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Real Time Science Displays for the Proportional Counter Array Experiment on the Rossi X-ray Timing Explorer

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Abstract. The Rossi X-ray Timing Explorer (*RXTE*) spacecraft contains a large Proportional Counter Array (PCA) experiment which produces high count rates for many X-ray sources. Telemetry from *RXTE* is returned via the NASA Tracking and Data Relay Satellite System (TDRSS) which provides a stream of nearly continuous real time data packets. This allows opportunity for some serious real time interpretation and decision making by the experiment controller, duty scientist, and Guest Observer (GO), if present. The GOs also have the option of arranging for the remote display of programs at their home institution. This paper briefly describes the available Science Monitoring subsystem display options.

1. Introduction

The PCA is one of three experiments on *RXTE*, and was developed at the Goddard Space Flight Center (GSFC). The *RXTE* experiment software effort was widely distributed, and the Instrument Teams (IT) were contracted to deliver much supporting code for their hardware experiment. During 1992, it was decided to use C++ for all of the software associated with the Science Operations Facility (SOF), but this decision was revised in mid-1993. At this time the Guest Observer Facility (GOF) elected to stay in line with the well established practices of the Office of Guest Investigator Programs (OGIP) and High Energy Astrophysics Science Archive Research Center (HEASARC) activities within NASA at GSFC. The SOF was committed to using C++ and continued with this approach. The SOF build deliveries were driven by the inexorable requirement to keep up with the spacecraft's aggressive schedule, and the need to support various tests and mission simulations. The GOF development was under far less pre-launch pressure. Since almost all GOF code is written in FORTRAN using FITS and FTOOLS, there could be no commonality with the SOF object-oriented C++ environment. This fundamental decision meant that the original requirement for an integrated system with extensive analysis capability in the SOF, was no longer feasible. Resources did not allow the duplication of the functionality of the analysis tools that the GOF was required to produce.

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The PCA C++ code produced for the SOF was developed using Object Center^{TM} from CenterLine Software Inc. The GUI used is TAE+, which is a commercially available NASA product. Individual graphs were produced using the Athena Tools plotter widget set. Code was delivered to the following SOF subsystems: Command Generation (CG), Mission Monitoring (MM), Health and Safety (HS), and Science Monitoring (SM). In this paper we discuss only the SM subsystem contributions.

2. Design Requirements

The PCA experiment contains five similar detectors, each of which produces identical housekeeping data packets for the HS displays. These packets contain many detector parameters and some X-ray rates, but no spectral information. Most science data packets are generated by the Electronic Data System (EDS), which is provided by the Massachusetts Institute of Technology (MIT). This sophisticated data selection and compression system allows many pre-programmed data modes to be run simultaneously in the six Event Analyzers (EAs) devoted to the PCA. Extensive details on the PCA/EDS combination can be found in the *RXTE* NRA (1995). Further details of the *RXTE* spacecraft and mission can be found in Swank et al. (1994) and Giles et al. (1995). The requirements for the SM displays are summarized in Table 1, in approximate order of increasing scientific interest.

Table 1. PCA Science Monitoring Requirements.

Basic things to examine and look for in real time.
Do spectra look typical? Are they free of spikes, gaps and noise?
Are the spectra from all Xe layers in all detectors similar (total of 30)?
Are all the internal calibration spectra normal?
Has the source been detected?
How does the source intensity vary with time?
What sort of spectral shape does the X-ray source have?
How does the spectrum vary with time?
How do the source intensity and spectrum translate into telemetry loading?
What is the source hardness ratio, and how does it vary with time?
Are "slow" time scale periodic or aperiodic features visible?
Are "faster" time scale features visible in the on-board EDS modes?

Given the practicalities following the SOF/GOF split, the PCA team chose to emphasize the following aspects in SOF displays: real time or near real time graphical displays, visual impact and clarity, multiple options within a predefined set of choices, limited analysis capability but export of data to external tools like IDL, and support for only a few of the many EDS modes, concentrating on Standard Modes 1 and 2. Remember that detailed analysis is not intended with this real time system. If GOs are present at the SOF during their observations and need to do higher level tasks, such as background subtraction or spectral fitting in near real time, the GOF's Fits Formatter (XFF) system can be used. A SOF copy of XFF can be run to produce temporary FITS files on an estimated 15–30 minute time frame. The precise time scale depends on the data flow from the NASA PACOR system into GSFC and "fast" FITS files made in this way may be very incomplete. Normally, a 24 hour period elapses before all late packets are assumed to have arrived. Once the FITS files are created, they can be studied using the GOF FTOOLS.

3. Science Monitoring Displays

The set of display programs developed to address these monitoring requirements is detailed in Table 2. These displays can all be run individually or, more commonly, selected from a main GUI interface.

Table 2. PCA Science Monitoring Displays.

Main group	Sub Group	Description
STD Mode 1	Cal. Spectra	Raw 256 bin spectra every 128 s
	Light Curve (LC)	8 LC's. Each 1024×0.125 s points
Temporal	Power Spectra (PS)	Power spectrum of STD Mode 1 LC
Science	PS History	2-D color coded power, freq. vs. time
	Layer LC's	Select keV range from STD Mode 2
	Energy LC's	Select 4 keV ranges from STD Mode 2
STD Mode 2	Spectra	Xenon and Propane spectra every 16 s.
	Diagnostic Rates	29 rates (× 5 PCU's) every 16 s.
Spectral	Base Summation	Derived from STD Mode 2, Xe signals
Science		added raw or with gain/offsets applied
	Recommend	Base summation mapped to the 6 energy bands of the GOF RECOMMD program
	Colors vs. Time	3 definable keV bands using Base Mode
	Spectral History	2-D color coded intensity, keV vs. time
Others	EDS FFT	On-board EDS FFT spectra mode
	EDS Delta Time	On-board EDS Delta Time Binned Mode
	Event Selection	A tool to examine basic Event Mode
	Slew Detection	A derivative of Event Selection

The main GUI allows multiple instances of programs to be started, e.g., it is common to run four light curve options at the same time—0.125, 1, 8, and 16 s temporal resolution. These displays then span 128 s, 1024 s, 2.28 hours, and 18.2 hours respectively. Standard Modes 1 (mainly temporal) and 2 (mainly spectral) are always present. These displays have too many features and options for a detailed discussion (see User Guide, Rhee 1995; Design Guide, Giles 1995). A document containing sample screens for the PCA real time SM subsystem is referenced on the WWW *RXTE* SOF page. New options are carefully tested before transfer to the SOF configuration controlled environment.

4. Operations

RXTE was a fixed price program that was completed within budget and on time with respect to goals set $\sim$4 years prior to the planned launch. *RXTE* was launched on 30th December 1995 and has already produced a vast amount of high quality timing data on a wide variety of X-ray sources. The various PCA monitoring displays have proved very effective in supporting the mission and have allowed the sort of interactive decision making that was hoped for. The duty scientist and experiment controllers monitor the observation in progress, to try and ensure that it is proceeding as planned, and that modifications to the observing modes are not required. *RXTE* can also be slewed rapidly to point at new Targets Of Opportunity. The PCA instrument team has permanent access to the SOF data flow, to monitor their experiment using the same display programs. Guest observers need not be present at GSFC—they routinely monitor their observation in real time from their home institution using remote displays of the same suite of programs running in the SOF. *RXTE* has already made many public observations and this is expected to continue in the future. The SOF are in the process of providing a mechanism for real time public data to be seen by anyone in the world via a WWW interface to the PCA display programs.

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