PCA Science Monitoring Design Concepts, Screen Functions, Use, SOC Interface

XTE-PCA Software Module

PCA-SM-EXP-V6.2

Build 4.5.3

Version 6.2

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by

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Foreword

The PCA science group are responsible for providing to the SOC an agreed set of software products together with their associated documentation and test data/results. Such deliveries are governed by the details to be found in the PCA IAD and ICD documents.

In order to facilitate the production of this code and documentation a series of documents have been produced that are intended to contain as much relevant and accurate information as is available that pertains to the title and subject matter of each delivery item. This document should also present and explain the concepts and plans for the use the supplied information.

This document is concerned with the topic of PCA SCIENCE MONITORING which encompasses the following areas:

- EDS Standard Mode 1 screen displays
- EDS Standard Mode 2 screen displays
- Science Modes derived from Std. Mode 1
- Science Modes derived from Std. Mode 2
- Other supported EDS Modes

The PCA group will also produce additional software for its own use, in its own external environment. This software will also be provided to the SOC but is not governed by such rigorous product assurance requirements although it also requires documentation.

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NOTE

At the time of writing the two history display utilities (Spectral & Temporal) do not have all the functionality that was intended for their “baseline” requirements.

1.0 Introduction

The PCA team at GSFC is required to deliver a number of software modules to the Science Operations Center (SOC) for the XTE mission. This document attempts to examine and pull together all the aspects relating to the development of the software for the display of the returned PCA / EDS Science Data. Various standard screen layouts are detailed.

This document is not intended to be a user manual for the PCA Science Monitoring programs. It addresses some details and provides some insights not covered in the software design document or in the user manual.

1.1 Document History

Earlier releases of this document are tabulated below.

Version No.	Date
1.0	1 / 18 / 94
2.0	never existed
3.0	never existed
4.0	12 / 5 / 94
5.0	8 / 16 / 95
6.0	10 / 31 / 95
6.1	12 / 5 / 95
6.2	this version

1.2 Document Organization

Section 2 - describes the various data sources for the program

Section 3 - summarizes the menu functions and screen display designs for Std. Mode 1

Section 4 - summarizes the menu functions and screen display designs for Std. Mode 2

Section 5 - describes additional Science Mode displays that are based on the STD. 1 Mode data packets

Section 6 - describes additional Science Mode displays that are based on the STD.2 Mode data packets

Section 7 - describes science displays based on specific EDS Modes such as the FFT mode and the delta time binned mode

Section 8 - details unresolved issues

1.3 Relevant Documents

Specific PCA Documents:-

PCA Science Monitoring, PCA-HK-EXP-V4.0, Hwa-Ja Rhee, August, 1995

PCA Science Monitoring Users Guide, PCA-HK-DES-V4.0, Hwa-Ja Rhee, August, 1995

General PCA Documents:-

PCA Housekeeping - Status, Screen Functions, Recall Modes, SOC Interfaces, PCA-SIM-EXP-V6.1, Barry Giles, December 5, 1995

PCA Commands - Types, Sequences, Use, Configurations, Screen Functions, Verification, SOC Interface., PCA-CMD-EXP-V6.1, Barry Giles, December 5, 1995

PCA Calibration - General Activities & Procedures, Types, Algorithms, Response matrix, SOC interface., PCA-CAL-EXP-V1.0, Barry Giles, June 4, 1993

Software Product Assurance Plan between the XTE Science Operation Center and the PCA Principal Investigator Team - Aileen Tousignant & Barry Giles, PCA team, February 12, 1993.

Interface Control Document for the PCA Command, Telemetry and Monitoring between the XTE Science Operation Center and the PCA Principal Investigator Team. XTE-SOC-PCA-ICD-V1.0, Rahim Choudhary et al., March, 1994

General SOC Documents:-

Software Development Standards - Leon Herreid, XTE SOC, November 16, 1992.

SOC Product Assurance Plan - Eunice Eng, XTE SOC, in preparation, 1993

XTE SOC Software Development Plan, SOC-STN-017, V0.2, September 7, 1993

2.0 The Supported Modes

There are many hundreds of EDS modes but these can be grouped into several families:

- Event Modes
- Binned Modes
- Single Bit Modes
- Pulsar Fold Modes
- FFT Modes
- Delta Time Binned Modes
- Burst Catcher Event Modes
- Burst Catcher Binned Modes
- Burst Trigger Modes

This extensive set are far to rich in variety and great in number to support in a general sense and it was not an obvious choice as to which were going to prove the most popular.

The standard modes were expected to cover the needs of a substantial fraction of Guest Observers (GO's) and also the monitoring requirements of the Science Operation Facility (SOF) and the PCA team. This assumption was proved valid following the selection of the successful 1st NRA proposals where a very large fraction only requested GOODXENON1 & 2. These xenon data in these modes is essentially the same as that in the Standard Modes both in energy and temporal resolution.

It also now seems likely that very few non Instrument Team (UCSD, MIT, GSFC) GO's will be present at the SOF while their observations are conducted. There are also no plans at present to make some of these monitoring programs available at the GO's home institution. There are no real technical problems with this though possibly some security ones. This may happen in the future once XTE operations are routinely established.

3.0 Genera Data Flow Issues

The data analyzed and displayed by the PCA Science Monitoring suite of software can operate on data from several different sources:

- Real time data
- Saved packet data file

3.1 Real Time Data

The normal mode of operations is to be looking at the incoming real time packets and always leave this going. Any investigation of earlier data should be carried out by starting another instance of the program.

The established convention for Event Analyzers (EA's) is for:

- EA5 to be running Standard Mode 1
- EA6 to be running Standard Mode 2

This leaves EA's 1, 2, 3, & 7 free for any other Guest Observer selected modes. EA's 4 & 8 are reserved for use by the ASM.

3.2 Saved Packet Data File

The program has some flexibility in the source of its incoming data. Rather than look at real time data it can be directed to read a pre-existing packet data file. This data could have been saved at any time within the SOF subsystem or PCA computer network. A GUI structure is used to select the data file to be read.

3.3 General Features

The main GUI allows all the various processes to be started and any number can be in operation at the same time. The full GUI set is:

- Calibration (STD 1)
- Light Curves (STD 1)
- Power (Temporal)] from STD 1
- Power History (Temporal)]
- Spectra (STD 2)
- Rates (STD 2)
- Base Summation (Spectral)] from STD 2
- Recommend (Spectral)]
- Colors VS Time (Spectral)]
- Spectral History (Spectral)]
- EDS FFT
- EDS Delta Time

All these processes can also be started individually and a set of Alias's has been build and setup on the main PCA monitoring machine (PCAMON).

A couple of general features have been incorporated into all the PCA Science Monitoring programs.

3.3.1 Mission Elapsed Time (MET) Graph

An option exists for each process to pop up a graph of the MET in the incoming packet headers. If the packets are in sequence and at the correct interval (none missing) the graph will be a horizontal line. Missing packets will cause a spike.

3.3.2 Missing Data Pop-Up

On average, and ignoring TDRSS gaps, the real time data will arrive at roughly regular intervals. It is therefore possible to start a clock counting the elapsed time since the last packet was received and after a predetermined gap pop-up a small screen to indicate that data is overdue. The timing is obtained from the internal workstation clock. The margin chosen depends on the packet frequency. For Standard Mode 1 the packets are expected within 160 seconds (1.25 x 128) and for Standard 2 within 24 seconds (16 x 1.5). The pop-up shows the following information:

Data Continuity Monitor	
Current Time (UT)	15:22:27
Last Packet Received (UT)	14:54:49
Elapsed Time	00:27:38

3.4 Old Data & Replay Data - Count Rates

All arriving data has its MET packet header time examined and if it is from an earlier time than the last plotted temporal segment (light curves in STD 1 or rates in STD 2) then it is not used. Both old, out of sequence data, and replay data that has mostly already been received in real time will be dropped.

3.5 Old Data & Replay Data - Spectra

Two possibilities exist for the spectral data:

1. All arriving data has its MET packet header time examined and if it is from an earlier time than the last used/plotted spectra then it is dropped. This leads to a loss of some “valid” integration data that arrives late. X-ray source made weaker
2. All arriving data is used. This leads to some “double counting” of replay data. X-ray source made stronger

At present option 2 is being used.

3.6 Completeness Of Real Time Data

The flow of science data from the XTE spacecraft to the SOF relies on a fairly involved series of packet exchanges between many NASA & commercial facilities. The NASA data organization PACOR do not, in their ICD with the SOF, guarantee to deliver 100% of the data either in real time or in later file dump replays.

Tests during the XTE mission simulations have shown that packets are always missing from the real time data flow and on occasions these can reach a surprisingly high percentage with perhaps 25% missing. Therefore all analysis or interpretation of any real time science data must always make allowance for this potential loss of data.

Later PACOR send the SOF a dump of a complete 24 hours of data after they have tidied it all up and incorporated any late arriving packets into their system. This file delivery constitutes the “best” that will ever be available and is expected to be close to 100% complete for routine operations. This file will be delivered to the SOF about 8 hours after the close of the previous 24 hour period. The SOF then process this data to provide a summary to be passed on with it to the archiving & GO data distribution system. This complete data set is referred to as the Level Zero or Processed Data.

At this point the real time data in the SOF becomes somewhat obsolete though they intend to keep the received real time data for a period of about 14 days.

4.0 EDS Standard Mode 1

The EDS Standard 1 Mode is sometimes referred to as the “light curves” mode. This Event Analyzer mode is always present unless the detectors are all switched off as in the SAA region. As such it forms a vital part of the performance monitoring of the entire PCA experiment. The Standard 1 Mode contains three types of data partitions:

- Light curves - individual PCU’s
- Light curves - summed over all 5 PCU’s
- Calibration spectra

The Standard Mode 1 data is read out every 128 seconds and produces a telemetry rate of 1.22 kbps.

4.1 Light Curves Mode

The light curves mode provide a plot of source count rate or intensity against time. Eight types of parameter can be plotted plus a composite of the 5 PCU’s overlaid in different colors.

4.1.1 Light Curves - Individual PCU’s

There are 5 five light curves in this partition. For each PCU there will be a xenon light curve with 1024 data points. Each point represents the total counting rate of good xenon events in a 125 ms time interval. All layers and all energies are summed together. The data is telemetered using 16 bit bins so roll around effects are very unlikely as there would need to be > 65535 events in a single PCU in 1/8 second.

4.1.2 Light Curves - Summed Over All PCU’s

There are three light curves in this partition. These curves contain rates summed over all 5 PCU’s and again have 1024 data points giving 0.125 second temporal resolution. The three rates are:

- VLE rate
- Propane event rate
- Total event rate of events not counted elsewhere in STD Mode 1

All three rates use 16 bit bins. After launch the VLE rate, which initially only used 4 bit bins, was found to roll round dramatically as the rate proved to be much higher than expected.

4.1.3 Light Curve Display Options

The light curve display menu options allows a selection from:

OPTIONS
Sum All Good Xenon (PCU’s 1-5 added)
Sum All Very Large Events
Sum All Propane Events

OPTIONS
Sum All Other Events
PCU 1
PCU 2
PCU 3
PCU 4
PCU 5
All 5 PCU's (overlaid in different colors)

The horizontal scale can be changed by binning up incoming data so that a much longer period of time is visible within the 1024 plotted points. It would normally be sensible to run one instance of the program with the basic 128 second window to see variability on the 1/8 second time scale and start another instance for the longer time scale. Up to ~4.5 hours can be seen at one time with the data binned into 16 second bins. The light curves scroll to the left as new data arrives. The full set of time span options available are:

OPTIONS	BASIC TIME BIN	PLOT TIME SPAN
X 1	125 ms	128 sec
X 2	250 ms	256 sec
X 4	500 ms	512 sec
X 8	1 sec	1024 sec
X 16	2 sec	2048 sec
X 32	4 sec	4096 sec
X 64	8 sec	8192 sec
X 128	16 sec	16384 sec (~4.5 hours)
X 256	32 sec	32768 sec (~9.1 hours)
X 512	64 sec	65536 sec (~18.2 hours)

The vertical axis can be plotted in several linear or logarithmic scales.

4.1.4 Missing Data Gaps

Data always arrives in Standard Mode 1 in 128 second "lumps" so these segments are always full of data points or are rejected and never arrive. Packets may be lost due to data corruption for various reasons and then fail an acceptance test at some stage in the packet exchange process before the packet finally arrives at the Ingest machine in the SOF.

Data can be shown in a continuous mode without gaps with each received packet butted up to the next. This does not preserve the temporal relationship of the incoming packets and when the longer term displays are activated it is more appropriate to have gaps in the plot to space the packets out. This is the default mode. The information shown in the information box, at the centre of the window, gives the MET time for the start of the last packet received and also the “plot bin” this corresponds to on the screen. Once the screen has filled with light curve segments (some packets after start-up) this last packet will always be the one at the right hand side of the display

4.2 Calibration Spectra Mode

In the incoming data there are 30 spectra of calibration events, one for each layer (6) of each PCU (5). These spectra contain 256 energy bins and are telemetered using 4-bit bins. Calibration events are defined to be events with the calibration flag set and single xenon layer flags set with no VLE, propane or xenon veto flags set.

4.2.1 Calibration Spectra Displays - Real Time Option

Each calibration display window shows 6 spectra for each PCU arranged in the following layout:

L1	R1
L2	R2
L3	R3

Each PCU can be selected individually or the sum of all 5 can be displayed. Since the gains are not matched this summed option may at times result in excessive smoothing. The above block of six graphs can be considered as a single plane of a 3D data cube of graphs. The other dimension contains the 5 PCU’s and the combined sum.

Roughly very 128 seconds, or as new data arrives, the displays are refreshed with the new data.

4.2.2 Calibration Spectra Displays - Integrating Option

There is also an integration array where all the above incoming spectra can be summed. It is possible to switch the display back and forth between the “live” and the “integrating” arrays. This integration can be activated and left running in the “background”.

The calibration event rates are very low being typically only 0.5 a second on each layer in each PCU. It is therefore necessary to integrate for some time to build up suitable statistics. Such a spectrum shows quite a number of calibration lines which are then used by the PCA team to provide the energy calibration scale and fed into the response matrices. All these spectra are uncorrected by the EDS and therefore provide the information required to be up-linked to the EDS for its on-board gain & offset corrections.

5.0 EDS Standard Mode 2

The EDS Standard 2 Mode is sometimes referred to as the “spectral” mode. This Event Analyzer mode is always present unless the detectors are all switched off as in the SAA region. As such it forms a vital part of the performance monitoring of the entire PCA experiment. The Standard 2 Mode contains three types of data partitions:

- Xenon spectra - all layers, all PCU’s
- Propane spectra - all 5 PCU’s
- Rates

The Standard Mode 2 data is read out every 16 seconds and produces a telemetry rate of 3.25 kbps.

5.1 Xenon Spectra Option - All Layers, All PCU’s

For each PCU there will be 6 xenon spectra, each with 129 data points. The spectra will be for L1, R1, L2, R2, L3 & R3. The energy mapping and bin counter size vary quite a bit across the energy range to achieve minimum telemetry usage. The initial mapping at launch was found to exhibit roll over in several locations when observing an extremely bright source such as GRO J1744-28 at the peak of a burst. Several mappings were tried and after some experimentation the one below became the new standard.

Bin channel mapping:-

Xenon EDS Channel #	PCA PHA Channel #	No. of bins Added
0	0 - 4	5
1	5	1
etc. until		
49	53	1
50	54 - 55	2
etc. until		
90	134 - 135	2
91	136 - 138	3
etc. until		
124	235 - 237	3
125	238 - 241	4
126	242 - 245	4
127	246 - 249	4
128	250 - 255	6

L1 & R1 bin depths:-

Xenon EDS Channel #	Bin Size (bits) L1 & R1
0	16
etc. until	
67	16
68	8
etc. until	
127	8
128	16

L2, R2, L3 & R3 bin depths:-

Xenon EDS Channel #	Bin Size (bits) L2. R2, L3 & R3
0	8
etc. until	
9	8
10	16
etc. until	
65	16
66	8
etc. until	
127	8
128	16

5.2 Propane Spectra Option - All PCU's

For each PCU there will be 1 propane spectra with 33 data points. The energy mapping and bin counter size vary quite a bit across the energy range to achieve minimum telemetry usage. This mapping is tabulated below.

Propane EDS Channel #	PCA PHA Channel #	No. of bins Added	Bin Size (bits)
0	0 - 3	4	16
1	4	1	16
etc. until			
24	27	1	16
25	28 - 29	2	16

Propane EDS Channel #	PCA PHA Channel #	No. of bins Added	Bin Size (bits)
26	30 - 31	2	16
27	32 - 33	2	16
28	34 - 35	2	16
29	36 - 39	4	16
30	40 - 63	24	16
31	64 - 127	64	16
32	128 - 255	128	16

5.2.1 Xenon & Propane Spectra - Real Time Option

The calibration display window shows 9 spectra for each PCU arranged in the following layout:

L1	R1	VP
L2	R2	**L1+R1+L2+R2+L3+R3**
L3	R3	**L1+R1+L2+R2 - 2 * (L3+R3)**

Each PCU can be selected individually or the sum of all 5 can be displayed. Since the gains are not matched this summed option may at times result in excessive smoothing. The above block of nine graphs can be considered as a single plane of a 3D data cube of graphs. The other dimension contains the 5 PCU's and the combined sum.

Roughly very 16 seconds, or as new data arrives, the displays are refreshed with the new data.

The sum of all PCU's panel is particularly useful in that the 3 plots on the right hand side of the display show:

- The total PCA Propane spectra
- The total PCA Xenon spectra (L1 + R1 + L2 + R2 + L3 + R3)
- The PCA source - background estimate (L1 + R1 + L2 + R2) - 2 * (L3 + R3)

The source - background estimate assumes that:

- Real detector background is distributed within all xenon layers equally (not true for cosmic x-ray background)
- Real X-ray sources tend to be soft and so produce relatively few counts on the bottom PCU layers (L3 & R3). The assumption is that most photons are stopped in the front two layers.

5.2.2 Calibration Spectra - Integrating Option

There is also an integration array where all the above incoming spectra can be summed. It is possible to switch the display back and forth between the “live” and the “integrating” arrays. This integration can be activated and left running in the “background”. This feature functionally works the same way as that for the calibration spectra but is now integrating up real X-ray source photons.

5.3 Rates Mode

For each PCU there will be 29 additional rates all measured using 16 bit bins. The rates monitored are:

EDS Rate #	PCA Rate	Group
1	VLE - any event with VLE flag set	A
2	Vp & L1	A
3	Vp & R1	A
4	Vx & L1	A
5	Vx & R1	A
6	Vx & L2	A
7	Vx & R2	A
8	Vx & L3	A
9	Vx & R3	A
10	L1 & R1	A
11	L2 & R2	A
12	L3 & R3	A
13	Any 3 Discriminators	B
14	Any 4 Discriminators	B
15	Any 5 Discriminators	B
16	Any 6 Discriminators	B
17	Any 7 Discriminators	B
18	Any 8 Discriminators	B
19	Calibration rate (any event with Alpha set but not VLE)	B
20	Low energy veto events	B
21	Medium energy veto events	B
22	High energy veto events	B
23	Vp + one LLD in lower xenon layers	B
24	L1 & L2	B
25	R1 & R2	B
26	L2 & L3	B
27	R2 & R3	B

EDS Rate #	PCA Rate	Group
28	Other 2 LLD events	B
29	Events with no LLD (all flags 0)	B

In the above table:

- Vp is the veto propane layer (front layer)
- Vx is the xenon veto signal (sides & back)
- LLD stands for Low Level Discriminator
- Alpha stands for the calibration alpha source

5.3.1 Rates Display Options

Since the incoming data only provides one data point every 16 seconds it can take some time for the rate light curves to accumulate in a real time mode. Due to limitations in the plotting widget used only 5 plots can be drawn simultaneously in a window. The 29 parameters have therefore been divided into an A & B set so up to 5 from each can be plotted at the same time. The A & B graph sets are defined in the previous table.

All 29 rates are being accumulated in a ring buffer that has a length of 512. Once the rates display mode is selected switching to a new rate display from set A or B will show the maximum history available. This will normally be the last 512 (~2.3 hours of data) data points assuming the program has been running for some time and the ring buffer has been filled.

6.0 Science Modes Derived From Std. Mode 1

The basic Standard Mode1 data contains eight simple time series. The options in this section convert this data to a Power Spectrum form to display the frequency components present.

6.1 Power Spectrum Mode

The power spectra of any light curve are computed using standard calls to Rogue Wave Library methods in the SOF. The normalization chosen is discussed below.

6.1.1 Power Spectrum - Real Time Option

The Power Spectra display mode works on the same set of 8 raw light curves as are described in sections 4.1.3 plus the combined PCU light curve. These are:

- PCUA good xenon (PCU's 1 + 2 + 3 + 4 + 5)
- PCU 1 - 5 good xenon rates (each one separate)
- VLE rate
- Good Propane events
- Total event rate of events not counted elsewhere in STD Mode 1

Any one of these basic 1024 point light curves can be turned into 512 point power spectrum and plotted with a linear or logarithmic vertical axis. The chosen spectra is then refreshed every 128 seconds or so as new data comes in.

6.1.2 Power Spectrum - Integrating Option

Consecutive power spectra can also be integrated in a "background" mode rather like that for the energy spectra displays. This integration is really an averaging process where the noise should gradually smooth out and the signal build up.

It is possible to switch back and forth between the live and integrating options without loss of data.

6.1.3 Leahy Normalization

For normalization we have chosen the method described by Leahy et al 1983.

ref: Leahy, D.A., Darbro, W., Elsner, R.F., Weisskopf, M.C., Sutherland, P.G., Kahn, S., and Grindlay, J.E., 1983, ApJ, 266, 160

This normalization is defined such that the power spectrum of time series obeying Poisson statistics will have an expected value of 2 and that the powers in the case of Poisson statistics obey the chi squared distribution with two degrees of freedom.

$$P_j = \left[2 \left| X_j \right|^2 \right] / N_{ph} \qquad (j = 1, 2, ... N/2)$$

Where N_{ph} is the total number of photons in the time series.

Integrating up the power spectra while on a random background signal will result in the trace smoothing out towards a constant horizontal line at a vertical height of 2.0.

6.2 Power Spectrum History Mode

This display mode consists of two graph areas on the screen as shown below:

<-- 512 -->

Light Curve and/or Power Spectrum (refreshed by incoming data every 128 seconds or so)		
F_{max}	<------ Spectra “latest” ----->	F_{min}
....		
....		
F_{max}	<------ Spectra “oldest” ----->	F_{min}

The upper window shows individual incoming light curves and/or power spectra every 128 seconds or so. The derived 512 element power spectra are then color coded using various “color map” options and plotted across the screen in the lower window section. Each new “strip” is added at the top and the rest slide down one pixel position.

Each temporal spectral element occupies a single pixel on the screen so the lower window can accommodate 512 spectra (~18 hours) before data drops off the bottom of the display. Missing data is shown as a gap. The power spectra are plotted horizontally as this is more efficient with Xwindows which is used for the lower color contour plot region.

The light curves this mode can operate on are defined by the data present in the Standard Mode 1 data packets (8 types). In addition the power spectral history of all 5 PCU added together can be tracked. That is obtained by adding the light curves of PCU’s 1-5 before taking the power spectrum.

Within the Xwindows region:

- The vertical axis represents time steps. The most recent power spectra is at the top and the oldest is at the bottom. Missing data is shown as gaps
- The horizontal axis represents frequency with the highest to the right (4 Hz) and the lowest to the left (DC component)
- The plotted color represents the power spectral intensity. Various intensity - color mappings are available

NOTE

At the time of writing this display utility does not have all the functionality that was intended for its “baseline” requirements.

7.0 Science Modes Derived From Std. Mode 2

The basic Standard Mode 2 data contains rather detailed information about the many layers in each PCU and has a distinct engineering or test bias in terms of the options available.

For a more scientific perspective the basic Standard Mode 2 data has been used to construct a series of new modes which as a starting point always treat all 5 PCU's as added together. These can be added together in two ways:

- Raw Addition
- Corrected (keV energy) Addition

It is also possible to select from:

- L1 + R1 + L2 + R2 + L3 + R3
- L1 + R1 + L2 + R2 - 2 * [L3 + R3] - "mock" background subtracted

7.1 PCA / EDS Gain & Offset Adjustment

The on-board corrections that the EDS performs can be duplicated on the ground. The basic rules are that:

- If PCU ID is returned NO on-board corrections are applied
- If PCU ID is lost then the on-board corrections are applied

The data returned in Standard Mode 2 does not have the on-board EDS gain and offset corrections applied. The display described earlier in which all the PCU Xenon spectra are added together will result in a broadening of the energy resolution as the 5 PCU detector gains will never be the same. To correct the gains we use the same data file that the PCA team provide to the MIT EDS team to correct the Standard Mode 2 data in a similar way to that done on the spacecraft. Note that this cannot in fact be exactly identical since the on-board corrections are done on 255 raw channels and the corrections applied here are done on only 128 channels that have a varying bin width mapping as defined earlier. An example of a typical correction data file is given in Appendix A.

The basic algorithm used is governed by the following rules:

- All data are integer numbers in the range 0 - 255
- Gain is applied first - specified as +-m/256 channels
- Offset applied second - specified as +-n channels
- Equation is new = [[(old * (256 + gain) + 128] / 256] + offset

Specific rules the EDS applies are:

- Values are limited to the range 0 - 255
- Values below 0 and above 255 are considered "out of band"
- Values are rounded to the nearest integer
- Values exactly between two integer values are rounded up

- Values of zero for Gain & Offset cause no change
- + values cause an expansion of scale, - values a contraction

The expansion and contraction cases are considered separately since each has slightly different complications.

7.1.1 Processing Common To Expansion & Contraction

The first step is to convert the 129 bins returned from the EDS Standard Mode 2 back to the full 255 using the mapping given in section 5.1. Single bins map to themselves. An old bin that maps to two bins on the new scale has 1/2 the counts placed in each new bin. An old bin that maps to three bins on the new scale has 1/3 the counts placed in each bin etc.

The next step is to apply the gain & offset equation given above to the new set of 255 bins. Due to the nature of the arithmetic used (the ground process mimics the on-board process) the conversion introduces “holes” for an expansion in energy scale and “spikes” for a contraction of the energy scale. To keep track of these effects a new “reference” vector is created at the same time in the following way:

- Set all bins in the reference vector equal to 1
- Apply the same gain & offset correction as for the real spectral data
- The reference vector will now contain a pattern of counts of 0, 1 or 2 which are markers of what must also have happened to the real data vector. The 0’s mark the positions of the holes and the 2’s mark the spikes

7.1.2 Expansion Of Energy Range

An expansion in scale leads to “empty” bins in the new energy vector. Gaps (0’s) in the reference vector are used as the index for modifying the real spectra.

- Gaps are filled by taking the average of the adjacent bins. This introduces “extra” counts in the total sum of the new spectrum compared to the old
- The spectrum is then normalized by calculating the bin in the old spectrum (#n) that maps to bin #255 in the new spectrum. The total counts in the energy range is then conserved by scaling the new total (#1 to #255) to match the old total (#1 to #n)
- Information will be lost at the high energy end when they are shifted above #255

7.1.3 Compression Of Energy Range

A contraction in scale causes some bins to “double up” creating spikes. Spikes (2’s) in the reference vector are used as the index for modifying the real spectra.

- Spikes are reduced by halving their value. This causes a “loss” of counts in the new spectrum compared to the old
- The spectrum is then normalized by calculating the bin in the new spectrum (#n) that maps to bin #255 in the old spectrum. The total counts in the energy range is then conserved by scaling the new total (#1 to #n) to match the old total (#1 to #255)
- Some high energy bins are now set to zero as there is no knowledge of the counts previously lost above the #255 bin in the old spectrum

7.1.4 Spectral Bin Number To keV Conversion

The total number of energy channels provided by the ADC in each PCU is 255. These are intended to span the energy range 0 - 60 keV in a linear fashion with each bin representing about 0.25 keV. This energy scaling may not be quite exact and could change with time so many screen displays of spectra simply work in bins rather than keV. When a corrected spectrum is selected the keV scale is drawn on the upper horizontal axis in addition to the usual bin number scale on the lower horizontal axis.

The precise relationship may be important in the spectral science displays in the following sections so the conversion relationship has been added to the gain & offset file used by the Science Monitoring subsystem. This conversion is of the form:

$$Y\ (\text{keV}) = A * \text{Channel No.} + B$$

The 5 PCU gains will normally be adjusted on-board to provide an energy scale of 0.25 keV per channel. The Pulse Height Analyzer (PHA) is assumed to be very linear.

7.2 Spectral Base Mode

The Base Mode is the simplest of these science options. In this option the incoming Xenon spectra are all added together and individual PCU identity and layer information is lost. Two forms of addition within each PCU can be made:

- L1 + R1 + L2 + R2 + L3 + R3
- L1 + R1 + L2 + R2 - 2 * [L3 + R3] - “mock” background subtracted

The individual PCU’s can then be added in two ways:

- Raw spectra added
- Gain & Offset corrected spectra added

These choices and the resulting spectrum form the basis for all the following modes in this section. The final spectrum can be refreshed every 16 seconds as data comes in or can be integrated. It is possible to switch back and forth between the live and integrating options without loss of data.

7.3 Spectral Recommd Mode

The suite of GOF software available to Guest Observers for preparing proposals includes a telemetry rate estimation program called RECOMMD. This program takes as inputs the target X-ray flux in 6 pre-defined wave bands and then “recommends” suitable EDS observing modes based on trade-off’s generally between energy and temporal resolution. The telemetry loading of that input event rate and EDS mode is also calculated. Since telemetry usage allocated may be exceeded if the target is unexpectedly bright it is important for the SOF to have tools to allow new estimates to be made based on the observed state of the source.

This mode divides up the added spectrum into the 6 pre-defined wave bands used by RECOMMD so that the 6 sums can be used immediately as input to the program. These 6 rates expressed as c/sec can be integrated averages. The 6 defined ranges are:

RECOMMD Channel	PCU Channel Range	PCU Channel Range ~keV
1	0 - 13	0.00 - 3.28
2	14 - 17	3.28 - 4.22
3	18 - 23	4.22 - 5.63
4	24 - 35	5.63 - 8.44
5	36 - 49	8.44 - 11.72
6	50 - 249	11.72 - 58.36

The six ranges are fixed in the program and are not adjustable.

The final spectrum can be refreshed every 16 seconds as data comes in or can be integrated. It is possible to switch back and forth between the live and integrating options without loss of data.

7.4 Spectral Colors Mode

The Colors mode allows 3 different energy ranges to be defined using slider bars on a sub-menu. The ranges are defined in both PHA bin numbers and in keV. These ranges can overlap in any way, butt up to each other or leave gaps in the spectrum. Each region is shown in a different color.

The lower panel of the display shows a strip chart of the various ratios possible between the three defined spectral regions and allows several color ratios to be tracked at the same time The more common form of a single color ratio between two defined spectral ranges is available by just ignoring the extra options.

The final spectrum can be refreshed every 16 seconds as data comes in or can be integrated. It is possible to switch back and forth between the live and integrating options without loss of data.

7.5 Spectral History Mode

This display mode consists of two graph areas on the screen as shown below:

<-- 256 -->

min		min
oldest spectrum		newest spectrum
max		max
oldest	Light Curve	latest

The upper window shows individual incoming energy spectra every 16 seconds or so. The 256 element spectra are those provided by the "Spectral Base Mode" and color coded using various "color map" options and plotted down the screen. Each new "strip" is added at the right and the rest slide across to the left. Each spectral element is drawn 2 screen pixels high by 2 pixels wide. Since the full Xwindow screen only shows 4096 seconds of data (16 x 256) an option exists to pre-bin the incoming data by factors of x 2, 4, 8, and 16 before plotting. The lower light curve is just the sum of counts in the above spectral strip.

Within the Xwindows region:

- The vertical axis represents energy with channel #0 at the top and channel #255 (~60 keV) at the bottom
- The horizontal axis represents time or rather incoming packet sequence. Missing packets are shown as gaps. Partially missing data (if using the bin up feature) is scaled accordingly
- The plotted color represents the spectral height. The mapping is logarithmic and a bar scale indicates the count - color relationship. Several color maps are available

NOTE

At the time of writing this display utility does not have all the functionality that was intended for its "baseline" requirements.

8.0 Other Supported EDS Modes

The earlier sections of this document describe the display concepts for the two Standard Modes (1 & 2) and the modes derived from them. These 2 standard modes are rather special for many reasons in particular the fact that they:

- Will always be going (on source, Earth occults & slews but not through the SAA)
- Provide standard form calibration data

A possible major deficiency in the real time monitoring options available is that no temporal sampling at faster than 0.125 seconds is available. Perhaps a few suitable modes may be selected and the present suite of supported modes extended at some time in the future.

As an interim measure the existing “rough” modes to display EDS FFT and Delta Time Binned Modes have been brought within the present GUI so as to be easily executable. These allow displays of the data from any of the appropriate EDS modes which can get down to 1 microsecond temporal resolution.

The FFT or Delta Time Binned Modes may be expected (if running) on EA’s 1, 2, 3 or 7.

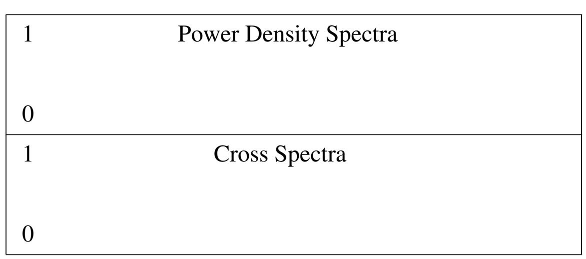
8.1 EDS FFT Mode

The data products produced by the FFT mode are:

- summed Power Density Spectrum (PDS) of band 1 (129 points)
- summed PDS of band 2 (129 points)
- summed Cross Spectra (CS) between bands 1 & 2
- series of means for band 1
- series of means for band 2

A full definition of the mode can be found in the XTE NRA. All data sets before the FFT operation is performed have 256 data points. All PCU’s are combined for this analysis. To support this mode PCA have taken the unmodified old code produced jointly by Mike Lijeski (SOF) and Ed Morgan (MIT) and simply called it from the main GUI. The spectra are normalized to a height of one.

The display has two windows:



8.2 EDS Delta Time Binned Mode

This mode works on a single energy range with the sum of the Good Xenon signals from all 5 PCU's. To support this mode PCA have taken the unmodified old code produced jointly by Mike Lijeski (SOF) and Ed Morgan (MIT) and simply called it from the main GUI.

Some of the Delta Time Binned modes listed in the 1st XTE NRA have 128 bins and some have 1024 bins. The readout time varies from 1 second to 64 seconds.

The display has two windows and several control buttons for the integration mode in the lower window:

1		Delta Binned Mode		
0				
1		Integrated Delta Binned Mode		
0				
START	STOP	FREEZE	THAW	CLEAR

A random event rate will produce an exponential decay curve which should get "smoother" with time as it is integrated. A source of widely varying intensity will produce a complicated profile.

This mode is particularly useful for examining PCA dead time down at the fastest sampling time scales.

9.0 Notes

10.0 Appendix A

```
//
// RCS:$Id$
//
//  FILE - EDSgain
//
//  Organisation ID:
//  XTE_PCA
//
//  Author:
//  GILES ALAN B
//
//  File ID:
//  SOC_xxxx
//
//  File Version:
//  V_4.4        Build 4.5.3
//
//  Creation Date (yr.mon.day) / Time:
//  1995.11.3    16:33
//
//  Description:
//
//
//  EDS / PCA Gain & Offset values
//
//
//  Template file for EDS Gain & Offset adjustment command
//  values derived from PCA calibration data
//
//  1)  All data are integer numbers in the range 0 to 255
//  2)  Gain applied first - specified as +-m/256 channels
//  3)  Offset applied second - specified as +-n channels
//  4)  EDS applies the following rules to the computedc channel value:
//        i) values are limited to the range 0 - 255
//       ii) values below 0 and above 255 are considered "out of band"
//      iii) values are rounded to the nearest integer
//       iv) values exactly between two integer values are rounded up
//        v) Values of zero for Gain & Offset cause no change
//  5)  Equation is:    new = [ old * ( 1 +  gain / 256 ) ] + offset
//  6)  Channel No. to keV, last line has A & B constants
//        equation is keV = [ ( Ch # ) * A ] + B
//        only applicable after gain corrections are done
//
//
//   Typer
//   Table   |      SLOT GAIN          |     SLOT OFFSET
//   Address |  1    2    3    4    5   |  1    2    3    4    5
//____________________________________________________________________________
//
       0        0    0    0    0    0      0    0    0    0    0
       1       24   22   29   10    2      1    1    1    0    0
       2        0    0    0    0    0      0    0    0    0    0
       3        0    0    0    0    0      0    0    0    0    0
       4        0    0    0    0    0      0    0    0    0    0
       5        0    0    0    0    0      0    0    0    0    0
       6        0    0    0    0    0      0    0    0    0    0
       7        0    0    0    0    0      0    0    0    0    0
   0.2500     0.0
//
//  End of File
```