Chandra X-Ray Observatory Center

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

Rev. 1.7 —10/01/99

`http://icxc.harvard.edu/icd/HTML/`

Submitted: ____________________________ ____________

Adam Dobrzycki — Date
HRC Scientist, CXC Science Data Systems

Concurred: ____________________________ ____________

Michael Juda — Date
HRC Scientist, CXC Development & Operations Group

Concurred: ____________________________ ____________

Arnold Rots — Date
Archive Scientist, CXC Archives

Concurred: ____________________________ ____________

Kenny Glotfelty — Date
CXC Data Systems Group Leader, Level 1 Pipelines

Concurred: ____________________________ ____________

Janet De Ponte — Date
Manager, CXC Data Systems

Concurred: ____________________________ ____________

Martin Elvis — Date
Manager, CXC Science Data Systems

Approved: ____________________________ ____________

Harvey Tananbaum — Date
Director, CXC

Document and Change Control Log			
Date	**Version**	**Section**	**Status**
12/24/97	0.9	all	Initial draft
01/13/98	1.0	all	New FITS recommendations included
01/14/98	1.01	all	DATE... keyword entries corrected in tables
02/06/98	1.1	all	Generic FITS info removed; comments from AR, JCM, JHK, DPH, JC, WMcL; Appendices with sample headers added; MTYPEx and MFORMx keywords added, ACSYSx keywords removed; STARTMRF and STOPMRF removed, STARTMJF added; several typos corrected.
03/06/98	1.2	all	Comments from JHK, DPH, WMcL, JCM, MJ, AR, DMcE; BPIXFILE keyword added. File naming convention revised. Columns with event counts added to deadtime factor file. HRC-S2 replaced with HRC-SI.
03/31/98	1.3	all	Summary files info removed. Deadtime correction file modifications: removed GTI extension, removed table stat keywords. ASC-FITS-1.1 recommendations included. Naming convention revised. HISTORY keywords added to record input files. Coordinate column TLMIN/TLMAX entries corrected. DataModel keywords added to column info.
04/30/98	1.3.1	event data	ASCYSn keywords added
05/08/98	1.3.2	event data	Comments from MJ, KAF: STATUS format changed from 1J to 32X
05/20/98	1.3.3	all	DATAMODE keyword removed AR replaced PZ as ASC Archive representative
06/15/98	1.4	all	Comments from MJ, WMcL, AR, JCM TFORM for sky coordinates changed to 1D Column names for Secondary Science counts and Primary Science counts in DTF file changed ADCCORF, GAINCORF, and DEGAP... keywords added Several typos corrected
11/03/98	1.5	DTF stats, bad pixel list	Deadtime factor stats part added Bad pixel list part added Applicable Document list updated Appendices with sample headers replaced with detailed listings of header components `changebar` macros applied, to mark changes (caveat: package is not bug-free; some changebars are erroneous)
01/22/99	1.6	all	AXAF and ASC references replaced with CXO and CXC, where appropriate (these changes are not marked with changebars) Appendix with sample header components removed. DEGAP_X... and DEGAP_Y keywords replaced with DEGAP_V and DEGAP_U, respectively. RAWX and RAWY columns in the event list changed format to 1J, and their legal ranges for both detectors were modified. TDETX and TDETY columns in the event list changed format to 1J; their legal ranges for HRC-S were modified. Legal range for CHIP_ID in the event list and bad pixel list changed for HRC-S to 1–3. EXTNAME, HDUNAME, HDUCLASn keywords in bad pixel list modified to to conform to REGION definition. FITS names reference changed to Guide to AXAF Data Products.
10/01/99	1.7	DTF	TFORM for STATUS column in Deadtime Factor File changed from '3X' to '8X'

Unresolved issues

The following are the most important unresolved issues, as of 10/01/99 :

1. Volume, size, and frequency estimates are not included.
2. Mission Timeline file is not included

Contents

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Chapter 1

Introduction

This document describes the interface to be employed in transferring the products of HRC Standard Data Processing from the CXC Level 1 processing pipeline to the CXC Data Archive, according to the requirements stipulated in Applicable Document 1.

1.1 Purpose

HRC Level 1 processing, described in Applicable Document 1, consists of standard event processing (applying ADC correction [if necessary], determination of event detector coordinates, gain correction, coordinate transformations, event attribute flagging). This document describes the structure and content of:

- Event file,
- Deadtime file, containing time history of the deadtime correction factor during the observation,
- Deadtime Statistics file,
- Bad pixel list.

1.2 Scope

This interface shall apply to all HRC-specific data products that are generated by CXC Level 1 pipelines and distributed to the CXC Data Archive (see Applicable Documents 1 and 2) during the course of the CXO mission.

1.3 Applicable documents

1. ASC AMO-2400 (SE03)
   ASC Data System Requirements (ASC.302.93.0008)
2. ASC AMO-2401 (DS01)
   ASC Data System Software Design (ASC.500.93.0006)

3. NOST 100-1.1
   Definition of the Flexible Image Transport System (FITS)
   `http://www.cv.nrao.edu/fits/`

4. OGIP 93-001
   HEASARC FITS Standards:
   `http://legacy.gsfc.nasa.gov/docs/heasarc/ofwg/ofwg_intro.html`
   `ftp://legacy.gsfc.nasa.gov/fits_info/ofwg_recomm/recomm.txt`

5. ASC FITS File Designers' Guide v. 1.4.3
   `http://hea-www.harvard.edu/~arots/asc/fits/ascfits.ps`

6. Guide to AXAF Data Products v. 1.9
   `http://hea-www.harvard.edu/~arots/asc/fits/content.txt`

7. SAO-HRC-TLIST-98-313
   HRC Telemetry List, Rev A
   `http://hea-www.harvard.edu/HRC/operations/tlm_lst.txt`

8. HRC Data Products: Level 0 to ASC Archive Interface Control Document, v. 1.6
   `http://hea-www.harvard.edu/asclocal/sds/development/ICD/`

9. Analysis Reference Data for HRC Level 1 Pipeline CXC Archive Interface Control Document v. 1.4
   `http://hea-www.harvard.edu/asclocal/sds/development/ICD/`

10. SDS-7.2
    FITS conventions for the Data Model
    `http://hea-www.harvard.edu/~jcm/asc/docs/ps/SDS07.ps`

11. SDS-9.0
    FITS names for ASC Coords
    `http://hea-www.harvard.edu/~jcm/asc/docs/ps/SDS09.ps`

1.4 Functional description

1.4.1 Data content summary

HRC data sets generated by the Level 1 processing pipeline shall consist of data files conforming to the FITS format (Applicable Document 3) and further conforming to HEASARC standards (Applicable Document 4). HRC Level 1 files contain Binary Table ("BINTABLE") extensions. Following rules outlined in Applicable Document 5, the Event Files will contain null (i.e. with no data) primary header, followed by main binary table (the "principal HDU"), and an auxiliary extension ("auxiliary HDU"). The Deadtime, Deadtime Factor stats, and Bad Pixel files will all contain null primary header, followed by one principal HDU.

1.4.2 Timing and sequencing characteristics

The "natural" subdivision of HRC Level 1 processing is the Observation Interval (OBI). HRC Level 0 data will therefore be processed in batches by the Level 1 Pipeline. Each "batch" spans the period of a single OBI.

1.4.3 Recipients and utilization

The primary recipients of HRC Level 1 data products, via distribution from the archive, are CXO 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 1.5 (grating) and 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 HRC science telemetry packets and their data fields, as specified in Applicable Document 7, or changes to HRC Level 0 data products, as described in Applicable Document 8, may affect the Level 1 data products described in the current document.

1.5 Assumptions and constraints

For each OBI Level 1 processing shall generate a set of product files as shown in Table 2.1. Level 1 products shall be created on a UNIX file system. While they are being written, their FITS headers may contain invalid keyword values (e.g. NAXIS2, the number of binary table rows). Care must be taken not to read or copy these files until they are complete.

1.6 Products not covered

HRC 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 CXO Level 1 products, are not currently included within the interface defined by this document.

Chapter 2

Detailed interface specifications

2.1 Labeling and identification

The data files generated by the Level 1 processing pipeline shall be assigned external names as shown in Table 2.1. The names obey the following convention
(Applicable Document 6):

```
hrc<s><t><v>_<c><l>.fits
```

where: <s> specifies data source, with possible values (not all are applicable for HRC data): x=XRCF, f=Flight, t=TRW, b=Ball Bros., c=other lab calibration, s=simulated, and u=unknown, <t> is a 9-digit time stamp (integer part of TSTART, padded with leading zeros), <v> is the processing run ID "N###", <c> specifies the contents of the file (see Table 2.1), and <l> denotes the processing level, i.e. will be set to '1' for all Level 1 data.

File name	**Contents**
*_evt1.fits	Event records
*_dtf1.fits	HRC deadtime factor versus time
*_dtfstat1.fits	HRC deadtime factor stats
*_bpix1.fits	HRC bad pixel list
*_mtl1.fits	HRC mission timeline table

Table 2.1: HRC Level 1 Data Product Files

Additional, non-instrument-specific data products output by the HRC Level 1 processing pipeline include (but may not be limited to) the following (all TBR): High Background file, Aspect Offset file, Mission Timeline file, and Good Time Interval file.

2.2 Substructure definition and format

The reader is referred to Applicable Documents 5 and 6 for a detailed discussion of the components of the primary header and all extensions of the FITS files.

2.2.1 Primary Header keywords

This header contains four keywords that are required in all FITS files. In addition, it contains: short versions of configuration control, timing info, and observation info keywords (Applicable Documents 5 and 6). The header ends with a terminating END keyword.

2.2.2 Principal HDU Header keywords

The principal HDU is further described by an extension header. The header, composed of lines of 80-byte ASCII characters, contains a group of mandatory FITS extension keywords, and long versions of configuration control keywords, observation information keywords, timing-related keywords, and keywords defining each column of the binary table that follows the header (Applicable Documents 5 and 6).

Additional keywords are required for columns that have coordinate systems attached.

The header ends with a terminating END keyword.

2.2.3 Auxiliary HDU Header keywords

Auxiliary HDU headers contain the FITS mandatory keywords, and configuration control, observation information, and timing keywords in short versions (Applicable Documents 5 and 6).

Column definition keywords, and—if needed—coordinate system-related keywords are present in the auxiliary HDU header.

The header ends with a terminating END keyword.

2.3 Event Data Files

The Event Data File contains two extensions, a principal HDU binary table containing the information on HRC events and one auxiliary HDU binary table containing information on Good Time Intervals.

2.3.1 Principal HDU: Event Data

During Level 1 processing event coordinates undergo several transformations. All six detector amp readouts AU1, AU2, AU3, AV1, AV2, and AV3 are corrected for AMP readout nonuniformity. Values of Coarse Positions CRSU, CRSV and corrected amp readouts AU1, AU2, AU3, AV1, AV2, AV3 are used to calculate Raw Coordinates RAWX, RAWY (no degapping correction applied) and Chip Coordinates CHIPX, CHIPY (with degapping correction applied). CHIPX, CHIPY are converted to Tiled Coordinates TDETX, TDETY and Focal Plane Coordinates DETX, DETY. Finally, DETX, DETY are converted to Sky Pixel Coordinates X,Y by applying the aspect solution.

World Coordinate System (WCS) keywords are attached to the X, Y columns to give an RA and Dec coordinate system. WCS may also be attached 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.

Table 2.2 lists keywords specific to the Event Data extension.

Table 2.3 lists the contents of the Event Data File principal HDU binary table.[1]

[1] Values of TLMAX for (DETX,DETY) and (X,Y) in Table 2.3 are for pointed observations only. These values can and will be exceeded in special cases, like slew or observations of Solar System bodies.

```
EXTNAME = 'EVENTS  '           / Table name
CONTENT = 'EVT1    '           / What data product
HDUNAME = 'EVENTS  '
HDUCLASS= 'OGIP    '
HDUCLAS1= 'EVENTS  '
HDUCLAS2= 'ALL     '
SHYPLUS =                  0  / HRC knife edge pos, Y plus axis
SHYMINUS=                  0  / HRC knife edge pos, Y minus axis
BPIXFILE= 'badpixfile'         / Bad pixel file used
ADCCORF = 'adccorrfile'        / ADC correction file used
GAINCORF= 'gaincorrfile'       / Gain correction file used
DEGAP   = 'NO_DEGAP'           / 'NO_DEGAP', 'COEFF', or '<filename>'
DEGAP_V1=                1.5 /  V degap linear factor (if DEGAP='COEFF')
DEGAP_V2=               0.01 /  V degap quadratic factor (if DEGAP='COEFF')
DEGAP_U1=                1.5 /  U degap linear factor (if DEGAP='COEFF')
DEGAP_U2=               0.01 /  U degap quadratic factor (if DEGAP='COEFF')
TCTYP19 = 'RA---TAN'           / Sky WCS
TCTYP20 = 'DEC--TAN'           / Sky WCS
TCRVL19 =  0.000000000000000E0  / Sky coord of 1st axis (deg.)
TCRVL20 =  0.000000000000000E0  / Sky coord of 2nd axis (deg.)
TCDLT19 =-3.472222222222222E-5  / X degrees per pixel
TCDLT20 = 3.472222222222222E-5  / Y degrees per pixel
TCROT20 =  0.000000000000000E0  / Rotation angle (degrees)
TCRPX19 =              16384.5 / Pixel corresponding to TCRVL19
TCRPX20 =              16384.5 / Pixel corresponding to TCRVL20
TCUNI19 = 'deg     '           / Unit of sky coords
TCUNI20 = 'deg     '           / Unit of sky coords
MTYPE1  = 'RAW     '           / RAW is ASC-HRC-1.1
MFORM1  = 'RAWX,RAWY'          / Components of RAW
MTYPE2  = 'CHIP    '           / CHIP is ASC-HRC-1.1
MFORM2  = 'CHIPX,CHIPY'        / Components of CHIP
MTYPE3  = 'TDET    '           / TDET is ASC-HRC-1.1
MFORM3  = 'TDETX,TDETY'        / Components of TDET
MTYPE4  = 'DET     '           / DET is ASC-FP-2.1
MFORM4  = 'DETX,DETY'          / Components of DET
MTYPE5  = 'SKY     '           / SKY is ASC-FP-2.1
MFORM5  = 'X,Y     '           / Components of SKY
ACSYS1  = 'RAW:AXAF-HRC-1.1'
ACSYS2  = 'CHIP:AXAF-HRC-1.1'
ACSYS3  = 'TDET:AXAF-TDET-1.0'
ACSYS4  = 'DET:AXAF-FP-1.2'
ACSYS5  = 'SKY:AXAF-FP-1.2'
```

Table 2.2: FITS keywords specific to Event Data extension.

#	TTYPE	TUNIT	TFORM	TLMIN	TLMAX	Comment
1	TIME	s	1D			Time tag (TT)
2	CRSV		1I	0	63/191	Coarse position V axis
3	CRSU		1I	0	63/15	Coarse position U axis
4	AMP_SF		1I	0	3	Amplitude scale factor
5	AV1		1I	0	4095	V axis ADC 1
6	AV2		1I	0	4095	V axis ADC 2
7	AV3		1I	0	4095	V axis ADC 3
8	AU1		1I	0	4095	U axis ADC 1
9	AU2		1I	0	4095	U axis ADC 2
10	AU3		1I	0	4095	U axis ADC 3
11	RAWX	pixel	1J	0	16383/4095	Raw X (no degapping)
12	RAWY	pixel	1J	0	16383/49151	Raw Y (no degapping)
13	CHIPX	pixel	1I	1	16384/4096	Chip X (degapping applied)
14	CHIPY	pixel	1I	1	16384	Chip Y (degapping applied)
15	TDETX	pixel	1J	1	16384/49368	Tiled X
16	TDETY	pixel	1J	1	16384/4096	Tiled Y
17	DETX	pixel	1D	0.5	32768.5/65534.5	Focal plane X
18	DETY	pixel	1D	0.5	32768.5/65534.5	Focal plane Y
19	X	pixel	1D	0.5	32768.5/65534.5	Sky X
20	Y	pixel	1D	0.5	32768.5/65534.5	Sky Y
21	PHA	chan	1I	0	255	Pulse height
22	PI	chan	1I	0	255	Pulse invariant
23	SUMAMPS		1I	0	24570	Sum of all amp readouts
24	CHIP_ID		1I	0/1	0/3	Chip ID
25	STATUS		32X			Event status bits

Table 2.3: Event Data HDU contents (one entry per event). Multiple TLMIN and TLMAX entries indicate HRC-I/HRC-S values.

2.3.2 Auxiliary HDU: Good Time Intervals

Table 2.4 lists keywords specific to the GTI extension. The contents are shown in Table 2.5.

```
EXTNAME = 'GTI     '           / Table name
CONTENT = 'GTI     '           / What data product
HDUNAME = 'GTI     '
HDUCLASS= 'OGIP    '
HDUCLAS1= 'GTI     '
HDUCLAS2= 'ALL     '
MTYPE1  = 'TIME'
MFORM1  = 'START,STOP'          / Components of TIME
METYP1  = 'R'                   /
```

Table 2.4: FITS keywords specific to GTI extension.

#	TTYPE	TUNIT	TFORM	TLMIN	TLMAX	Comment
1	START	s	1D			GTI start
2	STOP	s	1D			GTI stop

Table 2.5: Good Time Interval auxiliary HDU contents

2.4 Deadtime Factor Files

For each OBI, one HRC Deadtime Factor File is created. The file contains null primary header and one principal HDU—a binary table containing the information on HRC deadtime factor.

2.4.1 Principal HDU: Deadtime Factor versus Time

The deadtime information is derived from HRC Secondary Science and from the HRC Level 1 Event Data file.

The header contains long versions of Configuration Control, Timing and Observation info header components. Table 2.6 lists keywords specific to the Dead Time Factor extension.

The contents of the primary HDU binary table are described in Table 2.7. Each entry contains the information on the HRC deadtime in a given time interval. The default time interval is the duration of a science frame. The STATUS bits are set when there are exceptions in the secondary science data or if the data are corrupted.

```
EXTNAME = 'DTF     '           / Table name
CONTENT = 'DTF     '           / What data product
HDUNAME = 'DTF     '
HDUCLASS= 'ASC     '
HDUCLAS1= 'TEMPORALDATA'
HDUCLAS2= 'DTCOR   '
DTF_MIN =            0.9000000 / Min value of deadtime factor
DTF_MAX =            1.0000000 / Max value of deadtime factor
DTF_RLEN=                2.050 / Default length of the DTF record in seconds
```

Table 2.6: FITS keywords specific to DTF extension.

#	TTYPE	TUNIT	TFORM	TLMIN	TLMAX	Comment
1	TIME	s	1D			Time tag of the data record (TT)
2	DTF		1D	0.0	1.0	Deadtime factor
3	DTF_ERR		1D			Deadtime factor error
4	PROC_EVT_COUNT	count	1J			Primary science counts
5	TOTAL_EVT_COUNT	count	1J			Secondary science total counts
6	VALID_EVT_COUNT	count	1J			Secondary science valid counts
7	STATUS		8X			Entry status

Table 2.7: Deadtime Factor HDU contents (one entry per time interval)

2.5 Deadtime Factor Statistics Files

The Deadtime Factor Statistics Files file contains null primary header and one binary table principal HDU.

2.5.1 Principal HDU: Deadtime Factor Statistics

The deadtime factor statistics information is derived from the HRC deadtime factor file.

The header contains long version of Configuration Control keywords, and short Timing and Observation info header components.

Table 2.8 lists keywords specific to the Dead Time Factor extension. This extension contains one row with the information on the properties of HRC deadtime factor, such as the values of χ^2 and reduced χ^2 statistics, number of degrees of freedom, deadtime factor variability flag, etc. The contents of the primary HDU binary table are described in Table 2.9.

```
EXTNAME = 'DTFSTATS'          / Name of this binary table extension
CONTENT = 'DTFSTATS'          / What data product
HDUNAME = 'DTFSTATS'
HDUCLASS= 'ASC     '
HDUCLAS1= 'DTFSTATS'
```

Table 2.8: FITS keywords specific to DTF stats extension.

#	TTYPE	TUNIT	TFORM	TLMIN	TLMAX	Comment
1	DTCOR		1D	0.0	1.0	Deadtime factor
2	DTF_CHISQ		1D			Deadtime factor χ^2
3	DTF_RCHISQ		1D			Deadtime factor reduced χ^2
4	DTF_MIN		1D	0.0	1.0	Lowest deadtime factor in the data
5	DTF_MAX		1D	0.0	1.0	Highest deadtime factor in the data
6	DTF_DEGFREE		1J			Number of degrees of freedom
7	RED_CHISQ_LIMIT		1D			Reduced χ^2 threshold above which deadtime factor is considered variable
8	DTF_VAR		1L			Deadtime factor variability flag

Table 2.9: Deadtime Stats HDU contents.

2.6 Bad Pixel List File

The Bad Pixel List file contains null primary header and one binary table principal HDU.

2.6.1 Principal HDU: Bad Pixel List

The bad pixel list is derived for each OBI from the overall HRC bad pixel list, described in Applicable Document 9

The header contains long version of Configuration Control keywords, and short Timing and Observation info header components.

Table 2.10 lists keywords specific to the Bad Pixel extension. This extension contains in consecutive rows the descriptions of spatial regions on the detector which are considered unusable. The list contains regions such as detector defects, detector edges, and hot regions. The contents of the primary HDU binary table are described in Table 2.11.

The STATUS column provides coded information on the bad region in the following way:

- Bit 1 is set to 1 if the considered entry describes a region that has always been and always will be considered "dead" (e.g. physically damaged regions).
- Bit 2 is set to 1 for detector edges, which do not provide meaningful event locations.
- Bit 3 is set to 1 for regions that became bad during the lifetime of the mission and based on the time info in the overall bad pixel list (Applicable Document 9) are considered bad during the OBI.

Remaining bits in the STATUS bitarray are kept as spare.

```
EXTNAME = 'REGION  '           / Name of this binary table extension
CONTENT = 'BADPIX  '           / What data product
HDUNAME = 'REGION  '
HDUCLASS= 'ASC     '
HDUCLAS1= 'REGION  '
HDUCLAS2= 'STANDARD'
MTYPE1  = 'CHIP    '           / CHIP is ASC-HRC-1.1
MFORM1  = 'CHIPX,CHIPY'        / Components of CHIP
ACSYS1  = 'CHIP:AXAF-HRC-1.1'
```

Table 2.10: FITS keywords specific to bad pixel extension.

#	TTYPE	TUNIT	TFORM	TLMIN	TLMAX	Comment
1	CHIP_ID		1I	0/1	0/3	Chip ID
2	SHAPE		16A			shape of bad element
3	COMPONENT		1I			component index
4	CHIPX	pixel	2I	1	16384/4096	chip X
5	CHIPY	pixel	2I	1	16384	chip Y
6	STATUS		8X			Status bitarray (see text)

Table 2.11: Bad pixel HDU contents. Slashed entries for TLMIN and TLMAX in CHIP_ID and CHIPX indicate HRC-I/HRC-S values. SHAPE will always be 'RECTANGLE'.

2.7 Mission Timeline file

TBR

2.8 Volume, size, and frequency estimates

TBR