LOFT Large Area Detector
An Analysis of the usage/popularity of the many PCA/EDS/EA data modes on RXTE

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Issue	Date	Changed Section	Description of Change
1	1 October 2013	All	First issue
2	27 August 2014	All	Small text changes
		All	Changes to many data values in text
		Section 4.1	Correct errors down Goodtime column
		Section 4.1	Change to a smaller summary table
		Appendix A	Add full EA modes table to document

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1 Introduction

The NASA Rossi X-ray Timing Explorer (RXTE) (Bradt et al., 1990) mission which flew from late 1995 to early 2012 became one of NASA's longest running astrophysics missions. RXTE contained 3 complimentary experiments - the Proportional Counter Array (PCA) provided by the Goddard Space Flight Center (GSFC), the High Energy X-ray Timing Experiment (HEXTE) provided by The University of California at San Diego (UCSD) and the All Sky Monitor (ASM) provided by the Massachusetts Institute of Technology (MIT). The large area, high time resolution, PCA provides the 'bench-mark' for many aspects of the Large Area Detector (LAD) experiment proposed on the ESA LOFT mission.

The PCA comprised 5 notionally identical Proportional Counter Unit (PCU) detectors. These detectors were comprehensively described, particularly the calibration aspects, in Jahoda et al. (2006) (and references therein). Only a few of these details are directly relevant to the study reported here. The scientific data from the PCA (ignoring housekeeping, health & safety and commanding) was all produced by a single additional box known as the Experiment Data System (EDS). This box was also provided by MIT and although operated and monitored as a separate device by the MIT team was, for scientific purposes, effectively part of the PCA and was routinely operated by the staff of the Science Operation Facility (SOF) at GSFC. The Guest Observer Facility (GOF), also at GSFC, ran the proposal rounds and generated the final package of FITS format data files delivered to a successful Principal Investigator (PI) once their observations had been executed. The PI then had one year's priority on the data before it became public.

The EDS had many operating modes which a PI could select to optimise the use of the data from the PCA and ensure that they got the required information back to the ground, particularly for the brighter X-ray sources. The types of operating modes available and the frequency or 'popularity' of their use form the subject of this report. This information may serve as a guide to the suitable data modes for inclusion with the LAD experiment on LOFT since this will essentially be observing the same set of target sources. Such follow-on observations by the LAD will have a ~16x increase in area (compared to the whole PCA) with corresponding increase in detected count rate and telemetry loading, much better energy resolution and more PHA channels.

1.1 RXTE telemetry - data rates and storage capacity

RXTE was planned with a mean telemetry rate dictated by the allowed links through the NASA Tracking and Data Relay Satellite (TDRS). It was also one of the early spacecraft to have a solid state recorder system rather than a tape recorder. This on-board store was 800 Mbit in size but only a certain fraction of it, on a mean rate basis, was available to the PCA/EDS. The details of the strategy used to record tracks and dump information to the ground is outside the scope of this document. The detector area of the PCA and known X-ray source intensities indicated that there was insufficient capacity to store all generated data on board so some form of data compression was required, particularly for the brightest targets. The EDS was designed to run various processing modes, or pairs of modes, to achieve this reduction in bit rate consistent, where possible, with the PI's science requirements.

A crucial parameter for any such buffer store is the ratio of input data rate (from the PCA/EDS) to the output rate (telemetry dumps to ground). All the EDS modes were scoped to a fully functioning PCA and the TDRS availability as agreed with NASA prior to launch. The EDS did not perform data compression as such but attempted to efficiently optimise the use of the available telemetry rate. Two factors then made this compression less important over time.

Firstly, the on-going noise issues with increasing numbers of PCU's (PCU 3 & 4 in March 1996, PCU 1 in March 1999 and PCU 0 in April 2006) resulted in numbers of them being 'rested' when maximum PCA area was judged to be non-essential to the scientific goals of PI proposals. Less area naturally translated into lower mean count rates than originally envisaged. Secondly, and in particular, the failure of one of the two on-board transponders in September 1999 resulted in a re-negotiation with NASA of the TDRS availability. This led to a 10-20 times increase in throughput and telemetry was not a major constraint from then onwards.

2 Overview of command database

All the information required for this study is contained in the vast number of commands sent to RXTE during its ~16 year mission. The commanding for RXTE was based initially on Daily Activity Plans (DAP's) which developed into Weekly Activity Plans (WAP's). These human readable ASCII text files followed a rather rigidly defined structure as they were then translated to the machine readable versions which were actually sent through the command system to the spacecraft. Each observation specification was packaged between an observation Start time line and an observation End time line. The intermediate lines contained the following in order, if present – PI (name), SOURCE (name), TARGET (position), EDS (modes 1-6), HEXTE (commands), EVENTS (slews, SAA passes, Earth occultations), DCFS (some HEXTE commands), MACROS (PCU's on/off, PCA_VLE, PCA_HRM), GOODTIME (set of good data times), TOTAL_GT (sum of GOODTIME's), TDRS (command contacts). All times were expressed both in calendar/time mode and in Mission Elapsed Time (MET). MET is the elapsed time in seconds since the start of the clock some two years before launch (00:00 UT on January 1st 1994). This early clock start date was chosen so that the test data acquired during integration and mission simulations was logged on the same database as the actual mission. A typical short observation command sequence is shown below in section 2.3.

The scheduling of observations from the accepted pool for each proposal cycle was a tricky juggling act to balance out many factors such as minimising slew times between targets and optimising the generated telemetry rates with weaker sources being interspersed between stronger ones to reduce the mean data rate. There was also the need to get through all the accepted proposals in each cycle with some targets having fixed constraints such as simultaneous coordinated observations at other wavelengths. The DAP's/WAP's can be downloaded on a daily or weekly basis from the RXTE web pages (see references). It is important to realise that the planned observation sequences were quite often not what actually happened due to the planned schedule being changed to accommodate the many Target Of Opportunity (TOO) observations that came up at short notice. These TOO observations were routinely fitted in once confidence in the RXTE Attitude Control System (ACS) was established. To minimise 'knock-on' effects the scheduling often attempted to quickly return to the established plan to minimise disruption and the previously scheduled 'bumped' observations were then slotted in at a later time.

The required 'as-flown' records were established by the various duty staff in the SOF who created a file for each day of the mission adding various comment lines where appropriate. These daily files are also available from the RXTE High Energy Astrophysics Science Archive Research Center (HEASARC) facility and are known as 'obscat' files (see references). Although referred to as daily files they do not actually stop and start at 00:00 hours since all observations within a single file are complete and the last one therefore rolls across the zero mark into the following 24 hour period. Unfortunately the obscat file observations do not contain any flag to indicate whether a target source was classified as extragalactic or not (i.e. 'weak' or 'strong' source).

2.1 Observation Goodtimes and PCU safeing issues

Outside the scope of this report, but worth mentioning here, is the fact that these files do not represent precisely the final 'good time' obtained on a particular target source. Once the various PCU detector noise problems emerged MACROS (not present in example at 2.3) were incorporated into the command load to rest specific detectors by turning them off and later, back on. Although this commanding information is also therefore in the obscat files this still ignores the fact that, potentially at any time, a PCU could be switched off by the on-board software device added to look for emerging noise and 'safe' a problem detector. The times of these turn-off events, though known, are not present in the obscat files. However, such triggers were exceedingly rare for PCU 2 (0-4 numbering system) throughout the mission so this study assumes that there is always at least one PCU operating for the indicated Goodtime intervals. In the latter stages of the mission even PCU 2 was 'rested' during long slews as a precautionary measure.

2.2 Source names and slew targets

Source names usually reference the accepted name of a particular X-ray target but these can vary a little and so there is some redundancy of names when using strict character strings for name comparisons (trivial upper vs. lower case differences are easy to trap). The target names used were as shown on the accepted PI proposals. Since the previous and new target positions are known the system created the information lines 'start_slew' and 'end_slew' in the EVENTS list for new targets (as in 2.3). The 'start_slew' commences at the beginning of the observation and based on the known slew performance of ~6 deg./min (plus ~500 sec. overhead per manoeuvre), RXTE would be on target by the 'end_slew' time. This is when the first GOODTIME commences (as in 2.3) unless other EVENT list items preclude this. The important thing here is that slews were typically completed in a few minutes so any observations beginning with a slew to a new target are still mostly on target with a stationary attitude. Although not included in the Goodtime the slew data itself can be retrieved and has been used for a number of purposes.

In the obscat files (but not in the WAP's) the extension '_Slew' was appended to the end of the source name when moving RXTE to a new target. Often, RXTE would move off to another target on completion of the observation sequence in which case the following observation would also have the '_Slew' extension. Continuing observations of the same source would use the same target name but with the '_Slew' extension dropped. Thus a catalogue of every observed target name usually has at least one '_Slew' version plus usually a matching non-slew version.

The above discussion refers to routine slews but on many occasions RXTE was commanded to slew more slowly using the RASTERS command, perhaps to scan a cross on the sky to determine the position of a new X-ray source or to perform raster scanning of a box on the sky such as the mapping campaign near the Galactic Centre. These files often have the '_Slew' extension only for the first move to the target location and the various individual RASTERS specified within a single WAP observation are 'expanded' into separate observations in the corresponding obscat file. The use of such scanning data is more complex than for when RXTE was stationary. The extension 'S' was added to the Obs. ID for raster scans and the extension 'R' for raster grids.

In the final processing carried out by the RXTE GOF to generate FITS files for the PI's, the slew data was actually split in half to provide them with background data adjacent to their target source. The first half of the slew had the extension 'Z' added to the Obs. ID code (see 2.3) appropriate for the prior PI and was bundled with their set of files. The second half had the extension 'A' added to the Obs. ID and went to the following PI. All slew data were also acquired while running a particular event mode (`E_62US_64M_0_1S_L1R1`) to provide a uniform 'slew database'. Although the slews took place relatively quickly this mode continued running for the whole duration of that particular observation. In addition to the S, R, Z and A extensions a further set exist (G, C, F, T, U, D, H, V, W) but will not be discussed here.

The numbers of various slew type observations are tabulated below.

Extension code	Type of motion	Tot. No. Obs.
Z	Slew after observation	99,738
A	Slew before observation	99,742
S	Raster scan	37,298
R	Raster grid	1,536

2.3 A typical observation command sequence

A typical short observation command sequence from the RXTE turn-on week in early 1996 is shown below. All 6 Event Analysers (EA's) in the EDS were always specified with those slots not actually being used or reserved as 'place-holders' denoted by the word 'Null'.

```
1996:001:23:44:00 000063157441 OBSERVATION 00004-01-01-00 START
        PI:  KEITH  JAHODA
    SOURCE:  PRE-IOC_ORIENTATION
    TARGET:  RA=176.000000, DEC=22.000000
       EDS:  Null
             Null
             Null
             Standard1
             Standard2
             Null
     HEXTE:  IDLE (LLDA=DEF, DWELLA=DEF, ROCKA=DEF)
             IDLE (LLDB=DEF, DWELLB=DEF, ROCKB=DEF)
    EVENTS:  start_slew   23:44:00 (000063157441)
             end_slew     23:46:00 (000063157561)
             in_saa       00:04:00 (000063158641)
             out_saa      00:30:00 (000063160201)
             in_saa       01:47:00 (000063164821)
             out_saa      02:08:00 (000063166081)
             in_saa       03:29:00 (000063170941)
             out_saa      03:44:00 (000063171841)
GOODTIME: 23:46:00 (000063157561) to 00:04:00 (000063158641)
          00:30:00 (000063160201) to 01:47:00 (000063164821)
          02:08:00 (000063166081) to 03:29:00 (000063170941)
          03:44:00 (000063171841) to 12:07:00 (000063202021)
1996:002:12:07:00 000063202021 OBSERVATION 00004-01-01-00 END
```

Every observation had a unique identification number known as an Obs. ID. This number is in the first line of the command sequence and in the example above is the rather trivial case '00004-01-01-00'. The first part indicates that this is approved observation program #004 in round 00 [early 'In Orbit Checkout' (IOC) period]. Over the whole mission the PI proposal rounds ran from 1-16 (10 – 90, 91 – 96). The following numbers in the Obs. ID represent the target number (a PI could have multiple targets within their approved program) and an incrementing sequence number for the observations made of each particular target.

2.4 Completeness of 'obscat' database

The 5847 daily obscat file names in the HEASARC archive run from OCday00730 to OCday6578. The day number part of the file name is somewhat arbitrary but refers to the number of elapsed days since the start of the RXTE MET clock. This start time was chosen to be well before launch so that all the various integration tests were tagged and logged with a common reference time base. Since each individual observation sequence normally starts at the end time of the preceding observation and ends at the start time of the following observation this 'chain' of intervals can be summed and compared to the overall duration of the mission. This interval (last end time on last day minus first start time on first day) is 505,305,365 seconds according to the relevant MET's. The summation of the ~350,000 individual observations actually comes up 322,150 seconds short but this 'missing time' is largely accounted for by an initially unnoticed ACS failure on RXTE that occurred in 2001 on day 330. The result of this is that files OCday2887 (Tue, 27 Nov) and OCday2888 (Wed, 28 Nov) were never created and they are missing from the data base. The failure actually occurred towards the beginning of OCday2886 and RXTE then resumed routine observations towards the end of OCday2889 so this gap is actually 322,346 seconds long.

Small gaps occasionally occur when SOF staff have manually edited up the obscat files after changes occurred, such as execution of a TOO, and not made the end time of the preceding observation identical to the start time of the following one. Small positive gaps are not a problem since the Goodtimes recorded in the files are still valid. The ~20 anomalies discovered (mostly trivial but one sizable negative gap) have been reported to the remnants of the RXTE team at GSFC and, at the time of writing, it is unclear if resources will allow any corrections to be made to the obscat files. The overall remaining discrepancy is less than 200 seconds and has been ignored in subsequent analysis. The ~570 occurrences of the EDS EA mode 'Unknown' have also been reported in a similar fashion. Almost all these occur in the first year of the mission.

The set of files covering the full RXTE mission contain:

No. observation sequences	346,843
No. observation sequences (with _Slew extension)	199,562
No. discrete EDS modes	346
No. target names (with _Slew extension ignored)	1,678

The numbers of discrete target and slew observations are based on unique character string comparisons and, as previously mentioned, there will be some redundancy in these totals which it was not necessary to remove for this particular analysis.

The EDS design and function is reported in various documents on the RXTE web pages. It is not proposed to describe in great detail here the complexities of the EDS design and function. The comprehensive and useful relevant documents (see references) are the two produced by the MIT team for the initial RXTE NASA Research Announcement (NRA) to help PI's select the most appropriate data modes when writing their formal proposals for observing time.

Very briefly, the EDS consisted of a system crate with 8 event analyser slots equally split into an A and B side for redundancy. One of the 4 EA's on each side was dedicated to running the ASM experiment leaving 3 available for the PCA experiment. Of the 6 available EA's, two were dedicated to running modes Standard1 and Standard2 leaving a total of 4 EA slots for the PI to specify operating modes to suit their planned observations. Exactly the same set of PCA data was delivered to all 6 EA slots, so any mode could run in any slot except for a single case. The pair of burst trigger and catcher modes, if selected, had to be run on the same A or B side. GoodXenon 1 & 2 could be split across sides, as could Standard 1 & 2, but these pairs were commonly grouped together on the same side. Standard 1 & 2, when running, were conventionally placed in slots 4 & 5. Particularly in the later stages of the mission, when SOF resources were becoming more limited, EA arrangements for the command loads were often created from earlier observations using a simple cut & paste editing process.

The full set of discrete EDS modes used are discussed in the following sections.

2.5 EDS EA usage through mission

With 6 possible EA slots it is interesting to look at the number of these that were actually selected for use during the whole ~16 year mission (**including IOC**). The following table illustrates this usage:

No. of selected EA's	0	1	2	3	4	5	6	Total
No. Obs.	39	46	40	633	12,910	15,075	318,100	346,843
% of total Obs.	0.01	0.01	0.01	0.18	3.72	4.35	91.71	100.0
Goodtime (ksec)	186.9	11.7	426.0	2,557.2	33,391.5	9,618.9	309,398.0	355,590.1
% of total Goodtime	0.05	0.0	0.12	0.72	9.39	2.71	87.01	100.0

Reference to the RXTE NRA shows that PI's were encouraged to use all 6 available EA's and the Appendix 1 section of the document indicates the telemetry loading for each of the many observing modes available, for various source counting rates, so choices could be optimised. Clearly most PI's did select 6 EA's (or 4/5). Many smaller selections of EA's (0, 1, 2, or 3) fall within the first 4 weeks after launch (one week turn-on plus three week IOC). For this reason all the following analysis was restricted to day 29+ (OCday0758 onwards) since this will more accurately reflect the overall EA mode preferences of PI's during the mission.

Using only 4 EA's (Standard 1 & 2 plus GoodXenon 1 & 2 – see later) would seem an ideal choice for all the Extragalactic and weak source Galactic observations since this set provides ALL the information required for lower intensity targets. Extragalactic sources alone were expected to be observed for approximately half of the mission. Although many PI's selected modes for all EA slots there is no easy way of knowing their intention and what, if any, use was made of any 'extra' data formats. Only 3.7% of observations representing 9.4% of Goodtime actually used just 4 EA's. Using less than 4 EA's seems to make little sense but a few observations were conducted this way after the IOC period. Assessing PI choices is also confused by the SOF routinely adding low data overhead place-holder EA modes (see 3.6 and 3.12) even if the PI had only requested 4 modes to be used. This was to allow rapid real-time switching to a TOO target since the place-holder slot could be easily changed to a different mode that better suited the new target.

An important by-product of having multiple independent modes was the convincing demonstration that early observations of high frequency QPO phenomena existed in several modes and thus could not be artefacts of the data system.

3 EDS data modes

MIT developed the comprehensive set of EA modes well before launch, most of which were fully supported by the RXTE Guest Observer Facility (GOF) with corresponding FITS data files being provided to the PI's. Following launch a few extra modes were developed for special applications. More generally, the emerging PCU noise issues resulted in detector high voltages being lowered reducing the gain and corresponding keV-PHA relationship. This resulted in some new versions of existing modes but these were always identified with new mode names. Sco X-1 was a particular challenge, being by far the brightest X-ray source, with a significant probability of two events occurring within the 10 microsecond anticoincidence window for a PCU. This rate was routinely monitored in Standard 2 mode and was important for studies of the kHz QPO in Sco X-1.

Analysis of all the obscat files shows that 346 discrete EDS mode names were used throughout the mission but these reduce to a subset of only 19 different types once redundancy and similarity are removed. These 19 basic types are shown in the following table with each one then being briefly discussed:

GROUP	BASE MODE	No. in GROUP	Description / Type of Mode
1	STANDARD 1	3	] Standard 1 & 2 almost always present as pair
2	STANDARD 2	6	]
3	GOODXENON 1	4	] GoodXenon 1 & 2 usually present as pair
4	GOODXENON 2	4	]
5	TRANSPARENT	6	Test mode - Transparent 1, 2 & 3 (used as 3 EA's)
6	GOODVLE	2	Test mode - to examine saturating PCU VLE pulses
7	Null	1	Defines unused Event Analyser (EA) slot
8	Unknown	1	Incomplete file data ?
9	E_	75	Event mode – many options
10	B_	71	Binned mode – many options
11	F_	14	FFT mode
12	D_	7	Delta time mode
13	PF_	49	Pulsar Fold mode
14	SB_	77	Single Bit mode – many options
15	PSB_	1	Test mode – Propane Single Bit mode
16	CB_	8	burst Catcher Binned mode
17	CE_	5	burst Catcher Event mode
18	TLA_	10	High priority burst triggers
19	TLM_	2	Low priority burst triggers
	Total	346	

3.1 Standard 1 mode

Standard1 was mainly a timing mode containing 1024 point ‘light curves’ for each PCU with 0.125 sec. resolution. It also contained 256 bin PHA calibration spectra. This mode was always present and is used here to define the base line reference for the total Goodtime acquired during the entire mission.

Since Standard 1 and Standard 2 were virtually always running together (not always during the 28 day IOC period), their contents formed the majority of the options for the real-time PCA science monitoring displays in the SOF at GSFC (see Giles, 1997). Parallel display capabilities were duplicated for the PCA team in their own building at GSFC and a subset of display options were also available, on request, for PI’s at their home institution or at remote ground-based observatories. Although so many EA modes were available it was not necessary to have the ability to decode and monitor all of them just to check that the PCA performance was nominal. This was a substantial development saving in addition to having a uniform set of results for all observed X-ray sources. The correct functioning of the EDS (and EA’s) was monitored by the MIT team.

3.2 Standard 2 mode

Standard2 was mainly a spectral mode. Spectra were included for each xenon anode chain in all PCU’s with 129 PHA channels and for the propane layers with 33 PHA channels. A variety of internal PCU count rates were also included. Exceedingly rarely, Standard 2 mode seems to have been dropped for some reason but Standard 1 was always present. After the IOC period Standard 1 & 2 were present for >~ 99.7 % of the total mission Goodtime.

Earlier, the addition of an automatic real-time TSM trip off device was mentioned to ‘safe’ PCU’s which started showing noise problems. Since such testing had to be present all the time this software was ‘piggy-backed’ onto the Standard2 mode but was invisible to the PI user.

3.3 GoodXenon 1 mode

GoodXenon 1 & 2 were intended to be run as a pair of EA’s. Every valid Xenon event was tagged with the time to 1 microsecond, PCU ID, anode layer information, and a 256 channel PHA energy. This formed a complete package of information for the PI and no further information was required for many science targets. GoodXenon 1 & 2 were ideal for all Extragalactic sources and other relatively low count rate Galactic X-ray sources.

3.4 GoodXenon 2 mode

Not having GoodXenon 2 running when GoodXenon 1 was present makes no sense but very occasionally did happen. Typical examples are for ‘_Slew’ observations when burst trigger, burst catcher, Standard 1, Standard 2 and the regular slew E_ mode are running. GoodXenon 1 is then usually running in the 6th EA slot. For continuing observations of the same source the E_ mode then reverts to GoodXenon 2.

3.5 Transparent mode

MIT intended this mode to be for test purposes only. It used 3 EA’s in parallel to send back complete information about every event detected by the PCU’s including all types of internal background events.

3.6 GoodVLE mode

This mode was added by MIT during the mission to examine the occurrence of huge saturating Very Large Event (VLE) pulses which were occasionally seen by the PCU's. These non X-ray events (perhaps due to particle showers resulting from collisions of a high energy cosmic ray with the spacecraft body) occurred at a rate of about one per hour, lasted 1-2 ms and were seen simultaneously in most PCU's (Jones et al., 2008). The more typical VLE pulses (events above 100 keV) were well known for their effect on a proportional counter and monitoring them was included in the baseline PCA design (the VLE count rate for each PCU is in Standard 2 mode). The rate for these 'normal' VLE pulses was 65-100 per second in each PCU. However, a paper published in Nature purporting to have evidence for small trans-Neptune bodies in the outer Solar System (using brief count rate dips in PCA observations of Sco X-1) led to a more in-depth study with the creation of this special mode. Later in the mission, GoodVLE was also used as an EA place-holder.

3.7 Null mode

Not really a mode at all but since all EA's slots had to be specified with 'something', any not being used were defined with the word 'Null'. In reality a previous mode could still be resident in that EA but setting it to 'Null' defined it as non-running. If a slot was set to 'Null' it couldn't be re-filled later in real time to accommodate a TOO change without a complete re-plan. If a slot was actually running a 'place-holder' mode, it could be simply commanded at any later time to initiate a new and different mode.

3.8 Unknown mode

Again, not really a mode at all but a number of obscat records do have the word 'Unknown' used in the list of 6 possible EA modes for the 6 slots. Almost all these occasions occur during the first year of the mission and clearly, in a strict sense, seem to imply just incomplete record keeping. A real mode was probably present where the word 'Unknown' occurs.

3.9 Event mode (E_)

This mode was often used by PI's. Configurations were of the form: E_ttt_cco_ll_rr where ttt is the time bin, cc is the number of PHA channels, o specifies channel boundary options, ll is the lower channel cut-off and rr is the readout time. A large number of possible combinations were created before launch and 75 versions were selected during the mission. Two modes were most common with the first of these (the mode for '_Slew' observations) being dominant: E_62US_64M_0_1S_L1R1 and E_125US_64M_0_1S

3.10 Binned mode (B_)

This mode was also often selected by PI's, sometimes in combination with an E_ mode for brighter X-ray targets. Such pairings occurred for 19,050 observations or 29,372.75 ksec of Goodtime. Configurations were of the form: B_ttt_ccX_O_hh_B where ttt is the time bin, cc is the number of PHA channels, X specifies channel boundary options, hh is the upper channel boundary and B is the bin depth (counter size).

3.11 FFT mode (F_)

This mode performed a standard type FFT process on the time series data being accumulated. In reality it was rarely used.

3.12 Delta Time mode (D_)

This mode might also seem at first sight to not be very useful (like the FFT mode) but was often selected to fill an 'empty' EA slot with low data overhead. This mode provided an autocorrelation function by building up a histogram of the short time intervals between consecutive X-ray events and was an excellent way of monitoring the PCA dead time (as noted in the NRA). In reality it was mostly used as an EA place-holder so another mode could easily be substituted for convenient real-time TOO changes. Configurations were of the form: D_ttt_ll_hh_bb_rr_B where ttt is the time bin, ll & hh are the lower and upper PHA energy channels, bb is the bin depth (counter size) and rr is the readout time. The mode D_1US_0_249_1024_64S_F was selected for ~56% of both total Goodtime and observations made.

3.13 Pulsar Fold mode (PF_)

This mode was also rarely used. In fact it was only used for the occasional observation run on the Crab as part of the standard calibration activities of the PCA team. This mode potentially required a special build by MIT for each use as it had a unique folding period built into it. In reality, a new version was created only when the required Crab pulsar folding period had changed by more than 1 microsecond. Clearly, this was only ever an approximate analysis due to unaccounted Doppler shift components. For this reason, and the effort in using it, this mode was dropped later in the mission when increased telemetry capacity allowed the use of a regular event mode.

3.14 Single Bit mode (SB_)

This mode was quite often selected. Configurations were of the form: SB_tt_ll_hh_R where tt is the time bin, ll & hh are the lower and upper PHA energy channels and R is the readout time. The mode generates a continuous string of 1's or 0's, a 0 for each clock time tick and a 1 for an X-ray event. Less telemetry is required for single bit mode, compared to binned mode, if only a few counts are expected in each time bin. For bright sources the single bit mode could be used for the lower PHA energy channels with the upper set of PHA channels running on a paired event mode. This joint option was not suitable for very high count rates. A special option created for Dutch scientists employed two simultaneous SB_ modes, with different PCU selections, which allowed subtraction of Poisson noise from the light curves.

3.15 Propane Single Bit mode (PSB_)

This mode is essentially the same as for SB_ but logs events from the propane layer in a PCU rather than from the xenon layers. It was an experimental mode added by MIT to examine its scientific potential.

3.16 Burst Catcher Binned mode (CB_)

This mode 'caught' a string of X-ray events, logging them as a binned time sequence. This binned option was intended for use when accumulating >32k events following a triggering pulse. The start trigger pulse came from another EA running one of the burst trigger modes below (TLA_ or TLM_). How the data was saved to the spacecraft depended on whether a low or high priority trigger was in use. Both triggering and catching configurations must have the same specified interval duration and be on the same A or B side of the EDS.

3.17 Burst Catcher Event mode (CE_)

This mode is similar to the CB_ mode but captured a string of up to 32k X-ray events without binning the data. Options existed to dump all saved contents to the spacecraft for every received trigger within the observation duration or only the last one that occurred depending on whether a low or high priority trigger was in use.

3.18 High priority burst trigger mode (TLA_)

This option provided an initiating trigger pulse for both of the burst capture modes (CB_ and CE_). High priority triggers cause every burst catcher data set to be dumped to the spacecraft subject to bandwidth limitations. All TLA_ modes also triggered the HEXTE experiment.

3.19 Low priority burst trigger mode (TLM_)

This option provided an initiating trigger pulse for both of the burst capture modes (CB_ and CE_). Low priority triggers cause only a single burst catcher data set to be dumped to the spacecraft. The TLM_ modes did not trigger the HEXTE experiment. The TLM_ mode was based on simple level discrimination on the X-ray count rate. Modes THM_ (hardness trigger) and TEM_ (edge trigger) were never used.

4 Popularity / usage of EA modes

The table in this section shows the main usage of the various EA modes by the many PI's during the RXTE mission and thus forms a useful summary of their popularity. To save space only modes used more than 2% of the total Standard 1 Goodtime are shown here. The full set, containing 346 mode types, are listed in Appendix A.

The table shows 4 main columns of numbers on the right hand side. The left pair of these show the number of observations using each particular mode and the corresponding percentage as a fraction of the total number of all observations (defined as the sum of all Standard 1 observations). The right pair show the corresponding values but using the sum of Goodtime (GT) ksec rather than the number of observations. A summation line under each mode type gives the equivalent values for all modes within the group including those used very rarely and not included as individual line items.

As an example, Standard 2 (group 2) has 6 variations in its group but only two exceeded the 2% threshold value and are actually itemised. Similarly, there were 75 Event modes (E_ type, group 9) used during the mission but only the 6 that exceed the 2% threshold are listed here. In Appendix A the remaining 69 E_ modes are summed together in the line listed as 'Others'. Considering all the E_ modes together, it can be seen that at least one of these was selected for 295,860 observations or 85.5% of all the observations made. All these E_ observations totalled 211,240 ksec of Goodtime representing 59.6% of the total mission Goodtime. The most popular E_ mode (E_62US_64M_0_1S_L1R1) was used for 57.2% of all observations made representing 20.3% of the total mission Goodtime.

4.1 Summary of main EA modes used (> 2 % Standard mode 1 Goodtime)

Excludes 28 day IOC period

No. EDS EA modes	:	346
No. EDS EA mode groups	:	19
Total no. observations	:	346085
Total Goodtime	:	354364.71

Group	EDS Modes	No. Modes in Group	No. Obs. in Mode	On Source Obs. % Obs. / Total Obs.	Total GT (ksec)	% GT / Total GT
1	STANDARD1B		345676	99.88	353637.9	99.79
	STANDARD1	3	346027	99.98	354232.8	99.96
2	STANDARD2A		4381	1.27	7320.6	2.07
2	STANDARD2F		340909	98.50	344950.8	97.34
	STANDARD2	6	345603	99.86	352795.8	99.56
3	GOODXENON1_2S		240939	69.62	202991.3	57.28
3	GOODXENON1_16S		26470	7.65	34383.2	9.70
	GOODXENON1	4	270489	78.16	242373.7	68.40
4	GOODXENON2_2S		230700	66.66	199644.6	56.34
4	GOODXENON2_16S		26432	7.64	34172.9	9.64
	GOODXENON2	4	260172	75.18	238801.5	67.39
5	TRANSPARENT	-				
6	GOODVLE1_2S		45020	13.01	41689.4	11.76
6	GOODVLE2_2S		17206	4.97	31973.5	9.02
	GOODVLE	2	62226	17.98	73663.0	20.79
7	Null	-				
8	Unknown	-	572	0.17	1883.2	0.53
9	E_16US_16B_36_1S		8239	2.38	10638.2	3.00
9	E_62US_64M_0_1S_L1R1		197966	57.20	71778.1	20.26
9	E_125US_64M_36_1S		6382	1.84	9009.6	2.54
9	E_125US_64M_0_1S		27170	7.85	57575.2	16.25
9	E_32MS_256M_ALPHA_2LLD_1S		11410	3.30	15707.5	4.43
9	E_32MS_256M_0_255_2LLD_1S		33062	9.55	23099.8	6.52
	E_*****	75	295860	85.49	211240.4	59.61
10	B_8MS_16A_0_35_H_4P		6071	1.75	7475.0	2.11
10	Others	70	16760	4.84	28263.0	7.98
	B_*****	71	22831	6.60	35737.9	10.09

11	F_*****	-				
12	D_1US_0_249_1024_64S_F		195055	56.36	241788.3	68.23
	D_ *****	7	196700	56.84	244717.2	69.06
13	PF_*****	-				
14	SB_125US_0_13_1S		11189	3.23	19908.0	5.62
14	SB_125US_14_35_1S		4748	1.37	14657.3	4.14
14	SB_125US_0_249_1S		6625	1.91	14658.9	4.14
	SB_*****	77	51638	14.92	102183.8	28.84
15	PSB_*****	-				
16	CB_125US_1M_0_249_H		58524	16.91	40616.2	11.46
16	CB_8MS_64M_0_249_H		37818	10.93	56756.9	16.02
	CB_*****	8	99110	28.64	101970.5	28.78
17	CE_*****	-				
18	TLA_1S_10_249_1S_5000_F		48241	13.94	40693.5	11.48
18	TLA_1S_10_249_1S_10000_F		20019	5.78	17803.7	5.02
18	TLA_1S_10_249_1S_1000_F		8026	2.32	12226.2	3.45
	TLA_	10	79957	23.10	76583.3	21.61
19	TLM_*****	-				

5 Summary of main RXTE PCA findings

The above table, and full version in Appendix A, provide a number of insights into the design and performance of the EDS during the RXTE mission.

- The EDS provided a very powerful and flexible system. Its modular approach allowed changes to be developed and experiments carried out during flight with little risk to the integrity of the system.
- As various operational constraints emerged for the PCA during the long RXTE mission it was relatively straightforward to modify the EDS performance to suit the changing requirements.
- The two standard modes provided a uniform data set throughout the entire mission. (There was also a 'standard' E_ mode for regular slew observations).
- The two standard modes also allowed 'simplified' PCA science monitoring in the SOF at GSFC.
- Guest Observers tended to use a lot of the modes on offer but had clear favourites both of actual modes and options within those modes (see table in 4.1 and Appendix A).
- The Event mode used for slews (E_62US_64M_0_1S_L1R1) was used for 57% of all observations made representing 20.3% of total mission Goodtime.
- The Single Bit modes also proved surprisingly popular. A mode of this type was in use for 28.9 % of the total mission Goodtime.

- The EDS did not use any sophisticated data compression as such but attempted to efficiently optimise bandwidth by using two complimentary EA modes for bright X-ray sources. A Binned mode operated up to some keV energy (PHA channel) and an Event mode operated in parallel above that same threshold value. Before launch, many pair options were created by MIT to match different X-ray source spectra (different threshold positions and source count rates). A detailed analysis shows that such pairings of B_ and E_ modes occurred for 21,873 observations (6.3 % of total observations) representing a total Goodtime of 31,206.7 ksec (8.8 % of total Goodtime). Such pairings were strongly recommended in the RXTE NRA but became less necessary for much of the later stages of the RXTE mission when less than 5 PCU's were operating and the X-ray count rate was correspondingly lower than originally envisaged. The increase in available telemetry during the mission also reduced the need for these efficient mode pairings.
- When catching 'trigger events' on RXTE there seems to be a mismatch between observations using (CB_ or CE_) and (TLA_ or TLM_) since they only function correctly as a pair of modes. Although this suggests that such systems are too complicated for all PI's to use effectively the case has been made to the author that PI's who needed this feature became expert at using it. These various combinations provided powerful and flexible burst catching options.
- The table in section 2.4 demonstrates that RXTE was a very 'active' satellite with ~58% of all observations made involving some kind of spacecraft motion (slews, scans & rasters). Much of this activity was associated with repeated targeting of extragalactic sources.
- Unfortunately, the introduction of low telemetry 'place-holder' modes, by the RXTE SOF, into slots not specified by a PI somewhat compromises trying to assess the 'popularity' of their specific science mode choices.

6 Aspects with possible relevance for the LAD on LOFT

The above analysis leads to a number of conclusions that may provide guidance towards planning for the data modes to be developed for the LAD experiment on the LOFT mission.

- The priority should always be to try and get basic event data to the ground.
- Excessive limitations should not be designed in at the start for a mission so far from launch.
- Concerns well before the launch of RXTE on telemetry volumes, PI data volumes, storage and processing speeds all greatly diminished with the passage of time.
- Less frequent target changes would result in more on-source time. On RXTE, the SOF always attempted to perform slews in a way that minimised data loss.
- Standard mode(s), like RXTE Standard 1 & 2, are under consideration for the LAD. Their utility for semi real-time monitoring on the ground should not be underestimated.
- Automatic mode switching was not performed on the PCA / EDS (apart from burst triggering and capture) but, with some hysteresis, seems a good idea for the LAD on bright sources as LOFT will have less real time contact and monitoring ability (no TDRS equivalent).
  - An option should exist to continue accumulating basic event data at a high rate even on bright sources (far greater than mean telemetry rate capacity)
  - When the total reaches some limit, on-board logging could be frozen or allowed to overwrite, either case leading to an observation gap with data 'lost' or nothing recorded. A standard mode of some sort, if present, could of course still log some more limited data across the gap.
  - A quite sophisticated software device would be required to prevent LAD mode switching during powerful or extended x-ray bursts.
- Something equivalent to the EDS Transparent mode to get ALL data (including SDD addresses etc.) back for some brief period seems a good idea as a general diagnostic tool. By this I do not mean as a calibration or setup function, but to allow investigation of any 'funnies' present, perhaps in a single SDD, when the system is exposed to a high X-ray count rate. The concern here is that temporal power spectrum analysis is an incredibly powerful technique for pulling out weak periodic

signals and the potential for low level but contaminating 'noise' must be capable of being tracked down.

- RXTE/PCA/EDS did not have any powerful loss-less data compression capability as such but something somewhat equivalent was included and needed, especially in the early operational years.
  - As mentioned in the previous section, the PCA optimised telemetry usage for bright sources by using selected pairs of E_ and B_ modes. On the LAD, the two planned PHA bin sizes of 60 eV up to 30 keV and 2 keV for 30–60 keV (512 channels, 9 bits) seem to be fixed and would be fine for basic event data but might be made adjustable (semi-logarithmic etc.) for binned data on bright X-ray sources.
  - Perhaps a special data mode optimised to get most/all data back on bright sources but focused specifically on/around the ~6 keV Iron line feature is worth considering.
- Some form of routinely running LAD dead time monitor seems worth considering. With hindsight, the potential utility of this signal / information in near real-time was not adequately available to the RXTE SOF operations or for monitoring by the PCA team.
- The PCA used a specific event mode during all slews to get a standardised observation set for subsequent global all-sky analysis. On the LAD would this just be the normal event mode ?
- Since the SDD's should see events equivalent to the 'normal' and large saturating VLE pulses in the PCA, what effect will they have on the LAD ?
  - the small area SDD's (~1/25 of a PCU) are not comparable to a VLE pulse in the PCA which can 'latch-up' the analogue electronics chain in an entire PCU for many 100's of microseconds BUT there are 16 SDD's (32 pipelines) feeding each MBEE unit.
  - The particle shower hypothesis (most PCU's at the same time) does suggest that the LAD may be similarly affected. A significant difference is that the LAD detectors are not 'half buried' within the spacecraft structure but are mounted on panels out in free space away from the main spacecraft mass. Normal VLE's events might be expected at a rate of 2-3 cs^{-1} SDD^{-1}.
  - What will the LAD be doing to monitor 'normal' and saturating VLE events and minimise their impact on the system ?
- As noted earlier, the 6 available EA's in the EDS provided considerable flexibility in dealing with arising operational problems or unforeseen events. For instance, how would the LAD operate after launch if say one panel failed to fully deploy ? Would all X-ray counts from that panel be lost (panel switched off) or could on-the-fly modifications allow the addition of a 1 bit tag to specify if counts were from 'good' or 'bad' panels ?
- The large LAD area would enable sensitive searches for millisecond scale bursts. While not commenting on the scientific merits or cost/benefit of such an idea, this could be done on the ground or possibly in real time on the spacecraft (see Giles 1997, for a possible processing technique).
- The LAD multi-element design, incorporating 2006 SDD's (126 modules) rather than only 5 PCU's, potentially provides an opportunity to search for ultra-fast (microsecond) bursts due to the low system dead time. This is an opportunity to search new parameter space (see 4.2 in Orlandini and Boldt, 1993). As far as I am aware, this idea has not been tried out on RXTE data or was unsuccessful and has not been written up.

Despite all of the above comments, there is much to be said for keeping it simple !

7 Acknowledgements

I thank members of the 'old' PCA team and other former RXTE colleagues at GSFC and MIT for pointing out some corrections and relevant omissions in an early draft of this report. I also thank the Antarctic and Climate Ecosystems Cooperative Research Centre at the University of Tasmania, Australia, for the use of computer facilities to perform the data analysis and produce this document.

8 References

The NASA RXTE home page is at:
http://heasarc.gsfc.nasa.gov/docs/xte/xtegof.html

DAP's and WAP's can be downloaded on a daily or weekly basis from the RXTE pages at:
http://heasarc.gsfc.nasa.gov/cgi-bin/xte/sts.pl

'obscat' files can be downloaded from the NASA HEASARC facility at:
ftp://heasarc.gsfc.nasa.gov/FTP/xte/timelines/obscat/

The RXTE NRA is at:
http://heasarc.gsfc.nasa.gov/docs/xte/appendix_f_ps.html
Chapter 7 for EDS instrument description
Appendix 1 for EDS configurations (all mode option details)

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Appendix A Full list of RXTE/PCA/EDS/EA modes

Excludes 28 day IOC period

No. EDS EA modes	:	346
No. EDS EA mode groups	:	19
Total no. observations	:	346085
Total Goodtime	:	354364.71

Group	EDS Modes	No. Modes in Group	No. Obs. in Mode	On Source Obs. % Obs. / Total Obs.	Total GT (ksec)	% GT / Total GT
1	Standard1		0	0.00	0.0	0.00
1	STANDARD1		351	0.10	594.9	0.17
1	STANDARD1B		345676	99.88	353637.9	99.79
	STANDARD1	3	346027	99.98	354232.8	99.96
2	Standard2		0	0.00	0.0	0.00
2	STANDARD2		311	0.09	524.1	0.15
2	STANDARD2_4S		0	0.00	0.0	0.00
2	STANDARD2A		4381	1.27	7320.6	2.07
2	STANDARD2F		340909	98.50	344950.8	97.34
2	STANDARD2_1S		2	0.00	0.4	0.00
	STANDARD2	6	345603	99.86	352795.8	99.56
3	GOODXENON1_2S		240939	69.62	202991.3	57.28
3	GOODXENON1_16S		26470	7.65	34383.2	9.70
3	GOODXENON1WITHPROPANE_2S		2935	0.85	4663.1	1.32
3	GOODXENON1WITHPROPANE_16S		145	0.04	336.1	0.09
	GOODXENON1	4	270489	78.16	242373.7	68.40
4	GOODXENON2_2S		230700	66.66	199644.6	56.34
4	GOODXENON2_16S		26432	7.64	34172.9	9.64
4	GOODXENON2WITHPROPANE_2S		2895	0.84	4647.9	1.31
4	GOODXENON2WITHPROPANE_16S		145	0.04	336.1	0.09
	GOODXENON2	4	260172	75.18	238801.5	67.39
5	TRANSPARENT1_PCU1_4S		56	0.02	158.5	0.04
5	TRANSPARENT2_PCU1_4S		56	0.02	158.5	0.04
5	TRANSPARENT3_PCU1_4S		56	0.02	158.5	0.04
5	TRANSPARENT1_PCU2_4S		21	0.01	55.9	0.02
5	TRANSPARENT2_PCU2_4S		21	0.01	55.9	0.02
5	TRANSPARENT3_PCU2_4S		21	0.01	55.9	0.02
	TRANSPARENT	6	231	0.07	643.3	0.18

6	GOODVLE1_2S		45020	13.01	41689.4	11.76
6	GOODVLE2_2S		17206	4.97	31973.5	9.02
	GOODVLE	2	62226	17.98	73663.0	20.79
7	Null		42441	12.26	84382.0	23.81
	Null	1	42441	12.26	84382.0	23.81
8	Unknown		572	0.17	1883.2	0.53
	Unknown	1	572	0.17	1883.2	0.53
9	E_1US_4M_0_1S		10	0.00	34.5	0.01
9	E_1US_1M_18_1S		0	0.00	0.0	0.00
9	E_1US_4A_50_8S		17	0.00	37.9	0.01
9	E_1US_4A_36_1S		4	0.00	4.7	0.00
9	E_1US_1M_0_1S		24	0.01	89.7	0.03
9	E_2US_8B_14_1S		3	0.00	4.1	0.00
9	E_2US_8B_36_1S		3	0.00	16.7	0.00
9	E_4US_16B_0_1S		61	0.02	90.9	0.03
9	E_4US_4B_0_1S		20	0.01	12.1	0.00
9	E_4US_16M_50_1S		26	0.01	81.3	0.02
9	E_4US_16A_0_1S		53	0.02	131.5	0.04
9	E_8US_8C_0_1S		20	0.01	42.4	0.01
9	E_8US_8B_24_1S		21	0.01	34.1	0.01
9	E_8US_8B_36_1S		15	0.00	34.4	0.01
9	E_8US_32M_0_1S		55	0.02	187.7	0.05
9	E_8US_8A_0_1S		63	0.02	106.9	0.03
9	E_8US_8B_18_1S		0	0.00	0.0	0.00
9	E_8US_32B_0_1S		46	0.01	78.5	0.02
9	E_8US_8M_0_1S		3	0.00	2.5	0.00
9	E_8US_32B_14_1S		108	0.03	183.6	0.05
9	E_8US_32M_36_1S		44	0.01	46.0	0.01
9	E_16US_16B_0_1S		50	0.01	124.9	0.04
9	E_16US_64M_50_8S		5	0.00	41.0	0.01
9	E_16US_16B_36_1S		8239	2.38	10638.2	3.00
9	E_16US_16M_50_1S		19	0.01	50.1	0.01
9	E_16US_64M_0_1S		1036	0.30	2487.7	0.70
9	E_16US_64M_36_1S		469	0.14	750.4	0.21
9	E_16US_64M_0_8S		337	0.10	812.2	0.23
9	E_16US_64M_24_8S		16	0.00	50.9	0.01
9	E_16US_64M_24_1S		269	0.08	574.7	0.16
9	E_16US_16B_24_1S		39	0.01	91.8	0.03
9	E_16US_64M_36_8S		23	0.01	136.1	0.04
9	E_16US_64M_18_1S		320	0.09	843.7	0.24
9	E_16US_64M_14_1S		263	0.08	664.0	0.19
9	E_16US_64M_14_8S		0	0.00	0.0	0.00
9	E_16US_64M_18_8S		9	0.00	11.4	0.00
9	E_16US_16M_0_1S		10	0.00	85.0	0.02
9	E_31US_16M_50_1S		0	0.00	0.0	0.00
9	E_31US_16M_36_1S		12	0.00	237.7	0.07
9	E_31US_16M_0_8S		5	0.00	9.2	0.00
9	E_62US_32M_36_1S		2582	0.75	5322.9	1.50
9	E_62US_32M_24_1S		336	0.10	324.2	0.09

9	E_62US_64M_0_1S_L1R1		197966	57.20	71778.1	20.26
9	E_62US_32M_14_8S		19	0.01	124.4	0.04
9	E_62US_32B_18_1S		0	0.00	0.0	0.00
9	E_62US_14M_0_13_1S		34	0.01	44.6	0.01
9	E_62US_32M_50_1S		36	0.01	160.4	0.05
9	E_62US_32M_0_1S		40	0.01	180.4	0.05
9	E_125US_64M_36_1S		6382	1.84	9009.6	2.54
9	E_125US_64M_14_1S		441	0.13	1129.3	0.32
9	E_125US_64M_24_1S		359	0.10	1308.1	0.37
9	E_125US_64M_0_8S		27	0.01	140.7	0.04
9	E_125US_64M_0_1S		27170	7.85	57575.2	16.25
9	E_125US_64M_50_1S		196	0.06	559.6	0.16
9	E_125US_64M_18_1S		576	0.17	846.9	0.24
9	E_125US_VLE_1S		318	0.09	399.7	0.11
9	E_250US_128M_18_8S		48	0.01	135.1	0.04
9	E_250US_128M_24_1S		12	0.00	39.3	0.01
9	E_250US_128M_50_1S		53	0.02	157.2	0.04
9	E_250US_128M_14_1S		4	0.00	21.3	0.01
9	E_250US_128M_50_8S		4	0.00	22.2	0.01
9	E_250US_128M_18_1S		38	0.01	163.6	0.05
9	E_250US_128M_0_1S		1000	0.29	946.6	0.27
9	E_250US_128M_0_8S		13	0.00	65.4	0.02
9	E_250US_128M_24_8S		87	0.03	176.8	0.05
9	E_250US_128M_14_8S		3	0.00	9.6	0.00
9	E_500US_64M_0_1S		866	0.25	692.8	0.20
9	E_500US_64M_14_8S		21	0.01	39.5	0.01
9	E_500US_64M_36_1S		324	0.09	693.7	0.20
9	E_1MS_128M_50_8S		38	0.01	44.6	0.01
9	E_1MS_128M_0_8S		283	0.08	633.8	0.18
9	E_1MS_128M_0_1S		137	0.04	320.8	0.09
9	E_1MS_128M_50_1S		258	0.07	538.3	0.15
9	E_32MS_256M_ALPHA_2LLD_1S		11410	3.30	15707.5	4.43
9	E_32MS_256M_0_255_2LLD_1S		33062	9.55	23099.8	6.52
	E_	75	295860	85.49	211240.4	59.61
10	B_62US_4M_0_35_Q		16	0.00	18.2	0.01
10	B_125US_1M_0_87_H		114	0.03	329.3	0.09
10	B_125US_8A_0_49_Q		7	0.00	9.6	0.00
10	B_250US_8A_0_49_Q		3	0.00	1.5	0.00
10	B_250US_2A_0_13_Q		86	0.02	298.7	0.08
10	B_250US_4M_0_35_Q		14	0.00	27.1	0.01
10	B_250US_2A_0_49_H		155	0.04	431.2	0.12
10	B_250US_4A_0_17_Q		15	0.00	67.3	0.02
10	B_250US_1M_0_249_H		35	0.01	56.3	0.02
10	B_250US_4M_0_49_Q		27	0.01	51.5	0.01
10	B_250US_2A_8_39_H		9	0.00	6.1	0.00
10	B_250US_1M_0_87_H		175	0.05	294.7	0.08
10	B_250US_2PCU_0_249_H		931	0.27	669.8	0.19
10	B_500US_4A_0_49_H		12	0.00	7.8	0.00
10	B_500US_2A_0_13_Q		21	0.01	39.5	0.01
10	B_500US_1M_0_87_H		11	0.00	23.2	0.01
10	B_1MS_4A_0_23_Q		4	0.00	9.7	0.00
10	B_1MS_4B_0_23_Q		6	0.00	20.8	0.01
10	B_1MS_8A_0_49_Q		19	0.01	63.3	0.02

10	B_1MS_8A_0_23_Q		215	0.06	313.8	0.09
10	B_1MS_2A_0_13_Q		255	0.07	560.8	0.16
10	B_1MS_4A_0_17_H		4	0.00	37.5	0.01
10	B_1MS_8B_0_49_Q		55	0.02	52.8	0.01
10	B_2MS_16A_0_23_Q		90	0.03	184.0	0.05
10	B_2MS_16B_0_49_Q		9	0.00	61.5	0.02
10	B_2MS_4B_0_35_H		329	0.10	731.8	0.21
10	B_2MS_2A_0_23_H		18	0.01	34.3	0.01
10	B_2MS_4A_0_35_H		15	0.00	34.5	0.01
10	B_2MS_16A_0_49_Q		18	0.01	46.5	0.01
10	B_2MS_2A_0_49_H		15	0.00	19.6	0.01
10	B_2MS_8B_0_49_Q		43	0.01	85.6	0.02
10	B_2MS_4A_0_13_Q		35	0.01	96.3	0.03
10	B_2MS_16A_0_35_Q		1205	0.35	2216.0	0.63
10	B_2MS_8B_0_35_Q		5303	1.53	6769.5	1.91
10	B_2MS_4A_0_49_H		3	0.00	7.2	0.00
10	B_4MS_8B_0_49_H		36	0.01	50.0	0.01
10	B_4MS_4B_0_23_H		21	0.01	34.1	0.01
10	B_4MS_8A_0_35_H		2079	0.60	2887.4	0.81
10	B_4MS_16B_0_49_H		0	0.00	0.0	0.00
10	B_4MS_4A_0_13_Q		33	0.01	106.8	0.03
10	B_4MS_16A_0_35_H		349	0.10	701.8	0.20
10	B_4MS_16B_0_249_H		122	0.04	263.8	0.07
10	B_4MS_16B_0_249_Q		36	0.01	55.7	0.02
10	B_4MS_4B_0_35_H		15	0.00	34.4	0.01
10	B_4MS_16A_0_249_Q		20	0.01	31.9	0.01
10	B_4MS_8A_0_23_H		3	0.00	15.5	0.00
10	B_4MS_16A_0_249_H		171	0.05	275.7	0.08
10	B_4MS_8A_0_49_H		43	0.01	147.1	0.04
10	B_8MS_32M_0_35_H		37	0.01	66.7	0.02
10	B_8MS_14M_0_17_H		33	0.01	54.4	0.02
10	B_8MS_16A_0_35_H		2080	0.60	3768.3	1.06
10	B_8MS_16A_0_49_H		34	0.01	52.2	0.01
10	B_8MS_16A_0_35_H_4P		6071	1.75	7475.0	2.11
10	B_8MS_8A_0_49_H		33	0.01	51.2	0.01
10	B_8MS_8A_0_17_H		9	0.00	11.4	0.00
10	B_8MS_8A_0_23_H		16	0.00	113.4	0.03
10	B_8MS_8A_0_35_H		55	0.02	103.3	0.03
10	B_16MS_64M_0_249_H		228	0.07	778.4	0.22
10	B_16MS_14M_0_17_H		15	0.00	82.3	0.02
10	B_16MS_10M_0_13_H		26	0.01	209.5	0.06
10	B_16MS_16A_0_35_H		8	0.00	120.7	0.03
10	B_16MS_16B_0_49_H		271	0.08	574.6	0.16
10	B_16MS_16A_0_49_H		162	0.05	261.8	0.07
10	B_16MS_46M_0_49_H		222	0.06	401.8	0.11
10	B_32S_256M_0_255_H		6	0.00	16.6	0.00
10	B_32S_256M_0_255_F		29	0.01	113.3	0.03
10	B_62MS_32M_0_35_H		108	0.03	298.4	0.08
10	B_62MS_14M_0_17_H		114	0.03	376.1	0.11
10	B_250MS_128M_0_254		888	0.26	1874.0	0.53
10	B_500MS_32M_0_35		150	0.04	576.6	0.16
10	B_500MS_20M_0_23		36	0.01	76.3	0.02
	B_	71	22831	6.60	35737.9	10.09

11	F_1US_0_24_249_16S		16	0.00	21.4	0.01
11	F_1US_0_18_249_16S		11	0.00	23.2	0.01
11	F_4US_0_18_249_16S		0	0.00	0.0	0.00
11	F_4US_0_24_249_16S		0	0.00	0.0	0.00
11	F_16US_0_18_249_16S		0	0.00	0.0	0.00
11	F_31US_0_24_249_16S		36	0.01	195.2	0.06
11	F_62US_0_24_249_16S		36	0.01	211.6	0.06
11	F_125US_0_18_249_16S		0	0.00	0.0	0.00
11	F_125US_0_24_249_16S		66	0.02	236.0	0.07
11	F_125US_0_14_249_16S		18	0.01	46.5	0.01
11	F_500US_0_24_249_64S		54	0.02	128.0	0.04
11	F_500US_0_12_249_64S		0	0.00	0.0	0.00
11	F_500US_0_18_249_64S		17	0.00	122.4	0.03
11	F_4MS_0_18_249_64S		47	0.01	138.0	0.04
	F_	14	301	0.09	1122.2	0.32
12	D_1US_0_249_1024_16S_F		123	0.04	439.3	0.12
12	D_1US_0_249_128_4S_F		573	0.17	618.3	0.17
12	D_1US_0_249_128_1S_F		835	0.24	1490.8	0.42
12	D_1US_0_249_128_1S_2LLD_F		14	0.00	28.9	0.01
12	D_1US_0_255_1024_16S_ALL_F		64	0.02	140.0	0.04
12	D_1US_0_249_1024_16S_H		36	0.01	211.6	0.06
12	D_1US_0_249_1024_64S_F		195055	56.36	241788.3	68.23
	D_	7	196700	56.84	244717.2	69.06
13	PF_CRAB_4D		0	0.00	0.0	0.00
13	PF_CRAB_3D		12	0.00	7.8	0.00
13	PF_CRAB_3G		9	0.00	7.5	0.00
13	PF_CRAB_3H		26	0.01	17.8	0.01
13	PF_CRAB_5H		26	0.01	81.3	0.02
13	PF_CRAB_6H		26	0.01	81.3	0.02
13	PF_CRAB_3I		14	0.00	10.8	0.00
13	PF_CRAB_3K		12	0.00	9.8	0.00
13	PF_CRAB_3M		3	0.00	2.4	0.00
13	PF_CRAB_3O		9	0.00	5.6	0.00
13	PF_CRAB_3P		9	0.00	5.9	0.00
13	PF_CRAB_3U		18	0.01	15.8	0.00
13	PF_CRAB_3V		33	0.01	19.8	0.01
13	PF_CRAB_3W		3	0.00	1.3	0.00
13	PF_CRAB_3X		28	0.01	90.8	0.03
13	PF_CRAB_3Y		6	0.00	4.6	0.00
13	PF_CRAB_3DD		3	0.00	2.2	0.00
13	PF_CRAB_3EE		3	0.00	1.8	0.00
13	PF_CRAB_3GG		3	0.00	2.6	0.00
13	PF_CRAB_3HH		45	0.01	12.9	0.00
13	PF_CRAB_3II		24	0.01	13.1	0.00
13	PF_CRAB_3JJ		12	0.00	6.1	0.00
13	PF_CRAB_3KK		2	0.00	1.2	0.00
13	PF_CRAB_3LL		3	0.00	1.6	0.00
13	PF_CRAB_3MM		3	0.00	2.1	0.00
13	PF_CRAB_3NN		3	0.00	1.9	0.00
13	PF_CRAB_3PP		3	0.00	2.4	0.00
13	PF_CRAB_3QQ		3	0.00	2.3	0.00

13	PF_CRAB_3RR		3	0.00	1.3	0.00
13	PF_CRAB_3TT		3	0.00	1.9	0.00
13	PF_CRAB_3UU		6	0.00	3.8	0.00
13	PF_CRAB_3VV		12	0.00	6.1	0.00
13	PF_CRAB_3WW		41	0.01	27.0	0.01
13	PF_CRAB_3XX		3	0.00	2.5	0.00
13	PF_CRAB_3YY		3	0.00	2.3	0.00
13	PF_CRAB_3AAA		3	0.00	2.6	0.00
13	PF_CRAB_3BBB		3	0.00	1.9	0.00
13	PF_CRAB_3CCC		2	0.00	1.6	0.00
13	PF_CRAB_3FFF		3	0.00	1.5	0.00
13	PF_CRAB_3GGG		3	0.00	1.7	0.00
13	PF_CRAB_3HHH		3	0.00	1.8	0.00
13	PF_CRAB_3III		30	0.01	63.9	0.02
13	PF_CRAB_3JJJ		6	0.00	3.3	0.00
13	PF_CRAB_3KKK		3	0.00	1.7	0.00
13	PF_CRAB_3LLL		4	0.00	7.4	0.00
13	PF_CRAB_3MMM		3	0.00	2.5	0.00
13	PF_CRAB_3NNN		3	0.00	2.9	0.00
13	PF_CRAB_3OOO		9	0.00	10.0	0.00
13	PF_CRAB_3PPP		54	0.02	72.5	0.02
	PF_	49	541	0.16	632.7	0.18
14	SB_16US_0_249_250MS		3	0.00	5.7	0.00
14	SB_31US_0_249_500MS		2	0.00	5.8	0.00
14	SB_31US_0_13_500MS		13	0.00	43.1	0.01
14	SB_31US_14_17_500MS		10	0.00	38.9	0.01
14	SB_31US_14_23_500MS		3	0.00	4.1	0.00
14	SB_31US_24_49_500MS		3	0.00	4.1	0.00
14	SB_31US_50_249_500MS		1	0.00	3.5	0.00
14	SB_31US_0_249_500MS_PCU135		119	0.03	64.1	0.02
14	SB_31US_0_249_500MS_PCU24		119	0.03	64.1	0.02
14	SB_31US_0_249_500MS_L1R1_PCU13		119	0.03	64.1	0.02
14	SB_31US_0_249_500MS_L1R1_PCU24		42	0.01	27.8	0.01
14	SB_62US_0_249_500MS_2LLD		34	0.01	42.2	0.01
14	SB_62US_0_23_500MS		414	0.12	671.6	0.19
14	SB_62US_24_249_500MS		409	0.12	655.5	0.18
14	SB_62US_0_17_500MS		198	0.06	570.8	0.16
14	SB_62US_18_35_500MS		130	0.04	429.6	0.12
14	SB_62US_24_49_500MS		70	0.02	90.3	0.03
14	SB_62US_0_49_500MS		13	0.00	36.3	0.01
14	SB_62US_0_35_500MS		262	0.08	571.2	0.16
14	SB_62US_18_49_500MS		68	0.02	141.2	0.04
14	SB_62US_0_13_500MS		288	0.08	195.0	0.06
14	SB_62US_14_23_500MS		288	0.08	195.0	0.06
14	SB_62US_0_249_500MS		47	0.01	166.1	0.05
14	SB_62US_36_249_500MS		18	0.01	19.6	0.01
14	SB_125US_0_13_1S		11189	3.23	19908.0	5.62
14	SB_125US_0_17_1S		2193	0.63	3012.4	0.85
14	SB_125US_18_35_1S		795	0.23	2712.7	0.77
14	SB_125US_0_249_1S_2LLD		1480	0.43	6652.2	1.88
14	SB_125US_14_17_1S		1718	0.50	3786.3	1.07
14	SB_125US_14_23_1S		568	0.16	1274.0	0.36
14	SB_125US_24_35_1S		271	0.08	402.8	0.11

14	SB_125US_0_23_1S		25	0.01	112.2	0.03
14	SB_125US_24_49_1S		92	0.03	159.2	0.04
14	SB_125US_24_249_1S		204	0.06	1089.3	0.31
14	SB_125US_18_23_1S		872	0.25	2268.9	0.64
14	SB_125US_18_249_1S		38	0.01	52.6	0.01
14	SB_125US_14_249_1S		363	0.10	1636.4	0.46
14	SB_125US_8_13_1S		4998	1.44	5806.3	1.64
14	SB_125US_8_249_1S		4101	1.18	6300.7	1.78
14	SB_125US_36_49_1S		32	0.01	118.9	0.03
14	SB_125US_50_249_1S		89	0.03	253.1	0.07
14	SB_125US_8_39_1S		225	0.07	284.1	0.08
14	SB_125US_40_249_1S		225	0.07	284.1	0.08
14	SB_125US_14_35_1S		4748	1.37	14657.3	4.14
14	SB_125US_0_49_1S		83	0.02	226.3	0.06
14	SB_125US_0_35_1S		109	0.03	332.3	0.09
14	SB_125US_36_249_1S		7	0.00	52.3	0.01
14	SB_125US_0_249_1S		6625	1.91	14658.9	4.14
14	SB_250US_36_249_2S		144	0.04	113.0	0.03
14	SB_250US_14_17_2S		332	0.10	709.9	0.20
14	SB_250US_18_49_2S		148	0.04	189.9	0.05
14	SB_250US_14_35_2S		730	0.21	2241.6	0.63
14	SB_250US_8_13_2S		107	0.03	199.5	0.06
14	SB_250US_40_249_2S		9	0.00	6.1	0.00
14	SB_250US_0_35_2S		54	0.02	101.8	0.03
14	SB_250US_36_49_2S		6	0.00	32.1	0.01
14	SB_250US_14_249_2S		147	0.04	250.7	0.07
14	SB_250US_50_249_2S		155	0.04	457.6	0.13
14	SB_250US_0_249_2S_2LLD_PCU135		931	0.27	669.8	0.19
14	SB_250US_0_249_2S_2LLD_PCU24		931	0.27	669.8	0.19
14	SB_250US_0_13_2S		2767	0.80	3695.0	1.04
14	SB_250US_14_23_2S		93	0.03	207.5	0.06
14	SB_250US_24_35_2S		93	0.03	198.4	0.06
14	SB_250US_0_17_2S		279	0.08	267.4	0.08
14	SB_250US_18_23_2S		10	0.00	35.5	0.01
14	SB_250US_24_49_2S		6	0.00	32.1	0.01
14	SB_250US_0_49_2S		168	0.05	287.5	0.08
14	SB_250US_18_35_2S		145	0.04	152.7	0.04
14	SB_250US_0_249_2S_2LLD		496	0.14	1110.8	0.31
14	SB_250US_18_249_2S		15	0.00	67.3	0.02
14	SB_500US_18_35_2S		9	0.00	18.9	0.01
14	SB_500US_36_49_2S		9	0.00	18.9	0.01
14	SB_500US_14_17_2S		24	0.01	43.5	0.01
14	SB_500US_18_23_2S		24	0.01	43.5	0.01
14	SB_500US_50_249_2S		42	0.01	70.0	0.02
14	SB_500US_0_17_2S		17	0.00	98.4	0.03
14	SB_500US_0_13_2S		24	0.01	43.5	0.01
	SB_	77	51638	14.92	102183.8	28.84
15	PSB_125US_0_35_1S		8	0.00	3.7	0.00
	PSB_	1	8	0.00	3.7	0.00
16	CB_32US_1M_0_249_Q		10	0.00	47.4	0.01
16	CB_125US_1M_0_249_H		58524	16.91	40616.2	11.46

16	CB_500US_4M_0_249_H		2026	0.59	3044.7	0.86
16	CB_500US_16B_0_249_Q		489	0.14	928.0	0.26
16	CB_500US_4A_8_249_H		150	0.04	80.9	0.02
16	CB_500US_16A_0_249_Q		3	0.00	5.0	0.00
16	CB_2MS_64M_0_249		90	0.03	491.4	0.14
16	CB_8MS_64M_0_249_H		37818	10.93	56756.9	16.02
	CB_	8	99110	28.64	101970.5	28.78
17	CE_1US_4A_0		14	0.00	36.4	0.01
17	CE_1US_4M_0		6	0.00	28.2	0.01
17	CE_4US_16M_0		10	0.00	52.6	0.01
17	CE_125US_64M_0		1196	0.35	2551.4	0.72
17	CE_250US_128M_0		3	0.00	19.8	0.01
	CE_	5	1229	0.36	2688.5	0.76
18	TLA_1S_10_249_1S_5000_F		48241	13.94	40693.5	11.48
18	TLA_1S_10_249_1S_2000_F		2809	0.81	4256.6	1.20
18	TLA_1S_10_249_1S_10000_F		20019	5.78	17803.7	5.02
18	TLA_1S_10_249_1S_1000_F		8026	2.32	12226.2	3.45
18	TLA_1S_10_249_1S_20000_F		286	0.08	157.4	0.04
18	TLA_250MS_10_249_250MS_2000_FN		477	0.14	915.6	0.26
18	TLA_250MS_10_249_250MS_1000_FN		64	0.02	347.6	0.10
18	TLA_250MS_10_249_250MS_100_FN		3	0.00	19.8	0.01
18	TLA_250MS_10_249_250MS_500_FN		5	0.00	50.1	0.01
18	TLA_250MS_10_249_250MS_200_FN		27	0.01	112.7	0.03
	TLA_	10	79957	23.10	76583.3	21.61
19	TLM_31US_0_249_500MS_QN		14	0.00	36.4	0.01
19	TLM_1MS_0_249_2S_HN		500	0.14	496.4	0.14
	TLM_	2	514	0.15	532.8	0.15