Chandra X-Ray Center

ACIS Data Products:
Level 1 to CXC Archive Interface Control Document

Rev. 2.2 — September 11, 2000

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Document and Change Control Log			
Date	**Version**	**Section**	**Status**
10/31/97	0.1	all	Original release
11/4/97	0.2	all	Updates based on WMcL, JdP comments
11/10/97	0.3	all	Updates based on JMcD, DWK comments
03/05/98	1.0	all	Made compatible w/ ASC-FITS-1.0; updated file formats and contents based on revised tool functionality
06/17/98	1.1	4	Added GTI definitions; updated exposure stats, mask, and bad pix file definitions
07/02/98	1.2	4	KJG, DMcE comments; per-SR processing paradigm
07/28/98	1.3	3	WMcL, DMcE comments; removed FITS specs
08/06/98	1.4	3	Further WMcL, DMcE, KJG comments
08/11/98	1.5	3	Made badpix and mask files 1 extension per CCD
09/15/98	1.6	1,3	Updated Appl. Docs pointers; incorporated WMcL, KJG, AR comments (esp. EXT/HDU keywords)
10/22/98	1.7	3	Updated exp. stats, bias file keywords; added doc pointer for coord system keywords, removed from evt list header; changed STATUS to 16X; revised mask file description
11/04/98	1.7.1	3	Fixed various typos
12/11/98	1.7.2	3	Explicitly describes ONTIME/LIVETIME keywords in GTI exts
02/10/99	1.8	3	Changed TUNIT='coded' to 'n/a'; added description of new CC 3x3 modes; changed EXPTIME to 1E; changed GRD_SCHM to GRADESYS; dealt w/ special case of PHA=0
04/06/99	1.9	3	Added SPL_THR, SPL_FILE keywords to faint mode event headers; removed TLMIN/MAX for ENERGY; added pixel order and TDIMn keyword to PHAS definition
06/04/99	1.10	3	Clarified a few points, esp. file naming convention for alternating frame time mode
08/05/99	1.11	3	Added NODE_ID column to event data files; changed the four amplifier designations to be 0-3 instead of A-D in the exposure statistics and bias map file headers

Document and Change Control Log			
Date	**Version**	**Section**	**Status**
11/05/99	2.0	3.3, 3.5, 3.6, 3.8	Modified description of COMPONENT and STATUS columns in bpix1.fits file; Modified STATUS column of events file; Added TLMVER, FSW_VERS, and FP_TEMP keywords to events header; Modified format of initial overclock keywords
02/09/00	2.1	3.3, 3.8	Described computation of FP_TEMP; Revised CC 3x3 mode section; changed TLMIN/MAX for CHIPX/Y and TDETX/Y
09/07/00	2.2	3.3, 3.4, 3.7	Added FLSHTIME; Changed TLMIN/MAX of CHIPX/Y, DETX/Y, X/Y, PI; Changed TFORM of STATUS

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1.0 Introduction

This document describes the interface to be employed in transferring the products of ACIS Standard Data Processing from the CXC Level 1 processing pipeline to the CXC Data Archive, according to the requirements stipulated in Applicable Documents 5 and 7 (Document 5 has precedence where Documents 5 and 7 are contradictory).

1.1 Purpose

ACIS Level 1 processing, described in Applicable Documents 6 and 12, consists of standard event processing (bias subtraction [if necessary], event grading, pulse height summation, gain (and possibly CTI) correction, coordinate transformations, event attribute flagging). This document describes the structure and content of the resulting Event files and (optional) Bias Map files. In addition, it describes the structure and content of Exposure Statistics, Bad Pixel List, Spatial Mask, and Summary files that are generated from Level 0 products during Level 1 processing.

1.2 Scope

This interface shall apply to all ACIS-specific data products that are generated by CXC Level 1 pipelines and distributed to the CXC Data Archive (see Applicable Documents 5 and 6; Document 5 has precedence where Documents 5 and 6 are contradictory) during the course of the Chandra mission.

1.3 Applicable Documents

	Document	Description
1	MIT 36-01103 Rev. J	ACIS Flight Software Requirements Specification SDM02 http://acis.mit.edu/sreqj/
2	MIT 36-53200 Rev. 01	ACIS Flight Software Detailed Design Specification SDM03 http://acis.mit.edu/acis/sdetail-01/
3	MIT 36-53204 Rev. K	ACIS Instrument Procedures and Command Language http://acis.mit.edu/ipcl/
4	ASC-ICD-ACISL0-2.9	ACIS Level 0 to Archive Interface Control Document http://space.mit.edu/ASC/docs/
5	SDS-1.0	ASC Data Products Guide http://hea-www.harvard.edu/asclocal/sds/docs/jcmdocs/
6	ASC AMO-2400 (SE03)	ASC Data System Requirements (ASC.302.93.0008)
7	ASC AMO-2401 (DS01)	ASC Data System Software Design (ASC.500.93.0006)
8	NOST 100-1.1	Definition of the Flexible Image Transport System (FITS) http://fits.gsfc.nasa.gov/documents.html
9	... OGIP-93-001	HEASARC FITS recommendations: http://heasarc.gsfc.nasa.gov/docs/heasarc/ofwg/ofwg_recomm.html http://legacy.gsfc.nasa.gov/docs/heasarc/ofwg/docs/summary/ogip_93_001_summary.html
10	ASC-FITS-1.3	ASC FITS File Designer's Guide http://hea-www.harvard.edu/~arots/asc/fits/ascfits.ps
11	SDS-2.0 Rev 4.2	AXAF Coordinate Systems http://head-cfa.harvard.edu/~jcm
12	...	ASC Science Data Systems Toolbook
13	ASC-FITS-REGION-1.0	FITS REGION Binary Table Design http://hea-www.harvard.edu/~arots/
14	SDS-9.0 Rev 2 Draft	FITS Names for ASC Coordinates http://hea-www.harvard.edu/asclocal/sds/docs/jcmdocs/ps/SDS09.ps
15	content.txt	Guide to AXAF Data Products http://hea-www.harvard.edu/~arots/asc/fits/content.txt

1.4 Functional Description

1.4.1 Data Content Summary

All ACIS data sets generated by the Level 1 processing pipeline shall conform to the FITS format (Applicable Document 8), including relevant HEASARC and CXC standards (Applicable Documents 9 and 10, respectively). These files contain header keyword entries and binary table (BINTABLE) extensions (except for bias files, which contain binary image arrays).

1.4.2 Source and Transfer Method

ACIS Level 1 products shall be created by the ACIS Level 1 Pipeline. An overview of this pipeline is provided in Applicable Document 6; detailed descriptions of the ACIS Level 1 Pipeline tools are provided in Applicable Document 12.

1.4.3 Recipients and Utilization

The primary recipients of ACIS Level 1 data products, via distribution from the archive, are Chandra observers, who will utilize these data products for scientific data analysis. The CXC may also make use of specific Level 1 data products for instrument calibration, instrument and/or spacecraft monitoring and trends analysis, and validation and verification of the Level 0 and Level 1 software and of the data products themselves. Level 1 data products will also be used in Level 2 (standard data analysis) pipelines, the products of which will be used for all of the above purposes.

1.4.4 Pertinent Relationships with Other Interfaces

Changes to the definition of ACIS science telemetry packets and their data fields, as specified in Applicable Document 2, or changes to ACIS Level 0 data products, as described in Applicable Document 4, may affect the Level 1 data products described in the current document.

1.5 Assumptions and Constraints

For each ACIS science event run reported in the Chandra telemetry stream, Level 1 processing shall generate a set of product files as shown in Table 1.

1.6 Products Not Covered

ACIS Level 1 products that are used for maintenance and diagnostic purposes (i.e., that are not supplied to the User for science data analysis), and/or are generic Chandra Level 1 products, are not currently included within the interface defined by this document.

2.0 Access

2.1 Access Tools; Input / Output Protocol

Since ACIS Level 1 products obey the formatting rules described in Applicable Document 8, they may be accessed by any software that conforms to those standards, including all versions of the `FITSIO` libraries that support the `BINTABLE` extension. In addition, since they adhere to HEASARC and CXC standards (Applicable Documents 9 and 10), ACIS Level 1 data product files are compatible with the input/output routines that constitute the CXC Data Model.

2.2 Timing and Sequencing Characteristics

The “natural” subdivision of ACIS Level 1 processing is the Science Run, which is also the “atomic unit” of ACIS telemetry and hence of Level 0 processing. This is in keeping with the general philosophy of CXC Level 1 pipeline processing, which is that processing will proceed on batches of data, each batch encompassing a single Observation Interval (OBI). Under certain circumstances, such as perigee passage, very long pointings, or an ACIS on-board computer crash, a single ACIS observation may need to be broken into several Science Runs, and hence several OBIs, for the sake of simplicity in Level 1 processing. For perigee passage or long pointings, the need for multiple Science Runs can be anticipated and standard Level 1 processing shall proceed under the multiple OBI scenario. Under anomalous conditions, however, such as an ACIS on-board computer crash, standard Level 1 processing threads may not be desirable, much less possible.

3.0 Detailed Interface Specifications

3.1 Labeling and Identification

The data files generated by the Level 1 processing pipeline shall be assigned external names as shown in Table 1. The names obey the following convention:

`acis`*sTTTTTTTT*`n`*PPP*`_`*c*`_`*type*`1.fits`

where '`acis`' specifies that this is an ACIS data product file, '*s*' denotes the origin of the data (possible values: `x = XRCF, f = flight, t = TRW, b = Ball, s = simulation`), '*TTTTTTTT*' is the time tag at the start of the OBI in which the data were taken (*TTTTTTTT* = `TSTART`), '`n`*PPP*' specifies the processing pass (*PPP* = pass number), '*c*' is an (optional) filename discriminator specifying either CCD ID (for bias image files; see Section 3.6) or exposure cycle (for event files obtained in interleaved frame time mode; see Section 3.3.4), '*type*' specifies the file type (see Table 1, below), and the '`1.fits`' specifies that this is a FITS file created by Level 1 software.

Table 1: ACIS Level 1 Data Product Files

Title	File Name	Contents
event data	`*_`*c*`_evt1.fits`	event records; *c* specifies frame cycle (optional); includes telemetry GTI tables
standard GTIs	`*_flt1.fits`	chip-specific GTI tables, representing merged telemetry and standard GTIs
bias images	`*_`*c*`_bias1.fits`	bias images, 1 per active CCD; *c* specifies CCD_ID (optional: "faint with bias" mode only)
exposure stats table	`*_stat1.fits`	exposure by exposure vital statistics; dropped exposures
spatial mask	`*_msk1.fits`	mask generated from subarrays &/or BEP window lists
bad pixel lists	`*_bpix1.fits`	bad pixel and column lists
Level 1 summary	`*_sum1.fits`	ACIS setup and event summary information

Additional, generic and/or non-instrument-specific data products (e.g., the Mission Time Line file) can be output by the ACIS Level 1 processing pipeline; these will be described in a forthcoming revision of this ICD (TBD).

3.2 Substructure Definition and Format

3.2.1 Header / Trailer Description Details

All ACIS Level 1 products shall consist of files in FITS format, as defined in Applicable Document 8. Each FITS file is comprised of a primary component and optional extension components. Each of these components is divided into two parts: a header section and an (optional) data section. The length of each section is a multiple of 2880 bytes. The header section is further subdivided into 80-byte "records" containing only ASCII characters.

With the exception of bias image files, all ACIS Level 1 files contain Binary Table extensions. Hence ACIS Level 1 products shall conform to one of two FITS file "designs" as defined in Applicable Document 10: Principal Image (bias files) or Auxiliary Null + Principal Table +

(optional) Auxiliary Table(s) (all other products). Table 2 shows the keyword sections that should be present in the headers of the Auxiliary Null section of all ACIS Level 0 products, according to Applicable Document 10 (its Table 6; see also Appendix 1 of that document). This header is divided into sections comprised of keywords that are generic to all CXC L1 data; the meaning and content of these keywords are described in detail in Applicable Document 10. Each 80 byte line is left justified and ASCII blank filled on the right. Following the `'END'` keyword, ASCII blanks are appended until the header length is a multiple of 2880 bytes (36 lines).

Table 2: Format of a Level 1 Auxiliary Null FITS Keyword Header

```
SIMPLE  =                    T / FITS STANDARD
BITPIX  =                    8 / Binary Data
NAXIS   =                    0 / No image data array present
EXTEND  =                    T / There may be standard extensions
COMMENT
COMMENT   AXAF FITS Event File: ACIS Level 1
COMMENT
.............Required keywords (see Applicable Document 10):..........
.............Section M: mandatory FITS keywords for HDU type..........
.............Section CC (short): configuration control keywords......
.............Section T (short): timing keywords......................
.............Section O (short): observation info keywords............
END
```

The binary tables are further described by an extension header (the Principal Extension header) that immediately follows the Auxiliary Null header of Table 2. The format of such a "generic" FITS binary table extension follows the recommendations of Applicable Document 10 and is shown in Table 2. The header, composed of lines of 80-byte ASCII characters, begins with a group of "required" keywords (`XTENSION` through `GCOUNT`), and continues with required Chandra keywords[1] followed by ACIS-specific keywords. These keywords are largely replicated from the corresponding Level 0 product files. However, in certain cases (e.g., the observation information component) additional keywords must be inserted. Also, as described in Applicable Document TBD, filenames of input data files (and/or intermediate, unarchived data products) used by pipeline tools, and the tool names themselves, are encoded in `HISTORY` keywords. The header continues with product-specific keywords, if required, and ends with `TFIELDS` and groups of keywords (`TFORM`*m* through `TLMAX`*m*) that define each column of the binary table that follows the FITS header. After the terminating `'END'` keyword, ASCII blank bytes are added until the length of the extension header is a multiple of 2880 bytes. In the file definition Tables that follow, each Level 1 product is defined in terms of its product-specific keywords and its binary table fields.

The table itself immediately follows the extension header. Its length is determined by the values of the `NAXIS1` and `NAXIS2` keywords in the extension header and blank bytes are added until it, too, is a multiple of 2880 bytes in length.

1. In the case of conflicts between this ICD and Applicable Document 15 in the definition of `CONTENT` and `HDUCLAS` keywords, Applicable Document 15 shall take precedence.

Table 3: Format of a Level 1 FITS Principal Binary Table Extension Header

```
XTENSION= 'BINTABLE'      / This is a binary table
BITPIX  =              8 / Bits per 'pixel'
NAXIS   =              2 / Number of 'axes'
NAXIS1  =           size / Width of a table row in bytes
NAXIS2  =           rows / Number of rows of binary data
PCOUNT  =              0 / Random parameter count (required but ignored)
GCOUNT  =              1 / Number of data groups
COMMENT
.............Required keywords (see Applicable Document 10):..........
.............Section M: mandatory FITS keywords for HDU type..........
.............Section CC: configuration control keywords..............
.............Section T: timing keywords...............................
.............Section O: observation info keywords......................
COMMENT
COMMENT           AXAF FITS File: ACIS-specific Keywords
COMMENT
READMODE= 'TIMED   '            / CCD exposure mode
DATAMODE= 'FAINT   '            / CCD event telemetry mode
STARTMJF=                     0 / Maj frame containing start of 1st Sci Run
STARTMNF=                     0 / Min frame containing start of 1st Sci Run
STOPMJF =                     0 / Maj frame containing end of last Sci Run
STOPMNF =                     0 / Min frame containing end of last Sci Run
COMMENT
COMMENT  Product-specific keywords are inserted here
COMMENT
TFIELDS =              m / Number of data fields per row
.............Section TC:table coordinate keywords.....................
COMMENT
COMMENT Groups of keywords to describe each column of the binary extension
COMMENT
TFORM1  =             nC / Dimension and data type of first field
TTYPE1  = 'name1   '     / Label of first field
TUNIT1  = 'units1  '     / Data units of first field (optional)
TLMIN1  =        minval1 / Minimum field value (optional)
TLMAX1  =        maxval1 / Maximum field value (optional)
.
.
.
TFORMm  =             nC / Dimension and data type of m'th field.
TTYPEm  = 'namem   '     / Label of m'th field
TUNITm  = 'unitsm  '     / Data units of m'th field (optional)
TLMINm  =        minvalm / Minimum field value (optional)
TLMAXm  =        maxvalm / Maximum field value (optional)
END
```

followed by padding sufficient to make the binary table header a multiple of 36 lines (2880 bytes)

FITS binary table contents

(*size* x *rows*) bytes of binary data

followed by padding sufficient to make the length of the binary table a multiple of 2880 bytes

3.3 Event Data Files (*_evt1.fits)

As described in Applicable Document 1, ACIS event data are obtained in one of two different readout modes (timed exposure [TE] or continuous clocking [CC]) and can be telemetered in a variety of formats (which fall under the general categories of "faint" or "graded"). Level 1 Event Data Extension specifications for the principal combinations of readout and telemetry packing modes - `TE faint, TE graded, CC faint,` and `CC graded` - are described in Tables 4-7.

There are two TE data-taking modes that have distinct event record types output by Level 0 but are also described by the `TE faint` data format (Table 5): `TE very faint` and `TE faint with bias. TE faint with bias` Level 1 event data files will be identical in every respect to `TE faint` files; `TE very faint` Level 1 event data files will differ only in the `PHAS` field, which has a format of `25I`.

Similarly, `CC 3x3 faint` and `CC 3x3 graded` modes require modifications to the file formats described in Tables 6 and 7, respectively. For `CC 3x3 faint`, the modification is to the `PHAS TFORM` field, which becomes 9I rather than 3I; for `CC 3x3 graded`, there is the addition of a `CORN_PHA` column analogous to that in `TE graded` mode, and there may be a modification of the `TLMAX` for `FLTGRADE` (TBD).

The value of `FP_TEMP` is specified by the value of the entries[i].value field in the deaHousekeepingData telemetry packet when the values of the fields entries[i].ccdId and entries[i].queryId are `CCD_DESELECT` and `DEAHOUSE_CNTL_ADC_FPTEMP_11` (or `DEAHOUSE_CNTL_ADC_FPTEMP_12`), respectively. If the value of entries[i].value is `X`, `FP_TEMP` = 26.85 + 0.1863 * `Y` + 1.415E-5 * Y^2 - 1.885E-9 * Y^3 (Kelvin), where, `Y` = (`X` - 2048) / 1.255. This computation of `FP_TEMP` is performed at Level 0. Only one of `DEAHOUSE_CNTL_ADC_FPTEMP_11` and `DEAHOUSE_CNTL_ADC_FPTEMP_12` will yield a valid temperature in the calibrated range from 133 K to 373 K.

3.3.1 Event Coordinate Columns

During Level 1 processing, event coordinates, which originate (at Level 0) in the CCD coordinate system, undergo multiple transformations as described in Applicable Documents 11 and 12. Coordinates in the `CCDX`, `CCDY` system (or `CCDX`, `TROW` for CC 3x3 modes) are converted to `CHIPX,CHIPY` merely by adding 1 to each value of `CCDX`, `CCDY` (or `CCDX`, `TROW`). `NODE_ID` is an index to the serial read amplifier, of which there are four per CCD. The value of `NODE_ID` is determined by the values of `CCDX` and `ORC_MODE`, which are described in Applicable Document 4. If `ORC_MODE`, which has valid values of 0, 1, 2, and 3, has a value of 0 or 1, `NODE_ID` = `CCDX`/256. Since `CCDX` has valid values in the range of 1-1022, the valid values of `NODE_ID` are 0, 1, 2, and 3. If `ORC_MODE` = 2, `NODE_ID` = 2*(`CCDX`/512) (i.e. 0 or 2). If `ORC_MODE` = 3, `NODE_ID` = 2*(`CCDX`/512)+1 (i.e. 1 or 3). Note that this identification scheme for the four nodes of a CCD is not universal. In some files, the nodes are identified using the letters A, B, C, and D, instead of 0, 1, 2, and 3, respectively. `CHIPX,CHIPY`, combined with `CCD_ID`, specify Tiled Detector Coordinates `TDETX,TDETY` (in integer pixels) and Focal Plane Coordinates `DETX,DETY`. Finally, `DETX,DETY` are converted to Sky Pixel Coordinates `X,Y` by applying the aspect solution. As described in Applicable Documents 10 and 14, `MTYPEn`, `MFORMn`, and `ACSYSn` keywords are attached to each system, to specify its origin. World Coordinate System WCS keywords are also assigned to the `X,Y` columns to give an RA and Dec tangent plane coor-

dinate system; to the DETX,DETY columns to give the off-axis angle and azimuth relative to the HRMA; and to the CHIPX,CHIPY columns to give millimeters on the chip (TBD).

3.3.2 Event Energy Columns

During Level 1 processing event pulse heights (energies), whose encryption at Level 0 depends on whether ACIS was in faint or graded mode (see Applicable Document 4), may undergo multiple transformations as described in Applicable Document 12. The PHAS (pulse height amplitudes; faint modes only) column contains the 3x3 pixel island ADU values, corrected for CTI if CTI corrections were requested during Level 1 processing (TBD). The PHAS array retains the flight software pixel order, i.e., (-1,-1),(-1,0),(-1,1),(0,-1), ...) (see Applicable Document 4, Appendix A). This order is specified via the keyword TDIMn in the table definition section of the keyword headers of each variety of event file, where TDIMn='(3,3)' for TE faint and CC 3x3 faint mode data, TDIMn='(5,5)' for TE very faint mode data.

The PHA (pulse height amplitude) column in each event file contains the total ADU of the pixels that are both above the "split threshold" and are considered part of the event according to the grading scheme in use (e.g., the ASCA system generally excludes so-called "detouched" corner pixels from event PHA). The ENERGY column contains the nominal energy of the event in eV, after randomizing PHA within a PHA bin and applying CCD node-specific gain corrections. The PI (pulse invariant) column then represents the same nominal, gain-corrected event energy, but binned to a configurable, convenient number of channels (default: 1024 bins of width 14.6 eV), to facilitate spectral modeling.

The result PHA<=0 is to be handled as a special case, in which ENERGY and PI are both set to 0 and TNULL=0 for PHA, ENERGY, and PI.

3.3.3 Event Grade Columns

During Level 1 processing event grades, whose presence at Level 0 depends on whether ACIS was in faint or graded mode (see Applicable Document 4), are determined in the flight software bitmap system (faint mode only) and/or the (ACIS, ASCA, or user-defined) binned grade system (see Applicable Document 12). The former appears in Level 1 event lists as the FLT-GRADE column, the latter as the GRADE column.

3.3.4 Timed-Exposure modes (Tables 4,5)

Typically a single CCD exposure time will apply to all events obtained in TE mode observations by ACIS. In such cases, Level 1 software produces a single event file from the (up to 6) Level 0 event files output by telemetry processing of a single science run. This event file will be named *_evt1.fits (see Sec. 3.1 for expansion of the '*').

However, in TE readout mode, ACIS can be configured to "interleave" frames with two different frame times. This special mode is indicated by a non-zero value of DTYCYCLE in the header of the Level 0 parameter block file and by the value of the CYCLE keyword in the Level 0 output event file. If DTYCYCLE is non-zero (corresponding to CYCLE='B'), then DTYCYCLE CCD frames of ("secondary") frame time EXPTIMEB will be obtained for each frame of ("primary") frame time EXPTIMEA (where both EXPTIMEA and EXPTIMEB are contained in the parameter block file header). In such cases, during "Level 0.5" processing, two event files are created for each active FEP for a given science run (*_fA_evt0a.fits [EXPTIMEA] and *_fB_evt0a.fits [EXPTIMEB], where 'f' denotes FEP_ID) and events are collated into the

two files depending on the frame in which they were obtained. Level 1 processing of these input event files then results in two files, `*_e1_evt1.fits` and `*_e2_evt1.fits`.

Table 4: TE Faint Event Data File

Additional FITS Keyword Header Items

```
EXTNAME = 'EVENTS  '
HDUNAME = 'EVENTS  '
CONTENT = 'EVT1    '
HDUCLASS= 'OGIP    '
HDUCLAS1= 'EVENTS  '
HDUCLAS2= 'ALL'
COMMENT
COMMENT     ACIS setup keywords
COMMENT
FIRSTROW=              1 / Index of first row of CCD (sub)array readout
NROWS   =           1024 / Number of rows in (sub)array readout
EXPTIME =            3.2 / commanded exposure time (s)
FLSHTIME=            0.0 / Duration of the flush before each frame (s)
CYCLE   = 'P'            / data from primary (P) or secondary (S) exposures
COMMENT
COMMENT     Applied event correction/flagging reference files
COMMENT
BIASFIL0= 'acis0Vnn_nns000000000_1_bias0'/ bias file used: CCD 0
BIASFIL1= 'acis0Vnn_nns000000000_3_bias0'/ bias file used: CCD 1
BIASFIL2= 'acis0Vnn_nns000000000_0_bias0'/ bias file used: CCD 2
BIASFIL3= 'acis0Vnn_nns000000000_4_bias0'/ bias file used: CCD 3
BIASFIL6= 'acis0Vnn_nns000000000_6_bias0'/ bias file used: CCD 6
BIASFIL7= 'acis0Vnn_nns000000000_5_bias0'/ bias file used: CCD 7
BPIXFILE= 'acis1f000000000n001_bpix1'/ bad pixel file used
COMMENT
COMMENT     Applied event calibration/transform reference files/systems
COMMENT
SPL_THR =                         13 / split threshold (0 if file used)
SPL_FILE= 'NONE'             / split threshold file
GAINFILE= 'ACISgain_V1.0.fits'/ PHA to PI gain table file
GRD_FILE= 'ACISgrades_v1.0.fits'    / Event grading scheme lookup table file
GRADESYS= 'ACIS'              / Event grading scheme: ASCA/ACIS/USER...
ONTIMEm =                     1234.5 / ONTIME for CHIP m
LIVTIMEm=                     1234.5 / LIVETIME for CHIP m
EXPOSURm=                     1234.5 / EXPOSURE for CHIP m
...
ONTIMEn =                     1234.5 / ONTIME for CHIP n
LIVTIMEn=                     1234.5 / LIVETIME for CHIP n
EXPOSURn=                     1234.5 / EXPOSURE for CHIP n
TLMVER  = 'P006    '         / Telemetry revision number (IP&CL)
FSW_VERS=                 27 / ACIS flight software version number
FP_TEMP =              153.2 / Average temperature of focal plane (K)
```

FITS binary table contents (one entry per event)					
#	**TTYPE**	**TUNIT**	**TFORM**	**LO/HI**[a]	**Comment**
1	TIME	s	1D	n/a	S/C TT corresponding to mid-exposure
2	CCD_ID	n/a	1I	0/9	CCD reporting event
3	NODE_ID	n/a	1I	0/3	CCD serial readout amplifier node
4	EXPNO	n/a	1J	$0/2^{31}-1$	Exposure number of CCD frame containing event
5	CHIPX	pixel	1I	1/1024	X position of center pixel of event, chip coords
6	CHIPY	pixel	1I	1/1024	Y position of center pixel of event, chip coords
7	TDETX	pixel	1I	1/8192	X position of event, ACIS tiled detector coordinates
8	TDETY	pixel	1I	1/8192	Y position of event, ACIS tiled detector coordinates
9	DETX	pixel	1E	0.5/8192.5	X position of event, ACIS detector coordinates
10	DETY	pixel	1E	0.5/8192.5	Y position of event, ACIS detector coordinates
11	X	pixel	1E	0.5/8192.5	X position of event, sky coordinates
12	Y	pixel	1E	0.5/8192.5	Y position of event, sky coordinates
13	PHAS	adu	9I	-4096/4095	3x3 array of bias-corrected pixel pulse heights
14	PHA	adu	1J	0/36855	total pulse height of event
15	ENERGY	eV	1E	n/a	nominal energy of event (eV)
16	PI	chan	1I	1/1024[b]	pulse invariant energy of event
17	FLTGRADE	n/a	1I	0/255	event grade, flight system
18	GRADE	n/a	1I	varies	“binned” event grade (ACIS/ASCA/USER system)
19	STATUS	n/a	32X	n/a	event status bits

a. The value of TLMIN is given by “LO”, the value of TLMAX is given by “HI”.

b.) These default values can, in principle, be different and are determined during the processing of the data.

Table 5: TE Graded Event Data File

Additional FITS Keyword Header Items
EXTNAME = 'EVENTS '
HDUNAME = 'EVENTS '
CONTENT = 'EVT1   '
HDUCLASS= 'OGIP   '
HDUCLAS1= 'EVENTS '
HDUCLAS2= 'ALL'
COMMENT
COMMENT ACIS setup keywords
COMMENT
FIRSTROW= 1 / Index of first row of CCD (sub)array readout
NROWS = 1024 / Number of rows in (sub)array readout
EXPTIME = 3.2 / commanded exposure time in units of s
FLSHTIME= 0.0 / Duration of the flush before each frame (s)
CYCLE = 'P' / data from primary (P) or secondary (S) exposures
COMMENT
COMMENT Applied event correction/flagging reference files
COMMENT
BPIXFILE= 'acis1f000000000n001_bpix1'/ bad pixel file used
COMMENT
COMMENT Applied event calibration/transform reference files
COMMENT
GAINFILE= 'ACISgain_V1.0.fits'/ PHA to PI gain table file
GRD_FILE= 'ACISgrades_v1.0.fits' / Event grading scheme lookup table file
GRADESYS= 'ACIS' / Event grading scheme: ASCA/ACIS/USER...
ONTIME*m* = 1234.5 / ONTIME for CHIP *m*
LIVTIME*m*= 1234.5 / LIVETIME for CHIP *m*
EXPOSUR*m*= 1234.5 / EXPOSURE for CHIP *m*
...
ONTIME*n* = 1234.5 / ONTIME for CHIP *n*
LIVTIME*n*= 1234.5 / LIVETIME for CHIP *n*
EXPOSUR*n*= 1234.5 / EXPOSURE for CHIP *n*
TLMVER = 'P006 ' / Telemetry revision number (IP&CL)
FSW_VERS= 27 / ACIS flight software version number
FP_TEMP = 153.2 / Average temperature of focal plane (K)

FITS binary table contents (one entry per event)					
#	**TTYPE**	**TUNIT**	**TFORM**	**LO/HI**[a]	**Comment**
1	TIME	s	1D	n/a	S/C TT corresponding to mid-exposure
2	CCD_ID	n/a	1I	0/9	CCD reporting event
3	NODE_ID	n/a	1I	0/3	CCD serial readout amplifier node
4	EXPNO	n/a	1J	$0/2^{31}-1$	Exposure number of CCD frame containing event
5	CHIPX	pixel	1I	1/1024	X position of center pixel of event, chip coords
6	CHIPY	pixel	1I	1/1024	Y position of center pixel of event, chip coords
7	TDETX	pixel	1I	1/8192	X position of event, ACIS tiled detector coordinates
8	TDETY	pixel	1I	1/8192	Y position of event, ACIS tiled detector coordinates
9	DETX	pixel	1E	0.5/8192.5	X position of event, ACIS detector coordinates
10	DETY	pixel	1E	0.5/8192.5	Y position of event, ACIS detector coordinates
11	X	pixel	1E	0.5/8192.5	X position of event, sky coordinates
12	Y	pixel	1E	0.5/8192.5	Y position of event, sky coordinates
13	PHA	adu	1J	0/36855	total pulse height of event
14	CORN_PHA	adu	1I	-4096/4095	mean of event corner pixel PHA
15	ENERGY	eV	1E	n/a	nominal energy of event (eV)
16	PI	chan	1I	1/1024[b]	pulse invariant energy of event
17	FLTGRADE	n/a	1I	0/255	event grade, flight system
18	GRADE	n/a	1I	varies	“binned” event grade (ACIS/ASCA/USER system)
19	STATUS	n/a	32X	n/a	event status bits

a. The value of TLMIN is given by “LO”, the value of TLMAX is given by “HI”.

b.) These default values can, in principle, be different and are determined during the processing of the data.

3.3.5 Continuous Clocking Event Files (Tables 6,7)

Continuous-clocking (CC) Level 1 event data files are similar to the Timed Exposure (TE) Level 1 event files. The principle difference between the CC and TE files is that the column `CHIPY` contains timing information instead of spatial information for CC files. (If a source is extended, the values of `CHIPY` are a combination of the spatial information along this axis and the timing information.)

The column `CHIPY` = `TROW` + 1, where `TROW` is the name of a column in the Level 0 events file.

The values assigned to the columns `TDETX` and `TDETY` are based on the values in the columns `CHIPX` and `CHIPY` in the usual manner (see Applicable Document 11).

To compute the values of the columns `DETX`, `DETY`, `X`, and `Y`, the position of the source along the Y axis of the CCD needs to be known. Since the values of the column `CHIPY` depend on the dither of the instrument, the value of `CHIPY` of an event is assumed to be the value associated with the `TIME` of the event, `RA_TARG`, `DEC_TARG`, and the aspect solution at t = `TIME`. Using this technique, the values of `X` and `Y` are corrected for the effects of dither and lie along a line in the `X-Y` plane.

The column `SKY_1D` represents the one-dimensional distribution of events along the spatial dimension associated with `CHIPX`. This coordinate is computed separately for ACIS-I and ACIS-S. For ACIS-S, `SKY_1D` is obtained (1) by using pixlib to compute the right ascension (`RA`) and declination (`DEC`) associated with the `X` and `Y` coordinates of an event, (2) by computing the spatial difference between these coordinates and `RA_TARG` and `DEC_TARG` (`THETA` = $\cos^{-1}$[cos(`DEC`) * cos(`DEC_TARG`) * cos(`RA`-`RA_TARG`) + sin(`DEC`) * sin(`DEC_TARG`)]), and (3) by setting `SKY_1D` = `FPX0` + `C` * `THETA`. The coordinates `RA`, `RA_TARG`, `DEC`, and `DEC_TARG` are in units of degrees and the sines and cosines will need to handle them accordingly. The constant `C` converts `THETA` from degrees into arcseconds and can have either a positive or negative sign. The sign of `C` is given by the sign of `X'` = cos(`ROLL_NOM`) * (`X` - `FPX0`) - sin(`ROLL_NOM`) * (`Y` - `FPY0`), where `FPX0` and `FPY0` are parameters of `FP_1d1` in the appropriate file `pix_pixel_plane.par`. For ACIS-I, replace `ROLL_NOM` with `ROLL_NOM` - 90°.

Inclusion of the keyword `EXPTIME` in the CC mode event file header is TBD.

Table 6: CC Faint Event Data File

Additional FITS Keyword Header Items

```
EXTNAME = 'EVENTS  '
HDUNAME = 'EVENTS  '
CONTENT = 'EVT1    '
HDUCLASS= 'OGIP    '
HDUCLAS1= 'EVENTS  '
HDUCLAS2= 'ALL'
EXPTIME =            0.003 / inferred row clocking time (s)
COMMENT
COMMENT     Applied event correction/flagging reference files
COMMENT
BIASFIL0= 'acis0Vnn_nns000000000_1_bias0'/ bias file used: CCD 0
BIASFIL1= 'acis0Vnn_nns000000000_3_bias0'/ bias file used: CCD 1
BIASFIL2= 'acis0Vnn_nns000000000_0_bias0'/ bias file used: CCD 2
BIASFIL3= 'acis0Vnn_nns000000000_4_bias0'/ bias file used: CCD 3
BIASFIL6= 'acis0Vnn_nns000000000_6_bias0'/ bias file used: CCD 6
BIASFIL7= 'acis0Vnn_nns000000000_5_bias0'/ bias file used: CCD 7
BPIXFILE= 'acis1f000000000n001_bpix1'/ bad column file used
COMMENT
COMMENT     Applied event calibration/transform reference files
COMMENT
SPL_THR =                          13 / split threshold (0 if file used)
SPL_FILE=  'NONE'              / split threshold file
GAINFILE= 'ACISgain_V1.0.fits'/ PHA to PI gain table file
GRD_FILE= 'ACISgrades_v1.0.fits' / Event grading scheme lookup table file
GRADESYS= 'ACIS'               / Event grading scheme: ASCA/ACIS/USER...
ONTIMEm =                      1234.5 / ONTIME for CHIP m
LIVTIMEm=                      1234.5 / LIVETIME for CHIP m
EXPOSURm=                      1234.5 / EXPOSURE for CHIP m
...
ONTIMEn =                      1234.5 / ONTIME for CHIP n
LIVTIMEn=                      1234.5 / LIVETIME for CHIP n
EXPOSURn=                      1234.5 / EXPOSURE for CHIP n
TLMVER  = 'P006    '          / Telemetry revision number (IP&CL)
FSW_VERS=                   27 / ACIS flight software version number
FP_TEMP =                153.2 / Average temperature of focal plane (K)
```

FITS binary table contents (one entry per event)

Field	TTYPE	TUNIT	TFORM	LO/HI[a]	Comment
1	TIME	s	1D	n/a	S/C TT corresponding to CCD row readout
2	CCD_ID	n/a	1I	0/9	CCD reporting event
3	NODE_ID	n/a	1I	0/3	CCD serial readout amplifier node
4	EXPNO	n/a	1J	$0/2^{31}-1$	Exposure number of CCD frame containing event
5	CHIPX	pixel	1I	1/1024	X position of center pixel of event, chip coords
6	CHIPY	pixel	1I	1/512	Y position of center pixel of event, chip coords

Field	TTYPE	TUNIT	TFORM	LO/HI[a]	Comment
7	TDETX	pixel	1I	1/8192	X position of event, ACIS tiled detector coordinates
8	TDETY	pixel	1I	1/8192	Y position of event, ACIS tiled detector coordinates
9	DETX	pixel	1E	0.5/8192.5	X position of event, ACIS detector coordinates
10	DETY	pixel	1E	0.5/8192.5	Y position of event, ACIS detector coordinates
11	X	pixel	1E	0.5/8192.5	X position of event, sky coordinates
12	Y	pixel	1E	0.5/8192.5	Y position of event, sky coordinates
13	SKY_1D	arcsec	1E	varies	A 1D spatial coordinate
14	PHAS	adu	9I	-4096/4095	3x3 array of bias-corrected pixel pulse heights (ADU)
15	PHA	adu	1J	0/36855	total pulse height of event (ADU)
16	ENERGY	eV	1E	n/a	nominal energy of event (eV)
17	PI	chan	1I	1/1024[b]	pulse invariant energy of event
18	FLTGRADE	n/a	1I	0/255	event grade, flight system
19	GRADE	n/a	1I	varies	“binned” event grade (ACIS/ASCA/USER system)
20	STATUS	n/a	32X	n/a	event status bits

a. The value of TLMIN is given by “LO”, the value of TLMAX is given by “HI”.

b.) These default values can, in principle, be different and are determined during the processing of the data.

Table 7: CC Graded Event Data File

Additional FITS Keyword Header Items

```
EXTNAME = 'EVENTS  '
HDUNAME = 'EVENTS  '
CONTENT = 'EVT1    '
HDUCLASS= 'OGIP    '
HDUCLAS1= 'EVENTS  '
HDUCLAS2= 'ALL'
EXPTIME =            0.003 / inferred row clocking time (s)
COMMENT
COMMENT     Applied event correction/flagging reference files
COMMENT
BPIXFILE= 'acis1f000000000n001_bpix1'/ bad pixel file used
COMMENT
COMMENT     Applied event calibration/transform reference files
COMMENT
GAINFILE= 'ACISgain_V1.0.fits'/ PHA to PI gain table file
GRD_FILE= 'ACISgrades_v1.0.fits' / Event grading scheme lookup table file
GRADESYS= 'ACIS'                 / Event grading scheme: ACIS/ASCA/USER/...
ONTIMEm =                     1234.5 / ONTIME for CHIP m
LIVTIMEm=                     1234.5 / LIVETIME for CHIP m
EXPOSURm=                     1234.5 / EXPOSURE for CHIP m
...
ONTIMEn =                     1234.5 / ONTIME for CHIP n
LIVTIMEn=                     1234.5 / LIVETIME for CHIP n
EXPOSURn=                     1234.5 / EXPOSURE for CHIP n
TLMVER  = 'P006    '         / Telemetry revision number (IP&CL)
FSW_VERS=                 27 / ACIS flight software version number
FP_TEMP =              153.2 / Average temperature of focal plane (K)
```

FITS binary table contents (one entry per event)

Field	TTYPE	TUNIT	TFORM	LO/HI[a]	Comment
1	TIME	s	1D	n/a	S/C TT corresponding to CCD row readout
2	CCD_ID	n/a	1I	0/9	CCD reporting event
3	NODE_ID	n/a	1I	0/3	CCD serial readout amplifier node
4	EXPNO	n/a	1J	$0/2^{31}-1$	Exposure number of CCD frame containing event
5	CHIPX	pixel	1I	1/1024	X position of center pixel of event, chip coords
6	CHIPY	pixel	1I	1/512	Y position of center pixel of event, chip coords
7	TDETX	pixel	1I	1/8192	X position of event, ACIS tiled detector coordinates
8	TDETY	pixel	1I	1/8192	Y position of event, ACIS tiled detector coordinates
9	DETX	pixel	1E	0.5/8192.5	X position of event, ACIS detector coordinates

Field	TTYPE	TUNIT	TFORM	LO/HI[a]	Comment
10	DETY	pixel	1E	0.5/8192.5	Y position of event, ACIS detector coordinates
11	X	pixel	1E	0.5/8192.5	X position of event, sky coordinates
12	Y	pixel	1E	0.5/8192.5	Y position of event, sky coordinates
13	SKY_1D	arcsec	1E	varies	A 1D spatial coordinate
14	PHA	adu	1J	0/36855	total pulse height of event (ADU)
15	ENERGY	eV	1E	n/a	nominal energy of event (eV)
16	PI	chan	1I	1/1024[b]	pulse invariant energy of event
17	FLTGRADE	n/a	1I	0/255	event grade, flight system
18	GRADE	n/a	1I	varies	“binned” event grade (ACIS/ASCA/USER system)
19	STATUS	n/a	32X	n/a	event status bits

a. The value of TLMIN is given by “LO”, the value of TLMAX is given by “HI”.

b.) These default values can, in principle, be different and are determined during the processing of the data.

3.3.6 ACIS Level 1 Event File Telemetry GTI Extensions

The specification of good time intervals (GTIs) for ACIS must be capable of taking into account periods when the instrument was dropping exposures from specific CCDs due to telemetry saturation. Telemetry dropout can also manifest itself in the form of dropped events and/or exposure records from specific CCDs, and such a circumstance is also interpreted as “bad exposure(s)” (and hence a “bad time interval”) by the Level 1 software. The telemetry good times are derived from the “dropped exposures” extension of the exposure statistics file (Section 3.5) and are contained in a set of up to 6 table extensions (Table 8), one per CCD, that comprise the telemetry GTI extensions of the Level 1 Event File. In addition, the requisite Data Model keywords describing these GTI extensions must be present in the principal (event) extension (TBD).

Table 8: Good Time Interval Event File Extension

Additional FITS Keyword Header Items

```
EXTNAME = 'GTI'                  / GTI table extension
EXTVER  =                      n / extension for CCD_ID=n
CCD_ID  =                      n / GTI is for this CCD
FEP_ID  =                      m / FEP corresponding to CCD
HDUNAME = 'GTIn    '
CONTENT = 'GTI     '
HDUCLASS= 'OGIP    '
HDUCLAS1= 'GTI     '
HDUCLAS2= 'ALL     '
DTCOR   =                        / Dead time correction
```

FITS binary table contents (one entry per GTI)

#	TTYPE	TUNIT	TFORM	LO/HI	Comment
1	START	s	1D	n/a	GTI start time
2	STOP	s	1D	n/a	GTI stop time

3.4 Standard GTI files (*_flt1.fits)

As described in Section 3.3.6, the ACIS event file contains up to 6 telemetry GTI extensions, one per CCD. To populate the "Standard" GTI file extensions, described in Table 9, the telemetry good times (Table 8) are merged with the other, "standard" telescope and spacecraft GTIs. The `ONTIME`, `LIVETIME`, `EXPOSURE`, and `DTCOR` keywords in the "Observation Information" header component of each GTI extension contain values corresponding to the CCD in question, while `ONTIME LIVETIME`, `EXPOSURE`, and `DTCOR` in the primary file extension refer to the nominal aim point CCD.The requisite Data Model keywords describing these GTI extensions must be present in the primary file extension (TBD).

Table 9: Standard Good Time Interval Extension

Additional FITS Keyword Header Items

```
EXTNAME = 'GTI'                    / GTI table extension
EXTVER  =                        n / extension for CCD_ID=n
CCD_ID  =                        n / GTI is for this CCD
FEP_ID  =                        m / FEP corresponding to CCD
HDUNAME = 'GTIn    '
CONTENT = 'GTI     '
HDUCLASS= 'OGIP    '
HDUCLAS1= 'GTI    '
HDUCLAS2= 'STANDARD'
FLSHTIME=                      0.0 / Duration of flush before each frame (s)
ONTIMEm =                   1234.5 / ONTIME for CHIP m
LIVTIMEm=                   1234.5 / LIVETIME for CHIP m
EXPOSURm=                   1234.5 / EXPOSURE for CHIP m
...
ONTIMEn =                   1234.5 / ONTIME for CHIP n
LIVTIMEn=                   1234.5 / LIVETIME for CHIP n
EXPOSURn=                   1234.5 / EXPOSURE for CHIP n
```

FITS binary table contents (one entry per GTI)

#	TTYPE	TUNIT	TFORM	LO/HI[a]	Comment
1	START	s	1D	n/a	GTI start time
2	STOP	s	1D	n/a	GTI stop time

a. The value of TLMIN is given by "LO", the value of TLMAX is given by "HI".

3.5 Exposure Statistics Files (*_stat1.fits)

An Exposure Statistics file is created for each science run (Table 10). This file contains up to seven extensions, each pertaining to the sequence of ACIS CCD exposures processed and recorded into telemetry. The first extension is a binary table with one row for each exposure generated by each CCD. This extension is almost entirely derived from a merge operation on the (per-CCD) Exposure Records Files generated by Level 0 processing (see Applicable Document 4, Sec. 4.4.4). The exception is the `OVRCLOCK` column, which is derived by straightforward addition of the values contained in the `DELTOCLK(i)` column of the Level 0 Exposure Records file and the values in the `INITOCLi` keywords contained in the Level 0 Bias File (or the Level 0 event file, in the case of `faint with bias` mode) for the same CCD.

The exposure statistics extension is followed by up to six extensions, 1 per active CCD, containing “dropped exposures” tables. These extensions effectively provide a record of time intervals (i.e. exposure numbers) during which CCDs were and were not reporting exposures into telemetry (the `MISEXP` column), and/or time intervals during which events are determined to be missing by Level 1 software, due to telemetry dropouts or other anomalies (the `MISEVT` column). For the `MISEXP` column, the possible values are 0 (a Level 0 exposure record file entry exists) or 1 (no exposure record file entry exists). For the `MISEVT` column, the possible values are 0 (no. of events in Level 0 event file = no. telemetered), 2 (no events in Level 0 event file, but at least 1 event was sent, according to Level 0 exp. records file), 3 (no. of events in Level 0 event file < no. telemetered), or 4 (no. of events in Level 0 event file > no. telemetered).

Table 10: Exposure Statistics File

Additional FITS Keyword Header Items, extension 1

```
EXTNAME = 'EXPSTATS'              / Table name
HDUNAME = 'EXPSTATS'
CONTENT = 'EXPSTATS'
HDUCLASS= 'ASC     '
HDUCLAS1= 'TEMPORALDATA'
HDUCLAS2= 'EXPOSURES'
INITOCmA=                     123 / Average init overclock for CCD m, node A
INITOCmB=                     123 / Average init overclock for CCD m, node B
INITOCmC=                     123 / Average init overclock for CCD m, node C
INITOCmD=                     123 / Average init overclock for CCD m, node D
...
INITOCnA=                     123 / Average init overclock for CCD n, node A
INITOCnB=                     123 / Average init overclock for CCD n, node B
INITOCnC=                     123 / Average init overclock for CCD n, node C
INITOCnD=                     123 / Average init overclock for CCD n, node D
CYCLE   = 'P'            / data from primary (P) or secondary (S) exposures
```

FITS binary table contents, extension 1 (one entry per exposure)

#	TTYPE	TUNIT	TFORM	LO/HI	Comment
1	TIME	s	1D	n/a	S/C TT corresponding to mid-exposure
2	CCD_ID	n/a	1I	0/9	CCD to which statistics apply
3	EXPTIME	s[a]	1E	0.0/10.0	Duration of exposure (TE), or row readout time (CC)
4	EXPNO	n/a	1J	$0/2^{31}-1$	exposure number since start of science run
5	EVTSENT	n/a	1J	$0/2^{31}-1$	number of events sent in data records
6	THR_PIX	n/a	1J	$0/2^{20}$	pixels above respective threshold level
7	DROP_AMP	n/a	1J	$0/2^{31}-1$	# discarded events due to corrected amplitude
8	DROP_POS	n/a	1J	$0/2^{31}-1$	# discarded events due to CCD position
9	DROP_GRD	n/a	1J	$0/2^{31}-1$	# discarded events due to grade code
10	BERR_SUM	n/a	1J	$0/2^{31}-1$	# pixel bias errors so far in science run
11	OVRCLOCK	adu	4I	-4096/4095	output node overclock values

a. TSCAL = 0.1 for timed exposure mode; TSCAL = 0.00001 for continuous clocking.

Additional FITS Keyword Header Items, extensions 2-N (N<=7)

```
EXTNAME = 'DROPEXP'                / Dropped exposures
EXTVER  =                      n  / extension for CCD_ID=n
HDUNAME = 'DROPEXPn '
CONTENT = 'DROPEXP '
HDUCLASS= 'ASC     '
HDUCLAS1= 'TEMPORALDATA'
HDUCLAS2= 'EXPOSURES'
CCD_ID  =                        n / CCD ID (0-9)
FEP_ID  =                        n / FEP ID (0-5)
```

FITS binary table contents, extensions 2-N (N<=7) (one entry per time interval)

#	TTYPE	TUNIT	TFORM	LO/HI	Comment
1	TIME	s	1D	n/a	S/C TT corresponding to start of time interval
2	EXPNO	n/a	1J	$0/2^{31}-1$	exposure number corresponding to start of time interval
3	MISEVT	n/a	1I	0/4	Events missing from L1 evt file? (0=no)
4	MISEXP	n/a	1I	0/1	L0 exposure record exists for this EXPNO (0) or not (1)?

3.6 Bias Map Files (*_c_bias1.fits)

Bias Map files are created and output by the Level 1 pipeline on a CCD by CCD basis for `TE faint with bias` mode *only*. For all other modes, it is assumed the User will receive the Bias Map files produced by Level 0 software, and should refer to these files for bias data. For information on the format and content of Level 0 Bias Map files, see Applicable Document 4.

"Good" bias map pixel values are in the range 0-4093. Pixels belonging to the current bad-pixel or bad-column lists that are telemetered to the ground as part of the event record will be assigned the value `PIXEL_BAD` (decimal 4095). Pixels that have caused parity errors during a science run before the bias map was copied to the telemetry stream will be assigned the value `BIAS_BAD` (decimal 4094). Pixels whose bias values are unknown (because events have not been extracted from those pixels or their neighbors) are assigned the value `BIAS_UNKNOWN` (decimal 4096)

The format of the Level 1 bias map file, like that of the Level 0 TE bias map file (see Section 4.4.9 and Table 19 of Applicable Document 4), is a 1024x1024 image. Header sections CC, T and O are obtained from the input event file.

Table 11: TE Bias Map File

FITS Keyword Header
`SIMPLE  =  T / FITS STANDARD`
`BITPIX  =  16 / 16-bit image pixels`
`NAXIS  =  2 / 2-dimensional image`
`NAXIS1  =  1024 / Number of pixels per row`
`NAXIS2  =  1024 / Number of rows`
`EXTEND  =  T / FITS dataset may include extensions`
`EXTNAME = 'BIAS  '`
`EXTTYPE =  4`
`HDUNAME = 'BIAS  '`
`CONTENT = 'BIAS1  '`
`HDUCLASS= 'ASC  '`
`HDUCLAS1= 'IMAGE  '`
`HDUCLAS2= 'BIAS  '`
`CTYPE1  = 'CHIPX'  / X coordinate system`
`CTYPE2  = 'CHIPY'  / Y coordinate system`
`CRPIX1  =  1 / X reference pixel (column)`
`CRPIX2  =  1 / Y reference pixel (row)`
`CRVAL1  =  0. / reference value`
`CRVAL2  =  0. / reference value`
`CDELT1  =  0.024 / X pixel increment (mm)`
`CDELT2  =  0.024 / Y pixel increment (mm)`
`COMMENT`
`COMMENT  AXAF FITS TE Bias File: ACIS Level 1`
`COMMENT`
`.....Required keywords (see Applicable Document 9):.....`
`.....Section CC: configuration control keywords.....`
`.....Section T: timing keywords.....`
`.....Section O: observation info keywords.....`
`COMMENT`

Table 11: TE Bias Map File (Continued)

FITS Keyword Header

`COMMENT`
`COMMENT  AXAF FITS TE Bias File: Special ACIS Keywords`
`COMMENT`
`READMODE= 'TIMED   '  / CCD exposure mode`
`DATAMODE= 'FAINT_BIAS'  / CCD telemetry mode`
`FEP_ID  =  0 / FEP id: 0 - 5`
`CCD_ID  =  7 / CCD id: 0 - 9`
`STARTROW=  0 / Index of first CCD row telemetered`
`ROWCNT  =  1023 / Number of CCD rows telemetered`
`INITOCLA=  794 / Average initial overclock for node A`
`INITOCLB=  553 / Average initial overclock for node B`
`INITOCLC=  700 / Average initial overclock for node C`
`INITOCLD=  655 / Average initial overclock for node D`
`END`

followed by padding sufficient to make the header a multiple of 36 lines (2880 bytes)
FITS image array
1024 x 1024 image pixels—16-bit signed integers

3.7 Mask Files (*_msk1.fits)

The CCD active surface (subarray) descriptions and Level 0 BEP event processing window lists (which include event energy selection and event sampling criteria) are captured by Level 1 processing in the Mask File (Table 12), which (in combination with Bad Pixel List files; Section 3.8) is used by exposure map tools to determine exposure times and photon detection efficiencies as a function of position on the sky. See the description of `acis_build_mask` in Applicable Document 12.

The mask file contains one extension per active CCD. Each entry in each of these extensions corresponds to a BEP window as defined in the 2-D or 1-D window list files output by Level 0 (see Applicable Document 4); in the absence of such windows for a given CCD (i.e., no BEP windows defined for the science run in question) the default entry corresponds to the active (sub)array as specified in the Parameter Block. The mask extension format makes use of the REGION table format described in Applicable Document 13, where `SHAPE` is ‘rectangle’. The `COMPONENT` column is used to combine windows. The notation `!RECTANGLE` indicates a region of exclusion formed by e.g. the overlap of a given window by a second, superceding window. The `OVERLAP` column contains a bitmap specification of window overlap. If, for example, the 2nd and 5th windows of `CCD_ID` = 0 overlap, then the 5th bit of the `OVERLAP` column will be set for the 2nd window and the 2nd bit of the `OVERLAP` column will be set for the 5th window.

Note that, as per Rev 2.8 of Applicable Document 4, certain “native hex” values in headers (e.g., the `GRADEMA`*n* keywords) are encoded as hex in the keyword fields, while others (e.g., `PBLOCK`) appear as long integers with hex translation inserted in the comment field.

Table 12: Mask file extension

Additional FITS Keyword Header Items: Mask Extension(s)
EXTNAME = 'MASK' / Mask extension
EXTVER = *n* / extension for CCD_ID=*n*
HDUNAME = 'MASKn '
CONTENT = 'MSK '
HDUCLASS= 'ASC '
HDUCLAS1= 'REGION '
HDUCLAS2= 'MASK '
MTYPE1 = 'chip ' / data_model keyword
MFORM1 = 'CHIPX,CHIPY' / data_model keyword
CCD_ID = *n* / CCD ID
FEP_ID = *m* / FEP ID
FIRSTROW= 1 / first row of CCD subarray, CHIP coords
LASTROW = 1024 / last row of CCD subarray, CHIP coords
PHAMIN = 0 / Minimum acceptable pulse height
PHARANGE= 65535 / Range of accepted pulse heights
GRADEMA1='FFFFFFFF' / Hex bit pattern of accepted grade flags
GRADEMA2='FFFFFFFF' / Hex bit pattern of accepted grade flags
GRADEMA3='FFFFFFFF' / Hex bit pattern of accepted grade flags
GRADEMA4='FFFFFFFF' / Hex bit pattern of accepted grade flags
GRADEMA5='FFFFFFFF' / Hex bit pattern of accepted grade flags
GRADEMA6='FFFFFFFF' / Hex bit pattern of accepted grade flags
GRADEMA7='FFFFFFFF' / Hex bit pattern of accepted grade flags
GRADEMA8='FFFFFFFF' / Hex bit pattern of accepted grade flags
STARTBEP= 0 / BEP timer value at TSTART
DTYPE1 = 'STARTBEP' / DM Keyword: Descriptor name.
DFORM1 = 'V ' / DM Keyword: Descriptor datatype.
STOPBEP= 0 / BEP timer value at TSTOP
DTYPE1 = 'STOPBEP' / DM Keyword: Descriptor name.
DFORM1 = 'V ' / DM Keyword: Descriptor datatype.
PBLOCK = 123456789 / parameter block ID = 'FFFFFFFF'
WIND_ID = 123456789 / window block ID = 'FFFFFFFF'
DTYCYCLE= 0 / Number of Secondary exposures per Primary

FITS binary table contents: mask extension(s) (one entry per window or per CCD)					
#	**TTYPE**	**TUNIT**	**TFORM**	**LO/HI[a]**	**Comment**
1	SHAPE	n/a	16A	n/a	shape of window (default: rectangle)
2	COMPONENT	n/a	1I	0/6	component index
3	CHIPX	pixel	2I	1/1024	Window bottom left/top right corner X, CHIP coords
4	CHIPY	pixel	2I	1/1024	Window bottom left/top right corner Y, CHIP coords
5	WINDOW	n/a	1I	0/5	window index (0-5); up to 6 per CCD
6	SAMP_CYC	n/a	1I	0/255	Event sampling: 0=reject all, 1= accept all, 2=accept every other, 3=accept every 3rd...
7	PHAMIN	chan	1I	0/4095	Minimum event amplitude accepted by window (ADU)
8	PHAMAX	chan	1J	0/ 65535	Maximum event amplitude accepted by window (ADU)
9	OVERLAP	n/a	1I	n/a	Window overlap bitmap

a. The value of TLMIN is given by “LO”, the value of TLMAX is given by “HI”.

3.8 Bad Pixel List Files (*_bpix1.fits)

Bad pixel/column lists, as captured in the Analysis Reference Data contained in the CXC Archive and in Level 0 CCD Bias Maps and Bias Error files specific to a science run, are compiled and output at Level 1. The resulting products are Bad Pixel List files (Table 13). The file extension includes the time at which a bad pixel (or bad column) was reported or catalogued. The criteria for assigning a `TIME` to each element in the bad pixel table are detailed in the description of `acis_build_badpix` (see Applicable Document 12).

Each extension of the bad pixel list file contains the bad pixel/column list for an active CCD. The format is that of the REGION table described in Applicable Document 13, where `SHAPE` is ‘point’ for bad pixels and ‘rectangle’ for bad columns (though the ‘rectangle’ shape is not restricted to bad columns; e.g., a contiguous group of bad pixels may best be described as a rectangle).

Each bad pixel or bad column is a single component. Therefore, the column `COMPONENT` should be numbered sequentially from 1 for each bad pixel or bad column entry in the file. The values in the column `COMPONENT` may be used to analyze data with subsets of the bad pixel list.

The column `STATUS` contains a bit-map description of the reason a bad pixel or column is flagged as bad. Seven bits are used at the present. These bits (0-6) indicate that (0) the pixel is flagged as bad in the add-pixel calibration ARD file, (1) the column is flagged as bad in the bad-pixel calibration ARD file, (2) the column lies along one of the node boundaries at `CHIPX` = 256, 257, 512, 513, 768, or 769, (3) the pixel is good, but is adjacent to a bad pixel or column (This condition does not apply to the node boundaries.), (4) a bias-parity error has been reported for the pixel in the corresponding Level 0 *_berr0.fits file, (5) the pixel has been recorded as bad in the corresponding bias map (i.e. the pixel has a value of 4095 in the bias map), and (6) a bias error has been reported for the pixel in the bias map (i.e. the pixel has a value of 4094 in the bias map).

Table 13: Bad Pixel List File

Additional FITS Keyword Header Items: Bad Pixel extension(s)
`EXTNAME = ‘AXAF_BADPIX  ‘  / Bad pixel extension`
`EXTVER  =  n  / extension for CCD_ID=n`
`HDUNAME = ‘AXAF_BADPIXn ‘`
`CONTENT = ‘BADPIX  ‘`
`HDUCLASS= ‘ASC  ‘`
`HDUCLAS1= ‘REGION  ‘`
`CCD_ID  =  n / CCD ID`
`FEP_ID  =  m / FEP ID`
`STARTBEP=  0 / BEP timer value at TSTART`
`DTYPE1  = ‘STARTBEP’  / DM Keyword: Descriptor name.`
`DFORM1  = ‘V  ‘  / DM Keyword: Descriptor datatype.`
`STOPBEP=  0 / BEP timer value at TSTOP`
`DTYPE1  = ‘STOPBEP’  / DM Keyword: Descriptor name.`
`DFORM1  = ‘V  ‘  / DM Keyword: Descriptor datatype.`
`MFORM1  = ‘CHIPX,CHIPY’`
`MTYPE1  = ‘chip  ‘`

FITS binary table contents: Bad Pixel extension(s) (one entry per bad pixel/column)					
#	**TTYPE**	**TUNIT**	**TFORM**	**LO/HI**	**Comment**
1	SHAPE	n/a	16A	n/a	shape of bad element (pixel= point; column=rectangle)
2	COMPONENT	n/a	1I	$1/2^{15}-1$	component index
3	CHIPX	pixel	2I	1/1024	bad pixel/column (or bias error) X, CHIP coords
4	CHIPY	pixel	2I	1/1024	bad pixel/column (or bias error) Y(s), CHIP coords
5	TIME	s	1D	n/a	Time associated. w/ bad pixel or bias error
6	STATUS	n/a	16X	n/a	origin of bad pixel (bitmap)

3.9 Level 1 Summary File (*_sum.fits)

Accompanying each Level 1 dataset is a Summary File (TBD), whose elements are mainly derived from the Parameter Block and Science Run Report files generated by Level 0 processing. Additional table columns describe the number of exposures telemetered for each CCD, as well as the total number of events reported for each CCD.

The format is slightly different depending on whether the instrument was configured for TE readout mode (Table 14) or CC readout mode (Table 14).

Table 14: Level 1 Summary File, Timed Exposure mode

Additional FITS Keyword Header Items

```
EXTNAME = 'SUMMARY'     / Table name
CONTENT = 'ACIS_SUMMARY'
COMMENT
COMMENT  The following keywords are derived from the
COMMENT  LO Science Run Report file
COMMENT
EXPTOT  =            335 / total number of exposures produced
BERR_CNT=              0 / number of pixel bias map errors detected
DEA_ERRS=              0 / errors detected on DEA Interface Board, 1 flag
TERMCODE=              1 / Code indicating the reason for the end of run
SOFT_VER=             11 / Instrument software version number
COMMENT
COMMENT  The following keywords are derived from the
COMMENT  L0 Parameter Block file
COMMENT
FEP_MODE=              2 / 0:Raw; 1:Histogram; 2:3x3; 3:15 TBD
BEP_MODE=              1 / 0:Faint; 1:Faint Bias; 2:Graded; 3:15 TBD
SUM_2X2 =              0 / On-chip summing. 0:None; 1:Sum 2x2
NOBADPIX=              1 / Disable bad pixel map. 0:Use map; 1:Ignore map
NOBADCOL=              1 / Disable bad column map. 0:Use map; 1:Ignore mp
BIAS_CAL=              1 / Enable bias calibration. 0:Don't compute; 1:Comp
SENDBIAS=              0 / Telemeter bias data. 0:Don't send; 1: Send
STARTROW=              0 / Index of first row to clock out CCDs
ROWCNT  =           1023 / One less than the number of rows to clock out
OCLKPAIR=              8 / Number of pairs of overclock pixels per output
ORC_MODE=              0 / Output register clocking mode
EXPTIMEA=             35 / Primary exposure time in units of 1/10s
EXPTIMEB=              0 / Secondary exposure time in units of 1/10s
DTYCYCLE=              0 / Number of Secondary exposures per Primary
PHAMIN  =              0 / Minimum acceptable pulse height
PHARANGE=             -1 / Range of accepted pulse heights
GRADEMA1='FFFFFFFF'      / Hex bit pattern of accepted grade flags
GRADEMA2='FFFFFFFF'      / Hex bit pattern of accepted grade flags
GRADEMA3='FFFFFFFF'      / Hex bit pattern of accepted grade flags
GRADEMA4='FFFFFFFF'      / Hex bit pattern of accepted grade flags
GRADEMA5='FFFFFFFF'      / Hex bit pattern of accepted grade flags
GRADEMA6='FFFFFFFF'      / Hex bit pattern of accepted grade flags
GRADEMA7='FFFFFFFF'      / Hex bit pattern of accepted grade flags
GRADEMA8='FFFFFFFF'      / Hex bit pattern of accepted grade flags
```

FITS binary table contents (one entry per active FEP)

Field	TTYPE	TUNIT	TFORM	TLMAX [a]	Comment
1	FEP_ID	n/a	1I	5	Front end processor ID
2	CCD_ID	n/a	1I	9	CCD ID
3	VIDRESP	n/a	1I	1	CCD video chain response selection, 0 for 1:1
4	EVT_THR	adu	4I	4095	Event thresholds for nodes A-D (TLMIN=-4096)
5	SPL_THR	adu	4I	4095	Split thresholds for output nodes A-D
6	VID_OFF	n/a	4I	4095	Video offsets for CCD output nodes A-D
7	CCD_ERRS	n/a	1I	1	code indicating errors on DEA during science run
8	FEP_ERRS	n/a	1I	255	code indicating errors on FEP during science run
9	EXP_SENT	n/a	1I	0/???	total number of exposures telemetered
10	EVT_SENT	n/a	1J	0/???	total number of events telemetered

a. TLMIN = 0 unless noted.

Table 15: Level 1 Summary File, Continuous Clocking mode

Additional FITS Keyword Header Items

```
EXTNAME = 'SUMMARY'      / Table name
CONTENT = 'ACIS_SUMMARY'
COMMENT
COMMENT  The following are derived from the L0 Science Run Report file
COMMENT  (as are last 2 columns of the binary table)
COMMENT
EXPTOT  =            335 / total number of exposures produced
EXPSENT =             50 / total number of exposures telemetered
BERR_CNT=              0 / number of pixel bias map errors detected
DEA_ERRS=              0 / errors detected on DEA Interface Board, 1 flag
TERMCODE=              1 / Code indicating the reason for the end of run
SOFT_VER=             11 / Instrument software version number
COMMENT
COMMENT  The following are derived from the L0 Parameter Block file
COMMENT  (as are remaining columns of the binary table)
COMMENT
FEP_MODE=              2 / 0:Raw; 1:Histogram; 2:1x3; 3:15 TBD
BEP_MODE=              1 / 0:Faint; 1:Graded; 2:15 TBD
NOBADCOL=              1 / 0:Use bad CC column map; 1:Ignore bad column map
BIAS_CAL=              1 / 0:Don't recompute bias maps; 1:Recompute maps
SENDBIAS=              0 / 0:Don't Telemeter bias maps; 1: Telemeter them
SUMROW  =              0 / Number of CCD rows to sum (powers of 2)
SUMCOL  =              0 / Number of CCD columns to sum (powers of 2)
OCLKPAIR=              8 / Number of pairs of overclock pixels per output
ORC_MODE=              0 / Output register clocking mode
PHAMIN  =              0 / Minimum acceptable pulse height
PHARANGE=             -1 / Range of accepted pulse heights
GRADEMAP='FFFF'          / Hex bit pattern of accepted grade flags
```

FITS binary table contents (one entry per active FEP)

Field	TTYPE	TUNIT	TFORM	TLMAX [a]	Comment
1	FEP_ID	n/a	1I	5	Front end processor ID
2	CCD_ID	n/a	1I	9	CCD ID
3	VIDRESP	n/a	1I	1	CCD video chain response selection, 0 for 1:1
4	EVT_THR	adu	4I	4095	Event thresholds for nodes A-D (TLMIN=-4096)
5	SPL_THR	adu	4I	4095	Split thresholds for output nodes A-D
6	VID_OFF	n/a	4I	4095	Video offsets for CCD output nodes A-D
7	CCD_ERRS	n/a	1I	1	code indicating errors on DEA during science run
8	FEP_ERRS	n/a	1I	255	code indicating errors on FEP during science run

a. TLMIN = 0 unless noted.

3.10 Volume, Size, and Frequency Estimates

TBD.