AXAF Science Center

Analysis Reference Data for: ACIS Level 1 & 2 Pipelines and Tools

ASC Archive Interface Control Document

(http://space.mit.edu/ASC/docs/ACIS_ARD_ICD.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

Unresolved Issues

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

Contents

List of Tables

1 Introduction

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

The ARD are typically derived calibration products or parameters used in Level 1 and 2 processing pipelines or in interactive analysis. ARD are in turn derived from Calibration Interface Products (CIP[1]) ARD may be identical to CIP, may be derived by re-formatting (e.g., ASCII table to FITS BINTABLE), or many-to-one processing. 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.

Formatting NOTE: Text formatted between horizontal rules (like this block) provide some historical context regarding alternative choices considered, which may still be debated.

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 8, consists of processing of ACIS Level 0 (telemetry) products, described in Applicable Document 7, to derive bias-subtracted, graded, PHA-summed, gain- and/or CTI-corrected event lists and ancillary products (bad pixel lists, window files, telemetry GTI file and event GTI extensions), described in Applicable Document 8. 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 9 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 ASC Data Archive (see Applicable Document 2 and the "ASC Data System Software Design," Applicable Document 3) during the course of the AXAF 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)

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

3. ASC AMO-2401 (DS01)
   ASC Data System Software Design (ASC.500.93.0006)

4. ASC Tools Catalog
   Link on: `http://???`

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. ACIS Data Products:
   Level 0 to ASC Archive Interface Control Document
   `link on http://space.mit.edu/ASC/docs/docs.html`

8. ACIS Data Products:
   Level 1 to ASC Archive Interface Control Document
   `link on http://space.mit.edu/ASC/docs/docs.html`

9. ACIS/HRC 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 (5).

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 AXAF 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.

3.4 Assumptions and Constraints

It is assumed that ASC 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 ASC 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.

4 Event Grades

Data Product Summary

Analysis Reference Data Product	Event_grade_sys
Instrument(s)	ACIS
Level	1
Scientist/SDS	J. Kastner
Scientist/Cal	B. McNamara
Filetype	FITS bintable
Created by tool	TBD
Used by tool(s)	acis_process_events
Sample file	event_grade_sys.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	TE_grade_map	TE_grade_map	ASC, CORRECTION, ACISCAL	Timed Exposure mode grade mapping, 256 rows (1 row per flight grade)
3	BINTABLE	CC_grade_map	CC_grade_map	ASC, CORRECTION, ACISCAL	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

4.3 Special Header Keywords

```
GRADESYS= 'ASCA'            / event grade system: ACIS, ASCA, USER, ...
```

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 2 event grade system ARD files, one each for the ACIS and ASCA systems.

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.

5 Bad Pixels and Columns

Data Product Summary

Analysis Reference Data Product	ACIS_badpix
Instrument(s)	ACIS
Level	1
Scientist/SDS	J. Kastner
Scientist/Cal	N. Schulz
Filetype	FITS bintable
Created by tool	TBD
Used by tool(s)	acis_format_events
Sample file	acis_badpix.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 7), 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 8), 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.

5.1 File Structure

The bad pixel/bad column Analysis Reference Data file shall conform to the file structure and format described in Sec. 3.8 and Table 12 of the ACIS L1 ICD (Applicable Document 8).

5.2 Special Header Keywords

5.3 Size Estimate

5.4 Unresolved Issues

6 Bias

Data Product Summary

Analysis Reference Data Product	ACIS_bias
Instrument(s)	ACIS
Level	1
Scientist/SDS	J. Kastner
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 7), 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 7).

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

7 Gain

Data Product Summary

Analysis Reference Data Product	ACIS_gain
Instrument(s)	ACIS
Level	1
Scientist/SDS	J. Kastner
Scientist/Cal	N. Schulz
Filetype	FITS bintable
Created by tool	TBD
Used by tool(s)	acis_process_events, acis_calc_pi
Sample file	acis_gain.fits

7.1 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	ACIS_gain	ACIS_gain	ASC, CORRECTION, ACISCAL	gain coefficients, 1 set per CCD node
3	BINTABLE	ACIS_mean_gain	ACIS_mean_gain	ASC, CORRECTION, ACISCAL	mean gain coefficients, 1 set per CCD

7.2 Column Descriptions

For ACIS, gain is calculated as a 3rd-order polynomial, i.e.,

$$\mathrm{PI} = a_0 + a_1 \times \mathrm{PHA} + a_2 \times \mathrm{PHA}^2 + a_3 \times \mathrm{PHA}^3$$

where a_i are the gain coefficients called, respectively, `OFFSET` (a_0), `GAIN_ORD1` (a_1), `GAIN_ORD2` (a_2), and `GAIN_ORD3` (a_3) in the table columns below.

7.2.1 ACIS_gain table (node by node gain)

Columns for *ACIS_gain* HDU

TTYPE	TUNIT	TFORM	TLMIN	TLMAX	TDBIN	TNULL	Comment
CCD_ID	none	1I	0	9	1	0	CCD ID (0-9)
CCDNODE	none	1I	0	3	1	0	CCD node (0-3)
OFFSET	eV	1E	—	—	1	0	gain coefficient a_0
GAIN_ORD1	eV/chan	1E	—	—	1	0	gain coefficient a_1
GAIN_ORD2	eV/chan$\hat{2}$	1E	—	—	1	0	gain coefficient a_2
GAIN_ORD3	eV/chan$\hat{3}$	1E	—	—	1	0	gain coefficient a_3

7.2.2 ACIS_mean_gain table (CCD names and mean gain for each CCD)

Columns for *ACIS_mean_gain* HDU

TTYPE	TUNIT	TFORM	TLMIN	TLMAX	TDBIN	TNULL	Comment
CCD_ID	none	1I	0	9	1	0	CCD ID (0-9)
CCD_NAME	none	1A	—	—	—	—	CCD name
OFFSET	eV	1E	—	—	1	0	gain coefficient a_0
GAIN_ORD1	eV/chan	1E	—	—	1	0	gain coefficient a_1
GAIN_ORD2	eV/chan$\hat{2}$	1E	—	—	1	0	gain coefficient a_2
GAIN_ORD3	eV/chan$\hat{3}$	1E	—	—	1	0	gain coefficient a_3

7.3 Special Header Keywords

7.4 Size Estimate

The 1st extension of each file will have 10×4 rows (one row for each node of each CCD) and the second will have 10 rows (1 per CCD).

A new acis_gain ARD product will be produced each time the gain table is updated during the mission to reflect changes in ACIS performance, and/or each time the ACIS gain calibration is revised for a particular epoch in the life of ACIS. Hence acis_gain.fits files should proliferate as the mission proceeds. (We will need a file naming convention for these and other ARD files to ensure uniqueness in file names).

7.5 Unresolved Issues

8 CTI

Data Product Summary

Analysis Reference Data Product	ACIS_CTI
Instrument(s)	ACIS
Level	1
Scientist/SDS	J. Kastner
Scientist/Cal	N. Schulz
Filetype	FITS bintable
Created by tool	TBD
Used by tool(s)	acis_process_events, acis_calc_pi
Sample file	acis_CTI.fits (not yet available)

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	ACIS_CTI	ACIS_CTI	ASC, CORRECTION, ACISCAL	CTI coefficients, 1 set per CCD node
3	BINTABLE	ACIS_CCD_names	ACIS_CCD_names	ASC, CORRECTION, ACISCAL	CCD names

8.2 Column Descriptions

8.2.1 CTI coefficient table

For each CCD of ACIS, parallel and serial (alternatively, X and Y, or CCD column and row) charge loss is calculated from the parallel and serial CTI coefficients P_a, P_b and S_a, S_b, respectively, as follows:

$$C_X = P_b(n) \times (\mathrm{PHA}^{P_a(n)})$$

$$C_Y = S_b(n) \times (\mathrm{PHA}^{S_a(n)})$$

where C_X and C_Y are the parallel and serial charge loss and n is the CCD node. The values of P_a, P_b, S_a, S_b are stored in table columns `CTI_PA`, `CTI_PB`, `CTI_SA`, `CTI_SB`, respectively.

Columns for *ACIS_CTI* HDU

TTYPE	TUNIT	TFORM	TLMIN	TLMAX	TDBIN	TNULL	Comment
CCD_ID	none	1I	0	9	1	0	CCD ID (0-9)
CCDNODE	none	1I	0	3	1	0	CCD node (0-3)
CTI_PA	—	1E	—	—	1	0	parallel CTI, coefficient a
CTI_PB	—	1E	—	—	1	0	parallel CTI, coefficient b
CTI_SA	—	1E	—	—	1	0	serial CTI, coefficient a
CTI_SB	—	1E	—	—	1	0	serial CTI, coefficient b

8.2.2 CCD names table

Columns for *ACIS_CCD_names* HDU

TTYPE	TUNIT	TFORM	TLMIN	TLMAX	TDBIN	TNULL	Comment
CCD_ID	none	1I	0	9	1	0	CCD ID (0-9)
CCDNAME	none	1A	—	—	—	—	CCD name

8.3 Special Header Keywords

8.4 Size Estimate

The 1st extension of each file will have 10×4 rows (one row for each node of each CCD) and the second will have 10 rows (1 per CCD).

A new acis_CTI ARD product will be produced each time CTI coefficients are updated during the mission to reflect changes in ACIS performance, and/or each time the ACIS CTI calibration is revised for a particular epoch in the life of ACIS. Hence acis_CTI.fits files should proliferate as the mission proceeds. (We will need a file naming convention for these and other ARD files to ensure uniqueness in file names).

8.5 Unresolved Issues

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')
```

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
```