Publication Year	1996
Acceptance in OA	2023-02-08T12:25:40Z
Title	Requirements specification for the EPIC MOS Camera System (EMCS)
Authors	LA PALOMBARA, NICOLA
Handle	http://hdl.handle.net/20.500.12386/33280

EST	EPIC

DOCUMENT TYPE:	SYSTEM REQUIREMENTS
TITLE:	REQUIREMENTS SPECIFICATION FOR THE EPIC MOS CAMERA SYSTEM (EMCS)
DOCUMENT No.:	EPIC-LAB-SR-002
ISSUE No.:	4
DATE:	September 1996
PAGE:	1 of VI, 39, A1, B1, C3, D2, E1, F1, G2
PREPARED BY:	NICOLA LA PALOMBARA
APPROVED BY:	GABRIELE VILLA (P.M.)
CONFIGURED BY:	NICOLA LA PALOMBARA (C.C.M.)

DISTRIBUTION LIST

NAME	COMPANY	DEPT.	N.
G.Villa	EST		1
G. Bignami	EST		1
M.J.L.Turner	LUX		1
M.Arnaud	SAP		1
C.Reppin	MPE		1
P.F. Tua	EST		1
N.La Palombara	EST		1
M.Conte	EST		1
M.Balasini	EST		1
G. Cafagna	EST		1
A. Mambretti	LABEN		3
H. Eggel	ESA		3

* = First page only

CHANGE - RECORD

Issue	Date	Page	Description of Change	Release
1	May, 1994	ALL	This document superseeds LABEN document TL 9145 for the MOS Camera System.	EBDR
2	September, 1994	ALL	Implementation of the changes agreed upon during the August 1-2 meeting in Milan with the exception of the points still ‘open’.	ASI End of phase B2
3	February, 1995	ALL	Closure of the ‘open points’ according to the EST comments and implementation of the changes agreed upon during the December 1994 Consortium Meeting.	ASI Mid-phase B3
4	September, 1996	ALL	Document updating due to design modifications.	EFDR

TABLE OF CONTENT

1. SCOPE

1.1. Purpose

The purpose of this document is to establish the engineering requirements for the design, development, qualification, and production of the **E**PIC **M**OS **C**amera **S**ystem (**EMCS**).

1.2. Experiment Overview

The **E**uropean **P**hoton **I**maging **C**amera (**EPIC**) experiment will be flown on the ESA XMM (X-ray Multi-mirror Mission) satellite and consists of four systems:

´ Two EPIC MOS Camera Systems (EMCS);

- One EPIC PN Camera System (EPCS); and

- One EPIC Radiation Monitoring System (ERMS).

The camera systems will investigate faint x-ray sources in the spectral region 0.1 - 15 keV. The detectors of the three camera systems are placed on the focal planes of three XMM telescopes, one camera head per telescope. The ERMS measures continuously the space radiation environment providing broad band count rates and energy spectra above 50 keV for electrons and 5 MeV for protons.

1.3. Document Overview

Sects. 3 through 9 establish the system requirements which are then allocated to the units of EMCS in Sect. 10. It is understood that the next lower-level documents are the unit requirement specifications for each unit of EMCS. There are several appendices for establishing specific requirements.
Each requirement is numbered.
In addition, there are requirements set on external systems, i.e., spacecraft or ground facilities: these requirements are in italics.

1.4. Acronyms

APID	Application Identifier
BOL	Beginning of Life
CAL EGSE	Calibration EGSE
CAL MOGSE	Calibration MOGSE
CCD	Charge Coupled Device
CDMS	Command and Data Management System
ED-EGSE	ESA-Deliverable EGSE
ED-MGSE	ESA-Deliverable Mechanical Ground Support Equipment
EGSE	Electronic Ground Support Equipment
EMAE	EPIC MOS Analog Electronics
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EMCH	EPIC MOS Camera Head
EMCR	EPIC MOS Control & Recognition (Unit)
EMDH	EPIC MOS Data Handling (Unit)
EMI	Electromagnetic Interference
EMVC	EPIC MOS Voltage Converter (Unit)
EOL	End of Life
EPIC	European Photon Imaging Camera
EQM	Engineering and Qualification Model
EST	EPIC System Team
FIT	Failure Inverse Time
FM	Flight Model
GSE	Ground Support Equipment
HBR	High Bit Rate
IC-EGSE	Integration and Calibration EGSE
LBR	Low Bit Rate
LEOP	Low Earth Orbit Phase
MOGSE	Mechanical/Optical Ground Support Equipment
MOS	Metal-Oxide Semiconductor
OBDH	On-Board Data Handling
PI	Principal Investigator
SCET	Spacecraft Elapsed Time
SID	Structure Identifier
SMP	Science Mission Phase
SOW	Statement of Work
STM	Structural Thermal Model
S/C	Spacecraft
TC	Telecommand
TE	Test Equipment
TM	Telemetry
XMM	X-Ray Multi-Mirror Mission

2. APPLICABLE AND REFERENCE DOCUMENTS

2.1. Applicable Documents

All the documents listed in this Section shall be applicable to the extent agreed upon by ESA and the EPIC P.I.. In case of conflict between this document and the documents listed herebelow, precedence shall be given to the documents listed herebelow. When no issue number is specified, the latest issue published before the date of issuance of this document shall be considered.

RS-PX-0016	Issue 6	X-Ray Multimirror Mission, Experiment Interface Document, Part A, ESA.
RS-PX-0020	Issue 5	X-Ray Multimirror Mission, Experiment Interface Document, Part B, ESA.
RS-PX-0024	Issue 1	X-Ray Multimirror Mission, Experiment Interface Document, Part C, ESA.
RS-PX-0017	Issue 1	Product Assurance Requirements for XMM Experiments, ESA.
EPIC-EST-SP-001	Issue 3	EMCS Electrical I/F Specification, EST

2.2. Reference Documents

All the documents listed in this Section shall be considered as a guideline to the extent established in this document. In case of conflict between this document and the documents listed herebelow, precedence shall be given to this document. When no issue number is specified, the latest issue published before the date of issuance of this document shall be considered.

EPIC-LAB-PL-005	Issue 4	Product Assurance Plan for the EPIC Experiment, LABEN.
PSS-01-609		Radiation Design Handbook, ESA.
EPIC-IFC-PL-0101	Issue 2	Procurement Plan, EST.
EPIC-LAB-PL-003	Issue 4	Design, Development and Qualification Plan for the EPIC Experiment, LABEN.
EPIC-EST-PL-002	Issue 3	Cleanliness and Contamination Control Plan, EST.
EPIC-EST-PL-005	Issue 1	Electromagnetic Compatibility Test Plans, EST.

3. SYSTEM PERFORMANCE CHARACTERISTICS

3.1. Baseline Assumptions

3.1.1. The purpose of EMCS is:

a) to detect single X-ray photons in the energy range between 0.1 keV and 15 keV;

b) to measure the photon arrival position on the focal plane of the telescope at pixel level;

c) to measure the photon energy using the conversion process in silicon; and

d) to perform timing studies by measuring the arrival time of the single photons.

3.1.2. The EMCS detector is made of 7 identical CCD's located on the telescope focal plane as is shown in Fig. 3.1-1. The center of the focal plane coincide with the center of the central CCD (# 1).

3.1.3. Each CCD is made of two areas, as is shown in Fig. 3.1-2:

a) The integration area of 602 x 610 pixels (rows x columns; 24.080 mm x 24.400 mm) where the image is formed (the pixels exceeding the 600 are used as overscanning features);

b) the storage area having the same number of pixels (602 x 610) but smaller dimensions (7.224 mm x 24.400 mm).

The reason of this structure lies in the relatively short time for transferring the image from the integration area to the storage area in comparison with the longer time for reading the charge of all the pixels. Each CCD has two equivalent readout nodes and it can be read by each of them; there is the possibility that the central CCD is read simultaneously by both the nodes.

3.1.4. Due to its critical position, CCD1 has two dedicated output channels. The total number of output channels of the detector is eight.

3.1.5. There are two types of read-out of the CCD's:

a) Imaging; and
b) Timing.

These two types are summarized in Appendices A and B, respectively. It must be noted that these types of read-out of the CCD's do not coincide with the modes of operation of the EMCS which are established in this document.

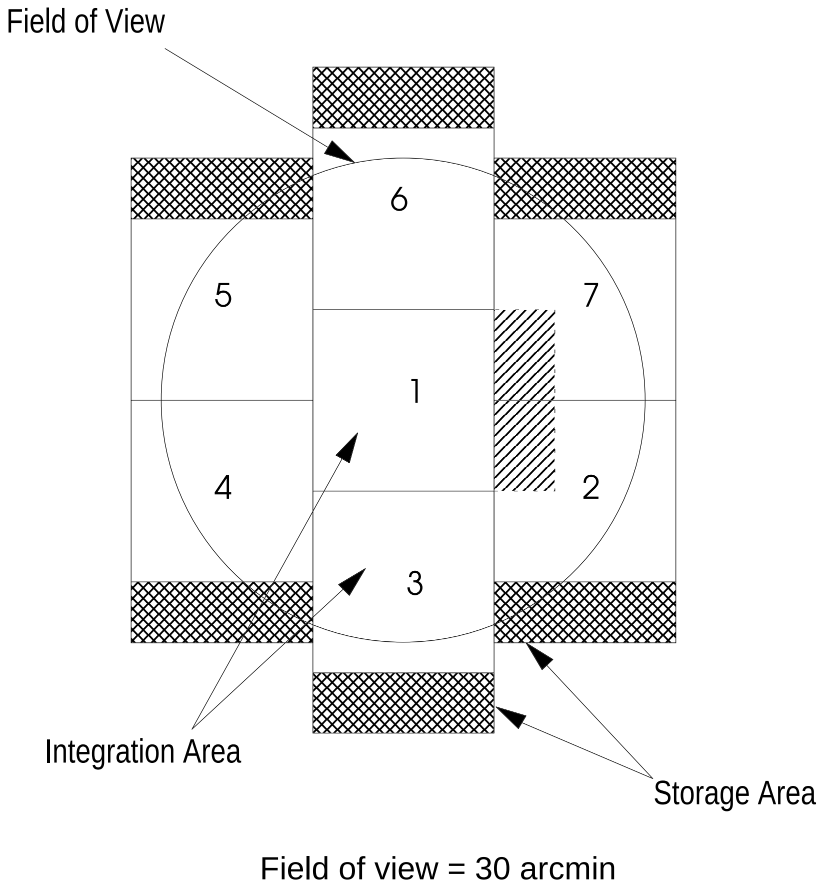

Fig. 3.1-1 - Layout of the CCD's

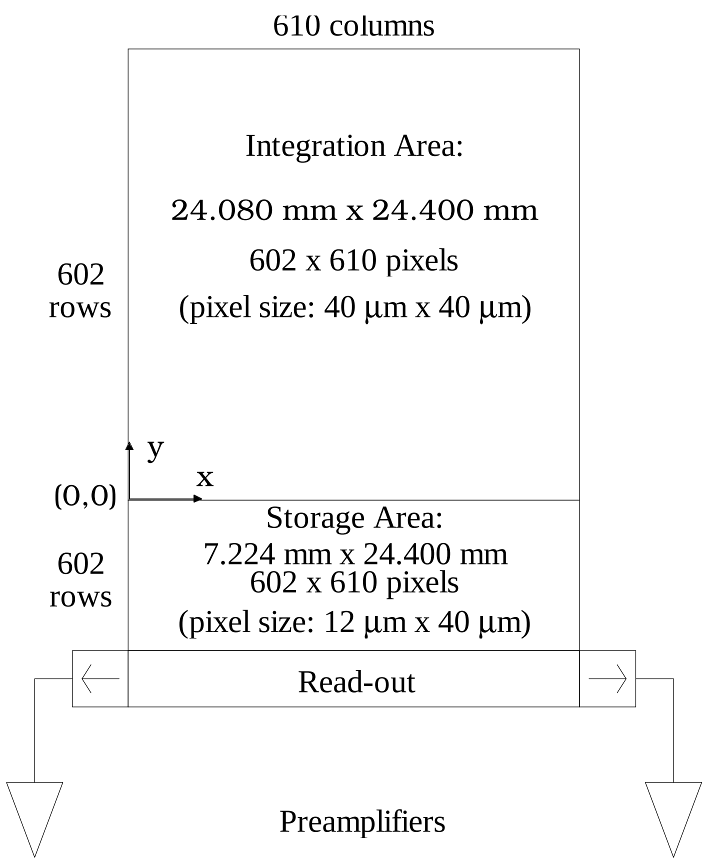

Fig. 3.1-2 - Structure of a single CCD

3.2. Major System Capabilities

3.2.1. Photon Energy Determination

3.2.1.1. EMCS shall be capable to extract all the energy parameters of the single photon events in order to allow the full energy reconstruction on ground.

3.2.1.2. The single pixel energy shall be determined by EMCS with a resolution of at least 12 bits.

3.2.1.3. The full energy range shall be 0.1 keV - 15 keV.

3.2.1.4. The target error is 0.1 % of the full energy range.

3.2.2. Cosmic Ray Rejection

3.2.2.1. EMCS shall reject the cosmic ray traces. The goal for cosmic ray rejection efficiency shall be 99.9 %.

3.2.2.2. Any implementation of this capability shall not generate additional intermediate spurious scientific data.

3.2.3. Bright Pixel Rejection

3.2.3.1. The bright pixels shall be rejected in order not to saturate the telemetry.

3.2.3.2. A table of bright pixels shall be stored in EMCS. The total number of bright pixels per CCD that EMCS can store shall be 50.

3.2.4. Filters of the CCD's

3.2.4.1. EMCS shall have a filter wheel mechanism in order to protect the CCD's as well as to filter the telescope output in relation to the brightness of the images to be observed.

3.2.4.2. The filter wheel mechanism shall have six positions:

- ◊ closed (protective plate);
- ◊ open (blank);
- ◊ filter a;
- ◊ filter b;
- ◊ filter c;
- ◊ filter d.

3.2.4.3. The characteristics of these filters shall be established according to the sensitivity of the CCD's and the brightness of the images to be observed.

3.2.5. Calibration Sources

3.2.5.1. EMCS shall have the capability of in-flight calibration.

3.2.5.2. In the baseline design, the calibration source is fixed and it directly illuminates the CCDs through one of the 6 holes of the filter wheel (each nearby one of the 6 filter wheel standard positions).

3.2.5.3. As alternative, there shall be a calibration source mechanism with four positions:

- ◊ off;
- ◊ on (source a);
- ◊ off;
- ◊ on (source b).

3.2.5.4. The characteristics of the sources shall be established according to the characteristics of the CCD's.

3.2.6. Data Packet Preparation

3.2.6.1. The output of EMCS shall comply with the packet telemetry standard for the XMM Satellite, ESA document RS-PX-0032.

3.2.6.2. The scientific information transfer should be maximized and the use of the limited telemetry should be optimized.

3.2.6.3. The source packet preparation rules of Appendices E and F shall apply.

3.3. Other System Capabilities

3.3.1. OBDH Bus Data Rate

3.3.1.1. The electronics of EMCS shall have the capability to transmit on the OBDH bus at an overall average rate of 16 kbit/s, if enough scientific data are collected.

3.3.2. SCET and Local Time Management

3.3.2.1. EMCS shall have the capability to receive the S/C Elapsed Time (SCET) sent by the CDMS on the OBDH interrogation bus according to RS-PX-0016.

3.3.2.2. EMCS shall have the capability to re-synchronize its own time counter(s) within the precision of its own electronics whenever the appropriate message is received from the OBDH bus.

3.3.2.3. EMCS shall use the interrogation bus clock in between two SCET messages.

3.3.3. Read-out Sequence Generation

3.3.3.1. Basic read-out sequencies shall be stored on-board, activated by telecommand, and operated via uplinked parameters. New read-out sequencies may be uplinked.

3.3.4. Thermal Control

3.3.4.1. EMCS shall have the capability to control the temperature of the CCD's.

3.3.4.2. This capability shall be implemented for all the modes of operation with the exception of the off mode. The required temperature range depends on the mode of operation and is established in the following Sections.

3.3.5. Event Data Storage

3.3.5.1. EMCS shall have the capability to store scientific data up to 40,000 events. These data may be unprocessed (intermediate data).

3.4. Scientific Modes of Operation

3.4.1. General

3.4.1.1. There shall be two direct scientific modes of operation:

a) Prime Mode; and
b) Fast Mode.

3.4.1.2. These modes shall be direct, i.e., the output data from EMCS shall be only an event list.

3.4.1.3. In addition, degraded configurations shall be planned (see Sect. 3.4.4) for specific needs.

3.4.2. Prime Mode

3.4.2.1. EMCS shall enter this mode from the idle mode upon reception of appropriate telecommand from the OBDH bus.

3.4.2.2. EMCS units shall be reconfigured according to the parameters of the telecommand under the supervision of the master unit.

3.4.2.3. After reconfiguration, the master unit shall command the other units to start the operations of this mode.

3.4.2.4. In imaging read-out CCD1 through CCD7 shall be read from one node. A complete chain, including ADC, Event Detection Units and one Sequencer, is devoted to each node of the central CCD and to each pair of peripheral CCDs. CCD2 through CCD7 shall be read only with the full window option, i.e.:

$$x_0 = y_0 = 1 \ , \quad \Delta x = 610 \quad \text{and} \quad \Delta y = 602$$

and with the minimum T_{int} greater than T_0 (see Appendix A).

3.4.2.5. The nodes of CCD1 through CCD7 shall be read approximately at the same time (no synchronization is required).

3.4.2.6. The Prime mode shall be divided into two submodes:

a) Full Window; and
b) Partial Window.

3.4.2.7. In the Full Window submode, CCD1 shall operate with the full window option and with the minimum T_{int} greater than T_0 for this option.

3.4.2.8. In the Full Window submode, there shall be an overall time unit corresponding to a macroframe. This time unit shall be less than 4.8 s ± 20 %.

3.4.2.9. In the Full Window submode, the macroframe shall be composed of one frame of CCD1 through CCD7.

3.4.2.10. In the Partial Window submode, CCD1 shall operate with the partial window option and with the minimum T_{int} greater than T_0 for this option.

3.4.2.11. If CCD1 is read from both nodes simultaneously, the time unit shall be less than 2.4 s ± 20 % and the macroframe shall be composed of two frames of CCD1 and one frame of CCD2 through CCD7.

3.4.2.12. The EMCS shall:

a) determine the photon energy according to Sect. 3.2.1.;
b) reject the cosmic rays according to Sect. 3.2.2.;
c) reject the contribution from bright pixels according to Sect. 3.2.5.;

on a **frame by frame** basis on the output coming from the seven CCD's.

3.4.2.13. Since the output from the EMCS detector is made of eight channels (two from CCD1 and six from CCD2 through CCD7), the two half-frames from the two channels of CCD1 (if active) shall need special processing on ground.

3.4.2.14. The implementation of the requirements of Sects. 3.2.1. and 3.2.2. shall occur in three steps:

a) An event recognition algorithm of the type described in Appendix C shall be used;
b) An upper threshold shall be applied; and
c) A lower threshold shall be applied.

3.4.2.15. Science report packets shall be prepared according to Sect. 3.2.6.

3.4.2.16. A science report packet shall be put in the EMCS output queue as soon as it is prepared.

3.4.2.17. The data storage area of Sect. 3.3.5 shall be allocated to the different CCD channels in a suitable manner.

3.4.2.18. In case the rate of the incoming scientific events is greater than the transmission rate on the OBDH bus, EMCS shall send a warning message to the CDMS. This message shall be sent when the storage area is about 50% filled.

3.4.2.19. In case the scientific data storage area is about being filled, the new incoming data shall be rejected on a frame by frame basis. The number of events rejected shall be counted and included in an HK source packet together with the start time and the end time of this overflow condition. The ending of the overflow condition is set when the related storage area is less than about 25% filled.

3.4.2.20. HK source packets shall be sent to the OBDH bus at least every 8 s.
3.4.2.21. No Telecommands will be accepted in this mode with the exception of “Enter EMCS IDLE Mode” and “Enter EMCS SAFE STAND-BY Mode”.

3.4.2.22. The EMCS shall control the temperature of the CCD's at a level pre-defined by TC.

3.4.2.23. The status of the Filter Wheel, CCDs, thermal control temperature, calibration source, etc. will depend on experiment configuration performed in IDLE mode.
3.4.2.24. In this mode Shroud, Annealing and HOPs heaters will be off.

3.4.2.25. EMCS shall exit this mode upon reception of a telecommand from the OBDH bus and shall enter in the IDLE mode or in the SAFE STAND-BY mode (only in emergency case).

NOTE: It is not allowed to remove the primary power in this mode.

3.4.3. Fast Mode

3.4.3.1. EMCS shall enter this mode from the idle mode upon reception of telecommands from OBDH bus.

3.4.3.2. EMCS units shall be reconfigured according to the parameters of the telecommand under the supervision of the master unit.

3.4.3.3. After reconfiguration, the master unit shall command the other units to start the operations of this mode.

3.4.3.4. CCD1 shall be read in timing read-out (see Appendix B) from either one of the two nodes.

3.4.3.5. On the output of CCD1, EMCS shall:

a) determine the photon energy according to Sect. 3.2.1.; and
b) reject the cosmic rays according to Sect. 3.2.2.

on a line by line basis (bright pixel rejection is not required).

3.4.3.6. The implementation of the requirements of Sects. 3.2.1. and 3.2.2. shall occur in two steps:

a) An event recognition algorithm of the type described in Appendix C shall be used; and
b) An upper threshold shall be applied.

3.4.3.7. CCD2 through CCD7 shall be read in imaging mode from one node with the full window option, i.e., $x_0 = y_0 = 1$, $\Delta x = 610$, $\Delta y = 602$ and with the minimum T_{int} greater than T_0.

3.4.3.8. The nodes of CCD2 through CCD7 shall be read simultaneously (but no synchronization is required).

3.4.3.9. For the output coming from the six peripheral CCD's, EMCS shall:

a) determine the photon energy according to Sect. 3.2.1.;
b) reject the cosmic rays according to Sect. 3.2.2.;
c) reject the contribution from bad pixels according to Sect. 3.2.5.;

on a frame by frame basis .

3.4.3.10. For the output of the six peripheral CCD's, the implementation of the requirements of Sects. 3.2.1. and 3.2.2. shall occur in three steps:

a) An event recognition algorithm of the type described in Appendix C shall be used;
b) An upper threshold shall be applied; and
c) A lower threshold shall be applied.

3.4.3.11. Science report packets shall be prepared according to Sect. 3.2.6.

3.4.3.12. A science report packet shall be put in the EMCS output queue as soon as it is prepared.

3.4.3.13. The data storage area of Sect. 3.3.5 shall be allocated to the different CCD channels in a suitable manner.

3.4.3.14. In case the rate of the incoming scientific events is greater than the transmission rate on the OBDH bus, EMCS shall send a warning message to the CDMS. This message shall be sent when the storage area is about 50% filled.

3.4.3.15. For the scientific data coming from CCD1, in case the related storage area is about being filled, the new incoming data shall be rejected on a cycle by cycle basis (See Sect. E 3.7.3.). The number of (16 bit) words rejected shall be counted and included in an HK source packet together with the start time and the end time of this overflow condition. The ending of the overflow condition is set when the related storage area becomes less than about 25% filled.

3.4.3.16. For the scientific data coming from CCD2 through CCD7, in case the related storage area is about being filled, the new incoming data shall be rejected on a frame by frame basis. The number of events rejected shall be counted and included in an HK source packet together with the start time and the end time of this overflow condition. The ending of the overflow condition is set when the related storage area becomes less than about 25% filled.

3.4.3.17. HK source packets shall be sent to the OBDH bus at least every 8 s.

3.4.3.18. No Telecommands will be accepted in this mode with the exception of “Enter EMCS IDLE Mode” and “Enter EMCS SAFE STAND-BY Mode”.

3.4.3.19. The EMCS shall control the temperature of the CCD's at a level pre-defined by TC.

3.4.3.20. The status of the Filter Wheel, CCDs, thermal control temperature, calibration source, etc. will depend on experiment configuration performed in IDLE mode.

3.4.3.21. In this mode Shroud, Annealing and HOPs heaters will be off.

3.4.3.22. EMCS shall exit this mode upon reception of telecommands from the OBDH bus and shall enter the IDLE mode or in the SAFE STAND-BY mode (only in emergency case).

NOTE: It is not allowed to remove the primary power in this mode.

3.4.4. Degraded Configurations

3.4.4.1. Definition

All the EMCS configurations which have not been described in Sects. 3.4.1. are called degraded configurations because they do not use the full performance characteristics of EMCS. The use of degraded configurations may be necessary because of two reasons:

a) The image under observation is not near the central region of the focal plane, but is located in the areas occupied by the peripheral CCD's .
b) Failures have occurred in EMCS.

3.4.4.2. Configurations for Special Observations

3.4.4.2.1. It shall be possible to implement a degraded configuration for special observations such that:

a) One of the peripheral CCD shall work with the same performance of CCD1 for the prime mode;
b) The data from a second peripheral CCD may be ignored; and
c) All the other CCD's shall work with the same performance of the peripheral CCD's for the prime mode.

3.4.4.2.2. It shall be possible to implement a degraded configuration for special observations such that:

a) One of the peripheral CCD shall work with the same performance of CCD1 for the fast direct mode;
b) The data from a second peripheral CCD may be ignored; and
c) All the other CCD's shall work with the same performance of the peripheral CCD's for the fast direct mode.

3.4.4.3. Configurations Due to Electronics Failure

3.4.4.3.1. General Definition

The failure recovery requirements of Sect. 3.10.3. are of the uppermost importance for designing the EMCS electronics. They determine the characteristics of the degraded configurations and hence the requirements on the type of redundancy which has to be implemented. A list of the major degraded configurations shall be prepared by EST.

3.4.4.3.2. Threshold Configuration

A simplified configuration is planned in case of failure of the electronics which implements the event recognition algorithm. The energy of each pixel above a programmable threshold is transmitted to ground whatever the energies of the adiacent pixels are. On-board processing is not required. EMCS performance is limited by the output rate on the OBDH bus and hence only one CCD is active at a time and the frame rate will be limited by the limiting output rate.

3.5. Engineering Modes of Operation

3.5.1. General

3.5.1.1. During the Scientific Mission Phase (SMP), the engineering modes of operation shall be as follows:

a) Off;
b) Initialization;
c) Safe Stand-by;
d) Idle;
e) Offset/Variance;
f) CCD Diagnostics;
g) Extraheating - Annealing;
h) Extraheating - Deicing;
i) Extraheating - CCD's Decontamination;
l) In-Flight Test.

The characteristics of these modes are defined in the following sections.

3.5.1.2. During the Launch and Early Orbit Phase (LEOP), the engineering modes of operation shall be as follows:

a) Off;
b) Initialization;
c) Safe Stand-by;
d) Idle.

The characteristics of these modes are defined in the following sections.

3.5.1.3. In addition to the previous modes of operation, there shall be an on-ground test mode for on-ground testing purposes.

3.5.2. Off Mode

3.5.2.1. In off mode, no primary power is supplied to EMCS and all the units are off.

3.5.2.2. In off mode, the filter wheel shall be in closed position, in order to protect the CCD's. (Provisions have been made so that the filter wheel is turned to the closed position before disconnecting the primary power: see nominal transition from safe stand-by mode to the off mode).

3.5.2.3. The off mode shall be characterized by the following conditions:

a) The Door Mechanism shall be in open position during SMP (in closed position during LEOP);
b) The Venting Valve shall be in closed position during SMP; during LEOP it shall be open when powered to allow pressure equalization in the CCD cameras;
c) The Calibration Source Mechanism shall be in off position;
d) The S/C-controlled stand-by heaters shall be on;
e) The temperature is monitored by two thermistors (placed on focal plane and primary radiator) powered by S/C.

3.5.2.4. The S/C shall control the temperature of the CCD's. This temperature shall be kept in the range between -150 and 0 °C.

3.5.2.5. In case of emergency transition to the off mode, CDMS shall include the telecommand to turn the filter wheel to the closed position in the telecommand packet, if EMCS was not in Annealing mode. If the emergency transition is performed starting by the Annealing mode, special operations shall be undertaken to allow safety filters moving. (It must be noted that the filter wheel is already in the closed position in the safe stand-by mode).

3.5.3. Initialization Mode

3.5.3.1. This mode of operation shall be entered from the off mode and when primary power is applied to EMCS only.

3.5.3.2. Each EMCS unit shall initialize itself. At the end of each unit initialization procedure, the master unit shall collect HK telemetry related to the initialization results from the other units as well its internal data.

3.5.3.3. An HK telemetry packet containing all the initialization data report shall be prepared by EMCS and put in the output queue for the transmission via TLM.

3.5.3.4. EMCS shall be capable to recognize whether it is EMCS1 or EMCS2 through the plug of the test connector of the master unit.

3.5.3.5. The status of all the HW devices shall not be changed from that of the off mode, during both SMP and LEOP (It must be noted that the difference between LEOP and SMP lies in the status of the HW devices).

3.5.3.6. Focal plane temperature control by S/C will not be active.

3.5.3.7. At the end of all the previous operations, EMCS shall enter the safe stand-by mode by default, during both SMP and LEOP.

3.5.3.8. At the end of all the previous operations, EMCS shall enter the on-ground test mode by default if the harness is in the on-ground configuration.

3.5.4. Safe Stand-by Mode

3.5.4.1. This mode of operation shall be entered from the initialization mode by default, or from the idle mode upon reception of OBDH telecommands, from the on-ground test mode through appropriate commands from the EGSE through the master unit test connector or from any other mode (by TLC) only due to emergency reasons.

3.5.4.2. The filter wheel shall be in the closed position.

3.5.4.3. EMCS shall perform the thermal control of the CCD's. The temperature of the CCD's shall be kept at -130 °C ± 5 °C.

3.5.4.4. The heating devices (Heaters and HOPs) controlled by EMDH will be off.

3.5.4.5. By default, the HK telemetry shall be prepared periodically.

3.5.4.6. If activated by telecommand, the HK telemetry shall be periodic.

3.5.4.7. During LEOP, it shall be possible to change the status of the door mechanism and the venting valve only in this mode of operation. Upon reception of appropriate telecommands, EMCS shall operate the door mechanism and the venting valve to the open position. Once these operations are performed, the transition to the SMP safe stand-by mode shall occur (see Sect. 3.6).

3.5.4.8. During SMP, it shall be possible to load, patch, and dump SW to/from EMCS.

3.5.4.9. EMCS shall exit this mode to enter either the off mode or the idle mode upon reception of OBDH telecommands.

3.5.4.10. In the transition to the off mode, EMCS is not permitted to turn the filter wheel to the closed position autonomously (It must be noted that the filter wheel is already in the closed position in this [safe stand-by] mode, see 3.5.4.2).

3.5.5. Idle Mode

3.5.5.1. This mode of operation shall be entered from any mode of operation with the exception of the off mode, the initialization mode, and the on-ground test mode.

3.5.5.2. The status of the Filter Wheel, CCDs, thermal control temperature, calibration source, HOPs, etc. will depend on experiment configuration performed by Telecommands that in this mode are immediately executed.

3.5.5.3. The EMCS master unit shall acquire its own HK data as well as the HK data from the other EMCS electronic units periodically and forward them to OBDH bus for the transmission via TLM.

3.5.5.4. EMCS shall perform the thermal control of the CCD's. The temperature of the CCD's shall be last settled, depending upon the previous mode.

3.5.5.5. In this mode Shroud and Annealing heaters will be off.

3.5.5.6. EMCS shall exit this mode upon reception of telecommands from the OBDH bus in order to enter one of the following modes:

a) Safe Stand-by;
b) Prime;
c) Fast;
d) Offset/Variance;
e) CCD Diagnostics;
f) Extraheating - Annealing;
g) Extraheating - Deicing;
h) Extraheating - CCD's Decontamination; and
i) In-Flight Test.

NOTE: It is not allowed to remove primary power in this mode.

3.5.6. Offset/Variance Mode

3.5.6.1. This mode of operation shall be entered from the idle mode upon reception of appropriate telecommands from the OBDH bus.

3.5.6.2. One CCD shall be read in imaging read-out mode with full window option and one-node reading.

3.5.6.3. One frame shall be read after having discarded n frames, with $n > 0$ and $n <$ TBD. The energy of all the pixel shall be stored temporarily in the EMDH and then the offset and the variance shall be calculated on-board according to the algorithms of Appendix D.

3.5.6.4. The output offset table and variance shall be stored within EMCS and shall be transmitted to the OBDH bus.

3.5.6.5. At the end of the transmission of all the data, EMCS shall wait for further telecommands from the OBDH whether to exit this mode or to start again the necessary sequence of operations of this mode for the transmission of one other shot of data (related to either the same or a different CCD).

3.5.6.6. No Telecommands will be accepted in this mode with the exception of “Enter EMCS IDLE Mode” or “Enter EMCS SAFE STAND-BY Mode”.

3.5.6.7. The status of the Filter Wheel, CCDs, thermal control temperature, calibration source, etc. will depend on experiment configuration performed in IDLE mode.

3.5.6.8. EMCS shall perform the thermal control of the CCD's. The temperature of the CCD's shall be kept at a level pre-defined by TC.

3.5.6.9. In this mode Shroud, Annealing and HOPs heaters will be off.

3.5.6.10. EMCS shall exit this mode in the following conditions:
- to enter automatically the IDLE mode when Offset/Variance calculation has been performed, Offset/Variance has been sent to ground and Offset table has been loaded in the EMCR;
- to enter the IDLE mode, by Telecommand, interrupting the Offset/Variance calculation or transmission to Ground/EMCR;
- to enter the SAFE STAND-BY mode, by Telecommand, only in emergency case.

NOTE: It is not allowed to remove primary power in this mode.

3.5.7. CCD Diagnostics Mode

3.5.7.1. This mode of operation shall be entered from the idle mode upon reception of appropriate telecommands from the OBDH bus.

3.5.7.2. One CCD shall be read in imaging/timing read-out mode with full/partial window option and one-node reading.

3.5.7.3. One frame shall be read. EMCS shall be capable to store the energy values of all the pixels of the selected CCD in RAM.

3.5.7.4. Data from the other CCD's shall be ignored.

3.5.7.5. The energy of each pixel (relevant to one frame only) and the H/K data shall be transmitted at the appropriate rate to the OBDH bus without processing.

3.5.7.6. No Telecommands will be accepted in this mode with the exception of “Enter EMCS IDLE Mode” or “Enter EMCS SAFE STAND-BY Mode”.

3.5.7.7. The status of the Filter Wheel, CCDs, thermal control temperature, calibration source, etc. will depend on experiment configuration performed in IDLE mode.

3.5.7.8. At the end of the transmission of all the data, EMCS shall wait for further telecommands from the CDMS whether to exit this mode or to start again the necessary sequence of operations of this mode for the transmission of one other shot of data (related to either the same or a different CCD).

3.5.7.9. EMCS shall perform the thermal control of the CCD's. The temperature of the CCD's shall be kept at a level pre-defined by TC.

3.5.7.10. In this mode Shroud, Annealing and HOPs heaters will be off.

3.5.7.11. EMCS shall exit this mode in the following conditions:
- to enter automatically the IDLE mode when Diagnostic data have been sent to ground;
- to enter the IDLE mode, by Telecommand, interrupting the Diagnostic data collection and transmission to Ground;
- to enter the SAFE STAND-BY mode, by Telecommand, only in emergency case.

NOTE: It is not allowed to remove primary power in this mode.

3.5.8. Extraheating - Annealing Mode

3.5.8.1. This mode of operation shall be entered from the idle mode upon reception of appropriate telecommands from the OBDH bus.

3.5.8.2. The filter wheel shall be turned to the open position if it were in a different position before entering this mode.

3.5.8.3. The Door will be open.

3.5.8.4. The CCD's shall be off.

3.5.8.5. The temperature of the CCD's shall be kept at 130 °C (fine setting can be performed by Telecommand).

3.5.8.6. EMCS focal plane thermal control will be active using Annealing and Secondary Shroud heaters.

NOTE: The CCD's shall be kept at that temperature for about 36 hours.

3.5.8.7. In this mode CCD and HOPs heaters will be off.

3.5.8.8. No Telecommands will be accepted in this mode with the exception of “Enter EMCS IDLE Mode” or “Enter EMCS SAFE STAND-BY Mode”.

3.5.8.9. An appropriate HK telemetry shall be sent to the OBDH bus.

3.5.8.10. During perigee passages, if it is deemed necessary for safety reasons, the filter wheel shall be turned to the closed position.

3.5.8.11. EMCS shall exit this mode in the following conditions:
- to enter the IDLE mode, by Telecommand, interrupting the Annealing process;
- to enter the SAFE STAND-BY mode, by Telecommand, only in emergency case.

NOTE: It is not allowed to remove primary power in this mode.

3.5.9. Extraheating - Deicing Mode

3.5.9.1. This mode of operation shall be entered from the idle mode upon reception of appropriate telecommands from the OBDH bus.

3.5.9.2. The filter wheel shall be turned to the open position if it were in a different position before entering this mode.

3.5.9.3. The CCD's shall be off.
3.5.9.4. The Door will be open.

3.5.9.5. EMCS shall keep the temperature of the CCD's at -70 °C (fine setting can be performed by Telecommand).

3.5.9.6. EMCS focal plane thermal control will be active using CCD and Secondary Shroud heaters.

3.5.9.7. In this mode HOPs and Annealing heaters will be off.

3.5.9.8. The temperature of the secondary shroud shall be kept at the wanted value using the EMCS controlled secondary shroud heaters only. The temperature shall be monitored from ground in an open loop manner via HK telemetry (reaction time can be in the order of few minutes).

NOTE: The secondary shroud shall be kept at that temperature for about 1 hour.

3.5.9.9. No Telecommands will be accepted in this mode with the exception of “Enter EMCS IDLE Mode” or “Enter EMCS SAFE STAND-BY Mode”.

3.5.9.10. An appropriate HK telemetry shall be sent to the OBDH bus. The secondary shroud temperature shall be included in the HK telemetry.

3.5.9.11. During perigee passages, if it is deemed necessary for safety reasons, the filter wheel shall be turned to the closed position.

3.5.9.12. EMCS shall exit this mode in the following conditions:

- to enter the IDLE mode, by Telecommand, interrupting the Deicing process;
- to enter the SAFE STAND-BY mode, by Telecommand, only in emergency case.

NOTE: It is not allowed to remove primary power in this mode.

3.5.10. Extraheating - Decontamination Mode

3.5.10.1. This mode of operation shall be entered from the idle mode upon reception of appropriate telecommands from the OBDH bus.

3.5.10.2. The filter wheel shall be open.

3.5.10.3. The door shall be open.

3.5.10.4. The CCD's shall be off.

3.5.10.5. The temperature of the CCD's shall be kept at -20 °C (fine setting can be performed by Telecommand) using the EMCS heaters only.

3.5.10.6. EMCS focal plane thermal control will be active using Annealing and Secondary Shroud heaters.

3.5.10.7. The temperature of the secondary shroud shall be kept at the wanted value using the EMCS controlled secondary shroud heaters only. The temperature shall be monitored from ground in an open loop manner via HK telemetry (reaction time can be in the order of few minutes).

3.5.10.8. In this mode CCD and HOPs heaters will be off.
NOTE: The CCD's shall be kept at that temperature for about 3 hours.

3.5.10.9. An appropriate HK telemetry shall be sent periodically to the OBDH bus.

3.5.10.10. No Telecommands will be accepted in this mode with the exception of “Enter EMCS IDLE Mode” or “Enter EMCS SAFE STAND-BY Mode”.

3.5.10.11. During perigee passages, if it is deemed necessary for safety reasons, the filter wheel shall be turned to the closed position.

3.5.10.12. EMCS shall exit this mode in the following conditions:
- to enter the IDLE mode, by Telecommand, interrupting the Decontamination process;
- to enter the SAFE STAND-BY mode, by Telecommand, only in emergency case.

NOTE: It is not allowed to remove primary power in this mode.

3.5.11. In-Flight Test Mode

3.5.11.1. This mode of operation shall be entered from the idle mode upon reception of appropriate telecommands from the OBDH bus.

3.5.11.2. The status of the Filter Wheel, CCDs, thermal control temperature, etc. will depend on experiment configuration performed in IDLE mode.

3.5.11.3. In tests using electronic simulation of the sources all the experiment works as in observation: the data are not readout from the CCDs but they are generated at the EMAE or EMCR level.
3.5.11.4. In tests dedicated to specific H/W and S/W functions are grouped different EMDH and EMCR tests (memory area test, H/W test, etc.) which can be individually triggered: during test execution some of the standard functions performed by the unit under test could be suspended.

3.5.11.5. Predefined digital patterns shall be generated at the beginning of the digital part of the electronic chain in order to test the functions of the electronic chain related to the elaboration of the scientific data.

3.5.11.6. The above mentioned patterns shall be stored permanently in EMCS and located in the same unit containing the A/D converter.

3.5.11.7. EMCS H/K data will be available via TLM, if not interrupted due to execution of particular tests.

3.5.11.8. EMCS shall perform the thermal control of the CCD's.

3.5.11.9. In this mode Secondary Shroud, Annealing and HOPs heaters will be off.

3.5.11.10. In this mode the Calibration Source will not be active.

3.5.11.11. Besides, provisions shall be made to test some specific functions at unit level.

3.5.11.12. EMCS shall exit this mode in the following conditions:
- to enter the IDLE mode, by Telecommand, interrupting the in-flight test process;
- to enter the SAFE STAND-BY mode, by Telecommand, only in emergency case.

NOTE: It is not allowed to remove primary power in this mode.

3.5.12. On-Ground Test Mode

3.5.12.1. There shall be an on-ground test mode in order to satisfy the on-ground verification needs for qualification and acceptance.

3.6. Status of H/W Devices vs. EMCS Modes of Operation

3.6.1. The status of H/W devices as a function of the modes of operation is shown in Tables 3.6-1 and 3.6-2 for LEOP and SMP, respectively.

	Door Mech.	Door HOP	Vent. Valves	Filter Wheel	Cal. Source	CCD's	S/C Heater	EPIC CCD Heater	Anneal Heater	Sec. Shroud Heater	EMCS Units
LEOP Off	Closed	Off	Closed	Closed	Off	Off	On	Off	Off	Off	Off
LEOP Initializ.	Closed	Off	Closed	Closed	Off	Off	Off	On	Off	Off	On
LEOP Safe Stand-by	Closed	Off	Closed	Closed	Off	Off	Off	On	Off	Off	On
LEOP Idle	Closed	On	Open	Open	Off	Off	Off	On	Off	Off	On

Table 3.6-1 Status of H/W devices as a function of the LEOP modes of operation.

	Door Mech.	Door HOP	Vent. Valves	Filter Wheel	Cal. Source	CCD's	S/C Heater	EPIC CCD Heater	Anneal. Heater	Sec. Shroud Heater	EMCS Units
SMP Off	Open	Off	Closed (3)	Closed (1)	Off	Off	On	Off	Off	Off	Off
SMP Initializ.	Open	Off	Closed (3)	Closed (1)	Off	Off	Off	On	Off	Off	On
SMP Safe Stand-by	Open	Off	Closed (3)	Closed	Off	Off/On	Off	On	Off	Off	On
Idle	Open	Off	Closed (3)	Any Position	Off/On	Off/On	Off	On	Off	Off	On
Prime	Open	Off	Closed (3)	Any Position	Off/On	On	Off	On	Off	Off	On
Fast	Open	Off	Closed (3)	Any Position	Off/On	On	Off	On	Off	Off	On
Offset/ Variance	Open	Off	Closed (3)	Any Position	Off/On	On	Off	On	Off	Off	On
CCD Diagn.	Open	Off	Closed (3)	Any Position	Off/On	On	Off	On	Off	Off	On
Anneal.	Open	Off	Closed (3)	Open (2)	Off	Off	Off	Off	On	On	On
Deicing	Open	Off	Closed (3)	Open (2)	Off	Off	Off	On	Off	On	On
CCD Decont.	Open	Off	Closed (3)	Open (2)	Off	Off	Off	Off	On	On	On
In-Flight Test	Open	Off	Closed (3)	Any Position	Off/On	Off/On	Off	On	Off	Off	On

(1) Closed if previous Power Off followed nominal path (i.e., transition through Safe Stand-by); otherwise Any Position.
(2) Closed during perigee passages.
(3) Provided that pressure equalization process is done on the experiment ...

Table 3.6-2 Status of H/W devices as a function of the SMP modes of operation.

3.7. Transitions between Modes of Operation

3.7.1. The transitions in between the modes of operation of EMCS shall occur according to the diagram of Fig.3.7 -1.

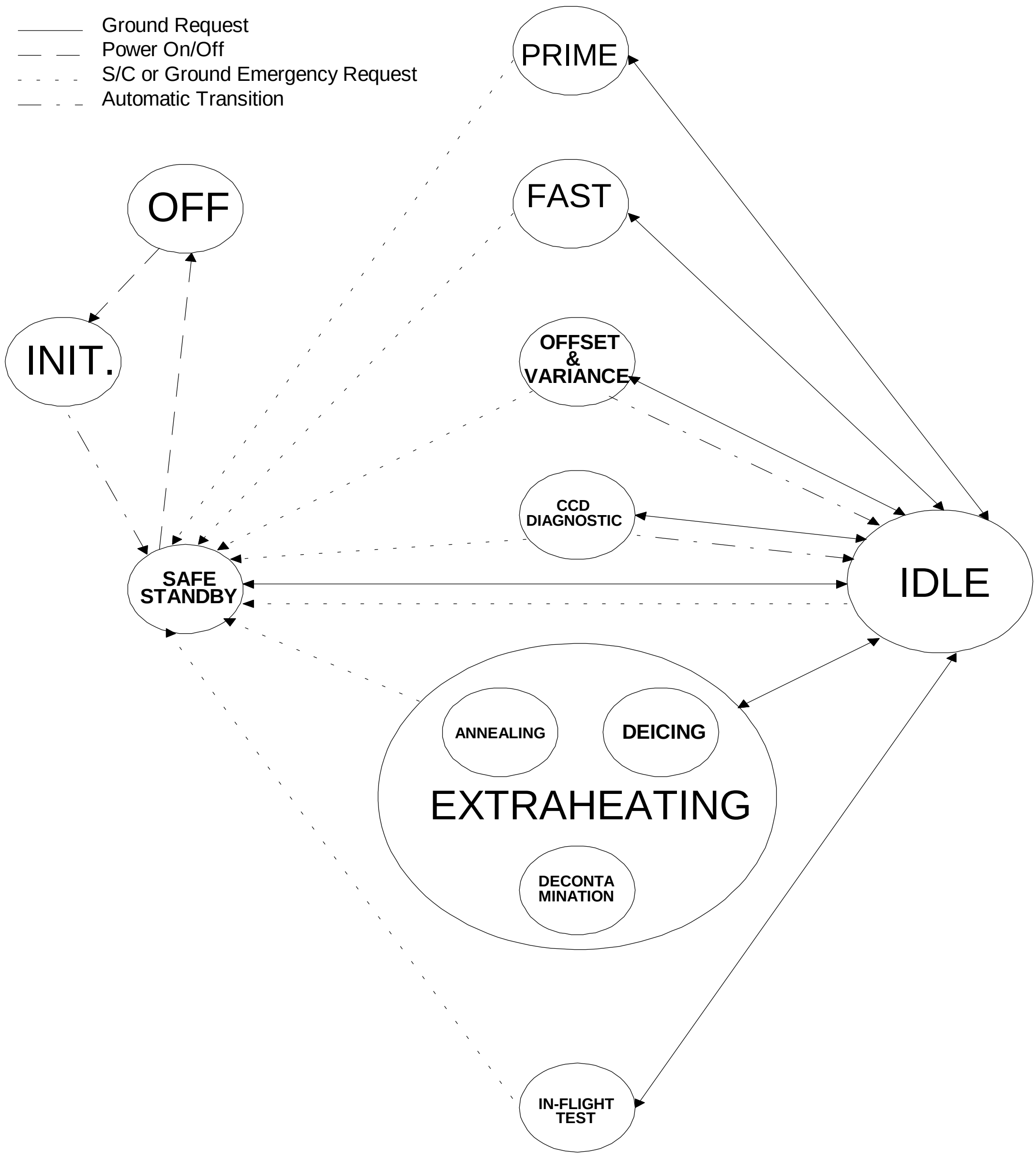

Fig. 3.7-1. - Transitions between the modes of operation of EMCS.

3.8. Cross-Reference of Capabilities

3.8.1. The cross-reference of the major capabilities versus the modes of operation is shown in Tables 3.8-1 and 3.8-2 for LEOP and SMP, respectively.

	Science Data Processing	Science Source Packets	HK Source Packets	SW Patch	SW Dump	Parameters Patch Dump	S/C Heater Control	EPIC CCD Heater Control	EMCS Units
LEOP Off	No	No	No	No	No	No	On	Off	Off
LEOP Initializ.	No	No	No	No	No	No	Off	On	On
LEOP Safe Stand-by	No	No	Yes	Yes	Yes	No	Off	On	On
LEOP Idle	No	No	Yes	No	Yes	Yes	Off	On	On

Table 3.8-1 Cross-reference of the major EMCS capabilities for LEOP.

	Science Data Processing	Science Source Packets	HK Source Packets	SW Patch	SW Dump	Parameters Patch Dump	S/C Heater Control	EPIC CCD Heater Control	EMCS Units
SMP Off	No	No	No	No	No	No	On	Off	Off
SMP Initializ.	No	No	No	No	No	No	Off	On	On
SMP Safe Stand-by	No	No	Yes	Yes	Yes	No	Off	On	On
Idle	No	No	Yes	No	Yes	Yes	Off	On	On
Prime	Yes	Yes	Yes	No	No	No	Off	On	On
Fast	Yes	Yes	Yes	No	No	No	Off	On	On
Offset/ Variance	No	No	Yes	No	No	No	Off	On	On
CCD Diagn.	Yes	Yes	Yes	No	No	No	Off	On	On
Anneal.	No	No	Yes	No	No	No	Off	On	On
Sec. Shroud De-Icing	No	No	Yes	No	No	No	Off	On	On
CCD Decont.	No	No	Yes	No	No	No	Off	On	On
In-Flight Test	Yes (1)	Yes (1)	Yes (1)	No	Yes	Yes	Off	On	On

(1): According to the selected in-flight test procedure.

Table 3.8-2 Cross-reference of the major EMCS capabilities for SMP.

3.9. External Electrical Interface Requirements

3.9.1. Power Interface

3.9.1.1. Primary Power Interface

3.9.1.1.1. EMCS shall be capable to receive power from the S/C primary power line (nominal and redundant) with the following characteristics:

a) Min. Voltage: +26 V;
b) Nominal Voltage: +28 V; and
c) Max. Voltage: +30 V.

3.9.1.1.2. EMCS shall be capable to safely survive any standing or fluctuating voltage between 0 V and +30 V.

3.9.1.1.3. EMCS shall be capable to operate with nominal performance when subject to the perturbations specified in RS-PX-0016, Sect. 5.9.4.2.

3.9.1.1.4. The EMCS max. power consumption on the primary power line shall not exceed the following values:

a) Average/BOL: 95.1 W;
b) Average/EOL: 98.1 W;
c) Peak/BOL: 101 W;
d) Peak/EOL: 98.8 W.

The peak power is defined in RS-PX-0016, Sect. 5.8.1.5.4.

3.9.1.1.5. The EMCS in-rush current shall never be greater than 1.5 times the current consumption of the whole EMCS.

3.9.1.1.6. The duration of the in-rush current shall not exceed 0.5 ms.

3.9.1.1.7. The rate of change of the inrush current shall not exceed 1 A/μs.

3.9.1.1.8. The instantaneous rate of load current change shall not exceed $5 \cdot 10^4$ A/s. Pulse repetition frequency shall not exceed 1 Hz unless confined to the limits of admissible ripple current.

3.9.1.2. Converter Synchronization Interface

3.9.1.2.1. EMCS shall be capable to receive two converter synchronization lines, one for each primary power line, with frequency of 131.072 kHz ± 0.1% and to operate at that frequency or at half of it.

3.9.1.2.2. In the absence of a clock signal, the EMCS converters shall be free running at a nominal frequency of 131.072 kHz ± 0.1% or 65.536 kHz ± 10%.

3.9.1.2.3. EMCS shall be capable to receive a synchronization signal of 5 V, squarewave ground free (transformer coupled).

3.9.1.2.4. The EMCS input impedance shall be 5 kΩ in parallel to 200 pF.

3.9.1.3. Secondary Power Interface

3.9.1.3.1. EMCS shall be capable to provide secondary power to the DBU of the OBDH System by means of two independent power lines (nominal and redundant) with the following characteristics:

a) Min. Voltage: +5.7 V;
b) Nominal Voltage: +6.0 V; and
c) Max. Voltage: +6.3 V.

3.9.1.3.2. The nominal secondary power line shall be active when primary power is applied to EMCS through the nominal primary power line. The redundant secondary power line shall be active when primary power is applied to EMCS through the redundant primary power line.

3.9.1.3.3. The DBU maximum average current is 200 mA.

3.9.2. OBDH Bus Interface

3.9.2.1. EMCS shall provide a redundant interface to the DBU of the OBDH bus according to the Digital Bus Interface (DBI) standard as specified in ESA document, TTC-B-01.

3.9.2.2. EMCS shall provide an interface to:

- ♣ Interrogation Bus; and
- ♣ Response Bus.

3.9.2.3. The EMCS DBI electrical characteristics shall be compliant with RS-PX-0016, Sect. 5.8.4.3.

3.9.3. Stand-by Heater Interface

3.9.3.1. EMCS shall have a nominal and a redundant interface for a (CCD) stand-by heater powered by the S/C. This heater is allocated in order to satisfy the requirement of para. 3.5.2.4 during the off mode. The use of protective fuses is allowed.

3.9.3.2. The heater characteristics shall be in accordance with RS-PX-0020.

3.9.4. Thermistor Interface

3.9.4.1. The EMCS shall have an interface for two (TBC) thermistors conditioned by the S/C.

3.9.4.2. The thermistor characteristics shall be in accordance with RS-PX-0020.

3.10. Failure Detection, Isolation, and Recovery

3.10.1. Failure Detection

3.10.1.1. EMCS should have failure detection capability especially in the following elements:

a) Interfaces;
b) Memories; and
c) Microprocessors.

This capability should be implemented at unit level as well as at inter-unit level.

3.10.1.2. A partial failure/degradation detection capability at pixel level is already implemented through the CCD diagnostics mode of Sect. 3.5.10. and an on-ground analysis.

3.10.1.3. A partial failure detection capability for the scientific electronics channels is already implemented through the in-flight test mode of Sect. 3.5.11. and an on-ground analysis.

3.10.2. Failure Isolation

3.10.2.1. Any first failure of any EMCS unit shall not induce any failure to other units.

3.10.2.2. Any first failure of any EMCS unit shall not result in a short-circuit.

3.10.2.3. Any "ORing" circuitry within EMCS shall have current limiting capabilities.

3.10.2.4. Any hot-redundant part within EMCS shall have current limiting capabilities.

3.10.3. Failure Recovery

3.10.3.1. Any first failure in EMCS but excluding the CCD's and the filter wheel mechanism shall not result in performance degradation with the following exception:

a) the read-out time of no more than two peripheral CCD's may be doubled; or
b) the read-out time of the central CCD may be doubled.

The degradation is intended to be with respect to the prime and fast mode as established in this specification.

3.10.3.2. The bright-pixel failure is recovered by implementing a rejection algorithm in compliance with para. 3.2.3.

4. PHYSICAL CHARACTERISTICS

4.1. The weight of EMCS with the exclusion of the internal harness shall be less than 72.0 kg.

5. EMC AND ENVIRONMENTAL REQUIREMENTS

5.1. At system level no EMC and environmental requirements are established. The requirements at unit level are given in Sect. 9.6.

6. RELIABILITY

6.1. The EMCS reliability over a period of 2 years shall be greater than 0.80.

6.2. The EMCS reliability over a period of 10 years shall be greater than 0.40.

6.3. The EMCS reliability shall be calculated according to LABEN document TL 8536.

7. SOFTWARE MAINTAINABILITY

7.1. During the mission, it shall be possible to modify the software code stored in the EMCS units.

7.2. It shall be possible to modify all the data stored in the EMCS units containing software.

8. COMPUTER RESOURCE RESERVE CAPACITY

8.1. All the memories of EMCS shall be sized with a reserve capacity of at least 20% with respect to the maximum need as derived from the requirements of this specification.

8.2. The idle time of all the microprocessors of EMCS should be kept to at least 30% of the CPU time.

9. CHARACTERISTICS OF THE UNITS

9.1. Definition

9.1.1. EMCS shall have the following subordinate elements:

- EPIC MOS Proton Shield, **EMPS** (one of);
- EPIC MOS Camera Head, **EMCH** (one of);
- EPIC MOS Analog Electronics, **EMAE** (one of);
- EPIC MOS Control & Recognition, **EMCR** (one of);
- EPIC MOS Voltage Converter, **EMVC** (one of);
- EPIC MOS Data Handling, **EMDH** (one of); and
- EMCS Internal Harness **EMIH**.

9.2. Physical Characteristics

9.2.1. Weight

9.2.1.1. The weight of EMPS shall be less than 4.500 kg.

9.2.1.2. The weight of EMCH shall be less than 27.500 kg.

9.2.1.3. The weight of EMAE shall be less than 8.500 kg.

9.2.1.4. The weight of EMCR shall be less than 7.500 kg.

9.2.1.5. The weight of EMVC shall be less than 4.000 kg.

9.2.1.6. The weight of EMDH shall be less than 15.000 kg.

9.2.1.7. The weight of EMIH shall be less than TBD kg.

9.3. Allocation of System Performance Requirements

9.3.1. EMPS

9.3.1.1. The EMPS shall shield the CCD's from cosmic ray background to the computed level.

9.3.1.2. The EMPS shall shield the CCD's from background visible light to the computed level.

9.3.2. EMCH

9.3.2.1. The EMCH shall contain the CCD's.

9.3.2.2. The EMCH shall contain the minimum electronics that must be located directly near the CCD's.

9.3.2.3. The EMCH scientific output shall be made of analog signals as generated by preamplifiers, i.e., any signal conditioning shall be performed by the downstream (in the direction of the scientific data) electronics.

9.3.2.4. The EMCH shall have 14 scientific output channels, one for each node of each CCD.

9.3.2.5. The EMCH shall contain a cooling system necessary to cool down the CCD's to the required temperature.

9.3.2.6. The EMCH shall contain the filter wheel mechanism of Sect. 3.2.4.

9.3.2.7. The Filter Wheel shall be driven by a stepper motor controlled by the EMAE.

9.3.2.8. The EMCH shall have a system to verify the integrity of the filters. This system has to be operated only on ground.

9.3.2.9. The EMCH shall contain the calibration source mechanism of Sect. 3.2.5.

9.3.2.10. The calibration source mechanism shall be controlled by the EMAE.

9.3.2.11. The EMCH shall have a venting valve.

9.3.2.12. The EMCH shall have a protective door and a door mechanism containing door bellows.

9.3.2.13. The EMCH shall have a pressure sensor to monitor the pressure of the door bellows.

9.3.2.14. The EMCH shall be capable to be evacuated on ground.

9.3.2.15. The EMCH shall have two vacuum sensors to monitor the pressure of the camera itself: one sensor is powered via TLC and is monitored via TLM, the other sensor is powered and monitored via EGSE.

9.3.2.16. The EMCH pressure shall be monitored up to TBD hours before launch.

9.3.2.17. The door bellows pressure shall be monitored up to TBD hours before launch.

9.3.2.18. The EMCH shall have the following heaters:

1) Annealing Heater;
2) CCD Thermal Control Heater;
3) Secondary Shroud Heater; and
4) Stand-by Heater (controlled by the S/C).

9.3.2.19. The EMCH shall have thermistors controlled by the EMAE.

9.3.2.20. The EMCH shall have at least one thermistor controlled by the S/C through the interface defined in Sect. 3.9.4.

9.3.3. EMAE

9.3.3.1. The EMAE shall generate the appropriate clocks for the required functioning of the CCD's.
9.3.3.2. The EMAE shall generate the appropriate bias voltages for the required functioning of the CCD's.

9.3.3.3. The EMAE shall convert the analog signals from the EMCH into digital signals with a 12 bit resolution.

9.3.3.4. The EMAE shall send the digital signals to the EMCR through 8 channels: 2 channels shall be related to the central CCD, while the other channels shall be related pairwise to pairs of the peripheral CCD's.

9.3.3.5. The EMAE shall manage the thermal control of the CCD array. This function shall be performed when the unit is powered on with the exception of the annealing mode and the CCD decontamination mode (see also note 3 of Table 3.6-2).

9.3.3.6. The EMAE shall drive the Filter Wheel Mechanism.

9.3.3.7. The EMAE shall drive the Calibration Source.

9.3.3.8. The EMAE shall be capable to receive commands from EMCR through a redundant interface.

9.3.3.9. The EMAE shall allow read out of the relevant parameters including temperatures, heaters power consumption, voltages, calibration source position and filter wheel position.

9.3.3.10. The EMAE shall be capable to receive secondary power from the EMCR.

9.3.4. EMCR

9.3.4.1. The EMCR shall be capable to acquire the digital signals from EMAE through 8 channels.

9.3.4.2. The EMCR shall implement the event recognition algorithm of para. 3.4.2.14. a) and para. 3.4.3.10 a).

9.3.4.3. The EMCR shall implement the event recognition algorithm of para. 3.4.3.6. a).

9.3.4.4. The implementation of the previous algorithms shall occur separately for each input channel.

9.3.4.5. The EMCR shall send the data to the EMDH through 8 channels.

9.3.4.6. The EMCR shall have the capability to store and load all the read-out sequences of para. 3.5.3. with the relevant parameters.

9.3.4.7. The EMCR shall have the capability to store permanently, i.e., in PROM, all the data and the program necessary for its full performance.

9.3.4.8. The EMCR shall be capable to perform temperature control in the annealing mode and in the CCD decontamination mode.

9.3.4.9. The EMCR shall be capable to send commands to the EMAE and to collect HK data from the EMAE.

9.3.4.10. The EMCR shall be capable to acquire and process the monitors from EMVC.

9.3.4.11. The EMCR shall be capable to receive commands from the EMDH and send HK data to the EMDH through a redundant interface.

9.3.4.12. The EMCR shall be capable to receive secondary power (main and redundant) from the EMVC.

9.3.4.13. The EMCR shall be capable of "oring" the secondary power and forwarding it to the EMAE.

9.3.5. EMVC

9.3.5.1. The EMVC shall be capable to receive unconditioned primary power (two lines: main and redundant) from EMDH.

9.3.5.2. The EMVC shall be capable to receive converter synchronization signals (two lines: main and redundant) from EMDH.

9.3.5.3. The EMVC shall be capable to generate temperature monitors for controlling its internal status.

9.3.5.4. The EMVC shall be capable to generate the necessary secondary power output for EMCR and EMAE.

9.3.6. EMDH

9.3.6.1. The EMDH shall be the master unit of the EMCS and hence it shall perform all the functions of Sect. 3 assigned to the master unit.

9.3.6.2. The EMDH shall be capable to receive the intermediate data from the EMCR through 8 channels.

9.3.6.3. The EMDH shall perform the upper/lower thresholding of para. 3.4.2.14 and 3.4.3.10.

9.3.6.4. The EMDH shall perform the upper thresholding of para. 3.4.3.6.

9.3.6.5. The EMDH shall be capable to reject the contribution from bright pixels of para. 3.2.3. and to store the bright pixel table.

9.3.6.6. The EMDH shall be capable to implement the pattern discrimination related to the event recognition algorithm of para. 3.4.3.6. a).

9.3.6.7. The EMDH shall be capable to implement the algorithms of Sect. 3.5.6. for the offset/variance mode.

9.3.6.8. The EMDH shall be capable to implement the non-destructive data compression of Sect. E4.

9.3.6.9. The EMDH shall have the capability of OBDH packet terminal according to RS-PX-0016.

9.3.6.10. The EMDH shall implement the telecommand and telemetry packet structure of RS-PX-0032.

9.3.6.11. The EMDH shall prepare and store in the appropriate queue source packets according to Sect.s 3.4.2, 3.4.3, and 3.5.3 through 3.5.12.

9.3.6.12. The EMDH shall manage the output overflow condition of para.s 3.4.2.18., 3.4.2.19, 3.4.3.14, 3.4.3.15, and 3.4.3.16.

9.3.6.13. The EMDH shall be capable to store 360,000 (16-bit) words of scientific intermediate data in order to fulfill the EMCS requirement of Sect. 3.3.5.

9.3.6.14. The EMDH shall implement the requirement of Sect. 3.3.2. on SCET and local time management.

9.3.6.15. The EMDH shall be capable to manage the telecommand packets received from the OBDH and to forward the appropriate commands to the EMCR.

9.3.6.16. The EMDH shall manage the SW patch and dump of the EMCR.

9.3.6.17. The EMDH shall manage the collection of the HK data from the EMCR.

9.3.6.18. The EMDH shall be fully cold redundant.

9.3.6.19. The EMDH shall be capable to receive primary power from the S/C and to re-route it to the EMVC.

9.3.6.20. The EMDH shall be capable to control and forward primary power to EMCH.

9.3.6.21. The EMDH shall have the capability to store permanently, i.e., in PROM, all the data and the program necessary for its full performance.

9.3.6.22. The EMDH shall control the Venting Valve.

9.3.6.23. The EMDH shall control the Door Mechanism.

9.3.6.24. The EMDH shall control the secondary shroud heater according to the telecommands received.

9.4. External Interfaces

9.4.1. All the external electrical interfaces are allocated to the EMDH.

9.4.2. Primary power shall be routed directly from the EMDH to the EMVC.

9.4.3. The EMDH shall provide converter synchronization to the EMVC.

9.4.4. The stand-by heater lines of Sect. 3.9.3. shall be routed directly from the EMDH to the EMCH.

9.4.5. The thermistor lines of Sect. 3.9.4. shall be routed directly from the EMDH to the EMCH.

9.5. Internal Interfaces

9.5.1. The intenal interfaces are defined in EPIC-EST-SP-001.

9.6. EMC and Environmental Requirements

9.6.1. The EMC design requirements of RS-PX-0016, Sect. 5.9.3 shall apply to all the EMCS units.

9.6.2. The environmental requirements of RS-PX-0016 shall apply to all the EMCS units.

10. PRECEDENCE

In case a conflict arises between two different requirments, then the precedence of the requirements shall be (the top requirement has the highest precedence):

a) Performance characteristics;

b) Reliability; and

c) Physical and electrical characteristics.

11. VERIFICATION REQUIREMENTS

11.1. Test Requirements

11.1.1. The test requirements of RS-PX-0016, Sect. 6.5, shall apply.

11.2. Calibration Requirements

11.2.1. The calibration requirements shall be defined in an appropriate document.

11.3. Facilities and Facility Equipment

11.3.1. Transport Container for EMCH

11.3.1.1. The transport container for EMCH shall satisfy the environmental and monitoring requirements of EMCH.

11.3.2. Cleanleness

11.3.2.1. The facilities shall satisfy the cleanleness requirements of the EMCH.

11.4. Verification Matrix

11.4.1. Verification of requirements shall be performed by inspection (I), analysis (A), and test (T) at the level of system (S), subassembly (SA), and unit (U).

12. PREPARATION FOR DELIVERY

12.1. The preservation of articles or materials subject to deterioration, corrosion, contamination or any other physical damage through exposure to air, moisture or any other element during fabrication storage and any interim storage or transportation cycle shall be carried out with a suitable method. Materials used for packaging shall be fully compatible with the equipment to be delivered.

12.2. Painted surfaces shall be wrapped with cardboard, paper, foam sheet or any other protective covering. Precision surfaces shall be coated with non-water soluble anticorrosion coating.

12.3. Special requirements and precautions shall be documented in supplementary instructions or shall appear in the packaging procedures or handling instructions, as appropriate.

12.4. The units shall be preserved and packaged in order to avoid material performance degradation. The packaging method shall not impose any design penalty.

12.5. Reusable containers shall be designed for packaging, transportation and handling in order to prevent any damage to the item to be delivered. The containers shall allow safe transportation within the specified environment.

12.6. Internal and external containers shall be marked and labelled including precautionary marking necessary to ensure safety of personnel and facilities. Reusable containers shall be identified with the wording: "Reusable Container - Do not Destroy - Retain for Reuse". In addition, special labels are to be affixed to provide specific P.A. requirements/cautions, e.g., opening in clean room only, static discharge sensitive item, critical item etc.

12.7. A copy of the acceptance data package shall be sent together with the end item unit. An envelope containing instructions to open and remove the content shall be attached externally to the container.

APPENDIX A - Imaging Read-out for a Single CCD

A 1. Parameters

There are 6 parameters for the imaging read-out of a single CCD. They are as follows:

$$\mathrm{IMPAR} \equiv [x_0, y_0, \Delta x, \Delta y, T_{int}, \mathrm{N}]$$

where:

x_0 = x-position of the pixel at the lower left-hand corner of the window;

y_0 = y-position of the pixel at the lower left-hand corner of the window;

Δx = window size in the x-direction in number of pixels;

Δy = window size in the y-direction in number of pixels;

T_{int} = frame integration time;

N = (1,0) read-out from left node;
(0,1) read-out from right node;
(1,1) read-out from both nodes.

The full window option means:

$$x_0 = y_0 = 1 \quad \text{and} \quad \Delta x = 610, \Delta y = 602$$

A 2. Full Window Option

In the full window option, the following sequence of operations is performed:

a) The image is transferred from the integration area to the storage area by shifting the rows 602 times;

b) Pixels of the lowermost line of the storage area (read-out line) are read out either from one node or from both nodes (half-line to each node) (TBC);

c) The image in the storage area is shifted by one row;

... The operations b) and c) are repeated for a total of 602 times;

d) The operation a) is repeated starting with a time delay of T_{int} from the time when the previous operation a) ended.

N.B: It is understood that T_{int} can be both greater and lower than T_0, where T_0 is the read out time for a frame. In principle, if T_{int} is less than T_0, the CCD is operated by first rejecting the image formed in the integration area during the readout of the previous frame and then using the sequence listed above with a time delay of T_{int}. In this case, the CCD is "active" only partially, i.e., during a periodic window in time.

A 3. Partial Window Option

The partial window option is similar to the full window option with the only difference that only the pixels in the window (x_0, y_0, Δx, Δy) are actually read out while the others are rejected. Since T_0 is smaller than that in the full window case, then T_{int} can be smaller.

APPENDIX B - Timing Read-out for a Single CCD

B 1. Parameters

There are 3 parameters for the timing read-out of a single CCD. They are as follows:

$$\text{TMPAR} \equiv [\Delta x, \Delta y, N]$$

where:

Δx = size in the x-direction (in number of pixels) of the strip of columns which are under observation. This strip is always located centrally with respect to the CCD;

Δy = size in the y-direction (in number of pixels) of the section of the strip that is binned (summed);

N = (1,0) read-out from left node;
(0,1) read-out from right node;
(1,1) read-out from both nodes.

B 2. Sequence of Operations

The following sequence of operations is performed:

a) The image is partly transferred from the integration area to the storage area by shifting the rows Δy times; the Δy rows that enter the storage area are integrated into the topmost row (602nd);

b) The content of the storage area is shifted by one row (after this operation, the 602nd row of the storage area has no charge);

c) The content of the read-out line (the lowermost of the storage area) is read either fully (if Δx=610) or partly (if Δx<610). In the latter case, the pixels not belonging to the strip are rejected. The reading can occur from one or both nodes (TBC) according to the option selected;

d) The operation a) is repeated.

It is understood that no valid information is obtained for the first 600 times that this sequence is performed, because at the beginning the storage area does not contain valid information.

APPENDIX C - Event Recognition Method

C 1. Two-Dimensional Method

The two-dimensional method applies to a window of N x M pixels. The logical steps are as follows:

1) Two rows of pixels with zero energy are added at both the top and the bottom of the window. Two columns of pixels with zero energy are added at both the right and the left of the window. The result is a (N+4) x (M+4) window.

2) Starting from the top left, all the partial 5x5 matrices of pixels are compared with the set of patterns of Fig. C 1-1 with the following provisions:

   a) The energy of the central pixel is the highest;
   b) The energy of the black pixels of the patterns P1...P32 is above a given threshold energy E_{Th};
   c) The energy of the white pixels with solid line of the patterns P1...P32 is below a given threshold energy E_{Th};
   d) The energy of the white pixels with dashed line of the patterns P1...P32 are don't care.

   (The pattern numbering of Fig. C1-1 is not mandatory)

3) If a pattern is recognized, then the following values are found:

   a) x-position (with respect to the CCD) of the central pixel;
   b) y-position (with respect to the CCD) of the central pixel;
   c) identification number of the pattern;
   d) E_1 = energy of the central pixel;
   e) E_2 = sum of the energies of the pixels above the threshold excluding the central pixel itself;
   f) E_3 = sum of the energies of the pixels below the threshold of the inner 3x3 matrix of the pattern; and
   g) E_4 = sum of the energies of the 16 peripheral pixels.

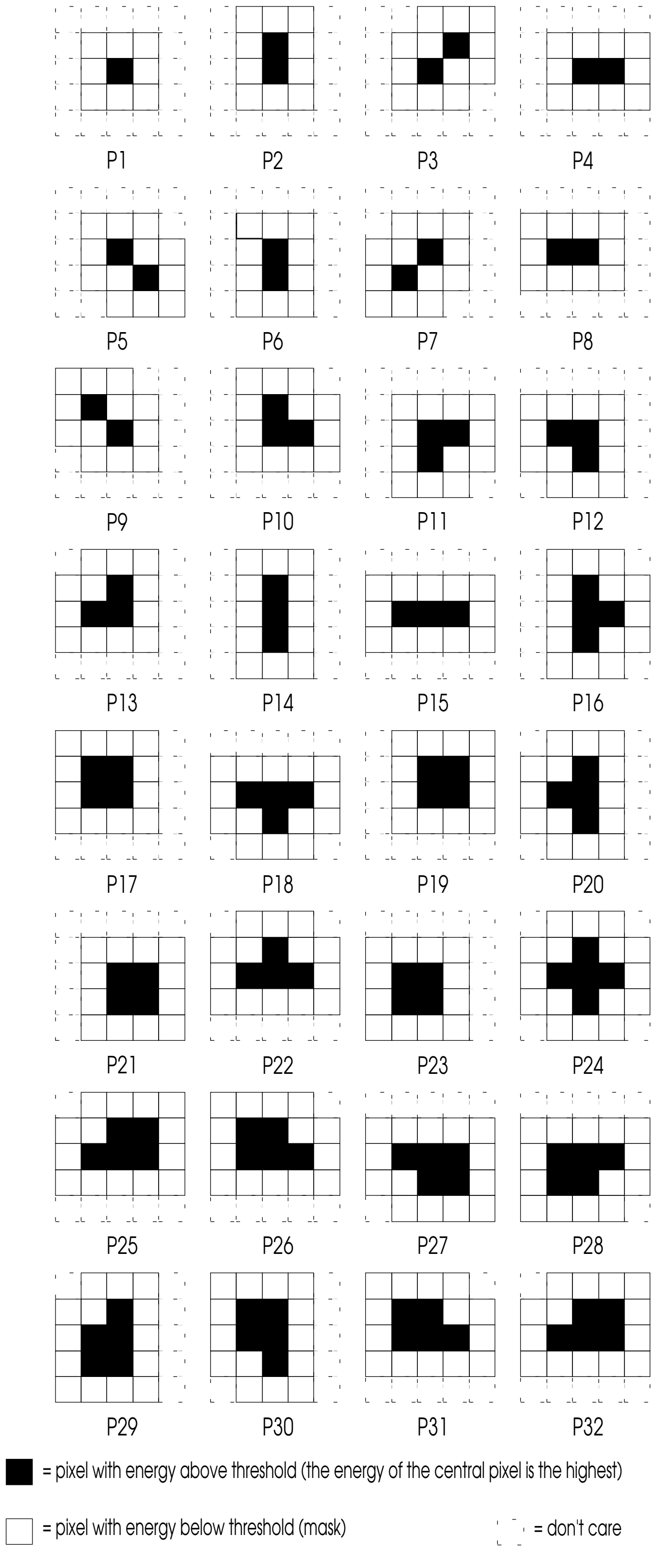

Fig. C1-1 - Set of two-dimensional patterns

C 2. One-Dimensional Method

The one-dimensional method is based on the search of the patterns of Fig. C2-1, where:

a) the energy of the black pixels is above a given threshold energy E_{Th};
b) the energy of the white pixels is below a given threshold energy E_{Th};

If a pattern is recognized, then the following values are found:

a) x-position (with respect to the CCD) of the brightest pixel;
b) # of the read-out (y-position);
c) identification number of the pattern;
d) E_1 = energy of the brightest pixel;
e) E_2 = energy of the other pixel (case P1).

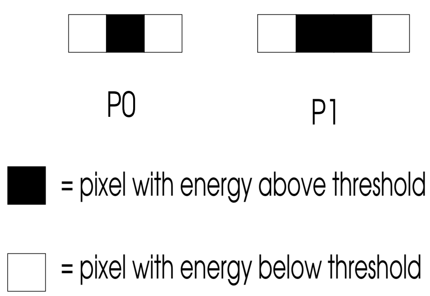

Fig. C2-1 - Set of one-dimensional patterns

APPENDIX D - Offset and Variance Algorithms

D 1. Column/Row Average

Let N_c be the number of columns. Let N_r be the number of rows. Let $E(i,j)$ be the raw energy of the pixel (i,j) corresponding to the ith column and the jth row. Let $N^c(i)$ be the number of pixels of the ith column with valid energy. Let $N^r(i)$ be the number of pixels of the jth row with valid enegy. The average of the ith column is defined as:

$$A^c(i) = \frac{1}{N^c(i)} \sum_{j=1}^{N_r} E(i,j)$$

where the summation is over the pixels with valid energy. The average of the jth row is defined as:

$$A^r(j) = \frac{1}{N^r(j)} \sum_{i=1}^{N_c} E(i,j)$$

where the summation is over the pixels with valid energy.

D 2. Total Average

The total average is defined as:

$$A^{tot} = \frac{1}{N_r} \sum_{j=1}^{N_r} A^r(j) = \frac{1}{N_c} \sum_{i=1}^{N_c} A^c(i)$$

D 3. Column/Row Offset

The column/row offset is defined as:

$$O^c(i) = A^c(i) - \frac{A^{tot}}{2} - \frac{B}{2}$$

and

$$O^r(j) = A^r(j) - \frac{A^{tot}}{2} - \frac{B}{2}$$

where B is the bias which should be set to zero, generally.

D 4. Variance

The variance is defined as:

$$\sigma = \sqrt{\frac{\sum_{i,j}\left(E(i,j) - O^{c}(i) - O^{r}(j)\right)^{2}}{N^{v}}}$$

where the summation is over the pixels with valid energy and N^v is the total number of pixels with valid energy, i.e.:

$$N^{v} = \sum_{j=1}^{N_r} N^{r}(j) = \sum_{i=1}^{N_c} N^{c}(i)$$

APPENDIX E - Packet Telecommands and Telemetry

EMCS Telemetry/Telecommand characteristics and requirements are specified in EPIC-EST-SP-001.

APPENDIX F - Formats of the Scientific Telemetry

The formats of the scientific telemetry are specified in EPIC-EST-SP-001.

APPENDIX G - Event Rates

G 1. Estimated Event Rates

The event rates relative to a single CCD at the interface between EMCR and EMDH have been investigated for different limiting cases. The results derived from the data presented at the EPIC Consortium Meeting held in December 1994 are shown in Table G1-1 which also contains the main assumptions on the CCD parameters.

ESTIMATED EVENT RATES FROM A SINGLE CCD (Event/s)

CCD Read-out (a) ⇒	Imaging Partail Window 100x100 One node (0.11 s)	Imaging Full window Two nodes (1.1 s)	Imaging Full window Two nodes (1.1 s)	Imaging Full window one node (2.2 s)	Timing one node 54 lines 54 pixels/line (0.87 ms)
Source type ⇒	Single point source at pile-up limit	Extended source	Crowded field	None	Single point source at pile-up limit
Source contribution (event/s)	100	1200	1200	0	1440
Sky background (event/s)	2	2	2	2	2
Cosmic ray background (event/s)	1	1	1	1	3
Bright Pixels (event/s)	13	46	46	23	0
Noise at 3 σ (b) (event/s)	123	442	442	221	84
Total (event/s)	239	1691	1691	247	1529

(a): Assumed values of the main parameters.
(b): 3 σ corresponds to 0.135 %; and

Noise = 0.00135 * [# of pixels per frame]/[frame time] (imaging);
Noise = 0.00135 * [# of pixels per line]/[line time] (timing).

Table G1-1 Estimated event rate from a single CCD at the EMCR-EMDH interface.

G 2. Maximum Allowed Rates

The maximum allowed rates at the interface between EMCR and EMDH shall be as follows [These values were established following the prediction contained in the EST communication Prot155/LC/MC, dated September 29, 1994].

G 2.1 For the channel related to **one node** of a CCD in imaging read-out, the maximum number N of events per frame shall be such that:

$$(N / T_F) < 1112 \text{ events/s},$$

where is the frame time, i.e., the time interval between the beginning of two consecutive frames. The frame time shall be never lower than 0.1125 s.

G 2.2 For the channel related to **one node** of a CCD in timing read-out, the events shall be divided in cycles. The number of events per cycle shall not be greater than 1400. The cycle time interval shall not be lower than 890 ms, i.e., the event rate shall never be greater than 1573 events per second.

G 2.3 Full performance of the prime mode of operation shall be guaranteed when the following conditions are met on the rate of the events transmitted by EMCR to EMDH:

a) the total rate of the events is be less than or equal to 8368 event/s;

b) the rate of the events due to noise is less than or equal to 6804 event/s;

c) the rate of the events due to bright pixels is less tha or equal to 350 event/s;

d) the rate of the events due to cosmic rays is less than or equal to 14 event/s;

e) the rate of the valid X-ray events is less than or equal to 1200 event/s.

G 2.4 Full performance of the fast mode of operation shall be guaranteed when the following conditions are met on the rate of the events transmitted by EMCR to EMDH:

a) the total rate of the events in both imaging and timing channel mode is be less than or equal to 7708 event/s;

b) the rate of the events due to noise is less than or equal to 5916 event/s;

c) the rate of the events due to bright pixels (imaging channel mode) is less tha or equal to 300 event/s;

d) no events due to bright pixels are transmitted in timing channel mode;

e) the rate of the events due to cosmic rays is less than or equal to 14 event/s;

f) the rate of the valid X-ray events in timing channel mode is less than or equal to 1440 event/s.

g) the rate of the valid X-ray events in imaging channel mode is less than or equal to 30 event/s.