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:

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

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

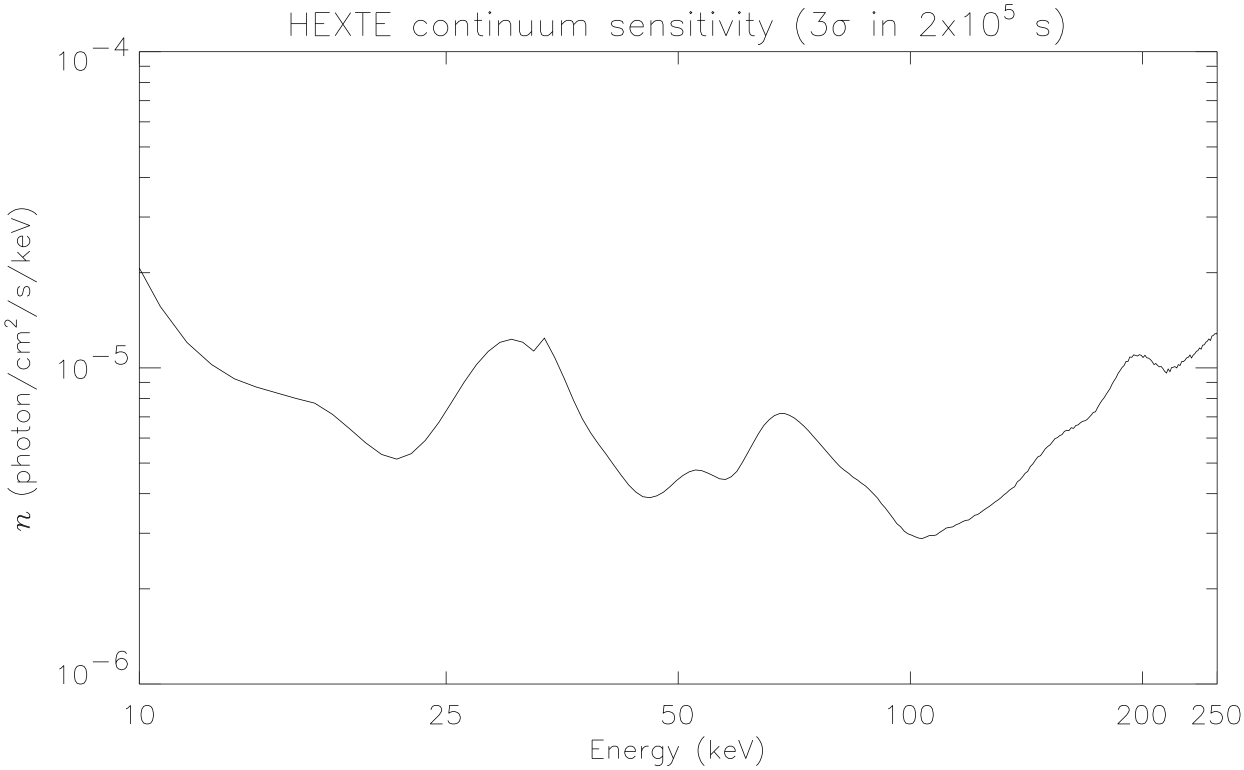

FIGURE 10.1. Background-limited continuum sensitivity as a function of energy for the HEXTE, for a 3-σ detection in 2×10^5 s observing time using two-cluster beamswitching. The dead-time fraction has been taken into account. Detection flux limits for unresolved spectral lines can be found by multiplying 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

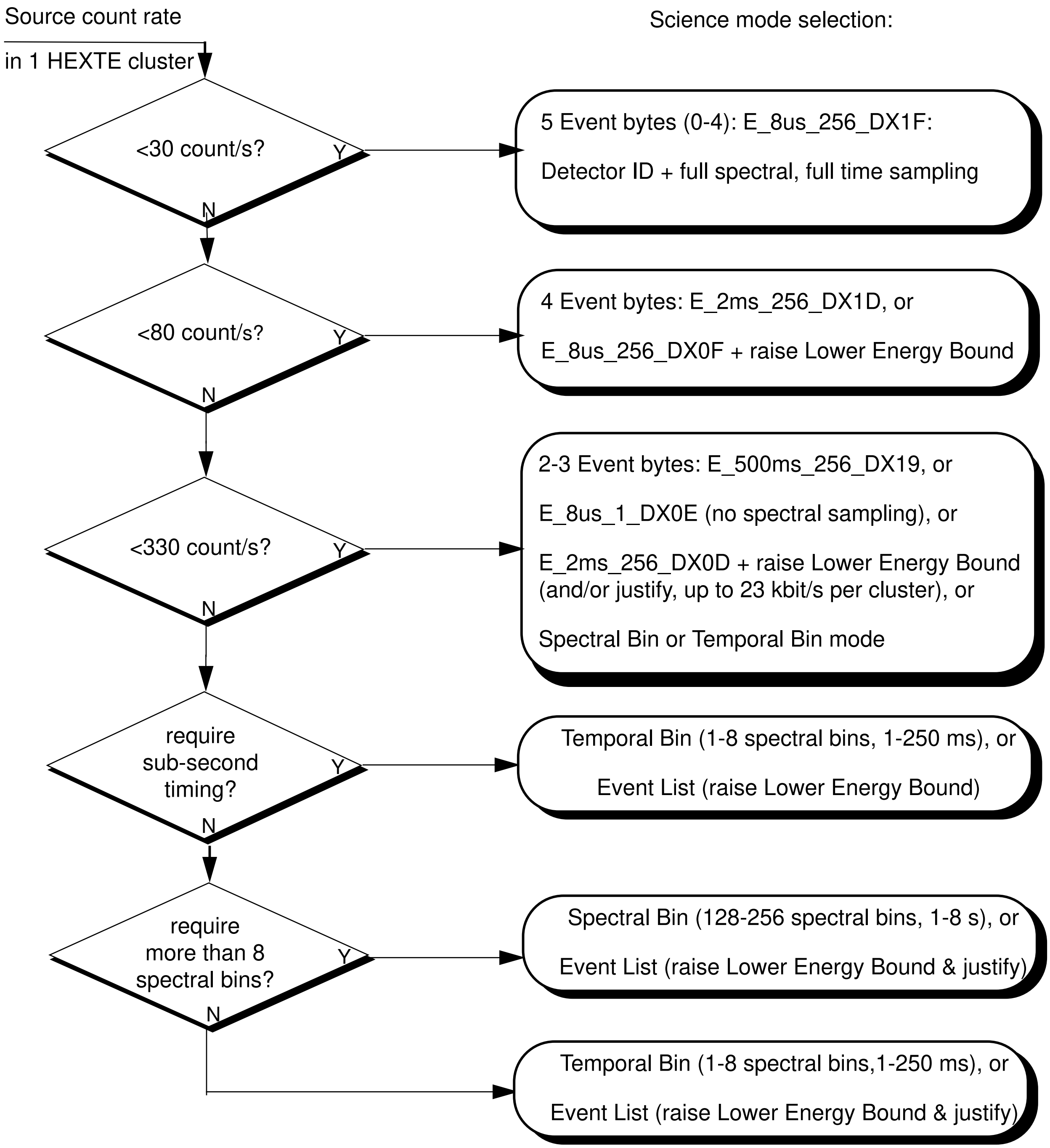

FIGURE 10.2. Flowchart showing recommended HEXTE Science Mode configurations as a function of source count rate (per HEXTE cluster) a assuming that both HEXTE clusters are source/background switching and configured identically, with a background of 40 count/s. Event List mode can be used for bright sources 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 × $2^{(\text{bits per bin})}$),

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 × $2^{(\text{bits per bin})}$).

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) Bin depth:			8192 bins/IDF (1.95 ms bins) Bin depth:			4096 bins/IDF (3.9 ms bins) 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.