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GFZ Section 2.3

CHAMP: Overview of Final ME Products and Format Description

Scientific Technical Report STR19/10 – Data

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CHAMP: Overview of Final ME Products and Format Description

GFZ Section 2.3

November 11, 2019

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1. Introduction

This text describes the content of the data files with the final public magnetic field time series derived from measurements by the satellite CHAMP from 2000 until 2010 – or of important associated data.

1.1. Document structure

1. After this intro follows a brief general description of the CHAMP satellite mission, the relevant instrumentation and the type of data gathered. The four products described here are derivatives of only a small subset of the CHAMP data, connected to magnetic and electric field time series.
2. For the products in the focus of this document, the data types, the used file formats and the directory structure of the *public* data are outlined.
3. The third and final part of this document is an appendix, where some older, canonical documents are collected. These texts and tables partly served as data descriptions or READMEs already during the mission phase of CHAMP or were accompanied with delivered data sets. These documents are presented here in the appendix, so far as there are still applicable, mostly unchanged. The technical description of the final Level-3 1 Hz magnetic field product is more detailed than the ones for the other products.

1.2. Acronyms and miscellaneous definitions

Name	Description
CHAMP	CHAllenging Minisatellite Payload
FGM	Instrumentation on CHAMP : FluxGate Magnetometer
ISDC	Information System and Data Center, GFZ
ME	Magnetic/Electric Field(s)
NEC	Earth Centered Earth Fixed reference frame, North-East-Centre
OVM	Instrumentation on CHAMP , Overhauser magnetometer
PLP	Instrumentation on CHAMP , Planar Langmuir Probe
ASC	Advanced Stellar Compass
PLPT	Name-id of a data set using Planar Langmuir Probe data, but with Temperatures included
SCI	SCIence data
CDF	Common Data Format, by NASA, see https://cdf.gsfc.nasa.gov/
MJD	Modified Julian Day, a floating point number number used at least for the CHAMP and Swarm satellite missions
ISDC	Information System and Data Center, GFZ, Global Earth Science Data

Table1: List of acronyms

1.3. Times, Positions and Systems

- MJD (Modified Julian Day) is a time representation used in several ESA and other satellite missions. It can be taken as the time distance to the beginning of the year 2000.0 in floating point days. Unlike the standard JD (Julian Date) day counter, this MJD day is starting at midnight. See in the Swarm Documentation SW-HB-DTU-GS-0001, Section 3.3, Standards and Conventions.

- Epoch: Internal standard time representation for the CDF format used for the time series in CHAMP CDF files. It has a precision down to milliseconds, which is sufficient for the ME products. CDF-internally it is stored as the milliseconds passed since a given epoch.
- Positions: The positions, if given in the products, i.e. radius (or altitude), longitude and latitude, are given in a mere spherical, geocentric coordinate system, not in a geodetic one. Subsequently the reference level for *altitude* is not an ellipsoid or such, but just a reference sphere with the (in geomagnetic context) common radius of 6371.2 km. The latitude and longitude are angles in floating point degrees, radius and altitude are given in km.
- Coordinate Systems: There is a distinction between two flavours of reference systems:
  1. The physical coordinate systems, like the celestial frame (Conventional Celestial Reference System, CRS, i.e. J2000) or the Conventional Terrestrial Reference Systems (TRS) or the derived local systems like the North-East-Center system in a TRS system.
  2. The more technical, arbitrary satellite related coordinate systems, like a common satellite body-fixed system, or a synthetic system created for the optical bench using and combining the ASC attitude signals, or the individual reference frames of the measuring sensors (i.e. the FGM sensor), if applicable. This sensor systems are usually important for the instrument specific in-flight calibration of the readings. See the designations in the description of the Variables for the Level 3 Mag product for example.

2. CHAMP

CHAMP (CHAllenging Minisatellite Payload) was a German small satellite mission for geoscientific and atmospheric research and applications, managed by GFZ . With its highly precise, multifunctional and complementary payload elements (magnetometer, accelerometer, star sensor, GPS receiver, laser retro reflector, ion drift meter) and its orbit characteristics (near polar, low altitude, long duration) CHAMP generated highly precise gravity and magnetic field measurements simultaneously for the first time and over a 10 years period. The measurements include both the spatial and temporal variations of the two fields. The CHAMP mission has opened a new era in geopotential research and has become a significant contributor to the International Decade of Geopotential Research. With the satellite CHAMP launched by a Russian COSMOS launch vehicle on July 15, 2000 and an initial altitude of 454 km, the mission ended on September 19 2010, after ten years, two month and four days, or after 58277 orbits.[1]

For further information please see the CHAMP website at GFZ (https://www.gfz-potsdam.de/champ/) and the technical references and technical documentations indicated in sections 4.1 and 4.2.

2.1. Instrumentation

CHAMP products are categorised by the area of interest (here ME, *magnetic and electric fields*). In focus are data like FGM and MAG for magnetic field readings, ASC for related and used attitude information from the star camera on the boom and PLP data from the *Planar Langmuir Probe*, here named as PLPT, because processed electron temperature data are merged in (see Rother et al., 2010). The instruments dedicated for orbit determination and analyses of gravitational potential are not mentioned further.

[1] Mostly cited from the old CHAMP website.

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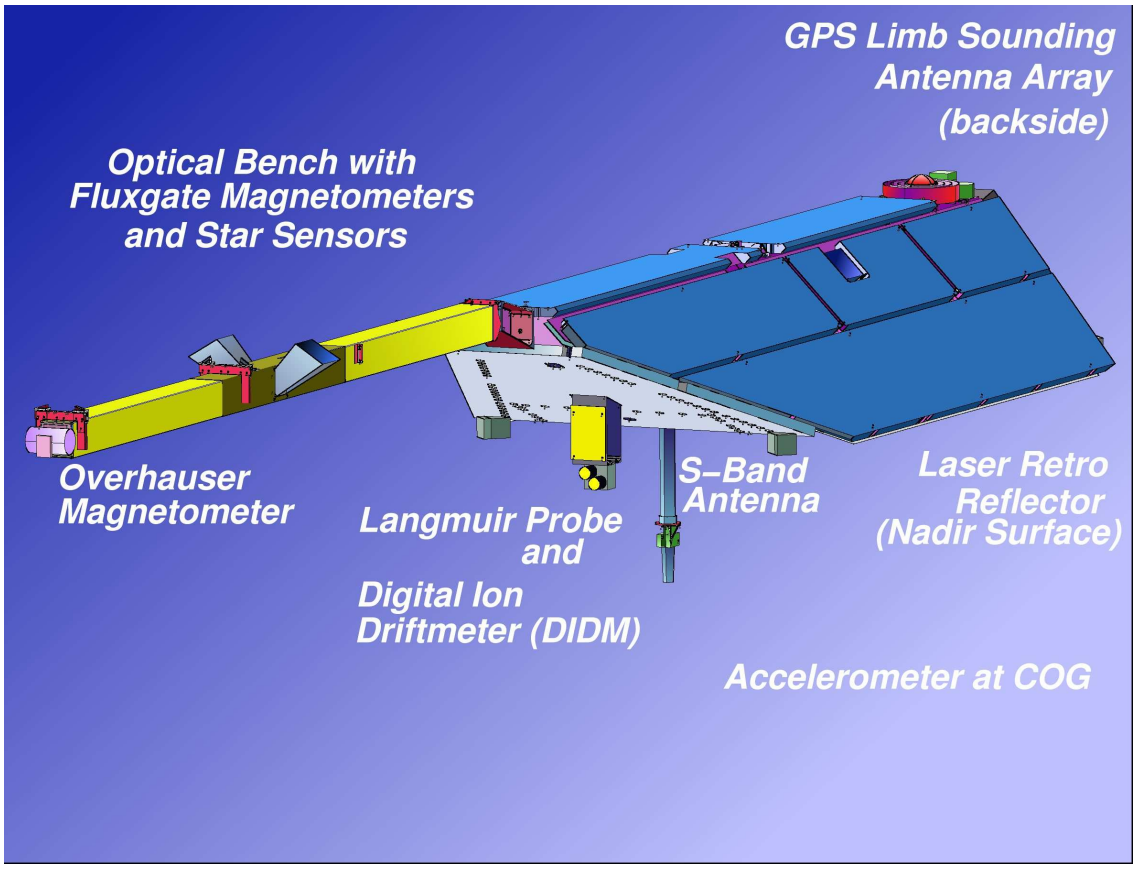

The most significant data sources for the products described are:

Overhauser Magnetometer OVM: Scalar magnetometer installed at the tip of the CHAMP boom (Figure 1). The available sampling rate is 1 Hz, the time coverage of the data is expected to be nearly perfect. As an instrument to measure the absolute intensity of the magnetic field (without instrument specific or temperature dependencies) it is needed in particular for the in-flight calibration of the vector magnetic field instruments.

Star Sensors ASC: Two pairs of advanced star sensors, one pair inserted on top of the body, the other pair mounted on an optical bench at CHAMP 's boom (Figure 1). The pairing of the sensors is intended to supply redundancy against dazzling by the sun or the moon. The quality of the available attitude information is best in periods, where both sensors of a pair are not blinded and delivering mergeable attitude information. The nominal sampling rate is 1 Hz.

Fluxgate Magnetometer FGM: Two vector magnetometer mounted together with the ASC sensors on the optical bench of the boom (Figure 1). The FGM sensor is able to gather magnetic field vectors by a much higher frequency than the scalar magnetometer OVM or the ASC instrument. The internal maximal sampling rate was 50 Hz. For in-flight calibration and in scientific standard products 1 Hz averages were used.

Planar Langmuir Probe (PLP): The Langmuir Probe, mounted at the front of the CHAMP satellite on the Digital Ion Drift (DIDM) Meter (Figure 1), is heading in nominal flight direction and is able to measure satellite potential, the electron density of the environment and the electron temperature. The period between usable readings is expected to be 15 s.

2.2. Data

There is a distinction between magnetic field readings and related formats on one hand and the ones for star camera data (ASC) and data from the Planar Langmuir Probe (PLP) on the other. The Level 3 data are intended be finally corrected data, focusing on the internal consistency. Level 2 data are calibrated and corrected time series as well, but more limited on one dedicated instrument.

Product Identifier	Level	**Source**	Comment
CH-ME-3-MAG	3	FGM, OVM, ASC	Combined magnetic field time series
CH-ME-3-ASC-BOOM	3	ASC	Processed, cleaned quaternions describing the satellite attitude
CH-ME-2-FGM-SCI	2	FGM, ASC	Vector magnetic field in NEC and sensor FGM-system in unaveraged 50 Hz time resolution
CH-ME-2-PLPT	2	PLP	Electron Density and Temperature

Table 2: Product overview.

The ASC (CH-ME-3-ASC-BOOM) and PLP (CH-ME-2-PLPT) data product are ASCII files, while the magnetic field readings are in a binary format (CDF), a usual distribution format for magnetic field readings from LEO satellite missions. The reading efficiency, flexibility and the possibility to embed all information and data attributes may be paid by some programming overhead required. Several data processing environments like Python, Matlab or IDL provide tools for accessing CDF-files.

During and after the CHAMP mission various versions of the time series (ASC and magnetic field) were produced and used in the scientific community, in particular of the 1 Hz magnetic field readings. These were accessible via the ISDC (Information System and Data Center), a dedicated data portal at GFZ. The ISDC was transferred from the old system to a combination of an FTP-server (data access) with front-end (https://isdc.gfz-potsdam.de/). The public data sets accessible via the new ISDC, as described in this document, in particular CH-ME-3-MAG, are intended to supersede all former versions. The old ISDC-server with the previous versions will not be longer available.

In this document we describe Level 2 and 3 data products indicated in Table 2: these levels denominate different stages of calibration, finalisation and averaging/merging. In particular the MAG Level 3 product CH ME 3 MAG is the time series data product for the magnetic field readings and intended to be the fully and final corrected ME data set in 1 Hz time resolution to be used by most of the scientific community.

In particular for external field studies, 50 Hz magnetic field readings are available as FGM-SCI Level 2 files. In this product, all floating values values are given as DOUBLE to have a homogeneous data representation. Subsequently the size of a single, daily FGM-SCI 50 Hz file is of about 300 MByte.

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3. Formats and Directory Layout

The fact of the disparate formats of the data is mainly caused by historical decisions and customs.

This document, in particular the parts in the appendix, is a collection of existing descriptions, which may had accompanied the data for quite a while. For the products in CDF format, the CDF skeleton representations, a technical, but exhaustive CDF related description of the products internal structure, are given as well. (See Sections A.3.3 and A.1.3.)

3.1. CDF Files

The specific format of the files for the magnetic field readings may not need any description here, as these files are in CDF (Common Data Format) and are intended to be self-describing. CDF is a binary format with a set of library functions for efficient access. As maintained by NASA, CDF is used in the solar, satellite, space physics and astronomical community. Users are referred to the CDF homepage http://cdf.gsfc.nasa.gov/ and particularly the FAQ at http://cdf.gsfc.nasa.gov/html/FAQ.html for more information on the format.

For accessing the CHAMP CDF data, a working CDF installation is required. The software is known to be compatible with all relevant platforms. An installed CDF package offers a set of ready-to-use *tool-kits*, which allow browsing inside the CDF files as well as an interactive extraction of selected data and even limited modification. Accessing the CDF library functions directly in the user's own programs will grant the highest efficiency and flexibility. Some common interpreter languages such as Matlab, Python and IDL also support access to CDF files with easy-to-use interfaces. From the beginning the CHAMP data were created with the older CDF version 2.6.7, as it was intended to use the same CDF library version for all CHAMP ME data. Newer versions of the CDF library claim to be backward compatible to earlier versions, but there may be some minor quirks.

In contrast to this tradition, the Level-2 FGM-SCI-NEC have been produced with CDF version 3.3.0. This Level 2 50 Hz FGM-SCI data are (loss-less) compressed internally to significantly reduce the file-size. This should be transparent for the users accessing the files directly or indirectly via processing software by the CDF library, but the size-reduction is paid by an increased time required for reading.

This text gives first an overview of the content of the data file types (see Appendix 4.2), in a CDF-format case followed by the CDF Skeleton, a CDF-internal, complete technical description of the CDF file layout.

In the CH-ME-FGM-SCI case only a short tabulated overview is given; the valid format description is the CDF skeleton text!

Pleas keep in mind: For the uncompressing of the data during access with the CDF library functions you may need writing access on the data file location or your working directory.

3.2. ASCII Listings

The (old but still valid) description of the ASCII file type CH-ME-3-ASC-BOOM is provided in Appendix reproduced in the appendix A.2.2. The used data format for the ASC-data is a non-standard ASCII list format without fully regular white-spaced delimited columns, but still divided in a descriptive header and in a data record section.

The CH-ME-2-PLPT product shows simple ASCII listing layout. A hash (#)-indicated readable header is followed by a data body. The body is a listing with regularly formatted white-space delimited columns.

3.3. Directory Layout

The data sets available in the corresponding `ME` subdirectory on the FTP server of the new ISDC are splitted into Level-2 and Level-3 data, not by the sensors). The four products (see Table 2) are given in daily files, the files are grouped by years in accordingly named directories.

```
champ
   |
   +--- ME
        |
        +---Level2
        |   |
        |   +---NEC-SCI
        |   |   |
        |   |   +---<years>
        |   |       |
        |   |       +---<daily-files>
        |   +---PLPT
        |       |
        |       +---<years>
        |           |
        |           +---<daily-files>
        +---Level3
            |
            +---ASC-BOOM
            |   |
            |   +---<years>
            |       |
            |       +---<daily-files>
            |
            +---MAG
                |
                +---<years>
                    |
                    +---<daily-files>
```

4. Further Documentation and References

4.1. References

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A. More Detailed Descriptions

A.1. Level 3 Final Magnetic Field Time Series

A.1.1. Name identifier

The identifier of this data type in the product file name is `CH-ME-3-MAG`.

A.1.2. Description

The following description is included here from a plain ASCII file, which had served as a description of the final MAG Level 3 product file and partly accompanied the data. It is embedded here literally and unchanged, with it's own, unrelated section numbering.

```
   Format description of CHAMP L3 MAG data files
-------------------------------------------------

   Helmholtz Centre Potsdam
   GFZ German Research Centre For Geosciences
   Section 2.3, Earth's Magnetic Field


   Jan Rauberg,
   Ingo Michaelis,
   Martin Rother,
   Hermann Luehr.

   24 March 2014.

   Text Version 1.03



1. INTRODUCTION
---------------

This  text briefly describes  the content  of the  data files  that contain
magnetic field time series measured by the satellite CHAMP from 2000 until
2010.  Described are  the so-called  Level 3  data files,  the  final data
product,  and  the  fully  corrected  (and  for the  time  being  the  best
available) data set.

The specific format of the files itself does not need any description here,
as the files are all in CDF  (Common Data Format).  This is a binary format
with a set  of library functions for efficient  access. Maintained by NASA,
they  are used  in the  solar,  satellite, space  physics and  astronomical
community.     Users     are     referred     to     the     CDF     homepage
'http://cdf.gsfc.nasa.gov/'       and       particularly       the       FAQ
'http://cdf.gsfc.nasa.gov/html/FAQ.html'  for  general  information.  For
accessing the  CHAMP L3 CDF data,  a working CDF  installation is required.
The software  is known  to be compatible  with all relevant  platforms.  An
installed CDF package offers a set  of ready to use toolkit programs, which
allow browsing inside the CDF files as well as an interactive extraction of
```


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selected data and even limited modification. Using calls to the CDF library functions in the user's own programs will grant the highest efficiency and flexibility. Some common interpreter languages such as 'Matlab' and 'IDL' support CDF with easy-to-use interfaces. The data are created with the older CDF version 2.6.7, as it is intended to use the same CDF library version for all CHAMP ME data. Newer versions of the CDF library claim to be backward compatible to earlier versions, but there may be some minor quirks.

Subsequently this text focuses on the semantics of labelling data columns inside CHAMP L3, describing the data content, and providing useful hints for users.

2. GENERAL OUTLINE

The CHAMP L3 data files hold:

* time series of the measured and corrected vector magnetic field

  -- in local Cartesian North-East-Center coordinates,

  -- in coordinates of the FGM sensor system,

  -- a scalar magnetic field value,

  -- a time stamp in native format supported by CDF ,

  -- the position in geocentric coordinates,

  -- the quaternion vector from the star camera which was used for the rotation of the measured vector into the NEC system

  -- a set of flags dedicated to give information about the status and quality of the corresponding data.

See detailed description of the named variables below.

* as common for CDF files, global attributes and variable-attached attributes only described in limited detail.

Each of the CHAMP L3 data files are named following the convention 'CH-ME-3-MAG+YYYY-MM-DD.cdf',

* where 'YYYY' is the integer year with four digits,

* 'MM' the month of the year as integer of two digits, with a leading zero if necessary,

* 'DD' the day of the month as integer in two digits, with a leading zero if necessary.

There is no version number, but history information is available as a

dedicated 'global attribute' inside each CDF file. There is exactly one file for each day in this L3 version and there is no data overlap to neighbouring days. The time, formatted in the native format supported by CDF, is UTC. The precision in time is one millisecond. In case of an additional leap-second, data belonging to this additional second are dropped entirely.

3. DESCRIPTION OF VARIABLES

3.1 IN BRIEF

A good CDF product file claims to be self-describing by embedded information inside each CDF file, which is a generic feature of the CDF. An overview and additional comments on the content follow. We start with a short list of the variables available. Variables can be divided further into two categories: the data variables like time, position, or corrected/processed magnetic field measurements and some descriptive flags, holding status and quality information on variables.

Variable	Brief Description	Type	CDF-dim
EPOCH	CDF epoch, time stamp of record	epoch	0
GEO_LAT	geocentric latitude	real8	0
GEO_LON	geocentric longitude	real8	0
GEO_ALT	geocentric altitude (above 6371.2)	real8	0
GEO_STAT	status information returned during interpolating RSO or PDO position data	int4	1[3]
FGM_VEC	vector data in FGM coordinate system,	real4	1[3]
FGM_SCAL	scalar data based on both, OVM and FGM data This is of higher quality than |FGM|	real4	0
FGM_FLAGS	flags for FGM as heritage directly from Level 1 or gained during processing Level 3	byte	1[2]
NEC_VEC	vector data in NEC coordinate system	real4	1[3]
ASC_QUAT	quaternion vector of star camera used to calculate transformation into NEC	real8	1[4]
ASC_MODE	star camera modes - 0 or 1 for camera 1 - 4 (body and boom)	byte	0
ASC_STAT	status information of star camera - 5 digits in decimal representation	int4	0

3.2 DESCRIPTION

It is highly recommended to pay attention to the flags, which are described in fully below. The following are extended general comments on the naming conventions of variables:

EPOCH: The CDF epoch format is an internal time representation of the CDF-library, which should be transparent to the user and can be converted to other time representations, in particular to a readable

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civil time, by CDF library functions. The epoch format seems to be entirely appropriate for the time period and span of the CHAMP data set, and it supports the required accuracy down to the millisecond.

GEO_LAT, GEO_LON: This latitude and longitude position information is given in degree and is in a geocentric coordinate system (WGS84); for comparison with locations in geodetic coordinates on the surface of the Earth the variable GEO_LAT needs to be converted. The accuracy of the positioning given is expected to be in the range less than the dimension of the spacecraft.

GEO_ALT: Altitude information is given in km above a reference sphere with a radius of 6371.2 km, a value commonly used in geomagnetic modelling.

GEO_STAT: The positions given are derived from other CHAMP product files. The related processing includes interpolation, handling small gaps and switching to the CHAMP PDO product instead of the default RSO product, if the latter shows too large or too many gaps. There are three integer values, the optimal values are 0 (no gaps), 20 (interpolation is able to use the full default set of base points), and 0 (the RSO position data are used).

NEC_VEC: This product provides corrected magnetic field vector data in a local Cartesian coordinate system moving with the satellite. The component x points towards geographic North, y towards East, and z to the Earth's center; NEC (North-East-Center) coordinate system. It has much in common with the spherical coordinate system (radius, theta, phi), but with different signs.

The magnetic field time series in this NEC system requires orbit and attitude information for its transformation from the magnetometer system into the NEC frame. There is some additional noise introduced by the transformations. The dependence on data from several instruments causes additional data gaps. These are filled with NaN (not a number).

FGM_VEC: This is the corrected magnetic field vector in a coordinate system moving with the satellite, and the axes are aligned with the FGM-1 sensor. The advantage of this data product lies in the fact that the readings are not affected by the noise and uncertainty of the attitude information provided by the star sensor for a transformation into the NEC system. The vector data in FGM system may allow derivation of independent correction (Euler) angles between FGM and ASC (star camera) system as by-product of co-estimating during geomagnetic modelling, if desired.

FGM_SCAL: A hybrid product of scalar OVM readings and FGM vector field readings, calibrated and merged with the intention to combine the advantages of both instruments, the absolute accuracy of the OVM magnetometer and the lower noise level of the FGM readings.

FGM_FLAGS: There are flags contained in two bytes providing information about the instrument status and data quality. In case of good data the first byte is zero. However, for some application data with non-zero

flag may also be useful. More details about the flags are given below.

ASC_QUAT: The attitude information is provided by the star camera(s) as quaternions, four double precision values, describing the orientation of the corresponding star camera in celestial coordinates. There are two ASC camera heads on the boom providing the attitude of the Common Reference frame which is used for the transformation of the vector magnetometer data into the NEC frame.

ASC_MODE: The bit field of flags carried by this byte is indicating which star cameras on CHAMP had been active. There are two ASC camera heads on the boom close to the vector magnetometer (on a common optical bench) and two ASC camera heads on the body of CHAMP. Only camera heads on the boom have been used. More details are given below.

ASC_STAT: This variable provides information about the internal processing, e.g. the star camera quality information. The most significant information is stored in the first digit indicating which of the star camera has contributed Common Reference attitude (single mode) or whether both ASCs contributed providing an improved attitude (dual mode). More details are given below.

3.3 DESCRIPTION OF THE FLAGS

First we give a brief recommendation of which flags to look for and what are expected to be reasonable values (see 3.3.1), we then attempt to describe the flags' content (see 3.3.2) in more detail.

3.3.1 RECOMMENDED FLAGS

The following flags contain the most important information. Expected default values which indicate the best data quality are listed.

GEO_STAT:
1. 0
2. 20
3. 0

FGM_FLAGS:
byte1
bit2-3 (sample freq 50Hz) = 00
bit4 (no torquer correction) = 0
other bits can be neglected

byte2
bit4 (no L3 correction) = 0
other bits can be neglected

ASC_STAT:
1. digit = 7 (dual mode boom)

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other digits can be neglected

3.3.2 BRIEF FLAG DESCRIPTION

In the following the flag variables are described in more detail. The flags are of different types, one is a set of integers (GEO_STAT), where the values can directly be used; others are one or more bit-fields (FGM_FLAGS, ASC_MODE); and the last is an integer(ASC_STAT), where the digits of the decimal representation is the information carriers.

For each flag first the data type is given, followed by the order of information given in square brackets, i.e. the referenced bit location inside the flag value (FGM_FLAGS) or the order of the integers. For single bits: 1 is true or set, 0 is false or unset.

GEO_STAT

array of three integers [1, 2, 3]

1. first integer

   gap length of position base points ('RSO'/'PDO'), should be zero. In the case, that RSO is insufficient (too large or with too much gaps), PDO is used instead (if available during the period and the quality of the PDO data are high enough).

2. third integer

   number of base points used for spline interpolation of the positions to fit the raster points required by the magnetic field measurements; the default number of base points is 20; if there are less than the default, the quality of the position may be slightly degraded.

3. second integer

   this integer is 0 or 1. It indicates the source of the positional information; the 'RSO' positions are the standard data source, and originate during a later processing stage; PDO are then the fall-back data.

value	indicating
0	using RSO positions (default)
1	using PDO positions (fall back)

FGM_FLAGS

array of two bytes, both interpreted as bit-fields; the default should be zero for both bytes, but using the 'redundant' on board system (first byte, bit 5) or a reduced sampling frequency (first byte, bits 3,2) seems acceptable and are not necessarily degrading; but missing HK data result in reduced data quality.

bits of byte 1, in the order: [8 7 6 5 4 3 2 1]

bit(s)	comment
1	adc (first sample is abnormal or not); ok (0), not ok (1)
3+2	bits indicating 00 sample freq is 50 Hz 01 sample freq is 10 Hz 10 sample freq is 1 Hz 11 sample freq is illegal
4	no HK of the torquer current are available for correction; ok (0), no data (1)
5	redundant OBDU (OnBoardDataUnit); off (0), on (1)
6	bad average distribution; ok (0), bad (1)
7	the OVM frequency is corrected; (0), no (1)
8	no HK data are available for correction in ovm processing; ok (0), no HK (1)

bits of byte 2, in the order: [8 7 6 5 4 3 2 1]

bit	flag comment
1	on L3 processing, ovm is interpolated; ok (0), interp (1)
2	on L3 processing, fgm is interpolated; ok (0), interp (1)
3	on L3 processing, delta is interpolated; ok (0), interp (1)
4	on L3 processing, value is not corrected; ok (0), no corr (1)
5	empty
6	FGM Burst mode; compression on (1), off (0)
7	L2 ovm gps error corrected; no (0), corr (1)
8	L2 fgm gps error corrected; no (0), corr (1)

ASC_MODE

bits, in the order [8 7 6 5 4 3 2 1].

bit	comment
8 - 5	Not used
4	camera 1 (boom)
3	camera 2 (boom)
2	camera 3 (body)
1	camera 4 (body)

ASC_STAT

digits in a integer number of maximal five digits:

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```
with digits ordered by 12345:

  place comment
  ------------------------------------------------------------

  1     a mode in the range 0 - 7  [multiplier is 10000]

        val comment
        ------------------------------------------------------
         0  no data
         1  not available
         2  single data boom, chu2cr static
         3  not available
         4  not available
         5  not available
         6  single data boom, chu2cr dynamic
         7  dual data boom

  2     filtered (0: no, 1: yes)   [multiplier is 1000]

  3     chu2cr (angle estimation method) [multiplier is 100]
        chu - camera head unit reference frame,
        cr  - common reference frame

        val comment
        ------------------------------------------------------
         0  static
         1  dynamic
         2  dual

  4     jump correction     [multiplier is 10]

        flagging application and effect of jump correction
        (chu1, chu2 - boom; chu3, chu4 - body)

        val comment
        ------------------------------------------------------
         0  no
         1  chu1 or chu3
         2  chu2 or chu4
         3  (chu1 and chu2) or (chu3 and chu4)

  5     flagging interpolating of data-gaps [multiplier is 1]

        val comment
        ------------------------------------------------------
         0  no
         1  chu1 or chu3
         2  chu2 or chu4
         3  (chu1 and chu2) or (chu3 and chu4)


4. ADDITIONAL HINTS
-------------------
```

4.1. With the CDF toolbox program 'cdfexport' it is possible to create listing files from L3 CDF data files using the command line without additional programming. By initially using 'cdfexport' on a CDF file interactively in a terminal, a file with current settings can be saved (see 'action' menue). Assuming an appropriately installed 'cdfexport' is in the search path of the shell and the settings file written during the interactive use of 'cdfexport' is named 'default.set', a command in a 'bash' shell may look like (some environment variables set for shortening...):

```
IN__FILE='CH-ME-3-MAG+2010-09-03.cdf'
OUT_FILE='ch-me-3-mag-out.list'
OPTIONS='-batch text -settings default.set'

cdfexport ${OPTIONS} -text ${OUT_FILE} ${IN__FILE}
```

For details it may be required to read the CDF user manual, in particular the 'Toolkit Reference' section.

A.1.3. CDF Skeleton

```
! Skeleton table for the "CH-ME-3-MAG.cdf" CDF.
! Generated: Friday, 15-Mar-2019 01:55:26
! CDF created/modified by CDF V2.6.7
! Skeleton table created by CDF V3.7.0_0

#header

                     CDF NAME: CH-ME-3-MAG+*.cdf
                DATA ENCODING: NETWORK
                     MAJORITY: ROW
                       FORMAT: SINGLE

! Variables  G.Attributes  V.Attributes  Records  Dims  Sizes
! ---------  ------------  ------------  -------  ----  -----
    0/12           8             13         0/z      0
! CDF_COMPRESSION: None
! (Valid compression: None, GZIP.1-9, RLE.0, HUFF.0, AHUFF.0)
! CDF_CHECKSUM: None
! (Valid checksum: None, MD5)


#GLOBALattributes

! Attribute         Entry       Data
! Name              Number      Type       Value
! ---------         ------      ----       -----

  "PRODUCT"             1:    CDF_CHAR     { "CH-ME-3-MAG" } .
```


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```
  "TITLE"               1:    CDF_CHAR     { "CHAMP ME MAG" } .

  "HISTORY"             1:    CDF_CHAR     { "skeleton version: " -
                                               "2014-Mar-10" }
                        2:    CDF_CHAR     { "level 3 processor version:" -
                                               " 2014-Mar-10" }
                        3:    CDF_CHAR     { "CDF created: Wed Apr 20 " -
                                               "14:12:35 2016" } .

  "MJD2000"             1:    CDF_DOUBLE   { 3681.0 } .

  "EPOCH_S"             1:    CDF_EPOCH    { 29-Jan-2010 00:00:00.140 } .

  "EPOCH_E"             1:    CDF_EPOCH    { 29-Jan-2010 23:59:59.140 } .

  "NR_OF_RECORDS"       1:    CDF_INT4     { 86400 } .

  "MAG_ID"              1:    CDF_INT2     { 1 } .


#VARIABLEattributes

  "VALIDMIN"
  "VALIDMAX"
  "SCALEMIN"
  "SCALEMAX"
  "UNIT"
  "FORMAT"
  "HEADS"
  "SYSTEM"
  "MODEL"
  "REFRADIUS"
  "SAMPLE"
  "INFO"
  "FILLVAL"


#variables

! No rVariables.


#zVariables

! Variable          Data      Number                 Record   Dimension
! Name              Type     Elements  Dims  Sizes  Variance  Variances
! --------          ----     --------  ----  -----  --------  ---------

  "EPOCH"         CDF_EPOCH      1       0              T

  ! VAR_COMPRESSION: None
  ! (Valid compression: None, GZIP.1-9, RLE.0, HUFF.0, AHUFF.0)
  ! VAR_SPARSERECORDS: None
  ! (Valid sparserecords: None, sRecords.PAD, sRecords.PREV)
```

```
  ! VAR_PADVALUE: 01-Jan-0000 00:00:00.000

  ! Attribute       Data
  ! Name            Type       Value
  ! --------        ----       -----

    "VALIDMIN"    CDF_INT4     { 1 }
    "UNIT"        CDF_CHAR     { "millisecond since 01-Jan-0000 " -
                                 "00:00:00.000 (CDF epoch)" }
    "FORMAT"      CDF_CHAR     { "F20.10" }
    "INFO"        CDF_CHAR     { "time, UT (epoch)" } .

  ! RV values were not requested.


! Variable          Data      Number                 Record   Dimension
! Name              Type     Elements  Dims  Sizes  Variance  Variances
! --------          ----     --------  ----  -----  --------  ---------

  "GEO_LAT"       CDF_REAL8      1       0              T

  ! VAR_COMPRESSION: None
  ! (Valid compression: None, GZIP.1-9, RLE.0, HUFF.0, AHUFF.0)
  ! VAR_SPARSERECORDS: None
  ! (Valid sparserecords: None, sRecords.PAD, sRecords.PREV)
  ! VAR_PADVALUE: 4.67632e-310

  ! Attribute       Data
  ! Name            Type       Value
  ! --------        ----       -----

    "VALIDMIN"    CDF_REAL8    { -90.0 }
    "VALIDMAX"    CDF_REAL8    { 90.0 }
    "UNIT"        CDF_CHAR     { "degree" }
    "FORMAT"      CDF_CHAR     { "F15.10" }
    "SYSTEM"      CDF_CHAR     { "geocentric geographic" }
    "INFO"        CDF_CHAR     { "latitude" }
    "FILLVAL"     CDF_REAL8    { nan } .

  ! RV values were not requested.


! Variable          Data      Number                 Record   Dimension
! Name              Type     Elements  Dims  Sizes  Variance  Variances
! --------          ----     --------  ----  -----  --------  ---------

  "GEO_LON"       CDF_REAL8      1       0              T

  ! VAR_COMPRESSION: None
  ! (Valid compression: None, GZIP.1-9, RLE.0, HUFF.0, AHUFF.0)
  ! VAR_SPARSERECORDS: None
  ! (Valid sparserecords: None, sRecords.PAD, sRecords.PREV)
  ! VAR_PADVALUE: 4.67632e-310
```


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```
  ! Attribute       Data
  ! Name            Type       Value
  ! --------        ----       -----

    "VALIDMIN"    CDF_INT4     { -180 }
    "VALIDMAX"    CDF_INT4     { 180 }
    "UNIT"        CDF_CHAR     { "degree" }
    "FORMAT"      CDF_CHAR     { "F15.10" }
    "SYSTEM"      CDF_CHAR     { "geocentric geographic" }
    "INFO"        CDF_CHAR     { "longitude" }
    "FILLVAL"     CDF_REAL8    { nan } .

  ! RV values were not requested.


! Variable          Data      Number                 Record   Dimension
! Name              Type     Elements  Dims  Sizes  Variance  Variances
! --------          ----     --------  ----  -----  --------  ---------

  "GEO_ALT"       CDF_REAL8      1       0              T

  ! VAR_COMPRESSION: None
  ! (Valid compression: None, GZIP.1-9, RLE.0, HUFF.0, AHUFF.0)
  ! VAR_SPARSERECORDS: None
  ! (Valid sparserecords: None, sRecords.PAD, sRecords.PREV)
  ! VAR_PADVALUE: 4.67632e-310

  ! Attribute       Data
  ! Name            Type       Value
  ! --------        ----       -----

    "VALIDMIN"    CDF_INT4     { 0 }
    "VALIDMAX"    CDF_INT4     { 1000 }
    "UNIT"        CDF_CHAR     { "km" }
    "FORMAT"      CDF_CHAR     { "F10.6" }
    "SYSTEM"      CDF_CHAR     { "geocentric geographic" }
    "REFRADIUS"   CDF_REAL4    { 6371.2 }
    "INFO"        CDF_CHAR     { "altitude above reference sphere" }
    "FILLVAL"     CDF_REAL8    { nan } .

  ! RV values were not requested.


! Variable          Data      Number                 Record   Dimension
! Name              Type     Elements  Dims  Sizes  Variance  Variances
! --------          ----     --------  ----  -----  --------  ---------

  "GEO_STAT"      CDF_INT4       1       1     3        T         T

  ! VAR_COMPRESSION: None
  ! (Valid compression: None, GZIP.1-9, RLE.0, HUFF.0, AHUFF.0)
  ! VAR_SPARSERECORDS: None
  ! (Valid sparserecords: None, sRecords.PAD, sRecords.PREV)
  ! VAR_PADVALUE: 1583833392
```

```
  ! Attribute       Data
  ! Name            Type       Value
  ! --------        ----       -----

    "FORMAT"      CDF_CHAR     { "I5" }
    "INFO"        CDF_CHAR     { "status information for positions; " -
                                 "column 1 - number of gaps in " -
                                 "interpolation interval; column 2 - " -
                                 "flag for PDO used instead of RSO; " -
                                 "column 3 - number of basePoints used " -
                                 "for interpolation" }
    "FILLVAL"     CDF_INT4     { -1 } .

  ! RV values were not requested.


! Variable          Data      Number                 Record   Dimension
! Name              Type     Elements  Dims  Sizes  Variance  Variances
! --------          ----     --------  ----  -----  --------  ---------

  "FGM_VEC"       CDF_REAL4      1       1     3        T         T

  ! VAR_COMPRESSION: None
  ! (Valid compression: None, GZIP.1-9, RLE.0, HUFF.0, AHUFF.0)
  ! VAR_SPARSERECORDS: None
  ! (Valid sparserecords: None, sRecords.PAD, sRecords.PREV)
  ! VAR_PADVALUE: 4.16817e+18

  ! Attribute       Data
  ! Name            Type       Value
  ! --------        ----       -----

    "VALIDMIN"    CDF_INT4     { -99999 }
    "VALIDMAX"    CDF_INT4     { 99999 }
    "UNIT"        CDF_CHAR     { "nT" }
    "FORMAT"      CDF_CHAR     { "F15.3" }
    "SYSTEM"      CDF_CHAR     { "CHAMP FGM-1 sensor system" }
    "SAMPLE"      CDF_CHAR     { "1 Hz" }
    "INFO"        CDF_CHAR     { "B-vector in FGM-1 sensor system" } .

  ! RV values were not requested.


! Variable          Data      Number                 Record   Dimension
! Name              Type     Elements  Dims  Sizes  Variance  Variances
! --------          ----     --------  ----  -----  --------  ---------

  "FGM_SCAL"      CDF_REAL4      1       0            T

  ! VAR_COMPRESSION: None
  ! (Valid compression: None, GZIP.1-9, RLE.0, HUFF.0, AHUFF.0)
  ! VAR_SPARSERECORDS: None
  ! (Valid sparserecords: None, sRecords.PAD, sRecords.PREV)
```


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```
  ! VAR_PADVALUE: 4.16817e+18

  ! Attribute       Data
  ! Name            Type       Value
  ! --------        ----       -----

    "VALIDMIN"    CDF_INT4     { 0 }
    "VALIDMAX"    CDF_INT4     { 99999 }
    "UNIT"        CDF_CHAR     { "nT" }
    "FORMAT"      CDF_CHAR     { "F15.3" }
    "SYSTEM"      CDF_CHAR     { "CHAMP FGM-1 sensor system" }
    "SAMPLE"      CDF_CHAR     { "1 Hz" }
    "INFO"        CDF_CHAR     { "scalar B-field in FGM-1 sensor system" } .

  ! RV values were not requested.


! Variable          Data      Number                  Record   Dimension
! Name              Type     Elements  Dims  Sizes  Variance  Variances
! --------          ----     --------  ----  -----  --------  ---------

  "FGM_FLAGS"     CDF_UINT1      1       1     2        T         T

  ! VAR_COMPRESSION: None
  ! (Valid compression: None, GZIP.1-9, RLE.0, HUFF.0, AHUFF.0)
  ! VAR_SPARSERECORDS: None
  ! (Valid sparserecords: None, sRecords.PAD, sRecords.PREV)
  ! VAR_PADVALUE: 48

  ! Attribute       Data
  ! Name            Type       Value
  ! --------        ----       -----

    "VALIDMIN"    CDF_UINT1    { 0 }
    "VALIDMAX"    CDF_UINT1    { 255 }
    "UNIT"        CDF_CHAR     { "bit field" }
    "FORMAT"      CDF_CHAR     { "I8" }
    "INFO"        CDF_CHAR     { "FGM quality information (flags),### " -
                               "bits of byte 1 (8 7 6 5 4 3 2 1): # 1 " -
                               "- adc (first sample anormal = 1, ok = " -
                               "0); # 3,2 sample frequency (00 = " -
                               "sample freq is 50 Hz,  01 = sample " -
                               "freq is 10 Hz,  10 = sample freq is  1" -
                               " Hz,  11 = sample freq is illegal); # " -
                               "4 - torquer overlap (ok = 0, not ok = " -
                               "1); # 5 - OnBoardDataUnit (OBDU) " -
                               "(standard = 0, redundant = 1); # 6 - " -
                               "bad average distribution (ok = 0, bad " -
                               "= 1); # 7 - ovm frequency correction " -
                               "(no = 0, yes = 1); # 8 - ovm hk " -
                               "overlapped (yes = 0, no = 1); ### bits" -
                               " of byte 2 (8 7 6 5 4 3 2 1): # 1 - L3" -
                               " ovm interpolated (no = 0, yes = 1); #" -
                               " 2 - L3 fgm interpolated (no = 0, yes " -
```

```
                                "= 1); # 3 - L3 delta interpolated (no " -
                                "= 0, yes = 1); # 4 - L3 value " -
                                "corrected for OVM (ok = 0, no = 1); # " -
                                "5 - empty; # 6 - FGM Burst mode " -
                                "(compression on = 1, off = 0); # 7 - " -
                                "L2 ovm GPS error corrected (no = 0, " -
                                "corrected = 1); # 8 - L2 fgm GPS error" -
                                " corrected (no = 0, corrected = 1); " } .

  ! RV values were not requested.


! Variable          Data      Number                 Record   Dimension
! Name              Type     Elements  Dims  Sizes  Variance  Variances
! --------          ----     --------  ----  -----  --------  ---------

  "NEC_VEC"       CDF_REAL4      1       1     3        T         T

  ! VAR_COMPRESSION: None
  ! (Valid compression: None, GZIP.1-9, RLE.0, HUFF.0, AHUFF.0)
  ! VAR_SPARSERECORDS: None
  ! (Valid sparserecords: None, sRecords.PAD, sRecords.PREV)
  ! VAR_PADVALUE: 4.16817e+18

  ! Attribute       Data
  ! Name            Type       Value
  ! --------        ----       -----

    "VALIDMIN"    CDF_INT4     { -99999 }
    "VALIDMAX"    CDF_INT4     { 99999 }
    "UNIT"        CDF_CHAR     { "nT" }
    "FORMAT"      CDF_CHAR     { "F15.3" }
    "SYSTEM"      CDF_CHAR     { "NEC (North East Centered) system" }
    "SAMPLE"      CDF_CHAR     { "1 Hz" }
    "INFO"        CDF_CHAR     { "B-vector in NEC system" }
    "FILLVAL"     CDF_REAL4    { nan } .

  ! RV values were not requested.


! Variable          Data      Number                 Record   Dimension
! Name              Type     Elements  Dims  Sizes  Variance  Variances
! --------          ----     --------  ----  -----  --------  ---------

  "ASC_QUAT"      CDF_REAL8      1       1     4        T         T

  ! VAR_COMPRESSION: None
  ! (Valid compression: None, GZIP.1-9, RLE.0, HUFF.0, AHUFF.0)
  ! VAR_SPARSERECORDS: None
  ! (Valid sparserecords: None, sRecords.PAD, sRecords.PREV)
  ! VAR_PADVALUE: 4.67632e-310

  ! Attribute       Data
  ! Name            Type       Value
```


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```
  ! --------        ----       -----

    "VALIDMIN"    CDF_INT4     { -1 }
    "VALIDMAX"    CDF_INT4     { 1 }
    "UNIT"        CDF_CHAR     { "-" }
    "FORMAT"      CDF_CHAR     { "F15.10" }
    "SAMPLE"      CDF_CHAR     { "1 Hz" }
    "INFO"        CDF_CHAR     { "ASC quaternions for ICRF " -
                                 "(International Celestial Reference " -
                                 "System) -> CRF (Common Reference " -
                                 "System) transformation" }
    "FILLVAL"     CDF_REAL8    { nan } .

  ! RV values were not requested.


! Variable          Data      Number                 Record   Dimension
! Name              Type     Elements  Dims  Sizes  Variance  Variances
! --------          ----     --------  ----  -----  --------  ---------

  "ASC_MODE"      CDF_UINT1      1       0              T

  ! VAR_COMPRESSION: None
  ! (Valid compression: None, GZIP.1-9, RLE.0, HUFF.0, AHUFF.0)
  ! VAR_SPARSERECORDS: None
  ! (Valid sparserecords: None, sRecords.PAD, sRecords.PREV)
  ! VAR_PADVALUE: 48

  ! Attribute       Data
  ! Name            Type       Value
  ! --------        ----       -----

    "VALIDMIN"    CDF_UINT1    { 1 }
    "VALIDMAX"    CDF_UINT1    { 15 }
    "UNIT"        CDF_CHAR     { "bit field" }
    "FORMAT"      CDF_CHAR     { "I2" }
    "INFO"        CDF_CHAR     { "Star camera mode (from left to right):" -
                                 " 1st A1 Camera 1 Boom; 2nd A2 Camera 2" -
                                 " Boom; 3rd B1 Camera 1 Body; 4rd B2 " -
                                 "Camera 2 Body" }
    "FILLVAL"     CDF_UINT1    { 0 } .

  ! RV values were not requested.


! Variable          Data      Number                 Record   Dimension
! Name              Type     Elements  Dims  Sizes  Variance  Variances
! --------          ----     --------  ----  -----  --------  ---------

  "ASC_STAT"      CDF_UINT4      1       0              T

  ! VAR_COMPRESSION: None
  ! (Valid compression: None, GZIP.1-9, RLE.0, HUFF.0, AHUFF.0)
  ! VAR_SPARSERECORDS: None
```

```
  ! (Valid sparserecords: None, sRecords.PAD, sRecords.PREV)
  ! VAR_PADVALUE: 1583833392

  ! Attribute       Data
  ! Name            Type       Value
  ! --------        ----       -----

    "VALIDMIN"    CDF_UINT4    { 1 }
    "VALIDMAX"    CDF_UINT4    { 99999 }
    "UNIT"        CDF_UCHAR    { "integer field" }
    "FORMAT"      CDF_UCHAR    { "I5" }
    "INFO"        CDF_UCHAR    { "star camera quality information, ### " -
                                 "1st digit is flagging ASC source: 0 = " -
                                 "no data available,  2 = single data " -
                                 "boom, chu2cr static, 6 = single data " -
                                 "boom + chu2cr dynamic, 7 = dual data " -
                                 "boom; ### 2nd digit is filtered flag: " -
                                 "0 = no, 1 = yes; ### 3rd digit is " -
                                 "flagging chu2cr transformation mode: 0" -
                                 " = static, 1 = dynamic, 2 = dual; ### " -
                                 "4th digit is flagging jump correction:" -
                                 " 0 = no, 1 = chu1/3, 2 = chu2/4, 3 = " -
                                 "chu1/3 and chu2/4; ### 5th digit is " -
                                 "flagging interpolated gaps: 0 = no " -
                                 "interpolation 1 = chu1/3, 2 = chu2/4, " -
                                 "3 = chu1/3 and chu2/4;" }
    "FILLVAL"     CDF_INT4     { 0 } .

  ! RV values were not requested.


#end
```


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A.2. Attitude information from the star cameras on the boom

A.2.1. Name Identifier

The identifier of this data type in the product file name is `CH-ME-3-ASC-BOOM`.

A.2.2. Description

The following description is included here from a plain ASCII file, which had served as a description of the ASC data and partly accompanied the data. It is embedded here literally and mostly unchanged, with it's own, unrelated section numbering.

```
The CHASC-Format (CHAMP Advanced Stellar Compass Star Format)          Level 3
------
follows the CHACC-Format

Last Revision: 21-Aug-2001.


1. Format description:
----------------------
1.1. general:

- the length of a line should not exceed 80 characters

- the CHACC-format data files consists of a header and data lines.

- comment lines are possible at any position (except of the first line),
  the first character of a comment line is '*'

1.2. header:

The header consists of
- the first line (= format identification line), which starts with '%'
- additional lines, every header line consists of a
  first character '+', followed by a keyword (9 characters)
  and header data (details given below), this lines
  may be given in any order

The header ends with the first line, which doesn't start with '*', '%' or '+'.

Detailed header lines format description:
=========================================================================

- First line (format and data revision identification line)

Columns 1 - 6     A6   '%chxxx'          format identifier:
                       '%chacc' = Accelerometer data Level-1 or -2
                       '%chasc' = only Advanced Stellar Compass Level-2 data
                       '%chfgm' = only formatted fgm-data
                       '%chshk' = satellite housekeeping data (OG relevant)
Column  7         1X                     unused
Column  8 -19     A12  'version x.x '    format version
```

```
Column  20        1X                    unused
Columns 21-32     A12  'revision y  '   data revision
Column  33        1X                    unused
Columns 34-37     I4                    year of file creation
Column  38        1X                    unused
Columns 39-40     I2                    month of file creation
Column  41        1X                    unused
Columns 42-43     I2                    day of file creation
Column  44        1X                    unused
Columns 45-46     I2                    hour of file creation
Column  47        1X                    unused
Columns 48-49     I2                    minute of file creation
Columns 50        1X                    unused
Columns 51-59     A9                    Name of the institution (abbreviated)
Columns 60        1X                    unused
Columns 61-80     A20                   Name of the operator

- satellite identification

Columns 1 -10     A10  '+satellite'     keyword
Column  11        1X                    unused
Columns 12-18     I7                    SLR adopted COSPAR number of the satellite
Column  19        1X                    unused
Columns 20-39     A20                   name of the satellite

- data type specification

  This line specifies the data, which are kept in the file.

Columns 1 -10     A10  '+data_____'     keyword
Colums  11-....   n(1X,A3)              list of the keywords of all data types
                                        of the data lines below (including
                                        the time), the keywords are identical to the
                                        keywords used in the data lines
                                        n = number of different data types (including time)
                                        (see the examples below)

- reference systems specification line

Columns 1 -10     A10  '+reference'     keyword
Columns 11-....   n(1X,A3)              list of the abbreviations of the reference systems
                                        of the different data types (including the time),
                                        the order of this keywords corresponds with the
                                        order of the data type keywords in the
                                        '+data_____'-line above!
                                        Examples for reference system keywords:
                                        'gps' - GPS-Time
                                        'utc' - Coordinated universal time
                                        'gpp' -
                                        'cis' - Conventional Intertial System
                                        'ifx' - Instrument Fixed System
                                        'sbf' - Spacecraft Body Fixed
                                        '---' - for thrusters and H/K data, where
                                        no reference system is required
```


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```
                                        (see examples below)

- first epoch specification

Columns 1 -10     A10  '+first____'      keyword
Column  11        1X                     unused
Columns 12-15     I4                     year of first epoch
Column  16        1X                     unused
Columns 17-18     I2                     month of first epoch
Column  19        1X                     unused
Columns 20-21     I2                     day of first epoch
Column  22        1X                     unused
Columns 23-24     I2                     hour of first epoch
Columns 25        1X                     unused
Columns 26-27     I2                     minute of first epoch
Columns 28        1X                     unused
Columns 29-38     F10.7                  second of first epoch


- last epoch specification

Columns 1 -10     A10  '+last_____'      keyword
Column  11        1X                     unused
Columns 12-15     I4                     year of last epoch
Column  16        1X                     unused
Columns 17-18     I2                     month of last epoch
Column  19        1X                     unused
Columns 20-21     I2                     day of last epoch
Column  22        1X                     unused
Columns 23-24     I2                     hour of last epoch
Columns 25        1X                     unused
Columns 26-27     I2                     minute of last epoch
Columns 28        1X                     unused
Columns 29-38     F10.7                  second of last epoch


- Attitude calibration BOOM data ( Euler Angles or Quaternions)
  for transformation from ASC into CR (common reference) system

Columns  1 - 10    A10  '+asc'X'cr_e'    keyword
Column  11         1X                    unused
Columns 12 - 44   3(X,F10.5)             Attitude value in Euler Angles (3-1-3)
                                         order of euler angles :
                                         PHI, THETA, PSI

Columns 1 - 10    A10  '+asc'X'cr_q'     keyword
Column  11        1X                     unused
Columns 12 - 67   4(X,F13.10)            Attitude value in quaternions
                                         order of Quaternions:
                                         q1,q2,q3 = vector part, q4 = scalar
                                         part

                                         'X' = Nr. of Camera Head Unit (CHU)
                                         for example
```

```
                                        1 = CHU 1 of BOOM
                                        2 = CHU 2 of BOOM
                                        3 = CHU 3 of BODY
                                        4 = CHU 4 of BODY

- Attitude calibration BODY data (Quaternions)
  for transformation from CR (common reference) system to S/C system

Columns 1 - 10    A10  '+cr2sc____'      keyword
Column  11        1X                     unused
Columns 12 - 67   4(X,F13.10)            Attitude value in Quaternions
                                         order of Quaternions:
                                         q1,q2,q3 = vector part, q4 = scalar
                                         part

- For Attitude data: filter for smoothing the quaternions

Columns 1 - 10    A10  '+filt_____'      keyword
Column  11        1X                     unused
Columns 12 - 14   A3                     keyword for the applied filters:
                                         examples for filter keywords
                                         'pol' - polynomial filter
                                         'box' - boxcar average
                                         'spl' - cubic spline interpolation
                                         ' no' - used no filter
Column  15        1X                     unused
Columns 16 - 18   I2                     length of filter interval in sec

- For Attitude data: format description of the data

Columns 1   10    A10  '+format___'      keyword
Column  11        1X                     unused
Columns 12 - 14   A3                     format keyword
Columns 15        1X                     unused
Column  16 - 33   A18                    format description for keyword
Column  34        1X                     unused
Columns 35 - 37   A3                     format keyword
Columns 38        1X                     unused
Column  39 - 68   A30                    format description for keyword


- processing software specification

Columns 1 -10     A10   '+software_'     keyword
Column  11        1X                     unused
Columns 12-51     A40                    processing software name and version number


- additional header lines for the specification of more file attributes are tbd.!


1.3. data

The data are given in data lines combined in data blocks.
```


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```
The basic structure of a single line is a keyword of 3 characters,
followed by the data.
A data blocks starts with a data line containing a measurement
epoch.  All these following data lines are related to this epoch and
these lines may be given in any order.
A new epoch line starts a new data block.
The last data block ends with the '%eof'-line.

Detailed data lines format description:
=======================================================================

- UTC Time Line

Columns 1 - 3     A3   'tim'   keyword
Column  4         1X           unused
Columns 5 - 8     I4           year
Column  9         1X           unused
Columns 10-11     I2           month
Column  12        1X           unused
Columns 13-14     I2           day
Column  15        1X           unused
Columns 16-17     I2           hour
Column  18        1X           unused
Columns 19-20     I2           minute
Column  21        1X           unused
Columns 22-31     F10.4        second

- Attitude line

Columns 1 - 3     A3   'att'   keyword
Column  4         1X           unused
Columns 5   8     I4           star imager 1 - 4 flags
                               In the order: asc_a1, asc_a2, asc_b3,asc_b4
                               meaning: star imager included to this data
                               '0' = not included
                               '1' = included
Column  9         1X           unused
Columns 10 - 64   4(X,F13.10)  Attitude value in quaternions
                               (value range of all components: -1.0 .... +1.0)
                               order of Quaternions:
                               q1,q2,q3 = vector part, q4 = scalar part
Column  65        F5.2         relative errors

1.4. last line

the content of the last line is '%eof',  this indicates the end of the file

2. Examples :

This is an example for an attitude data file (level-2 product).
All numbers are dummies, this is no simulation

2.1. Attitude Level-2-Data
     (Advanced Stellar Compass, boom, preprocessed, CH-ME-2-ASC-BOOM)
```

```
%chasc version 2.0  revision 0   2001  8 20 15:35 GFZ              Sungchan Choi
+satellite 0003902 CHAMP
+data_____ tim att
+reference utc cis
+first____ 2001 04 10 00 00  0.1400000
+last_____ 2001 04 10 00 06  6.1400000
+asc1-cr_e     1.74100  128.99541   -0.00285
+asc1-cr_q  0.9024604684  0.0139371969  0.0064337971  0.4304990868
+asc2-cr_e   179.10812 -129.00436   -0.00515
+asc2-cr_q -0.0069842388 -0.9025747103  0.4304634224  0.0033696754
+filt_____ pol   20
+format___ tim (A3,1X,I4,4(1X,I2.2),1X,F10.4) att (A3,1X,4I1,4(1X,F13.10),F5.2)
+software_ ch_me_asc_12_boom version 2.00
*comment1
*comment2
tim 2001 04 10 00 00     0.1400
att 1100 -0.0830847653  0.1131861781  0.4020327729  0.9047958114 0.00
tim 2001 04 10 00 00     1.1400
att 1100 -0.0828501589  0.1126905249  0.4020747622  0.9048605320 0.00
tim 2001 04 10 00 00     2.1400
att 1100 -0.0826159053  0.1121952117  0.4021164244  0.9049249847 0.00
tim 2001 04 10 00 00     3.1400
att 1100 -0.0823815405  0.1117007710  0.4021569265  0.9049895171 0.00
tim 2001 04 10 00 00     4.1400
att 1100 -0.0821461056  0.1112050308  0.4021982087  0.9050536224 0.00
tim 2001 04 10 00 00     5.1400
att 1100 -0.0819105174  0.1107091754  0.4022388075  0.9051177202 0.00
tim 2001 04 10 00 00     6.1400
att 1100 -0.0816752929  0.1102138866  0.4022794854  0.9051813417 0.00
tim 2001 04 10 00 00     7.1400
att 1100 -0.0814403208  0.1097188218  0.4023195848  0.9052448321 0.00
tim 2001 04 10 00 00     8.1400
att 1100 -0.0812048087  0.1092235528  0.4023597151  0.9053080438 0.00
tim 2001 04 10 00 00     9.1400
att 1100 -0.0809692855  0.1087274666  0.4023999038  0.9053709904 0.00
tim 2001 04 10 00 00    10.1400
att 1100 -0.0807332073  0.1082314770  0.4024401212  0.9054336229 0.00
%eof
```

2.2. Attitude Level-2-Data
(Advanced Stellar Compass, body, preprocessed, CH-OG-2-ASC-BODY)

```
%chasc version 2.0  revision 0   2001 08 20 15:00 GFZ              Sungchan Choi
+satellite 0003902 CHAMP
+data_____ tim att
+reference gps cis
+first____ 2000 07 26 00 00  0.0000000
+last_____ 2000 07 26 01 06 21.0000000
+cr2sc____  -0.0000935753 -0.0017925315  0.0020178324  0.9999963492
+filt_____  NO
+format___ tim (A3,1X,I4,4(1X,I2.2),1X,F10.4) att (A3,1X,4I1,4(1X,F13.10),F5.2)
+software_ ch_me_asc_12_body version 2.00
```


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```
*comment1
*comment2
tim 2000 07 26 00 00    0.00
att 0011  0.0135647896 -0.6965858498 -0.0398309235  0.7162385524 0.00
tim 2000 07 26 00 00    1.00
att 0011  0.0138079955 -0.6961402894 -0.0407884789  0.7166131123 0.00
tim 2000 07 26 00 00    2.00
att 0011  0.0140468713 -0.6956966916 -0.0417497755  0.7169838011 0.00
tim 2000 07 26 00 00    3.00
att 0011  0.0142814132 -0.6952508367 -0.0427094054  0.7173550293 0.00
tim 2000 07 26 00 00    4.00
att 0011  0.0145139589 -0.6948016786 -0.0436583696  0.7177283157 0.00
tim 2000 07 26 00 00    5.00
att 0011  0.0147483274 -0.6943533633 -0.0446004585  0.7180993724 0.00
tim 2000 07 26 00 00    6.00
att 0011  0.0149780274 -0.6939057331 -0.0455469784  0.7184678009 0.00
tim 2000 07 26 00 00    7.00
att 0011  0.0152030139 -0.6934541405 -0.0465009150  0.7188378845 0.00
tim 2000 07 26 00 00    8.00
att 0011  0.0154267566 -0.6930068647 -0.0474468395  0.7192025541 0.00
tim 2000 07 26 00 00    9.00
att 0011  0.0156573986 -0.6925560261 -0.0483866187  0.7195691402 0.00
tim 2000 07 26 00 00   10.00
att 0011  0.0158894551 -0.6920992184 -0.0493338949  0.7199391500 0.00
tim 2000 07 26 00 00   11.00
att 0011  0.0161171456 -0.6916450166 -0.0502725961  0.7203055535 0.00
tim 2000 07 26 00 00   12.00
att 0011  0.0163439432 -0.6911930056 -0.0512053890  0.7206685287 0.00
tim 2000 07 26 00 00   13.00
att 0011  0.0165736482 -0.6907388374 -0.0521476014  0.7210310784 0.00
%eof
--------------------------------------------------------------------------------
```

A.3. Vector magnetic data with high time resolution

A.3.1. Name identifier

The identifier of this data type in the product file name is `CH-ME-2-FGM-SCI`.

A.3.2. Tabulated overviews

The following description lists the `CDF` contents in a tabulated way, first the global options, followed by the variables itself. The value items with the name part `_List` do have the `VAR-TYPE` attribute `metadata` and are added for convenience on display and plotting with the dedicated software tool.

Global Options

		Global Option/`NETWORK_ENCODING`
Name	Typ	Description
		Global/`gAttributes`
PRODUCT	CDF_CHAR	CH-ME-2-FGM-SCI
TITLE	CDF_CHAR	CHAMP ME MAG SCI (50Hz)
HISTORY	CDF_CHAR	skeleton version 2018-May-08
MJD2000	CDF_INT4	Modified Julian Day (2000) of first vector
NR_OF_RECORDS	CDF_CHAR	0
CREATOR	CDF_CHAR	fgmsci2cdf (Ingo Michaelis)
REFRADIUS	CDF_CHAR	6371.2 km
File_naming_convention	CDF_CHAR	source_mission_group_data_ version_descriptor_datatype_yyyyMMdd
Data_type	CDF_CHAR	Fluxgate Magnetometer
Logical_source	CDF_CHAR	CH-ME-2-FGM-SCI
Logical_source_description	CDF_CHAR	[CALIBRATED] Fluxgate Magnetometer Magnetic field > nT
Logical_file_id	CDF_CHAR	CH-ME-2-FGM-SCI-yyyy-mm-dd
Mission_group	CDF_CHAR	ME
PI_affiliation	CDF_CHAR	GFZ Potsdam
Source_name	CDF_CHAR	CHAllenging Minisatellite Payload
Project	CDF_CHAR	CHAMP - CHAllenging Minisatellite Payload
PI_name	CDF_CHAR	GFZ Potsdam
COSPAR_ID	CDF_CHAR	2000-039B
Data_version	CDF_CHAR	2
TEXT	CDF_CHAR	FluxGate Magnetometer
Instrument_type	CDF_CHAR	FluxGate Magnetometer
Descriptor	CDF_CHAR	Fluxgate Magnetometer
Datatype	CDF_CHAR	Fluxgate Magnetometer
Discipline	CDF_CHAR	Geoscience, Athmospheric science
Acknowledgement	CDF_CHAR	DLR, GFZ
LINK_TITLE	CDF_CHAR	CHAMP - CHAllenging Minisatellite Payload
spase_DatasetResourceID	CDF_CHAR	spase://...
Generated_by	CDF_CHAR	fgmsci2cdf (I.M.)
Rules_of_use	CDF_CHAR	tbd
Generation_date	CDF_CHAR	0000-00-00
HTTP_LINK	CDF_CHAR	`https://www.gfz-potsdam.de/champ/`
LINK_TEXT	CDF_CHAR	CHAMP - CHAllenging Minisatellite Payload
MODS	CDF_CHAR	Rev- 2018-05-08
Time_resolution	CDF_CHAR	0.02s typical

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Other Attributes

Global/vAttributes
INFO, UNITS, VALIDMIN, VALIDMAX, FORMAT, SYSTEM, VAR_TYPE, FILLVAL, FIELDNAM, CATDESC, TIME_BASE, DISPLAY_TYPE, DEPEND_0, LABLAXIS, LABL_PTR_1

Variables

Data Record/rVariables		
Data Record/zVariables		
EPOCH	CDF_EPOCH	Timestamp
GEO_LAT	CDF_DOUBLE	Latitude, geocentric geographic, in degree
GEO_LON	CDF_DOUBLE	Longitude, geocentric geographic, in degree
GEO_ALT	CDF_DOUBLE	Altitude above reference sphere, in km
QUALITY	CDF_INT2	Quality Information
FGM_VEC	CDF_DOUBLE[3]	B-Field-Vector, 3 Components in FGM-1 sensor system
NEC_VEC	CDF_DOUBLE[3]	B-Field-Vector, 3 Components in NEC system
ASC_QUAT	CDF_DOUBLE[4]	ASC quaternions for ICRF (International Celestial Reference System) -¿ CRF (Common Reference System) transformation
ASC_MODE	CDF_UINT1	Bit field for star camera mode (from left to right): 1st A1 Camera 1 Boom; 2nd A2 Camera 2 Boom; 3rd B1 Camera 1 Body; 4rd B2 Camera 2 Body
ASC_STAT	CDF_UNIT4	Integer field: star camera quality information, ### 1st digit is flagging ASC source: 0 = no data available, 2 = single data boom, chu2cr static, 6 = single data boom + chu2cr dynamic, 7 = dual data boom ### 2nd digit is filtered flag: 0 = no, 1 = yes, ### 3rd digit is flagging chu2cr transformation mode: 0 = static, 1 = dynamic, 2 = dual ### 4th digit is flagging jump correction: 0 = no, 1 = chu1/3, 2 = chu2/4, 3 = chu1/3 and chu2/4; ### 5th digit is flagging interpolated gaps: 0 = no interpolation 1 = chu1/3, 2 = chu2/4, 3 = chu1/3 and chu2/4
Quality_List	CDF_CHAR	Quality List
B_List	CDF_CHAR	B_list
Quat_List	CDF_CHAR	Quat_List

A.3.3. CDF Skeleton

```
#header

CDF NAME: ch-me-2-fgm-sci.cdf
DATA ENCODING: NETWORK
MAJORITY: ROW
FORMAT: SINGLE
```

```
! Variables  G.Attributes  V.Attributes  Records  Dims  Sizes
! ---------  ------------  ------------  -------  ----  -----
    0/10           7             7         0/z      0


#GLOBALattributes

! Attribute          Entry       Data
! Name               Number      Type        Value
! ---------          ------      ----        -----

  "PRODUCT"                     1:   CDF_CHAR   { "CH-ME-2-FGM-SCI" } .
  "TITLE"                       1:   CDF_CHAR   { "CHAMP ME MAG SCI (50Hz)" } .
  "HISTORY"                     1:   CDF_CHAR   { "skeleton version 2018-May-08" } .
  "MJD2000"                     1:   CDF_CHAR   { "0.0" } .
  "NR_OF_RECORDS"               1:   CDF_CHAR   { "0" } .
  "CREATOR"                     1:   CDF_CHAR   { "fgmsci2cdf (I.M.)" } .
  "REFRADIUS"                   1:   CDF_CHAR   { "6371.2 km" } .
  "File_naming_convention"      1:   CDF_CHAR   { "source_mission_group_data_data_" -
                                                  "version_descriptor_datatype_yyyyMMdd" } .
  "Data_type"                   1:   CDF_CHAR   { "FGM>Fluxgate Magnetometer" } .
  "Logical_source"              1:   CDF_CHAR   { "CH-ME-2-FGM-SCI" } .
  "Logical_source_description" 1:   CDF_CHAR   { "[CALIBRATED] Fluxgate Magnetometer " -
                                                   "Magnetic field>nT" } .
  "Logical_file_id"             1:   CDF_CHAR   { "CH-ME-2-FGM-SCI-yyyy-mm-dd" } .
  "Mission_group"               1:   CDF_CHAR   { "ME" } .
  "PI_affiliation"              1:   CDF_CHAR   { "GFZ Potsdam" } .
  "Source_name"                 1:   CDF_CHAR   { "CH>CHAllenging Minisatellite Payload" } .
  "Project"                     1:   CDF_CHAR   { "CHAMP - CHAllenging Minisatellite Payload" } .
  "PI_name"                     1:   CDF_CHAR   { "GFZ Potsdam" } .
  "COSPAR_ID"                   1:   CDF_CHAR   { "2000-039B" } .
  "Data_version"                1:   CDF_CHAR   { "2" } .
  "TEXT"                        1:   CDF_CHAR   { "FluxGate Magnetometer" } .
  "Instrument_type"             1:   CDF_CHAR   { "FluxGate Magnetometer" } .
  "Descriptor"                  1:   CDF_CHAR   { "FGM>Fluxgate Magnetometer" } .
  "Datatype"                    1:   CDF_CHAR   { "SCI>Fluxgate Magnetometer" } .
  "Discipline"                  1:   CDF_CHAR   { "Geoscience" }
                                2:   CDF_CHAR   { "Athmospheric science" } .
  "Acknowledgement"             1:   CDF_CHAR   { "DLR, GFZ" } .
  "LINK_TITLE"                  1:   CDF_CHAR   { "CHAMP - CHAllenging Minisatellite Payload" } .
  "spase_DatasetResourceID"     1:   CDF_CHAR   { "spase://..." } .
  "Generated_by"                1:   CDF_CHAR   { "fgmsci2cdf (I.M.)" } .
  "Rules_of_use"                1:   CDF_CHAR   { "tbd" } .
  "Generation_date"             1:   CDF_CHAR   { "0000-00-00" } .
  "HTTP_LINK"                   1:   CDF_CHAR   { "https://www.gfz-potsdam.de/champ/" } .
  "LINK_TEXT"                   1:   CDF_CHAR   { "CHAMP - CHAllenging Minisatellite Payload" } .
  "MODS"                        1:   CDF_CHAR   { "Rev- 2018-05-08" } .
  "Time_resolution"             1:   CDF_CHAR   { "0.02s typical" } .



#VARIABLEattributes

  "INFO"
```


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```
  "SAMPLE"
  "UNITS"
  "VALIDMIN"
  "VALIDMAX"
  "FORMAT"
  "SYSTEM"
  "VAR_TYPE"
  "FILLVAL"
  "FIELDNAM"
  "CATDESC"
  "TIME_BASE"
  "DISPLAY_TYPE"
  "DEPEND_0"
  "LABLAXIS"
  "LABL_PTR_1"


#variables

! No rVariables.


#zVariables

! Variable          Data      Number                 Record   Dimension
! Name              Type     Elements  Dims  Sizes  Variance  Variances
! --------          ----     --------  ----  -----  --------  ---------

  "EPOCH"         CDF_EPOCH      1       0              T

  ! Attribute       Data
  ! Name            Type       Value
  ! --------        ----       -----

    "INFO"        CDF_CHAR     { "time, UT (epoch)" }
    "UNITS"       CDF_CHAR     { "millisecond since 01-Jan-0000 00:00:00.000 (CDF epoch)" }
    "FORMAT"      CDF_CHAR     { "F20.0" }
    "VALIDMIN"    CDF_EPOCH    { 01-Jan-2000 00:00:00.000 }
    "VALIDMAX"    CDF_EPOCH    { 01-Jan-2011 00:00:00.000 }
    "FILLVAL"     CDF_EPOCH    { 31-Dec-9999 23:59:59.999 }
    "TIME_BASE"   CDF_CHAR     { "0 AD" }
    "FIELDNAM"    CDF_CHAR     { "Timestamp" }
    "CATDESC"     CDF_CHAR     { "Timestamp" }
    "VAR_TYPE"    CDF_CHAR     { "support_data" } .

  ! RV values were not requested.


! Variable          Data      Number                 Record   Dimension
! Name              Type     Elements  Dims  Sizes  Variance  Variances
! --------          ----     --------  ----  -----  --------  ---------

  "GEO_LAT"      CDF_DOUBLE     1       0              T
```

```
  ! Attribute       Data
  ! Name            Type       Value
  ! --------        ----       -----

    "INFO"          CDF_CHAR     { "latitude" }
    "UNITS"         CDF_CHAR     { "degree" }
    "VALIDMIN"      CDF_DOUBLE   { -90.0 }
    "VALIDMAX"      CDF_DOUBLE   { 90.0 }
    "FILLVAL"       CDF_DOUBLE   { -1.0e+31 }
    "FORMAT"        CDF_CHAR     { "F15.10"}
    "SYSTEM"        CDF_CHAR     { "geocentric geographic" }
    "FIELDNAM"      CDF_CHAR     { "Geocentric latitude" }
    "CATDESC"       CDF_CHAR     { "Position" }
    "DEPEND_0"      CDF_CHAR     { "EPOCH" }
    "LABLAXIS"      CDF_CHAR     { "Latitude" }
    "VAR_TYPE"      CDF_CHAR     { "data" }
    "DISPLAY_TYPE"  CDF_CHAR     { "time_series" } .

  ! RV values were not requested.


! Variable          Data      Number                 Record   Dimension
! Name              Type     Elements  Dims  Sizes  Variance  Variances
! --------          ----     --------  ----  -----  --------  ---------

  "GEO_LON"     CDF_DOUBLE     1       0              T

  ! Attribute       Data
  ! Name            Type       Value
  ! --------        ----       -----

    "INFO"          CDF_CHAR     { "longitude" }
    "UNITS"         CDF_CHAR     { "degree" }
    "VALIDMIN"      CDF_DOUBLE   { -180.0 }
    "VALIDMAX"      CDF_DOUBLE   { 180.0 }
    "FILLVAL"       CDF_DOUBLE   { -1.0e+31 }
    "FORMAT"        CDF_CHAR     { "F15.10"}
    "SYSTEM"        CDF_CHAR     { "geocentric geographic" }
    "FIELDNAM"      CDF_CHAR     { "Geocentric longitude" }
    "CATDESC"       CDF_CHAR     { "Position" }
    "DEPEND_0"      CDF_CHAR     { "EPOCH" }
    "LABLAXIS"      CDF_CHAR     { "Longitude" }
    "VAR_TYPE"      CDF_CHAR     { "data" }
    "DISPLAY_TYPE"  CDF_CHAR     { "time_series" } .

  ! RV values were not requested.


! Variable          Data      Number                 Record   Dimension
! Name              Type     Elements  Dims  Sizes  Variance  Variances
! --------          ----     --------  ----  -----  --------  ---------

  "GEO_ALT"        CDF_DOUBLE     1       0              T
```


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```
  ! Attribute       Data
  ! Name            Type       Value
  ! --------        ----       -----

    "INFO"          CDF_CHAR     { "altitude above reference sphere" }
    "UNITS"         CDF_CHAR     { "km" }
    "VALIDMIN"      CDF_DOUBLE   { 0.0 }
    "VALIDMAX"      CDF_DOUBLE   { 999.9 }
    "FILLVAL"       CDF_DOUBLE   { -1.0e+31 }
    "FORMAT"        CDF_CHAR     { "F10.6"}
    "SYSTEM"        CDF_CHAR     { "geocentric geographic" }
    "FIELDNAM"      CDF_CHAR     { "Geocentric altitude" }
    "CATDESC"       CDF_CHAR     { "Position" }
    "DEPEND_0"      CDF_CHAR     { "EPOCH" }
    "LABLAXIS"      CDF_CHAR     { "Altitude" }
    "VAR_TYPE"      CDF_CHAR     { "data" }
    "DISPLAY_TYPE"  CDF_CHAR     { "time_series" } .

  ! RV values were not requested.


! Variable          Data      Number                 Record   Dimension
! Name              Type     Elements  Dims  Sizes  Variance  Variances
! --------          ----     --------  ----  -----  --------  ---------

  "QUALITY"        CDF_INT2     1       1     2        T         T

  ! Attribute       Data
  ! Name            Type       Value
  ! --------        ----       -----

    "INFO"          CDF_CHAR     { "Quality information" }
    "UNITS"         CDF_CHAR     { "Bit-Field" }
    "VALIDMIN"   CDF_INT2     { 0 }
    "VALIDMAX"   CDF_INT2     { 32767 }
    "FILLVAL"       CDF_INT2     { 32768 }
    "FORMAT"        CDF_CHAR     { "I16"}
    "FIELDNAM"      CDF_CHAR     { "Quality" }
    "CATDESC"       CDF_CHAR     { "FGM" }
    "DEPEND_0"      CDF_CHAR     { "EPOCH" }
    "LABLAXIS"      CDF_CHAR     { "Quality" }
    "VAR_TYPE"      CDF_CHAR     { "data" }
    "LABL_PTR_1"    CDF_CHAR     { "Quality_List" }
    "DISPLAY_TYPE"  CDF_CHAR     { "time_series" } .

  ! RV values were not requested.


! Variable          Data      Number                 Record   Dimension
! Name              Type     Elements  Dims  Sizes  Variance  Variances
! --------          ----     --------  ----  -----  --------  ---------

  "FGM_VEC"     CDF_DOUBLE     1       1     3        T         T
```

```
  ! Attribute       Data
  ! Name            Type       Value
  ! --------        ----       -----

    "INFO"          CDF_CHAR     { "B-vector in FGM-1 sensor system" }
    "UNITS"         CDF_CHAR     { "nT" }
    "VALIDMIN"   CDF_DOUBLE   { -99999.9 }
    "VALIDMAX"   CDF_DOUBLE   {  99999.9 }
    "FILLVAL"       CDF_DOUBLE   { -1.0e+31 }
    "FORMAT"        CDF_CHAR     { "F15.3"}
    "SAMPLE"        CDF_CHAR     { "50 Hz" }
    "SYSTEM"        CDF_CHAR     { "CHAMP FGM-1 sensor system" }
    "FIELDNAM"      CDF_CHAR     { "FGM_FGM" }
    "CATDESC"       CDF_CHAR     { "FGM" }
    "DEPEND_0"      CDF_CHAR     { "EPOCH" }
    "LABLAXIS"      CDF_CHAR     { "B_FGM" }
    "VAR_TYPE"      CDF_CHAR     { "data" }
    "LABL_PTR_1"    CDF_CHAR     { "B_List" }
    "DISPLAY_TYPE"  CDF_CHAR     { "time_series" } .

  ! RV values were not requested.


! Variable          Data      Number                 Record   Dimension
! Name              Type     Elements  Dims  Sizes  Variance  Variances
! --------          ----     --------  ----  -----  --------  ---------

  "NEC_VEC"     CDF_DOUBLE     1       1     3        T         T

  ! Attribute       Data
  ! Name            Type       Value
  ! --------        ----       -----

    "INFO"          CDF_CHAR     { "B-vector in NEC system" }
    "UNITS"         CDF_CHAR     { "nT" }
    "VALIDMIN"   CDF_DOUBLE   { -99999 }
    "VALIDMAX"   CDF_DOUBLE   {  99999 }
    "FILLVAL"       CDF_DOUBLE   { -1.0e+31 }
    "FORMAT"        CDF_CHAR     { "F15.3"}
    "SAMPLE"        CDF_CHAR     { "50 Hz" }
    "SYSTEM"        CDF_CHAR     { "NEC (North East Centered) system" }
    "FIELDNAM"      CDF_CHAR     { "FGM_NEC" }
    "CATDESC"       CDF_CHAR     { "FGM" }
    "DEPEND_0"      CDF_CHAR     { "EPOCH" }
    "LABLAXIS"      CDF_CHAR     { "B_NEC" }
    "VAR_TYPE"      CDF_CHAR     { "data" }
    "LABL_PTR_1"    CDF_CHAR     { "B_List" }
    "DISPLAY_TYPE"  CDF_CHAR     { "time_series" } .

  ! RV values were not requested.


! Variable          Data      Number                 Record   Dimension
! Name              Type     Elements  Dims  Sizes  Variance  Variances
```


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```
! --------          ----     --------  ----  -----  --------  ---------

  "ASC_QUAT"     CDF_DOUBLE     1       1     4        T         T

  ! Attribute       Data
  ! Name            Type       Value
  ! --------        ----       -----

    "INFO"         CDF_CHAR       { "ASC quaternions for " -
                                    "ICRF (International Celestial Reference System) " -
                                    " -> CRF (Common Reference System) transformation" }
    "VALIDMIN"   CDF_DOUBLE   { -1.0 }
    "VALIDMAX"   CDF_DOUBLE   { 1.0 }
    "FILLVAL"       CDF_DOUBLE   { -1.0e+31 }
    "FORMAT"        CDF_CHAR     { "F15.10"}
    "UNITS"         CDF_CHAR     { " " }
    "SAMPLE"        CDF_CHAR     { "50 Hz" }
    "FIELDNAM"      CDF_CHAR     { "ASC_QUAT" }
    "CATDESC"       CDF_CHAR     { "ASC" }
    "DEPEND_0"      CDF_CHAR     { "EPOCH" }
    "LABLAXIS"      CDF_CHAR     { "Quaternion" }
    "VAR_TYPE"      CDF_CHAR     { "data" }
    "LABL_PTR_1"    CDF_CHAR     { "Quat_List" }
    "DISPLAY_TYPE"  CDF_CHAR     { "time_series" } .

  ! RV values were not requested.


! Variable          Data      Number                 Record   Dimension
! Name              Type     Elements  Dims  Sizes  Variance  Variances
! --------          ----     --------  ----  -----  --------  ---------

  "ASC_MODE"     CDF_UINT1     1       0              T

  ! Attribute       Data
  ! Name            Type       Value
  ! --------        ----       -----

    "INFO"          CDF_CHAR     { "Star camera mode (from left to right):" -
                                   "1st A1 Camera 1 Boom;" -
                                   "2nd A2 Camera 2 Boom;" -
                                   "3rd B1 Camera 1 Body;" -
                                   "4rd B2 Camera 2 Body"}
    "UNITS"         CDF_CHAR     { "bit field" }
    "VALIDMIN"   CDF_UINT1    { 1 }
    "VALIDMAX"   CDF_UINT1    { 15 }
    "FILLVAL"       CDF_UINT1    { 255 }
    "FORMAT"        CDF_CHAR     { "I2"}
    "SAMPLE"        CDF_CHAR     { "50 Hz" }
    "FIELDNAM"      CDF_CHAR     { "ASC_MODE" }
    "CATDESC"       CDF_CHAR     { "ASC" }
    "DEPEND_0"      CDF_CHAR     { "EPOCH" }
    "LABLAXIS"      CDF_CHAR     { "Mode" }
    "VAR_TYPE"      CDF_CHAR     { "data" }
```

```
    "DISPLAY_TYPE"  CDF_CHAR     { "time_series" } .

  ! RV values were not requested.


! Variable          Data      Number                 Record   Dimension
! Name              Type     Elements  Dims  Sizes  Variance  Variances
! --------          ----     --------  ----  -----  --------  ---------

  "ASC_STAT"     CDF_UINT4     1       0              T

  ! Attribute       Data
  ! Name            Type       Value
  ! --------        ----       -----

    "INFO"         CDF_CHAR     { "star camera quality information," -
                                  "### 1st digit is flagging ASC source:" -
                                  "0 = no data available," -
                                  "2 = single data boom, chu2cr static," -
                                  "6 = single data boom + chu2cr dynamic," -
                                  "7 = dual data boom" -
                                  "### 2nd digit is filtered flag: 0 = no, 1 = yes" -
                                  "### 3rd digit is flagging chu2cr transformation mode:" -
                                  "0 = static, 1 = dynamic, 2 = dual" -
                                  "### 4th digit is flagging jump correction:" -
                                  "0 = no, 1 = chu1/3, 2 = chu2/4, 3 = chu1/3 and chu2/4;" -
                                  "### 5th digit is flagging interpolated gaps:" -
                                  "0 = no interpolation " -
                                  "1 = chu1/3, 2 = chu2/4, 3 = chu1/3 and chu2/4" }
    "UNITS"        CDF_CHAR     { "integer field" }
    "VALIDMIN"  CDF_UINT4    { 1 }
    "VALIDMAX"  CDF_UINT4    { 99999 }
    "FILLVAL"      CDF_UINT4    { 4294967295 }
    "FORMAT"       CDF_CHAR     { "I5"}
    "SAMPLE"       CDF_CHAR     { "50 Hz" }
    "FIELDNAM"     CDF_CHAR     { "ASC_STAT" }
    "CATDESC"      CDF_CHAR     { "ASC" }
    "DEPEND_0"     CDF_CHAR     { "EPOCH" }
    "LABLAXIS"     CDF_CHAR     { "Status" }
    "VAR_TYPE"     CDF_CHAR     { "data" }
    "DISPLAY_TYPE" CDF_CHAR     { "time_series" } .

  ! RV values were not requested.


! Variable          Data      Number                 Record   Dimension
! Name              Type     Elements  Dims  Sizes  Variance  Variances
! --------          ----     --------  ----  -----  --------  ---------

  "Quality_List"    CDF_CHAR      10       1     2       F         T

  ! Attribute       Data
  ! Name            Type       Value
  ! --------        ----       -----
```


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```
    "CATDESC"     CDF_CHAR     { "Quality_List" }
    "FIELDNAM"    CDF_CHAR     { "Quality_List" }
    "FORMAT"      CDF_CHAR     { "A11" }
    "VAR_TYPE"    CDF_CHAR     { "metadata" }
    "UNITS"       CDF_CHAR     { " " } .

  ! NRV values follow...

    [1] = { "quality 00" }
    [2] = { "quality 01" }



! Variable          Data      Number                 Record   Dimension
! Name              Type     Elements  Dims  Sizes  Variance  Variances
! --------          ----     --------  ----  -----  --------  ---------

  "B_List"    CDF_CHAR      2       1     3       F         T

  ! Attribute       Data
  ! Name            Type       Value
  ! --------        ----       -----

    "CATDESC"     CDF_CHAR     { "B_List" }
    "FIELDNAM"    CDF_CHAR     { "B_List" }
    "FORMAT"      CDF_CHAR     { "A11" }
    "VAR_TYPE"    CDF_CHAR     { "metadata" }
    "UNITS"       CDF_CHAR     { "nT" } .

  ! NRV values follow...

    [1] = { "Bx" }
    [2] = { "By" }
    [3] = { "Bz" }



! Variable          Data      Number                 Record   Dimension
! Name              Type     Elements  Dims  Sizes  Variance  Variances
! --------          ----     --------  ----  -----  --------  ---------

  "Quat_List"    CDF_CHAR      2       1     4       F         T

  ! Attribute       Data
  ! Name            Type       Value
  ! --------        ----       -----

    "CATDESC"     CDF_CHAR     { "Quat_List" }
    "FIELDNAM"    CDF_CHAR     { "Quat_List" }
    "FORMAT"      CDF_CHAR     { "A11" }
    "VAR_TYPE"    CDF_CHAR     { "metadata" }
    "UNITS"       CDF_CHAR     { " " } .
```

```
  ! NRV values follow...

    [1] = { "q1" }
    [2] = { "q2" }
    [3] = { "q3" }
    [4] = { "q4" }

#end
```


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A.4. Electron density and temperatures

A.4.1. Name identifier

The identifier of this data type in the product file name is `CH-ME-2-PLPT`.

A.4.2. Description

As the file format is a mere whitespace delimited ASCII listing without a complex structure, a copy of the list-header and a brief, cutout example are sufficient as a description.

List header

```
# CH-ME-2-PLPT+YYYY-MM-DD_V
#
#     created from : <file name> (temperature corrected)
#                @ : YYYY-MM-DD by rauberg
#
# first time (UTC) : YYYY-MM-DD hh:mm:s.sss
#       mjd  (UTC) : <mjd2000>
#       gps  (gps) : <gps second, integer>
#
# end   time (UTC) : YYYY-MM-DD hh:mm:s.sss
#       mjd  (UTC) : <mjd2000, float>
#       gps  (gps) : <gps second, integer>
#
#-------------------------------------------------------------------------------------
#     GPS YYYY MM DD hh mm ss       radius   latitude    longitude  electron     electron
#                                            geocentr     geocentr   density  temperature
#     [s]                             [km]      [deg]        [deg]  [1/cm^3]          [K]
#-------------------------------------------------------------------------------------
<data>
```

Brief cutout example

```
# CH-ME-2-PLPT+2006-01-02_1.dat
#
#     created from : plp_den_YYYYDDD.dat (temperature corrected)
#                @ : 2012-01-27 by rauberg
#
# first time (UTC) : 2006-01-02 00:00:06.000
#       mjd  (UTC  : 2193.0000694444
#       gps  (GPS) : 820195220
#
# end   time (UTC) : 2006-01-02 23:59:51.000
#       mjd  (UTC  : 2193.9998958333
#       gps  (GPS) : 820281605
#
#
#-------------------------------------------------------------------------------------
#     GPS YYYY MM DD hh mm ss       radius   latitude    longitude  electron     electron
#                                            geocentr     geocentr   density  temperature
#     [s]                             [km]      [deg]        [deg]  [1/cm^3]          [K]
```

```
#-------------------------------------------------------------------------------------------
820195220 2006 01 02 00 00 06   6714.93143   64.88687    172.41561     96900        2338.5
820195235 2006 01 02 00 00 21   6715.05692   63.90709    172.60759    102000        2438.4
820195250 2006 01 02 00 00 36   6715.18597   62.92690    172.78238    104000        2348.3
820195265 2006 01 02 00 00 51   6715.31854   61.94636    172.94177    102000        2329.2
820195280 2006 01 02 00 01 06   6715.45450   60.96551    173.08733    102000        2320.7
820195295 2006 01 02 00 01 21   6715.59383   59.98437    173.22042    103000        2362.3
820195310 2006 01 02 00 01 36   6715.73639   59.00298    173.34223    103000        2284.0
820195325 2006 01 02 00 01 51   6715.88215   58.02136    173.45380    110000        2195.8
820195340 2006 01 02 00 02 06   6716.03098   57.03953    173.55605    122000        2116.5
820195355 2006 01 02 00 02 21   6716.18283   56.05752    173.64980    130000        2107.1
820195370 2006 01 02 00 02 36   6716.33757   55.07535    173.73578    142000        2027.7
820195385 2006 01 02 00 02 51   6716.49514   54.09303    173.81462    153000        2008.3
[...]
```


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