SOFTWARE DESIGN OF THE XMM SCIENCE OPERATIONS CENTRE

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ABSTRACT. This paper describes the experience of applying ESA's procedures and strict system development standards to the analysis and design of the XMM SOC. It will be described the software design principles, the functional concept, its interfaces, its major subsystems and its hardware architecture. The development will make use of existing common infrastructure software at ESOC. However some of its subsystems (e.g. IAS, PPS and PCS) will re-use existing software (mainly science software packages) developed in support of previous international missions. At the time of presentation (September 96) the XMM SOC Software Requirements Phase will be at its initial stage. Additionally this paper will address how the CCSDS (Consultative Committee for Space Data Systems) standards are used for packaging the data in FITS format. The aim is to provide self-documenting data to the investigators at the science data centres and home institutes. As the subsystems of any SOC / Data Centre / Archive combination are the same, although they may have different weight and might be handled by different entities, this paper will also outline how the XMM SOC software will be developed in order to be used by future ESA missions (Integral, Rosetta, First).

1. INTRODUCTION

The X-Ray Multi-Mirror Mission (XMM) is a high throughput X-ray spectroscopy mission (photon energy range from 0.1 Kev to 10 Kev), which is the second cornerstone of the ESA long term scientific plan. The XMM is a facility type observatory open to the world-wide astronomical community, which will offer a major step forward in the field of X-ray astrophysics in the 21st Century. It is envisaged as a long duration facility class mission aimed at performing detailed imaging spectrophotometry on a wide variety of X-ray sources. The observatory will be placed in a 48 hour highly eccentric inclined orbit to allow uninterrupted observations up to 41 hours using the groundstation of Redu (Belgien). The scientific instruments are :

- EPIC European Photon Imaging Camera
- RGS Reflection Grating Spectrometer
- OM Optical Monitor

The XMM spacecraft will be operated in a continuous interactive mode from a Mission Operations Centre (MOC), located at Darmstadt, Germany. Science operations will be conducted from a Science Operations Centre (SOC), located at Villafranca, Madrid, Spain.

2. INTERFACES

Figure 1 shows the place of the XMM SOC Control System (XSCS) in the XMM Ground Segment, which in the operational configuration will consist of the following elements :

- The Ground Stations
  - ESA Kourou and Redu ground stations in LEOP
  - Redu alone after LEOP
- The Mission Operations Centre (MOC), including ;
  - XMM Monitoring and Control Systems (XMCS)
  - Flight Dynamics System (FDS)
  - Operations Archive
  - XMM Simulator
  - On Board Software Maintenance System (OBSMS)
- The Science Operations Centre (SOC)
- The Science Survey Centre (SSC)
- The External Observers

Communications and lines between the various elements

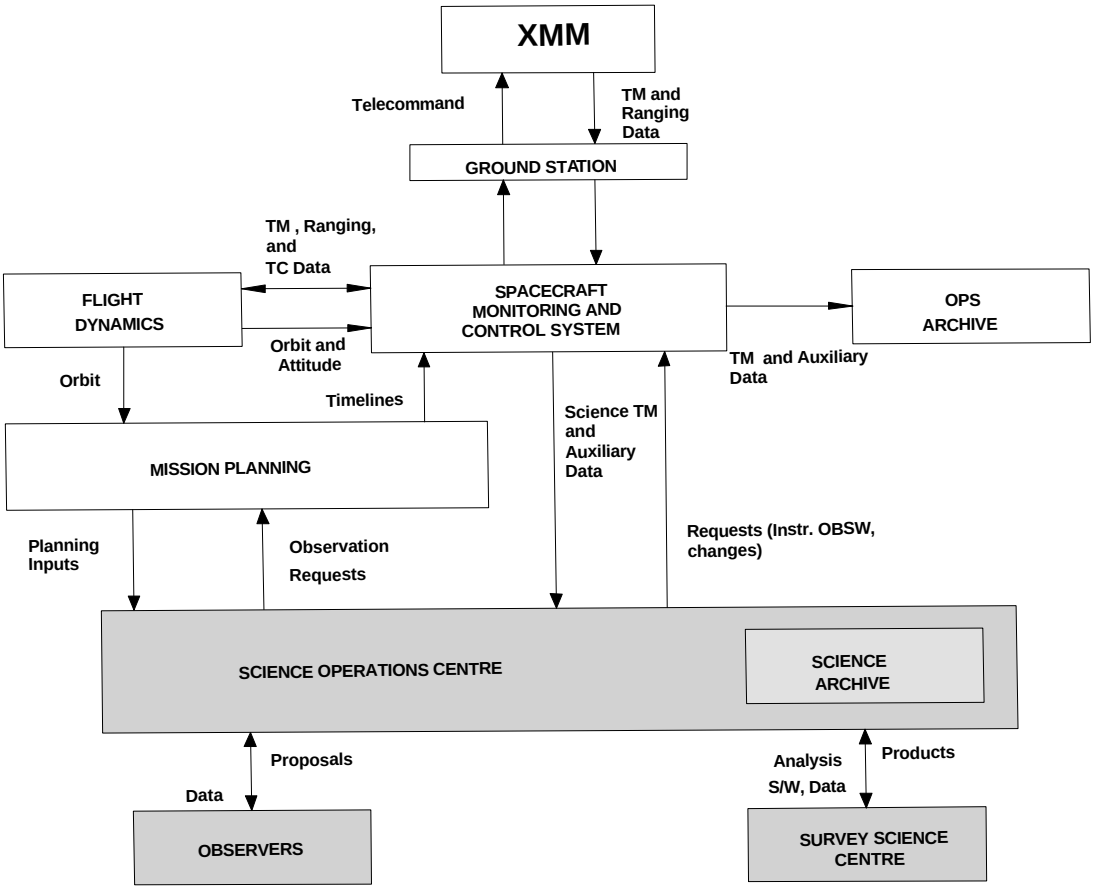

Figure 1 : XMM Ground Segment Overview

3. MISSION OPERATIONS CONCEPT

XMM Mission Operations have been divided into the following mission phases :

- **Pre-Launch Phase** , starting 30 days prior to Launch and terminating at Launch minus eight hours
- **Launch and Early Orbit Phase** (LEOP), starting at launch minus eight hours, including Ariane lift-off, orbital injection, check-out of essential spacecraft functions, performance of first orbit manoeuvre. This phase will last a few days.
- **Switch-on Phase** will include completion of the spacecraft checkout, further orbit manoeuvres and achievement of the operational orbit, initial instrument testing, and opening of the telescope door. This phase will last about 2 weeks.
- **Calibration Phase** will include the initial calibration of all instruments as well as further spacecraft performance testing. This phase will last about 1 month.
- **Scientific Performance Verification Phase** will include determination and demonstration of the Observatory's scientific capability. This phase will last about 2 months.
- **Scientific Mission Phase** will then commence until mission termination. This phase will last 2 years.
- **Post Mission Phase** will commence after mission termination

The XMM SOC operational concept has been split into the following four parts :

- **Mission Planning :** collection and selection of observations which are then passed to the MOC in the form of a Preferred Observation Sequence (POS).
- **Observation Execution :** performing the observation, including on-line modifications.
- **Data Evaluation and Analysis :** on-line monitoring and off-line assessment of the quality of the observation data.
- **Data Archiving :** the storage of and access to all the data and products generated from the mission .

4. SYSTEM DEFINITION

The SOC functional concept is based on a number of different subsystems, each intended to allow the SOC to perform the necessary tasks in the planning, execution and follow up of science operations. The SOC subsystems are as follows :

- The Proposal Handling Subsystem (PHS)
- The Sequence Generation Subsystem (SGS)
- The Payload Calibration Subsystem (PCS)
- The Payload Monitoring Subsystem (PMS)
- The Observation Data Subsystem (ODS)
- The Instrument Software Subsystem (ISS)

- The Archive Management Subsystem (AMS)
- The Interactive Analysis Subsystem (IAS)
- The Pipeline Processing Subsystem (PPS)

Each subsystem is classed as either a Real Time Subsystem or an off-line subsystem, i.e. :

- Real Time subsystems i.e. subsystems involved on-line in real time operations
- Off-line subsystems i.e. subsystems which are primarily used for data analysis

Figure 2 shows a functional overview of the XMM SOC.

4.1 PROPOSAL HANDLING SUBSYSTEM (PHS)

The PHS allows users to create proposals at their home site and to submit for inclusion in the XMM archive. The PHS allows the Proposal Handler to manage the proposals, verify their technical quality, enhance the observations within a proposal and to enter this information and other proposal data into the Proposal information database. This information is used during proposal operational expansion for generation of sequences for each active instrument of an observation.

4.2 SEQUENCE GENERATION SUBSYSTEM (SGS)

For any given revolution the SGS will select proposals from the Proposal Database, order them in time according to various criteria and embed the resulting event sequences into an overall schedule for use in the MOC.

4.3 PAYLOAD CALIBRATION SUBSYSTEM (PCS)

The PCS provides all functions to perform the following calibration activities :

- Calibration of the alignment between the instrument fields of view and the satellite pointing direction, using attitude sensor data and instrument data
- Calibration of the instrument response to selected celestial sources or to internal calibration sources

4.4 PAYLOAD MONITORING SUBSYSTEM (PMS)

The PMS provides the facilities necessary to monitor the instrument status, health and performance in real time, display images, assess the quality of the current observation with respect to success / fail criteria and to submit requests to the Mission Operations Centre (MOC) for changes to the current observation, spacecraft attitude or spacecraft mode. The PMS is the only SOC subsystem having a real time interface with the MOC.

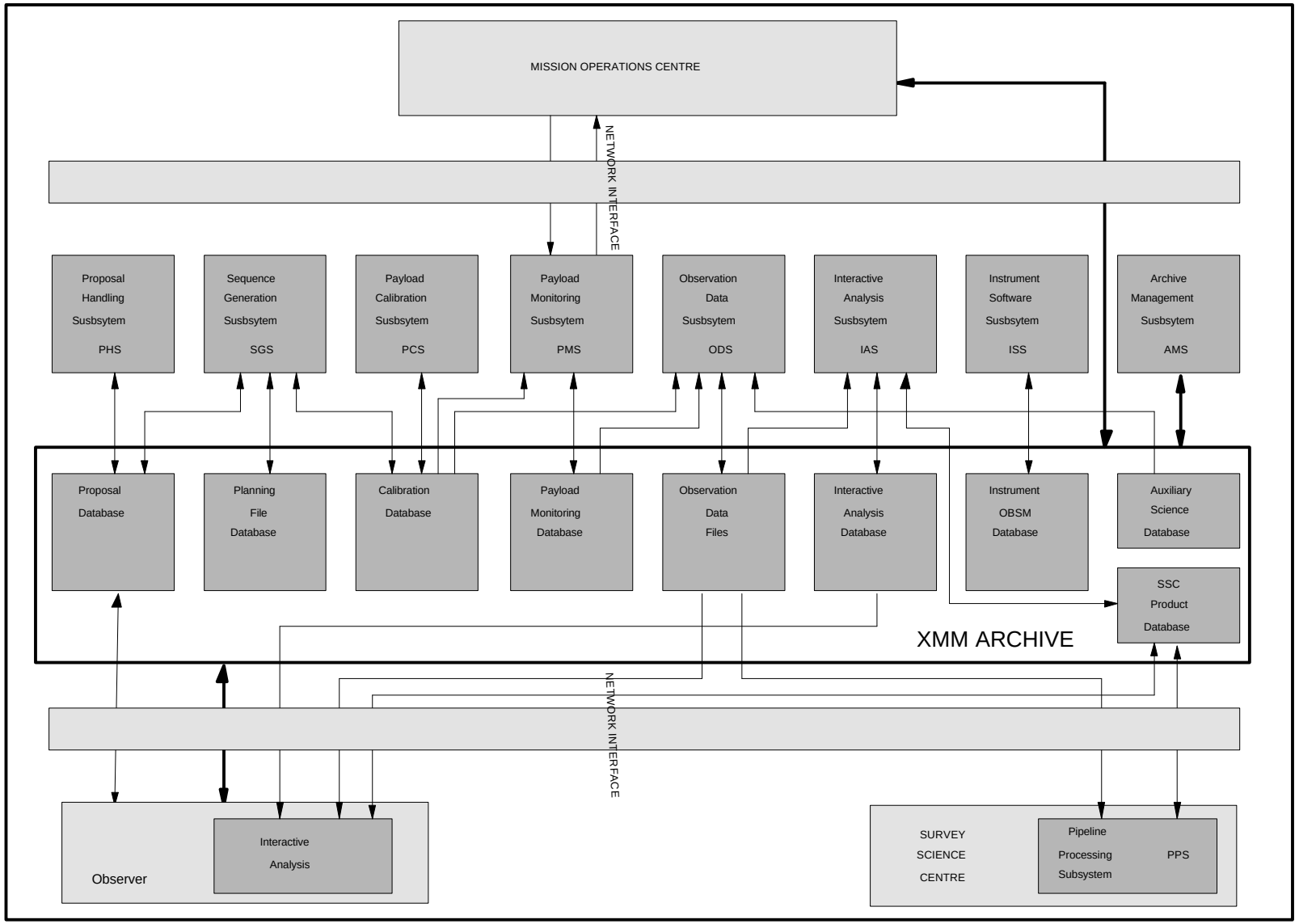

Figure 2 : XMM SOC Functional Overview

4.5 OBSERVATION DATA SUBSYSTEM (ODS)

The ODS provides the facilities necessary to accept all inputs needed for the Observation Data File generation, to assemble the ODF into the required format, to maintain configuration control and to define access rights on the files. The ODS is also responsible for generation of the Slew data Files.

4.6 INSTRUMENT SOFTWARE SYSTEM (ISS)

The ISS will provide all tools and equipment necessary to provide the post launch instrument on-board software maintenance and validation capability. The ISS will be divided in two parts :

- Instrument Software Maintenance Environment (ISME) comprising editors, compilers, linkers, debuggers specific to the language and the processors used.
- Instrument Software Validation Environment (ISVE) utilising the SOC Simulator

4.7 ARCHIVE MANAGEMENT SUBSYSTEM (AMS)

The AMS provides the facilities needed to manage all aspects of the XMM archive, to control access and to maintain configuration control of archived data items. The AMS also provides a general data facility for the collection and processing of Auxiliary Science Data , the generation of inputs to the production of the XMM Express and issue of the AO's. The XMM Archive is the repository for all XMM SOC mission data. Request for access to the archive will be serviced by an archive server. The AMS will provide a configuration control function to ensure reliable and safe storage and retrieval of all archived items. The AMS will allow a number of different categories of users to access the archive via the archive server. The AMS will provide a mechanism to manage and control access to the archive, by means of privileges to prevent unauthorised access to private or mission critical data.

4.8 INTERACTIVE ANALYSIS SUBSYSTEM (IAS)

The IAS will provide all facilities needed to perform interactive analysis on an Observation Data File, selection of Interactive Analysis Tools and storage of results.

4.9 PIPELINE PROCESSING SUBSYSTEM (PPS)

The PPS is the subsystem responsible for the generation of pipeline data products from the XMM data.

5. XMM SOC HARDWARE FACILITY CONCEPT

The hardware facility concept defined for the SOC is described here in terms of the following :

- **Ground Segment Communications**, represented by the communications links between the various elements of the XMM ground Segment

- **Computer Hardware Configuration**, whose concept is as follows :
    - A prime VAX machine with a dedicated standby machine together with front-end SUN workstations will provide the PMS functionality.
    - A set of SUN / UNIX platforms and PCs used as X-terminals with a windowing environment will provide the processing power for all remaining SOC functions.
    - The VAX/SUN/PC will be connected locally by a redundant high bandwidth LAN. This SOC LAN will allow communication between the machines and also provide SOC-wide access to the SOC archive which will be centralised and suitable redundant.
    - Standards peripherals (data storage, printers, juke box) will be connected to the overall system
    - Standard networking equipment (bridges, transceivers, terminal servers)

6. XSCS - XMM SOC CONTROL SYSTEM

Previously, Science Operations Centres have been developed on a mission specific basis. However, for the XMM SOC, it is ESA's intention that use should be made of the SCOS 1B mission control system kernel, software developed for other control centres and public domain / COTS software.

The XSCS will be developed according to ESA Software Engineering Standards Issue 2 [1]. The functionality of the XSCS will be described in a Software Requirements Document which will be based on a set of requirements produced by the users [2].

When analysed, the SCOS 1B functionality corresponding to those of the XMM SOC can be summarised as belonging to the following categories :

- telemetry reception and link management - telemetry receiver and routing
- telemetry processing - telemetry processor, telemetry monitoring, messages and alarms
- data storage - data filing and retrieval, RDBMS, FOP (Flight Operations Procedure) handling
- performance analysis - performance evaluation
- MMI - human computer interface, displays, access control, user configurable functions

The main reason for the use of SCOS 1B is for monitoring of the payloads performed by the PMS.

There exist different science software packages which could be potentially re-used in the PCS / IAS / PPS SOC subsystems. The packages indicated below are currently under consideration for re-use :

- XSPEC
- XRONOS
- XIMAGE
- XSELECT
- IRAF
- MIDAS
- FTOOLS
- SAOimage
- ETOOLS

7. XMM SOC DATA DISTRIBUTION

Data Distribution is performed either automatically or upon request. The science data will be in FITS file format. Distribution itself takes place electronically across a public network by file transfer, or in the case where the data requested is large or there is no network capability by CD-ROM. Security will be ensured at the SOC by implementing a security “firewall” between the data distribution subsystem and the remainder of the SOC.

All the data will be transfer using the mechanisms suggested by the CCSDS Panel 2 recommendations. This has the advantage that the user can browse and see the relationships between separate files, but also is able to access the data files directly for ingestion into his processing software. In addition all the data will be registered with a Control Authority Office, of which ESOC has one assigned for each of the EURECA, CLUSTER and HUYGENS missions already.

8. CONCLUSIONS

This paper describes the requirements of the XMM SOC and discusses how these have affected its design and future implementation. The following considerations have influenced the approach taken :

- Advanced Functionality

  The XSCS is required to support a number of functions which have not previously been provided on systems developed by ESOC.

- Low Risk

  The core functions of the XSCS - PMS (Payload monitoring Subsystem) are based on the re-use of software from previous missions and the ESOC’s infrastructure software.

- Re-usability for future missions

  As the subsystems of any SOC / Data Centre / Archive combination are the same, although they may have different weight and might be handled by different entities, the SOC software will be developed following a modular design and use of standard interfaces such that could be used as building blocks for the support of future ESA missions (Integral, Rosetta, First).

REFERENCES

1. ESA Software Engineering Standards ESA PSS-05-0, Issue 2 (1992)
2. XMM SOC User Requirements Document Issue 1 (1996)