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The on-ground acquisition and data analysis system for the PDS detector on board the SAX satellite(*)

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Summary. — The Phoswich Detection System (PDS) is the high-energy (15–300 keV) instrument on board the Italian-Dutch X-ray astronomy satellite SAX. Functional tests were carried on at BICRON (Newbury, Ohio, USA) and at LABEN (Vimodrone, Italy). Full ground calibrations have been performed between the end of 1994 and the beginning of 1995. We describe in the following the system that we used to acquire and analyse the data coming from the PDS experiment during the ground tests and calibrations. It will be used to store and maintain data during both the pre-operational and the operational phases. In a previous report (DAL FIUME D., FRONTERA F., ORLANDINI M. and TRIFOGLIO M., *AIP Conf. Proc.*, **61** (1994) 395) we described the general architecture of the data analysis system. In this report we give a detailed description of the entire system, including the hardware and software developed by LABEN to acquire data during on-ground tests. A complete description of the different modules, user interface, inter-process communications, analysis and display tools are presented. Current status of the project is discussed.

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1. – Introduction

PDS [1] is the high-energy (15–300 keV) instrument on board the SAX satellite [2] (the launch of which was performed on April 30, 1996). It is composed of a square array of four

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phoswich (NaI(Tl)/CsI(Na)) units for a total geometric area of 800 cm^2. The detector is surrounded by active shields (CsI(Na)) on the lateral sides and by a thin plastic scintillator on the front side. The field of view is limited to 1.4° by means of graded hexagonal mechanical collimators (Ta-Sn-Cu). The lateral shields will be operated also as a Gamma Ray Burst Monitor [3].

The telescope is operated via an analog processor that analyses the signals coming from the various subsystems composing the telescope. The result of this analysis is then processed by two microprocessors (PDS Intelligent Terminal — PDS IT): one dedicated to data acquisition from the analog processor and the other dedicated to handle data transfer and communications with the On Board Data Handling (OBDH).

More details on the detector and on its performances can be found [1] and in this issue [4].

Tests on the detector electronics have been performed at LABEN premises (Vimodrone, Italy). Tests on the integrated detector, and the complete ground calibrations have been carried out between the end of 1994 and the beginning of 1995. The calibrations of the Gamma Ray Burst Monitor [3], [5] took place in summer 1995, with the PDS detector integrated in the SAX satellite.

In-flight deep calibrations and performance verification took place in the first two months after commissioning of the satellite. In the operative phase routine calibrations will be performed on a typical rate of one per day and long-term history files, including some quantities relevant for calibrations and long-term trend analysis, will be stored by Telespazio at SDC (Scientific Data Center — located at Telespazio premises — Rome). In the first part of the mission a relevant part of these data must be timely processed by our group in order to produce the first set of calibration data usable by SAX PDS end users.

In this report we describe the on-ground system to acquire and analyse data from PDS ground tests and calibrations. The data collection, analysis and archival system developed at TESRE to host the data of PDS was also used during the deep calibration and performance verification phase of the satellite.

2. – Data acquisition during ground tests and calibrations

During the ground calibrations, data from PDS were acquired using LABEN ITE (Instrument Test Equipment), a complex data acquisition system composed by a probe of the data buses on SAX (BTB probe) and a VAXstation.

Data come from the PDS IT, composed of one analog processor and one digital processor, the latter composed of two 80C86-like microprocessors, on the SAX BUSes: the Response Bus (RB) and the Block Transfer Bus (BTB). The first one carries information on the health of the instrument (engineering HK, echos, responses to interrogations from IT to the central data handling system of SAX). The second one transfers the scientific data in packets ready to be inserted into the SAX telemetry. These buses connect all the ITs (one for each telescope) to the SAX On Board Data Handling system (OBDH).

During the ground tests the RB and the BTB are probed by a dedicated instrument developed by LABEN. It retrieves output data from PDS coming on the RB and BTB and sends these data via TCPIP to a VAXstation, where they are stored in files on the hard disk. The LABEN ITE can control the data flow, with a dynamic display of the packets being transferred from PDS via bus probe.

Data from LABEN ITE are then transferred to the PDS Data Analysis System, where the analysis and archiving is performed. The data flow scheme is outlined in fig. 1.

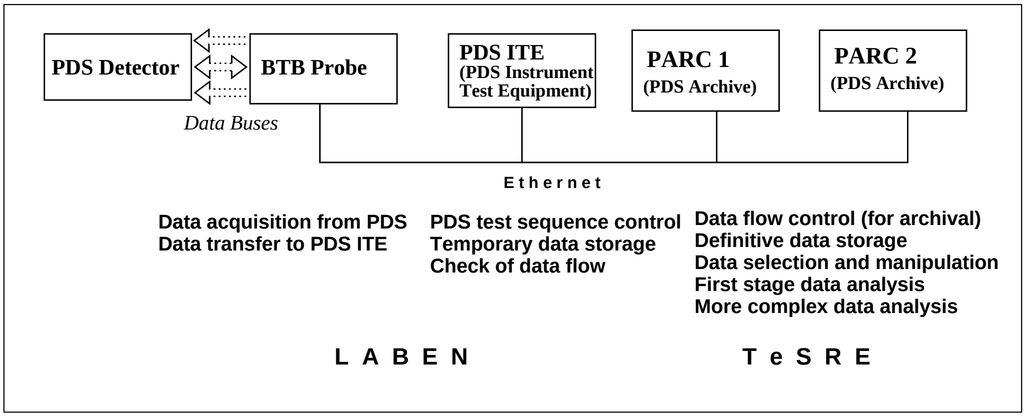

Fig. 1. – Block diagram of the data flow during the on-ground tests and calibrations.

3. – Description of ITE

The PDS Instrument Test Equipment (ITE) developed by LABEN, an ALENIA Finmeccanica company, is the ground Test Equipment of the SAX PDS instrument for both test and calibration activities.

It is mainly a computer-controlled system which interfaces, with a dedicated front-end, the OBDH BEP (On Board Data Handling Bus Emulator and Probe) and the PDS Electronic Unit. The ITE has also the capability to position, on a vertical plane (600×600 mm), a collimated X-ray or gamma calibration source. The main features of the test equipment, as shown in fig. 2, can be summarized as follows:

VAXstation host computer: VAX/VMS workstation mod.3100, SPX, 30MB of RAM, DEC Window I/F, 208 MB HD, TK 50 tape unit; it drives the BEP FEC (Front End Crate) executing several Test Sequences, such as BEP set-up, data acquisition and archiving, data display and processing; *28 Volt DC power supply* for on board PDS experiment; *PC 386 DX*, 4MB of RAM, equipped with Ethernet I/F and AT6400 motor indexer board; *a system to move on two axes* in the vertical plane the collimated calibration sources; the system is computer driven; *the Ethernet* thin wire Local Area Network (LAN) which connects the PC, the OBDH BEP and the VAXstation for communications and resources sharing.

3·1. *BEP front end crate*. – The OBDH BEP is an intelligent electric equipment which allows the direct access to the OBDH Bus: the *Interrogation*, the *Response* and the *Block Transfer* Bus. The Interrogation Bus is a dedicated line of a full duplex bus that transmits interrogation messages (on 32 bit instructions) from the CTU (Central Terminal Unit) to the ITU (Intelligent Terminal Unit). The Response Bus and the Block Transfer Bus are the lines that send response messages (on 16 bit data) from the interrogated ITU to the CTU.

3·2. *Two axes translation stages system*. – The Translation Stages System is a part of the PDS ITE Mechanical Ground Support Equipment (MGSE) subsystem to be used either in a stand-alone operating configuration or in a full integrated configuration inside the PDS instrument test and calibration set. The Stages System moves, under PC control,

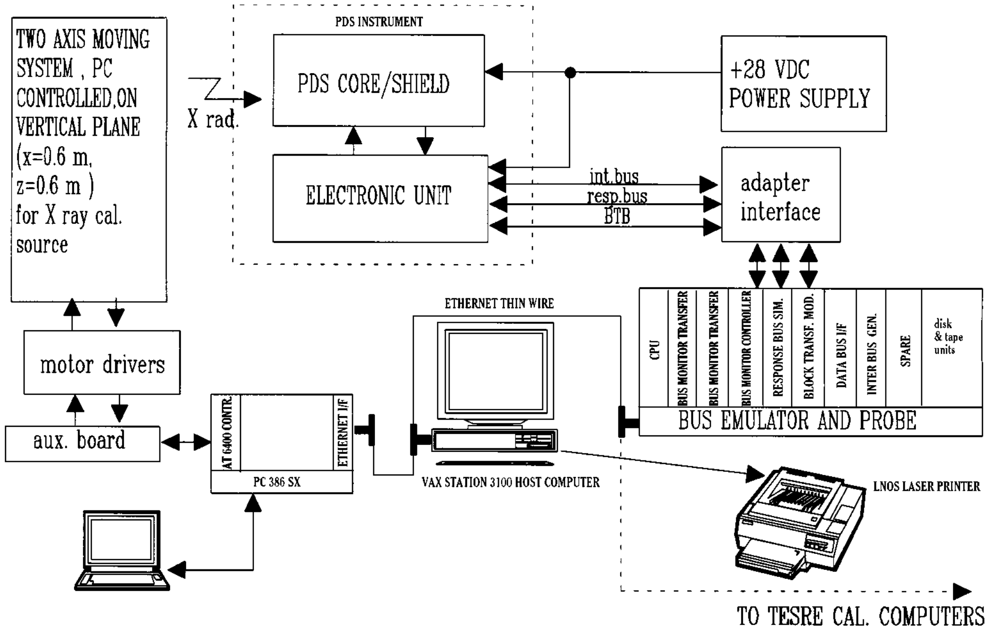

Fig. 2. – Layout of the Instrument Test Equipment configuration during calibrations.

a collimated X-ray source. The source is moved on a 600 × 600 mm vertical plane. This allows to irradiate all the PDS detectors (Phoswich Units, Lateral Shield Units, Top Shield Unit) in the relevant positions.

3·3. *ITE software.* – The ITE S/W consists of three main packages, running on different H/W platforms such as VAX, PC and embedded processor (MC68030), and performs various tasks.

Instrument monitoring and data acquisition. The user can perform tests on PDS by running an appropriate test sequence written in TEL, a specific language developed in LABEN. Via the TEL language interpreter, running on VAX platforms, the user controls the test equipment facilities and sends macro commands to the Instrument through the Interrogation Bus.

The on-line software package enables the user, operating in a graphical environment, to control and examine the BTB OBDH Telemetry Source Packet (TSP), while they are being acquired. Data are stored in files for the off-line data analysis.

The off-line data processing allows data extraction and histogram generation from the BTB data file. It allows to read congruent types of scientific data and to process them in order to build histogram and associated configuration files. The data products can be analysed using the SOFIA analysis program, running on a PC, that allows to evaluate the spectral characteristics such as peak centroid, peak FWHM, peak resolution as well as associated errors.

4. – Data acquisition, archiving and analysis

The data storage on the ITE workstation is temporary. The final archiving and data analysis is performed into the PDS ARChive (PARC) workstations.

The complete H/W configuration of the archive is the following: three HP 9000/700 workstations + one DEC 5000/33 workstation; magnetic disks with about 6 GB of disk space; one drive for magneto-optical rewritable optical disks; one drive for CD-ROM optical disks; one drive for DAT magnetic tapes.

The front end to data coming from PDS is composed of some modules for on-line and off-line analysis. The on-line modules: transfer data from ITE to PARCs in almost real time; handle events (as changes in the PDS temporary files); handle inter-process communication (as data or information passage through sockets); display some relevant housekeepings. The off-line modules: reformat input data; display data and perform data reduction/accumulation. archive data in the PDS relational DataBase.

The almost real time control of PDS is performed using data transfer via TCP/IP sockets. A program running on VMS acts as a dispatcher of PDS data to UNIX workstations. The data transferred are the scientific data (from the Block Transfer Bus), engineering data (from the Response Bus), log data (created by the execution of the test sequence on ITE). Data are read as soon as they are written to the VMS disk and are sent via sockets to three listeners, one for each data type, resident on one or more UNIX machines. Each of these listeners archives data on local UNIX disks and can send the data, again via dedicated sockets, to other processes that analyse and display them. Data are available for analysis almost in real time. A set of simple protocols used in data transmission allows a limited set of events to be handled by the listeners (as change in input/output files, suspend operations, cleanup of data communication channels).

All the data reduction package is "insensitive" to differences in the data format between data acquired in the different phases of PDS life. The differences between format of data acquired during calibration and testing phases and format of data in Final Observation Tapes (FOTs) during the operational phase, are handled with a dedicated library and external configuration files in a completely transparent way [6], [7].

5. – The insertion in the PDS relational DataBase

The PDS Archive is based on the INGRES (t.m. of Ask Corporation) relational DataBase. For each calibration record, we foresee to archive the following information: the archive location of all the ancillary files related to a calibration, together with all the information needed by a user in order to analyse and reconstruct the calibration; results from the first level analysis (first processing of spectra and pseudo-images); results from the second level analysis (PHA/ADC channel conversion, trend analysis, etc.).

External tools to perform more sophisticated analysis can be used on data extracted from the DataBase. The results of this analysis will be again archived in the DataBase for further use.

To this goal, we built a Graphical User Interface (GUI) by Windows4GL scripts within the DataBase itself. The tasks that can be performed by means of the GUI are: viewing of DataBase records; creation, insertion and update of DataBase records (allowed only to authorized users — AUs); extraction of sets of records satisfying user conditions; plotting of one parameter *vs.* another (correlation plot); fitting of correlation plots with linear, semilog or power law relations.

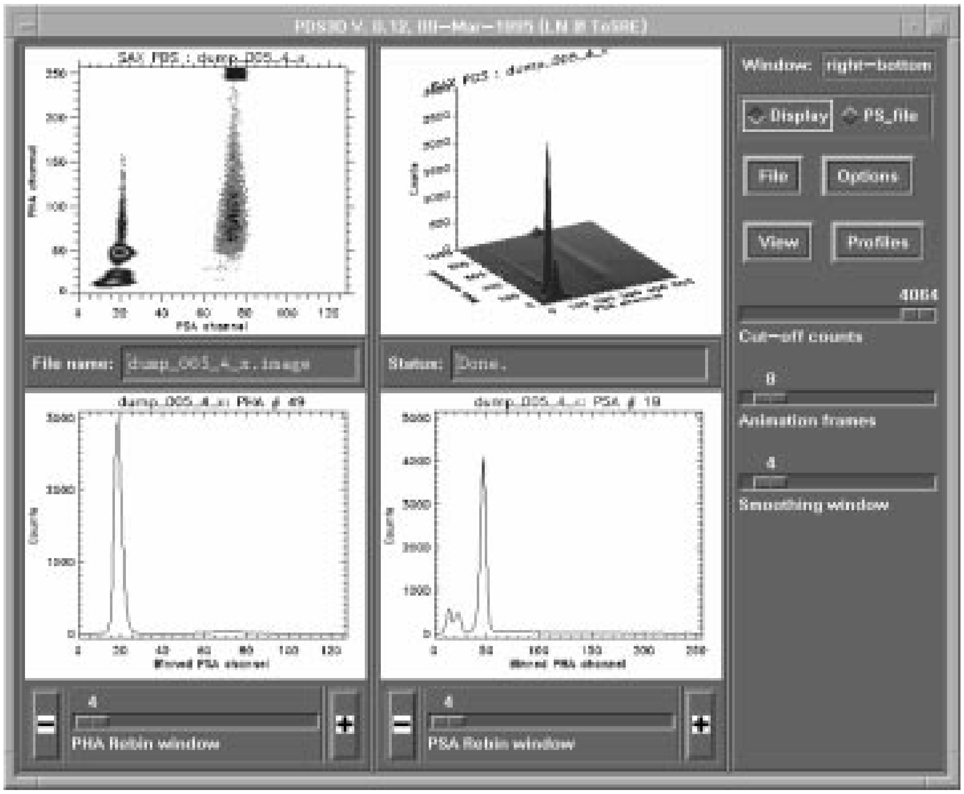

Fig. 3. – SAX PDS Counts *vs.* PHA channel *vs.* PSA channel displayed with IDL. The four windows, from top-left clockwise, represent, respectively: shaded surface, pseudo image, a PHA profile, and a PSA profile.

6. – The data reduction and display

IDL (t.m. of Research Systems Inc.) was chosen as a graphical representation and manipulation tool for the SAX PDS data. We took advantage of the capability of IDL to build GUIs by writing user friendly, widget-based, programs. In doing this, we assume that the users have access to an X Window System. IDL has seven basic widgets but several "compound widgets" and User Library routines that make use of widgets are available. More have been developed at the TESRE Institute. This allows most of the functionalities of our programs to be available just by using the mouse.

Spectra, time series and pseudo-images (counts *vs.* rise time *vs.* energy channel) are all accessible by widget-based programs. The first two types of data (two-dimensional) are managed by a single program that recognizes them. Pseudo-images are instead managed by a separate program the GUI of which is presented in fig. 3. It shows the data both as a shaded surface and as a pseudo-image using the SHADE_SURF and TV procedures. Two profiles, in PHA channels and PSA channels, respectively, are shown in the two bottom graphics windows. These can be exported to a temporary file for further processing by the first program. Note that a rebinning factor of four was used both in PSA and PHA channels. The gray buttons in the command panel are pull-down menus that, in turn, include nested pull-down menus. The current plotting window (displayed at the top right) is selected by one of these sub-menus in the Options menu. Graphic output can be alternatively sent to a PostScript file simply acting on the toggle button at the top of the command panel.

Default start-up settings are set internally to the programs but they can be overwritten by values reported in a user-defined file via an environment variable. Other information exchanges with the user make use of widget-based windows.

Thanks to the capability of IDL to spawn external processes via the `SPAWN` procedure, and to access external routines contained in sharable object libraries via the `CALL_EXTERNAL` function, once the data have been displayed, manipulated and, in some way, selected, further analysis (*e.g.*, complex model fitting) can be performed invoking external tools. Results can then be returned to IDL for displaying and further processing.

We also implemented an IDL program that can communicate with external programs via named pipes actually acting as a *plot server*. It was effectively used to monitor the PDS HK on-line.

REFERENCES

[1] Frontera F., Dal Fiume F., Pamini M., Poulsen J. M., Basili A., Franceschini T., Landini G., Silvestri S., Costa E., Cardini D., Emanuele A. and Rubini A., *Adv. Space Res.*, **11** (1991) 281.
[2] Scarsi L., *Astron. Astrophys. Suppl. Ser.*, **97** (1993) 371.
[3] Pamini M., Natalucci L., Dal Fiume D., Frontera F., Costa E. and Salvati M., *Nuovo Cimento C*, **13** (1990) 337.
[4] Frontera F., Cinti M. N., Dal Fiume D., Landini G., Nicastro L., Orlandini M., Zavattini G., Costa E., Schreiner R. S., Rosza C. M., Raby P. S., White J., Chiaverini V., Monzani F., Poulsen J. M. and Suetta E., *Nuovo Cimento C*, this issue, p. 797.
[5] Alberghini F., Dal Fiume D., Frontera F. and Pizzichini G., *AIP Conf. Proc.*, **307** (1994) 638.
[6] Chiappetti L., *SAX Data Analysis Working Group Report 15/91*, 1991.
[7] Chiappetti L., *SAX Data Analysis Working Group Report 20/92*, 1992.