DESCRIPTION OF THE HALOSAT CALIBRATION FILES

Version 1.4

DATE 12 Mar 2020

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DOCUMENT TITLE : Description of the HaloSat Calibration files			
ISSUE	DATE	PAGES AFFECTED	DESCRIPTION
Version 1	28 Nov 2018	all	First version
Version 1.1	14 Jan 2020	6	Format fixes
Version 1.2	28-Jan 2020		Format fixes
Version 1.3	20-Feb 2020		Table of content and CDB values
Version 1.4	12-Mar-2020		Add logo

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1 Introduction

This document describes the format of HaloSat Calibration Files stored in the CALibration DataBase (CALDB). CALDB includes the results obtained from the analysis of the ground calibration data and also those derived from calibration observations in orbit during the mission. The results are stored in the OGIP CALDB structure in FITS file format, adhering in principle to the standard OGIP format. These files are recorded in CALDB for archival purposes and they are used in the HaloSat data analysis by end-users. The files required by the pipeline processing are not included. The HaloSat calibration files are produced by the HaloSat team at University of Iowa and delivered to the HEASARC that add the CALDB keywords and ingest the files.

1.1 Scope

This document provides a naming convention and header structure for the calibration files with a brief description.

1.1 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

1.2 Acronyms

ARF	Ancillary Response File
BCF	Basic Calibration File
CALDB	Calibration Database
CIF	Calibration File
CPF	Calibration Product File
FITS	Flexible Image Transport System
GSFC	Goddard Space Flight Center
HDU	Header Data Unit
HEASARC	High Energy Astrophysics Science Archive Research Center
HFWG	High Energy FITS Working Group
HK	House-Keeping
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
SDD	Silicon Drift Detector

2 HaloSat Calibration File Set

The chapter lists the naming convention for the CALDB files and the different calibration type products stored in CALDB.

2.1 File Naming Convention

The filename convention is the following:

<mi>_<int>_<datatype>_<date>vxxx.<ext>

The five components in the brackets shall include lower-case alphabets [a-z] and/or number letters [0-9] only. They indicate:
mi is a 2-letter string that identifies the mission, and is set to "hs", named after the HaloSat mission.
int is a 3-digit string identifying the instrument. This is set to:

- 'sdd' for files valid for all the sensors ;
- 's14' , 's58' and 's38' for files valid for the detector unit 1, 2, and 3 respectively

datatype is the calibration data identifier. The string should describe the file content unambiguously within 8 characters long;
date the date when the file should first be used, with the format: YYYYMMDD;
version is a three digits integer giving the file issue number;
ext is set to 'fits' but few exceptions (ex 'rmf' or 'rsp' for the redistribution matrix) .

2.2 Directory Structure

The CALDB for HaloSat is divided in the following directories :

/halosat

/sdd

/bcf /cpf /index

/… /…

The /bcf and /cpf contain the basic and high-level calibration files. Both the /bcf and /cpf have subdirectories indicating the file type. The /index directory contains the index file used by CALDB to retrieve the correct file.

2.3 HaloSat Data-type

Table 2.1 contains a summary of all the different types of the calibration files

Table 2.1

Datatype	*Cal directory*	*Description*
alignment	bcf	alignment file star tracker telescope
rmf	cpf	Redistribution matrix
arf	cpf	Ancillary file

Table 2.1 – Data types and short description of HaloSat files

3 HaloSat Calibration File Set

All HaloSat 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). Not all are applicable to HaloSat. Chapters 4 gives the exact CALDB keywords and the values used for HaloSat as well as a description of different FITS-file format.

3.1 Mandatory Keywords

Table 3.1a lists the mandatory keywords (see Note after table 3.1a) in the headers of the primary block and of all the extensions of all the Calibration FITS files. The text for the comment column is shown as it should appear in the files. Remarks on specific comments are added in italics.

Table 3.1a		
Keyword name	**Keyword value**	**Comment**
TELESCOP	'HALOSAT'	/ Telescope (mission) name
INSTRUME	<instrument>	/ Instrument Name
DETNAM*	<detector name> or 'NONE'	/ Detector name
DATE	YYYY-MM-DDThh:mm:ss	/ File creation date (YYYY-MM-DDThh:mm:ss UT)
CHECKSUM	<up to date checksum>	/ HDU checksum updated <date>
DATASUM	<up to date datasum>	/ Data unit checksum updated <date>

Table 3.1a – Mandatory header keywords for all the HaloSat science and calibration FITS files

Note : * DETNAM is mandatory only is needed to describe components of the main instrument.

Table 3.1b lists the values for the INSTRUME keyword in the HaloSat calibration and science files. HaloSat do not use DETNAM.

Table 3.1b		
Keyword Name	**Keyword String**	**Description (*not* FITS comment)**
INSTRUME	SDD	SDD for file common for all HaloSat detectors.
	SDD14	SSD14 for data related only to detector 14.
	SDD38	SSD38 for data related only to detector 38.
	SSD54	SSD54 for data related only to detector 54.

Table 3.1b – Parameter values for HaloSat instruments

Table 3.1c lists the additional mandatory keywords common in the header of every table. Each CALDB keyword has different values for different calibration files. The values for the CALDB and EXTNAME keywords are specified for each data-type in the chapter for each instrument.

Table 3.1c		
Keyword name	**Keyword value**	**Comment**
EXTNAME	<FITS extension name>	/ Name of extension
ORIGIN	<organization name>	/ Origin of the file
CALDB Keywords		
CCLSxxxx	OGIP-class of calibration file (either BCF or CPF)	/ Basic Calibration File *or* / Calibration Product File
CDTP*xxxx*	<datatype code>	/ Real data, not subroutine
CCNMxxxx	<extension codename>	/ OGIP Class
CDESxxxx	<descriptive string>	/ Brief descriptive
CVSDxxxx	<date from which the file is valid>	/ UTC date when file should first be used
CVSTxxxx	<time from which the file is valid>	/ UTC time when file should first be used

Table 3.1c – Mandatory header keywords for FITS extensions for tables

Tables 3.1d to 3.1e list the header keywords required in some specific cases. The keyword content is described in the sections for individual files when needed. Note that the "CBDnxxxx" keyword should be used to differentiate otherwise identical extensions in a file. The first CBD keyword should be named CBD10001, the second CBD20001, and so on. The CBD-keyword values should follow the syntax "KEYWORD (SELECTION)" if the "KEYWORD" is the parameter on which selections are made. In all other cases should contain string or expression.

Table 3.1d		
Keyword name	**Keyword value**	**Comment**
CBDnxxxx	Array describing parameter limitations of the dataset	<*various*>
TDIMnnn	Number of elements & Ordering of *n*-d array	/ Array dimensions
HDUCLASS	'OGIP '	/ Format conforms to OGIP standards
HDUDOC	<document number string>	/ Documents describing the files
HDUCLAS*n*	<character string to classify the extension>	/(Specific to the type)
HDUVERS*n*	<string giving the format version>	/ Version of family of formats (OGIP memo CAL/GEN/92-002a)

Table 3.1d – Header keywords required in some specific cases for extensions for tables

Note: HDUDOC is used in these files.

Table 3.1e		
Keyword name	**Keyword value**	**Comment**

CTYPE<n>	<n-th Coordinate axis name>	/ Coordinate axis name
CRPIX<n>	<n-th axis reference pixel>	/ <N> axis reference pixel
CRVAL<n>	<Coordinate for CRPIX<n>>	/ Coord of <N> ref pixel
CDELT<n>	<Increment for n-th axis>	/ <N> axis increment

Table 3.1e – Header keywords required for extensions for image-type data

The keywords in the table 3.1f should be present if the binary table contains columns related to time.

Table 3.1f		
Keyword name	**Keyword value**	**Comment**
TIMESYS	TT	/ Time System
MJDREFI	51544	/ Reference MJD (Integer part)
MJDREFF	0.00074287037037037	/ Reference MJD (Fractional part)
CLOCKAPP	T	/ If clock corrections are applied (F/T)

Table 3.1f – Table header keywords required to specify time

4 Specific File format

4.1 Alignment file

This file records the alignment matrix between the spacecraft and the detector. This is used within software that calculates quantities related to the pointing. The filename is

hs_sdd_alignYYYYMMDDvxxx.fits

The file has an empty primary header containing keywords that specify the alignment matrix.

4.1.1 File Format

The information is stored in the primary header. The following table lists the specific settings for some of the CALDB keywords relevant to this file.

Table 4.1.1

Keyword name	Keyword value	Comment
TELESCOP	'HALOSAT'	/ Telescope (mission) name
INSTRUME	'SDD'	/ Instrument Name
ORIGIN	'UNIVERSITY OF IOWA'	/ Source of FITS file
CCLS0001	'BCF'	/ Basic Calibration File
CDTP0001	'DATA'	/ Calibration file contains data
CCNM0001	'ALIGNMENT'	/ Type of calibration file
CVSD0001	2018-07-01	/ UTC date when file should first be used
CVST0001	00:00:00	/ UTC time when file should first be used
CDES0001	'HALOSAT BORESIGHT'	/Brief descriptive
ALIGNM11	value	/ Component of the alignment matrix
ALIGNM12	value	/ Component of the alignment matrix
ALIGNM13	value	/ Component of the alignment matrix
ALIGNM21	value	/ Component of the alignment matrix
ALIGNM22	value	/ Component of the alignment matrix
ALIGNM23	value	/ Component of the alignment matrix
ALIGNM31	value	/ Component of the alignment matrix
ALIGNM32	value	/ Component of the alignment matrix
ALIGNM33	value	/ Component of the alignment matrix
ROLLSIGN	1	/ Sign of roll positive direction about boresight

ROLLOFF	0.0	/ Offset of roll angle in degrees
DATE	YYYY-MM-DDThh:mm:ss	/ File creation date (YYYY-MM-DDThh:mm:ss UT)
CHECKSUM	<up to date checksum>	/ HDU checksum updated <date>
DATASUM	<up to date datasum>	/ Data unit checksum updated <date>

Table 4.1.1 – Alignment Description File Primary Header Keywords

4.2 Response matrices (RMF) file

The HaloSat response has two component RMF (Redistribution/Response Matrix File) and ARF (Ancillary Response File). There is a file for each component. The format for the RMF is listed in this section, the ARF is section 4.3.

There are two RMF file. One is the diagonal response used for fitting the particle background , the other contains the redistribution matrix for fitting all the X-ray spectra . The filenames are :

hs_sdd_diagYYYYMMDDvxxx.rmf diagonal response

hs_sdd_avgnoiseYYYYMMDDvxxx.rmf normal response

These responses are valid for all the three detectors, where YYYYYMMDD is the validity date and XXX is the version number.

4.2.1 File Format

The rmf files have an empty primary header with two bintable extensions named EBOUNDS and SPECRESP MATRIX. The EBOUNDS extension contains the following columns :

- CHANNEL : contains the channel number.
- E_MIN: contains the value in keV of the min energy included in the channel.
- E_MAX: contains the value in keV of the max energy included in the channel.

The SPECRESP MATRIX contains the following columns:

- ENERG_LO : contains the low energy of the energy bin.
- ENERG_HI : contains the high energy of the energy bin.
- N_GRP : contain the number of groups within the matrix array.
- F_CHAN : contains the value of the first channel.
- N_CHAN : contains the values the number of channels.
- MATRIX : contains the matrix array of the response.

Both RMFs have the same format. The only difference is in the number of elements in the MATRIX array .

Table 4.2.1 reports the setting and names for these columns in the two extensions.

Table 4.2.1			
Extension N.	**Type**	**Ext. Name**	
0	PRIMARY		
1	BINTABLE	EBOUNDS	
	Column Names	Format	Units

Table 4.2.1			
Extension N.	**Type**	**Ext. Name**	
	CHANNEL	I	chan
	E_MIN	E	keV
	E_MAX	E	keV
2	BINTABLE	SPECRESP MATRIX	
	ENERG_LO	E	keV
	ENERG_HI	E	keV
	N_GRP	I	
	F_CHAN	1I	
	N_CHAN	1I	
	MATRIX	nE*	

Table 4.2.1 – Columns for the EBOUNDS and Redistribution Matrix extensions

*NOTE : the array is 455E for the matrix valid for all observations , and 1E for the diagonal matrix

4.2.2 Header keywords rmf

Table 4.2.2. lists the keywords and values for the EBOUNDS and SPECRESP MATRIX extensions.

Table 4.2.2		
Keyword name	**Keyword value**	**Comment**
Primary		
TELESCOP	'HALOSAT'	/ Telescope (mission) name
INSTRUME	'SDD'	/ Instrument Name
ORIGIN	'UNIVERSITY OF IOWA'	/ Source of FITS file
DATE	YYYY-MM-DDThh:mm:ss	/ File creation date (YYYY-MM-DDThh:mm:ss UT)
CHECKSUM	<up to date checksum>	/ HDU checksum updated <date>
DATASUM	<up to date datasum>	/ Data unit checksum updated <date>
Extension 1 : EBOUNDS Keywords header		
EXTNAME	'EBOUNDS'	/ Extension name
TELESCOP	'HALOSAT'	/ Telescope (mission) name
INSTRUME	'SDD'	/ Instrument Name

ORIGIN	‘UNIVERSITY OF IOWA’	/ Origin of FITS file
CHANTYPE	‘PI’	/ Channel Pulse Invariant
DETCHANS	455	/ Total number of channels
HDUCLASS	‘OGIP ‘	/ Format conforms to OGIP standards
HDUCLAS1	‘RESPONSE’	/extension contains response data
HDUCLAS2	‘EBOUNDS’	/extension contains energy boundary
HDUVERS	‘1.2.0’	/ Version of file format
CCLS0001	'CPF'	/Dataset Calibration File
CDTP0001	'DATA'	/Calibration file contains data
CCNM0001	'EBOUNDS'	/Type of calibration data
CVSD0001	'YYYY-MM-DD'	/Validity start date (UTC)
CVST0001	'hh:mm:ss'	/Validity start time (UTC)
CDES0001	‘ENERGY BOUNDARY’	/Brief description summary
CBD10001	‘(string)’ **	/Boundary keyword
DATE	YYYY-MM-DDThh:mm:ss	/ File creation date (YYYY-MM-DDThh:mm:ss UT)
CHECKSUM	<up to date checksum>	/ HDU checksum updated <date>
DATASUM	<up to date datasum>	/ Data unit checksum updated <date>
Extension 2 : MATRIX Keywords header		
EXTNAME	‘SPECRESP MATRIX’	/ Extension name
TELESCOP	‘HALOSAT'	/ Telescope (mission) name
INSTRUME	‘SDD’	/ Instrument Name
ORIGIN	‘UNIVERSITY OF IOWA’	/ Origin of FITS file
CHANTYPE	‘PI’	/ Channel Pulse Invariant
DETCHANS	455	/ Total number of channels
HDUCLASS	‘OGIP ‘	/ Format conforms to OGIP standards
HDUCLAS1	‘RESPONSE’	/extension contains response data
HDUVER2	‘RSP_MATRIX’	/extension contains energy boundary
HDUVERS	‘1.3.0’	/ Version of file format
TLMIN4	1	/first channel in the response
CCLS0001	'CPF'	/Dataset Calibration File

CDTP0001	'DATA'	/Calibration file contains data
CCNM0001	'SPECRESP MATRIX'	/Type of calibration 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	'REDISTRIBUTION MATRIX'	/Brief description summary
CBD10001	'{string)' **	/Boundary keyword
CBD20001	'CHAN(1-455)'	/Boundary keyword
DATE	YYYY-MM-DDThh:mm:ss	/ File creation date (YYYY-MM-DDThh:mm:ss UT)
CHECKSUM	<up to date checksum>	/ HDU checksum updated <date>
DATASUM	<up to date datasum>	/ Data unit checksum updated <date>

Table 4.2.2 – Keywords setting for the EBOUNDS and SPECRESP MATRIX extensions

** NOTE: the value for the keyword CBD10001 specifies the matrix type. This is set to 'DIAGONAL' for the 'diag' file 'XRAYS' for the 'avgnoise' file.

4.3 Ancillary response (ARF) file

The ancillary response contains the effective area of HaloSat to be used together with RMF. The filename is:

hs_sdd_allYYYYMMDDvxxx.arf

This single ARF is applicable to all three detectors, where YYYYYMMDD is the validity date and XXX is the version number.

4.3.1 File Format

The arf files has an empty primary header with one bintable extension named SPECRESP containg the following columns :

- ENERG_LO: contains the value in keV of the min energy included in the channel.
- ENERG_HI: contains the value in keV of the max energy included in the channel.
- SPECRESP: contains the area in cm**2.

Table 4.3.1 shows the file format.

Table 4.3.1			
Extension N.	**Type**	**Ext. Name**	
0	PRIMARY		
1	BINTABLE	EBOUNDS	
	Column Names	Format	Units
	ENERG_LO	E	keV
	ENERG_HI	E	keV

Table 4.3.1			
Extension N.	**Type**	**Ext. Name**	
	SPECRESP	E	cm**2

Table 4.3.1 – Keywords setting for the SPECRESP extension

4.3.2 Header keywords arf

Table 4.3.2. lists the keywords and values for the EBOUNDS and SPECRESP MATRIX extensions.

Table 4.3.2		
Keyword name	**Keyword value**	**Comment**
Primary		
TELESCOP	'HALOSAT'	/ Telescope (mission) name
INSTRUME	'SDD'	/ Instrument Name
ORIGIN	'UNIVERSITY OF IOWA'	/ Source of FITS file
DATE	YYYY-MM-DDThh:mm:ss	/ File creation date (YYYY-MM-DDThh:mm:ss UT)
CHECKSUM	<up to date checksum>	/ HDU checksum updated <date>
DATASUM	<up to date datasum>	/ Data unit checksum updated <date>
Extension 1 : SPECRESP Keywords header		
EXTNAME	'SPECRESP'	/ Extension name
TELESCOP	'HALOSAT'	/ Telescope (mission) name
INSTRUME	'SDD'	/ Instrument Name
ORIGIN	'UNIVERSITY OF IOWA'	/ Origin of FITS file
HDUCLASS	'OGIP '	/ Format conforms to OGIP standards
HDUCLAS1	'RESPONSE'	/extension contains response data
HDUCLAS2	'SPECRESP'	/extension contains ancillary response
HDUVERS	'1.1.0'	/ Version of file format
CCLS0001	'CPF'	/Dataset Calibration File
CDTP0001	'DATA'	/Calibration file contains data
CCNM0001	'SPECRESP'	/Type of calibration data
CVSD0001	'YYYY-MM-DD'	/Validity start date (UTC)
CVST0001	'hh:mm:ss'	/Validity start time (UTC)
CDES0001	'ANCILLARY RESPONSE'	/Brief description summary

CBD10001	‘(XRAYS)’	/Boundary keyword
DATE	YYYY-MM-DDThh:mm:ss	/ File creation date (YYYY-MM-DDThh:mm:ss UT)
CHECKSUM	<up to date checksum>	/ HDU checksum updated <date>
DATASUM	<up to date datasum>	/ Data unit checksum updated <date>

Table 4.2.3 – Keywords setting for the SPECRESP extension