Interface Control Document (ICD)

DEC/MEC - DPU

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List of Abbreviations

AC	Alternating Current
ADC	Analog-to-Digital Converter
ADP	Acceptance Data Package
AIV	Assembly Integration & Verification
ASA	Austrian Space Agency
ASI	Agenzia Spaziale Italiana
AVM	Avionic Model
CDR	Critical Design Review
CIDL	Configuration Item Data List
CNES	French Space Agency
CoI	Co-investigator
CRC	Cyclic Redundency Check
CSL	Centre Spatial de Liège
DAC	Digital-to-Analog Converter
DEC/MEC	(PACS) Detector & Mechanism Controller
DC	Direct Current
DDR	Detailed Design Review
DLR	German Aerospace Agency
DPU	(PACS) Digital Processing Unit
EEPROM	Electrically Erasable PROM
EM	Engineering/Electrical Model
EMC	Electro-Magnetic Compatibility
EMI	Electro-Magnetic Interference
ESA	European Space Agency
ESOC	European Space Operations Centre
ESTEC	European Space Research and Technology Centre
FM	Flight Model
FPU	Focal Plane Unit
FS	Flight Spare
GSE	Ground Support Equipment
HIFI	Heterodyne Instrument for FIRST
HK	HouseKeeping
H/W	Hardware
I/F	Interface
ICC	Instrument Control Centre
ICD	Interface Control Document
IFSI	Istituto di Fisica dello Spazio Interplanetario
IID-A	Instrument Interface Document - Part A
IID-B	Instrument Interface Document - Part B
IIDR	Instrument Intermediate Design Review
ILT	Instrument-Level Test
IR	Infrared
ISVR	Instrument Science Verification Review
LOU	Local Oscillator Unit (of HIFI)
MRB	Material Review Board
NA	Not Applicable
NASA	National Aeronautic and Space Administration (U.S.A.)
NCR	Non Conformance Report
OBS	On-Board Software
PACS	Photodetector Array Camera and Spectrometer
PDR	Preliminary Design Review
PFM	Proto-Flight Model
PI	Prime Investigator
PRODEX	Programme de Développement d'Expériences Scientifiques
PROM	Programmable ROM
QM	Qualification Model
RAM	Random Access Memory
ROM	Read-Only Memory
S/C	SpaceCraft
SPIRE	Spectral and Photometric Imaging REceiver
SPU	(PACS) Signal Processing Unit
S/S	Sub-System
S/W	Software
SPC	Science Programme Committee (ESA)
STM	Structural/Thermal Model
SVM	SerVice Module
TB	Thermal Balance (Test)
TBC	To Be Confirmed
TBD	To Be Defined
TRB	Test Review Board
TRR	Test Readiness Review
TV	Thermal Vacuum (Test)
TVC	Thermal-Vacuum Chamber
URD	User Requirement Document
WP	Work Package

Table of Contents

1 Scope

1.1 Introduction

The Photodetector Array Camera and Spectrometer (PACS) is an imaging spectrometer-photometer which forms part of the science payload of the Herschel Space Observatory (formerly called FIRST), an ESA cornerstone mission (CS4) to be launched in 2007 on Ariane 5.

1.2 Purpose

MPE document [RD4] identifies critical interfaces between separately developed subunits of the PACS instrument.

The purpose of this ICD is to document the interface between the DEC/MEC (CSL responsibility) and the DPU (IFSI responsibility).

The DEC/MEC, being subordinated to the DPU, is selected as the interface "driver". However, the content of this ICD shall reflect an agreement between CSL and IFSI.

The present description applies to the Proto-Flight Model (PFM). Deviations of other models (AVM and QM) are noted in italic. Breadboards and prototypes, not delivered to the PI, are not documented here.

There is no mechanical/thermal interface between the DPU and the DEC/MEC.

Interfaces between the DEC/MEC or DPU and the FIRST satellite are not addressed here. They are controlled by AD1 and RD1.

1.3 Organisational Responsibilities

The PACS project activities including project management and system engineering will be done at MPE-Garching under the direction of A. Poglitsch (PI). Design, fabrication, testing, and integration of the flight units will be done at Co-I and commercial facilities as appropriate.

In this programme the CSL, as a Co-I Institute, is responsible for the design, production and unit-level verification of:

- the focal plane Grating Assembly;
- the Detector & Mechanism Controller (DEC/MEC);
- the Warm Interconnecting Harness.

2 Documents

2.1 Applicable Documents

[AD1]	ESA PT-IID-A-04624	FIRST/PLANCK Instrument Interface Document - Part A
[AD2]	ESA PT-RQ-04410	PA Requirements for FIRST/PLANCK Scientific Instruments

2.2 Reference Documents

[RD1]	ESA PT-PACS-02126	Instrument Interface Document - Part B - Instrument "PACS"
[RD2]	PACS-ME-PL-002	PACS Design, Development and Verification Plan
[RD3]	PACS-ME-PL-005	Operating Modes of the PACS Instrument
[RD4]	PACS-ME-ID-001	PACS Instrument Interface Requirement Document
[RD5]	PACS-CR-RD-001	DPU/ICU On-board Software URD
[RD6]	no ref.	Contribution to the PACS SPU Concept (TUW)
[RD7]	VIG4.1R200	Virtuoso user guide – Eonic systems
[RD8]	PACS-CL-TN-005	DEC/MEC Software preliminary specification
[RD9]	BSSC(96)2	Guide to applying the ESA software engineering standards to small software projects
[RD10]	PACS-CL-SP-001	DEC/MEC software User Requirements Document
[RD11]	PACS-CL-TN-004	DEC/MEC to SPU interface description
[RD12]	no ref.	FIRST instrument commanding concepts (draft) K J KING
[RD13]	PACS-TW-TN-001	Raw data transmission protocol (TUW – D. Hönigmann)
[RD14]	43299-IM-RP-4	FIRSA interfacing – Interface specification to the driving unit (IMEC)
[RD15]	DSPM-DAS-1402-E	Specification of the Open Heterogeneous Multiprocessor Architecture
[RD16]	DIPSAPII-DAS-31-06	SMCS332 User Manual
[RD17]	DIPSAPII-DAS-31-07	SMCS-lite user manual
[RD18]	UoD-DICE-TN-9201	SpaceWire standard draft Issue C
[RD19]	1355-1995 (ISO/IEC 14575)	IEEE Standard for Heterogeneous InterConnect (HIC)
[RD20]	PACS-CL-ID-005	DEC/MEC Commands and HK lists
[RD21]	DIPSAPII-DAS-11-05	Mosaic020 User's Manual.
[RD22]	PACS-CL-SR-002	DEC/MEC User's Manual

2.3 Procedures and Standards

[PS1]	ECSS-Q-20	Space Product Assurance, Quality Assurance
[PS2]	ECSS-Q-60A	Electrical, Electronic and Electromechanical Components
[PS3]	ECSS-Q-70A	Materials, Mechanical Parts and Processes
[PS4]	ECSS-M-40A	Configuration Management
[PS5]	ECSS-E-40-DR	Space Engineering - Software

3 Definitions

3.1 Interface Basic Description

The DEC/MEC is the only interface between the instruments physical components (mechanisms and detectors) and the other data handling units (DPU and SPU). The functions of the DEC/MEC are briefly described below.

3.1.1 Commanding

Normally, the DEC/MEC can be commanded by the DPU in "direct mode", where the DPU can request any available function, such as moving a mechanism, changing the detector timing, etc. to be executed immediately.

At other times defined by the DPU programming or ground control, the DEC/MEC can be put by the DPU in an autonomous data acquisition sequence execution mode.

3.1.2 Data acquisition session

The following section describes the sequence of events (both hardware and software) that have to be handled by the instrument during a data acquisition session.

- pointing the object to be observed

This function will be managed by the spacecraft, and the DPU will be informed.

- setting instrument mode

This function will be managed by the DPU, the DPU will select the photometry or spectrometry mode by switching on/off the DEC or the BOL etc.

- acquiring images

This function will be managed by the DEC/MEC. The DPU will send a « file » of instructions to perform autonomously a number of acquisitions (detector integration cycles) while controlling the mechanisms in the cold focal plane. The syntax will allow a limited subset of the direct commands to be stored and executed later.

The DPU is allowed to stop / restart / abort the sequence at any point.

The DPU should refrain from entering direct commands while a sequence is running.

3.1.3 Instrument mode

The following settings are considered part of the « instrument mode ». They have to be commanded by the DPU before putting the DEC/MEC in its autonomous data acquisition mode, and may not be changed during acquisition.

- detectors parameters

on / off, integration capacitor select, clock frequency, number of clock periods between readouts, number of readouts per ramp

- spectrometry or photometry mode
- sequence parameters (chopper movement, grating movement)
- filter wheels positions
- black bodies (calibration sources T°)

3.1.4 Housekeeping

Housekeeping parameters are updated by a variety of internal processes. They are sent to DPU at regular interval (fixed).

3.1.5 Diagnostic Housekeeping

Diagnostic housekeeping can be ordered by DPU to perform HK acquisition of a few measures at a higher rate (up to 256Hz). The list of parameters that are sent to the DPU and the frequency of parameters acquisition can be set by the DPU.

4 Electrical Interface

4.1 Scope

As far as applicable, this section shall contain the following information :

- A list of all connectors external to instrument units defining the connector identifier, the function and the connector type/specification;
- A drawing for each connector defining the pin function and the type of interface circuit;
- A detailed circuit drawing for each interface circuit type to ensure interface compatibility;
- A table of signal characteristics for each interface circuit type with numerical parameter values for nominal and failure cases to ensure interface compatibility and to ensure that failures cannot propagate.

4.2 Connector Listing

Table 4.1 - DPU-to-DEC/MEC Connector List.

DPU		DEC/MEC		Functions
Label	**Type**	**Label**	**Type**	
FPDPU_J07	MDM9S	FPDMC_J01A	MDM9S	nominal communication line (IEEE1355)
FPDPU_J08	MDM9S	FPDMC_J01B	MDM9S	redundant communication line (IEEE1355)

4.3 Physical Description

Connectors and cable assemblies are according to RD18 (ECSS-E-50-12).

5 Communication Description

5.1 MEC / DPU Communication Link

5.1.1 Hardware

Spacewire standard running at reduced speed (10 Mbps) using LVDS transceivers.

The low level link is supposed to deliver strings of data bytes delimited by « end of message » control characters.

In the Virtuoso OS terminology, this would be called “raw link” mode.

5.1.2 Communication principles

The DPU protocol principles are the following :

- The DEC/MEC is a “coprocessor” to the DPU. All transactions are initiated by the DPU.
- All transactions are acknowledged with a message indicating success or failure
- There is no buffering of commands inside the DEC/MEC (except for the specific commands list called a sequence).
- The DPU must wait for the acknowledge before sending the next command. In case no ACK or NACK is received within 100 msec, it means that something is going wrong in the DEC/MEC.
- The DPU commands and the DEC/MEC replies should be protected by the hardware parity mechanism, by a software checksum, or by other means. This mechanism is not part of the syntax described here.

5.1.3 Timing issues

The actual execution of some commands (e.g. moving the grating over a large angle) may take a long time (seconds). The DEC/MEC will acknowledge the command when the move starts, and the DPU will be free to send other commands. The DPU should use the HK data to watch the execution status, and refrain from sending commands that could interfere.

If one of the following time-out is reached, the DMC shall be considered having problems :

- ACK or NACK of trigger commands shall be received less than 200ms after the trigger commands has been sent.
- ACK or NACK of load/dump/write commands shall be received less than 200ms after the command has been sent
- ACK or NACK of check commands shall be received less than 500ms after the command has been sent. The maximum length that can be checked will be presented in the User Manual.
- HK packets shall be received every 2 seconds with a maximum jitter of 600ms (if a long check command is being executed at the worst time).

5.2 Command formats

5.2.1 Command types

The following section lists the commands that shall be available to the DPU for controlling the DEC/MEC in immediate execution mode, i.e. each command is executed when ordered by the DPU.

Command	Arguments	reply	
Write	ID, length, data	Ack or NAK	
Dump/Check/Load	Pointer, length	Pointer, length, data or NAK	
Trigger	Action ID, parameter	Ack or NAK	

Note that, to preserve 32-bit alignment, we may need to add 2 spare bytes at the end of some packets. These spare bytes never appear in this document.

5.2.2 Memory commands

5.2.2.1 Principles

The MEC physical memory will be mapped into the addressable space visible from the DPU

It will be divided in several areas with specific usage.

In that way many possible commands from the DPU can be implemented as « write address range » commands where the starting address and range uniquely identifying the target memory area

The following areas are foreseen :

Name	Contents	Read/write by DPU	remarks
PROM	rom area for fixed code : bootstrap loader, self check	Dump/Check	
EEPROM	reprogrammable area for code and data : initial operating system image, application program image, initial values of operating parameters	Dump/Check	
PRAM	Live copy of application code + Virtuoso kernel	Dump/Check	
DRAM	Instrument parameters	Dump/Load/ Check/Write	See list in [RD20]

5.2.2.2 Memory Load Commands

Load commands can be used to load a new memory content at a specified address. This command shall be used only for patching.

0x0001	Address 1	Address 2	Length	Data	Checksum
2 bytes	2 bytes	2 bytes	2 bytes	<Length>SAUs	2 bytes

- **Address 1 :**
  - **Memory ID**: MSB of address 1 identifies memory of processor (see details in Memory ID definition);
  - **Address :** LSB of address 1 corresponds to the MSB of the real address.
- **Address 2** : the 2 LSB of the real address.
- **Length**: number of SAUs in the data field, SAU = 32 bits for Data RAM and SAU= 48 bits for Program RAM
- **Data**: maximum is 51 SAUs, for SAU = 32 and 34 SAUs for SAU = 48
- **Checksum**: CRC of Data Field calculated as in appendix 4 of PS-ICD

If operation has succeeded, a positive acknowledge will be issued :

ACK load

0x0081
2 bytes

If operation has failed, a negative acknowledge will be issued :

NACK load

0x00F1	Error code	Parameter
2 bytes	2 bytes	4 bytes

Possible error code: A2h, A3h, A4h, A5h, ABh

Parameter shall contain the wrong parameter according to the Error code field:

Error code A2h: The 3 MSB are spare and the 1 LSB is Invalid Memory ID.

Error code A3h: The 1 MSB is spare and the 3 LSB are Invalid address.

Error code A4h: The 2 MSB are spare and the 2 LSB are Invalid Length

Error code A5h: The 2 MSB are spare and the 2 LSB are Invalid checksum received

Error code ABh: The 2 MSB are spare and the 2 LSB are Invalid checksum value calculated after re-read the memory written.

5.2.2.3 Memory Dump Commands

At reception of this command the DEC/MEC shall read the memory area specified and shall send to the DPU as many as needed ACK dump packets containing the total Memory Length specified in the command. The Last ACK Dump, which defines the completion of the command, is identified by a specific value in the packet identification.

Dump command:

0x0002	Address 1	Address 2	Length
2 bytes	2 bytes	2 bytes	2 bytes

- **Address 1 :**
  - **Memory ID**: MSB of address 1 identifies memory of processor (see details in Memory ID definition);
  - **Address :** LSB of address 1 corresponds to the MSB of the real address.
- **Address 2** : the 2 LSB of the real address.
- **Length** : number of SAUs to be dumped, SAU = 32 bits for Data RAM and SAU = 48 bits for Program RAM.

ACK dump intermediate (Packets previous to the last)

0x0182	Address 1	Address 2	Length	Data	checksum
2 bytes	2 bytes	2 bytes	2 bytes	<Length> SAUs	2 bytes

Data: maximum is 249 SAUs, for SAU = 32 and 166 SAUs for SAU = 48

Note : Address 1, Address2 and Length are related to the content of this packet

ACK dump (Last Packet).

0x0082	Address 1	Address 2	Length	Data	checksum
2 bytes	2 bytes	2 bytes	2 bytes	<Length> SAUs	2 bytes

Data: maximum is 249 SAUs, for SAU = 32 and 166 SAUs for SAU = 48

Note : Address 1, Address2 and Length are related to the content of this packet

NACK dump

0x00F2	Error code	Parameter
2 bytes	2 bytes	4 bytes

Possible error code: A2h, A3h, A4h

Parameter shall contain the wrong parameter according to the Error code field:

Error code A2h: The 3 MSB are spare and the 1 LSB is Invalid Memory ID

Error code A3h: The 1 MSB is spare and the 3 LSB are Invalid address

Error code A4h: The 2 MSB are spare and the 2 LSB are Invalid Length

5.2.2.4 Memory Check Commands

Check commands can be used to check that the memory is still valid at a given address.

The format of this packet is :

0x0003	Address 1	Address 2	Length
2 bytes	2 bytes	2 bytes	2 bytes

- **Address 1 :**
  - **Memory ID**: MSB of address 1 identifies memory of processor (see details in Memory ID definition);
  - **Address :** LSB of address 1 corresponds to the MSB of the real address.
- **Address 2** : the 2 LSB of the real address.
- **Length** : number of SAUs to be checked, SAU = 32 bits for Data RAM and SAU = 48 bits for Program RAM.

ACK check

0x0083	Address 1	Address 2	Length	Checksum
2 bytes	2 bytes	2 bytes	2 bytes	2 bytes

Length: number of SAUs where the checksum was performed

NACK check

0x00F3	Error code	Parameter
2 bytes	2 bytes	4 bytes

Possible error code: A2h, A3h, A4h

Parameter shall contain the wrong parameter according to the Error code field:

Error code A2h: The 3 MSB are spare and the 1 LSB is Invalid Memory ID

Error code A3h: The 1 MSB is spare and the 3 LSB are Invalid address

Error code A4h: The 2 MSB are spare and the 2 LSB are Invalid Length

5.2.2.5 Write Commands

Write commands can be used for entering parameters, modifying set-points, transmitting a sequence file, uploading code, etc… Write commands does not use directly an address but a parameter identifier.

DPU must be conscious that it shall be appropriate to switch off a process before writing parameters related to this process to avoid inconsistent process behaviour (i.e : if MEC copies its parameters while the process is performing a calculation using these parameters !).

The list of valid addresses and their affectation shall be available in the User Manual Document [RD22].

The format of this packet is :

0x0006	Spare	Param ID	Length	Data	Checksum
2 bytes	2 bytes	2 bytes	2 bytes	<Length> in 32 bits word	2 bytes

- **Param ID**: logical identifier mapped on an address in memory.
- **Length**: number of 32bits words in the data field
- **Data**: maximum is 509 words
- **Checksum**: CRC of Data Field calculated as in appendix 4 of PS-ICD

If operation has succeeded, a positive acknowledge will be issued :

ACK write

0x0086
2 bytes

If operation has failed, a negative acknowledge will be issued :

NACK write

0x00F6	Error code	Parameter
2 bytes	2 bytes	4 bytes

Possible error code: A4h, A5h, A6h, ABh

Parameter shall contain the wrong parameter according to the Error code field:

Error code A4h: The 2 MSB are spare and the 2 LSB are Invalid Length

Error code A5h: The 2 MSB are spare and the 2 LSB are Checksum computed on the packet received (different from the one in the packet)

Error code A6h: The 2 MSB are spare and the 2 LSB is Invalid Param ID.

Error code ABh: The 2 MSB are spare and the 2 LSB are Invalid checksum value calculated after re-read the memory written.

5.2.3 Trigger commands

Trigger commands are used to start/stop sequences and to execute direct commands (i.e. : move grating, validate/invalidate science data, load DEC parameters, ….)

The list of command ID and parameters as well as a description of every direct command shall be available in the DEC/MEC User's Manual [RD22].

The format of this packet is :

0x0004	Spare	Command ID	SID	Parameter
2 bytes	2 bytes	2 bytes	2 bytes	4 bytes

If operation has succeeded, a positive acknowledge will be issued :

ACK Trigger

0x0084
2 bytes

NACK Trigger

0x00F4	Error code	Parameter
2 bytes	2 bytes	4 bytes

Possible error code: A7h, A8h, A9h, Aah, Ach

Parameter shall contain the wrong parameter according to the Error code field:

Error code A7h: The 2 MSB are spare and the 2 LSB is Invalid Trigger Cmd ID

Error code A8h: The 2 MSB are spare and the 2 LSB is Invalid SID

Error code A9h: The 4 bytes corresponds to the Invalid parameter of the SID

Error code Aah: parameter not used

Error code Ach: parameter not used

5.2.4 Housekeeping

5.2.4.1 Principles

The housekeeping function consists in presenting to the DPU, at regular interval (2 sec), a measurement or a list of measurements taken at specific points in the instruments, and a table of status indicators for important instrument functions.

There will be a nominal scanning process, internal to the DEC/MEC software, that will measure cyclically all housekeeping measurements and store them in a memory area.

The housekeeping measurements are sent to the DPU automatically. If the DPU does not receive any HK packet during 2.6 sec, the DEC/MEC should be considered as dead.

The map of the housekeeping data area will be part of the DMC User Manual document.

The measurements are generally given raw (ADC units) and the ground segment is supposed to perform the conversion to engineering units.

Structure of HK packets (max length = 509 words) :

0x00870000	Length	Hk measurements
4 bytes	4 bytes	4 bytes * Length

5.2.5 Diagnostic Housekeeping

There will be a diagnostic mode where one or a few channels will be sampled repetitively at a programmable rate, up to readout frequency (max 256Hz).

DPU shall be able to define the list of HK measures the MEC shall include in the HK Diagnostic Packets. This list shall be modifiable through a standard write command. This list shall contain only one or a few measurements.

Structure of HK Diagnostic Packets (max length = 250 words) :

0x00880000	Length	Hk Diag data
4 bytes	4 bytes	4 bytes * Length

The data in the HK packets will be ordered in the order defined by the Hk Diag List.

The format of the Hk Diag List as well as a complete and detailed list of the HK parameters will be available in the DEC/MEC User's Manual [RD22].

5.3 NACK for unknown command

This NACK answer is foreseen for the case of receiving a command with unknown command ID.

0x01FF	Error Code	Parameter
2 bytes	2 bytes	4 bytes

Error code = A1h (Invalid Command ID)

The parameter field is defined as follows: the 2 MSB are spare and the 2 LSB is Invalid Command ID.

5.4 Memory ID Definition

Memory ID = ssstmmmm (8 bits)

sss	Identifies the subsystem. DPU=000b DEC=001b SPUS=010b (short) SPUL=011b (long) SPUB=100b (both SPUs and REBA-SPU) (Not checked by the SPU_SUSW)
t	0b: Program Memory (SAU =48) 1b: Data Memory (SAU = 32)
mmmm	Identifies the block inside the memory type. 0000b: PROM 0001b: RAM 0011b: EEPROM

The first 3 bits (sss), which identify the subsystem, shall not be checked by the DEC/MEC. In the ACK/NACK response, if Memory ID is transmitted, it will be the original value.

Memory ID codes for DEC/MEC Program Memory.

Memory ID tmmmm bits (hex)	Memory type	SAU	Absolute address (hex) At start-up execution	Absolute address (hex) At application execution
0	PROM	48	00.0000 – 00.7FFF	18.0000 - 18.7FFF
1	RAM	48	80.0000 – 87.FFFF	00.0018 – 07.FFFF
3	EEPROM	48	8E.0000 – 8F.FFFF 90.0000 – 91.FFFF	0E.0000 – 0F.FFFF 10.0000 – 11.FFFF

Memory ID codes for DEC/MEC Data Memory.

Memory ID tmmmm bits (hex)	Memory type	SAU	Absolute address (hex)
11	RAM	32	0000.0000- 0007.FFFF

5.5 Error codes

Value (hex)	Error code meaning
A1h	Invalid header : unknown command
A2h	Invalid Memory ID
A3h	Invalid address field
A4h	Invalid Data Length
A5h	Invalid checksum (checksum received does not corresponds to the calculated over the Data field received)
A6h	Invalid Param ID (for write command)
A7h	Invalid Trigger command ID
A8h	Invalid SID field (applicable to trigger commands only)
A9h	Invalid Parameter field (applicable to trigger commands only)
AAh	Could not start the execution of a trigger command
ABh	Invalid checksum after re-reading the memory area written in a Load command.
ACh	Invalid mode (for trigger commands only)