Nationaal Lucht- en Ruimtevaartlaboratorium
National Aerospace Laboratory NLR

NLR-TP-98236

Test and Verification Equipment for the Attitude & Orbit Control System of the XMM satellite

H.A. van Ingen Schenau, L.C.J. van Rijn and J. Spaa

Nationaal Lucht- en Ruimtevaartlaboratorium

National Aerospace Laboratory NLR

NLR-TP-98236

Test and Verification Equipment for the Attitude & Orbit Control System of the XMM satellite

H.A. van Ingen Schenau, L.C.J. van Rijn and J. Spaa

This report is based on a presentation to be held on the DASIA 98 Conference, DAta Systems In Aerospace, organised by EUROSPACE, 25-28 May 1998, Athens, Greece.

Division:	Space & Informatics
Issued:	March 1998
Classification of title:	Unclassified

Contents

(11 pages in total)

TEST AND VERIFICATION EQUIPMENT FOR THE ATTITUDE & ORBIT CONTROL SYSTEM OF THE XMM SATELLITE

by
H.A. van Ingen Schenau, L.C.J. van Rijn, J. Spaa

National Aerospace Laboratory NLR
P.O. Box 153, 8300 AD Emmeloord, The Netherlands
Tel. +31 527 248 218; Fax: +31 527 248 210
E-mail: ingen@nlr.nl; lvrijn@nlr.nl; spaa@nlr.nl

ABSTRACT

The National Aerospace Laboratory NLR in the Netherlands has developed a new generation of Test and Verification Equipment (TVE) for testing of Attitude and Orbit Control Subsystems of spacecraft. Based on a prototype TVE developed for ESA, test equipment has been developed for Matra Marconi Space for AOCS subsystem and system level testing of the XMM and INTEGRAL scientific satellites.

This paper describes the test concept and the architecture of the XMM test system with its main features, the incremental development and delivery, and experiences obtained during development and use of the system. The described work has also been performed under ESA contract.

1. INTRODUCTION

Based on experiences with the production and use of various test systems for the ISO, SAX, SOHO and other satellites, the National Aerospace Laboratory NLR in the Netherlands has developed a new generation of generic Test and Verification Equipment (TVE) with re-usable hardware and software for testing of Attitude and Orbit Control Subsystems (AOCS) of spacecraft [Ref. 1].

The TVE had to be usable from the early stage of the AOCS development up to the integration of the AOCS in the spacecraft environment i.e. open loop tests with a single unit up to closed loop tests with any combination of real and simulated AOCS units should be supported.

A prototype TVE was built for ESA/ESTEC to demonstrate the new approach with re-usable hardware and software [Ref. 2]. This prototype has recently been developed into a fullblown AOCS test system able to meet the requirements for both subsystem and system level testing of the AOCS of the XMM and INTEGRAL satellites.

2. TEST CONCEPT

Figure 1 gives a schematic overview of a generic AOCS for spacecraft. The diagram reflects the cyclic nature of the AOCS. A complete AOCS, together with dynamics and environment can be considered as a loop which is actively closed by the Attitude Control Computer (ACC).

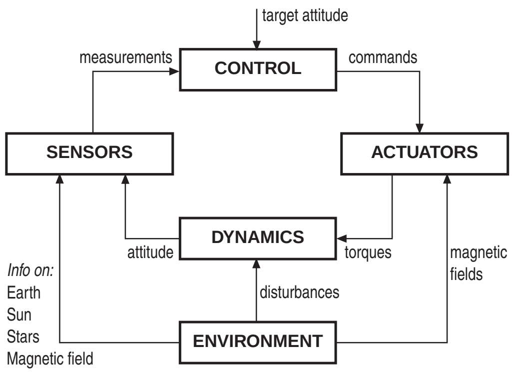

Fig. 1 Generic attitude control system

In the integration and test phase the AOCS subsystem is gradually built up depending on the schedule of incoming units. Verification of attitude control modes and real-time behaviour is done in the early period of integration using a combination of real and simulated units.

The test concept described in this paper is based on a static closed loop test facility (no real motion). The test configuration is shown in figure 2. The dynamics and environment simulation is responsible for the computation of stimuli for the sensor units and the processing of monitor data from the actuator units. The stimulated sensors will deliver sensor measurements to the ACC via the MACS attitude control databus. In the ACC the received data will be fed into the attitude control laws, which results in commanding of the actuator units. The response of the actuator units is measured with a monitoring device and routed back to the corresponding dynamics and environment model. In this way the loop is closed.

The MACS interface has to be programmable to reflect any combination of real and simulated units. If real sensor and/or actuator units are not available they are to be simulated with the MACS unit simulator function.

Integrating sensor units requires in addition a test interface that allows the sensor unit to sense physical stimuli, e.g. optical stimuli for a fine sun sensor. In a static test bench the sensor head can be bypassed. The stimuli signals are then fed into the sensor electronics.

For actuator units a similar situation occurs. The actuator is mostly not used, and the outputs of the actuator electronics are monitored by test electronics and fed into simulation software that computes the effect on the satellite dynamics.

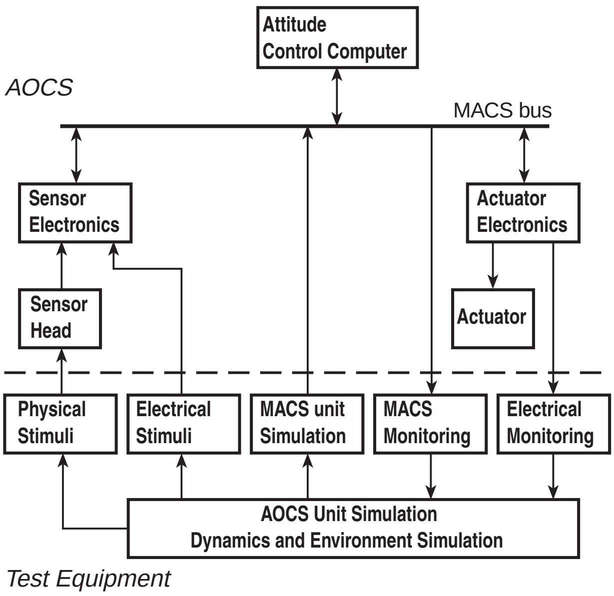

Fig. 2 Test configuration

The test configuration allows static closed loop simulation of an AOCS with real hardware in the loop and provides access to all important data in order to measure the behaviour of the AOCS. Stimuli, monitoring and simulator data are available and all MACS bus events can be read by the MACS monitoring function.

3. XMM

3.1 The AOCS of the XMM satellite

The X-Ray Multi-Mirror (XMM) satellite is the second cornerstone mission in the ESA Horizon 2000 scientific programme which is due for launch in the latter half of 1999. XMM is an observation satellite dedicated to the study of the soft X-ray part of the electromagnetic spectrum. To allow long uninterrupted observations, without disturbances generated by the earth radiation belts, the satellite will be placed into a highly eccentric 48 hours geosynchronous orbit.

The XMM AOCS consists of various sensors and actuators linked by a Modular Attitude Control System (MACS) bus to the ACC. The AOCS interfaces to the Power Distribution Unit, to the Reaction Control System, and via the On-Board Data Handling (OBDH) bus to the OBDH subsystem. The ACC provides the nominal control functions of the AOCS and contains the AOCS software. It is controllable by the ground via the OBDH bus. Its main functions are: OBDH Telecommand execution, generation of OBDH packet Telemetry, execution of control algorithms and generation of MACS bus instructions.

Matra Marconi Space (MMS) in Bristol as the AOCS contractor is responsible for verification of the AOCS at subsystem level. The verified AOCS system is delivered by MMS to Dornier Satellitensysteme in Friedrichshafen, the spacecraft prime contractor, who is responsible for verification of the AOCS at a system level. The Test Equipment (T/E), both for subsystem and system level testing is developed by NLR under a subcontract to MMS.

3.2 XMM AOCS Test Equipment Requirements

In this section the main requirements for the XMM T/E are summarized [Ref. 3].

The XMM T/E should comprise all electrical ground support equipment needed to support AOCS subsystem testing during the integration and verification programme at subsystem and system level. The T/E for subsystem level testing is called AOCS Electrical Ground Support Equipment (EGSE), for system level testing it is called AOCS Special Check Out Equipment (SCOE).

At start of the XMM AOCS T/E development, MMS already had developed and validated software to simulate the environment, dynamics, and AOCS units. The T/E should allow easy integration of this Simulation Software (SSW) without significant modifications to reduce validation effort.

The introduction of hardware in the loop required several safety measures. The most important are that all electrically connected interfaces are to be equipped with overvoltage protection and current limiting circuitry, and that stimuli as well as monitor interfaces are to be optically isolated.

Another major requirement on the T/E was the possibility for 40 Hz closed loop simulation including electrical stimuli and monitoring, asynchronous to the AOCS cycle.

To support efficient testing, the T/E was required to be easy configurable in terms of AOCS hardware configuration, Telemetry (TM) and Telecommand (TC) definitions, initial conditions and test set-up. It should be possible to use manual and automatic test procedures written in a high level language.

An extensive Graphical User Interface was required to provide access to all important data flows. Especially monitoring of MACS bus traffic, TM and model data was important. The T/E was also required to be able to register selections of the above mentioned data for post-run analyses.

The T/E should support testing of autonomous operations of the AOCS for 72 hours. System stability and data archiving capabilities should match these long duration tests.

For system level tests control resides with the spacecraft Core EGSE. This means that the SCOE should be equipped with a suitable Core EGSE Interface. At this stage, the AOCS is integrated within the satellite. As a result, TM/TC is routed differently. TM is acquired from a dedicated TM/TC Front End, TC is routed via the Core EGSE.

To facilitate easy migration from subsystem to system level tests, re-use of test scripts and the TM/TC definitions was required.

4. ARCHITECTURE OF THE XMM T/E

The T/E is composed of the modules: Front End (FE), Test Software (TSW) and Simulation Software (SSW). These modules are shown in figure 3.

The FE contains interfaces to the MACS and OBDH buses and dedicated stimuli and monitoring electronics for connection to the sensor and actuator units.

The main function of the TSW is the automated execution of real-time tests. The TSW has a window-based user interface and offers all relevant data handling i.e. conversion, routing, monitoring, display and archiving. Also graphical user interfaces for post processing are provided.

The SSW is responsible for simulation of the satellite dynamics, the space environment and missing AOCS units.

Within figure 3, three levels of data presentation can be distinguished in the path from the tester towards

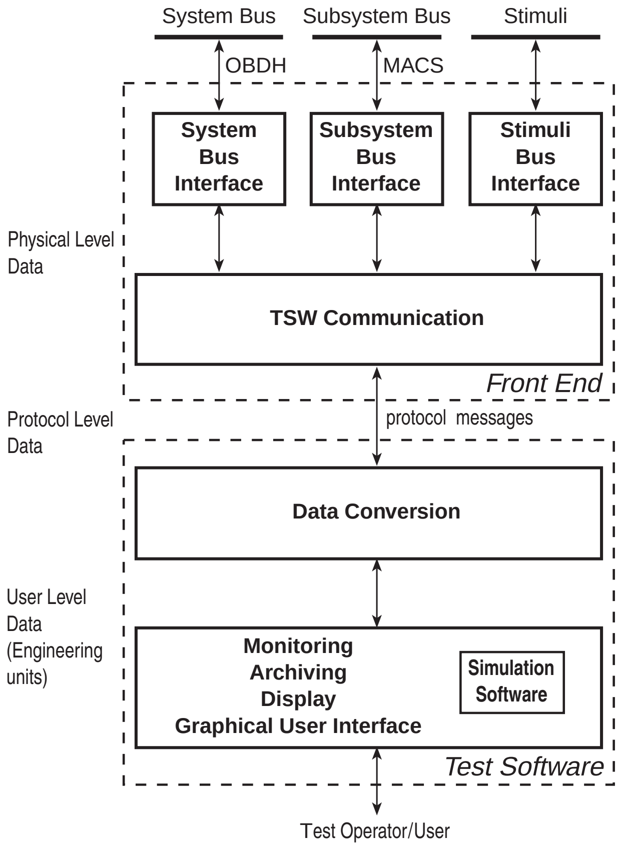

Fig. 3 Architecture of the Test Equipment

the interfaces with the AOCS system.

- The first data level is the user level. Test data is specified using engineering data types like velocity, voltage, angles, etc. On this level the SSW interfaces with the TSW.
- The second data level is the protocol level. All data exchange between the TSW and the FE takes place via protocol messages. The data conversion takes care that the protocol level data presentation is effectively hidden from the user.
- The third data level is the physical level. In the FE all received protocol messages are processed and result in the appearance of the corresponding commands on the MACS and OBDH bus, and electrical or physical stimuli for the AOCS system. The FE monitors (selected parts) of MACS and OBDH bus traffic, and actuator signals. The collected data is converted back to the protocol level.

4.1 Front End

The FE is a modular VME system. It provides interfaces to the OBDH bus, the MACS bus and the stimuli and monitoring interfaces of the AOCS units. All interfaces are built in two layers: a low-level

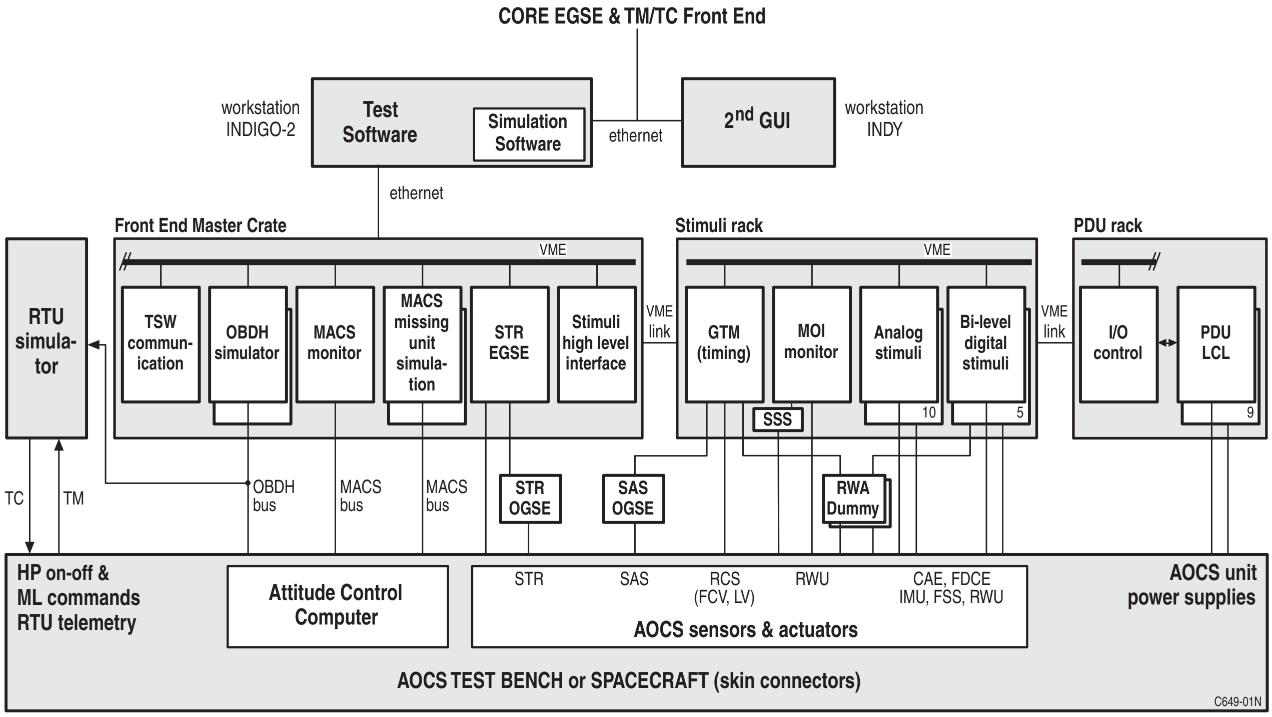

Fig. 4 XMM Test Equipment

hardware interface and a high-level protocol processor. The low-level boards contain specialised electronics matching the high satellite bus frequencies. The high level general purpose single board computers handle the conversion from bus hardware signals to the protocol data level, including buffering and time-tagged execution. The high-level protocol processors allow inclusion of project-specific middle-level protocols, such as the OBDH Remote Bus Interface protocol.

The AOCS EGSE FE consists of four major components: FE Master crate, Stimuli and monitor equipment, Power Distribution Unit (PDU) simulator, and Remote Terminal Unit (RTU) simulator. The first three are housed in VME crates inter-connected via VME extenders. The AOCS SCOE FE is not equipped with the PDU Simulator and the RTU simulator.

A detailed overview of the XMM Test Equipment is given in figure 4.

4.1.1 Front End Master crate

The FE Master crate houses high level VME processor boards and low level VME interface boards. These comprise the following modules:

- TSW Communication module which routes the protocol messages.
- OBDH interface which controls the acquisition of TM, transmission of packet TCs and the simulation of OBDH bus services to the AOCS computer.
- MACS interface which monitors all MACS bus traffic and contains a programmable MACS simulator for the replacement of up to 32 missing AOCS units. The MACS interface allows time tagged transactions and selective monitoring using instruction qualification masks.
- Stimuli high-level interface to control the Stimuli and Monitoring Electronics and the PDU Simulator.
- Star Tracker EGSE interface to control the Star Tracker electronics, and to stimulate the Star Tracker via the Optical Ground Support Equipment (OGSE). The Star Tracker equipment is developed by Officine Galileo. The Star Tracker EGSE and the OGSE together provide the physical stimuli for the Star Tracker.

Communication between CPUs on the high level processor boards takes place with 16 Mbps.

4.1.2 Stimuli and Monitoring Equipment

The Stimuli and Monitoring equipment has interfaces with the electronics of real (physical) AOCS units to support hardware-in-the-loop testing. VME boards with generic input and output channels were developed.

Circa 140 channels are available, a.o. bi-level current/voltage stimuli and high resolution current stimuli sources. These channels have fully isolated test interfaces and overvoltage and overcurrent protection.

Type VME board	Range (adjustable)	Accuracy	Nr.	Stimuli & monitoring channels
ASI boards Analog Stimuli	-50to+50mA	0.002 % + 0.001 % /°C FSR	12	CAE
	0to+50mA		5	FDCE
5 channels/ board	-16to+16mA		8	IMU stimulation
	-333to 0μA		16	Fine Sun Sensor
calibration per channel	-11to+11V		8	IMU simulation
BSI boards Bi-Level Digital	0/13 V	1 %	4	RWU (Direction)
	0/-40 μA	1 %	32	FSS (Coarse)
12ch./board	0/18to32mA	1 %	22	FSS optical I/F
GTM board Timing	40 Hz SYNC		1	Simulation Cycle
	0 to 16kHz		4	Tacho simulation (RWA dummy)
	LV, FCV "ON" time	4 %	10	RCS-El. simulator
	TTL		6	SAS OGSE laser diodes switching
MOI board Monitor	0 to 5V	0.02 %	4	WDE magn. signal
	0/ 5V bilevel	1 %	4	WDE polarity signal
	ON/OFF		3	Separation Signal switches
	HCMOS		1	Suspend/go signal

Table 1: Characteristics of stimuli and monitoring test interfaces

Table 1 gives the characteristics of the stimuli and monitoring test interfaces. The Stimuli and Monitoring main functions are:

- Electrical and optical stimulation of AOCS sensors for open and closed loop testing, e.g. for gyro's (IMU), fine sun sensors, sun acquisition sensor.
- Monitoring of the drive currents of the Wheel Drive Electronics and simulation of reaction wheel speed. Reaction Wheel Assembly dummies are included to provide a realistic load for the electronics.
- Reaction Control System simulation for input to the Control and Actuation Electronics.
- Simulation of input signals to the Failure Detection and Correction Electronics.
- Health check and calibration facilities for the stimuli and monitoring signals.

Transfer via the VME extenders to/from the stimuli electronics is within one microsecond.

4.1.3 Power Distribution Unit Simulator

The PDU simulator contains 28 V switchable Latching Current Limited channels in the range from 1 to 8.5 A and provides power for the various AOCS units on the AOCS test bench. All channels can be locally or remotely controlled. Trip and channel on/off status monitoring is available.

4.1.4 Remote Terminal Unit Simulator

The RTU simulator has connections with the AOCS units for transmission of RTU TCs and the acquisition of RTU TM. The RTU simulator receives and sends the information via the OBDH bus by means of Interrogations and Responses. The connections with the AOCS units consist of high power on/off and memory load commands, and a large number of digital status and analog telemetry channels.

4.2 Test Software

The XMM TSW is based on the general purpose simulation support tool PROSIM (Programme and Real time Operations SIMulation), developed by NLR as a system independent simulation program for advanced flight systems. The characteristics of the simulated systems are implemented using simulation models describing the specific behaviour of that system. To facilitate testing of AOCS subsystems, PROSIM has been extended with interfaces to the FE, the TM/TC FE and the Core EGSE, TM/TC processing functions, dedicated user interfaces and data archiving functions.

The TSW as shown in figure 5 consists of a real-time part, enclosed within the dashed line, taking care of the activities related to the closed loop simulation, data acquisition and routing, TM/TC processing, test script execution, and a non real-time part taking care of data archiving and user interfacing. For the SCOE, interfacing with the TM/TC FE and the Core EGSE is also included. The real-time part of the TSW has been designed to run on a single- or multi-processor workstation. Its real-time processes are controlled by a dedicated scheduler that can be synchronised with the operating system clock or with the arrival of protocol messages containing actuator data sent by the FE with a frequency of 40 Hz. The user interfaces are loosely coupled to the real-time processes via TCP/IP connections and can be executed on the real-time workstation and/or remote workstations.

The computers used are an SGI Indigo2 workstation and an Indy workstation running under the operating system IRIX 5.3. The Indy workstation is used to run a second user interface.

The real-time processes communicate mainly via a static Global Data Store (GDS) for user level data and a dedicated dynamic FIFO bufferpool for protocol level data (see also Fig. 3). The buffer pool facilitates decoupling of time-critical processes on one hand and data archiving and user interface related processes on the other hand. The open structure of these interfaces, combined with the precise scheduling of the involved processes, provides reliable direct access to all important data for test scripts, the graphical user interfaces and archiving processes.

An important function of the TSW is the automated execution of real-time AOCS tests. These tests are in general controlled via scripts written in Mission Definition Language (MDL). MDL scripts can be used as Automatic Test Procedures (ATPs) since they can be initiated by certain conditions in the GDS. MDL scripts can also be initiated by other ATPs or via the Graphical User Interface by the test conductor. Note that all MDL scripts are executed synchronously with the SSW at a frequency of 40 Hz. MDL commands can also be executed interactively in a dedicated Manual Commanding window.

The Graphical User Interface includes facilities for defining test setup and test control, monitoring of MACS bus traffic, monitoring/modification of GDS variables, telecommanding and display of telemetry.

During the test runs all kinds of data can be registered. The TSW provides postprocessing facilities to inspect this registered data afterwards. Postprocessing includes a variety of plotfunctions for GDS variables and certain parameters of protocol messages.

4.3 Simulation Software

The XMM SSW is developed by MMS in Bristol. It provides simulation of the satellite dynamics, the space environment and AOCS units. The function of the SSW depends on the presence and configuration of the real AOCS units during the actual test. The SSW can simulate sensor heads, actuators or complete sensor and actuator units. The SSW interfaces to the TSW via the GDS, described in the previous section. This part of the GDS includes simulation variables for engineering data like torque magnitudes and attitudes.

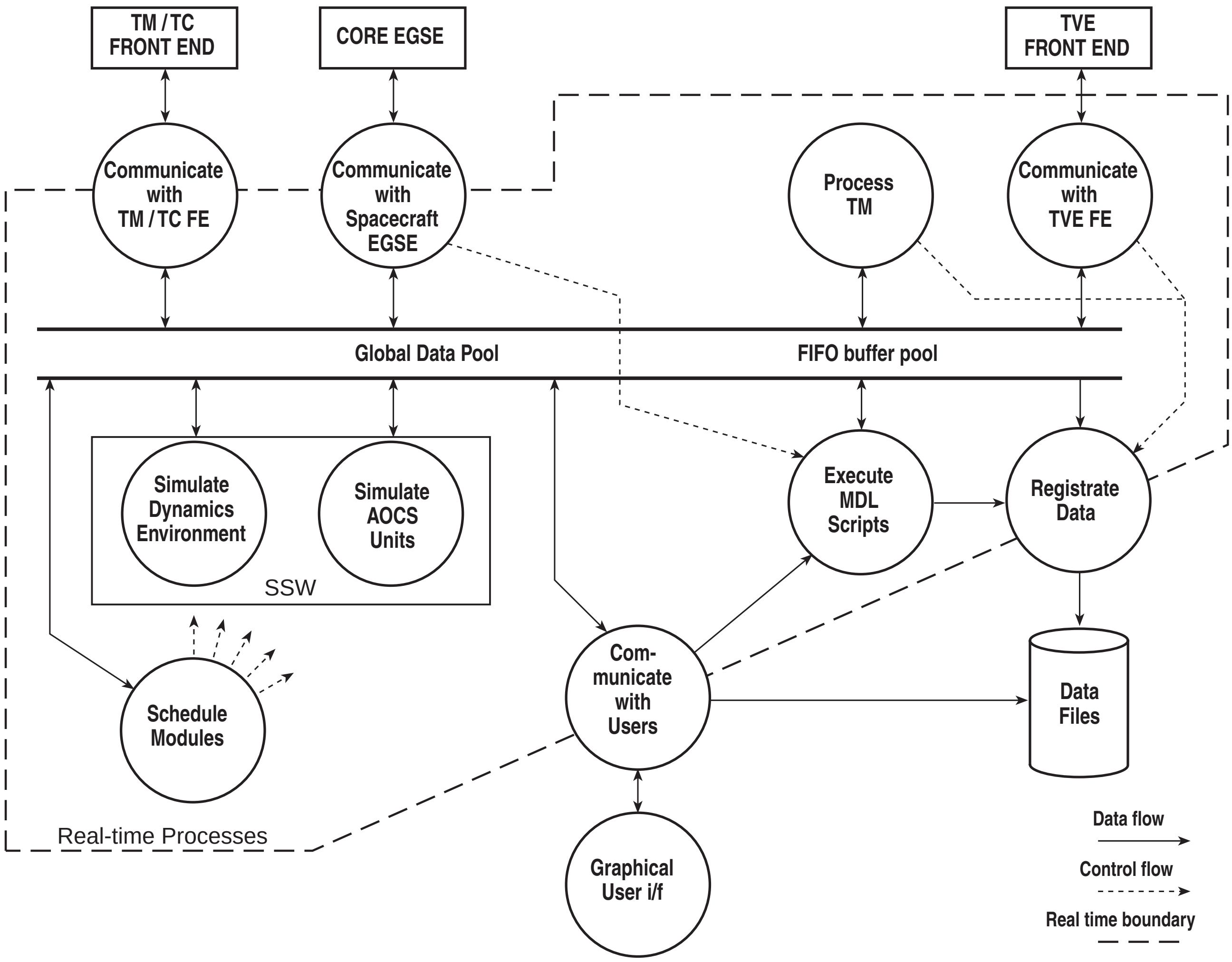

Fig. 5 Test Software Overview

5. INCREMENTAL APPROACH

The modular configuration of the XMM AOCS T/E and the definition of clear interfaces between the components of the T/E allowed those components to be individually developed, tested, and subsequently integrated.

In fact the interfaces to the MACS bus, the OBDH bus and the stimuli and monitoring interfaces of the AOCS units can be tested individually, depending on the available hardware and software to drive the interfaces. Since the MACS and OBDH bus interfaces were re-used from the TVE prototype equipment, with only minor adaptations, those interfaces could be tested in a partly integrated system without the availability of the complex stimuli and monitoring equipment which was still in the implementation phase then. To that end MMS provided NLR with a development model of the ACC. Consequently, integration of stimuli and monitor equipment did not require the MACS and OBDH bus interfaces to be re-tested.

In November 1996 schedule constraints required MMS and NLR to set up a partial delivery scheme compliant with the test strategy of subsequently integrating AOCS units into the software simulated AOCS system. The incremental approach applied within the development phase thus had to be extended towards the operational phase.

The first partial delivery comprised the complete AOCS EGSE hardware, together with some basic software functionalities, allowing MMS to start Electrical Model (EM) check out and integration. The delivered system allowed individual AOCS units to be tested with respect to behaviour on the satellite databuses, functional behaviour, and electrical behaviour with respect to sensor and actuator electronics. As the amount of TM/TC was very limited, use of the TM/TC database was not required in that stage.

In close cooperation between MMS and NLR, EM subsystem testing was continued by MMS, while the remaining software functionalities were developed and integrated in the test configuration by NLR. The commonality of the AOCS EGSE and AOCS SCOE system allowed NLR to continue software integration testing on the SCOE system which was still available at NLR at that time. The XMM AOCS T/E basic concept allowed NLR to run test sequences used by MMS without the availability of real AOCS units, to resemble the operational aspects as much as possible.

The second partial delivery allowed closed loop testing by extending the system with FE - TSW synchronisation at 40 Hz and automatic calibration of electrical stimuli/monitoring values.

The third, final, EGSE delivery completed the TSW with displays for MACS Spy data, TM/TC database processing, dedicated TM displays and on line plotting of model data.

The fourth delivery (to Dornier) consisted of the complete SCOE hardware and the EGSE TSW extended with the interface to the Core EGSE Command Interface and the interface to the TM/TC Front End.

The incremental approach provided early availability of the T/E for AOCS tests and also resulted in an early validation of the T/E itself in an operational environment.

6. XMM EXPERIENCES

6.1 Experiences related to incremental approach

The introduction of an incremental delivery scheme has some consequences. On one hand early use of the system in an operational environment lead to early detection of problems. On the other hand, new deliveries required formal regression tests. Datasets resulting from operational use of the system could be used instead of generated test data sets to test newly developed functionalities (e.g. registered MACS data and TM was used to test the MACS Spy and TM displays).

Precise configuration and version control as applied in this project proved to be very valuable. It allowed re-generation of earlier delivered software versions required for software maintenance while concurrently new versions were developed.

6.2 Critical technologies

The VME based test equipment is a complex system. It consists of 44 VME boards in 3 VME crates interconnected by VME extenders. Combination of certain VME boards with the VME extender resulted in reflections of handshake signals on the VME bus. Furthermore, power supply and grounding were also critical issues.

Note that the overall closed loop timing involves periodically sending of actuator data from FE to dynamics simulation in the TSW, followed by sending stimuli messages calculated by the dynamics simulation to the FE. A significant variation was noticed in the transport times of these messages.

Occasionally the delay was too large for closed loop tests. Several sources were found for this delay. Within the FE, interprocess communication between VME processor units was not tightly synchronised. Especially messages sent to the transport layer collided repeatedly. This was fixed by varying the interprocess retransmission timing. With respect to the interaction between the TSW and the IRIX operating system, several enhancements have been implemented. It appeared to be necessary to use high priority network interface daemons. Active polling of incoming messages by a dedicated real-time process further reduced the delay. In the final configuration one problem remained. The reaction of the operating system on the arrival of Ethernet messages incidentally takes longer than the available 10ms margin. A timeout mechanism has been introduced to start the simulation cycle based on old actuator data.

6.3 User experiences

Detailed analysis of the AOCS test results on subsystem level showed that the timing problem mentioned above had no impact on the test results. Also on system level no impact has been observed so far.

As reported by MMS [Ref. 4], the XMM T/E has been successfully applied to the XMM AOCS EM test campaign and showed to be efficient in test execution and AOCS debugging.

7. INTEGRAL

The INTEGRAL satellite, also belonging to the ESA horizon 2000 programme, is dedicated to the fine spectroscopy and fine imaging of celestial gamma-ray sources with concurrent source monitoring in the X-ray and optical energy ranges.

For cost effectivity, INTEGRAL is based on re-use of the XMM Service Module. For the same reason, the XMM T/E was selected as a basis for the INTEGRAL T/E. Therefore NLR was selected to build the INTEGRAL test systems under a contract to MMS, the INTEGRAL AOCS contractor. The INTEGRAL main contractor is Alenia Spazio in Turino.

The INTEGRAL T/E hardware is virtually the same as the XMM T/E hardware. Only the software, mainly related to TM/TC processing, was to be adapted. At start of the INTEGRAL subsystem level testing, the XMM EGSE system was still in use. Therefore, a new INTEGRAL EGSE system has been delivered to MMS. After completion of the XMM test campaign at MMS, the XMM EGSE will be configured as the INTEGRAL SCOE and delivered to Alenia Spazio for system level testing.

8. CONCLUSIONS

Experiences during development of the XMM test system resulted in the following conclusions:

- The division of the Test Equipment into a dedicated Front End servicing the high speed AOCS interfaces and workstations hosting flexible Test Software and Simulation Software is a suitable concept for open and closed loop AOCS tests. Although the Ethernet interface used for Test Software - Front End communication introduces some uncertainty in the closed loop timing.
- Integration of the Simulation Software in the Test Software proved to be quite easy.
- The modularity made it possible to deliver the XMM test system in parts, enabling concurrent further development and AOCS testing.

Some conclusions reported by the customer [Ref. 4] were:

- The XMM AOCS Test Equipment has successfully been applied during XMM satellite subsystem and system tests.
- AOCS integration was assisted by the ability to rapidly reconfigure AOCS units as real or simulated, as well as reconfiguring the Test Equipment from open loop to closed loop mode.
- The accessibility of all important dataflows for display, registration and use in test scripts makes the Test Equipment an excellent problem diagnosis tool.

9. ACKNOWLEDGEMENTS

We would like to thank the XMM team at MMS, Dornier and ESTEC for the close cooperation and support during the development of the XMM T/E.

10. REFERENCES

1. Sonnenschein, F.J., Nicolai, R.J., Versteeg, M.H.J.B., Beerthuizen, P.G., Kollen, J.H., Rossem, P.H. van, Storni, B. (NLR, Fokker Space B.V., Adelsy), A new generation Test and Verification Equipment for Attitude Control Systems, NLR TP 94142 L, and ESA International Conference on Spacecraft Guidance, Navigation and Control Systems, Proceedings WPP-071.
2. Sonnenschein, F.J., Spaa, J., Ingen Schenau, H.A. van, Versteeg, M.H.J.B., Timmermans, L.J., TVE: Test and Verification Equipment for Attitude and Orbit Control Systems, Executive Summary, NLR CR 97641.
3. Youngs, A.C., Wilkinson, J.K.H., XMM AOCS Test Equipment Requirements Specification, XM-RS-MMB-0011, Issue 5.
4. Youngs, A.C., (MMS-UK) The Application of the ESA Test and Verification Equipment (TVE) to the XMM AOCS project, ESA International Workshop on Spacecraft Attitude and Orbit Control Systems, Proceedings WPP-129.

11. ACRONYMS AND ABBREVIATIONS

ACC	Attitude Control Computer
AOCS	Attitude and Orbit Control Subsystem
ASI	Analog Stimuli Interface (Generic VME board)
ATP	Automatic Test Procedure
BSI	Bi-level Stimuli Interface (Generic VME board)
CAE	Control and Actuation Electronics
CPU	Central Processing Unit
EGSE	Electrical Ground Support Equipment
EM	Electrical Model
ESA	European Space Agency
ESTEC	European Space Research and Technology Centre
FCV	Flow Control Valve
FDCE	Failure Detection and Correction Electronics
FE	Front End
FSS	Fine Sun Sensor
FIFO	First In First Out
GDS	Global Data deScription of data pool
GTM	Timing RCS monitor VME board
GUI	Graphical User Interface
HP	High Power (command)
Hz	Hertz
IMU	Intertial Measurement Unit
INTEGRAL	International Gamma-Ray Astrophysics Laboratory
I/O	Input/Output
IP	Internet Protocol
ISO	Infrared Space Observatory
LCL	Latching Current Limiter
LV	Latch Valve
MACS	Modular Attitude Control Systems
MDL	Mission Definition Language
ML	Memory Load (command)
MOI	Monitor Interface (Generic VME board)
MMS	Matra Marconi Space
ms	millisecond
NLR	National Aerospace Laboratory
OBDH	On-Board Data Handling (spacecraft system bus)
OGSE	Optical Ground Support Equipment
PDU	Power Distribution Unit
PROSIM	Programme and Real-time Operations SIMulation support tool
RCS	Reaction Control Subsystem
RTU	Remote Terminal Unit
RWA	Reaction Wheel Assembly
RWU	Reaction Wheel Unit
SAX	Satellite per Astronomia a raggi X
SAS	Sub Acquisition Sensor
SCOE	Special Check-Out Equipment
SGI	Silicon Graphics Inc.
SOHO	Solor and Heliosperic Observatory
SSW	Simulation Software
STIM	Stimuli
STR	Star Tracker
TC	Telecommand
TCP	Transmission Control Protocol
TE	Test Equipment
TM	Telemetry
TSW	Test Software
TVE	Test and Verification Equipment
VME	Versa Module Eurocard
XMM	X-Ray Multi Mirror Mission