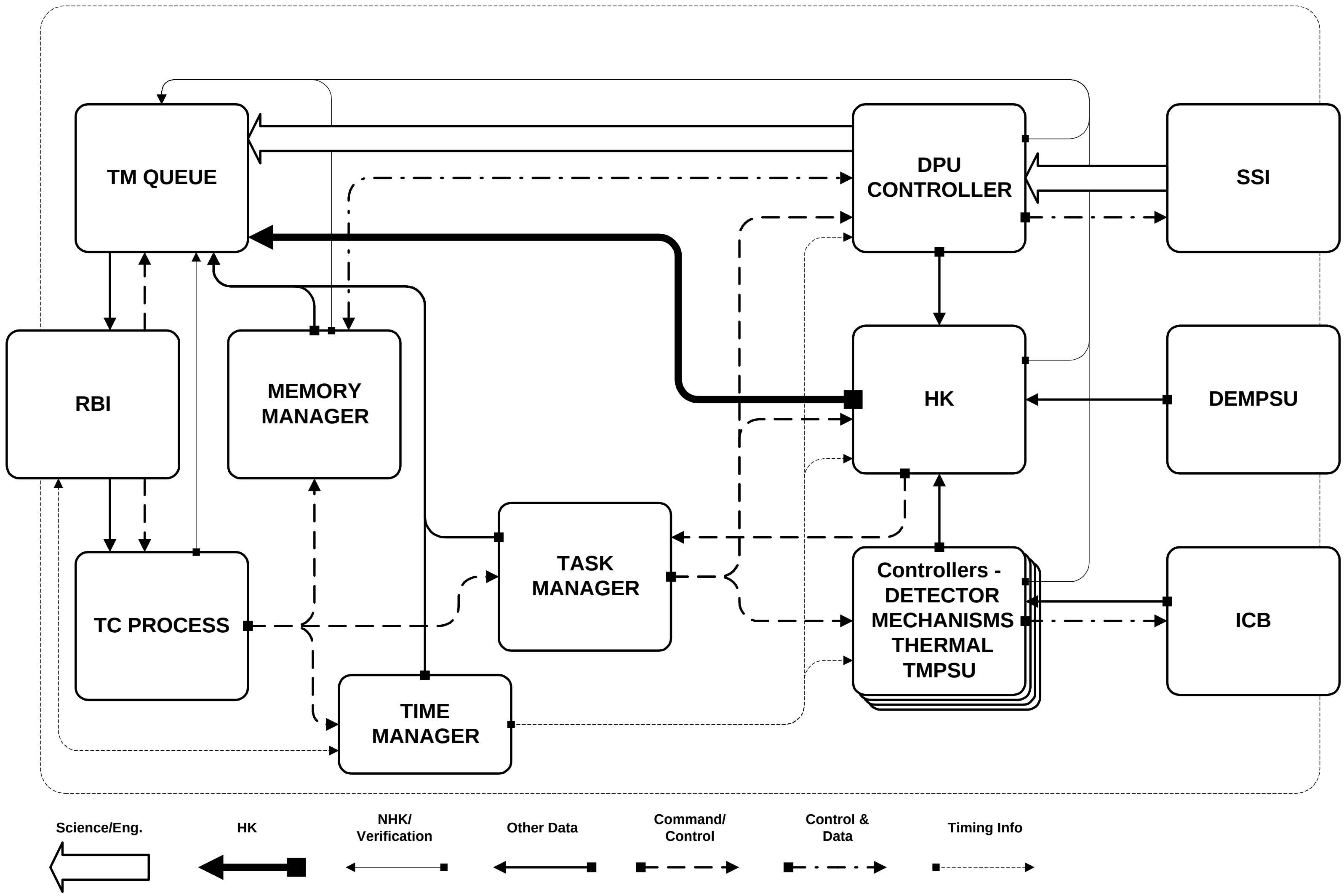
Code Address (hex)		Description
Start	End	
0	3FF	Bootstrap
400	3FFF	Basic Mode
4000	FFFF	Operational Mode

Data Address (hex)		Description
Start	End	
2AF	2D7	Bootstrap Deduced ICU Status
2DA	2FC	Bootstrap Filter Wheel Acceleration Table
3F4	3FF	Memory Loading Work Area
400	403	RBI Communications Area (CCA)
404	5F3	TC Queue
5F4	9FF	TM Queue
A00	A0A	RBI Code Work Area
A0B	A0B	SSI Code Work Area
FC0	FCF	DEBUG Area
1000	1B00	Basic Mode Operands
4000	7000	Operational Mode Operands
7000	EAFF	Heap
EB00	FCFF	Main Program Stack
FD00	FFFF	Interrupt Stack

XMM-OM ICU EM BASIC S/W OVERVIEW



XMM-OM ICU EM OPERATIONAL S/W OVERVIEW



2.3.3 DPU

2.3.3.1 Overview

The detector is a photon-counting system. Estimates of the count rate from the field (2e5/sec) imply that for a 1024 x 1024 format image, the bit rate would be 4 Mbit/second. This grossly exceeds the available data rate for XMM as a whole.

To compress this bit rate, the DPU software stores the images in an accumulating memory, for a time compatible with scientific objectives (typically 1000 seconds). However, the spacecraft attitude may drift by more than one imaging pixel on these time scales and produce image blurring. It is the primary goal of the DPU software to compensate for this.

A secondary requirement is to provide high time resolution data of a reduced set of scientific data. For example, some X-ray targets will have interesting intensity variations with time-scale much shorter than an image collection interval. The data is extracted for limited portions of the image on time scales from milliseconds to seconds. It must also provide engineering and housekeeping. In addition, the data is also compressed.

All data types are sent to the ICU for reformatting into packets.

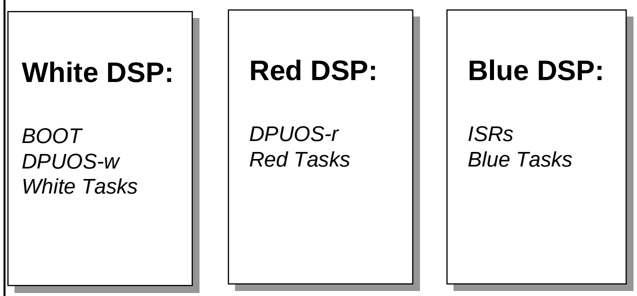
The diagrams overleaf illustrate the main software components in each processor, there functionality in each DPU mode (Boot and DPUOS) and their inter-relationships.

2.3.3.2 Global RAM Map

The global ram is divided as follows:-

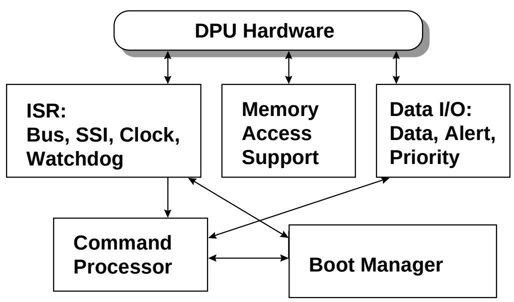
start (hex)	end (hex)	description	comment
0	7fff	PROC	
8000	fffff	big word memory	spilt in half for current and previous exposure
100000	3fffff	unused	
400000	5fffff	small word memory	ping-pong area for data acquisition and tracking
600000	6fffff		fast mode data store
700000	7fffff		compressed data store
800000	dfffff	unused	
e00000	~e10000	RAM program code area	white swap unit codes
e30000	~e31000		blue codes
e50000	~e53000		red codes
e70000	~e73000		white dpuos codes
e7ff00	e7ffff		loader lookup table
f00000	ffffff	ROM code area	Addresses at the very high end are reserved by Motorola

XMM-OM DPU FLIGHT S/W OVERVIEW



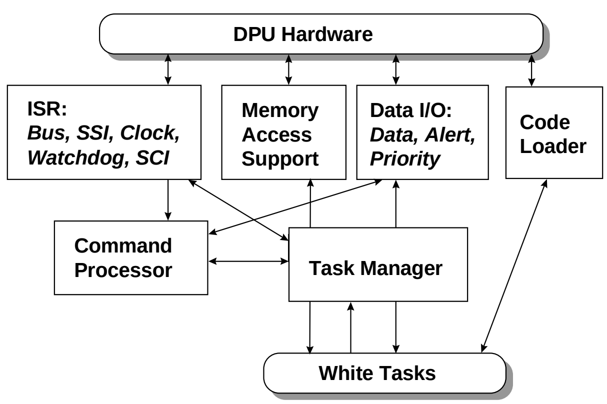
Each of the 4 processors (DSP) in the DPU (white, red, blue 1/2) has different software complement and functionality.

XMM-OM White DSP BOOT



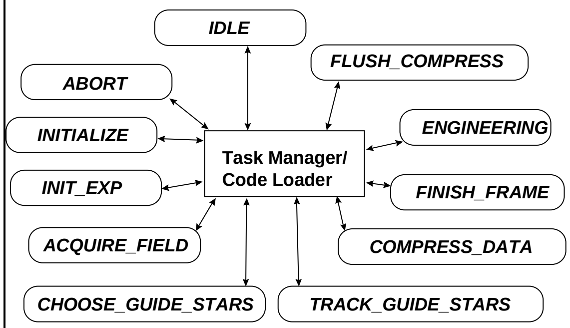
At power-on and reboot, the DPU is in the White DSP Boot state. It supports basic command processing and program upload.

XMM-OM White DSP, DPUOS-w



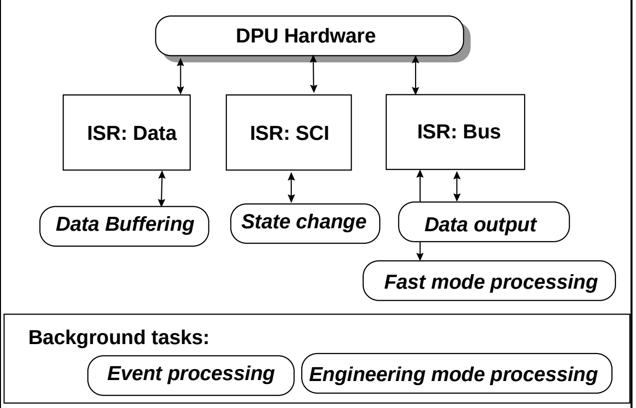
Under normal operation, the White DSP is in the DPUOS state with full DPUOS functionality. The White DSP environment supports C codes.

XMM-OM White DSP, White Tasks



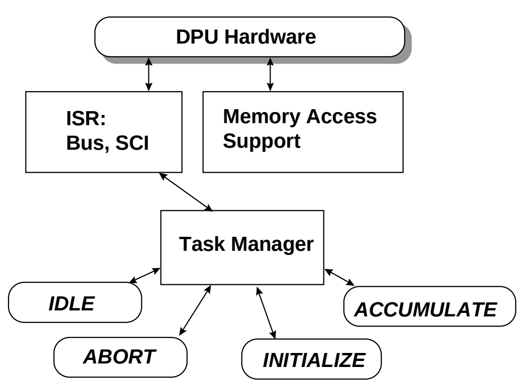
The scientific data processing functionality of theWhite DSP is performed by a complement of tasks in high-level codes. These tasks can consists of one or more “swap units.”

XMM-OM Blue DSP S/W Configuration



The Blue DSP software consists of a suite of interrupt service routines and selectable background tasks. The Blue DSP environment does not support C codes.

XMM-OM Red DSP, DPUOS-r & Red Tasks



The Red DSP software consists of an abridged version of the DPUOS and dedicated data processing tasks. The Red DSP environment supports C codes.

3. Operational Procedures

This section takes the form of an explanatory supplement to the Integrated Functional Test Procedure document (APP-7). It should be read in conjunction with APP-4, which details the format of the relevant TC and TM packets.

3.1 Switch-On

3.1.1 Overview

This section describes the turn on procedure. It is assumed that the OM is switched off at the beginning of the procedure. At the end of the procedure, the OM is switched on and will be in basic mode.

3.1.2 Switch-On OM Prime Power

This action causes the bootstrap to run.

Amongst the safing actions the bootstrap performs is ensuring that the filter wheel is in a position to block the detector aperture. As the fine sensor is not available to allow precise positioning (as this is only available via the detector electronics when the secondary power is switched on in operational mode), the bootstrap moves the filter wheel until the start of the coarse sensor range is seen. It then moves 44 steps further on to roughly centre the wheel at the blank position. See the section on moving the filter wheel for more information on the relationship between the filter wheel and the coarse and fine sensors.

As the OM was off when the bootstrap commenced and is therefore considered a cold start, a jump to the start of the basic mode code is then performed (see mode description section).

3.1.3 Checking Housekeeping

As soon as the basic mode starts, housekeeping (HK) acquisition commences. As it takes 10 secs to acquire all the HK and as it will have taken up to 5 secs for the bootstrap to complete (mainly to move the filter wheel), a time interval of up to 15 secs for the first HK packet to become available after turn on is normal.

As we should be in basic mode, the appropriate flags (H5395 = 0, H5405 = 0) should be set in the housekeeping.

As a result of the bootstrap operation. the coarse sensor should be set. The fine sensor may also be set. This, however, is a function of how close the bootstrap managed to move the filter wheel to its centred position. This depends on the position at which the coarse sensor was first detected, which is a function of the efficiency of the time dependent illuminating LED.

As there is no secondary power available in this mode (see mode section), the heat production is minimal. Therefore the two main heaters are turned on permanently. The other two heaters are for focusing purposes only and are therefore left off.

By checking the value of the DEMPSU voltages, it is possible to confirm that the DPU is now powered. No other HK regarding the DPU is available.

The heater commands were sent using the ICB. There should have been no errors. Therefore, the ICB error count parameter (H5350) should remain a zero.

As part of the initialisation process for basic mode, the RBI watchdog is enabled. This can be confirmed by examining the least significant bit of the RBI configuration register, which should be set.

3.2 Basic Mode Test

3.2.1 Overview

It is assumed that the OM is in basic mode at the start of this procedure. It verifies that

- we have two way communication with the spacecraft in basic mode.
- bad commands are correctly rejected.
- provided operational mode code has been loaded since the last cycle of the keep alive power (see next section), the keep alive power has maintained the ICU memory contents.

3.2.2 Check Test Commands

A command with a type and subtype both set to zero is invalid. An unsuccessful command acceptance packet - TM(3,2), TPN = 91202 - with a code corresponding to Illegal Packet Type should be received. Additionally the bad packet counter in the HK should increase by one.

A valid command with a type and subtype of TC(13,1) should result in a successful command acceptance packet - TM(3,1), TPN = 91100. Additionally the good packet counter in the HK should increase by one.

3.2.3 Dump and Verify Keep Alive

Provided we have previously loaded up ICU operational mode code since the keep alive power was last cycled, that code should still be present. The start address for the code is 4000 hex. Therefore by sending a dump memory command of 16 words from address 4000 hex with a MID corresponding to ICU instruction space, the contents may be verified.

3.3 Operational Mode Test

3.3.1 Overview

This procedure ensures that all the necessary code to support operational mode is loaded and basic check-out tests are performed. It is assumed that the OM is already in basic mode.

3.3.2 Switch to ICU Operational Mode

The appropriate memory load commands (TC(6,1), MID = 0->1, MFN = H4100) are sent to load up ICU operational mode code. The housekeeping bad packet counter should be checked to ensure there were no bad packets. The good packet counter should be checked before and after loading the code to ensure that it has increased by the correct number.

Once the code has been correctly loaded, a mode change command (TC(5,5), MFN = H9001) runs the ICU operational code.

The first HK packet collected in operational mode will appear in 10 secs. The OM state parameter (H5395) should be set to 1 to confirm we are in operational mode.

A valid command with a type and subtype of TC(13,1) should result in a successful command acceptance packet - TM(3,1), TPN = 91100. Additionally the good packet counter in the HK should increase by one. This checks that we have two-way communication in this mode.

3.3.3 Check Housekeeping

On commencement of operational mode, the secondary power to the detector electronics is automatically switched on(see modes description and overall block diagram). This can be validated from the HK by noting the increase in values for the switched current monitors for the TMPSU (Pref. H5280 through H5305).

An open loop heater control algorithm should have started running on switching to operational mode. With the secondary power now enabled, thermal input has increased. Therefore it is no longer required for the two main heaters to be on all the time. The other two heaters are for focusing purposes only and are left off. Therefore the HK should show one or more of the main heaters on at this time. For more detail on the algorithm used, see the heater control test section.

By checking the value of the DEMPSU voltages, it is possible to confirm that the DPU is powered. The DPU heartbeat count (PREF=H5410) should be increasing by one every housekeeping packet.

The heater commands are sent using the ICB. There should have be no errors. If there are, the last error status will have been written to the ICB status word in the HK. Any value other than zero is an error. The ICB error count parameter (H5350) should remain a zero.

The RBI watchdog should still be enabled. This can be confirmed by examining the least significant bit of the RBI configuration register, which should be set.

3.3.4 Switch to Full Operational

In order to ensure that

1. we have communication with the DPU before loading up the DPU operational mode code
2. the DPU is in a known state

an ‘ic_reset_dpu’ is sent (TC(5,3), TID = A4 hex, FID = 1, MFN=H7201). This command forces the DPU into its equivalent of ICU basic, known as Boot Idle. A ‘DPU Boot Ready Alert’ is issued by the DPU and forwarded to the ground as an Event Report (TM4,1), SID=91 hex, TPN = 92201) if this is accepted. It will now be receptive to memory load commands.

A further check that all is well with the DPU is that the heartbeat count is incrementing once every 10 secs (and therefore, normally once every housekeeping packet).

The required memory load commands are then sent (TC(6,1), MID = 20 hex -> 27 hex, MFN = H4120 -> H4127).

The DPU can then be switched to its equivalent of ICU Operational, known as DPUOS Idle, by sending an ‘ic_load_dpuos’ command (TC(5,3), TID = A4 hex, FID = 2, MFN=H7202). A ‘DPUOS Ready Alert’ is issued by the DPU and forwarded to the ground as an Event Report (TM4,1), SID=92 hex, TPN = 92202) if this is accepted. The combination of ICU operational and DPUOS then forms Full Operational.

3.4 *Moving the Filter Wheel*

3.4.1 Overview

The filter wheel movement is controlled by one software task (TID = 60, MFN = H5600). The type of movement performed is determined by the last call to one of the following associated Load Task Parameters command

FID	Type of Movement	MFN
04	Move to specified Filter Number	H7604
05	Move to specified Absolute Step Position	H7605
06	Move the specified number of steps relative to current position	H7606
07	Move the specified number of Fine Sensor Pulses relative to current position	H7607
08	Move to Datum	H7608
09	Move to Coarse Sensor	H7609

A contingency stop task (MFN = H6600) is provided to abort the movement of the wheel prematurely. This only has meaning for the EM as safeguards in the software to prevent the filter wheel moving more than one revolution are not present.

There are additional commands to control other aspects of the filter wheel.

FID	Action	MFN
00	Set Coarse Position Sensor LED Current	H7600
01	Set Fine Position Sensor LED Current (not supported for EM)	H7601
02	Set Step Rate of Filter Wheel	H7602
03	Reset Filter Wheel Position Counter (contingency)	H7603

This test performs two tests

1. Moving the filter wheel until the coarse sensor is seen.
2. Moving the filter wheel until it is at the datum position. This requires that both the coarse and fine sensors are seen -see Overview section earlier.

It is assumed throughout that the OM is in operational state (either ICU or FULL). This is because we only have full control over the filter wheel in this mode, as explained in the overview section earlier.

3.4.2 Test of Filter Wheel Coarse

It is assumed that the filter wheel is already at the coarse sensor. This is because, if the OM has only just been booted up, the bootstrap safing procedure will have placed it in that position. This can be confirmed by examining the Coarse Position Sensor in the HK (H5240).

If present at the coarse sensor, a command must be sent to move the filter wheel away from any region that the coarse sensor may be seen. This is achieved in this particular test by moving the f/w 1000 steps away from its current position, using command H7606 to specify the movement and then H5600 to request it.

At the end of the movement, the HK should show the coarse sensor as on and the filter wheel step counter value (H5265) should have increased by 1000 (although it may have ‘wrapped around’ to zero at a value of 2200). An event report (TPN = 92600), indicating that the f/w has reached its requested position, is also issued.

3.4.3 Test of Filter Wheel Datum

A command is sent to move the filter wheel to the datum position. This is achieved using command H7608 to specify the movement and then H5600 to request it.

At the end of the movement, the HK should show the coarse and fine sensors as ON (H5250 and H5150 respectively) and the filter wheel step counter value (H5265) should be set to 0. An event report (TPN = 92600), indicating that the f/w has reached its requested position, is also issued.

3.5 Moving the Dichroic (Beam Deflector)

3.5.1 Overview

This test moves the dichroic to the two extremes of its allowed movement.

The dichroic movement is controlled by one software task (TID = 65, MFN = H5650). The type of movement performed is determined by the parameters supplied to the associated Load Task Parameters command.

FID	Type of Movement	MFN
00	Set Direction of Dichroic Movement	H7650

Using the command above, if parameter H0375 (the 'method') is zero, this indicates that the dichroic is to be moved to its maximum excursion in the direction specified by the sign of parameter H0370, +ve = secondary to primary (clockwise), -ve = primary to secondary (anti-clockwise).

Using the command above, if parameter H0375 (the 'method') is one, this indicates that the dichroic is to be moved to a discrete number of steps given by the magnitude of H0370 in the direction specified by the sign of parameter H0370 (+ve = secondary to primary, -ve = primary to secondary).

A contingency stop task (MFN = H6650) is provided to abort the movement of the dichroic prematurely. This only has meaning in ground-based tests with the EM.

There is an additional command to control the rate of movement of the dichroic.

FID	Action	MFN
01	Set Step Rate of Dichroic	H7651

It is assumed throughout the test that the OM is in operational state (either ICU or FULL). This is because we only have control over the dichroic in this mode.

3.5.2 Rotate Dichroic Clockwise

Using the H7650 command, the parameter H0375 (the 'method') is set to zero and H0370 (the direction) is set to 1, thus indicating that the dichroic is to be moved to its maximum excursion in the clockwise direction.

The dichroic is then commanded to move by the H5650 command. At the end of the movement, the HK should show the dichroic step counter value (H5275) set to 32. An event report (TPN = 92600), indicating that the dichroic has reached its requested position, is also issued.

3.5.3 Rotate Dichroic Anti-Clockwise

Using the H7650 command, the parameter H0375 (the 'method') is set to zero and H0370 (the direction) is set to -1, thus indicating that the dichroic is to be moved to its maximum excursion in the anti-clockwise direction.

The dichroic is then commanded to move by the H5650 command. At the end of the movement, the HK should show the dichroic step counter value (H5275) set to -32. An event report (TPN = 92600), indicating that the dichroic has reached its requested position, is also issued.

3.6 Heater Control

3.6.1 Overview

A ‘heater box’, containing four resistors, is provided with the EM to simulate the four instrument heaters, which are as follows:

HTR1	Main Interface
HTR2	Forward Tube
HTR3	Metering Rods Focusing
HTR4	Secondary Mirror Focusing

HTR1 and HTR2 will be used in the FM in an closed loop fashion to maintain the interface temperature within tight limits (TBC). For the EM, they are used in an open loop manner.

HTR3 and HTR4 will be used in the FM to compensate for any focus shift that occurs after launch.

For this test it is assumed that the OM is in operational mode as basic mode does not support heater switching. This is because there is no secondary power available in that mode (see mode section) and so heat production is minimal. Therefore the two main heaters are turned on permanently. The two focusing heaters are left off.

For the EM, an open loop heater control algorithm (TID = 67, MFN = H5670) starts running on switching to operational mode. With the secondary power now enabled, thermal input has increased. Therefore it is no longer required for the two main heaters to be on all the time. By default, HTR1 is left on all the time, whilst HTR2 has an 80% duty cycle. The two focusing heaters are again left off.

The purpose of this test is to energise individual heaters. As the energising of individual heaters is considered a non-nominal operation in flight, a separate contingency task (TID = 66, MFN = H5660) is provided to do this. In the FM, this task should be started once the normal heater control task described above is disabled by using the appropriate command (MFN = 6670). However, for the EM, it is sufficient to stop the normal heater task.

3.6.2 Preparing for Heater Switching

The open loop thermal control task is disabled with the appropriate stop task command (MFN = H6670). For the EM only, this implicitly starts the contingency heater control task. A value of ‘offoffoffoff’ (zero in raw value) for the heater status word (H5240) in the HK indicates that all heaters are now off.

3.6.3 Switching Individual Heaters

The next section of the test consists of using the appropriate Load Task Parameter commands (FID=0, MFN=H7660) to specify which heaters are to be energised. The value of the heater configuration parameter used within that command (H0380) and the expected value (5240) in the HK, are detailed below.

Heater	**H0380**	**H5240**
All Off	0	offoffoffoff
Main Interface	8	onoffoffoff
Forward Tube	4	offonoffoff
Metering Rods	2	offoffonoff
Secondary Mirror	1	offoffoffon

After each energising of the heater, the heater is commanded off.

3.6.4 Disabling Heater Switching

Finally, normal heater control is re-established by up-linking the appropriate start task command (TID = 67, MFN=H670).

3.7 Image Acquisition Tests

3.7.1 Overview

In order to acquire an image with the EM, either as a full frame or with several windows, the following sequence of events occurs:-

1. The OM is placed in full operational mode.
2. The DPU must then:-
   a) have all processors enabled
   b) have the memory in which the image will be accumulated set to zero
   c) be informed of the exposure number ‘label’ for data
   d) be informed or calculate where the image from the each detector window is to be accumulated
   e) accept and accumulate events from the detector.
3. The detector electronics must then:-
   a) be configured in the correct data acquisition mode. This is different for full frame and windowed.
   b) be informed of the energy threshold above which events are to be considered valid.
   c) have the centroid tables loaded so that events can be centroided
   d) have the window bit map table loaded so that only events from the required areas (windows) of the detector are processed and all events are labelled with an appropriate window ID. This will differ between windowed and full frame mode.
4. The image is then acquired by commanding the detector electronics to start integration
5. After sufficient time to accumulate a meaningful image, in this case 2 minutes, the detector electronics is commanded to stop the integration.
6. The DPU is then commanded to stop accumulating events.
7. The area of memory containing one or more image windows is then dumped.

In the following sections, the description given applies to both full frame and windowed accumulation, except where indicated.

This test assumes that both the DPU and ICU operational codes have already been uplinked.

3.7.2 Complete DPU Reset

We must first ensure that the OM is in full operational mode. This is done as follows:

1. The IC_RESET_DSP command (MFN=H7201) is sent to place the DPU in ‘boot idle’ mode.
2. A DA_DPU_BOOT_READY event (TPN=92202) received within 5 seconds indicates this has been achieved.
3. The IC_LOAD_DPUOS command (MFN=H7202) is then sent to place the DPU in DPUOS mode.
4. A DA_DPUOS_READY event (TPN=92292) received within 5 seconds indicates this has been achieved.

All the DPU processors must then be enabled by sending the following sequence of commands.

Command	MFN	Description	Parameters		
			H0270	H0520	H0530
IC_ENBL_DSP	H7207	Enable Blue 1 DSP	2	0	1
IC_ENBL_DSP	H7207	Enable Blue 2 DSP	2	1	1
IC_ENBL_DSP	H7207	Enable Red DSP	2	2	1

Note that after the first command, an invalid DA_BLUE1_S_ALERT exception report occurs (TPN=92235). This is a known problem and can be ignored.

The OM is now in full operational mode.

The following clears to zero all memory areas that are to contain accumulated images.

1. Send the IC_INIT_DPU command (MFN=H7248).
2. Within 2 minutes, reception of the DA_EOT_INIT_DPU event (TPN=92210) indicates memory areas have now been cleared.

It can now be assumed that the DPU is completely reset and therefore is in a ‘clean’ state.

3.7.3 Preparing the DPU for Image Acquisition

The command IC_SET_EXP_ID (MFN=H7238) to specify the exposure number (PREF H0520 = exposure number) is sent first. PREF H0270 should be set to 2.

It is then necessary to send 16 commands that specify for each of the possible 16 windows, parameters that specify the location where each event from each window is to be accumulated. The address is given by:-

$$\text{address} = aa_i + ((X + kx_i)\ \&\ 01FF) * bb_i + (Y + ky_i)\ \&\ 01FF$$

where

i = the window number - this is assumed to be found in bits 4⇒1 of the event data sent to the DPU (see Data Transmission Formats in the section on the Detector Processing Electronics). Note that it is therefore possible, in full frame mode, to obtain a window ID of zero, even though in the windowed modes such an ID would result in no data being transmitted.

aa_i, kx_i, ky_i, bb_i = parameters supplied by the IC_LOAD_DET_WDW (MFN=H7245) and are detailed in the table below

X,Y = the co-ordinates of a given event. These are assumed to be found in bits 22⇒14 and bits 13⇒5 of the event data sent to the DPU (see Data Transmission Formats in the section on the Detector Processing Electronics)

Description	n	i	x0	y0	xsize	ysize	ID	kx_i	bb_i	aa_i (hex)	ky_i
PREF	H0770	H0780	H0790	H0800	H0810	H0820	H0830	H0840	H0850	H0860	H0870
Window 0	16	0	0	0	512	512	0	0	512	400000	0
Window 1	16	1	0	512	512	512	1	0	512	440000	0
Window 2	16	2	0	1024	512	512	2	0	512	480000	0
Window 3	16	3	0	1536	512	512	3	0	512	4C0000	0
Window 4	16	4	512	0	512	512	4	0	512	500000	0
Window 5	16	5	512	512	512	512	5	0	512	540000	0
Window 6	16	6	512	1024	512	512	6	0	512	580000	0
Window 7	16	7	512	1536	512	512	7	0	512	5C0000	0
Window 8	16	8	1024	0	512	512	8	0	512	600000	0
Window 9	16	9	1024	512	512	512	9	0	512	640000	0
Window 10	16	10	1024	1024	512	512	10	0	512	680000	0
Window 11	16	11	1024	1536	512	512	11	0	512	6C0000	0
Window 12	16	12	1536	0	512	512	12	0	512	700000	0
Window 13	16	13	1536	512	512	512	13	0	512	740000	0
Window 14	16	14	1536	1024	512	512	14	0	512	780000	0
Window 15	16	15	1536	1536	512	512	15	0	512	7C0000	0

Detector Window Parameters

The above commands are sent to the DPU White DSP. However, the information they contain is required where the accumulation is actually performed i.e. both the Blue DSPs. Therefore a further command IC_SEND_SCI_CMD (MFN=H7211 with PREFs H0270 = 2, H0522 = 5, H0890 = AB HEX) is sent requesting the transmission of the information from the White to the Blue DSPs via the DPU internal SCI pathway.

Finally, it is necessary to start the Blue 1 and Blue 2 DSPs accumulation algorithms, although at this stage no data is being sent. This is done by sending two IC_ENBL_EVENTS commands, both with PREF H0270 =2 and PREF H0530=1, but with PREF H0520 set to first 0 and then 1.

The DPU is now ready for image acquisition.

3.7.4 Preparing the Detector Processing Electronics

The detector electronics acquisition mode is now set, using the PREF H0110 parameter of the Load Task Parameter command (MFN=H7130, TID=13 hex, FID = 0). If we are accumulating a windowed image, we specify that the detector electronics acquisition mode is 2 (High Resolution, Windowed). For a full frame image, this is set to 3 (High Resolution, Full Frame).

This can be confirmed within 20 seconds by examining PREF H5215 of the HK, which should change to the value given in H0110.

The event threshold is now set using another Load Task Parameter command (MFN=H7131, TID=13 hex, FID=1) with PREF H0120 = 30.

It is now necessary to load up the centroid lookup table so that event centroiding takes place. For the EM a ‘perfect’ detector is assumed, so channel boundaries with appropriate values are uplinked. This is done using the Load Task Parameters command (MFN=H7100, TID=10 hex, FID=0) with parameter values given as per the following table. Note that they are scaled from their usual values within the range -1.00 to +1.00.

Description	Pref	Value
Enable/Disable Verification	H0010	0
X Centroid Table Boundary 0	H0020	-1000
X Centroid Table Boundary 1	H0021	-750
X Centroid Table Boundary 2	H0022	-500
X Centroid Table Boundary 3	H0023	-250
X Centroid Table Boundary 4	H0024	0
X Centroid Table Boundary 5	H0025	250
X Centroid Table Boundary 6	H0026	500
X Centroid Table Boundary 7	H0027	750
X Centroid Table Boundary 8	H0028	1000
Y Centroid Table Boundary 0	H0030	-1000
Y Centroid Table Boundary 1	H0031	-750
Y Centroid Table Boundary 2	H0032	-500
Y Centroid Table Boundary 3	H0033	-250
Y Centroid Table Boundary 4	H0034	0
Y Centroid Table Boundary 5	H0035	250
Y Centroid Table Boundary 6	H0036	500
Y Centroid Table Boundary 7	H0037	750
Y Centroid Table Boundary 8	H0038	1000

The centroid lookup table is then loaded by sending the command to start the Load Centroid Table task (MFN=H5100, TID=10 hex). Within 2 minutes an event report (TPN=92100) with the Event Code (H7000) set to 10 hex indicates that the table is now loaded.

It is now required to load up the Window Bit Map Table to specify from which areas of the detector events are to be accepted. This is obviously different depending on whether we wish to take a full frame image or a windowed one. However, in both cases the same two commands are send but with differing parameters.

First, parameters describing the windows are uplinked. This is done using the Load Task Parameters command MFN=7110 (TID=11 hex, FID =0). The parameters are given by the following table.

			Windowed	**Full Frame**
Enable/Disable Verification = 1/0		H0010	0	0
No of Windows		H0040	2	1
X_{low}	**Parameters for Window 1 (Units are CCD pixels)**	H0050	64	64
Y_{low}		H0051	15	15
X_{size}		H0052	64	256
Y_{size}		H0053	64	256
X_{low}	**Parameters for Window 2 (Units are CCD pixels)**	H0054	216	0
Y_{low}		H0055	77	0
X_{size}		H0056	64	0
Y_{size}		H0057	64	0
	All remaining parameters	H0058-H0109	0	0

The window bitmap table is then loaded by sending the command to start the Load Window Table task (MFN=H5110, TID=11 hex). Within 2 minutes an event report (TPN=92100) with the Event Code (H7000) set to 11 hex indicates that the table is now loaded. At this point the camera head is now started.

The Detector Processing Electronics is now ready for image acquisition.

3.7.5 Acquiring the Image

The image is now acquired by sending the command MFN=H5130 (TID=11 hex). This starts the detector integration task. After 2 minutes, this task and the image integration, is stopped by sending the command MFN=H6130.

3.7.6 Finishing the Acquisition

Before the image acquisition is completely finished, we must disable the DPU Blue DSP accumulation algorithms. This is done by sending two IC_ENBL_EVENTS commands, both with PREF H0270 =2 and PREF H0530=0 (the latter indicating that this is, despite the name, actually a disable command), but with PREF H0520 set to first 0 and then 1.

3.7.7 Dumping the Image

The accumulated images are then dumped using *DPU* memory management commands to dump the DPU memory, as opposed to the standard memory management commands. This is because of a known software problem in the EM rather than any fundamental limitation. This is done by sending a set of IC_DUMP_RAM commands (MFN=H7221). A careful study of the memory accumulation formula and data table given above will reveal the following correspondence between window and memory location. The images are stored in column order.

Window	start address (hex)	end address (hex)
0	400000	43FFFF
1	440000	47FFFF
2	480000	4BFFFF
3	4C0000	4FFFFF
4	500000	53FFFF
5	540000	57FFFF
6	580000	5BFFFF
7	5C0000	5FFFFF
8	600000	63FFFF
9	640000	67FFFF
10	680000	6BFFFF
11	6C0000	6FFFFF
12	700000	73FFFF
13	740000	77FFFF
14	780000	7BFFFF
15	7C0000	7FFFFF

Table 3Z1

Note that the frame tags will be interpreted as events from window zero at co-ordinates (0,0) and will thus lead to a large accumulation of events at address `0x400000`.

4. Telecommand Summary

The following tables summarises the telecommand packets. They indicate where this model differs from the specification given in App - 4.

4.1 Task Commands

4.1.1 Start Task Commands -TC(5,1)

Sub-System	TID (Hex)	Task Function	MFN	EM Status	
				Basic	Operational
Detector	10	Start Load Centroid Table	H5100	-	Supported
	11	Start Load Window Table	H5110	-	Supported
	12	Start Load DPU Deduced Window Table	H5120	-	-
	13	Start Detector Integration	H5130	-	Supported
	14	Start High Voltage Ramp-up/down	H5140	-	-
	17	Start High Voltage Direct Control	H5170	-	-
	18	Start/Reset Camera Head Electronics (Contingency only)	H5180	-	Supported
Digital Processing Unit (DPU)	A4	Direct DPU Control Task	N/A	-	Supported
	A5	Start Science Data Acquisition	H5250	-	-
Instrument Control Bus(ICB)	41	ICB Load Port Task	H3410	-	Always running, not stoppable
RBI Watchdog	50	Watchdog Enable	H5510	Supported	Supported
Telescope Module Power Supply (TMPSU)	60	Start Move Filter Wheel	H5600	-	Supported
	65	Start Move Dichroic	H5650	-	Supported
	66	Start Heater Control (Contingency)	H5660	-	-
	67	Start Heater Control	H5670	-	Supported
	69	Turn on Switchable Secondary Voltages	H5690	-	Supported
DEM Power Supply Unit (DEMPSU)	80	Reset of DEM-PSU Latchup Protection Circuits	H5800	-	-
Housekeeping	D0	Enable Housekeeping	H5700	Supported	Supported

4.1.2 Stop Task Commands - TC(5,2)

Sub-System	TID (Hex)	Task Function	MFN	EM Status	
				Basic	**Operational**
Detector	10	Stop Load Centroid Table	H6100	-	Supported
	11	Stop Load Window Table	H6110	-	Supported
	12	Stop Load DPU Deduced Window Table	H6120	-	-
	13	Stop Detector Integration	H6130	-	Supported
	14	Stop High Voltage Ramp-up/down	H6140	-	-
Digital Processing Unit (DPU)	A5	Stop Science Data Acquisition	H6250	-	-
Instrument Control Bus(ICB)	41	ICB Load Port Task	H4410	-	Always running, not stoppable
RBI Watchdog	50	Watchdog Disable	H6510	Supported	Supported
Telescope Module Power Supply (TMPSU)	60	Stop Move Filter Wheel	H6600		Supported
	65	Stop Move Dichroic	H6650	-	Supported
	66	Stop Heater Control (Contingency)	H6660	-	-
	67	Stop Heater Control	H6670	-	Supported
	69	Turn off Switchable secondary voltages	H6690	-	Supported
Housekeeping	D0	Disable Housekeeping	H6700	Supported	Supported

4.1.3 Load Task Parameters - TC(5,3)

4.1.3.1 Non DPU-Related Load Task Parameters

Sub System	TID (Hex)	Associated Task	FID (Hex)	Load Task Description	MFN	EM Status	
						Basic	Operational
Detector	10	Start/Stop Load Centroid Table	00	Load Centroid Table Boundaries	H7100	-	Supported but no verification
	11	Start/Stop Load Window Table	00	Load Window Table	H7110	-	Supported but no verification
	12	Start/Stop Load DPU Deduced Window Table	00	Enable/Disable Verification	H7120	-	-
	13	Start/Stop Detector Integration	00	Set Acquisition Mode	H7130	-	Supported
			01	Set Single Event Threshold	H7131	-	Supported
			04	Set Flood LED Current	H7134	-	-
			05	Enable Frame Tag	H7135	-	Supported, not tested
	14	Start/Stop High Voltage Ramp	00	Load HV Ramp Parameters	H7140	-	-
	17	Start/Stop High Voltage Direct Control	00	High Voltages: $V_{cathode}$, V_{mcp1}, V_{mcp23}	H7170	-	-
TMPSU	60	Move Filter Wheel	00	Set Coarse Position Sensor LED Current	H7600	-	Supported
			01	Set Fine Position Sensor LED Current	H7601	-	-
			02	Set Step Rate of Filter Wheel	H7602	-	Supported
			03	Reset Filter Wheel Position Counter	H7603	-	Supported, not tested
			04	Set Filter Number	H7604	-	Supported, not tested
			05	Set Absolute Step Position	H7605	-	Supported, not tested
			06	Set Relative Step Position	H7606	-	Supported
			07	Set Number of Fine Sensor Pulses	H7607	-	Supported, not tested
			08	Set next move to Datum	H7608	-	Supported
			09	Set next move to Coarse Sensor	H7609	-	Supported
	65	Move Dichroic	00	Set Direction of Dichroic Movement	H7650	-	Supported
			01	Set Step Rate of Dichroic	H7651	-	Supported
	66	Heater Control (Contingency)	00	Heater Configuration	H7660	-	Supported
	67	Heater Control	01	Control Parameters Main I/F Heater	H7671	-	-
			02	Control Parameters Forward Tube Heater	H7672	-	-
			03	Control Parameters Metering Rods	H7673	-	-
			04	Control Parameters Secondary Mirror	H7674	-	-
RBI	50	Watchdog Control	00	Reset Watchdog Parameters	H7150	Supported	Supported
	65	Move Dichroic	00	Set Direction of Dichroic Movement	H7650	-	Supported
			01	Set Step Rate of Dichroic	H7651	-	Supported
	66	Heater Control (Contingency)	00	Heater Configuration	H7660	-	Supported
	67	Heater Control	01	Control Parameters Main I/F Heater	H7671	-	-
			02	Control Parameters Forward Tube Heater	H7672	-	-
			03	Control Parameters Metering Rods	H7673	-	-
			04	Control Parameters Secondary Mirror	H7674	-	-
ICB	41	ICB Load	00	Load ICB Directly	H7410	-	Supported, not fully tested

4.1.3.2 DPU Related Load Task Parameters

The TID for all the following commands is A4 (hex)

None of these commands are supported in **Basic** Mode for EM. Some may (TBC) be supported for FM.

Category	Mnemonic	FID (Hex)	MFN	EM Status (Operational only)
Basic DPUOS manipulation and IO commands	IC_RESET_DSP	01	H7201	Supported
	IC_LOAD_DPUOS	02	H7202	Supported
	IC_ENBL_LOAD_CODE	03	H7203	Supported
	IC_SEL_RAM_BANK	04	H7204	Supported
	IC_LOAD_CODE	05	H7205	Supported
	IC_SEL_KLINGON	06	H7206	Untested
	IC_ENBL_DSP	07	H7207	Supported
	IC_ENBL_EVENTS	08	H7208	Supported
	IC_DIRECT_DATA	09	H7209	Supported, not tested for EM
	IC_GEN_BAD_CMD_ID	0A	H7210	Supported, not tested for EM
	IC_SEND_SCI_CMD	0B	H7211	Supported
	IC_SEL_SCI_LNK_TST	0C	H7212	Not supported, may be obsolete
	IC_REQ_DATA	0D	H7213	Supported
	IC_SYNCH_CLK	0E	H7214	Not Supported, to be implemented
	IC_FLUSH_QUEUE	0F	H7215	Untested
Memory management	IC_DUMP_LOCAL_RAM	10	H7216	Supported, not tested for EM ???
	IC_LOAD_LOCAL_RAM	11	H7217	Supported, not tested for EM ???
	IC_ENBL_RAM_TST	12	H7218	Unsupported, may be obsolete
	IC_ENBL_ROM_TST	13	H7219	Unsupported, may be obsolete
	IC_DUMP_PROG_RAM	14	H7220	Not supported, to be implemented
	IC_DUMP_RAM	15	H7221	Supported
	IC_DUMP_RAM_N_ZERO	16	H7222	Untested
	IC_LOAD_GLOBAL_RAM	17	H7223	Supported, not tested for EM ???

The table continues overleaf.

Category	Mnemonic	FID (Hex)	MFN	EM Status (Operational Only)
Exposure configuration commands	IC_REPORT_TRK	22	H7234	Supported, not tested for EM
	IC_REPORT_DIAGS	23	H7235	Supported, not tested for EM
	IC_SET_FRAME_TIME	24	H7236	Supported, not tested for EM
	IC_SET_EXP_TIME	25	H7237	Supported, not tested for EM
	IC_SET_EXP_ID	26	H7238	Supported
	IC_CONF_GS_SEL	27	H7239	Supported, not tested for EM
	IC_LOAD_REF_STARS	28	H7240	Supported, not tested for EM
	IC_LOAD_FILT_CONF	29	H7241	Untested
	IC_LOAD_MEM_WDW	2A	H7242	Supported, not tested for EM
	IC_LOAD_SCI_WDW	2B	H7243	Supported, not tested for EM
	IC_ENBL_VERBOSE	2C	H7244	Supported, not tested for EM
	IC_LOAD_DET_DTW	2D	H7245	Supported
Major task invocation commands	IC_INIT_DPU	30	H7248	Supported
	IC_INIT_EXP	31	H7249	Supported, not tested for EM
	IC_ACQUIRE_FLD	32	H7250	Supported, not tested for EM
	IC_CHOOSE_GS	33	H7251	Supported, not tested for EM
	IC_TRACK_GS	34	H7252	Supported, not tested for EM
	IC_ABORT_DPU	35	H7253	Supported, not tested for EM
	IC_ENBL_ENG	36	H7254	Supported, not tested for EM
	IC_FLUSH_CMPRS	37	H7255	Supported, not tested for EM

4.1.4 Report Task Parameters - TC(5,4)

None of these commands is supported in **Basic** Mode.

Sub System	TID (Hex)	Associated Task	FID (Hex)	Parameter Description	MFN	EM Status
Detector	10	Start/Stop Load Centroid Table	00	Centroid Table Boundaries	TBD	Not Supported
	11	Start/Stop Load Window Table	00	Window Parameters	TBD	Not Supported
	12	Start/Stop Load DPU Deduced Window Table	00	Enable/Disable Verification	TBD	Not Supported
	13	Start/Stop Detector Integration	00	Acquisition Mode	TBD	Not Supported
			01	Single Event Threshold	TBD	Not Supported
			04	Flood LED Current	TBD	Not Supported
			05	Enable Frame Tag	TBD	Not Supported
	14	Start/Stop High Voltage Ramp	00	HV Ramp Parameters	TBD	Not Supported
	17	Start/Stop High Voltage Direct Control	00	High Voltages: $V_{cathode}$, V_{mcp1}, V_{mcp23}	TBD	Not Supported
RBI	50	Watchdog Control	00	Watchdog Parameters	TBD	Not Supported
TMPSU	60	Move Filter Wheel	00	Coarse Position Sensor LED Current	TBD	Not Supported
			01	Fine Position Sensor LED Current	TBD	Not Supported
			02	Step Rate of Filter Wheel	TBD	Not Supported
			03	New Filter Wheel Position Counter	TBD	Not Supported
			04	Filter Number	TBD	Not Supported
			05	Absolute Step Position	TBD	Not Supported
			06	Relative Step Position	TBD	Not Supported
			07	Number of Fine Sensor Pulses	TBD	Not Supported
	65	Move Dichroic	00	Direction of Dichroic Movement	TBD	Not Supported
			01	Step Rate of Dichroic	TBD	Not Supported
	66	Heater Control (Contingency)	00	Heater Configuration	TBD	Not Supported
	67	Heater Control	01	Control Parameters Main I/F Heater	TBD	Not Supported
			02	Control Parameters Forward Tube Heater	TBD	Not Supported
			03	Control Parameters Metering Rods	TBD	Not Supported
			04	Control Parameters Secondary Mirror	TBD	Not Supported
ICB	47		0	TMPSU Currents and F/W Coarse Sensor	H7670	Supported, not tested
	58	ICB Read	2	Digital Electronics Status Word	H7182	Supported, not tested
	58		3	Digital Bitmap Datum	H7183	Supported, not tested
	58		4	Digital Centroid Table Datum	H7184	Supported, not tested
	58		5	ADC Housekeeping, HV Status, Fine Sensor	H7185	Supported, not tested
	58		6	Initiate ADC	H7186	Supported, not tested

4.1.5 Mode Transition - TC(5,5)

The mode transition command is supported for the EM only in basic mode.

Mode Transition	MFN	EM Status
Go to Initial	H9000	Ignored
Go to Safe	H9001	Renamed Operational
Go to Idle	H9002	Not Supported
Go to Science	H9003	Not Supported
Go to Engineering and Calibration	H9004	Not Supported

4.2 Memory Maintenance

4.2.1 Load Memory - TC(6,1)

MID (Hex)	Description	MFN	EM Status	
			Basic	Operational
0	ICU Operand/Data Space	H4000	Supported	-
1	ICU Instruction Space	H4001	Supported	-
10	DPU Blue 1 DSP Local Memory	TBD	-	-
11	DPU Blue 2 DSP Local Memory	TBD	-	-
12	DPU Red DSP Local Memory	TBD	-	-
13	DPU White DSP Local Memory	TBD	-	-
14	DPU Global Memory (24 bit words)	TBD	-	-
15	DPU Global Memory (16 bit words)	TBD	-	-
20	DPU Program Ram Bank 0	H4020	-	Supported
21	DPU Program Ram Bank 1	H4021	-	Supported
22	DPU Program Ram Bank 2	H4022	-	Supported
23	DPU Program Ram Bank 3	H4023	-	Supported
24	DPU Program Ram Bank 4	H4024	-	Supported
25	DPU Program Ram Bank 5	H4025	-	Supported
26	DPU Program Ram Bank 6	H4026	-	Supported
27	DPU Program Ram Bank 7	H4027	-	Supported

4.2.2 Dump Memory - TC(6,2)

MID (Hex)	Description	MFN	EM Status (Operational Only)
0	ICU Operand/Data Space	H4100	Supported
1	ICU Instruction Space	H4101	Supported
10	DPU Blue 1 DSP Local Memory	H4110	-
11	DPU Blue 2 DSP Local Memory	H4111	-
12	DPU Red DSP Local Memory	H4112	-
13	DPU White DSP Local Memory	H4113	-
14	DPU Global Memory (24 bit words)	H4114	Supported, but not tested -
15	DPU Global Memory (16 bit words)	H4115	Not Supported - 16 bit memory covered by MID 14 but padded to 24 bits
20	DPU Program Ram Bank 0	H4120	-
21	DPU Program Ram Bank 1	H4121	-
22	DPU Program Ram Bank 2	H4122	-
23	DPU Program Ram Bank 3	H4123	-
24	DPU Program Ram Bank 4	H4124	-
25	DPU Program Ram Bank 5	H4125	-
26	DPU Program Ram Bank 6	H4126	-
27	DPU Program Ram Bank 7	H4127	-

4.2.3 Calculate Memory Checksum - TC(6,3)

MID (Hex)	Description	MFN	EM Status (Operational Only)
0	ICU Operand/Data Space	H4200	Supported
1	ICU Instruction Space	H4201	Supported

4.3 Telemetry Maintenance

4.3.1 Report TM Packet Generation Status - TC(9,1)

Not supported for EM.

4.3.2 Enable Generation of All TM Packets - TC(9,2)

Not supported for EM.

4.3.3 Disable Generation of All TM Packets - TC(9,3)

Not supported for EM.

4.3.4 Enable Generation of Specific Packets - TC(9,4)

Not supported for EM.

4.3.5 Disable Generation of Specific Packets - TC(9,5)

Not supported for EM.

4.4 Onboard Time Management

4.4.1 Enable Time Synchronisation - TC(10,2)

Supported but not fully tested for EM. Present for both operational and basic modes.

4.4.2 Add Time Code - TC(10,3)

Supported but not fully tested for EM. Present for both operational and basic modes.

4.4.3 Enable Time Verification - TC(10,4)

Supported but not fully tested for EM. Present for both operational and basic modes.

4.5 Test Command

MFN = H000, TC(13,1).

Supported for EM for both basic and operational modes.

5. Telemetry Summary

The following tables summarises the telemetry packets. They indicate where this model differs from the specification given in App - 4.

5.1 Periodic Telemetry

5.1.1 Housekeeping

TM(1,1), SID = 0, TPN = 90000.

<table>
<tr><th colspan="4">Description</th><th>PREF</th><th>EM Status</th></tr>
<tr><td colspan="3">Wait Resolution (Accuracy of A to D)</td><td rowspan="22">Detector Analogue Processing Electronics</td><td>H5100</td><td rowspan="10">Not Supported</td></tr>
<tr><td>1</td><td rowspan="4">Focusing</td><td rowspan="8">Thermistors</td><td>H5105</td></tr>
<tr><td>2</td><td>H5110</td></tr>
<tr><td>3</td><td>H5115</td></tr>
<tr><td>4</td><td>H5120</td></tr>
<tr><td>1</td><td rowspan="4">General</td><td>H5125</td></tr>
<tr><td>2</td><td>H5130</td></tr>
<tr><td>3</td><td>H5135</td></tr>
<tr><td>4</td><td>H5140</td></tr>
<tr><td colspan="3">High Voltage Enabled/Disabled</td><td>H5145</td></tr>
<tr><td colspan="3">Fine Pick-Off Sensor</td><td>H5150</td><td>Supported</td></tr>
<tr><td colspan="2">V_{mcp1}</td><td rowspan="3">High Voltage Monitor</td><td>H5155</td><td rowspan="11">Not Supported</td></tr>
<tr><td colspan="2">V_{mcp23}</td><td>H5160</td></tr>
<tr><td colspan="2">$V_{cathode}$</td><td>H5165</td></tr>
<tr><td colspan="2">+5 V</td><td rowspan="4">Low Voltage Monitor</td><td>H5170</td></tr>
<tr><td colspan="2">+15 V</td><td>H5175</td></tr>
<tr><td colspan="2">-15 V</td><td>H5180</td></tr>
<tr><td colspan="2">2.5 V Reference</td><td>H5185</td></tr>
<tr><td colspan="3">Filter Wheel Pickoff (Analogue)</td><td>H5190</td></tr>
<tr><td colspan="2">Pair 1</td><td rowspan="2">Flood LED Bias Current</td><td>H5195</td></tr>
<tr><td colspan="2">Pair 2</td><td>H5200</td></tr>
<tr><td colspan="3">Fine Position Sensor LED Drive Current</td><td>H5205</td></tr>
</table>

Housekeeping (continued).

Description				PREF	EM Status
Integration Enabled/Disabled			Digital Detector Processing Electronics	H5210	Supported
Acquisition Mode				H5215	
Frame Tag Enabled/Disabled				H5220	
Table Access Mode/Centroid Table Ready				H5225	
Camera Start/Stop - Window Table Ready				H5230	
Event Detect Threshold				H5235	Not Supported
Commanded Heater Status			TMPSU	H5240	Supported
Coarse Position Sensor LED Current				H5245	
Coarse Position Sensor Status				H5250	
Secondary Voltage Status				H5255	
Last Commanded Filter Wheel Phase				H5260	
S/W Filter Wheel Position Counter				H5265	
Last Commanded Dichroic Phase				H5270	
S/W Dichroic Step Counter				H5275	
Current +25	Switched	Secondary Voltages		H5280	
Current +15				H5285	
Current +11				H5290	
Current +5.3				H5295	
Current -5.3				H5300	
Current -15				H5305	
Current +28	Unswitched			H5310	
Current +5				H5315	

Housekeeping (continued).

Description		PREF	EM Status
ICB Status Register Last Error	ICB	H5320	Supported
SSI Interface Status Register	SSI	H5325	Supported
Time Synchronisation Active	S/C Interface	H5330	Supported
Time Verification Active		H5335	Supported
RBI Status Register		H5340	Supported
RBI Configuration Register		H5345	Supported
ICB Error Count	Errors	H5350	Supported
SSI Error Count		H5355	Supported
SCI Error Count		H5360	Not Supported
MON+5DPU	DEMPSU	H5365	Supported
MON+5ICU		H5370	Supported
MONVSBDPU (Keep Alive)		H5375	Supported
MONVSBICU (Keep Alive)		H5380	Supported
TC Good Packet Count	Packet Counters	H5385	Supported
TC Bad Packet Count		H5390	Supported

Housekeeping (continued).

Description			PREF	EM Status
OM State		General	H5395	Supported
Active DEM			H5400	Supported
ICU State		ICU	H5405	Supported
Heartbeat Count		DPU	H5410	Supported
Current DPU DD_xxx Data Type			H5415	Not Supported
Drift x			H5420	Not Supported
Drift y			H5425	Not Supported
Drift Roll			H5430	Not Supported
Number of Frames so far this Exposure			H5435	Not Supported
Exposure Time (Frames)			H5440	Not Supported
Exposure ID			H5445	Not Supported
DPU State (0 /1 = BOOT/DPUOS)			H5450	Supported
Blue 1 DSP Status	0/1 = Off/On		H5455	Supported
Blue 2 DSP Status			H5460	Supported
Red DSP Status			H5465	Supported
Blue 1 DSP Data Capture			H5470	Supported
Blue 2 DSP Data Capture			H5475	Supported
Current Swap Unit ID			H5480	Supported
Current DPU Task ID			H5485	Supported
Status (TBD)		Tasks	H5490	Not Supported

5.1.2 Diagnostic Periodic Engineering

Not supported for EM.

5.2 Verification

5.2.1 Successful Command Acceptance - TM(3,1)

TPN = 91100. Supported for EM for both basic and operational mode.

5.2.2 Unsuccessful Command Acceptance - TM(3,2)

TPN = 91200. Supported for EM for both basic and operational mode.

Code	Reason	TPN	EM Status
0	Illegal APID	91200	Supported
1	Incorrect Checksum	91201	Supported
2	Illegal Packet Type	91202	Supported
3	Illegal Packet SubType	91203	Supported
4	Illegal Parameter Value	91204	Supported
5	Invalid Length	91205	Supported
8	Illegal TID	91208	Supported
9	Illegal FID	91209	Supported
10	Illegal Mode	91210	Not Supported
11	Illegal MID	91211	Supported
12	Illegal Start Address	91212	Supported
13	Non-existent memory	91213	Not Supported
19	Illegal SID	91219	Not Supported

5.2.3 Unsuccessful Command Execution - TM(3,4)

Supported only in operational mode.

Code	Reason	TPN	EM Status
128	Task Stopped by command early	91400	Not Supported
129	ADA Exception	91401	Not Supported
130	Command too soon	91401	Supported for memory load

5.3 Non-Periodic Housekeeping

5.3.1 Event Reports - TM(4,1)

5.3.1.1 Non DPU Events

Supported in operational mode only

Sub-System	Event Description	SID (Hex)	Event Code	TPN	EM Status
DETECTOR	Centroid Table Loaded	10	0010	92100	Supported
	Window Table Loaded		0011		
TMPSU	Filter Wheel at Requested Position	60	0060	92600	Supported
	Dichroic at Requested Position		0061		

5.3.1.2 DPU Events

Operational Mode only.

Category	Mnemonic	Alert Code (Hex)	SID (Hex)	TPN	EM Status
Synchronous	DA_HBEAT	A500	90	92200	**See NOTE 1**
Asynchronous Health & Status	DA_DPU_BOOT_READY	A510	91	92201	**See NOTE 2**
	DA_DPUOS_READY	A511	92	92202	**See NOTE 2**
	DA_ECHO_ICU_CMD	A512	93	92203	**See NOTE 1**
	DA_BEGOF_EXP	A513	94	92204	**See NOTE 2**
	DA_ENDOF_EXP	A514	95	92205	**See NOTE 2**
	DA_DATA_ALERT	A515	96	92206	**See NOTE 1**
	DA_DATA_END	A516	97	92207	**See NOTE 1**
	DA_DONE_FLD_DATA	A517	98	92208	**See NOTE 1**
	DA_COMPLETE_EXP	A518	99	92209	**See NOTE 2**
Major Milestones	DA_EOT_INIT_DPU	A520	9A	92210	**See NOTE 2**
	DA_EOT_ACQUIRE_FLD	A521	9B	92211	**See NOTE 2**
	DA_EOT_CHOOSE_GS	A522	9C	92212	**See NOTE 2**
	DA_EOT_INIT_EXP	A523	9E	92213	**See NOTE 1**
	DA_EOT_ENG	A524	9F	92214	**See NOTE 1**
	DA_SWITCH_FRAME	A525	A0	92215	**See NOTE 1**
	DA_TRK	A526	A1	92216	**See NOTE 1**
	DA_SENT_CMPRSSQ	A527	A2	92217	**See NOTE 2**
	DA_EOT_FLUSH_CMPRS	A528	A3	92218	**See NOTE 1**

Continued overleaf.

Category	Mnemonic	Alert Code (Hex)	SID (Hex)	TPN	EM Status
Minor Milestone	DA_EOS_INIT_DPU	A530	A4	92219	**See NOTE 1**
	DA_EOS_CALBGD	A531	A4	92219	**See NOTE 1**
	DA_EOS_SCANBS	A532	A4	92219	**See NOTE 1**
	DA_EOS_RSTR_STARS	A533	A4	92219	**See NOTE 1**
	DA_EOS_MAKEAGS_ID	A534	A4	92219	**See NOTE 1**
	DA_EOS_CALDRFT	A535	A4	92219	**See NOTE 1**
	DA_EOS_SCANGS	A536	A4	92219	**See NOTE 1**
	DA_EOS_DOWINDOW	A537	A4	92219	**See NOTE 1**
	DA_EOS_GETREF	A538	A4	92219	**See NOTE 1**
	DA_EOS_LOCATEGS	A539	A4	92219	**See NOTE 1**
	DA_EOS_ABORT	A53A	A4	92219	**See NOTE 1**
	DA_EOS_DLVRDATA	A53B	A4	92219	**See NOTE 1**
	DA_EOS_ENG	A53C	A4	92219	**See NOTE 1**
	DA_EOS_COMPRESS	A53D	A4	92219	**See NOTE 1**
	DA_DONE_SAA	A53E	A4	92219	**See NOTE 1**

NOTE -

1. These alerts are always forwarded in the auxiliary science stream - TM(15,4) - EM only.
2. These alerts are supported by the DPU but are not forwarded in the auxiliary science stream = EM only

5.3.2 Exception Reports - TM(4,2)

5.3.2.1 Non-DPU Exception Reports

These are only supported in operational mode.

Sub-System	Description	SID (Hex)	Exception Code	Parameter (hex) and Description	TPN	EM Status
DETECTOR	Centroid Table Load Failed	11	0010	0 = MACSbus Error (Others TBD)	92101	Not Supported
	Window Table Load Failed		0011	0 = MACSbus Error (Others TBD)		Not Supported
ICB	MACSbus (ICB) Error	41	0040	ICB Status Register	92401	
TMPSU	Loss of Filter Wheel Position	61	0060	0 = MACSbus Error	92601	Not Supported
				1 = Abort of command		Supported but gives incorrect error
				2 = Loss of Fine Sensor		
				(Others TBD)		
	Loss of Dichroic Position		0061	0 = MACSbus Error		Not Supported
				1 = Abort of Command		Supported but incorrect error
				(Others TBD)		
SSI	SSI Error	31	0030	6 = Invalid Length 7 = Overflow at end 8 = Overflow 9 = Put length too long C = Queue collision 89 = Put Overflow	92501	Supported Supported Supported Supported Supported Supported

5.3.2.2 DPU Exception Reports

Supported in operational mode only for EM.

Category	Mnemonic	Alert Code (Hex)	SID (Hex)	TPN	EM Status
Synchronous Exceptions	DA_HBEAT	A500	B0	92220	Not Supported
Asynchronous Exceptions	DA_BOOT_READY	A510	B1	92221	Not Supported
	DA_CLK_SYNCH_ERROR	A580	B2	92222	TBI
	DA_PROG_RAM_ERROR	A581	B3	92223	Supported
	DA_BOTTOM_WHITEDSP	A582	B4	92224	Supported
	DA_CID_TOO_LARGE	A583	B5	92225	Supported
	DA_BAD_CMD	A584	B6	92226	Supported
	DA_DPU_ABORTING	A585	B7	92227	Supported
	DA_BAD_BLOCK	A586	B8	92228	Supported
	DA_ZERO_LENGTH_DQ	A587	B9	92229	Supported
Coloured DSP Exceptions	DA_SCI_RCVR_ERROR	A590	BA	92230	Supported
	DA_SCI_HBEAT_ERROR	A591	BB	92231	Supported
	DA_RED_E_ALERT	A592	BC	92232	Supported
	DA_RED_S_ALERT	A593	BD	92233	Supported
	DA_BLUE1_E_ALERT	A594	BC	92234	Supported
	DA_BLUE1_S_ALERT	A595	BD	92235	Supported
	DA_BLUE2_E_ALERT	A596	BC	92236	Supported
	DA_BLUE2_S_ALERT	A597	BD	92237	Supported

Continued Overleaf

Category	Mnemonic	Alert Code (Hex)	SID (Hex)	TPN	EM Status
Global Memory Access Exceptions	DA_GADE_RPI	A5A0	BE	92238	Supported
	DA_GADE_RPIA_L	A5A1	BF	92239	Supported
	DA_GADE_RPIA_H	A5A2	C0	92240	Supported
	DA_GADE_WPI	A5A3	BE	92241	Supported
	DA_GADE_WPIA_L	A5A4	BF	92242	Supported
	DA_GADE_WPIA_H	A5A5	C0	92243	Supported
	DA_GADE_RBI	A5A6	BE	92244	Supported
	DA_GADE_RBIA_L	A5A7	BF	92245	Supported
	DA_GADE_RBIA_H	A5A8	C0	92246	Supported
	DA_GADE_WBI	A5A9	BE	92247	Supported
	DA_GADE_WBIA_L	A5AA	BF	92248	Supported
	DA_GADE_WBIA_H	A5AB	C0	92249	Supported
	DA_GADE_RSI	A5AC	BE	92250	Supported
	DA_GADE_RSIA_L	A5AD	BF	92251	Supported
	DA_GADE_RSIA_H	A5AE	C0	92252	Supported
	DA_GADE_WSI	A5AF	BE	92253	Supported
	DA_GADE_WSIA_L	A5B0	BF	92254	Supported
	DA_GADE_WSIA_H	A5B1	C0	92255	Supported

5.3.3 Major Anomaly Reports - TM(4,3)

This packet type (TPN = 92700) is not supported for the EM.

5.4 Task Management

5.4.1 Task Parameter Reports - TM(5,4)

Supported only on operational mode only

TID	Sub-System	FID	Descriptions	TPN	EM Status
47	TMPSU	0	TMPSU Currents and Filter Wheel Coarse Sensor	93670	Supported but not fully tested
58	Detector	2	Digital Electronics Status Word	93182	Supported but not fully tested
		3	Digital Bitmap Datum	93183	Supported but not fully tested
		4	Digital Centroid Table Datum	93184	Supported but not fully tested
		5	ADC Housekeeping, HV Status, Fine Sensor	93185	Supported but not fully tested
		6	Initiate ADC port contents	93186	Supported but not fully tested
All Others				-	Not Supported

5.5 *Memory Maintenance*

5.5.1 Memory Dump Reports - TM(6,2)

MID (Hex)	**Description**	**TPN**	**EM Status**	
			Basic	Operational
0	ICU Operand/Data Space	94200	Supported but not tested	Supported but not tested
1	ICU Instruction Space	94201	Supported but not tested	Supported but not tested
10	DPU Blue 1 DSP Local Memory	TBD	-	-
11	DPU Blue 2 DSP Local Memory	TBD	-	-
12	DPU Red DSP Local Memory	TBD	-	-
13	DPU White DSP Local Memory	TBD	-	-
14	DPU Global Memory (24 bit words)	94214	-	Supported
15	DPU Global Memory (16 bit words)	94215	-	Not Supported, 16 bit data padded to 24 bit instead (see MID 14)
20	DPU Program Ram Bank 0	94220	-	Supported but not tested.
21	DPU Program Ram Bank 1	94221	-	Supported but not tested.
22	DPU Program Ram Bank 2	94222	-	Supported but not tested.
23	DPU Program Ram Bank 3	94223	-	Supported but not tested.
24	DPU Program Ram Bank 4	94224	-	Supported but not tested.
25	DPU Program Ram Bank 5	94225	-	Supported but not tested.
26	DPU Program Ram Bank 6	94226	-	Supported but not tested.
27	DPU Program Ram Bank 7	94227	-	Supported but not tested.

5.5.2 Memory Checksum Reports - TM(6,3)

MID (Hex)	**Description**	**TPN**	**EM Status (0perational Only)**
0	ICU Operand/Data Space	94300	Supported but not fully tested
1	ICU Instruction Space	94301	Supported but not fully tested

5.6 Telemetry Management

This packet type - TM(9,1) is not supported for EM.

5.7 Onboard Time Management Reports

5.7.1 Time Verification Report

The packet type is supported for the EM

5.8 Science

Operational Mode only.

Class	Data Description	Mnemonic	SID (hex)	Sub-Type	TPN	EM Status
Priority	Window Data	DP_WDW	E1	4	97401	See NOTE 1 below
	Field Acquisition Data	DP_FAQ	E2	4	97402	See NOTE 1 below
	Blue Fast Mode Data	DP_BFAST	E3	4	97403	See NOTE 1 below
Regular	Tracking History	DD_TRH	F1	4	97417	See NOTE 1 below
	Reference Frame Data	DD_REF	F2	4	97418	See NOTE 1 below
	Image Mode Data	DD_IMG	F3	1	97419	See NOTE 1 below
	Fast Mode Data	DD_FST	F4	2	97420	See NOTE 1 below
	Engineering Data	DD_ENG	F6	3	97420	See NOTE 1 below
Alerts	Auxiliary Alert Data	DA_xxx	FF	4	97431	Supported

where the sub-type categories are as follows:

Sub-Type	Category
1	Image Data
2	Timing Data
3	Diagnostic Data
4	Science HK and Auxiliary Data

NOTE 1 - for the EM only, all DPU data, with the exception of memory dumps, are formatted and sent out as if they were all Alert Data Records. However, in nominal EM operation, where the science data dump is replaced with a memory dump, this should only consist of DPU alerts.