DESCRIPTION OF THE BAT CALIBRATION FILES

Version 1.5

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CHANGE RECORD PAGE (1 of 2)

DOCUMENT TITLE Requirements Document DOCUMENT DATE:			
ISSUE	DATE	PAGES AFFECTED	DESCRIPTION
First draft	20 Nov 2004		First draft version (released with CALDB)
Revision	24 Dec 2004	Several	Add new file pulseflt ; change column names in the params file ; change units in the gain/offest columns ; add place holder column in the linear and quadratic correction.
Version 1	4 Jan 2005	Several	Clean up format for the gselcal, pulsecal,pulsefit and quadres
Version 1.1	29 March 2005		Add new file to store systematic error for spectral analysis
Version 1.2	7 October 2005		Add keywords to the 'aperture' file
Version 1.3	5 April 2006		Add new file : distortion map
Version 1.4	16 Nov 2006		Add new file format bad pixel and GTI
Version 1.5	23 May 2007		Add new file raw background x simulation

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1 Introduction

This document describes the format of BAT Calibration Files and their organization into the BAT CALibration DataBase (BATCALDB, chapter 2).

The Calibration Data are the results of the calibration activities and they are recorded in the Calibration Database for archive purposes and/or to be used in the BAT Pipeline processing software. Specifically some the BAT CALDB files are used in the BAT pipeline to create Level 1 and Level 2 calibrated files. They are also used in the Level 3 Data Products Generation and analysis either via pipeline or interactive processing.

The files are stored in CALDB in FITS format with the layout described in this document. Whenever possible standard OGIP layouts were used.

This first version of the document is not complete and the files currently present in CALDB do not all following the described format. This will be corrected in the next data files release.

1.1 Applicable Documents

[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

[4] - A Panchromatic Gamma Ray Burst MIDEX Mission - Phase A Study Report in response to AO-98-0SS-03

1.2 Definitions, acronyms and abbreviations

ARF	Ancillary Response File
BAT	Burst Alert Telescope
BCFS	BAT Calibration File Set
EEF	Encircled Energy Fraction
FITS	Flexible Image Transport System
GNEST	Ground Network for Swift
GRB	Gamma Ray Burst
GSFC	Goddard Space Flight Center
GTI	Good Time Intervals
HEASARC	High Energy Astrophysics Science Archive Research Center
HK	Housekeeping
OGIP	Office of the Guest Investigator Programs
PHA	Pulse Height Amplitude
PI	Pulse Invariant
PSF	Point Spread Function
RMF	Redistribution Matrix File
SDC	Swift Data Center
SSC	Swift Science Center
TBD	To Be Defined
TBC	To Be Confirmed

2 BAT CALDB

The BAT calibration database (BATCALDB) 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 the OGIP standard.

The BAT calibration files are produced by the BAT Calibration team (GSFC/NASA) and delivered to the SSC that take care to verify the validity, integrity and format of the files and whether the proper CALDB mandatory keywords are included correctly.

The BATCALDB is delivered finally by the SSC to HEASARC. The delivery occurs each time the BATCALDB is updated.

2.1 Scope

During the course of the Swift mission the BATCALDB shall provide:

- a way to store and archive BAT calibration data;
- naming convention and header structure for BAT calibration files;
- indexing for software access to BAT calibration data based on FITS header keywords;
- a traceable history of BAT calibration data in the database by maintaining the history of versions

3 BAT Calibration File Set (BCFS)

The Calibration Files are stored into the BATCALDB database. They are used in the data reduction software and in the data analysis.

3.1 File Naming Convention

The BCFS constituents are named as follows:

swb<datatype>[<date>]v<version>.ext

where:

datatype is the calibration data type identifier (at most eight characters long);

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: 'rsp' is used for the redistribution matrix and 'teldef' is used for the telescope definition file.

There are some exceptions to this naming convention to conform the names of some datatypes to the ones more frequently used by other missions. Names adopted for each datatype are described in the related paragraph.

3.2 BCFS Datatypes

Table 1 lists the files included into the BCFS with a short description.

datatype	***Cal directory***	***Used in pipeline***	***description***
teldef (*)	bfc	yes	Telescope definition file. This includes the Boresight definition and the distortion
distort	bcf	yes	Distortion map
aperture	bcf	yes	Contain the coded mask configuration for the BAT.
depthdist	bfc	yes	Depth distribution of counts in the CZT.
ebound	bfc	yes	Energy channel boundary for different binning
parms	bfc	yes	Parameters use to describe the BAT response and CZT characteristics
pulsecal pulseflt	bcf	yes	Pulser DAC to energy. Linear coefficients .
quadres	bcf	yes	ADU to pulser DAC. Quadratic correction coefficients.
gsecal	bfc	yes	Gain offset table from ground calibration
badpix	bfc		Bad pixel table
gti	bfc		Contain time interval of when the detector was

rsp	cpf	yes	Response function that contains the standard 160 Energy edge boundary
syserr	cpf	In xspec	Systematic error for spectral analysis
bkspec	cpf	In xspec	Raw Background file for simulation

Table 1 -Datatypes and short description of BCFS files

4 BCFS Files General Description

All BCFS files are FITS files. Keywords required by FITS OGIP standards and listed in this paragraph are described in documents [1], [2] and [3] (section 1.1). See chapter 5 for a detailed description of BAT calibration FITS files.

4.1 Mandatory keywords

Table 2 lists the mandatory keywords to be added to the primary header and to the headers of all extensions of the BCFS Fits files. See documents [1] [2] (section 1.1) for keyword description.

keyword name	***keyword value***	***comment***
TELESCOP	'SWIFT'	/ Telescope (mission) name
INSTRUME	'BAT'	/ Instrument Name
DATE	YYYY-MM-DDThh:mm:ss	/ Creation Date This keyword is omitted for empty Primary Headers.
CHECKSUM	<up to date checksum>	/ HDU checksum updated <date>
DATASUM	<up to date datasum>	/ Data unit checksum updated <date>

Table 2 –BCFS mandary header keywords

Table 3 lists the BCFS additional mandatory keywords common to all table headers. Each CALDB keywords has different values for different BCFS Calibration Files. The CALDB keywords and the EXTNAME keyword are specified for each datatype in the related paragraph in section 5.

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
CREATOR	< task name and version number>	/ Creator
CONTENT	<short description of the content>	/File content
FILENAME	<file name>	/ File name
VERSION	<version number>	/ Extension version number
CALDB keywords:		
CCLS*xxxx*	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
CCNM*xxxx*	<extension codename>	/Type of Calibration data
CDES*xxxx*	<descriptive string>	/ Description
CVSD*xxxx*	<start valid data>	/UTC date when file should first be used

CVST*xxxx*	<start valid time>	/UTC time when file should first be used

Table 3 - BCFS Table Headers mandatory keywords

Table 4 lists BCFS table header keywords required under certain circumstances. These keywords are specified, when necessary, for each *datatype* in the related paragraph in section 5.

Keyword name	***Keyword value***	***Comment***
CBD*nxxxx*	array describing parameter limitations of the dataset	/ Parameter boundary
CSYSNAME	spatial coordinate system in use	/spacial coord system used in this dataset
TDIM*nnn*	Number of elements & Ordering of *n*-d array	/ Array dimensions
HDUCLASS	'OGIP '	/ format conforms to OGIP standards
HDUDOC	<document number>	/ Document describing the format
HDUCLAS*n*	<character string to classify the extension	/ (Specific to the type)
HDUVERS*n*	<string giving the format version>	/ Version of file format
TIMESYS	TT	/ Time system
MJDREFI	51910	/ Reference MJD, Interger part
MJDREFF	7.4287037e-4	/Reference MJD, fractional part
CLOCKAPP	F	/ If clock corrections are applied (F/T)

Table 4 - BCFS Table Headers keywords required under certain circumstance

The order in which the header keywords are layout in the calibration files is the following :

- Required FITS keywords
- Descriptive column keywords for binary table
- EXTNAME, TELESCOP, INSTRUME, FILTER, ORIGIN, CREATOR, VERSION, FILENAME, CONTENT
- TIMESYS, MJDREFI, MJDREFF, CLOCKAPP
- CALDB keywords
- Comment keywords
- Additional Local keywords
- DATA, DATASUM, CHECKSUM

The description of the calibration file within this document includes the file structure, the setting of CALDB keywords and specific keywords related to the file

5 BCFS files format

5.1 Telescope Definition File

5.1.1 File Name

The file name of the Telescope Definition Calibration file does not conform to the standard naming convention described in paragraph 3.1.

swbYYYYMMDDvNNN.teldef

5.1.2 Description

The BAT data reduction software requires as input the Telescope Definition file (teldef). This is a FITS file containing in the primary HDU a set of keywords describing the telescope and instrument characteristics, the coordinate systems definition and the transformations between them. This file has been introduced for the first time for the ASCA mission. There are three sets of coordinates defined for the SWIFT BAT: raw, detector and sky. The keyword NCOORDS is set therefore to 3 (NCOORDS=3) and the keywords COORDn are set to:

COORD0='RAW'

COORD1='DET'

COORD2='SKY'

The RAW and DET coordinates are identical and they describe the shape of the BAT. The BAT is made by 32786 CzT individual detectors arranged into a letter “D” shape. The RAW and DET coordinates describe instead a rectangular shape with each detector treated as pixel in the rectangle. There are 286 pixels in the X direction and 173 in the Y direction, but not all have a corresponding active detector.

The SKY coordinates run from 1 to 1000 pixels in each of the X and Y directions.

The conversion from RAW to DET involves two steps:

The RAW coordinates are transformed in a set of internal coordinates. This is done to support detectors that are made by more than one sub-unit, each one with its own RAW coordinates system;

The internal coordinates system is transformed into a detector coordinates system.

The first transformation uses the formula:

Xint = COE_Xn_B * RAWX + COE_Xn_C * RAWY + COE_Xn_A

Yint = COE_Yn_B * RAWX + COE_Yn_C * RAWY + COE_Yn_A

The second transformation uses the formula:

DETX = DET_XCEN + DETXFLIP * (Xint - INT_XCEN - DET_XOFF)/DET_SCAL

DETY = DET_YCEN + DETYFLIP * (Yint - INT_YCEN - DET_YOFF)/DET_SCAL

DET_XCEN = DETXPIX1 + (DET_XSIZ - 1)/2.0

DET_YCEN = DETYPIX1 + (DET_YSIZ - 1)/2.0

Since for the BAT the RAW and DET coordinates are the same the INT_XCEN, INT_YCEN, DET_XOFF and DET_YOFF are set as :

INT_XCEN =DET_XCEN

INT_YCEN = DET_YCEN

DET_XOFF = 0

DET_YOFF = 0

The conversion from DET to SKY coordinates occurs via a separate transformation. The components of the 3x3 alignment matrix are specified in the teldef file and give the orientation of the detector coordinates with respect to the spacecraft axes. This matrix is specified is the ALIGNMij keywords.

The file contains also keywords containing other information about the detector such as the focal length of the telescope and the optical axis are also included following the document "Teldef File Format Specification".

5.1.3 File Format

Extension N.	*Type*	*Ext. Name*
0	PRIMARY	

Table 5 - Telescope Description Calibration File Format

5.1.4 Primary Header Keywords

All keywords listed in Table 2 and Table 3 are included in the header for this HDU. Below are listed specific setting of some of the CALDB keywords and others relevant to this file.

keyword name	*keyword value*	*comment*
Table 2 - BCFS mandatory header keywords		
CALDB Keywords		
CCLS0001	'BCF'	/ Dataset is Basic Calibration File
CCNM0001	'TELDEF'	/ Type of calibration data
CDTP0001	'DATA'	/ Calibration file contains data
CVSD0001	'2001-01-01'	/ UTC date when calibration should first be used
CVST0001	'00:00:00'	/ UTC time when calibration should first be used
CDES0001	'TELESCOPE DEFINITION FILE'	/Description

Table 6 - Telescope Description File Primary Header Keywords

The following is a listing of the teldef header. The values for the alignment matrix corresponds to the pre-launch setting and are listed here as example of the format. These will be changed after in-flight calibration .

```
COMMENT
COMMENT   ---------------------------------------------------------------------
COMMENT   Generic Coordinate Keywords
COMMENT   ---------------------------------------------------------------------
NCOORDS =                    3 / Number of coordinates defined in this file
COORD0  = 'RAW     '           / 1st coordinate system (RAWX,RAWY)
COORD1  = 'DET     '           / 2nd coordinate system (DETX,DETY)
COORD2  = 'SKY     '           / 3rd coordinate system (X,Y)
COMMENT   ---------------------------------------------------------------------
COMMENT   RAW Coordinate Definition
COMMENT   These are the pixel coordinates in the telemetry
COMMENT   ---------------------------------------------------------------------
RAW_XSIZ=                  286 / RAW address space x size (pixels)
RAWXPIX1=                  0.0 / RAW address space x first pixel number (pixel)
RAW_XSCL=                0.420 / RAW X scale (mm/pixel)
RAW_XCOL= 'RAWX    '           / Name of raw X column in event files
RAW_YSIZ=                  173 / only one pixel per segment
RAWYPIX1=                  0.0 / arbitrary coordinate of single pixel
RAW_YCOL= 'RAWY    '           / Name of raw Y column in event files
RAW_YSCL=                0.420 / RAW Y scale (mm/pixel)
RAW_UNIT= 'pixel     '           / physical unit of RAW coordinates
COMMENT ---------------------------------------------------------------------
COMMENT DET coordinate definition
COMMENT DET coordinates are fixed to the detector, look-up
COMMENT ---------------------------------------------------------------------
DET_XSIZ=                  286 / DET address space x size (pixels)
DETXPIX1=                  1.0 / DET address space x first pixel number (pixel)
DET_XSCL=                0.420 / DET X scale (mm/pixel)
DET_XCOL= 'DETX    '           / Name of DET X column in event files
DET_YSIZ=                  173 / DET address space y size (pixels)
DETYPIX1=                  1.0 / DET address space y first pixel number (pixel)
DET_YSCL=                0.420 / DET Y scale (mm/pixel)
DET_YCOL= 'DETY    '           / Name of DET Y column in event files
DET_UNIT= 'pixel     '           / physical unit of DET coordinates
COMMENT ---------------------------------------------------------------------
COMMENT Translation from RAW to DET coordinates:
COMMENT This translation comes in two parts. First there is a translation to
COMMENT an intermediate coordinate system as follows:
COMMENT     Xint = COE_X0_A + COE_X0_B * RAWX + COE_X0_C * RAWY
COMMENT     Yint = COE_X0_A + COE_X0_B * RAWX + COE_X0_C * RAWY
COMMENT
COMMENT ---------------------------------------------------------------------
COMMENT BAT ====== raw and det are the same
COE_X_A =                    0
COE_X_B =                    1 / These could be used to align the DET
COE_X_C =                    0 / coordinates to the spacecraft axes or to
COE_Y_A =                    0 / align the XRT and UVOT coordinate with one
COE_Y_B =                    0 / another.
COE_Y_C =                    1
COMMENT ---------------------------------------------------------------------
COMMENT ... followed by a translation from the intermediate coordinates
COMMENT to the DET coordinates as follows:
COMMENT
OMMENT   DETX = DET_XCEN + DETXFLIP * (Xint - INT_XCEN - DET_XOFF) / DET_SCAL
COMMENT   DETY = DET_YCEN + DETYFLIP * (Yint - INT_YCEN - DET_YOFF) / DET_SCAL
```

```
COMMENT
COMMENT         DET_XCEN = DETXPIX1 + (DET_XSIZ - 1) / 2.0
COMMENT         DET_YCEN = DETYPIX1 + (DET_YSIZ - 1) / 2.0
COMMENT
COMMENT          PIXELY
COMMENT            ^
COMMENT            |
COMMENT            |  x (DET_XOFF,DET_YOFF)
COMMENT            |
COMMENT            +--------> PIXELX
COMMENT
COMMENT   (DET_XOFF,DET_YOFF) is origin of the DET coordinates
COMMENT
DET_XOFF=                   0.0 / X Offset between intermediate and DET coords
DET_YOFF=                   0.0 / Y Offset between intermediate and DET coords
DETXFLIP=                     1 / do not flip x-axis in RAW -> DET
DETYFLIP=                     1 / do not flip y-axis in RAW -> DET
DET_SCAL=                   1.0 / no scaling done
DET_ROTD=                   0.0 / no rotation done
COMMENT ---------------------------------------------------------------------
COMMENT SKY coordinate definition:
COMMENT ---------------------------------------------------------------------
SKY_XSIZ=                  1000 / SKY address space x size (pixels)
SKYXPIX1=                   1.0 / SKY address space x first pixel number (pixel)
SKY_XCOL= 'X       '            / Name of SKY X column in event files
SKY_YSIZ=                  1000 / SKY address space y size (pixels)
SKYYPIX1=                   1.0 / SKY address space y first pixel number (pixel)
SKY_YCOL= 'Y       '            / Name of SKY Y column in event files
SKY_UNIT= 'deg     '            / physical unit of SKY coordinates
SKY_FROM= 'DET     '            / SKY coords are calculated from DET coords
COMMENT ---------------------------------------------------------------------
COMMENT Translation from DET to SKY:
COMMENT
COMMENT SKY coordinates are a tangent-plane projection of RA and Dec.
COMMENT The DET->SKY transformation is done by first adding a third axis
COMMENT perpendicular to each coordinate system, then rotating one with respect
COMMENT to the other and projecting onto the original 2-D SKY coordinates.
COMMENT
COMMENT The 3-D rotation between DET and SKY has two components.
COMMENT One is the orientation of the spacecraft with respect to the celestial
COMMENT sphere. The other is the rotation of the DET axes to make them line up
COMMENT with the satellite axes. Note that we assume the telescope axis is
COMMENT directly over the center of the DET coordinates. Any misalignment is
COMMENT respresented by a fictitious tilt.
COMMENT The orientation of the DET coordinates with respect to the
COMMENT satellite axes is specified by the following matrix:
COMMENT ---------------------------------------------------------------------
ALIGNM11=                   0.0 / DET -> SAT coordinates alignment matrix Mij
ALIGNM12=                   1.0
ALIGNM13=                   0.0
ALIGNM21=                   0.0 / [3x3 rotation matrix, common to all sensors]
ALIGNM22=                   0.0
ALIGNM23=                   1.0 / SATX =    M11*DETX + M12*DETY + M13*DETZ
ALIGNM31=                   1.0 / SATY =    M21*DETX + M22*DETY + M23*DETZ
ALIGNM32=                   0.0 / SATZ =    M31*DETX + M32*DETY + M33*DETZ
ALIGNM33=                   0.0
ROLLSIGN=                    -1 / Swift Roll convention
COMMENT ---------------------------------------------------------------------
COMMENT The plate scale is determined from the size of the SKY pixels in the
```

```
COMMENT focal plane and the focal length of the telescope.
COMMENT 1 mm roughly corresponds to atan(1/FOCALLEN) radians on tke sky.
COMMENT ---------------------------------------------------------------------
FOCALLEN=             1000.055 / Telescope focal length (mm)
COMMENT ---------------------------------------------------------------------
COMMENT  The true optical axis position is not used in the coordinate
COMMENT transformations, but is needed to calculate the detector response.
COMMENT ---------------------------------------------------------------------
OPTAXISX=                142.5 / optical axis x in DET coordinates (pixel)
OPTAXISY=                 87.0 / optical axis y in DET coordinates (pixel)
HISTORY ---------------------------------------------------------------------
```

5.2 Aperture Map

5.2.1 File Name

swbapertureYYYYMMDDvNNN.fits (full)

swbaperedgeYYYYMMDDvNNN.fits (edge)

swbaperfluxYYYYMMDDvNNN.fits (flux)

5.2.2 Description

These files contain information about the BAT coded mask configuration. Their file format consists of a primary array image where the value of each pixel is set as follows:

- -1 when a pixel in the array corresponds to a position of lead tile
- 1 when a pixel in the array corresponds to a position free from lead tail
- 0 when a pixel in the array corresponds to an un-coded or shielded portion of the mask

The array is 487 x 243 pixels and its coordinates system is listed in the WCS keywords. The header also contains keywords that define the position and orientation of the mask and the tile properties. These keywords are identified with the prefix MASK. An additional set of keywords with prefix DET defines the detector plane position and properties respect to the detector plane.

The alignment of the mask is measured on orbit and the values of the header keywords are updates if necessary as consequence of these calibration measurements. The content of the array might change after launch if the tail pattern changes (tail may fall off). A new file is issue if there are changes in header keywords or the array content as a result of the calibration activities.

There are 3 types of "aperture" file: "full" aperture, "flux" and "edge". The last two files, flux and edge, were introduced in Aug 2005 to optimize the data analysis. While the format did not change, the APERTURE keyword and a CALDB boundary keyword were added to all types of aperture files to be able to distinguish between them.

5.2.3 File Format

Extension N.	*Type*	*Ext. Name*

0	PRIMARY	

Table 7- Aperture Map File Format

5.2.4 Primary Header Keywords

All keywords of Table 2 & 3 –BCFS mandatory header keywords

Keyword name	***Keyword value***	***comment***
Table 2 & 3 - BCFS mandatory header keywords		
CALDB Keywords		
CCLS0001	'BCF'	/ Dataset is Basic Calibration File
CCNM0001	'CODED_MASK'	/ Type of calibration data
CDTP0001	'DATA'	/ Calibration file contains data
CVSD0001	'2001-01-01'	/ UTC date when calibration should first be used
CVST0001	'00:00:00'	/ UTC time when calibration should first be used
CBD10001	'APERTYPE("XXXX")'	/Parameter Boundary
CDES0001	'BAT Coded mask (aperture) pattern'	/Description
Aperture keyword in flux file		
APERTYPE	"FLUX"	/Mask aperture optimized for flux
Aperture keyword in edge file		
APERTYPE	"MASK_EDGE"	/Mask edge map for det. screening
Aperture keyword in full file		
APERTYPE	"DETECTION"	/Mask aperture optimized for detection

Table 8- Aperture Map File Format

Where XXX in the boundary keyword has the values FLUX, MASK_EDGE and DETECTION fro the full, edge or flux aperture file respectively. The following are the aperture map keywords in the primary header. Note that the keyword starting with the prefix MASK change between the different files.

```
COMMENT   ------------------------------------------------------
COMMENT   BAT aperture header
COMMENT     $Id: aperture.head,v 1.12 2003/08/21 15:32:31 craigm Exp $
CTYPE1  = 'BAT_X'   / Title of this axis
CRPIX1  = 0.5       / Reference pixel is corner of 1st pixel (in pixels)
CRVAL1  = -121.75   / Value of BATX at reference point
CUNIT1  = 'cm'      / Units of BATX
CDELT1  = 0.5       / Spacing of pixels in cm
CTYPE2  = 'BAT_Y'   / Title of this axis
CRPIX2  = 0.5       / Reference pixel is corner of 1st pixel (in pixels)
CRVAL2  =  -60.75   / Value of BATY at reference point
CUNIT2  = 'cm'      / Units of BATY
```

```
CDELT2  = 0.5      / Spacing of pixels in cm
COMMENT   -----------------------------------------------------
COMMENT          Mask position and orientation parameters
COMMENT   Position of mask in BAT_X/Y/Z coordinates
MASKBATX= 0.0      / [cm] Center of mask tile plane in BAT_X
MASKBATY= 0.0      / [cm] Center of mask tile plane in BAT_Y
MASKBATZ= 100.3    / [cm] Top of mask tile plane in BAT_Z
MASKOFFX= -0.109   / [cm] Offset of mask in BAT_X (BAT Cal Memo 2003-06-03)
MASKOFFY= +0.078   / [cm] Offset of mask in BAT_Y
MASKOFFZ= +0.105   / [cm] Offset of mask in BAT_Z
COMMENT   Rotation of mask (Euler angles)
COMMENT      - order of rotations: Z, Y, X
MASKPSI0=   0.0    / [deg] Mask Euler rotation about X-axis
MASKPSI1=   0.0    / [deg] Mask Euler rotation about Y-axis
MASKPSI2=   0.0    / [deg] Mask Euler rotation about Z-axis
COMMENT   -----------------------------------------------------
COMMENT          Mask tile properties
MASKCELX= 0.5      / [cm] Size of mask cell in BAT_X
MASKCELY= 0.5      / [cm] Size of mask cell in BAT_Y
MASKCELZ= 0.1      / [cm] Size of mask cell in BAT_Z
COMMENT   -----------------------------------------------------
COMMENT          Detector plane position parameters
DETBATX = 0.0      / [cm] Center of detector plane in BAT_X
DETBATY = 0.0      / [cm] Center of detector plane in BAT_Y
DETBATZ = 0.35     / [cm] Top of detector plane in BAT_Z
DETOFFX = 0.0      / [cm] Offset of detector plane in BAT_X
DETOFFY = 0.0      / [cm] Offset of detector plane in BAT_Y
DETOFFZ = 0.0      / [cm] Offset of detector plane in BAT_Z
COMMENT   -----------------------------------------------------
COMMENT          Detector size properties
DETCELX = 0.42     / [cm] Size of detector pitch cell in BAT_X
DETCELY = 0.42     / [cm] Size of detector pitch cell in BAT_Y
DETCELZ = 0.20     / [cm] Size of detector cell in BAT_Z
DETSIZEX= 0.40     / [cm] Size of detector in BAT_X
DETSIZEY= 0.40     / [cm] Size of detector in BAT_Y
DETSIZEZ= 0.20     / [cm] Size of detector in BAT_Z
```

5.3 Depth distribution

5.3.1 File Name

swbdepthdisYYYYMMDDvNNN.fits

5.3.2 Description

This file contains the counts distribution recorded at various depths in a single CZT detector per unit of incident photon flux as function of photon energy and angle. This has been parametrized by storing the a set of chebyshev coefficients that describe the distribution. The file format consists of in a primary array and a binary table, CENTER DISTRIBUTION, containing the following columns :

- PHOTON_ENERGY : contains the incident photon energy in keV;
- TANX : is the angle of the incident photon tan(theta_x) and defined in the bat coordinates system as BAT_X/BAT_Y ;

- TANY : is an angle of the incident photon tan(theta_y) and defined in the bat coordinates system BAT_Y/BAT_Z;
- PHOTONPEAK : contains the chebyshev coefficients for the main photon peak;
- CD_ESC : contains the chebyshev coefficients for the Cd (Cadmium) peak ;
- TE_ESC : contains the chebyshev coefficients for the Te (Tellurium) peak .

5.3.3 File Format

Extension N.	***Type***	***Ext. Name***	
0	PRIMARY		
1	BINTABLE	CENTRE DISTRIBUTIONS	
	Column Names	**Format**	**Units**
	PHOTON_ENERGY	E	-
	TANX	E	-
	TANY	E	-
	PHOTOPEAK	20E	-
	CD_ESC	20E	-
	TE_ESC	20E	-

Table 9 - BAT Depth Distribution Calibration File Format

5.3.4 Primary Header Keywords

All keywords of Table 2 - BCFS mandatory header keywords

5.3.5 Extension 1 - Header Keywords

keyword name	***keyword value***	***Comment***
Table 2 & 3 - BCFS mandatory header keywords		
CALDB Keywords		
CCLS0001	'BCF'	/ Dataset is a Basic Calibration File
CCNM0001	'DEPTH_DIST'	/ Type of calibration data
CDTP0001	'DATA'	/ Calibration file contains data
CVSD0001	'2001-01-01'	/ UTC date when calibration should first be used
CVST0001	'00:00:00'	/ UTC time when calibration should first be used
CDES0001	'Chebyshev Coefficents for exp(counts/(photons/cm^2/dx)	/ Description
Depth Distribution extension keywords		
EXTNAME	'CENTRE DISTRIBUTIONS'	/ Name of this binary table extension

Table 10 – BAT depth distribution Calibration file extension 1 keywords

5.4 Energy boundary

5.4.1 File Name

swb4eboundYYYYMMDDvNNN.fits and swb80eboundYYYYMMDDvNNN.fits

5.4.2 Description

These files contain the energy edges of a channel for the default setting used by the on-board BAT software when accumulating a light curve or a spectrum. There are two files one defining the channel energy boundaries for the light curve as accumulated on–board and the other the channel energy boundaries for the spectrum. There are 4 standard channels for the light curves and 80 for the spectra. The channel numbering in both cases starts from 0, therefore they run from 0-3 and 0-79 respectively. The channels refer in both cases to PI. The file format consists of a primary header with a binary table extension, EBOUNDS, containing 3 columns:

- CHANNEL: contains the channel number;
- E_MIN : contains the lower energy boundary of the channel;
- E_MAX : contains the upper energy boundary of the channel.

Updates of these files are expected during the early calibration phase of the mission as result of the calibration activities.

5.4.3 File Format

Extension N.	***Type***	***Ext. Name***	
0	PRIMARY		
1	BINTABLE	EBOUNDS	
	Column Names	**Format**	**Units**
	CHANNEL	I	chan
	E_MIN	E	keV
	E_MAX	E	keV

Table 11- Default Bounds Calibration File Format

5.4.4 Primary Header Keywords

All keywords of Table 2 - BCFS mandatory header keywords

5.4.5 Extension 1 - Header Keywords

keyword name	*keyword value*	*comment*
Table 2 & 3 - BCFS mandatory header keywords		
CALDB Keywords		
CCLS0001	'BCF'	/ Dataset is a Basic Calibration File
CCNM0001	'EBOUNDS'	/ Type of calibration data
CDTP0001	'DATA'	/ Calibration file contains data
CVSD0001	'2001-01-01'	/ UTC date when calibration should first be used
CVST0001	'00:00:00'	/ UTC time when calibration should first be used
CDES0001	'Ebounds table for the four channel rate data'	/Description
CDB10001	'MODE(4)Chan''	/Parameter boundary
	'DETCHAN(4)'	/Parameter boundary
Ebound keywords		
EXTNAME	'EBOUNDS'	/ Name of the binary table extension
HDUCLASS	'OGIP'	/Format conforms to OGIP/GSFC standards
HDUCLAS1	'RESPONSE'	/ Response Extension
HDUCLAS2	'EBOUNDS'	/Energy Boundary
CHANTYPE	PI	/Type of Channel (PHA, PI etc)
DETCHANS	80	/Total number of detector channels

Table 12- Ebounds Calibration File extension 1 keywords

5.5 Response Matrix Incident Photon Energy Scale

5.5.1 File Name

swbresponseYYYYMMDDvNNN.rsp

5.5.2 Description

This is the on-axis RSP for the BAT. The BAT software includes a tool that calculates and RSP appropriate for each position and coding. The file format consists of an empty primary table and two binary table extensions named 'MATRIX' and 'EBOUNDS'. The 'MATRIX' includes the following columns:

- ENERG_LO: lower energy bound of the energy bin;
- ENERG_HI: upper energy bound of the energy bin;

- N_GRP: number of channel subset for the energy bin;
- F_CHAN: channel number of the of the start of each ' channel subset' for the energy bin;
- N_CHAN: number of channels within each 'channel subset' for the energy bin;
- MATRIX: response values for each 'channel subset' for the energy bin.

The column ENERG_LO and ENERG_HI contain the standard bin edges.

The ‘EBOUNDS’ extension includes the following columns :

- CHANNEL : contains the channel number
- E_MIN: Channel lower energy boundary in keV
- E_MAX: Channel upper energy boundary in keV

5.5.3 File Format

Extension N.	***Type***	***Ext. Name***	
0	PRIMARY		
1	BINTABLE	MATRIX	
	Column Names	**Format**	**Units**
	ENERG_LO	E	keV
	ENERG_HI	E	keV
	N_GRP	I	-
	F_CHAN	47I	-
	N_CHAN	47I	-
	MATRIX	212E	-
2	BINTABLE	EBOUNDS	
	Column Names	**Format**	**Units**
	CHANNEL	I	-
	E_MIN	E	keV
	E_MAX	E	keV

Table 13- BAT Response Matrix Incident Energy Scale Calibration File Format

5.5.4 Primary Header Keywords

All keywords of Table 2 - BCFS mandatory header keywords

5.5.5 Extension 1 - Header Keywords

keyword name	***keyword value***	***comment***

Table 2- BCFS mandatory header keywords		
CALDB Keywords		
CCLS0001	'CPF'	/ Dataset is a Calibration Product File
CCNM0001	'SPECRESP MATRIX’	/ Type of calibration data
CDTP0001	'DATA'	/ Calibration file contains data
CBD20001	‘DETCHANS(80)’	/Parameter Boundary
CBD30001	‘CHAN(0-79)’	/Parameter Boundary
CBD40001	‘CHANTYPE(“PI”)’	/Parameter Boundary
CVSD0001	'2001-01-01'	/ UTC date when calibration should first be used
CVST0001	'00:00:00'	/ UTC time when calibration should first be used
CDES0001	'BAT template response matrix’	/ Description
EXTNAME	SPECRESP 'MATRIX’	/ Extension name
HDUCLASS	'OGIP'	/Format conforms to OGIP/GSFC standards
HDUCLAS1	‘RESPONSE’	/ Response Extension
HDUCLAS2	‘RSP_MATRIX’	/Extension contains RSP
TLMIN4	0	/First channel in the response
TLMAX4	79	/Last channel in the response
CHANTYPE	PI	/Type of Channel (PHA, PI etc)
DETCHANS	80	/Total number of detector channels

Table 14- BAT response matrix Extension Calibration File Format

5.5.6 Extension 2 - Header Keywords

All keywords listed in Table 2 and Table 3 are included in the header for this HDU. Below are listed specific setting of some of the CALDB keywords and others relevant to this file.

keyword name	***keyword value***	***comment***
Table 2 & 3- BCFS mandatory header keywords		
CALDB Keywords		
CCLS0001	'CPF'	/ Dataset is a Calibration Product File
CCNM0001	'EBOUNDS'	/ Type of calibration data
CDTP0001	'DATA'	/ Calibration file contains data
CBD10001	‘DETCHANS(80)’	/ Parameter boundary
CBD20001	‘CHAN(0-79)’	/Parameter boundary

CBD30001	‘CHANTYPE(PI)’	/ Parameter boundary
CVSD0001	'2001-01-01'	/ UTC date when calibration should first be used
CVST0001	'00:00:00'	/ UTC time when calibration should first be used
CDES0001	‘BAT Response Matrix :Ebounds extension’	/Description
Response Matrix File Keywords		
EXTNAME	'EBOUNDS’	/ Extension name
HDUCLASS	'OGIP'	/Format conforms to OGIP/GSFC standards
HDUCLAS1	‘RESPONSE’	/Response Extension
HDUCLAS2	‘EBOUNDS’	/Energy boundary
CHANTYPE	‘PI’	/Type of channel (PHA, PI, etc)
DETCHANS	80	/Total number of detector channels

Table 15 - Response Matrix Calibration File Extension 2 Keyword

5.6 Detector Parameters to generate the response

5.6.1 File name

swbparamsYYYYMMDDvNNN.fits

5.6.2 Description

This file contains the parameters used to produce the shape of the BAT response and parameters that describe the intrinsic property of the CZT detectors. The file format consists of an empty primary header with two binary table extensions, MTFUNC_PARMS and MT_VALUES containing 12 and 3 columns respectively. The columns in the first extension are :

- TANX : is the angle of the incident photon tan(theta_x) and defined in the bat coordinates system as BAT_X/BAT_Y ;
- TANY : is an angle of the incident photon tan(theta_y) and defined in the bat coordinates system BAT_Y/BAT_Z;
- THETA : altitude of incident photons (radians):
- PHI : azimuth of incident photons (radians):
- VOLTAGE: contains the bias voltage of CZT detectors (volts):
- T_SIGMA : contains the energy resolution :
- T_GAIN_CFF : contains the power-law coefficient for adjusting the gain;
- T_GAIN_IND : contains the power law index for adjusting the gain;
- T_EXP_LAMB : contains the length of exponential tail :
- T_EXP_CFF : contains the power law coefficient for size of exp tail ;
- T_EXP_IND: contains the power law index for size of exp tail ;

- T_NORM_ADJ : contains the overall normalization adjustment.

The header contains also the mean of the values listed in the columns in keywords named after the columns and keywords related to the photon transmission parameters. The columns in the second extension are:

- mutau_e : is the μ-τ product for electrons;
- mutau_h : is the μ-τ product for holes;
- fraction : is the fraction of detectors with these values

Updates to this file are expected as results of on-orbit calibrations.

5.6.3 File Format

Extension N.	***Type***	***Ext. Name***	
0	PRIMARY		
1	BINTABLE	MTFUNCT_PARAMS	
	Column Names	**Format**	**Units**
	TANX	E	
	TANY	E	
	THETA	E	rad
	PHI	E	rad
	VOLTAGE	E	V
	T_SIGMA	E	keV
	T_GAIN_CCF	E	
	T_GAIN_IND	E	
	T_EXP_LAMB	E	
	T_EXP_CFF	E	
	T_EXP_IND	E	
	T_NORM_ADJ	E	
2	BINTABLE	MT_VALUES	
	Column Names	**Format**	**Units**
	mutau_e	E	cm**2/V
	mutau_h	E	cm**2/V
	fraction	E	

Table 16 – BAT Parameters Calibration File Format

5.6.4 Primary Header Keywords

All keywords of Table 2 - BCFS mandatory header keywords.

5.6.5 Extension 1 - Header Keywords

Specific setting of some of the CALDB keywords and others relevant to this file are listed below.

keyword name	*keyword value*	*Comment*
Table 2 & 3 - BCFS mandatory header keywords		
CALDB Keywords		
CCLS0001	'BCF'	/ Dataset is a Basic Calibration File
CCNM0001	'MTFUNC_PARMS'	/ Type of calibration data
CDTP0001	'DATA'	/ Calibration file contains data
CBD10001	'FLUXMETH("WEIGHTED")'	/Parameter boundary
CVSD0001	'2001-01-01'	/ UTC date when calibration should first be used
CVST0001	'00:00:00'	/ UTC time when calibration should first be used
CDES0001	'Paramters used by mutau_func to generate the response matrix'	/ Description
Params keywords		
EXTNAME	'MTFUNC_PARMS'	/Name of the binary table extension

Table 17 – BAT Parameters Calibration File Extension 1 Keywords

The following keywords are also present in this extension's header. Some of the keyword values corresponds to the pre-launch setting and will change in-flight. Here they are listed to show an example of the file format.

```
COMMENT
COMMENT  *** mean calibration parameters ***
COMMENT
VOLTAGE =                 200. / bias voltage of czt detectors
SIGMA   =                  1.4 / energy resolution standard deviation
COMMENT                        = 5.6 / 4
GAIN_CFF=              0.98125 / power-law coefficient for adjusting gain
COMMENT                        = 3.925 / 4
GAIN_IND=               0.0064 / power-law index for adjusting gain
COMMENT                        = 1.0064 - 1
EXP_CFF =                 0.23 / power-law coefficient for size of exp tail
EXP_IND =                  6.5 / power-law index for size of exp tail
EXP_LAMB=                 0.26 / length of exponential tail
NORM_ADJ=                  1.0 / overall normalization adjustment
COMMENT                        = fitted flux / "true" flux
COMMENT
COMMENT  *** photon transmission parameters ***
COMMENT
SRC_RHO =                  1.0 / source packaging density (g/cm3)
SRC_LCFF=               2133.5 / source packaging low-E absorption coefficient
SRC_LIND=              -3.0445 / source packaging low-E absorption index
SRC_HCFF=               0.5490 / source packaging high-E absorption coefficient
SRC_HIND=              -0.2552 / source packaging high-E absorption index
SRC_SMTH=                1.226 / source packaging smoothly broken power law join
SRC_THCK=                0.277 / source packaging thickness (cm)
AIR_RHO =            0.0012929 / air density (g/cm3)
```

```
AIR_LCFF=                5307.0 / air low-E absorption coefficient
AIR_LIND=                -3.028 / air low-E absorption index
AIR_HCFF=                0.5715 / air high-E absorption coefficient
AIR_HIND=               -0.2886 / air high-E absorption index
AIR_SMTH=                 1.182 / air smoothly broken power law joining index
PSV_LCFF=                 407.0 / passive material low-E absorption coefficient
PSV_LIND=                  -2.6 / passive material low-E absorption index
PSV_HCFF=                 0.162 / passive material high-E absorption coefficient
PSV_HIND=                -0.262 / passive material high-E absorption index
PSV_SMTH=                   1.5 / passive material smoothly broken power law join
PB_RHO  =                 11.35 / lead density (g/cm3)
PB_LCFF =              199826.0 / lead low-E absorption coefficient
PB_LIND =              -2.58574 / lead low-E absorption index
PB_HCFF =              575578.1 / lead high-E absorption coefficient
PB_HIND =              -2.50726 / lead high-E absorption index
COMMENT
```

5.6.6 Extension 2 - Header Keywords

Specific setting of some of the CALDB keywords and others relevant to this file are listed below.

keyword name	*keyword value*	*Comment*
Table 2 & 3- BCFS mandatory header keywords		
CALDB Keywords		
CCLS0001	'BCF'	/ Dataset is a Basic Calibration File
CCNM0001	'MT_VALUES'	/ Type of calibration data
CDTP0001	'DATA'	/ Calibration file contains data
CVSD0001	'2001-01-01'	/ UTC date when calibration should first be used
CVST0001	'00:00:00'	/ UTC time when calibration should first be used
CDES0001	'mu-tau products for electrons and holes for CZT detectors'	/ Description
Params keywords 2nd extension		
EXTNAME	'MT_VALUES'	/Name of the binary table extension

Table 18 – BAT Parameters Calibration File Extension 2 Keywords

5.7 Linear gain correction

5.7.1 File Name

swbpulsecalYYYYMMDDvNNN.fits swbpulsefltYYYYMMDDvNNN.fits

5.7.2 Description

These files contain the linear gain correction for the BAT pulser to energy scale , providing the conversion between pulser DAC (digital analog converter) setting and photon energy (keV).

The “pulsecal” is based on ground calibration of the gain and the “pulseflt” is instead the values of the gain table loaded on board and used by the on-board software. The file format for both files consists of an empty primary header and a binary table extension, BAT_MAP, containing two columns :

- GAIN : scale factor between pulser DAC and keV. This is an array of 286 x173 values one for each of the detector ‘pixel’ of the BAT ;
- OFFSET : DAC zero-point for an incident energy of 0 keV. This is an array of 286 x173 values one for each of the detector ‘pixel’ of the BAT .

The content is combined with the quadratic component of the gain to obtain the proper keV/chan conversion. The content is updated by delivery a new file in CALDB. These updates are expected to be frequent since depend on changes on the temperature stability and detector electronics.

5.7.3 File Format

Extension N.	***Type***	***Ext. Name***	
0	PRIMARY		
1	BINTABLE	BAT_MAP	
	Column Names	**Format**	**Units**
	GAIN	49478E	4069*V/keV
	OFFSET	49478E	4096*V

Table 19 – BAT Linear Energy Scale Calibration File Format

The GAIN and OFFSET columns have the TDIM keyword specified as

TDIMn = ‘(286,173)’ /array dimension

5.7.4 Primary Header Keywords

All keywords of Table 2 - BCFS mandatory header keywords.

5.7.5 Extension 1 - Header Keywords

Below are listed specific setting of some of the CALDB keywords and others relevant to this file.

keyword name	***keyword value***	***comment***
Table 2 & 3 - BCFS mandatory header keywords		
CALDB Keywords		
CCLS0001	'BCF'	/ Dataset is Basic Calibration File
CCNM0001	'PULSER_GAIN'	/ Type of calibration data
CDTP0001	'DATA'	/ Calibration file contains data
CVSD0001	'2001-01-01'	/ UTC date when calibration should first be used

CVST0001	'00:00:00'	/ UTC time when calibration should first be used
CBD10001	"SOURCE("XXXX")	/Parameter boundary
CDES0001	'Table relating energy to cal pulser DAC levels'	/Description
Pulsecal File Keywords		
EXTNAME	'BAT_MAP'	/ Extension name

Table 20 – Pulscal Calibration File Extension 1 Keywords

where XXXX is set to "FLIGHT" for the pulseflt file and "GROUND" for the "pulsecal"

5.8 Quadratic Gain Parameter Corrections

5.8.1 File Name

swbquadresYYYYMMDDvNNN.fits

5.8.2 Description

This file contains the quandratic component to the gain correction. The file format consists of an empty primary header and a binary table extension, BAT_MAP, containing three columns :

- GAIN2: This is an array of 286 x173 values one for each of the detector 'pixel' of the BAT ;
- GAIN : scale factor between pulser DAC and keV. This is an array of 286 x173 values one for each of the detector 'pixel' of the BAT ;
- OFFSET : DAC zero-point for an incident energy of 0 keV.

The quadratic component is expected to be less variable of the linear component. The values in the file are derived from 11-point cal sweeps and are the best quadratic fits to the curve relating the pulser DAC value (proportional to voltage) to the ADC channel. The content is combined with the quadratic component of the gain to obtain the proper keV/chan.

5.8.3 File Format

Extension N.	***Type***	***Ext. Name***	
0	PRIMARY		
1	BINTABLE	BAT_MAP	
	Column Names	**Format**	**Units**
	GAIN2	49478E	4096*V/adu**2
	GAIN	49478E	4096*V/adu
	OFFSET	49478E	4096*V

Table 21 – Quadratic Gain Parameters Calibration File Format

The GAIN2, GAIN and OFFSET columns have the TDIM keyword specified as

TDIMn = '(286,173)' /array dimension

5.8.4 Primary Header Keywords

All keywords of Table 2 - BCFS mandatory header keywords.

5.8.5 Extension 1 - Header Keywords

All keywords listed in Table 2 and Table 3 are included in the header for this HDU. Below are listed specific settings of some of the CALDB keywords and others relevant to this file.

keyword name	*keyword value*	*comment*
Table 2 & 3- BCFS mandatory header keywords		
CALDB Keywords		
CCLS0001	'BCF'	/ Dataset is Basic Calibration File
CCNM0001	'DET_GAIN'	/ Type of calibration data
CDTP0001	'DATA'	/ Calibration file contains data
CVSD0001	'2001-01-01'	/ UTC date when calibration should first be used
CVST0001	'00:00:00'	/ UTC time when calibration should first be used
CDES0001	'Table of quadratic corrections to gain/offset values'	/Description
Quadratic Gain File Keywords		
EXTNAME	'BAT_MAP'	/ Name of the binary table extension

Table 22 – Quadres Calibration File Extension 1 Keywords

5.9 Gain offset Correction table pre-launch

5.9.1 File Name

swbgsecalYYYYMMDDvNNN.fits

5.9.2 Description

This file contains the gain offset correction table used during ground calibration. The format consists in a binary table with the following columns: TIME, EXPOSURE, GAIN and OFFSET. During the mission the gain-offset file is sent periodically from the satellite on ground by the BAT. The flight version contains other columns relevant to the observation when these values were recorded. The flight gain-offset file are not stored in CALDB but instead are kept with the data set where the specific gain-offset file is applied. This CALDB file is therefore expected not to change during flight.

5.9.3 File Format

Extension N.	*Type*	*Ext. Name*
0	PRIMARY	

Extension N.	*Type*	*Ext. Name*	
1	BINTABLE	BAT_MAP	
	Column Names	**Format**	**Units**
	TIME	D	s
	EXPOSURE	D	s
	GAIN	49478J	keV/adu
	OFFSET	49478J	adu

Table 23 – gain offset correction table Calibration File Format

The columns gain and offset contain a data array. The dimension of the array is specified the keyword TDIM with the following value (286,173).

5.9.4 Primary Header Keywords

All keywords of Table 2 - BCFS mandatory header keywords.

5.9.5 Extension 1 - Header Keywords

All keywords listed in Table 2 and Table 3 are included in the header for this HDU. Below are listed specific settings of some of the CALDB keywords and others relevant to this file.

keyword name	*keyword value*	*comment*
Table 2 & 3- BCFS mandatory header keywords		
CALDB Keywords		
CCLS0001	'BCF'	/ Dataset is Basic Calibration File
CCNM0001	‘GSE_GAIN'	/ Type of calibration data
CDTP0001	'DATA'	/ Calibration file contains data
CVSD0001	'2001-01-01'	/ UTC date when calibration should first be used
CVST0001	'00:00:00'	/ UTC time when calibration should first be used
CDES0001	'linear gain and offset from ground data’	/Description
Quadratic Gain File Keywords		
EXTNAME	'BAT_MAP'	/ Name of the binary table extension

Table 24 – Quadres Calibration File Extension 1 Keywords

The header template contains also several other keywords which will be documented elsewhere since are part of the format of the gain-offset table sent by the BAT on ground with the telemetry.

5.10 Systematic Error

5.10.1 File Name

swbsyserrYYYYMMDDvNNN.fits

5.10.2 Description

This file contains the systematic error that should be applied to the standard OGIP spectrum. The values are to be placed in the column SYS_ERR of a spectrum. The format consists in a binary table with the following columns: CHANNEL, SYS_ERR, E_MIN, and E_MAX. The format uses the TYPE II spectra format where a spectrum is stored as an array in a single row. Therefore all the columns in the systematic error calibration file are vectors with a size equal to the number of channel 80 in total. These values are for spectra derived in PI channels.

5.10.3 File Format

Extension N.	***Type***	***Ext. Name***	
0	PRIMARY		
1	BINTABLE	BAT_MAP	
	Column Names	**Format**	**Units**
	CHANNEL	80I	
	SYS_ERR	80D	
	E_MIN	80D	keV
	E_MAX	80D	keV

Table 25 – systematic error Calibration File Format

5.10.4 Primary Header Keywords

All keywords of Table 2 - BCFS mandatory header keywords.

5.10.5 Extension 1 - Header Keywords

All keywords listed in Table 2 and Table 3 are included in the header for this HDU. Below are listed specific settings of some of the CALDB keywords and others relevant to this file.

keyword name	***keyword value***	***comment***
Table 2 & 3- BCFS mandatory header keywords		
CALDB Keywords		
CCLS0001	'CPF'	/ Dataset is a Calibration Product File
CCNM0001	'SYS_ERR	/ Type of calibration data
CDTP0001	'DATA'	/ Calibration file contains data
CVSD0001	'2003-01-01'	/ UTC date when calibration should first be used

CVST0001	'00:00:00'	/ UTC time when calibration should first be used
CDES0001	'BAT systematic error'	/Description
CBD10001	'FLUXMETH("WEIGHED")'	/Parameter Boundary
CBD20001	'DETCHANS(80)'	/Parameter Boundary
CBD30001	'CHANTYPE("PI")'	/Parameter Boundary
Quadratic Gain File Keywords		
EXTNAME	'SYS_ERR'	/ Name of the binary table extension

Table 26 – Systematic error Calibration File Extension 1 Keywords

5.11 Distortion Map File

5.11.1 File Name

swbdistortYYYYMMDDvNNN.fits

5.11.2 Description

The file contains the non-linear distortion data. This consists in small set of shifts that are applied to the measured images positions in order to obtain the BAT correct position. The data are stored as data cube in the primary header of a FITS file containing two arrays each of 100X50 elements. The arrays are the values of the offsets in the tangent plane coordinates systems (IMX IMY). The first contains the IMX offsets, the second is contains the IMY values. Two sets of coordinate systems describe the arrays : one is for the sky and the other is for the tangent plane coordinates. The sky coordinates uses the keywords : CTYPEn, CRVALn, CRPIXn, CDELTn, CUNITn. The tangent plane uses the keywords: CTYPEnT, CRVALnT, CRPIXnT, CDELTnT, CUNITnT.

5.11.3 File Format

Extension N.	*Type*	*Ext. Name*
0	PRIMARY	

Table 27 – Distortion map Description Calibration File Format

5.11.4 Primary Header Keywords

All keywords listed in Table 2 and Table 3 are included in the header for this HDU. Below are listed specific setting of some of the CALDB keywords and others relevant to this file.

keyword name	*keyword value*	*comment*
Table 2 - BCFS mandatory header keywords		
CALDB Keywords		
CCLS0001	'BCF'	/ Dataset is Basic Calibration File

CCNM0001	'DET_POSCOR'	/ Type of calibration data
CDTP0001	'DATA'	/ Calibration file contains data
CVSD0001	'2001-01-01'	/ UTC date when calibration should first be used
CVST0001	'00:00:00'	/ UTC time when calibration should first be used
CDES0001	'NONLINEAR DISTORTION CORRECTION'	/Description

Table 28 – Distortion map File Primary Header Keywords

5.12 Bad Pixel Map File

5.12.1 File Name

swbbadpixYYYYMMDDvNNN.fits

5.12.2 Description

The file contains the detector quality maps where each pixel gives the quality (bad or good) for each of the detector. The file format consists of an empty primary header and with several FITS IMAGE extensions each valid from a specific time period. The array is 286 x 173 pixels and it is described by the WCS using the keyword CTYPEn, CRVALn and CRPIXn, set for detector coordinates (NOTE CDELTn CUNITn are omitted, but the increment is 1 and the unit is pixel).

The pixel value are set to 0 if the detector is consider good and different from zero if should be excluded from the analysis. In each map there a keyword BREASON describing the reason why the map was created.

5.12.3 File Format

Extension N.	*Type*	*Ext. Name*
0	PRIMARY	
N	IMAGE	BADPIX_N

Table 29 – Bad pixel map Description Calibration File Format

5.12.4 Primary and Image Header Keywords

All keywords listed in Table 2 and Table 3 are included in the header for this HDU. Below are listed specific setting of some of the CALDB keywords and others relevant to this file.

keyword name	*keyword value*	*comment*
Table 2 - BCFS mandatory header keywords		
CALDB Keywords		
CCLS0001	'BCF'	/ Dataset is Basic Calibration File

CCNM0001	'BADPIX'	/ Type of calibration data
CDTP0001	'DATA'	/ Calibration file contains data
CVSD0001	'YYYY-MM-DD'	/ UTC date when calibration should first be used
CVST0001	'00:00:00'	/ UTC time when calibration should first be used
CDES0001	'BAT global quality map'	/Description
Additional keywords		
BREASON	'xxxxxxxxxxxxxxxxxxxxx'	Reason for map transition
GOODVAL	0	Good pixels have a map value of zero

Table 30 – Bad pixel image extension File Primary Header Keywords

The CVSDnnnn keyword value changes for any new extension in the file as well as the string describing the reason for the new map (BREASON).

5.13 GTI File

5.13.1 File Name

swbbadtimesYYYYMMDDvNNN.fits

5.13.2 Description

The file contains time intervals that describe times when the data were good or bad, The file format consists of an empty primary header and a good time interval extension. The columns are

- START : gives the start time of the interval in second from the MJDREF.
- STOP : gives the stop time of the interval in second from the MJDREF.
- QUALITY: give an integer value fro data quality. The values are : 0 (goods), 1 (mostly good data), 2 (mostly bad data) , 4 (bad data)
- COMMENT: give a short explanation on that interval

5.13.3 File Format

Extension N.	*Type*	*Ext. Name*
0	PRIMARY	
1	BINTABLE	STDGTI

Table 27 – GTI Description Calibration File Format

5.13.4 Primary Header Keywords

All keywords of Table 2 - BCFS mandatory header keywords.

5.13.5 Extension 1 - Header Keywords

All keywords listed in Table 2 and Table 3 are included in the header for this HDU. Below are listed specific settings of some of the CALDB keywords and others relevant to this file.

keyword name	*keyword value*	*comment*
Table 2 & 3- BCFS mandatory header keywords		
CALDB Keywords		
CCLS0001	'BCF'	/ Dataset is Basic Calibration File
CCNM0001	'STDGTI'	/ Type of calibration data
CDTP0001	'DATA'	/ Calibration file contains data
CVSD0001	'2004-11-01'	/ UTC date when calibration should first be used
CVST0001	'00:00:00'	/ UTC time when calibration should first be used
CDES0001	'BAT Good/Bad Science Time Interval'	/Description
Quadratic Gain File Keywords		
EXTNAME	'STDGTI'	/ Name of the binary table extension
MJDREF	5.1910000700E+04	Reference date

Table 22 – GTI Calibration File Extension 1 Keywords

5.14 Background spectral file for simulation

5.14.1 File Name

swbbkgspecYYYYMMDDvNNN.

5.14.2 Description

This is the typical raw background spectrum for the BAT (outside of the SAA) to use when simulating the spectrum. This file is used with the tool *batphasimerr* which calculates realistic error bars of the spectra to be used as input in the Xspec fakeit. The file format consists of an empty primary table and two binary table extensions named 'SPECTRUM' and 'EBOUNDS'. The 'SPECTRUM' includes the following columns:

- CHANNEL: Channel number;
- RATE: Instrument background rate ;
- STAT_ERR: Error on the rate;
- RATE_DET: Background rate per detector, where the number of detectors are 32768.

The 'EBOUNDS' extension contains the following columns :

- CHANNEL: Channel number;
- E_MIN: Channel lower energy boundary in keV;

- E_MAX: Channel upper energy boundary in keV

5.14.3 File Format

Extension N.	*Type*	*Ext. Name*	
0	PRIMARY		
1	BINTABLE	SPECTRUM	
	Column Names	**Format**	**Units**
	CHANNEL	I	-
	RATE	D	count/s
	SYS_ERR	D	count/s
	RATE_DET	D	count/s
2	BINTABLE	EBOUNDS	
	Column Names	**Format**	**Units**
	CHANNEL	I	-
	E_MIN	E	keV
	E_MAX	E	keV

Table 23- BAT background spectrum Calibration File Format

5.14.4 Primary Header Keywords

All keywords of Table 2- BCFS mandatory header keywords

5.14.5 Extension 1 - Header Keywords

keyword name	*keyword value*	*comment*
Table 2,3,4- BCFS mandatory header keywords		
CALDB Keywords		
CCLS0001	'CPF'	/ Dataset is a Calibration Product File
CCNM0001	'BKGRND_SPEC’	/ Type of calibration data
CDTP0001	'DATA'	/ Calibration file contains data
CBD20001	‘DETCHANS(80)’	/Parameter Boundary
CBD30001	‘CHAN(0-79)’	/Parameter Boundary
CBD40001	‘CHANTYPE(“PI”)’	/Parameter Boundary
CBD50001	‘BKGTYPE("LOW")'	/Parameter Boundery
CVSD0001	'2001-01-01'	/ UTC date when calibration should first be used

CVST0001	'00:00:00'	/ UTC time when calibration should first be used
CDES0001	'BAT typical background spectrum'	/ Description
Spectral file specific keywords		
EXTNAME	'SPECTRUM'	/ Extension name
HDUCLASS	'OGIP'	/Format conforms to OGIP/GSFC standards
HDUCLAS1	"SPECTRUM'	/ Response Extension
HDUCLAS2	'TOTAL'	/Extension contains RSP
HDUCLAS3	'RATE'	/Spectrum is count/s
TLMIN4	0	/First channel in the response
TLMAX4	79	/Last channel in the response
CHANTYPE	PI	/Type of Channel (PHA, PI etc)
DETCHANS	80	/Total number of detector channels
EXPOSURE	XX	/[s} Accumulate Exposure
GAINAPP	T	/Gain correction has been applied
GAINMETH	'FIXEDDAC'	/Cubic ADU to energy correction at fixed DAC app
FLUXMETH	"RAW"	/Flux extraction method
NGODDPIX	32768	/Number of BAT detectors

Table 24- BAT background file 1st Extension

5.14.6 Extension 2 - Header Keywords

All keywords listed in Table 2 and Table 3 are included in the header for this HDU. Below are listed specific setting of some of the CALDB keywords and others relevant to this file.

keyword name	***keyword value***	***comment***
Table 2 & 3- BCFS mandatory header keywords		
CALDB Keywords		
CCLS0001	'CPF'	/ Dataset is a Calibration Product File
CCNM0001	'EBOUNDS'	/ Type of calibration data
CDTP0001	'DATA'	/ Calibration file contains data
CBD20001	'DETCHANS(80)'	/ Parameter boundary
CBD30001	'CHAN(0-79)'	/Parameter boundary
CBD40001	'CHANTYPE(PI)'	/ Parameter boundary
CBD50001	'BKGTYPE(LOW)"	/Parameter boundary
CVSD0001	'2001-01-01'	/ UTC date when calibration should first be used

CVST0001	'00:00:00'	/ UTC time when calibration should first be used
CDES0001	‘BAT Typical Background Spectrum’	/Description
GTI Specific File Keywords		
EXTNAME	'EBOUNDS’	/ Extension name
HDUCLASS	'OGIP'	/Format conforms to OGIP/GSFC standards
HDUCLAS1	‘RESPONSE’	/Response Extension
HDUCLAS2	‘EBOUNDS’	/Energy boundary
CHANTYPE	‘PI’	/Type of channel (PHA, PI, etc)
DETCHANS	80	/Total number of detector channels
GAINAPP	T	/Gain correction has been applied
GAINMETH	‘FIXEDDAC’	/Cubic ADU to energy correction at fixed DAC app

Table 25 – Background file Calibration File Extension 2 Keyword

6 File distribution and maintenance

The Calibration Files are produced by the BAT Calibration team and delivered to the SSC which in turn will delivery the BAT CALDB to the HEASARC .

The BAT CALDB files include data results obtained before launch from ground calibration tests and those obtained during flight. Calibration observations will be performed in flight after launch and periodically repeated to monitor the instrument performance. Therefore it is expected for the Calibration files to change or to be updated during the mission as result of the analysis of these calibration observations. The Calibration Team will provide updated files to the SSC/BAT. In the table below all calibration files are listed with the following information:

- Institute charged to produce them;
- the first release deadline;
- the foreseen periodicity of files delivery after launch.

Filename	Institution / Person	First release	Periodicity after launch
Telescope definition file: Boresight	GSFC/BAT Team	Delivered	
Aperture Map	GSFC/BAT Team	Delivered	Less < 1 per year
Depth distribution	GSFC/BAT Team	Delivered	No change
Ebounds, 4 channels/ 80 channelx	GSFC/BAT Team	Delivered	Less < 1 per year
Response Matrix	GSFC/BAT Team	Delivered	Less < 1 per year
BAT Parameters	GSFC/BAT Team	Delivered	~ 1 per year
Linear Gain. Ground table	GSFC/BAT Team	Delivered	1 month or more
Liner Gain. Flight table	GSFC/BAT Team	Delivered	
Quadratic Gain	GSFC/BAT Team	Delivered	Less < 1 per year
Gain offset correction table for ground calibration	GSFC/BAT Team	Delivered	No Change
Systematic error	GSFC/BAT Team	Delivered	