HEASARC Calibration Memo CAL/GEN/92-011

Required and Recommended FITS keywords for Calibration Files

Ian M George,
Lorraine Breedon,
&
Michael F. Corcoran

Codes 662,
NASA/Goddard Space Flight Center,
Greenbelt, MD 20771

Version: 1998 Nov 20

SUMMARY

This document gives a list of FITS keywords which are required or recommended to be included in any calibration data files to be incorporated into the HEASARC CALDB. The defined values of each keyword are also given.

Intended audience: primarily HEASARC programmers, authors of calibration files & downstream software.

Log of Significant Changes to this document

Release Date	Sections Changed	Brief Notes
1992 Oct 02	First Draft	
1993 May 18	All	Reviewed & updated
1994 Jan 05	The `CBD`*nxxxx* String	New syntax introduced
1994 Dec 19	All	New `CCNM`*xxxx* values
		(and made `LaTeX2HTML` compatible)
1998 Nov 20	All	reviewed and updated by MFC; revised list of CCNM0001 values
2004 Apr 01	All	made tth compatible
2004 Jul 14	Appendix B	added discussion of `NONE` boundary value

Contents

1 INTRODUCTION

In order to facilitate software and user identification/access of the numerous calibration datasets within the HEASARC calibration database (CALDB), the location, contents and quality of all datasets will be contained with Calibration Index Files (CIFs). The CIFs provide a link between processing/analysis software and the calibration datasets. A detailed description of the contents, format and operation of CIFs is given in CAL/GEN/92-008. A number of required keywords need to be present within the FITS file extension header of every calibration dataset contained within the HEASARC CALDB. These keywords and defined keyword values are given in this document.

Furthermore, while limited human & software checks are performed as part of the ingestion of calibration datasets into the CALDB, it is the responsibility of suppliers of calibration datasets to ensure the appropriate keywords are both present and their values are in the correct format. Authors of calibration datasets are urged to contact the HEASARC Calibration Team if this document is unclear, and/or does not cover their specific needs. In particular, in cases where the list of defined keyword values is insufficient, new values may be defined in consultation with the HEASARC Calibration Database team.

Please send e-mail to caldbhelp@olegacy.gsfc.nasa.gov for more information.

2 REQUIRED KEYWORDS

The following keywords (also listed in Table 2) are required if a calibration data file is to be indexed in the Calibration Index File:

- `TELESCOP` - the name of the satellite/mission.
  Defined values are given in HEASARC/93-013 (George & Angelini 1993, available on-line as postscript and html

  versions).
  Value to be inserted into **TELESCOPE** column of CIF.
- `INSTRUME` - the name of the instrument.
  Defined values are given in OGIP/93-013 (George & Angelini 1993).
  Value to be inserted into **INSTRUME** column of CIF.
- `DETNAM` - (if applicable) the name of the detector, required only in cases where the value of the `INSTRUME` keyword is insufficient.
  Defined values are given in OGIP/93-013 (George & Angelini 1993).
  Value to be inserted into **DETNAM** column of CIF.
- `FILTER` - (if applicable) the name of the filter in use.
  This keyword is not required for instruments without a moveable filter or for calibration data files for which filter information is not relevant.

Defined values are given in OGIP/93-013 (George & Angelini 1993).
Value to be inserted into **FILTER** column of CIF.

- `CCLS0001` - the HEASARC-specified "class" of this calibration file.
  Defined values:

  - `CCLS0001` = `'PCF'`; dataset is a Primary Calibration File
  - `CCLS0001` = `'BCF'`; dataset is a Basic Calibration File
  - `CCLS0001` = `'CPF'`; dataset is a Calibration Product File
  - `CCLS0001` = `'USR'`; dataset has been constructed by a User, and is not part of the official HEASARC calibration database.

  Value to be inserted into **CAL_CLAS** column of CIF.

- `CDTP00001` - code describing whether the 'calibration dataset' consists of real data, or 'virtual' data (*ie* a taskname and associated parameter inputs – see also CAL/GEN/92-013, George, Zellar & White 1993).
  Allowed values:

  - `CDTP0001` = `'DATA'`; dataset contains calibration data
  - `CDTP0001`= `'TASK'`; dataset contains a task name and associated input parameters values.

  Value to be inserted into **CAL_DTYP** column of CIF.

- `CCNM0001`- codename of the dataset to be used within CIF to describe the contents (for downstream software).
  Allowed values: see Section A at the end of this document
  Value to be inserted into **CAL_CNAM** column of CIF.

- `CBD`*nxxxx* - string giving parameter limitations on dataset (if any) to be used within CIF to further describe the contents for downstream software (in association with the value of the `CCNM`*xxxx* keyword).
  Allowed values: see Section B at the end of this document
  Value to be inserted into **CAL_CBD** column of CIF.

- `CVSD0001` - the UTC date (in either `dd/mm/yy` or `yyyy-mm-dd` format) when this calibration data should first be used.
  Value to be inserted into **CAL_VSD** column of CIF.

- `CVST0001`- the UTC time (in `hh:mm:ss` format) on the day `CVSD`*xxxx* when this calibration data should first be used.
  Value to be inserted into **CAL_VST** column of CIF.

- `CDES`*xxxx* - a string giving a brief descriptive summary of this dataset.
  Value to be inserted into **CAL_DESC** column of CIF.

Table 1: Required Keywords for Calibration Datasets

Keyword	**Description**	**Required/Optional**
`TELESCOP`	Name of satellite or mission	required
`INSTRUME`	Name of instrument or Detector	required
`DETNAM`	Name of specfic detector if INSTRUME insufficient	optional
`FILTER`	Name of Filter in use (if any)	optional
`CCLS0001`	HEASARC class of file	required
`CDTP0001`	HEASARC data type code	required
`CCNM0001`	HEASARC calibration dataset codename (see also Section **??**)	required
`CBD`$nxxxx$	Calibration Dataset parameter limitations (see also Section B)	optional
`CVSD0001`	Start date of validity of calibration dataset	required
`CVST0001`	Start time of validity of calibration dataset	required
`CDES`$xxxx$	Description of Calibration Dataset	required

where $xxxx$ is a number of the form `0001`, `0002`, `0003` *etc* and n a single-digit integer between 1 and 9. The $xxxx$ values are used to identify the respective set of keywords associated with each dataset should 2 or more datasets be included within in single extension. In the vast majority of cases, only one calibration dataset is stored in a given extension (indeed, this is strongly recommended), thus $xxxx$ = `0001` can be used. The use of the n digit is described in Section B.

3 RECOMMENDED KEYWORDS

The following keywords are recommended to be present in each FITS calibration file extension to be indexed in the calibration index file. Their presence in a FITS file extension is not currently required by any CALDB software routines or subroutines.

- `CTEL`*xxxx* - the name of the satellite/mission.
  This keyword is useful if the calibration dataset in a given extension is applicable to more than one X-ray mission; for example, a table of atomic constants which are used by both ROSAT and ASCA should have

  ```
  CTEL0001= 'ROSAT   ' / used applicable to the ROSAT mission
  CTEL0002= 'ASCA    ' / data applicable to the ASCA mission
  ```

  Defined values are the same as those used for the `TELESCOP` keyword and are given in HEASARC/93-013 (George & Angelini 1993).

- `CINS`*xxxx* - the name of the instrument.
  This keyword is useful if the calibration dataset in a given extension is applicable to more than one X-ray instrument; for example, a table of gains which are used by both SIS0 and SIS1 on ASCA should have

  ```
  CINS0001= 'SIS0     ' / used applicable to the SIS0
  CINS0002= 'SIS1     ' / data applicable to the SIS1
  ```

  The values of these keywords are the same as those for the `INSTRUME` keyword as given in OGIP/93-013 (George & Angelini 1993)

- `CDT`*nxxxx* - (if necessary) the name of the detector, required only in cases where the value of the `INSTRUME` keyword is (or the `CTEL`*xxxx* keywords, if present, are) insufficient to fully identify the calibration data. n is an integer from 1-9 which identifies the instrument, while the *xxxx* are indices which identify the individual detector. For example an effective area curve applicable to CCD chips 0,2 and 4 of the ASCA SIS0 and chip 1,3 of SIS1 would have:

  ```
  CINS0001= 'SIS0    '  / data applicable to the SIS0
  CINS0002= 'SIS1    '  / data applicable to the SIS1
  CDT10001= 'CCD0    '  / data applicable to the CCD0 for CINS0001 (i.e. SIS0)
  CDT10002= 'CCD2    '  / data applicable to the CCD1 for CINS0001 (i.e. SIS0)
  CDT10003= 'CCD4    '  / data applicable to the CCD4 for CINS0001 (i.e. SIS0)
  CDT20001= 'CCD1    '  / data applicable to the CCD1 for CINS0002 (i.e. SIS1)
  CDT20002= 'CCD3    '  / data applicable to the CCD3 for CINS0003 (i.e. SIS1)
  ```

  Note: a given calibration dataset can thus store information for up to 9999 detectors for up to 9 instruments; additional instrument data should be placed in separate file extensions. The

Table 2: Recommended Keywords for Calibration Datasets

Keyword	**Description**
CTEL*xxxx*	Name of satellite or mission
CINS*xxxx*	Name of Instrument(s) for given mission
CDT*nxxxx*	Name of detector(s) for given instrument(s) (if necessary)
CFI*nxxxx*	Name of Filter in use (if any)

values of the CDT*Nxxxx* keywords are the same as that of the DETNAM keyword, and are given in OGIP/93-013 (George & Angelini 1993).

- CFI*nxxxx* -the name of the filter in use for detector *xxxx* of instrument *n*. This keyword is not to be used for instruments without a moveable filter or for calibration data files for which filter information is not relevant. Values should be the same as those used for the FILTER keyword, as given in OGIP/93-013 (George & Angelini 1993).

These recommended keywords have been defined to uniquely identify single datasets which may be appropriate to two or more individual instruments/detectors and so minimize the number of files/extensions of calibration data which needs to be written and archived. In practice such combinations can become quite complicated; we recommend that clarity never be sacrificed for efficiency.

REFERENCES

George, I.M. & Yusaf, R.,1992. HEASARC Calibration Memo CAL/GEN/92-020. `http://heasarc.gsfc.nasa.gov/docs/heasarc/caldb/docs/memos/cal_gen_92_020/cal_gen_92_020.html`

George, I.M. & Zellar, R., 1992. HEASARC Calibration Memo CAL/GEN/92-019. `http://heasarc.gsfc.nasa.gov/docs/heasarc/caldb/docs/memos/cal_gen_92_019/cal_gen_92_019.html`

George, I.M. & Zellar, R., 1992. HEASARC Calibration Memo CAL/GEN/92-021. `http://heasarc.gsfc.nasa.gov/docs/heasarc/caldb/docs/memos/cal_gen_92_021/cal_gen_92_021.html`

George, I.M. & Zellar, R., 1992. HEASARC Calibration Memo CAL/GEN/92-022. `http://heasarc.gsfc.nasa.gov/docs/heasarc/caldb/docs/memos/cal_gen_92_022/cal_gen_92_022.html`

George, I.M. & Zellar, R., 1992. HEASARC Calibration Memo CAL/GEN/92-023.

George, I.M. & Zellar, R., 1992. HEASARC Calibration Memo CAL/GEN/92-024. `http://heasarc.gsfc.nasa.gov/docs/heasarc/caldb/docs/memos/cal_gen_92_024/cal_gen_92_024.html`

George, I.M. & Zellar, R., 1992. HEASARC Calibration Memo CAL/GEN/92-025.

George, I.M. & Zellar, R., 1992. HEASARC Calibration Memo CAL/GEN/92-026.

George, I.M. & Angelini, L., 1993. HEASARC Memo OGIP/93-013. `http://heasarc.gsfc.nasa.gov//docs/heasarc/ofwg/docs/general/ogip_93_013/ogip_93_013.html`

George, I.M. & Arnaud, K.A., 1993. HEASARC Calibration Memo CAL/GEN/92-002a (addendum to CAL/GEN/92-002a). `http://heasarc.gsfc.nasa.gov/docs/heasarc/caldb/docs/memos/cal_gen_92_002a/cal_gen_92_002a.html`

George, I.M. & Zellar, R., 1993. HEASARC Calibration Memo CAL/GEN/92-003.

http://heasarc.gsfc.nasa.gov/docs/heasarc/caldb/docs/memos/cal_gen_92_003/cal_gen_92_003.html

George, I.M. & Angelini, L., 1994. *Legacy*, **4**, in press (OGIP/93-001). http://heasarc.gsfc.nasa.gov/docs/heasarc/caldb/docs/memos/cal_gen_92_003/cal_gen_92_003.html

George, I.M., Arnaud, K.A., Pence, W. & Ruamsuwan, L., 1992. *Legacy*, **2**, 51. http://heasarc.gsfc.nasa.gov/docs/journal/calibration_rqmts2.html

George, I.M., Pence, W. & Zellar, R. 1993. HEASARC Calibration Memo CAL/GEN/92-008. http://heasarc.gsfc.nasa.gov/docs/heasarc/caldb/docs/memos/cal_gen_92_008/cal_gen_92_008.html

George, I.M., Zellar, R. & White, N.E., 1993. (CAL/GEN/92-013).

Zellar, R. & George, I.M., 1993. (CAL/GEN/92-017)

Most of the above references are also available via anonymous ftp from ftp://legacy.gsfc.nasa.gov/caldb/docs/memos

A DEFINED CCNM0001 VALUES

The value of the `CCNM0001` keyword provides the means for downstream software to check that a given calibration dataset is indeed what is required by the user, and as a pointer as to whether or not further calibration inputs are required for a given software task.

In the following section we provide a list of values for the `CCNM0001` keywords. This list will be updated as new values are defined.

A.1 Multi-Mission/Multi-Instrument Values of `CCNM0001`

These keyword values represent general properties which almost all X-ray missions and instruments share. These values appear in at least one file in the HEASARC CALDB.

A.1.1 CCNM0001 = 2D_PSF

Dataset contains a 2-dimensional mini-image of the point spread function, centered on the peak, and normalized to one detected photon.

A.1.2 CCNM0001 = COLLRESP

Collimator Response

A.1.3 CCNM0001 = DETEFF

Dataset is an n-dimensional grid giving the efficiency of the detector as a function of energy, position, and any other necessary parameters. The dimensions and contents are obviously highly detector-specific. Detailed file formats are given in CAL/GEN/92-025 (George & Zellar 1992).

A.1.4 CCNM0001 = DET_EFF

Deprecated; same as DETEFF

Table 3: Multi-mission Values of `CCNM0001` Currently in Use at the HEASARC CALDB

CCNM0001 value	**Description**	**see Section**
2D_PSF	2-dimensional Point Spread Function (Image)	A.1.1
COLLRESP	Collimator Response (potentially energy dependent)	A.1.2
DETEFF	Efficiency of Detector (only)	A.1.3
DET_EFF	Detector Efficiency	A.1.4
DETMAP	Detector Map	A.1.6
EBOUNDS	Redistribution Matrix Energy Boundaries	A.1.7
EEF	Encircled Energy Fraction Point Spread Function	A.1.5
EFFAREA	Effective Area of Optics (only) (may include on-axis values only)	A.1.8
ENERGY_GRID	Standard Energy grid used for calibration datasets	A.1.9
FATOM	Atomic data used for Filter transmission	A.1.10
FTRANS	Filter Transmission	A.1.11
HKCONV	Housekeeping data Conversion parameters	A.1.12
MATRIX	Redistribution Matrix	A.1.13
RPSF	Radial Profile Point Spread Function	A.1.14
SPECRESP	Spectral response	A.1.15
SPECRESP MATRIX	Redistribution & Spectral response Matrix	A.1.16
TVIGNET	Total Vignetting function of optics (*ie* with obscuration factor included)	A.1.17
VIGNET	Vignetting function (only) of optics (*ie* excluding obscuration factor)	A.1.18
WATOM	Atomic data used for Window transmission	A.1.10
WTRANS	Transmission of the detector/instrument window	A.1.11
XSECT	Atomic absorption Cross-sections	A.1.21

A.1.5 CCNM0001 = EEF

Dataset contains a (1-dimensional) encircled energy fraction profile of the the point spread function, constructed using concentric annuli centered on the peak.

A.1.6 CCNM0001 = DETMAP

Detector Map

A.1.7 CCNM0001 = EBOUNDS

Dataset is a 1-dimensional list (as a function of energy) listing the (nominal) energy boundaries for each raw detector PHA channel. Constructed from the associated Detector Redistribution Matrix, with the energies corresponding to the maxima in the matrix for the lower and upper channel boundaries (and thus defining the nominal gain (energy→channel) relationship).
Use: Spectral analysis of PHA data (in conjunction with an RMF containing `CCNM0001` = `'MATRIX'` dataset and an ARF containing a `CCNM0001` = `'SPECRESP'` dataset; or equivalently with an RMF containing a `CCNM0001` = `'SPECRESP MATRIX'` dataset).
Usual Origin: `EBOUNDS` extension within an RMF.
See CAL/GEN/92-002 (George *et al.* 1992) and its addendum, CAL/GEN/92-002a (George & Arnaud 1993).

A.1.8 CCNM0001 = EFFAREA

Dataset is a 3-dimensional grid giving the effective area of the instrument optics (only) as a function of energy, and off-axis position. For off-axis angles, any reduction in geometric area due to obscuration by the telescope structure and the effects of vignetting are assumed to be included. However, should there be `CBD`*nxxxx* keywords with values:
`'THETA(0.0)arcmin'`, and
`'PHI(0.0)arcmin'`,
the 3-d dimensional dataset will be assumed to have been collapsed to a 1-d list of **on-axis** effective area as a function energy. In such cases a `CCNM0001` = `'TVIGNET'` calibration dataset (or `CCNM0001` = `'VIGNET'` and `CCNM0001` = `'OBSCFACT'` datasets) will be assumed to be required to calculate an off-axis effective area. Detailed file formats are given in CAL/GEN/92-019 (George & Zellar 1992).

A.1.9 CCNM0001 = ENERGY_GRID

Contains the lower and upper boundaries to the standard incident energy grid used for many PSPC calibration files.

A.1.10 CCNM0001 = FATOM *or* WATOM

Data table consists of one or both of 2 (optional) calibration datasets:

1. the mass absorption coefficient of each chemical component within the filter/window as a function of energy
2. the effective thickness of each chemical component within the filter/window as a function of position.

Detailed file formats are given in CAL/GEN/92-023 (George & Zellar 1992).

A.1.11 CCNM0001 = FTRANS *or* WTRANS

Dataset is a 3-dimensional grid giving the transmission of a filter/window as a function of energy and position. Detailed file formats are given in CAL/GEN/92-024 (George & Zellar 1992).

A.1.12 CCNM0001 = HKCONV

Dataset is in a highly instrument-specific format, and contains information necessary to convert satellite housekeeping information to physical units.

A.1.13 CCNM0001 = MATRIX

Dataset is a 2-dimensional matrix (energy vs PHA channel) describing the redistribution of photons within a detector, constructed by folding together (only) the components due to the:

- Detector Gain (*ie* given the basic energy→channel relationship.
- Detector Energy Resolution (including escape peaks, partial charge tails *etc*)

Use: Spectral analysis of PHA data (in conjunction with an ARF containing `CCNM0001` = `'SPECRESP'` dataset).
Usual Origin: `MATRIX` extension within an RMF.
See CAL/GEN/92-002 (George *et al.* 1992) and its addendum, CAL/GEN/92-002a (George & Arnaud 1993).

A.1.14 CCNM0001 = RPSF

Dataset contains a (1-dimensional) radial profile of the the point spread function, constructed using concentric annuli centered on the peak. The dataset should be normalized to one detected photon and expressed in units of photons per (physical) unit area.

A.1.15 CCNM0001 = SPECRESP

Dataset is a 1-dimensional list (as a function of energy) containing the spectral response of an instrument (*ie* telescope + filter + detector) constructed by folding together the components due to:

- Effective Area of the Telescope/Collimator (including vignetting)
- Filter Transmission (if any)
- Detector Window Transmission
- Detector Efficiency
- any additional energy dependent effects (*eg* corrections due to the *psf*)

Use: Spectral analysis of PHA data (in conjunction with an RMF containing `CCNM0001` = `'MATRIX'` dataset).
Usual Origin: `'SPECRESP'` extension within an ARF.
See CAL/GEN/92-002 (George *et al.* 1992) and its addendum, CAL/GEN/92-002a (George & Arnaud 1993).

A.1.16 CCNM0001 = SPECRESP MATRIX

Dataset is a 2-dimensional matrix (energy vs PHA channel) describing the redistribution of photons within a detector **and** the energy response of the instrument (*ie* telescope + filter + detector). Constructed by folding together the components due to the:

- Detector Gain (*ie* given the basic energy→channel relationship.
- Detector Energy Resolution (including escape peaks, partial charge tails *etc*)
- Effective Area of the Telescope/Collimator (including vignetting)
- Filter Transmission (if any)
- Detector Window Transmission

- Detector Efficiency
- any additional energy dependent effects (*eg* corrections due to the *psf*)

(thus a combination of the information alternatively contained within CCNM0001 = 'MATRIX' and CCNM0001 = 'SPECRESP' datasets).
Use: Spectral analysis of PHA data.
Usual Origin: MATRIX extension within an RMF.
Generally not recommended.
See CAL/GEN/92-002 (George *et al.* 1992) and its addendum, CAL/GEN/92-002a (George & Arnaud 1993).

A.1.17 CCNM0001 = TVIGNET

Dataset is a 3-dimensional grid giving the total vignetting function (including the effects of obscuration) of the instrument optics (only) as a function of energy, and off-axis position. For use calculating the off-axis effective area, this dataset must be used in conjunction with on-axis data from a CCNM0001 = 'EFFAREA' calibration dataset. Detailed file formats are given in CAL/GEN/92-021 (George & Zellar 1992).

A.1.18 CCNM0001 = VIGNET

Dataset is a 3-dimensional grid giving the vignetting function of the instrument optics (only, excluding the effects of obscuration) as a function of energy, and off-axis position. For use calculating the off-axis effective area, this dataset must be used in conjunction with on-axis data from a CCNM0001 = 'EFFAREA' calibration dataset **and** with the relevant off-axis data from a CCNM0001 = 'OBSCFACT' calibration dataset. Detailed file formats are given in CAL/GEN/92-021 (George & Zellar 1992).

A.1.19 CCNM0001 = WATOM

Same as FATOM

A.1.20 CCNM0001 = WTRANS

Same as FTRANS

Table 4: Example `CCNM0001` values containing coordinate transformations

CCNM0001	**Coordinate Transformation**	
value	**from**	**to**
RAW2PHY	Raw Detector	Physical Detector
RAW2LIN	Raw Detector	Linearized Detector
PHY2ECL	Physical Detector	(Celestial) Ecliptic

A.1.21 CCNM0001 = XSECT

Dataset is a 2-dimensional grid listing the absorption cross-sections (or mass absorption coefficients) as a function of energy and element/compound which have been used during the construction of other calibration datasets.

A.1.22 CCNM0001 Values for Coordinate Transformations

The `CCNM0001` keyword is a string which explicitly describes the coordinate transform stored. Currently defined transformations are given in Table 4 (see also CAL/GEN/92-003, George & Zellar 1993, available on-line as postscript and html versions). It is strongly recommended that the transform is further described within the file via copious `COMMENT` lines. Detailed file formats of calibration files storing the necessary transformation information are described in HEASARC/92-016 (George & Yusaf 1992). The number and details of the coordinate transforms required is, of course, highly instrument-specific. It is recommended that usage of these keywords be confined to basic calibration file (`CCLS0001='BCF     '`) data only.

A.2 Proposed CCNM0001 values

The following values of CCNM00010001 have been proposed for use in calibration datasets in the HEASARC CALDB, but are not yet used by any archived dataset.

A.2.1 CCNM0001 = BADPIX

Dataset contains the location of all 'bad' pixels (*ie* those pixels from which the scientific data should be disregarding during scientific analysis), along with the date they went bad, and a flag to indicate the reason. Detailed file formats are given in CAL/GEN/92-026 (George & Zellar 1992).

A.2.2 CCNM0001 = BKGRND_EVTS

Dataset consists of a "standard event list" for that mission/instrument, but contains only background photons. Such a dataset can be analyzed in the same way as a "source event list" so as to obtain the corresponding background lightcurve/spectrum/image *etc*

A.2.3 CCNM0001 = BKGRND_EVTS_DARKEARTH

Dataset consists of a "standard event list" for that mission/instrument, but contains only background photons WITHOUT inclusion of cosmic ("sky") background events (as, for example, a dataset compiled by staring at the dark earth). Such a dataset can be analyzed in the same way as a "source event list" so as to obtain the corresponding background lightcurve/spectrum/image *etc*,

A.2.4 CCNM0001 = BKGRND_EVTS_BRIGHTEARTH

Dataset consists of a "standard event list" for that mission/instrument, but contains only background photons compiled by staring at the bright earth. Such a dataset can be analyzed in the same way as a "source event list" so as to obtain the corresponding background lightcurve/spectrum/image *etc*,

A.2.5 CCNM0001 = DETMSK

Dataset is 2-dimensional listing the unobscured regions of an imaging detector.

Table 5: Proposed List of MULTI-MISSION Values for `CCNM0001`

CCNM0001 value	**Description**	**see Section**
Proposed Multi-mission Values		
BADPIX	Bad Pixel map	A.2.1
BKGRND_EVTS	Background events dataset	A.2.2
DETMSK	Detector Mask	A.2.5
DET_ENRES	Detector Energy resolution	A.2.6
DET_GAIN	Detector Gain	A.2.7
DET_POSCORR	Detector Position corrections	A.2.8
DET_POSRES	Detector Position resolution	A.2.9
OBSCFACT	Obscuration Factor of the optics (*ie* the geometric vignetting factor only)	A.2.10
TEMP	(Detector) Temperature History	A.2.11

A.2.6 CCNM0001 = DET_ENRES

Dataset contains the energy resolution of the detector as a function of energy. The format and details of precisely what values are stored are considered detector-specific

A.2.7 CCNM0001 = DET_GAIN

Dataset contains the gain of the detector. The format and details of precisely what values are stored are considered detector-specific

A.2.8 CCNM0001 = DET_POSCORR

Dataset contains correction factors and/or offsets such as to correct the detected positions of events to a 'standard' grid in the detector coordinate system. The format and details of precisely what values are stored are considered detector-specific

A.2.9 CCNM0001 = DET_POSRES

Dataset contains the position resolution of the detector. The format and details of precisely what values are stored are considered detector-specific

A.2.10 CCNM0001 = OBSCFACT

Dataset is a 2-dimensional grid giving the **geometrical** obscuration factor (also sometime referred to as the geometric vignetting function or collimator response) of the optics/collimator as a function of off-axis position. For use calculating the total vignetting function, this dataset must be used in conjunction with a `CCNM0001 = 'VIGNET'` calibration dataset. This dataset is assumed to have already have been included in `CCNM0001 = 'TVIGNET'` and `CCNM0001 = EFFAREA` datasets (unless the latter is applicable on-axis only – see Section A.1.8). Detailed file formats are given in CAL/GEN/92-019 (George & Zellar 1992).

A.2.11 CCNM0001 = TEMP

Dataset is a simple list of (detector) temperature vs time.

A.3 Mission/Instrument Specific Values of `CCNM0001`

The following values of `CCNM0001` represent calibration data which are instrument or mission specific, and have been defined at the request of the individual project.

A.3.1 CCNM0001 = ASCALIN

This is a **non-standard** codename, only used for the ASCA/SIS. It is used in the *ASCA* Telescope Definition File. Created 1993 Jun 07 (Eric Gotthelf, ASCA GOF, NASA/GSFC). This SIS telescope definition file defines the detector address space along with the transformation needed to reconstruct the focal plane location of the individual SIS CCD chips. Further data parameterizes the telescope optics and boresight alignment. All data is contained within the keywords of the Primary Header. There is no data in the Primary Array.

A.3.2 CCNM0001 = ASCALIN_FLF

This is a **non-standard** codename, only used for the ASCA/GIS.

A.3.3 CCNM0001 = ASCALIN_POW2

This is a **non-standard** codename, only used for the ASCA/GIS. It represent GIS raw to linearized coordinate transformation maps.

A.3.4 CCNM0001 = EDS_COR

XTE/PCA EDS gain corrections

A.3.5 CCNM0001 = GRIDTRNS

This is a **non-standard** codename, only used for the ASCA/GIS. It represents the transmission for the GIS2 window grid

A.3.6 CCNM0001 = PART_BKGD_MAP_AP

After-pulse Detector background map for the ROSAT PSPC.

Table 7: MISSION-SPECIFIC Values of CCNM0001 used at the HEASARC CALDB

CCNM0001 value	Description	see Section
Mission/Instrument-specific Values		
ASCALIN	ASCA/SIS Telescope Definition File	A.3.1
ASCALIN_FLF	ASCA/GIS Unknown	A.3.2
ASCALIN_POW2	ASCA/GIS Unknown	A.3.3
EDS_COR	XTE/PCA EDS gain corrections	A.3.4
GRIDTRNS	ASCA/GIS Unknown	A.3.5
PART_BKGD_MAP_AP	ROSAT/PSPC After-pulse contribution to background	A.3.6
PART_BKGD_MAP_EXT	ROSAT/PSPC External contribution to Background	A.3.7
PART_BKGD_MAP_INT	ROSAT/PSPC Internal contribution to Background	A.3.8
RTIBOUNDS	ASCA/GIS Unknown	A.3.9
SGC_E	ROSAT/PSPC Spatial Gain correction, E-dependent terms	A.3.10
SGC_POS	ROSAT/PSPC Spatial Gain correction, position-dependent terms	A.3.11
WC_E	ROSAT/PSPC Window Correction, E-dependent terms	A.3.13
WC_POS_X	ROSAT/PSPC Window Correction, X-dependent terms	A.3.14
WC_POS_Y	ROSAT/PSPC Window Correction, Y-dependent terms	A.3.15
WINTHICK	ASCA/GIS Unknown	A.3.12

Notes by Steve Snowden (02/03/94): Created using as many afterpulse events as could be isolate using strongly affected pointed observations and the survey completion data. This detector map is for the afterpulse background component of PSPC B

A.3.7 CCNM0001 = PART_BKGD_MAP_EXT

ROSAT PSPC external particle background detector map. Notes by Steve Snowden (02/03/94): Created using a devignetted detector map. This detector map is for the externally produced particle background component for both PSPCs.

A.3.8 CCNM0001 = PART_BKGD_MAP_INT

ROSAT PSPC Internal particle background detector map. Notes by Steve Snowden (02/03/94): Created using the particle background calibration of Plucinsky et al. 1993, ApJ, 418, 519 This detector map is for the internally produced particle background component for the PSPC B.

A.3.9 CCNM0001 = RTIBOUNDS

This is a **non-standard** codename, only used for the ASCA/GIS. This type of file should be used to reject GIS background events based on their invariant rise-time (RTI) values. (RTI values are RT values which have been corrected for any intrinsic position dependent fluctuations by the GISLIN task.) Therefore, this file should only be applied to corrected science extension data.

A.3.10 CCNM0001 = SGC_E

ROSAT PSPC Spatial Gain Correction: Energy-dependent term. Notes from J. Turner, 1995 Oct 06: This dataset was converted to FITS format by Rehana Yusaf (FTOOLS) from the ASCII file GNAMPL_NEW.DAT used by SASS.

The dataset is used to correct for small-scale non-linearities which are introduced into the positions assigned to PSPC events by the detector wires. This dataset contains the energy-dependent correction vector, stored as a function of intermediate pulse-height (PH_3) in column SGC_HF_E. This dataset is assumed to be valid for both PSPCs. It should be noted that further vectors, which are a function of position (only), are also required to correct the position of each event for these electronic effects. Furthermore, an additional correction due to the bulging of the detector window must be performed on the position of each event before totally linearized detector coordinates are obtained. Finally it should be noted that PH_3 is NEITHER observed PHA channel NOR derived PI channel, but is instead a partially corrected pulse-height bin. See HEASARC Calibration Memo CAL/ROS/95-010 for further details

A.3.11 CCNM0001 = SGC_POS

ROSAT PSPCB Spatial Gain Correction: Position-dependent terms. NOTES from J. Turner, 1995 Oct 06: This dataset was converted to FITS format by Rehana Yusaf (FTOOLS) from the ASCII file GAIN_KOR3_B.DAT used by SASS.The dataset is used to correct for small-scale non-linearities which are introduced into the positions assigned to PSPC events by the detector wires. This dataset contains the two position-dependent correction vectors, stored in columns SGC_LF_Y & SGC_HF_Y, both of which vary as a function of position (stored in column Y_1). It should be noted that a further vector, which is a function of pulse height (only), is also required to correct the position of each event for these electronic effects. Furthermore, an additional correction due to the bulging of the detector window must be performed on the position of each event before totally linearized detector coordinates are obtained. See HEASARC Calibration Memo CAL/ROS/95-010 for further details

A.3.12 CCNM0001 = WINTHICK

This is a **non-standard** codename, only used for the ASCA/GIS. Data of this type represents the spatial variation of thickness in GIS2 Be window

A.3.13 CCNM0001 = WC_E

ROSAT PSPC Window Correction: Energy-dependent correction term.

A.3.14 CCNM0001 = WC_POS_X

ROSAT/PSPC Window Correction, X-dependent terms

A.3.15 CCNM0001 = WC_POS_Y

ROSAT/PSPC Window Correction, Y-dependent terms

B THE CALIBRATION BOUNDARY KEYWORDS

The calibration boundary keywords provide a means of specifying the limitations or parameter boundaries of a calibration dataset (*eg* the energy range, range of spatial coordinates, range of temperatures, range of HV settings *etc* over which the dataset is valid) which the author of the dataset would like to indicate to downstream software.

B.1 Naming scheme for the boundary keywords

The calibration boundary keywords are named `CBD`$nxxxx$ where $xxxx$ is the calibration dataset within that extension (as described above), and n is an integer index in the range 1–9 specifying the boundary reference number[1]. Thus the limits on each calibration dataset within an extension can be denoted via the keywords `CBD1`$xxxx$, `CBD2`$xxxx$, `CBD3`$xxxx$, ..., `CBD9`$xxxx$.

The ordering of the various strings is not crucial (*ie* which parameter limitations is specified by `CDB1`$xxxx$, which by `CDB2`$xxxx$ *etc* is not crucial), although the values of n within the `CBD`$nxxxx$ keywords **must be sequential starting at 1**. However, when checking for any limitations on a given parameter the (CIF) access software will first check the string stored in `CDB1`$xxxx$, then `CDB2`$xxxx$ *etc*, thus it an advantage to store the most important limitations (from the point of view of downstream software) first.

B.2 Number of keywords

By default the CALDB software can accomodate up to **nine** of these keywords.

B.3 CBD Keyword Values

B.3.1 NULL Values

The `CDBn`$xxxx$ keywords are optional. It is sometimes convenient for software which writes calibration FITS files to include all 9 CBD keywords all FITS headers. In such cases unused boundary keywords should be filled with the NULL boundary value. For boundary keywords the NULL value is represented with the string "NONE", for example:

```
CBD20000 = 'NONE ' / only a single boundary keywords exists
CBD30000 = 'NONE ' / only a single boundary keywords exists
```

[1] It is anticipated that a maximum of 9 will be easily sufficient for all calibration datasets, though an extension making n a hexadecimal number is possible if this is not the case (however this is not implemented at the time of writing).

```
CBD40000 = 'NONE ' / only a single boundary keywords exists
CBD50000 = 'NONE ' / only a single boundary keywords exists
CBD60000 = 'NONE ' / only a single boundary keywords exists
CBD70000 = 'NONE ' / only a single boundary keywords exists
CBD80000 = 'NONE ' / only a single boundary keywords exists
CBD90000 = 'NONE ' / only a single boundary keywords exists
```

Important Note: while the order of calibration keywords is in general unimportant, for NULL value keywords order is important in that, if the first calibration keyword has a null value (i.e. `CBD10000 = 'NONE'`) all other keyword values will be ignored.

B.3.2 Syntax of the CBD*nxxxx* boundary keywords

The value of each `CBD`*nxxxx* keyword is a character string which refers to a different dimension of parameter space, and has the following format:

$$\texttt{CBD}nxxxx =' expr(VALDES1, VALDES2, ..., VALDESj)units' \qquad (1)$$

where *expr* is a special character string describing the boundary parameter, $VALDESj$ is the $j^{\rm th}$ value descriptor specifying the set of values for which the parameter is valid, and *units* is the physical units of $VALDESj$. The allowed values of *expr* are listed in Section B.4, and the allowed values of the *units* string are as for the `TUNITS`*n* keyword and summarized in OGIP/93-001 (George & Angelini 1994).

Each of the value descriptors, $VALDESj$, can have four possible forms, any of which can be included/combined in the same `CBD`*nxxxx* keyword value:

1. $VALDESj = m.n$
   representing a single real number, $m.n$, for which the boundary parameter is valid. Only a single integer m need to specified in the case of an integer boundary value.
2. $VALDESj = minval : maxval$ or $VALDESj = minval - maxval$ representing a range of continuous values between *minval* and *maxval* (where *minval* and *maxval* both have the form $m.n$ given above) for which the boundary parameter is valid.
3. $VALDESj = cstr$
   representing a single character string, *cstr* for which the(character) boundary parameter is valid. In this syntax, double quotes (`"`) can be included as the first and last characters of *cstr* to force a value to be interpreted as a string. The double quotes are **required** if *cstr* would otherwise be interpreted as either a single integer/real or as a ranges of integers/reals.
4. $VALDESj = BOOLEAN$
   representing a single character string, either T or F representing the boolean value "true" or "false", respectively. This syntax is useful is the data is only valid when a certain indicator or status flag (for eg. high voltage "on" status) is true.

Examples of these formats are given below.

B.3.3 Examples

1. `CBD`$nxxxx$ = `'THETA(0,5)deg'`
   indicates that the dataset is valid for the parameter `THETA` at 0.0 degrees and at 5.0 degrees, but is **NOT** valid for the range 0.0 < `THETA` < 5.0 degrees.
   `'THETA(0.0,5.0)deg'`, `'THETA(0.0,5)deg'`, `'THETA(0,5.0)deg'` are equivalent.

2. `CBD`$nxxxx$ = `'THETA(0-5)deg'`
   indicates that the dataset is valid for all values of the parameter `THETA` in the range 0.0 ≤ `THETA` ≤ 5.0 degrees.
   `'THETA(0.0-5.0)deg'`, `'THETA(0.0-5)deg'`, `'THETA(0-5.0)deg'` are equivalent.

3. `CBD`$nxxxx$ = `'PARAM(LOW,HIGH)'`
   indicates that the dataset is valid for values of the parameter `PARAM` equal to 'LOW' or 'HIGH', but is **NOT** valid for any other values such as (say) 'MEDIUM'.
   `'PARAM("LOW",HIGH)'`, `'PARAM(LOW,"HIGH")'` `'PARAM("LOW","HIGH")'` are equivalent.

4. `CBD`$nxxxx$ = `'GRADE("0234")'`
   indicates that the dataset is valid for values of the character-string parameter `GRADE` equal to the character string value '0234' (only) Here the double quotes are required. Without them, the dataset would be incorrectly interpreted as valid for `GRADE`=234.0.

5. `CBD`$nxxxx$ = `'PARAM("0234",0,2-4)'`
   demonstrates a combination of the above $VALDESj$ types within a single CBD$nxxxx$ keyword. The example indicates that a dataset is valid for the parameter `PARAM` equal to the string `'0234'`, but also valid for `PARAM`=0.0 and 2.0 ≤ `PARAM` ≤ 4.0. While allowed, no requirement for a mixing of strings & numerical values has yet been encountered and is therefore **strongly discouraged**.

6. `CBD`$nxxxx$ = `'HIGH_VOLTAGE_STATUS(T)'`
   indicates that the dataset is only valid if the high voltage status is TRUE

B.4 Allowed formats of *expr*

Currently only the simplest type of parameter expression is supported, namely a format in which the *expr* string is simply the name of a parameter, *pname*, denoting that the calibration dataset is valid for parameter *pname* values between *min* and *max* (in units given by *units*). The allowed values of the *pname* string are as for the standard column/keyword names listed in CAL/GEN/92-003 (George & Zellar 1993, available on-line as pdf and html versions). Those defined at the time of writing are also listed in Table 8 for convenience.

<u>Example</u>
A calibration dataset, which was the only such dataset within the extension (hence had $xxxx$ =

Table 8: Example *pname* values for the CBD*nxxxx* keyword

pname **string**	**Parameter**	**Type of Units**
Spatial Coordinates		
RAWX	Raw detector coordinates in a cartesian frame	*(detector specific)*
RAWY	Raw detector coordinates in a cartesian frame	*(detector specific)*
DETX	Linearized detector coordinates in a cartesian frame	*(detector specific)*
DETY	Linearized detector coordinates in a cartesian frame	*(detector specific)*
PHYX	Physical detector coordinates in a cartesian frame	physical linear
PHYY	Physical detector coordinates in a cartesian frame	physical linear
THETA	Off-axis angle (θ) in XMA polar coordinate frame	angular
PHI	Azimuthal angle (ϕ) in XMA polar coordinate frame	angular
ALPHA	Off-set angle in image plane from XMA optical axis (along $\phi = 0°$ vector)	angular
BETA	Off-set angle in image plane from XMA optical axis (along $\phi = 90°$ vector)	angular
Other (multi-mission) Parameters		
CHAN	(Detector) ADC channel	unitless
ENERG	Photon energy	physical
HV	(Detector) High Voltage	physical
MODE	(Detector) Operating Mode	unitless
PANG	Pair Opening Angle	angular
PICH	Pulse Invariant detector channel	unitless
TEMP	(Detector) Temperature	physical
Mission/Instrument-specific Parameters		
ECHO	ASCA/SIS 'echo correction' applied/not-applied	unitless
GRADE	ASCA/SIS photon 'grade'	unitless
SPLIT	ASCA/SIS split threshold	unitless

0001), and which was valid for photon energies in the range 0.501–2.0 keV, off-axis angles in the range 0–54.2 arcmin, and all azimuthal angles (0–360°) would have

```
CBD10001 = 'ENERG(0.501-2)keV'
CBD20001 = 'THET(0-54.2)arcmin'
CBD30001 = 'PHI(0-360)deg'
```

A calibration dataset, which was the only such dataset within the extension (hence had $xxxx =$ 0001), and which was valid for photon energies in the range 1 eV – 10 MeV, an off-axis angle 5.4 arcmin (only), and azimuthal angles 0–90° and 180°–270° (but nowhere else) would have

```
CBD10001 = 'ENERG(1-10000000)eV'
CBD20001 = 'THETA(5.4)arcmin'
CBD30001 = 'PHI(0-90,180-270)deg'
```

B.5 The Number of Limitations Required

The number of parameter-space limitations (*ie* CBD$nxxxx$ keywords) required for a given calibration dataset depends upon the dataset itself, the characteristics of the specific instrument to which it refers, and the likelihood that other ($Qual = 0$) datasets with the same CCNM$xxxx$ codename will ever exist in the archive at any time.

The following two detailed examples should help illustrate this point:

Example 1:
Consider an imaging instrument for which one requires to store a series of point-spread-function *psf* calibration datasets for various off-axis positions in the form of radial-profiles. However, it is known (or suspected) that the *psf* is a function of energy, yet the energy dependency has not (yet) been adequately parameterized such that the datasets can be stored as a virtual calibration file and standalone software task). One therefore wishes to store radial profiles appropriate for several 'standard' energy ranges (*eg* in the 3 bands 0–1 keV, 1–2 keV & 3–3.5 keV) in separate files. Each file would have the identical value of the CCNM0001 keyword, namely CCNM0001 = 'R_PSF ' (Section A.1.14). In order to allow the CALDB software to distinguish between the 3 files, each file header would have a unique value of the CBD10001 keyword, such as:

```
CCNM0001 = 'R_PSF      ' / radial point spread function
CBD10001 = 'ENERG(0-1)keV ' / energy range appropriate to this rspf
```

for file 1,

```
CCNM0001 = 'R_PSF      ' / radial point spread function
CBD10001 = 'ENERG(1-2)keV ' / energy range appropriate to this rspf
```

for file 2, and

```
CCNM0001 = 'R_PSF      ' / radial point spread function
CBD10001 = 'ENERG(3-3.5)keV ' / energy range appropriate to this rspf
```

for file 3.

Example 2:
Continuing from the above example, consider now that it is suspected that the *psf* may also be a function of detector temperature. If the above datasets were obtained at a detector temperature of 273 K, each file could contain the header keyword `CBD20001` ='`TEMP(273)K `' in order to document the detector temperature at which the information in the file is appropriate.

Clearly the hardware and GOF teams will have the best idea as to which parameter boundaries are necessary for a given dataset, and thus the specification of of the necessary `CBD`*nxxxx* keyword values is primarily their responsibility. However, these teams are encouraged to refer to pre-existing calibration datasets within the CALDB and to the requirements of downstream software tasks prior to delivery to the HEASARC.