Appendix F: The XTE Technical Appendix

Technical Appendix

to the XTE NRA

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Chapter 1

Overview of the XTE Technical Appendix

1.1 Purpose and Scope

This appendix provides proposers with detailed technical information about XTE and its scientific instruments. The person who reads this appendix will be able to (i) determine when XTE can observe a specific source; (ii) determine whether the observation can be made as a TOO; (iii) identify the capabilities of XTE for scientific studies; (iv) determine whether a proposed observation is feasible; (v) determine how to best use XTE's capabilities.

The first item is covered in Chapter 2 which discusses the constraints imposed upon a given observation. Chapter 3, which covers the second item, describes the data rights and TOOs.

The third item is covered in Chapters 4 (PCA), 5 (HEXTE), 6 (ASM), and 7 (EDS) which contain descriptions of each of the scientific instruments and their operating modes.

The fourth and fifth items are covered in Chapters 8, 9, and 10 which contain, respectively, a complete walk-through to determine an EDS configuration using software tools provided by the XTE GOF and the HEASARC, feasibility examples for the PCA, and for HEXTE. The “feasibility” of the EDS is covered in each of these chapters as needed. The complexity of the XTE's data system requires a proposer to demonstrate the feasibility of a particular observation and to specify the data mode/configurations and telemetry rates of the proposed observation. The reader is urged to read very carefully the EDS section (Chapter 7) to understand fully the capabilities of the EDS.

Additional information describing software, the XTE User's committee, and related issues are presented in appendices to this appendix.

1.2 A Quick Comparison of the XTE Instruments

A line drawing of XTE is visible in Figure 1 showing the location of XTE's instruments. The user can propose observations with two of XTE's instruments: the PCA (Proportional Counter Array) and HEXTE (High-Energy X-ray Timing Experiment). Data from the third instrument, the ASM (All-Sky Monitor) are not proprietary. The two instruments are co-aligned but cover different energy ranges so the two instruments complement each other. The following briefly describes the two instruments. Proposers are urged to read the detailed properties of each instrument.

- Energy range: the PCA has Xenon (Xe) proportional counters covering the 2-60 keV range; HEXTE uses NaI/CsI phoswich detectors covering the 15-250 keV range.
- Energy resolution: the PCA resolution is 18% at 6 keV while the HEXTE resolution is 18% at 60 keV.
- Effective area: the PCA has 3000 cm^2 at 3 keV, 6000 cm^2 at 10 keV, and 800 cm^2 at 50 keV. HEXTE has 1200 cm^2 at 50 keV, 1100 cm^2 at 100 keV, and 300 cm^2 at 200 keV.
- field of view: the fields-of-view of both instruments are 1^o FWHM circular.
- temporal resolution: the PCA has a 1 μs time resolution while HEXTE has 10 μs time resolution.

Proposers will receive data from both instruments as a result of a successful proposal.

1.3 Update

The material in this technical appendix will be updated prior to each NRA.

Comments are welcome. E-mail comments to `xtenra@athena.gsfc.nasa.gov`.

Chapter 2

Observing Constraints

2.1 Scheduling

The list of successful proposals generated by the proposal review will be fed into the SPIKE scheduler (Scientific Planning Interactive Knowledge Expert system) to produce two mission time lines: a long-term time line that will cover about six months of observations with a resolution of ~1 week; and a short-term time line that will cover about a week of observations with a resolution of ~1 minute. The short-term timeline will be updated every week. SPIKE automatically takes into account the various constraints on XTE observations and chooses the most efficient overall time line within these constraints. The constraints are described below.

2.2 Constraints

The constraints on how and when XTE can observe a given target fall into four broad categories:

- viewing constraints, i.e., when during a year a source may be observed
- sampling constraints, i.e., when during a day a source may be observed
- operational constraints, i.e., how a source may be observed
- user-imposed constraints, i.e., how the source is to be observed

The issue of feasibility (i.e., whether the instruments can observe a given target) is considered separately in Chapters 9 (for observations using PCA) and 10 (for observations using HEXTE). Each constraint category is covered in a separate section below.

2.3 Viewing Constraints

The only viewing constraint is the sun avoidance constraint. For XTE, the solar avoidance angle is $>30^{o}$. In other words, XTE will not point closer to the Sun than 30^{o}. A solar avoidance angle of $>30^{o}$ leaves approximately 93% of the sky visible to XTE, permitting coordinated observations with ground-based observers.

2.4 Sampling Constraints

2.4.1 South Atlantic Anomaly

Satellites launched into low-Earth equatorial orbits pass through the South Atlantic Anomaly (SAA). SAA passages occur consecutively on about 6 of the 14-15 satellite orbits per day. During passage through the SAA, the high particle flux renders the instruments unusable. Even after emerging from the SAA, the level of induced radiation, which will be seen as a background component, may be enhanced.

2.4.2 Earth occultation

Sources not near the orbit poles will suffer Earth occultation. Typically, Earth occultations last about 30 minutes and occur every satellite orbital period (100 minutes).

2.4.3 Regions of low geomagnetic rigidity

In the six orbits per day which do not pass through the SAA, there are still regions of high particle background where the geomagnetic rigidity is low. Regions of low geomagnetic rigidity produce intervals with enhanced backgrounds. It is not completely clear how the instruments will be affected by these regions prior to launch. The usual practical effect is to reduce the amount of “good” observing time per day for weak sources. Proposers should not expect continuous data streams even for sources not affected by Earth occultation.

2.5 Operational Constraints

2.5.1 Direct contact

Communications with the spacecraft are through the Tracking Data Relay Satellite System (TDRSS). TDRSS contact can be maintained during approximately 70-80% of each orbit, but there may be additional limitations, for example, when the space shuttle is in orbit. Contact will occur through the MA (Multiple Access) and SA (Single Access) telemetry links. There will be a 10-minute command contact every orbit. The data that are used in monitoring observations and in determining the presence of TOOs will be delivered each orbit. The details of TDRSS scheduling should not constrain most XTE users. This section is largely included to remind users that telemetry, and hence telemetry contacts, will be a limitation.

2.5.2 Maneuvering and attitude determination

XTE is a three-axis stabilized spacecraft in which the instruments can be pointed anywhere in the sky but at least 30^o away from the Sun. The roll axis of the spacecraft is defined to be along the pointing vector of the PCA and HEXTE optical axes. The pitch axis is parallel to the axis of rotation of the solar panels, while the yaw axis is aligned with the ASM boom. Rotation around the roll axis is restricted to keep the Sun off the spacecraft's thermal radiators (The Sun will never be more than 5^o from the X-Z plane during an observation.). Pitch is restricted to an interval between 0^o and 150^o, where 0^o is defined as the roll axis points directly away from the Sun; 90^o is defined as the yaw axis pointing directly at the Sun. Rotation around the yaw axis is unrestricted.

The spacecraft attitude control system (ACS) contains optical star trackers, gyroscopes, digitial fine Sun sensors, coarse Sun sensors, magnetometers, reaction wheels, and torquer bars to determine and to control attitude during any conditions. The star trackers are CCDs capable of tracking about 5 stars as faint as 6^{th} magnitude in a field of approximately 8^ox8^o. Two trackers, each offset by a few degrees from the PCA and HEXTE boresights, have fields-of-view overlapping the target direction. The gyros are capable of holding attitude to within 10” over half an orbit without star tracker information. Their accuracy is not expected to be affected appreciably by spacecraft maneuvers. The fine Sun sensors are positioned such that they provide information at all legitimate attitudes during orbit day with an accuracy of about 1’. Attitude solutions will be in the telemetry stream. Other data will also be available so attitude may be recomputed at a later date.

2.5.3 Minimum viewing time

Maneuvers will likely be scheduled during SAA passages or earth occultations. XTE can maneuver at $\sim 6^o$ per minute; approximately 500 sec of overhead occurs per maneuver. Approximately 20 maneuvers per day are anticipated.

Therefore, the minimum on-target time will be 256 sec. This choice is a multiple of the basic HEXTE observing cycle length (the on-source/off-source nodding of the HEXTE clusters). A time of this length minimizes the impact of short points on the overall efficiency.

2.5.4 Multiple pointings and raster scans at large extended objects

Multiple pointings are defined as offsets occuring within $0^o.5$ of a particular direction (i.e, a move followed by a dwell) and will be considered multiple targets for the proposal process. Raster scans (slow drifts across the target followed by a small maneuver to set up for the next drift) are permissible provided the minimum viewing time (defined above) is not violated for the entire raster scan. The user who wishes a raster scan of a target will be expected to provide the RA and Dec of the end points of each scan line of the raster as well as the limits on the slew (drift) rate. The size of the raster box may be alternatively specified. Users should note that a specific orientation of the raster may not be achievable within the orientation limits of the spacecraft (Section 2.5.2 above).

2.5.5 Spacecraft jitter

As the XTE spacecraft orbits the Earth, it is buffeted by high-altitude atmospheric turbulence causing the instantaneous attitude to jitter. The 3σ rate of fluctuation is expected to be 0.1-0.2 arcmin per X sec. This jitter can not be corrected for and limits the precision to which one can constrain source variability.

2.5.6 Telemetry rates and on-board storage capacity

The spacecraft and ground systems can support scheduled access to the satellite for tens of minutes per orbit at rates of 48-1024 Kbps. Command telemetry can be accommodated at 1kbps. The on-board storage capacity is ~906 Mbits. The average telemetry rate for the PCA/EDS is ~18 Kbps (which includes the Standard Modes rates of ~3.3 Kbps) while the HEXTE limit is ~5 Kbps. Users must justify telemetry rates that are greater than the Standard Mode values.

2.6 User-imposed Constraints

2.6.1 Coordinated Observations

Coordinated observations occur when the user desires multiple bandpass coverage of a target. The multiple bandpasses can be XTE/ground-based (i.e., optical or infrared) or XTE/other satellite-based. The constraint must be specified as a particular time to start and to stop the observation (specified in absolute time: Year, Month, Day, Hour, Minute). The user must supply as much information as possible about the non-XTE bandpasses to be included. ‘Special handling’ may be indicated; approximately four such targets will be handled per month. ‘Special handling’ emphasizes the importance of matching the absolute coordinated schedule and permits the investigator to change the schedule up to 60 days prior to the start of the observation. The ‘special handling’ flag will be reviewed for its appropriateness by the peer evaluation panel.

2.6.2 Phase-dependent Observations

A phase-dependent observation is one in which XTE must observe the target at a particular point in the target’s orbit. The user must specify the Epoch and Phase of the observation as well as the phase window in which the observation is to be done.

2.6.3 Contiguous Observations

This constraint is used to eliminate interruptions to the data stream in an observation of a target. Please note that XTE will be operated in a “contiguous” mode as the default. The average target will thus obtain quasi-contiguous data by default, with interruptions resulting from SAA, earth occultation, and other standard orbital constraints. If an observation is desired to be done without interruptions (say from Earth occultation or SAA passage), the observation will require a contiguous constraint. Such a constraint must be justified in the proposal.

2.6.4 Time-of-Day Observations

This constraint is most clearly applicable to ground-based observers who want XTE observations at the same time as their optical observations, but for which a "coordinated observation" is overly restrictive. For example, if an object is to be studied every night for 4 nights, there is little use in specifying a coordinated observation of length 4 days. The user must specify the UT times to start and to end the observation.

2.6.5 Monitoring Observation

The monitoring constraint is used to check the target's flux or state over a long interval of time in a repetitive manner.

2.6.6 Alternate Targets

Alternate targets will be permitted at a limited level. The criteria for a target to be accepted as an alternate are given below. Basically, alternate targets provide the GO with an option to not waste observing time if a particular source appears "uninteresting". *It will be the proposer's responsibility to provide the alternate target at the time the proposal is submitted*. The target and the alternate will be judged by the review committee. Read the criteria *very* carefully.

- the alternate target observation must be at least 4 orbits in duration and have approximately the same earth occultation schedule as the original target (an efficiency constraint);
- the user must be present during the observation or an iron-clad conditional must be specified;
- the review committee must approve the target, the alternate, and the conditional;
- only one alternate per target will be permitted
- the instrument configuration must be identical for target and alternate
- the alternate must produce the same or a lower telemetry rate;
- a limit of 1 alternate target per month will be permitted during the Cycle-1 period (as a test of the procedure).

Note that the proposer does *not* receive additional time for the alternate. The time awarded to the proposal is awarded to the target plus the alternate. Time expended in slewing to the target and checking the conditional is charged against the total time awarded to the proposal. Necessarily, the alternate will receive less exposure time. In addition, the alternate target is *not* carried over to a subsequent observing cycle. In other words, if the primary target is observed, separate observations will not be scheduled for the alternate nor will the alternate become a target on the next cycle's observing list.

Chapter 3

Data Rights and Targets of Opportunity (TOO)

This chapter will discuss the data rights from all possible observations including targets of opportunity (henceforth, TOOs). The procedures the user *must* use to submit a TOO proposal will also be described.

3.1 Data Rights

An XTE investigator will have a proprietary period of 1 year for any data obtained by observations from a successful proposal in response to an XTE NRA. The proprietary period will apply regardless of the type of constraint placed on the observation. For example, one exception usually cited is the case of a proposal to monitor an AGN for one year in, say, 12 equally-spaced observations. If such a proposal is accepted, then the investigator will have a 1-year proprietary period on each installment of the full data set.

The proprietary period applies to any data obtained from any instrument available to the proposal process (in other words, proposals to use the PCA or HEXTE). Note that a PI can not submit a proposal for ASM observations, so no proprietary period applies to any ASM data. Funding-only proposals are permissible, but an accepted proposal to analyze ASM data does not earn proprietary data rights for the data used in the investigation. Furthermore, no proposals may be submitted for slew data nor data obtained during the check-out phase of the mission (IOC period). Proprietary data rights do not accrue for these data. Proprietary rights for TOO data are described under the Targets of Opportunity section. The data obtained during the IOC phase will be made public on a time scale faster than the PI data are made public. At the time this section was written, that time scale was planned to be about 3-4 months. Slew data accumulated near a user's target will be given to that user, but will not be considered proprietary. The slew data will enter the public archive at a rate faster than the proprietary data enter the archive. Initially, that rate will be very slow to prevent a heavy load on the XTE SOC and GOF during the early phases of the mission.

3.2 Targets of Opportunity (TOOs)

One of the primary design criteria for XTE is the rapid response to TOOs. The design calls for a 7-hour response to an ASM-triggered event. Such a fast response will require a careful interaction of the XTE timeline planning team with the GOF and potential users. Some users will, of course, be interested in interrupting any scheduled observation to examine the current transient while the PI whose observation faces interruption will want no interruption. Every observation, even a time-critical one, faces a potential interruption as a result of a transient. On the other hand, a TOO may not be immediately acted upon because a time-critical observation must first be completed. Only a limited number of TOOs will be done on a monthly basis. At the time this text was written, approximately 10% of the available time will be allocated to TOOs.

There are three categories of TOOs to be discussed:

- an NRA-approved proposal TOO;
- a formal, one-page Request for Observations (RFO) in response to a real-time transient (e.g., a ground-based observer may submit an RFO based upon an observed optical target);
- internal SOC TOOs (i.e., targets for which no approved proposal or request exists).

Note that a formal procedure will be instituted for responding to real-time TOOs. *This procedure will be adhered to, by all, regardless of the nature of the transient (even a Galactic supernova!).* This procedure will be described below.

3.2.1 NRA-approved TOO

TOOs generated by an NRA-approved proposal will be similar in spirit to the *International Ultraviolet Explorer* model. Users may submit a proposal that contains a TOO observation. Proposals will not be permitted that mix TOO and non-TOO targets. Proposal TOOs will be graded by targets (as has been done with ROSAT and ASCA targets). The highest-priority TOO targets stand the best chance of observation; the lowest-priority targets have no guarantee of observations. Hence, a grade C TOO target stands a good chance of being over-ridden by a higher-priority TOO or time-critical observation.

If the proposal is approved, depending upon the TOO's target grade, time may be allocated to the proposal, but that time will remain unscheduled. Two types of NRA-approved TOOs may then exist: "external", which will require activation by the PI because the trigger will be, for example, a change in the optical flux of the target, and "internal", which will have a trigger based upon an increased flux in the ASM. The second type can be completely handled by the SOC, provided the trigger is well-defined. It will be the user's responsibility to see that the activation criterion is clear.

The first type, the “external” NRA-approved TOO, will require activation by the proposer. It will be the responsibility of the user to notify the SOC that the proposal TOO is to be activated. The procedure for activating such a TOO will be identical to the “formal, one-page” observation request (described below). In other words, phoning to activate a proposal TOO is *not sufficient*. A formal, one-page request (RFO) will be required. This formality may be observed by extracting the appropriate sections from the original proposal along with the proposal title. The one-page request, in this case, should contain the following information:

- a brief review of the activation criteria and how they have been met
- a brief review of the observation to be done

While this formality may seem unnecessary, the intent is to track and to document the time-line in detail, as well as to serve as a reminder of the observing program for the duty scientist. The original proposal should *not* be re-submitted to request activation.

TOOs generated from an NRA-approved proposal will fundamentally disrupt the scheduled timeline. There is no guarantee an NRA-approved proposal will be done if a higher-priority, time-critical observation is on the schedule, or if another, higher-priority TOO appears. In addition, the total number of TOOs performed per month will be limited by operational or man-power constraints.

Data rights from an NRA-approved TOO will be identical to any other NRA-approved proposal. Funding rights will also be identical to any other NRA-approved proposal.

3.2.2 Formal, one-page Request for Observation (RFO)

This section describes the procedure that a user will use for generating a TOO outside of the formal NRA proposal period. The “formal, one-page” adjective describes what the requester will *have* to submit to the SOC for approval by the Project Scientist (or an appointed deputy). Only after approval is given will the SOC begin preparations to interrupt the schedule and to re-orient XTE to the TOO target. The RFO is intended to be formal, yet brief.

This procedure will lead to a managed database of what sources have been studied by which users. Such a database will be used during the next proposal process in judging which proposals could achieve their scientific aims using data already available in the archive.

The procedure will be as follows.

- The potential RFO-TOO proposer will determine whether the target falls within the portion of the sky visible to XTE. This is a relatively weak constraint given the sky coverage available to XTE.
- The potential RFO-TOO proposer will determine whether the target can be detected by XTE (sensitivity and background issues are pertinent here).
- The potential RFO-TOO proposer will prepare a one-page request formally asking for an observation of a TOO. The one-page RFO *must* address the following issues.

- the science to be obtained from the observation
- why the science can not be obtained from an NRA-approved pointing or ...
- ... why the science can only be obtained during this TOO
- the likelihood of additional transient behaviors (i.e., does this source recur? if it does, what happens if *no* data are obtained during the current transient behavior?)
- if data already exist in the archive, why will that data not yield the same science?
- how urgent is the TOO (i.e., can the scientific aims be achieved with an observation done 2 days from now, or must it be done immediately)?
- a calculation of the expected count rate, source confusion limit, spectrum, and other feasibility questions
- instrument configurations and an observing plan

The formal, one-page request should then be submitted to the XTE SOC electronically (e-mail address = `xtetoo@athena.gsfc.nasa.gov`).

If the proposed observation is accepted, the timeline re-scheduling will begin as soon as possible. Please note that the minimum response time for a TOO scheduled in this manner may be longer than the ~7 hours for NRA-approved proposals. Note also that *no* proprietary data rights nor funding accrue to the proposer of a TOO obtained in this manner.

Some negotiation between the TOO proposer and the XTE SOC and between the XTE SOC and the scheduled investigator may be necessary to achieve the optimum blend of TOO response time and minimizing disruptions of the existing timeline.

3.2.3 Internal SOC TOOs

This category describes those transients for which no NRA-approved TOO proposal or Project Scientist-approved RFO-TOO exists. For example, the ASM may be expected to see approximately 1 transient per day (assuming transient rates similar to that observed with BATSE). Some of these ASM-discovered sources are unlikely to have an approved proposal or RFO awaiting the outburst. Operationally, internal SOC TOOs will be handled exactly as described in Section 3.2.2 above.

Chapter 4

PCA Instrument Description

The PCA and EDS should be considered as a single experiment by proposers but since they are built by different institutions their technical descriptions are presented here in separate chapters. The interface between the two subsystems is also covered within this chapter. It is important to note that NO event selection occurs within the PCA electronics. Every detected event is passed to the EDS where a vast range of options exist for event rejection, selection and processing. The EDS also provides the μs time stamp for every photon detected by the PCA.

The PCA is co-aligned with the High Energy X-ray Timing Experiment (HEXTE) on XTE and both experiments have the same field of view. Together the two experiments provide simultaneous spectroscopic coverage from 2 - 200 keV with an overlap from about 20 keV to 60 keV.

4.1 General Principles

The PCA experiment on XTE consists of 5 identical sealed and collimated (1^0 FWHM), xenon/methane multi-anode proportional counters sensitive to x-rays in the energy range 2 - 60 keV. The total effective area at the peak of the efficiency curve is approximately 7,000 cm^2. The data system can tag the relative time of arrival of each event with an accuracy of 1 μs. The overall absolute time accuracy is maintained by the spacecraft to better than 1 ms. Following the design principles of the HEAO-1 A2 HED detectors, the PCA adopts the interleaved anode connection scheme with an active propane anti-coincidence layer in the front and an anti-coincidence xenon/methane layer on the three other sides of the detector. The interleaved anode connection scheme and the anti-coincidence layers allows rejection of background events caused by charged particles with high efficiency which significantly reduces the residual background event rate at lower energies.

In general terms the EDS provides many commandable observing modes for the proposer to select from whereas the PCA provides almost none (only the HRM level). The PCA commandable parameters will normally be entirely under the control of the PCA PI team who will maintain the detectors in the optimum state for all observers. A good understanding of the design and operation of the PCA experiment is essential when selecting appropriate EDS modes for any particular observation and these combined characteristics are covered in the feasibility chapter.

4.2 The PCU Detectors

Since the 5 Proportional Counter Units (PCU's) are essentially identical and operate independently much of this chapter will refer to only a single detector module. Each PCU has an effective area of approximately 1,400 cm^2 and its internal construction and general design are based very closely on the HEAO-1 A2 detectors. In the following numerical values should be taken as approximate.

4.2.1 Physical Description

Figure 4.1 shows a cross section view of a single PCU and the following describes the components from the top down, adhering to the non-metric engineering terminology of 0.001 in = 1 mil = 25.4 microns.

- Each PCU is covered by a thermal shield consisting of aluminized 1/3 mil Kapton. The thermal shield is part of the passive thermal design of the PCA and each detector is thermally connected to the XTE spacecraft. The thermal shield will not be illuminated by direct sunlight except for observations which are < 45 degrees away from the sun. (The baffles which accomplish this are part of the spacecraft.)
- Each PCU contains 5 collimator modules. Each module is formed from 3 mil beryllium-copper sheets which are tin-coated, stamped into half-hexagonal form, stacked, and then heated which causes the tin coating to solder the sheets together. Each module is a cube about 8 inches on a side and each hexagonal cell is about 1/8 inch across the flats. The bottom surface is polished and coated with a small amount of uralane to protect the mylar window. Each of the 5 modules also has a 1 square cm mirror bonded to the front surface. These were used to align the modules within their surrounding frame before they were fixed in position with epoxy.
- Immediately behind the collimator is a 20 mil beryllium-copper shoe which duplicates the footprint of the first interior grid. A one mil mylar window with 700 angstroms of sputter-deposited aluminum on each side is held in place between the shoe and the first grid. A second window is held between the first and second grids. The two windows and the first grid form the boundaries of a 1.3 cm deep volume which is filled with propane.

- The propane volume serves primarily as an electron veto region and front charged particle anti-coincidence shield. The propane detector has twenty anodes across its width on 1.3 cm centers, each being separated by thin solid aluminum walls that support the second window. The propane nominal pressure is 1.05 atmospheres. The double gas volume design requires that this pressure be less than or equal to the pressure behind the second window at all times during the filling and operation of the detector.
- Below the second window is the xenon volume. This consists of four more wire grids, each with twenty anodes at approximately the same spacing as for the propane volume. These anodes are separated by wire wall cathodes (5 across a cell side) and this volume is normally filled with xenon plus 10% methane mixture at a total pressure of 1.10 atmospheres. All anode and cathode wires are made from gold coated, 2 mil diameter, stainless steel wire. The wires are installed under tension (~110 gram) sufficient to stay taut at the lower survival temperature of -25^0C but low enough not to yield at the highest temperatures considered for baking out the detectors (60^0C). Wire tension is checked after installation by measuring the fundamental acoustic frequency of each wire. The upper 3 of the 4 xenon grid layers are used for x-ray detection.
- The bottom of the 4 xenon anode layers plus the xenon layer anodes nearest the sides form a veto detector for charged particles. The lower surface ground plane of the bottom layer is defined by a beryllium-copper back plate. This also provides some shielding from events which are created in the dead (i.e. non-instrumented) xenon volume at the rear of the counter. Mounted on this plate is an Americium-241 source which provides a continuous, low-level energy calibration signal of tagged events.
- A detector housing (the outer box) and a rear cover complete the detector structure. Mounted on the rear cover is a pressure transducer (for the xenon volume) and a getter pump which is filled with a zirconium/vanadium/iron alloy that is activated by external heating just before the detector is filled. There is also a second pressure transducer for the propane volume mounted on the side of the detector.
- Each PCU is covered by a graded shield of tantalum (60 mil) over tin (20 mil) to reduce the cosmic X-ray background flux and absorb the hard X-ray and gamma ray events generated in the spacecraft by cosmic ray impacts. The tin thickness is chosen to absorb escape photons generated from interactions in the outer tantalum layer.

4.2.2 PCU Anode Signals

Each PCU contains a stack of electronics boxes that ultimately produce signals from 9 independent anode chains. The internal anode connections that produce these 9 signals are shown in Figure 4.2.

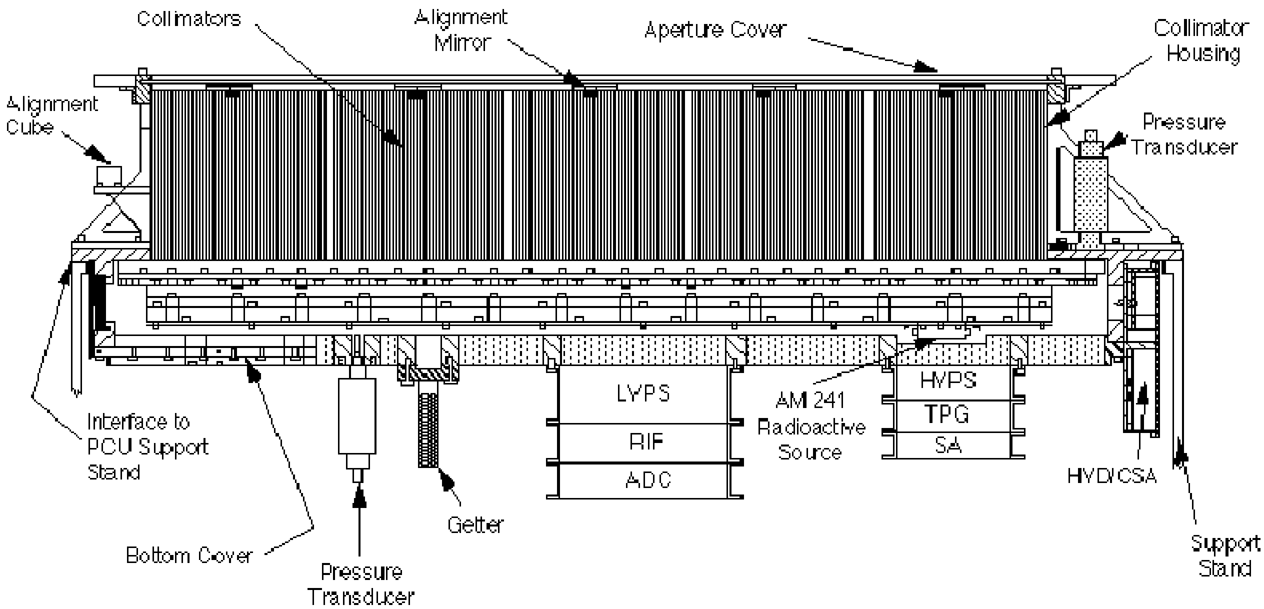

Fig. 4.1 Cross section view of a PCU. The function of the various components is discussed in the text.

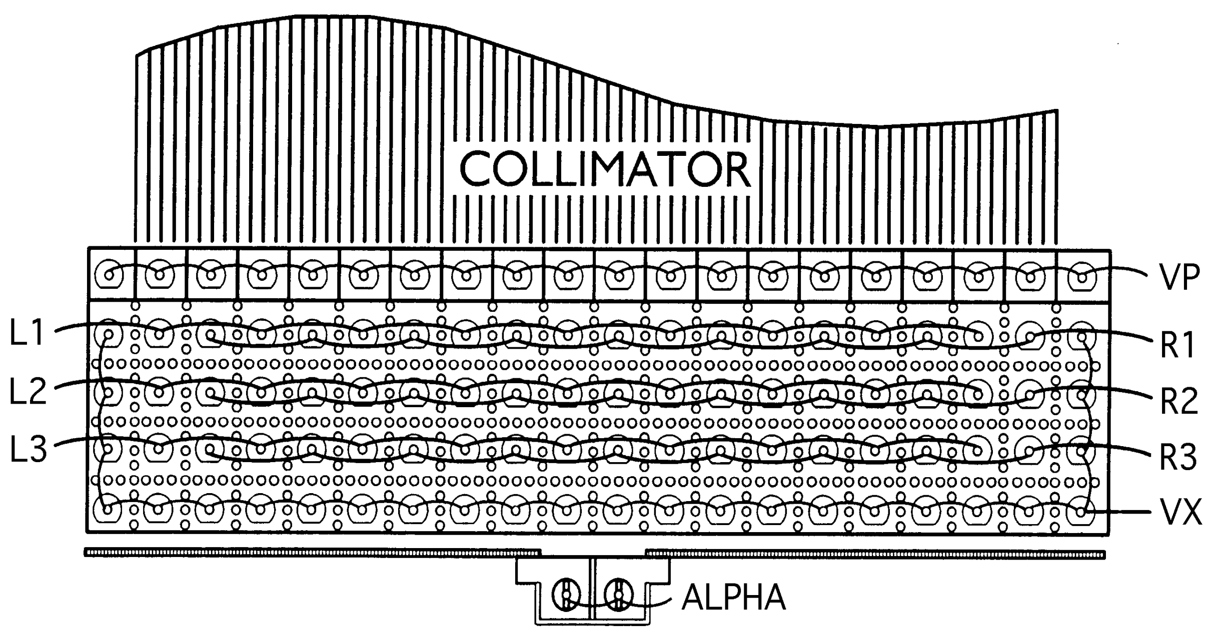

Fig. 4.2 The anode and signal connections for the 9 independent channels of analog electronics. The interleaved anodes provide rejection of charged particle background.

The PCU signals are also summarized in Table 4.1:

TABLE 4.1. The 9 PCU Signal Chains

Signal	Description
VP	All propane anodes connected together
L1 & R1	1st xenon layer has 2 interleaved sets of anodes
L2 & R2	2nd xenon layer has 2 interleaved sets of anodes
L3 & R3	3rd xenon layer has 2 interleaved sets of anodes
VX	xenon veto layer
ALPHA	event from calibration source alpha detector

Note that the symbols L & R do not refer to Left or Right in the sense that the width of the detector is divided in half, but in the sense of the odd- and even-numbered anodes, looking down the detector from the HV distribution box end.

4.2.3 Electronics Description

The electronics for the PCA has been designed in a very modular style and a discussion of the unit boxes introduces many of the commandable features.

4.2.3.1 Electronics Boxes

Each PCU contains the following electronics boxes which are mostly mounted on the back of the detector:

- Charge Sensitive Amps (CSA)

  Each anode chain has a low noise amp inside the CSA box mounted on the end of the detector.

- Shaping Amp (SA)

  Eight of the anode chains (not ALPHA) have a Lower Level Discriminator (LLD) that can be commanded to 4 states - 1 keV, 1.5 keV, 2 keV, & off. In the off state, all events from that anode chain are inhibited. The ALPHA signal has a Lower Level Discriminator (LLD) that can be commanded to 4 states - high, medium, low, & off. A total of 9 LLD flags are available from the 9 anode chains to indicate in which anode chain the analyzed pulse was detected. If two or more LLD flags are set the origin of the 8 bit pulse height is ambiguous. Saturating pulses, termed Very Large Events (VLE's), in any of the 6 main xenon or propane anode chains (not VX or ALPHA) also set a single VLE flag bit.

- Test Pulse Generator (TPG)

  The TPG box contains a pulse generator that can be operated in two modes and directed to any of the possible 9 anode chains. In the RAMP mode, the generator produces analog pulses which cycle through all the ADC PHA channels. In the MONO mode, up to 16 discrete lines are generated; 14 within the PHA energy range, one above the maximum channel and one at the level of VLE triggers. The TPG pulses on the ALPHA chain test the discriminator level only.

- Analog Digital Converter (ADC)

  Each PCU contains a single ADC that provides a 256-channel pulse height analysis for the propane and 6 xenon signals. The differential non-linearity of the 12-bit ADC is minimized by using a dither circuit and by ignoring the 4 least significant bits. The dither process allows the ADC to perform the conversion in different ADC channels, thus distributing the error over several channels. As a consequence of dithering, the upper six channels of PHA data contain erroneous data and must not be used.

- Remote Interface (RIF)

  The RIF box acts as the interface point between the PCU and the spacecraft for commanding and the construction of the housekeeping data. The housekeeping data packets are actually constructed by the spacecraft as the PCA contains no processors. The housekeeping parameters are described in more detail in a following section.

- Low Voltage Power Supply (LVPS)

  Each PCU has one LVPS which can be turned on / off through relay commands. This unit supplies the other electronics boxes with line voltages.

- High Voltage Power Supply (HVPS)

  Each PCU contains two separate HV power supplies. All the xenon anodes (L1, R1, L2, R2, L3, R3 & VX) are connected to one supply and the propane layer (VP) to the other. The nominal operating voltage for xenon is 2050 V and for propane 2800 V. Both supplies are commandable through fifteen 20-volt steps with the lowest setting being reserved for a special voltage some 1000 volts below the nominal operating position. This "low" command level is used for passage through the South Atlantic Anomaly (SAA) since gas multiplication no longer occurs at such low voltages. The HV units both have additional commands to reduce their outputs to 0 V (off) and to switch on or off the relays providing the units with power.

4.2.3.2 Very Large Events (VLE)

VLE's are events which deposit more than 75 keV of energy in any one of the six active xenon layers or the propane layer. The detector gains will always be adjusted so that the upper limit of the ADC corresponds to about 60 keV so there is a small energy gap before a VLE flag is generated. Hence, no distinction is made between “small” VLE’s that do not cause longer term effects or “giant” events that cause saturation in various parts of the analog electronics chain and affect the final stage output for 100’s of microseconds.

In the lab small events are relatively common, say 10 per PCU per second, and giant events are rare, say < 1 a second. The distribution will differ in orbit. The period of time for which disturbances exist can be measured in the lab and a duration vs. frequency analysis made. Unfortunately this precise study cannot be repeated in orbit; a limited analysis will be made using the adjustable VLE window feature and by observation of the effects on the time difference between events.

Each of the 6 xenon and propane signal chains have 4 possible VLE window settings as shown in Table 4.2. Only approximate values are given as the precise values, which have all been measured, depend on individual component tolerances. The residual positive overshoot from an unsuppressed VLE pulse causes a long string of rapidly recurring very low energy trigger pulses. The duration of the pulse train depends on the initial pulse size. The repetition interval for the triggers is about 10 μs which is the shortest period in which a PCU analysis can be performed. These low-energy triggers occur below the typical lower level discriminator setting at 1 keV (ADC channel 4-5). Virtually all on-board modes in the EDS will reject these unwanted pulses but they can be studied on an individual basis using the EDS Transparent Mode. The trade-off with VLE window selection is made between dead time and distortion of the spectrum. For the best spectral measurements of weak sources, a long window is best. For timing measurements with minimum dead time the short window is preferable. The optimum choices will be determined during the in-orbit checkout period.

TABLE 4.2. Typical VLE Window Durations

Cmd	Duration μs	Effect
0	12	Minimum dead time, ringing occurs & following events have a slightly higher energy
1	60	Effects from smaller more frequent VLE’s suppressed
2	150 (default)	Effects due to all but largest events suppressed
3	550	Relatively large dead time, minimum ringing & minimum distortion of energy spectrum

4.2.3.3 Pulse Timing

Every event detected by the PCA is timed to 1 μs in the EDS. The front-end discriminator pulse width of each layer depends on the pulse height, with typical values of less than 10 μs for pulse height below 10 keV up to 15 μs for pulse heights of 23 keV. The detector dead time caused by each event depends on its pulse height and, to a lesser extent, on what combination of possible simultaneous events occur within the same short time interval. To a first-order approximation, all the events will cause the same amount of dead time which is equal to the ADC busy time of about 8.5 μs. In addition, occasional, single VLE events having a similar ADC busy time will be passed to the EDS and any following events will be inhibited for the VLE window duration.

The period of time that elapses between the initial triggering of an event in the PCU analog electronics and its subsequent time stamp in the EDS has been measured in the lab. This time is fixed and is 18.2 μs for all PCU's.

4.2.3.4 SAA Definition

The XTE orbit will pass through the South Atlantic Anomaly (SAA) high particle flux areas up to 6 times a day with data losses of up to 10 - 20 minutes for each pass. The times of entry and exit for the SAA are computed by the Scheduling Program SPIKE as part of the command scheduling operations. All detector HV units will be commanded to the "low" position at the specified entry time by the spacecraft on-board program timer and restored to their prior HV settings at the following exit time. The "low" voltage is some 1000 volts below the nominal operating voltage in the realm where charge multiplication does not occur. This procedure avoids stressing the HV systems by completely turning them off.

The definition of the SAA shape that SPIKE uses to compute the times of SAA passages is provided to the SOF by the PI team who will continually refine the SAA boundary as flight data is obtained. This task is part of the ongoing PI support activities and is a by product of the PCA background modelling activities. Before launch, a SAA definition with "generous" safety margins will be used; these margins will probably be reduced as operating experience is acquired. SPIKE can also be instructed to add a safety buffer to its computed times.

4.2.3.5 HV Safety & HRM Rates

Each PCU has a separate, hardware back-up to the primary SAA entry commands. This feature also protects the detector in the event of unexpected, sudden, HV breakdown-induced events. A High Rate Monitor (HRM) level can be specified in each PCU. Eight of the 14 rates (8-second integrations) produced for the housekeeping telemetry are checked against this HRM threshold and can set a flag if any one exceeds the setting. If a check in the subsequent 8 seconds produces another excess above the HRM threshold, another flag is set in the housekeeping that indicates that two consecutive flags have occurred. Finally, if a third consecutive excess occurs the HV units in that PCU are switched OFF (not to the low setting) and another flag bit set. That PCU will now stay off until a recovery is specifically commanded. All PCU's therefore need at least 24 seconds (3 x 8) above the HRM rates before tripping off. Each PCU will only trip the off command after 3 consecutive eight second accumulations exceeding the HRM threshold. The detectors could be on for as long as 24 seconds in the SAA if the voltage is not reduced at the right time. This would reduce to ~16 seconds for very high rates.

The HV veto triggers in the 5 PCU's are not inter-linked and the HRM rates can be set differently in each unit. The HRM setting for L1, R1, L2, R2, L3, R3, VX, & VP will normally be left at the default level of about 8192 counts/sec by the PCA team. Since in general the front xenon layers (L1 & R1) and the propane layer (VP) will see the most counts when a PCU is looking at an x-ray source, GO's must determine if their target source is likely to exceed this rate at any time for a 24-second period. If so, the GO must propose to raise the HRM settings on all PCU's to a higher level.

The default HRM rate should be suitable for the majority of possible x-ray targets but "bright" sources will require it to be set several times higher than the maximum expected anode rates (see section 4.4). If an HRM veto trigger occurs data will be lost from that PCU and, depending on the operational circumstances, it may be some time before the unit can be turned back on.

4.2.4 Detector Thermal Control

The temperatures of all 5 PCU's are sent to the ground in spacecraft housekeeping telemetry. Heaters are switched on if the detectors fall below their nominal operating limit. The PCA survival temperature range is -15 to + 35 degrees C and the nominal operating range is -10 to +25 degree C. Heaters are set to come on at -14 +-2 degrees C. The detectors should not get this cold except in a powered down situation. The PCA ground software running in the Science Operation Facility (SOF) accesses and displays the PCU temperatures. These temperatures are returned in spacecraft data packets and not in the PCA housekeeping telemetry.

4.2.5 Alpha Calibration Source

Each PCU's gain and resolution is monitored using several atomic and nuclear x-ray lines accompanying alpha decays of an Am^{241} source. This source is located inside a parasitic small proportional counter, referred to as the alpha counter, located at the bottom of the main counter (see Fig. 4.2). When a disintegration occurs, the alpha particle is detected by the alpha counter while the x-rays are detected as if they were normal x-rays coming in through the collimator. The coincidence between the alpha detection and the x-ray detection serves as a flag to indicate that this particular event is a calibration event. During all observations, pulse height spectra of these flagged events are accumulated in a partition of the EDS Standard Mode l every 128 seconds.

The Am^{241} source has an activity of 5 nCi which produces an event rate of 0.5 counts/sec in each of the main six xenon signal chains. This count rate ensures that a statistically significant data set is accumulated for each layer every day. Since not all the alpha particles can get out of the source holder, as most of the x-rays do, a small fraction of the x-rays associated with the Am^{241} source do not get flagged and thus become part of the background. These events therefore create some low level line features in the "source" spectrum that are identical to the calibration spectrum. This rate can be measured accurately and can be subtracted out from the real observational data. The typical alpha tagging efficiency is about 80%.

4.2.6 Housekeeping Data

Every 8 seconds the spacecraft builds a “Housekeeping” packet of data for each of the 5 PCU’s. The samples returned in each packet are “frozen” at the same moment in time and are thus directly comparable. They are also synchronized to the 16-second basic rocking period of HEXTE and the 16-second sampling of the EDS in Standard Mode 2 i.e. two 8-second sets fall exactly within the 16-second period. The housekeeping packet for each PCU contains:

- 14 rate summations for the preceding 8-second interval
- 44 command & status monitor items
- 7 electronics temperatures
- 7 analog & digital voltages
- xenon & propane volume pressures
- xenon & propane direct HV readings
- 18 items for diagnostic testing

The PCA housekeeping produces no spectral data. This type of “calibration data” is provided within the partitions of the EDS Standard Modes 1 & 2.

The spacecraft always produces housekeeping packets for each PCU every 8 seconds, even through the SAA and Earth occultation, unless a PCU is completely turned off and its RIF box cannot respond. With all PCU’s active, the PCA produces 89 bytes a second of housekeeping telemetry.

4.2.7 EDS Interface

The EDS is described in detail in another chapter but it is important to summarize the data exchange from the PCU’s to the Event Analyzers (EA’s) in the EDS:

- Every event detected in a PCU is transferred to the EDS - NO rejection or selection occurs in the PCA
- All time tagging (to 1 μs) is added in the EDS
- All 6 EA’s used in the EDS by the PCA see ALL events from ALL detectors

Events detected in a PCU are passed to the EDS as a 19-bit serial data stream (+ a start & stop bit) at a rate of 4 MHz. Each of the EA’s in the EDS has a serial multiplexer that can receive data asynchronously from all PCU’s. The complete set of information transferred for every event is given in Table 4.3.

TABLE 4.3. PCU - EDS Event Data Serial Bit Package

Bits	Description	Bits	Description
0	VX PHA lsb	13	Xe L2 LLD flag
1	VX PHA msb	14	Xe R2 LLD fag
2	VLE flag	15	Xe L3 LLD flag
3 - 10	8 bit PHA (lsb - msb) *	16	Xe R3 LLD flag
11	Xe L1 LLD flag	17	VP LLD flag
12	Xe R1 LLD flag	18	ALPHA LLD flag

* Xe or VP event bit order

If two or more LLD flags are set, the origin of the 8-bit pulse height is ambiguous. The moment an EA completely receives a 19-bit data packet, a 15-bit “time stamp” with 1 μs resolution is latched and appended to it. A further 3 bits are also added giving the address of the PCU the data came from. As previously mentioned the period of time that elapses between an event triggering the PCU analog electronics and its subsequent EDS time stamp is 18.2 μs for all PCU’s.

In principle, any combination of the 19 bits may be set but some are exceedingly unlikely and many would represent events that will normally be rejected by the EDS. The EDS however can be programmed to process these bits in many ways; normally it will process the data with a suitable set of configurations as part of its many modes of operation.

A complete description of every event requires 37 bits (19 + 15 + 3); all this information can be returned to the ground by running three EA’s in parallel in Transparent Mode. This EDS mode will normally only be used by the PCA PI team for special calibration purposes as it uses a large amount of telemetry capacity. Since the overall background activity rate in each PCU may be ~400 counts/sec, and 48 bits (3 x 16) must be used to send all of the information, the required telemetry for a complete description of the background is ~100 kbps. For most EDS modes, the 37 bits are mapped to only 15 bits for entry to a 16-bit wide FIFO within the EA. All EA’s reserve the msb of their 16 bit word size for “tick” marks (see chapter on EDS).

4.3 Detector Performance

A very large amount of ground calibration data has been obtained and archived for future use. This data has been analyzed to provide the usual measures of performance for proportional counters but naturally this applies to ground-based measurements and many of these parameters will be re-determined during the in-orbit checkout period. The current or estimated performance of each PCU is presented in the following sections.

4.3.1 Collimator Response

All the individual collimator blocks for the PCA have been tested in a parallel light beam to obtain the direction of peak transmission. The lower face (next to the window) of the modules were then machined normal to this axis and a 1 square cm mirror bonded to the front surface, again normal to the established optical axis. Groups of 5 modules were then epoxied into the collimator housing using the small reference mirrors to establish relative alignment. They are typically within 30 arc-seconds of each other. The net detector optical axis, calculated by averaging the axes of the 5 mirrors and verified via measurement in the parallel light beam, is < 1 arc minute off from the normal to the mounting surface for 4 of the 5 detectors and < 2 arc minute off for the 5th detector. A larger primary reference mirror is also attached to the frame which is co-aligned to the mean axis of the 5 small mirrors. This serves as the primary reference surface for adjusting the PCU's on the mounting cradles on the spacecraft.

The collimator response to x-rays has been measured at a beam facility at Goddard. This beam, because of its 8-arc minute divergence, can only serve to qualitatively characterize the collimator response. Figure 4.3 shows the transmission efficiency as a function of the angle. The plateau around the maximum is mostly caused by the divergence of the beam. The collimators exhibit a true "flat top" response of about 2 arc minute and the X ray and optical axes have been found to coincide. Additional measurements have been made at higher energies to examine collimator "leakage" and at low energies to examine reflection effects.

The collimator response will be re-measured in orbit by performing multiple scans across a suitable bright and constant point source.

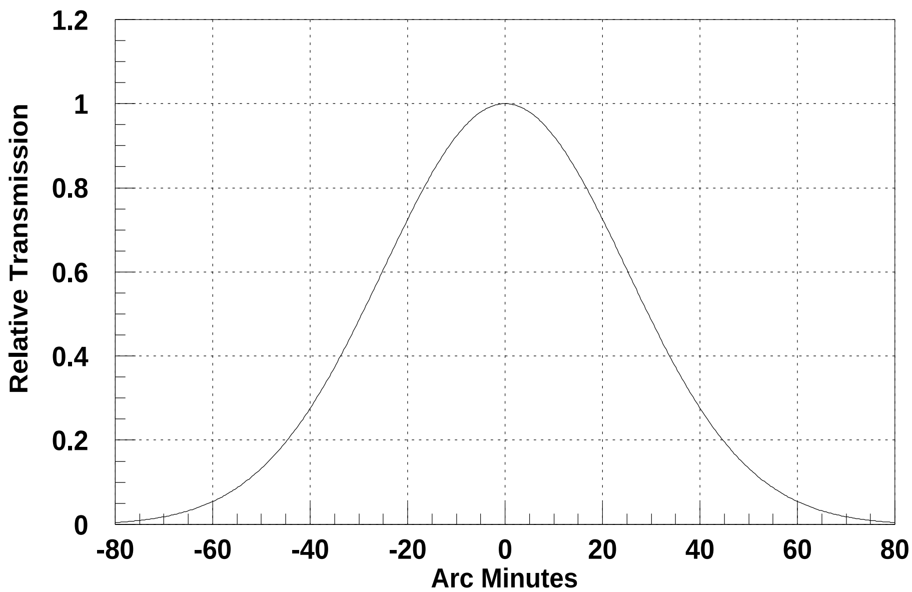

Fig. 4.3 Collimator relative transmission as a function of off axis angle in arc minutes. This is a fit to ground test data obtained in a long beam facility The beam divergence dominates effects due to collimator irregularities, reflection effects and various other residual misalignments.

4.3.2 Boresite Determination

Each PCU will be bolted to the spacecraft and shimmed to co-align the 5 fields of view within about 1-2 arc minute but launch vibration or thermal distortion after launch may increase the dispersion of the 5 viewing axes. In any case, the same procedure used to map the collimator response will provide the relative pointing axes. These offsets can be extracted from the 5 overlapping, though not quite coincident, approximately circular fields of view. The optimum position that maximizes the effective area for all 5 PCU's will be defined and five X - Y offsets from this boresite determined. These offset values will be redetermined at intervals throughout the mission by the PCA PI team. In the GOF software, the offsets will be used to calculate the PCA effective areas and the boresite will become the PCA on-target pointing vector.

4.3.3 Energy Resolution

The energy resolution has been extensively mapped in the lab using a variety of radioactive sources. The resolution over the whole area of each PCU is exceedingly uniform and has a typical value for the xenon layers of 18% at 6 keV and 9% at 22 keV. The propane layer has a resolution of 18% at 5.9 keV just after filling but the resolution of each PCU will degrade at different rates. Figure 4.4 shows a plot of xenon energy resolution against incident x-ray energy. Some very slow degradation with time can be expected.

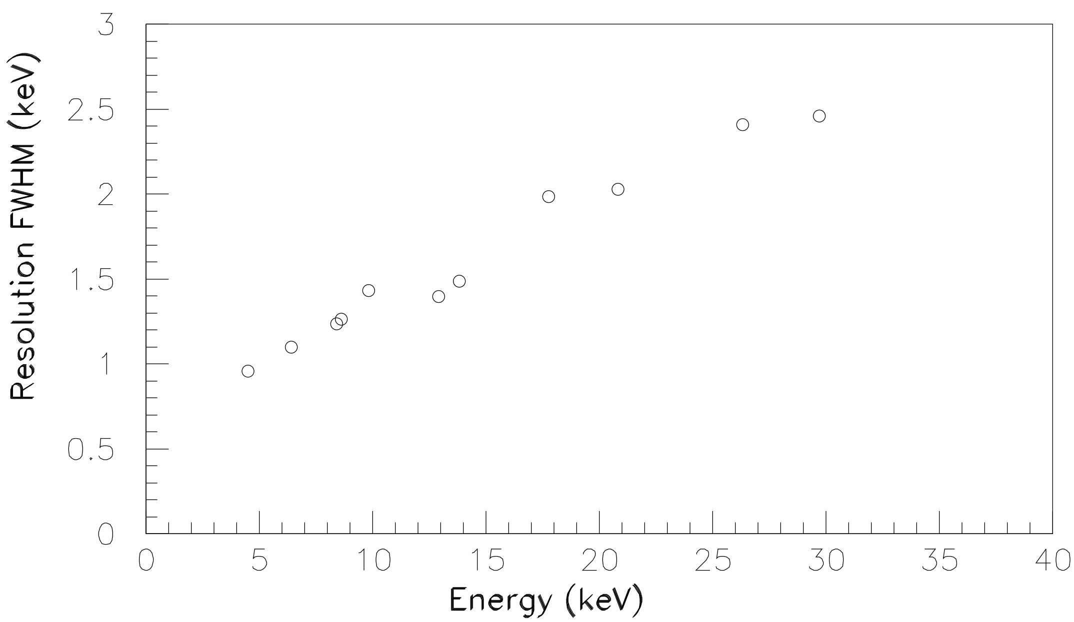

Fig. 4.4 Xenon L1 layer energy resolution vs. energy for a single PCU.

The PCA PI team has determined a series of “standard” response matrices from the ground test data and these have been delivered to the GOF in a form that complies with the OGIP / HEASARC standards. The number of response matrices is quite large as shown in Table 4.4. In addition to these frequently required anode combinations, the GOF has a tool for combining the response matrices from individual anode chains into any new combination.

TABLE 4.4. Response Matrices

Type Of Signal	Anode Combinations	Number of Matrices
Basic xenon signals	L1, R1, L2, R2, L3, R3 - for each PCU	30
Basic propane signals	VP - for each PCU	5
Front xenon layer	L1 + R1 - for each PCU	5
Rear xenon layers	L2 + R2 + L3 + R3 - for each PCU	5
PCU - xenon	Sum of all 6 xenon signals - each PCU	5
Whole PCA - propane	Sum of all PCU propane layers	1
Whole PCA - xenon	Sum of all xenon layers, all PCU's	1

The internal Am^{241} calibration source provides the ability to continuously monitor the PCU's performance and the PI team will revise the response matrices after launch and at regular intervals throughout the mission. A typical calibration spectrum is shown in Figure 4.5.

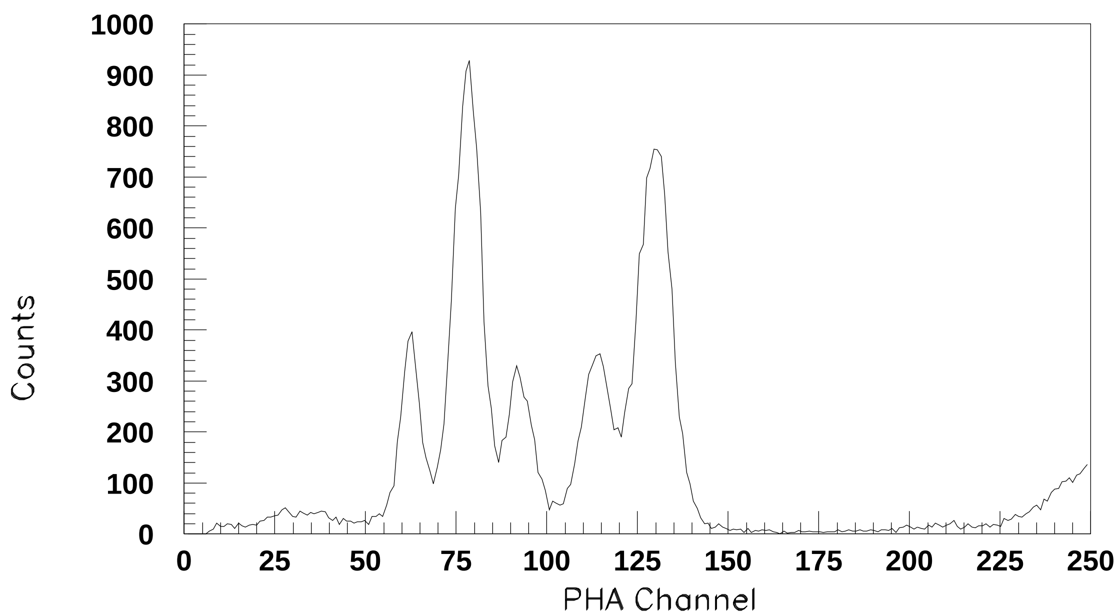

Fig. 4.5 Typical Am^{241} calibration spectrum from the L1 xenon layer for a single PCU. Each pulse height channel has a width of about 0.25 keV.

If two or more LLD flags are set, the origin of the 8-bit pulse height is ambiguous. Such events are, however, primarily due to particles that leave tracks in the detector (and which we desire to reject) and secondarily to events that are split between two anodes due to the initial photo-electric absorption occurring near an anode boundary or to the re-absorption of a xenon K-escape photon. While these effects will cause us to reject some bona fide X-ray events the detector response function does take that loss into account.

In addition to the typical response complications, such as absorptions of photoelectrons by the window and K- and L-escapes that are associated with a proportional counter of this type, the multi-layer structure of the XTE/PCA counters necessitate some unique corrections. As a price for efficient background rejection, some of the bona fide x-rays are rejected as background events if their photoelectron clouds drift into and trigger two adjacent layers. The probability that an x-ray is rejected by this effect, referred to as charge division, is dependent upon the energy of the x-ray, ranging from a fraction of a percent for x-rays with energy below the xenon L-edge, to as much as 15 percent for those photons with energies above the xenon K-edge. This effect has been measured with precision with a monochromatic x-ray beam at different energies.

4.3.4 Deadtime Corrections

A primary goal of XTE is to detect source variations on sub-millisecond or microsecond time scales. To do this effectively requires a very detailed knowledge of the PCA deadtime. For lower energy x-rays, the dead time is about 10 μs for each event. The effective dead time of each PCU is a weighted combination of the individual dead times resulting from the many possible event / flag combinations that can occur within the xenon and propane volumes. These effects can be measured and characterized by exhaustive testing of a single detector in the laboratory but the space environment will result in a different distribution of background event types. It will be possible to repeat this work in orbit during the check-out phase using Transparent Mode on the EDS and offsetting by known amounts from a bright and constant x-ray source.

TABLE 4.5. Typical Dead Time Effects

Source	**X-ray Source Rate (c/s) / PCU**	**X-ray Interaction Rate / PCU** (c_x)	**Total Interaction Rate / PCU** (c_r)	**Output X-ray event rate** (c_{go})	**% x 100 Effective Deadtime** ($1 - c_{go} / c_x$)	**Output X-ray Event Rate** ($c_{go} - b_{go}$)
Background	0	100 (b_x)	1,500 (b_r)	98.5 (b_{go})	1.5	0.0
1 mCrab AGN	15	115	1,515	113.3	1.5	14.8
Crab	3,000	3,100	4,500	2,963.6	4.4	2,865.1
10 Crab	30,000	30,100	31,500	21,966.6	27.0	21,868.1
20 Crab (Sco X-1)	60,000	60,100	61,500	32,492.5	42.6	32,394.0

notes to the table:

1. Col. 2 Estimated source rate in one PCU
2. Col. 3 X-ray interaction rate due to source plus background single xenon anode interactions
3. Col. 4 Total raw event rate (X-ray + particle). Almost simultaneous events on different anodes are called 1 event with several flags with a deadtime about that of an event on one anode
4. Col. 5 The good event rate output to the EDS
5. Col. 6 Deadtime fraction in percent x 100
6. Col. 7 X-ray events due to the source sent to the EDS. The source rate is

$$s = c_{go} e^{c_r t} - b_{go} e^{b_r t} \quad \text{where} \quad c_{to} = c_r e^{-c_r t}, \; b_{co} = b_r e^{-b_r t} \quad \text{and} \quad t = \text{deadtime}$$

but the implicit calculation will only be necessary for the brightest sources.

Approximate dead times for typical x-ray sources are given in Table 4.5. Note that the raw background, although it is mostly rejected in the EDS, always contributes to dead time (usually a small amount). The count rate seen for Sco X-1 in each detector is approaching the maximum that each PCU can output for a “random” input flux.

4.3.5 Background Subtraction

The overall background event rate in a PCU in the laboratory is about 160 counts/sec. This rate is dominated by cosmic rays traversing the detector. Of the 160 events, 125 are rejected by the anti-coincidence logic. The other 35 events, with 25 in the propane layer and 10 in the xenon layers, constitute the raw background. Figure 4.6a shows the pulse height spectra of these remaining events for the propane layer and Figure 4.6b for the xenon L1 layer. The lines near 13, 16, and 26 keV are a mixture of x-rays associated with the Am^{241} source and from some other element, probably Thorium present as a contaminant in the detector materials.

From the experience gained with other missions, the orbital background rate is typically two to three times as high as in the laboratory. By multiplying the above rate by a factor of three, we find that the background rates of the XTE PCA are comparable to those of HEAO-1 A2 on a per square cm per sec basis. The charged particle rejection efficiency of a typical PCU has been measured to be 98% per layer. Thus the probability of a minimum ionizing or through-going particle not being rejected is ~ 10^{-6}. The residual background is due largely to Compton scattering of x-rays generated from interactions in the spacecraft.

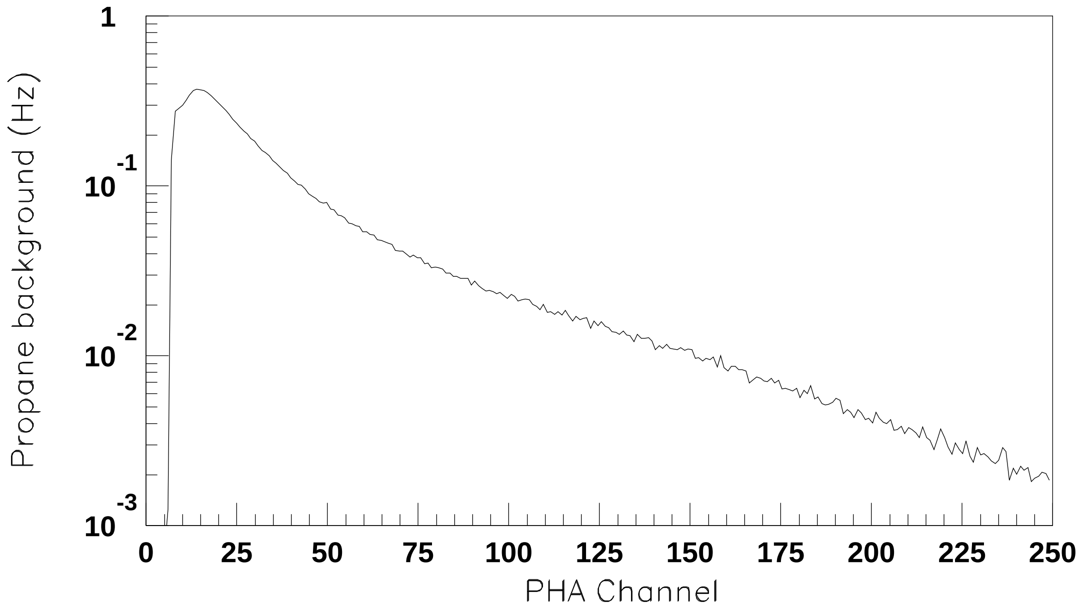

Fig. 4.6a Background spectrum from the propane layer of a single PCU (0 - 60 keV). Probably electrons of low energy generated in collimator and detector materials.

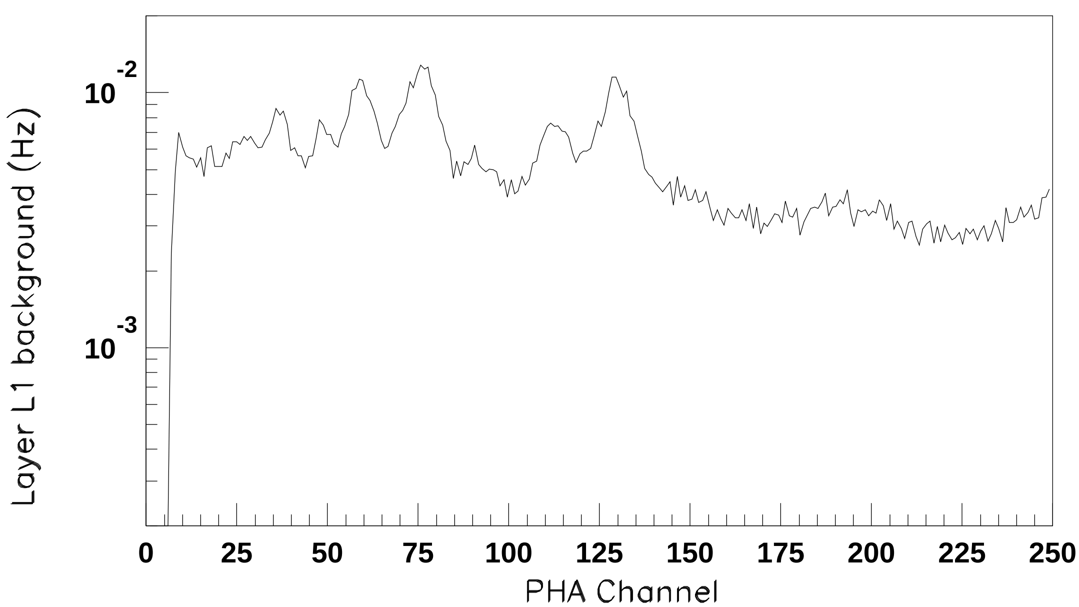

Fig. 4.6b Background spectra from the L1 xenon layer of a single PCU (0 - 60 keV).

4.3.5.1 GOF Background Model

XTE will be in a low Earth orbit at a planned height of 600 km and since the 5 PCU's are fixed rigidly to the spacecraft, the background determination problem is similar to that of HEAO-1 and GINGA rather than EXOSAT. The XTE detectors are very similar in design and concept to the HEAO-1 A2 units but are physically much larger and heavier. Although HEAO-1 was in a lower orbit, it has been assumed as a starting point that the PCA performance can be scaled from the HEAO-1 experience. Old data have therefore been extensively analyzed to re-explore the in-orbit background, rejection efficiencies, and veto rate correlations seen by that mission.

This study has enabled a set of techniques to be devised that are expected to prove effective for the real PCA data. The work has been performed in such a way that once real data become available, the analysis can be repeated in an on-going fashion to replace the initial model as rapidly as possible. The PCA PI team will refine and improve the background model throughout the mission. GO's with observations scheduled early in the mission must appreciate that problems may exist for fainter sources during those early phases.

4.3.6 Sensitivity

The estimated sensitivity based on extrapolations from laboratory measurements and old HEAO-1 A2 data suggest a performance in orbit as shown in Table 4.6. Users should not base their proposals on these values which are given for comparative purposes only. They should use the GOF supplied tools for all proposal preparation calculations.

TABLE 4.6. PCA Count Rates

Signal	c / sec 2 - 10 keV	c / sec 10 - 30 keV	c / sec 30-60 keV
particle background	14	34	36
collimated diffuse background	9.1	3.3	0.2
diffuse leakage in E range	0	0	1
1 milli Crab AGN	12	3.5	0.2
Crab	12,000	2,550	94

The xenon and propane energy response curves for the entire PCA are given in Figure 4.7.

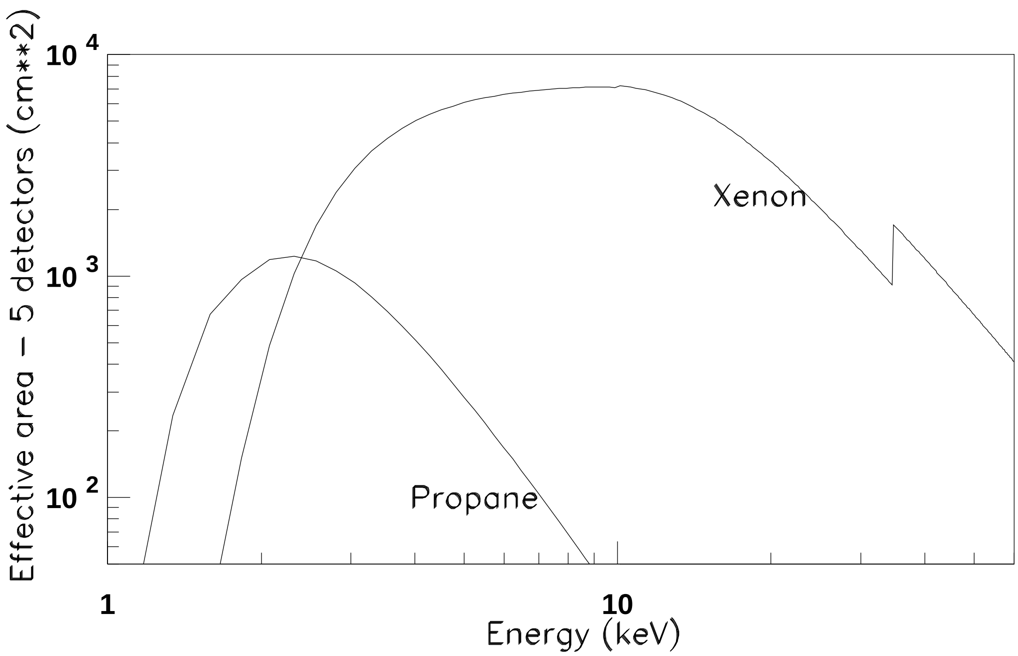

Fig. 4.7 Energy response and effective area of the complete PCA experiment (all 5 PCU's) for the propane and xenon sections.

The propane layer is principally intended to act as a veto layer to reduce the background rate but could be used as a lower energy detector for brighter sources. The propane gas only provides useful detection efficiency in the range 1.8 - 3.5 keV with a peak sensitivity near 2.5 keV.

4.3.7 PCA / EDS Gain & Offset Adjustment

As previously explained, the xenon PHA signals pouring into each EA in the EDS come from 30 anode chains (5 detectors each having 6 layers). It is not possible to match exactly the gains of all these signals by varying the HV supply voltages as these have limited adjustment and also power multiple anode chains. In actual fact the L1, R1, L2, R2, L3 & R3 gains within each detector are very similar so normally all gain corrections are made just by detector ID. Should any individual anode chain drift this will be identified by the PCA team and the EDS allows some more specific correction strategies to be applied. In any case all such activities will be completely transparent to the user. It is possible that the “raw” PHA channel numbers corresponding to a specific energy may differ between detectors by up to +/-10%.

The gain and offset parameters applied will be determined by the PCA team as part of their ongoing calibration activities. These values are sent to the EDS, not the PCA, and the PCA team calculates them from the tagged calibration data that are continuously accumulated in EDS standard mode 2. The propane signals can also be matched using gain and offset adjustments. As detector gains drift with time, for whatever reason, new gain and offset values will be determined and supplied to the SOC. At the same time revised response matrices will also be delivered to the GOF.

All EDS modes except the following ones have the gain & offset corrections applied:

- Standard Mode 1
- Standard Mode 2
- Transparent Modes (multiple EA's)
- GoodXenon Modes (2 EA's)

The arithmetic operations performed within the EDS to match the PCU gains are simple in form due to processing speed constraints in the real time environment. Further details on the gain & offset feature can be found in the EDS technical chapter.

4.3.8 Relative Timing Accuracy

The timing system on XTE comprises three key pieces:

- Hardware clock - master oscillator
- Software Clock
- Universal Time Correction Factor (UTCF)

The master hardware clock on XTE is a dual oven, highly stable, crystal oscillator. This oscillator has an accuracy of one part in 10^9 per day but its frequency can also be adjusted in small amounts to track the nominal frequency with the desired degree of accuracy. The basic 1 μs clock in the EDS used for x-ray timing is synchronized to the 1 Hz distributed spacecraft clock which is derived from the master oscillator. Relative timing accuracy is therefore limited only by the stability of the spacecraft clock. All time tagging or binning of x-rays from the PCA (EDS & housekeeping) and HEXTE are derived from the same 1 Hz spacecraft clock pulses, so difficulties in merging the data in a temporal sense are minimized.

Corrections to an absolute time (UTC) will be determined by the spacecraft at regular intervals as described elsewhere in this document. The current determined correction factor or UTCF is returned in the spacecraft telemetry every 8 seconds.

4.4 PCA Commands Requiring GO Consideration

The PCA team will control all aspects of the PCA operation and commanding. GO's should note that their flexibility in commanding the PCA/EDS experiment in fact lies in the EDS section with its multiple Event Analyzers's and diverse choice of operating modes. Guest observers do not need to make any NRA input concerning PCA commanding except for the following special case:

- The choice of HRM settings (0 - 2^{21}, default of 8192 c/s)

Since the default applies to any single PCU anode and the front layers L1 & R1 will see the greatest source flux this threshold rate corresponds to a source with a strength of approximate 5 Crabs.

IMPORTANT

If GO's expect their proposed source to exceed 2-3 Crabs equivalent for any continuous period exceeding 24 seconds, perhaps during a flare, then they should request that the HRM rate be increased for the observation. The NRA form does not provide a special box for this input. Requests, with justification, for raising the HRM value should be made in the space available for remarks.

The PCA team will, in exceptional circumstances and on a case-by-case basis, consider any unusual requests by GO's to depart from normal operating procedure but only when both appropriate and safe for the instrument.

Chapter 5

The High Energy X-Ray Timing Experiment (HEXTE)

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5.1 General Principles

The HEXTE consists of two independent clusters each containing four NaI(Tl)/CsI(Na) phoswich scintillation detectors passively collimated to a 1^o FWHM field-of-view and co-aligned with the PCA (**Figure 5.1**). Each detector has a net open area of about 225 cm^2 and covers the energy range 15-250 keV, with an intrinsic spectral resolution better than 9 keV at 60 keV. The phoswich detector architecture employed ensures a low background through the efficient shielding of the primary NaI detector crystal by the CsI shield/light guide crystal. The two clusters contain mutually orthogonal "rocking" mechanisms, which can be moved independently to provide near-simultaneous measurements of the internal and cosmic x-ray backgrounds at 1.5^o or 3^o on either side of the source. The HEXTE's increase in sensitivity over its predecessor (HEAO-1 A4) is attained by virtue of its larger collecting area (~8 times the HEAO-1 A4 area) and improved suppression of systematic effects compared to previous satellite-borne instruments in this energy range. The actively shielded cluster organization for the HEXTE reduces systematic background variations, while further systematic effects have been eliminated by the use of continuous *Automatic Gain Control* **(AGC).** The entire system requires about 45 W, exclusive of heater power, weighs about 400 kg, and is allotted 5 kbit/s of telemetry on average. The HEXTE was designed and built at the Center for Astrophysics & Space Sciences, the University of California, San Diego. **Table 5.1** summarizes the HEXTE instrument's characteristics.

The HEXTE instrument detects each incident x-ray photon individually, and outputs data from these events in flexible formats to provide spectroscopy and timing from 7.6μs upwards, limited primarily by photon statistics (for faint sources) and the restrictions on the telemetry rate (for bright sources). An x-ray photon interacting with sufficient energy deposition will generate an event which has arrival-time and energy-related parameters associated with it. (However, note that like the PCA, the

HEXTE is a spectro-photometer, not an imaging instrument, and no position information is obtained from the detectors). For brighter sources, the high event rates will allow only a fraction of this information to be telemetered at the allocated 5 kbit/s. The HEXTE on-board data processor therefore permits the selection of any desired subset of the event data to be transmitted, consistent with this telemetry rate. In addition to two Standard Modes, three Science Modes (described later) are available to users, providing the necessary flexibility in data formatting and compression, in order to achieve the timing and energy resolution requirements required for their scientific objectives.

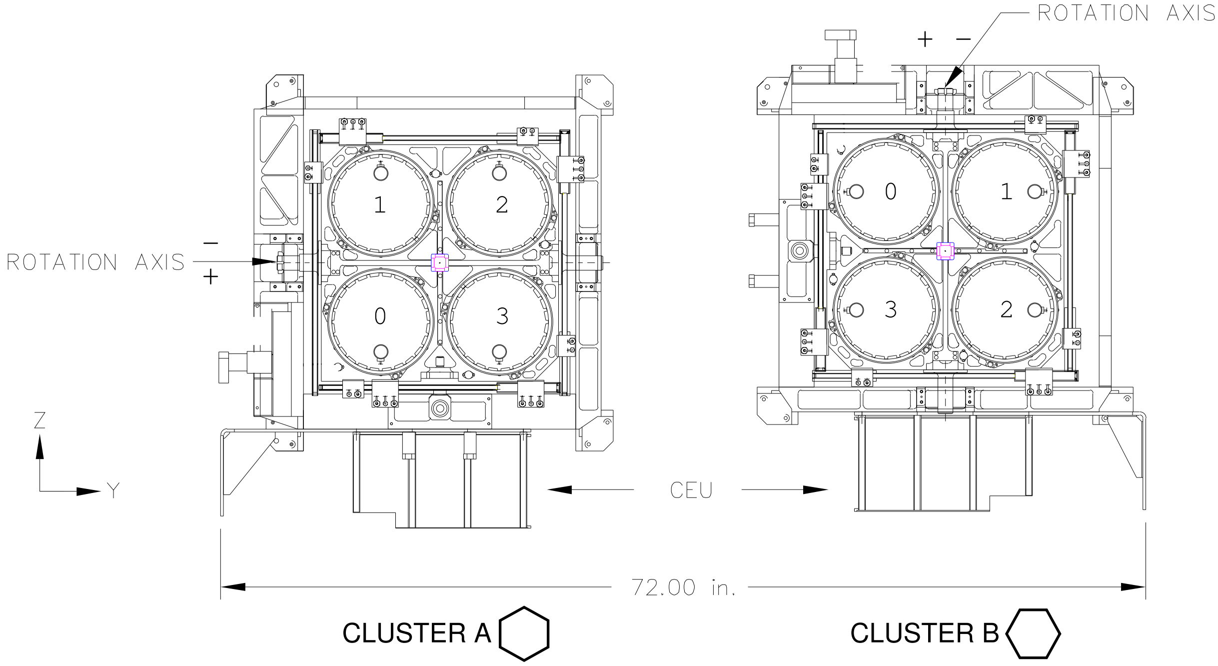
TABLE 5.1. High Energy X-ray Timing Experiment Characteristics

Characteristic	**Value**
Detectors	2×4 NaI(Tl)/CsI(Na) phoswich scintillators
Field of view	2.2° FWZI, 1° FWHM (Section 5.3.1)
Energy range	12-250 keV in 256 channels (Section 5.3.2)
Energy resolution	$\Delta E/E \propto E^{-0.5}$, 15% at 60 keV (Section 5.3.4)
Time sampling	7.6 µs (maximum), 0.98 ms (bright sources)
Net open detector area	890 cm^2 per cluster (Section 5.3.3)
Live-time fraction on-source	60% (Section 5.3.9)
Count rate from Crab Nebula (12-250 keV)	250 count/s per cluster
Count rate from internal background (12-250 keV)	90 count/s per cluster (Section 5.3.7)
Source/background dwell cycle	16 to 128 s, 2 s motion (Section 5.2.3)
Gain Calibration source	^{241}Am (lines at 17 and 60 keV)
Gain variation	<1% (Section 5.3.6)
Allocated telemetry rate	5 kbit/s (orbital average)

5.2 Physical Description

Each HEXTE cluster consists of a mounting structure that attaches to the RXTE spacecraft and an array of 4 detector modules, each containing a phoswich detector, photomultiplier tube (PMT), collimator, gain control detector and associated electronics. These detector units are mounted on a shaft which can rotate to either $\pm 1.5^{\circ}$ or $\pm 3.0^{\circ}$ about the nominal source-pointing direction of RXTE (**Figure 5.1**). The two clusters are oriented such that the axes of their rocking motions are mutually orthogonal, while the on-source look directions are closely co-aligned. This enables the sampling of four background positions about the source pointing (**Figure 5.3**).

Each detector unit utilizes two types of detectors. The primary function of the instrument (to measure high energy cosmic x-rays) is accomplished via thallium-doped sodium iodide (NaI(Tl)) scintillation crystals viewed by photomultiplier tubes. In addition, particle detectors are used to reject contaminating events from cosmic ray interactions, and to provide a signal from the calibration source which is used for automatic gain control.



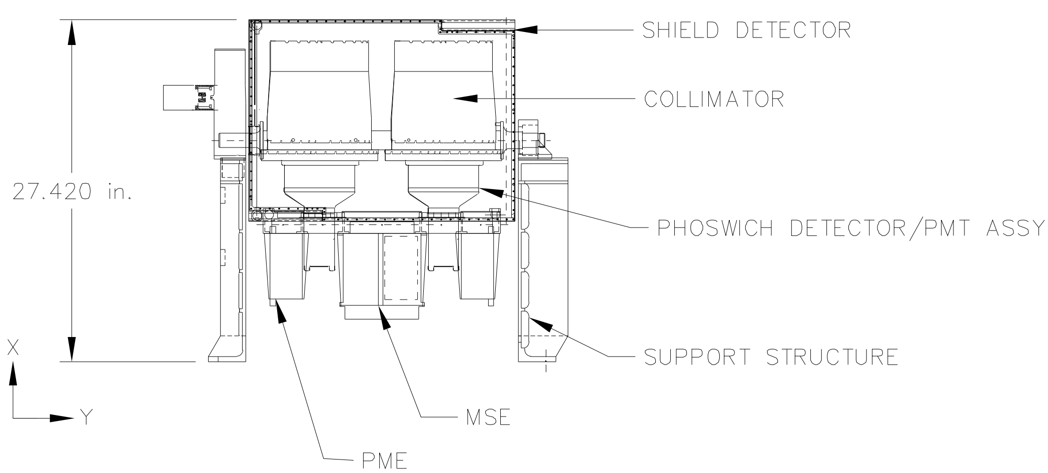


FIGURE 5.1. (a) Top view of the two HEXTE clusters, oriented as mounted on the spacecraft with orthogonal rocking axes; the phoswich detectors are numbered as they appear in telemetry. The hexagons below each cluster show the orientation of the collimator cells. (b) Side view of cluster A with the CEU removed shows the Module Support Electronics (MSE), Phoswich Module Electronics (PME), shield detectors, collimators, and the phoswich detector/photomultiplier tube assemblies. The RXTE spacecraft's *(x,y,z)* axes are shown in each view.

5.2.1 Phoswich X-ray Detector Assemblies

Detection of x-rays from astronomical sources is accomplished by a 4 phoswich scintillator/photomultiplier tube assemblies in each HEXTE cluster. The field of view of each detector is defined by a Pb collimator which also houses the gain control source and coincidence detector. Magnetic shielding in 3 connected sections surrounds the photomultiplier tube, the detector crystal housing and the collimator (see **Figure 5.2**). In this way each phoswich photomultiplier tube is embedded within a magnetic shield environment to reduce the effects of orbital variations of the external magnetic field.

5.2.1.1 Phoswich Detector/Photomultiplier Tube Modules

The primary HEXTE detectors consist of NaI(Tl) scintillation crystals of diameter 7.2 in and thickness 0.125 in, each optically coupled to a single 5-in photomultiplier tube (PMT) through an intervening 2.25-in thick CsI(Na) shield crystal and 0.25-in thick quartz window, as shown in Figure 5.2. The CsI(Na) crystal tapers down to the quartz window diameter, which matches the photomultiplier photocathode diameter (4.5 in typically). The CsI crystal provides uniform viewing of the primary NaI crystal by the photomultiplier and active anticoincidence shielding against x-ray events not originating in the forward direction, and events with only partial energy loss in the NaI. This configuration is known as a *phoswich.*

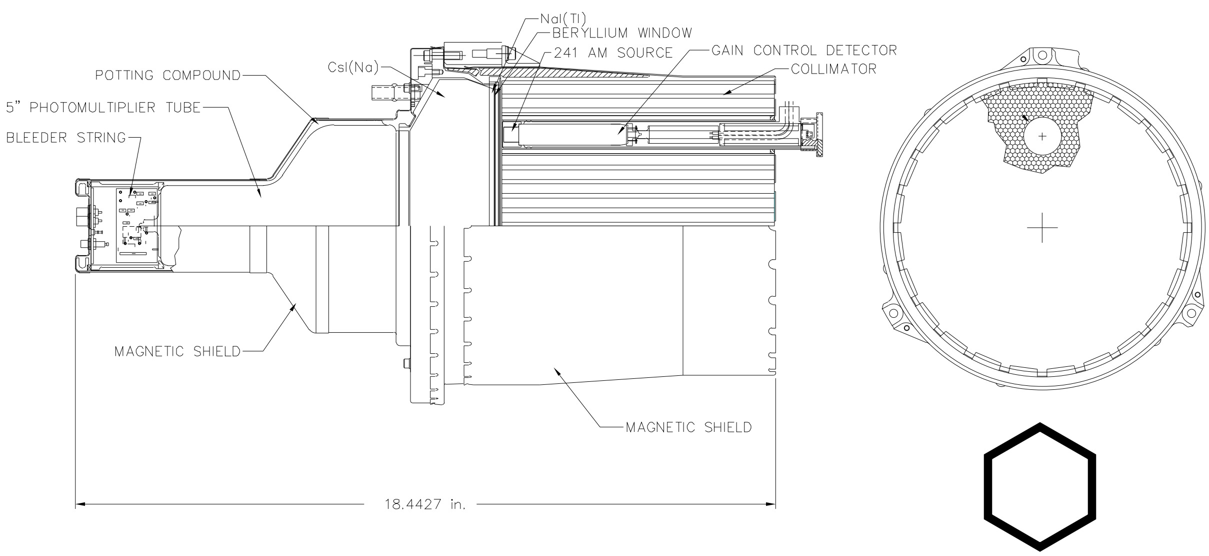


FIGURE 5.2. Side (cutaway) and top views of a HEXTE phoswich detector assembly, showing the photomultiplier tube, phoswich detector, collimator and gain control detector with part of the external magnetic shield. The top view shows the position of the gain calibration source and detector in the field of view, together with an expanded view of a single hexagonal collimator cell shown in the same orientation.

When an x-ray in the HEXTE energy range enters a phoswich detector, it will generally interact with an Iodine atom in the NaI crystal. This interaction occurs at a single point in the crystal and causes an electron to be ejected from the atom. This electron then excites the light-generating modes of the crystal to create a “scintillation” (pulse of light), whose intensity is proportional to the energy of the original x-ray. This light is viewed through a CsI light guide by a photomultiplier tube. This tube converts the pulse of light into an amplified electrical charge pulse. Thus, the HEXTE amplifiers and subsequent electronics deal with a peak voltage of the pulse that is, again, proportional to the x-ray’s initial energy. By calibrating the exact relation between incident x-ray energy loss and the digitized value of the voltage pulse height, the inferred incident energy of the x-ray is revealed.

Charged particles, such as are found in orbit, also cause the detectors to emit light that is picked up by the photomultiplier tubes, and such events must be identified so they can be ignored electronically (they outnumber x-rays by about 100 to 1). Those particles entering from the sides are detected by the plastic anti-coincidence shield detectors which surround each HEXTE cluster (**Section 5.2.2.1**), while cosmic rays entering the face of the detector will generally interact in both the NaI and CsI crystals.

The scintillation pulses generated within the two crystals exhibit different characteristic rise times: roughly 0.25 μs in NaI(Tl) and 0.63 μs in CsI(Na). Each signal from the photomultiplier tube is pulse-shape analyzed to distinguish pure NaI(Tl) energy loss (i.e. a good event) from events containing some proportion of the slower component, indicating an energy loss in the CsI(Na) shield crystal (i.e. an event to be rejected). Rejected events can be either charged particles that stimulate both crystals, or incompletely absorbed Compton-scattered x-rays that deposit only partial energy in the NaI crystal.

The crystals are contained in an opaque, hermetically sealed housing to prevent degradation of the NaI by water vapor and to shield the photomultiplier from stray light. The housing incorporates a 0.020-in thick beryllium x-ray entrance window to provide a light seal and a minimum of low energy photoelectric absorption of incident x-rays. The crystals are wrapped in teflon sheet, 0.010 in thick, and are highly polished to provide the maximum uniform light collection by the photomultiplier tube, and, therefore, maximize energy resolution. The photomultiplier tube and its attendant high voltage divider network (bleeder string), coupling elements, and connectors are surrounded by potting material to meet vibration and thermal requirements, as well as to prevent electrical discharges at all ambient pressures. Ribbing moulded into the potting material provides a light seal and the compression properties to absorb thermal expansion and contraction without stressing the photomultiplier tube. The entire potted assembly is contained within a metallic housing that also acts as a magnetic shield.

5.2.1.2 Collimators

The field-of-view of the HEXTE phoswich detectors is defined through the passive collimation of incident x-rays by a honeycomb structure of hollow hexagonal tubes, which are constructed from a composite of 94% lead and 6% antimony (for strength). The structure is epoxied within a magnetic shield housing (see Figure 5.2). Due to the manufacturing process the walls of each hexagonal tube are 0.004 in thick on four of the six edges, and twice that on the other two. Thus, the mean wall thickness is 0.005 in. The collimator tubes are 7.14 in long and 0.125 in across as measured from flat-to-flat of the hexagons. This gives a Full Width at Half Maximum (FWHM) response of about 1° and a

Full Width at Zero Intensity (FWZI) response of about 2.2° diameter; the response as a function of off-axis angle is shown in **Figure 5.4**. The open fraction of the collimator assembly is approximately 85%, such that each detector has roughly 225 cm^2 of face-on open area to the sky when viewed through its collimator.

The detector crystal housing also contains a 0.2-in thick ring of lead that suppresses high energy x-rays incident on the crystals from the side. Similarly, the collimator housing incorporates a lead ring to block radiation entering obliquely close to its base.

5.2.2 Particle Background Detectors

Since the HEXTE's phoswich x-ray detectors are also sensitive to cosmic ray particles, each HEXTE instrument cluster includes a set of particle anticoincidence shield detectors. Each cluster also contains a single trapped-radiation particle detector which monitors the particle environment and provides control signals for the raising and lowering of all detector high voltages in the event of increased particle fluxes, primarily in the *South Atlantic Anomaly* (**SAA**). In addition, each phoswich assembly is equipped with an α-particle coincidence detector associated with its ^{241}Am calibration source used for gain control.

5.2.2.1 Shield Anticoincidence Detectors

The anticoincidence shield system consists of four flat scintillation detector modules configured in a four-sided box around the x-ray detectors (see **Figure 5.1**). These shields provide a prompt indication of a phoswich event which may have been generated by an energetic particle interaction in the passive mass elements of the instrument. A particle intersecting the detector volume also intersects a shield with 85% probability. The 0.25-in thick plastic scintillator sheets (Bicron 440) are viewed by two 0.5-in photomultiplier tubes via two wavelength-shifting light guides positioned along two sides of each sheet. The anticoincidence detectors are used to reduce spurious background from effects such as Cerenkov radiation in the photomultiplier glass and secondary particles generated in the collimators.

5.2.2.2 Particle Monitors (SAA detection)

Each instrument cluster includes a single particle monitor detector for measurement of the ambient particle flux of the detector systems as they pass through the trapped radiation belts of the South Atlantic Anomaly (SAA). Each particle monitor consists of a simple hemispherical shaped plastic scintillator (Bicron 440) of about 0.4 in diameter coupled to a 0.5-in photomultiplier tube and surrounded by a thin absorber to define the low energy cutoff to which the unit will respond (~0.2 MeV). These detectors provide a signal to the control system to reduce the photomultiplier high voltages during times of high particle flux. This protects the phoswich and shield PMTs from high anode currents which would cause long-term gain changes due to aging effects.

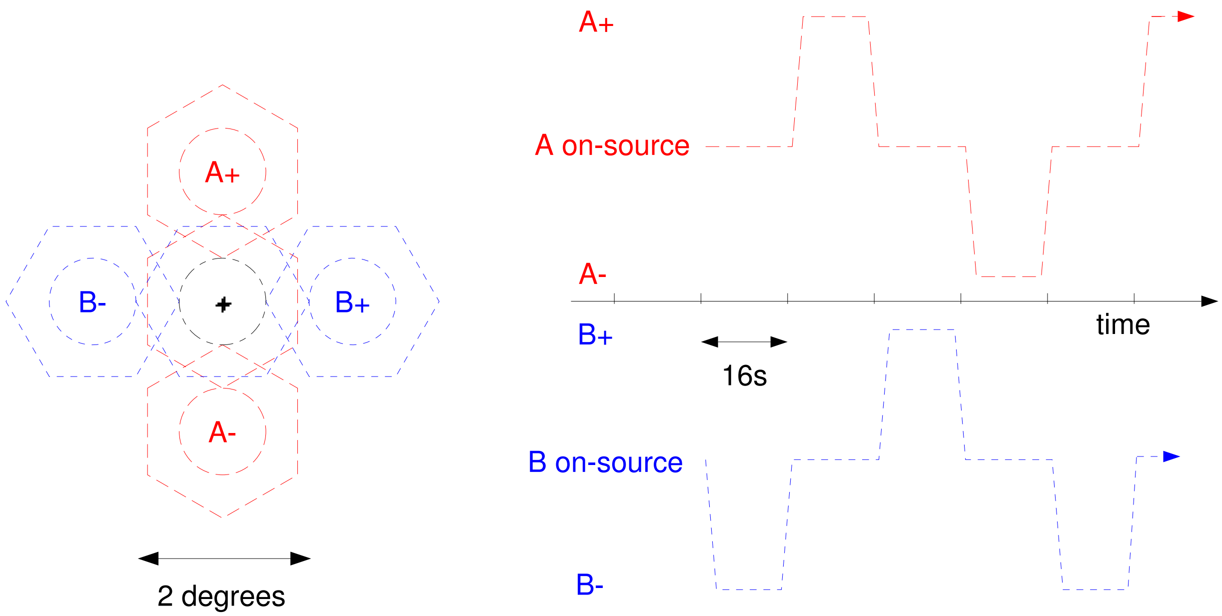


FIGURE 5.3. (a) **Source and background fields of view. Circles denote the FWHM response, and hexagons the field-of-view boundaries. (b) Timing pattern for synchronized two-cluster source/background beamswitching; note that the resulting on-source coverage is continuous (1.5 degr ee beamswitching and 16s on-source dwell time assumed here).**

5.2.2.3 Gain Control Detectors and Calibration Source

Each phoswich detector module has a calibration x-ray source mounted in the collimator immediately above its entrance window, in the detector's field-of-view (Figure 5.2). The calibration source consists of a small quantity (activity level about 18 nCi) of the radionuclide ^{241}Am suspended within a solid cylindrical pellet of scintillation plastic (Bicron 440). The scintillation plastic is optically coupled to a 0.5-in photomultiplier tube. ^{241}Am is chosen as the dopant in the scintillator since its primary decay scheme yields a 59.6 keV x-ray in coincidence with an ~4 MeV α–particle. The 59.6 keV photon exits the plastic and serves as a calibration reference line for the phoswich detector while the α-particle, which is stopped within the plastic, generates a coincidence signal to indicate that the event originated in the calibration source. **Section 5.3.6** details how these AGC events are used in a feedback loop and for continuous gain monitoring.

5.2.3 Source/Background Beamswitching Mechanism

A simple rocking mechanism is used to move each cluster's detectors between alternate on- and off-source fields-of-view. The rocking axes are fixed relative to the spacecraft (Figure 5.1), and the off-source positions can be selected to be either 1.5° or 3.0° from the source, with the option of one- or two-sided rocking. A beamswitch cycle consists of *dwelling* (i.e. accumulating data) at the on-source position, moving to an off-source position, dwelling there, rapidly moving back to the on-source position, dwelling there, moving to the other off-source position, dwelling there, and finally rapidly moving back to the on-source position. This cycle is then repeated continuously throughout any given observation. The on-source dwell time can be selected to be 16, 32, 64 s or 128 s. These motions are phased with respect to the data taking intervals such that a cluster spends the full dwell time when on-source, but uses 2s of the dwell time allotted to off-source observing for the motion from and to the on-source position. Data acquisition is inhibited for 2 s during these transitions off- and onto source; consequently, 4 s less is available for the off-source dwell time each cycle. Movement of the two clusters is synchronized such that at least one cluster is taking data on-source at any time; the nominal timing pattern is shown in **Figure 5.3b**. Since the rocking axes of the two clusters are orthogonal to each other, four background regions are usually sampled around a given source position by HEXTE, as shown in **Figure 5.3a**. Thus, the presence of a contaminating in a single background region can be identified, and one other background field will still be available for the cluster in question. The HEXTE clusters can be configured individually to avoid contaminating sources in advance through use of 3.0° and/or one-sided rocking (two-sided rocking is recommended, if possible).

The rocking mechanism may also be commanded to dwell indefinitely (i.e. *stare*) at any of the on- or off-source positions in order to satisfy scientific objectives such as fast timing on bright sources where background subtraction is not important. The cluster mechanism's position during any data taking interval is indicated in telemetry by one of six indications: -3°, -1.5°, 0°(two settings), +1.5°, or +3°. A secondary position readout comes from a 10-bit shaft encoder that provides a continuous measure of the mechanism cam angle, and is used as a diagnostic in case of a failure in the system.

5.3 Performance

Performance estimates for the HEXTE instrument have been derived from a combination of pre-launch calibration results, dedicated calibration observations made during In-Orbit Checkout, and continuing calibration observations performed during the RXTE mission.

5.3.1 Field-of-View (Beam Profile)

The HEXTE detectors' field-of-view is defined passively by the honeycomb of hexagonal tubes that make up the collimators. As for the PCA, each HEXTE detector/collimator assembly has been aligned such that its peak response direction is close to the nominal look-direction (x-axis) of RXTE. For sources off-axis, the detector open area visible through the collimators is decreased geometrically; the collimator response as a function of off-axis angle θ is therefore the convolution of a hexagonal aperture with itself. For the collimator tube dimensions given earlier, 50% of on-axis response is reached at about $\theta = 0.5^{\circ}$, while zero response defines a roughly circular boundary at $\theta = 1.1^{\circ}$. A model collimator response is shown in **Figure 5.4**, normalized to unity on-axis ($\theta = 0^{\circ}$). The cross-sections are consistent with laboratory measurements using a real collimator. In practice, the sharp peak of the collimator response is smoothed out somewhat by the deviations in the alignment of the detectors within each HEXTE cluster (~1 arcmin, as measured during in-orbit checkout), and by the slow residual motion (<0.1 arcmin) of the spacecraft's pointing axis. Ideally the collimator response

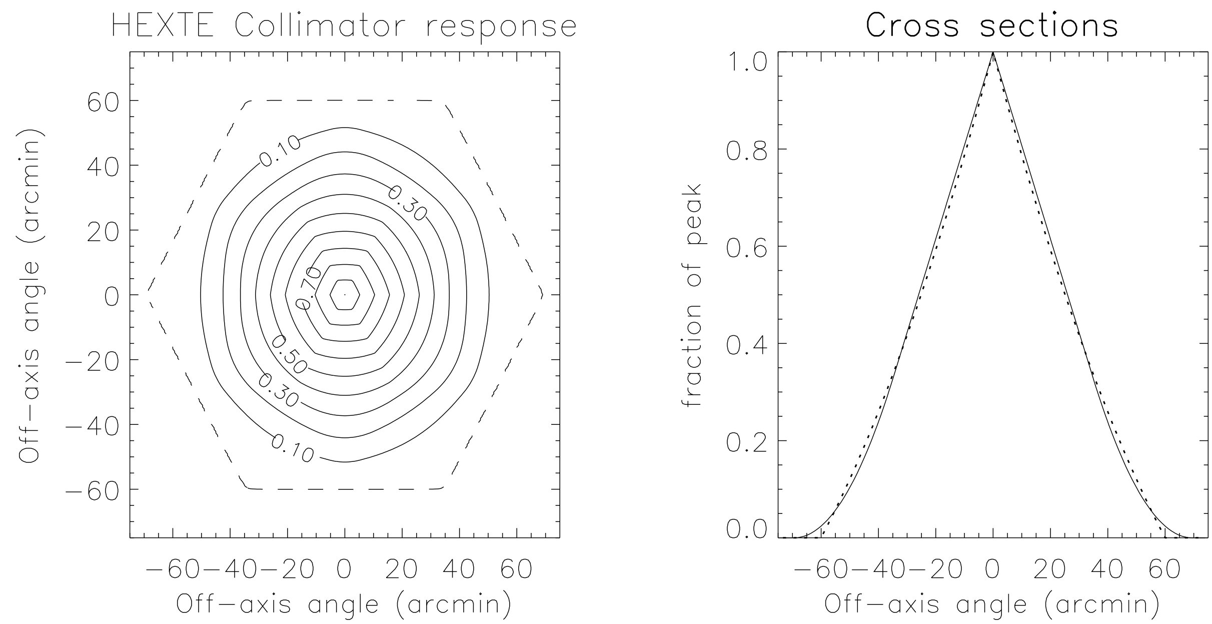


FIGURE 5.4. Model collimator response ("beam profile") of the HEXTE field-of-view, normalized to the peak (on-axis) value. (a) Two-dimensional response, with the hexagonal cells oriented horizontally (point-to-point); contour levels are at 0 (dashed line), 10, 20...100% of peak. (b) Cross sections of the collimator response along the point-to-point (solid line) and flat-to-flat (dotted line) diameters across the hexagonal cells.

will be independent of energy, but in practice a small fraction (~1%) of the incident source flux may be Compton-scattered off the interior of the collimator walls. The resulting detected spectrum would then be a function of the source spectral shape, but for most sources this would be a negligible addition to the background.

5.3.2 Energy Range

Scintillation pulses are analyzed by the event selection logic and assigned a *Pulse Height Analyzer* (**PHA**) channel number from 0 to 255 which is a measure of incident photon energy (in fact, the PHA channel number ≈ peak energy in keV). At normal gain, these channels are roughly 1 keV wide and arranged such that the PHA channel number corresponds to the peak photon energy in keV. The minimum acceptable energy is defined by the *Lower Level Discriminator* (**LLD**) which may be set to any value from 5-50 keV, though values in the range 10-30 keV prove the most useful. The *Upper Level Discriminator* (**ULD**) level defines the upper bound of the instrument, which corresponds to about 250 keV at nominal gain

5.3.3 Effective Area

The *on-axis effective area* of a HEXTE detector is defined as its efficiency in producing an a detected scintillation pulse event for each incident x-ray photon, multiplied by its open area to the sky in the

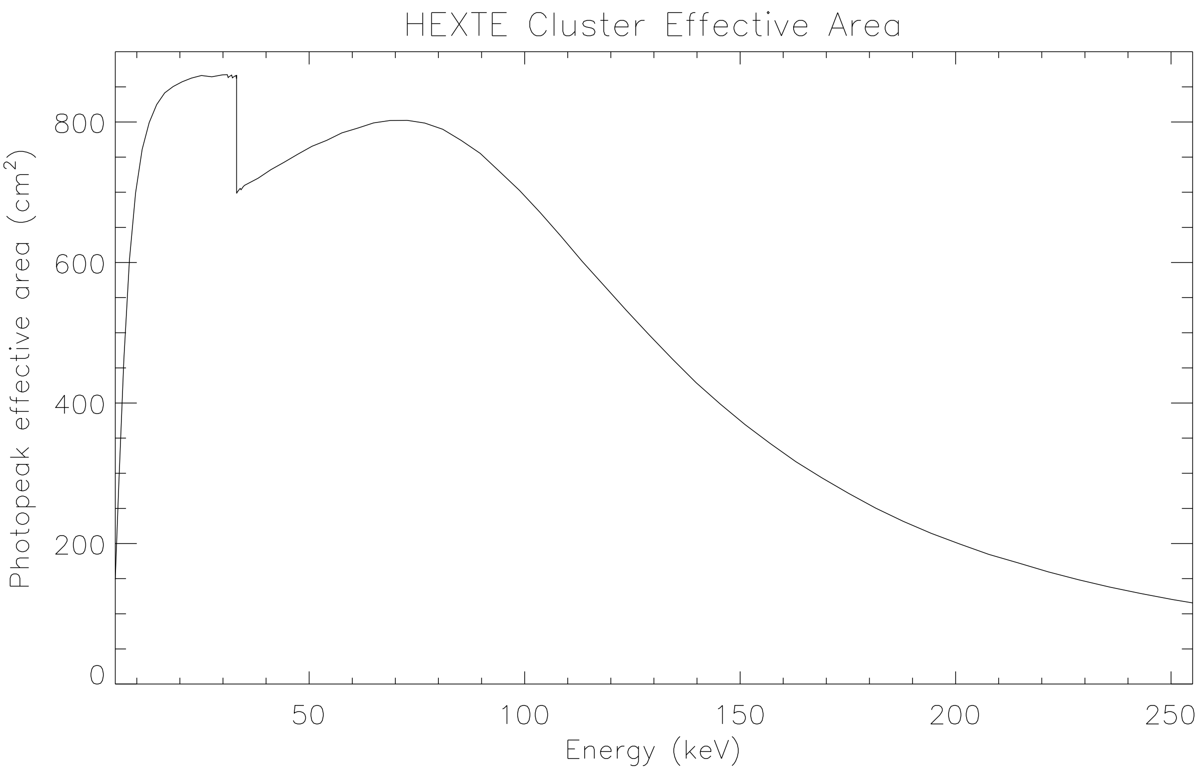


FIGURE 5.5. On-axis effective area of the four HEXTE phoswich+collimator assemblies which comprise HEXTE Cluster A, assuming a net open area of 890.342 cm^2 per detector. The Iodine K-edge is at 33.17 keV. Note that this curve must be scaled by the live-time fraction (Section 5.3.8) before calculating count rates.

on-axis look direction. *Non*-detected photon interactions include absorption in the detector window, those partial energy loss events in the NaI (Compton scattering) which are captured and rejected by the CsI layer, and photons which pass through the NaI undetected.

Extensive Monte-Carlo simulations of the phoswich detectors have been performed. **Figure 5.5** shows the effective area as a function of energy for “photopeak” interactions, i.e. complete x-ray energy loss in the NaI, which is the significant contributor to the HEXTE’s sensitivity (these events appear as diagonal elements in the response matrix); this curve has been scaled to Cluster A’s net open area of 890 cm^2. The sharp edge at 33.17 keV is the K-escape energy of Iodine. Note that in order to estimate the *measured* count rate for a given source, this effective area must be multiplied by the detector *live-time fraction* (**Section 5.3.9**)

5.3.4 Spectral Resolution

X-ray photons of a given energy will produce a spread in detected pulse height due to the Poisson fluctuations in the number of photo-electrons produced per event. The intrinsic energy resolution of the phoswich detectors can be described roughly by a gaussian function with FWHM increasing as $\sqrt{\text{Energy}}$, to which must be added a small term proportional to energy due to the gain variations across the face of each detector. For an average phoswich detector, the resolution FWHM (in channels or keV) at PHA channel *e* (≈*E* keV) is given approximately by

$$FWHM = \sqrt{e} \times \sqrt{0.0055e + 1.09}$$

Summing data from the detectors in a HEXTE cluster degrades this resolution somewhat due to this lightly different PHA channel centroids of the line-spread function in each detector at a given energy. Nevertheless, the 256 PHA channels (numbered 0-255) still over-sample the HEXTE resolution by at least a factor of 2. The user may select contiguous sub-ranges of PHA channels and/or group them on-board into larger spectral bins, according to the Science Mode telemetry format in use.

5.3.5 The HEXTE Response Matrix

All of the effects described above - detection efficiency, detector gain and spectral resolution -can be embodied in the HEXTE response matrix, which describes the transformation from an input photon spectrum to a PHA count rate spectrum (to which one must add the internal background). An example of such a matrix is shown in **Figure 5.6**, which shows the (almost linear) energy/PHA channel conversion gain, and the increase in resolution-broadening with energy. The photopeak response,

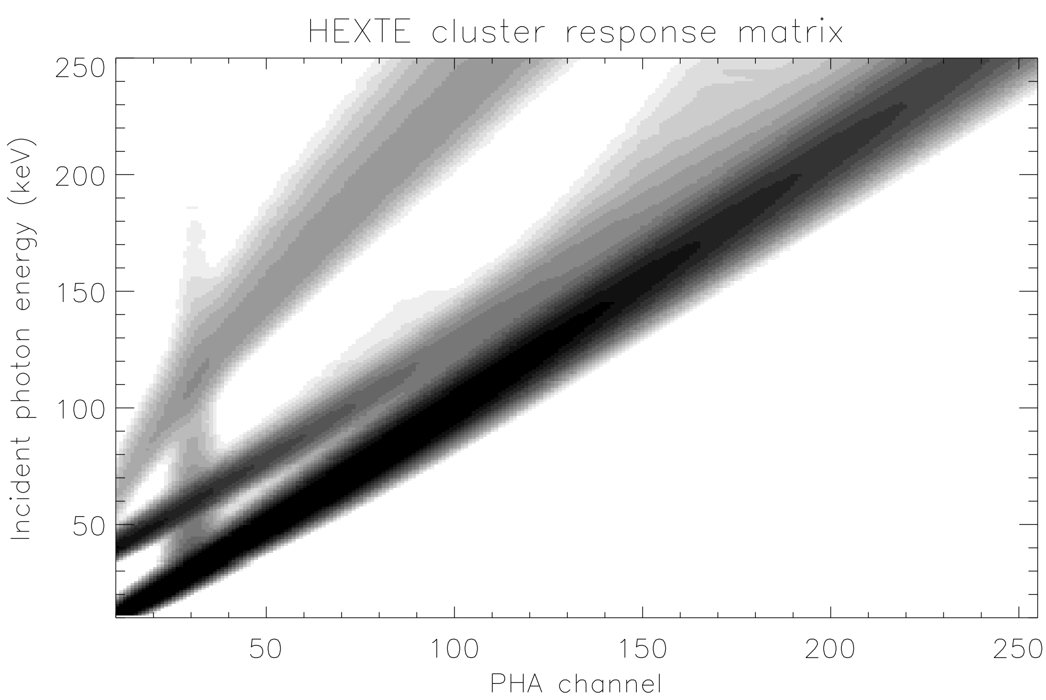


FIGURE 5.6. Model HEXTE detector response matrix, showing the PHA channel spectra produced by photons from 10 to 250 keV in units of counts per (photon cm^{-2}) on a logarithmic scale covering 3 orders of magnitude. The dominant terms are the resolution-broadened photopeak (diagonal) and K-escape interaction peaks (offset diagonal). At a much lower level, Compton scattering and partial energy loss events in the CsI also contribute. The vertical feature is due to K-shell x-rays from the "dead layer" in the detector.

described earlier provides the dominant, diagonal term in this matrix. However, there are significant off-diagonal terms, which are also broadened by the pulse-height resolution. For instance, the K-escape interaction with Iodine reduces an incoming x-ray's apparent energy by 33 keV, giving rise to a secondary peak in the response for a given input energy above this threshold. Other terms in the matrix arise from interactions such as Compton-scattering in the NaI, Compton back-scattering of x-rays from the CsI, and the detection of Iodine K-shell x-rays ejected from a "dead layer" which absorbs incoming x-rays without producing a primary scintillation. The HEXTE team are continually improving the accuracy of the response matrix through Monte-Carlo modelling of the detector materials and geometry, and by comparison with model fits to in-orbit data on bright sources.

5.3.6 Automatic Gain Control and Calibration Spectrum

Even with the magnetic shielding around each detector, the gain (or pulse-height/energy relation) is affected by the magnetic fields encountered throughout an orbit. Secular changes in the gain also occur due to aging of the phototubes. To counteract these effects, the AGC system is designed to stabilize each phoswich detector's gain, such that photon events of a given energy will always produce counts in the same PHA channels. X-rays of 59.6 keV energy from the ^{241}Am source interact in the NaI in coincidence with the associated alpha particle interaction in the gain control detectors

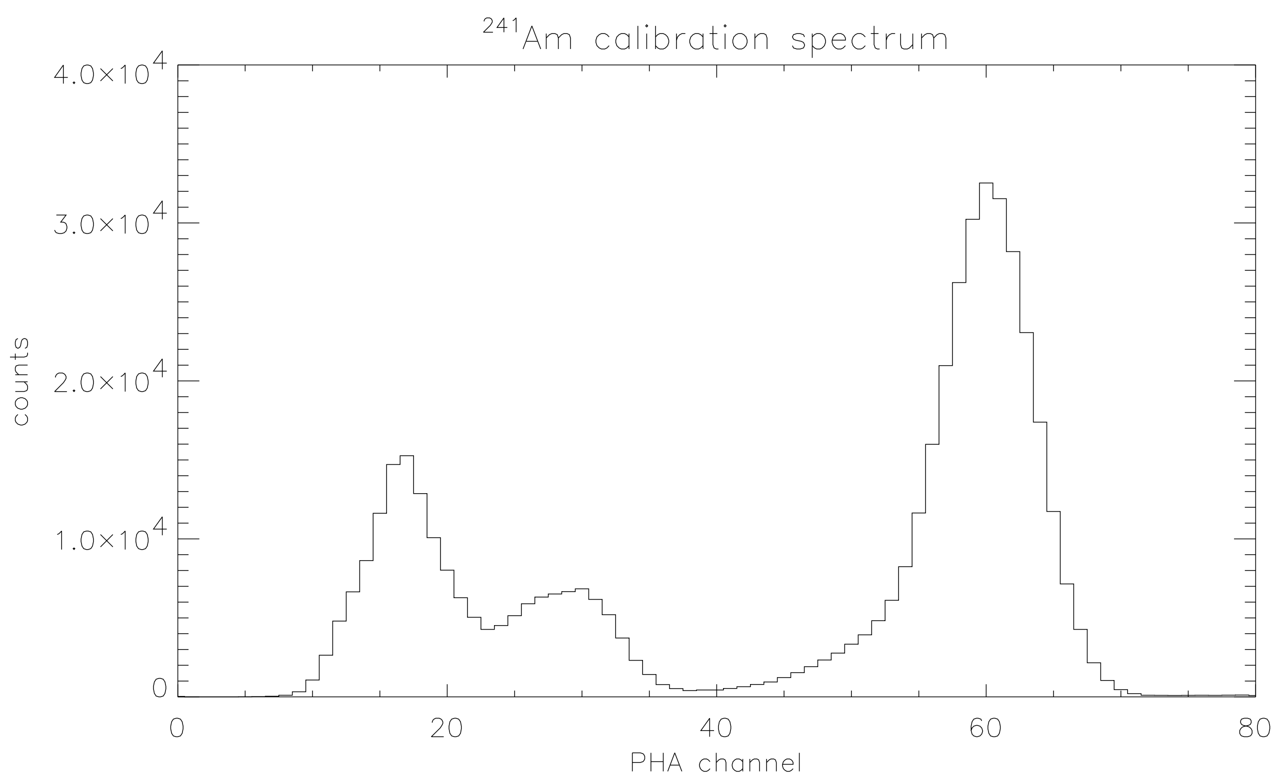


FIGURE 5.7. HEXTE PHA histogram spectrum of the ^{241}Am gain control and calibration source.

(described above). These NaI events are used to provide the gain control feedback signal that adjusts the PHA conversion gain to preserve the energy/PHA channel relation. Coarse gain settings are accomplished by selecting one of 256 high voltage steps (5% gain change per step) and fine steps can be commanded by the AGC system within the range 0.2% to 0.0125%. The AGC updates the gain every 0.5 s. In this manner short-term gain variations are kept to $<1\%$.

All events detected in the phoswiches in coincidence with the α–particle events in the gain control detectors are separately accumulated into a calibration spectrum which is acquired over 32 Instrument Data Frames (8.5 minutes). The result is a very clean ^{241}Am spectrum with a line at 59.6 keV, a blend around 25 to 30 keV, and the L-shell blend around 17 keV (**Figure 5.7**). These spectral features will provide constant monitoring of the gain and resolution for each phoswich detector throughout the mission. With this system, meaningful comparisons and co-additions of datasets may be made between spectral observations taken many months apart.

5.3.7 Background Spectrum and Background Subtraction

The anti-coincidence shielding around each HEXTE cluster vetoes almost all particle scintillations in the detectors. The remaining background spectrum is intrinsic to the HEXTE and is dominated by x-rays emitted in the decay of radioactive products, which are produced by high energy particles interacting with the detector materials (principally lead in the collimators and iodine in the phoswiches themselves). During an orbit of the RXTE this background will vary by a factor of 1.5 to 2. To a first approximation the HEXTE background rate outside the SAA region is proportional to the cosmic ray particle flux, which varies from point-to-point due to geomagnetic cutoff. There are delayed components after passage through the SAA, however, from the activation of radioactive daughters in the detector material itself, as well as in surrounding matter, by SAA protons.

A typical HEXTE cluster background spectrum from RXTE Cycle 1 is shown in **Figure 5.6**. The large spectral feature at 30 keV is a blend of x-ray lines from de-excitation of spallation-created daughters of Iodine in the detector (which decay promptly by K-capture). The next-largest feature at 73-87 keV are K x-rays from the Pb collimators. The total background in the 15-250 keV range is 90-100 count/s per HEXTE cluster.

Background estimation is provided to a very good first order by the source/background beamswitching. The current DEFAULT on-source dwell time for the HEXTE is 16 s, which is the least efficient; however the effectiveness of removing systematic background variations using longer dwells is still under investigation. Estimates of secular variations in the HEXTE background have been made based on HEAO-A4 data, and predict that systematic errors in background subtraction can be kept below the Poisson noise level over a 5×10^5 s observation of a faint source; early results from RXTE Cycle 1 appear to confirm this. However, longer exposure times will not be able to elicit a fainter detection since they will be compromised by cosmic x-ray background fluctuations and other systematics.

For a given 16 s on-source data accumulation, the background rate estimate will be the average of the last 6 s of the previous off-source accumulation plus the first 6 s of the following off-source accumu-

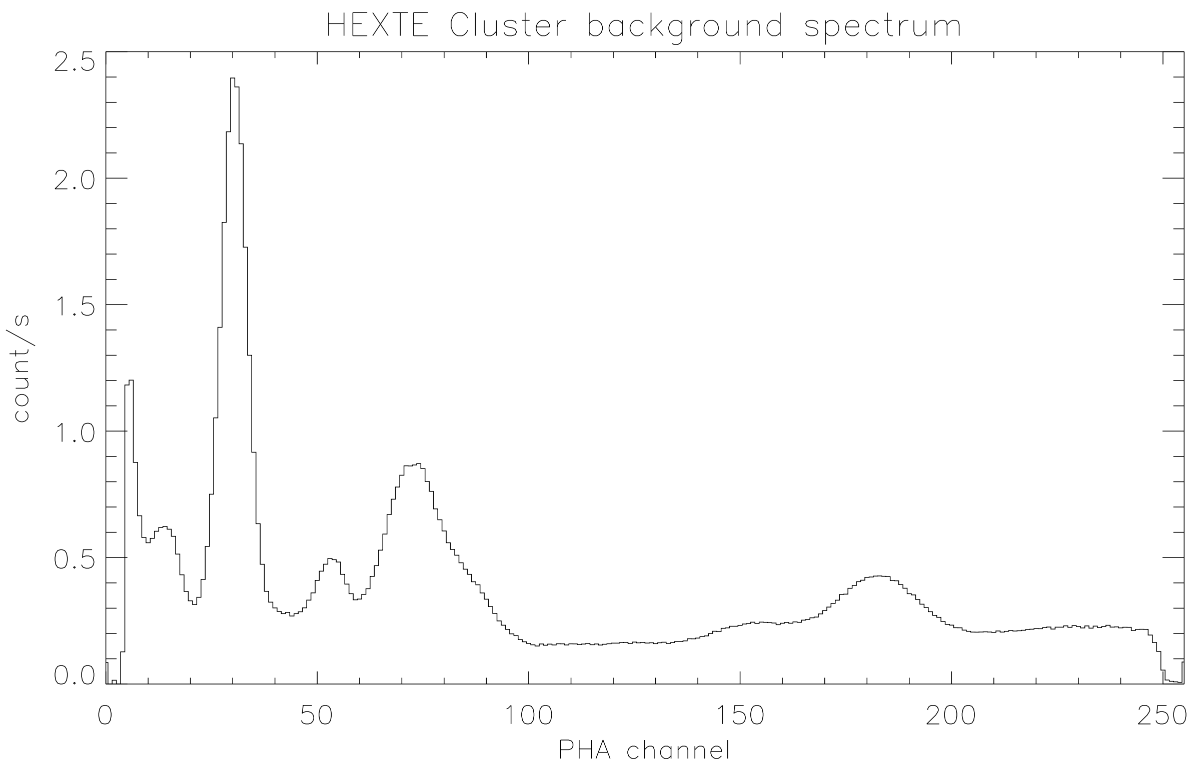


FIGURE 5.8. Measured in-orbit background spectrum for HEXTE cluster A (sum of 4 detectors); the PHA channel number roughly corresponds to energy in keV. Spectral features are due to x-rays from the radioactive decays products induced in the detector materials by energetic particles.

lation. (Remember that 2 s is lost at each end of the off-source observation while the rocking mechanism is in motion). For a typical background rate of 90 count/s per HEXTE cluster, the resulting interpolated background rate is limited by Poisson statistics to about 3% accuracy per cycle.

The observer will typically co-add the two off-source datasets for each cluster, after testing for the presence of a contaminating source. Users may also wish to make an empirical fit to the off-source data versus time for estimating the on-source background contribution. For those observations where off-source observations are not made (e.g. dwelling on-source for temporal investigations of bright sources), the HEXTE background may be modelled using orbital parameters and particle veto rates, but not to the precision available when beamswitching. If background estimates are important in this case, users are encouraged to contact the HEXTE team for advice.

5.3.8 Time Sampling

The HEXTE is capable of time-tagging events to 7.6 μs when used in Event List mode. For high count rate sources, which would saturate the telemetry in this mode, users may still perform fast timing in Temporal Bin Mode, which can produce light curves with time bins as small as 1 ms (**Section 5.6**). Calibration of the absolute timing accuracy is performed via the spacecraft clock, while relative timing tests between the HEXTE and the PCA have verified the coincidence to within the 7.6 μs precision of the HEXTE measurements.

5.3.9 Dead-time and "Lost Events" Data

Dead-time in the HEXTE originates in the detector electronics, which takes 16–30 μs to process a typical scintillation pulse (but much longer for MeV particles, see below). This dead-time is measured for each HEXTE detector assembly by a gated counter which increments for each 1/2 spacecraft clock cycle (1.91 μs) for which the detector electronics is busy. The dead-time counter is also incremented during the on- (off)-source motion of the HEXTE cluster which lasts for 2 s, and is included in the dead-time count for the preceding (following) off-source dwell.

The dead-time counter's value is normally telemetered every 16 s (but as fast as every 1 s in Spectral Bin and Burst List modes). For dead time estimates on shorter timescales, modelling of the source behavior becomes necessary. While an accepted event is being pulse-height analyzed after passing the event-selection criteria, the HEXTE processor can also register the detection of up to 3 *Lost Events*, which are those accepted events which were received while the analyzer electronics were still busy (and the dead time counter was incrementing). Although no energy information is available for these events, they can be used to model bright, rapid (<1s) changes in source flux, and as an aid to absolute flux determination.

During RXTE's Cycle 1 it was discovered that the dead-time counter value alone underestimates the time for which the event selection logic is unavailable for event processing, due to the long periods of dead-time following impacts by high energy particles (known as XULD events). A typical charged particle rate is 150 count/s per phoswich, with each event causing about 2.5 ms of deadtime. This results in a dead-time fraction ~40%, which is equivalent to a reduction in the HEXTE's effective area by the same amount. While the dead-time counter does not account adequately for such events, accurate dead-time estimates can be recovered in the data analysis by a simple combination of dead-time counter values and HEXTE Housekeeping monitor rates (specifically, the ULD and XULD rates), all of which are telemetered every 16 s. On shorter time scales the particle rates are roughly constant, but for a particle rate of 150 count/s, the Poisson uncertainty in the dead-time is 8% on 1 s timescales.

The HEXTE proposal preparation materials, including the PIMMS and *HEXTEmporize* software, as well as the response matrices and background spectra used in XSPEC simulations, include the effects of this additional dead-time at the orbital average level (40%). Therefore, users do not need to make explicit corrections for dead-time when planning HEXTE observations.

5.3.10 Performance changes since launch

5.3.10.1 Changes in spectral resolution

As the photomultiplier tubes age, their efficiency at converting scintillations into an electrical signal is reduced. The Automatic Gain Control system adjusts the detector high voltages to compensate for this effect, such that the energy/channel relation for each detector will remain constant throughout the mission. However, the reduced efficiency is accompanied by a decrease in spectral resolution which cannot be corrected by the AGC system. In the first 15 months of launch, this has caused the FWHM response of an individual detector, expressed as $\Delta E/E$, to increase by 2% (eg. from 15.5% to 15.7% at 60keV). Despite this small increase, acceptable spectral fits may still be obtained to all data throughout RXTE Cycles 1 to 3 using a single set of response matrices.

5.3.10.2 Loss of spectral information from phoswich detector PWB2

On 1996 March 6 at 11:27:12 UT, detector 2 in cluster B (**Figure 5.1**) lost its ability to provide spectral information; all accepted photon events between the lower and upper energy discriminators produce counts in PHA channels 1 and 2 only, regardless of their incident energy in this range. However, data from this detector may still be used to provide a broad-band flux as a function of time. The only drawback is that without a gain calibration spectrum, automatic gain control is no longer possible for this detector, resulting in a drift of the high voltage as the spacecraft passes through the changing magnetic field in its orbit. This translates into gain variations (or variations in the effective upper and lower energy bounds) of around 2% per orbit, with a secular gain decrease of the same order over a month. Bright, soft-spectrum sources will therefore produce count rate variations in this detector due to the changing effective lower energy bound. However, for most faint source observations this effect should be negligible and this detector operates effectively as a 12-250 keV photometer. Note that since the PHA channels 1 and 2 lie outside the pre-defined PHA channel ranges of Archive Temporal Bin mode (q.v.), counts from PWB2 will not appear in this mode's telemetry.

5.4 Data System

The HEXTE data system is based on a Harris MD-80C286/883 microprocessor running at 4.915 MHz which controls data collection, processing and output to the telemetry stream. Available memory includes 128 kilobytes of Read-Only Memory (ROM) and 512 kbyte of Random Access Memory (RAM).

5.4.1 HEXTE Timing Signals and the Instrument Data Frame (IDF)

Data input, data processing, data output, and various functions within HEXTE utilize the following telemetry timing signals as a reference:

- Engineering Major Frame: 64.0 second period
- Science Major Frame: 1.0 second period (64 per Engineering Major Frame)
- Science Minor Frame: 0.03125 second period (32 per Science Major frame)
- Spacecraft clock: 1.048576 MHz frequency.

Since the shortest on-source/off-source beamswitching cycle period is one Engineering Major Frame, consisting of four on- and off-source phases of roughly equal length, it is convenient to define a time unit consisting of 16 Science Major Frames:

- *Instrument Data Frame* (**IDF**): 16.0 s period.

The source/background beamswitching cycle is defined in multiples of this 16 s IDF. All data accumulation and output intervals in the Science Modes described later are multiples or sub-multiples of the IDF.

The HEXTE electronics also contain two crystal-controlled oscillators for precision timing: a 9.830 MHz oscillator provides a timing reference for the microprocessor, and an 8.000 MHz oscillator provides a reference frequency for the electronics' pulse height and pulse shape time-to-digital converters.

5.4.2 Event Selection

The event selection logic provides the criteria used to accept or reject an event. In addition to anti-coincidence shield rejection, the input pulse is compared against lower and upper levels by discriminators, and *Pulse Shape Discriminators* (**PSD**s) define an acceptable range in pulse rise-time. These will normally be used to provide clean NaI-only pulses with total energy loss measured and maximum background rejection. These good events are passed to the pulse height analyzers which convert the energy-related pulse height into an 8-bit channel number. *Pulse Shape Analyzers* (**PSA**s) convert the rise-time-related pulse shape into a 6-bit number.

5.4.3 Event Definition

For each phoswich event that passes the event selection logic, data from the various detectors and other subsystems are combined to form the 7-byte *event code* that contains all the possible information about the event. The event code byte map is summarized in **Table 5.2**. This event code is the basis for all scientific processing; if the event selection logic does not pass an event, it cannot be included in the HEXTE telemetry. Lost Events (defined earlier) are counted and this number is included as a 2-bits in the event code of the event being analyzed when they arrived.

From Table 5.2 it can be seen that event code bytes 5 and 6 are unnecessary for most user observations, since these contain either redundant time counters, or flags which are zero under normal operation. Byte 4 contains diagnostic pulse shape information, which may be used for subsequent event selection but can be omitted for bright sources, and for observations with a high setting for the Lower Energy Bound. The event information of interest to most users is therefore contained in bytes 0-3, which are available directly in Event List Science Mode, or can be reformatted into one of the binned Science Modes to keep within telemetry constraints when the count rates are high.

5.5 Standard Telemetry Formats and Data Products

The HEXTE flight software has three basic types of telemetry data products: Housekeeping, Standard Modes, and Science Mode. Housekeeping and data from the Standard Modes are produced in fixed format for every HEXTE pointing to provide basic spacecraft diagnostic information, and basic spectral and timing information for the source under study. The Science Mode is selected and configured by the user to meet the scientific needs of their observing program, and is described along with other Guest Observer configurations in the following section. Housekeeping and Standard Modes run continuously and produce roughly 1 kbit/s of telemetry data, leaving 4 kbit/s (on average) for the selected Science Mode.

5.5.1 Housekeeping

Housekeeping contains (1) the analog-to-digital conversions of various temperatures, voltages, and currents, which are available on 64 and 128 s timescales, (2) the instrument configuration (i.e. digital status) which is available on 16, 64 and 128 s timescales depending upon the parameters, and (3) the rates accumulators for all discriminator and coincidence functions, which are available every 16 s. Phoswich-related rate accumulators, which record particle events responsible for dead time, collect data for 4 s sequentially at each of the 4 phoswiches.

5.5.2 Standard (Archive) Modes

The purpose of the HEXTE Standard Modes (also known as Archive Modes) is to provide a basic temporal and spectral record of every source observed, independent of the Science Mode chosen by the user. Two Standard Mode data products are generated within HEXTE every 16 s in a fixed format. The dead time for each phoswich detector is included with the Standard Modes data each IDF (16 s), and the data products themselves are described below:

5.5.2.1 Archive Spectral Bin Mode (Energy Spectra)

This mode produces a compressed pulse height histogram (energy spectrum) for each phoswich detector every 16 s. The first 64 PHA channels are combined two-at-a-time into the first 32 archive spectrum bins with 16-bit depth per bin; the second 64 phoswich PHA channels are combined four-at-a-time into the next 16 archive histogram bins with 8-bit depth per bin; and the final 128 phoswich PHA channels are combined eight-at-a-time into the last 16 archive histogram bins with 8-bit depth per bin. This compression causes only a small loss of information; virtually all cosmic x-ray sources

TABLE 5.2. Contents of the seven HEXTE event code bytes generated for each processed event.

Byte	Bit	Description[1]	Byte	Bit	Description[1]
0: Pulse Height channel	0	PHA Bit 0 (≈1 keV)	**4: Pulse Shape channel**	0	Science Major Frame Counter Bit 3 (8 s)
	1	PHA Bit 1 (≈2 keV)		1	AGC Flag
	2	PHA Bit 2 (≈4 keV)		2	PSA Bit 0
	3	PHA Bit 3 (≈8 keV)		3	PSA Bit 1
	4	PHA Bit 4 (≈16 keV)		4	PSA Bit 2
	5	PHA Bit 5 (≈32 keV)		5	PSA Bit 3
	6	PHA Bit 6 (≈64 keV)		6	PSA Bit 4
	7	PHA Bit 7 (≈128 keV)		7	PSA Bit 5
1: 7.63 µs timing	0	Event Time Bit 0 (7.629394535 µs)	**5: Shield Event Flags**	0	Shield 1 Flag
	1	Event Time Bit 1 (15.25878907 µs)		1	Shield 2 Flag
	2	Event Time Bit 2 (30.51757813 µs)		2	Shield 3 Flag
	3	Event Time Bit 3 (61.03515625 µs)		3	Shield 4 Flag
	4	Event Time Bit 4 (122.0703125 µs)		4	Shield 5 Flag (not used)
	5	Event Time Bit 5 (244.140625 µs)		5	CsI (PSULD) Flag
	6	Event Time Bit 6 (488.28125 µs)		6	XULD Flag
	7	Event Time Bit 7 (976.5625 µs)		7	Test Pulse Generator (TPG) Flag
2: 2 ms timing	0	Event Time Bit 8 (1.953125 ms)	**6: Frame counters**	0	Science Major Frame Counter Bit 0 (1 s)
	1	Event Time Bit 9 (3.90625 ms)		1	Science Major Frame Counter Bit 1 (2 s)
	2	Event Time Bit 10 (7.8125 ms)		2	Science Major Frame Counter Bit 2 (4 s)
	3	Event Time Bit 11 (15.625 ms)		3	Science Major Frame Counter Bit 3 (8 s)
	4	Event Time Bit 12 (31.250 ms)		4	Science Major Frame Cntr Bit 4 (16 s)
	5	Event Time Bit 13 (62.500 ms)		5	Science Major Frame Cntr Bit 5 (32 s)
	6	Event Time Bit 14 (125.00 ms)		6	Science Major Frame Cntr Bit 6 (64 s)
	7	Event Time Bit 15 (250.00 ms)		7	Science Major Frame Cntr Bit 7 (128 s)
3: Detector Identity, Lost Events, 1 s timing	0	Event Time Bit 16 (500.00 ms)			
	1	Lost Events Counter Bit 0			
	2	Lost Events Counter Bit 1			
	3	Detector ID Bit 0			
	4	Detector ID Bit 1			
	5	Science Major Frame Cntr Bit 0 (1 s)			
	6	Science Major Frame Cntr Bit 1 (2 s)			
	7	Science Major Frame Cntr Bit 2 (4 s)			

1. The time or spectral sampling precision corresponding to each event bit is shown in parentheses.

in the 10-250 keV range decrease in intensity with energy, while the HEXTE's FWHM spectral resolution (measured in PHA channels) also broadens with energy.

5.5.2.2 Archive Temporal Bin Mode (Light Curves)

This mode produces four light-curves with 16-bit bins from the sum of all 4 phoswich detectors in a cluster, with 1 s temporal sampling every 16 s. The four light curves represent the PHA channel (and, therefore, approximate energy in keV) ranges of 15-29, 30-61, 62-125, and 126-250.

5.6 Guest Observer Configurations

The HEXTE observing configuration is based upon a dictionary of 23 different commands, each with an associated set of parameters. Most of these commands are outside the domain of users, including the event selection logic, the AGC configuration, and the heater settings. Those settings which must be defined for each HEXTE cluster by the user are listed below:

- Configure the source/background beamswitching mechanism
- Select the Lower Energy Bound
- Select the Science Mode telemetry format, and its parameters
- Configure the Burst Trigger (if selected)

The HEXTE clusters may be configured together, or separately (e.g. with one cluster staring on-source and the other performing source/background switching). If a user wishes a configuration other than that available to users in general, the HEXTE team must be contacted in advance.

5.6.1 Beamswitching (Rocking) Mechanism

The rocking mechanism is configured by selecting:

1. `On-source dwell time:` 0 (continuous stare), 16, 32, 64, 128 s, or DEFAULT (currently 16 s).

If "DEFAULT" is selected, the HEXTE team will set the dwell time to provide the best background subtraction, as determined from in-orbit calibrations. Note that 4 s is always lost from the off-source dwell to allow for motion off- and then back on-source during the time the other cluster is dwelling on-source (Figure 5.3). The selectable beamswitch (rocking) angles for each cluster are either:

2. `continuous stare (dwell = 0s):` 0° (i.e. on-source), +1.5, -1.5, +3.0, -3.0 degree positions, or
   `two-sided source/background switching:` ±1.5 or ±3.0 degree beamswitching, or
   `one-sided source/background switching:` +1.5, -1.5, +3.0, -3.0 beamswitching

Users may also request the DEFAULT pointing directions, which will be on-source for stare (0 s dwell time) observations, or $\pm 1.5^{\circ}$ source/background switching otherwise. Users should research and specify the sky positions of any possible contaminating sources within a 2.5° radius of their source of interest, so that contaminating sources in the background fields can be avoided by using 3° or one-sided rocking once their observation is scheduled. In such cases, 3° two-sided rocking is normally preferred, since users will still have two independent measurements of the background. The HEXTE team have provided a software program, *HEXTErock*, which calculates the sky coordinates of the various off-source cluster positions for a given observing configuration. Using a graphical interface, *HEXTErock* may also be accessed on the World Wide Web via the RXTE Guest Observer Facility web site.

5.6.2 Lower Energy Bound

The lower energy bound of the science processing from the phoswich detectors (which includes both Standard and Science Mode data) can be selected in the range 5 keV to 30 keV, to the nearest 0.2 keV. Values between 10 and 30 keV prove the most useful, and the DEFAULT value of 12 keV will be the most commonly scheduled.

For a medium-bright steep spectrum source, however, a user may be able to keep within telemetry limits and still use Event List mode (see below) by increasing the lower energy threshold and thereby sacrificing the lowest energy PHA channels. For very bright sources, or high background conditions, increasing the lower energy bound will also decrease the overall detector dead time, and the consequent need for Lost Events data Note though that increasing the lower energy bound will also prevent events below the new threshold from appearing in the Standard Modes data products.

Setting a lower energy bound *below* the default value of 12 keV does increase the overlap in spectral coverage with the PCA instrument, but the HEXTE's decreased effective area and higher background rate at low energies makes such settings of dubious practical use, except for spectral features in the PCA/HEXTE overlap range, and for burst-triggering. Therefore, if a lower energy bound below the DEFAULT value of 12 keV is desired, users should contact the HEXTE team for advice.

5.6.3 Science Modes

In addition to the Standard Modes provided for all observations, each HEXTE cluster provides a Science Mode which can be specified by the user. There are three basic Science Modes. Event List mode transmits information about each incoming event, and therefore the telemetry rate depends on source strength. Spectral Bin mode produces binned PHA spectral data with up to 256 spectral bins at 1 to 16 s intervals, while Temporal Bin mode produces light-curves with sub-second time bins covering up to 8 contiguous spectral bands. Both of the binned modes have a fixed telemetry rate for the user's selected spectral and temporal sampling. A fourth mode (Burst List) can be enabled to run in parallel with any of these three basic Science Modes to capture photon events from rapid outbursts. Finally, if the Standard Mode data products prove sufficient for a user's scientific goals, then "IDLE" Science Mode may be selected for one or both of the HEXTE clusters.

All Science Mode packet data headers (sent every 16 s) contain the dead time average per detector, the rocking mechanism position, and the parameters of the particular Science Mode. The HEXTE Science Mode is normally implemented by uplinking a table of parameters and then selecting them. It is not necessary for both clusters to use the same Science Mode, but this is usually desirable, especially if source/background beamswitching is selected for both.

The HEXTE Science modes, and their relevant parameters, are described below. The HEXTE Feasibility Chapter gives more information on their uses, with specific examples. The HEXTE team have also provided a software tool, *HEXTEmporize*, to assist users in selecting the appropriate parameters for their observations, consistent with their source count rates and the HEXTE's telemetry constraints.

5.6.3.1 Event List Mode (Event-by-Event)

The Event List mode is an event-by-event list of a user-selected subset of the 7-byte event code for each photon detected. This list is stored in a variable length buffer, since the number of events are dependent on the source intensity, up to the maximum buffer size which corresponds to a telemetry rate of 23 kbit/s per HEXTE cluster. Any combination of the 7 bytes comprising the event code may be selected for inclusion in telemetry, but only the first 5 bytes provide useful information to observers. Subsequent data analysis will be able to generate light curves and/or spectra, depending upon the event code bytes selected. The user must therefore make the following selections:

1. `Include byte #0?`: Yes or No...
2. `Include byte #1?:` Yes or No...
3. `Include byte #2?:` Yes or No...

...and so on for all 7 bytes. Refer to **Table 5.2** for the contents of each byte in the 56-bit event code. This mode will be appropriate for the majority of sources observed by the HEXTE; faint sources may be observed using bytes 0-4 for maximum spectral and temporal sampling.

5.6.3.2 Spectral (Histogram) Bin Mode: Energy Spectra at 1 s to 16 s intervals

The Spectral Bin mode produces a pulse height histogram (energy spectrum) at time intervals from 1s to 16 s, either for each detector, or, alternatively for the sum of all 4 detectors in a cluster. This mode is appropriate for producing spectra of bright sources which cannot be accommodated by Event List mode. The histograms can be tailored to each observation and telemetry rate by choosing the frequency at which spectra are generated, the grouping of PHA channels into spectral bins, and highest PHA channel (or highest energy) of interest. The count capacity of each bin must be chosen to be adequate for the expected count rates in each bin. The selectable parameters of this mode are:

1. `Number of histogram spectra per detector per IDF (16s interval):` 2, 4, 8 or 16 (corresponding to one histogram spectrum every 8, 4, 2 or 1 s).

   Note that the dead time counter will be transmitted with each histogram spectrum, i.e. as fast as every 1 s if 16 spectra per IDF is selected. This is the shortest timescale on which the dead time counter can be sampled in any Science Mode.

2. `Number of distinct detector IDs per cluster:` 4 (separate detector spectra) or 1 (= sum of 4 detectors). Separate detector spectra are always recommended.

These first two parameters determine the total number of spectra produced per IDF. The energy coverage and spectral binning of these spectra are set by specifying:

3. `Highest PHA channel # required` (roughly, the highest energy in the spectrum in keV): 127, or 255 (remember that HEXTE PHA channels are numbered starting from 0).

4. `Number of spectral bins: 64, 128`, or 256 (but never more than the highest PHA channel #+1).

Each spectral bin will then bin together a number of PHA channels given by (highest PHA channel+1) ÷ (number of spectral bins per histogram). Since the PHA channels over-sample the HEXTE's energy resolution by at least a factor of 4, this rebinning causes minimal loss of spectral information.

Finally the capacity of the spectral bins (maximum number of counts they can hold) must be specified:

5. `Depth of the spectral bins:` 4, 8 or 16 bits (0-15, 0-255 or 0-65535 counts).

5.6.3.3 Temporal (Multiscalar) Bin Mode: Light Curves in 1 to 8 Spectral Bands

This telemetry mode provides light curves with time bins from 0.98 ms to 1 s, with 2, 4, 6 or 8 spectral energy ranges (hence the "Multi-"scalar name). These data may be provided for each detector in a cluster, or the sum of all 4 detectors. This mode is only applicable to observers of very bright sources and should only be selected in consultation with the HEXTE team.

One of the (up to) 8 light curves may be assigned to accumulate the Lost Events data on the same time scale as the other light curves. This enables the proper intensity to be calculated for each time bin for a very bright source. Note that as for Event List mode, the dead time is reported only as a 16-s average at the end of each IDF. The user-selectable parameters for this mode are:

1. `Total number of light curve spectral bands:` 1 to 8

2. `Include a Lost Events light curve in one of these bands?:` Yes or No

3. `Number of distinct light curve detector IDs per cluster:` 4 detectors, or 1 = sum of 4

These determine the total number of light curves telemetered in this mode. The spectral bands covered by each light curve are then set by specifying:

4. `Lowest PHA channel # for 1st light curve spectral band:` 0 to 254
5. `PHA upper channel # for 1st spectral band's light curve:` 1 to 255
   `PHA upper channel # for 2nd spectral band's light curve:` 2 to 255
   `PHA upper channel # for 3rd spectral band's light curve:` 3 to 255...

...and so on for the number of spectral bands selected. Note the important restriction that the channel ranges so specified *must be contiguous and in ascending order.* The HEXTE Feasibility Chapter provides recommended values for the PHA channel boundaries.

Finally, the time sampling and time bin depth for all the light curves must be selected:

6. `Number of time bins per IDF (16s interval):` 128, 256, 512, 1024, 2048, 4096, 8192, or 16384. (These correspond to time bin sizes of 125, 62.5, 31.25, 15.625, 7.8125, 3.09625, 1.953125, or 0.9765625 ms).
7. `Time bin depth:` 4, 8 or 16 bits (0-15, 0-255 or 0-65535 counts/bin).

5.6.3.4 Burst Trigger/Burst List Mode

This is a specialist mode used to capture a "snapshot" of full temporal/spectral resolution event data in cases when the source is too bright for Event List mode. If this mode is desired, users must first contact the HEXTE team for advice on the settings described below.

When enabled, the Burst List mode runs in parallel with one of the three primary Science Modes, accumulating an Event List (event code bytes 0-3) in a circular buffer containing 25560 events per cluster. Upon satisfaction of a burst trigger, the buffer accumulates a software commandable number of post trigger events, then freezes its contents, and awaits the command to download its contents in place of the normal science data. In addition, since this mode is expected to be used for high and variable count rates, dead time counter values are stored at 1 s sampling for the 12 IDFs after the trigger.

After downloading the contents of the Burst List buffer in about 2.5 minutes, the data processor awaits a ground command to reset the buffer and re-enable the trigger, and then automatically returns telemetry to the selected Science Mode. Dead time counter values will also be available at 1 s sampling for the 12 IDFs after the trigger.

A burst trigger can be generated by any of four sources: a digital ground command, a trigger received from the EDS electronics, a trigger received from the other HEXTE cluster, or an internally calculated burst trigger. Ground commands can disable the response from internal or external sources of triggers. The ground command trigger can also be used to take a "snapshot" of a bright source will full spectral and temporal resolution.

A local burst-trigger can be issued on the detection of an increase in the recent average event rate exceeding a threshold, which is user-selectable. However, this internal trigger mode will only be useful for observations with no source/background switching, i.e. staring on-source, since a spurious trigger would be generated each time a cluster moved on- or off-source.

The complete list of user parameters for this mode is:

1. `Set burst trigger:` NO (i.e. off), EXTERNAL (from the EDS, or other cluster), or INTERNAL.

Then if the INTERNAL burst trigger is set:

2. `Integration interval:` 3.9, 7.8, 15.6, 31.3, 62.5, 125, 250, 500 ms, 1, 2, 4, 8, or 16 s, (corresponding to 4096, 2048, 1024, 512, 256, 128, 64, 32, 16, 8, 4 or 1 intervals per IDF)
3. `No.of integration intervals (`***m***`)for running average:` 4, 8, 16, 32, 64 or 128
4. `Trigger` χ^2 `threshold:` 1 to 100 (for internal trigger only)
5. `Percentage of events to be stored before/after trigger:` set in 0.5% steps from 0-100%

The χ^2 threshold statistic is calculated from the number of counts $\boldsymbol{n_1}$ in the most recent integration interval, and the total number of counts $\boldsymbol{N_m} = \Sigma\, \boldsymbol{n_i}$ summed over $\boldsymbol{m}$ intervals:

$$\chi^2 = \frac{(n_1 - N_m/m)^2}{(n_1 + N_m/m^2)}$$

Therefore, triggers will occur both for an increase or drop in count rate. For this reason, the internal burst trigger is normally activated only when the cluster is staring on-source, since source/background beamswitching would otherwise cause false triggers which do not relate to the source.

Once the trigger is satisfied, the Burst List is frozen in the HEXTE data buffer until it is downloaded to ground and Burst List processing is commanded to resume. However, subsequent triggers are still counted by the on-board processor, and this number is telemetered to ground (the counter is reset upon dumping the contents of the Burst List buffer).

Chapter 6

The XTE All-Sky Monitor

6.1 Introduction

6.1.1 ASM Scientific Objectives

The purpose of the XTE All-Sky Monitor (ASM) is at least threefold. First, the ASM monitors ~80% of the sky every ~90 minutes and can be used to alert observers to the appearance of transients or to other time-variable phenomena, such as high-low state changes in Cygnus X-1 or turn-ons of Hercules X-1. The acquisition of the active celestial source by the PCA and HEXTE will then be possible within a few hours. The ASM will provide accurate positions (~3' by 15' error boxes) for bright transients. This positional accuracy is adequate to acquire the source with the PCA, which then can be used to further reduce the size of the error box while performing detailed studies. These capabilities of the ASM will also enable fruitful observations of time-variable X-ray sources to be conducted in other regions of the spectrum, e. g., at optical and radio wavelengths.

Second, the ASM will yield long-term intensity histories of ~50 bright X-ray sources with a time resolution of ~1.5 hours, and an additional ~25 X-ray sources will be monitored with a sampling timescale ~1 day. The intensities derived from the analysis of ASM data will be available in a public archive. These intensity histories will facilitate many scientific investigations, such as searches for eclipses or other periodic behavior, and determination of the frequency of transient-like outbursts.

Third, cumulative count rate data from each X-ray detector, telemetered in ~0.1 s bins, will be used to study short-term intensity variations from particularly intense sources. X-ray bursts and periodic pulsations are typical of the phenomena that can be investigated using this data. For example, the pulse arrival time for a 200 mCrab pulsar away from the galactic bulge, such as Cen X-3, can be measured to a precision of ~ 10% of the pulse period once every satellite orbit.

6.1.2 ASM Observations and Data Policy

All ASM observations will be planned at the GSFC Science Operations Facility using software developed at MIT. In general, the ASM will be fully dedicated to the performance of its sky monitoring function. There may be exceptional circumstances, however, in which the ASM is used to observe specific X-ray sources for more time than the exposure in the usual sky-survey mode. No formal proposals to conduct specific observations will be considered; informal suggestions of such observations may be taken under consideration but the number of such observations will be highly limited.

The basic results of monitoring the sky with the ASM and, indeed, all of the telemetered data will be publically available in the short-term. This includes data obtained from somewhat extended observations of sources of exceptional interest.

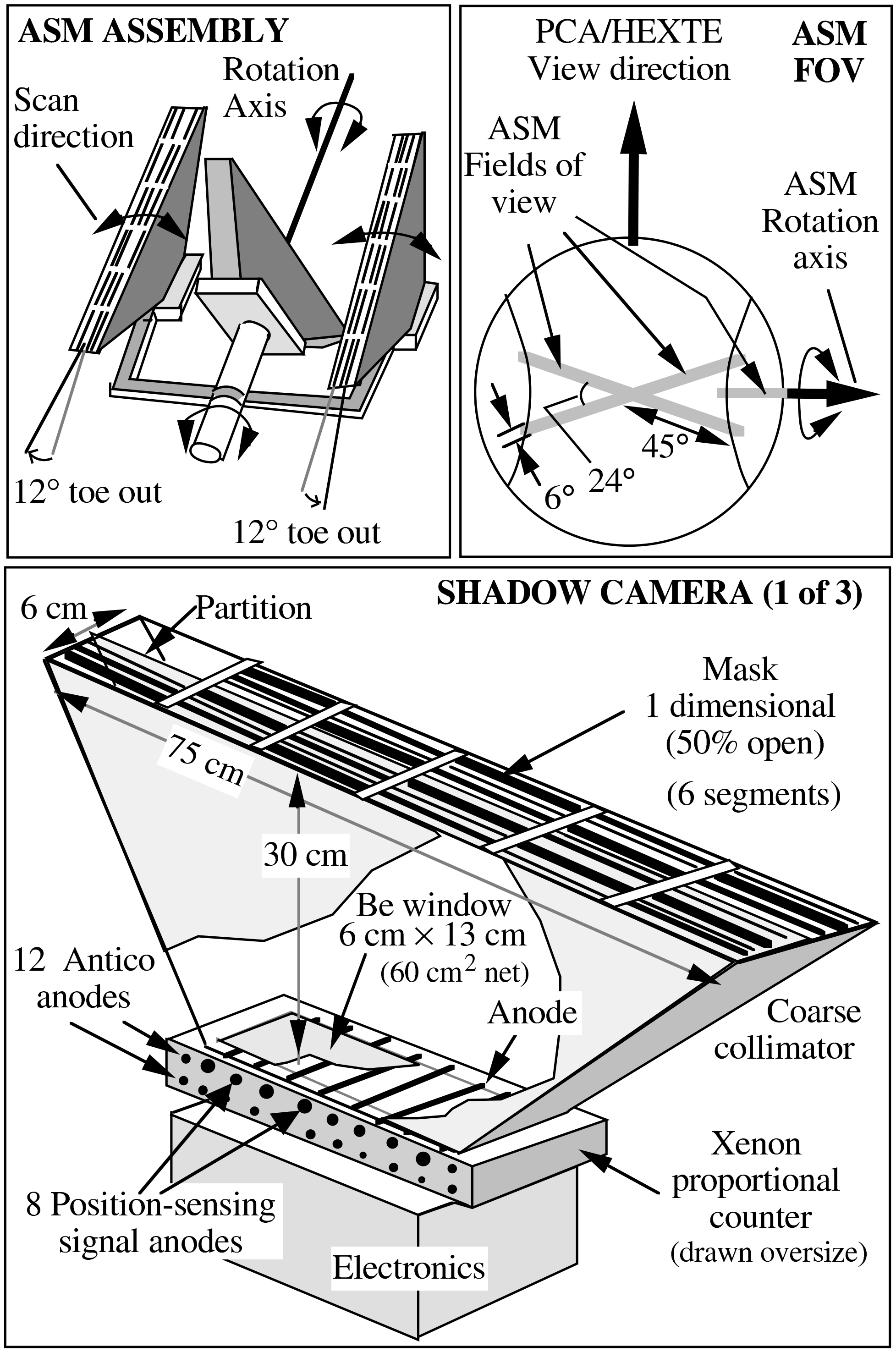
Since the results of the near-real time analysis will be publically available within hours after the data are telemetered from the spacecraft, Guest observers may plan to utilize ASM data in defining 'Targets of Opportunity' proposals for XTE observations using the PCA and HEXTE. Guest observers may also wish to use the ASM public archive to verify during the days or weeks preceding PCA observations that their selected EDS configurations are consistent with the actual intensities of their bright X-ray targets.

6.2 ASM Instrumentation

6.2.1 A Summary of the Design of the XTE All-Sky Monitor

The ASM consists of three basically identical Scanning Shadow Cameras (SSCs) mounted on an assembly that can be rotated by a motor drive (see Figure 1, next page). An SSC consists mainly of a position-sensitive proportional counter, electronics, low- and high-voltage power converters, a coarse collimator, a slit mask, a thermal shield, and a weak X-ray emitting calibration source. Each position-sensitive proportional counter (PSPC) views the sky through a coded mask. The mask is a flat screen perforated with 6 different sets of parallel slits, and is held above the PSPC window by a coarse collimator.

The mask casts an X-ray shadow of every X-ray source in the SSC field of view (FOV) upon the PSPC. The PSPC, in turn, is used to measure the displacements and strengths of the shadow patterns, and to thereby infer the celestial locations and intensities of the X-ray sources. To perform this task, the PSPC (and electronics) obtains X-ray photon energies and positions (one coordinate only) by the charge division technique applied to each of 8 resistive anodes.


ASM ASSEMBLY
Rotation Axis
Scan direction
12° toe out
12° toe out
PCA/HEXTE View direction
ASM FOV
ASM Fields of view
ASM Rotation axis
45°
24°
6°
SHADOW CAMERA (1 of 3)
6 cm
Partition
Mask 1 dimensional (50% open)
(6 segments)
75 cm
30 cm
Be window 6 cm × 13 cm (60 cm2 net)
12 Antico anodes
Anode
Coarse collimator
Xenon proportional counter (drawn oversize)
8 Position-sensing signal anodes
Electronics

The ASM will be operated so that data is accumulated in a series of exposures, or "dwells". During each dwell, the rotation drive will not be active, so that the orientation of the SSCs will be fixed in relation to the sky. The data obtained during each dwell will be accumulated by the EDS into histograms of counts binned as function of position for each of the PSPC anodes. These "position histograms" contain, in principle, the superposition of the mask shadows from each X-ray source in the FOV.

The position histograms are analyzed in near-real time in the Science Operations Facility at GSFC. The goal of the analysis is to extract estimates of source intensities and, when appropriate, source celestial locations. This is accomplished by fitting the actual data with model responses of each SSC to the known bright X-ray sources within the field of view. The fit residuals are then examined for evidence of previously unknown sources. Alarms for targets of opportunity are reported to XTE duty scientists if any new X-ray source is detected with the ASM, or if the measured intensity or spectral shape exceeds an alarm threshold that is pre-defined for each known X-ray source.

Each of the three SSC's has a net active area for detecting X-rays of ~30 cm^2 (60 cm^2 active area without the slit mask). The nominal sensitive range of the ASM is 2 to 10 keV. Position histograms are separately recorded for several energy bands (e.g., 3 or 4) within this range of sensitivity.

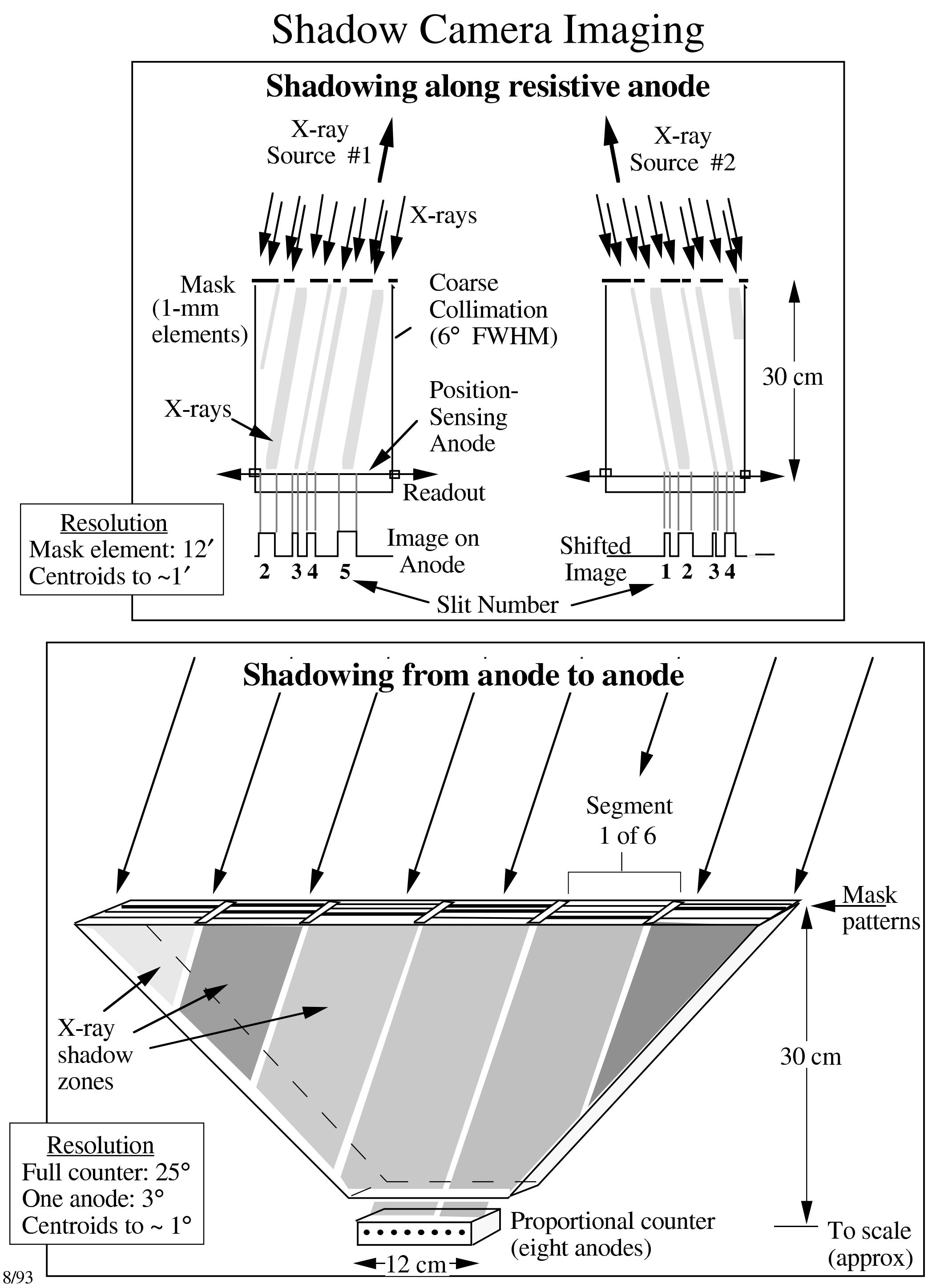
6.2.2 Scanning Shadow Camera

6.2.2.1 Position Sensitive Proportional Counter & Electronics

Each SSC utilizes a sealed multi-wire proportional counter for the detection and measurement of the position of each X-ray event in the coordinate perpendicular to the slits in the mask plate. A schematic diagram of an SSC is shown in Figure 2 (next page). Each PSPC is constructed with 8 resistive anodes (carbon-coated quartz fibers of 0.018 mm diameter), which are mounted to run along the desired direction of position sensing. Cathode ("ground") wires, which are electrically connected to the detector body, are placed so as to electrically define 8 separate rectangular volumes, each containing a resistive anode along its centerline. These cells are each 14.2 mm deep, with a 15.2 mm separation between anode wires. Cells with metal wire anodes are located below and to the sides of the position-sensing layer to provide anticoincidence signals to reduce the non-X-ray background rate.

Each PSPC is operated with the anodes at ground potential and the detector body and cathode wires at a negative potential of approximately -1800 V. This eliminates the requirement for high-voltage-rated bypass capacitors at every preamp input. The detectors have a gain of ~15000, so that a 6 keV photon yields a total of ~0.5 pC of charge to the preamplifier inputs.

Each end of each resistive anode wire is connected to a charge-sensitivepreamplifier. These preamps force the anodes to appear, in a small signal sense, to be grounded at both ends, so that when a cloud of electrons is collected on the uniformly resistive anode the charge is divided and current passes toward both anode ends in inverse proportion to the total resistance along the path to each preampli-


Shadow Camera Imaging
Shadowing along resistive anode
X-ray Source #1
X-ray Source #2
X-rays
Mask (1-mm elements)
Coarse Collimation (6° FWHM)
30 cm
X-rays
Position-Sensing Anode
Readout
Resolution
Mask element: 12′
Centroids to ~1′
2 3 4 5
Image on Anode
Shifted Image
1 2 3 4
Slit Number
Shadowing from anode to anode
Segment 1 of 6
Mask patterns
X-ray shadow zones
30 cm
Resolution
Full counter: 25°
One anode: 3°
Centroids to ~ 1°
Proportional counter (eight anodes)
12 cm
To scale (approx)
8/93

fier. The ratio of the amount of charge collected at one anode end to the total charge collected at both ends therefore provides a measure of the position of the electron cloud along the anode wire. As with any proportional counter, the total charge collected from the event is roughly proportional to the energy of the incident photon.

The charge collected at each anode end is impressed across a small capacitor (typically 2 pF) in the preamplifier feedback loop. The resulting voltage signals from the two preamps are conventionally amplified and filtered, and then summed to generate a trigger signal. Whenever the trigger signal exceeds a threshold, the pair of amplified and filtered signals are peak- stretched and held while downstream logic processes the event. Assuming that a simultaneous event has not occurred on one of the anticoincidence anodes, a 12 bit A/D converter processes the voltage from one end of the signal anode and then the voltage from the other end. The digitized pulse heights (denoted as pulse heights A and B) are transmitted to the Experiment Data System (EDS). The electronics for each shadow camera is capable of processing one event every ~80 microseconds.

Anticoincidence anodes are terminated only at one end since positional information from them is not of interest. In fact, all of the anticoincidence anodes are tied together to feed a single preamp. All of the analog electronics are identical to those used for each end of the resistive anodes.

The X-ray entrance window consists of a 50 μm thick beryllium foil which is glued on the interior surface of a strongback plate with 28 (2 rows of 14) rectangular openings. The counters are filled with a 95% xenon and 5% CO_2 gas mixture at a total absolute pressure of 1.2 atm.

A latch within the SSC turns off the high voltage if the count rate of the detector exceeds a preset threshold (~4000 count s^{-1}) such as may happen if the high voltage is inadvertently left on during a South Atlantic Anomaly crossing. This latch must be reset by a serial command or power reset.

6.2.2.2 PSPC Energy Resolution

Laboratory pulse height spectra of several X-ray emission lines indicate the spectral resolution of each PSPC at various photon energies. The average results are as follows (expressed as a fractional FWHM, i.e. $\delta E / E$, at the specified E(keV)).

0.21 @ 8.0 keV
0.21 @ 6.4 keV
0.23 @ 4.5 keV
0.27 @ 2.3 keV

6.2.2.3 PSPC Position Resolution

The position resolution of the PSPC (detector and electronics) has been measured in the laboratory at several photon energies. When the PSPC is illuminated at normal incidence through a very narrow slit, the typical measured position resolution (FWHM) is as follows:

0.30 mm (3.6') at 2.3 keV,
0.25 mm (3.0') at 4.5 keV,
0.22 mm (2.6') at 6.4 keV,
0.20 mm (2.4') at 8.0 keV.

6.2.2.4 PSPC In-flight Spectral Calibration

During flight the active volume of each PSPC will be illuminated with the 5.9 keV X-ray emission line from a calibration source containing a radioactive isotope of iron (^{55}Fe). The source is mounted inside the coarse collimator and does not illuminate the entire detector uniformly. The amount of ^{55}Fe (~50 nCi per detector) was chosen to produce a count rate of approximately 1 count s^{-1} in the detector. This intensity is weak compared to the predicted count rate due to the diffuse X-ray background, ~40 counts s^{-1}, yet is strong enough to enable the detector gain to be measured in ~5000 seconds.

6.2.2.5 SSC Coarse Collimator

The coarse collimator holds the slit mask in the desired position with respect to the PSPC, shields the PSPC from X-rays coming from undesired directions, and partially defines the overall field of view. The collimator consists of a outer enclosure, which is a thin dip-brazed aluminum structure, and a central partition, a thin aluminum sheet which divides the interior volume into two separate halves and serves to reduce the size of the field of view.

6.2.2.6 Slit Mask

The slit mask is a thin (0.040 in) aluminum sheet which is penetrated by a number of parallel slits. The aluminum is effectively opaque to X-radiation in the 2 - 10 keV band. The surface of the mask is conceptually subdivided into 12 (6 x 2) subsections, each of which is further conceptually subdivided into 31 “elements” of size 1 mm (0.041”) by 110 mm (4.35”). Each element may be either “open”, i.e. a machined opening, or “closed”, i.e., opaque aluminum. Each of the 12 subsections contains ~ 15 open and ~ 16 closed elements in one of 6 carefully chosen pseudo-random patterns.

In the long dimension of the mask, the six subsections are spaced with a spatial period of 4.8 inches, which is also the overall length of the beryllium window of the PSPC. In the short dimension, the two subsections fall on either side of the partition of the coarse collimator.

The mask and PSPC window are 30.0 cm apart. Thus, a 1 mm wide mask element subtends an angle of 1/300 radian or 12 arcmin at the the PSPC.

6.2.2.7 Thermal Shield

The X-ray entrance aperture (i.e., the slit mask) is covered with a thermal shield to help moderate temperature swings of the SSCs. The shield consists of Kapton which is 0.00033 inches thick and has a 30 nm layer of SiO deposited on the exterior surface and 50 nm of aluminum on the interior surface.

6.2.3 ASM Instrument Assembly

6.2.3.1 Assembly of SSCs

Two of the shadow cameras are mounted with the centers of their FOVs oriented 90^o from the axis of rotation. The centers of the fields of these SSCs (#1 and #2) point in the same direction, but their long axes are tilted by $+12^o$ and -12^o relative to the instrument rotation axis (see Fig. 1). The third shadow camera (SSC #3) is mounted with the center of its FOV pointed parallel to the rotation axis. When the cameras rotate through 360^o, the combined SSC exposure areas cover the entire sky, except for a 45^o half-angle cone centered toward the base of the instrument.

6.2.3.2 Drive Assembly

Rotation of the shadow camera assembly in either direction at a speed of 1.5^o per second is provided by means of a stepping motor and gear train. The range of the shadow camera assembly rotation is limited to 540^o by a mechanical stop to protect the electrical connections between the ASM and the rest of the S/C, which pass through a flex capsule in the ASM Drive Assembly. The rotatable assembly is normally prevented from hitting the mechanical stops by electrical limits which reduce the angular range slightly. Two angle sensing units (gear-driven potentiometers) measure the rotation of the shadow camera assembly relative to the fixed base of the ASM. These potentiometers provide useful readouts over $\sim 340^o$ out of 360^o of rotation of their shafts. The coarse position potentiometer is geared down sufficiently to have, in practice, no gap in coverage. The readouts are accurate to at least 10 bits referenced to one rotation of the potentiometer shaft (i.e., 340^o). An accurate reference orientation ("home") of the SSC assembly provides a known starting point for a series of rotations.

The motor controller responds to serial commands indicating the direction of motion and the number of motor steps. These are translated into the drive currents required by the motor and executed immediately. The controller itself has no memory of current or reference position; it relies on the EDS to provide all appropriate motion commands.

6.2.4 ASM Celestial Observations

6.2.4.1 SSC Field of View

The FOV of each SSC is 6^{o} by 90^{o} full width at half maximum (FWHM), with the long direction parallel to the slits in the mask. The full width of the FOV is 12^{o} by 110^{o}.

6.2.4.2 SSC Effective Area

In Figure 3 (next page) the effective area of an individual SSC is shown as a function of the X-ray photon energy. The geometric area of the window beneath open mask slits (~30 cm^2) is modified by the quantum efficiency of Xe (for a cell depth of 14.2 mm and 95% composition at 1.2 atm) and the absorption cross sections of the Be window and the instrument's thermal shield. The upper curve in Figure 3 corresponds with the center of an SSC FOV, while the lower curve shows the effective area for an X-ray source offset by 30^{o} along the long axis (only) of the collimator.

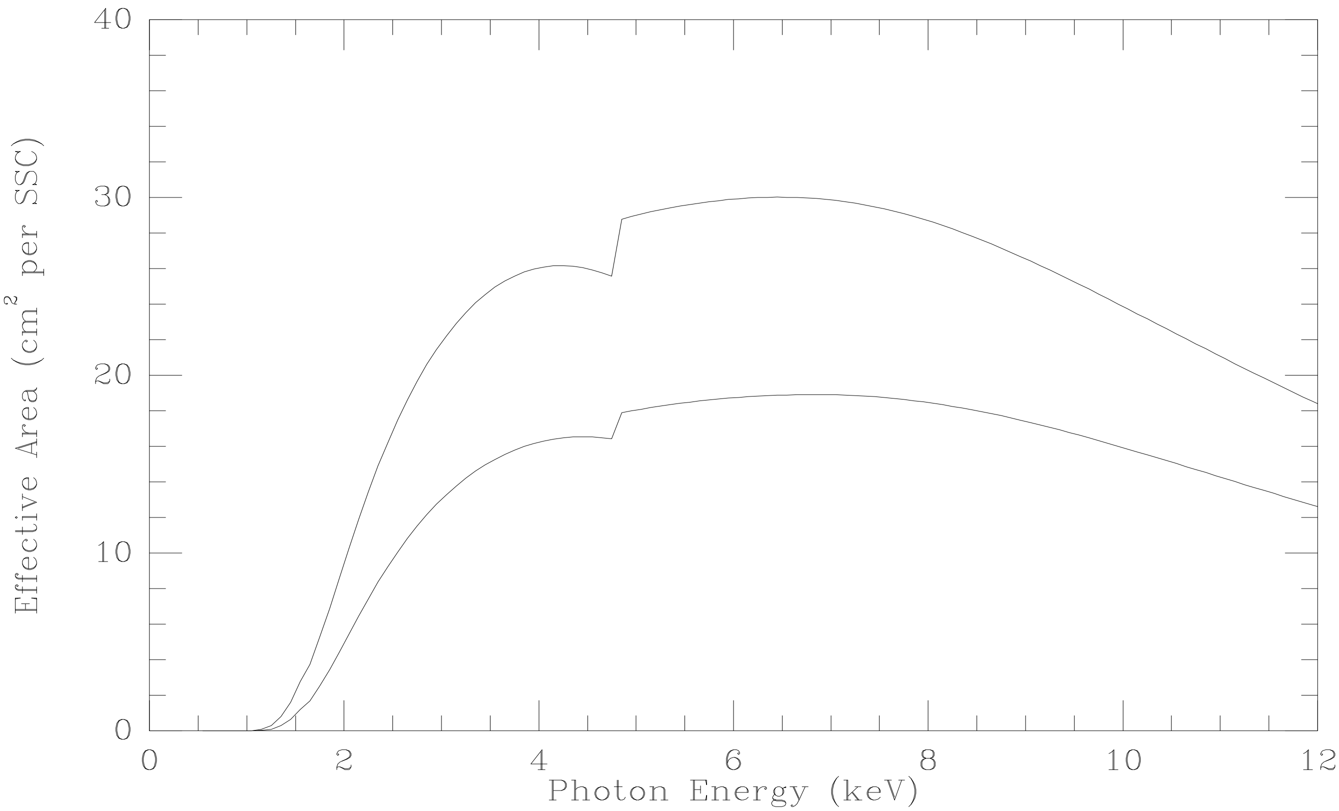
6.2.4.3 ASM-EDS Interface

All electrical connections to the ASM, with the one exception of chassis ground, come from or through the EDS. Science data from the detectors is transmitted to the EDS over a series of three serial lines, one per SSC. Serial commands and engineering data are carried between the EDS and the ASM on a party-line data bus. There are also connections to carry electrical power to the ASM, to read out thermistors in the ASM when the instrument is not operating, and to control the operation of the high voltage power supplies in the SSCs. The serial science data generated in each SSC is transmitted over a dedicated 500 kbps serial RS-422 data line to both of the ASM Event Analyzers (EAs).

The science data consists of a series of 28 bit event descriptors, one descriptor per X-ray event, which are formatted as follows:

<u>Bit Function:</u>
0-3 event / anode code
4-15 pulse height A
16-27 pulse height B.

The primary data bus connects all four of the ASM assemblies, i.e., the three SSC's and the Drive Assembly, with the ASM EA on side B of the EDS. The secondary data bus is intended as a backup of the primary bus in case of a failure, and connects the ASM EA on side A of the EDS to the Drive Assembly. This secondary bus can be used to command the Drive Assembly but cannot be used to transfer Drive Assembly engineering data to the EDS.


40
30
20
10
0
Effective Area (cm² per SSC)
0
2
4
6
8
10
12
Photon Energy (keV)

6.2.4.4 EDS Processing of ASM Data

The amount of raw information on an event by event basis is too large to be telemetered directly to the ground. At 28 bits per event (i.e., not considering time bits), the diffuse X-ray background alone generates a raw data rate of 3 detectors x 40 counts/s x 28 bits/event = 3360 bps. Therefore, to reduce the data rate data substantially, the science data is compressed within the EDS prior to transfer to the S/C telemetry system.

A 10-bit time tag is appended to the event/anode code and A and B pulse heights for each event upon arrival at each of the ASM event analyzers. The total pulse height, A+B, and “electrical event position”, A/(A+B), are computed in the EDS for use in compressing and telemetering the ASM data.

The EDS will normally compress the ASM data by way of two modes; a third option will also be available. One ASM Event Analyzer (EA) will normally run the Position Histogram Mode so as to control the rotation of the ASM and to accumulate data in the form of position histograms. The other ASM Event Analyzer will run Multiple Time Series Mode, which will produce time series, background, and pulse height spectra data products. A third mode, ASM Event-by-Event Mode, is also available to be run in one of the Event Analyzers in place of one of the other modes. Since this mode does not compress the data, it is intended to be used only for very special cases such as ASM diagnostics.

The EA running Position Histogram Mode will execute a series of dwells and send commands to the Drive Assembly to perform rotations according to the prescribed plan. For each of the dwells, the EA will accumulate a position histogram for each of the 24 resistive anodes (eight per detector) for each of up to 5 pulse height intervals. A position histogram simply consists of numbers of counts as a function of position; the position bins are equal linear intervals in the measured A/(A+B) value. The number of position bins in a position histogram is a commandable parameter, with a maximum of 512. The nominal number of bins yields an average position bin of width 0.25 mm which corresponds to 3.0 arcmin.

The EA running the Multiple Time Series Mode generates three data products. First, time series data consists of the number of X-ray events, in each detector and in each of 3 pulse height intervals, which have occurred in contiguous ~0.1 second time intervals. The size of the time bin may be changed by command, down to a minimum of 1 msec, but timescales faster than 0.1 second may result in a high telemetry rate or may result in gaps in the data obtained in this mode. Second, non-X-ray background data for each detector are accumulated in one second time bins. Third, pulse height spectra are accumulated separately for each of the 24 resistive anodes, and these spectra are typically written into the telemetry stream every 200 s. These spectra are used to monitor the gain of the detectors. Multiple Time Series Mode runs continuously without knowledge of the rotation angle or rate of the ASM motor drive.

In the optional Event-by-Event Mode, event data from one detector are simply telemetered on an event-by-event basis with no compression. Of course, data on many events will be lost when this option is utilized.

Normally, the ASM EA on side B of the EDS will run Position Histogram Mode, and so will receive commands to carry out the ASM observing program, while the EA on side A will run Multiple Time Series Mode. The ASM EA on side B of the EDS also acquires and telemeters ASM housekeeping data. A more detailed discussion of the EDS processing of ASM data may be found in the EDS Observers Manual.

6.2.4.5 ASM Sensitivity

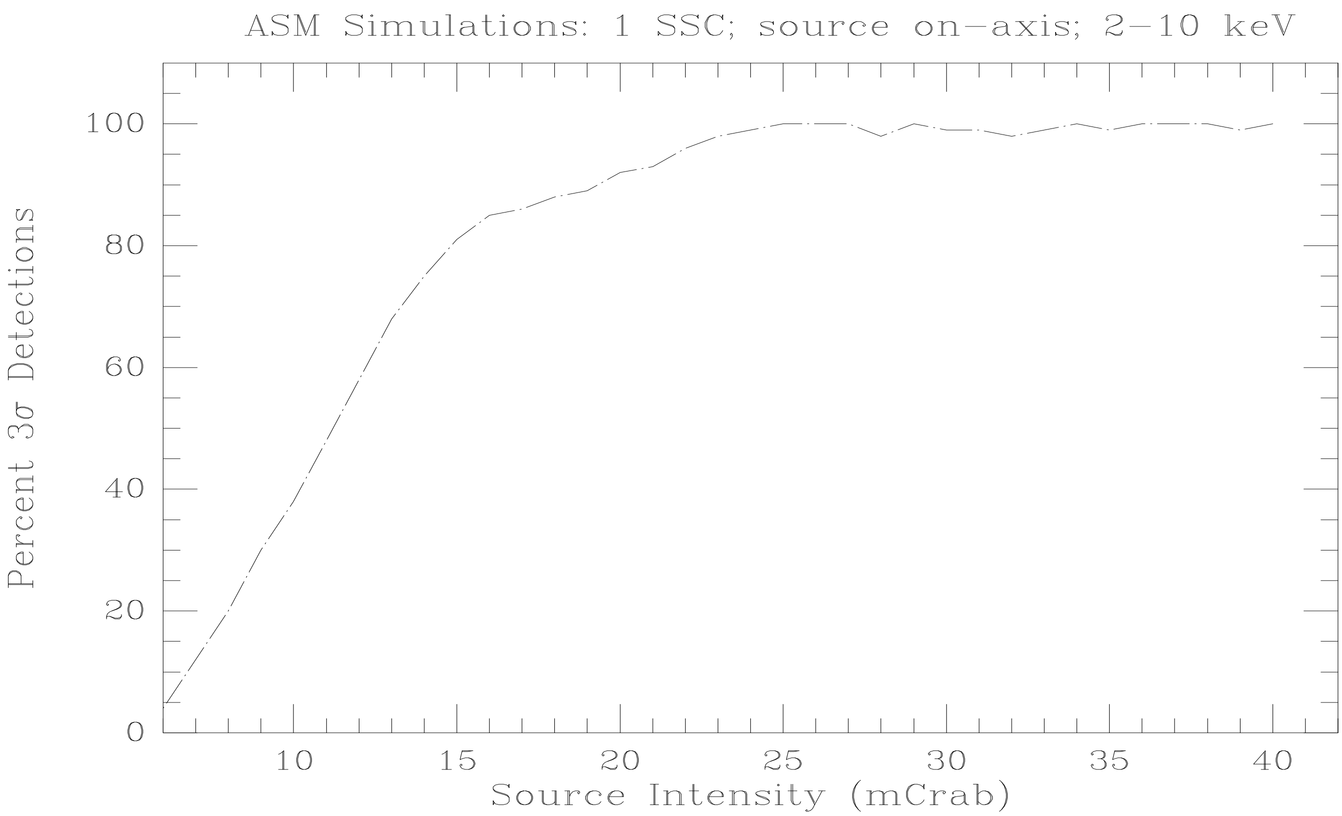
SSC position histogram data have been simulated for a variety of X-ray source intensities, assuming that the source is in the center of the FOV, the SSC dwell time is 100 s, the position histograms include events from the full instrumental energy range of 2 to 10 keV, and the total background rate (diffuse X-ray background plus some particle events not rejected by antico circuits) is 49 counts s^{-1} SSC^{-1}. In Figure 4 (next page) we show the probability of obtaining a detection with a level of significance above 3σ as a function of X-ray source intensity, which is expressed in mCrab (1 mCrab ~ 1.06 μJy at 5.2 keV, and a 10 mCrab source is estimated to produce a net count rate of 0.91 count s^{-1} SSC^{-1}).

These simulations indicate that X-ray sources with intensities above 20 mCrab are detected at or above the 3σ significance level more than 90% of the time in a series of 100 s dwells. In practice, X-ray sources are not always centered in the FOV, and, for fields in the Galactic bulge, there are likely to be a number of sources in the FOV at one time. On the other hand, these factors will be compensated for, to some degree, by the fact that a source will appear in several dwells per celestial scan, given the 3-SSC geometry and the nominal plan of 6^{o} rotations between dwells. Thus, Figure 4 is considered to be a first-order estimate (for fields without bright sources) of the ASM detection threshold per celestial scan, which nominally corresponds to a timescale of 90 min, or 1 satellite orbit.

6.2.4.6 Determination of Celestial Positions

“New” X-ray sources can be located on the sky with the ASM with an accuracy that depends on the source intensity and a host of other factors, including the accuracy of the SSC geometric calibrations, the pointing stability of the XTE spacecraft, the quality of aspect solutions, etc. Source position information is derived from the data analysis applied to both a single SSC/dwell, and also to the combination of multiple dwells and multiple SSCs.

Two-dimensional information on the celestial location of a source in the shadow patterns is contained in a given set of (8) position histograms for a single dwell from one SSC. Since the PSPC anodes are aligned perpendicular to the mask slits, the displacement of the shadow patterns in “anode position space” corresponds to the angular distance of the X-ray source from the center of the FOV projected along the “short axis” of the SSC FOV. The X-ray source position along the “long axis” is con


ASM Simulations: 1 SSC; source on-axis; 2-10 keV
Percent 3σ Detections
0
20
40
60
80
100
10
15
20
25
30
35
40
Source Intensity (mCrab)

strained, with much less accuracy, by determining which of the (6) mask patterns is imaged upon each of the 8 anode cells.

Considering only the data from a single SSC - dwell, we expect to locate very bright X-ray sources to an accuracy of ~ 1' x 30', limited by systematic effects. For fainter X-ray sources, the position uncertainty is limited by photon counting statistics. Near the detection threshold, we estimate that the position uncertainty in the direction perpendicular to the mask slits will be similar to the angular size of a mask element, or 0.2^o. The same sources would be located along the long axis of the FOV with an accuracy of ~15 ^{o}.

The most effective "imaging" power of the ASM lies in the use of crossed SSC positions, which significantly reduces the position uncertainty along the direction corresponding to the long axis of the SSC. As the assembly of three SSCs rotates, each X-ray source in the accessible region of the sky is typically viewed by both SSC Nos. 1 and 2 (usually during different dwells) or by SSC No. 3 in at least two different dwells. For the case in which a source is viewed by SSCs No. 1 and No. 2, which have long axes rotated from one another by 24^o, the parallelogram resulting from the crossed lines of position has dimensions about 1 x 5 times the position uncertainty along the short-axis of an SSC. Thus, sources detected by these two SSCs can be located within error boxes that range in size from 0.2^o x 1.0^o to as small as 1' x 5' depending upon their strength. The lines of position derived from different dwells of SSC No. 3 intersect at an angle which depends on the angular distance of the source from the projection of the ASM drive rotation axis on the sky. The intersection angle from a series of scans with SSC No. 3 will be at least 6^o and can be as large as 90^o , resulting in the capability to constrain X-ray positions that compares favorably with the combined use of SSC Nos. 1 and 2.

6.3 ASM Operations & Data Analysis

6.3.1 ASM Observation Plan

The operation of the ASM will consist of alternating periods of data accumulation (i.e., dwells) and rotations of the SSC assembly. During an interval of data accumulation, which lasts typically ~90 seconds, the orientation of the SSCs is held fixed. After each data collection interval the shadow cameras are normally rotated by ~6^o to view another region of the sky. A series of dwells and rotations would achieve relatively uniform coverage of up to 83% of the celestial sphere for each 360^o rotation, which is designed to take one ~90 min satellite orbit. The ASM rotation axis shifts every time the XTE spacecraft is reoriented to point the PCA and HEXTE to a new target. The portion of the sky accessible to the ASM changes as well so that the entire sky is expected to be scanned by the ASM several times per day. The details of sky coverage of course depend on the details of the PCA & HEXTE observing program.

In practice, the useful ASM sky exposure will be reduced by occultations of the FOV by the Earth, South Atlantic Anomaly crossings, spacecraft manuevers, and the limited rotation range of the ASM drive assembly, which occasionally requires a rewind or a change in the direction of the instrument rotation. Also, in circumstances where better sensitivity or more complete temporal coverage of a specific region of the sky is desired, the shadow cameras can be pointed continuously in one direction.

The program of Drive Assembly rotations and data accumulation intervals is constructed in advance on the ground so as to maximize the time the SSCs view the sky, as opposed to the Earth. The observing plan is carried out via commands stored on the spacecraft and transmitted to the ASM via the EDS.

6.3.2 Quicklook and Definitive Analysis Software

The ASM data will be analyzed in near-real time at the XTE SOF as soon as the raw XTE telemetry is received, using an efficient subset of analysis algorithms ("quicklook analysis") sufficient to extract intensity measurements for bright sources and to find targets of opportunity (TOO) for subsequent pointed observations with the PCA and HEXTE. The quicklook results may also be useful to measure the intensity level of bright X-ray sources in order to confirm or modify the choice of EDS configurations for PCA observations that are about to take place.

More detailed ASM data analysis at MIT ("definitive analysis") will provide a more penetrating record of X-ray source intensities. The definitive analysis will generally yield better sensitivity and provide more X-ray spectral information by analyzing data from multiple SSC-dwells.

Both quicklook and definitive ASM results (well distinguished as to origin) will be delivered to the scientific community via a public archive. The raw ASM data will also be available through the archive. The XTE GOF will maintain the public archive, which is based on FITS files designed for compatibility with the HEASARC's FTOOLS analysis package.

The development of the ASM data analysis software and the performance of the definitive analysis are the responsibility of the ASM team at M.I.T.

6.3.3 ASM Data Analysis Methodology

The position histograms are analyzed in near-real time in the Science Operations Facility at GSFC.

The primary goal of the ASM data analysis is to extract estimates of source intensities and estimates of the celestial locations of "new" sources. This is accomplished in a multi-step procedure. First, the position histogram data is fit with the model responses of each SSC to the catalogued bright X-ray sources within the field of view. A linear least squares calculation yields the strengths of each of these sources. Second, the fit residuals are examined via a cross-correlation technique for evidence of previously unknown or unexpectedly bright sources. When a "new" source is found, its coordinates are entered into the source catalog and the procedure to calculate source intensities is iterated.

For the quicklook analysis, the data analysis will be performed on a dwell-by-dwell and SSC-by-SSC basis. For the definitive analysis, the analysis will be performed simultaneously on data from neighboring dwells and from multiple cameras.

6.3.4 Targets of Opportunity

6.3.4.1 XTE Perspective on TOO

Candidate targets of opportunity (TOOs) are defined in a general sense as celestial objects displaying unexpected and time-critical phenomena that should be brought to the attention of the XTE duty scientist who would then begin the evaluation process to determine whether the pointing schedule of XTE should be modified so as to include the object in a revised schedule. The ASM will be a major source of information on such objects in the X-ray sky. Here, the procedures for detecting possible TOOs and the criteria used in that process are discussed in some detail.

Both the quicklook and definitive analysis packages utilize an ASM X-ray source catalog that is used to determine the positions of X-ray sources in an SSC's field of view. The requirements for the contents and applications of this catalog makes it an ideal place to additionally store parameters needed for TOO criteria. The catalog will contain the TOO selection thresholds, enabling easy control of the TOO parameter and avoiding the need for a separate software platform to run the TOO search.

The intended use of the X-ray catalog for ASM data analysis is as follows. The catalog is a master list of all X-ray sources with accurate positions (uncertainty < 3') AND recorded instances of X-ray flux > 3 mCrab at 2-10 keV. Since many X-ray transients and novae appear bright only a small fraction of the time, the catalog must contain an X-ray status parameter that defines as "active" only the sources we may expect to detect with the ASM. If we do not "turn off" a subset of the catalog, the ASM analysis software will spend lots of CPU time modelling and then rejecting (from the model) X-ray sources that are 'always' hopelessly below the ASM detection threshold. Source intensities or upper limits will be routinely written for every source in an SSC FOV that is within the "active" subset of the X-ray catalog.

When the residuals from a given analysis solution are searched for evidence of an unaccounted X-ray source, a positive detection will cause a position determination and a reiteration of SSC model computations that include the unaccounted source. The positional constraints can then be checked against the positions of EVERY source in the X-ray catalog. Therefore, the concepts of "new" and "recovered" X-ray sources depend upon whether a "new" source is subsequently found in the inactive section of the X-ray catalog.

Unexpectedly large intensity or spectral changes of a source in the active section of the catalog can also result in a candidate TOO alarm. Intensity and spectral limits are listed as additional columns in the X-ray catalog (basically by specifying intensity and hardness ratio limits in specified SSC energy channels). The analysis interrogates this information as the final intensity records are written to the database, with alarms issued as the results warrant. The values provide individualized intensity and spectral "thermostats" for generating TOO alarms. Some approved XTE proposals with X-ray-state-contingent targets that could be diagnosed for observations with ASM data could also be effectively monitored by choosing appropriate TOO thresholds.

6.3.4.2 Types of Candidate TOOs

The candidate TOOs are classified below. Eight types are revealed by the ASM, while the remaining two refer to candidates communicated to XTE duty scientists by members of the scientific community.

- 1. "new" X-ray source detected in quicklook analysis,
- 2. former X-ray transient recovered in quicklook analysis,
- 3. quicklook intensity (instrumental) exceeds the established limits for a particular source,
- 4. quicklook hardness ratio exceeds the established limits for a particular source,
- 5. "new" X-ray source detected in definitive analysis,
- 6. former X-ray transient recovered in definitive analysis,
- 7. definitive intensity (instrumental) exceeds the established limits for a particular source,
- 8. definitive hardness ratio exceeds the established limits for a particular source,
- 9. guest observer informs the XTE GOF that a source has entered a state enabling observations for an approved TOO-type XTE program,
- 10. member of the astrophysics community informs the XTE GOF that some ongoing phenomenon warrants consideration for XTE observations, which would subsequently be assigned as public data.

6.3.4.3 TOO Alarms in the ASM Analysis Software

TOOs in categories 1-4 are reported directly to the SOF duty scientist by the ASM quicklook analysis software. TOOs in categories 5-8 are reported to the SOF duty scientist by MIT scientists. Criteria for TOO alarm *evaluation* depend on the XTE policy guidelines provided to the duty scientists, with ultimate decision responsibility held by the XTE Project Scientist.

Positions for every "new" X-ray detection will be searched against a well-chosen set of astronomical catalogs so as to shed light on the possible nature of the X-ray emission or outburst. XTE broadcasts to the scientific community will be made via the Internet as deemed appropriate.

6.4 The Public Data Archive

6.4.1 The ASM Database

The ASM public archive will be organized as a database with 8 sections. It is expected that the great majority of investigators acquiring ASM data or results in the public archive will be interested only in Database Sections 1, 4, 6, and 7. The sections of the database are:

(1) SSC pointing database, a table of SSC observations,

(2) raw position histograms stored with accompanying spacecraft and housekeeping information necessary for scientific analysis,

(3) solution parameters obtained from the analysis of ASM position histograms including both quick-look and definitive analysis results,

(4) X-ray source intensity histories with subclasses of instrumental or flux-calibrated histories, distinguished between quicklook and definitive analysis results,

(5) histograms of residuals from each SSC, after definitive analysis of single-dwell observations,

(6) raw time series data (from “Multiple Time Series” mode), including time series of both “good” detector events and raw background rates,

(7) raw pulse height spectra (from “Multiple Time Series” mode), and

(8) individual SSC events (from “Event-by-Event” mode).

The purpose of Database Section 3 is largely for diagnostic work by the PI team. Analysis parameters most useful to scientists (e.g. χ^2, number of sources in the FOV, etc) will be duplicated in Section 4. The residual histograms of Section 5 are used primarily at MIT to conduct multiple-dwell searches for fainter X-ray sources.

6.4.2 Database for X-ray Source Intensities

Both the quicklook and definitive analysis systems derive instrumental intensities and uncertainties for X-ray sources in the field of view. The instrumental strength (i.e., counts/ cm^2/ s) may then be converted to true energy flux (ergs/ cm^2/s in a defined range of photon energy) with the application of ASM calibration parameters and knowledge of the X-ray source spectrum. The flux-calibrated measurements would be suitable for any type of advanced scientific analysis. The instrumental intensities, which are corrected for all effects of observing geometry, may serve a large subset of scientific purposes (period analysis, TOO selection, etc.)

The efforts of flux calibration frequently improve with hindsight regarding the instrument and tailored consideration of the spectrum and variation of a particular X-ray source. For these reasons, it is desirable to create separate records of instrumental intensities and the calibrated fluxes derived from ASM observations. In such a design, the modification of calibration parameter histories can rapidly lead to revised X-ray light curves without having to analyze the raw data again.

In the XTE GOF, the effort to flux-calibrate the ASM intensity histories will depend on user initiation, and the community will perform such computations with support from the GOF and the FTOOLS software. Thus, the instrumental intensity histories are the final product routinely archived by the ‘quicklook’ and ‘definitive’ software packages for ASM data analysis.

Chapter 7

EDS Instrument Description

7.1 Introduction

This manual is intended to help *X-ray timing explorer* (XTE) observers use the *experiment data system* (EDS) in a proper and optimal fashion. The EDS is an on-board microprocessor-based electronics package that controls data acquisition and formatting for the *proportional counter array* (PCA) and the *all-sky monitor* (ASM).

The EDS can run any of 10 'modes' (programs), 7 for PCA data and 3 for ASM data, each of which is further defined with a set of parameters (e.g. energy bin boundaries, time bin widths, type of event). Examples are 'binned data' and 'FFT'. A designation of a particular mode together with a set of parameters is known as a *configuration*. The number of possible configurations consists of all combinations of modes and parameters and is therefore very large. A set of ~650 configurations are permanently recorded in the EDS and are available for selection by the observer. In addition, others are available for uplink to the EDS. Observers may suggest additional configurations.

The EDS consists of 8 parallel processing systems known as *event analyzers* (EAs) which can carry out different analyses in parallel on the incoming data streams. A configuration specifies completely the setup and operation of a single EA. The setup will be fixed during an *EA run.* An observation or a single pointing of the spacecraft will usually require only one EA setup for each of the available EAs. However, an observer might choose to change modes (i.e. configuration) of one or more EAs during an observation. In this chapter, an 'observation' usually alludes to a fixed EA setup. Occasionally we use the more precise 'EA run'.

This chapter covers the (1) basic theory of operation, and (2) the modes of data processing provided by EDS flight software. An adequate understanding of the operation of the system (for PCA observations) may be obtained by reading through “Time Signals and Counters” (Section 4.4 of this chapter). This should be sufficient preparation for Section 5 (“PCA Data Modes”) and for the chapter on “EDS Configurations” (Appendix 1). The EDS operation for the ASM is described in Section 6, and the ASM data modes are described in Section 7.

The configurations are described in another chapter (Appendix 1).

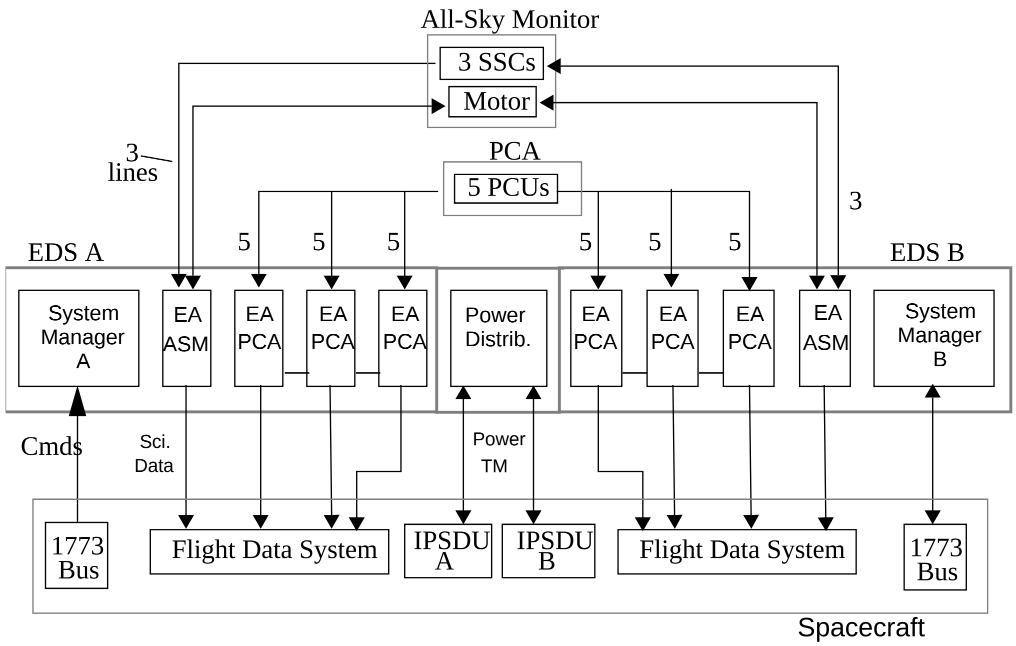
7.2 Experiment Data System (EDS)

The large effective area and excellent time resolution capability of the PCA creates a great strain on telemetry resources. If the data were to be telemetered simply as 48 bits (time, detector, and energy information) per individual PCA event, the nominal sustained PCA telemetry rate limit of ~20 kb/s would be exceeded for average total count rates above ~420 c/s. This limit is equivalent to an X-ray source intensity of only ~50 mCrab and makes no allowance for non-source background. The EDS thus serves to compress the PCA data by means of time and energy binning, folding to study periodic signals, etc. The EDS also converts ASM event data into a low-bandwidth form.

7.2.1 Interfaces

Figure 1 is a diagram of the flow of data into and out of the EDS. The EDS consists of two nearly identical halves, EDS-A and EDS-B; each contains 4 EA’s. Detector events in digital form are piped to the EAs from the five *proportional counter units* (PCUs) of the PCA and from the three *scanning shadow cameras* (SSCs) of the ASM. EDS-B normally controls the rotation of the ASM and handles housekeeping data from the SSCs and *drive assembly*. In case of failure, EDS-A can control the rotation drive, but can not monitor housekeeping data. Burst trigger signals can be sent to or from the HEXTE from EDS-A (not shown).

FIGURE 7.1. EDS Subsystems and Interfaces



Power is received from the S/C *instrument power switching and distribution units* (IPSDUs) together with clock signals, while housekeeping data flow from the EDS to the IPSDUs. Either IPSDU can power the entire EDS. A fiber optic link (1773 bus) to the spacecraft *flight data system* (FDS) provides discrete and serial commands. A set of eight RS422 serial links, one for each EA, provides high bandwidth paths (1 MHz each) over which science data is carried to the flight data system.

7.2.2 EDS Functions

The EDS allows the observer to recover the most desired information by providing multiple data-processing options and opportunities on board the XTE spacecraft. While the EDS can send PCA data on an event-by-event basis, it can also bin events with regard to time, photon energy, detector number, and event type (e.g., measurement chain). Pulse profile averaging (pulsar folding), and Fourier power spectrum averaging can be performed. There are supplementary options to record data at very high time resolution, and it is possible to identify X-ray burst-like episodes and send detailed data from them.

The eight EAs operate independently of one another. Six of the EAs are configured (in hardware) to service the PCA while two support the ASM. These are known as PCA EAs and ASM EAs respectively. Each PCA EA receives all PCA data. This permits several different data processing routines to operate on the data stream independently and simultaneously. The data system allows the outputs of the several EAs to be independently sent to the FDS as long as the total data rate remains within the limits of the overall system.

Two of the six PCA EAs will normally be dedicated to collecting *standard data*. The standard data produce a uniform database of time series measurements and X-ray spectra for all PCA observations. The remaining four PCA EAs will be configured to meet the needs of each particular observation, and thereby produce *selectable data*.

The observer should expect to receive the standard data obtained during the observation and should use this manual to understand the standard data contents and the options for choosing parallel configurations for the selectable data. The ASM data will not be provided to the observer but will be placed in the public domain in near real-time.

7.2.3 Telemetry Rates to FDS Buffer

The EDS can send data to the FDS at various rates, up to an aggregate total for all 8 EA's of ~500 kbps. (The FDS will accept 65 packets @ ≤1 kBy per second.) The rate from an individual EA is limited to ~300 kbps. In practice, the telemetry rate will generally be limited by other considerations, namely the ability of the spacecraft to store and telemeter the data, and the capacity of the ground-based systems to process and archive the data. Nominal sustained rates (or daily averages) will be of order 20 kb/s for the PCA, 5 kb/s for HEXTE and 3 kbs for the ASM. Much higher rates are possible for limited durations of time. It is the responsibility of the observer to configure EDS data modes such that the telemetry rates lie within the levels specified by the *science operations center* (SOC); see Chapter 8 on simulating data for the tools to use for estimating telemetry rates.

7.3 EDS Architecture

The EDS consists of three major types of subsystems. The types and total numbers of these subsystems in the entire EDS are (see Fig. 1):

- 6 PCA Event Analyzers,
- 2 ASM Event Analyzers,
- 2 System Managers, and
- 1 Power Distribution Board.

In the physical EDS, each of these systems is contained on a single multilayer printed circuit board. The EAs and system managers are grouped into two halves, EDS-A and EDS-B, as shown. This provides some degree of failure tolerance.

7.3.1 Event Analyzer

As noted above, the six identical PCA EAs operate on the data from the PCA, while two identical ASM EAs process the data from the ASM. Each PCA EA receives data from all 5 of the PCUs and each ASM EA receives data from all 3 SSCs.

Each EA contains (1) dedicated circuitry to select and classify event data, (2) a *digital signal processor* (DSP; TI 320C25) to operate on the selected data (e.g., to accumulate histograms), (3) a microprocessor (Harris 80C286) to carry out control functions, calculations, and transfers of data to the S/C, and finally (4) memory for storage of data and instructions. The PCA and ASM EA's are quite similar to each other but are not identical. All science data to be telemetered are sent to the S/C FDS directly (and independently) from the individual event analyzers.

If the interface limit of 65 packets per second is exceeded, telemetry packets will backlog in the EAs. In this situation, an EA generating less than 8 packets/s is guaranteed to transmit all its data. For EAs generating more than 8 packets/s, *complete partitions* (which typically consist of groups of packets) will be discarded if they cannot be telemetered before the EA back-end memory is needed for the next partition. This avoids the situation where every partition could be missing packets.

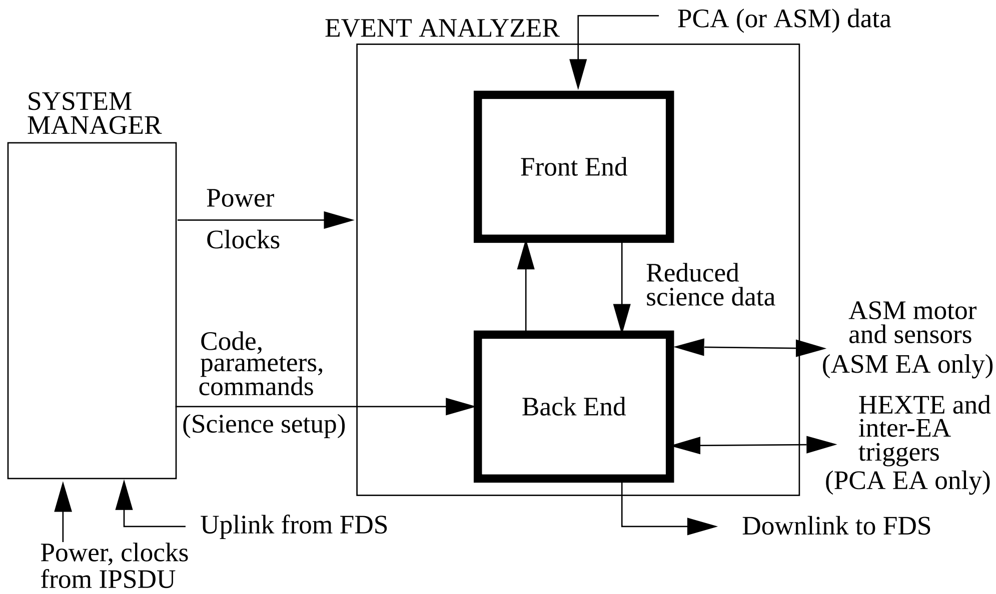
7.3.2 System Manager

The two system managers provide command and power services to the PCA and ASM event analyzers, communicate with the spacecraft via the 1773 data bus, and receive 28 VDC power and clock signals from the IPSDUs. The power is received via the power distribution board. Each system manager includes ground-preprogrammed read-only memory (ROM) in which is resident the flight software and preprogrammed EA configurations. The system manager also includes single-event-upset resistant read-write memory (Protected RAM = PRAM) which is used to hold additional uploaded flight software, additional EA configurations, and data indicating the proper configuration of the moment for the EAs. The PRAM can be loaded as needed during flight operations.

7.3.3 EA Front-End Back-End Concept

The architecture of an event analyzer (either for the PCA or the ASM version) can be described in terms of a *front end* and *back end* (Fig. 2). The Front End interfaces to the science instrument and is responsible for data collection and reduction. It operates as a slave to the Back End. The Back End is responsible for the overall management of the EA.

FIGURE 7.2. EDS: Front End – Back End functions



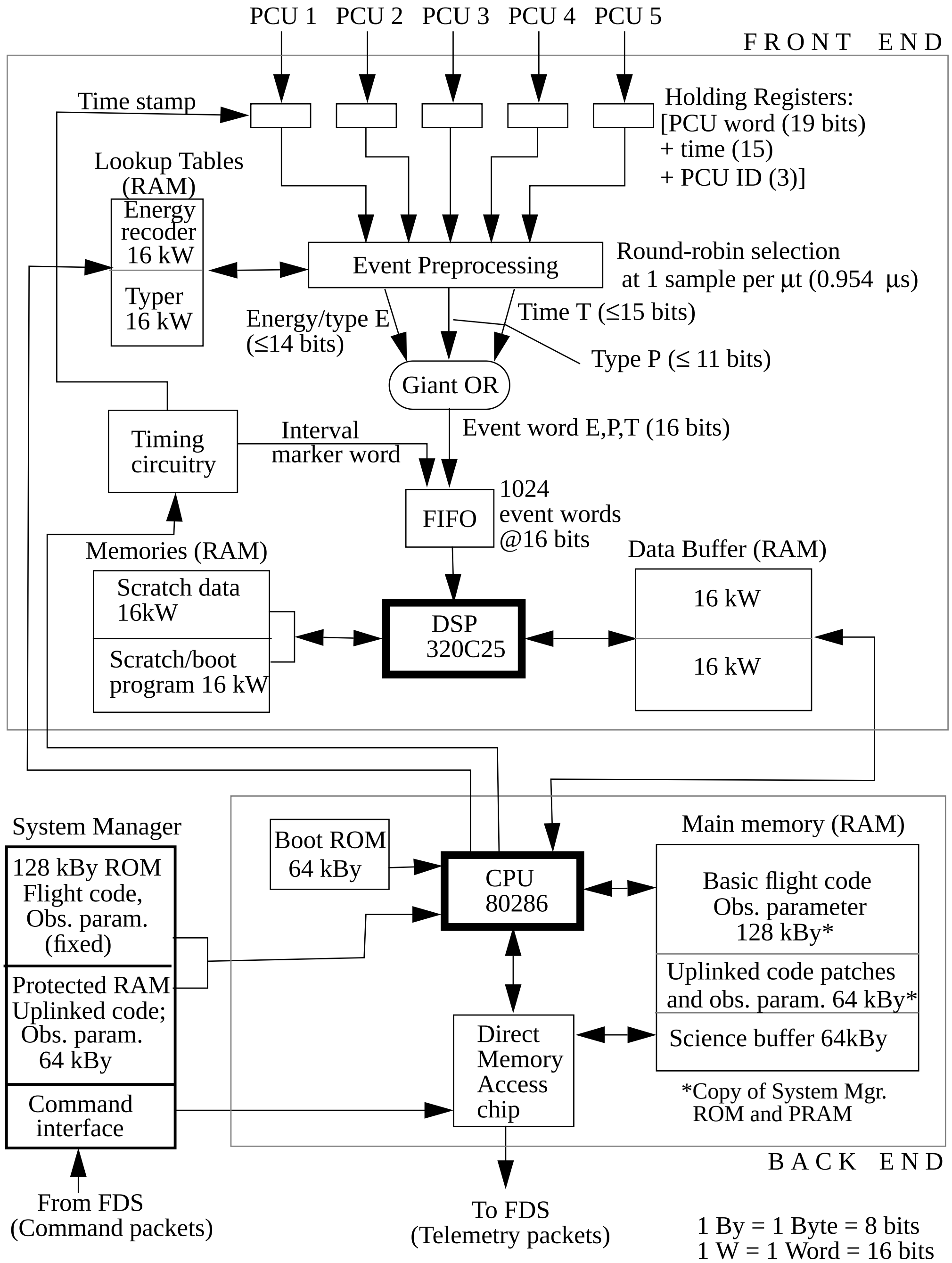
7.4 PCA Event-Analyzer Operations

EA operation is described in this section in sufficient detail to facilitate understanding of the individual data modes to be discussed below. An overview precedes a more detailed discussion. For purposes of illustration we usually assume that a PCA EA is being used in a binning mode.

7.4.1 PCA Event Analyzer Architecture

The internal architecture of the front and back ends of a PCA EA is shown in Fig. 3. The Front End comprises holding registers, event processing hardware (including timekeeping hardware and a "Giant Or", see below), typer and energy-recoder lookup tables, a FIFO (*first in first out*) register, the DSP, and a data buffer. The Back End comprises a microprocessor, memory, and support hardware.

FIGURE 7.3. EA Architecture



7.4.2 Overview of EA Operation.

Prior to the beginning of an observation, the desired configuration (mode and parameters) for each EA is specified as an address of the ROM or PRAM location where the configuration is located. If the configuration is not already in the ROM or PRAM, it is uploaded to the PRAM.

At the appropriate time, the system manager is commanded to send a reset command to the EA. The EA then reinitializes its own memory and hardware and then copies the contents of the system-manager ROM and PRAM into the EA back-end memory. This makes available to the CPU (in the Back End) the code, parameters, and commands required for the observation.

The Back End then prepares for the observation by loading *lookup tables* (LUT) and special registers in the Front End with values needed for recoding and classifying events, and it sets up the *timing circuitry*. It also provides software with appropriate parameters to the DSP. It then starts the accumulation of data at the beginning of the next even 16-s time boundary (lowest 4 bits of the spacecraft elapsed time in seconds are zero).

During the observation, as events arrive at the Front End, they are time stamped. Then, in the PCA EA only, each event is typed and recoded. For example, the 256 channel (8-bit) pulse height information may be reduced to 8 channels (3 bits). The recoded events (including time bits) are then sent to the DSP which builds sets of reduced data in the *data buffer* (DB). The structure of these sets, which may consist of histograms (binned data), lists of words describing individual events, Fourier power density spectra, etc. is described in the sections on the various EA modes. The DB in which the DSP collects the reduced data is typically divided into two sections of equal size.

The Back End defines time *Intervals*, which are of equal duration for the standard binning mode. During each of these Intervals, the DSP steadily deposits data into the active half of the data buffer (*half data buffer*, HDB). When the DSP has filled the HDB, the Front End starts to load the other half of the data buffer, and the Back End moves the just-completed data into its own memory and zeroes the locations of the just-read HDB. The data set just read from the HDB is known as a *partition*. Over the course of an observation, the DSP loads data alternately into the two halves of the DB, completing a partition with the passage of each Interval. This process allows data to be acquired and binned by the DSP without interruption.

Finally, the Back End converts the partition of data to *data packets* and forwards them with engineering data to the spacecraft FDS.

The next few sections of this chapter present the PCA EA operation in some more detail. We suggest that the reader review at least the next two sections, “PCA-EDS Interface” and “Time Signals and Counters” before going on to “Data Modes”.

7.4.3 PCA-EDS Interface

An X-ray photon produces an analog pulse in a PCU. Electronics located at the detector amplify this pulse and convert it to a digital pulse height. The event is also labeled with measurement chain identification and with flags giving the status of other measurement chains in the same detector for a total of 19 bits:

- 8 bits of pulse height (256 energy channels)
- 6 bits for xenon LLDs (each bit represents the state of the *lower-level discriminator* of one of the six principal xenon measurement chains: L1, R1, L2, R2, L3, R3
- VLE flag (*very large event*)
- Alpha flag (event detected in ^{241}Am calibration source layer)
- Propane flag (event from propane chamber)
- 2 bits for veto flag (veto-layer event; 3 pulse-height channels).

The PCU electronics transfers the data for each event directly to the EDS (via a 4 MHz serial link) where it is distributed to each of the 6 PCA EAs. This transfer proceeds asynchronously with sequential events (from one PCU) separated by at least 7 μs (start bit to start bit). Any event from a given PCU that occurs within ~10 μs of a previous event from that PCU is not transferred to the EDS by the PCU. This allows for detector recovery and insures that the EDS electronics has time to read every event from the PCA.

7.4.4 Time Signals and Counters

The time reference for the EDS is the spacecraft clock which outputs clock ticks on three lines with different intervals, each a binary subdivision of 1.0000 s.

- 2^{-20} s = 0.953674316406 μs = 1.0 *microtick* (μt)
- 2^{-5} s = 2^{15} μt = 31.2500 ms = 1.0 *minor tick*
- 1.00000000 s = 2^{20} μt = 1.0 *major tick*

The underlying clock is stable to about one part in 10^9. (See elsewhere in this manual.) The spacecraft also provides a count of the major ticks, which is known as *mission elapsed time* (MET). The logic of the EDS described herein makes use, almost exclusively, of the microticks and the three EA counters driven by them. All EDS data are time stamped relative to the MET reference provided by the S/C.

The microticks are counted in a 32-bit counter called an *Interval-tick generator* which can output pulses (*Interval ticks*) separated by a programmable *Interval duration* ranging from 2 to 2^{32} μt (1.9 μs to 4096 s). In practice the Interval duration will be greater than ~5 ms. The Interval duration can be programmed to change from one Interval to the next; the Back End accomplishes this by writing the desired time in microticks into an *Interval duration register* during the previous Interval. The Interval ticks are used to mark the times that the data buffer should be read out, to define the pulse period in the pulse folding mode, and as a reference for the time stamping of events. We distinguish this Interval with an initial capital. The spacecraft times of the Interval ticks can be derived from the telemetered data.

The first Interval of an observation always begins synchronously with a major tick which corresponds to a MET (mission elapsed time) value that is an integer multiple of 16 (seconds). This ensures synchronization of data collection between EAs and also between an EA and HEXTE, *if* the interval duration is less than 16 s and also a factor of 2^{-n} less than 16 s (n is an integer).

The microticks are counted in another 32-bit counter called a *bin-tick generator* which can output pulses (*bin ticks*) separated by a fixed programmable time ranging from 0.954 μs to 4096 s, in multiples of microticks. This time can not vary during an EA run. The bin ticks serve to define time bins into which data will be accumulated (in binned mode). The bin tick generator is reset at each Interval tick, so the first time bin of an Interval will commence synchronously with the beginning of an Interval. The time between bin ticks need not be a submultiple of the Interval though it is in most configurations. (Pulsar fold mode is the exception.)

Although the bin tick generator may be set to produce a tick at any multiple of 1 μt, in practice powers of two are generally preferred. This ensures that time bin boundaries between different EAs remain synchronous with each other and with HEXTE.

Finally, a *timebin counter* (15 bits) counts the bin ticks just defined. It too is reset with each Interval tick. This counter thus registers the number of bin ticks (or time bins) since the previous Interval tick. These 15 bits are used to time stamp individual events as they arrive from the PCUs. The time resolution of the time stamp is the time between adjacent bin-ticks, which is programmable as just described. A particular configuration may use fewer bits to conserve telemetry by limiting the count to, say, 16, so only 4 bits are used. This is accomplished by choosing a large interval between bin ticks (low time resolution) and/or by choosing frequent resets (with a small Interval). The entire 15 bits will constitute the time stamp, but the unused bits will be zeroes.

There is a *time bin mask register* that can mask out sets of 4-bits in the time stamp. This is also known as the ‘time-bin nibble mask’. If the value of the nibble mask is set to 1, the lowest 4 bits of the the time tag will be masked out (will read 0). If the value of the nibble mask is set to 2, the second 4 bits will be masked. If the value is set to 8 , the top 4 bits will be masked. The nibble mask is currently used only to reduce the number of time bits handled by a given EA when 1–μt time tagging is desired in the *‘transparent-3 event mode*’. In this case, three EA’s are used together to make the EDS completely transparent to the PCU words (including PCU ID and time stamps). Each EA will have a different mask applied. Between all three EA’s, all the time bits are recovered.

7.4.5 Holding Registers and Time Stamp

Upon arrival at an EA, the 19-bit event word is latched in a register (one for each PCU). Here 3 bits of PCU ID and the 15-bit time stamp (i.e., the contents of the timebin counter) are immediately (within 1 µt) appended to the 19-bit event word received from the PCU. The time stamp specifies the bin that will be incremented by the DSP in binning modes (see below). In event modes, the time-stamp bits are eventually passed on to telemetry.

The 15-bit time stamp allows one to count, for example, 2^{15} time bins, e.g. 1-µt (2^{-20} s) time bins if the Interval duration is set to 2^{-5} s. The preprogrammed configuration specifies the number of bits actually used and the time bin width. The bin boundaries are known to 1 µt for any choice of bin widths.

The time stamp is applied about ~18 µs after the arrival of an X-ray photon at the PCU. (See PCA chapter.) This delay is due to processing time in the PCU electronics and to the 5-µs transfer time (19 bits at 4 MHz). The delay has a random +/– 250 ns component, so if 5 photons arrive at the PCA simultaneously, they will arrive at an EA with a spread of times. The jitter in the application of the time-stamp is 1 – 2 ns. If two different EAs are configured to examine the same events, an occasional individual event can acquire different time stamps in the two EAs because of this latter jitter.

The preprocessing hardware cycles through and reads the five registers at a rate of 1 µt per event. Since each PCU is inhibited from sending a second event for at least 7 µs, this scheme assures that no events will be lost in this stage of processing, even in the extreme case when five events, one from each PCU, all arrive at the EDS within the same microsecond.

Very closely-spaced events may appear in different orders in two EAs, even if they acquire the same time stamp. Thus if two EAs in event mode are telemetering different information about a single event (as in transparent event mode), one should place the PCU ID in the event word in each participating EA to insure that the several parts will be properly recombined. This labeling is sufficient because no one PCU can telemeter two events with less than 7 µs separation.

7.4.6 Event Classification (Lookup Tables)

As noted earlier, front-end lookup tables had been loaded by the Back End as part of the setup for the observation. These are the *typer* and *energy recoder* tables which are used to select and recode the events. Portions of the digital word from the holding register are used as addresses within the tables, and the table content at each address contains the desired remapped value of the event type or pulse height. This content is the *output* of the table lookup operation. The outputs of the two tables together with the time stamp constitute the information upon which the DSP will operate as it lists or bins the events. Considerable compression originates here. The lookup cycle takes less than 1 µt; the lookup process thus keeps up with the previous processing; again no events will be lost.

7.4.6.1 Typer table lookup

The typer table contains 2^{14} words at 16 bits each. Fourteen bits describing the event are used as an *input address* into the table. They are:

- 3 bits of PCU ID (counter number, 1 to 5)
- 6 bits for xenon LLDs
- VLE Flag
- Alpha Flag
- Propane Flag
- 2-bit Veto Flag

The PCU ID bits allow one to classify events by PCU or to select/reject events from particular PCUs.

The 16 bits of content at each address are allocated as follows:

- 1-bit Reject code (MSB = 1)
- 3 bits of ‘alternate recoder selection’ (to be fed to energy recoder table)
- 11 bits of event ‘type’
- 1-bit time-disable code

The most significant bit of the typer table output indicates an event that should be rejected if MSB = 1; this event is not processed further. The most common use of the typer is to reject all but good xenon X-ray events. Those with flags indicating penetrating particles (detection in more than one xenon measurement chain), veto layer events, very large events, propane events, or calibration events would be rejected.

The typer feeds 3 bits of its output (*alternate recoder selection*) to the energy recoder table. The utility of this is discussed in Section 4.6.2 “Energy-recoder table lookup” below.

The event type can mimic the 11 input bits of flag and LLD information, or it can be reduced to only a few (or no) bits of information. For example one might wish to select and output labels for three types of events: good xenon events, penetrating charged particles (two or more LLD flags), and calibration events. In this example, the output ‘type’would only require the use of 2 bits. The input PCU ID may be combined with other flags to conserve telemetry. For example, for “good” xenon events the 6 LLDs per detector could be combined with the PCU ID to produce an LLD number of 0 to 29, which requires 5 bits. Alternately the typer (or the energy recoder) can output the PCU ID verbatim (3 bits) with somewhat less efficiency.

Since the typer can only output 11 bits of type information to the Giant OR and since the placement of these bits within the Giant OR word is restricted, it is sometimes desirable for the energy recoder to feed the PCU ID to the Giant OR. (The PCU ID is input to both tables.)

The use of a small number of event types provides significant data compression and leaves room in the final event word for more pulse height and timing information. For example, to maximize time resolution, one could choose to simply sum the events from all xenon measurement chains together and to reject all particle and calibration events. In this case, there would only be one type of selected event, and the reject/select code alone would suffice as the output. All other bits of each word in the table, and hence of the output, would be zero.

The time disable bit in the output inhibits the time-tag bits in the next step of the processing. It is used in configurations where it is desired to use one EA to bin two different event types with two different time scales. This is currently used only in the Standard 1 configuration wherein a single EA yields 1/8 second integrations of X-ray events and also 128-s integrations of calibration-source spectra. Here, the time stamp resolution is 1/8 s, so the high-rate X-ray events are binned with this resolution, while the time to accumulate a partition of data is set to 128 s (the Interval duration). For the calibration events, the time tag is disabled and the 128-s Interval duration becomes the binning time.

7.4.6.2 Energy-recoder table lookup

The energy recoder table also contains 2^{14} words each of 16 bits. The input address is a 14-bit word containing:

- 8 pulse height bits (256 channels)
- 3 PCU ID bits (5 detectors)
- 3 alternate recoder selection bits (8 pulse-height mappings).

The recoded information (the output) is less than or equal to the 14 bits of the input data. Again the MSB (bit 15) is reserved for a reject code; rejected events are not processed further. The energy/type bits may be located at any of the other 15 locations. These can include any combination of the input bits, including the PCU ID and the alternate recoder bits. The content of the table at each address thus consists of:

- 1-bit rejection code (MSB)
- 14 bits of recoded energy
- 1 bit not used (set to zero), can be at any of position except MSB.

The recoded energy consists typically of the recoded pulse height, e.g., a 3-bit pulse-height (8 broad channels), but may also contain PCU ID and alternate recoder selection bits. The pulse-height remapping potential is quite general. Thus, for example, one can recode pulse heights so that the pulse-height bin width increases with pulse height.

Since the PCU ID bits are part of the energy recoder address, the table content can reflect pulse-height calibrations that differ from detector to detector. For example, the recoded pulse height can be adjusted channel by channel to approximate a common 8-bit energy scale. This is called *gain correction.* It is useful for configurations which bin the events from all five PCUs together. The gain correction values are set by the PCA group. By default, gain corrections are applied to all configurations except for the Standard and transparent configurations. Gain correction may be disabled for one or both of the EDS sides (A,B).

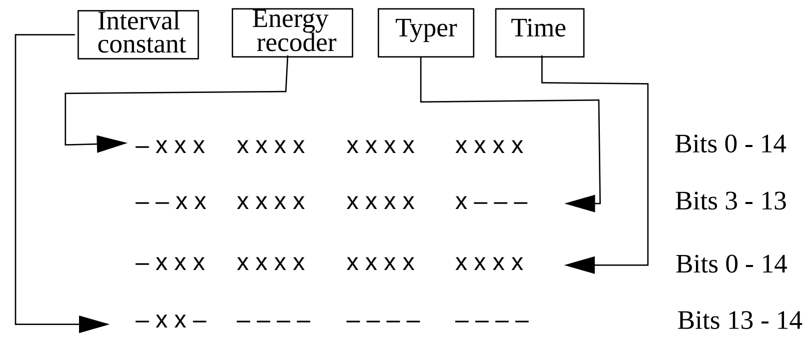
The alternate recoder selection bits (from the typer) are used as part of the address to distinguish different types of events (in one PCU) for which one may have different energy calibrations. It is used, for example, to provide different energy mappings for events from the xenon and propane chambers of the PCUs (see PCU description) in Standard mode 2.

7.4.7 Giant OR operation

The outputs of the typer and energy-recoder lookup tables and the time stamp are combined into a single 16-bit word by the *Giant OR* operator (see Figure 4). Fifteen bits of the 16-bit field are allocated to four subfields which receive the four inputs respectively. The typer contributes up to 11 bits of event type to the Giant OR within positions 3 – 13 (Fig. 4a). Similarly, the energy recoder contributes up to 14 bits of energy/type information within positions 0–14. The time stamp contains up to 15 bits which are in positions 0 – 14. The Interval constant contains up to 2 bits which are in positions 13–14. At the output of the Giant OR, a value of “1” for the most significant bit (MSB = bit 15) is asserted to indicate that this is a PCU event (and not an Interval marker word, see below).

FIGURE 7.4. Giant OR

(a) Available locations for science bits



(b) Example - 256 pulse height resolution

```
0 0 E E   E E E E   E E 0 0   0 0 0 0    Energy recoder: 256 pulse height chan
0 0 0 0   0 0 0 0   0 0 P P   0 0 0 0    Typer: 4 types (4 layers; 3 Xe and 1 P
0 0 0 0   0 0 0 0   0 0 0 0   T T T T    Time: 16 time bins (per Interval)
F 0 0 0   0 0 0 0   0 0 0 0   0 0 0 0    Real event marker; set to one; F = 1
0 N 0 0   0 0 0 0   0 0 0 0   0 0 0 0    Interval constant: Indicates half of
_______________________________________  data buffer to be loaded
F N E E   E E E E   E E P P   T T T T    Result of OR operation.
```

(c) Example - 4 pulse height channels; high time resolution

```
0 0 E E   0 0 0 0   0 0 0 0   0 0 0 0    Energy recoder: 256 pulse height channels
0 0 0 0   P P P P   0 0 0 0   0 0 0 0    Typer: 15 types (3 layers; 5 PCU)
0 0 0 0   0 0 0 0   T T T T   T T T T    Time: 256 time bins (per Interval)
F 0 0 0   0 0 0 0   0 0 0 0   0 0 0 0    Real event marker; set to one; F = 1
0 N 0 0   0 0 0 0   0 0 0 0   0 0 0 0    Interval constant: Indicates half of
_______________________________________  data buffer to be loaded
F N E E   P P PT    T T T T   T T T T    Result of OR operation.
```

* Interval Marker Words (F = 0) do not pass through the Giant OR. They are inserted into the Giant Or output stream in proper time-ordered sequence. They have the form: bit 15 = 0, bits 3-14 = 1, bit 2 = Interval-interrupt Enable F bit 1 = Spillage Flag; bit 0 = 0.

This design assumes that the values for the four inputs are arranged (by proper loading of the lookup tables) so that each quantity exclusively uses only a portion of the subfield available to it (Fig. 4b,c); these portions are chosen to not overlap. The effective number of bits assigned to time, type, and pulse height are assigned according to the requirements of the observation. Time-stamp bits are always arranged to the least significant bit side, while the energy recoder bits are usually placed in the most significant side with the typer bits in the middle. The locations within the input words that are outside the restricted fields are filled with zeros. This allows the inputs to be combined into a single word with an inclusive OR operation.

Since the time-stamp bits indicate the time since the previous Interval tick in units of bin ticks, many of the higher order bits will always be zeroes. For example, if one is binning data with 1-s timebins with Interval markers every 64 s, the time stamp will have values from 0 to 63 (6 bits).

In the example of Fig. 4b, a large number (8) of pulse-height bits are output from the energy recoder thereby restricting the number of bits allocated to type and time. In Fig. 4c, a small number of pulse-height bits makes room for more information about type and also for improved time resolution (for the same Interval duration).

There is a fourth input to the Giant OR, an operational code called the *Interval constant*. It consists of 1 or 2 bits depending upon the data mode. It appears in bits 14 (or 13–14) in the output and is obtained from a register previously loaded by the Back End. Typically its count changes by unity with each new Interval. It is used by the DSP as part of an address to the DB (see Section 4.9 just below).

7.4.8 Interval Markers

At the occurrence of an Interval tick, an *Interval marker* is placed in proper time-order among the time-stamped events at the output of the Giant OR. This marker is indicated by a value of “0” in the MSB. The Interval marker event also contains status flags, specifically *spillage* and *interval-interrupt enable* flags (see next two sections, 4.9 and 4.10).

7.4.9 Accumulation of a Partition; DSP Operation

The 16-bit recoded events from the Giant OR and the Interval markers are fed into a 1024-word-deep *first-in-first-out* (FIFO) register to absorb brief bursts of high counting rate. The DSP reads the event words and Interval markers from the FIFO and modifies the *data buffer* (DB) in a manner dependent upon the data mode in use. The data modes are described in Section 5 below “EDS PCA Data Modes”.

In binned mode, for example, 14 bits (0–13) are allocated to energy/type/time. These bits of the event word are the address of the energy/type/time bin within the DB that should be incremented. The task of the DSP for an individual event is simply to increment that bin. This is straightforward and rapid.

The DB consists of two half data buffers (HDB), each of 16 kWords @16 bits (Fig. 3). For most modes, the accumulation takes place alternately in the two halves of the buffer. The data will accumulate in a given HDB until the next Interval marker is received by the DSP.

The switch to the next HDB requires no additional calculation by the DSP; it simply uses the interval constant (bit 14 in binned mode; see above) in the event word as part of the address to the DB, so the

DSP automatically operates on the appropriate HDB. The DSP immediately begins to accumulate data in the other HDB while the CPU processes the data of the just-completed partition. The DSP thus continues in its tight loop without interruption through the entire observation.

The DSP processes the events that emerge from the FIFO at rates which depend on the mode (e.g. binned, FFT, etc.). Overflow of the FIFO is indicated by a *spillage flag* (in the next Interval marker word). Upon its occurrence, the hardware ceases writing into the FIFO until the beginning of the following Interval.

Events are lost when under the following circumstances: (1) the FIFO overflows (this is mode dependent, but generally unlikely), (2) in binned modes, the allocated 4, 8, or 16 bits per word in the DB overflow, (3) high rates in event modes fill the DB before readouts, (4) the FFT mode is in a processing interval, and (5) the EDS–FDS interface TM rate is saturated (500 kb/s).

7.4.10 Compression and Transmission

When the DSP reads the Interval marker from the FIFO with the *interval-interrupt enable flag* set, an interrupt signal is sent to the Back End which then performs mode-dependent functions. In binned mode, for example, it reads the just completed partition of data into its own memory and zeroes the memory locations just read. The back-end CPU can then operate on the data, e.g., to search for a flare or burst.

A *partition map*, unique to each configuration, is used to specify which bits of each 16-bit word are to be telemetered. The map can specify the lowest 4, 8, or 16 bits of any given word on a word-by-word basis. Thus a configuration can specify different word sizes for different energy channels, e.g., fewer bits at higher X-ray energies. The partition map can also indicate that entire words are not to be telemetered.

If the count in a DB word exceeds the maximum value that can be telemetered according to the partition map (i.e., 2^4 - 1, 2^8 - 1, or 2^{16} - 1), the value appears to have ‘rolled over’ in the telemetered data. No notice of such rolled over values is given to the observer.

The data are then formed into data packets and transferred to the spacecraft FDS.

7.4.11 Back-end (CPU) Operations

There are ~650 configurations in the system manager ROM, and others will be uploaded to system-manager PRAM. The PRAM will also contain the desired configuration for the upcoming EA run.

Upon an EA reset, the CPU memory is reinitialized. The CPU then copies the contents of both the ROM and PRAM into its own memory. It then sends to the spacecraft an *observation parameter dump* for transfer to the ground. This consists of all parameters that specify the configuration, including those for the two lookup tables and the partitiom map that will be used in the upcoming EA run. The CPU then loads the lookup tables and also the code needed by the DSP.

The Back End (with its CPU) controls the Front End. It starts and stops observations. During the observation, it controls interval generation (interval constant and interval duration) by loading the appropriate front-end registers during the preceding interval, it retrieves and compresses the data in the DB, and it creates data packets and transmits them to the FDS. It also can carry out simple analyses of the data it has retrieved from the DB. The CPU prefixes the data with a header (type of data, start time of integration, time interval, etc.).

During data acquisition, an interrupt to the CPU (see above) informs the CPU that it can (1) calculate and load into front-end registers the Interval duration and interval constant for the interval following that just started, (2) read out the partition from the DB or HDB, and (3) begin to process the just-read partition of data.

The CPU places a *partition number* in the header of the partition, as noted. This is referenced to the time of the beginning of the observation (or EA run). Since the time between partitions is well known (i.e., it was specified in the configuration of the observation), the time of the first data in a partition may be calculated. In modes where a single partition contains multiple Interval markers embedded in a stream of events (e.g. event encoded mode), the ground analysis software can count Interval markers within the partition. Since the Interval duration is known, absolute times (MET) can be calculated.

At the end of an EA run, the CPU checks the tables (typer, energy recoder, and partition map) for single-event upsets. The number and locations of errors are telemetered.

The Back End also receives and processes commands uplinked from the ground.

7.4.12 System Managers

7.4.12.1 EA memory repositories

The system manager ROM and Protected RAM (PRAM) is made available to all of the event analyzers in that half of the EDS. Upon reset (or power up) the EAs read first the ROM image, which contains the basic flight software code, and then the PRAM image. The EA can never write to the PRAM and it is, therefore, immune to corruption from software faults; it is also single-event-upset (SEU) immune.

7.4.12.2 Reboots

If an EA detects any error, it immediately does a reboot which initializes its memory and it again copies the ROM and PRAM images from the system manager. The reboot takes about 20 s.

As protection against buildup of undetected single-event upsets, each EA will be rebooted, by command, approximately once per orbit.

7.5 EDS PCA Data Modes

The individual event analyzers for the PCA can be operated in 7 modes, namely:

- Binned Data: Histograms according to pulse height, time, and event type; useful for time series and spectra with selectable resolutions.
- Pulsar Fold: Binned mode with pulse phase substituted for time; for pulse phase spectroscopy of short-period pulsars.
- Delta Binned: Histogram of time differences between events (one type of event only)
- Event Encoded: Pulse-height, time, and event type for each event transmitted as a 15-bit word. For rapid timing on less bright sources. There are two submodes:
    - Continuous: Data buffer halves read out alternately; continuous accumulation of data for modest rates.
    - Snapshot: Entire data buffer loaded and then read out; data accumulation interrupted during readout (i.e., some data lost).
- Burst Catcher:Two EA’s used, one to search data and generate a trigger (‘trigger EA’) and one to capture data at high time resolution (‘catcher EA’). Useful for brief unpredictable X-ray burst-like phenomena. There are three trigger modes, and two catcher submodes:
    - Triggers:Selectable trigger criteria (absolute rate, delta rise, and hardness)
    - Binned:Binned data with 25%–50% of data before trigger.
    - Event:Event mode with 32 kWord buffer used for capture. All burst-catcher ROM configurations use this submode.
- Single-Bit Code: String of ones and zeros representing events and clock ticks, respectively. For fast timing without danger of bin overflow. Highly efficient when time resolution is comparable to interval between events.
- Fast Fourier Transform (FFT): Accumulates simultaneously two channels of 256 time bins (e.g., two energy bands). Averages power density spectra and cross spectrum. For low telemetry rate surveillance of rapid time variability.

7.5.1 Binned Mode

The *binned mode* builds histograms consisting of counts of events with the same time-bin number, recoded pulse height and event type. One configuration could include separate histograms for “good” events, background events, propane layer events, and calibration events. The time bin duration is a selectable value in the range 1 μt (0.954 μs) to 2^{32} μt (4096 s). [1.0 microtick = 1.0 μt = 1.000×2^{-20} s]

The DSP executes this mode as follows. It uses the least significant 14 bits (0–13) of the 16-bit event word from the FIFO as an address within the *half data buffer* (HDB) currently accumulating data. Bit 14 (interval constant) defines which HDB is being addressed. The HDB contains 2^{14} words (16 kW), i.e. it can hold 2^{14} time/energy/type bins. The value stored at that address is then incremented by unity. The energy/type/time bins thus fill sequentially (in time). The data values "roll-over" to zero when incremented beyond their maximum (4, 8, or 16 bits according to the configuration). No flag is set to indicate a rollover.

The DSP also interprets an Interval marker as an address. Since the MSB is zero and since, in this mode, all the Interval marker words are identical, the address is a single location in the scratch RAM of the DSP, i.e. not in the DB. Thus this non-event word is conveniently trashed with no additional logic required of the DSP. However, when this word arrives at the DSP, the combination of MSB = 0 and the *interval-interrupt enable* bit asserted results in an interrupt to the Back End. This causes the Back End to read out the just-completed partition of data from the appropriate HDB, and to reinitialize that HDB with zeroes.

Configurations for the binned mode can be constructed that emphasize time resolution or, alternatively, pulse-height resolution. Yet another choice is to emphasize the 'type' of event. A wide range of intermediate choices are also available.

The selectable parameters for the *binned mode* are:

- Energy/type selections
- PCU selections (Any of 1,2,3,4,5)
- Time bin duration (0.954 μs to 4096 s) (Interval durations and hence timebins exceeding 16s can lead to loss of synchronization of data transfers in different EAs; see Section 4.4 "Time Signals and Counters".)
- Word size per bin (4, 8, or 16 bits); can vary with X-ray energy

7.5.2 Pulsar Fold Mode

The *pulsar fold mode* is essentially the same as binned data mode, except that the time bins are replaced with phase bins. The data can be binned according to pulse height and event type as well as phase, which allows one to do 'pulse-phase spectroscopy'.

This mode supports pulse periods in the range ~3 ms to 4096 seconds. Observers desiring lesser periods may fold on a multiple of the desired period, preferably at least 5 ms. (Observers wishing to use fold periods less than 5 ms are advised to consult with the operations center to obtain the latest performance characteristics of the EDS.) The pulse period may be specified with a precision of 2^{-16} μt (~1.5 $\times 10^{-11}$ s) to prevent a buildup of phase error during the accumulation of data.

In this mode, the Interval ticks coincide, to an accuracy of 1 μt, with the times of zero pulse phase. The time between Interval ticks, i.e., the Interval duration, is an integer number of microticks (0.954 μs); this number of microticks is modulated up and down by unity as needed from pulse cycle to pulse cycle to approximate the desired period and to keep the Interval ticks close to zero phase. If the observer accurately specifies the pulse period with the full available precision, the pulse folding could proceed for ~30,000 periods with a phase error that is less than 1 μt . We expect that, in practice, pulse profiles will usually be averaged over shorter times.

The duration of a phase bin is defined by the bin-tick duration (also in integer microticks). The first phase bin begins at the Interval tick. The last phase bin will be shorter than the other phase bins unless the bin width happens to be commensurate with the pulse period. It is the length of the last phase bin that is varied by the aforementioned modulation of the pulse period. Thus its average width will not be an integer number of microticks.

The number of bins to be accumulated is given by the product of the numbers of phase bins, pulse-height bins, and event types. Each of these numbers is selectable, but the total is limited to a maximum of 16384 by the size of the HDB. Again, the histogram values may be telemetered as 4, 8 or 16 bit words.

In pulsar fold mode, the Interval markers occur at the end of each pulsar period and do not initiate a readout, until the end of the accumulation period after N Intervals. This does not require any change in the DSP code from binned mode.

The selectable parameters for the *pulsar fold mode* are:

- Energy/type selections
- PCU selections (Any of 1,2,3,4,5)
- Pulsar period (5 ms to 4096 s)
- Number of phase bins (2 to 16,384)
- Word size per bin (4, 8, or 16 bits)
- Data accumulation time (no. of pulse periods)

7.5.3 Delta Binned Mode

The EDS is also capable of running a variation of binned mode, called *delta binned mode*, in which a histogram of the time between events is generated for a single selectable energy range and a single selectable type.

The desired events are selected by the Front End; all other events are rejected. The time resolution is set by the period of the bin-tick generator, just as for all other modes. Upon receipt of an event, the DSP subtracts the time of the previous event from the time of the current event. The difference is used as an address to the data buffer, and that location is incremented by unity. There are 2^{14} = 16,384 bins in the HDB; this is the maximum number of time-difference bins. For most observations, fewer than 1000 need be telemetered. Thus, if the time resolution is 1 µt, the maximum tabulated inter-event time would be 16.384 ms, or ~ 1ms if only 1000 bins are used. If the time resolution is 16 µt, the maximum would be ~16 ms for 1024 bins, and 0.26 s for the full memory. The latter is the average time between events for 2–10 keV background from a single PCU. Thus the practical time resolutions range from 1 to ~16 µt.

If an inter-event time exceeds 16,384 times the time resolution, the time difference rolls over, and the bin that is incremented corresponds to the inter-event time modulo 16,384 times the time resolution .

The accumulation and readouts occur just as in normal binned mode. The histogram values may be telemetered as 4, 8 or 16 bit words, and the Interval marker signals the switching of the two HDBs. The bins roll over if filled; no flag is set.

One possible configuration of this mode is to provide 1 s integrations of histograms containing 1024 bins with 1 µt time differences. Time differences of 1 µt to ~1 ms are measured. With this, one can explore the dead time of an individual PCU.

The selectable parameters for the *delta time bin mode* are:

- Energy/type selection (one energy/type only)
- PCU selections (1 group consisting of any of 1,2,3,4,5)
- Time resolution (0.954 µs to 4096 s; ~16 µs is the practical maximum).
- No. of bins to telemeter; max is 16,384.
- Energy/type/time selection
- Word size per bin (4, 8, or 16 bits); can vary with delay time
- Readout time (Interval duration)

7.5.4 Event Encoded Mode

The *event encoded* (EE) mode provides data in which each event is individually described. The DSP stores the 16-bit recoded event word directly and sequentially into the active HDB (16 kWords) or the full DB (32 kWords). Thus, the time of each event is obtained together with some combination of detector ID, pulse height, and event type according to the details of the configuration. All of this information can occupy no more than 15 bits of the recoded 16-bit event word. The most significant bit (MSB) is used to distinguish an event from an Interval marker.

The Interval markers are used for two purposes in this mode. First, the markers are recorded in the buffer at their proper sequential position to serve as time references. (These are labeled with MSB = 0.) Thus the time stamp of any event in the buffer is a count of bin ticks since the previous Interval marker word in the stored sequence of events. For example, if Interval markers occur every 2^{-7} s = 7.8125 ms or, equivalently 2^{13} = 8192 μt, a time stamp of 13 bits would suffice to subdivide the Interval into 1 μt resolution elements: $2^{-13} \times 7.812$ ms = 1 μt = 0.954 μs.

Secondly, the Interval markers are used to trigger the readout of the HDB by the BackEnd at the end of an *accumulation interval*. This occurs when the *N*th Interval marker is counted. The number ***N*** is a parameter of the event encoded mode configuration. The accumulation interval can be set to values between 1/8 s to 4096 s. (These are the practical limits; the technically allowed range is much greater.) After the readout, the Back End loads the just-read buffer with *end-of-data marks*. Thus, at the subsequent readout, the Back End will retrieve data from only the locations containing real events.

The data must be sent in 16-bit words for proper operation of the mode. Use of the partition map to reduce the bits per word eliminates the higher-order bits which contain the indicator that the word is a true event or an interval marker (MSB).

There are two basic methods for reading out the data, *continuous mode* and *snapshot mode*. In the former, the two halves of the data buffer are sequentially filled as in the binned mode. In the latter, the entire buffer is used for each accumulation. These are discussed below.

This mode can consume large amounts of telemetry for bright sources. For example, the Crab nebula at 10^4 cts/s and 16 bits per event yields a telemetry rate of 160,000 kb/s, or 8 times the nominal sustained PCA telemetry rate quoted earlier. Such an observation could be carried out only for a short duration (~40 minutes, once per day).

The selectable parameters for the *event encoded mode* are:

- Energy/type selections
- PCU selections (Any of 1,2,3,4,5)
- Time resolution (0.954 μs – 4096 s)
- Time-marker interval (Interval marker; > 4 ms)
- Accumulation interval (1/8 s – 4096 s; practical limits)
- Continuous or snapshot modes (see below)

7.5.4.1 Continuous EE mode

In the *continuous EE mode*, the two halves of the data buffer are alternately read out, as in the binned mode. Each readout occurs at the end of an accumulation interval (*N* Interval markers).

The HDB can store up to $2^{14} - 1 = 16383$ events and time markers @16 bits (16 kWords). If the rate of events is sufficiently low and/or the frequency of readouts is sufficiently high, the accumulation is ‘continuous’; no events are lost. On the other hand, if the event rate is too high, the HDBs will fill before the accumulation interval ends. In this case, one obtains regularly spaced samples of 16 k events with temporal gaps between them. The lost events are counted and the count is telemetered. In this high-rate situation, the continuous mode becomes discontinuous! Generally, one would prefer to make the accumulation interval sufficiently short so that the events are not likely to fill the HDB.

For our example of the Crab nebula at 10 kct/s, an accumulation interval of 1 s would clear the 16-k HDB when it is about 2/3 filled. But if the counting rate should exceed 16 kct/s, gaps would appear in the data at intervals of 1 s.

As noted above, the Back End telemeters only recorded events (and not the unfilled part of the buffer). Thus the telemetry rate will be directly tied to the actual event rate plus overhead. If the source suddenly becomes very strong, an unexpectedly high telemetry rate would result. The data produced could exceed the capacity of the spacecraft solid-state recorder.

A different strategy would be to limit the telemetry by specifying a rather long accumulation interval. In this case, the event rate would fill the half data buffer sometime before the readout occurred, and events would be lost. This is the ‘discontinuous’ high-rate situation described above. In this case, the telemetry rate is limited by the size of the data buffer and the number of times it is read out per second.

Most observational needs should be met with the configurations in ROM, each of which is based on an accumulation interval of 1 s or 8 s.

7.5.4.2 Snapshot mode

If the event rate is so high that one cannot telemeter all events, the snapshot mode is an alternative to the ‘continuous’ mode. The snapshot mode can yield a longer train of contiguous data (32 k events and time markers) than the 16 k events provided by the continuous mode.

In this case, the entire (both halves) 32 kWord DB is loaded sequentially until the accumulation interval ends. Usually, the accumulation interval will be set sufficiently long to allow the DB to fill completely with 32 k events and time markers. In either case, at the end of the accumulation interval, the Back End reads out the data buffer and loads it with end-of-data marks. Accumulation begins again after a *dummy interval* sufficient to allow these operations (~70 ms). The temporal gap could be significantly longer than the dummy interval if the DB is filled well before the end of the accumulation interval.

7.5.4.3 Event-encoded configurations

The following three EE configurations, *mixed, time,* and *transparent,* illustrate the capability of the EE mode. Such configurations may be used in either continuous or snapshot modes. For more information see the Configurations chapter.

- In the *mixed EE configuration*s, an event is specified by a mixture of time and type/energy bits. For example, if 8 time bits are used, up to 7 bits may be selected in any combination from the bits available to the typer or energy recoder. If time markers are specified to occur every 2^{-7} s = 8 ms, the time bits are sufficient to specify the time of the event with an accuracy of 2^{-15} s (~31 µs). This configuration is useful for the less frequent high-energy events in high-rate sources. It will typically have a low-energy cutoff, and events below that energy will be telemetered in binned mode.
- In the *timed EE configuration*, an event is specified by time bits only. The 15 time bits are sufficient to specify the time of the event with an accuracy of 2^{-20} s (1 µt). In this case. the Interval markers would be programmed to occur at 2^{-5} s (31.250 ms).
- In the *transparent EE configuration,*, the EDS telemeters *all* information about every selected event. This includes all information received from the PCU, the detector ID and all the time bits. The time bits are sufficient to specify the time of the event with an accuracy of 2^{-20} s (1 µt = 0.9537 µs). This format uses the resources of three EAs, each of which, for example, processes only a portion of the time stamp. This mode is useful for system diagnostics.

7.5.5 Burst Trigger and Catcher Modes

7.5.5.1 Trigger and catcher event analyzers

The objective of *burst catcher mode* is to capture a brief segment of data during an X-ray burst or similar phenomenon with a high time resolution that could not be sustained continuously by the telemetry system. This mode normally operates with at least one *trigger EA* and at least one *catcher EA*. The trigger EA detects X-ray burst-like phenomena and sets a *burst flag* upon each such occurrence. In the absence of a burst, the catcher EA continuously writes data into the DB with old data being overwritten; the data is not telemetered to the ground. When the catcher EA receives a burst flag signal, its Back End transfers the data currently in the DB into its own memory. The timing is such that both pre and post ‘*burst-onset*’ data can be captured. These data may then be sent to the ground.

7.5.5.2 Burst Trigger Mode

The trigger EA runs a variation of binned mode in which the Back End analyzes each partition of data to see if a programmed counting rate or hardness ratio threshold has been exceeded. The trigger EA configuration specifies that one of the following three algorithms is to be used in carrying out this analysis:

- Absolute rate (or level) Trigger: Does the number of counts in any bin from a single energy range exceed the threshold?
- Delta rise (or edge) Trigger: Does the number of counts in any bin from a single energy range exceed the mean of the N bins preceding it by the threshold value?
- Hardness Trigger: Does the ratio of the count in any bin from one energy range to that of the corresponding bin for another energy range exceed a threshold? The calculation ignores any pair of bins for which the denominator is zero.

If these algorithms are not sufficient, the EDS has the capability to receive new trigger algorithms via upload after launch.

The trigger may operate in either *absolute* or *most interestin*g mode, and thereby generate, respectively, either *high-priority burst flag*s or *low-priority burst fla*gs. In absolute mode, the trigger threshold is maintained at the value specified by the configuration. In most interesting mode, the trigger threshold is raised with each burst to the level of that burst. The flag priority determines whether and when the burst is telemetered (see below).

The trigger EA may optionally telemeter its accumulated binned data to the ground. The partition header packets for these data are always telemetered; these indicate whether or not the trigger threshold was exceeded. Even if the partition data is not telemetered, each partition header requires one packet of telemetry. At a readout time of 32 ms, one uses 1/2 the allowable packet count for the EDS-FDS interface. A readout time of at least 250 ms is a more conservative and practical value.

The trigger EA normally will bin with relatively coarse time resolution to obtain sufficient statistics per time bin and to minimize the number of bins the Back End must examine during each Interval. Since the trigger EA analyzes a partition of data after the partition is transferred to the back-end memory, one may choose a relatively short readout time to minimize the time delay between the occurrence of a burst and the generation of a burst flag.

The selectable parameters for burst trigger mode (*trigger EA)* are:

- Energy/type selections
- PCU selections (Any of 1,2,3,4,5)
- Time bin duration (0.954 µs to 4096 s)
- Word size per bin (4, 8, or 16 bits)
- Trigger algorithm
- Absolute threshold or most-interesting mode
- Telemeter header data only
- Readout time (32 ms to 4096 s; 32 ms could saturate the EDS–FDS interface)

- Send trigger to HEXTE

7.5.5.3 HEXTE Burst Flags

A burst flag may also be received from HEXTE, and this is treated as a high-priority burst flag (see below). Catcher EAs have the option of ignoring the HEXTE burst flag. EDS high-priority burst flags may also be sent to HEXTE.

7.5.5.4 Catcher EA Priorities and Modes

When a burst flag is received by an EA running the burst catcher mode, data from both before and after the time of the trigger is captured. If the flag is *high priority*, the captured burst is immediately sent to the S/C to be telemetered. If the flag is *low priority*, the burst is stored in the back-end memory, and it will be overwritten by subsequent bursts. At the end of an observation (EA run), the last low priority burst detected is sent to the FDS. This burst is the one that most exceeded the original trigger threshold. If additional EAs and/or HEXTE are generating triggers, a high-priority burst from one of them could overwrite a low-priority burst awaiting the end of the EA run.

The DSP program code supports two catcher modes: a *binned catcher mode* or an *event catcher mode*. These are fundamentally similar to the binned and event encoded modes described above, except for the extra provisions to sense the trigger and capture the burst data.

The event catcher mode should be useful for short events (< few seconds) at Crab-like intensities. This is limited by the 32,767 events that can be stored in the data buffer. The normal (non-burst-catcher) modes should prove adequate in most cases of longer bright events, e.g. classic X-ray bursts. Binned catcher mode should prove useful for sustained events. All burst-catcher configurations in the ROM utilize event-catcher mode. Binned catcher modes may be requested by the observer; many such modes should be in PRAM prior to launch.

7.5.5.5 Binned burst-catcher mode

In binned catcher mode, the Interval ticks of the catcher EA must be synchronized to the Interval ticks of the trigger EA for the mode to operate as designed, and for the description below to be valid. This condition ensures that 25% to 50% of the ‘captured’ data precedes the ‘burst onset’ time, i. e. the time of the rate or spectral change that caused the trigger flag to be set.

In this mode, the entire DB is logically divided into four equal parts rather than the usual two. The four quarters fill cyclically. The switch from one quarter to another occurs at Interval ticks via changes of the Interval constant (bits 13 - 14 in the event word). As each quarter is about to be filled, the Back End loads it with zeros.

If the trigger threshold is exceeded during Interval N, the trigger Back End will discover this fact during Interval N+1, and the burst flag will be set. During Interval N+2, the flag causes the catcher Back

End to read into its own memory the data for Interval N–1 (the oldest data in the DB). At the same time, the catcher Front End is accumulating N+2 data in the appropriate quarter buffer. During accumulation of N+3 data, the N data are read out. Similarly the post-onset data N+1 and N+2 are read out while accumulation continues. The readouts then cease. One thus obtains a train of data consisting of four quarters with the burst onset in the 2nd of the four quarters.

If the high-priority trigger flag continues to be set because the trigger criterion continues to be satisfied, the readout of the quarter buffers continues until the two quarters following the last trigger are read out. This continuous stream of high-time resolution data could well saturate the telemetry interface or the FDS solid-state recorder.

Four quarter buffers of data yield a total of 2^{15}= 32,768 bins for accumulation according to event type, pulse height and time.

The Interval-tick duration for an X-ray burst might typically be set to 1 or 4 seconds, giving a data train of 4 or 16 s. As usual, one will specify the word size as 4, 8, or 16 bits to minimize telemetry while avoiding overflows.

The selectable parameters for *binned burst-catcher mode* (*catcher EA*) are:

- Energy/type selections
- PCU selections (Any of 1,2,3,4,5)
- Time bin duration (0.954 µs to 4096 s)
- Word size per bin (4, 8, or 16 bits); can vary with X-ray energy
- Trigger selection (any of high priority, low priority, HEXTE)
- Interval duration.

7.5.5.6 Event burst-catcher mode

In event burst-catcher mode, the catcher EA operates similarly to the event encoded mode (including mixed, timed, and transparent formats) described above. It makes use of the entire data buffer; it is capable of capturing $2^{15} - 1$ = 32,767 contiguous events and/or Interval markers per burst, each consisting of 16 bits (15 bits of science). The entire data buffer is used as a cyclic buffer with the oldest data being continuously overwritten until a trigger is received. A floating end-of-data mark indicates the boundary between the oldest and newest events. The Interval markers interspersed in the data as time references need not be synchronized with the Interval ticks of the trigger EA.

There is a configurable *capture delay* (an integer number of time-marker intervals) measured from the reception of the trigger flag which allows the capture of post-onset data. At the end of the delay, the accumulation of data in the DB is stopped. The entire 32 kWords of the catcher DB is then read out. After a transfer interval, the accumulation resumes.

In this mode, an unexpectedly bright burst could fill the buffer and begin to overwrite itself before the trigger (with delay) stops the accumulation. If the trigger flag remains on, the CPU will continue to grab and process contiguous groups of 32 k events with gaps for the readouts. This also could saturate the telemetry system.

The selectable parameters for *event burst-catcher mode* (*catcher EA*) are:

- Energy/type selections
- PCU selections (Any of 1,2,3,4,5)
- Time resolution (0.954 μs – 4096 s)
- Word size per bin (4, 8, or 16 bits)
- Time marker intervals (> 4 ms)
- Capture delay (no. of time-marker intervals)
- Trigger selection (any of high priority, low priority, HEXTE)

7.5.6 Single-Bit Mode

In *single-bit mode*, the reduced data consist of a string of zeroes and ones; a ‘zero’ denotes the occurrence of a regularly-spaced time-bin boundary while a ‘one’ denotes the occurrence of a detector event. This mode provides excellent time resolution with minimal telemetry without the danger of overflow of time bins. However, it generates telemetry data at a source intensity dependent rate. The time bin size is selectable between 2^{-20} s (1 μt) and 4,096 s. The single-bit mode can only be carried out on a single choice of event/type, including a choice of a set of PCU detectors.

This mode is optimal when the bin size is chosen to be comparable to the reciprocal of the event rate. For example, 1 ms time bins are optimum for an event rate of 1000 c/s. If the rate is substantially lower, an excessive number of boundaries (with no events) are telemetered, and event mode might be more efficient. At a substantially higher rate than optimal, a large number of event bits per boundary could be more efficiently telemetered in binned mode.

The DSP uses 16-bit arithmetic, so it can accumulate up to $2^{16} - 16$ ‘ones’ and ‘zeros’ in a given partition. i.e. 65520 events and time boundaries. These bits are loaded sequentially into the active half of the DB; the first 16 events/boundaries will occupy the first 16-bit word and so forth. The 65520 events/boundaries occupy only about 1/4 of the 16 kW in the HDB.

Upon the occurrence of the Interval tick, the accumulation begins in the other HDB. If the Interval tick occurs before all 65520 locations are filled, no data are lost. If, on the other hand, the maximum number is reached before the Interval tick occurs, the mode will keep a count of the lost events.

The SOC will convert these data to a standard binned-mode format before delivery to observers.

The selectable parameters in *single bit mode* are:

- Energy/type selection (one only)
- PCU selections (Any of 1,2,3,4,5)
- Time bin duration (0.954 μs to 4096 s)
- Interval duration (Readout interval of HDB; 5 ms to 4096 s)

7.5.7 FFT Mode

In FFT mode, Fourier power density and cross spectra are computed and summed. To accomplish this, the EA first simultaneously generates two time series histograms, each of which consists of counts in 256 sequential time bins. The time series are accumulated and stored using 16-bit words. The events in each time series are those selected according to observer-specified criteria; the two time series will generally differ in their energy ranges. The time during which events are accumulated to form the two time-series is called an *accumulation interval*. Its length is 256 times the time bin size but cannot be less than 4 ms.

Following the accumulation interval, the DSP calculates the mean number of counts per bin for each time series and subtracts the mean from the count in each time bin. The two means are saved. The DSP then computes the power density spectra (PDS, the sum of the squares of the real and complex components of the Fourier transform) of the two mean-subtracted time series and the cross spectrum (CS, the complex product of 2 transforms, $A \times B^*$). The PDS and CS are based upon 256-point decimation-in-time complex FFTs. The individual transforms are calculated using 16-bit integer arithmetic. These computations take place during a *processing interval* of duration 12 ms.

In order to avoid roundoff error due to the use of 16-bit integer arithmetic, a number of scaling operations are performed in FFT mode. First, the two time series are each scaled by a configurable scaling factor. Second, after each of the eight stages of calculation of the FFTs, the intermediate data values are divided by 2. Third, prior to summing, the two PDS and the CS are scaled by a configurable value. Details are in the “FFT Mode Module Specification” (not in this package).

The collection of events and computation of the PDS and CS is repeated a selectable number of times, e.g. a few hundred. As each PDS/CS is completed, the results are summed to the previous total. For example, the second set of spectra (2 PDS and 1 CS) is added, point by point, to the first set. The third set is added to the previous total, and so forth until the configured number of spectra have been summed. The summed spectra constitute, in effect, averages of each spectrum. The PDS and CS are accumulated into 32 bit numbers. The sum of all the accumulation and processing intervals prior to telemetry of the summations is called the *product interval*.

During a *transfer interval*, which immediately follows each product interval, the three summed spectra and the means of the individual data sets are copied into back-end memory, packed and sent to the

FDS as telemetry packets. After the data have been copied, the data buffer is reinitialized with zeroes and the process begins anew.

The FFT mode has a selectable time bin size between 2^{-20} s (0.954 µs) and 4096 s.

Dead time is inherent in the operation of FFT Mode. Events received during Processing or Transfer Intervals are not processed. The percentage of live time (i.e., percentage of time accumulating photons into the time series) of the FFT mode is a function of the time bin size, as follows:

$$Efficiency = \frac{256 \Delta t_{bin} N_{PDS}}{N_{PDS}(I_{proc} + I_{accum}) + I_{trans}}$$

where N_{PDS} is the number of summations in the readout, Δt_{bin} is the time bin width, and the three intervals I are the processing, accumulation and transfer intervals. The processing interval is 12 ms, the accumulation interval is $I_{proc} = 256\ \Delta t_{bin}$, and the transfer interval ~70 ms. The efficiency ranges from ~2% at 1 µt bins to ~25% at 16 µt bins and ~70% at 100 µt, where we have taken the transfer interval to be negligible compared compared to the overall product time (sum of accumulation and processing intervals).

The selectable parameters for the *FFT mode* are as follows:

- energy/type selection #1
- energy/type selection #2
- PCU selections (Any of 1,2,3,4,5) #1
- PCU selections (Any of 1,2,3,4,5) #2
- time-bin duration (0.954 µs to 4096 s)
- number of PDS and CS to sum together
- time-series and spectra scaling parameters.

7.6 EDS-ASM Operations

7.6.1 ASM-EDS Interfaces

Each X-ray photon which is detected in a position-sensing chamber of a *scanning shadow camera* (SSC) generates a signal which is amplified by two analog electronic measurement chains, one at each end of a resistive anode. The two pulse heights are converted to digital 12-bit numbers and transferred on a serial line (one for each SSC) to the ASM Event Interface. Background event data are also transferred on an event-by-event basis to the EDS over the same set of serial lines. Each data word received by the EDS comprises a 4-bit event code and two 12-bit pulse heights. The event code contains the anode number for “good” X-ray events or a code indicating one of *four types of background* *events* (multi-anode event, position-sensing anode and veto layer coincidence, veto layer event, A and/or B pulse height exceeds the upper level discriminator).

All events transmitted from the ASM over the event interface are received by each of the two ASM Event Analyzers.

A second interface, the control interface, consists of a shared bi-directional serial data bus. With this interface, the EDS can obtain ASM engineering and housekeeping information, and control the SSC signal processing and the ASM rotation drive. Only the ASM EA on EDS Side B can utilize the command and housekeeping interface; the ASM EA on EDS Side A can send rotation commands but cannot monitor housekeeping.

7.6.2 ASM EA Functions

The data processing in the ASM EAs operates quite similarly to the PCA EAs except that there is no typing and recoding of events in hardware. The front end of an ASM EA receives event data from the three SSCs and places this information (4-bit event code and 2 12-bit pulse heights) together with a 2-bit SSC ID and a 10-bit time tag into a series of three 16-bit words which are transferred into the FIFO register. Interval markers are also inserted into the FIFO at times which depend on the details of the EA configuration. The DSP therefore reads one-word interval markers as usual and three-word event descriptions. It extracts the event code, the SSC ID, the A and B pulse heights, and the time-stamp from each event description in order to perform further processing according to the active configuration.

The DSP selects events according to preset criteria, computes event energies (i.e., A+B) and anode positions (i.e., N [A/(A+B)] where N is the number of position bins) as required, computes bin numbers from the SSC and anode IDs, event energies, and event positions, and builds histograms or event lists in the data buffer (DB). This activity results in the creation of a partition of data for each Interval as described above for the PCA event analyzers.

The Back End of an ASM EA processes the partitions in the same manner as described above for the PCA EAs. In addition, it controls and monitors the rotation drive assembly and the acquisition of housekeeping and engineering data from the three SSCs.

7.7 ASM Data Processing Modes:

7.7.1 Position Histogram

This is the primary operating mode of the ASM and serves to monitor source intensities and to search for unpredicted outbursts from sources. The EA running this mode controls the rotations of the ASM *drive assembly*, acquires engineering housekeeping data from the three SSCs and the drive assembly, and processes the event data from the three SSCs to produce and telemeter position histogram data. The ASM EA on Side B of the EDS can run this mode with its full functionality, whereas that on Side A does not monitor housekeeping.

Position histogram mode performs “dwell sequences”, which are planned in advance on the ground and uploaded to the ASM EA via the spacecraft and an EDS system manager PRAM load. A *dwell sequence* is basically a series of “dwells”, each of which is followed by a rotation of the drive assembly. A dwell is an interval of time, typically between 80 and 100 seconds, during which the drive assembly does not rotate so that the SSC’s maintain a fixed orientation relative to the sky. Events are collected and processed into position histograms during dwells. After each dwell, the position histogram data is transferred to the spacecraft to be sent to the ground.

Each set of dwell sequence parameters contains two ASM drive-assembly slew angles; these slews are performed prior to the first dwell in order to begin the dwell sequence with the SSCs in the optimum orientation to avoid viewing the Earth during the subsequent ~100-s dwells. In addition to the two slew parameters, a dwell sequence is specified by a number of dwells, a dwell duration, and an angle to rotate after each dwell (one constant value per dwell sequence).

Position histograms consist of counts binned as a function of position for each of the 8 resistive anodes in each of the three detectors, and for each of, nominally, three energy channels. The number of position bins, the number of energy channels, and the energy channel boundaries are parameters for position histogram mode.

Position histogram mode also collects and telemeters engineering housekeeping data from the drive assembly and the 3 SSCs. This is done once each dwell in parallel with the collection of event data.

7.7.2 Multiple Time Series

This mode produces three types of binned data products, namely (1) *time-series histograms*, (2) *background event histograms*, and (3) *pulse-height histograms*. These data products are produced continuously on an Interval-by-Interval basis without regard to the status of the drive assembly, i.e., regardless of whether the SSCs are stationary or rotating.

Time-series histograms consist of counts of “good X-rays” per time bin for each detector for each of a few (1 – 5) energy bands. Each time bin can be as short as 0.001 seconds but will typically be ~0.1 seconds so that the resulting telemetry rate is modest. These data may be useful for studying the pulsations of a few bright X-ray pulsars or for searching for pulsations from newly-discovered bright transient sources.

Background-event histograms consist of the counts of each of the four types of background event (see Section 6.1 “ASM - EDS Interfaces”) in one-second time bins for each of the three detectors.

Pulse-height histograms consist of pulse-height spectra of “good X-ray” events for each of the eight resistive anodes in each of the three detectors. The pulse-height spectra will consist of 32 or 64 channels and are accumulated over time intervals of ~100 seconds. These data will primarily be used to monitor the location of the 5.9 keV spectral line from the weak ^{55}Fe sources in the instrument and to thereby determine the energy-to-pulse-height conversion gain of each of the detectors. Each spectrum is expected to contain roughly 32 pulse-height bins.

7.7.3 Event by Event

In this mode, the DSP stores three-word event descriptions in sequence in the data buffer. The event descriptions are telemetered after the data collection interval has ended. The mode may be configured so that either *all* types of events are selected and stored or only *good* X-ray events are selected and stored. Only data from one of the three SSCs is selected. Therefore, the selection of an SSC ID and choice of ‘good’ or ‘all events’ are options for this mode. This mode will see restricted use since it can result in telemetry rates that are very high. It will be used for diagnostics and calibration.

Chapter 8

Simulating Data: XSPEC, PIMMS, Recommd, and the FTOOLS Tasks

At the minimum, proposers are required to estimate the PCA count rate for their source as well as the resulting telemetry rate. All estimated rates will be thoroughly reviewed by the XTE GOF staff during the technical assessment prior to the proposal review.

In this chapter, the reader will be given a tour of XSPEC, PIMMS, recommd (the EDS configuration selector), and one of the FTOOLS tasks, in that order. Having read through this chapter, the reader should be able to simulate a spectrum with the proper flux, estimate a count rate, obtain the optimal EDS mode and configuration, and simulate an observation.

8.1 Using XSPEC

XSPEC is a fairly large and sophisticated program. It has extensive on-line help. XSPEC allows the user to fit spectral data or produce a fake spectrum. It can be used before or after PIMMS to obtain an estimate of a source's count rate. The basic steps to simulate a spectrum are:

- define a model
- read in the response matrix and effective area file
- generate the fake spectrum
- fit the spectrum (if desired)

The on-line help can be consulted at any point, or you may obtain a copy of the `XSPEC` manual by e-mail request to `humphrey@heasrc.gsfc.nasa.gov`. In the sections that follow, the text that is on the user's screen during an `XSPEC` session appears in `typewriter` font.

8.1.1 Defining a model

Models are constructed from basic components. A list of the components available may be obtained by typing

```
XSPEC> model ?
```

Information about the model command may be obtained by typing

```
XSPEC> help model
```

Basic help can be obtained by working through the walk-through presented at the front of the `XSPEC` manual. The example that will be presented below is that of NGC 4151, a relatively low-luminosity source from XTE's point of view. The example below should probably be followed for any weak sources, as the example uses response matrices for all three layers of the PCA. As one might predict, we shall find that this source generates a low count rate in the PCA, so the EDS configuration should be an event mode. Additional comments will be forthcoming later in this section.

The parameters of the NGC 4151 model have been taken from the paper of Weaver et al. 1992, ApJ, 402, L11. This paper describes the observation of NGC 4151 with *BBXRT*. NGC 4151 was chosen for this simulation for several reasons. First, it is an IOC target to measure the HEXTE sensitivity to flux variations. Second, it illustrates the nature of the simulations necessary for weak sources (i.e., consider each layer of the PCA). Third, the spectrum has an Fe line, so this source can demonstrate the spectral resolution available with the XTE instruments (i.e., proportional counter resolution). Finally, given the weakness of the source, a particular EDS configuration can be suggested that will likely have wide applicability.

The model chosen for this source is an absorbed power law with a gaussian to represent the Fe line (the model is illustrative and is not meant to be definitive of AGN in general, nor NGC 4151 in particular). The model is specified by:

```
XSPEC> mo wabs pcfabs power
```

Once the model is specified, `XSPEC` will prompt the user for parameter values. The default values are as listed in the prompt header. A "return" will accept these default values. The column density adopted from the *BBXRT* data is 7.0×10^{22} cm^2, the adopted power law index is 1.68; the partial covering absorption was assumed to be 3.0×10^{22}cm^2 with a covering fraction of 0.9. The power law normalization will be determined shortly. An Fe line at 6.35 keV with a sigma of about 0.3 keV will be added to the model later.

8.1.2 Generating a Fake Data File

The following will step through the entire prescription for generating a fake spectrum for a weak source using all three layers of the PCA. Generating a spectrum for the first layer will be done in detail; appropriate changes can be made for the other layers. The reader should be aware that there are several "contortions" that must be followed so that XSPEC will respond in a statistically correct manner. First, we must generate a model. Properly, the model should use the red-shift versions of each component (i.e., zwabs, zpower, etc.); that detail will be ignored for this simulation.

```
XSPEC> mo wabs pcfabs power
 Input parameter value, delta, min, bot, top, and max values for ...
 Mod parameter 1 of component 1 wabs nH 10^22
 1.000 1.0000E-03 0. 0. 1.0000E+05 1.0000E+06
7.0                                     (change default to 7.0)
Mod parameter 2 of component 2 pcfabs nH 10^22
 1.000 1.0000E-03 0. 0. 1.0000E+05 1.0000E+06
3.0                                     (change default to 3.0)
 Mod parameter 3 of component 2 pcfabs CvrFract
 0.5000 1.0000E-02 0. 5.0000E-02 0.9500 1.000
0.9                                     (change default to 0.9)
 Mod parameter 4 of component 3 powerlaw PhoIndex
 1.000 1.0000E-02 -3.000 -2.000 9.000 10.00
1.68                                    (change default to 1.68)
 Mod parameter 5 of component 3 powerlaw norm
 1.000 1.0000E-03 0. 0. 1.0000E+05 1.0000E+06
 ---------------------------------------------------------------
 mo = wabs[1] pcfabs[2] (powerlaw[3])
 Model Fit Model Component Parameter Value
 par par comp
   1  1   1   wabs       nH 10^22   7.00000       +/- 0.
   2  2   2   pcfabs     nH 10^22   3.00000       +/- 0.
   3  3   2   pcfabs     CvrFract   0.900000      +/- 0.
   4  4   3   powerlaw   PhoIndex   1.68000       +/- 0.
   5  5   3   powerlaw   norm       1.00000       +/- 0.
 ----------------------------------------------------------------
 5 variable fit parameters
```

Now, the fake spectrum must be generated. The 'none' on the command line below indicates that no response matrix has yet been specified, so XSPEC should prompt the user for one. The 'show' command (following the fakeit output) allows the user to check the status of the files. The reader should note that no background file nor auxiliary (effective area) file has yet been specified. Furthermore, the model normalization has not been set. Count rates at this point are pure fiction. The reader should also note that the fake spectrum to be generated will be for the first layer only. The background, response, and effective area files are available on the anonymous FTP account (`legacy.gsfc.nasa.gov`).

```
XSPEC> fakeit none
 For fake data, file # 1 needs response file: 5det_l1.rmf
 Use counting statistics in creating fake data? (y)
 Input optional fake file prefix (max 12 chars):
 Override default values for file # 1
 Fake data filename (5det_l1.fak): 5det_l1_t.fak
 T, A, Bkg, cornorm ( 1.0000 , 1.0000 , 1.0000 , 0. ): 10000.0
 Net count rate (cts/cm^2/s) for file 1 0.4848 +/- 6.9764E-03
 Chi-Squared = 299.8 using 256 PHA bins.
 Reduced chi-squared = 1.194
XSPEC> show
 15:32:33 26-Oct-94
 Fit statistic in use is Chi-Squared
 Minimization technique is Lev-Marq
 Convergence criterion = 1.0000000000000D-02
 Querying enabled
 Prefit-renorming enabled
 Log file : xspec.log
 Information for file 1
 belonging to plot group 1, data group 1, det id = XTE PCA
 Current data file: 5det_l1_t.fak
 No current background
 No current correction
 Response (RMF) file : 5det_l1.rmf
 Auxiliary (ARF) file : none
 Gain correction : 0.000 0.00
 Noticed channels 1 to 256
 File observed count rate 0.4848 +/-6.97639E-03 cts/cm^2/s
 0.4848 +/-6.97639E-03 cts/s
 After correction of 0. ; Model predicted rate: 0.4853
 ---------------------------------------------------------------
 mo = wabs[1] pcfabs[2] (powerlaw[3])
 Model Fit Model Component Parameter Value
 par par comp
    1   1   1   wabs      nH 10^22    7.00000     +/- 0.
    2   2   2   pcfabs    nH 10^22    3.00000     +/- 0.
```

```
   3   3   2   pcfabs    CvrFract    0.900000    +/- 0.
   4   4   3   powerlaw  PhoIndex    1.68000     +/- 0.
   5   5   3   powerlaw  norm        1.00000     +/- 0.
 ---------------------------------------------------------------
 Chi-Squared = 299.8 using 256 PHA bins.
 Reduced chi-squared = 1.194
```

8.1.3 Specify Background and Effective Area

At this point, the background file and effective area file must be specified, again, for layer 1. XSPEC always looks for a background spectrum to use with the model when generating a fake spectrum. To obtain the proper statistical response, the user wants that background spectrum to be free of statistics so that it can be incorporated into the source + background correctly. The background files (cxb_ib_x.fak, where ‘x’ is the layer ID) in the anonymous FTP account do **not** include statistics and should be considered as ‘seed’ files only.

Return now to the example, where we specify the effective area (.arf) and the background.

```
XSPEC> backgr cxb_ib_l1.fak
 Net count rate (cts/cm^2/s) for file 1 -42.17 +/- 6.5684E-02
 Chi-Squared = 4.2184E+05 using 256 PHA bins.
 Reduced chi-squared = 1681.
XSPEC> arf 5det_l1.arf
 Chi-Squared = 2.4511E+09 using 256 PHA bins.
 Reduced chi-squared = 9.7654E+06
```

A ‘show’ at this point would reveal that the background and auxiliary file pointers have been set.

8.1.4 Apply Background Statistics

The background file that has been read in does **not** have any statistics on the individual channel bins. To obtain proper χ^2 statistics, the background spectrum must have the proper statistics. To achieve that goal, another ‘fakeit’ must be used prior to generating a “real” fake spectrum. This time, set the model continuum normalization to zero; the ‘fakeit’ request will then generate statistics on the background as that will be the only “data” XSPEC sees.

```
XSPEC> newpar 5 0.0
 5 variable fit parameters
 Chi-Squared = 1.6015E+07 using 256 PHA bins.
 Reduced chi-squared = 6.3805E+04
XSPEC> fakeit
```

```
 Use counting statistics in creating fake data? (y)
 Input optional fake file prefix (max 12 chars):
 Override default values for file # 1
 Fake data filename (cxb_ib_l1.fak):test-bk.fak (Note name change)
 T, A, Bkg, cornorm ( 10000. , 1.0000 , 1.0000 , 0. ): 100000.0
 Net count rate (cts/cm^2/s) for file 1 -4.1750E-02+/- 6.8503E-02
 Chi-Squared = 25.48 using 256 PHA bins.
 Reduced chi-squared = 0.1015
```

(A parenthetical comment: the user should note that, if s/he wishes to re-use this background file for other sources, then it should be renamed so it is saved (the name change), and one of the keywords should be fixed. The keyword in question is the ‘`backfile`’ keyword. When the background file is generated, the keyword points to the seed file (the ‘`cxb_ib_X.fak`’ file). Properly, the background file should point to itself, since XSPEC automatically subtracts the background file if the XSPEC-associated background pointer is set. If the keyword ‘`backfile`’ points to itself, then, if this file is ever read into XSPEC as a data file, the user will be alerted that it is really a background file. To fix the ‘`backfile`’ keyword, use the following FTool:

```
    grppha test-bk.fak
    chkey backfile test-bk.fak)
```

8.1.5 Set Model Normalization

Restore the model normalization to 1.0 and be certain the background file pointer is set to the no-statistics background (the “seed” file ‘`cxb_ib_l1.fak`’). Fake the spectrum and look at the count rate. It should be rather high. Now set the background file pointer to the proper background file (recall that XSPEC automatically subtracts the background) (‘`test-bk.fak`’). Check the flux.

```
XSPEC> flux 2 10
 Model flux 0.2711 photons (2.4537E-09 ergs)cm**-2 s**-1 ( 2.000-
10.000)
```

The count rate (1652 cts/s) and the 2-10 keV flux obtained are not correct because the model normalizations appropriate to NGC 4151 have not been set. The Weaver et al. paper includes the flux in the 2-10 keV energy band. The continuum normalization follows from the ratio of the published flux to the calculated flux. In this case, the published continuum flux is approximately 1.37×10^{-10} ergs s^{-1} cm^{-2} in the 2-10 keV band. As the calculated flux is about 2.45×10^{-9} ergs s^{-1} cm^{-2}, the power law normalization should be about 0.056.

```
XSPEC> newpar 5 0.056
 6 variable fit parameters
 Chi-Squared = 86.86 using 256 PHA bins.
 Reduced chi-squared = 0.3475
```

With the model normalization now set, re-set the background to the seed file (‘cxb_ib_l1.fak’) and fake the spectrum again. The result should be the simulated spectrum of NGC 4151 using the *first* layer of the PCA.

```
XSPEC> fakeit
Use counting statistics in creating fake data? (y)
 Input optional fake file prefix (max 12 chars):
 Override default values for file # 1
 Fake data filename (test-bk.fak):cxb_ib_l1.fak
 T, A, Bkg, cornorm ( 1.00000E+05, 1.0000 , 1.0000 , 0. ): 10000.0
 Net count rate (cts/cm^2/s) for file 1 92.46 +/- 0.1295
 Chi-Squared = 145.3 using 256 PHA bins.
 Reduced chi-squared = 0.5788
```

The above contortions have produced a fake data file, with proper pointers and statistics, for the *first* PCA layer. The prescription above should be repeated for layers 2 and 3 (5det_l2.rmf, 5det_l3.rmf, etc.) if the contributions of the other two layers will be significant. If the contributions of layers 2 and 3 are not significant, the reader may skip the next section.

8.1.6 Generate Final Spectrum

First, treat the fake data files created as “observed” data files. (Ignore any warning messages about detector ID mismatches.) Having worked through the tedious process in the sections above, the user will note that once the data files are read in, so, too, are the effective area files, the background files, and the response matrices.

```
XSPEC> data 5det_l1_t.fak 5det_l2_t.fak 5det_l3_t.fak
 Net count rate (cts/cm^2/s) for file 1 92.46 +/- 0.1295
 Net count rate (cts/cm^2/s) for file 2 15.81 +/- 7.9917E-02
 Net count rate (cts/cm^2/s) for file 3 7.631 +/- 7.5193E-02
 Chi-Squared = 405.0 using 768 PHA bins.
 Reduced chi-squared = 0.5309
XSPEC> show
 15:50:56 26-Oct-94
 Fit statistic in use is Chi-Squared
 Minimization technique is Lev-Marq
 Convergence criterion = 1.0000000000000D-02
 Querying enabled
 Prefit-renorming enabled
 Log file : xspec.log
 Information for file 1
 belonging to plot group 1, data group 1, det id = XTE PCA XTE PCA
```

```
 Current data file: 5det_l1_t.fak
 Background file :cxb_ib_l1.fak
 No current correction
 Response (RMF) file : 5det_l1.rmf
 Auxiliary (ARF) file : 5det_l1.arf
 Noticed channels 1 to 256
 File observed count rate 92.46 +/-0.12953 cts/cm^2/s
 92.46 +/-0.12953 cts/s
 After correction of 0. ; Model predicted rate: 82.62

 Information for file 2
 belonging to plot group 2, data group 1, det id = XTE PCA XTE PCA
 Current data file: 5det_l2_t.fak
 Background file :cxb_ib_l2.fak
 No current correction
 Response (RMF) file : 5det_l2.rmf
 Auxiliary (ARF) file : 5det_l2.arf
 Noticed channels 1 to 256
 File observed count rate 15.81 +/-7.99168E-02 cts/cm^2/s
14.15 +/-7.99168E-02 cts/s
 After correction of 0. ; Model predicted rate: 14.07

 Information for file 3
 belonging to plot group 3, data group 1, det id = XTE PCA XTE PCA
 Current data file: 5det_l3_t.fak
 Background file :cxb_ib_l3.fak
 No current correction
 Response (RMF) file : 5det_l3.rmf
 Auxiliary (ARF) file : 5det_l3.arf
 Noticed channels 1 to 256
 File observed count rate 7.631 +/-7.51929E-02 cts/cm^2/s
 6.863 +/-7.51929E-02 cts/s
 After correction of 0. ; Model predicted rate: 6.905

 -------------------------------------------------------------
 mo = wabs[1] pcfabs[2] (powerlaw[3])
 Model Fit Model Component Parameter Value
 par par comp
  1   1   1   wabs            nH 10^22   7.00000   +/- 0.
  2   2   2   pcfabs          nH 10^22   3.00000   +/- 0.
```

```
  3   3   2   pcfabs          CvrFract   0.900000  +/- 0.
  4   4   3   powerlaw        PhoIndex   1.68000   +/- 0.
  5   5   3   powerlaw        norm       5.000E-02 +/- 0.
 -------------------------------------------------------------
 Chi-Squared = 405.0 using 768 PHA bins.
 Reduced chi-squared = 0.5309
```

Now, issue the final ‘fakeit’ request, entering a realistic observation time.

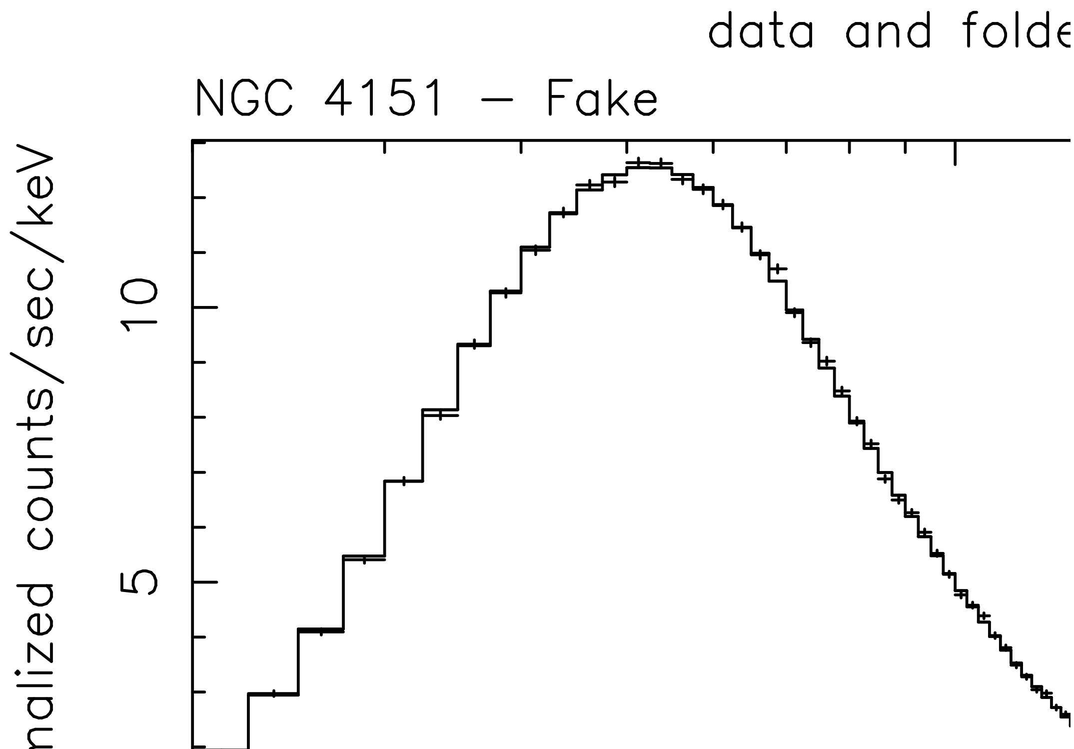
```
XSPEC> fakeit
 Use counting statistics in creating fake data? (y)
 Input optional fake file prefix (max 12 chars):
 Override default values for file # 1
 Fake data filename (5det_l1_t.fak): 5det_test.fak
 T, A, Bkg, cornorm ( 10000. , 1.0000 , 1.0000 , 0. ): 1000.0
 Override default values for file # 2
 Fake data filename (5det_l2_t.fak): 5det_test2.fak
 T, A, Bkg, cornorm ( 10000. , 1.0000 , 1.0000 , 0. ): 1000.0
 Override default values for file # 3
 Fake data filename (5det_l3_t.fak): 5det_test3.fak
 T, A, Bkg, cornorm ( 10000. , 1.0000 , 1.0000 , 0. ): 1000.0
 Net count rate (cts/cm^2/s) for file 1 92.61 +/- 0.3735
 Net count rate (cts/cm^2/s) for file 2 15.78 +/- 0.2077
 Net count rate (cts/cm^2/s) for file 3 7.534 +/- 0.1867
 Chi-Squared = 776.5 using 768 PHA bins.
 Reduced chi-squared = 1.018
XSPEC> backgr 1:1 test-bk1.fak 2:2 test-bk2.fak 3:3 test-bk3.fak
XSPEC> flux 2.0 10.0
Model flux 1.5179E-02 photons (1.3741E-10 ergs) cm**-2 s**-1 ( 2.00-
10.00)
```

Figure 1 (next page) shows the result of the above simulation. Note the peak at about 5 keV. The PCA effective area is largest at this energy. Also note that χ^2 is approximately the number of degrees of freedom, as required. The flux is within a few percent of the published value.

8.1.7 Add Fe Line

Now, add the gaussian component representing the iron line, and fake the spectrum again. The same procedure should be followed to obtain the gaussian normalization as was done for the continuum normalization. Here, the correct normalization is already “known”.

```
XSPEC> addcomp 4 gauss
```




```
Input parameter value, delta, min, bot, top, and max values for ...
Mod parameter 6 of component 4 gaussian LineE
6.500 5.0000E-02 0. 0. 100.0 100.0
6.4
Mod parameter 7 of component 4 gaussian Sigma
0.1000 5.0000E-02 0. 0. 10.00 20.00
0.3
Mod parameter 8 of component 4 gaussian norm
1.000 1.0000E-03 0. 0. 1.0000E+05 1.0000E+06
5.0e-4
---------------------------------------------------------------
mo = wabs[1] pcfabs[2] (powerlaw[3] + gaussian[4])
Model Fit Model Component Parameter Value
par par comp
  1   1   1    wabs       nH 10^22    7.00000    +/- 0.
  2   2   2    pcfabs     nH 10^22    3.00000    +/- 0.
```

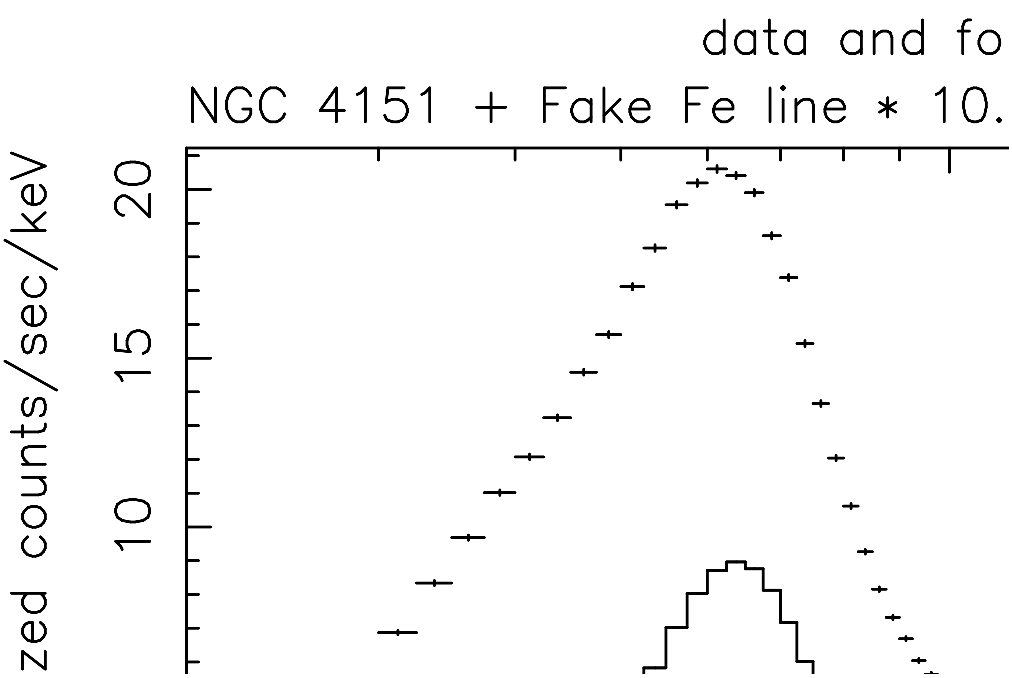
```
   3   3   2    pcfabs    CvrFract    0.900000   +/- 0.
   4   4   3    powerlaw  PhoIndex    1.68000    +/- 0.
   5   5   3    powerlaw  norm        5.0000E-02 +/- 0.
   6   6   4    gaussian  LineE       6.40000    +/- 0.
   7   7   4    gaussian  Sigma       0.300000   +/- 0.
   8   8   4    gaussian  norm        5.0000E-04 +/- 0.
 -------------------------------------------------------------
 8 variable fit parameters
 Chi-Squared = 883.9 using 768 PHA bins.
 Reduced chi-squared = 1.163
XSPEC> backgr 1:1 cxb_ib_l1.fak 2:2 cxb_ib_l2.fak 3:3 cxb_ib_l3.fak
XSPEC> fakeit
 Use counting statistics in creating fake data? (y)
 Input optional fake file prefix (max 12 chars):
 Override default values for file # 1
 Fake data filename (5det_test.fak): 5det_t1_G.fak
 T, A, Bkg, cornorm ( 1000.0 , 1.0000 , 1.0000 , 0. ):
 Override default values for file # 2
 Fake data filename (5det_test2.fak): 5det_t2_G.fak
 T, A, Bkg, cornorm ( 1000.0 , 1.0000 , 1.0000 , 0. ): 1000.0
 Override default values for file # 3
 Fake data filename (5det_test3.fak): 5det_t3_G.fak
 T, A, Bkg, cornorm ( 1000.0 , 1.0000 , 1.0000 , 0. ): 1000.0
 Net count rate (cts/cm^2/s) for file 1 94.90 +/- 0.3766
 Net count rate (cts/cm^2/s) for file 2 15.75 +/- 0.2076
 Net count rate (cts/cm^2/s) for file 3 7.915 +/- 0.1877
 Chi-Squared = 649.4 using 768 PHA bins.
 Reduced chi-squared = 0.8545
XSPEC> eqw 4
Additive group equiv width for model 4 (gaussian): 214. eV
```

The result does not show a particularly strong iron line. Increase the normalization of the iron line by a factor of 10 (science fiction, but useful for illustration).

```
XSPEC> newpar 8 5.0e-3
 8 variable fit parameters
 Chi-Squared = 1.1760E+04 using 768 PHA bins.
 Reduced chi-squared = 15.47
XSPEC> fakeit
 Use counting statistics in creating fake data? (y)
 Input optional fake file prefix (max 12 chars):
```

```
 Override default values for file # 1
 Fake data filename (5det_test1_G.fak):
 T, A, Bkg, cornorm ( 1000.0 , 1.0000 , 1.0000 , 0. ):
 Override default values for file # 2
 Fake data filename (5det_test2_G.fak):
 T, A, Bkg, cornorm ( 1000.0 , 1.0000 , 1.0000 , 0. ):
 Override default values for file # 3
 Fake data filename (5det_test3_G.fak):
 T, A, Bkg, cornorm ( 1000.0 , 1.0000 , 1.0000 , 0. ):
 Net count rate (cts/cm^2/s) for file 1 117.2 +/- 0.4054
 Net count rate (cts/cm^2/s) for file 2 16.30 +/- 0.2089
 Net count rate (cts/cm^2/s) for file 3 7.959 +/- 0.1878
 Chi-Squared = 663.5 using 768 PHA bins.
 Reduced chi-squared = 0.8730
XSPEC> eqw 4
Additive group equiv width for model 4 (gaussian): 2.14 keV
```

The figure shows the spectrum with continuum model normalization set to zero so the line component is visible.



8.1.8 Fitting the Fake Spectrum

At this point, the desired data have been completely simulated. The user may wish to fit the simulated data (using the `fit` command) to see the extent of the errors. Once the spectrum has been fit, the χ^2 contours may be generated (by using the `steppar` command) to evaluate the scientific return that may be expected. Remember to switch between the background file without statistics (for generating a fake spectrum) and the background file with statistics (for fitting, or checking the flux).

8.1.9 Summary of Fake Spectrum Generation

To provide more ‘forest’ after the ‘trees’ of the past 8 sections, an outline is listed below of the steps to produce a fake spectrum.

a. Create a model

b. Use ‘fakeit none’ (will prompt user for redistribution matrix and effective area file). Note that the fake spectrum generated at this point will not have the proper statistics, nor any information from the background.

c. Set the background file pointer to the no-statistics seed file. Set the model normalization to zero.

d. Use ‘fakeit’ to generate a fake background file with the proper statistics. Rename this file so it is not over-written.

e. Re-set the model normalization. Check that the background file pointer is still set to the no-statistics seed file. Use ‘fakeit’ to generate a model file with the proper statistics on source + background.

f. Set the background file pointer to the background file with the proper statistics that you saved in (d) above. Use the ‘flux’ command to generate the model flux.

g. Adjust the model normalization so that the flux will be the correct flux for the source. Re-set the background file pointer so that it points to the background file without statistics.

h. Use ‘fakeit’ to generate the final fake spectrum for the first layer. Repeat steps b-h for layers 2 and 3 if necessary.

8.2 Using `PIMMS`

Now that we’ve simulated a spectrum, we want to check that the count rate is reasonable. `PIMMS` (Portable, Interactive, Multi-Mission Simulator) allows the user to produce a count rate. Whether the user uses `PIMMS` before or after XSPEC is by choice. The use of one can serve as a check on the use of the other. See Appendix 2 to obtain a copy of `PIMMS`.

The models available in `PIMMS` are a power law, thermal bremsstrahlung, and blackbody. Other models may be imported (see the `PIMMS` manual for help on this feature). The general approach to estimating a count rate is to specify the instrument (the default is the *ASCA* SIS), select a model, and specify the product (the default is a count rate). The user then activates `PIMMS` by using the ‘GO’ command.

The initial header for `PIMMS` is:

```
*** PIMMS Version 1.2 (1993 May 26 release) ***
 Reading mission directory, please wait
 * PIMMS simulation product is COUNT
 count rates for various instruments or intrinsic fluxes can be
estimated
 <--- Use ‘PRODUCT’ to simulate images
 * Current model is BREMSSTRAHLUNG, kT= 10.0000 keV; NH = 1.000E+21
 <--- Use ‘MODEL’ command to change
 * By default, input rate is taken to be
 Flux ( 2.000- 10.000 keV) in ergs/cm/cm/s
 <--- Use ‘FROM’ command to change the default
 * Simulation product will be
 Count rate in ASCA SIS
 <--- Use ‘INSTRUMENT’ command to switch to another instrument
```

We are interested in estimating a count rate for the PCA on XTE, so the command is:

```
 PIMMS > instrument xte pca
```

The model choice is the power law absorbed by a hydrogen column of $7 x 10^{22}$ cm^{-2}. As `PIMMS` does not have a rich suite of models, we will only consider the continuum contribution. The next command tells `PIMMS` to calculate the count rate based upon the 2-10 keV flux of NGC 4151 (with units of ergs cm^{-2} s^{-1}, indicated by the key word “ergs”). The resulting count rate, 174.7 counts/sec, is somewhat close to the estimated count rate from `XSPEC` (118 counts/sec).

```
 PIMMS > mo pl 1.68 7.0e+22
 PIMMS > go 1.8e-10 flux ergs 2-10
 * For power law model with photon index = 1.6800; NH = 7.000E+22
 and a flux ( 2.000- 10.000keV) of 1.800E-10 ergs/cm/cm/s
 (Model normalization = 6.577E-02)
 * PIMMS predicts 1.747E+02 cps with XTE PCA
 PIMMS >
```

8.3 Using `recommd`

`recommd` is the EDS configuration recommendation tool. It was written by Dr. A. Rots of the XTE GOF. `recommd` generates a table of recommended configurations for the EDS for given count and telemetry rates. It assumes that the user has used `PIMMS` or `XSPEC` to generate a count rate for each of the following 6 energy bands: 0-3.2 keV, 3.2-4.3 keV, 4.3-5.7 keV, 5.7-8.6 keV, 8.6-12.1 keV, and 12.1-60.0 keV for the PCA. `PIMMS` will generate count rates for each of these bands as a default option whenever the chosen instrument is the XTE PCA. `recommd` is available from the anonymous FTP account.

The input to `recommd` consists of:

- the number of Event Analyzers to be used;
- the allowed telemetry rate (a guest observer must argue increasingly effectively for telemetry rates above 20 kbps);
- an estimate of the observing efficiency (for now, assume 50%);
- the desired time resolution (or “optimize” or “don’t care”);
- the spectral resolution desired (or “optimize” or “don’t care”);
- the count rates in the above-mentioned energy bands
- the quantity of output desired from `recommd`.

The output of `recommd` will be the top N (as specified by the user) possible EDS configurations that match the observer’s criteria and will be ranked in order of decreasing suitability. Guest observers are free to choose any of the configurations, however, configurations that are less suitable may need additional justification in the proposal.

```
===> RECOMMD, the EDS Configuration Selection Assistant  $Revision: 2.3
===> Results (up to 4 Event Analyzers) for:

     Time resolution:  1.000000 s,     Number of channels  : 128.000000
     alpha =  0.500, beta =  0.500,    alpha =  2.000, beta =  0.125

     Telemetry rate : 18.000000 kb/s, Observing efficiency: 65.000000
     alpha =  4.000, beta =  0.125, gamma =  1.000, breakpoint factor =  1.49
     alpha =  4.000, beta =  0.062 for count capacity
     Bonus factor for detector (PCU) Id:  1.0
     The input source spectrum leads to the following estimates for each of the six canon-
ical bands:
____________________________________________________________________________________
Channel limits          0.0- 13     14- 17     18- 23     24- 35     36- 49   50-249
Energy limits (keV):  0.0- 3.2    3.2- 4.3   4.3- 5.7   5.7- 8.6   8.6-12.1  12.1-60.0
Weights:                0.167      0.167      0.167      0.167      0.167      0.167
Source spectrum:        7.13      12.95      16.03      24.23      15.68      42.88
```

```
Fraction in layer 1:    0.99        0.96       0.95       0.94       0.74       0.48
Background spectrum:    5.84        1.80       2.76       5.28       5.96      69.20
Fraction in layer 1:    0.56        0.55       0.54       0.53       0.51       0.44
S/N (all layers):       1.644       3.183      3.453      4.108      2.985      3.185
S/N (layer 1 only):     1.914       3.275      3.569      4.276      2.759      2.280
S/N (layers 2+3):       0.031       0.354      0.439      0.574      1.295      2.232
```

The above section of the `recommd` output regurgitates the input parameters. Note the appearance of an ‘alpha’ and a ‘beta’ parameter for the time resolution and the number of channels. The alpha and beta parameters are weights placed upon the user’s choice of the respective parameters. In this particular example, greater spectral resolution receives higher weight than the time resolution, hence the alpha parameter is larger than the beta parameter. The absolute values of alpha and beta are not adjustable by the user, only their relative values. The output above also reproduces the input spectrum and calculates the signal-to-noise in each energy band in the layers.

The material that follows is the output of `recommd`. Only the top 7 recommended configurations are shown here for brevity. (Note that the output may change in detail, but not in spirit. Consult the anonymous FTP account for additional help.)

```
     For this source you may want to consider configurations with spectral distribution
indicator M, if available.

===> Please check whether Standard Mode 2 might satisfy your requirements already
===> You may not need a special configuration

     Recommended Configurations:

Suitability   TLMRate    Configuration    ConfigId   TLM     T_Res   Num    Max    logSuit.
                                                     Rate            Chan   CntRate
         (avg total PCA)
1.30431e+03  11.021  GoodXenon1_16s    0x01000024   5.510  0.000001  256   894.9    3.5405
           ( 10.163  GoodXenon2_16s    0x01000025   5.510  0.000001  256   895.9    3.5405

1.30242e+03  11.149  GoodXenon1_2s     0x01000016   5.574  0.000001  256 8063.0    3.5405
           ( 10.247) GoodXenon2_2s     0x01000017   5.574  0.000001  256 8063.0    3.5405

7.47413e+01   5.517  E_16us_64M_0_8s   0x01000041   5.517  0.000016   64 1919.9    4.1352
             (6.586)

7.45504e+01   5.631  E_16us_64M_0_1s   0x01000040   5.631  0.000016   64 16255.0   4.1352
            ( 6.660)

7.26623e+01   7.602  E_250us_128M_0_8s 0x0100004f   7.602  0.000250  128 1791.0    4.1470
            ( 7.941)

7.25272e+01   7.716  E_250us_128M_0_1s 0x0100004e   7.716  0.000250  128 16127.0   4.1470
```

```
           ( 8.016)

5.14963e+01  10.400  B_16ms_10M_0_13_H  0x02000028   5.094  0.016000   10 15937.5    0.0920
           (  9.760) E_16us_64M_14_8s   0x0100006b   5.306  0.000016   64  1919.9   3.7498
```

The columns are briefly described. The ‘suitability’ measures each configuration, that are then ranked from high suitability to low, and is the sum of the suitabilities for each mode independently. The ‘TLM Rate’ column lists the total telemetry rate for both the binned and the event modes. The configuration column lists the exact configuration label that should be entered on the proposal. The ‘ConfigID’ column is an internal representation of the exact configuration. The second ‘TLM Rate’ column lists the telemetry rate for each of the configurations independently. The time resolution (‘TimeRes’) should be optimized, as the input choice was a “don’t care” condition. The number of channels (‘NumChn’) lists the number of spectral channels to be used for that configuration. Finally, the ‘MaxCntRate’ column indicates the maximum count rate for that configuration within the alloted telemetry. In the example above, the maximum count rate is always above the estimated source count rate.

Note that the top recommended configurations are the GoodXenon configurations. For weak sources, this is perhaps the most appropriate choice, as every event is telemetered to the ground. For brighter sources, binned event modes are necessary to remain within reasonable telemetry limits.

The user is free to choose any of the configurations. The chosen configuration will be checked, however, for its overall suitability. Large differences between the chosen and the most suitable configuration(s) must be justified in the feasibility section of the proposal. The user should note that there are situations where a slight increase in the telemetry rate can yield considerably more information than the `recommd` output may suggest. For example, in the sample above, one of the recommended configurations (near the bottom) is a binned event mode, generating 5.09 kbps. For a slight increase in telemetry (5.09 kbps vs. 5.51 kbps), the user can request a GoodXenon events configuration and download every event. `‘recommd’` is an advisor, but should not be a substitute for good knowledge of the capabilities of the EDS nor informed thought.

8.4 Using the FTOOLS Routines

In this section, an illustration of the use of the FTOOLS tasks will be given. Only two FTOOLS will be demonstrated (the ‘fakelc’ and ‘addsine’ routines), but the other FTOOLS will resemble the demonstration to be presented here. The FTOOLS are available from the anonymous FTP account on `legacy.gsfc.nasa.gov` in the `software/` directory. Considerable information is available, including user guides, developers guides, and installation guides. Instructions on obtaining access to the FTP account are presented in Appendix 2 of this technical manual.

The general approach to using the FTOOLS to simulate timing behavior is the generation of a light curve. The first FTOOL that must be used is ‘fakelc’, the fake light curve generator. Once the fake light curve exists, it may be modified by adding additional timing behavior to it. For example, the demonstration here will add a sine wave to the fake light curve. All of the FTOOLS tasks are stand-alone FORTRAN programs. Parameter-prompting provides the user interface to the software.

8.4.1 Using 'fakelc'

'fakelc' generates a fake light curve. The user must supply a file name, whether 'fakelc' should generate a binned or event light curve (at the time of writing, only the binned mode will work with other FTOOLS in subsequent use), the observation start time, the bin size and its units, the mean intensity and its units, and a noise option. The file name can be any string; the generated file will be a FITS file that conforms with the OGIP FITS file standards. The time span of the observation time is the total exposure (i.e. 'live') time, exclusive of data gaps. The user may specify that data gaps be inserted, either according to earth occultations and SAA passages in the XTE orbit, or at fixed intervals. See the help file for full details. The input intensity may be either "count/s" or "count" per bin size. In event mode, if count is used, a rate is computed using the bin size. The noise options are (1) Poisson noise and (2) Gaussian noise. The choice of Gaussian noise requires specification of the sigma of the distribution.

The output of 'fakelc' is a FITS file containing the light curve. This light curve may be examined with any software capable of handling the FITS file. The software package `XRONOS`, the timing leg of the XANADU triad of software (`XSPEC` and `XIMAGE` are the other two) will read and plot this light curve. An example of a 'fakelc' run appears below. (Parameters from the previous run appear in paranthesis, and are used as the defaults).

```
unix> fakelc
Name of output FITS file (testg3.lc): testg4.lc
Type of Light Curve: (E) Event or (B) Binned (B): B
Bin Size/Sampling Precision (0.1):
Units for bin size (s=sec, d=days) (s):
Mean intensity (10):
Units for intensity (count/s):
Noise Option (1):
Total Time span of the obsesrvation (1000):
Units for the time span (s=sec, d=days) (s):
```

8.4.2 Using 'addsine'

'addsine' allows the user to add a sine curve to the fake light curve generated with 'fakelc'. The output file from 'fakelc' is the input file to 'addsine' (and to most of the other FTOOLS tasks used for timing simulations). The 'time interval to have sine added to' represents the time intervals (in MJD) in which the sine wave will be added. Those intervals are specified as 'start_time-stop_time'. Either the start or the stop time may be omitted to signify the default for the missing item. Additional parameters are listed in the log file below and include the period of the sine curve, its amplitude, the time of phase zero, and the noise option. The user may also specify a pulse shape to be inserted at the given period.

The output of 'addsine' is another FITS file that again can be used in FITS-compatible software such as XRONOS.

```
unix> addsine
Name of FITS file and [ext#] (testg3.lc): testg4.lc
Name of output FITS file (testg3a.lc): testg4a.lc
Time interval(s) to have sine added to (-):
Period of Sine curve (20): 1000.0
Units for period (s or d) (s):
Amplitude of Sine Curve (20):
Time of Zero Phase of Sine Curve (in MJD) (49000):
Noise Option (1):
```

8.4.3 Additional FTOOLS for Timing Simulation

The following FTOOLS tasks exist for timing simulation at the time this section was written (8/94):

- addshots - add shot noise to an input light curve
- perdgrm - perform Fourier analysis on a light curve using J. Scargle's algorithm (this routine is capable of handling unevenly distributed data)

8.5 Using XRONOS

XRONOS provides the user a tool for timing analysis in a manner similar the use XSPEC provides for spectra. XRONOS is available from the anonymous FTP account on `legacy.gsfc.nasa.gov` in the `software/` directory. XRONOS is a shell wrapped around a series of "stand-alone" FORTRAN programs that each handle a single aspect of timing analysis. For example, once inside XRONOS, the command 'acf' calls the autocorrelation function.

Available analysis tools within XRONOS include:

- plot light curve for 1, 2, or 3 time series plus ratio and color-color (if appropriate)
- perform epoch folding for 1 or 2 time series
- perform epoch folding search for periodicities
- power spectrum density analysis
- autocorrelation function analysis

- cross-correlation function analysis

Additional capabilities are likely to be forthcoming.

The user has full control of the binning used in the analysis when using `XRONOS`. As such, of fundamental importance in are the following definitions.

- Bins: these are the time bins of the time series *being analyzed;*
- Newbins: these correspond to the time resolution with which the analysis is done; clearly, newbins cannot be shorter than the longest bin duration of the time series;
- Intervals: this is defined as the number of newbins over which the analysis is done;
- Frames: this consists of the average of the results of the analysis of one or more contiguous intervals; a frame may consist of only one interval.

Full details are contained in the `XRONOS` User's Manual, available from the HEASARC (`humphrey@heasarc.gsfc.nasa.gov).` An example is not presented here as a walk-through exists in the `XRONOS` manual.

Chapter 9

PCA Feasibility

To discuss the feasibility of various types of astrophysical observations with the Proportional Counter Array it is necessary to discuss both the PCA and EDS as a single system together with the constraints imposed by the XTE spacecraft systems. The principle user of telemetry capacity is the PCA/EDS combination. The amount of data this produces depends on the selected EDS Modes and is very variable.

The reader should note that many of the instrument-specific details are covered in the PCA chapter. A reader familiar with, for example, the feasibility chapter of the ASCA SIS, will notice differences between the SIS chapter and the description to be presented here in that many details vital to a proposer of an SIS observation were described in the feasibility chapter itself. The combination of the PCA and EDS requires a different approach.

9.1 PCA Count Rates

The PCA response, both energy and timing, depends on the event rate. This dependence is completely negligible when the event rate in one detector is below about 10,000 counts/sec, approximately equal to 5 Crabs. Efforts have been made to characterize the detector response for the relatively "normal" event rates. When the event rate in a detector becomes abnormally high, say, above 10,000 counts/sec, there are a number of complicating factors (see section 9.4 for details). The user is advised to keep this in mind when observing the brightest sources.

Bright galactic x-ray sources are a class of primary targets for XTE. Efforts have been made to insure that the proportional counters will function properly under intense x-ray illumination. But still the GO has to take into account the detector dead time when extremely bright sources (above 10

Crab) are to be observed. For example, a PCA detector has a dead time of 10 μs for each event, and in particular, this deadtime is of the paralyzable type. In other words, to a good approximation, the output rate and input rate are related by $r_{out} = r_{in} \exp(-r_{in} (10\ \mu s))$, which will reach a maximum of 36,000 events/sec when r_{in} = 100,000. A higher r_{in} than 100,000 events/sec will produce a lower output rate. Therefore when one is to observe any x-ray transients which will produce more than 100,000 counts/sec in one proportional counter, one has to do offset pointing in order to maximize the output event rate.

9.2 Background Determination and Sensitivity

The background in the PCA detectors, consisting of "internal" events not due to the transmission of source plus diffuse sky X-rays through the collimator, should be about the level of 1-2, 10, and 120 mCrab in count rates in the 2-10, 10-30, and 30-60 keV ranges, respectively. The spacecraft pointing will be held to an accuracy of about 10'' during observations and the PCA X-ray sky backgrond will be about constant during the observation. For some percent of the spacecraft orbit, when the source direction is not occulted by the earth and the satellite is not traversing regions of high charged particle concentration, the internal background will vary by 10-20% in a predictable manner. A burst of charged particles could cause an increase in background, but it will also cause an increase in the veto rates and be identifiable. Such events are expected to be infrequent during the majority of the mission. Thus the internal background for most observations can be assumed to be known within 10% and close to the nominal values given in the section below.

The deadtime depends on background, but the contribution is expected to be sufficiently small that we think that the simple approximation of a constant 10 μs deadtime per interaction for other events in the same detector is an adequate approximation for estimating feasibility of high time resolution sensitivities.

For sources a few mCrabs in intensity, the signal to noise increases as the square root of the observing time. For sources that are a fraction of the background in an energy range of interest, uncertainty in the background determines the limiting sensitivity. For a long observation the fluctuations in the internal background will average out and the limiting sensitivity will result from the uncertainty in the sky background in a particular direction.

9.2.1 Instrumental and Cosmic Backgrounds

Results from previous proportional counter experiments suggest that the in-orbit background, during good observing times, is 2-3 times that observed in the laboratory. PCU laboratory background spectra have a continuum and several lines (see fig. 6b in the PCA Instrument description chapter (chapter 4)). The line components are due to unflagged calibration events and to residual radioactivity in the collimator. It is assumed that the line components will have the same magnitude in orbit as in the lab, and the continuum component (which is fit as a low order polynomial) will be three times larger. The accompanying figures show the background spectrum computed from laboratory data and the above assumptions for each Xenon detection layer, and summed over all five detector units. Note that these spectra have statistical error bars representative of a 1 x 10^4 sec observation. The two figures show the same data plotted versus energy and detector channel.

The cosmic background has been estimated by taking a 40 keV bremsstrahlung spectrum normalized

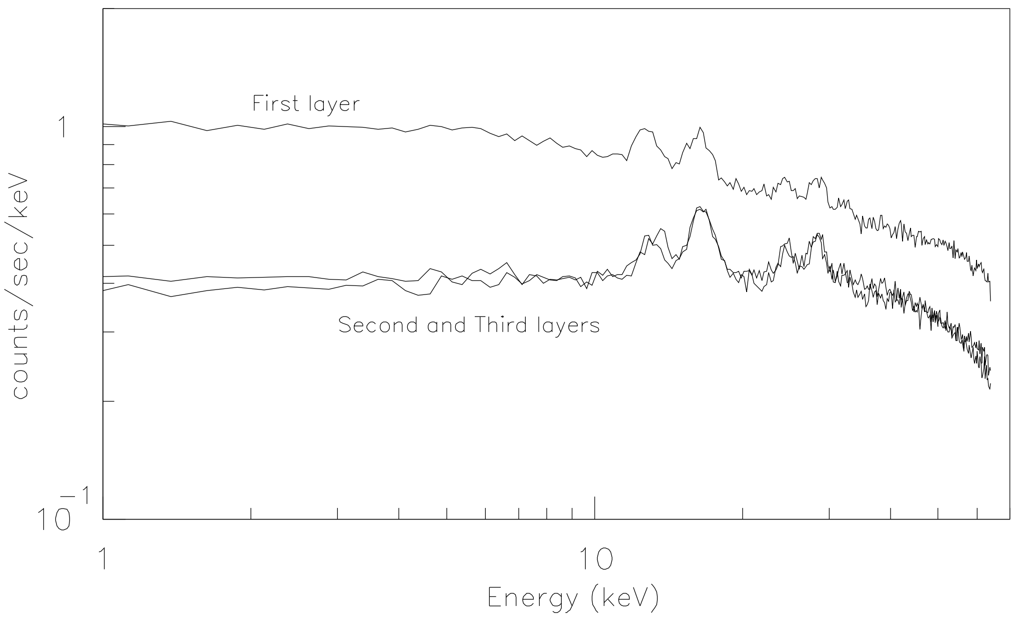


FIGURE 9.1. PCA background spectrum showing counts as a function of energy.

by 7 x 10^{-4}. This gives a flux of 1.6x10^{-12} erg/sec/cm^2/keV at 10 keV. Under the assumption that the PCA effective solid angle is 1 square degree this matches the flux reported by Marshall et al. (1980, ApJ, 235, 4) of 3.2 keV/sec/cm^2/sr/keV at 10 keV. For the purposes of making sensitivity estimates it is assumed that a 1 mCrab source has a spectrum with N(E) = 0.005 $E^{-1.7}$ photons/sec/cm^2 absorbed by a neutral column with N(H) = 3x10^{20} cm^{-2}.

9.2.2 Sensitivity Estimates

Using the instrumental and cosmic background estimates described previously we have computed the counting rates over three broad energy bands for each Xenon layer. These rates are given in the following table.

TABLE 9.1. Broad Band Rates (counts/sec)

	1 mCrab AGN	Cosmic Bkgd	Inst. Bkgd
2-10 keV			
layer 1	10.2	8.54	7.66
layer 2	0.52	0.47	3.16
layer 3	0.13	0.07	3.36
10-30 keV			
layer 1	1.80	1.80	15.5
layer 2	1.02	0.92	9.49
layer 3	0.66	0.56	9.38
30 - 60 keV			
layer 1	0.116	0.06	14.4
layer 2	0.086	0.06	10.7
layer 3	0.080	0.06	10.5

All entries in the table are counts/sec summed over 5 detectors for each of the indicated layers.

Using these numbers we have estimated the sensitivity in the 3 bands as a function of observing time. The sensitvity curves have been calculated assuming the signal to noise ratio is,

$$S / N = s T / ((s + b_c + b_i) T)^{1/2} ,$$

where s is the source strength (cts/sec), b_c is the cosmic background rate, b_i the instrumental background rate, and T is the length of the observation (sec). These results are displayed in the accompanying figures (Figure 9.3), one for each energy band, and for different assumed source intensities (see the figure headings). The user should be aware that source detection will be additionally complicated by fluctuations in the cosmic background, estimated to be about 10% / beam for the PCA field of view, as well as uncertainties in the instrumental background model, though these uncertainties should decrease as more is learned during the mission. Also note that the 2-10 keV curves were computed using the 1st Xenon layer only, while the curves for the higher energy bands were computed by summing all the layers.

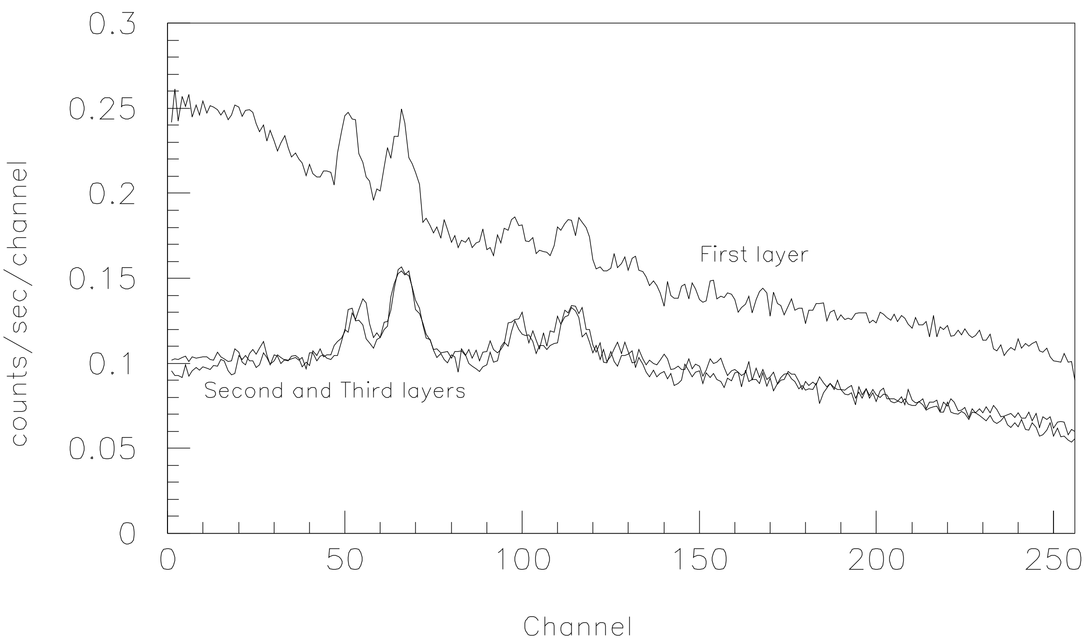


FIGURE 9.2. PCA background spectrum showing counts as a function of detector channel.

9.3 Spectral Resolution

The spectral resolution attainable with the PCA Xenon layers is approximately 18% at 6 keV and 9% at 22 keV. The propane layer has a resolution of 18% at 5.9 keV. These values will suffer some long term degradation during flight, but should remain quite good for the first two years of the mission (see also PCA Instrument Description). In principal the PCA can provide 256 channel pulse height spectra, however, in practice the final energy resolution of the data relayed to the ground will depend on several factors.

- The gain uniformity between all PCU's
- The selected EDS mode and its energy bin remapping prescription

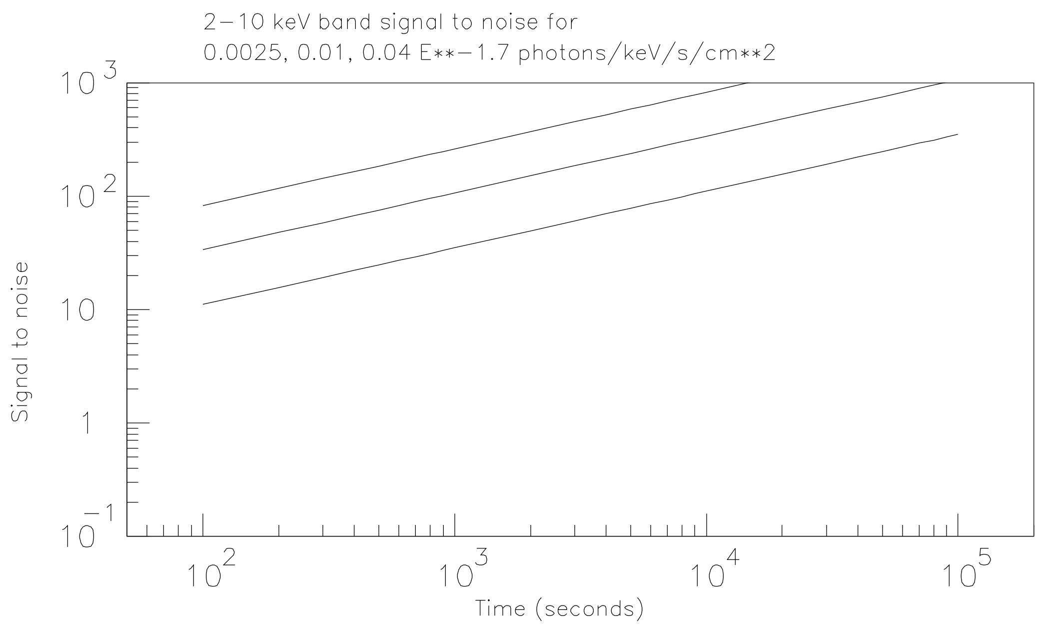


FIGURE 9.3. Plots showing the time necessary to reach a given signal to noise level.

Observers interested in spectral line searches and studies should be aware that EDS modes which do not retain the individual detector ID information will apply a gain and offset correction to all PHA values that will reduce the overall spectral resolution ultimately attainable with some modes. Observers wishing to retain the highest spectral resolution capabilites of the instrument should ensure that they receive “raw” PHA data with all detector ID information, but recognize that this may require trade-offs in temporal resolution or other observing parameters in order to remain within telemetry constraints. For more information see the PCA Instrument Description (Chapter 4).

9.4 Timing Characteristics

There are several timing characteristics of the PCA that are worthy of mention.

- The PCA/EDS logs photon arrival times with much finer resolution than the instrumental dead time. Although not unique this is rare in comparison with previous astronomical x-ray instruments
- Since time tagging is performed separately for each PCU it is possible for the first time to search for correlations at μs time scales
- FFT’s can be performed on-board or on the ground with frequencies up to ~500 kHz. This is far beyond the 0.1 - 1 kHz range of previous experiments

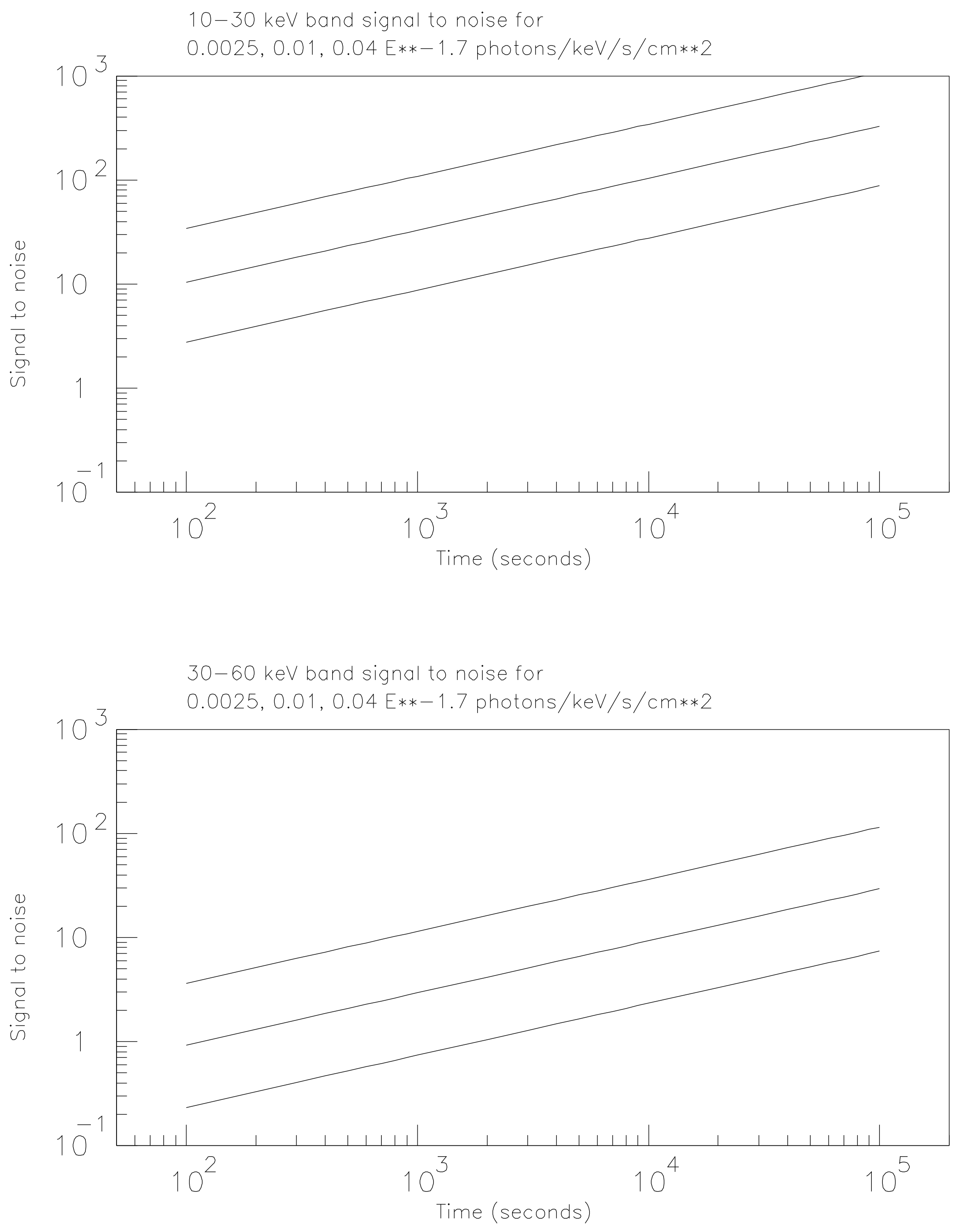


FIGURE 9.3. (continued) Plots showing the time necessary to reach a given signal-to-noise level.

In principle, the XTE/PCA instrument has been designed to allow one to study phenonmena on time scales from a couple of hours, which are set by the satellite orbital period, down to microseconds. In practice, however, a number of factors have to be properly taken into account before such a vast range of timescales can be addressed. At the writing of this document, efforts are still underway to understand and to characterize these factors. Here we briefly describe the effects that we have uncovered so far, some of which are of the general nature that exist in every other real detector, while others are rather unique to the XTE/PCA detectors. A detailed document describing the various factors will be made available at a later date.

A PCA detector has a deadtime of 10 microseconds for each event. This deadtime is of the paralyzable type. In particular, the deadtime is pulse-height dependent. In other words, a 30 keV x-ray will generate a larger deadtime than a 5 keV one. Since for the great majority of real x-ray sources, most of the detected photons have an energy of 10 keV or less , a constant deadtime is a very good approximation. This approximation is certainly valid for both energy spectral analyses and for timing analyses when the count rate is low, say less than 10,000 counts per second per detector, or when the time scale investigated is much larger, say, by a factor of ten, than the deadtime.

When the count rate becomes extremely high and/or the time scale investigated comes close or comparable to the detector deadtime of 10 microseconds, a number of otherwise innocuous effects start to become important. Among these are the following;

- The energy-dependency of the deadtime.
- The anticoincidence logic that is used to reject background starts to reject a significant number of genuine events.
- The Very-Large-Event (VLE) window, which is set to eliminate the ringing of electronics following unusally large depositions of energy by either x-rays or charged particles, shows a clear signature in the power spectrum.
- The fact that several anode chains in one detector share the same analog-digital converter (ADC) will show up as a modification to the idealization of paralyzability of the detector deadtime.
- The detector gain and resolution as a function of the count rate.

A formalism that will properly take these factors into account is being developed and will be made available at a later time.

9.5 Telemetry Limitations

All previous X-ray satellites have had various telemetry limitations and in some cases these have been particularly severe. In comparison to the earlier satellites, XTE has enormous data handling and telemetry capabilities, but there are still sometimes serious practical limitations since the detectors are so large and the detected event rates so great for the brighter sources. There are several important aspects for telemetry usage:

- The mean usage rate - how constant or predictable is the source flux

- The total expected usage - i.e, the usage summed over all EAs over the total observing time
- If the source is unexpectedly bright - how fast might the allowed capacity be filled?

A unique aspect of XTE proposals is that, in addition to requesting a specific amount of observing time, the proposer must nominate specific telemetry configurations which affect the amount of telemetry required. For many objects, particularly extragalactic ones, this will not be a difficult calculation, as the sources will be relatively weak. Even in such a situation, however, the required telemetry to achieve the proposed science must be evaluated to “free up” capacity for other proposals within that “observing day” that need large amounts of telemetry to meet their science objectives. Thus for XTE, the principal of altruism becomes a very important concept. The interspersing of “low” telemetry requirement observations between “high” requirement ones is another requirement on the scheduling program SPIKE. Any “accumulated credit” only persists until the next data dump opportunity.

9.5.1 XTE Solid State Recorder

Although the telemetry system and the on-board data recording and playback are not formally part of the joint PCA/EDS experiment some simple understanding of their principles of operation is worthwhile. The telemetry estimations are an integral part of the feasibility assessment because careless choices could result in irregular return of data packets and data being lost. Unexpected or unanticipated source behavior can also lead to data loss for bright objects.

The XTE spacecraft does not have a tape recorder but it does have a ~920 Mbit solid state recorder. The recorder operates in a “bucket” form with data from the PCA/EDS flowing into it while at the same time data is being removed, usually nearly continuously, for down-link through the TDRSS system. The maximum possible gap between any down-link is assumed to be 4 orbits. The Virtual Channels (VC’s) in the recorder are sized to suit typical subsystem telemetry requirements. At the mean 20 kbps EDS science rate, the 4-orbit criteria is just met in VC 6 (see below). If an observed x-ray source suffers Earth Occultation and the XTE orbit also passes through the SAA the effective permissible on source telemetry rate may approach twice the continuous average. The data flow should be quasi-continuous for most of the time, however downlink will not be continuous for a number of reasons:

- The data is in packets, some of which arrive every 128 seconds
- There is a gap in coverage between TDRSS East and TDRSS West - the so called “zone of exclusion” (ZOE). After such a period, stored data will rapidly be replayed and emptied from the recorder
- Various technical problems or Shuttle activities may delay the final arrival of packets at the SOC ground system at GSFC

The solid state recorder is operated in several virtual channels which are shared between the spacecraft systems and the various experiments as partially shown in the Table 1.1. If the mean input to a VC channel (e.g. output from EDS) is greater than its mean output to the telemetry system, which is dependant on TDRSS contacts, then that channel will fill up. VC channels can be operated in two modes. Once full each VC channel can be in:

- An overwrite mode - old data is lost
- A wait for space to be freed up mode - current data is lost

The default state for XTE science VC data will be the “wait for space” option. XTE contact with TDRSS is normally through the Multi Access (MA) service but Single Access (SSA) service must be scheduled for dumping large parts of the solid state memory at high speed. This will be required when exiting the TDRSS ZOE and for any observations producing high data rates that substantially fill the EDS science virtual channel (VC 6).

9.5.2 Summary Of Telemetry Performance

The following table summarizes the key features of the telemetry system for the PCA/EDS combination. Notice that the user selection of EA Modes in the lower part of the Table dominates the storage capacity.

TABLE 9.2. Summary of Telemetry Performance

Item	Rate kbps	Recorder Capacity Mbits	Virtual Channel (VC)	Status
PCA Housekeeping	0.7	218 (included with all spacecraft data)	1	Always present
EDS Standard Mode 1	1.2	116 (included with ASM)	4	Always present except in SAA
EDS Standard Mode 2	2.1			Always present except in SAA
Other PCA EA’s				
Normal - total average	< 20	454	6	Optional Combinations, Normally OFF in SAA & Earth Occult.
Burst < ~ 30 minutes	at 256			
Burst < ~ 15 minutes	at 512			

9.5.3 Procedure To Calculate Telemetry

The following steps are required to calculate the telemetry requirements for any particular X-ray source:

- Run `PIMMS` or `XSPEC` for the target source spectrum and intensity to get the expected PCA counting rate versus energy
- Using `recommd`, select the desired configurations (see EDS Description, chapter 7) for the 4 user-selectable EA’s and specify the total observing time.

- Adjust the 4 EAs configurations (you may use none of them; in that case, your data will appear via the two Standard Modes) to reduce or to increase the telemetry as required for the desired science return.
- Experiment a bit with the source's spectral shape and rate to determine some upper and lower bounds to the possible counting rates you might expect from the source.

When running `recommd`, it is not necessary to retain a telemetry margin for the two Standard Modes and the housekeeping because these are already allowed for. They also use VC tracks different from the tracks used for PCA/EDS science data, so only serious technical problems should cause loss of the Standard Mode data.

9.6 Feasibility Studies: Specific Examples

The best way to illustrate the capabilities of the PCA/EDS is to present some examples. The following examples have been chosen to represent a range of typical sources. Note that these examples are not necessarily complete (i.e., they do not all start from a power law index and proceed to an EDS configuration); Chapter 8 contains a more detailed description from start to finish for a faint source with an emission line. The purpose of these examples is to illustrate choosing EDS configurations and their associated telemetry for a sampling of source intensities and properties. These examples should not be used in lieu of learning how the EDS works, or about the multitude of configurations possible, nor used in lieu of a calculation.

To aide proposers in choosing appropriate EDS configurations, the tool `recommd` (pronounced "recommend") is available. (For further information about `recommd`, see Chapter 8.) `recommd` takes background-subtracted source spectra and produces a list of recommended sets of EDS configurations. The user may also specify specific spectral and timing resolution requirements, modify the duty cycle (i.e. "observation efficiency"), and emphasize certain parts of the spectrum. Among its output items, `recommd` gives the telemetry in kilobits per second (kbps) of each individual configuration. This telemetry takes account of the type of mode, the timing and energy resolution, the overheads (e.g. time markers), and (where appropriate) the count rates. In addition, `recommd` provides approximate estimates for the signal-to-noise ratios.

`recommd` suggests only Binned, Event and Single Bit configurations. The proposer may specify additional configurations (e.g. FFT mode) as may be appropriate for the science objectives. Some of the examples below feature configurations in addition to those produced by `recommd`.

`recommd` uses as input a 6 channel PCA spectrum, given in counts/s. The channel and approximate energy boundaries are given in Table 9.3. Chapter 8 illustrates how to obtain this spectrum for a particular source using either `PIMMS` or `XSPEC`. In each of our examples below, we give this 6 channel spectrum. Also, unless otherwise mentioned, we use the default input values for `recommd`'s various options, and generally seek only 2 configurations from `recommd`. Note that the default observing efficiency of 65 % is appropriate only for observations expected to be spread over many satellite orbits. Objects observed for less than an orbit, or objects near the satellite orbit poles will have efficiencies larger than this. Examples here used version 2.3 of `recommd`.

See Chapter 7 for details about the EDS modes, and Appendix 1 for further details about the EDS configurations.

TABLE 9.3. Channel and Corresponding Energy Boundaries for PCA 6-channel Spectra

Channels:	**0 - 13**	**14 - 17**	**18 - 23**	**24 - 35**	**36 - 49**	**50 - 249**
Energies (keV):	0.0 - 3.2	3.2 - 4.3	4.3 - 5.7	5.7 - 8.6	8.6 - 12.1	12.1 - 60.0

9.6.1 The Crab

The six-point XTE spectrum, in counts per second, for the Crab is:

Energies (keV):	**0 - 3.2**	**3.2 - 4.3**	**4.3 - 5.7**	**5.7 - 8.6**	**8.6 - 12.1**	**12.1 - 60.0**
Crab	3304	2672	3206	3626	1971	1791

These count rates were obtained using a photon index of 1.8 and an absortion of 7.1 x 10^{21} cm^{-2}. We give here three scenarios for different telemetry and timing resolution requests.

9.6.1.1 Microsec Time Resolution, 256 kbps Telemetry Rate

In this example we seek the highest time resolution, and we facilitate this by requesting a generous telemetry rate. The high telemetry rate, however, cannot be sustained for more than the satellite's orbit, so the observation will take less than an orbit. Hence, the observing efficiency is 100 %. Thus, for microsec resolution, with a telemetry request up to 256 kbps, an observing efficiency of 100%, and requesting as much spectral resolution as possible within these limits, `recommd` gives:

EDS Configuration	**Time Resolution**	**Energy Range**	**Telemetry**
E_1us_4B_0_1s	1 µs	0.0 - 60.0 keV	267.0 kbps

This single Event Mode gives hight time resolution and limited spectral resolution as a result of the timing request and of the generous telemetry allocation. It produces 4 energy channels over the entire 0 - 60 keV range. The "B" spectral channel distribution, which is recommended, is reasonable since "B" was designed for the Crab.

A good alternative is:

EDS Configuration	**Time Resolution**	**Energy Range**	**Telemetry**
SB_31us_0_13_500 ms	31 µs	0.0 - 3.2 keV	36.3 kbps
E_1us_1M_14_1s	1 µs	3.2 - 60.0 keV	221.8 kbps

This Event configuration provides no spectral information, but retains the detector ID for where the event occurred. If one would rather have the detector ID than some crude spectral information, this configuration would be the right choice. If the time resolution requirement were relaxed, one could have spectral information as well as detector ID.

9.6.1.2 Millisec Time Resolution, Normal (18 kbps) Telemetry Rate

If we request as much spectral resolution as possible within the telemetry limit, a time resolution of 1 ms, an observing efficiency of 65%, and give higher weight to energies between 4.35 and 8.75 keV, `recommd` produces a set of four Single Bit Mode configurations, each with 0.5 ms resolution and each covering a different energy band. The two canonical bands (c.f. Table 9.3) between 4.3 and 8.6 keV are each covered by one configuration, while the remaining configurations cover two bands apiece. The configurations, their energy bands, and their telemetry are:

EDS Configuration	**Time Resolution**	**Energy Range**	**Telemetry**
SB_500us_0_17_2s	500 µs	0.0 - 4.3 keV	8.2 kbps
SB_500us_18_23_2s	500 µs	4.3 - 5.7 keV	5.4 kbps
SB_500us_24_35_2s	500 µs	5.7 - 8.6 keV	5.8 kbps
SB_500us_36_249_2s	500 µs	8.6 - 60.0 keV	6.0 kbps

Note that these configurations give a summed telemetry of 25.4 kbps.

Alternatively, one might decide to ignore the high energy band and just select a single binned configuration, like:

EDS Configuration	**Time Resolution**	**Energy Range**	**Telemetry**
B_1ms_8B_0_49_Q	1 ms	0.0 - 12.1 keV	32.6 kbps

This covers the band 0.0 - 12.1 keV with 8 spectral channels. The large telemetry of 32.6 kbps requires good arguments to defend this configuration against the first choice.

9.6.1.3 One Second Time Resolution, Normal (18 kbps) Telemetry Rate

Here we assume 65% observing efficiency, request as much spectral resolution as possible, and assign higher weight to energies between 4.35 and 8.75 keV. `recommd`'s first choice looks perfectly suited to the task:

EDS Configuration	Time Resolution	Energy Range	Telemetry
B_250ms_128M_0_254	250 ms	0.0 - 60.0 keV	21.7 kbps

This is the quarter-second Binned configuration that covers the entire energy range with high spectral resolution; in addition, it retains detector IDs (i.e. separate histograms are collected for each of the five detectors). The higher weight does not make any difference here.

9.6.2 A Medium Intensity Source

For this example, we wish to retain moderate spectral resolution at the low energies within the nominal telemetry budget. For our spectrum we choose an absorbed power law with photon index 1.8 and absorption of 7.1 x 10^{21} cm^{-2}. With a total count rate of ~ 8400 counts/s, the 6-channel PCA spectrum is:

Energies (keV):	0 - 3.2	3.2 - 4.3	4.3 - 5.7	5.7 - 8.6	8.6 - 12.1	12.1 - 60.0
Medium Source	1289	1167	1536	1942	1187	1265

Specifying 16 energy bins and optimizing the timing resolution, `recommd` gives the following pair of configurations:

EDS Configuration	Time Resolution	Energy Range	Telemetry
B_16ms_16B_0_49_H	16 ms	0.0 - 12.1 keV	8.1 kbps
E_1us_4M_50_8s	1 µs	12.1 - 60.0 keV	23.8 kbps

If the observer desired more energy information at the higher energies, one of the other Event modes suggested by `recommd` may be chosen.

Running `recommd` with a 12 kbps telemetry allocation results in less energy information at the higher energies but with a big telemetry savings:

EDS Configuration	Time Resolution	Energy Range	Telemetry
B_16ms_16B_0_49_H	16 ms	0.0 - 12.1 keV	8.1 kbps
SB_250us_50_249_2s	250 µs	12.1 - 60.0 keV	5.5 kbps

Proposers are encouraged to look for such telemetry savings when possible.

9.6.3 Weak Source, Low Telemetry Requirement

This source is covered in Chapter 8 as a demonstration of the use of `PIMMS`, `XSPEC`, and `recommd`.

9.6.4 Very Bright Source, High Telemetry Requirement

The following describes the EDS feasibility of observing a very bright TOO with the intensity and spectrum of A0620-00 (V616 Mon, Nova Mon). The spectral parameters used are

- power law_1, index = 4.70
- power law_1 normalization = 3500.0
- power law_2, index = 2.0
- power law_2 normalization = 0.20
- absorption column = 3.2×10^{21} cm^{-2}

The predicted count rates in counts/sec in the canonical PCA energy bands from `XSPEC` for the above parameters are:

Energies (keV):	0-3.2	3.2 - 4.3	4.3 - 5.7	5.7 - 8.6	8.6 - 12.1	12.1 - 60.0
X-ray Nova	80,553	31,633	19,877	9224	1809	545

With this input, `recommd` produces a list of pairs of Event and Binned modes, with the Event mode taking the higher energies. From the list, we choose a Binned mode which favors time resolution over energy resolution at the low energies. To catch the high energy tail, an Event mode with more channels is chosen. In addition to these, we have added two FFT modes, which together provide spectra and cross spectra for timescales between 1 microsecond and 4 ms.

EDS Configuration	Time Resolution	Energy Range	Telemetry
B_4ms_8A_0_49_H	4 ms	0.0 - 12.1 keV	16.3 kbps
E_4us_16M_50_8s	4 µs	12.1 - 60.0 keV	12.1 kbps
F_1us_12_249_16s	1 µs	0.0-3.2, 3.2-60.0	3.4 kbps
F_125us_12_249_16s	125 µs	0.0-3.2, 3.2-60.0	1.8 kbps

Utilizing 210 kbps and an observing efficiency of 100 %, the EDS modes and the corresponding telemetry rates produced are:

EDS Configuration	Time Resolution	Energy Range	Telemetry
B_2ms_8A_0_23_H	2 ms	0.0 - 5.7 keV	32.6 kbps
E_16us_64M_24_1s	16 µs	5.7 - 60.0 keV	192.2 kbps

D_1us_0_249_128_1s_F	1 µs	0.0 - 60.0 keV	2.5 kbps
F_31us_0_12_249_16s	31 µs	0.0-3.2, 3.2-60.0	2.9 kbps

Again, the Binned and Event configurations were chosen from the output of recommd, using the same criteria as for the 36 kbps case. Note that the summed telemetry for a set of configurations need only be less that the requested telemetry allocation divided by the observing efficiency. We replaced one of the FFT modes with a Delta-Binned mode to facilitate auto-correlation calculations at the smallest time scales. The disadvantage with the 1-µs FFT mode is the large dead-time associated with the mode. The disadvantage with the Delta-Binned mode is that it doesn't give the cross-spectra. In our two examples of available telemetry, we show both to illustrate the trade-offs. The final decision should be made in light of the the science goals.

9.6.5 Periodic Signal Detection

In this example, we first compute the 5-sigma detection limits for periodic signals in "Bright" and "Faint" sources. We compute these empirically by creating fake light curves using the FTOOLs `FAKELC` and `ADDSINE`. The dc level, which represents all sources of background and the steady component of the source, can be created using the FTOOL `FAKELC`. This dc level is created without adding noise. The sinusoidal variation can then be added using the FTOOL `ADDSINE`. Poisson statistics are applied to the summed dc and sinusiodal intensity. (See Chapter 8 for further details about `FAKELC` and `ADDSINE`). The resulting light curve may be analyzed using the `DPS` function in `XRONOS`, which gives the confidence level for detection of a signal (see Chapter 8 for information about `XRONOS`). `DPS` allows the user to specify the length of the FFT and to sum the resulting FFTs when appropriate. We chose FFT lengths that gave the greatest sensitivity to detected periods.

Table 9.4 gives the 5-sigma detection limits for various periods in both the Bright and Faint sources. The "Obs. Time" is the total length of the light curve, in seconds. The lengths of the light curves are such that each has ~1600 complete cycles of the period. Light curves are of contiguous data, without data gaps. The Bright dc level corresponds to an ~0.5 Crab source in the PCA, while Faint corresponds to a source intensity of ~ 6 mCrab in the PCA. The PCA background of 90 cts/s is included in the Bright and Faint dc levels.

TABLE 9.4. Amplitudes of Sinusoidal Variations Giving 5σ Detections

Period	**Bright (8000 cts/s)**	**Faint (190 cts/s)**	**Obs. Time**
33.47 ms	100 cts/s	18 cts/s	54 s
0.856 s	35 cts/s	5 cts/s	1380 s
3.57 s	15 cts/s	1.5 cts/s	5790 s

Note that the 1.5 cts/s amplitude of the 3.57 s period in the Faint source corresponds to a peak-to-peak modulation of 3% relative to the background-subtracted source count rate.

We next choose EDS modes. First, we use `XSPEC` to obtain the 6-channel PCA spectrum. Using a power law with a photon index of 1.05, and a column of 3x10^{21} cm^{-2}, and scaled approximately to our Bright and Faint source levels, we obtain

TABLE 9.5. PCA 6 Channel Spectrum for the Bright & Faint Source

Energies (keV):	0-3.2	3.2-4.3	4.3-5.7	5.7-8.6	8.6-12.1	12.1-60.0
Bright	657	695	1081	1758	1414	2305
Faint	8.3	8.8	13.7	22.2	17.9	29.1

Note that that the background counting rate **is not** included in the spectral channels given above. This is because `recommd` assumes the input spectrum is from the source only, and will add the background itself. Inputting this into `recommd`, using the default 65 % efficiency, specifying at least 10 microsecond timing, optimizing the energy resolution, we choose the following EDS configurations:

Intensity	EDS Configuration(s)	Timing Resolution	Energy Range	Telemetry
Bright	SB_62us_0_249_500ms	62 µs	0.0 - 60.0	24.8 kbps
Faint	GoodXenon1_16s	1 µs	0.0 - 60.0	5.2 kbps
	GoodXenon2_16s	1 µs	0.0 - 60.0	5.2 kbps

The GoodXenon configurations use 2 EAs to give 256 energy channels with detector and layer ID in 1 microsecond time bins. Note that to maximize the timing resolution within the telemetry request, the Bright source level sacrifices all energy information. The count rate is low enough for the Faint source that both timing and energy information can be maximized via the GoodXenon configurations.

In addition, for P = 33.47 ms, it is also appropriate to choose an FFT mode. Because the FFT mode performs 2 FFT’s from different energy ranges, the particular configuration must be chosen considering the spectrum. The energy split may be dictated from the science objectives (e.g. searching for hard lags), or from counting statistics considerations. Choosing the split at the first channel, and choosing the timing resolution so as to get sufficient number of cycles (5) in the FFT’s 256-pt transform, an appropriate FFT configuration woud be:

F_4ms_0_12_249_64s

The telemetry for the FFT mode is negligible, ~ 0.3 kbps. The other periods are too large to be reasonably detectable using the FFT mode.

9.6.6 QPO Observation and FFTs

9.6.6.1 General considerations

If the event rate is high and the desired time bin size is small, the EDS FFT mode can be used to search for periods efficiently within the telemetry constraints. However, because the FFT mode analyzes time series in fixed lengths of 256 bins, the frequency resolution and Nyquist frequency may not always be suitable for a particular science objective. On the other hand, if the time bin size is large (e.g. on the order of milliseconds), one can send down all the time series in a Binned mode and compute the FFT offline.

9.6.6.2 Determining the time bin size

Two factors may be considered for determining the time bin size: (a) the Nyquist frequency, i.e. the highest frequency to be examined, and (b) the telemetry rate constraint. The bin size should be the larger of these:

$$T_b = \max(1 / (2 F_{nyquist}), N_b N_e / R_t),$$

where $F_{nyquist}$ is the Nyquist frequency, N_b the number of bits of storage allocated for each time bin, N_e the number of energy bands, and R_t the maximum telemetry rate.

9.6.6.3 Determining the number of points per FFT

There are two factors that determine the number of points in one FFT: (a) the desired frequency resolution, and (b) the event rate.

If the width of the QPO is W_{qpo}, one desires to have N_{pix} frequency pixels to charaterize the QPO peak. Then the number of points in the FFT should be

$$N_{fft} > N_{pix} / (2 T_b W_{qpo}).$$

On the other hand, one should have at least a few, say, $N_{ph} = 10$, photons for each time series. This demands the $N_{fft} > N_{ph} / (R_0 T_b)$, where R_0 is the estimated event rate. The number of data points to be analyzed in the FFT is then

$$N_{fft} = \max(N_{pix} / (2 T_b W_{qpo}), N_{ph} / (R_0 T_b)).$$

9.6.6.4 Determining the duration of the observation

The average QPO power contained in a typical Fourier frequency is

$$P = (rms^2 N_b R_0 T_b) / N_{pix}.$$

This power is computed using Leahy's normalization, in which white noise has a power P = 2. The *rms* is the fractional root-mean-square variation relative to the dc level. To obtain a 5-sigma detection, we require

$$P / (2 / \sqrt{N_s}) > 5,$$

where N_s is the total number FFT's to average. Thus we have

$$N_s > (10\ N_{pix} / (rms^2\ N_b\ R_0\ T_b))^2$$

9.6.6.5 An Example

Suppose a source has the following characteristics:

- Count rate: 3314 counts/sec (200 mCrab)
- QPO Frequency: 50 Hz
- QPO Peak Width: 5%, i.e., FWHM = 5 Hz
- Fractional RMS: 2 %

We select a Nyquist frequency of 250 Hz, resulting in a binning of T_b = 2 ms. To have 20 pixels under the 5 Hz peak, we require 20 / (2 x 2ms x 5Hz) = 1000 bins in each FFT. Rounding off to the nearest integer power of 2, we have N_{fft} = 1024. Thus each time series is 1024 x 2ms = 2.048 sec long, which on average would have ~ 6700 events in it. Each bin will contain, on average, 13 events. If we further split the light curve into different energy bins and use 4 bits for each bin, the Binned mode telemetry per energy bin is:

4 bits / bin x 1024 time bins / 2.048 secs = 2 kbps.

Using the formula for N_s from above, we have

$$N_s > (10 \times 20 / (2\%^2 \times 1024 \times 3314 \times 2ms))^2 = 5427$$

Thus the total observation is: 5427 x 2.048 = 11,115 secs.

To determine appropriate EDS modes, we first note that the requirement of N_{fft} = 1024 bins eliminates the possibility of using any of the FFT modes, which construct FFT's based on 256-point time series. We also note that a 12 ksec observation will likely encounter only two earth-occultations. Hence we set the observing efficiency at 75 %. Using a 200 mCrab source with a Crab-like spectrum, the count rates in the canonical PCA bands are:

Energies (keV):	0 - 3.2	3.2 - 4.3	4.3 - 5.7	5.7 - 8.6	8.6 - 12.1	12.1 - 60.0
200 mCrab	661	534	641	725	394	358

Specifying 2 ms timing resolution and optimizing the energy resolution, `recommd` gives the following EDS configurations:

EDS Configuration	Time Resolution	Energy Range	Telemetry
B_2ms_8B_0_49_Q	2 ms	0.0 - 12.1 keV	16.3 kbps
E_16us_64M_50_8s	16 µs	12.1 - 60.0 keV	9.1 kbps

Chapter 10

HEXTE Feasibility of Observations

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10.1 Introduction

The design and performance characteristics of the HEXTE has been covered in the Instrument Description chapter, together with the Standard Mode data products and the parameters defining the various Science Mode configurations available to the user. In this chapter, formulae and tables are provided for calculating exposure times and signal-to-noise ratios from the properties of a source of interest, as well as a guide to choosing the appropriate Science Mode and its configuration parameters, subject to the limitations imposed by the 5 kbit/s mean telemetry rate allocation.

10.2 Detection sensitivity

It is expected that the HEXTE's sensitivity will be limited primarily by Poisson counting statistics: from the source or the background, or both. Two different sensitivities are of interest: (i) the minimum detectable flux in a HEXTE energy resolution element, and (ii) the minimum time needed to detect a strong source. The former sensitivity is an indication of the time necessary to make meaningful spectral accumulations. The latter sensitivity relates to how quickly a broad band detection can be made, and, therefore, the timescale of variability to which the HEXTE is sensitive with minimal spectral information.

For sources fainter than, or comparable to the background count rate in a given energy range of interest, source/background beamswitching is essential for obtaining the best sensitivity performance of the HEXTE. Since the HEXTE background count rate in a cluster is always at least 0.1 count/s per

PHA channel (**Figure 5.8**), normal "$\sqrt{n}$ statistics" may be used in calculating sensitivities for exposure times longer than about 100 s.

Note that the total HEXTE exposure time which proposers must request includes any source/background beamswitching, but as for the PCA, does *not* include the observing efficiency of the RXTE satellite (i.e. occultation by the earth, inactive periods during passage through the SAA, and slews).

10.2.1 Broad-band and timing observations

If both HEXTE clusters are beamswitching, then one cluster will always be pointing on-source while another spends a roughly equal time observing the background either side (neglecting the 4 s each cycle for cluster motion). In this -source case, the *signal-to-noise ratio* (**SNR**) in a spectral band for a HEXTE observation time *t* is given by:

$$SNR = \frac{C\sqrt{t}}{\sqrt{C + 2B}} \quad \text{(EQ 10.1)}$$

where C is the measured source count rate and B is the background count rate (per cluster), both integrated over the energy (or PHA channel) range of interest. These count rates can be obtained for any arbitrary range using the HEXTE calibration data files with the XSPEC software package. For the four Standard Mode (Archive Temporal Bin) energy bands, users may obtain count rates either from the PIMMS package, or from **Table 10.1** below, which lists background and representative source count rates in these bands (assuming a source spectrum similar to that of the Crab Nebula).

TABLE 10.1. Source and background count rates in 4 spectral bands

PHA channel range (≈energies in keV)	100mCrab source rate S[1] count/s per cluster	Background rate B count/s per cluster
12-29	14.3	11.86
30-61	5.0	17.93
62-125	2.2	22.39
126-250	0.38	21.34

1. Assuming a photon spectral index of 2.08 and F(2-10 keV) $=2.1\times10^{-9}$ erg cm^{-2} s^{-1}

Using these count rates and Equation 10.1, users may also estimate the shortest time-scale on which significant flux variations can be detected in a spectral band, and choose the temporal and spectral sampling accordingly for their Science Mode configurations.

Where the source count rate is much fainter than the background ($C \ll B$) Equation 10.1 simplifies to the *background-limited* regime. It should be noted that since most astrophysical sources display photon spectra which are strongly decreasing with energy, even the brightest sources at low energies become background-limited at the high end of the HEXTE's energy range.

For source count rates much brighter than background, the Poisson noise of the source itself dominates and the noise just becomes $\sqrt{Ct}$, the square-root of the total number of source counts received in the band. An additional factor of $\sqrt{2}$ may be then achieved by configuring both clusters to dwell on-source in STARE mode, as long as accurate background subtraction is not required. Similarly, for timing studies of faint but periodic phenomena on <16s scales (eg. pulse minus off-pulse spectroscopy, or period searches), users should also select STARE mode for both HEXTE clusters, thereby maximizing the on-source effective area to detect the temporal signal, and avoiding possible aliasing problems due to the source/background beamswitching.

10.2.2 Spectral observations

If a source's flux density is n photon cm^{-2} s^{-1} keV^{-1}, the source count rate in a HEXTE cluster will be nA count s^{-1} keV^{-1}, where A is the live-time-corrected effective area of the HEXTE cluster at that energy (i.e. **Figure 5.5**, multiplied by the live-time fraction of 60% for the HEXTE). For a background count rate of b count s^{-1} keV^{-1} (**Figure 5.8**), by substituting into Equation 10.1 with $C=nA\Delta E$ and $B=b\Delta E$ it is easy to show that resulting SNR in the small energy band ΔE is given by:

$$SNR = \frac{nA\sqrt{\Delta E t}}{\sqrt{2b + nA}} \qquad \text{(EQ 10.2)}$$

This expression can be rearranged to yield the minimum detectable flux per HEXTE PHA channel as a function of source flux for the background-limited case ($nA \ll b$), using $\Delta E \approx 1$ keV per channel. However, since the HEXTE's PHA channels greatly over-sample the spectral resolution, a more useful concept is the detectable continuum flux density in a *resolution element*, where ΔE is now the FWHM resolution of the HEXTE detectors (**Section 5.3.4)**. This quantity is shown in **Figure 10.1** for a 3-σ detection (SNR=3) in 200,000 s. For example, the HEXTE can detect a continuum source of flux density $n=4\times10^{-6}$ photon cm^{-2} s^{-1} keV^{-1}, in the ΔE=11 keV-wide energy resolution element centered at 100 keV, at the 3-σ level in an exposure time $t=2\times10^{5}$ s. (For an AGN-like spectrum of power-law photon index=1.7, this is roughly equivalent to a 2-10 keV flux of 5×10^{-11} erg cm^{-2} s^{-1}). At this energy, the HEXTE is roughly 2 times more sensitive than the OSSE on board the Compton Gamma-Ray Observatory. Values for other combinations of SNR and t can be obtained by scaling the curve appropriately according to Equation 10.2. The plot may also be used to calculate the detection limit for any unresolved spectral feature.

10.2.3 Systematic effects in background subtraction

Systematic effects in the residual background are not included in the treatment above. Source/background beamswitching has been shown to subtract the HEXTE internal background to better than 1%. RMS fluctuations in the cosmic x-ray background, ~8% per HEXTE field of view, become important

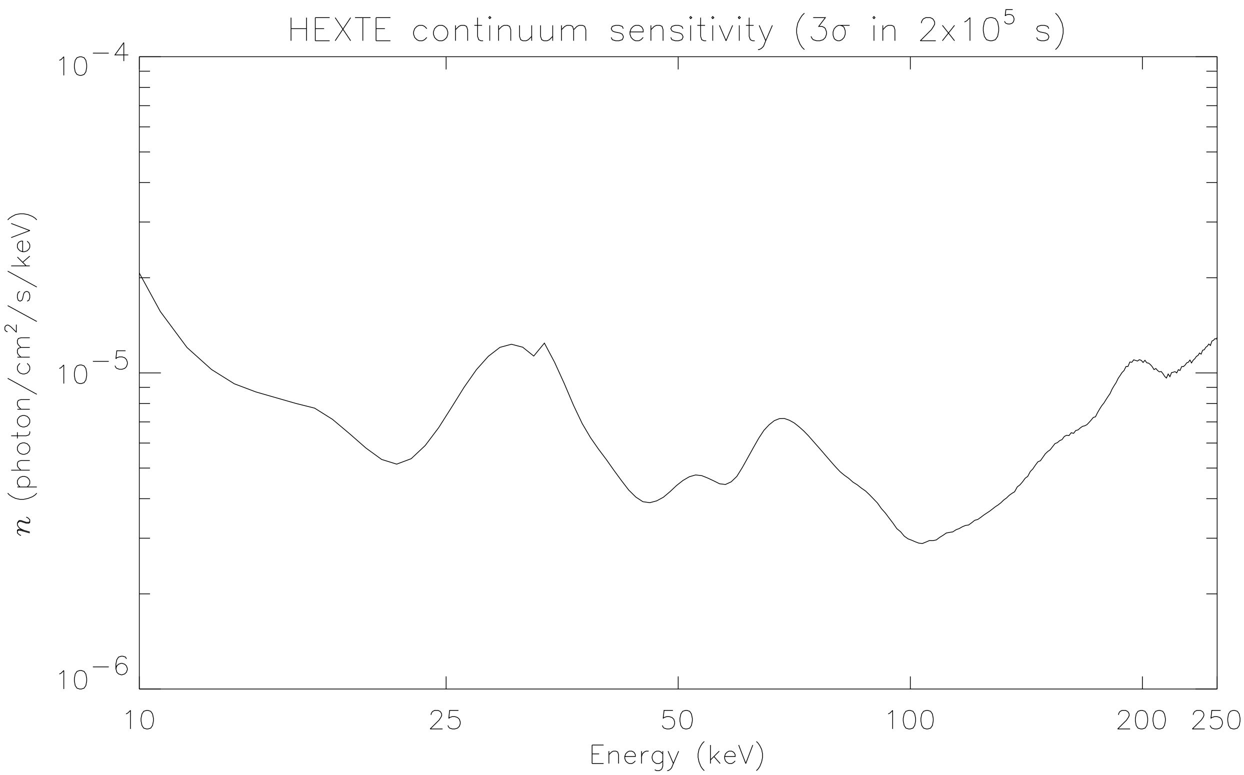

FIGURE 10.1. Background-limited continuum sensitivity as a function of energy for the HEXTE, for a 3-σ detection in 2×10^5 s observing time using two-cluster beamswitching. The dead-time fraction has been taken into account. Detection flux limits for unresolved spectral lines can be found by multiplying this curve by the FWHM resolution (Section 5.3.4). Broad-band detection limits may be calculated directly using Equation 10.1.

below 30 keV for total exposure times longer than about 500 ks, which sets an effective upper limit on the feasible exposure times for faint source detection. However, individual source and background fields may show a larger non-uniformity in the cosmic background, or additional contaminating sources may be present at low flux levels. In these cases, two-sided beamswitching enables users to check for such residual effects by comparison of spectra taken at the “+” and “-” background positions.

10.3 Telemetry limitations

The HEXTE Housekeeping and Standard Modes science data, which run continuously, use roughly 1 kbit/s of telemetry in total, and an additional allocation of 5 kbit/s (averaged over 4 orbits) is available for the Science Mode data from both clusters. Typically, the HEXTE will not produce Science Mode data for about 40% of each orbit during earth-occults and SAA passes. Allowing some margin for higher efficiencies, this means that Science Mode telemetry rates may be comfortably scheduled up to about 8.0 kbit/s, or about 4.0 kbit/s for each HEXTE cluster if they are configured identically.

While the majority of sources may be observed in Event List mode, those brighter than a few tenths of the Crab Nebula may be observed more efficiently using one of the binned modes (Spectral or Temporal Bin) to stay within, or close this telemetry allocation.

Higher telemetry rates can certainly be accommodated, and are encouraged if justified scientifically - see the proposal instructions for details. However, the maximum possible telemetry rate from a HEXTE cluster is set by the telemetry buffer size in each Cluster Electronics Unit, and corresponds to 23 kbit/s per cluster, averaged over a 16-s IDF. Note that while configurations which might exceed this limit will still be accepted by the Remote Proposal Submission software, they will not be scheduled for observation.

10.4 Science Mode selections

For most applications, the choice of which HEXTE Science Mode to use (Event List, Histogram Bin or Multiscalar Bin) is straightforward. The flowchart in **Figure 10.2** depicts the selection process based on source count rate and desired temporal and spectral sampling for the 8 kbit/s recommended telemetry allocation. For faint sources, choosing one of the Event List mode options will provide the maximum information to construct spectra and/or light curves as part of the off-line data analysis. For brighter sources, Spectral (Histogram) Bin and Temporal (Multiscalar) Bin Science Modes provide fixed-format spectra or light curves, which can be configured in spectral coverage, and spectral and temporal sampling. Additionally, users can elect to telemeter their data from each cluster's 4 detectors individually, or add them to produce a combined cluster spectrum (saving a factor of 4 in telemetry usage). Independent confirmation of a spectral or temporal feature in all 4 phoswich detectors may be more desirable, however, for detailed spectral work or small temporal signatures. This is especially true for Cluster B, which has one detector (PWB2) producing no spectral information and not subject to automatic gain control.

With the multitude of spectral and temporal configurations offered within each Science Mode, the selection of the Science Mode *parameters* themselves is not always straightforward, especially for very bright sources where telemetry rate and bin overflow considerations must be taken into account together. For this reason, a software program (*HEXTEmporize*) has been provided to assist users in composing a suitable Science Mode configuration and constructing a configuration name similar in form to those used by the EDS; this HEXTE configuration name must be entered on proposal target forms. *HEXTEmporize* requires estimates of source count rate in 4 energy bands to approximate the source spectrum; these count rates can be derived from simulations with XSPEC or PIMMS, or from the conversions listed in Table 10.1.

The following subsections provide telemetry rates, rollover count rates and examples of some useful configurations for each Science Mode. Users are reminded that for each HEXTE cluster, they must also specify the lower energy bound and the source/background switching parameters. The Instrument Description chapter provides details of these options and a complete listing of possible values

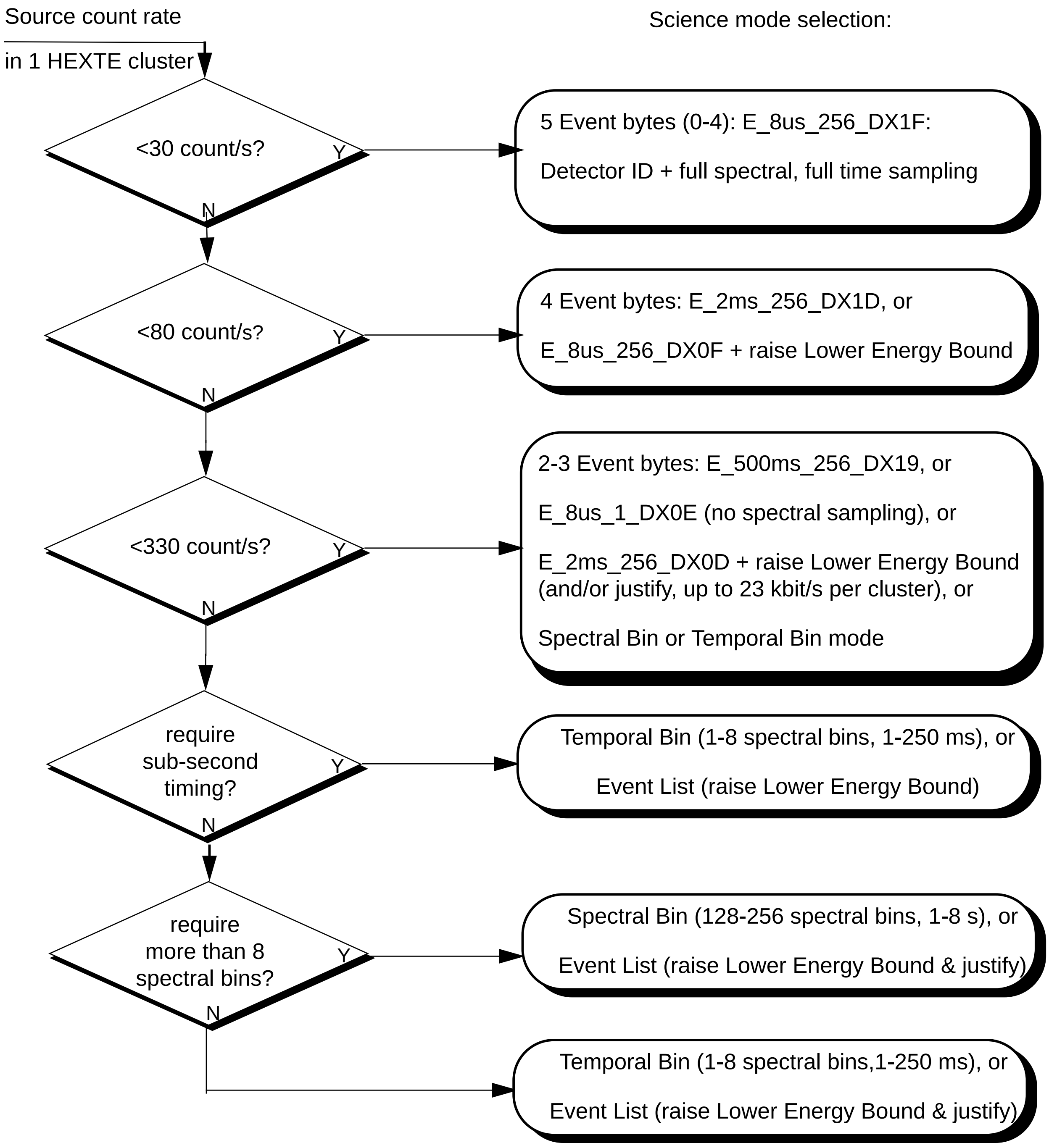

FIGURE 10.2. Flowchart showing recommended HEXTE Science Mode configurations as a function of source count rate (per HEXTE cluster) a assuming that both HEXTE clusters are source/background switching and configured identically, with a background of 40 count/s. Event List mode can be used for bright sources up to a telemetry rate of 23 kbit/s per cluster, but should be justified above the source count rates shown.

for the Science Mode parameters. Users requiring further information or assistance with selecting an appropriate Science Mode configuration are also invited to contact the HEXTE team.

10.4.1 Event List Mode

This is the only Science Mode whose telemetry rate depends on source flux. The telemetry rate is given by:

```
telemetry rate (bit/s) = total count rate (both clusters) × (bytes per event) ×
8 bits.
```

When both clusters are source/background switching, at any instant one cluster is producing counts from the background only and the other is observing the source+background. The total count rate is then given by (source rate per cluster + 2×background rate per cluster). When both clusters are staring on-source, however, the total count rate is 2×(source + background per cluster). Source count rates between the lower energy bound and 250 keV may be calculated for any spectral shape using the PIMMS software, or the conversions listed in Table 10.1. (For comparison, the Crab Nebula produces about 250 count/s in one HEXTE cluster, 12-250 keV).

For the majority of (weak) sources, data may be taken with both HEXTE clusters in Event List mode without exceeding the telemetry allocation, thereby allowing subsequent spectral and temporal binning by the observer as part of their data analysis. Full spectral and temporal sampling can be achieved by requesting the first 4 event code bytes (i.e. bytes 0-3), since the higher event bytes are normally used only for calibration and testing by the HEXTE team (refer to **Table 5.2**). If the Lower Energy Bound is set below 15 keV (e.g. at its DEFAULT value of 12 keV), then the pulse-shape (PSA) byte should be added for superior background subtraction at low energies. For sources marginally brighter, Event List may still be acceptable if the Lower Energy Bound is raised. Even a small increase from 12 keV (the default value) to 15 keV is often sufficient to reduce the counting rate, especially from soft sources.

Note, though, that raising the lower Energy Bound *higher* than 15 keV also affects the Standard Modes data products, so that no information below this energy is recorded by the HEXTE. Since the long-term goal of the Standard Modes data is to provide a nearly uniform public archive of HEXTE data from 15-250 keV, this strategy should only be requested if essential. Alternatively, if a source is too bright to telemeter 4 or 5 event bytes, then a smaller subset of event bytes may be selected, with a sacrifice in spectral or temporal resolution, or detector identity.

10.4.2 Spectral (Histogram) Bin Mode

Spectral Bin mode is designed to obtain PHA histogram spectra of source counts at time intervals of 1 s to 16 s, by counting each event in up to 256 spectral bins.The telemetry rate is set by the number of spectra generated per IDF (16-s interval) and the size (in bits) of each histogram spectrum, and is given by:

```
telemetry rate (bit/s) = (spectra per IDF ÷ 16 s) × detector IDs per cluster (1
or 4) × (bins per spectrum × bits per bin).
```

Although this telemetry rate is independent of source brightness, bright sources will fill up the spectral bins rapidly, and above a certain count rate will cause them to "roll over" (i.e. start counting again from zero). This count rate is determined by the capacity (or "depth") of a spectral bin and its temporal and spectral coverage. In terms of the parameter table values listed in the HEXTE Instrument Description this is given by:

```
rollover count rate (count/s/spectral bin) = (spectra per IDF ÷ 16 s) ×(detector
IDs per cluster × 2^(bits per bin)),
```

where the width of a spectral bin in PHA channels (1 PHA channel covers roughly 1 keV) is given by

```
spectral bin width = (1 + highest PHA channel#) ÷ (bins per spectrum).
```

Table 10.2 lists the telemetry rates and rollover count rates (per spectral bin) for the Histogram Bin modes. (For comparison, the Crab Nebula is expected to produce a count rate of 10 count/s per cluster at 15 keV, so would cause rollover in the lowest spectral bins for some parameter selections). **Section 10.5.3.1** gives examples of the most useful Spectral Bin configurations.

TABLE 10.2. Spectral Bin telemetry usage per cluster (bit/s) & rollover count rates (count/s/bin)[1]

Detector IDs per cluster	Spectra per IDF (time interval)	256 spectral bins Bin depth:			128 spectral bins Bin depth:			64 spectral bins Bin depth:		
		4 bits	8 bits	16 bits	4 bits	8 bits	16 bits	4 bits	8 bits	16 bits
4	2 (8s)	500 (8)	1000 (128)	2000	250 (8)	500 (128)	1000	125 (8)	250 (128)	500
4	4 (4s)	1000 (16)	2000 (256)	4000	500 (16)	1000 (256)	2000	250 (16)	500 (256)	1000
4	8 (2s)	2000 (32)	4000 (512)	8000	1000 (32)	2000 (512)	4000	500 (32)	1000 (512)	2000
4	16 (1s)	4000 (64)	8000 (1024)	16000	2000 (64)	4000 (1024)	8000	1000 (64)	2000 (1024)	4000
1	2 (8s)	125 (2)	250 (32)	500	62.5 (2)	125 (32)	250	31.25 (2)	62.5(32)	125
1	4 (4s)	250 (4)	500 (64)	1000	125 (4)	250 (64)	500	62.5 (4)	125(64)	250
1	8 (2s)	500 (8)	1000 (128)	2000	250(8)	500 (128)	1000	125(8)	250 (128)	500
1	16 (1s)	1000 (16)	2000 (256)	4000	500 (16)	1000 (256)	2000	250 (16)	500 (256)	1000

1. Rollover count rates (count/s/bin) are shown in parentheses where they may cause problems for users; bin depths should be selected such that these count rates are not exceeded in a spectral bin.

10.4.3 Temporal (Multiscalar) Bin Mode

Temporal Bin Science Mode was designed to produce light curves with sampling from 1 to 250ms for very bright sources which can not normally be observed in Event List mode. Due to the large number of parameters which can be optimized for individual sources, and the options offered by other modes which preserve the HEXTE's spectral sampling (eg. raising the Lower Energy Bound and using Event

List mode), users should consult the HEXTE team for advice before proposing to use Temporal Bin mode.

The telemetry rate is given by:

```
telemetry rate (bit/s) = (time bins per IDF ÷ 16 s) × (no. of light curve bands
×detector IDs per cluster)× (bits per time bin).
```

The first factor gives the number of time bins per second in each light curve, while the second factor gives the total number of light curves produced by each cluster. As for Spectral Bin mode, the number of IDs per cluster is either 1 or 4 depending on whether the spectra from individual detectors are summed, or telemetered separately.

Users have the flexibility in choosing up to 8 contiguous spectral bands for their light curves by specifying the upper PHA channel boundaries for each band. However, the resolution of the HEXTE detectors means that narrow spectral bands at high energies will not be useful. To aid in the selection of spectral bands and provide some uniformity amongst the many possibilities for channel boundaries, the recommended values for the upper PHA channel bounds of each spectral range are given below:

1, 2, 10, 12, 14, 17, 21, 25, 29, 33, 37, 41, 46, 50, 55, 61, 67, 75, 84, 94, 104, 115, 125, 139, 151, 165, 179, 193, 209, 225, 241, 250, 255

By choosing upper PHA channel boundaries from this list, spectral bands will be no smaller than 1 FWHM resolution at any energy. For example, a resolution element FWHM centered at 30 keV can be covered by PHA channels 26 to 33, while a resolution element at 200 keV can be covered by PHA channels 194-209. These channel boundaries are used in the Temporal Bin configurations which can be accessed and edited using *HEXTEmporize*. However, the loss of spectral information from detector PWB2 during Cycle 1 complicates the selection of channel bounds for use on HEXTE cluster B. Users should therefore consult the HEXTE team for advice.

The high count rates for bright sources will fill up the time bins rapidly, and above a certain count rate will cause the bin counts to “roll over” (start again at zero) before being collected and transmitted to the ground. The count rate at which this occurs is determined by the capacity (“depth”) of the time bins (= $2^{(\text{bits per bin})}$ - 1) and their temporal and spectral coverage, and is given by:

```
rollover count rate (count/s/spectral band) = (time bins per IDF ÷ 16 s) ×
(detector IDs per cluster × 2^(bits per bin)).
```

Telemetry rates and rollover count rates for Temporal Bin mode are shown in **Table 10.3**. As can be seen from the Table, many combinations of parameters exceed the maximum possible telemetry rate of 23 kbit/s per cluster, e.g. 8 spectral bands at 0.98 ms resolution (which would require 32.77 kbit/s). Such configurations will not be scheduled. Other selections produce telemetry rates above the HEXTE allocation of ~8 kbit/s, which can be accommodated if justified scientifically. There are also a number of parameter combinations which produce information inferior in some respect (spectral or temporal sampling) to that already available in the Standard Modes data; most of these have telemetry rates less than about 1 kbit/s.

TABLE 10.3. Temporal Bin telemetry rates (bit/s) and rollover count rates (count/s per spectral band)[1]

IDs / cluster	spectral bands	16384 bins/IDF (0.98ms bins)			8192 bins/IDF (1.95 ms bins)			4096 bins/IDF (3.9 ms bins)		
		Bin depth:			**Bin depth:**			**Bin depth:**		
		4 bits (Q)	**8 bits (H)**	**16 bits (F)**	**4 bits**	**8 bits**	**16 bits**	**4 bits**	**8 bits**	**16 bits**
4	1	16384	*****	*****	8192	16384	*****	4096	8192	16384
4	2	*****	*****	*****	16384	*****	*****	8192	16384	*****
4	4,	*****	*****	*****	*****	*****	*****	16384	*****	*****
4	6	*****	*****	*****	*****	*****	*****	*****	*****	*****
4	8	*****	*****	*****	*****	*****	*****	*****	*****	*****
1	1	4096	8192	16384	2048	4096	*****	1024	2048	4096
1	2	8192	16384	*****	4096	8192	16384	2048	4096	8192
1	4	16384	*****	*****	8192	16384	*****	4096	8192	16384
1	6	*****	*****	*****	12288	*****	*****	6144	12288	*****
1	8	*****	*****	*****	16384	*****	*****	8192	16384	*****
IDs / cluster	**spectral bands**	**2048 bins/IDF (7.8 ms bins)**			**1024 bins/IDF (15.63 ms bins)**			**512 bins/IDF (31.25 ms bins)**		
		4 bits	**8 bits**	**16 bits**	**4 bits**	**8 bits**	**16 bits**	**4 bits**	**8 bits**	**16 bits**
4	1	2048	4096	8192	1024	2048	4096	512 (2048)	1024	2048
4	2	4096	8192	16384	2048	4096	8192	1024 (2048)	2048	4096
4	4	8192	16384	*****	4096	8192	16384	2048 (2048)	4096	8192
4	6	12288	*****	*****	6144	12288	*****	3072 (2048)	6144	12288
4	8	16384	*****	*****	8192	16384	*****	4096 (2048)	8192	16384
1	1	512 (2048)	1024	2048	256 (1024)	512	1024	128 (512)	256	512
1	2	1024 (2048)	2048	4096	512 (1024)	1024	2048	256 (512)	512	1024
1	4	2048 (2048)	4096	8192	1024 (1024)	2048	4096	512 (512)	1024	2048
1	6	3072 (2048)	6144	12288	1536 (1024)	3072	6144	768 (512)	1536	3072
1	8	8192 (2048)	16384	*****	2048 (1024)	4096	8192	1024 (512)	2048	4096
IDs / cluster	**spectral bands**	**256 bins/IDF (62.5 ms bins)**			**128 bins/IDF (125 ms bins)**			**64 bins/IDF (250 ms bins)**		
		4 bits	**8 bits**	**16 bits**	**4 bits**	**8 bits**	**16 bits**	**4 bits**	**8 bits**	**16 bits**
4	1	256 (1024)	512	1024	128 (512)	256	512	64 (256)	128	256
4	2	512 (1024)	1024	2048	256 (512)	512	1024	128 (256)	256	512
4	4	1024 (1024)	2048	4096	512 (512	1024	2048	256 (256)	512	1024
4	6	1536 (1024)	3072	6144	768 (512)	1536	3072	384 (256)	768	1536
4	8	2048 (1024)	4096	8192	1024 (512)	2048	4096	512 (256)	1024	2048
1	1	64 (256)	128	256	32 (128)	64	128	16 (64)	32	64
1	2	128 (256)	256	512	64 (128)	128	256	32 (64)	64	128
1	4	256 (256)	512	1024	128 (128)	256	512	64 (64)	128	256
1	6	384 (256)	768	1536	192 (128)	384	768	96 (64)	192	384
1	8	512 (256)	1024	2048	256 (128)	512	1024	128 (64)	256	512

1. Rollover count rates are given in parentheses where they are low enough to be a potential problem for users.

10.5 HEXTE Science Mode Configuration Examples

In addition to the information presented above and in Figure 10.2, the *HEXTEmporize* software will enable users to compose HEXTE Science Mode configuration names, and to calculate the associated HEXTE telemetry rates and rollover count rates for their source of interest. Since *HEXTEmporize* does not assign preferences to Science Modes (unlike the PCA/EDS *recommd* tool), some practical examples of HEXTE Science Modes are presented below. Most users should find that their specific needs are met by one of the examples given. Variants on these examples may be constructed entering the configuration name into *HEXTEmporize*'s "List/Verify" option, and then customizing it with the "Compose/Edit" menu. Friendly human assistance may also be obtained from the RXTE GOF or directly from the HEXTE team.

In the examples below, count rates refer to the net source rates in a single HEXTE cluster. Note that any given source can be made to appear less bright in the HEXTE by raising the Lower Energy Bound, at the expense of losing all timing and spectral information (including that contained in the Standard Modes data) below this threshold.

10.5.1 Faint Source (<75 count/s): Spectrophotometry and Timing

Since faint source observations are background-limited at all energies, source/background beam-switching is required to make meaningful detections of them. However, to reduce the 16 s rocking period's harmonics in power spectral analysis of the source flux, users may select the longer 32 or 64s beamswitch dwell times with little detriment to background subtraction.

For the majority of faint source observations the most suitable HEXTE Science Mode is:

1. **`E_8us_256_DX1F`**: Detector events with 256-channel spectroscopy & 7.6 µs timing:

Event code bytes 0-4 are telemetered giving: 7.6 µs time resolution, 256 spectral channels, pulse shapes, events' detector identity preserved. If sub-ms timing is not important, users may keep within telemetry limits by dropping one event byte:

2. **`E_2ms_256_DX1D`**: Detector events with 256-channel spectroscopy & 2 ms time sampling:

Event code bytes 0, 2, 3 & 4are telemetered giving 1.9531 ms time sampling, 256 spectral channels, pulse shapes, events' detector identity preserved.

10.5.2 Medium Intensity Source (75-330 count/s)

For a large number of medium intensity sources, the Event List modes given above may still be used at a reasonable telemetry rate simply by raising the cluster's Lower Energy Bound from 12 keV (the default) to 15 keV. Not only does this reduce the source count rate in the HEXTE (especially for soft spectrum sources), but the Pulse Shape event byte also becomes unnecessary, and so may be dropped from the telemetry. An example of such a Science Mode is:

3. **`E_8us_256_DX0F`**: Detector events with 256-channel spectral & 7.6 μs time sampling.

This Science Mode preserves the maximum time and spectral sampling and may be used with a 15 keV Lower Energy Bound. As mentioned above, setting the Lower Energy Bound *above* 15 keV (up to 30 keV) will remove counts from the Standard Modes light curves (the lower energy band is fixed at 15-30 keV) and so should be justified as necessary.

10.5.2.1 Spectrophotometry

As with faint sources, beamswitching is essential for measuring the high energy spectra of medium-bright sources. Event List modes may still be employed at these count rates, though at a correspondingly higher telemetry rate. Users may therefore wish to consider requesting a smaller number of bytes per event to stay close to the HEXTE telemetry allocation, as in these examples:

1. **`E_2ms_256_DX0D`**: Detector events with 256-channel spectral & 2ms time sampling
2. **`E_500ms_256_DX19`**: Detector events with 256-channel spectral & 500 ms time sampling.

Although these Event List modes yield a higher time-sampling than the Standard Modes data, users who are not interested in sub-second timing should consider one of the Spectral Bin modes given below. These have the advantage of a fixed, low-rate telemetry format together with frequent dead-time counter readings.

10.5.2.2 Timing

Either beamswitching or staring on-source may be employed for timing observations, depending on the user's preference for hard X-ray spectroscopy (using the Standard Modes spectra), or high throughput timing with the continuous coverage of two HEXTE clusters on-source. As mentioned above, the HEXTE count rates in Event List mode may be reduced by raising the Lower Energy Bound from 12 to 15 keV, or even higher (up to 30 keV) at the expense of the Standard Modes light curve data.

1. **`E_8us_1_DX0E`**: Detector events with 7.6 μs timing in 1 broad energy band (Lower Energy Bound to 250 keV)

1. **`E_2ms_1_DX0C`**: Detector events with 2ms timing in 1 broad energy band (Lower Energy Bound to 250 keV).

10.5.3 Bright or Bursting Source (>330 count/s)

At high counting rates (> 1 Crab) users must make definitive choices in their scientific goals, since the spectral/temporal trade-offs are more severe. Event List mode may not be possible due to the 23 kbit/s per HEXTE cluster physical limit, unless the Lower Energy Bound is raised in order to reduce the HEXTE count rate, sacrificing all HEXTE data at lower energies. Therefore users should familiarize themselves with one of the binned modes for formatting the counts received. The relative merits of staring on-source or source/background beamswitching are the same as those discussed above for a medium-bright source.

10.5.3.1 Spectrophotometry: Spectral Bin Mode

Spectral (Histogram) Bin mode accumulates spectra at selected intervals of 8s to 1s, and can accommodate even the brightest sources imaginable at a reasonable telemetry rate. Another advantage of this mode is that dead-time estimates are available for each individual spectrum, i.e. as fast as every 1 s. (In both Event List and Temporal Bin mode, dead-time counter values are telemetered only every 16 s). Most scientific observations can be served by one of these selections:

1. **`B_1s_255S_0_255_DQ`**: Spectra and dead-times every 1 s, with detector ID and 4-bit bins. Telemetry rate = 4.1 kbit/s per cluster, bins roll over at 60 count/s per cluster per PHA channel.
2. **`B_2s_256S_0_255_DH`**: Spectra and dead-times every 2 s, with detector ID and 8-bit bins. Telemetry rate = 4.1 kbit/s per cluster, bins roll over at 510 count/s per cluster per PHA channel.
3. **`B_4s_256S_0_255_DF`**: Spectra and dead-time values every 4 s, with detector ID and 16-bit bins. Telemetry rate = 4.1 kbit/s per cluster, bins practically never roll over.

This last mode is the slowest recommended binned configuration (=1/4 the shortest beamswitch dwell time), and provides full detector and spectral information, in addition to 4s sampling of the phoswich dead-time counters.

10.5.3.2 Sub-second Timing: Temporal Bin Mode

For very bright source observations requiring a time sampling less than 1s users must either raise the Lower Energy Bound to use Event List mode (q.v.), or otherwise sacrifice much of the HEXTE's spectral capability (but remember that the Standard Modes will still provide a spectrum every 16 s). Temporal Bin mode provides light curves in up to 8 spectral bands. Some examples of this mode are given below:

1. **`B_8ms_4A_15_250_DQ`**: 8 ms timing in 4 standard spectral bands, with detector ID. Telemetry rate = 8.19 kbit/s (rollover at 7680 count/s per spectral band)
2. **`B_62ms_8C_15_250_DQ`**: 62 ms timing in 8 spectral bands chosen for Crab-like source spectra, with detector ID. Telemetry rate = 2.05 kbit/s per cluster

3. **B_2ms_4A_15_250_Q**: 2 ms timing in 4 spectral bands, with no detector ID. Telemetry rate = 8.19 kbit/s (rollover at 7680 count/s per spectral band).

The *HEXTEmporize* software can be used to edit these configurations to produce other timing/spectral band combinations. However, if a Temporal Bin mode is selected for cluster B, the HEXTE team can configure a replacement or additional spectral band to capture the broad-band data from detector PWB2, which produces counts only in PHA channels 1 and 2 since its loss of spectral capability in RXTE Cycle 1. *Users must therefore consult the HEXTE team in advance for assistance in selecting a suitable Temporal Bin mode*.

10.5.3.3 Burst List Mode (CE_8us_256_DX0F)

As described in the HEXTE Description chapter, Burst List mode may be selected to run in parallel with any Binned Science Mode to produce an Event List snapshot for 25000 events around a burst trigger. If selected to run in parallel with Spectral Bin or Temporal Bin mode for staring observations of a bright source (i.e. no source/background beamswitching, which would otherwise generate false triggers), a possible choice of INTERNAL trigger parameters might be the following:

Integration interval: 1s

Number of integrations for χ^2: 16

Trigger threshold for χ^2: 10

Percentage of before/after events: 10%/90%

However, observers are strongly urged to contact the HEXTE team when considering the use of Burst List mode due to its complexity and the operational burdens it imposes on the XTE SOF, who are required to send real-time commands to enable Burst List processing, and to command the dumping of the Burst List buffer to ground in real-time.

Appendix 1

EDS Configurations

Ap.1.1 Introduction

This document describes the EDS configurations available to the guest observer. Each configuration can be specified by referencing its name.

If the configurations described here cannot adequately address the goals of a particular observation, the observer may request that other configurations be generated. Such requests will be honored within the limits of XTE project resources. For example, there are no pulsar fold configuration lists, since any use of the pulsar fold mode would have to be tailored to a specific pulsar. Thus, specific pulsar fold configurations will be generated for those observations which require the use of pulsar fold mode. Anyone wishing to specify new configurations should first read the appropriate section of the EDS Observers Manual and then contact the XTE GOF.

An up to date list of available configurations, including newly created configurations, will be available to all GOs via the GOF anonymous FTP account (`legacy.gsfc.nasa.gov`)

The reader should notice that each configuration described below generally requires one EA. Since 4 PCA EAs are available besides those running the standard configurations, the use of "cocktails" (i.e., using various EA's for different tasks), will be the rule rather than the exception. The user should keep in mind that regardless of how many EA's are used, the total telemetry must stay within the overall allocation for the observation.

Chapter 8 gives several examples of configuration choices.

Pulse height channel numbers are used to specify configurations. When X-ray photon energies are given below, we have assumed that the PCUs will operate with the nominal gain, for which pulse height channel 250 corresponds to 60 keV.

The various tables in the following sections give maximum count rates beyond which “rollovers” or data losses may occur. These maximum rates often exceed by orders of magnitude what is expected from the large majority of sources. For convenience of the user (and as a reference), we give in Table 1.1, “Count rate estimates for some bright sources.,” on page 176 the expected approximate TOTAL counting rates in the PCA of some of the very brightest sources in the range 1 - 60 keV. For sources with a counting rate greater than 100,000 cts/s, offset pointing may be required to prevent degradation of the detectors.

TABLE Ap.1.1. Count rate estimates for some bright sources.

Source	Total (cts/s)	<3.25 keV	<4.25 keV	<5.75 keV	<8.75 keV	<12.25keV
Sco X-1[a]	109,830[b]	25,850	47,280	76,240	96,630	106,030
Crab[c]	16,570	3,300	5,970	9,180	12,800	14,780
Cyg X-1[d]	8,380	1,290	2,450	3,990	5,930	7,120
A0620[e]	143,640[b]	80,550	112,190	132,060	141,280	143,090

a. Thermal Bremsstrahlung model T=5keV, normalization=32., wabs=$3.5x10^{21}$.

b. For instrument health, the PCA may require offset pointing to keep the count rate below 100,000.

c. Power law model: photon index=2.1, normalization=10.9, wabs=$3.45x10^{21}$.

d. Power law model: photon index=1.8, normalization=3.3, wabs=$7.1x10^{21}$.

e. 2 component power law model: photon index 1=4.7, normalization=3500., photon index 2=2.0, normalization=0.2, wabs=$3.2x10^{21}$.

Ap.1.2 Standard Configurations

Two of the EAs will always be running standard configurations to provide a common format for instrument monitoring, archival research and to make it easier to compare observations of different sources. The GO will be given the resulting standard data along with the rest of his/her data. Any information provided by the standard configurations does not need to be provided by the configurations selected for the 4 remaining PCA EAs. For many investigations the standard data is all that is needed.

Gain corrections are not applied to any of the standard data.

Ap.1.2.1 Standard 1

There are two unrelated parts to Standard 1, timing data and calibration data.

Every PCA event sent to the EDS is counted in exactly one of the Standard 1 bins.

The timing data consist of 8 time series, with 1/8 s time bins. Each readout of Standard 1 will contain 1024 time bins for each of the 8 time series. The 8 time series are defined in Table 1.2, "Time series in Standard 1," on page 177.

TABLE Ap.1.2. Time series in Standard 1

#	Description
1	Rate of good xenon events in PCU 1
2	Rate of good xenon events in PCU 2
3	Rate of good xenon events in PCU 3
4	Rate of good xenon events in PCU 4
5	Rate of good xenon events in PCU 5
6	Rate of all events not counted elsewhere
7	Rate of propane events in all PCUs
8	Rate of VLE events in all PCUs

The calibration data bins all events with a single xenon LLD and the alpha flag (see PCU instrument description for definition) set. These events are binned into 256 channel spectra separately for each xenon LLD and PCU. These spectra are readout once every 128 s.

Ap.1.2.2 Standard 2

Standard 2 provides full spectra separately for each anode and detector. The data provided in Standard 2 consists of xenon Spectra, propane Spectra and background rates. Normally Standard 2 data is read out every 16 s, however for very bright sources (> ~50,000 cts/s) faster readout times should be used to prevent bins from rolling over (e.g., more than 255 counts in a 8-bit bin).

Every event produced by the PCA will be counted in exactly one of the Standard 2 bins.

The xenon spectra comprise 129 channels for each of the six xenon anodes in each of the 5 PCUs.

The propane spectra comprise 33 channels for each of the 5 PCUs.

Background data comprise the rates of 29 types of events for each of the 5 PCUs. These events are monitored in Standard 2 to help with background modelling and deadtime corrections. The definitions of the 29 rates are given in Table 1.3, "," on page 178. In this table, V_x corresponds to the surrounding veto (or antico) layer of the PCU. Events on the veto layer are recorded with one of 3 energies, here labelled low, medium and high. L1-3 and R1-3 are the main xenon anodes. V_p denotes the propane layer. In the background rates numbered 13 through 18, the six xenon layers, the propane layer and the veto are all counted as discriminators. The VLE rate is the total rate of events with the VLE flag set. The calibration rate is the total rate of events with the calibration flag set and the VLE flag not set. Note that this is different from the calibration rates in Standard 1, where the calibration flag and a single xenon LLD flag must be set. For more information on the meaning of these flags, please refer to the PCA users manual. The "&" symbol in this table means that both specified flags must be set. For example, "V_p & L1" specified the rate of events where both the top "left" xenon layer and the propane layer, and no other anodes were simultaneously triggered. The "|" indicates a logical "or". For example, "Vp&(L2|L3|R2|R3)" specifies events that simultaneously triggered the propane layer and any one of the back 2 xenon layer anodes.

TABLE Ap.1.3.

#	Description
1	VLE rate
2	Vp & L1
3	Vp & R1
4	Vx & L1
5	Vx & R1
6	Vx & L2
7	Vx & R2
8	Vx & L3
9	Vx & R3
10	L1 & R1
11	L2 & R2
12	L3 & R3
13	Any 3 Discriminators
14	Any 4 Discriminators
15	Any 5 Discriminators
16	Any 6 Discriminators
17	Any 7 Discriminators
18	Any 8 Discriminators
19	Calibration
20	Low Energy Veto
21	Medium Energy Veto
22	High Energy Veto
23	Vp & (L2 | L3 | R2 | R3)
24	L1 & L2
25	R1 & R2

TABLE Ap.1.3.

#	Description
26	L2 & L3
27	R2 & R3
28	Other 2 LLD events
29	All flags 0.

Ap.1.3 Binned Mode Configurations with no Cutoff

In addition to the Standard configurations in Section Ap.1.2 on page 176, there are binned configurations that bin all events. These configurations are listed in Table 1.4, "Binned configurations with no high energy cutoff.," on page 179. The first two of these modes use a variable number of bits per channel, using more bits for lower energy channels where the count rate is higher. Gain corrections are applied to all of these configurations.

TABLE Ap.1.4. Binned configurations with no high energy cutoff.

Name	Time Bin Size	#bits/bin	# chan	PCU ID	Telem. (kbps)
B_250ms_128M_0_254	0.25 s	16,8,4[a]	128[b]	Yes	22.2
B_16ms_64M_0_249	16 ms	8,4[c]	64[d]	No	26.7
B_4ms_16X_0_249_H	4 ms	8	16[e]	No	32.9
B_4ms_16X_0_249_Q	4 ms	4	16[f]	No	16.5

a. 16 bit bins are used for the lowest 36 channels, 8-bit bins are used for the next 40 channels and 4-bit bins for the top 52 channels.

b. The 128 channels are: 0-4, 5-54:1, 56-135:2, 136-232:3, 236-239, 240-244, 245-249,250-254.

c. 8-bit bins are used for the lowest 20 channels and 4-bit bins are used for the top 44 channels.

d. The channels are: 0-4,5-6,7-15:1, 16-43:2, 44-46, 47-49,50-52, 53-55, 56-58,59-61, 62-64,65-67, 68-71, 72-75, 76-79, 80-83,84-87, 88-91, 92-96, 97-101, 102-106, 107-111. 112-116, 117-121, 122-126, 127-131, 132-137, 138-143, 144-149, 150-155, 156-161, 168-174, 175-181, 182-188, 189-195, 196-202, 203-209, 210-217, 218-225, 226-233, 234-243, 244-249.

e. There are 3 options for the energy channel boundaries:

A: 0-7,8-9,10,11,12,13,14,15,16-17,18-19,20-22,23-26,27-30, 31-35, 36-63, 64-249.
B: 0-9,10-11,12-13,14-16, 17-19, 20-22, 23-25, 26-28. 29-31, 32-35, 36-41, 42-49, 50-63, 64-91, 92-127, 128-249.
M: 0-8, 9-13, 14-20, 21-29, 30-39, 40-51, 52-65, 66-79, 80-95, 96-113, 114-133, 134-154, 155-177, 178-201, 202-227, 228-249.

f. There are 2 options for the energy channel boundaries:
A: 0-7,8-9,10,11,12,13,14,15,16-17,18-19,20-22,23-26,27-30, 31-35, 36-63, 64-249.
B: 0-9,10-11,12-13,14-16, 17-19, 20-22, 23-25, 26-28. 29-31, 32-35, 36-41, 42-49, 50-63, 64-91, 92-127, 128-249.

Ap.1.4 Low Energy Binned Mode Configurations

Binned mode configurations are appropriately used when the count rate is high and not all events can be telemetered via an event mode configuration. This section describes the available binned mode configurations designed to be used in conjunction with an event mode configuration with a low energy cutoff (Section Ap.1.7 on page 187). The upper energy cutoff of the binned mode should match the low energy cutoff of the event mode. Typically one would choose the cutoff such that 500 to 1000 events/s would have energies above the cutoff.

Table 1.5, “Binned mode configurations for 0-3.0 keV,” on page 180 through Table 1.9, “Binned mode configurations for under 11.7 keV,” on page 185 lists the binned mode configurations that will be available for binning events with a upper channel cutoff.

In these tables, column 1 specifies the name of the configuration. The naming convention for these configurations is B_ttt_ccX_0_hh_B, where ttt is the time bin size, cc is the number of energy channels, X selects the channel boundary option, hh specifies the upper channel boundary, an B is one of Q,H or F specifying that 4, 8 or 16 bit bins have been used. If there is more than one channel boundary option, an “X” has been left in the name in column 1, and the GO must choose one of the options listed in the table footnotes. The energy channel boundaries in binned mode are named with the same convention as in Event mode. If the configuration uses a variable number of bits per bin (typically more bits for lower energy channels), the “_B” is left off the name.

Column 2 lists the time resolution of the configuration. Column 3 lists the number of energy channels. Column 4 shows the number of bits used to telemeter each bin. Column 5 shows the telemetry rate that will be required to support this configuration. The telemetry rate does not depend on the count rate. The last column shows, approximately, the maximum rate of events below the cutoff energy that can be supported without risking rollover of counts.

TABLE Ap.1.5. Binned mode configurations for 0-3.0 keV

Name	Time	#Chan	#bits/bin	Telem (kbps)	Max Rate (cts/s)
B_500ms_10M_0_13	0.5 s	10[a,b]	16,4[c]	6.5	350,000
B_62ms_10M_0_13_H	62 ms	10[d,b]	8	6.5	103,000
B_16ms_10M_0_13_H	16 ms	10[b]	8	5.1	80,000
B_8ms_4A_0_13_H	8 ms	4[e]	8	4.1	64,000
B_4ms_4A_0_13_Q	4 ms	4[e]	4	4.1	3,000
B_2ms_4A_0_13_Q	2 ms	4[e]	4	8.2	6,000

TABLE Ap.1.5. Binned mode configurations for 0-3.0 keV

Name	Time	#Chan	#bits/bin	Telem (kbps)	Max Rate (cts/s)
B_2ms_2A_0_13_Q	2 ms	2[f]	4	4.1	3,000
B_1ms_2A_0_13_Q	1 ms	2[f]	4	8.2	6,000
B_1ms_4A_0_13_Q	1 ms	4[e]	4	16.5	12,000
B_500us_2A_0_13_Q	0.5 ms	2[f]	4	16.5	12,000
B_500us_4A_0_13_Q	0.5 ms	4[e]	4	33.0	24,000
B_250us_2A_0_13_Q	0.25 ms	2[f]	4	33.0	24,000

a. Ten channels are provided separately by PCU and for the 6 xenon and propane layers.

b. 10 channels: 0-4,5,6,7,8,9,10,11,12,13.

c. The front xenon layers and the propane layer use 16 bit bins, all others use 4 bit bins.

d. Ten channels are provided separately by PCU

e. 4 channels: 0-7, 8-9, 10-11, 12- 13.

f. 2 channels: 0-10, 11-13.

TABLE Ap.1.6. Binned mode configurations for 0-4.0keV

Name	Time	#Chan	#bits/bin	Telem Rate (kbps)	Max Rate (cts/s)
B_500ms_14M_0_17	0.5 s	14[a,b]	16, 4[c]	9	350,000
B_62ms_14M_0_17_H	62 ms	14[a,d]	8	9	143,000
B_16ms_14M_0_17_H	16 ms	14[a]	8	7	115,000
B_8ms_14M_0_17_H	8 ms	14[a]	8	14	230,000
B_8ms_8A_0_17_H	8 ms	8[e]	8	8	128,000
B_4ms_8A_0_17_H	4 ms	8[e]	8	16	256,000
B_4ms_4X_0_17_H	4 ms	4[f]	8	8	128,000
B_2ms_4X_0_17_H	2 ms	4[f]	8	16	256,000
B_2ms_2X_0_17_H	2 ms	2[g]	8	8	128,000
B_1ms_4X_0_17_H	1 ms	4[f]	8	33	350,000
B_1ms_4X_0_17_Q	1 ms	4[f]	4	16	12,000
B_1ms_2X_0_17_H	1 ms	2[g]	8	16	256,000
B_1ms_2X_0_17_Q	1 ms	2[g]	4	8	6,000
B_500us_4X_0_17_Q	0.5 ms	4[f]	4	33	24,000
B_500us_2X_0_17_Q	0.5 ms	2[g]	4	16	12,000
B_250us_4X_0_17_Q	0.25 ms	4[f]	4	66	48,000
B_250us_2X_0_17_Q	0.25 ms	2[g]	4	33	24,000

TABLE Ap.1.6. Binned mode configurations for 0-4.0keV

Name	Time	#Chan	#bits/bin	Telem Rate (kbps)	Max Rate (cts/s)
B_125us_4X_0_17_Q	0.125 ms	4[f]	4	132	96,000
B_125us_2X_0_17_Q	0.125 ms	2[g]	4	66	48,000

a. 14 Channels: 0- 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17.

b. The 14 channels are provided separately by PCU and for the 6 xenon and propane layers.

c. The front xenon layers and the propane layer use 16 bit bins, all others use 4 bit bins.

d. 14 channels are provided separately by PCU.

e. 8 Channels: 0-7, 8, 9, 10, 11, 12-13, 14-15, 16-17.

f. There are two options for the 4 energy channels:

Option A: 0-8, 9-10, 11-13, 14-17.
Option B: 0-10, 11-12, 13-14, 15-17.

g. There are two options for the 2 energy channels:

Option A: 0-11, 12-17.
Option B: 0-13, 14-17.

TABLE Ap.1.7. Binned mode configurations for 0-5.4 keV

Name	Time Bin	#chan	#bits/bin	Telem. (kbps)	Max Rate (< 5.4)
B_500ms_20M_0_23	0.5 s	20[a,b]	16,4[c]	13	350,000
B_62ms_20M_0_23_H	62 ms	20[a,d]	8	13	200,000
B_16ms_20M_0_23_H	16 ms	20[a]	8	10	160,000
B_16ms_16A_0_23_H	16 ms	16[e]	8	8	128,000
B_8ms_20M_0_23_H	8 ms	20[a]	8	21	300,000
B_4ms_16A_0_23_H	4 ms	16[e]	8	33	350,000
B_2ms_16A_0_23_Q	2 ms	16[e]	4	33	25,000
B_1ms_16A_0_23_Q	1 ms	16[e]	4	66	50,000
B_8ms_8X_0_23_H	8 ms	8[f]	8	8	128,000
B_4ms_8X_0_23_H	4 ms	8[f]	8	16	256,000
B_2ms_8X_0_23_H	2 ms	8[f]	8	33	350,000
B_2ms_8X_0_23_Q	2 ms	8[f]	4	16	12,000
B_1ms_8X_0_23_Q	1 ms	8[f]	4	33	25,000
B_500us_8X_0_23_Q	0.5 ms	8[f]	4	66	50,000
B_4ms_4X_0_23_H	4 ms	4[g]	8	8	128,000
B_2ms_4X_0_23_H	2 ms	4[g]	8	16	256,000
B_1ms_4X_0_23_H	1 ms	4[g]	8	33	350,000

TABLE Ap.1.7. Binned mode configurations for 0-5.4 keV

Name	Time Bin	#chan	#bits/bin	Telem. (kbps)	Max Rate (< 5.4)
B_1ms_4X_0_23_Q	1 ms	4[g]	4	16	12,000
B_500us_4X_0_23_Q	0.5 ms	4[g]	4	33	25,000
B_250us_4X_0_23_Q	0.25	4[g]	4	66	50,000
B_125us_4X_0_23_Q	0.125 ms	4[g]	4	132	100,000
B_2ms_2X_0_23_H	2 ms	2[h]	8	8	128,000
B_1ms_2X_0_23_H	1 ms	2[h]	8	16	256,000
B_1ms_2X_0_23_Q	1 ms	2[h]	4	8	6,000
B_500us_2X_0_23_Q	0.5 ms	2[h]	4	16	12,000
B_250us_2X_0_23_Q	0.25 ms	2[h]	4	33	25,000
B_125us_2X_0_23_Q	0.125 ms	2[h]	4	66	50,000

a. 20 Channels: 0-4, 5, 6, 7, 8, 9,10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23.

b. The 20 channels are provided separately by PCU and for the 6 xenon and propane layers.

c. The front xenon layers and the propane layer use 16 bit bins, all others use 4 bit bins.

d. 20 channels are provided separately by PCU.

e. 16 Channels: 0-6, 7-8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22-23.

f. There are two options for the 8 channels:

Option A: 0-7, 8-9, 10-11, 12-13, 14-15, 16-17, 18- 20, 21-23.
Option B: 0-9, 10-11, 12-13, 14-15, 16-17, 18-19, 20-21, 22-23.

g. There are two options for the 4 channels:

Option A: 0-8, 9-11, 12-15, 16-23.
Option B: 0-11, 12-15, 16-19, 20-23.

h. There are three options for the 2 channels:

Option A: 0-11, 12-23.
Option B: 0-13, 14-23.
Option C: 0-15, 16-23.

TABLE Ap.1.8. Binned mode configurations for 0-8.2 keV

Name	Time Bin	#chan	#bits/bin	Telem (kbps)	Max Rate (cts/s)
B_500ms_32M_0_35	0.5 s	32[a,b]	16,4[c]	21	350,000
B_62ms_32M_0_35_H	62 ms	32[d]	8	21	330,000
B_16ms_32M_0_35_H	16 ms	32[a]	8	16	256,000
B_8ms_32M_0_35_H	8 ms	32[a]	8	33	350,000
B_16ms_16A_0_35_H	16 ms	16[e]	8	8	128,000
B_8ms_16A_0_35_H	8 ms	16[e]	8	16	256,000
B_4ms_16A_0_35_H	4 ms	16[e]	8	33	350,000

TABLE Ap.1.8. Binned mode configurations for 0-8.2 keV

Name	Time Bin	#chan	#bits/bin	Telem (kbps)	Max Rate (cts/s)
B_2ms_16A_0_35_Q	2 ms	16[e]	4	33	24,000
B_1ms_16A_0_35_Q	1 ms	16[e]	4	66	50,000
B_8ms_8X_0_35_H	8 ms	8[f]	8	8	128,000
B_4ms_8X_0_35_H	4 ms	8[f]	8	16	256,000
B_2ms_8X_0_35_Q	2 ms	8[f]	4	16	12,000
B_1ms_8X_0_35_Q	1 ms	8[f]	4	33	24,000
B_500us_8X_0_35_Q	0.5 ms	8[f]	4	66	48,000
B_4ms_4X_0_35_H	4 ms	4[g]	8	8	128,000
B_2ms_4X_0_35_H	2 ms	4[g]	8	16	256,000
B_1ms_4X_0_35_Q	1 ms	4[g]	4	16	12,000
B_500us_4X_0_35_Q	0.5 ms	4[g]	4	33	24,000
B_250us_4X_0_35_Q	0.25 ms	4[g]	4	66	48,000
B_125us_4X_0_35_Q	0.125 ms	4[g]	4	132	96,000
B_62us_4X_0_35_Q	62 µs	4[g]	4	264	200,000
B_1ms_2X_0_35_H	1 ms	2[h]	8	16	256,000
B_1ms_2X_0_35_Q	1 ms	2[h]	4	8	6,000
B_500us_2X_0_35_Q	0.5 ms	2[h]	4	16	12,000
B_250us_2X_0_35_Q	0.25 ms	2[h]	4	33	25,000
B_125us_2X_0_35_Q	0.125 ms	2[h]	4	66	50,000
B_62us_2X_0_35_Q	62 µs	2[h]	4	132	100,000
B_31us_2X_0_35_Q	31 µs	2[h]	4	264	200,000

a. 32 Channels: 0-4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35.

b. The 32 channels are provided separately by PCU and for the 6 xenon and propane layers.

c. The front xenon layers and the propane layer use 16 bit bins, all others use 4 bit bins.

d. 32 channels are provided separately by PCU.

e. 16 Channels: 0-8, 9-10, 11, 12, 13, 14, 15, 16-17, 18-19, 20-21, 22- 23, 24-25, 26-27, 28-29,30-32,33-35.

f. There are two options for the 8 channels:

Option A: 0-7, 8-9, 10-11, 12-13, 14-15, 16-17, 18-21, 22-35.
Option B: 0-10, 11-13, 14-16, 17-19, 20-22, 23-26, 27-30, 31-35.

g. There are three options for the 4 channels:

Option A: 0-9, 10-13, 14-17, 18-35.
Option B: 0-13, 14-18, 19-25, 26-35.
Option M: 0-9, 10-15, 16-23, 24-35.

h. There are three options for the 2 channels:

Option A: 0-12, 13-35.
Option B: 0-15, 16-35.
Option C: 0-19, 20-35.

TABLE Ap.1.9. Binned mode configurations for under 11.7 keV

Name	Time	#Chan	#bits/bin	Telem (kbps)	Max Rate (cts/s)
B_500ms_46M_0_49	0.5 s	46[a,b]	16,4[c]	30	350,000
B_62ms_46M_0_49_H	62 ms	46[a]	8	30	350,000
B_16ms_46M_0_49_H	16 ms	46[a]	8	24	350,000
B_8ms_46M_0_49_H	8 ms	46[a]	8	47	350,000
B_16ms_16X_0_49_H	16 ms	16[d]	8	8	128,000
B_8ms_16X_0_49_H	8 ms	16[d]	8	16	250,000
B_4ms_16X_0_49_H	4 ms	16[d]	8	33	480,000
B_2ms_16X_0_49_Q	2 ms	16[d]	4	33	24,000
B_1ms_16X_0_49_Q	1 ms	16[d]	4	66	48,000
B_500us_16X_0_49_Q	0.5 ms	16[d]	4	132	96,000
B_8ms_8X_0_49_H	8 ms	8[e]	8	8	128,000
B_4ms_8X_0_49_H	4 ms	8[e]	8	16	256,000
B_2ms_8X_0_49_Q	2 ms	8[e]	4	16	12,000
B_1ms_8X_0_49_Q	1 ms	8[e]	4	33	24,000
B_500us_8X_0_49_Q	0.5 ms	8[e]	4	66	48,000
B_250us_8X_0_49_Q	0.25 ms	8[e]	4	132	96,000
B_125us_8X_0_49_Q	0.125 ms	8[e]	4	264	200,000
B_4ms_4X_0_49_H	4 ms	4[f]	8	8	128,000
B_2ms_4X_0_49_H	2 ms	4[f]	8	16	250,000
B_1ms_4X_0_49_H	1 ms	4[f]	8	33	480,000
B_1ms_4X_0_49_Q	1 ms	4[f]	4	16	12,000
B_500us_4X_0_49_Q	0.5 ms	4[f]	4	33	24,000
B_250us_4X_0_49_Q	0.25 ms	4[f]	4	66	48,000
B_125us_4X_0_49_Q	0.125 ms	4[f]	4	132	96,000
B_62us_4X_0_49_Q	61 μs	4[f]	4	264	192,000
B_2ms_2X_0_49_H	2 ms	2[g]	8	8	128,000
B_1ms_2X_0_49_H	1 ms	2[g]	8	16	256,000
B_1ms_2X_0_49_Q	1 ms	2[g]	4	8	6,000
B_500us_2X_0_49_Q	0.5 ms	2[g]	4	16	12,000
B_250us_2X_0_49_Q	0.25 ms	2[g]	4	33	24,000

TABLE Ap.1.9. Binned mode configurations for under 11.7 keV

Name	Time	#Chan	#bits/bin	Telem (kbps)	Max Rate (cts/s)
B_125us_2X_0_49_Q	0.125 ms	2[g]	4	66	48,000
B_62us_2X_0_49_Q	62 µs	2[g]	4	132	96,000
B_31us_2X_0_49_Q	31 µs	2[g]	4	264	192,000

a. 46 Channels: 0-4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49.

b. The 46 channels are provided separately by PCU and for the 6 xenon and propane layers.

c. The front xenon layers and the propane layer use 16 bit bins, all others use 4 bit bins.

d. There are 2 options for the 16 channels:

Option A: 0-7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17-18, 19-21, 22-25, 26-29, 30-35, 36-49.

Option B: 0-8, 9-11, 12-13, 14-15, 16-17, 18-19, 20-21, 22-23, 24-25, 26-27, 28-29, 30-32, 33-35, 36-39, 40-44, 45-49.

e. There are 2 options for the 8 channels:

Option A: 0-7, 8-9, 10-11, 12-13, 14-15, 16-17, 18-21, 22-49.
Option B: 0-11, 12-14, 15-17, 18-21, 22-26, 27-32, 33-39, 40-49.

f. There are 3 options for the 4 channels:

Option A: 0-9, 10-13, 14-17, 18-49.
Option B: 0-15, 16-22, 23-32, 33-49.
Option M: 0-10, 11-20, 21-33, 34-49.

g. There are 3 options for the 2 channels:

Option A: 0-13, 14-49.
Option B: 0-19, 20-49.
Option C: 0-23, 24-49.

Ap.1.5 Pulsar Fold Mode Configurations

There are no pulsar fold mode configurations. Pulsar fold configuration will be created and uploaded as needed. The operation of and parameters needed for pulsar fold mode are described in the EDS Observer’s Manual.

Pulsar fold mode is most useful for X-ray pulsars with periods shorter than a few seconds, and count rates more than 1500 cts/s. For sources with lower count rates, one of the event modes in Section Ap.1.7 on page 187 will provide all the information needed to perform the folding on the ground. For bright sources with periods longer than a few seconds, one of the binned mode configuration will provide all the information needed to perform the folding on the ground. Of the presently known x-ray pulsars, the Crab is the only source where pulsar fold mode is unambiguously required. Pulsar fold may be useful for a few other known sources, especially in high intensity states.

When using the pulsar fold mode, the observer is responsible to determine the required accuracy of and value for the pulse period for each observation.

Ap.1.6 Delta-time Binned Mode Configurations

Delta binned mode provides a histogram of the time between selected events. Only a single energy band may be selected. In all these configurations, only good xenon events are selected. The delta-time binned mode can provide a good estimate of the autocorrelation function for very short delay times (less than mean time between events). This mode is also useful for providing a measure of the detector dead time (Zhang et. al. 1994) in parallel with other measurements.

The numbers of counts in the first few bins are, on the average, proportional to the square of the count rate, so care must be taken to prevent rollover of counts at high count rates.

For low count rates, there is a different concern. The times are calculated using a 14-bit number; thus a delay of 16,385 bins would be counted as a delay of 1 bin. If the bin size is 1 µs, 16,384 bins is 16 ms. If the event rate is 130 cts/s then 12.5% of the events will have a delay time greater than 16ms. For weak sources a longer time bin size should be chosen.

Table 1.10, “Delta-time bin configurations,” on page 187 lists the available delta-time binned configurations.

TABLE Ap.1.10. Delta-time bin configurations

Name	Time bin	Read out	Bits/bin	# Bins	Telem. (kbps)	Max Rate (cts/s)
D_4us_0_249_1024_64s_F	4 µs	64 s	16	1024	0.3	1,500
D_1us_0_249_1024_16s_H	1 µs	16 s	8	1024	0.6	3,000
D_1us_0_249_1024_16s_F	1 µs	16 s	16	1024	1.1	50,000
D_1us_0_249_1024_64s_F	1 µs	64 s	16	1024	0.3	25,000
D_1us_0_249_128_4s_F	1 µs	4 s	16	128	0.6	100,000
D_1us_0_249_128_1s_F	1 µs	1 s	16	128	2.4	200,000

Ap.1.7 Event Mode Configurations

For all sources it is advantageous to send some data in event mode. For sources with counting rates of <~ 1500 cts/s, or for brighter sources where a larger telemetry allocation has been obtained, it is possible to send all the “good X-ray” events to the ground in event mode. For sources where it is not possible to send all the photon data in event mode, it is still advantageous to send data for the higher energy photons in event mode. To facilitate this we provide 6 different low energy cutoff points as shown in Table 1.11, “Low energy cutoff values for event mode configurations,” on page 188. In this table we show the low energy boundary in column 1 in keV and the PCA raw pulse height in column 2.

TABLE Ap.1.11. Low energy cutoff values for event mode configurations

Energy	PH Chan
0 keV	0
3.0 keV	14
4.0	18
5.4	24
8.2	36
11.7	50

Event mode works by writing events and time markers into a buffer (16 bits per event). The buffer can hold up to 16384 events and time markers. The EDS configurations provide 2 options for reading out the buffer. The low rate option will read out the buffer every 8 seconds. This provides a maximum telemetry rate of 34 kbps. If the source counting rate exceeds 2000 cts/s events will be lost. There is also be a high rate readout time of 1 second. This provides a maximum telemetry rate of 265 kbps. Note that for a source with a counting rate below 2000 cts/s, the telemetry is almost the same for the high and low readout times. The difference is that if the counting rate increases above 2000 cts/s, the 8s readout time will lose events but keep the telemetry rate low, while the 1s readout will not lose events but the telemetry rate may get very high.

Table 1.12, “EDS event mode configurations,” on page 188lists the event mode configurations that are available. The guest observer has the option of trading energy resolution and anode/detector ID information for time resolution. Telemetry usage depends only on the counting rate of selected events and is independent of the trade-off between time resolution and energy resolution. Column 3 shows the information about the detector and/or anode that is contained in each event, so when PCU is listed it means the PCU ID is placed in each event. Where PCU,LLD is listed it means that both the PCU ID and anode code are available for each event. For the event mode configurations with very high time resolution, no information about the PCU ID is put in the events.

TABLE Ap.1.12. EDS event mode configurations

Time	# PH channels	Type	Time mark Interval
1 μs	1	PCU	4 ms
1 μs	4		8 ms
2 μs	2	PCU	4 ms
2 μs	8		8 ms
4 μs	4	PCU	4 ms
4 μs	16		8 ms
8 μs	8	PCU	4 ms

TABLE Ap.1.12. EDS event mode configurations

Time	# PH channels	Type	Time mark Interval
8 µs	32		8 ms
16 µs	16	PCU	4 ms
16 µs	64		8 ms
31 µs	16	PCU	8 ms
62 µs	32	PCU	8 ms
125 µs	64	PCU	8 ms
250 µs	128	PCU	8 ms
500 µs	64	PCU, LLD	8 ms
1 ms	128	PCU, LLD	8 ms

The Event mode configurations follow the following naming convention:

E_ttt_cco_ll_rr,

where ttt is the time bin size (column 1 of Table 1.12, "EDS event mode configurations," on page 188), cc is the number of energy channels, o is the channel boundary option, ll is the lower channel cutoff (column 2 of Table 1.11, "Low energy cutoff values for event mode configurations," on page 188) and rr is the readout time (either 8s or 1s). For example:

E_31us_16M_50_1s

is an event mode that selects all events with energy greater than 11.7 keV, labels every event with a time stamp accurate to 31 µs, a PCU id, a 4 bit energy that specifies one of 16 energy channels, uses option M for the energy boundaries and is read out once per second (high rate).

Four sets of energy channel boundaries have been defined and are labelled A,B,C, or M. Not all options are always available. The boundary options were chosen such that:

- A - The count rate for a source with a soft spectrum (A0620 in Table 1.1, "Count rate estimates for some bright sources.," on page 176) is roughly the same in all channels.
- B - The count rate for a source with a medium spectrum (Crab in Table 1.1, "Count rate estimates for some bright sources.," on page 176) is roughly the same in all channels.
- C - The count rate for a source with a hard spectrum (Cyg X-1 in Table 1.1, "Count rate estimates for some bright sources.," on page 176) is roughly the same in all channels.

- M - The channel width divided by the detector resolution is roughly the same for all channels.

TABLE Ap.1.13. Two Channel options

Name	Ch 1	Ch 2
2A_0	0-13	14-249
2B_0	0-23	24-249
2C_0	0-35	36-249
2M_0	0-49	50-249
2A_14	14-17	18-249
2B_14	14-23	24-249
2C_14	14-35	36-249
2M_14	14-99	100-249
2A_18	18-23	24-249
2B_18	18-29	30-249
2C_18	18-35	36-249
2M_18	18-103	104-249
2A_24	24-29	30-249
2B_24	24-35	36-249
2C_24	24-49	50-249
2M_24	24-109	110-249
2A_36	36-42	43-249
2B_36	36-49	50-249
2M_36	36-119	120-249
2A_50	50-63	64-249
2M_50	50-127	128-249

TABLE Ap.1.14. Four channel options

Name	Ch 1	Ch 2	Ch 3	Ch 4
4A_0	0-9	10-13	14-17	18-249
4B_0	0-13	14-23	24-35	36-249
4C_0	0-16	17-25	26-41	42-249
4M_0	0-35	36-79	80-159	160-249
4A_14	14-15	16-17	18-23	24-249
4B_14	14-20	21-29	30-45	46-249
4M_14	14-43	44-95	96-165	166-249
4A_18	18-19	20-23	24-29	30-249
4B_18	18-23	24-31	32-49	50-249
4M_18	18-47	48-99	100-171	172-249

TABLE Ap.1.14. Four channel options

Name	Ch 1	Ch 2	Ch 3	Ch 4
4A_24	24-26	27-31	32-49	50-249
4B_24	24-33	34-49	50-95	96-249
4M_24	24-59	60-109	110-174	175-249
4A_36	36-41	42-49	50-63	64-249
4M_36	36-71	72-119	120-179	180-249
4A_50	50-55	56-63	64-79	80-249
4M_50	50-85	86-131	132-187	188-249

TABLE Ap.1.15. Eight Channel Options

Name	1	2	3	4	5	6	7	8
8A_0	0-7	8-9	10-11	12-33	14-16	17-20	21-25	26-249
8B_0	0-11	12-14	15-17	18-21	22-27	28-35	36-49	50-249
8C_0	0-12	13-16	17-20	21-25	26-31	32-39	40-55	56-249
8M_0	0-9	10-19	20-35	36-59	60-95	96-139	140-191	192-249
8A_14	14	15	16	17-18	19-20	21-23	24-29	30-249
8B_14	14-17	18-20	21-24	25-29	30-36	37-45	46-61	62-249
8M_14	14-26	27-43	44-63	64-87	88-117	118-157	158-203	204-249
8A_18	18	19	20	21-22	23-24	25-27	28-33	34-249
8B_18	18-19	20-23	24-27	28-35	36-45	46-61	62-127	128-249
8M_18	18-30	31-47	48-67	68-91	92-123	124-159	160-204	205-249
8A_24	24-25	26-27	28-29	30-31	32-33	34-47	48-127	128-249
8B_24	24-28	29-33	34-39	40-45	46-61	62-99	100-139	140-249
8M_24	24-35	36-51	52-71	72-95	96-123	124-159	160-204	205-249
8B_36	36-39	40-44	45-49	50-57	58-69	70-99	100-139	140-249
8M_36	36-49	50-65	66-87	88-113	114-143	144-177	178-213	214-249
8B_50	50-52	53-56	57-61	62-67	68-77	78-89	90-127	128-249
8M_50	50-65	66-83	84-104	105-127	128-154	155-184	185-217	218-249

TABLE Ap.1.16. 16 channel options

Name	Lower bound of each channel[a]
16A_0	0, 8, 10, 11, 12, 13, 14, 15, 16, 18, 20, 23, 27, 31, 36, 64
16B_0	0, 10, 12, 14, 17, 20, 23, 26, 29, 32, 36, 42, 50, 64, 92, 128
16M_0	0, 9, 14, 21, 30, 40, 52, 66, 80, 96, 114, 134, 155, 178, 202, 228
16A_14	14, 15, 16, 17, 18, 19, 20, 21, 23, 25, 27, 29, 31, 36, 64, 128
16B_14	14, 16, 18, 20, 22, 24, 26, 29, 32, 36, 40, 45, 50, 64, 92, 128

TABLE Ap.1.16. 16 channel options

Name	Lower bound of each channel[a]
16M_14	14, 19, 25, 32, 40, 49, 59, 70, 82, 96, 114, 134, 155, 178, 202, 228
16B_18	18, 20, 22, 24, 26, 28, 30, 32, 34, 37, 40, 45, 50, 64, 92, 128
16M_18	18, 24, 31, 38, 46, 54, 64, 76, 89, 103, 118, 134, 155, 178, 202, 230
16B_24	24, 26, 28, 30, 32, 34, 37, 40, 44, 50, 57, 66, 78, 96, 128, 175
16M_24	24, 31, 38, 46, 54, 64, 76, 89, 103, 118, 134, 152, 171, 191, 212, 234
16B_36	36, 38, 40, 42, 44, 47, 50, 54, 59, 65, 72, 80, 90, 104, 128, 175
16M_36	36, 43, 50, 58, 66, 75, 85, 96, 108, 121, 135, 152, 171, 191, 212, 234
16M_50	50, 55, 61, 68, 76, 85, 95, 106, 118, 131, 145, 161, 178, 196, 215, 236

a. The upper bound of each channel is one less than the next channel's lower bound. The last channel has an upper bound of 249.

TABLE Ap.1.17. 32 channel options

Name	Lower bound of each channel[a]
32B_0	0, 6, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 39, 43, 48, 55, 63, 72, 82, 94, 114, 150
32M_0	0, 8, 10, 13, 16, 19, 23, 27, 31, 36, 41, 46, 52, 59, 66, 73, 80, 88, 96, 105, 114, 124, 134, 144, 155, 166, 178, 189, 202, 215, 228, 241
32B_14	14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 34, 36, 39, 43, 48, 55, 63, 72, 82, 94, 114, 150, 196
32M_14	14, 16, 18, 20, 23, 26, 30, 34, 38, 42, 47, 52, 58, 64, 70, 76, 83, 91, 99, 108, 117, 126, 136, 146, 156, 166, 178, 189, 202, 215, 228, 241
32B_18	18, 20, 22, 24, 26, 29, 32, 35, 39, 44, 49, 54, 59, 64, 70, 76, 83, 91, 99, 108, 117, 126, 136, 146, 156, 166, 178, 189, 202, 215, 228, 241
32M_18	18, 21, 24, 27, 30, 34, 38, 42, 46, 50, 55, 60, 65, 70, 75, 81, 87, 93, 100, 108,117, 126, 136, 146, 156, 166, 178, 189, 202, 215, 228, 241
32M_24	24, 27, 30, 34, 38, 42, 46, 50, 55, 60, 65, 70, 75, 81, 87, 93, 100, 108, 116, 124, 133, 142, 151, 160, 170, 180, 190, 200, 210, 220, 230, 240
32M_36	36, 39, 42, 45, 48, 51, 55, 59, 63, 67, 71, 75, 80, 85, 91, 97, 104, 111, 118, 125,133, 142, 151, 160, 170, 180, 190, 200, 210, 220, 230, 240
32M_50	50, 53, 56, 59, 63, 67, 71, 75, 79, 84, 89, 94, 99, 104, 109, 114, 119, 124, 130, 136, 143, 150, 158, 166, 175, 184, 193, 203, 213, 223, 233, 244

a. The upper bound of each channel is one less than the next channel's lower bound. The last channel has an upper bound of 249.

TABLE Ap.1.18. 64 channel options

Name	Lower bound of each channel[a]
64M_0	0, 5, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 47, 50, 53, 56, 59, 62, 65, 68, 72, 76, 80, 84, 88, 92, 97, 102, 107, 112, 117, 122, 127, 132, 138, 144, 150, 156, 162, 168, 175, 182, 189, 196, 203, 210, 218, 226, 234, 244[b]
64M_14	14, 15, 16, 17, 18, 19, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 49, 52, 55, 58, 61, 64, 67, 70, 73, 76, 79, 82, 85, 88, 92, 96, 100, 104, 108, 112, 116, 120, 124, 128, 132, 136, 141, 146, 151, 156, 161, 166, 171, 176, 181, 186, 192, 198, 204, 211, 218, 226, 234, 244[b]
64M_18	18, 19, 20, 21, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 49, 52, 55, 58, 61, 64, 67, 70, 73, 76, 79, 82, 85, 88, 92, 96, 100, 104, 108, 112, 116, 120, 124, 128, 132, 136, 140, 145, 150, 155, 160, 165, 170, 175, 180, 185, 190, 195, 200, 205, 210, 215, 220, 226, 232, 238, 244[b]
64M_24	24, 25, 26, 27, 28, 29, 30, 31, 32, 34, 36, 38, 40, 42, 44, 46, 49, 52, 55, 58, 61, 64, 67, 70, 73, 76, 79, 82, 85, 88, 92, 96, 100, 104, 108, 112, 116, 120, 124, 128, 132, 136, 140, 145, 150, 155, 160, 165, 170, 175, 180, 185, 190, 195, 200, 205, 210, 215, 220, 226, 232, 238, 244, 250[c]
64M_36	36, 37, 38, 39, 40, 41, 42, 43, 44, 46, 48, 50, 52, 54, 56, 58, 60, 62, 64, 66, 68, 70, 73, 76, 79, 82, 85, 88, 91, 94, 97, 100, 103, 106, 109, 112, 116, 120, 124,128, 132, 136, 140, 145, 150, 155, 160, 165, 170, 175, 180, 185, 190, 195, 200, 205, 210, 215, 220, 226, 232, 238, 244, 250[c]
64M_50	50, 52, 54, 56, 58, 60, 62, 64, 66, 68, 70, 72, 74, 76, 78, 80, 82, 84, 86, 88, 91, 94, 97, 100, 103, 106, 109, 112, 115, 118, 121, 124, 127, 130, 133, 136, 139, 142, 145, 148, 152, 156, 160, 164, 168, 172, 176, 180, 184, 188, 192, 196, 200, 204, 208, 212, 216, 220, 225, 230, 235, 240, 245, 250[c]

a. The upper bound of each channel is one less than the next channel's lower bound.

b. The last channel has an upper bound of 249.

c. The last channel has an upper bound of 254.

TABLE Ap.1.19. 128 channel options

Name	Lower bound of each channel[a]
128M_0	0, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 56, 58, 60, 62, 64, 66, 68, 70, 72, 74, 76, 78, 80, 82, 84, 86, 88, 90, 92, 94, 96, 98, 100, 102, 104, 106, 108, 110, 112, 114, 116, 118, 120, 122, 124, 126, 128, 130, 132, 134, 136, 139, 142, 145, 148, 151, 154, 157, 160, 163, 166, 169, 172, 175, 178, 181, 184, 187, 190, 193, 196, 199, 202, 205, 208, 211, 214, 217, 220, 223, 226, 229, 232, 236, 240, 245, 250
128M_14	14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 70, 72, 74, 76, 78, 80, 82, 84, 86, 88, 90, 92, 94, 96, 98, 100, 102, 104, 106, 108, 110, 112, 114, 116, 118, 120, 122, 124, 126, 128, 130, 132, 134, 136, 138, 140, 142, 144, 146, 148, 150, 152, 155, 158, 161, 164, 167, 170, 173, 176, 179, 182, 185, 188, 191, 194, 197, 200, 203, 206, 209, 212, 215, 218, 221, 224, 227, 230, 234, 238, 242, 246, 250

TABLE Ap.1.19. 128 channel options

Name	Lower bound of each channel[a]
128M_18	18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62,63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 76, 78, 80, 82, 84, 86, 88, 90, 92, 94, 96, 98, 100, 102, 104, 106, 108, 110, 112, 114, 116, 118, 120, 122, 124, 126, 128, 130, 132, 134, 136, 138, 140, 142, 144, 146, 148, 150, 152, 154, 156, 158, 161, 164, 167, 170, 173, 176, 179, 182, 185, 188, 191, 194, 197, 200, 203, 206, 209, 212, 215, 218, 221, 224, 227, 230, 234, 238, 242, 246, 250
128M_24	24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 82, 84, 86, 88, 90, 92, 94, 96, 98, 100, 102, 104, 106, 108, 110, 112, 114, 116, 118, 120, 122, 124, 126, 128, 130, 132, 134, 136, 138, 140, 142, 144, 146, 148, 150, 152, 154, 156, 158, 160, 162, 164, 167, 170, 173, 176, 179, 182, 185, 188, 191, 194, 197, 200, 203, 206, 209, 212, 215, 218, 221, 224, 227, 230, 233, 236, 239, 242, 245, 248, 250
128M_36	36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 98, 100, 102, 104, 106, 108, 110, 112, 114, 116, 118, 120, 122, 124, 126, 128, 130, 132, 134, 136, 138, 140, 142, 144, 146, 148, 150, 152, 154, 156, 158, 160, 162, 164, 166, 168, 170, 172, 174, 176, 178, 180, 182, 184, 186, 188, 191, 194, 197, 200, 203, 206, 209, 212, 215, 218, 221, 224, 227, 230, 233, 236, 239, 242, 245, 248, 250
128M_50	50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 108, 110, 112, 114, 116, 118, 120, 122, 124, 126, 128, 130, 132, 134, 136, 138, 140, 142, 144, 146, 148, 150, 152, 154, 156, 158, 160, 162, 164, 166, 168, 170, 172, 174, 176, 178, 180, 182, 184, 186, 188, 190, 192, 194, 196, 198, 200, 202, 204, 206, 208, 210, 212, 214, 216, 218, 220, 222, 224, 226, 228, 230, 232, 234, 236, 238, 240, 242, 244, 247, 250

a. The upper bound of each channel is one less than the next channel's lower bound. The last channel has an upper bound of 254.

Ap.1.8 2 Event Analyzer Event Mode configurations

By using 2 event analyzers, each in event mode, it is possible to collect every non-coincident xenon event, labeled with its PCU and LLD, time stamp it with 1 μs resolution. and keep all 256 energy channels. This is done by having the first EA telemeter the 8 bit energy, a 3 bit PCU ID, and a 3 bit LLD code. The second EA will telemeter the PCU id and the time stamp. Ground software uses the time stamps and PCU id to match up the two events and produce a single event list FITS file.

There will be 2 readout time options. With the fast readout time of 2 s, data on up to 8000 cts/s may be collected without loss. At this maximum count rate the 2 EAs will generate 265 kbps. With the slow readout time of 16 s, data on up to 1000 cts/s may be collected. At this maximum count rate the 2 EAs will generate 32 kbps. The selection of these configurations will require 2 names be selected on the proposal form.

TABLE Ap.1.20. EDS event mode configuration using 2 EAs

Name	Readout Time	Maximum Telemetry	Maximum Event Rate
Good_Xenon1_2s, Good_Xenon2_2s	2 s	263 kbps	8,000
Good_Xenon1_16s, Good_Xenon2_16s	16 s	33 kbps	1,000

Ap.1.9 Transparent configurations

The transparent configurations are a set of 3 event mode configurations designed to make the EDS look like a straight wire. When running the transparent configurations, no anti-coincidence rejection of events is applied, making these configurations largely unsuitable for science. However, they are very useful for verification testing and diagnosing problems in the EDS and PCA. There are 3 transparent configurations. They are designed to be run in parallel on separate Event Analyzers. The first 2 transparent configurations may be run together to get all the bits from every event and a time stamp with 1 ms resolution. All three transparent configurations may be run together to get all the bits from every event and a time stamp with 1 μs resolution. The transparent configurations will have a selection of 4 readout times listed in Table 1.21, “,” on page 195. The slower readout times (> 16 s) will be used in snapshot mode so that up to 32,000 events may be collected in each readout, whereas the faster readout times (16 s or less) will collect up to 16,000 events in each readout.

TABLE Ap.1.21.

Name	Readout time	Maximum telemetry	Maximum Event Rate
Transparent1_4s, Transparent2_4s, Transparent3_4s	4 s	197 kbps	4000 cts/s
Transparent1_16s, Transparent2_16s, Transparent3_16s	16 s	49 kbps	1000 cts/s
Transparent1_128s, Transparent2_128s, Transparent3_128s	128	12.5 kbps	256 cts/s
Transparent1_1024s, Transparent2_1024s, Transparent3_1024s	1024	1.5 kbps	32 cts/s

Ap.1.10 Event Burst Catcher Mode configurations

The Event Burst Catcher mode works by capturing 33,767 events plus time markers every time a trigger signal is received. If the trigger is high-priority the data will be immediately transferred to the S/C. If the trigger is low-priority, then the data is stored and only the data for the last trigger of each EA run is sent to the S/C.

TABLE Ap.1.22. EDS Burst Catcher Event Mode configurations

Name	Time	# PH channels	Type	Time mark Interval
CE_1us_1M_0	1 µs	1	PCU	4 ms
CE_1us_4X_0	1 µs	4[a]		8 ms
CE_2us_8X_0	2 µs	8[b]		8 ms
CE_4us_16X_0	4 µs	16[c]		8 ms
CE_8us_32X_0	8 µs	32[d]		8 ms
CE_16us_64M_0	16 µs	64[e]		8 ms
CE_31us_16X_0	31 µs	16[c]	PCU	8 ms
CE_16us_32M_0	62 µs	32[d]	PCU	8 ms
CE_125us_64M_0	125 µs	64[e]	PCU	8 ms
CE_250us_128M_0	250 µs	128[f]	PCU	8 ms
CE_500us_64M_0	500 µs	64[e]	PCU, LLD	8 ms
CE_1ms_128M_0	1 ms	128[f]	PCU, LLD	8 ms
CE_GoodXenon{1&2}[g]	1 µs	256	PCU, LLD	8 ms

a. The energy boundary options are the same as E_1us_4X_0_1s, (Table 1.14, “Four channel options,” on page 190)

b. The energy boundary options are the same as E_2us_8X_0_1s, (Table 1.15, “Eight Channel Options,” on page 191)

c. The energy boundary options are the same as E_4us_16X_0_1s, (Table 1.16, “16 channel options,” on page 191)

d. The energy boundary options are the same as E_8us_32X_0_1s, (Table 1.17, “32 channel options,” on page 192)

e. The energy boundaries are the same as E_16us_64M_0_1s, (Table 1.18, “64 channel options,” on page 193)

f. The energy boundaries are the same as E_250us_128M_0_1s, (Table 1.19, “128 channel options,” on page 193)

g. Requires 2 event analyzers for the catcher.

Ap.1.11 Binned Burst Catcher Mode Configurations

The following are examples of Binned Burst Catcher configurations. This mode is most useful for catch bursts that contain more than 32,000 events and for catching bursts of sources with significant persistent emission. For sources with little or no persistent emission and peak count rates in the burst of less than 16,000 counts/s, a continuous event mode configuration (see Section Ap.1.7) is the best way to catch bursts. The binned burst catcher must be run with a synchronous burst trigger configuration, which means the trigger and catcher configurations must both have the same interval duration. The binned burst catcher mode will provide 1 interval of data prior to the time of the initial high-priority trigger assertion, and 2 intervals of data following the final high-priority trigger assertion. If a low-priority trigger is received, 4 intervals of data will be saved on-board, overwriting any previously captured data. Upon receipt of a “terminate” command, this captured data is telemetered to the ground.

TABLE Ap.1.23. Binned Burst Catcher Configurations

Name	TimeBin	Interval Duration	Number channels	Bits/bin	Peak Telem.	Max Count rate
CB_2ms_64M_0_249	2 ms	0.25 s	64	8,4	200	350,000
CB_1ms_32X_0_249	1 ms	0.25 s	32	8,4	200	350,000
CB_500us_16X_0_249_Q	500 µs	0.25 s	16	4	133	100,000
CB_250us_8X_0_249_Q	250 µs	0.25 s	8	4	133	100,000
CB_125us_4X_0_249_Q	125 µs	0.25 s	4	4	133	100,000
CB_64us_2X_0_249_Q	64 µs	0.25 s	2	4	133	100,000
CB_32us_1M_0_249_Q	32 µs	0.25 s	1	4	133	100,000
CB_8ms_64M_0_249_H	8 ms	1 s	64	8	67	350,000
CB_4ms_32X_0_249_H	4 ms	1 s	32	8	67	350,000
CB_2ms_16x_0_249_H	2 ms	1 s	16	8	67	350,000
CB_1ms_8x_0_249_H	1 ms	1 s	8	8	67	350,000
CB_500us_4x_0_249_H	500 µs	1 s	4	8	67	350,000
CB_250us_2x_0_249_H	250 µs	1 s	2	8	67	350,000
CB_125us_1M_0_249_H	125 µs	1 s	1	8	67	350,000
CB_32ms_64M_0_249	32 ms	4 s	64	16,8	24	350,000
CB_16ms_32X_0_249	16 ms	4 s	32	16,8	24	350,000
CB_8ms_16x_0_249_H	8 ms	4 s	16	8	16	250,000
CB_4ms_8X_0_249_H	4 ms	4 s	8	8	16	250,000
CB_2ms_4X_0_249_H	2 ms	4 s	4	8	16	250,000
CB_1ms_2X_0_249_H	1 ms	4 s	2	8	16	250,000
CB_500us_1M_0_249_H	500 µs	4 s	1	8	16	250,000

TABLE Ap.1.23. Binned Burst Catcher Configurations

Name	TimeBin	Interval Duratio n	Number channels	Bits/bin	Peak Telem.	Max Count rate
CB_125ms_64M_0_249_F	125 ms	16 s	64	16	8	350,000
CB_64ms_32X_0_249_F	64 ms	16 s	32	16	8	350,000
CB_32ms_16X_0_249_F	32 ms	16 s	16	16	8	350,000
CB_16ms_8X_0_249_F	16 ms	16 s	8	16	8	350,000
CB_8ms_4X_0_249_F	8 ms	16 s	4	16	8	350,000
CB_4ms_2X_0_249_F	4 ms	16 s	2	16	8	350,000
CB_2ms_1X_0_249_F	2 ms	16 s	1	16	8	350,000

Ap.1.12 Burst Trigger configurations

Ap.1.12.1 High Priority Burst Triggers

The following high-priority trigger configurations are available for GO use. When using these triggers every triggered data set will be captured for each run, subject to the bandwidth limitations between the S/C and EDS. All of these configurations will trigger HEXTE. All of these configurations will use a single energy band covering channels 10-249.

TABLE Ap.1.24. High-priority burst trigger configurations.

Name	**Trigger**	Interval Duration	Time bin	Energy Channel.	Trigger Threshold
TLA_250ms_10_249_250ms_100_FN	Level	0.25 s	0.25 s	1	100 cts/bin
TLA_250ms_10_249_250ms_200_FN	Level	0.25 s	0.25 s	1	200 cts/bin
TLA_250ms_10_249_250ms_500_FN	Level	0.25 s	0.25 s	1	500 cts/bin
TLA_250ms_10_249_250ms_1000_FN	Level	0.25 s	0.25 s	1	1000cts/bin
TLA_250ms_10_249_250ms_2000_FN	Level	0.25 s	0.25 s	1	2000cts/bin
TLA_250ms_10_249_250ms_5000_FN	Level	0.25 s	0.25 s	1	5000cts/bin
TLA_1s_10_249_1s_500_F	Level	1 s	1 s	1	500 cts/bin
TLA_1s__10_249_1s_1000_F	Level	1 s	1 s	1	1000 cts/s
TLA_1s__10_249_1s_2000_F	Level	1 s	1 s	1	2000 cts/s
TLA_1s__10_249_1s_5000_F	Level	1 s	1 s	1	5000 cts/s
TLA_1s__10_249_1s_10000_F	Level	1 s	1 s	1	10000 cts/s
TLA_1s__10_249_1s_20000_F	Level	1 s	1 s	1	20000 cts/s
TLA_4s_10_249_4s_100_F	Level	4 s	0.25 s	1	100 cts/bin

TABLE Ap.1.24. High-priority burst trigger configurations.

Name	**Trigger**	Interval Duration	Time bin	Energy Channel.	Trigger Threshold
TLA_4s_10_249_4s_200_F	Level	4 s	0.25 s	1	200 cts/bin
TLA_4s_10_249_4s_500_F	Level	4 s	0.25 s	1	500 cts/bin
TLA_4s_10_249_4s_1000_F	Level	4 s	0.25 s	1	1000cts/bin
TLA_4s_10_249_4s_2000_F	Level	4 s	0.25 s	1	2000cts/bin
TLA_4s_10_249_4s_5000_F	Level	4 s	0.25 s	1	5000cts/bin
TLA_16s_10_249_4s_100_F	Level	16 s	0.25 s	1	100 cts/bin
TLA_16s_10_249_4s_200_F	Level	16 s	0.25 s	1	200 cts/bin
TLA_16s_10_249_4s_500_F	Level	16 s	0.25 s	1	500 cts/bin
TLA_16s_10_249_4s_1000_F	Level	16 s	0.25 s	1	1000cts/bin
TLA_16s_10_249_4s_2000_F	Level	16 s	0.25 s	1	2000cts/bin
TLA_16s_10_249_4s_5000_F	Level	16 s	0.25 s	1	5000cts/bin

Ap.1.12.2 Low Priority Burst Trigger configurations

The following low-priority trigger configurations are available for GO use. When using these triggers only one triggered data set will be captured for each EA run. None of these configurations will trigger HEXTE. Five of the configurations utilize level triggers (TL), 2 utilize hardness ratio triggers (TH), and two utilize edge triggers (TE).

TABLE Ap.1.25. Low-priority burst trigger configurations.

Name	**Trigger**	**Interval Duration**	**Time bin**	**Energy Channel.**	**Telemetry (bits/s)**
TLM_31us_0_249_500ms_QN	Level	0.5 s	31 µs	1	544
TLM_125us_0_249_2s_QN	Level	2 s	125 µs	1	136
TLM_1ms_0_249_2s_HN	Level	2 s	1 ms	1	136
TLM_4ms_0_249_1s_HN	Level	1 s	4 ms	1	272
TLM_31ms_0_249_8s_F	Level	8 s	31 ms	1	564
THM_4ms_0_14_249_1s_HN	Hardness	1 s	4 ms	2	272
THM_31ms_0_14_249_1s_F	Hardness	8 s	31 ms	2	564
TEM_4ms_0_249_1s_HN	Edge	1 s	4 ms	1	272
TEM_31ms_0_249_8s_F	Edge	8 s	31 ms	1	564

Ap.1.13 Single-Bit mode Configurations

The single-bit mode is used to provide a time series for 1 energy band per EA. To the guest observer single-bit mode data will look just like binned data. One advantage of single-bit mode is that the individual bins can not overflow.

Single-bit mode generates a 0 for every clock tick and a 1 for every event. The total telemetry rate is the sum of the clock tick rate and the event tick rate. So a source producing 3000 cts/s in the selected energy channel, when observed with a 0.25 ms single bit mode, would generate 7 kbps.

Single-bit mode operates with a buffer of 64k bits, which may be filled with either events or clock ticks. If a total of more than 64k events and clock ticks are seen within one readout time, data gaps will occur. If the buffer fills, a count of the number of events that were dropped is maintained.

The naming convention for single-bit mode configurations is SB_ttt_ll_hh_R, where ttt is the time bin size, ll and hh are the lower and upper boundaries of the selected energy band and R is the readout time.

Table 1.26, “Single-Bit configurations,” on page 200 lists the time bins available for single bit mode configurations. Table 1.27, “Lower and upper bounds (keV) for the energy channels for Single-bit configuration,,” on page 200list the available energy channels that may be selected. A single-bit mode configuration is specified by a time bin from Table 1.26, “Single-Bit configurations,” on page 200and an energy band from Table 1.27, “Lower and upper bounds (keV) for the energy channels for Single-bit configuration,,” on page 200. Pulse height corrections are applied to these channel boundaries.

TABLE Ap.1.26. Single-Bit configurations

Time Bin	Clock Rate	Readout Time	Maximum Rate (cts/s)
0.5 ms	2 kHz	2 s	30,000
0.25 ms	4 kHz	2 s	28,000
125 µs	8 kHz	1 s	54,000
62 µs	16 kHz	0.5 s	112,000
31 µs	32 kHz	0.5 s	96,000

TABLE Ap.1.27. Lower and upper bounds (keV) for the energy channels for Single-bit configuration,

Lower Energy (keV)	Upper Energy (keV)
0	3.0
0	4.0
0	5.4
0	8.2
0	11.7

TABLE Ap.1.27. Lower and upper bounds (keV) for the energy channels for Single-bit configuration,

Lower Energy (keV)	Upper Energy (keV)
0	58.4
3.0	4.0
3.0	5.4
3.0	8.2
3.0	11.7
3.0	58.4
4.0	5.4
4.0	8.2
4.0	11.7
4.0	58.4
5.4	8.2
5.4	11.7
5.4	58.4
8.2	11.7
8.2	58.4

Ap.1.14 FFT Mode configurations

The FFT mode works on two time series, each containing 256 points. Normally the two time series give counts as a function of time for two energy bands. The FFT mode works by first binning the data, with a prescale, into the two time series. Second, the mean of each time series is calculated, stored and subtracted from each time series. Third, the FFT is calculated with one time series in the real part and the other in the complex part. Fourth, the two Power Density Spectra (PDS) and Cross Spectra (CS) are calculated. The PDS and CS are summed up over a readout time. Dead time results since data is only collected during the first step. The data products produce by FFT mode are:

- summed PDS of band 1 (129 points)
- summed PDS of band 2 (129 points)
- summed CS between bands 1 and 2
- series of means for band 1
- series of means for band 2.

All the binning, mean subtraction, and FFT calculations are performed using 16-bit integers. There is no padding of the binned data, all 256 points are filled, and a 256 point FFT is performed. The minimum time interval for binning data (step 1 above) is 4ms, which results in extra dead time for time bins less than 15 us. The time needed for the other steps is 12ms.

The FFT requires at least 2 photons per time series to get a useful signal. Thus to effectively use the 1 μs time bins, one would like at least 2 photons per channel per 0.25 ms (256 x 1 μs time bins), which is ~16,000 cts/s, assuming the channels are chosen to split the counts equally. There is also a maximum count rate, due to the prescale, and 16-bit integer calculations.

In choosing an FFT mode the guest observer selects a time bin size (Table 1.28, "Time bin and readout time option for FFT configurations," on page 202) and a set of channel boundaries (Table 1.29, "Energy channel boundaries for FFT configurations," on page 202). The naming convention for FFT mode is:

F_ttt_l_m_h_r,

where ttt is the time bin size, l is lower bound of the lower energy channel, m is the upper bound of the lower channel and the lower bound of the upper channel, h is the upper bound of the upper channel, and r is the readout time. For example:

F_500us_0_12_249_64s

represents an FFT mode with 500 us time bins, which the 2 energy channels being 0 - 3.0 keV and 3.0 - 62.5 keV and a readout time of 64 s.

TABLE Ap.1.28. Time bin and readout time option for FFT configurations

Time Bin Size	Dead Time	Readout Time	Prescale	Telem. (kbps)	Max Rate (cts/s)
1 μs	98%	16s	8192	3.4	500,000
4 μs	93%	16s	8192	3.4	500,000
8 μs	86%	16 s	8192	3.4	500,000
16 μs	72%	16 s	8192	3.4	250,000
31 μs	56%	16 s	4096	2.9	250,000
62μs	38%	16 s	4096	2.3	125,000
125 μs	24%	16 s	4096	1.8	64,000
500 μs	7%	64 s	2048	0.5	32,000
4 ms	1%	64 s	1024	0.3	8,000

TABLE Ap.1.29. Energy channel boundaries for FFT configurations

Channel 1	Channel 2
0-11	12-249
0-13	14-249

TABLE Ap.1.29. Energy channel boundaries for FFT configurations

Channel 1	**Channel 2**
0-17	18-249
0-23	24-249

Appendix Ap.2 Software Support for Proposers

Ap.2.1 Items Available via Anonymous FTP

The following items are available to proposers via anonymous FTP at legacy.gsfc.nasa.gov. The subdirectories are listed in block parentheses.

- text of the XTE NRA in an ASCII or PostScript file [xte/nra]
- figures from the XTE NRA as PostScript files [xte/nra]
- VIEWING User's Guide and source code (described below) [software/]
- PIMMS User's Guide and source code (described below) [software/]
- XSPEC (described in Chapter 8; the installation is described below) [software/xanadu]
- recommd (described in Chapter 8; installation is described below) [xte/software/]
- timing simulation software (briefly described in Chapter 8; installation described below) [software/ftools/]
- the new RPS proposal preparation tools (described below)

Please consult the help file README for any problems or the FTPmap.txt file for a brief look at the locations of files.

Ap.2.2 VIEWING

VIEWING is a stand-alone program that allows users to calculate the XTE viewing window, either in interactive or batch mode. Recall that the viewing constraint on XTE is slight.

The following sample shows the most basic form in which VIEWING may be used:

```
$ viewing
Enter object name (<CR> to quit) > test
Enter RA (hh mm ss.s or dd.ddd) > 23.45
Enter Dec ((s)dd mm ss.s or (s)dd.ddd) > 33.21
 * test (at alpha= 24.0706, delta= 33.4314, precessed)
  is observable between 1992 Dec 24 and 1993 Feb 26
  is observable between 1993 Jun 24 and 1993 Aug 31
Enter object name (<CR> to quit) >
```

In this most basic form, VIEWING assumes a solar angle constraint of 30^{o}, a period of interest of 1 year starting from the current date, and an epoch of 1950.0 for the coordinate.

Options can be supplied on the command line as name-value pairs (i.e., name=value), which are:

- start=31-mar-93 to change the start date
- range=70-110 to change the solar angle range
- epoch=2000 to change the epoch
- input=file to read multiple sets of object name, RA, and Dec from the specified file
- output=file to save the results in a named file

This program is available via anonymous FTP at legacy.gsfc.nasa.gov in the pub/viewing directory together with up-to-date documentation. VIEWING currently runs on VAX/VMS machines, Sun workstations, and Ultrix DECstations. It is also available for remote use as part of MIPS. Those who wish to run VIEWING on other platforms should contact the XTE GOF at xtenra@athena.gsfc.nasa.gov.

Ap.2.3 PIMMS User's Guide

PIMMS (Portable, Interactive, Multi-Mission Simulator) is designed for the evaluation of source count rates as well as for the simulation of images and spectra. At the time of writing (Autumn 1994), PIMMS outputs information onto the terminal screen and can produce FITS image files. The capability to write photon data in binary FITS format is under development.

The multi-mission nature is fully realized for the evaluation of source count rates insofar as PIMMS allows the conversion of count rates among different missions. For example, given a spectral form - a 10keV bremsstrahlung, say - the observed Einstein IPC count rate can be converted to the XTE PCA count rate. For many GOs, PIMMS will be the easiest way to estimate PCA and HEXTE count rates for the targets that are a requirement of XTE proposals.

The multi-mission nature is less apparent in spectrum and image simulation. This is due to the limited number of calibration files available to PIMMS at the moment. Expansion of the capabilities of PIMMS is under development.

Both PIMMS and the XTE calibration database on which it relies are undergoing rapid development at the moment. More details are available from the anonymous FTP directory at legacy.gsfc.nasa.gov. PIMMS is located here (the software/ directory) as well as the most-current documentation.

PIMMS is currently supported on Sun workstations, VAX/VMS machines, and Ultrix DECstations.

Ap.2.4 How to Install XSPEC

At the HEASARC, many changes have been made to the XANADU X-ray analysis software package -- changes not only to increase options and facilities for the user, but also to allow for ease and flexibility in installation on VAX, Sun/UNIX, or DEC/Ultrix systems.

Previously, to install a XANADU package, the entire XANADU system was needed. Now, packages such as XSPEC, XRONOS, and XIMAGE are available separately, as is the XANADU library package (including the XANADU libraries, command files, and several packages, e.g., PGPLOT, QDP, FITSIO, that are bundled with XANADU). The entire XANADU system is also available as a single tar file (Unix) or backup file (VMS) for all systems.

For ease of file transfer, object code and built libraries are not included in these packages; they can be made available from HEASARC upon request. Installation scripts have been created to build XANADU and its packages from top to bottom. The necessary installation steps are: (i) obtain the appropriate files; (ii) select an area to put them; (iii) extract them from the save-set; (iv) edit a few minor lines depending upon the PI's particular setup, and (v) run the scripts.

Formerly, the XANADU package had to be installed at the "root" level on UNIX/ULTRIX systems. This restriction required the attention of a system manager. The current release of XANADU allows the base node to be placed an any directory level with only minimal changes by the installer.

After the files are extracted (explicit directions are included in the ftp directories), the installer may need to make several changes to ensure a smooth installation. First, the file initu.com (VMS) or initu.csh (UNIX) (initu.sh for non-csh UNIX users) may be changed to include the XANADU pathname. If the XANADU pathname is included, the VMS user need only include the file

@sitexanpath:[tools]initu (where sitexanpath is the full XANADU path at the installation) in their login.com. If this path is not included in the initu.com, the user must define the logical variable XANADU (with the /trans=conc option) in their login.com, and then type the line @XANADU:[tools]initu in the login.com. For UNIX/Ultrix csh installers, the file initu.csh can be edited to set the XANADU path as an environment variable (using setenv), and users will neeed to source initu.csh in their .cshrc file -- this statement must be in the .cshrc and not the .login file, or commands will cause certain packages to fail! In addition, the UNIX installer must set the environment variable EXT to the machine type (ulx for Ultrix, sun for Sun, etc.) in initu.csh, or it must be set in individual users' .cshrc scripts.

After the installer has finished editing the initu scripts, and has run it or sourced it, the script initp.com (VMS) or initp (UNIX/Ultrix) should be run or sourced to allow the use of various tools and to set the path of the XANADU library and other libraries. No editing of this script is required. For the VMS installer, all that remains is to run the appropriate installation scripts from the top of the XANADU tree. There is one remaining task for the UNIX or Ultrix installer: change several site-specific files to reflect the local XANADU path. This is not necessary in VMS because logical names can be used in data statements and are automatically converted -- but UNIX is a different story. The file chsitedef.sed (in the tools directory) must be edited to reflect the XANADU path. Then, the executable changesite must be run from the top-level XANADU directory. This step is absolutely necessary to obtain a working XANADU system.

After the above steps have been followed, installation is at hand. The UNIX/Ultrix installation is handled completely through the make system. To make all packages, type make install. Or type make xanlib to make just XANADU routines and libraries, and then make XSPEC, make XRONOS, or make XIMAGE. Under VMS, where make utilities are not common, .com files are provided that perform the same functions, named make_install.com, etc. Special instructions will be provided on request for sites that desire to keep old versions of XANADU available in addition to the improved version.

Once the installation is complete, all executables will be located in the appropriate bin directory for the system (XANADU:[vms.bin] or $XANADU/$EXT/bin) This directory is added to user paths when initu.csh is sourced, or on VMS when initu.com is run. Manuals for the various packages are available in on-line form via the xhelp command through those packages, or in hardcopy from HEASARC or through a printout of TeX versions included with the packages. A guide to the XANADU library routines is forthcoming from HEASARC/OGIP and will be available upon request.

Ap.2.5 How to Install `recommd`

The source code for `recommd` is C. The source is available from the anonymous FTP account (`legacy.gsfc.nasa.gov`). The following files must be transferred to make `recommd` work: `recommd.c`, `recommd.h`, and `edscfnam.txt`. The `recommd.1` file contains the Unix `man` page for `recommd`. An executable version may be obtained by invoking the C compiler on the user's machine. For example,

```
cc -o recommd recommd.c -lm
```

generates an executable called '`recommd.x`' that includes the necessary libraries (the '-lm'). '`recommd`' then behaves as described in Chapter 8.

Ap.2.6 How to Install the Timing Simulation Tools

The timing simulation tools are distributed as part of the FTOOLS software, available from the HEASARC on the anonymous FTP account (`legacy.gsfc.nasa.gov`, directory `software/`). The FTOOLS distribution contains user set-up scripts (see the `README` file under `software/ftools`). The code is distributed as source and binaries (the binaries are specific to particular machine architectures). The machine architectures currently supported are Sun, DEC Ultrix, ALPHA, and VMS.

The user does not need to download all of the FTOOLS distribution to obtain the timing simulation tools. The tools were developed, however, with the intent of using them within the FTOOLS environment.

Ap.2.7 How to Use the New RPS Proposal Submission Tools

In an effort to simplify the proposal submission process, the RPS (Remote Proposal Submission) software has been re-designed. Two versions of the new RPS exist: an automated e-mail submission system and an X-Mosaic form-based system. Both are described briefly below.

The automated e-mail system is an e-mail server that uses a few basic commands to process a user's request. The user starts the process by submitting a blank e-mail request (with the `Subject:` set to XTE) to `rps@legacy.gsfc.nasa.gov`. The blank request returns the help page which contains instructions and examples to obtain the blank forms, to submit the final version, etc. The blank form is ASCII text, so any text editor may be used to enter values. The entries are name:value entries; the order of the text is therefore immaterial. Once the form has been edited, it may be re-mailed to the above e-mail address. Verification is the default option (not submit). Some range checking is done and errors are flagged for the user. Other options include ‘submit’ which submits the form for verification and, if no errors are found, sends the form to the proposal database and ‘latex’ which returns a LaTeX version of the form.

The user should be aware that, during the testing of the automated e-mail server, there have been occasional long lags between the time a request is submitted for processing and the time the processed request is returned to the user. We believe this is a network traffic problem; if it occurs, however, please let us know by sending the details of who/what/when/where/ etc. to `xtenra@athena.gsfc.nasa.gov`.

The second RPS tool is the X-Mosaic form. Mosaic is a stateless server, so it functions in a manner similar to that of the automated e-mail server. The user must always ‘submit’ an action to the server to obtain or to update a result. The overall appearance of the Mosaic form is similar to the paper forms. This appearance was retained largely for convenience, although the layout of the form may evolve with use over upcoming proposal periods. On-line help is available as with most Mosaic applications.

The URL for the Mosaic form is: `http://legacy.gsfc.nasa.gov/cgi-bin/RPS.pl`.

Currently, only X-Mosaic is supported due to limitations for forms of PC-Mosaic and Mac-Mosaic. As these limitations are removed by upgrades to the server, RPS will be available.

Appendix Ap.3 XTE Personnel

Ap.3.1 Science Operations

- XTE Project Scientist: Dr. Jean Swank, swank@lheavx.gsfc.nasa.gov
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Ap.3.5 NRA and Technical Appendix Editor

- Dr. Eric M. Schlegel, eric@heasfs.gsfc.nasa.gov

Appendix Ap.4 Glossary of Abbreviations

This section contains a list of the abbreviations most frequently encountered in dealing with XTE. If an abbreviation is specific to a particular instrument or group, the instrument or group name is enclosed in parenthesis at the end of the abbreviation.

TABLE Ap.4.1.

Abbreviation	**Meaning**
ACS	Attitude Control System
ADC	Analog Digital Converter
AGC	Automatic Gain Control (HEXTE)
ASM	All-Sky Monitor
CEU	Cluster Electronics Unit (HEXTE)
CPU	Central Processing Unit (EDS)
CS	Cross Spectrum (EDS)
Cycle-1	The current NRA period
DB	Data Buffer (EDS)
DSP	DIgital Signal Processor (EDS)
EA	Event Analyzer (EDS)
EDS	Experiment Data System
EE	Event Encoded (EDS)
FDS	Flight Data System (s/c)

TABLE Ap.4.1.

Abbreviation	**Meaning**
FFT	Fast Fourier Transform (EDS)
FIFO	First In, First Out
FOV	Field Of View (ASM)
FS	Flight Software
FTOOLS	FITS tools (HEASARC)
FWHM	Full Width Half Maximum
FWZI	Full Width Zero Intensity
GO	Guest Observer
GOF	Guest Observer Facility
GSFC	NASA-Goddard Space Flight Center (PCA PI team)
HDB	Half Data Buffer (EDS)
HEASARC	High Energy Astrophysics Science Archive Research Center
HEXTE	High Energy X-ray Timing Experiment
HRM	High Rate Monitor (PCA)
HV	High Voltage
HVPS	High Voltage Power Supply (PCA)
IDF	Instrument Date Frame (HEXTE)
IOC	In-Orbit Check-out (phase of observation)
IPS-DU	Instrument Power Switching and Distribution Unit (s/c)
L1, L2, L3	odd-numbered anodes naming scheme (PCA)
LHEA	Laboratory for High Energy Astrophysics
LLD	Lower Level Discriminator (PCA, HEXTE)
LSB	Least Significant Bit (PCA/EDS)
LUT	Look-Up Table
LVPS	Low Voltage Power Supply (PCA)
MA	Multiple Access (TDRSS)
MET	Mission Elapsed Time
MIT	Massachusetts Institute of Technology (ASM, EDS PI team)
MOC	Mission Operations Center
MSB	Most Significant Bit (PCA/EDS)
MSE	Module Support Electronics (HEXTE)
NRA	NASA Research Announcement
OGIP	Office of Guest Investigator Programs
PCA	Proportional Counter Array
PCU	Proportional Counter Unit (PCA)

TABLE Ap.4.1.

Abbreviation	**Meaning**
PDS	Power Density Spectrum (EDS)
PH	Pulse Height
PHA	Pulse Height Analyzer
PIMMS	Portable, Interactive, Multi-Mission Simulator (HEASARC)
PME	Phoswich Module Electronics (HEXTE)
PRAM	Protected RAM (EDS)
PSA	Pulse Shape Analyzer (HEXTE)
PSD	Pulse Shape Discriminator (HEXTE)
PSPC	Position Sensitive Proportional Counter (ASM)
R1, R2, R3	even-numbered anodes naming scheme (PCA)
RAM	Random Access Memory
RFO	Request For Observation (one-page “proposal”)
RIF	Remote Interface (PCA)
ROM	Read Only Memory
SA	Single Access (TDRSS)
SAA	South Atlantic Anomaly
S/C	SpaceCraft
SOC	Science Operations Center (= SOF + GOF)
SOF	Science Operations Facility
SPIKE	Scientific Planning Interactive Knowledge Expert system
SSC	Scanning Shadow Camera (ASM)
SWG	Science Working Group
TDRSS	Tracking and Data Relay Satellite System
TOO	Target of Opportunity
TPG	Test Pulse Generator (PCA)
UCSD	Univ. of California, San Diego (HEXTE PI team)
ULD	Upper Level Discriminator (HEXTE)
VLE	Very Large Event (PCA)
VP	PCU signal chain: all propane anodes connected (PCA)
VX	Xenon Veto layer (PCA)
WSGT	White Sands Ground Terminal (telemetry)
XTE	X-ray Timing Explorer

Appendix Ap.5 In-Orbit Check-out (IOC) Phase Targets

The following is a list of the targets expected to be observed during the In-Orbit Check-out (IOC) phase of the mission. These targets will be observed during the first *n* days after launch, where *n* is expected to be about 30 days. The data obtained during the IOC phase will be placed in the public archive on a time-scale faster than the usual GO proprietary period. At the time of writing (Autumn 1994), the time before the data appear in the archive is expected to be about 4-5 months. Please note that the appearance of a target here does not preclude that target from being observed during the first round of proposals *provided the science can not be done with the IOC observation.* Observations obtained with XTE are so heavily tied to the configuration in which the data were obtained that one can imagine a particular, bright target being observed several times with different configurations without exhausting the possible science to be obtained. The proposal review committee will decide whether the science in a pending proposal could be obtained with the IOC data.

The detailed mode/configurations for the IOC observations listed below will be available via the anonymous FTP account (legacy.gsfc.nasa.gov) by 1994 December 1.

TABLE Ap.5.1.

Target	**Purpose of Observation**
Crab	Instrument boresights (define science axis) Field-of-view mapping HEXTE off-axis boresights

TABLE Ap.5.1.

Target	Purpose of Observation
Crab	Energy response for on-axis observations energy-dependent corrections to off-axis effective area Short-term stability of spacecraft, ground system clocks
Sco X-1	Reflection effects
Cosmic Background	PCA background model (at about 40 positions) Measure ASM collimator transmission
NGC 4151	HEXTE flux and variability for faint objects
Mkn 509	HEXTE and PCA flux overlap
Cas A	Measurements of PCA propane layer optical depth
Perseus	HEXTE resolution for steep spectrum source
SMC X-1	Weak fast pulsar (0.7 sec): test HEXTE event mode and ground pulse phase folding
Cyg X-2	Bright QPO source: recorder management of high rate data

Other tasks that will be performed with these observations:

- Test EDS --> HEXTE burst trigger and HEXTE --> EDS burst triggers
- Jitter characterization
- simple dead time model verification
- verifiy initial SAA model
- FFT signature for Crab with different VLE windows

Appendix 6

XTE NRA Contacts

For NRA help: `xtenra@athena.gsfc.nasa.gov`

or

Dr. Alan Smale
XTE Guest Observer Facility
Code 668
NASA-Goddard Space Flight Center
Greenbelt, MD 20771

FAX: 301-286-1682

Additional information may be found on the anonymous FTP area for XTE at:

`legacy.gsfc.nasa.gov`