The new SCOS-based EGSE of the EPIC flight-spare on-ground cameras

N. La Palombara[1], A. Abbey[2], F. Insinga[3], P. Calderon-Riano[4], M. Casale[4], M. Kirsch[5], J. Martin[5], R. Munoz[4], M. Palazzo[3], M. Poletti[3], S. Sembay[2], J.C. Vallejo[4], G. Villa[1]

ABSTRACT

After almost 15 years since its launch, the EPIC focal-plane cameras on-board the XMM-Newton observatory continue to operate smoothly. Since the mission was originally planned for 10 years, progressive instrument ageing and/or failures could require substantial changes in the operating software and in the command & telemetry database, which shall be tested with the on-ground flight-spare cameras. To this aim, the original Electrical Ground Support Equipment has been replaced with a new one based on SCOS2000, the same Mission Control System used by ESA for controlling the spacecraft. This was a demanding task, since it required both the recovery of the specialised knowledge regarding the original EGSE and the need to adapt SCOS for a special use. Very recently this work has been completed by fully replacing the EGSE of one of the two cameras, which is now ready to be used by ESA. Here we report the scope and purpose of this activity, the problems faced during its execution, and the adopted solutions.

Instrument overview

The XMM-Newton space observatory [1] is one of the "cornerstone" missions of the Horizon 2000 plan of the European Space Agency (ESA): it was launched in December 1999 and, although it was originally planned to work for ten years, after almost 15 years in orbit it continues to operate smoothly.
Since the launch the instrument teams of the European Photon Imaging Camera (EPIC), i.e. the telescope focal-plane detector, are maintaining two Flight Spare (FS) units on the ground, one for each of the two on-board types (MOS [2] and PN [3]). Since both cameras are representative copies of the corresponding on-board instruments, *ESA* required to keep them efficient, in order to make it possible the on-ground test of any change or update concerning the instrument SW, the TC&TM database or the commanding procedure. This possibility will be of increasing importance in the future, since the expected instrument degradation and the possible failures could require substantial changes in the instrument SW and database.
Both *FS* cameras are still operated through the same *Electrical Ground Support Equipment* (*EGSE*) which was used for the AIV tests before the satellite integration. It is based on the following items (Figure 1 bottom):

- the *Interface Simulator Unit* (*ISU*), which interfaces directly with the instrument Data Handling: it includes both the power I/F simulator, to power the instrument, and the front-end electronics, for the simulation of the spacecraft On-Board Data Handling (OBDH)
- the *Central Check-Out Equipment* (*CCOE*), which is the Master Test Processor used to operate the instrument, i.e. to send the TCs and to receive, display and archive the HK TM
- the *Instrument Station* (*IS*), which is the support unit used to receive, display and archive the scientific TM

In addition, the *EGSE* also injects/detects some "direct" signals (analog acquisition/monitoring, heater control, relay commands/status, etc.). The connections between *ISU* and *CCOE/IS* are established by means of TCP/IP links, using different ports for different services. Figure 1 (top) shows the 5 connections between the *CCOE* and the *ISU*:

- *HLCL link*, which carries commands to configure the *ISU* and receives errors and report messages from it
- *OBDH data link*, which is an unidirectional link able to receive reports informing about the *OBDH* bus
- *POWER control link*, which is used to setup and monitor the *ISU Power Interface Simulator* and trigger some power settings for the *FS* camera from the *ISU*
- *TC*, which issues the TC pkts from the *CCOE* to the *ISU* to be sent to the camera, and receives acknowledge/not-acknowledge and report messages coming from the camera
- *TM*, which is an unidirectional link able to transmit the camera TM pkts

This equipment was developed almost 20 years ago in order to support the instrument AIV and calibration tests before its integration on-board the XMM satellite [4]. Due to the obsolescence of this EGSE and to the need to harmonize the operations of the Spare instruments to those of the on-board cameras, it was proposed to replace part of the EGSE with newer HW running SCOS 2000 (S2K), the Mission Control System commonly used by ESA to operate its satellites, configured in the same way as it is in the ground segment of XMM-Newton. In the proposed new EGSE configuration both the CCOE and the IS are replaced by a S2K-based equipment, which reproduces both sections of the XMM Ground Segment: on one hand the Mission Control System (XMCS) of the ESA Mission Operation Centre (MOC), which manages the instrument operations; on the other hand, the Science Control System (XSCS) at the Science Operation Centre (SOC) for the monitoring and archiving of the scientific TM. In this scheme the direct interface with the instrument is still provided by the original ISU equipment, which, due to both technical and financial reasons, could not be replaced or modified.

The new EGSE architecture

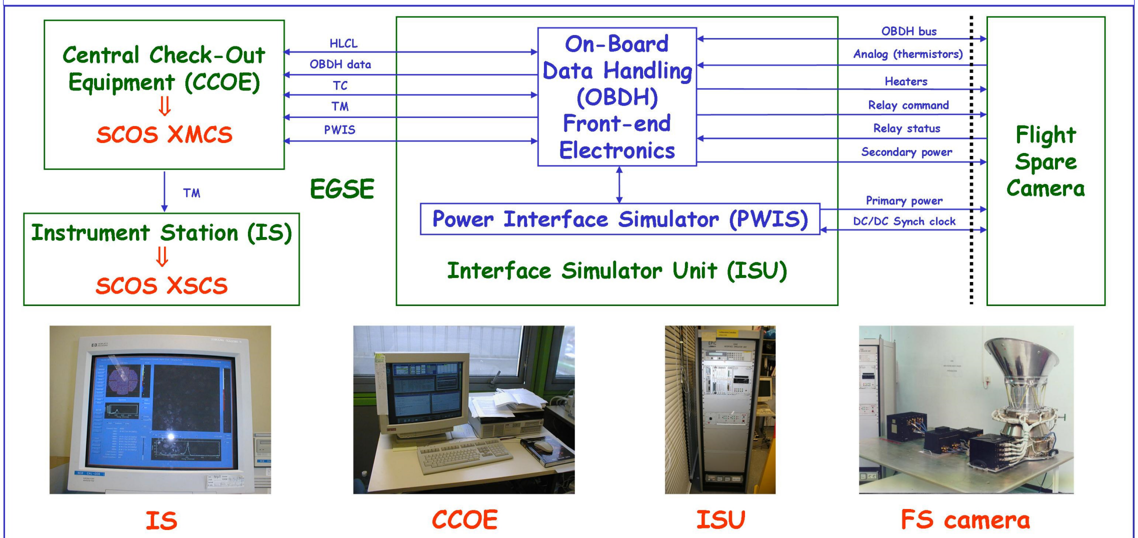
The updating of the EPIC EGSE with S2K had to face two main problems:

- S2K is a Mission Control System developed by ESA to manage the routine operations of the flying missions from the ground stations: this means that S2K it is not designed for an EGSE application, and requires a non-standard "ad-hoc" installation for the EPIC FS cameras
- S2K communication protocol is based on TC/TM "frames" instead of "packets": it is necessary to introduce a "protocol adapter" between the ISU and the S2K equipment in order to convert TCs (sent by S2K) into the OBDH protocol and TM PKTs (received by the ISU) into S2K format.

The required adapter, called "ISUIA" (ISU Interface Adapter), was implemented by Thales Alenia Space Italia as an independent node on the network, logically connected between the ISU and the S2K computer. The ISUIA is in charge to manage the TC&TM interfaces: TM packets coming from the ISU are encapsulated in "pseudo frames", while TC packets coming from the XMCS are unwrapped and the ancillary data are removed. The implementation of the interface specifications is limited to the aspects that are necessary in order to cope with the existing S2K, but does not include the full protocol; in the same way the information provided by S2K that is not relevant for ISU are discarded.
In the new configuration (Figure 2 top) the HLCL, OBDH and PWIS interfaces between ISU and CCOE are transferred to the ISUIA. In this way the setup and monitoring of the ISU can be performed at ISUIA level. From the architectural point of view, the ISUIA SW is made up of three high-level components:

- ISUIA Local Data Manager (LDM), for the ISU management
- ISUIA Protocol Adapter (PA), for the TM&TC conversion between the S2K and the OBDH format
- ISUIA Man-Machine Interface (MMI), for the ISUIA management by the operator

Figure 1: *Top*: Block diagram of the original EPIC EGSE, showing the interfaces between the single units. *Bottom*: images of the original EPIC EGSE and of the MOS camera.



Project development

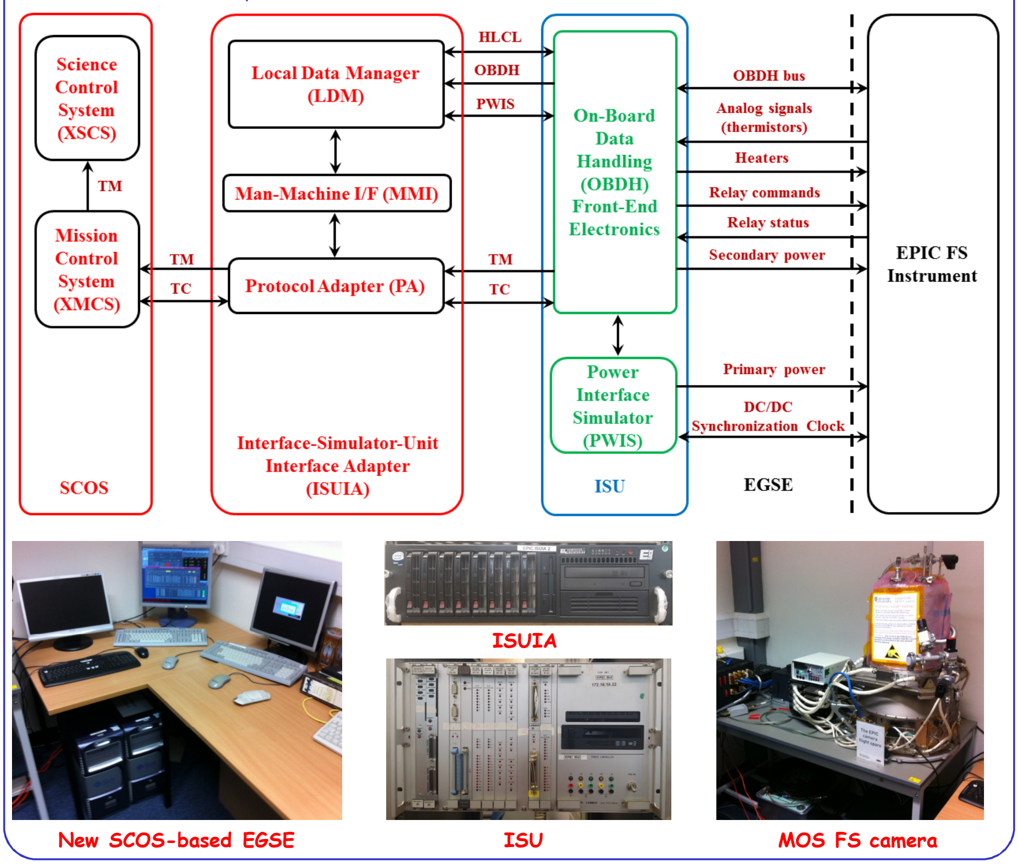
The ISUIA development went through different phases:
1. Analysis: detailed analysis of the S2K interface specifications, ending with a draft definition of the interfaces and the generation of the ISUIA Architectural Design Document (ADD)
2. Design: generation of the ISUIA Software Design Document (SDD), inclusive of both the software architecture and the complete interface definition
3. Coding & Debugging: coding of the ISUIA SW and test of single SW modules by using a SW debugger
4. Integration and Acceptance: test of the ISUIA in connection with the ISU and the S2K CCOE, in a configuration where the instrument is simulated (by the ISU embedded simulation capabilities)
5. Commissioning: test of the ISUIA in connection with the ISU and the S2K CCOE, in a configuration where a real instrument is present

After the SW Design, Coding and Debugging phase, we performed the first I/F tests between SCOS and ISU via ISUIA; in this case, since there was no interface with the real instrument, we used the ISU in OBDH simulation mode, relying on an internal loop back, to generate the HK telemetry and process the incoming TC packets. In this way we found and corrected an error in the encoding of the TM frame by ISUIA (a wrong length of the frame trailer was assumed). Then it was possible to send TCs from SCOS to ISU and to receive TM PKTs from ISU to SCOS: in both cases the sent/received PKTs were correctly displayed in the TM/TC packet history at MOC/SOC local level. This proved that the communication I/F provided by ISUIA was properly working.
The next step was the integration of the new SCOS-based EGSE with the real instrument (Figure 2 bottom). This was performed at the Leicester University, where the MOS FS camera is hosted since the XMM launch. With this configuration we performed three different test campaigns:
1)During the first one, the whole new EGSE was interfaced with the MOS FS instrument. We managed to properly transfer single TC and TM PKTs between S2K and the instrument, but not to receive a continuous flow of TM data in an automatic way (i.e. without a specific request from the ISU): this function, which is necessary for the test purposes and was ensured by the previous EGSE, could not be provided by the new EGSE configuration. After further off-line investigation, this problem was fixed by using a specific command at ISU level: it enables a loop sequence which can be used to keep the ISU requesting telemetry packets from the spare chain, in the same way as the OBDH does.
2)The loop sequence was successfully tested during a second test campaign.
3)During the third test campaign the final commissioning tests of the new EGSE were performed. To this aim, we executed the following procedures, which were adapted from the flight operations used for the on-board instruments:

- Normal switch-on
- Filter Wheel synchronization and rotation
- Acquisition of Diagnostic images for each of the seven camera CCDs
- Acquisition of Scientific data in Imaging mode
- Normal switch-off

These procedures were designed to be used with a fully operational camera cooled to operating temperature (-100° or -120° C), while during the commissioning tests the camera was at room temperature; as a consequence, the CCD images were saturated and the analogue chains were overloaded. However, all the operations where successfully performed; moreover, it was possible to see the CCD data using the Quick Look Facility (QLF) on the SOC WS, and also correct FITS files were produced. The data looked as expected taking into account the high operating temperature, therefore it was possible to assess that the system was properly working.
Finally, the spare chain system was successfully operated also with remote operation from the XMM SOC.

Figure 2: *Top*: block diagram of the new EPIC EGSE, updated with S2K and the ISUIA. *Bottom*: layout of the new EPIC EGSE and of the MOS FS camera at the Leicester University



1: INAF – IASF, Milano (I)
2: Leicester University, Leicester (UK)
3: Thales Alenia Space Italia, Gorgonzola (I)
4: ESA – ESAC, Madrid (E)
5: ESA – ESOC, Darmstadt (D)

[1] Jansen, F. et al., A&A 365, L1-L6 (2001)
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[4] Trifoglio, M. et al., Proc. SPIE 3445, p. 558-565 (1998)