XMM END-TO-END SYSTEM

FOR ON-BOARD TIME REFERENCE

PX-TN-00523

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Aug 96	3	All pages. - New accuracy requirements. - New STSP frequency - OBDH design freeze

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REFERENCE DOCUMENTS

RD1 Packet Telemetry Standard, ESA-PSS-04-106, issue 1, 1988

RD2 Standard RBI chip for OBDH interface, RBI-HAF-12663 / ESA-SCC-9544006.

RD3 Time Code Formats, CCSDS 301.0-B-2, issue Blue Book, issue 2, April 1990

RD4 Digital Bus Interface specification, THB/APO/K2/1386/av

RD5 XMM ph. B ITT, Experiment Interface Document, part A, RS-PX-0016, issue 2, February 1993

RD6 OBDH Bus Protocol Requirement Specification, XM-IF-DOR-0002, issue 4, 25/4/96

RD7 XMM Packet Structure Definition, PX-RS-0032, issue 5.2, March 1996

1 INTRODUCTION

This note presents the end-to-end time reference system as planned for the XMM spacecraft system. It describes the required onboard and ground based functions to allow the on board generation of timestamps with a certain accuracy and their correlation to UTC.

2 ONBOARD SYSTEM

On board the spacecraft there will be one central clock giving the Spacecraft Elapsed Time, SCET. The central clock will be located in the CDMU of the OBDH system and shall be the reference source of time information on board the spacecraft.The time distribution of XMM shall make use of the built-in time functions of the RBI component, which maintain local SCET copies. No other time system will be supported by the spacecraft.

The reconstructed CDMU clock frequency is provided to the experiments and the AOCS as a signal derived from the OBDH bus clock which in turn is driven by the central clock in the CDMU of the OBDH system. The frequency of this signal will be 524288 Hz (2^{19} Hz). This signal is used to increment the counter in the RBI chip.

The time conter in the RBI chip will after synchronisation with the CDMU always contain a copy of the SCET.

Two BroadCast Pulses (BCP) of the interrogation format have been allocated for synchronization. The BCPs are recovered from the interrogation formats by the RBI function. BCP2 provides a 1 Hz signal to which the subsystems synchronize when BCP2 is preceeded by a pulse on BCP3.

The OBDH sends a BCP4 to verify that the subsystems are synchronized to the central clock. The subsystems should on detection of a BCP4 pulse sample the clock register and generate a time verification packet.

3 TIME REFERENCE

Ideally all time information should be based on an absolute time reference such as the Universal Time Code, UTC. Such an approach would simplify the process of relating on board events to other events in the universe. However, the complexity of UTC, eg the existence of 'leap' seconds, would introduce complex operational procedures to maintain the correct UTC time on board the spacecraft. This makes UTC less attractive for on-board implementations. Another inconvenience with the 'leap second' is that elapsed time measurements are made more difficult.

For XMM a free running clock counting Spacecraft Elapsed TIme, SCET, is defined. The central clock is reset to zero and started at CDMU power on. The clock register cannot be corrected by telecommand. As a result the time may make 'jumps' when the clock register is hit by a Single Event Upset, SEU. The clock register is reset to zero if the CDMU is reset.

The frequency of the central oscillator shall not be adjusted in the operational phase. As a result the 'XMM second' my differ slightly from a real second. This does not affect the accuracy of time stamps. Since there will be a continous process of relating SCET to UTC, it is unimportant at which rate (as long as it is bounded) the SCET is incremented.

The latter approach has the advantage that there will be no discontinuities in the operation of the clock. On the other hand all errors will be accumulated and the relation to UTC will vary with the lifetime of the spacecraft. For this reason there will be a continous and regular process of relating SCET to UTC, which is described in more detail in section 6 below.

4 TIME FORMAT

All time information shall be based on seconds and binary fractions of seconds. The format shall be CCSDS Unsegmented time Code, CUC, as defined in RD1, p.43. For computer displays this may be converted into mission elapsed days hours etc. The mission elapsed time can then be converted into any time code such as Central European time.

The central clock will be implemented as a digital counter, made up of two parts, a coarse time counter and a fine time counter. The coarse time counter holds the 'XMM seconds' and the fine time holds binary fractions of an 'XMM second'. The fine time counter is incremented by the spacecraft central oscillator. The coarse time counter is incremented each second when the fine time counter wraps around. The read out value of the time counters will be the elapsed time since reset.

The central clock shall not wrap around during the XMM extended mission (10 yrs). As a result four octets of coarse time are required for the XMM mission (wrap around time approximately 120 years).

The XMM requirement on time accuracy, as stated below, is 100 μs. To meet this requirement two octets of fine time (with a resolution of 2exp-16 sec, ie approx. 15 μs) should be implemented.

Coarse Time				Fine Time	
000xxxxx	xxxxxxxx	xxxxxxxx	xxxxxxxx	xxxxxxxx	xxxxxxxx

figure 4-1 Central clock time format.

Local copies of the central clock do not need to implement the full format of the central clock.

5 CORRELATION TO UTC

In order to correlate SCET to UTC, standard time source packets will be transmitted from the OBDH to ground at regular intervals. The spacecraft central clock will be sampled at a known instant, T_{SCET}, relative to the instant of occurance of the leading edge of the first bit of the attached synchronization marker of the telemetry transfer frame of virtual channel 0 with a virtual channel count multiple of 16.

The SCET reading will then be packetized and transmitted to ground before next sample of the central clock is taken. For XMM a standard time source packet will be generated every 16th telemetry transfer frame of virtual channel 0. Considering that the minimum datarate on VC0 is of 4Kbps and with TM transfer frame length of 882 octets, this would correspond to a standard time source packet every ~30 seconds (during nominal operations the data rate in VC0 is going to be ~6Kbps increasing the standard time source packet frequency to every ~20 seconds).

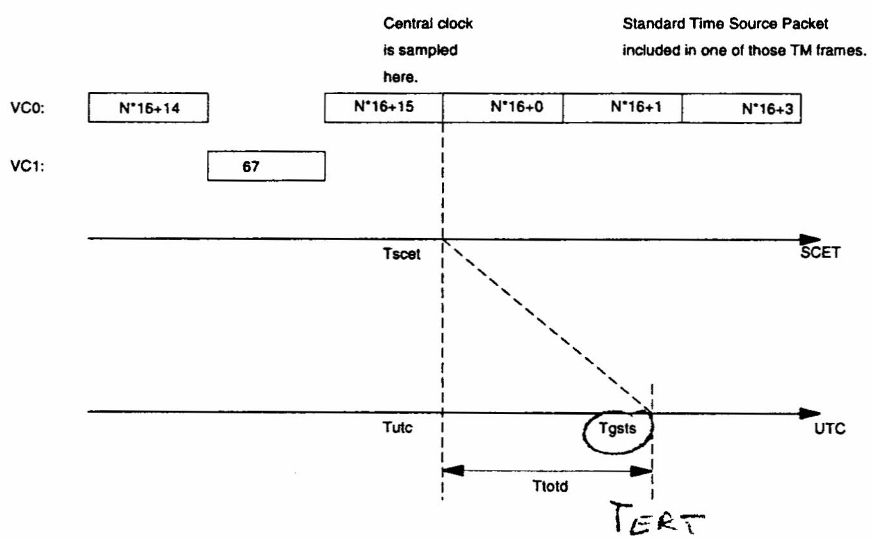

figure 5-1 Relating SCET to UTC, VC frame counts are provided inside the 'transfer frame boxes'.

The ground station will time stamp all transfer frames~~ of VC0 with frame count multiple of 16 upon reception~~. In doing this the ground station shall use a high accuracy UTC clock. ~~The ground station will then associate the ground station time stamp, t_{GSTS}, with the SCET sample, t_{SCET}, retrieved from the standard time source packet.~~ The time couple will then be forwarded to the mission control centre.

Earth reception time t_{ERT}

~~& By doing this~~,

The MOC will extract STSP from VC0 frames with counter mod 16 = 0 and associate ~~it with~~ SCET with t_{ERT}.

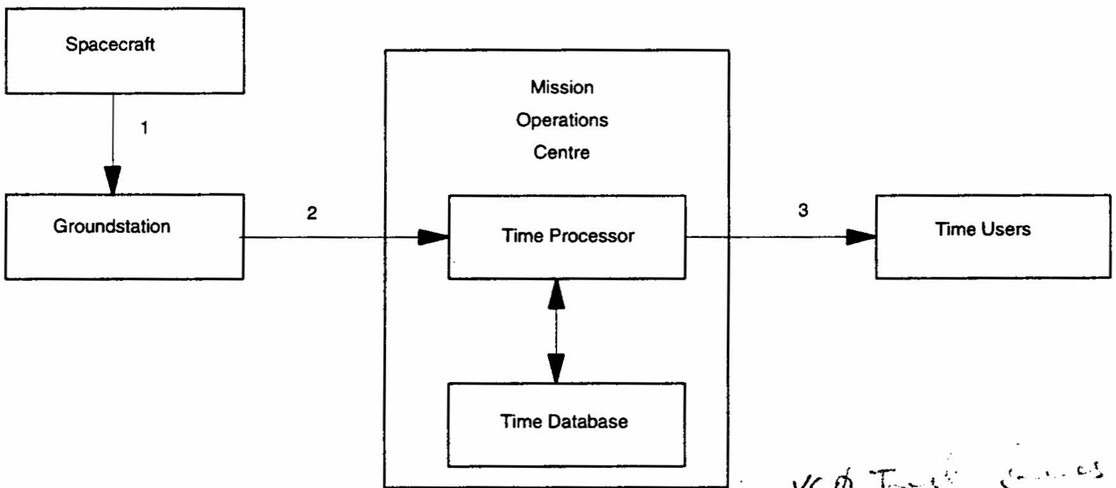

figure 5-2 Correlation of SCET to UTC. Legend to the dataflows indicated in the figure: 1: Standard Time Source Packet (t_{SCET}) 2: ~~Standard Time~~ Source Packet and the associated Ground Station Time Stamp (t_{SCET} and t_{GSTS}) and 3: Parameters for the Time Correlation Procedure.

The mission control centre will record all time couples and calculate the total delay, t_{TOTD}, between the moment of sampling the spacecraft central clock, t_{SCET}, and the moment of time stamping in the ground station, t_{GSTS}. The total delay includes delays onboard the spacecraft, the propagation delay from the spacecraft antenna to the ground station antenna and the ground station internal delays. The propagation delay is calculated as a function of the slant range of the spacecraft.

The above procedure allows the mission control centre to calculate, for each SCET sample, the corresponding UTC time, using the equation below:

$$t_{SCET} \Leftrightarrow t_{UTC} = t_{\overset{ERT}{\cancel{GS}}TS} - t_{TOTD}$$

The mission control centre will record the so obtained SCET-to-UTC couples and calculate the trends. The parameters of the resulting first order equation will be distributed to the users. The frequency at which the parameters will be distributed will depend on the stability of the on board oscillator and the accuracy requirements, typically the parameters will be updated with a period of 1 minute (TBC).

6 TIME CONVERSION PROCEDURE

On board events will be time stamped by the payload (and the spacecraft) with SCET. The SCET time stamps will be included in the telemetry and received by the end users of the data. The required parameters to convert the SCET time stamps to UTC are provided to the users by the Mission Operations Centre on the format given in the figure below.

SCET [CUC]	UTC corresponding to SCET			Scale Factor (SF) ?
	day	ms of day	μs of ms	δ UTC / δ SCET
6 octets	2 octets	4 octets	2 octets	4 octects

figure 6-1 Parameters for SCET to UTC conversion distributed to the users.

The UTC time references shall be provided on the CCSDS Day Segmented time code (CDS) with optional as defined in [RD3]. The epoch for the UTC time references shall be 1958 January 1.

The scale factor shall be provided as Real type 32-bit single format according tp ANSI/IEEE Std 754-1985, and PC(5,1) in RD7.

The parameters shall generated in the XMCS and transmitted as ground packets inserted in the XMM TM stream between the XMCS to the XSCS. They should be stored in a table or data base for use in the XMCS and the relevant streem of values appended to the Observation Data Files distributed to the users. The SCET translation to UTC shall be performed by linear interpolation.

To generate time tag command execution times and when the parameters of the Time Conversion Procedure are not available it will be necessary to extrapolate.

7 TIME ERROR BUDGET

The UTC time calculated from a SCET time stamp will have a limited accuracy. The total requirement for the accuracy is of 100 μs. These have been allocate as 50 μs on board inaccuracy and 50 μs on ground. The contributing factors and estimate of the of magnitude of those factors is listed below.

On board inaccuracy:

Eosc	4 μs	max drift of the central clock between two correlations
Edist	11 μs	on board time distribution delays from central clock to the subsystems.
Ecdms	9 μs	on board errors in the CDMS, ie inaccuracy of SCET sample with respect to start of transfer frame
Total on-board	**24 μs**	

On Ground inaccuracy:

Etrans	33 μs	propagation delay errors, ie inaccuracies in the knowledge of the slant range. (33 μs corresponds to 10 km) (TBC)
Egs	5 μs	ground station errors (TBC)
Ecalc	10 μs	interpolation / extrapolation errors (TBC)
Total On Ground	**48 μs**	(TBC)

The total error is thus estimated to be less than 72 μs.

8 PERFORMANCE REQUIREMENTS

It shall be required that a user SCET time stamp can be converted to UTC with a maximum error of 100 μs.

During and immediatelly after a non-contact period the absolute time error may exceed 2ms (but not 100ms TBC). In spacecraft survival mode the time error shall not exceed 500ms (TBC).

In the timing budget provided above 4 μs are allocated to oscillator drift error. This is in line with the requirement for the equipment of <= $1.5 * 10^{-7}$ in 2h time interval (e.g. 1ms/2h calculated over 30 seconds maximum interval between Standard Source Time Packets.

If the correlation parameters are generated less frequently than every Standard Source Time Packet, then the oscillator might drift proportionally.
With the current estimations, there are 28 μs of total margins in the error budget, theoretically allowing the correlation to be performed every 240 seconds.
Considering the uncertainty of the various errors in the budget, it is proposed to minimise the period for which the conversion parameters are valid. The shortest period that could be considered is the time elapsed between two standard time source packets, for XMM this is <30 seconds.

9 ON-BOARD TIME DISTRIBUTION

The electrical user interface for time distribution is implemented in the Digital Bus Interface, DBI, specified RD4 and RD5. The time distribution of XMM shall make use of the built-in time functions of the RBI component [RD2].

The reconstructed CDMS clock signal is provided via the Digital Bus Interface, DBI. The clock frequency is provided on the DBI signal RIR-CLK. This clock signal is derived from the OBDH bus Litton code which in turn is driven by the central clock in the CDMS node of the OBDH system. The frequency of this signal will be 524288 Hz (2 ^ 19 Hz).

Two BroadCast Pulses, BCPs, of the interrogation format have been allocated for synchronization. The BCPs are recovered from the interrogation formats by the RBI function. BCP2 provides a 1 Hz signal to which the subsystems synchronize when BCP2 is preceeded by a pulse on BCP3.

The OBDH sends a BCP4 to verify that the subsystems are synchronized to the central clock. The subsystems should on detection of a BCP4 pulse sample the clock register and generate an on-board-time verification packet.

To synchronize the subsystems the OBDH performs the following sequence of actions:

1/ The OBDH sends a telecommand packet instructing the user to enable the time synchronization function.

2/ The OBDH sets BCP3 to instruct the user to reset its clock register at the occurance of next BCP2.

3/ The OBDH sends a BCP2. The user then resets its clock register and increments the register with the clock frequency signal provided on the DBI interface.

4/ The OBDH sends a telecommand packet with a copy of the Central Clock reading taken at the moment the user clock register was reset. The user adds central clock reading to the current contents of its clock register.

The details of the Synchronisation and the verification procedure are defined in RD6.

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