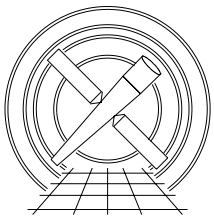
Chandra X-Ray Center



ACIS Level 1 & 2 Pipelines and Tools: Analysis Reference Data to CXC Archive Interface Control Document

(`http://space.mit.edu/ASC/docs/ARD_ICD/ACIS_ARD_ICD_2.0.ps.gz`)

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Document and Change Control Log			
Date	**Version**	**Section**	**Status**
3 March 98	0.0	all	Initial Draft: gain, CTI products descriptions
03 August 98	1.0	all	Broke off from Gratings ICD; added Event Grades product
20 August 98	1.1	5, 6	Added bad pixel and bias file sections
08 October 98	1.2	8, 9	Updated CTI format; added event/split threshold table
12 March 99	1.3	3.1, 4, 5, 7, 9	Clarified CONTENT etc. keywords; updated gain, event/split threshold, grade, bad pixel file keywords
16 December 99	2.0	7, 8	Described the format of the new gain-map product; removed section about CTI ARD

Unresolved Issues

The following is a list of unresolved, un-reviewed, or un-implemented items:

1. CONTENT, EXTNAME, HDUNAME, HDUCLASS keywords in all extensions require review; they should all be caldb.txt compliant in Rev 1.3.
2. Special keywords in primary event/split threshold ARD file extension require review.

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1 Introduction

This document describes the interface to be employed in transferring Analysis Reference Data (ARD) to or from the CXC Data Archive, according to the requirements stipulated in the "ASC Data System Requirements" (Applicable Document 2). The products described here are those used with the ACIS Level 1 and Level 2 pipeline-processing tools and with the ACIS analysis tools.

ARD are derived by re-formatting (e.g. from an ASCII table to a FITS BINTABLE) and processing the data of Calibration Interface Products (CIP[1]). The primary distinction is that the ARD are necessary or convenient for *analysis*, and are a subset of the CIP, which define the detailed *calibration*.

Together with pipeline and interactive processing data products, the ARD form a Data Dictionary.

Items boxed in the right margin (like this) are questions to be answered or TBD's to be replaced.

1.1 Purpose

Level 1 ACIS processing, described in Applicable Documents 2, 4, and 9, consists of processing of ACIS Level 0 (telemetry) products, described in Applicable Document 8, to derive bias-subtracted, graded, PHA-summed, gain-corrected event lists and ancillary products (bad pixel lists, window files, telemetry GTI file and event GTI extensions), described in Applicable Document 9. Level 2 ACIS processing then utilizes these products, plus exposure maps (output by exposure map tools) and candidate source lists (output by detect tools), to produce new products, such as images, spectra, and light-curves. See Applicable Document 10 for descriptions of these products. This document describes the structure and content of the reference data required for Level 1 and 2 ACIS processing and for further analysis, either via pipeline or interactive processing.

1.2 Scope

This interface shall apply to all data products that are used by ACIS Level 1 and 2 pipelines and distributed to the CXC Data Archive (see Applicable Document 2 and the "ASC Data System Software Design," Applicable Document 3) during the course of the Chandra mission.

2 Applicable Documents

1. AXAF Data Products Guide
   `http://hea-www.harvard.edu/asclocal/sds/CDR2/dp.ps`
2. ASC AMO-2400 (SE03)
   ASC Data System Requirements (ASC.302.93.0008)
3. ASC AMO-2401 (DS01)
   ASC Data System Software Design (ASC.500.93.0006)
4. ASC Tools Catalog
   Link on: `http://???`

[1] See `http://space.mit.edu/HETG/xrcf_cal/cal_prods.html#Overview` for a definition.

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5. HEASARC FITS CALDB Standards:
   `http://heasarc.gsfc.nasa.gov/docs/heasarc/caldb/caldb_intro.html`
   (and references therein.)
6. ASC FITS File Designers' Guide
   `http://hea-www.harvard.edu/ãrots/asc/fits/ascfits.ps` (and references therein).
7. AXAF CALDB Architecture
   `http://hea-www.harvard.edu/ãrots/asc/fits/caldb.txt`
8. ACIS Data Products:
   Level 0 to CXC Archive Interface Control Document
   `link on http://space.mit.edu/ASC/docs/docs.html`
9. ACIS Data Products:
   Level 1 to CXC Archive Interface Control Document
   `link on http://space.mit.edu/ASC/docs/docs.html`
10. ACIS/HRC Imaging Data Products:
    Level 2 to ASC Archive Interface Control Document
    `link on http://???`

3 Functional Description

3.1 Data Content Summary

Data sets read by the processing pipelines shall consist of data files conforming to the FITS format (See the "ASC FITS File Designers' Guide", Document 6) and references therein.) These files contain header keyword entries and binary table (BINTABLE) extensions. Following rules outlined in Applicable Document 6, all these files will contain a possibly null primary header followed by a main binary table (the "principal HDU") and auxiliary extensions ("auxiliary HDU"). Furthermore, FITS ARD files will conform to the HEASARC CALDB conventions (Applicable Document 5) and have CONTENT, EXTNAME and HDUCLASS keywords that conform to Applicable Document 7. In the event of a conflict in these keywords, Applicable Document 7 shall supersede this ICD.

Any other types of files will either be of types in common use (e.g., PostScript), or fully described here (e.g., ASCII region files of IRAF/PROS), or parameter files conforming to the SAO parameter interface.

Get param i/f ref.

3.2 Recipients and Utilization

The primary recipients of reference data products, via distribution from the archive, are Chandra observers, who will utilize these data products for scientific data analysis.

3.3 Pertinent Relationships with Other Interfaces

Changes to the definition of ACIS Calibration Interface Products, as described in Applicable Documents ??TBD, may affect the data products described in the current document.

TBD: CIP doc reference.

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3.4 Assumptions and Constraints

It is assumed that CXC pipeline processing uses ARD applicable to the time and instrument mode of ACIS observations, and that the ARD is updated as necessary when CIP are revised. It is also assumed that these products are extracted from the CXC archive and placed into an exportable calibration database (CALDB) for users.

3.5 Products Not Covered

Products that are used for maintenance and diagnostic purposes (those that are not supplied to the user for scientific data analysis) are not currently included within the interface defined by this document.

3.6 Substructure Definition and Format

The "ASC FITS Designers' Guide" (Applicable Document 6) defines and lists header components for the primary header and for all binary table extensions. These will be used with appropriate modifications for non-flight data (e.g., many Observation and Timing Components' keywords are irrelevant). The modified components are listed in Appendix A. These will be used in accordance with Table 6 in the "ASC FITS Designers' Guide."

In general, when FITS headers are shown, column or row numbers are arbitrary unless otherwise indicated. It is the *column name and its attributes* that specify the requirement. Additional columns or extensions not specified here are permitted in the file without violating the interface. Processing software can ignore them, pass them through, or use them if they are "known" quantities. (Example usage of this are columns derived from simulation containing *a priori* known values, to be directly compared with specified columns containing derived values.) Likewise, HDU order is arbitrary, except for the primary HDU. HDU are intended to be referenced by name, not position.

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4 Event Grades

Data Product Summary

Analysis Reference Data Product	Event_grade_sys
Instrument(s)	ACIS
Level	1
Scientist/SDS	G. Allen
Scientist/Cal	B. McNamara
Filetype	FITS bintable
Created by tool	TBD
Used by tool(s)	acis_process_events
Sample file	acisD1996-01-01gradeASCA1N0001.fits

Event Grades ARD files specify the mapping from *ACIS flight grade* — a value from 0 to 255 (0 to 3 for continuous clocking) that describes the bitmap geometry of each 3×3 (1×3 for continuous clocking) pixel event — to the "binned" grade, in the system of choice. It is convenient to think of the flight grade as an "objective" event attribute which merely specifies event charge split geometry given a split (charge) threshold, while the "binned" grade system applies a set of expectations as to what should constitute "good" and "bad" event geometries and groups flight grades accordingly. Hence, binned grades facilitate event screening.

For e.g. the ASCA system, binned grades range from 0 to 7, where 0 corresponds to single-pixel events (which are also assigned a flight grade of 0, since none of the 8 surrounding pixels are above split threshold) and 7 corresponds to all manner of multiple-pixel events (i.e., various combinations of surrounding pixels above threshold).

4.1 File Structure

The following table describes the file structure by Header-Data Unit number, type, extension name, content, and HDU classes. An asterisk (*) denotes the ASC principal HDU.

HDU	Type	EXTNAME	CONTENT	HDUCLASS		Description
1	Null	—	—	—		—
2 (*)	BINTABLE	AXAF_GRADE	CDB_ACIS_GRADE	ASC, GRADE	DETCHAR,	Timed Exposure mode grade mapping, 256 rows (1 row per flight grade)
3	BINTABLE	AXAF_GRADE	CDB_ACIS_GRADE	ASC, GRADE	DETCHAR,	Continuous Clocking mode grade mapping, 4 rows (1 row per flight grade)

4.2 Column Descriptions

Columns for *TE_grade_map* (*CC_grade_map*) HDU(s)

TTYPE	TUNIT	TFORM	TLMIN	TLMAX	TDBIN	TNULL	Comment
fltgrade	none	1I	0	255 (3)	1	-32767	flight grade
grade	none	1I	0	(varies)	1	-32767	binned grade

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4.3 Special Header Keywords

```
READMODE= 'TIMED'           / ACIS Read Mode
GRADESYS= 'ASCA'            / event grade system: ACIS, ASCA, USER, ...
CORNERS =                  1 / key to including corner pixels in total PHA
```

The CORNERS keyword (present only in the TE grades extension) can take on the following values:

```
-1 => never include corners in total PHA
 0 => always include corners
 1 => flight software (ACIS) convention (see ACIS flight s/w requirements
      spec, Sec 3.2.2.3.14)
 2 => ASCA convention (see http://heasarc.gsfc.nasa.gov/0/docs/asca/sis_grade.gif)
```

4.4 Size Estimate

The 1st extension of each file will have 256 rows (one row for each TE mode flight grade) and the 2nd extension will have 4 rows (one for each CC mode flight grade).

The ASC shall maintain at least 2 event grade system ARD files, one each for the ACIS and ASCA systems. In addition, it may be desirable to maintain 2 distinct ASCA system files: one with CORNERS= 1 and one with CORNERS= 2.

4.5 Unresolved Issues

The ACIS binned grade system — which also goes by the designation "event families" — still requires ratification by the ASC ACIS and the ACIS IPI science teams.

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5 Bad Pixels and Columns

Data Product Summary

Analysis Reference Data Product	ACIS_badpix
Instrument(s)	ACIS
Level	1
Scientist/SDS	G. Allen
Scientist/Cal	B. McNamara
Filetype	FITS bintable
Created by tool	TBD
Used by tool(s)	acis_format_events, acis_build_badpix
Sample file	acisD1997-04-17badpixN0001.fits

Although bad pixel and column information is contained in the telemetered bias data and hence in the Level 0 Bias file data products (see Applicable Document 8), the Level 1 pipeline also makes use of the archived Bad Pixel and Column file. This file is used to verify the telemetered bad pixel/column information or to provide this information in the event that the contemporaneous bias files are corrupted or otherwise unavailable.

Note that, while the structure of the file is identical to that defined in the ACIS Level 1 ICD (Applicable Document 9), additional data is contained in the Level 1 output bad pixel/column file as a result of the "merging" of the archived and telemetered bad pixel/column lists. The latter include so-called bias errors, whereas the ARD file referred to here contains only the locations of static bad pixels and columns. In addition, the following keywords must be present in each extension:

```
EXTNAME = 'AXAF_BADPIX'        /ACIS bad pixel/column extension
EXTVER  =                    n /bad pixel/columns ext for CCD_ID=n
HDUNAME = 'AXAF_BADPIXn'       /ACIS bad pixels & columns
CONTENT = 'CDB_ACIS_BADPIX'    /ACIS bad pixels & columns
HDUCLASS= 'ASC     '           /
HDUCLAS1= 'DETCHAR '           /
HDUCLAS2= 'BADPIX  '           /
```

5.1 File Structure

Aside from the specific header keywords listed in the preceding section, the bad pixel/bad column Analysis Reference Data file shall conform to the file structure and format described in Sec. 3.8 and Table 13 of the ACIS L1 ICD (Applicable Document 9).

5.2 Special Header Keywords

```
READMODE= 'TIMED   '           /ACIS Read Mode
CCD_ID  =                    n /CCD ID (e.g., CCD_ID = 0 => I0 = w203c4r)
```

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6 Bias

Data Product Summary

Analysis Reference Data Product	ACIS_bias
Instrument(s)	ACIS
Level	1
Scientist/SDS	G. Allen
Scientist/Cal	N. Schulz
Filetype	FITS bintable
Created by tool	TBD
Used by tool(s)	acis_format_events, acis_correct_bias
Sample file	acis_bias.fits

Bias is included in this ARD ICD, for completeness. Bias files will be produced by Level 0 software during a typical ACIS Science Run (see Applicable Document 8), and as such, constitute a different flavor of ARD from, for example, gain ARD files. That is, bias files will generally be included with the science (as opposed to calibration) data supplied to the User. In the event that bias images were not telemetered, become corrupted, or are otherwise not available for a given Science Run, however, we anticipate the need to use previously obtained bias files. Specifically, Level 1 software will have to revert to the bias files most recently obtained in the same ACIS observing configuration (CCD subarray dimension and readout mode) and telemetry packing mode.

6.1 File Structure

Each bias Analysis Reference Data file shall conform to the file structure and format described in Sec. 4.4.9 and Tables 19 and 20 of the ACIS L0 ICD (Applicable Document 8).

6.2 Special Header Keywords

6.3 Size Estimate

Each bias file is approximately 2.1 MBytes (Timed Exposure mode) or 1.1 MBytes (Continuous Clocking mode). Depending on the number of active CCDs, we expect to obtain between 1 and 6 bias files per ACIS Science Run — although not all Science Runs will include bias file data products, as ACIS must be explicitly commanded to telemeter bias.

6.4 Unresolved Issues

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7 Gain

Data Product Summary

Analysis Reference Data Product	ACIS_gain
Instrument(s)	ACIS
Level	1
Scientist/SDS	G. Allen
Scientist/Cal	N. Schulz
Filetype	FITS bintable
Created by tool	acis_gain_ard.pro
Used by tool(s)	acis_process_events
Sample file	acisD1999-09-16gainN0003_110.fits

7.1 File Structure

The following table describes the FITS file structure of the ACIS gain ARD file, including the Header-Data Unit number, type, extension name, content, and HDU classes. An asterisk (*) denotes the CXC principal HDU.

	HDU 0	HDU 1 (*)
Type	Null	BINTABLE
EXTNAME	—	AXAF_DETGAIN
CONTENT	—	CDB_ACIS_GAIN
HDUCLASS	—	ASC, DETCHAR, DETGAIN
Description	—	ENERGY and PHA vectors for each region of each CCD.

7.2 Column Descriptions

To compute the value of the ENERGY of an ACIS event:

i. Find the vectors ENERGY and PHA of the row in the gain ARD file that satisfies the conditions that

$$\begin{aligned} \text{chip id} &= \text{CCD_ID}, \\ \text{CHIPX_MIN} \leq \text{CHIPX} &\leq \text{CHIPX_MAX}, \text{ and} \\ \text{CHIPY_MIN} \leq \text{CHIPY} &\leq \text{CHIPY_MAX}, \end{aligned}$$

where "chip id" is the chip on which the event was detected, CHIPX and CHIPY specify the location on the chip at which the event was detected, and CCD_ID, CHIPX_MIN, CHIPX_MAX, CHIPY_MIN, and CHIPY_MAX are the names of columns in the gain ARD file, which are described in the table below.

ii. Find the two non-zero (real!) values of PHA_i and PHA_{i+1} in the vector PHA (see table below) such that

$$0 < \text{PHA}_i \leq \text{PHA} < \text{PHA}_{i+1},$$

where PHA is the pulse height amplitude of the event.

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iii. Set the ENERGY of the event to be

$$\mathrm{ENERGY} = \frac{\mathrm{PHA} - \mathrm{PHA}_i}{\mathrm{PHA}_{i+1} - \mathrm{PHA}_i}\Big(\mathrm{ENERGY}_{i+1} - \mathrm{ENERGY}_i\Big) + \mathrm{ENERGY}_i,$$

where ENERGY_i and ENERGY_{i+1} are the non-zero values in the vector ENERGY that correspond to the values of PHA_i and PHA_{i+1}, respectively (see table below).

This formula is valid if the value of the PHA of the event satisfies

$$0 < \mathrm{PHA}_1 \leq \mathrm{PHA} < \mathrm{PHA}_n,$$

where PHA_1 and PHA_n are the smallest and largest, respectively, non-zero values in the vector PHA. Here, n is the value specified in the corresponding row of the column named NPOINTS. This column specifies the number of useful data points in the vectors PHA and ENERGY. If $0 < \mathrm{PHA} < \mathrm{PHA}_1$,

$$\mathrm{ENERGY} = \max\left(\frac{\mathrm{PHA} - \mathrm{PHA}_1}{\mathrm{PHA}_2 - \mathrm{PHA}_1}\Big(\mathrm{ENERGY}_2 - \mathrm{ENERGY}_1\Big) + \mathrm{ENERGY}_1, 0\right).$$

If $\mathrm{PHA} \geq \mathrm{PHA}_n$,

$$\mathrm{ENERGY} = \frac{\mathrm{PHA} - \mathrm{PHA}_{n-1}}{\mathrm{PHA}_n - \mathrm{PHA}_{n-1}}\Big(\mathrm{ENERGY}_n - \mathrm{ENERGY}_{n-1}\Big) + \mathrm{ENERGY}_{n-1}.$$

7.2.1 ACIS_gain table (using a region-by-region grid)

Columns of Primary Extension of Gain ARD File

TTYPE	TUNIT	TFORM	TLMIN	TLMAX	TDBIN	TNULL	Comment
CCD_ID	—	1J	0	9	1	0	CCD ID (0-9)
CHIPX_MIN	pixel	1J	1	1024	1	0	lower CHIPX boundary for a region
CHIPX_MAX	pixel	1J	1	1024	1	0	upper CHIPX boundary for a region
CHIPY_MIN	pixel	1J	1	1024	1	0	lower CHIPY boundary for a region
CHIPY_MAX	pixel	1J	1	1024	1	0	upper CHIPY boundary for a region
NPOINTS		1J	1	20	1	0	number of useful data points in vectors PHA and ENERGY
PHA	adu	20E	—	—	1	0	vector of PHA values associated with vector of ENERGY values
ENERGY	eV	20E	—	—	1	0.	vector of ENERGY values associated with vector of PHA values

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7.3 Special Header Keywords

The gain (and CTI-induced apparent gain shift) of the ACIS detectors is sensitive to the focal-plane temperature, detector electronics assembly temperature, the grade-filtering scheme used, and the CCD readout mode. Therefore, the gain ARD file should include the following keywords.

```
READMODE= 'TIMED   '           / ACIS Read Mode
FP_TEMP =              183.200 / Focal-plane temperature (K)
DEA_TEMP=              281.200 / ACIS DEA temperature (K)
GRADESET= 'g02346  '           / ACIS grading scheme used
```

7.4 Size Estimate

The size of the binary table of the principal extension is 184 bytes per row (i.e. per region). At the moment, the maximum number of regions per CCD is 1024 (i.e. each CCD may have the gain specified in regions as small as 32×32 pixels). Therefore, the principal extension may be as large as 10 CCDs $\times$ 1024 regions/CCD $\times$ 184 bytes/region = 1.9 Mb.

A new ACIS gain ARD product will be produced each time the gain table is updated to reflect changes in ACIS performance and each time the ACIS gain calibration is revised for a particular epoch in the life of the mission.

7.5 Unresolved Issues

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8 Event and Split Thresholds

Data Product Summary

Analysis Reference Data Product	ACIS_evtspl
Instrument(s)	ACIS
Level	1
Scientist/SDS	G. Allen
Scientist/Cal	N. Schulz
Filetype	FITS bintable
Created by tool	TBD
Used by tool(s)	acis_process_events, acis_grade_events
Sample file	acisD1997-04-17evtsplN0001.fits

The primary purpose for the event & split threshold ARD file is to facilitate event grading on a node-by-node basis during L1 processing (see description of acis_grade_events in Applicable Document 4). For completeness, the ARD file also contains event thresholds and a list of CCD names, as split thresholds may only be applicable to specific devices and may be explicitly or implicitly tied to specific event thresholds.

8.1 File Structure

The following table describes the file structure by Header-Data Unit number, type, extension name, content, and HDU classes. An asterisk (*) denotes the ASC principal HDU.

HDU	Type	EXTNAME	CONTENT	HDUCLASS	Description
1	Null	—	—	—	—
2 (*)	BINTABLE	AXAF_EVTSPL	CDB_ACIS_EVTSPL	ASC, DETCHAR, EVT-SPL	event & split thresholds, 4 sets per CCD (1/node)

8.2 Column Descriptions

The 4-component integer arrays in which the event & split thresholds are stored are referenced such that indeces 0 through 3 correspond to CCD nodes A through D, in that order.

Columns for *ACIS_evtspl* HDU

TTYPE	TUNIT	TFORM	TLMIN	TLMAX	TDBIN	TNULL	Comment
CCD_ID	none	1I	0	9	1	0	CCD ID (0-9)
CCDNAME	none	16A	—	—	—	—	CCD name
EVT_THR	ADU	4I	0	4095	1	0	event thresholds (1 per CCD node)
SPL_THR	ADU	4I	0	4095	1	0	split thresholds (1 per CCD node)

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8.3 Special Header Keywords

In practice, adopted ACIS event and split thresholds may depend on CCD readout mode, focal plane temperature, and/or DEA (detector electronics assembly) temperature. Hence we include the following keywords (TBR):

```
READMODE= 'TIMED   '           /ACIS Read Mode
FP_TEMP =             -117.500 /ACIS focal plane temperature (C) (TBR keyword)
DEA_TEMP=              20.0000 /ACIS DEA temperature (C) (TBR keyword)
```

8.4 Size Estimate

The primary extension of each file will have 10 rows (one row for each each CCD).

A new acis_evtthr ARD product will be produced each time the event or split thresholds are updated during the mission to track changes in ACIS performance. They are unlikely to change frequently, however. (We will need a file naming convention for these and other ARD files to ensure uniqueness in file names).

8.5 Unresolved Issues

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A FITS Header Templates

The following header sections have been taken from the ASC FITS file specifications, with slight modifications to make them appropriate for calibration data, as opposed to observational data. The changes are primarily the omission of observation-related keywords. *In all cases, column numbers, axis numbers, and keyword values are representative!* The order or value should not be taken literally unless explicitly stated.

A.1 Components With No Changes

- Mandatory component for Image Primary Header (M)
- Mandatory component for Null Primary Header (M)
- Mandatory component for Binary Table extension (M)
- Mandatory component for Image extension (M)
- Full configuration control component (CC)
- Short configuration control component (Short CC)
- Configuration control component for null primary HDU (Null CC)

A.2 Components With Changes

A.2.1 Full timing component (T)

```
                              / Time information block-------------------------
DATE    = '1998-01-01T00:00:00'  / Date and time of file creation (UTC)
TIMEUNIT= 's       '
```

A.2.2 Short timing component (short T)

```
                              / Time information block-------------------------
DATE    = '1998-01-01T00:00:00'  / Date and time of file creation (UTC)
TIMEUNIT= 's       '
```

A.2.3 Full observation info component (O)

Only include those keywords which are determined by that stage of processing.

```
                              / Observation information block------------------
MISSION = 'AXAF    '           / Mission is AXAF
INSTRUME= '        '           / HRC, ACIS, EPHIN, S/C subsystems
DETNAM  = '        '           / Detector name
GRATING = 'NONE    '           / Grating
DATAMODE= '        '           / Datamode (varies only for science instr. data)
DATACLAS= 'SIMULATED'          / If fake data,
                               / include this (default is DATACLAS='OBSERVED')
```

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A.3 Short observation info component (short O)

```
                              / Observation information block------------------
MISSION = 'AXAF    '          / Mission is AXAF
TELESCOP= 'AXAF    '          / Telescope is AXAF
INSTRUME= '        '          / HRC, ACIS, EPHIN, S/C subsystems
```

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