PACKET UTILISATION DEFINITIONS FOR THE ESA XMM MISSION

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ABSTRACT

XMM, ESA's X-Ray Multi-Mirror satellite, due for launch at the end of 1999 will be the first ESA scientific spacecraft to implement the ESA packet telecommand and telemetry standards and will be the first ESOC-controlled science mission to take advantage of the new flight control system infrastructure development (based on object-oriented design and distributed-system architecture) due for deployment in 1995.

The implementation of the packet standards is well defined at packet transport level. However, the standard relevant to the application level (the ESA Packet Utilisation Standard) covers a wide range of on-board "services" applicable in varying degrees to the needs of XMM. In defining which parts of the ESA PUS to implement, the XMM project first considered the mission objectives and the derived operations concept and went on to identify a minimum set of packet definitions compatible with these aspects.

This paper sets the scene as above and then describes the services needed for XMM and the telecommand and telemetry packet types necessary to support each service.

INTRODUCTION

The introduction of packet TM and TC standards (Refs 1 and 2) has lead to a high degree of transparency in the operational interfaces between satellite on-board systems and the related ground systems, offering designers the potential for liberal definition of the data to be transported within TM and TC packets. The complexity of the on-board and ground systems can be greatly influenced by the

- the ***type of interaction*** (or service) and
- the ***structure and content of the packets*** used in this interaction

Only by careful definition of the packet structures and content can it be ensured that the satellite is provided with the information it needs (within command packets) for its operations functions and that the ground is provided with the information it needs (within telemetry packets) for execution of its operational tasks. This becomes even more significant now that satellite systems are increasingly implemented using on-board software.

In preparing for the XMM satellite development programme, it was

necessary to define the on-board services that will be needed to allow the XMM Flight Control System to undertake all mission operations. The services needed are driven by the mission objectives and the associated concept for conduct of the operations needed to satisfy these objectives.

The ESA Packet Utilisation Standard (ESA PUS) (Ref 3) was the reference standard for this the application-level interface and defines a wide range of services considered necessary for all future (unmanned) missions. The process of selecting services from the PUS and tailoring the packet related packet structures to suit the particular needs of any particular mission is referred to as "missionisation".

XMM OPERATIONS CONCEPT

The X-ray Multi-Mirror satellite (XMM) is an observatory in the soft X-ray region of the electromagnetic spectrum and is due for launch on Ariane 5 late in 1999. By virtue of the large collecting area of its telescope and the highly eccentric orbit, XMM will be able to perform long observations (upto 16 hours above 40,000 Km) of X-ray sources with an unprecedented sensitivity.

The satellite and its X-ray instruments will be controlled in real time from the European Space Operations Centre in Darmstadt, Germany, and employing a single ground station, will benefit from upto 22 hours of telemetry and telecommand contact every day. All science and housekeeping data will be transmitted in real time to the control centre for immediate processing (no bulk storage on board). In view of the on-line nature of satellite operations and the nearly continuous visibility from the ground and the desire to minimise on-board complexity, it was appropriate to identify straightforward almost "classical" ways for ground ***on-line control*** of the satellite while making use of the advantages offered by packets. The concept for ***safety management*** during planned (and unplanned) non-contact periods was defined to involve the use of delayed execution (time tagged) commands, a low degree of on-board monitoring and provision of a history of on-board events. Further, it was necessary to provide for ***operations maintenance*** in the form of telemetry management and definition and interaction with on board software.

XMM FLIGHT CONTROL SYSTEMS

A further constraint on definition of the ground/satellite interactions and hence the TM/TC services needed, relates to the Flight Control Systems infrastructure foreseen for XMM. Flight Control Systems for past missions (not utilising packets) involved handling of the individual characteristics of the TM/TC schemes by mission-specific software modules interacting with kernel systems offering basic functions only. These additional modules were needed to convert the peculiarities of the satellite data structures into a form processable within the kernel systems

and understandable to the Flight Operations Teams.

Recent advances in ground system technology (for example in the use of distributed workstation-based control systems and object-oriented techniques) now allow the development of multi-mission control systems offering a palette of services to potential users (missions). By defining data structure standards across the board, commonality between missions can be increased leading to a corresponding reduction in the need for mission-specific elements. This is the ultimate goal of the ESA PUS, a document now entering the approval stage.

The PUS defines the various operational requirements for on board functions and services and goes on to describe the TM/TC packet types and structures needed to support these services. The PUS then defines the format and content of the (variable) "Packet Data Field" being the user-defined part of the packet and including the "Source Data" for telemetry (Figure 1) and the "Application Data" for commands (Figure 3). The PUS further prescribes how the "Data Field Header", within the Packet Data Field is to be used (Figures 2 and 4) : two fixed fields in this header are reserved for identification of the ***Packet Type*** and ***Packet Subtype***. In this way, every packet in the ground or on-board systems is clearly identifiable in terms of its function and the processing needed.

XMM however, with its classical operations concept did not need to take advantage of the wide range of services available within the PUS : using the PUS as a starting point, the XMM project selected those services and related data structures of use in supporting the operational requirements (as documented in Ref 4) for all foreseen XMM mission scenarios .

XMM SERVICES

The services defined for XMM mission operations can be considered to fall into three major categories as follows (as documented in Ref 5):

1) ON-LINE CONTROL

Periodic Housekeeping Telemetry (TM Type 1) is required to permit the ground to derive and monitor the status, health and performance of the satellite systems and instruments.

Device Commands (TC Type 2) are required to configure the on board hardware using two subtypes :

- Pulse commands (Subtype 1)
- Register load commands (Subtype 2).

Telecommand Verification Service (TM Type 3) is required to allow the ground to positively verify all uplinked commands. Dedicated packets are required for each uplinked command indicating

- Successful Acceptance (Subtype 1)

- Unsuccessful Acceptance (Subtype 2)
- Successful Execution (Subtype 3)
- Unsuccessful Execution (Subtype 4)

Non-Periodic Telemetry (TM Type 4) is required to convey information related to non-periodic events (not contained in the periodic telemetry) to the ground. The service must provide for

- Event Reports (Subtype 1) for events of operational significance
- Exception Reports (Subtype 2) for notification of non-fatal errors
- Major Anomaly Reports (Subtype 3) for notification of major on-board anomalies

Task Management Service (TC Type 5) is required to control and interact with on-board software tasks. The service must provide for

- Start task (Subtype 1)
- Stop task (Subtype 2)
- Load task functional parameters (Subtype 3)
- Mode Transition (Subtype 4)

Science Telemetry (TM Type 15) is required to transport data from the XMM science instruments to the ground.

2) SAFETY MANAGEMENT

Time Tag Commands (TC and TM Type 7) are required to effect operations requiring well-defined execution times or which need to be executed in periods of non coverage or to ensure that the satellite is returned to its nominal state after any critical operation. The service must provide for

- Load a command into the time-tag buffer (Subtype 1)
- Report a summary of the contents of the time-tag buffer (Subtype 2)
- Report all commands in the time-tag buffer in detail (Subtype 3)
- Report a selected command in the time-tag buffer in detail (Subtype 4)
- Delete a selected command from the buffer (Subtype 5)
- Delete all commands in the time-tag buffer (Subtype 6)

On-Board Monitoring Service (TC and TM Type 8) is required to monitor a maximum of 30 parameters during periods when the ground does not have visibility of the spacecraft and to retain the results. The service must provide for

- Enable and refresh monitoring (Subtype 1)
- Disable monitoring (Subtype 2)
- Add to monitoring list (Subtype 3)
- Delete monitoring list (Subtype 4)
- Report the monitoring list contents (Subtype 5)
- Report the results of limit/status checks (Subtype 6)
- Report the minimum and maximum values over the period enabled (Subtype 7)

Non-Periodic Packet Storage Service (TC Type 11) is required to store all non-periodic packets (TC verifications reports, event reports, exception reports and major anomaly reports) in a cyclic buffer to permit the ground access to non-periodic packets generated at times when the ground has no contact with the satellite (planned and unplanned). The service must provide for

- Report stored packets (Subtype 1)
- Enable and refresh packet storage (Subtype 2)
- Disable packet storage (Subtype 3)

3) OPERATIONS MAINTENANCE

Memory Maintenance Service (TC and TM Type 6) is required to allow the ground to maintain the on-board software as needed to compensate for hardware failures, to resolve software non-compliance with design requirements, to account for new requirements or to enhance system performance. The service must provide for

- Load memory (Subtype 1)
- Dump memory (Subtype 2)
- Calculate Memory Checksum (Subtype 3)

Telemetry Management Service (TC and TM Type 9) is required to manage generation of telemetry packets by any particular application (on board subsystem or instrument). The service must provide for

- Report packet generation status (Subtype 1)
- Enable generation of all TM packets (Subtype 2)
- Disable generation of all TM packets (Subtype 3)
- Enable generation of specific TM packets (Subtype 4)
- Disable generation of specific TM packets (Subtype 5)

Telemetry Definition Service (TC and TM Type 10) is required to allow the ground to define new housekeeping packets (for the satellite systems only) if necessary for troubleshooting or anomaly rectification. The service must provide for

- Report new housekeeping packet definitions (Subtype 1)
- Define new housekeeping packet (Subtype 2)
- Delete new housekeeping packet definition (Subtype 3)

Test Commands (TC Type 13) are required to confirm that the on-board link to any application is alive.

DATA STRUCTURES

The definition of packet types is only completed when the data structures needed for each of the identified packets types and subtypes are expanded down to field level as is foreseen in the PUS. The purpose of each field, its length and its format must finally be agreed between satellite system and ground system developers. This final stage in the missionisation process for XMM has been initiated and is also documented in Ref 5.

CONCLUSION

This paper has summarised the way in which the XMM project has gone about selecting the on board services needed to fulfil the objectives of the mission and has outlined the data types defined in support of those services. One can draw three distinct conclusions from this process :

- Data required for the execution of satellite mission operations must comply with certain standards if it is to ensure that such operations are conducted in a safe and reliable manner.
- The structures defined for the transport of the data must follow established guidelines if the full advantages of the packet telemetry and telecommand standards are to be realised.
- Compliance with the derived packet structure requirements must be established across the whole satellite at system level if the benefits in common data structure definitions are to be felt in ground system development.

REFERENCES

1 ESA Packet Telemetry Standard (PSS-04-106, Issue 1, January 1988)

2 ESA Packet Telecommand Standard (PSS-04-107, Issue 2, April 1992)

3 ESA Packet Utilisation Standard (PSS-07-101, not yet approved)

4 XMM Operations Interface Requirements Document (XMM Ref : RS-PX-0028, Issue 2a, March 1994)

5 XMM Packet Structure Definition (XMM Ref : RS-PX-0032, Issue 2, 29 June 1994)

KEYWORDS

Packet Utilisation, Packet Structures, Missionisation, TM Packets, TC Packets, XMM

ACKNOWLEDGEMENTS

The author wishes to acknowledge the efforts made in the establishment of the XMM OIRD and the XMM PSD by members of the XMM Project at ESTEC and of the XMM team in ESOC.

SOURCE PACKET HEADER (48 bits)						PACKET DATA FIELD (VARIABLE)		
PACKET ID				PACKET SEQUENCE CONTROL		PACKET LENGTH	DATA FIELD HEADER	SOURCE DATA	PACKET ERROR CONTROL (Optional)
Version Number	Type	Data Field Header Flag	Application Process ID	Segment-ation Flags	Source Sequence Count				
3	1	1	11	2	14				
16				16		16	Variable	Variable	Variable

Figure 1. Telemetry Source Packet Fields (from Ref 1)

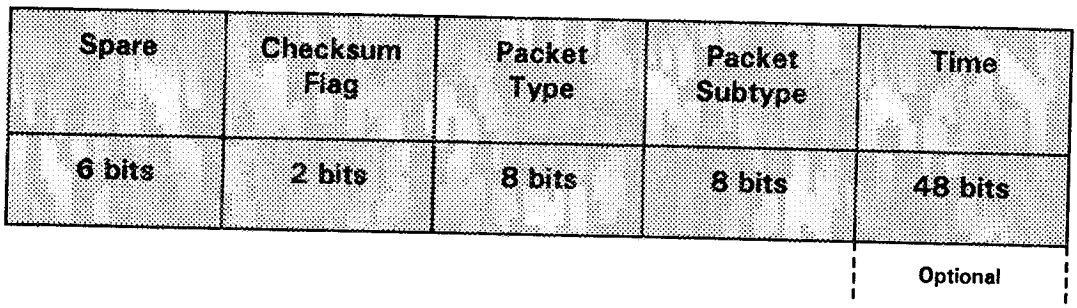

Figure 2. Telemetry Packet : Data Field Header (from Ref 5)

PACKET HEADER (48 bits)							PACKET DATA FIELD (VARIABLE)		
PACKET ID				PACKET SEQUENCE CONTROL		PACKET LENGTH	DATA FIELD HEADER	APPLIC-ATION DATA	PACKET ERROR CONTROL (Optional)
Version Number	Type	Data Field Header Flag	Application Process ID	Sequence Flags	Sequence Count				
3	1	1	11	2	14				
16				16		16	24	Variable	16

Figure 3. Telecommand Packet Fields (From Ref 2)

Spare	Checksum Type	Ack	Packet Type	Packet Sub-Type
2	2	4	8	8

Figure 4. Telecommand Packet : Data Field Header (from Ref 5)