XMM OPTICAL MONITOR

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XMM-OM TELECOMMAND AND TELEMETRY SPECIFICATION

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CHANGE RECORD

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1.draft	29 Mar ‘96	Red detector references deleted. Tables updated to PSD version 4 and above format. Major revisions to layout Include TMPSU and HK.
2	29 April ‘96	Comments Incorporated
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3	26-Feb-97	Issued - changed to letter size for US printing
3onc		Revisions to Filter Wheel commands. Revisions to Memory Management Commands Addition of READ ICB commands Typographic Corrections
4	7 Aug ‘97	‘Snapshot’ for EM Delivery
4onc	Aug ‘97	Corrected Allowed Heater Configs Fixed SSI/RBI Numbering Confusion Clarified format of DPU Events/Exceptions Distinquished between 16 and 24 bit DPU Global Memory Added additional errors to non-DPU exceptions Modified HK to show ICB last error instead Added additional Unsuccessful Execution error code Added details for direct writing to MACSbus ports Added details for direct reading from MACSbus ports
5	22-Sep-97	Update Released for consistency with EM User Manual
5onc		Updated f/w details Introduced bootstrap reports Corrected and enhanced exception error numbers Enhanced key definitions to direct ICB read/write tables Introduced camera halt/running command Clarified nature of ICB direct command. Corrected Format of Read ICB Directly command. Corrected ICB Direct Write contents table Added support for Detector Electronics Table Dumping Only 1 SID enabled or disabled at a time. Implemented change to BPE port numbers Only 1 flood LED now commanded DEMPSU off added. Removed various DPU commands Clarified Prime-Redundant flag in HK Added DPU Heartbeat Watchdog Updated Mode change command Added additional user command execution failure codes. Finalised control of HV and Temperatures.
6	6 Mar ’98	Formal Release Tracking Flag Added

TABLE OF CONTENTS

1. Introduction

1.1 Purpose and Scope

The purpose of this document is to specify the telecommand and telemetry packets that will be used to command, and downlink data from, the XMM Optical Monitor (OM).

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 The MIC Detector	XMM-OM/MSSL/RV/0003
APP-5 Document Reference removed	
APP-6 Overview of the XMM-OM DPU	XMM-OM/PENN/TC/0026
APP-7 XMM-OM Bootstrap Specification and Design	XMM-OM/MSSL/SP/153
APP-8 OM Heater Control	XMM-OM/MSSL/SP/165

1.3 Terms and Abbreviations

APID	Application Identifier
CRC	Cyclic Redundancy Code
DEM	Digital Electronics Module - this contains the DPU, ICU and power supply.
DMA	Direct Memory Access
DPU	Digital Processing Unit
FID	Function Identifier
F/W	Filter Wheel
ICB	Instrument Control Bus
LED	Light Emitting Diode
LSB	Least Significant Bit
MACSbus	Modular Attitude Control System bus
MID	Memory Identifier
MSB	Most Significant Bit
OM	Optical Monitor
PSD	Packet Structure Document
RBI	Remote Bus Interface
SCI	Serial Communications Interface - a serial interface connecting the DPU processors
SID	Structure Identifier
SSI	Serial Synchronous Interface
TBC	To Be Confirmed
TBD	To Be Defined
TC	Telecommand Packet
TID	Task Identifier
TM	Telemetry Packet
TMPSU	Telescope Module Power Supply Unit
VBWL	Variable Block Word Length
XMM	X-ray Multi Mirror

1.4 Bit Numbering Conventions

The following conventions are used in describing an N-bit field.

- The first bit in the field (starting on the left) is Bit 0 and is the left most justified bit in a diagram. The next bit is called Bit 1 and so on, up to Bit N-1, the bits being represented in this order from left to right in a diagram
- If the N-Bit field represents an "Unsigned Integer" value, Bit 0 is the Most Significant Bit (MSB) and Bit N-1 and the Least Significant Bit (LSB)
- If the N-Bit field represents a "Signed Integer" value, Bit 0 indicates the sign. Bit 0 = 0 indicates a positive number, and Bit 0 = 1 a negative number
- Adjacent groups of bits are described in terms of octets and words, where 1 octet = 1 byte = 8 bits and 1 word = 2 octets = 16 bits.

1.5 Word and Byte Alignment

For ease of coding, and to conform to APP-1, items in a packet representing a 16 bit word are word aligned, i.e. the offset from the start of the packet data field is an even number of octets. Similarly, octet long items will be at an offset from the start of the packet data field that is a multiple of 8 bits.

1.6 Packet Numbering Conventions.

Packet class and function is provided by packet type and packet subtype, included in the data field header of each packet which is described elsewhere in this document.

A telecommand packet type and subtype combination are represented by the letters TC followed, in brackets, by their numerical values separated by a comma e.g. TC(5,1) refers to Telecommand Packet Type 5, subtype 1.

A telemetry packet type and subtype combination are represented by the letters TM followed, in brackets, by their numerical values separated by a comma e.g. TM(5,1) refers to Telemetry Packet Type 5, subtype 1.

2. Telecommands

2.1 Overview

All telecommand packets will conform to the structure defined in APP-1. The template structure is repeated here for convenience.

PACKET HEADER (48 bits)							PACKET DATA FIELD		
Packet ID				Packet Sequence Control		Packet Length	Data Field Header	Applic-ation Data	Packet Error Control
Version Number	Type	Data Field Header Flag	Applic-ation Process ID	Sequence Flags	Sequence Count				
3	1	1	11	2	14				
16				16		16	16	N*16	16

Table 2-1 : Telecommand Packet Template

2.1.1 Packet Header

2.1.1.1 Packet ID

Version Number set to zero (as per APP-1)
Type set to 1, indicating it is a telecommand packet
Data Field Header set to 1, indicating the data field header is always present
Application Process ID (APID) This identifies the source-sink path for this packet. The APID for OM will have the value 1024.

2.1.1.2 Packet Sequence Control

Sequence Flags (bits 0 through 1) These 2 bits are set to “11” (binary), which means stand-alone packet.

The following field is provided to identify a particular telecommand packet.
Sequence Count (bits 2 through 15) Bit 2 : 0/1 if source = ground/on-board application respectively
Bits 3 through 15: the actual sequence count. The counter will:

- increment by 1 for each new command
- may be reset to zero by the source
- ‘wraps-around’ from full-scale to zero.

2.1.1.3 Packet Length

The Packet Length Field contains an unsigned integer “C”, where C = (Number of octets in Packet Data Field) - 1.

The maximum length of a Telecommand Packet Data Field is 242 octets. Therefore C <= 241.

2.1.2 Packet Data Field

The bulk of this section consists of detailed descriptions of the Packet Data Field for every OM supported packet type and subtype. It consists of up to 3 sub-fields

- Data Field Header (always present)
- Application Data (which may be zero in length)
- Packet Error Control (present only if so indicated by a flag in the Data Field Header)

A summary of the sub-fields is repeated here from APP-1 for convenience.

2.1.2.1 Data Field Header

The Data Field Header is defined as follows:

Spare	Checksum Type	Ack	Packet Type	Packet SubType
2 Bits	2 Bits	4 Bits	4 Bits	4 Bits

Table 2-2 : TC Data Field Header

The components are as follows:

Spare : Set to ‘00’ (binary).

Checksum Type : Indicates the presence or absence of a Packet Error Control Field at the end of the Packet Data Field.

- Value = 0 = No Checksum present.
- Value = 3 = Checksum field is present

Ack : Indicates the required acknowledgements from the OM for the command. These will take the form of up to two verification packets.

- Bit 4 = 1 = Acknowledge acceptance of packet
- Bit 5 = 0 = Not Used
- Bit 6 = 0 = Not Used
- Bit 7 = 1 = Acknowledge *failed* completion of execution

Packet Type : This identifies the class of the packet. The telecommand packet types supported by OM are given in the table below.

Packet Type	TC Packet Function
5	Task Management
6	Memory Maintenance
9	Telemetry Management
10	Time Management
13	Test Commands

Table 2-3 : TC Packet Types

Packet SubType : This, together with the Packet Type, indicates the function of the packet.

The complete list of TC Packets supported by OM is given by the following table.

NOTES

1. Reception of an unsupported packet type/subtype combination will generate an 'Unsuccessful Command Acceptance packet (see section 3.3.2)

General Category	Type, SubType	Function
TASK MANAGEMENT	5,1	Start Task
	5,2	Stop Task
	5,3	Load Task Functional Parameters
	5,4	Report Task Parameters
	5,5	Mode Transition
MEMORY MAINTENANCE	6,1	Load Memory
	6,2	Dump Memory
	6,3	Calculate Memory Checksum
TELEMETRY MANAGEMENT	9,1	Report TM Packet Generation Status
	9,2	Enable Generation of all TM Packets
	9,3	Disable Generation of all TM Packets
	9,4	Enable Generation of Specific Packets
	9,5	Disable Generation of Specific Packets
ON-BOARD TIME MANAGEMENT	10,2	Enable Time Synchronisation
	10,3	Add Time Code
	10,5	Enable Time Verification
TEST COMMANDS	13,1	Test Command

Table 2-4 : TC Packet Functions

2.1.2.2 Application Data

This constitutes the data element of the telecommand. The precise format depends on the values of type and subtype. The table in section 2.1.3 provides a summary. The meaning of the terms used is explained elsewhere in the document.

2.1.2.3 Packet Error Control

This field, if present, contains an error detection code (checksum) for the packet. This allows the OM to verify the integrity of the telecommand packet data. It is calculated over the complete packet *less* the final 16 bits of the Packet Error Control Field. Appendix 3 of APP-1 specifies the checksum method used.

2.1.3 Packet Structure Summary

The Telecommand Packet Structure is summarised in the following tables.

Packet	consists of	which consists of	which consists of	which consists of	Size (bits)
TC Packet	Packet Header	Packet ID	Version Number		3
			Type		1
			Data Field Header Flag		1
			APID		11
		Packet Sequence Control	Sequence Flags		2
			Sequence Count	Command Source	1
				Actual Sequence Count	13
		Packet Length			16
	Packet Data Field	Data Field Header	Spare		2
			Checksum Type		2
			Ack		4
			Packet Type		4
			Packet SubType		4
		Application Data	as summarised in next table.		N*16
		Packet Error Control(Optional)			16

Table 2-5 : TC Packet Summary

Cate-gory	Type, SubType	Application Data (Byte Offsets) 0	1	2	3	4	5	6	7	8 ⇒ end
Task Mgmt.	5,1	TID	Spare							
	5,2	TID	Spare							
	5,3	TID	FID	Parameters						
	5,4	TID	FID							
	5,5	MODE	Spare	Parameters						
Mem. Maint.	6,1	MID		Start Address				Data		
	6,2	MID		Start Address				Length		
	6,3	MID		Start Address				Length		
Tlm. Mgmt.	9,1									
	9,2									
	9,3									
	9,4	SID 1	Spare	SID 2	Spare	Repeat as required				
	9,5	SID 1	Spare	SID 2	Spare	Repeat as required				
Time Mgmt	10,2									
	10,3	Coarse Time				Fine Time				
	10,5									
Test	13,1									

Table 2-6 : TC Application Data Summary

2.2 Task Commands

This section defines the contents of the packet data field for the task management telecommand packets.

2.2.1 Overview

These commands initiate, stop or load parameters into a task, where a task is “a definite amount of actions to bring about a result for a user” (APP-1). Additionally, they are used to initiate a report of the last parameters loaded and initiate mode changes.

Each command type - dependent on applicability - may be further subdivided into the following sub-systems:

- Detector.
- Digital Processing Unit (DPU)
- Spacecraft Interface
- Instrument Control Bus (ICB)
- Serial Synchronous Interface (SSI)
- Telescope Module Power Supply Unit (TMPSU)
- DEM Power Supply

To understand the telecommand packet descriptions in this section, a brief description of key points of the above sub-systems follows.

2.2.1.1 Detector

A full description of this detector can be found in APP-4.

Load Detector Centroid Table Task - using counts from 3 adjacent pixels in both X and Y, each photon event detected is centroided to 1/8 of a pixel, thus providing a 2048*2048 resolution from the 256*256 pixel read out. This is achieved by the detector electronics feeding sum and difference signals into a look-up table (64K by 4 bits) for each axis that returns the required result. This task runs an on-board algorithm that generates the table. It requires 9 parameters, known as Centroid Table Boundaries, for each axis.

Load Detector Window Table Task - the detector electronics contains a window look-up table that is 64K by 4 bits. Each 4 bit location is associated with a 2 by 2 array of CCD pixels and defines whether that group of pixels is active and, if so, to which window they belong. This task runs an on-board algorithm that generates and loads the required table from the windows specified

Load DPU Deduced Windows into Detector Window Table Task - during the course of an exposure, the DPU will deduce the optimum detector windows required for the current observation. Parameters describing those windows are forwarded to, and stored by, the ICU. This task loads the window look-up table consistent with those stored parameters.

Detector Integration - this task controls the detector integration.

High Voltage Tasks - these control the detector high voltages.

2.2.1.2 Digital Processing Unit (DPU)

An overview of the DPU operation is given in APP-6 and some aspects are summarised below for convenience

Due to bandwidth limitations, it is not possible to telemeter every photon detected. Therefore the DPU is used to perform first level data reduction, primarily summing of the image. It must also correct for spacecraft drift to prevent blurring of the resulting image.

ACQUIRE FIELD Task - at the start of each new pointing, the DPU acquires a full format snapshot lasting one *frame* time (10-20 secs) behind a V filter. The co-ordinates of up to 16 *reference* stars of known positions are uplinked and compared with the co-ordinates of brightest stars detected in the field of view. This gives a correction to the commanded position.

CHOOSE GUIDE STARS Task - at the start of each exposure the DPU again acquires a full format snapshot lasting one frame time (10-20 secs) but this time using an observer selected filter. From this *reference* frame, the 10 brightest stars which meet acceptance criteria are selected as *guide* stars. Windows to surround these guide stars, as well as the science windows, are deduced and passed to the ICU so that the detectors can be set up.

WINDOWS - A set of non-overlapping data collection areas, known as memory windows, are set up in the DPU to contain the *science windows.* A memory window corresponds to a fixed sample of detector pixels. A science window may therefore move around within a memory window as the satellite drifts. Each memory window corresponds to one or more *detector windows.*

TRACK GUIDE STARS Task - the remainder of an exposure then consists of an integral number of *tracking* frames. During each of these frames, the guide stars are used to deduce the drift. This deduced drift is passed on to the ICU.

ACCUMULATE IMAGE Task - for those windows in which an Image mode exposure is to be obtained, the individual tracking frames are shifted to compensate for the drift and summed into an accumulating image for the duration of an exposure. This is achieved by the DPU alternating automatically between TRACK GUIDE STARS and ACCUMULATE IMAGE.

2.2.1.3 Spacecraft Interface

This takes the form of a Remote Bus Interface (RBI) which DMA’s packets to and from memory areas in the ICU. These memory areas contain the telecommand and telemetry queues.

2.2.1.4 Instrument Control Bus (ICB)

The Instrument Control Bus is implemented using the MACSbus standard. All commands to the detectors and mechanisms in the OM Telescope Module are implemented via this bus. Each unit and internal register is visible to the ICU as an address and sub-address combination. The ICU is the master, all other units are slaves.

2.2.1.5 Serial Synchronous Interface (SSI)

This provides the ICU with the command path to, and data path from, the DPU.

2.2.1.6 Telescope Module Power Supply Unit (TMPSU)

This converts power from the spacecraft 28V power bus to provide the OM Telescope Module regulated power rails used to power the mechanisms, heaters and detector. It also powers the filter wheel coarse position sensor system (the fine sensor system is powered via the detector electronics).

2.2.1.7 Filter Wheel Mechanism Control Tasks

The eleven optical elements are equispaced around the filter wheel. 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. A system of position sensors is provided to relocate the datum position, should it be lost, and to verify the wheel position during and after every traverse. 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 operational 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. This is used to determine the motor position to a single step.

Should either sensor fail, contingency tasks are provided to move the filter wheel using only the coarse or fine sensor, or to move the filter wheel by direct pulsing of the motor.

2.2.1.8 Dichoic Mechanism Control Task

The dichroic contains a mirror placed at 45° in the path of the incoming beam. The purpose of the mechanism is to steer the reflected light beam from one of two redundant detector systems. It will be traversed 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 29 steps from one position to the other. One further stop 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 dichroic task always drives the motor the maximum number of steps required in the specified direction. The drive frequency is 1 Hz.

2.2.1.9 DEM Power Supply

This provides the conditioned power for the ICU and DPU in the DEM. It provides latchup protection. A digital control to reset the DEM-PSU latchup circuits will come from the ICU.

2.2.2 Start Tasks

When a Start Task telecommand is received, the ICU will start the task specified by the Task ID (TID).

If a Load Task Parameters telecommand has already been received (see section 2.2.4), the task shall be started with the loaded parameters.

If a task is already running, it shall immediately use the parameters on receipt of the Load Task Parameters telecommand.

The following table lists the valid TID's.

Sub-System	TID (Hex)	Task Function
Detector	10	Load Centroid Table
	11	Load Window Table
	12	Load DPU Deduced Window Table
	13	Start/(Stop) Detector Integration
	14	High Voltage Ramp-up/down
	17	High Voltage Direct Control
	18	Start/Reset Camera Head Electronics (Contingency only)
Digital Processing Unit (DPU)	A4	Direct DPU Control
	A5	(Start/Stop) Science Data Acquisition
	A6	(Start/Stop) DPU Heartbeat Watchdog
Instrument Control Bus(ICB)	41	ICB Load Port
RBI Watchog	50	Watchdog Enable
Telescope Module Power Supply (TMPSU)	60	Move Filter Wheel
	65	Move Dichroic
	66	Heater Control (Contingency)
	67	Heater Control
	69	Turn on/off Switchable Secondary Voltages
DEM Power Supply Unit (DEMPSU)	80	Reset of DEM-PSU Latchup Protection Circuits/ DPU On
Housekeeping and Safing	D0	Enable Housekeeping
	D1	Enable Autonomous Safing

Table 2-7 : Start Task ID Summary

The format of all Start Task Telecommand Packet Data Fields is as follows:

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	-	Checksum Type and Ack	Data Field Header
1	1	-	Packet Type /SubType = 5,1	
2	1	Unsigned Integer	Task ID (TID)	Application Data
3	1		Spare	
4	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field

2.2.3 Stop Tasks

This command stops the task specified by the Task ID (TID).

However, this command is only supported for the tasks listed below because of one of the following reasons:

1. the task stops itself within a short period of time.
2. the task is deemed to be always running.
3. because it is not meaningful.

The following table lists the valid **TID**s.

Sub-System	TID (Hex)	Task Function
Detector	10	Load Centroid Table
	11	Load Window Table
	12	Load DPU Deduced Window Table
	13	(Start)/Stop Detector Integration
	14	High Voltage Ramp-up/down
Digital Processing Unit (DPU)	A5	(Start/Stop) Science Data Acquisition
	A6	(Start/Stop) DPU Heartbeat Watchdog
RBI Watchdog	50	Watchdog Disable
Telescope Module Power Supply (TMPSU)	60	Move Filter Wheel
	65	Move Dichroic
	66	Heater Control (Contingency)
	67	Heater Control
	69	Turn on/off Switchable secondary voltages
DEM Power Supply Unit (DEMPSU)	80	DPU Off
Housekeeping & Safing	D0	Disable Housekeeping
	D1	Disable Autonomous Safing

Table 2-8 : Stop Task ID's

The format of a Stop Task Telecommand Packet Data Field is as follows:

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	-	Checksum Type/Ack	Data Field Header
1	1	-	Packet Type /SubType = 5,2	
2	1	Unsigned Integer	Task ID (TID)	Application Data
3	1	-	Spare	
4	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field

2.2.4 Load Task Parameters

The format of a Load Task Telecommand Packet Data Field is as follows:

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	-	Checksum Type/Ack	Data Field Header
1	1	-	Packet Type /SubType = 5,3	
2	1	Unsigned Integer	Task ID (TID)	Application Data
3	1	Unsigned Integer	Function ID (FID)	
4	N*2	Unsigned Integers	N Parameters	
4+N*2	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field

Task ID (TID) is as for the Start Task Telecommand Packet.

Function ID (FID) , together with the TID, specifies the structure of the parameters that follow.

Parameters consist of 1 or more (16 bit) words.

N is defined by the TID-FID combination and is the number of (word length) parameters ($0 \leq N \leq 118$)

The following table summarises the defined Load Task Parameters commands.

Sub System	TID (Hex)	Associated Start Task	FID (Hex)	Load Task Description
Detector	10	Load Centroid Table	00	Load Centroid Table Boundaries
	11	Load Window Table	00	Load Window Table
	12	Load DPU Deduced Window Table	00	Enable/Disable Verification
	13	Detector Integration	00	Set Acquisition Mode
			01	Set Single Event Threshold
			04	Set Flood LED Current
			05	Enable Frame Tag
			06	Camera Running/Halted
	14	High Voltage Ramp	00	Load HV Ramp Parameters
	17	High Voltage Direct Control	00	High Voltages: $V_{cathode}$, V_{mcp1}, V_{mcp23}
DPU	A4	Direct DPU Control	00 ⇒ FF	DPU Commanding
RBI	50	Watchdog Control	00	Reset Watchdog Parameters
TMPSU	60	Move Filter Wheel	00	Set Coarse Position Sensor LED Current
			01	Set Fine Position Sensor LED Current
			02	Set Step Rate of Filter Wheel
			03	Reset Filter Wheel Position Counter
			04	Set Filter Number
			05	Set Absolute Step Position
			06	Set Relative Step Position
			07	Set Number of Fine Sensor Pulses
			08	Set next move to Datum
			09	Set next move to Coarse Sensor
	65	Move Dichroic	00	Set Direction of Dichroic Movement
			01	Set Step Rate of Dichroic
	66	Heater Control (Contingency)	00	Heater Configuration
	67	Heater Control	01 ⇒ 08	Control Parameters
ICB	41	ICB Load	00	Load ICB Directly

Table 2-9 : Detector Load Task Summary

2.2.4.1 Detector

2.2.4.1.1 Load Centroid Table Boundaries

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	-	Checksum Type/Ack	Data Field Header
1	1	-	Packet Type /SubType = 5,3	
2	1	Unsigned Integer	Task ID (TID) = 10 (hex)	Application Data
3	1	Unsigned Integer	Function ID (FID) = 00 (hex)	
4	2	Unsigned Integer	Enable/Disable Verification = 1/0	
6	18	Signed Integers	X Centroid Table Boundaries	
24	18	Signed Integers	Y Centroid Table Boundaries	
42	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field

2.2.4.1.2 Load Window Table Parameters

Offset*	Length (Octets)	Type	Description		Packet Data Field
0	1	-	Checksum Type/Ack		Data Field Header
1	1	-	Packet Type /SubType = 5,3		
2	1	Unsigned Integer	Task ID (TID) = 11 (hex)		Application Data
3	1	Unsigned Integer	Function ID (FID) = 00 (hex)		
4	2	Unsigned Integer	Enable/Disable Verification = 1/0		
6	2	Unsigned Integer	No of Windows = N_{win} ($1 \le N_{win} \le 15$)		
8	2	Unsigned Integer	X_{low}	Parameters for Window 1 (Units are CCD pixels)	
10	2	Unsigned Integer	Y_{low}		
12	2	Unsigned Integer	X_{size}		
14	2	Unsigned Integer	Y_{size}		
16	8	Unsigned Integers	Parameters for Window 2		
… and so on until ...					
120	8	Unsigned Integers	Parameters for Window 15		
128	2	Unsigned Integer	CRC		Error Control

* All offsets measured in octets from the start of the Packet Data Field

Note : The above packet is large enough to contain 15 windows. N_{win} is used to determine how many windows are actually present.

2.2.4.1.3 Enable/Disable Verification of DPU Deduced Window Table Parameters

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	-	Checksum Type/Ack	Data Field Header
1	1	-	Packet Type /SubType = 5,3	
2	1	Unsigned Integer	Task ID (TID) = 12 (hex)	Application Data
3	1	Unsigned Integer	Function ID (FID) = 00 (hex)	
4	2	Unsigned Integer	Enable/Disable Verification = 1/0	
128	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field

2.2.4.1.4 Set Acquisition Mode

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	-	Checksum Type/Ack	Data Field Header
1	1	-	Packet Type /SubType = 5,3	
2	1	Unsigned Integer	Task ID (TID) = 13 (hex)	Application Data
3	1	Unsigned Integer	Function ID (FID) = 00 (hex)	
4	2	Unsigned Integer	Acquisition Mode = M_{acq}	
6	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field

M_{acq} has the following values

M_{acq}	Description
0	Low Resolution, Windowed
1	Low Resolution, Full Frame
2	High Resolution, Windowed
3	High Resolution,. Full Frame
4	Engineering, x m/n data
5	Engineering, y m/n data
6	Engineering, event height
7	Engineering, event energy

Table 2-10 Detector Data Acquisition Modes

2.2.4.1.5 Set Single Event Threshold

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	-	Checksum Type/Ack	Data Field Header
1	1	-	Packet Type /SubType = 5,3	
2	1	Unsigned Integer	Task ID (TID) = 13 (hex)	Application Data
3	1	Unsigned Integer	Function ID (FID) = 01 (hex)	
4	2	Unsigned Integer	Threshold	
6	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field

2.2.4.1.6 Set Flood LED Current

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	-	Checksum Type/Ack	Data Field Header
1	1	-	Packet Type /SubType = 5,3	
2	1	Unsigned Integer	Task ID (TID) = 13 (hex)	Application Data
3	1	Unsigned Integer	Function ID (FID) = 04 (hex)	
4	2	Unsigned Integer	LED Current	
6	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field

2.2.4.1.7 Enable Frame Tag

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	-	Checksum Type/Ack	Data Field Header
1	1	-	Packet Type /SubType = 5,3	
2	1	Unsigned Integer	Task ID (TID) = 13 (hex)	Application Data
3	1	Unsigned Integer	Function ID (FID) = 05 (hex)	
4	2	Unsigned Integer	Enable/Disable = 1/0	
6	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field

2.2.4.1.8 Camera Halted/Running

This is a contingency command. Normally the camera is halted whilst the window table is being loaded, otherwise it is running.

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	-	Checksum Type/Ack	Data Field Header
1	1	-	Packet Type /SubType = 5,3	
2	1	Unsigned Integer	Task ID (TID) = 13 (hex)	Application Data
3	1	Unsigned Integer	Function ID (FID) = 06 (hex)	
4	2	Unsigned Integer	Running/Halted = 1/0	
6	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field

2.2.4.1.9 Load High Voltage Ramp Parameters

This command packet loads parameters that are used by the High Voltage Ramp-up/down task.

Note: Task TID=17 (hex) **must** be stopped when using this command.

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	-	Checksum Type/Ack	Data Field Header
1	1	-	Packet Type /SubType = 5,3	
2	1	Unsigned Integer	Task ID (TID) = 14 (hex)	Application Data
3	1	Unsigned Integer	Function ID (FID) = 00 (hex)	
4	2	Unsigned Integer	Voltage to be adjusted[1]	
6	2	Unsigned Integer	Value to be attained	
8	2	Unsigned Integer	Ramp Rate in Volts/sec	
10	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field

Notes:
1. 1 = $V_{cathode}$, 2 = V_{mcp1}, 3 = V_{mcp23}

2.2.4.1.10 High Voltage Direct Control

This command packet is present for contingencies. It would **not** be used on a regular basis. Its purpose is to directly control the detector high voltages.

Note: Task TID=14 (hex) **must** be stopped while using this command.

<table>
<tr><th>Offset*</th><th>Length (Octets)</th><th>Type</th><th colspan="2">Description</th><th>Packet Data Field</th></tr>
<tr><td>0</td><td>1</td><td>-</td><td colspan="2">Checksum Type/Ack</td><td rowspan="2">Data Field Header</td></tr>
<tr><td>1</td><td>1</td><td>-</td><td colspan="2">Packet Type /SubType = 5,3</td></tr>
<tr><td>2</td><td>1</td><td>Unsigned Integer</td><td colspan="2">Task ID (TID) = 17 (hex)</td><td rowspan="12">Application Data</td></tr>
<tr><td>3</td><td>1</td><td>Unsigned Integer</td><td colspan="2">Function ID (FID) = 00 (hex)</td></tr>
<tr><td rowspan="4">4</td><td rowspan="4">2</td><td>1 Bit</td><td colspan="2">Enable/Disable = 0/1</td></tr>
<tr><td>5 Bits</td><td>Spare</td><td rowspan="3">V_{mcp1}</td></tr>
<tr><td>1 Bit</td><td>Range</td></tr>
<tr><td>9 Bits</td><td>Offset</td></tr>
<tr><td rowspan="3">6</td><td rowspan="3">2</td><td>8 Bits</td><td>Spare</td><td rowspan="3">$V_{cathode}$</td></tr>
<tr><td>1 Bit</td><td>Range</td></tr>
<tr><td>7 Bits</td><td>Offset</td></tr>
<tr><td rowspan="3">8</td><td rowspan="3">2</td><td>8 Bits</td><td>Spare</td><td rowspan="3">V_{mcp23}</td></tr>
<tr><td>1 Bit</td><td>Range</td></tr>
<tr><td>7 Bits</td><td>Offset</td></tr>
<tr><td>10</td><td>2</td><td>Unsigned Integer</td><td colspan="2">CRC</td><td>Error Control</td></tr>
</table>

* All offsets measured in octets from the start of the Packet Data Field

2.2.4.2 *Digital Processing Unit*

From APP-3, the form of a 'raw' DPU command (i.e. as sent from the ICU to the DPU) is:

Offset (Bytes)	Length (Octets)	Description
0	2	A4xx (hex) - where xx = Command Identifier
2	2	N = No of 16 bit word command parameters
4	2*N	DPU Command Parameters (see below)

For ease of coding, the DPU is commanded by sending its 'raw' commands 'wrapped-up' in a Load Task Parameters packet to the DPU Direct Task. This task is deemed to be always running. Because the first word of a 'raw' DPU command is always of the form A4xx (hex), it is convenient to set the Task ID to 'A4' and the FID to 'xx'.

Thus, the format of all DPU Direct Load Task Parameter commands are as follows:

<table>
<tr><th>Offset*</th><th>Length (Octets)</th><th>Type</th><th colspan="2">Description</th><th>Packet Data Field</th></tr>
<tr><td>0</td><td>1</td><td>-</td><td colspan="2">Checksum Type/Ack</td><td rowspan="2">Data Field Header</td></tr>
<tr><td>1</td><td>1</td><td>-</td><td colspan="2">Packet Type /SubType = 5,3</td></tr>
<tr><td>2</td><td>1</td><td>Unsigned Integer</td><td>Task ID (TID) = A4 (hex)</td><td rowspan="4">'Raw' DPU Command</td><td rowspan="4">Application Data</td></tr>
<tr><td>3</td><td>1</td><td>Unsigned Integer</td><td>Function ID (FID) (see table overleaf)</td></tr>
<tr><td>4</td><td>2</td><td>Unsigned Integer</td><td>N = No of useful 16 bit word parameters</td></tr>
<tr><td>6</td><td>2*N</td><td>Unsigned Integer</td><td>DPU Command Parameters</td></tr>
<tr><td>6+2*N</td><td>2</td><td>Unsigned Integer</td><td colspan="2">CRC</td><td>Error Control</td></tr>
</table>

* All offsets measured in octets from the start of the Packet Data Field

The details of all DPU commands are defined in APP-3, section 8, and therefore will not be repeated here. However, it should be noted that any potentially variable length commands will be padded with zeros up to the maximum length for that command. They are summarised in the table below.

Category	Mnemonic	FID (Hex)
Basic DPUOS manipulation and IO commands	IC_RESET_DSP	01
	IC_LOAD_DPUOS	02
	IC_ENBL_LOAD_CODE	03
	IC_SEL_RAM_BANK	04
	IC_LOAD_CODE	05
	IC_SEL_KLINGON	06
	IC_ENBL_DSP	07
	IC_ENBL_EVENTS	08
	IC_DIRECT_DATA	09
	IC_POWER_DOWN_DPU[2]	0A
	IC_SEND_SCI_CMD	0B
	IC_REQ_DATA	0D
	IC_CLK_SYNCH_CLK	0E
	IC_FLUSH_QUEUE	0F
Memory [1] management	IC_DUMP_LOCAL_RAM	10
	IC_LOAD_LOCAL_RAM	11
	IC_DUMP_PROG_RAM	14
	IC_DUMP_RAM	15
	IC_DUMP_RAM_N_ZERO	16
	IC_LOAD_GLOBAL_RAM	17
Exposure configuration commands	IC_SET_TRK	20
	IC_BPE_BINNING	21
	IC_REPORT_TRK	22
	IC_REPORT_DIAGS	23
	IC_SET_FRAME_TIME	24
	IC_SET_EXP_TIME	25
	IC_SET_EXP_ID	26
	IC_CONF_GS_SEL	27
	IC_LOAD_REF_STARS	28
	IC_LOAD_FILT_CONF	29
	IC_LOAD_MEM_WDW	2A
	IC_LOAD_SCI_WDW	2B
	IC_ENBL_VERBOSE	2C
	IC_LOAD_DET_DTW	2D
Major task invocation commands	IC_INIT_DPU	30
	IC_INIT_EXP	31
	IC_ACQUIRE_FLD	32
	IC_CHOOSE_GS	33
	IC_TRACK_GS	34
	IC_ABORT_DPU	35
	IC_ENBL_ENG	36
	IC_FLUSH_CMPRS	37

Table 2-11: DPU Commands

1. These will normally be implemented via the Memory Management Packets.
2. Normally handled by a DEMPSU task stop command

2.2.4.3 RBI Watchdog

This command resets the RBI watchdog control parameters. The default values are timout = FFF (hex), Reset Interval = 8 secs.

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	-	Checksum Type/Ack	Data Field Header
1	1	-	Packet Type /SubType = 5,3	
2	1	Unsigned Integer	Task ID (TID) = 50 (hex)	Application Data
3	1	Unsigned Integer	Function ID (FID) = 00 (hex)	
4	2	Unsigned Integer	Timout (1/256 secs)	
6	2	Unsigned Integer	Reset Interval (secs)	
8	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field

2.2.4.4 *Telescope Module Power Supply (TMPSU).*

This section covers those commands that load parameters into TMPSU related tasks. These are the filter wheel and dichroic mechanisms and heater control.

2.2.4.4.1 Filter Wheel Commands

2.2.4.4.1.1 Set Filter Wheel Number

Specifies the filter wheel to be moved to by the Move Filter Wheel Task. The filter wheel numbers are defined as follows:

Filter Number	Filter Wheel Station	Description	Filter Position (steps from datum)
0	0	Blocked	1200
1	1	V	1400
2	2	Magnifier	1600
3	3	U (no bar)	1800
4	4	B	2000
5	5	White	0
6	6	Grism 2 (Visible)	200
7	7	UVW1	400
8	8	UVM2	600
9	9	UVW2	800
10	10	Grism 1 (UV)	1000
11	3	U (Barred)	1837

Table 2-12 : Filter Positions.

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	-	Checksum Type/Ack	Data Field Header
1	1	-	Packet Type /SubType = 5,3	
2	1	Unsigned Integer	Task ID (TID) = 60 (hex)	Application Data
3	1	Unsigned Integer	Function ID (FID) = 04 (hex)	
4	2	Unsigned Integer	Filter Wheel Number	
6	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field

2.2.4.4.1.2 Set Absolute Number of Steps of FW Movement

Specifies the position in steps from datum (maximum 2199) the filter wheel is to be moved to by the 'Move Filter Wheel' task. It is anticipated that this will only be used as a 'contingency' command in the event of e.g. sensor failure so that the filter wheel can be moved by 'dead reckoning'.

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	-	Checksum Type/Ack	Data Field Header
1	1	-	Packet Type /SubType = 5,3	
2	1	Unsigned Integer	Task ID (TID) = 60 (hex)	Application Data
3	1	Unsigned Integer	Function ID (FID) = 05 (hex)	
4	2	Unsigned Integer	Number of Steps	
6	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field

2.2.4.4.1.3 Set Relative Number of Steps of FW Movement

Specifies the position in steps (maximum 2199) the filter wheel is to be moved relative to its current position by the 'Move Filter Wheel' task. It is anticipated that this will only be used as a 'contingency' command in the event of e.g. sensor failure so that the filter wheel can be moved by 'dead reckoning'.

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	-	Checksum Type/Ack	Data Field Header
1	1	-	Packet Type /SubType = 5,3	
2	1	Unsigned Integer	Task ID (TID) = 60 (hex)	Application Data
3	1	Unsigned Integer	Function ID (FID) = 06 (hex)	
4	2	Unsigned Integer	Number of Steps	
6	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field

2.2.4.4.1.4 Set Number of Fine Sensor Pulses for F/W Steps

Specifies the number of fine sensor pulses the filter wheel is to be moved relative to its current position by the 'Move Filter Wheel' task. It is anticipated that this will only be used as a 'contingency' command in the event of e.g. coarse sensor failure so that the filter wheel can be moved by 'dead reckoning'.

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	-	Checksum Type/Ack	Data Field Header
1	1	-	Packet Type /SubType = 5,3	
2	1	Unsigned Integer	Task ID (TID) = 60 (hex)	Application Data
3	1	Unsigned Integer	Function ID (FID) = 07 (hex)	
4	2	Unsigned Integer	Number of Steps	
6	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field

2.2.4.4.1.5 Set Next F/W Movement to be to the Datum

Specifies that the next filter movement will be to the datum position.

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	-	Checksum Type/Ack	Data Field Header
1	1	-	Packet Type /SubType = 5,3	
2	1	Unsigned Integer	Task ID (TID) = 60 (hex)	Application Data
3	1	Unsigned Integer	Function ID (FID) = 08 (hex)	
4	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field

2.2.4.4.1.6 Set Next F/W Movement to be to the Coarse Sensor

Specifies that the next filter movement will be to the coarse sensor position.

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	-	Checksum Type/Ack	Data Field Header
1	1	-	Packet Type /SubType = 5,3	
2	1	Unsigned Integer	Task ID (TID) = 60 (hex)	Application Data
3	1	Unsigned Integer	Function ID (FID) = 09 (hex)	
4	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field

2.2.4.4.1.7 Set Coarse Position Sensor LED Current

Because of the long duration of the mission and the radiation environment, it is anticipated that the light emission of the LED used as a light source for the filter wheel coarse position sensor will deteriorate. The LED will therefore have to be driven harder to maintain a sufficient light level. This command supplies the setting for the coarse position sensor LED current to the Move Filter Wheel task.

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	-	Checksum Type/Ack	Data Field Header
1	1	-	Packet Type /SubType = 5,3	
2	1	Unsigned Integer	Task ID (TID) = 60 (hex)	Application Data
3	1	Unsigned Integer	Function ID (FID) = 00 (hex)	
4	2	Unsigned Integer	Coarse Position LED Current	
6	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field

2.2.4.4.1.8 Set Fine Position Sensor LED Current

This command supplies the setting for the fine position sensor LED current to the Move Filter Wheel task.

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	-	Checksum Type/Ack	Data Field Header
1	1	-	Packet Type /SubType = 5,3	
2	1	Unsigned Integer	Task ID (TID) = 60 (hex)	Application Data
3	1	Unsigned Integer	Function ID (FID) = 01 (hex)	
4	2	Unsigned Integer	Fine Position LED Current	
6	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field

2.2.4.4.1.9 Set Filter Wheel Step Rates

This command is used to specify the step rates of the filter wheel when in movement.

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	-	Checksum Type/Ack	Data Field Header
1	1	-	Packet Type/SubType = 5,3	
2	1	Unsigned Integer	Task ID (TID) = 60 (hex)	Application Data
3	1	Unsigned Integer	Function ID (FID) = 02 (hex)	
4	1	Unsigned Integer	Min Step Rate (Hz)	
5	1	Unsigned Integer	Max Step Rate (Hz)	
6	2	Unsigned Integer	Acceleration Rate (Hz/sec)	
8	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field

2.2.4.4.1.10 Reset Filter Wheel Position Counter.

This command is used to reset to a known value of the (s/w internal) Filter Wheel Position Counter. It is anticipated that this will be used only in contingencies.

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	-	Checksum Type/Ack	Data Field Header
1	1	-	Packet Type /SubType = 5,3	
2	1	Unsigned Integer	Task ID (TID) = 60 (hex)	Application Data
3	1	Unsigned Integer	Function ID (FID) = 03 (hex)	
4	2	Unsigned Integer	Filter Wheel Position	
6	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field

2.2.4.4.2 Dichroic Commands

2.2.4.4.2.1 Specify Dichroic Movement

This command specifies the movement the Move Dichroic command is to use.

If method is 0, the dichroic is moved to its maximum excursion in the direction indicated by the value of number.

If method is 1, the dichroic is moved by the magnitude of number steps in the direction indicated by the sign of number.

In both cases, a positive value of number indicates movement from Secondary to Primary, a negative value a movement from Primary to Secondary. A value of zero is considered positive.

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	-	Checksum Type/Ack	Data Field Header
1	1	-	Packet Type /SubType = 5,3	
2	1	Unsigned Integer	Task ID (TID) = 65 (hex)	Application Data
3	1	Unsigned Integer	Function ID (FID) = 00 (hex)	
4	2	Signed Integer	Number	
6	2	Unsigned Integer	Method = 0/1	
8	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field

2.2.4.4.2.2 Set Dichroic Step Rate

This command is used to specify the step rate of the dichroic when in movement.

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	-	Checksum Type/Ack	Data Field Header
1	1	-	Packet Type /SubType = 5,3	
2	1	Unsigned Integer	Task ID (TID) = 65 (hex)	Application Data
3	1	Unsigned Integer	Function ID (FID) = 01 (hex)	
4	2	Unsigned Integer	Step Rate (Hz)	
6	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field

2.2.4.4.3 Heater Commands

2.2.4.4.3.1 Heater Control (Contingency)

This command specifies the heater on/off configuration to be implemented by the 'Heater Control' task. It is only used in contingency situations and allows direct setting of all allowable heater configurations.

Note that the task identified by a TID of 67 (hex) must be stopped at this stage.

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	-	Checksum Type/Ack	Data Field Header
1	1	-	Packet Type /SubType = 5,3	
2	1	Unsigned Integer	Task ID (TID) = 66 (hex)	Application Data
3	1	Unsigned Integer	Function ID (FID) = 00 (hex)	
4	2	12 Bits	Spare	
		4 Bits	Heater Configuration (see below)	
6	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field

The heater configurations are defined as follows (a '-' indicates 'Off'):

Heater Configuration (Binary)	HEATER			
	Main Interface	Forward Tube	Metering Rods	Secondary Mirror
	Temperature Control		Focusing	
	HTR 1	HTR 2	HTR 3	HTR 4
0000	-	-	-	-
0001	-	-	-	On
0010	-	-	On	-
0100	-	On	-	-
0101	-	On	-	On
0110	-	On	On	-
1000	On	-	-	-
1001	On	-	-	On
1010	On	-	On	-
1100	On	On	-	-
1101	On	On	-	On
1110	On	On	On	-
all others	No Change of Heater Status			

Table 2-13 : Heater Configurations.

2.2.4.4.3.2 Heater Control

This command specifies the parameters to control the heaters. As more than one FID value controls a given heater (see table below), the most recent command uplinked will apply.

Note that task (TID = 66 (hex)) must be stopped while this is running.

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	-	Checksum Type/Ack	Data Field Header
1	1	-	Packet Type /SubType = 5,3	
2	1	Unsigned Integer	Task ID (TID) = 67 (hex)	Application Data
3	1	Unsigned Integer	Function ID (FID) (See table below)	
4	2	Integers	N Parameters (see table below)	
4+2*N	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field

The FID implies the structure of the data, the heater(s) and the algorithm or function as follows:-

FID	Heater(s)	Algorithm/Function[6]	N	Parameters		
				1	2	3
1	Interface	Closed Loop, Free Running	2	T_{min}[3]	T_{max}[3]	-
2	Interface	Open Loop, Free Running	2	On Time[1]	Cycle Time[1]	-
3	Forward	Closed Loop, Synched	3	T_{min}[3]	T_{max}[3]	Thermistor[2]
4	Forward	Closed Loop, Free Running	3	T_{min}[3]	T_{max}[3]	Thermistor[2]
5	Forward	Open Loop, Synched	2	On Time[1]	Cycle Time[1]	-
6	Forward	Open Loop, Free Running	2	On Time[1]	Cycle Time[1]	-
7	Focusing	Negative, Positive Focusing	3	On Time[1]	Cycle Time[1]	Focus Direction[4]
8	-	Set Sample Time	1	Sample Time[5]	-	-

Notes:

1. The ‘On Time’ is the amount the heater spends powered in the ‘Cycle Time’. The times are in units of ‘Sample Time’.
2. A ‘Thermistor’ value of 0 indicates the prime thermistor, a 1 indicates the redundant.
3. T_{min} and T_{max} are in ‘raw’ thermistor units.
4. The value of ‘Focus Direction’ requests focusing direction as follows:
    a) > 0 - positive focusing : only HTR3 (metering rods) powered.
    b) < 0 - negative focusing : only HTR4 (secondary mirror) powered.
    c) 0 - no focusing : both HTR3 and HTR4 are not powered. This is the default.
5. ‘Sample Time’ is in units of seconds in the range 1 through 20. The default is 10 secs.
6. Algorithms based on document APP-8.

2.2.4.5 Instrument Control Bus (ICB)

This section describes commands which control directly the OM Instrument Control Bus (ICB). They are provided to give a level of command redundancy for those units. The ICB is implemented using the MACSbus standard. All commands to the detector and TMPSU are sent via this bus. Each unit and internal register is visible to the ICU as an address and sub-address combination. The ICU is the master, all other units are slaves.

Note. For this command to work, the ICB Command task (TID = 41 (hex)) must have been started. ICB commands are sent by loading parameters to this task. This philosophy is adopted due to the potentially dangerous ‘back-door’ nature of this command.

2.2.4.5.1 Load Task ICB Directly Packet Data

This command sends a direct command to any device on the ICB by loading an appropriate value into the necessary address and sub-address combination.

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	-	Checksum Flag/Ack	Data Field Header
1	1	Unsigned Integer	Packet Type/SubType = 5,3	
2	1	Unsigned Integer	Task ID (TID) = 41(hex)	Application Data
3	1	Unsigned Integer	Function ID (FID) = 00(hex)	
4	2	Unsigned Integer	MACS Address	
6	2	Unsigned Integer	MACS Sub-Address	
8	2	Unsigned Integer	Value to be loaded	
10	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field

The contents of the MACS address and sub-addresses for the various ICB sub-systems are described overleaf.

See section 2.2.5.2 for commands to read the ICB ports directly.

<table>
<tr><th rowspan="2">Addr. (hex)</th><th rowspan="2">Sub System</th><th rowspan="2">Sub-Addr.</th><th rowspan="2">Description</th><th colspan="16">Bits</th></tr>
<tr><th>MSB</th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th>LSB</th></tr>
<tr><td>2</td><td>Reserved</td><td>0 ⇒ 31</td><td>Reserved</td><td colspan="16">Reserved</td></tr>
<tr><td rowspan="4">7</td><td rowspan="4">TMPSU</td><td>0</td><td>MISC</td><td colspan="3">CS</td><td colspan="4">FW_PSC</td><td>SE</td><td colspan="8">Don’t Care</td></tr>
<tr><td>1</td><td>ADC</td><td colspan="16">Don’t Care</td></tr>
<tr><td>2</td><td>Filter Wheel & Dichroic</td><td>F1</td><td>F2</td><td>F3</td><td>F4</td><td>D1</td><td>D2</td><td>D3</td><td>D4</td><td colspan="8">Don’t Care</td></tr>
<tr><td>4</td><td>Heaters</td><td>H1</td><td>H2</td><td>H3</td><td>H4</td><td colspan="12">Don’t Care</td></tr>
<tr><td rowspan="14">18</td><td rowspan="14">Detector</td><td>2</td><td>Camera Start/Stop</td><td colspan="14">Don’t Care</td><td>R</td><td>SC</td></tr>
<tr><td>3</td><td>Bitmap Address</td><td colspan="8">Bitmap Y Address</td><td colspan="8">Bitmap X Address</td></tr>
<tr><td>4</td><td>Bitmap Datum</td><td colspan="12">Don’t Care</td><td colspan="4">Map Data</td></tr>
<tr><td>5</td><td>Event Detect Threshold</td><td colspan="8">Don’t Care</td><td colspan="8">Event Height Threshold</td></tr>
<tr><td>7</td><td>Table Access Mode</td><td colspan="15">Don’t Care</td><td>TE</td></tr>
<tr><td>8</td><td>Lookup Table Address</td><td colspan="8">Lookup Address (M)</td><td colspan="8">Lookup Address (N)</td></tr>
<tr><td>9</td><td>Lookup Table Datum</td><td colspan="9">Don’t Care</td><td colspan="3">Y sub-pixel</td><td>X</td><td colspan="3">X sub-pixel</td></tr>
<tr><td>10</td><td>Acq Mode, Frame Tag</td><td colspan="12">Don’t Care</td><td>FE</td><td colspan="3">Int Mode</td></tr>
<tr><td>11</td><td>Integration Enable</td><td colspan="15">Don’t Care</td><td>IE</td></tr>
<tr><td>12</td><td>MUX Address</td><td colspan="12">Don’t Care</td><td colspan="4">MUX Address</td></tr>
<tr><td>13</td><td>$V_{cathode}$, V_{mcp23}</td><td>R2</td><td colspan="7">V_{mcp23}</td><td>RV</td><td colspan="7">$V_{cathode}$</td></tr>
<tr><td>14</td><td>Biases</td><td colspan="4">X</td><td colspan="4">X</td><td colspan="4">Fine Sensor Current</td><td colspan="4">Flood LED current</td></tr>
<tr><td>15</td><td>V_{mcp1}</td><td>EH</td><td colspan="5">Don’t Care</td><td>R1</td><td colspan="9">V_{mcp1}</td></tr>
</table>

Key

CS	Current Select Secondary Voltages
D1, D2, D3, D4	Phases 1 through 4 of the Dichroic Motor, 1 = energised
EH	Enable High Voltages, 1 = Enabled
F1, F2, F3, F4	Phase 1 through 4 of the Filter Wheel Motor, 1 = energised
FE	Frame Tag enabled if zero
FW_PSC	Set current of coarse sensor illuminating LED
IE	Integration Enabled is set to 1
H1, H2, H3, H4	Heaters, 1 = On, H1 = Main Interface, H2 = Forward Tube, H3 = Metering Rods , H4 = Secondary Mirror
R	Reset Camera Head
R1,R2,RV	Range Bits for V_{mcp1}, V_{mcp23}, $V_{cathode}$
SC	1 = Start Frame Readout, 0 = No Frame Readout, bitmap RAM loadable
SE	Secondary Voltages, 1 = Enabled
TE	Lookup Table access, 0 = Accessed by electronics, table **not** loadable
X	Don’t Care

2.2.5 Report Task Parameters

2.2.5.1 Most Recently Uploaded Parameters

This command causes the generation of a Task Parameter Report TM packet TM(5,4) containing the most recently uploaded set of parameters for the combination of TID and FID. TID and FID are as defined for Load Task Parameters.

NOTE - that this is not supported for the DPU Direct Task (TID = A4 hex).

The format of a Report Task Telecommand Packet Data Field is as follows:

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	-	Checksum Type/Ack	Data Field Header
1	1	-	Packet Type /SubType = 5,4	
2	1	Unsigned Integer	Task ID (TID)	Application Data
3	1	Unsigned Integer	Function ID (FID)	
4	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field

2.2.5.2 Read ICB Address Directly

This command requests that a value be read back from a specified MACSbus address and sub-address combination. As the TID and FID used do not correspond to any TC(5,3), it is used to downlink the value as an additional parameter (see section 2.3.4 of APP-1). It is a contingency command.

See section 2.2.4.5 for commands to write directly to the MACSbus ports.

Note. For this command to work, the ICB Command task (TID = 41 (hex)) must have been started. This philosophy is adopted due to the potentially dangerous ‘back-door’ nature of this command.

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	-	Checksum Flag/Ack	Data Field Header
1	1	Unsigned Integer	Packet Type/SubType = 5,3	
2	1	Unsigned Integer	Task ID (TID) = ICB Address + 40 (hex)	Application Data
3	1	Unsigned Integer	Function ID (FID) = ICB Subaddress	
4	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field

The value of TID and FID for the various ICB sub-systems is described below: A description of the response is given in section 3.5.

TID (hex)	Sub-system	FID	Description
42	Reserved	0 ⇒ 31	Reserved for MSSL ground development
47	TMPSU	0	TMPSU Currents and F/W Coarse Sensor
58	Detector	2	Digital Electronics Status Word
		3	Digital Bitmap Datum
		4	Digital Centroid Table Datum
		5	ADC Housekeeping, HV Status, Fine Sensor
		6	Initiate ADC

2.2.6 Mode Transition

Mode transitions are commanded by a packet with the following data field: (Note, in OM documentation, these are referred to as ‘states’.)

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	-	Checksum Flag/Ack fields	Data Field Header
1	1	Unsigned Integer	Packet Type/SubType= 5,5	
2	1	Unsigned Integer	Mode	Application Data
3	1	Unsigned Integer	Modifier	
4	2	Unsigned Integer	Parameter 1 (see table below)	
6	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field

The values allowed to “mode” are as follows:

MODE	Comment
0	Initial
1	Safe
2	Idle
3	Not used - Science mode is attained implicitly as a result of DPU commands
4	Engineering and Calibration

Table 2-14 : OM Modes

Mode	Modifier	Parameter 1 Description
0	0	0
1	Level of Safing , 0 = Full, 1 = Intermediate	Start Address of ICU Operational Code (0 is treated as standard start address)
2	0	0
4	0	0

2.3 Memory Maintenance

This section defines the packet data fields for the memory maintenance packets. This covers loading, dumping and calculating the checksum for a contiguous memory area.

In this section, **MID** identifies the destination memory AND the processor (ICU or DPU) as follows:

MID (Hex)	ICU & Detector Memory Description		
	Addresses	Sub-System	Description
0	0 - FFFF (hex)	ICU	Operand/Data Space
	10000 - 1FFFF (hex)	Detector Electronics	Window Bitmap Table
	20000 - 2FFFF (hex)		Centroid Look-up Table
1	0 - FFFF (hex)	ICU	Instruction Space

MID (hex)	DPU Local Memory Description
10	DPU Blue 1 DSP Local Memory
11	DPU Blue 2 DSP Local Memory
12	DPU Red DSP Local Memory
13	DPU White DSP Local Memory

MID (hex)	DPU Global Memory Description	START ADDRESS	END ADDRESS
14	DPU Big Word Memory (24 bit words)	000000	0FFFFF
15	DPU Small Word Memory (16 bit words)	400000	7FFFFF
20	DPU Program Ram Bank 0	E00000	E0FFFF
21	DPU Program Ram Bank 1	E10000	E1FFFF
22	DPU Program Ram Bank 2	E20000	E2FFFF
23	DPU Program Ram Bank 3	E30000	E3FFFF
24	DPU Program Ram Bank 4	E40000	E4FFFF
25	DPU Program Ram Bank 5	E50000	E5FFFF
26	DPU Program Ram Bank 6	E60000	E6FFFF
27	DPU Program Ram Bank 7	E70000	E7FFFF

2.3.1 Load Memory

When the ICU receives this packet, it writes the data to the memory block indicated by MID at the address specified. It does not support the MID =0, address range 1000 (hex) to 2FFFF (hex) option.

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	-	Checksum Flag/Ack fields	Data Field Header
1	1	Unsigned Integer	Packet Type/SubType = 6,1	
2	2	Unsigned Integer	MID	Application Data
4	4	Unsigned Integer	Start Address	
8	232	Unsigned Integers	Data to be loaded	
240	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field

2.3.2 Dump Memory

This packet causes a downlink of a *Memory Dump Report* containing the contents of the areas specified.

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	-	Checksum Flag/Ack	Data Field Header
1	1	Unsigned Integer	Packet Type/SubType = 6,2	
2	2	Unsigned Integer	MID	Application Data
4	4	Unsigned Integer	Start Address	
8	2	Unsigned Integer	Length to be dumped	
10	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field

2.3.3 Calculate Memory Checksum

The packet results in the downlink of a *Memory Checksum Report* for the specified areas.

Note - this command is supported for the ICU memory only.

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	-	Checksum Flag/Ack	Data Field Header
1	1	Unsigned Integer	Packet Type/SubType = 6,3	
2	2	Unsigned Integer	MID	Application Data
4	4	Unsigned Integer	Start Address	
8	2	Unsigned Integer	Length to be checked	
10	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field

2.4 Telemetry Management

This section defines the packet data fields for command packets associated with the telemetry management function. The telecommand type acts on periodic, non-periodic telemetry and science packets.

2.4.1 Report TM Packet Generation Status

This packet causes the generation status of all applicable packets to be downlinked to the ground.

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	-	Checksum Flag/Ack fields	Data Field Header
1	1	Unsigned Integer	Packet Type/SubType =9,1	
2	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field

2.4.2 Enable Generation of all TM Packets

As it is illegal to have the high rate housekeeping (SID = 1) enabled at the same time as either science data (SID = Fx hex) or low rate housekeeping (SID = 0), this command is unsupported by the OM.

2.4.3 Disable Generation of all TM Packets

On receipt of this command, generation of all applicable packets is disabled.

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	-	Checksum Flag/Ack fields	Data Field Header
1	1	Unsigned Integer	Packet Type/SubType = 9,3	
2	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field

2.4.4 Enable Generation of Specific Packets

On receipt of this command, generation of the specified housekeeping, science or non-periodic packet is enabled. Note that OM only supports the enabling of one packet type (as specified by the SID) at a time.

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	-	Checksum Flag/Ack fields	Data Field Header
1	1	Unsigned Integer	Packet Type/SubType =9,4	
2	1	Unsigned Integer	SID	Application Data
3	1	-	Spare	
4	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field

2.4.5 Disable Generation of Specific Packets

On receipt of this command, generation of the specified housekeeping, science or non-periodic packet is disabled. Note that OM only supports the disabling of one packet type (as specified by the SID) at a time.

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	-	Checksum Flag/Ack fields	Data Field Header
1	1	Unsigned Integer	Packet Type/SubType =9,5	
2	1	Unsigned Integer	SID	Application Data
3	1	-	Spare	
4	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field

2.5 Onboard Time Management

This section defines the contents of the packet data field for commands associated with the OBDH time management functions. The commands synchronises selected onboard applications to a common onboard time reference and verify this process.

2.5.1 Enable Time Synchronisation

The CDMU sends this command to the ICU to start the time synchronisation function.

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	-	Checksum Flag/Ack fields	Data Field Header
1	1	Unsigned Integer	Packet Type/SubType = 10,2	
2	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field

2.5.2 Add Time Code

On receipt of this command, the ICU adds the time information delivered in the data field to the local representation of the onboard time.

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	-	Checksum Flag/Ack fields	Data Field Header
1	1	Unsigned Integer	Packet Type/SubType = 10,3	
2	4	Unsigned Integer	Coarse Time	Application Data
6	2	Unsigned Integer	Fine Time	
8	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field

2.5.3 Enable Time Verification

This command enables the generation of a Time Verification Report TM(10,5).

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	-	Checksum Flag/Ack fields	Data Field Header
1	1	Unsigned Integer	Packet Type/SubType = 10,5	
2	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field

2.6 Test Command

This section defines the contents of the packet data field for the test telecommand packet. The test command's only function is to confirm that the link to the OM is alive and working - i.e. it is a 'NO-OP' command

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	-	Checksum Flag/Ack fields	Data Field Header
1	1	Unsigned Integer	Packet Type/SubType = 13,1	
2	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field

3. Telemetry

3.1 Overview

All telemetry packets will conform to the structure defined in APP-1. The template structure is repeated here for convenience.

<table>
<tr><td colspan="7">SOURCE PACKET HEADER (48 bits)</td><td colspan="3">PACKET DATA FIELD</td></tr>
<tr><td colspan="4">Packet ID</td><td colspan="2">Packet Sequence Control</td><td rowspan="3">Packet Length</td><td rowspan="3">Data Field Header</td><td rowspan="3">Source Data</td><td rowspan="3">Packet Error Control</td></tr>
<tr><td>Version Number</td><td>Type</td><td>Data Field Header Flag</td><td>Applic-ation Process ID</td><td>Segment-ation Flags</td><td>Source Sequence Count</td></tr>
<tr><td>3</td><td>1</td><td>1</td><td>11</td><td>2</td><td>14</td></tr>
<tr><td colspan="4">16</td><td colspan="2">16</td><td>16</td><td>16 or 64</td><td>N * 16</td><td>16</td></tr>
</table>

Table 3-1 : Telemetry Packet Template

3.1.1 Source Packet Header

3.1.1.1 Packet ID

Version Number set to 4 (as per APP-1)
Type set to 0, indicating it is a telemetry packet
Data Field Header set to 1, indicating the data field header is always present
Application Process ID (APID) This identifies the source-sink path for this packet. The APID value for OM will be 1024.

3.1.1.2 Packet Sequence Control

Segmentation Flags (bits 0 through 1) :
These 2 bits are normally set to "11" (binary), which means "unsegmented". However, for Science Packets TM(15,x) they are set as follows:

- 01 = First Source Packet of a Group
- 00 = Continuation Source Packet of a Group
- 10 = Last Source Packet of a Group
- 11 = Self Standing Source Packet (not part of a Group)

Sequence Count (bits 2 through 15) :
The sequence count. This counter:

- increments by 1 for each new telemetry packet.
- may be reset to zero by the source
- will 'wrap-around' from full-scale (2^{14}-1) to zero.

3.1.1.3 Packet Length

The Packet Length Field contains an unsigned integer "C", where

C = (Number of octets in Packet Data Field) -1

The maximum length of a Telemetry Packet Data Field is 512 octets. Therefore C <= 511.

3.1.2 Packet Data Field

This consists of 2 or 3 sub-fields

- Data Field Header (always present)
- Source Data (always present)
- Packet Error Control (present only if so indicated by a flag in the Data Field Header)

A summary of the sub-fields is repeated here from APP-1 for convenience.

3.1.2.1 Data Field Header

Data Field Header have the following structure

Spare	Checksum Flag	Packet Type	Packet SubType	Time
6 Bits	2 Bits	4 Bits	4 Bits	48 Bits
Mandatory	Mandatory	Mandatory	Mandatory	*Optional*

Table 3-2 : TM Data Field Header

Its components are as follows.

Spare : Set to all zeros i.e.000000(binary).

Checksum Flag : Indicates the presence or absence of a Packet Error Control Field at the end of the Packet Data Field.

- Value = 0 = No checksum present.
- Value = 3 = Checksum field is present (always true for OM telemetry).

Packet Type : This identifies the general category to which the telemetry source packet relates and, for OM, defines whether the Time field is present. The packet types applicable to OM are given in the table below.

Packet Type	TM Packet Category	Time Field
1	Periodic Telemetry Reports	✔
3	Telecommands Verification Reports	✔
4	Non-Periodic Telemetry Reports	✔
5	Task Management Reports	✘
6	Memory Maintenance Reports	✘
9	Telemetry Management Reports	✘
10	Time Management Reports	✘
15	Science Data	✘

Table 3-3 : TM Packet Types

Packet SubType : This, together with the Packet Type, uniquely identifies the nature of the telemetry contained in the packet.

The complete list of TM packets supported by OM is given by the following table.

General Category	Type, SubType	Service
PERIODIC TELEMETRY	1,1	Housekeeping Telemetry
TELECOMMAND VERIFICATION	3,1	Successful Command Acceptance
	3,2	Unsuccessful Command Acceptance
	3,4	Unsuccessful Command Execution
NON-PERIODIC TELEMETRY	4,1	Event Report
	4,2	Exception Report
	4,3	Major Anomaly Report
TASK MANAGEMENT	5,4	Task Parameter Report
MEMORY MAINTENANCE	6,2	Memory Dump Report
	6,3	Memory Checksum Report
TELEMETRY MANAGEMENT	9,1	TM Packet Generation Status Report
ON-BOARD TIME MANAGEMENT	10,5	Time Verification Report
SCIENCE DATA	15,x	Science Data

Table 3-4 : TM Packet Functions

Time: This field is optional for packet types 5,6,9,10 and 15. Its format is defined in appendix 5 of APP-1. It consists of 4 octets of coarse time, containing multiples of 1 second, and 2 octets of fine time, containing multiples of 2^{-16} of a second.
The table given under the description of Packet Type in this section indicates its presence or absence as a function of packet type.

Coarse Time				Fine Time	
2^{31}	2^{23}	2^{8}	2^{0}	2^{-1}	2^{-16}

Table 3-5 : TM Time Format

3.1.2.2 Source Data

This constitutes the data element of the telemetry report. The precise format depends on the values of type and subtype. The table in section 3.1.3 provides a summary. The meaning of the terms used is explained in the remainder of the document.

3.1.2.3 Packet Error Control

This field, which is always present in OM telemetry, contains an error detection code (checksum) for the packet. This allows the OM to verify the integrity of the telecommand packet data. It is calculated over the complete packet *less* the final 16 bits of the Packet Error Control Field.

3.1.3 Packet Structure Summary

The Telemetry Packet Structure is summarised in the following tables.

Packet	consists of	which consists of	which consists of	which consists of	Size (bits)
TM Packet	Source Packet Header	Packet ID	Version Number		3
			Type		1
			Data Field Header Flag		1
			APID		11
		Packet Sequence Control	Sequence Flags		2
			Sequence Count		14
		Packet Length			16
	Packet Data Field	Data Field Header	Spare		6
			Checksum Flag		2
			Packet Type		4
			Packet SubType		4
			Time (optional)	Coarse Time	32
				Fine Time	16
		Source Data	as summarised in table overleaf.		N * 16
		Packet Error Control (Optional)			16

Table 3-6 : TM Packet Summary

Category	Data Field Header and Source Data (Byte Offsets from Source Packet Header)															
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15⇒end
Periodic HK	CRC	1,1	Coarse Time				Fine Time		SID	Parameters						
Verification Reports	CRC	3,1	Coarse Time				Fine Time		TC Seq. Count							
	CRC	3,2	Coarse Time				Fine Time		TC Seq. Count		Err	N	Parameters			
	CRC	3,4	Coarse Time				Fine Time		TC Seq. Count		Err	N	Parameters			
Non-Periodic Telemetry	CRC	4,1	Coarse Time				Fine Time		SID		Parameters					
	CRC	4,2	Coarse Time				Fine Time		SID		Parameters					
	CRC	4,3	Coarse Time				Fine Time		SID		Parameters					
Task Management	CRC	5,4	TID	FID	Parameters											
Memory Maintenance	CRC	6,2	MID		Start Address				Data							
	CRC	6,3	MID		Start Address				Length		CRC Result					
TM Management	CRC	9,1	SID1	Stat 1	SID2	Stat 2	Repeat as required									
Time Management	CRC	10,5	Coarse Time				Fine Time									
Science	CRC	15,x	SID	Offset	Science Data											

Table 3-7 : TM Data Field and Source Data Summary

The terms used in the above table are explained in the text.

NOTE: Table entries with a background like this are part of the Data Field Header

3.2 *Periodic Telemetry Reports*

This section defines the contents of the packet data field for the periodic telemetry report packets.

3.2.1 Housekeeping

This packet type is used to transport periodically sampled housekeeping telemetry every 10 sec.

Offset*	Length (Octets)	Type	Description				Packet Data Field
0	1	Unsigned Integer	Checksum Flag				Data Field Header
1	1	Unsigned Integer	Packet Type/SubType = 1,1				
2	6	Time Field	Time				
8	1	Unsigned Integer	SID = 00(hex)				Source Data
9	1	Unsigned Integer	Wait Resolution (Accuracy of A to D)			Analogue Blue Processing Electronics	
10	2	Unsigned Integer	1	Focusing	Thermistors		
12	2	Unsigned Integer	2				
14	2	Unsigned Integer	3				
16	2	Unsigned Integer	4				
18	2	Unsigned Integer	1	General			
20	2	Unsigned Integer	2				
22	2	Unsigned Integer	3				
24	2	Unsigned Integer	4				
26	2	4 bits	Spare				
		1 Bit	High Voltage Enabled/Disabled				
		1 Bit	Fine Pick-Off Sensor				
		10 Bits	V_{mcp1}	High Voltage Monitor			
28	2	Unsigned Integer	V_{mcp23}				
30	2	Unsigned Integer	$V_{cathode}$				
32	2	Unsigned Integer	+5 V	Low Voltage Monitor			
34	2	Unsigned Integer	+15 V				
36	2	Unsigned Integer	-15 V				
38	2	Unsigned Integer	1.23 V Reference				
40	2	Unsigned Integer	Filter Wheel Pickoff (Analogue)				
42	1	4 Bits	Pair 1	Flood LED Bias Current			
		4 Bits	Pair 2				
43	1	4 Bits	Spare				
		4 Bits	Fine Position Sensor LED Drive Current				
44	1	1 Bit	Integration Enabled/Disabled			Digital Blue Processing Electronics	
		3 Bit	Acquisition Mode				
		1 Bit	Frame Tag Enabled/Disabled				
		1 Bit	Spare				
		1 Bit	Table Access Mode/Centroid Table Ready				
		1 Bit	Camera Start/Stop - Window Table Ready				
45	1	Unsigned Integer	Event Detect Threshold				

Continued overleaf.

* All offsets measured in octets from the start of the Packet Data Field.

Housekeeping (continued).

Offset*	Length (Octets)	Type	Description			Packet Data Field
46	1	4 Bits	Spare		TMPSU	Source Data
		4 Bits	Commanded Heater Status			
47	1	2 bits	Spare			
		4 Bits	Coarse Position Sensor LED Current			
		1 Bit	Coarse Position Sensor Status			
		1 Bit	Secondary Voltage Status			
48	2	4 Bits	Last Commanded Filter Wheel Phase			
		12 Bits	S/W Filter Wheel Position Counter			
50	1	4 Bits	Spare			
		4 Bits	Last Commanded Dichroic Phase			
51	1	2 Bits	Spare			
		6 Bits	S/W Dichroic Position Counter			
52	1	Unsigned Integer	Current +25	Switched	Secondary Voltages	
53	1	Unsigned Integer	Current +15			
54	1	Unsigned Integer	Current +11			
55	1	Unsigned Integer	Current +5.3			
56	1	Unsigned Integer	Current -5.3			
57	1	Unsigned Integer	Current -15			
58	1	Unsigned Integer	Current +28	Unswitched		
59	1	Unsigned Integer	Current +5			
60	1	4 Bits	Spare		ICB	
		4 Bits	ICB Status Register at last error			
61	1	8 Bits	SSI Interface Status Register		SSI	
62	2	14 Bits	S/W Version		S/W	
		1 Bit	Time Synchronisation Active		S/C Interface	
		1 Bit	Time Invalid Flag			
64	2	16 Bits	RBI Status Register			
66	2	16 Bits	RBI Configuration Register			
68	1	Unsigned Integer	ICB Error Count		Errors	
69	1	Unsigned Integer	SSI Error Count			
70	1	Unsigned Integer	Spare			
71	1	Unsigned Integer	SCI Error Count			
72	1		Spare			
73	1		Spare			
74	2	Unsigned Integer	TC Good Packet Count		Packet Counters	
76	2	Unsigned Integer	TC Bad Packet Count			

Continued overleaf.

* All offsets measured in octets from the start of the Packet Data Field.

Housekeeping (continued).

<table>
<tr><th>Offset*</th><th>Length (Octets)</th><th>Type</th><th colspan="3">Description</th><th>Packet Data Field</th></tr>
<tr><td rowspan="3">78</td><td rowspan="3">1</td><td>4 Bits</td><td colspan="2">Spare</td><td rowspan="3">General</td><td rowspan="23">Source Data</td></tr>
<tr><td>3 Bits</td><td colspan="2">OM State</td></tr>
<tr><td>1 Bit</td><td colspan="2">Prime/Redundant Flag (Prime = 0)</td></tr>
<tr><td rowspan="2">79</td><td rowspan="2">1</td><td>7 Bits-</td><td colspan="2">Spare</td><td rowspan="2">ICU</td></tr>
<tr><td>Unsigned Integer</td><td colspan="2">ICU State</td></tr>
<tr><td>80</td><td>2</td><td>Unsigned Integer</td><td colspan="2">Heartbeat Count</td><td rowspan="17">DPU</td></tr>
<tr><td>82</td><td>2</td><td>Unsigned Integer</td><td colspan="2">Current DPU DD_xxx Data Type</td></tr>
<tr><td>84</td><td>4</td><td>Signed Integer</td><td colspan="2">Drift x</td></tr>
<tr><td>88</td><td>4</td><td>Signed Integer</td><td colspan="2">Drift y</td></tr>
<tr><td>92</td><td>4</td><td>Signed Integer</td><td colspan="2">Drift Roll</td></tr>
<tr><td>96</td><td>2</td><td>Unsigned Integer</td><td colspan="2">Number of Frames so far this Exposure</td></tr>
<tr><td>98</td><td>2</td><td>Unsigned Integer</td><td colspan="2">Exposure Time (Frames)</td></tr>
<tr><td>100</td><td>4</td><td>Unsigned Integer</td><td colspan="2">Exposure ID</td></tr>
<tr><td rowspan="9">104</td><td rowspan="9">2</td><td>1 Bit</td><td colspan="2">DPU State (0 /1 = BOOT/DPUOS)</td></tr>
<tr><td>1 Bit</td><td>Blue 1 DSP Status</td><td rowspan="5">0/1 = Off/On</td></tr>
<tr><td>1 Bit</td><td>Blue 2 DSP Status</td></tr>
<tr><td>1 Bit</td><td>Red DSP Status</td></tr>
<tr><td>1 Bit</td><td>Blue 1 DSP Data Capture</td></tr>
<tr><td>1 Bit</td><td>Blue 2 DSP Data Capture</td></tr>
<tr><td>1 Bit</td><td colspan="2">Tracking = 0/1 = on/off</td></tr>
<tr><td>5 Bits</td><td colspan="2">Current Swap Unit ID</td></tr>
<tr><td>4 Bits</td><td colspan="2">Current DPU Task ID</td></tr>
<tr><td>106</td><td>4</td><td>32 bits</td><td colspan="2">ICU S/W Task Status Flags</td><td>Tasks</td></tr>
<tr><td>110</td><td>2</td><td>Unsigned Integer</td><td colspan="3">CRC</td><td>Error Control</td></tr>
</table>

* All offsets measured in octets from the start of the Packet Data Field.

3.2.2 Diagnostic Periodic Engineering.

In addition to the normal periodic housekeeping, there is a ‘diagnostic periodic engineering’ packet. Its format is identical in format to the above normal housekeeping, except that it is sent at a rate of 1 packet per 3 seconds and the SID has a value of 1.

Note: housekeeping packets as defined by a SID of zero MUST be disabled when this packet type is enabled.

It must NOT be used in conjunction with Science Data as there is insufficient telemetry capacity.

3.3 Verification

This section defines the contents of the packet data field for the telemetry verification report packets.

Note - in this section, TC Source Sequence Count is structured as follows:

Size (Bits)	Description
2	Spare (set to 00 binary)
1	Command Source = 0/1 = Ground/On-board
13	Actual Sequence Count

3.3.1 Successful Command Acceptance

This packet sub-type is used to transport information concerning successful telecommand acceptance to the ground.

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	Unsigned Integer	Checksum Flag	Data Field Header
1	1	Unsigned Integer	Packet Type/SubType = 3,1	
2	4	Unsigned Integer	Coarse Time	
6	2	Unsigned Integer	Fine Time	
8	2	Unsigned Integer	TC Source Sequence Count	Source Data
10	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field.

TC Source Sequence Count is the value copied from the Sequence Count field of the uplinked telecommand to which this packet relates. It therefore contains both the command source flag and the actual sequence count.

3.3.2 Unsuccessful Command Acceptance

This packet sub-type is used to transport information concerning unsuccessful telecommand acceptance to the ground. They are of the form:

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	Unsigned Integer	Checksum Flag	Data Field Header
1	1	Unsigned Integer	Packet Type/SubType = 3,2	
2	4	Unsigned Integer	Coarse Time	
6	2	Unsigned Integer	Fine Time	
8	2	Unsigned Integer	TC Source Sequence Count	Source Data
10	1	Unsigned Integer	Error Code	
11	1	Unsigned Integer	Number of Params N	
12	2*N	Unsigned Integers	N Parameters	
12+2*N	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field.

TC Source Sequence Count - the value copied from the Sequence Count field of the uplinked telecommand to which this packet relates. It therefore contains both the command source flag and actual sequence count.

Error Code - the reason for command acceptance failure. Those so far defined, and their associated parameters, are as follows:

Code	Reason	Number Params	Parameter 1	Parameter 2
0	Illegal APID	1	Illegal APID	-
1	Incorrect Checksum	2	Expected CRC	Found CRC
2	Illegal Packet Type	2	Detected Packet Type	Detected Packet SubType
3	Illegal Packet SubType	2	Detected Packet Type	Detected Packet SubType
4	Illegal Parameter Value	0	-	-
5	Invalid Length	1	Illegal Length	-
8	Illegal TID	1	Illegal TID	-
9	Illegal FID	2	Associated TID	Illegal FID
10	Illegal Mode	1	Illegal Mode	-
11	Illegal MID	1	Illegal MID	-
12	Illegal Start Address	1	Illegal Start Address-	
13	Non-existent memory	1	MID	-
19	Illegal SID	1	Illegal SID	-

Table 3-8 : Command Acceptance Failure Summary

3.3.3 Unsuccessful Command Execution

This packet sub-type is used to transport information concerning unsuccessful telecommand execution to the ground.

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	Unsigned Integer	Checksum Flag	Data Field Header
1	1	Unsigned Integer	Packet Type/SubType = 3,4	
2	4	Unsigned Integer	Coarse Time	
6	2	Unsigned Integer	Fine Time	
8	2	Unsigned Integer	TC Source Sequence Count	Source Data
10	1	Unsigned Integer	Error Code	
11	1	Unsigned Integer	No Parameters = N	
12	2*N	Unsigned Integers	N Parameters	
12+2*N	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field

TC Source Sequence Count is the value copied from the Sequence Count field of the uplinked telecommand to which this packet relates. It therefore contains both the command source flag and actual sequence count.

Error Code identifies the reason for command execution failure. Those so far defined, and their associated parameters, are as follows:

Code	Reason	No Params	Parameter Description
128	Task Stopped by command early	0	-
130	Command too soon	0	-
131	Command Rejected because of I/F failure	1	0 = ICB, 1 = SSI

Table 3-9 : Command Execution Failure Summary

3.4 Non-Periodic Housekeeping

This section defines the contents of the packet data field for non-periodic housekeeping telemetry packets.

3.4.1 Event Reports

This packet sub-type is used to transport telemetry that indicates non-critical events.

3.4.1.1 Non-DPU Event Reports

3.4.1.1.1 General Format

The general format for event report packets **NOT** relating to the DPU is:-

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	Unsigned Integer	Checksum Flag	Data Field Header
1	1	Unsigned Integer	Packet Type/SubType = 4,1	
2	4	Unsigned Integer	Coarse Time	
6	2	Unsigned Integer	Fine Time	
8	1	Unsigned Integer	SID (see tables below)	Source Data
9	1	-	Spare	
10	2	Unsigned Integers	Event Code	
12	2	Unsigned Integers	(16 bit word) Parameter	
14	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field.

The non-DPU Events so far defined are as follows:

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

Table 3-10: Non-DPU Event Summary

3.4.1.1.2 Bootstrap Report

There is an exception to the above format. At the start of the ICU basic / initial mode, the following packet is issued in the event of a nominal boot sequence. It is used to give a record of what happened during the boot process. The full explanation of the items is given in APP-7, together with the criteria for deciding if the operation was nominal. If the boot sequence was non nominal, an identically structured packet, but of the exception report sub-type is issued instead (see below).

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	Unsigned Integer	Checksum Flag	Data Field Header
1	1	Unsigned Integer	Packet Type/SubType = 4,1	
2	4	Unsigned Integer	Coarse Time	
6	2	Unsigned Integer	Fine Time	
8	1	Unsigned Integer	SID = D3 (hex)	Source Data
9	1	Unsigned Integer	Spare	
10	2	Unsigned Integer	Boot Type	
12	2	Unsigned Integer	Progress Flags	
14	2	Unsigned Integer	ICB Command Counter	
16	2	Unsigned Integer	ICB Sync Error Counter	
18	2	Unsigned Integer	ICB Extension Error Counter	
20	2	Unsigned Integer	ICB Transmit Error Counter	
22	2	Unsigned Integer	ICB Time Out Error Counter	
24	2	Unsigned Integer	Coarse Seen Flag	
26	2	Unsigned Integer	Steps Remaining Counter	
28	2	Unsigned Integer	Final Steps Counter	
30	2	Unsigned Integer	Last Filter Wheel Phase	
32	2	Unsigned Integer	Filter Wheel Safing Error Counter	
34	2	Unsigned Integer	ICB Initialisation	
36	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field.

3.4.1.2 DPU Event Reports

The data stream from the DPU to the ICU contain Alerts. Alerts are data blocks informing the ICU of changes in the status of the DPU. The format of these blocks is defined in the ICU-DPU Protocol Document (APP-3, section 7) and are of the general form

1st Word	2nd Word	Remaining Words
Alert Code	Number of Words (N_{words}) to follow	N_{words} of Data

Those DPU alerts of an information nature relevant to ground operations cause an event report packet to be sent to the ground. For ease of coding, the packet is constructed by adding a suitable packet header, SID and checksum around the alert. The format of the resulting packet data field is as follows:

Offset*	Length (Octets)	Type	Description		Packet Data Field
0	1	Unsigned Integer	Checksum Flag		Data Field Header
1	1	Unsigned Integer	Packet Type/SubType = 4,1		
2	4	Unsigned Integer	Coarse Time		
6	2	Unsigned Integer	Fine Time		
8	1	Unsigned Integer	SID (see Table overleaf)		Source Data
9	1	Unsigned Integer	Spare		
10	2	Unsigned Integer	DPU Alert Code	DPU Alert Block	
12	2	Unsigned Integer	N_{words}		
14	2*N_{words}	Unsigned Integers	N_{words} of Data		
14+2*N_{param}	2	Unsigned Integer	CRC		Error Control

* All offsets measured in octets from the start of the Packet Data Field.

As the layout, format and meaning of the parameters associated with each Alert Block are defined in App-3, section 7, they will not be repeated here. However, the table overleaf defines the associated SID’s.

The DPU events so far defined are as follows:

Category	Mnemonic	Alert Code (Hex)	SID (Hex)	Enabled (Default)
Synchronous	DA_HBEAT	A500	90	-
Asynchronous Health & Status	DA_DPU_BOOT_READY	A510	91	Yes
	DA_DPUOS_READY	A511	92	Yes
	DA_ECHO_ICU_CMD	A512	93	-
	DA_BEGOF_EXP	A513	94	Yes
	DA_ENDOF_EXP	A514	95	Yes
	DA_DATA_ALERT	A515	96	-
	DA_DATA_END	A516	97	-
	DA_DONE_FLD_DATA	A517	98	-
	DA_COMPLETE_EXP	A518	99	Yes
Major Milestones	DA_EOT_INIT_DPU	A520	9A	Yes
	DA_EOT_ACQUIRE_FLD	A521	9B	Yes
	DA_EOT_CHOOSE_GS	A522	9C	Yes
	DA_EOT_INIT_EXP	A523	9E	-
	DA_EOT_ENG	A524	9F	-
	DA_SWITCH_FRAME	A525	A0	-
	DA_TRK	A526	A1	-
	DA_SENT_CMPRSSQ	A527	A2	Yes
	DA_EOT_FLUSH_CMPRS	A528	A3	-
Minor Milestone	DA_EOS_INIT_DPU	A530	A4	-
	DA_EOS_CALBGD	A531	A4	-
	DA_EOS_SCANBS	A532	A4	-
	DA_EOS_RSTR_STARS	A533	A4	-
	DA_EOS_MAKEAGS_ID	A534	A4	-
	DA_EOS_CALDRFT	A535	A4	-
	DA_EOS_SCANGS	A536	A4	-
	DA_EOS_DOWINDOW	A537	A4	-
	DA_EOS_GETREF	A538	A4	-
	DA_EOS_LOCATEGS	A539	A4	-
	DA_EOS_ABORT	A53A	A4	-
	DA_EOS_DLVRDATA	A53B	A4	-
	DA_EOS_ENG	A53C	A4	-
	DA_EOS_COMPRESS	A53D	A4	-
	DA_DONE_SAA	A53E	A4	-

Table 3-11 : DPU Event Summary

3.4.2 Exception Reports

This packet sub-type is used to transport telemetry that indicates non-fatal anomalies.

3.4.2.1 Non-DPU Exception Reports

3.4.2.1.1 General Format

The general format for the majority of exception report packets **NOT** relating to the DPU is:-

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	Unsigned Integer	Checksum Flag	Data Field Header
1	1	Unsigned Integer	Packet Type/SubType = 4,2	
2	4	Unsigned Integer	Coarse Time	
6	2	Unsigned Integer	Fine Time	
8	1	Unsigned Integer	SID (see tables below)	Source Data
9	1	-	Spare	
10	2	Unsigned Integers	Exception Code	
12	2	Unsigned Integers	Parameter	
14	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field.

The non-DPU exception codes and parameters are defined overleaf.

The non-DPU exceptions supported by this format are as follows:

Sub-System	Description	SID (Hex)	Exception Code	Parameter (hex) and Description
DETECTOR	Centroid Table Load Failed	11	0010	0 = Macsbus Error
	Window Table Load Failed		0011	0 = Macsbus Error
	ADA Exception[1]		0012	y10x (hex)
ICB	ADA Exception[1]	41	0041	yCBx (hex)
RBI	RBI Watchdog ADA Exception[1]	51	50	y60x (hex)
	Telemetry Queue ADA Exception[1]		51	yF0x (hex)
TMPSU	Loss of Filter Wheel Position	61	0060	0 = Macsbus Error 1 = Abort of command 2 = Loss of Fine Sensor 3 = Loss of Coarse Sensor
	Loss of Dichroic Position		0061	0 = Macsbus Error 1 = Abort of command
	ADA Exception[1]		0062	y00x
SSI	SSI Error	31	0030	1 = embedded-actual length inconsistent 2 = actual word count > ffff hex 7 = Overflow at end of block 8 = data too soon 9 = embedded put length too long 11 = embedded word count > 1027 (decimal) B = output buffer full C = interrupt input queue full 89 = h/w Overflow detected during put.
			31	The Invalid DPU Block Type
	ADA Exception[1]		32	y70x
HK	HK ADA Exception[1]	02	0002	y30x (hex)
General	ICU Memory Manager ADA Exception[1]	D7	00D1	yC0x (hex)
	Time Manager ADA Exception[1]		00D2	yC1x (hex)
	All other ADA exceptions[1]		00D0	y00x (hex)

Notes:

1. The parameter is always of the form `yssx`, where:
   `y` is odd for ICU basic mode, even for ICU operational mode
   `ss` indicates the ADA package
   `x` indicates the code block within the package where the exception occurred

Table 3-12 : Non DPU Exception Summary

3.4.2.1.2 ICB Errors

There is an exception to the above format in the event of an ICB error. The format is as follows:-

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	Unsigned Integer	Checksum Flag	Data Field Header
1	1	Unsigned Integer	Packet Type/SubType = 4,2	
2	4	Unsigned Integer	Coarse Time	
6	2	Unsigned Integer	Fine Time	
8	1	Unsigned Integer	SID = 44 (hex)	Source Data
9	1	-	Spare	
10	2	Unsigned Integer	Command Word	
12	2	Unsigned Integer	Datum send/received	
14	2	Unsigned Integer	Status at end	
14	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field.

N.B. By default, this packet is disabled and requires the appropriate telemetry management command to enable it.

3.4.2.1.3 Bootstrap Report

There is a further exception to the above format. At the start of the ICU basic / initial mode, the following packet is issued in the event of a non-nominal boot sequence. It is used to give a record of what happened during the boot process. The full explanation of the items is given in APP-7, together with the criteria for deciding if the operation was nominal. If the boot sequence was nominal, an identically structured packet, but of the event report sub-type is issued instead (see above).

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	Unsigned Integer	Checksum Flag	Data Field Header
1	1	Unsigned Integer	Packet Type/SubType = 4,2	
2	4	Unsigned Integer	Coarse Time	
6	2	Unsigned Integer	Fine Time	
8	1	Unsigned Integer	SID = D4 (hex)	Source Data
9	1	Unsigned Integer	Spare	
10	2	Unsigned Integer	Boot Type	
12	2	Unsigned Integer	Progress Flags	
14	2	Unsigned Integer	ICB Command Counter	
16	2	Unsigned Integer	ICB Sync Error Counter	
18	2	Unsigned Integer	ICB Extension Error Counter	
20	2	Unsigned Integer	ICB Transmit Error Counter	
22	2	Unsigned Integer	ICB Time Out Error Counter	
24	2	Unsigned Integer	Coarse Seen Flag	
26	2	Unsigned Integer	Steps Remaining Counter	
28	2	Unsigned Integer	Final Steps Counter	
30	2	Unsigned Integer	Last Filter Wheel Phase	
32	2	Unsigned Integer	Filter Wheel Safing Error Counter	
34	2	Unsigned Integer	ICB Initialisation	
36	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field.

3.4.2.2 DPU Exception Reports

3.4.2.2.1 DPU Generated Exceptions

The data stream from the DPU to the ICU contains Alerts. Alerts are data blocks informing the ICU of changes in the status of the DPU, **including any exceptions**. The format of these blocks is defined in the ICU-DPU Protocol Document (APP-3, section 7) and are of the form:

1st Word	2nd Word	Remaining Words
Exception Alert Code	Number of Words (N_{words}) to follow	N_{words} of data

Those DPU alerts of an exception nature cause an exception report packet to be sent to the ground. For ease of coding, the packet is constructed by adding a suitable packet header, SID and checksum around the alert. The format of the resulting packet data field is as follows:

<table>
<tr><th>Offset*</th><th>Length (Octets)</th><th>Type</th><th colspan="2">Description</th><th>Packet Data Field</th></tr>
<tr><td>0</td><td>1</td><td>Unsigned Integer</td><td colspan="2">Checksum Flag</td><td rowspan="4">Data Field Header</td></tr>
<tr><td>1</td><td>1</td><td>Unsigned Integer</td><td colspan="2">Packet Type/SubType = 4,2</td></tr>
<tr><td>2</td><td>4</td><td>Unsigned Integer</td><td colspan="2">Coarse Time</td></tr>
<tr><td>6</td><td>2</td><td>Unsigned Integer</td><td colspan="2">Fine Time</td></tr>
<tr><td>8</td><td>1</td><td>Unsigned Integer</td><td colspan="2">SID (see Table overleaf)</td><td rowspan="5">Source Data</td></tr>
<tr><td>9</td><td>1</td><td>Unsigned Integer</td><td colspan="2">Spare</td></tr>
<tr><td>10</td><td>2</td><td>Unsigned Integer</td><td>DPU Exception Alert Code</td><td rowspan="3">DPU Alert Block</td></tr>
<tr><td>12</td><td>2</td><td>Unsigned Integer</td><td>N_{words}</td></tr>
<tr><td>14</td><td>$2*N_{words}$</td><td>Unsigned Integers</td><td>N_{words} of Data</td></tr>
<tr><td>$14+2*N_{param}$</td><td>2</td><td>Unsigned Integer</td><td colspan="2">CRC</td><td>Error Control</td></tr>
</table>

* All offsets measured in octets from the start of the Packet Data Field.

As the layout, format and meaning of the parameters associated with each Alert Block are defined in App-3, section 7, they will not be repeated here. However, the table overleaf defines the associated SID's.

The DPU exceptions so far defined are as follows (**Note** - they are all enabled by default):

Category	Mnemonic	Alert Code (Hex)	SID (Hex)
Asynchronous Exceptions	DA_CLK_SYNCH_ERROR	A580	B2
	DA_PROG_RAM_ERROR	A581	B3
	DA_BOTTOM_WHITEDSP	A582	B4
	DA_CID_TOO_LARGE	A583	B5
	DA_BAD_CMD	A584	B6
	DA_DPU_ABORTING	A585	B7
	DA_BAD_BLOCK	A586	B8
	DA_ZERO_LENGTH_DQ	A587	B9
Coloured DSP Exceptions	DA_SCI_RCVR_ERROR	A590	BA
	DA_SCI_HBEAT_ERROR	A591	BB
	DA_RED_E_ALERT	A592	BC
	DA_RED_S_ALERT	A593	BD
	DA_BLUE1_E_ALERT	A594	BC
	DA_BLUE1_S_ALERT	A595	BD
	DA_BLUE2_E_ALERT	A596	BC
	DA_BLUE2_S_ALERT	A597	BD
Global Memory Access Exceptions	DA_GADE_RPI	A5A0	BE
	DA_GADE_RPIA_L	A5A1	BF
	DA_GADE_RPIA_H	A5A2	C0
	DA_GADE_WPI	A5A3	BE
	DA_GADE_WPIA_L	A5A4	BF
	DA_GADE_WPIA_H	A5A5	C0
	DA_GADE_RBI	A5A6	BE
	DA_GADE_RBIA_L	A5A7	BF
	DA_GADE_RBIA_H	A5A8	C0
	DA_GADE_WBI	A5A9	BE
	DA_GADE_WBIA_L	A5AA	BF
	DA_GADE_WBIA_H	A5AB	C0
	DA_GADE_RSI	A5AC	BE
	DA_GADE_RSIA_L	A5AD	BF
	DA_GADE_RSIA_H	A5AE	C0
	DA_GADE_WSI	A5AF	BE
	DA_GADE_WSIA_L	A5B0	BF
	DA_GADE_WSIA_H	A5B1	C0
ADA Exception in DPU Manager			CF

Table 3-13 : DPU Exception Summary

3.4.2.2.2 DPU Related Exceptions Generated by the ICU

Some DPU related exceptions are detected by the ICU. These exceptions are of the following format.

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	Unsigned Integer	Checksum Flag	Data Field Header
1	1	Unsigned Integer	Packet Type/SubType = 4,2	
2	4	Unsigned Integer	Coarse Time	
6	2	Unsigned Integer	Fine Time	
8	1	Unsigned Integer	SID (see Table below)	Source Data
9	1	Unsigned Integer	Spare	
10	2	Unsigned Integer	Exception Code	
12	2	Unsigned Integer	Parameter	
14	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field.

Description	SID (Hex)	Exception Code	Parameter (hex)
Heartbeat Monitor Task ADA Exception[1]	CF	C0	e00x
DPU Memory Data Manager Task ADA Exception[1]		C1	e10x
Loss of DPU Heartbeat Exception	B0	A500	0
Unexpected DPU Reset[2]	B1	A510	0

Notes:

1. ‘x’ in the parameter field indicates the code block within the package where the exception occurred
2. This is issued when a DA_DPU_BOOT_READY is issued by the DPU without a preceding IC_RESET_DSP.

3.4.3 Major Anomaly Reports

This packet sub-type is used to transport telemetry that signifies the occurrence of a serious anomaly.

3.4.3.1 General Format

The general format for Major Anomaly Reports is:

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	Unsigned Integer	Checksum Flag	Data Field Header
1	1	Unsigned Integer	Packet Type/SubType = 4,3	
2	4	Unsigned Integer	Coarse Time	
6	2	Unsigned Integer	Fine Time	
8	1	Unsigned Integer	SID	Source Data
9	1	Unsigned Integer	Spare	
10	2*N	Unsigned Integers	Parameter	
10+2*N	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field.

The anomalies so far defined are as follows:

Sub-System	SID (Hex)	Description	Parameters
OM	D2	Emergency Transition to Safe State	Reason Code (TBD)

Table 3-14 : Anomaly Summary

3.5 Task Management

3.5.1 Task Parameter Report

This packet subtype is used to report the most recently uploaded task parameters. It is generated as a response to the telecommand Report Task Parameters TC(5,4).

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	Unsigned Integer	Checksum Flag	Data Field Header
1	1	Unsigned Integer	Packet Type/SubType = 5,4	
2	1	Unsigned Integer	TID	Source Data
3	1	Unsigned Integer	FID	
4	2*N	Unsigned Integers	N (16 bit word) Parameters	
4+2*N	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field.

TID and FID are as defined for Load Task Parameters TC(5,3), except in the case when TID and FID values correspond to a read of an ICB port. The contents of the single word that is then read back are detailed overleaf.

Contents of MACSBUS word read back.

<table>
<tr><th rowspan="2">TID (hex)</th><th rowspan="2">MACs Address (hex)</th><th rowspan="2">FID & MACs Sub Address</th><th rowspan="2">Sub-system</th><th rowspan="2">Description</th><th colspan="16">Bits</th></tr>
<tr><th>MSB</th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th>LSB</th></tr>
<tr><td>42</td><td>2</td><td>0 ⇒ 31</td><td>Reserved</td><td>Reserved for MSSL ground development</td><td colspan="16">Reserved</td></tr>
<tr><td>47</td><td>7</td><td>0</td><td>TMPSU</td><td>TMPSU Currents and F/W Coarse Sensor</td><td colspan="8">Current Value</td><td colspan="7">Don’t Care</td><td>CS</td></tr>
<tr><td rowspan="5">58</td><td rowspan="5">18</td><td>2</td><td rowspan="5">Detector</td><td>Digital Electronics Status Word</td><td colspan="8">Don’t Care</td><td>IA</td><td colspan="3">Int Mode</td><td>FE</td><td>X</td><td>TE</td><td>ME</td></tr>
<tr><td>3</td><td>Digital Bitmap Datum</td><td colspan="12">Don’t Care</td><td colspan="4">Datum</td></tr>
<tr><td>4</td><td>Digital Centroid Table Datum</td><td colspan="8">Don’t Care</td><td>0</td><td colspan="3">Y sub-pixel</td><td>0</td><td colspan="3">X sub-pixel</td></tr>
<tr><td>5</td><td>ADC Housekeeping, HV Status, Fine Sensor</td><td colspan="4">ADC Address Echo</td><td>HE</td><td>FP</td><td colspan="10">ADC HK Value</td></tr>
<tr><td>6</td><td>Initiate ADC</td><td colspan="16">Don’t Care</td></tr>
</table>

Key

CS	F/W Coarse Sensor seen = 1
FE	Frame Tag, 1 = No Frame Tags
FP	F/W Fine Sensor seen = 1
HE	High Voltages Enabled = 1
IA	Integration Active = 1
ME	0 = CCD clocks halted and access to Bitmap Ram, 1 = clocks running, no access to RAMs
TE	ICU can write to centroid lookup table = 1
X	Don’t Care

3.6 Memory Maintenance

This section defines the packet data fields for the memory maintenance report packets.
Note - in this section, **MID** identifies the destination memory AND the processor (ICU or DPU).

3.6.1 Memory Dump Report

These packets are generated as a result of a *Dump Memory* command

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	-	Checksum Flag	Data Field Header
1	1	Unsigned Integer	Packet Type/SubType = 6,2	
2	2	Unsigned Integer	MID	Source Data
4	4	Unsigned Integer	Start Address	
8	502	Unsigned Integers	Memory to be dumped	
510	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field

3.6.2 Memory Checksum Report

These packets are generated as a result of a *Calculate Memory Checksum* command

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	-	Checksum Flag	Data Field Header
1	1	Unsigned Integer	Packet Type/SubType = 6,3	
2	2	Unsigned Integer	MID	Source Data
4	4	Unsigned Integer	Start Address	
8	2	Unsigned Integer	Length	
10	2	Unsigned Integer	Checksum Result	
12	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field

3.7 Telemetry Management Report

This section defines the packet data fields for the telemetry management report packets.

3.7.1 TM Packet Generation Status Report

This packet sub-type is generated in response to a *Report TM Packet Generation Status* command.

For a packet length indicating that n SID's are present:

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	-	Checksum Flag	Data Field Header
1	1	Unsigned Integer	Packet Type = 9,1	
2	1	Unsigned Integer	SID 1	Source Data
3	1	Unsigned Integer	Status SID 1	
... and so on until...				
2+2*(n-1)	1	Unsigned Integer	SID n	
3+2*(n-1)	1	Unsigned Integer	Status SID n	
4+2*(n-1)	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field

N.B. The structure of the SID status octet is as follows:

Spare	Status
7 bit	1 bits

Spare = 0000000(binary);

Status
Status = 1 = Packet Enabled
Status = 0 = Packet Disabled

3.8 Onboard Time Management Reports

After reception of a TC(10,5) command, the ICU shall generate a Time Verification Report containing a copy of the local Spacecraft Elapsed Time.

Offset*	Length (Octets)	Type	Description	Packet Data Field
0	1	-	Checksum Flag	Data Field Header
1	1	Unsigned Integer	Packet Type = 10,5	
2	4	Unsigned Integer	Coarse Time	Source Data
6	2	Unsigned Integer	Fine Time	
8	2	Unsigned Integer	CRC	Error Control

* All offsets measured in octets from the start of the Packet Data Field

3.9 Science

This section defines the packet data fields for science packets.

3.9.1 Science Data Overview

The science data stream, which originates from the DPU, consists of interleaved blocks of Regular Data (mnemonics DD_xxx), Priority Data (mnemonics DP_xxx) and Alerts (Mnemonics DA_xxx). These are sorted on-board into three corresponding classes of science packets, as described below.

3.9.1.1 Regular Data

Regular science data is made available at the end of an exposure. It is stored in the DPU in the form of several large **DPU Production Data Sets** which may be many kilobytes in length. Each production data set consists of a

1. **Standard Data Set Header** which describes and prefixes a
2. **Data Body**.

The format of the standard data header is defined in Ref -3, section 4.

The **Data Body** is the data of scientific interest (e.g. an image). It may, or may not, be compressed, using the VBTWL algorithm. Compression will be active by default, its status indicated by a flag in the Standard Data Set Header. If it is compressed, the data body will be a concatenation of compressed *variable* length blocks, each with its own self-describing 128 bit long header. This header, and the Data Body format *prior* to compression, are also defined in Ref-3, section 4.

At the end of an exposure, each production data set is supplied to the ICU, upon request, in the form of a series of **DPU blocks** of data. These blocks are of type DD_xxx. They are obtained by the DPU ‘chopping’ the above **DPU production data set** into **Data Sections** an integer number of 16-bit words in length and prefixing each one with an **‘Extended DPU Header’** Each DPU block is subject to the constraint that the Extended DPU Header plus Data Section must not exceed 1029 16-bit words overall in length. The Extended DPU Header is defined in Ref-3, section 4.

These DPU blocks are then abutted together in the ICU memory. The resulting data is again ’chopped’, but by the ICU, into **DPU Block Segments** of up to 504 bytes (252 words) long. Each segment then has a ‘**Science Sub-Header’** and a standard packet header added, a checksum calculated and added to the end. The resulting packets are then transmitted to the ground - see the diagram overleaf illustrating this process and section 3.10. The format of the Science Sub-Header is described below.

Note that all packets associated with a given production data set will be sent as a group - e.g. all the image mode data for one window will be sent as one group. The first, continuation and last packet of each group will be indicated by the appropriate segmentation flags in the sequence control field in the packet header - see the introduction to section 3.0 for more details.

Each Science Sub-Header contains:

1. a SID identifying which type of science data is present in the packet.
2. information to assist data recovery in the event of packet loss: This is because, as a result of the above processes, a given DPU block may ‘span’ from one packet to another and thus become de-coupled from its associated Extended DPU Header. The information included is:
   a) an offset, in units of 16-bit words, indicating the start of the first valid DPU block with respect to the end of the science sub-header. If the packet contains only part of one DPU block, this offset will be set to zero. If this is the last packet of a group, this offset will be set to all 1’s.
   b) a counter (starting from zero) indicating the packet location within the group.

3.9.1.2 Priority Data

These blocks contain science data that is sent out as soon as it is available and without ICU request. Their format is described in Ref-3, section 5. These blocks are 'chopped' by the ICU into**DPU Block Segments** of up to 504 bytes (252 words) long. Each segment then has the '**Science Sub-Header'** (as defined for Regular Data) and a standard packet header added, a checksum calculated and added to the end. The resulting (one or more) packets are then transmitted to the ground - see the diagram overleaf illustrating this process and section 3.10 for format details. If more than one packet is required to transmit a given Priority Data Block, they are sent as one group. The first, continuation and last packet of each group are indicated by the appropriate segmentation flags in the packet sequence control field.

3.9.1.3 Alerts

These are blocks informing the ICU of the status of the DPU and its processing algorithms, and are sent out as soon as they are available and without ICU request. Their format is defined in Ref-3, section 7. They are normally forwarded as Non-Periodic Housekeeping and play no further role in the science data (see section 3.4).

However, if the Science Auxiliary Alert Data telemetry is enabled (SID = FF hex), the alerts are buffered up in the ICU into a **DPU Block Segment** until the next alert would cause the length of the block segment to exceed 252 16-bit words. A 'null' Science Sub-Header (with the offset set to all 1's and the packet counter set to zero), a standard packet header and a calculated checksum are added to the block segment as per the format described in section 3.10. The resulting packet is then transmitted to the ground. The process then repeats. See the diagram overleaf illustrating this process.

Note that therefore this packet type is never grouped.

3.10 Science Packet Format.

As a result of the processes described above, each packet data field of a science packet is of the following form.

Offset*	Length (Octets)	Type	Description		Packet Data Field
0	1	Unsigned Int	Checksum Flag		Data Field Header
1	1	Unsigned Int	Packet Type/SubType = 15,x		
2	1	Unsigned Int	Science Sub-Header	SID	Source Data
3	1	Unsigned Int		Offset (words)	
4	2	Unsigned Int		Packet Counter within Group	
6	2*N_{words}	Unsigned Ints	DPU Block Segment ($1 \le N_{words} \le 252$)		
6+2*N_{words}	2	Unsigned Int	Checksum		Error Control

* All offsets measured in octets from the start of the Packet Data Field

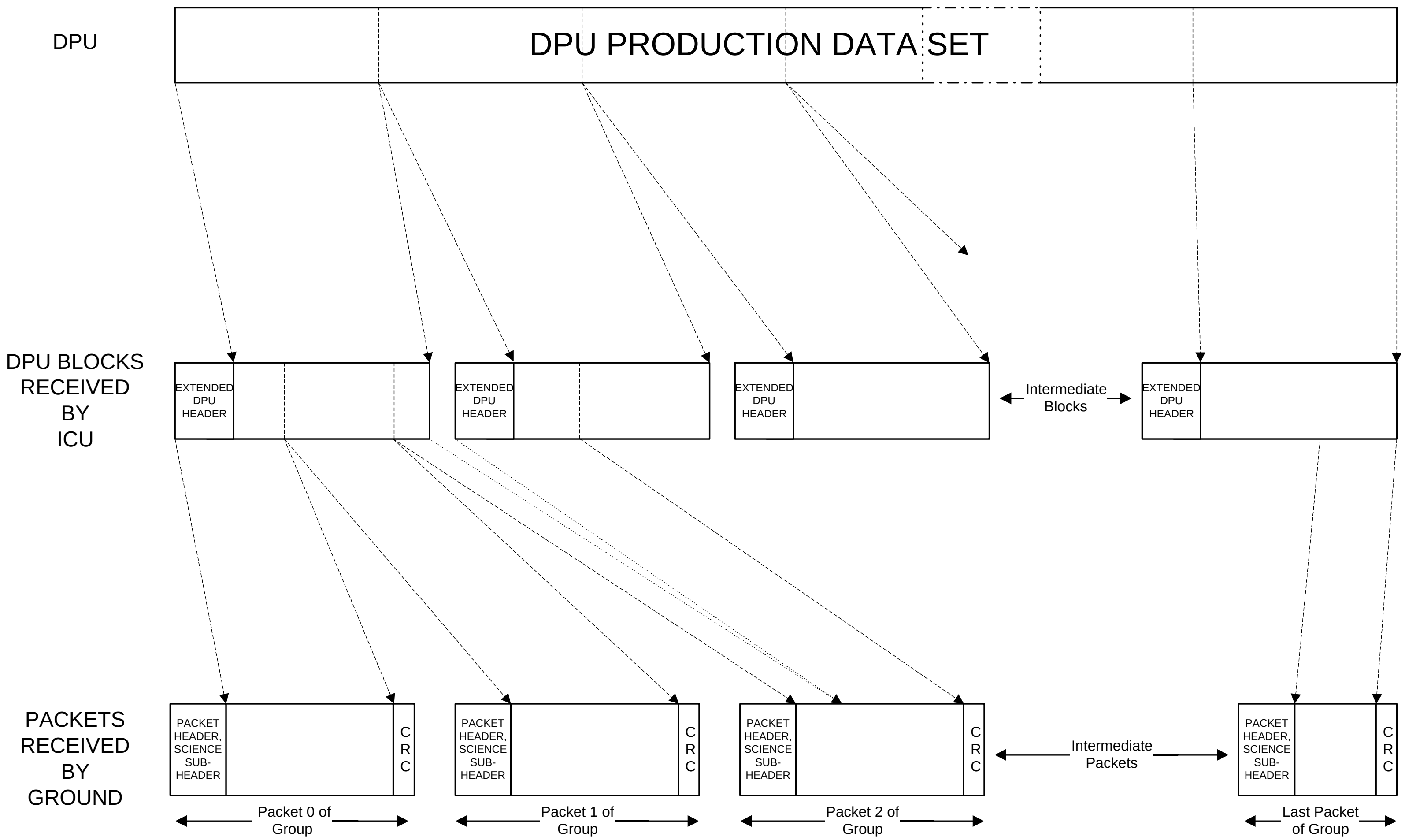
The value of SID and sub-type are as follows:

Class	Data Description	Mnemonic (see Ref-3)	SID (hex)	Sub-Type
Priority	Window Data	DP_WDW	E1	4
	Field Acquisition Data	DP_FAQ	E2	4
	Blue Fast Mode Data	DP_BFAST	E3	4
Regular	Tracking History	DD_TRH	F1	4
	Reference Frame Data	DD_REF	F2	4
	Image Mode Data	DD_IMG	F3	1
	Fast Mode Data	DD_FST	F4	2
	Engineering Data	DD_ENG	F6	3
Alerts	Auxiliary Alert Data	DA_xxx	FF	4

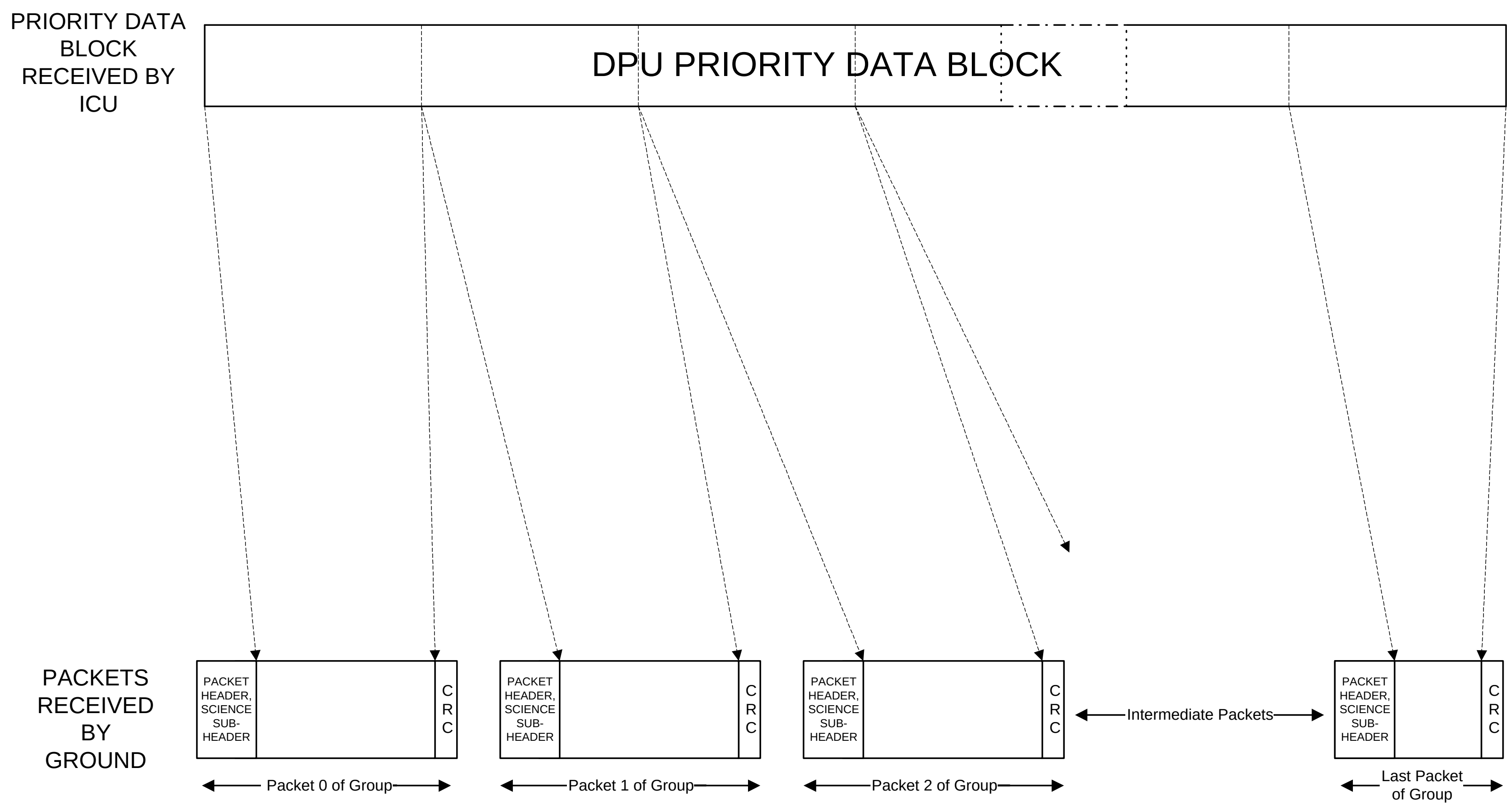
where the sub-type categories are as follows:

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

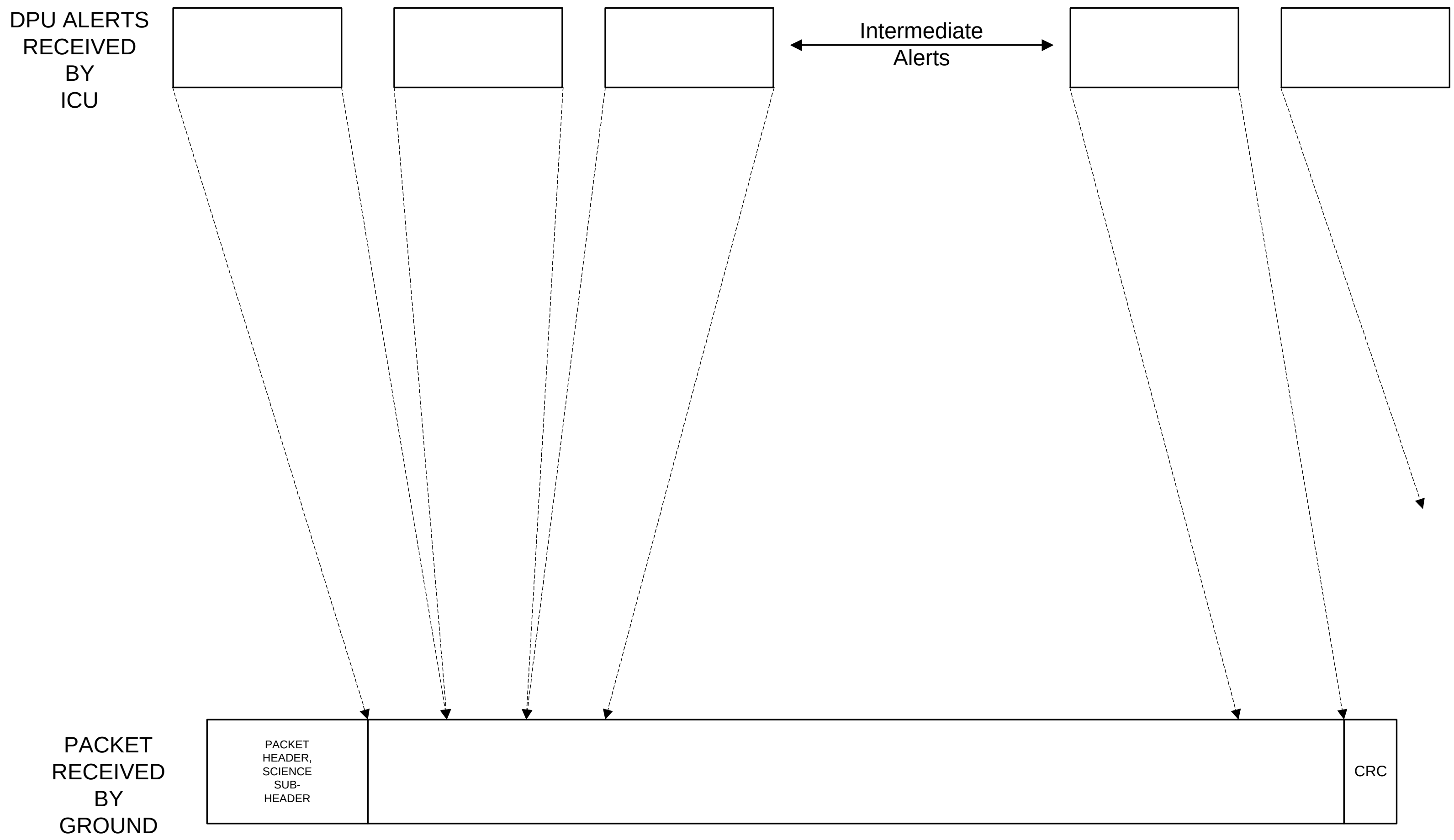
DPU REGULAR DATA TRANSMISSION



DPU PRIORITY DATA TRANSMISSION



DPU AUXILIARY ALERT DATA TRANSMISSION



4. SID Allocation

Note - not all of these may be used.

Class	System	SID (hex)	Description
Periodic HK		00	HK
		01	Diagnostic HK
Non-Periodic HK	Detector	10	Detector Event
		11	Detector Exception
		12	Detector Major Anomaly
	ICU	20⇒2F	Reserved for OM Internal Diagnostics
	ICB	41	ICB Exception
		42	ICB Major Anomaly
		44	ICB Error
	SSI	31	SSI Exception
		32	SSI Major Anomaly
	TMPSU	60	TMPSU Event
		61	TMPSU Exception
		62	TMPSU Major Anomaly
	DEM PSU	80	DEM PSU Event
		81	DEM PSU Exception
		82	DEM PSU Major Anomaly
	DPU	90⇒AF	DPU Event
		B0⇒CF	DPU Exception
		-	DPU Major Anomaly
	OM	D2	Autonomous Transition to Safe State
		D3	Bootstrap Event Report
		D4	Bootstrap Exception Report
Science	Priority	E1	Priority Window Data
		E2	Priority Field Acquisition Data
		E3	Priority Blue Fast Mode Data
	Regular	F1	Tracking History
		F2	Reference Frame Data
		F3	Image Mode Data
		F4	Fast Mode Data
		F6	Engineering Data
	Alerts	FF	Auxiliary Alert Data