XMM Optical Monitor

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Requirements Specification for the XMM Optical Monitor Digital Processing Unit

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1 Introduction

The specifications for the DPU are governed in the first case by the top-level OM system specifications, which require the following (derived from XMM-OM/MSSL/SP/0009):
F0000/1: There will be two completely redundant DPUs, each connected to all three detectors and one instrument controller
F0000/2: The DPU will accept data from the active blue detector at a continuous rate of $\leq 2 \times 10^5$ cts $\sec^{-1}$
F0000/3: The DPU will accept data from the red detector in a serial sequence of pixels, where the 24bit data words will be transmitted accepted at a typical rate of 2.5MHz, with line and frame sync data to delimit the stream.
F0000/4: The DPU will store accumulating data in a telemetry store memory. This will be transmitted to the ICU In packets as requested by the ICU during the collection of the subsequent image
F0000/5: The DPU memory will be managed in a manner which provides an indication to the ICU whether it is possible to commence new exposures
F0000/6: At the start of an image exposure, using either red or blue detector data (as required by the observer), the DPU will establish a set of tracking reference stars (up to a programmable number) without ground intervention
F0000/7: Data from the blue detector will be summed in the DPU for tracking periods of typically 10 seconds, without correction for spacecraft attitude changes
F0000/8: Every tracking period, using either blue or red detector data, the DPU will calculate ΔX, ΔY and $\Delta\theta$, the changes in spacecraft pointing with respect to the master frame. A TBD spacecraft absolute time reference datum will be appended to a header frame which contains the above information. Subject to the field and source countrates, system point response function etc., the calculation will be performed with an accuracy of $\leq \pm 0.5$arcsecs (rms) in X and Y, and 0.5 arcmin for rotation θ.
F0000/9: The calculated ΔX and ΔY will be applied to science data collected in that tracking frame, and this offset data co-added to an accumulating image. Any image blurring due to the complete DPU operation cycle will be $\leq$1 pixel. (This does not include spacecraft drift.)
F0000/10: The calculated ΔX, ΔY and $\Delta\theta$ together with the reference time datum and other TBD statistics relating to the guide or other bright stars, and will be passed to the ICU via the DPU-ICU interface.
F0000/11: If due to a spacecraft attitude manouver, or other cause, the DPU is unable to recognise the guide stars in 2 (TBC) or more consecutive star fields, then the DPU will save the current accumulated data, and recycle to the beginning of the lost observation.
F0000/12: If the spacecraft drift remains within specified limits, the random chance of lock being lost will be $\leq$1% (TBC) in a 10^5sec observation.
F0000/13: There will be two explicit observing modes: IMAGE Mode in which the shifted data are co-added, and FAST Mode in which the data are spatially censored and transmitted as time series. In the case of the Blue detector these modes may be mixed. There will also be two embedded modes, the bright star and auto fast modes.
F0000/14: The DPU will deal with the engineering modes of the two detectors by collecting images without data shifting.
F0000/15: At the start of an image exposure the DPU will establish the absolute pointing direction by reference to an uplinked star pattern file. The accuracy of location shall be $\leq$ 0.5arcsecs (95% full cone TBC) for more than 99% of fields.

2 Functional Description

A summary of the overall operation of the DPU is provided below. The functional description provides a reference for terminology of the sub-system specifications.

Photons detected with either the blue or red detector will be processed by the detector electronics, and the resulting data, in the form of X, Y and pulse height data (where appropriate) and TBD flags will be passed to the DPU.

In a typical ~8.5 arcminute field of view of 1024×1024 pixels of the blue detector, stars as bright as

$\sim 15^{th}$ magnitude will normally be observed, and these will produce ~200 cts/sec in the focal plane spot of ~1 arcsec. The whole field of view may produce up to 10^5 cts/sec from other stars and background light, and at these rates it is not possible to telemeter information for every photon detected. The DPU therefore must perform the required compression. In addition, due to drifts in the spacecraft attitude, the images will wander on the focal plane, and the accumulation of image data in the DPU memory must be accompanied by an appropriate shifting algorithm.

At the start of each exposure an *aquisition* sequence begins, with the accumulation of a master image of ~10 (TBC) seconds. This may be a coarse 17 arcmin square image of 1 arcsec pixels. Depending on the star field, typically the 10 brightest stars (which meet acceptance criteria such as range of field position, morphology etc.) are selected for a guide star file. These may also be compared with an uplinked star pattern of HST guide stars and the absolute position determined. As a result, scientist specified sky windows for data collection will be calculated in detector co-ordinates, and data collection windows in memory configured.

The master file is compared with the following sets of 10 secs sequentially accumulated images. The shifts in star images are measured with respect to the master guide star file and the image center (Δ X, Δ Y and $\Delta\theta$). These data are passed to the algorithm of the selected instrument mode, and to the ICU. In the former case the data are shifted in memory to maintain the required spatial registration, in the latter case the data are output for prompt housekeeping/RED detector steering or spacecraft AOCS updates.

The red detector image data must be treated by comparing successive image pairs to remove cosmic ray artefacts.

Finally the science data may require to be compressed prior to telemetry, so the DPU must hold the previous image data in memory while it is transmitted to the ICU in blocks on request..

The baseline design implements a flexible approach to maximize the scientific utility of the OM, so that the description of operation is not comprehensive (eg. timings and window sizes may vary from one observation to the next)

3 DPU Sub-System Requirements

3.1 Interface requirements

F0000/16 The DPU and Digital Power Supply Unit are contained in the Digital Electronics Module. The DEM is interfaced with the XMM spacecraft accortding to the provisions of Experiment Interface Document (EID) Part A (eg. sections 2.3,2.4,2.6,3.1,4.2,4.3,4.4,5.3,5.4,6)
F0000/17 The ICU will be contained in the DEM. The mechanical mounting interface and the electrical connections are specified in design specification document XMM-OM/PENN/SP/0002
F0000/18 The blue detector - DPU interface is specified in design specification document XMM-OM/PENN/SP/0002 and XMM-OM/MSSL/SP/0007
F0000 /19 The red detector - DPU interface is specified in design specification document XMM-OM/PENN/SP/0002 and XMM-OM/MSSL/SP/0007
F0000/20 The power supply - telescope power supply interface is specified in design specification document XMM-OM/PENN/SP/0002 and XMM-OM/MSSL/SP/0007

3.2 Performance requirements

F0000/21 The DPU is required to process 1M detector pixels data in the accumulating memory and re-register into 256k binned pixels in $\leq$10secs.
F0000/22 The DPU will not introduce more than 0.3″ rms (TBC) contribution to the OM resolution by the combination of position calculation or shift-and-add.
F0000/23 The DPU will enable time resolution in selected FAST mode windows with accuracy better than 2msec (TBC). More than one FAST window should be provided per observation if required by the observer.

3.3 Software requirements

F0000/24 All software requirements are listed in the Software Requirements Document, XMM-OM/MSSL/SP/
F0000/25 All software preparation and documentation will carried out in accord with the consortium agreed Software Assurance Plan

3.4 Power Supply

F0000/26 There is a single Digital Power Supply for each Digital Electronics Module. It is powered by the Spacecraft Power and Sync line, and a keep alive line. The redundant DEM Power Supply is connected to a redundant spacecraft power and sync line.
F0000/27 The DPU power supply should produce regulated power which is fed to the DPU processing unit itself, and other digital units of the Optical Monitor (Instrument Controller and Spacecraft Interface box - see XMM-OM/MSSL/SP/0007).
F0000/28 The power supply provides 6.0V to the DBU, 5.5 V to the digital electronics, and 3.5V as a keep-alive supply
F0000/29 The Digital Power Supply will provide 11.5W (average) of regulated power with an efficiency of not less than 70%. At the end of mission the average power is 12.4 W, peak power at end-of-life is 16.5W
F0000/30 The DPU Power Supply must provide inrush current of TBD A, a nominal current of TBD A ($\pm$TBD A) and the ripple and transient currents will be TBD.

3.5 Radiation Performance

The total absorbed radiation dose at mission end will be 20-30krads behind a total mass of 6mm aluminum (including spacecraft mass). At present the Agency requests that all boxes be designed with 3mm aluminum walls. The ESA supplied dose/depth curve defines the radiation levels to which all components must be tolerant
F0000/31 The DEM mechanical design will ensure that sufficient local shielding is available such that the radiation total dose after account for spacecraft shielding, is not greater than that tolerated by the DPU and ICU Electrical and Electronic parts.
F0000/32 The DPU will not operate during trapped proton belt passage at perigee ($\leq$40,000km nominally).
F0000/33 Components will be radiation hardened or tolerant, or otherwise uprated by appropriate contractor testing to demonstrate that that the level of screening around each component is sufficient to ensure its survival.
F0000/34 Program flow will be monitored with watch-dog timers and monitoring software to prevent the effects of upsets.
F0000/35 Any circuits employed should be of latch-up resistant technology. Alternatively to prevent destructive latch-up sensitive circuits will be protected by current limiting circuits.
F0000/36 In assessing the suitability of components for the radiation environment, the effects of increased current consumption with total dose must be included for a worst case power requirement to be accommodated within the power resource budget.

3.6 Other requirements

F0000/37 Product assurance will conform to the consortium PA plan (XMM-OM/MSSL/RD/0005). In particular, parts should be procured to MIL 883 RevC level B wherever possible. A Part Approval Document should be raised for all other items.
F0000/38 Error rate should be $\leq 2\times10^{-11}$ bit^{-1} s^{-1}.
F0000/39 Reliability figure after 5 years - one unit still operable with 98% probability (TBC).

3.7 Operating Mode requirements

F0000/40 Memory must be sufficient to store not less than 4 Meg 16 bit words and 1 Meg 24 bit words for science data.

3.7.1 Blue Image Mode

F0000/41 The system must locate and bin the previous track frame into the accumulating memory in $\leq$7sec (TBC)
F0000/42 The system must calculate the new relative pointing direction in $\leq$ 3 sec (TBC)
F0000/43 The system must accommodate two embedded modes:
either
Auto-FAST mode searches for up to 10 brightest objects from the reference frame and calculates brightness and position in every subsequent frame
or
Bright star Mode examines 10 brightest objects from each track frame and calculates brightness and position

3.7.2 Blue Fast Mode

F0000/44 Any of the 16 restricted non-contiguous windows in the field of view may be selected for FAST mode (each FAST window will limited to 512 pixels). There may be 0, 1 or 2 FAST mode windows per observation.
F0000/45 At observer specified time intervals (from 1msec to 1sec TBC) data from pixels in the windows are compared with the previous interval and difference data encoded.

3.7.3 Blue Engineering Test Modes

F0000/46 Up to 2048 x 2048 pixels in unbinned mode and shift and add registration will be stored to 16 bit depth and telemetered.
F0000/47 Events may be stored as raw data lists
F0000/48 Full images may be collected with modulo-8 spatial binning

3.7.4 Red Image Mode

The red detector has essentially identical operating modes as the primary blue detector. However, differences in the readout modes of the two detectors require different emphasis in data compression. The red detector does not offer prompt data on receipt of a photon, but must store images for a commandable length of time before readout. The interfaces with the detectors may be designed so that the DPU addresses a memory section which seems transparent to the detector type. The CCD is subject to image blemishes caused by cosmic rays, which must be recognized as transient within individual image frames. The range of image sizes or time resolutions may vary between the two detectors.

3.7.5 Red Image Mode

F0000/49 The image is collected on the CCD chip for a time commandable between $\sim$10 and $\sim$1000 secs. The data are read from the CCD experiment to a DPU buffer area, then to the RED image memory of up to 1000$\times$1000 pixels. Sequential memory locations are incremented with the contents of the 16bit data for each pixel.
F0000/50 A TBD cosmic ray event filter must be applied to recognize transient events not occurring in successive images. Image comparison and accumulation must take $\leq$50secs (TBC)

F0000/51 N images are summed together, and the resulting data (including cosmic ray pixel hit map) compressed and telemetered in a similar manner to the primary image mode.

3.7.6 Red Fast Mode

RED FAST mode is not available simultaneously with RED IMAGE mode
F0000/52 RED FAST data are read into memory in the same manner as RED IMAGE data, time resolution is defined entirely by the CCD readout mode
F0000/53 For the red detector, the TBD Engineering mode may require transmission of whole image frames without further processing.

3.8 Telemetry Mode Requirements

F0000/54 Table 1 shows the summary of mode characteristics to be offered by the DPU

Code	Mode Name	No. of Windows	Optional Binning
BIM	Blue image	up to 15	Yes
BFA	Blue fast	up to 15	Yes
BEN	Blue engineering	1	Yes
RIM	Red image	up to 15	Yes
RFA	Red fast	up to 15	Yes
REN	Red engineering	1	Yes

Telemetry Mode Combinations
Different combinations of the above instrument modes may be used to form a range of telemetry modes as shown in Table 2.

With the exception of the Engineering Mode in the case of the blue detector, any two modes can be available simultaneously, while in the case of the red detector, only one mode is possible at a time.

Mode Combinations

Combination	Blue Tracking	Red Tracking
1	BIM BFA RIM	
2	BIM BFA RFA	BIM BFA RFA
3	BIM BFA	BIM BFA
4	BIM RIM	
5	BIM RFA	BIM RFA
6	BFA RIM	
7	BFA RFA	BFA RFA
8	BEN	BEN
9	REN	REN

Note that binning can take place in either the detctor or the DPU or both. If binning is selected only at the detector, all of the pixels in this window will have the same binning factor. The binning in the DPU would allow different binning factors for different windows.