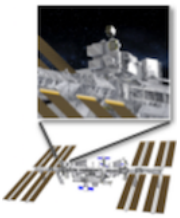

NICER
DESCRIPTION OF THE NICER CALIBRATION FILES

Version 1.1

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Table of Contents

1 Introduction 4
1.1 Scope 4
1.2 References 4
1.3 Acronyms 4
2 NICER Calibration File General 6
2.1 Filename convention 6
2.2 Directory Structure 6
2.3 Datatype 6
3 NICER General keywords 7
3.1 Mandatory Keywords 7
4 NICER Calibration Files 9
4.1 NICER Time Bias File 9
4.1.1 File Format 10
4.1.2 Header Keywords 10
4.2 NICER Gain Files 11
4.2.1 File Format 11
4.2.2 Header Keywords 12
4.3 NICER Alignment File 13
4.3.1 File Format 13
4.3.2 Header Keywords 13
4.4 NICER South Atlantic Anomaly File 14
4.4.1 File Format 14
4.4.2 Header Keywords 14

1 Introduction

This document describes the format of NICER Calibration Files and their organization into CALibration DataBase (CALDB). CALDB includes the pre-launch results obtained from the analysis of the ground calibration data and also those derived from calibration observations taken in flight during the lifetime of the mission. The results are stored in the OGIP CALDB structure as FITS file following whenever possible standard OGIP format layout. These files are recorded in CALDB for archival purposes and they are used in the NICER processing software. Specifically the CALDB files are used in the NICER pipeline to create Level 1 and Level 2 science files and in the interactive analysis.

The NICER calibration files are produced by the instrument teams and collected at GSFC. The files are checked at GSFC for their formats, mandatory CALDB keywords and their validity. Once the files have been checked and amended, a CALDB index is created. These files are then made available via the HEASARC that archives and distributes the data.

1.1 Scope

During the course of the Hitomi mission the CALDB provides:

- A way to store and archive the calibration data;
- A naming convention and header structure for the calibration files;
- An index for the software that access the calibration database using FITS header keywords;
- A traceable history of the calibration data by maintaining the history of versions.

1.2 References

[1] - BCF & CPF Calibration File Guidelines - OGIP Calibration Memo CAL/GEN/92-003

[2] - HFWG Recommendation R8 -1994 February 02

[3] - Required and Recommended FITS keywords for Calibration Files -OGIP Calibration Memo CAL/GEN/92-011

1.3 Acronyms

ARF	Ancillary Response File
BCF	Basic Calibration File
CALDB	Calibration Database
CIF	Calibration File
CPF	Calibration Product File
EEF	Encircled Energy Fraction
FITS	Flexible Image Transport System
GSFC	Goddard Space Flight Center
HDU	Header Data Unit
HEASARC	High Energy Astrophysics Science Archive Research Center
OGIP	Office of the Guest Investigator Programs

PHA	Pulse Height Amplitude
PI	Pulse Invariant
PSF	Point Spread Function
QE	Quantum Efficiency
RMF	Redistribution Matrix File

2 NICER Calibration File General

2.1 Filename convention

The filename convention is the following:

<mi><int><datatype>[<date>]Vxxx.ext

where:

mi is a 2 digit string that identifies the mission. The mission identifier string is set to 'ni' named after the initial of NICER.

int is a 3 digit string identifying the instrument and the subsystems. The instrument identifiers are set as follows:

- 'xti' for files applicable to all instruments unless noted.
- Instrument and subsystem is identified as follow 'xNN' where NN run from 00-67 for a total of 56 numbers

datatype is the calibration data type identifier. The string should describe the file content unambiguously within 8 characters long. Underscores or mathematical symbols are not allowed.

date is an integer giving the date when the file should first be used, with the format: YYYYMMDD;

version is a three digit integer giving the file issue number;

ext is set to 'fits' for all files with the following exceptions: 'rmf' or 'rsp' is used for the redistribution matrix and 'arf' is used for the ancillary response files.

2.2 Directory Structure

The CALDB of NICER is divided in the following directories :

/nicer

/xti

/bcf /cpf

/... /...

The /bcf and /cpf contain the basic and high level calibration file. Both the /bcf and /cpf have subdirectories indicating the

2.3 Datatype

Table 2.1 contains a summary of all the different type of calibration files :

Table 2.1

Datatype	Caldb directory	Used in pipeline	Description
flightpi	bcf	yes	Gain applied to fast chain and slow chain (1 file)
flightpifast	bcf	yes	Gain applied to fast chain (1 file)
timebias	bcf	yes	Calibration (1 file)
psf	bcf	yes	PSF at different off-axis angle (1file)
optmis	bcf	yes	Optic misalignment (1 file; 56 extensions) - used for response matrix
pntmis	bcf	yes	Pointing misalignment (1 file) – used by prefilter to compute RA/Dec

saareg	bcf	yes	Region file for mkf SAA region (lat/lon polygon region)
thresh	bcf	yes	Electronic threshold. (1 file with 56 extensions)
rmfN	bcf	yes	Containing the line spread function with qe and window transmission line (56 files one per detector)
arfN	bcf	yes	On-axis effective area. (56 files one per detector)

The files in light gray are not currently in caldb.

3 NICER General keywords

All NICER calibration files are FITS files. Keywords required by FITS OGIP standards and listed in this chapter are described in documents [1], [2] and [3] (see references in Section 1). Chapter 4 give the exact strings used in the CALDB keywords for the NICER XTI files as well as the description of different file FITS format.

3.1 Mandatory Keywords

Table 3.1 lists the mandatory keywords added to the primary and to the headers of all extensions of the Calibration FITS files. The text for the comment column is shown as appears in the file. Remarks on specific comments are added in italics.

Table 3.1		
Keyword name	Keyword value	Comment (as it should appear in the file)
TELESCOP	'NICER'	/Telescope (mission) name
INSTRUME	'XTI'	/Instrument Name Not applicable to general files
DETNAM	<detector name>	/Detector Name If calfiles are applicable to XTI subunits
DATE	YYYY-MM-DDThh:mm:ss	/Creation Date keyword is omitted from **empty** primary headers.
CHECKSUM	<up to date checksum>	/HDU checksum updated <date>
DATASUM	<up to date datasum>	/Data unit checksum updated <date>

Table 3.2 lists the additional mandatory keywords common to all table headers. Each CALDB keyword has different values for different Calibration Files. The values for the CALDB and the EXTNAME keywords are specified for each datatype in the chapter dedicated to each of the instruments.

Table 3.2		
Keyword name	Keyword value	Comment
EXTNAME	<extension name>	/Name of the binary table extension *or* /Name of the image extension

		This is omitted if data are stored in the Primary Header
ORIGIN	<organization name>	/ Source of FITS file
CALDB keywords:		
CCLSxxxx	OGIP-class of calibration file	/Dataset is a Calibration Product File /Dataset is a Basic Calibration File
CDTP*xxxx*	<datatype code>	/Calibration file contains data
CCNMxxxx	<extension codename>	/Type of Calibration data
CDESxxxx	<descriptive string>	/ Description
CVSDxxxx	<start valid data>	/UTC date when file should first be used
CVSTxxxx	<start valid time>	/UTC time when file should first be used

Table 3.1 and 3.2 list header keywords required in specific cases. These keywords are specified, when necessary, for each datatype. The keywords content is described in the chapters dedicated to each of the instruments.

Note that the "CBDnxxx" keyword, Table 3.3, should be used to differentiate otherwise identical extensions in a file or applicability of the extension. The first CBD keyword should be named CBD10001, the second CBD20001, etc... All CBD keywords should follow the syntax "KEYWORD (SELECTION)" where "keyword" is the quantity on which a selection is done.

For example, in order to distinguish between two extensions for the gain one applicable for the PI column and one to the PI_FAST column the keyword CBD10001 ='CHANTYPE(PI)' for the extension where the gain is calculated for the PI column and and CBD20001='CHANTYPE(PI_FAST)' for the extension where the gain is calculated for the PI_FAST.

Table 3.3		
Keyword name	Keyword value	Comment (as it should appear in the file)
CBDnxxxx	Array describing parameter limitations of the dataset	/Parameter boundaries
TDIMnnn	Number of elements & Ordering of *n*-d array	/Array dimensions
HDUCLASS	'OGIP '	/Format conforms to OGIP standards *(Only when applicable)*
HDUDOC	<document number>	/Document describing the format *(Only when applicable)*
HDUCLAS*n*	<character string to classify the extension	/(Specific to the type) *(Only when applicable)*
HDUVERS*n*	<string giving the format version>	/Version of file format *(Only when applicable)*

The keywords in the table 3.4 should be present if the binary table contains the TIME columns

Table 3.4

Keyword name	Keyword value	Comment (as it should appear in the file)
TIMESYS	TT	/Time system
MJDREFI	56658	/MJD reference day 2014-01-01 00:00:00 UTC
MJDREFF	0.0007775925926	/MJD reference (fractional of day)
CLOCKAPP	T	/If clock corrections are applied (F/T)

The content for the keywords INSTRUME, DETNAM, FILTER and DATAMODE are listed in the following tables. These strings are also used in the science data files.

Table 3.5		
Keyword Name	Keyword String	Explanation (not FITS comment)
INSTRUME	XTI	INSTRUME is set to XTI to indicate the collection of the 56 detector/optic modules
DETNAM	'xx'	DETNAM indicate instead the specific unit and is a string that contains two digit values ranging from 00-67 for a total of 56 numbers This keyword is only necessary when the files depend on the units

The XTI has 56 X-ray concentrators (XRC) each associated with a Silicon Drift Detector (SDD). The SSD are housed in a Focal Plane Modules (FPM) and eight FPMs are connected to a Measurement/Power Unit (MPU). In total there are 7 MPU.

4 NICER Calibration Files

Each of the subsection list the header of the NICER Calibration files.

4.1 NICER Time Bias File

This file contains the time bias of the different detectors that are included in the XTI. The instrument bias is defined as follows: the timestamp generated for each event by the XTI (once corrected for the GPS time) is the true GPS time plus a constant instrument bias. The filename is:

nixtitimebiasYYYYMMDDvxxx.fits

where YYYYMMDD to the start validity of the file.

The file has an empty primary header and a single bintable extension named TIME_BIAS with the following columns :

- DET_ID define the detector number. This is calculated as 10*MPU_ID+MPU_CHAN. There are in total 56 numbers and they are : 0-7, 10-17, 20-27, 30-37, 40-47 , 50-57 , 60-67 . This numbering identifies the 7 MPU and 8 Focal plane modules
- MPU_ID define the MPU number. Ranges from 0-6
- MPU_CHAN define a number of how the MPU are grouped. This is effectively the number of Focal Plane Modules. Ranges from 0-7.
- TIME_BIAS_SLOW contain the actual detector bias value for slow . The unit are ns.
- TIME_BIAS_FAST contain the actual detector bias value for fast . The unit are ns.

4.1.1 File Format

Table 4.1.1			
Extension N.	Type	Ext. Name	
0	PRIMARY		
1	BINTABLE	TIME_BIAS	
	Column Names	Format	Units
	DET_ID	1I	
	MPU_ID	1I	
	MPU_CHAN	1I	
	TIME_BIAS_SLOW	1I	ns
	TIME_BIAS_FAST	1I	ns

4.1.2 Header Keywords

All the extensions contain the keywords listed in Table 3.1 and Table 3.2. Since the time column is present also the keywords in Table 3.4 are mandatory. Specific settings of some of the CALDB keywords and others in Table 3.1 and Table 3.2 relevant to this file are listed below.

Table 4.1.2		
Keyword name	Keyword value	Comment
Table 3.1 & 3.2 & 3.4 - Mandatory header keywords		
CALDB and other Keywords for all extensions		
INSTRUME	XTI	/ Instrument name
EXTNAME	‘TIME_BIAS’	/Name of the binary table extension
NICSTATN	‘FLIGHT’	/ Data refers to Flight MPU configuration
CCLS0001	'BCF'	/Dataset is Basic Calibration File
CCNM0001	'TIME_BIAS'	/Type of calibration data
CDTP0001	'DATA'	/Calibration file contains data
CVSD0001	'YYYY-MM-DD'	/UTC date when calibration should first be used
CVST0001	'hh:mm:ss'	/UTC time when calibration should first be used
CDES0001	‘NICER XTI time bias’	/Description
CBD10001	“NICSTATN(“FLIGHT”)	/ Parameter boundary –flight

ORIGIN	NASA/GSFC	Source of FITS file
CREATOR	'ftcreate'	/Creator

4.2 NICER Gain Files

This file contains the temperature dependent coefficients used with the pulse height to derive the pulse invariant (PI). There are two type of coefficients, fast and slow and they are used to calculate respectively the column in the event file PI and PI_FAST. The file names for these gain files are :

nixtiflightpiYYYYMMDDvxxx.fits

nixtiflightpifastYYYYMMDDvxxx.fits

where YYYYMMDD to the start validity of the file. The 'flightpi' file has an empty primary header and one bintable extension named MPU_GAIN with the following columns:

- DET_ID define the detector number. This is calculated as 10*MPU_ID+MPU_CHAN. There are in total 56 numbers and they are : 0-7, 10-17, 20-27, 30-37, 40-47 , 50-57 , 60-67 . This numbering identifies the 7 MPU and 8 Focal plane modules
- MPU_ID define the MPU number. Ranges from 0-6
- FPM_ID define the housing serial number. This is the manufacturing number ranging between 1-70 to identify the 56 modules
- MPU_CHAN define a number of how the MPU are grouped. This is effectively the number of Focal Plane Modules. Ranges from 0-7.
- PULSE_MPU_A_TEMP contain the MPU analog temperature divide the pulse. The values are in units of Celsius.
- PULSE_MV contain the signal voltage for each pulse height. There 4096 values corresponding to the channel number . The value are in units of mV.
- PULSE_TEMP_COEFF contain the coefficient to calculate the temperature adjusted PHA. There are 4 coefficient per DET_ID.
- FPM_GAIN contain the focal plane module gain versus the pulser voltage in unit of kev/mV.
- FPM_OFFSET contain the focal plane module offset from the pulser voltage in unit of mV

The 'flightpi_fast' replace with the PULSE_TEMP_COEFF, FPM_GAIN and FPM_OFFSET with the following columns PIN_LO_ENERGY , PIN_HI_ENERGY

- PIN_LO_ENERGY lower energy in keV applicable to the coefficients (1D)
- PIN_HI_ENERGY higher energy in keV applicable to the coefficient (1D)
- PIN_LO_ADU_COEFF low energy coefficients in chan (4D)
- PIN_HI_ADU_COEFF high energy coefficients in chan (4D)
- FPM_GAIN_CORR_COEFF additional non-linear correction in keV (5D)
- DARK_MV (5D) offset function of the UnDER_COUNT
- NOM_UNDER_COUNT Nominal under count at calibration (1D)

4.2.1 File Format

Table 4.2.1

Extension N.	Type	Ext. Name	
0	PRIMARY		
1	BINTABLE	MPU_GAIN	
	Column Names	Format	Units
	DET_ID	1I	
	MPU_ID	1I	
	FPM_ID	1I	
	MPU_CHAN	1D	
	PULSE_MPU_A_TEMP	1D	Celsius
	PULSE_MV	4096D	mV
	PHA_TEMP_COEFF	4D	
	FPM_GAIN	1D	keV/mV
	FPM_OFFSET	1D	mV

4.2.2 Header Keywords

The primary extension keywords are listed in the Table 1.1 of this document and they are mandatory. All the extensions contain the keywords listed in Table 3.1 and Table 3.2. Specific settings of some of the CALDB keywords and others relevant to this file are listed below.

Table 4.2.2		
Keyword name	Keyword value	Comment
Table 3.1 & 3.2 - Mandatory header keywords		
CALDB Keywords		
INSTRUME	XTI	/ Instrument name
EXTNAME	‘TIME_BIAS’	/Name of the binary table extension
NICSTATN	‘FLIGHT’	/ Data refers to Flight MPU configuration
AUXCOLS	‘MPU_A_TEMP’	/ Auxiliary columns required to calculate gain
GAINMETH	‘MPU(PULSE_GRID)+MPU(MPU_A_TEMP)+FPM(LINEAR)'	/ Gain calculation method
CHANTYPE	‘XX”	/ PI or PI_FAST
CCLS0001	'BCF'	/Dataset is Basic Calibration File
CCNM0001	'MPU_GAIN’	/Type of calibration data

CDTP0001	'DATA'	/Calibration file contains data
CVSD0001	'YYYY-MM-DD'	/UTC date when calibration should first be used
CVST0001	'hh:mm:ss'	/UTC time when calibration should first be used
CDES0001	'NICER XTI time bias'	/Description
CBD10001	'NICSTATN("FLIGHT")'	/ Parameter boundery –flight
CBD20001	'CHANTYPE("XX")'	/ Parameter boundary - Pulse type PI/PI_FAST
ORIGIN	NASA/GSFC	Source of FITS file

where XX is either PI or PI_FAST

4.3 NICER Alignment File

This file contains the alignment matrix of the star tracker approximately co-aligned with X-ray boresight. filename is
nixtipntmisYYYYMMDDvxxx.fits
where YYYYMMDD to the start validity of the file. The file is an empty primary header with the alignment matrix keywords.

4.3.1 File Format

Table 4.2.1		
Extension N.	Type	Ext. Name
0	PRIMARY	

4.3.2 Header Keywords

The primary extension keywords are listed in the Table 1.1 of this document and they are mandatory.

Table 4.2.2		
Keyword name	Keyword value	Comment
Table 3.1 Mandatory header keywords		
CALDB Keywords		
CCLS0001	'BCF'	/Dataset is Basic Calibration File
CCNM0001	'ALIGNMENT'	/Type of calibration data
CDTP0001	'DATA'	/Calibration file contains data
CVSD0001	'YYYY-MM-DD'	/UTC date when calibration should first be used
CVST0001	'hh:mm:ss'	/UTC time when calibration should first be used
CDES0001	'NICER BORESIGHT'	/Description
ALIGNMxy		/ Component of the alignment matrix

ROLLSIGN	1	/ Sign of roll positive direction about boresight
ROLLOFF	0.0	/ Offset of roll angle in degrees

where x and y ranges from 1-3.

4.4 NICER South Atlantic Anomaly File

This file contains the region boundaries of the south Atlantic anomaly used in the process of the event screening .
The filename is:

nixtisaaregYYYYMMDDvNNN.fits

where YYYYMMDD is the data from when the file is valid.. Its structure is an empty primary header with bintable extensions with columns:

- SHAPE : contains the string that identify the shape of the region.
- X , Y , R: contain the X and Y coordinates in deg and the radius vector of region.
- ROTANG: contains the rotation angle in deg of the component of the region.
- COMPONENT: contain the component number of the region.
- ASCII_REGION: contains a string with the region specifies as an ascii.

4.4.1 File Format

Table 4.3.1			
Extension N.	Type	Ext. Name	
0	PRIMARY		
1–N	BINTABLE	FVT	
	Column Names	Format	Units
	SHAPE	16A	
	X	14E	deg
	Y	14E	deg
	R	14E	
	ROTANG	14E	deg
	COMPONENT	1I	
	ASCII_REGION	194A	

4.4.2 Header Keywords

The primary extension keywords are listed in the Table 1.1 of this document and they are mandatory. All the extensions contain the keywords listed in Table 3.1 and Table 3.2. Specific settings of some of the CALDB keywords and others relevant to this file are listed below.

Table 4.3.2		
Keyword name	Keyword value	Comment
Table 3.1 & 3.2 - Mandatory header keywords		
CALDB Keywords		
CCLS0001	'BCF'	/Dataset is Basic Calibration File
CCNM0001	'REGION'	/Type of calibration data
CDTP0001	'DATA'	/Calibration file contains data
CVSD0001	'YYYY-MM-DD'	/UTC date when calibration should first be used
CVST0001	'hh:mm:ss'	/UTC time when calibration should first be used
CBD10001	“REGTYPE(SAACONT)”	/Boundary keyword
CBD10002	“DETNAM(99)”	/Boundary keyword
CDES0001	‘NICER SAA Region’	/Description