R O S E T T A

FLIGHT REPORTS
of RPC–MAG

RO-IGEP-TR0028

Step by Step
Calibration Procedure
for RPC-MAG Data

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Ingo Richter

e-mail: i.richter@tu-bs.de
Institut für Geophysik und extraterrestrische Physik
Technische Universität Braunschweig
Mendelssohnstraße 3, 38106 Braunschweig
Germany

Contents

1 Introduction

This document describes calibration of the RPCMAG magnetic field data. Prior to launch intensive testing and a complete calibration of the instrument has been executed at the Magnetic Coil Facility *MAGNETSRODE*, operated by the Institute for Geophysics and extraterrestrial Physics, Technische Universität Braunschweig. The principle and basic parameters obtained by this ground calibration is described in detail in section 3.

The evaluated parameters have to be applied in a well defined way to the data measured in space. The step by step procedure leading to various data products is described in section 4 and its subchapters.

As the temperature calibration on ground was only possible in a limited temperature range (especially on the cold side) the offset calibration had to be improved by a sophisticated inflight calibration, using measured data of quiet magnetic field observations at temperatures down to -140°C. Furthermore shifts of the magnetic field data by offset jumps and variations in the s/c-residual magnetic field have to be taken into account to obtain proper data. All these inflight calibration issues are described in section 4.2.3.3.

2 Applicable Documents

- AD1: Richter I., Rahm M.,RO-IGM-TR-0002, Fluxgate Magnetometer Calibration for Rosetta: Report on the FM and FS Calibration Institut für Geophysik und Meteorologie, Braunschweig, Oktober 2001

- AD2: Othmer C., Richter I., RO-IGM-TR-0003, Fluxgate Magnetometer Calibration for Rosetta: Analysis of the FM Calibration Institut für Geophysik und Meteorologie, Braunschweig, Oktober 2001

- AD3: Eichelberger H., Schwingenschuh K.,Aydogar O., Baumjohann W. RO-IWF-TR0001, Calibration Report, Sample Rate and Frequency Response - Analysis of ROSETTA RPC-MAG IWF Graz, January 2002

- AD4: Richter I., RO-IGEP-TR-0007, RPC-MAG Software DDS2PDS User Manual Institut für Geophysik und extraterrestrische Physik, Braunschweig, January 2010

- AD5: Richter I., Diedrich A., Glassmeier K.H. RO-IGEP-TR-0009, EAICD, ROSETTA-RPC-MAG To Planetary Science Archive Interface Control Document Institut für Geophysik und extraterrestrische Physik, Braunschweig, August 2018

- AD6: Rosetta Mission Control System (RMCS) Data Delivery Interface Document, DDID, RO-ESC-IF-5003

- AD7: Diedrich A., Glassmeier K.-H., Richter I., RO-IGEP-TN0001, RPCMAG Internal Packet Definitions, Institut für Geophysik und extraterrestrische Physik, Technische Universität Braunschweig
- AD8: Lee C., PIU Magnetometer Processing Software Overview, RO-RPC-MA-6007
- AD9: Richter, I., Cupido E., ROSETTA PLASMA CONSORTIUM USER MANUAL, RO-RPC-UM
- AD10: Tsurutani, B.T., Gould, T., Goldsstein, B.E., Gonzalez, W.D., Sugiura, M.; Interplanetary Alfvén Waves and Auroral (Substorm) Activity: IMP8; Journal of Geophysical Research, Vol.95, No.A3, 2241-2252, 1990
- AD11: Richter I., RO-IGEP-TR-0074, RPCMAG Userguide: Proper Usage of Magnetic Field Data and potential Pitfalls, Institut fuer Geophysik und extraterrestrische Physik, Braunschweig, July 2018
- AD12: Beth A., Galand M., Nilsson H., Goldstein R., Mokashi P., Eriksson A., Richter I., Goetz C., Henri P., Vallieres X. Carr C., Allen T., RPC User Guide, August 2018

3 Ground Calibration

3.1 Summary

The ground calibration has been performed at the magnetic coil facility MAGNETSRODE. At this facility the magnetometers can be operated in known and stable magnetic field conditions. Artificial magnetic calibration fields can be applied in a range from -100000 nT to +100000 nT on each individual coil axis X_c, Y_c, Z_c. The absolute accuracy of the fields is better than 0.8 nT. Additionally to these DC fields AC fields can be applied in the same range with frequencies up to the order of Kilohertz. The device under test can not only be operated at room temperature but also in wide temperature range from $-196°$C up to $+200°$C using a special designed unmagnetic thermal box.

REMARK: At the time of the ROSETTA calibration only thermal equipment of the antecedent generation was available, allowing to change temperatures in the range $-70° C$ up to $+80° C$ only. Therefore extended offset calibration had to be done during the Inflight Calibration during the Extended Archiving Phase. The inflight calibration is described in details in section 4.2.3.3

The DC ground calibration comprises the determination of the following temperature dependent entities:

- Offset-Vector $\underline{B}_{\text{off}}(T)$
- Sensitivity-Matrix $\underline{\underline{\sigma}}(T)$
- Misalignment.Matrix $\underline{\underline{\omega}}(T)$

A coarse overview about the numerical values for both sensors outboard (OB) and inboard (IB) is given now:

OFFSETS:

$$\underline{B}_{\text{off,OB}}(T) = \begin{pmatrix} 214.5 \\ -79.9 \\ 384.7 \end{pmatrix} + \begin{pmatrix} -1.053 \\ 0.0730 \\ -1.6570 \end{pmatrix} \cdot T \quad [\text{nT}, \text{K}]$$

$$\underline{B}_{\text{off,IB}}(T) = \begin{pmatrix} 114.3 \\ -119.8 \\ 494 \end{pmatrix} + \begin{pmatrix} -0.565 \\ 0.731 \\ -1.673 \end{pmatrix} \cdot T \quad [\text{nT}, \text{K}]$$

SENSITIVITIES:

$$\underline{\underline{\sigma}}_{\mathrm{OB}}(T) = \begin{pmatrix} 1.091 & 0 & 0 \\ 0 & 1.09352 & 0 \\ 0 & 0 & 1.09289 \end{pmatrix} + \begin{pmatrix} -11.8 & 0 & 0 \\ 0 & -8.21 & 0 \\ 0 & 0 & -6.97 \end{pmatrix} \cdot 10^{-6} \cdot T \quad [\mathrm{nT}, \mathrm{K}]$$

$$\underline{\underline{\sigma}}_{\mathrm{IB}}(T) = \begin{pmatrix} 1.0907 & 0 & 0 \\ 0 & 1.09434 & 0 \\ 0 & 0 & 1.09413 \end{pmatrix} + \begin{pmatrix} -14.2 & 0 & 0 \\ 0 & -9.30 & 0 \\ 0 & 0 & -8.55 \end{pmatrix} \cdot 10^{-6} \cdot T \quad [\mathrm{nT}, \mathrm{K}]$$

MISALIGNMENT ANGLES:

$$\begin{aligned} \xi_{\mathrm{xy,OB}}(T) &= 90.0666 - 6.04 \cdot 10^{-5} \cdot T \quad [\,^\circ, \mathrm{K}] \\ \xi_{\mathrm{xz,OB}}(T) &= 90.0366 - 1.11 \cdot 10^{-4} \cdot T \quad [\,^\circ, \mathrm{K}] \\ \xi_{\mathrm{yz,OB}}(T) &= 90.0370 - 8.12 \cdot 10^{-5} \cdot T \quad [\,^\circ, \mathrm{K}] \end{aligned}$$

$$\begin{aligned} \xi_{\mathrm{xy,IB}}(T) &= 90.0348 + 8.54 \cdot 10^{-5} \cdot T \quad [\,^\circ, \mathrm{K}] \\ \xi_{\mathrm{xz,IB}}(T) &= 89.9587 + 3.71 \cdot 10^{-5} \cdot T \quad [\,^\circ, \mathrm{K}] \\ \xi_{\mathrm{yz,IB}}(T) &= 89.9433 + 1.20 \cdot 10^{-4} \cdot T \quad [\,^\circ, \mathrm{K}] \end{aligned}$$

The complete description and and background information concerning these parameters are presented in the next chapters.

3.2 Mathematical Description of the Ground Calibration

3.2.1 Basic Principle

The Magnetsrode Coil Facility (MCF) generates an artificial magnetic field $\underline{B}^c$ that can be considered as a calibrated, orthogonal magnetic reference field [a)]. The magnetometer under test at the center of the coil system (CoC) generates magnetic raw data $\underline{B}^r$. These data include an eventually existing residual field of the coil system $\underline{B}^{res}$ and the

[a)] During the calibration the temperature dependent sensitivity of the coil system is calculated every 3 minutes and taken into account as well as the static misalignment of the coil system to produce orthogonal, known fields.

magnetometer offset $\underline{B}^{off}$.

$$\underline{B}^{or} = \underline{B}^{off} + \underline{B}^{res}$$

Therefore, the first step of the calibration is the generation of offset and residual field corrected measured field data $\underline{B}^{m}$:

$$\underline{B}^{m} = \underline{B}^{r} - \underline{B}^{or}$$

The actual offset and residual field is automatically taken into account during the calibration analysis. Either a constant field or - if needed - a linear trend of $\underline{B}^{or}$ is subtracted from the raw data.

The relation between the calibration field and the magnetometer data is then defined by

$$\underline{B}^{m} = \underline{\underline{F}}\ \underline{B}^{c}$$

where $\underline{\underline{F}}$ is the complete calibration transfer matrix, defined by

$$\underline{\underline{F}} = \underline{\underline{S}}\ \underline{\underline{O}}\ \underline{\underline{R}}.$$

$\underline{\underline{S}}(T)$ represents the temperature dependent sensitivity.
$\underline{\underline{O}}(T)$ describes the temperature dependent internal sensor misalignment (orthogonalisation matrix).
$\underline{\underline{R}}(T)$ describes the rotation of the sensor against the coil axes. [b)]

The calibration algorithms compute the inverse matrices:

$$\begin{aligned} \underline{\underline{\phi}} &=: \underline{\underline{F}}^{-1} \\ &= \underline{\underline{R}}^{-1}\ \underline{\underline{O}}^{-1}\ \underline{\underline{S}}^{-1} \\ &=: \underline{\underline{\rho}}\ \underline{\underline{\omega}}\ \underline{\underline{\sigma}}\ . \end{aligned}$$

These matrices have the following shape:

$$\underline{\underline{\sigma}} = \begin{pmatrix} \sigma_1 & 0 & 0 \\ 0 & \sigma_2 & 0 \\ 0 & 0 & \sigma_3 \end{pmatrix} ,$$

$$\underline{\underline{\omega}} = \begin{pmatrix} 1 & \cos\xi_{xy} & \cos\xi_{xz} \\ 0 & \sin\xi_{xy} & \dfrac{\cos\xi_{yz} - \cos\xi_{xy}\cos\xi_{xz}}{\sin\xi_{xy}} \\ 0 & 0 & \sqrt{\sin^2\xi_{xz} - \dfrac{(\cos\xi_{yz} - \cos\xi_{xy}\cos\xi_{xz})^2}{\sin^2\xi_{xy}}} \end{pmatrix} ,$$

[b)] Also the rotation matrix is regarded as temperature dependent being able to consider any thermal setup inadequacies causing fractional rotations.

$$\underline{\underline{\rho}} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\lambda & -\sin\lambda \\ 0 & \sin\lambda & \cos\lambda \end{pmatrix} \begin{pmatrix} \cos\mu & 0 & \sin\mu \\ 0 & 1 & 0 \\ -\sin\mu & 0 & \cos\mu \end{pmatrix} \begin{pmatrix} \cos\nu & -\sin\nu & 0 \\ \sin\nu & \cos\nu & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

The rotation matrix $\underline{\underline{R}}$ is of interest just for the calibration to determine the right magnetometer parameters. The transfer function for the normal use of the magnetometer is just given by

$$\underline{\underline{\phi}} = \underline{\underline{\omega}}\,\underline{\underline{\sigma}}$$

3.2.2 Temperature Effects

In the last section the basic principle of calibrating a linear sensor has been described. Now the important question of temperature dependence shall be discussed.
Three aspects will be considered:

- Temperature influence on the OFFSET.
- Temperature influence on the SENSITIVITY.
- Temperature influence on the ALIGNMENT.

The temperature parameters were measured during the ground calibration at the Magnetsrode Coil Facility. To save some time, the two sensors IB and OB, were tested in parallel. For this purpose they were both placed in the temperature box. Thus, one sensor is fixed a few centimeters north and the other one is some centimeters south of CoC. Therefore, the calibration field acting at these positions is not the same as the reference field at CoC used for the other calibration tasks.

For this reason a special algorithm described below was developed to deduce the "true" temperature effects from the measurements with a slightly "wrong" field.

3.2.2.1 Temperature Influence on the OFFSET

Offset measurements are executed under zero field condition. Therefore, no geometrical problem, mentioned above, arises.
There are two methods to obtain the sensor offsets:

1. Assuming a properly working facility the residual field of the coil system $\underline{B}^{res}$ stays constant. This constant residual field has to be determined before the thermal measurements and must be subtracted to get the offset. The residual field determination and nulling is a standard procedure before any calibration.

   The temperature dependence of the offset can generally be computed as

   $$\underline{B}^{off}(T) = \sum_{k=0}^{n} \underline{B}_k^{off} \cdot T^k - \underline{B}^{res}$$

   The polynomial coefficients $\underline{B}_k^{off}$ are evaluated by the analysis software using a polynomial fit of zerofield measurements $\underline{B}^{off}(T_i)$ at all temperature levels T_i available.

2. A more accurate method uses the usual sensor rotations by 180° around two main axes to obtain the sensor offsets. Adding the measurement values from the normal and the turned position reveals the sensor offset

   $$\underline{B}^{off}(T_i) = \frac{\underline{B}^r_{0^\circ}(T_i) + \underline{B}^r_{180^\circ}(T_i)}{2},$$

   subtracting yields the coils system residual field:

   $$\underline{B}^{res}(t) = \frac{\underline{B}^r_{0^\circ}(t) - \underline{B}^r_{180^\circ}(t)}{2},$$

   This residual field is only time dependent and not a function of the sensor temperature. The temperature dependence of the sensor can then be determined using a polynomial fit of all complete sets of offset measurements $\underline{B}^{off}(T_i)$ at the specific temperature levels T_i:

   $$\underline{B}^{off}(T) = \sum_{k=0}^{n} \underline{B}_k^{off} \cdot T^k$$

For the ROSETTA ground calibration it was not possible to rotate the sensor by 180° whilst operated inside the temperature box. Therefore the first method had to be applied for measuring the temperature dependence of the offset. Thus the sum of offset and residual field were measured. This means that the constant residual field has to be subtracted to get the offset. It can be determined by comparing the standard offset measurements (180° sensor flipping at CoC) at the reference temperature T_1 with the "temperature offset measurement" (i.e. the offset as determined during the temperature cycle) at T_1.

Combining all this, the offsets for the ROSETTA sensors are expressed as

$$\underline{B}^{off} = \underline{a}_0 + \underline{a}_1 \cdot T$$

The fit-coefficients a_i are provided in the delivered calibration files.

3.2.2.2 Temperature Influence on the SENSITIVITY

The standard temperature model for a FGM sensor assumes a linear temperature dependence of the sensitivity. Therefore, the sensitivity components can be described as follows:

$$\sigma_i(T) = \sigma_{0,i} + \sigma_{1,i} \cdot T$$

Here $\sigma_{0,i}$ assigns the offset and $\sigma_{1,i}$ the slope of the i^{th} component of the sensitivity. Performing measurements at CoC would reveal exactly this behavior. As, however, the measurements are taken at an off–CoC position one gets a slightly different law

$$\sigma_i^1(T) = \sigma_{0,i}^1 + \sigma_{1,i}^1 \cdot T$$

where the 1 in the exponent assigns the off–CoC position.

At CoC just the reference sensitivity $\sigma_i^0(T_1)$ measured at T_1 is known (upper index 0 denotes CoC position) from an independent measurement outside the T–cycle. Thus the problem is the calculation of the temperature dependent sensitivity at CoC

$$\sigma_i^0(T) = \sigma_{0,i}^0 + \sigma_{1,i}^0 \cdot T$$

from the known coefficients.

Solution:
For the temperature T_1 the sensitivities at different places inside the coil system should only differ by a constant geometry correction factor

$$k_i = \frac{\sigma_i^1(T_1)}{\sigma_i^0(T_1)}.$$

As this factor is a temperature independent coil system parameter, $\sigma_i^0(T)$ can be deduced by

$$\sigma_i^0(T) = \frac{1}{k_i}\ \sigma_i^1(T).$$

Hence

$$\sigma_i^0(T) = \frac{1}{k_i}\ \left(\sigma_{0,i}^1 + \sigma_{1,i}^1 \cdot T\right)$$

delivers the desired result.

3.2.2.3 Temperature Influence on the ALIGNMENT

For the alignment a linear temperature dependency of the misalignment angles ξ_{xy}, ξ_{xz}, ξ_{yz} is assumed.

$$\xi_{ij}(T) = \xi_{0,ij} + \xi_{1,ij} \cdot T$$

Here $\xi_{0,ij}$ assigns the offset and $\xi_{1,ij}$ the slope of the ij–angle of the misalignment. Performing measurements at CoC would reveal exactly this behavior. As, however, the measurement are taken at an off–CoC position one gets a slightly different law

$$\xi^1_{ij}(T) = \xi^1_{0,ij} + \xi^1_{1,ij} \cdot T$$

where the 1 in the exponent assigns the off–CoC position.

At CoC just the reference angles $\xi^0_{ij}(T_1)$ measured at T_1 are known (upper limit 0 denotes CoC position) from an independent measurement. Thus the problem is the calculation of the temperature dependent angles at CoC

$$\xi^0_{ij}(T) = \xi^0_{0,ij} + \xi^0_{1,ij} \cdot T$$

from the known coefficients, or more precisely, to get the temperature dependent orthogonalisation matrix

$$(\underline{\underline{\omega^0}})(T) = \begin{pmatrix} 1 & \cos(\xi^0_{xy}(T)) & \cos(\xi^0_{xz}(T)) \\ 0 & \sin(\xi^0_{xy}(T)) & \frac{\cos(\xi^0_{yz}(T))-\cos(\xi^0_{xy}(T))\cdot\cos(\xi^0_{xz}(T))}{\sin(\xi^0_{xy}(T))} \\ 0 & 0 & \sqrt{\sin^2(\xi^0_{xz}(T)) - (\omega^0(1,2))^2} \end{pmatrix}$$

at CoC.

Solution:
The consideration of the sensitivity revealed a geometrical correction factor k_i which defines the transfer from off–CoC position to the CoC.
In the case of the alignment angles, however, a constant scalar factor is not the right tool to transform the angles, as these angles appear in cosine-terms of the orthogonalisation matrix. Therefore, the transformation is made by a geometrical correction matrix $\underline{\underline{K}}$ which is defined by the orthogonalisation ratio of measurements at CoC and an off–CoC position at constant temperature T_1.

$$\underline{\underline{K}} = (\underline{\underline{\omega^0}})^{-1}(T_1) \cdot (\underline{\underline{\omega^1}})(T_1)$$

As this matrix is a temperature independent coil system parameter, the desired orthogonalisation matrix $\omega^0(T)$ can be deduced by

$$(\underline{\underline{\omega^0}})(T) = (\underline{\underline{\omega^1}})(T) \cdot \underline{\underline{K}}^{-1}$$

Hence

$$(\underline{\underline{\omega^0}})(T) = \begin{pmatrix} 1 & \cos(\xi^1_{xy}(T)) & \cos(\xi^1_{xz}(T)) \\ 0 & \sin(\xi^1_{xy}(T)) & \frac{\cos(\xi^1_{yz}(T)) - \cos(\xi^1_{xy}(T)) \cdot \cos(\xi^1_{xz}(T))}{\sin(\xi^1_{xy}(T))} \\ 0 & 0 & \sqrt{\sin^2(\xi^1_{xz}(T)) - (\omega^1(1,2))^2} \end{pmatrix} \cdot \underline{\underline{K}}^{-1}$$

delivers the desired result.

3.3 Ground Calibration Coefficients

For the ROSETTA mission it was decided to fly magnetometer in the following configuration:

Unit	Selection
DPU	FS
IB–Sensor	FM–IB
OB–Sensor	FM–OB

Accordingly the calibration coefficients are available in the ground calibration files
`RPCMAG_GND_CALIB_FSDPU_FMIB.ASC`
`RPCMAG_GND_CALIB_FSDPU_FMOB.ASC`
for the Inboard and Outboard sensor operated with the Flight Spare Digital Processing unit (FSDPU) actually flying onboard ROSETTA. These files are delivered in the `CALIB` directory.

3.3.1 Final Results for the Flight IB Sensor

3.3.1.1 Offset

The sensor offset obeys the equation

$$\boxed{\underline{B}^{off} = \underline{a}_0 + \underline{a}_1 \cdot T - \underline{B}^{res}}$$

The calibration revealed:

$\underline{a}_0$ [nT]	$\underline{a}_1$ [nT/K]	$\underline{B}^{res}$ [nT]
114.3	-0.565	-2.0
-119.8	0.731	2.0
494.0	-1.673	-15.0

These coefficients are labeled A_0 and A_1 in the calibration files.

3.3.1.2 Sensitivity

Reference Temperature for Linearity/Sphere–Measurement: $T_1 = 17.39$ [°C]

Reference Sensitivities for Linearity/Sphere–Measurement at T_1 at CoC:

$\sigma_x^0(T_1)$ [1]	$\sigma_y^0(T_1)$ [1]	$\sigma_z^0(T_1)$ [1]
1.09045	1.09418	1.09398

The coefficients from the temperature calibration at the off-center position are

$\sigma_{0,x}^1$ [1]	$\sigma_{0,y}^1$ [1]	$\sigma_{0,z}^1$ [1]
1.09026	1.09354	1.09336

$\sigma_{1,x}^1$ [1/K]	$\sigma_{1,y}^1$ [1/K]	$\sigma_{1,z}^1$ [1/K]
-1.42E-005	-9.29E-006	-8.55E-006

The geometrical correction coefficient $\underline{k}$, caused by the 2 different positions during the linearity measurements and the temperature measurements is defined by

$$k_i = \frac{\sigma_i^1(T_1)}{\sigma_i^0(T_1)}$$

The evaluation reveals

k_x [1]	k_y [1]	k_z [1]
0.99959	0.99927	0.99929

Using this factor the desired temperature dependence of the sensitivity

$$\sigma_i^0(T) = \frac{1}{k_i}\left(\sigma_{0,i}^1 + \sigma_{1,i}^1 \cdot T\right)$$

can be evaluated. The needed coefficients

$$\begin{aligned} \sigma_{0,i}^0 &:= \frac{1}{k_i}\left(\sigma_{0,i}^1\right) \\ \sigma_{1,i}^0 &:= \frac{1}{k_i}\left(\sigma_{1,i}^1\right) \end{aligned}$$

for the sensitivity

$$\boxed{(S_{ii})^{-1} =: \sigma_i^0 = \sigma_{0,i}^0 + \sigma_{1,i}^0 \cdot T}$$

are:

$\sigma_{0,x}^0$ [1]	$\sigma_{0,y}^0$ [1]	$\sigma_{0,z}^0$ [1]
1.09070	1.09434	1.09413

$\sigma_{1,x}^0$ [1/K]	$\sigma_{1,y}^0$ [1/K]	$\sigma_{1,z}^0$ [1/K]
-1.42E-005	-9.30E-006	-8.55E-006

These coefficients are labeled SIGMA_00 and SIGMA_01 in the calibration files.

3.3.1.3 Alignment

Reference Temperature for Linearity/Sphere–Measurement: $T_1 = 17.39$ [°C]
Reference Misalignment for Linearity/Sphere–Measurement at T_1 at CoC:

$\xi^0_{xy}(T_1)$ [°]	$\xi^0_{xz}(T_1)$ [°]	$\xi^0_{yz}(T_1)$ [°]
90.0463	89.9416	89.9500

The alignment coefficients obtained from the temperature calibration at the off-center position are

$\xi^1_{0,xy}$ [°]	$\xi^1_{0,xz}$ [°]	$\xi^1_{0,yz}$ [°]
90.0348	89.9587	89.9433

$\xi^1_{1,xy}$ [°/K]	$\xi^1_{1,xz}$ [°/K]	$\xi^1_{1,yz}$ [°/K]
8.54E-005	3.71E-005	1.20E-004

The geometrical correction matrix $\underline{\underline{K}}$, caused by the 2 different positions during the linearity measurements and the temperature measurements is defined by

$$\underline{\underline{K}} = (\underline{\underline{\omega}}^0)^{-1}(T_1) \cdot (\underline{\underline{\omega}}^1)(T_1)$$

with the inverse misalignment matrix $\underline{\underline{\omega}} =: \underline{\underline{O}}^{-1}$, consisting of the direction cosines $\cos(\xi_{ij})$. The evaluation reveals

$$\boxed{(\underline{\underline{K}})^{-1} = \begin{pmatrix} 1.00000 & -0.00017 & 0.00031 \\ 0.00000 & 1.00000 & -0.00008 \\ 0.00000 & 0.00000 & 1.00000 \end{pmatrix}}$$

Using this matrix the desired temperature dependence of the alignment

$$\boxed{(\underline{\underline{\omega}}^0)(T) = (\underline{\underline{\omega}}^1)(T) \cdot \underline{\underline{K}}^{-1}}$$

can be evaluated. $(\underline{\underline{\omega}}^0)(T)$ results as

$$\boxed{(\underline{\underline{\omega}}^0)(T) = \begin{pmatrix} 1 & \cos(\xi^1_{xy}(T)) & \cos(\xi^1_{xz}(T)) \\ 0 & \sin(\xi^1_{xy}(T)) & \frac{\cos(\xi^1_{yz}(T)) - \cos(\xi^1_{xy}(T)) \cdot \cos(\xi^1_{xz}(T))}{\sin(\xi^1_{xy}(T))} \\ 0 & 0 & \sqrt{\sin^2(\xi^1_{xz}(T)) - (\omega^1(1,2))^2} \end{pmatrix} \begin{pmatrix} 1.00000 & -0.00017 & 0.00031 \\ 0.00000 & 1.00000 & -0.00008 \\ 0.00000 & 0.00000 & 1.00000 \end{pmatrix}}$$

with

$$\boxed{\xi^1_{ij}(T) = \xi^1_{0,ij} + \xi^1_{1,ij} \cdot T}$$

These coefficients are labeled XI_10 and XI_11 in the calibration files. The elements of the $\underline{\underline{K}}^{-1}$ matrix are labeled K_0, K_1, and K_2.

3.3.2 Final Results for the Flight OB Sensor

3.3.2.1 Offset

The sensor offset obeys the equation

$$\boxed{\underline{B}^{off} = \underline{a}_0 + \underline{a}_1 \cdot T - \underline{B}^{res}}$$

The calibration revealed:

$\underline{a}_0$ [nT]	$\underline{a}_1$ [nT/K]	$\underline{B}^{res}$ [nT]
214.5	-1.053	0.0
-79.9	0.073	4.0
384.7	-1.657	-20.0

These coefficients are labeled A_0 and A_1 in the calibration files.

3.3.2.2 Sensitivity

Reference Temperature for Linearity/Sphere–Measurement: $T_1 = 17.39$ [°C]

Reference Sensitivities for Linearity/Sphere–Measurement at T_1 at CoC:

$\sigma_x^0(T_1)$ [1]	$\sigma_y^0(T_1)$ [1]	$\sigma_z^0(T_1)$ [1]
1.09079	1.09338	1.09277

The coefficients from the temperature calibration at the off-center position are

$\sigma_{0,x}^1$ [1]	$\sigma_{0,y}^1$ [1]	$\sigma_{0,z}^1$ [1]
1.09066	1.09251	1.09217

$\sigma_{1,x}^1$ [1/K]	$\sigma_{1,y}^1$ [1/K]	$\sigma_{1,z}^1$ [1/K]
-1.18E-005	-8.20E-006	-6.97E-006

The geometrical correction coefficient $\underline{k}$, caused by the 2 different positions during the linearity measurements and the temperature measurements is defined by

$$k_i = \frac{\sigma_i^1(T_1)}{\sigma_i^0(T_1)}$$

The evaluation reveals

k_x [1]	k_y [1]	k_z [1]
0.99969	0.99907	0.99934

Using this factor the desired temperature dependence of the sensitivity

$$\sigma_i^0(T) = \frac{1}{k_i}\left(\sigma_{0,i}^1 + \sigma_{1,i}^1 \cdot T\right)$$

can be evaluated. The needed coefficients

$$\begin{aligned} \sigma_{0,i}^0 &:= \frac{1}{k_i}\left(\sigma_{0,i}^1\right) \\ \sigma_{1,i}^0 &:= \frac{1}{k_i}\left(\sigma_{1,i}^1\right) \end{aligned}$$

for the sensitivity

$$\boxed{(S_{ii})^{-1} =: \sigma_i^0 = \sigma_{0,i}^0 + \sigma_{1,i}^0 \cdot T}$$

are:

$\sigma_{0,x}^0$ [1]	$\sigma_{0,y}^0$ [1]	$\sigma_{0,z}^0$ [1]
1.09100	1.09352	1.09289

$\sigma_{1,x}^0$ [1/K]	$\sigma_{1,y}^0$ [1/K]	$\sigma_{1,z}^0$ [1/K]
-1.18E-005	-8.21E-006	-6.97E-006

These coefficients are labeled SIGMA_00 and SIGMA_01 in the calibration files.

3.3.2.3 Alignment

Reference Temperature for Linearity/Sphere–Measurement: $T_1 = 17.39$ [°C]
Reference Misalignment for Linearity/Sphere–Measurement at T_1 at CoC:

$\xi^0_{xy}(T_1)$ [°]	$\xi^0_{xz}(T_1)$ [°]	$\xi^0_{yz}(T_1)$ [°]
90.0711	90.0187	90.0576

The alignment coefficients obtained from the temperature calibration at the off-center position are

$\xi^1_{0,xy}$ [°]	$\xi^1_{0,xz}$ [°]	$\xi^1_{0,yz}$ [°]
90.0666	90.0366	90.0370

$\xi^1_{1,xy}$ [°/K]	$\xi^1_{1,xz}$ [°/K]	$\xi^1_{1,yz}$ [°/K]
-6.04E-005	-1.11E-004	-8.12E-005

The geometrical correction matrix $\underline{\underline{K}}$, caused by the 2 different positions during the linearity measurements and the temperature measurements is defined by

$$\underline{\underline{K}} = (\underline{\underline{\omega}}^0)^{-1}(T_1) \cdot (\underline{\underline{\omega}}^1)(T_1)$$

with the inverse misalignment matrix $\underline{\underline{\omega}} =: \underline{\underline{O}}^{-1}$, consisting of the direction cosines $\cos(\xi_{ij})$. The evaluation reveals

$$\boxed{(\underline{\underline{K}})^{-1} = \begin{pmatrix} 1.00000 & -0.00010 & 0.00028 \\ 0.00000 & 1.00000 & -0.00038 \\ 0.00000 & 0.00000 & 1.00000 \end{pmatrix}}$$

Using this matrix the desired temperature dependence of the alignment

$$\boxed{(\underline{\underline{\omega}}^0)(T) = (\underline{\underline{\omega}}^1)(T) \cdot \underline{\underline{K}}^{-1}}$$

can be evaluated. $(\underline{\underline{\omega}}^0)(T)$ results as

$$\boxed{(\underline{\underline{\omega}}^0)(T) = \begin{pmatrix} 1 & \cos(\xi^1_{xy}(T)) & \cos(\xi^1_{xz}(T)) \\ 0 & \sin(\xi^1_{xy}(T)) & \frac{\cos(\xi^1_{yz}(T)) - \cos(\xi^1_{xy}(T)) \cdot \cos(\xi^1_{xz}(T))}{\sin(\xi^1_{xy}(T))} \\ 0 & 0 & \sqrt{\sin^2(\xi^1_{xz}(T)) - (\omega^1(1,2))^2} \end{pmatrix} \begin{pmatrix} 1.00000 & -0.00010 & 0.00028 \\ 0.00000 & 1.00000 & -0.00038 \\ 0.00000 & 0.00000 & 1.00000 \end{pmatrix}}$$

with

$$\boxed{\xi^1_{ij}(T) = \xi^1_{0,ij} + \xi^1_{1,ij} \cdot T}$$

These coefficients are labeled XI_10 and XI_11 in the calibration files. The elements of the $\underline{\underline{K}}^{-1}$ matrix are labeled K_0, K_1, and K_2.

3.3.3 Calibration of the Sensor Thermistors

The sensor temperatures are measured using standard PT1000 thermistors inside the sensors. Table 1 shows a part of the manufacturer's provided nominal function derived from the following third order polynomial functions $T(U)$.

$$T(U) = c_0 \ + \ c_1 U \ + \ c_2 U^2 \ + \ c_3 U^3$$

with

$$\boxed{\begin{array}{l} c_0 = \text{-}368.61072 \\ c_1 = \ 458.49304 \\ c_2 = \text{-}356.02890 \\ c_3 = \ 180.00644 \end{array}}$$

T [°C]	R(T) [Ω]	U(T) [V]	T [°C]	R(T) [Ω]	U(T) [V]
-150.000	423.219	0.743420	10.0000	1039.14	1.27399
-140.000	461.402	0.789310	20.0000	1078.40	1.29715
-130.000	499.567	0.832850	30.0000	1117.77	1.31951
-120.000	537.730	0.874230	40.0000	1157.26	1.34112
-110.000	575.906	0.913610	50.0000	1196.86	1.36201
-100.000	614.108	0.951160	60.0000	1236.58	1.38222
-90.0000	652.351	0.987000	70.0000	1276.41	1.40178
-80.0000	690.646	1.02128	80.0000	1316.36	1.42072
-70.0000	729.005	1.05408	90.0000	1356.43	1.43907
-60.0000	767.436	1.08552	100.000	1396.60	1.45686
-50.0000	805.950	1.11569	110.000	1436.90	1.47411
-40.0000	844.555	1.14466	120.000	1477.31	1.49084
-30.0000	883.256	1.17251	130.000	1517.84	1.50708
-20.0000	922.061	1.19931	140.000	1558.48	1.52286
-10.0000	960.974	1.22512	150.000	1599.24	1.53818
0.000000	1000.00	1.25000			

Table 1: Calibration data for the sensor PT1000 thermistor, nominal data provided by the manufacturer.

Therefore, the raw temperature T_s^r of sensor s (s={IB | OB}), measured in [e°C], is obtained by applying the polynomial coefficients to the sensor output voltage.

$$\boxed{\begin{aligned} T_{\mathrm{IB}}^r(U_{\mathrm{T,IB}}) &= c_0 + c_1 U_{\mathrm{T,IB}} + c_2 U_{\mathrm{T,IB}}^2 + c_3 U_{\mathrm{T,IB}}^3 \\ T_{\mathrm{OB}}^r(U_{\mathrm{T,OB}}) &= c_0 + c_1 U_{\mathrm{T,OB}} + c_2 U_{\mathrm{T,OB}}^2 + c_3 U_{\mathrm{T,OB}}^3 \end{aligned}}$$

The temperature calibration at Magnetsrode revealed that the following temperature offsets have to be considered to get the calibrated temperature data T_s^c in °C.

$$\boxed{\begin{aligned} T_{\mathrm{IB}}^O &= -1.5\ °\mathrm{C} \\ T_{\mathrm{OB}}^O &= -2.7\ °\mathrm{C} \end{aligned}}$$

$$\boxed{\begin{aligned} T_{\mathrm{IB}}^c &= T_{\mathrm{IB}}^r - T_{\mathrm{IB}}^O \\ T_{\mathrm{OB}}^c &= T_{\mathrm{OB}}^r - T_{\mathrm{OB}}^O \end{aligned}}$$

In the calibration file the polynomial coefficients c_i are labeled T_0, T_1, T_2, T_3 and the thermistor offset correction $T_{\mathrm{IB,OB}}^O$ is denoted T_OFF.

4 Step by Step Processing of measured Flight Data

In the last section it was described how the parameters characterizing a fluxgate sensor were obtained. The present section shows now in detail how these parameters and additional entities have to be applied to convert the received binary telemetry data from the s/c into scientific usable data of various levels. The data products themselves and the differences between the levels are described in the AD5.

4.1 Generation of EDITED Raw Data

The ROSETTA s/c transmits the binary data from the RPC-MAG instrument via the RPC-PIU, the OBDH, the HGA, and deep space antennae to the DDS at ESOC were the data are stored in binary format. That format is described in AD6,AD7, and AD9.

These binary data are input of the RPCMAG RAW2ASCII s/w which converts the binary data into human readable ASCII data. This conversion from binary to ASCII data is straight forward according to the packet definitions described in AD6, AD7, and AD9 and not subject of the document in hand.

After the conversion Housekeeping (HK) and science data are available in the format of ADC counts. Magnetic field data are given in individual instrument coordinates. The relation between these individual unit reference frames (URF) of each sensor wrt. the s/c coordinates is defined in the `RPCMAG_SC_ALIGN.TXT` file to be found in the `CALIB` directory as well as in the latest version of the SPICE frame kernel definition file `ROS_Vnn.TF` to be found on the ESA server (nn denotes the current version of the file).

4.1.1 Housekeeping Data

The following data are available:

Data	Description
TIME_UTC	UTC TIME OF OBSERVATION: YYYY-MM-DDTHH:MM:SS.FFFFFF
TIME_OBT	S/C CLOCK AT OBSERVATION TIME, SECONDS SINCE 00:00 AT 1.1.2003: SSSSSSSSS.FFFFF
T_OB	TEMPERATURE OF THE RPCMAG OUTBOARD SENSOR. VALUE IS GIVEN IN ADC_COUNTS
T_IB	TEMPERATURE OF THE RPCMAG INBOARD SENSOR. VALUE IS GIVEN IN ADC_COUNTS
STAGE_A_ID	FILTER TYPE IDENTIFICATION FLAG A
STAGE_B_ID	FILTER TYPE IDENTIFICATION FLAG B
FILTER_CFG	FILTER CONFIGURATION FLAG
MAG_REF_VOLTAGE	MAGNETOMETER REFERENCE VOLTAGE: 2.5 V. VALUE IS GIVEN IN ADC_COUNTS
MAG_NEG_VOLTAGE	MAGNETOMETER NEGATIVE SUPPLY VOLTAGE:-5V. VALUE IS GIVEN IN ADC_COUNTS
MAG_POS_VOLTAGE	MAGNETOMETER POSITIVE SUPPLY VOLTAGE:+5V. VALUE IS GIVEN IN ADC_COUNTS
BX_OB	MAGNETIC FIELD X COMPONENT, UNCALIBRATED RAW DATA, INSTRUMENT COORDINATES, OB-SENSOR VALUE IS GIVEN IN 16 BIT ADC_COUNTS
BY_OB	MAGNETIC FIELD Y COMPONENT, UNCALIBRATED RAW DATA, INSTRUMENT COORDINATES, OB-SENSOR. VALUE IS GIVEN IN 16 BIT ADC_COUNTS
BZ_OB	MAGNETIC FIELD Z COMPONENT, UNCALIBRATED RAW DATA, INSTRUMENT COORDINATES, OB-SENSOR. VALUE IS GIVEN IN 16 BIT ADC_COUNTS

These HK data are not needed for the calibration of science data. They only provide auxiliary information about the instrument status. The needed temperature is stored also in the science data.

4.1.2 Science Data

The following data are available:

Data	Description
TIME_UTC	UTC TIME OF OBSERVATION: YYYY-MM-DDTHH:MM:SS.FFFFFF
TIME_OBT	S/C CLOCK AT OBSERVATION TIME, SECONDS SINCE 00:00 AT 1.1.2003: SSSSSSSSS.FFFFF
BX_OB	MAGNETIC FIELD X COMPONENT, UNCALIBRATED RAW DATA, INSTRUMENT COORDINATES, OB-SENSOR. VALUE IS GIVEN IN 20 BIT ADC_COUNTS
BY_OB	MAGNETIC FIELD Y COMPONENT, UNCALIBRATED RAW DATA, INSTRUMENT COORDINATES, OB-SENSOR. VALUE IS GIVEN IN 20 BIT ADC_COUNTS
BZ_OB	MAGNETIC FIELD Z COMPONENT, UNCALIBRATED RAW DATA, INSTRUMENT COORDINATES, OB-SENSOR. VALUE IS GIVEN IN 20 BIT ADC_COUNTS
T_OB	TEMPERATURE OF THE RPCMAG OUTBOARD SENSOR. VALUE IS GIVEN IN ADC_COUNTS
T_IB	TEMPERATURE OF THE RPCMAG INBOARD SENSOR. VALUE IS GIVEN IN ADC_COUNTS
QUALITY	THE DATA QUALITY IS CODED FOR EACH VECTOR. CODE: 0= GOOD DATA; 1= BAD DATA EACH SENSOR HAS ITS OWN QUALITY BIT BIT0:X, BIT1:Y,BIT2:Z, BIT3=0:OB, BIT3=1 IB

The QUALITY entry of the RAW DATA only reflects possible problems during the transmission from ROSETTA to the Ground station, and does not make any statement about the scientific quality. This will only be treated in the CALIBRATED data.

4.2 Generation of LEVEL_A Data

The LEVEL_A data are the first step of calibrated data. LEVEL_A HK data are directly obtained from the EDITED RAW by application of the nominal conversion algorithm to convert ADC counts to physical values.

LEVEL_A Science data also take the ground calibration, temperature effects and a specific timeshift into account. Finally data are available in instrument coordinates.

4.2.1 General remarks concerning the conversion of digital values

The RPCMAG instrument contains seven 20bit ADCs. 3 are used for the digitalization of magnetic field data measured by the OB sensor, 3 are used for the magnetic field data of the IB sensor, and the seventh, which is operated with a multiplexer, converts various Housekeeping (HK) data. The reference voltage of the ADCs is 2.5 V. The converters are operated in a bipolar mode, thus input voltages in the range of ±2.5V can be converted. The relation of input voltage and counts is:

$$\begin{aligned} \text{00000h} &\iff -2.5\text{V} \\ \text{80000h} &\iff 0V \\ \text{FFFFFh} &\iff +2.5\text{V} \end{aligned}$$

Due to the small input range some voltage adaption has to be done in the MAG instrument for certain HK values:

- the 2.5V reference voltage is monitored behind a voltage divider 100016Ω/(100000Ω+100016Ω)=0.499 as 1.2497 V nominal voltage.
- the +5V supply voltage is monitored behind a voltage divider 90956Ω/(99972Ω+90956Ω)=0.476 as 2.38V nominal voltage.
- the -5V supply voltage is monitored behind a voltage divider 27400Ω/(100024Ω+27400Ω)=0.215 as -0.997 V nominal voltage.
- the temperatures are measured as the voltage drop of PT1000 thermistors connected to the 2.5V reference voltage via a 1kΩ serial resistor:

$$U(T) = U_{ref} \cdot \frac{1}{\frac{R_{ser}}{R(T)} + 1}$$

Therefore, the nominal voltages at 273 K are 1.25 V. Conversion to temperatures are obtained by application of 3rd order polynomials.

RPCMAG sends always 20bit data to the PIU. The PIU reduces the amount of data in the following way:

Science data:

Data	PIU-Input	PIU-Output	PIU-Operation
Magnetic field IB	20 bit	20 bit	subtract 2^{19}
Magnetic field OB	20 bit	20 bit	subtract 2^{19}

Housekeeping data:

Data	PIU-Input	PIU-Output	PIU-Operation
Magnetic field OB	20bit	16bit	subtract 2^{19} right shift by 4 digits
2.5V Ref. Voltage	20bit	20bit	subtract 2^{19}
+5V Supply Voltage	20bit	8bit	subtract 2^{19} skip highest 4bits subtract offset 79F7h right shift by 4 digits
-5V Supply Voltage	20bit	8bit	subtract 2^{19} skip highest 4bits subtract offset -370Eh right shift by 3 digits
Temperature OB	20bit	16bit	subtract 2^{19} right shift by 4 digits
Temperature IB	20bit	16bit	subtract 2^{19} right shift by 4 digits

4.2.2 Housekeeping Data

4.2.2.1 Nominal Conversion of ADC Counts to Physical Housekeeping Data: Magnetic Field Values

Housekeeping magnetic field data are available as 16 Bit values. The operational range is ±16384 nT.

Definitions:

$$\begin{aligned} B_{MAX} &= +16384 \text{ nT} \\ B_{MIN} &= -16384 \text{ nT} \\ COUNTS16 &= 2^{16} = 65536 \\ NOMINAL_{FACTOR} &= \frac{B_{MAX} - B_{MIN}}{COUNTS16 - 1} \end{aligned}$$

The TLM data contain 16bit data. The relation between the ADCvalues and the PIU output (TLM) is:

$$TLM = (ADCvalue - 2^{19}) \;\; shr \; 4$$

The data range of these TLM data is 0…+counts16-1. The decimal representation of these unsigned integers are the EDITED RAW HK DATA. Unit is [counts].

In the first step of the conversion to physical values an offset of $\frac{counts16}{2}$ is added if the value is smaller than $\frac{counts16}{2}$ and subtracted in the other case. The nominal relation between these $CONVERTED\_DATA$ and magnetic field is now as follows:

$$\begin{aligned} 0000\text{h} &\Longleftrightarrow B_{MIN} \\ 8000\text{h} &\Longleftrightarrow 0 \\ \text{FFFFh} &\Longleftrightarrow B_{MAX} \end{aligned}$$

To convert these values into uncalibrated [engineering, enT] nanotesla values, the following algorithm has to be applied:

$$B = Converted\_Data * Nominal\_Factor + B_{min} \;\; [enT]$$

4.2.2.2 Nominal Conversion of ADC Counts to Physical Housekeeping Data: Reference Voltage

Housekeeping data contain the values of the ADC reference voltage, available as 20 Bit values. The nominal value is 2.5 V. The typical real monitored voltage of the ADC, behind a voltage divider, is 1.2497V.

Definitions:

$$
\begin{aligned}
U_{MAX} &= +2.5\text{V} \\
U_{MIN} &= -2.5\text{V} \\
COUNTS20 &= 2^{20} = 1048576 \\
VOLT\_DIVIDER &= 100016/200016 = 0.49996 \\
NOMINAL\_FACTOR &= \frac{U_{max} - U_{min}}{counts20 - 1}
\end{aligned}
$$

The TLM data contain 20bit data. The relation between the ADCvalues and the PIU output (TLM) is:

$$TLM = (ADCvalue - 2^{19})$$

The data range of these TLM data is 0...+counts20-1. The decimal representation of these unsigned integers are the EDITED RAW HK DATA. Unit is [counts].

In the first step of the conversion to physical values an offset of $\frac{counts20}{2}$ is added if the value is smaller than $\frac{counts20}{2}$ and subtracted in the other case. The nominal relation between these converted data and magnetic field is now as follows:

$$
\begin{aligned}
\text{0000h} &\Longleftrightarrow U_{MIN} \\
\text{8000h} &\Longleftrightarrow 0 \\
\text{FFFFh} &\Longleftrightarrow U_{MAX}
\end{aligned}
$$

To convert these values into voltages the following algorithm has to be applied:

$$U_{REF} = \frac{converted\_data * Nominal\_Factor + U_{min}}{volt\_divider} \text{ [V]}$$

4.2.2.3 Nominal Conversion of ADC Counts to Physical Housekeeping Data: Positive Supply Voltage

Housekeeping data contain the values of the positve supply voltage, available as 8 Bit values. The nominal value is +5.0 V. The typical real monitored voltage of the ADC, behind a voltage divider, is 2.38V.

Definitions:

$$\begin{aligned}
U_{MAX} &= +2.5\text{V} \\
U_{MIN} &= -2.5\text{V} \\
U_{REF} &= +2.4996\text{V} \\
U_{CENTER} &= +5.0\text{V} \\
COUNTS8 &= 2^8 = 256 \\
VOLT_DIVIDER &= 90956/(99972 + 90956) = 0.476389 \\
CAL_FACTOR &= \frac{U_{ref}}{(counts20 - 1) \cdot volt_divider} \cdot 512 = 0.002562
\end{aligned}$$

The TLM data contain 8bit data. The relation between the ADCvalues and the PIU output (TLM) is:

$$TLM = ((((ADCvalue - 2^{19}) \;\; shr \; 4) - 79F7h) \;\; shr \; 4)$$

The data range of these TLM data is 0…+counts8-1. The decimal representation of these unsigned integers are the EDITED RAW HK DATA. Unit is [counts].

In the first step of the conversion to physical values these unsigned integer TLM values are converted to signed integers, thus an offset of counts8 is subtracted if the value is greater than $\frac{counts8}{2}$. The nominal relation between these converted data and the original voltage is now as follows:

80h	=	-128d	$\Longleftrightarrow$	4.673 V
00h	=	0d	$\Longleftrightarrow$	5.00 V
7Fh	=	127d	$\Longleftrightarrow$	5.327 V

To convert these values into voltages, the following algorithm has to be applied:

$$U+ = cal\_fak \cdot converted\_data + U_{center} \text{ [V]}$$

4.2.2.4 Nominal Conversion of ADC Counts to Physical Housekeeping Data: Negative Supply Voltage

Housekeeping data contain the values of the negative supply voltage, available as 8 Bit values. The nominal value is -5.0 V. The typical real monitored voltage of the ADC, behind a voltage divider, is 0.997V.

Definitions:

$$
\begin{aligned}
U_{MAX} &= +2.5\text{V} \\
U_{MIN} &= -2.5\text{V} \\
U_{REF} &= +2.4996\text{V} \\
U_{CENTER} &= -5.0\text{V} \\
COUNTS8 &= 2^8 = 256 \\
VOLT\_DIVIDER &= 27400/(100024 + 27400) = 0.21503 \\
CAL\_FACTOR &= \frac{U_{ref}}{(counts20 - 1) \cdot volt\_divider} \cdot 256 = 0.002838
\end{aligned}
$$

The TLM data contain 8bit data. The relation between the ADCvalues and the PIU output (TLM) is:

$$TLM = ((((ADCvalue - 2^{19}) \quad shr\ 4) + 370Eh) \quad shr\ 3)$$

The data range of these TLM data is 0...+counts8-1. The decimal representation of these unsigned integers are the EDITED RAW HK DATA. Unit is [counts].

In the first step of the conversion to physical values these unsigned integer TLM values are converted to signed integers, thus an offset of counts8 is subtracted if the value is greater than $\frac{counts8}{2}$. The nominal relation between these converted data and the original voltage is now as follows:

80h	=	-128d	$\Longleftrightarrow$	-5.36 V
00h	=	0d	$\Longleftrightarrow$	-5.00 V
7Fh	=	127d	$\Longleftrightarrow$	-4.64 V

To convert these values into voltages, the following algorithm has to be applied:

$$U+ = cal\_fak \cdot converted\_data + U_{center} \text{ [V]}$$

4.2.2.5 Nominal Conversion of ADC Counts to Physical Housekeeping Data: Sensor Temperatures

Housekeeping data contain the values of the sensor temperatures, available as 16 Bit values. The temperature range is of the sensors is $-200°\text{C} \ldots + 200°\text{C}$, according to ADC input voltages of 0.5V ... 1.6V.

Definitions:

$$
\begin{aligned}
U_{MAX} &= +2.5\text{V} \\
U_{MIN} &= -2.5\text{V} \\
COUNTS16 &= 2^{16} = 65536 \\
NOMINAL\_FACTOR &= \frac{U_{max} - U_{min}}{counts16 - 1}
\end{aligned}
$$

The TLM data contain 16bit data. The relation between the ADCvalues and the PIU output (TLM) is:

$$TLM = (ADCvalue - 2^{19}) \;\; shr \; 4$$

The data range of these TLM data is 0...+counts16-1. The decimal representation of these unsigned integers are the EDITED RAW HK DATA. Unit is [counts].

In the first step of the conversion to physical values an offset of counts16/2 is added to the TLM data.

To convert these values into voltages, the following algorithm has to be applied:

$$U(T) = (TLM\_data + \frac{counts16}{2}) \cdot Nominal\_Factor + U_{min} \; [V]$$

The calibrated temperatures can be derived from these voltages by application of a 3rd order calibration polynomial:

$$T = T_0 + T_1 * U(T) + T_2 * U^2(T) + T_3 * U^3(T)$$

The coefficients T_i are:

$$
\begin{aligned}
T_0 &= -368.6107 \\
T_1 &= +458.4930 \\
T_2 &= -356.0289 \\
T_3 &= +180.0064
\end{aligned}
$$

4.2.2.6 Data Availability

The following data are available after application of the conversion algorithms described in the last two section:

Data	Description
TIME_UTC	UTC TIME OF OBSERVATION: YYYY-MM-DDTHH:MM:SS.FFFFFF
TIME_OBT	S/C CLOCK AT OBSERVATION TIME, SECONDS SINCE 00:00 AT 1.1.2003: SSSSSSSSS.FFFFF
T_OB	TEMPERATURE OF THE RPCMAG OUTBOARD SENSOR. VALUE IS GIVEN IN KELVIN
T_IB	TEMPERATURE OF THE RPCMAG INBOARD SENSOR. VALUE IS GIVEN IN KELVIN
STAGE_A_ID	FILTER TYPE IDENTIFICATION FLAG A
STAGE_B_ID	FILTER TYPE IDENTIFICATION FLAG B
FILTER_CFG	FILTER CONFIGURATION FLAG
MAG_REF_VOLTAGE	MAGNETOMETER REFERENCE VOLTAGE: 2.5 V. VALUE IS GIVEN IN VOLT
MAG_NEG_VOLTAGE	MAGNETOMETER NEGATIVE SUPPLY VOLTAGE:-5V. VALUE IS GIVEN IN VOLT
MAG_POS_VOLTAGE	MAGNETOMETER POSITIVE SUPPLY VOLTAGE:+5V. VALUE IS GIVEN IN VOLT
BX_OB	MAGNETIC FIELD X COMPONENT, UNCALIBRATED RAW DATA, INSTRUMENT COORDINATES, OB-SENSOR VALUE IS GIVEN IN NANOTESLA
BY_OB	MAGNETIC FIELD Y COMPONENT, UNCALIBRATED RAW DATA, INSTRUMENT COORDINATES, OB-SENSOR. VALUE IS GIVEN IN NANOTESLA
BZ_OB	MAGNETIC FIELD Z COMPONENT, UNCALIBRATED RAW DATA, INSTRUMENT COORDINATES, OB-SENSOR. VALUE IS GIVEN IN NANOTESLA

4.2.3 Science Data

The generation of LEVEL_A Science data is performed in the following steps:

1. Eliminate all EDITED RAW data vectors which are labeled as bad (i.e a problem occurred during the transmission in one or more components). Every vector containing a QUALITY flag $\neq 0$ will not be used.
2. Transform all remaining the EDITED RAW data (ADC counts) to physical values. This is done using the nominal conversion procedure described in section 4.2.3.1.
3. Apply the results of the ground calibration. Refer to section 4.2.3.2.
4. Calculate the right offset from the extended temperature model. Refer to section 4.2.3.3.
5. Apply right time shift according to actual Filter Mode. Refer to section 4.2.3.4.

4.2.3.1 Nominal Conversion of ADC Counts to Physical Science Data: Magnetic Field Values

Scientific magnetic field data are digitized with 20 Bit. The operational range is ±15000 nT.
Definitions:

$$\begin{aligned} B_{MAX} &= +15000 \text{ nT} \\ B_{MIN} &= -15000 \text{ nT} \\ COUNTS &= 2^{20} = 1048576 \\ NOMINAL\_FACTOR &= \frac{B_{MAX} - B_{MIN}}{COUNTS - 1} \end{aligned}$$

The TLM data contain signed 20bit data. The data range of these values in decimal representation is $-\frac{counts20}{2} \ldots + \frac{counts20}{2} - 1$. These signed integers are the EDITED RAW DATA. Unit is [counts].
In the first step of conversion to physical values an offset of $\frac{counts20}{2}$ is added, which yields to data in the range of 00000h:FFFFFh. The nominal relation between these converted TLM data and magnetic field is now as follows:

$$\begin{aligned} 00000\text{h} &\iff B_{MIN} \\ 80000\text{h} &\iff 0 \\ \text{FFFFFh} &\iff B_{MAX} \end{aligned}$$

To convert these data into uncalibrated [engineering, enT] nanotesla values, the following algorithm has to be applied:

$$B = [TLMdata + \frac{counts20}{2}] \cdot Nominal\_Factor + B_{min}\ [enT]$$

4.2.3.2 Application of Ground Calibration Results

1. Calibrate the sensor temperatures (ref. to section 3.3.3):

$$\begin{aligned} T^c_{\mathrm{IB}}(U_{\mathrm{T,IB}}) &= c_0 + c_1 U_{\mathrm{T,IB}} + c_2 U^2_{\mathrm{T,IB}} + c_3 U^3_{\mathrm{T,IB}} - T^O_{\mathrm{IB}} \\ T^c_{\mathrm{OB}}(U_{\mathrm{T,OB}}) &= c_0 + c_1 U_{\mathrm{T,OB}} + c_2 U^2_{\mathrm{T,OB}} + c_3 U^3_{\mathrm{T,OB}} - T^O_{\mathrm{OB}} \end{aligned}$$

   The voltages $U_{\mathrm{T,IB}}$, and $U_{\mathrm{T,OB}}$ are the thermistor EDITED RAW data T_IB and T_OB. from the data file.

2. Calculate the actual, temperature dependent sensor offset (cf. sections 3.3.1.1, 3.3.2.1):

$$B^{off}_{s,i} = a_{s,0} + a_{s,1} \cdot T^c_s$$

3. Generate the offset corrected magnetic field raw data:

$$B^m_{s,i} = B^r_{s,i} - B^{off}_{s,i}$$

   The $B^r_{s,i}$ values are the converted magnetic field raw data from the last subsection.

4. Calculate the actual, temperature dependent sensitivity (cf. sections 3.3.1.2, 3.3.2.2):

$$(S_{s,ii})^{-1}(T) =: \sigma^0_{s,i}(T) = \sigma^0_{0,s,i} + \sigma^0_{1,s,i} \cdot T^c_s$$

5. Evaluate the temperature dependent sensor misalignment (cf. sections 3.3.1.3, 3.3.2.3):

$$\underline{\underline{O}}_s^{-1}(T) =: \underline{\underline{\omega}}^0_s(T) = \begin{pmatrix} 1 & \cos(\xi^0_{xy}(T)) & \cos(\xi^0_{xz}(T)) \\ 0 & \sin(\xi^0_{xy}(T)) & \frac{\cos(\xi^0_{yz}(T)) - \cos(\xi^0_{xy}(T)) \cdot \cos(\xi^0_{xz}(T))}{\sin(\xi^0_{xy}(T))} \\ 0 & 0 & \sqrt{\sin^2(\xi^0_{xz}(T)) - (\omega^0(1,2))^2} \end{pmatrix}$$

6. Apply calibration matrices to produce calibrated data:

$$\begin{aligned} \underline{B}^c_s &= \underline{\underline{O}}_s^{-1}(T)\ \underline{\underline{S}}_s^{-1}(T)\ \underline{B}^m_s \\ &= \underline{\underline{\omega}}_s^{(}T)\ \underline{\underline{\sigma}}_s(T)\ \underline{B}^m_s \end{aligned}$$

4.2.3.3 Inflight Calibration: Offset Calculation using an Extended Global Temperature Model and S/C-Residual Field Treatment

Due to limited equipment at the ground calibration site at the beginning of the Millennium the temperature calibration could only be conducted in the temperature interval from -70°C to +80° C. During flight it turned out, that this range is not broad enough - The lowest temperature measured at the OB sensor was about -140°C.

The first attempts to improve the offset behavior were already carried out in the early mission phases, with limited amount of data available. These activities led to pure temperature models up to version 008 and were used for datasets versions up to V6.0. Those models tried to fit the offset and s/c residual field initially to an overall polynomial temperature model or - in later phases - a day by day polynomial model of order up to degree 5 and individual shifts for each day to guarantee smooth and steady transitions at the date limits.

Furthermore we recognized, that the assumed temperature effects seen in the previous phases of short observation periods (due to limited operation time) up to 2010, proved to be probably only slight temperature offset drifts but mainly changes of the s/c magnetic field caused by s/c current changes, attitude changes, thruster operations, etc. Already at that time it turned out, that an high order temperature model based on up to 5th order polynomials is not the right means to improve the DC component of the magnetic field data. It worthwhile mentioning again, that not the sensor offset is causing grand problems, but the varying s/c field!

After the busy operation times at the comet with not much leeway for software improvements, the ROSETTA project was prolonged to the Enhanced Archiving Phase where new knowledge and ideas could be pursued.

Thus the course of the old inelegant and inadequate inflight calibration was completely changed to a global approach. For the first time in the mission there was the opportunity of quasi-continuous operations at 67P/C-G for almost 3 years from 2014 - 2016, gaining long term magnetic field time series, and learning a lot about the spacecraft and the other payload. From all that measurements we perceived that the s/c is very dirty in terms of magnetic properties. Lots of "magnetic noise" at various time scales is generated. On the low frequency side of the spectrum signatures of various switched currents flowing on the s/c and also of thrusters being operated could be identified. Additionally other P/L instruments are generating magnetic disturbances. However, due to the complexity of the system it is hardly possible to distinguish between all the sources. We made the attempt to investigate about 200 s/c HK parameters and to analyse their impact on the magnetic field time series. There are some correlations - thruster activities - but still lots of unspecified noise and no way to to write robust and fool proof s/w to eliminate all these disturbances automatically.

In essence, a new global calibration model was created using constraints and conditions described below, considering a bunch of jump and temperature drift effects. To obtain better magnetic field data various correction features were implemented in the global offset model. All these improvements are treated in that extended calibration model, named model 009 and leading to datasets of version V9.0.

Calibration Model 009 Properties:

- The model is based on inflight data of calm (according to magnetic field conditions) phases of solar wind observations on the on hand and times where ROSETTA was operated inside a diamagnetic cavity at 67P/C-G on the other hand. This means that special phases of higher magnetic field as e.g swing-bys at Earth or CME events, etc. were not taken as offset and residual field model input.
- Furthermore time periods of known s/c disturbances were excluded for model-forming. These are e.g. times of PHILAE activation and thruster operation times during Wheel Offloading operations (WOL) or Orbit Correction Manoeuvres (OCM).
- For the sensitivity and the alignment the original linear model derived from the ground calibration is sufficient, but the offset behavior needs to be treated different for the extended temperature range. Thus, the selected inflight magnetic field data of the complete mission are compared with the temperature data and fitted against the temperature. It became apparent that a polynomial (3rd order) fit would be sufficient for most of the temperatures but that there where several temperature ranges (around ≈145 K, ≈167 K, ≈182 K, ≈237 K) where the residual field changes were more irregular than a low order polynomial. Therefore the idea of a polynomial fit was discarded and a point by point model with a resolution of 0.1 K was generated. This model is available for IB and OB in the inflight calibration files

  - `CALIB\INFLIGHT_OFF__OB_20180305_009.ASC`
  - `CALIB\INFLIGHT_OFF__IB_20180305_009.ASC`

  listed in appendix C.3 and C.4.
- Solar Wind stastitics: We assume that the long term average of the pure solar wind field – not influenced by planetary magnetospheres or cometary environment – is zero:
$$< B_{sw}^{CSEQ} >_{\text{quiet mission phases}} = 0$$
  This is compatible with the usual long term solar wind properties found int the literature (refer to AD10).
- During 2015 and early 2016 ROSETTA detected 665 time intervals of a diamagnetic cavities. From the plasmaphysics we know, that the magnetic field has to be exactly zero during such events:
$$B^{\text{CSEQ}}(t = \text{cavity}(i)) = 0; \qquad (i = 1 \quad \ldots 665)$$

- On November 12, 2014 PHILAE was separated from ROSETTA. This event was accompanied by a specific jump of the residual s/c-magnetic field, which has to be taken into account individually for data obtained before and after that time:

  SDL: Separation of Philae $\rightsquigarrow$ Jump $\Delta B^{\mathrm{URF}}(t_{sep}) = (-8.35, -14.9, -4.11)$ nT
  For all data BEFORE t_{sep} : $B_{new} = B_{\mathrm{old}} - \Delta B^{\mathrm{URF}}$

- From the joint analysis of RPCMAG and ROMAP data after the landing on 67P/C-G the absolute magnetic field at a specific time could be computed. This fixed value is used to shift the RPCMAG data for that time:

  Field adjustment using ROMAP after Landing:

$$\begin{aligned} B_{\mathrm{RPCMAG}}(\mathrm{t} = \texttt{2014-11-12T19:00}) &= B_{\mathrm{ROMAP}}(\mathrm{t} = \texttt{2014-11-12T19:00}) \\ &= (1.6, 1.6, 1.6)\ \mathrm{nT} \end{aligned}$$

- During cruise the absolute field can be estimated using s/c rotations. Lets assume an ideally calibrated magnetometer, a non-vanishing s/c-residual field and an external zerofield. If the s/c would now fly some turns or rolls the magnetometer readings in s/c-coordinates would stay constant but not zero due to the residual field. In a celestial coordinate system (e.g. CSEQ), however, the transformed magnetic field data would show variations according to the attitude changes. If, however, the magnetometer would be calibrated according to the sum of intrinsic magnetometer offset and s/c residual field, the readings would be zero in s/c coordinates and no variations would be seen in the celestial system. This means for the general situation, that one should shift the magnetometer readings in s/c- or better instrument-coordinates that way, that the variation of the transformed magnetic field in a celestial system is minimized. Thus only the external field changes would remain, ideally. Due to lots of different changes in the s/c field this algorithm does not work perfectly, but the offsets obtained for separated time intervals, improve the data quality drastically:

$$VAR(B_x^{CSEQ}) + VAR(B_y^{CSEQ}) + VAR(B_z^{CSEQ}) \stackrel{!}{=} min$$

  In the S/W this is achieved by shifting the data in instrument(CLA, CLE-data) coordinates, transform them to the CSEQ System, and iterate the whole process until a minimization in CSEQ (CLC, CLG-data) is obtained. If there is no correlation between the s/c rotation and the magnetic field signature –represented in CSEQ-coordinates– the sum of sensor offsets and s/c field is balancing the DC level of the magnetic field – represented in instrument-coordinates – to zero.

- For the data processing the time series are separated in various time intervals. These should be chosen according to switch on / switch off times of the RPCMAG instrument or reboot times after system crashes. Due to not hysteresis effects inside the core material it is reasonable that the instrument offset might vary for different intervals. Additionally also times of obvious s/c-state changes can be used as extra time interval boundaries, where the field might jump.

- The model is calculated using 10 min mean values of the magnetic field.

- Consideration of all these constraints and boundary conditions led to the LABVIEW S/W packages
`MAG_OFFSET_DETERMINATOR_CLE_CLG_TEMPERATURE_AUTO_SW_CAV_SDL_V10A_OB.vi`
and
`MAG_OFFSET_DETERMINATOR_CLE_CLG_TEMPERATURE_AUTO_SW_CAV_SDL_V10A_IB.vi`
which were used to calculate the models.

Due to the high level of s/c activity and lots of uncertainties it was not possible to clean the time series completely but to gain significant improvement in comparison to any different methods else applied to our data. Instead of perfect data cleaning, each magnetic field vector was labeled by meaningful quality flags indicating any remaining problems (refer to AD5 for details.)

The improvement of the temperature dependency of the sensor offset is done is the following way:
The original ground calibrated data $\underline{B}_s^c$ (cf. item 6 in section 4.2.3.2) has to be transformed as

$$\underline{B}_s^{c,new} = \underline{B}_s^c - \underline{B}_{off,s}^{new}(T).$$

Here

$$B_{\mathrm{off,s,i}}^{new}(t, \tilde{T}_{\mathrm{s}}) = B_{s,i}^{corr}(\tilde{T}_{\mathrm{s}}) + B_{s,i}^{jump}(t)$$

describes the temperature dependent part and the time (jump) dependent part of the model-correction-components to be found in the inflight calibration files mentioned above. As temperature the reduced temperature $\tilde{T} = T_s - T_s^O$ has to be used.

After all these operations, which have to be performed for every individual vector with the actual parameters, the offset behavior is modelled sufficiently.

Appendix C lists the relevant lines of the correction parameter and presents the offsets that have been applied to the LEVEL A data at certain times in order to minimize visibility of rotational effects visible in CSEQ - data.

REMARK:

The generation of the initial LEVEL_A data (and higher levels) has been done without INFLIGHT correction (as models where not available without any data). These ground calibrated data are not provided to any external archive. In the next iterations steps the ground calibrated data have been fed into the model generator, where all automatic and manual correction steps were performed in order to create the first model. In further steps the model has been tweaked manually at certain points — where necessary — to obtain the finally used model 009.

4.2.3.4 Application of Filter Mode dependent Time Shifts

Finally the timestamps of the measured data have to be adjusted. As the data are filtered by a mode dependent digital filter (refer to AD8 for details) the data are delayed for a certain amount of time. The timeshift was first recognized at the first Earth swing by, where the magnetic field data measured were in nearly perfect accordance to the POMME magnetic field model of the Earth - except a tiny time shift of a few seconds. This behavior was later proofed and tested with the FGM spare unit at Imperial College. The theoretical timeshifts - verified by this test - are compiled in the following table. The shifts are valid for the actual primary sensor, which is usually the OB sensor. The table shows the times to be added to the time stamp of the vector to get the real physical event time:

SID	Mode Name	Packet Length [s]	Time to add to PRIMARY data timestamp [s]
SID1	Minimum	1024	223.7
SID2	Normal	32	8.2
SID3	Burst	16	0
SID4	Medium	32	1.35
SID5	Low	128	27.7
SID6	Test	16	0

For the SECONDARY vectors the situation is different as these vectors are not filtered but just picked out of the data stream. The following table applies for the time shift of the SECONDARY vectors.

SID	Mode Name	Packet Length [s]	Time to add to SECONDARY data timestamp [s]
SID1	Minimum	1024	1023.95
SID2	Normal	32	31.95
SID3	Burst	16	15.95
SID4	Medium	32	31.95
SID5	Low	128	127.95

All these needed corrections are applied automatically by the pipeline software.

At this stage the data processing for generation calibrated LEVEL_A data in Instrument coordinates is complete. The created data files contain the following entities:

Data	Description
TIME_UTC	UTC TIME OF OBSERVATION: YYYY-MM-DDTHH:MM:SS.FFFFFF
TIME_OBT	S/C CLOCK AT OBSERVATION TIME, SECONDS SINCE 00:00 AT 1.1.2003: SSSSSSSSS.FFFFF
BX	MAGNETIC FIELD X COMPONENT, CALIBRATED DATA, TEMPERATURE CORRECTED, INSTRUMENT COORDINATES VALUE IS GIVEN IN NANOTESLA
BY	MAGNETIC FIELD Y COMPONENT, CALIBRATED DATA, TEMPERATURE CORRECTED, INSTRUMENT COORDINATES VALUE IS GIVEN IN NANOTESLA
BZ	MAGNETIC FIELD Z COMPONENT, CALIBRATED DATA, TEMPERATURE CORRECTED, INSTRUMENT COORDINATES VALUE IS GIVEN IN NANOTESLA
T	TEMPERATURE OF THE RPCMAG SENSOR. VALUE IS GIVEN IN KELVIN
QUALITY	QUALITY FLAG, cf. EAICD chapter 3.3

4.3 Generation of LEVEL_B Data

4.3.1 Rotation from Instrument Coordinates to s/c–Coordinates

At the next stage the calibrated data in instrument coordinates (URF, in uvw-coordinates) have to be rotated to s/c-coordinates. This operation is defined by a fixed rotation, specific for the IB and OB sensor. The rotation matrices have been measured on ground at the ESTEC cleanroom using an optical measurement system for determination the mounting angles of the sensor wrt. the stowed and deployed boom orientations. The coefficients of the rotation matrices $\underline{\underline{R_{UVW2SC}}}$ are stored in the `RPCMAG_SC_ALIGN.TXT` file located in the `CALIB` directory. It is also listed in appendix B.3. The desired magnetic field is given by:

$$\begin{aligned} \underline{B}_{s/c}^{IB} &= \underline{\underline{R_{UVW2SC}}}^{IB}\ \underline{B}_{URF}^{IB} \\ \underline{B}_{s/c}^{OB} &= \underline{\underline{R_{UVW2SC}}}^{OB}\ \underline{B}_{URF}^{OB} \end{aligned}$$

After this operation the data are available in s/c-coordinates, called LEVEL_B data.

Data	Description
TIME_UTC	UTC TIME OF OBSERVATION: YYYY-MM-DDTHH:MM:SS.FFFFFF
TIME_OBT	S/C CLOCK AT OBSERVATION TIME, SECONDS SINCE 00:00 AT 1.1.2003: SSSSSSSSS.FFFFF
BX	MAGNETIC FIELD X COMPONENT, CALIBRATED DATA, TEMPERATURE CORRECTED, S/C-COORDINATES VALUE IS GIVEN IN NANOTESLA
BY	MAGNETIC FIELD Y COMPONENT, CALIBRATED DATA, TEMPERATURE CORRECTED, S/C-COORDINATES VALUE IS GIVEN IN NANOTESLA
BZ	MAGNETIC FIELD Z COMPONENT, CALIBRATED DATA, TEMPERATURE CORRECTED, S/C-COORDINATES VALUE IS GIVEN IN NANOTESLA
T	TEMPERATURE OF THE RPCMAG SENSOR. VALUE IS GIVEN IN KELVIN
QUALITY	QUALITY FLAG, cf. EAICD chapter 3.3

4.4 Generation of LEVEL_C Data

4.4.1 Rotation from s/c–Coordinates to Celestial Coordinates

For a meaningful interpretation of the magnetic field data, a dynamic rotation from s/c-coordinates to a celestial coordinate system is needed. As ROSETTA is a deep space mission the ECLIPJ2000 frame [c)] was chosen as a convenient celestial coordinate system for the early "pre cometary" mission phases [d)]. The ECLIPJ2000 frame is related to the Equinox of the EPOCH J2000. It is a righthanded system with X pointing from the Sun to Vernal Equinox, Y perpendicular to X in the ecliptic plane, and Z perpendicular to the ecliptic plane, pointing up.

The rotation from s/c–coordinates

$$\begin{aligned} \underline{B}^{IB}_{ECLIP} &= \underline{\underline{R_{SC2ECLIP}}}(t, \underline{r})\ \underline{B}^{IB}_{s/c} \\ \underline{B}^{OB}_{ECLIP} &= \underline{\underline{R_{SC2ECLIP}}}(t, \underline{r})\ \underline{B}^{OB}_{s/c} \end{aligned}$$

to the ECLIPJ2000 frame is dependent on time and location of ROSETTA as the spacecraft changes its attitude along its trajectory. To calculate the rotation matrices two possibilities are available.

Historically this was done using the OASW (orbit and attitude s/w) and the right ATNR (nominal Attitude files) and ORER, ORHR, ORMR,... file (Trajectory position files wrt. the SUN, EARTH, MARS,...) provided by ESA FDT (flight dynamics team). During the proceeding mission also SPICE kernels for ROSETTA were available, which make it much easier to evaluate the right position and orientation of ROSETTA. Therefore, the pipeline software was changed concerning all the celestial mechanics calculations - now the SPICE system is used exclusively for any coordinate transformations and geometric computations.

After hibernation ROSETTA was operated in the vicinity of comet 67P/Churyumov-Gerasimneko. Therefore, the standard coordinate system for LEVEL_C (and related higher level) data was changed from ECLIPJ2000 to the CSEQ-system [e)], as this is the only one, which takes the plasma-physical symmetry properties concerning Sun, Solar wind, and Comet into account.

[c)] Starting from the ECLIPJ2000 frame it is easy to transform the data any reasonable coordinate system for a specific mission phase, e.g. GSE-, MSO-, CSO-, CSEQ-coordinates. This can be done by application of the right SPICE kernel and the SPICE transformation routines widely available for all major programming languages.

[d)] For the planet swing-bys and the asteroid fly-bys more convenient local systems might be chosen. Specific information is provided in the related data *.LBL files

[e)] For its defintion refer to the EAICD (AD5)

Also the rotation from s/c–coordinates

$$\underline{B}^{IB}_{CSEQ} = \underline{\underline{R}}_{SC2CSEQ}(t, \underline{r})\ \underline{B}^{IB}_{s/c}$$
$$\underline{B}^{OB}_{CSEQ} = \underline{\underline{R}}_{SC2CSEQ}(t, \underline{r})\ \underline{B}^{OB}_{s/c}$$

to the CSEQ frame is dependent on time and location of ROSETTA as the spacecraft changes its attitude along its trajectory.

After the described rotation the data are available in ECLIPJ2000/CSEQ coordinates, called LEVEL_C data.

Data	Description
TIME_UTC	UTC TIME OF OBSERVATION: YYYY-MM-DDTHH:MM:SS.FFFFFF
TIME_OBT	S/C CLOCK AT OBSERVATION TIME, SECONDS SINCE 00:00 AT 1.1.2003: SSSSSSSSS.FFFFF
POSITION_X	SPACECRAFT POSITION, X COMPONENT, ECLIPJ2000/CSEQ VALUE IS GIVEN IN KILOMETER
POSITION_Y	SPACECRAFT POSITION, Y COMPONENT, ECLIPJ2000/CSEQ VALUE IS GIVEN IN KILOMETER
POSITION_Z	SPACECRAFT POSITION, Z COMPONENT, ECLIPJ2000/CSEQ VALUE IS GIVEN IN KILOMETER
BX	MAGNETIC FIELD X COMPONENT, CALIBRATED DATA, TEMPERATURE CORRECTED, ECLIPJ2000/CSEQ-COORDINATES VALUE IS GIVEN IN NANOTESLA
BY	MAGNETIC FIELD Y COMPONENT, CALIBRATED DATA, TEMPERATURE CORRECTED, ECLIPJ2000/CSEQ-COORDINATES VALUE IS GIVEN IN NANOTESLA
BZ	MAGNETIC FIELD Z COMPONENT, CALIBRATED DATA, TEMPERATURE CORRECTED, ECLIPJ2000/CSEQ-COORDINATES VALUE IS GIVEN IN NANOTESLA
QUALITY	QUALITY FLAG, cf. EAICD chapter 3.3

4.5 Generation of LEVEL_E Data

LEVEL_E data are averaged CALIBRATED LEVEL_A data. The data are averaged in the time domain and represent the magnetic field in instrument coordinates. LEVEL_E data are usually not generated in the standard archive process. The average is calculated in the following way. All data within a given average interval of n seconds are summed up and divided by the number of data in this interval. The timetag of such a newly averaged data point is the time of the middle of the regarded average interval.

LEVEL_E data are stored in the following structure.

Data	Description
TIME_UTC	UTC TIME OF OBSERVATION: YYYY-MM-DDTHH:MM:SS.FFFFFF
TIME_OBT	S/C CLOCK AT OBSERVATION TIME, SECONDS SINCE 00:00 AT 1.1.2003: SSSSSSSSS.FFFFF
BX	MAGNETIC FIELD X COMPONENT, CALIBRATED DATA, TEMPERATURE CORRECTED, INSTRUMENT-COORDINATES, n SECOND AVERAGE, VALUE IS GIVEN IN NANOTESLA
BY	MAGNETIC FIELD Y COMPONENT, CALIBRATED DATA, TEMPERATURE CORRECTED, INSTRUMENT-COORDINATES, n SECOND AVERAGE, VALUE IS GIVEN IN NANOTESLA
BZ	MAGNETIC FIELD Z COMPONENT, CALIBRATED DATA, TEMPERATURE CORRECTED, INSTRUMENT-COORDINATES, n SECOND AVERAGE, VALUE IS GIVEN IN NANOTESLA
QUALITY	QUALITY FLAG, cf. EAICD chapter 3.3

4.6 Generation of LEVEL_F Data

LEVEL_F data are averaged LEVEL_B data. The data are averaged in the time domain and represent the magnetic field in s/c-coordinates. LEVEL_F data are generated in the standard archive process with an average interval of one second and 60 seconds. The average is calculated in the following way. All data within a given average interval of n seconds are summed up and divided by the number of data in this interval. The timetag of such a newly averaged data point is the time of the middle of the regarded average interval.

LEVEL_F data are stored in the following structure.

Data	Description
TIME_UTC	UTC TIME OF OBSERVATION: YYYY-MM-DDTHH:MM:SS.FFFFFF
TIME_OBT	S/C CLOCK AT OBSERVATION TIME, SECONDS SINCE 00:00 AT 1.1.2003: SSSSSSSSS.FFFFF
BX	MAGNETIC FIELD X COMPONENT, CALIBRATED DATA, TEMPERATURE CORRECTED, S/C-COORDINATES, n SECOND AVERAGE, VALUE IS GIVEN IN NANOTESLA
BY	MAGNETIC FIELD Y COMPONENT, CALIBRATED DATA, TEMPERATURE CORRECTED, S/C-COORDINATES, n SECOND AVERAGE, VALUE IS GIVEN IN NANOTESLA
BZ	MAGNETIC FIELD Z COMPONENT, CALIBRATED DATA, TEMPERATURE CORRECTED, S/C-COORDINATES, n SECOND AVERAGE, VALUE IS GIVEN IN NANOTESLA
QUALITY	QUALITY FLAG, cf. EAICD chapter 3.3

4.7 Generation of LEVEL_G Data

LEVEL_G data are averaged LEVEL_C. The data are averaged in the time domain and represent the magnetic field in the same celestial coordinates as in the related LEVEL_C data. Thus mainly ECLIPJ2000 before the comet phase and the CSEQ frame at 67P/C-G was used. LEVEL_G data are generated in the standard archive process with an average interval of one second and 60 seconds. The average is calculated in the following way. All data within a given average interval of n seconds are summed up and divided by the number of data in this interval. The timetag of such a newly averaged data point is the time of the middle of the regarded average interval.

LEVEL_G data are stored in the following structure.

Data	Description
TIME_UTC	UTC TIME OF OBSERVATION: YYYY-MM-DDTHH:MM:SS.FFFFFF
TIME_OBT	S/C CLOCK AT OBSERVATION TIME, SECONDS SINCE 00:00 AT 1.1.2003: SSSSSSSSS.FFFFF
POSITION_X	SPACECRAFT POSITION, X COMPONENT, ECLIPJ2000/CSEQ VALUE IS GIVEN IN KILOMETER
POSITION_Y	SPACECRAFT POSITION, Y COMPONENT, ECLIPJ2000/CSEQ VALUE IS GIVEN IN KILOMETER
POSITION_Z	SPACECRAFT POSITION, Z COMPONENT, ECLIPJ2000/CSEQ VALUE IS GIVEN IN KILOMETER
BX	MAGNETIC FIELD X COMPONENT, CALIBRATED DATA, TEMPERATURE CORRECTED, ECLIPJ2000/CSEQ-COORDINATES, n SECOND-AVERAGE, VALUE IS GIVEN IN NANOTESLA
BY	MAGNETIC FIELD Y COMPONENT, CALIBRATED DATA, TEMPERATURE CORRECTED, ECLIPJ2000/CSEQ-COORDINATES, n SECOND-AVERAGE, VALUE IS GIVEN IN NANOTESLA
BZ	MAGNETIC FIELD Z COMPONENT, CALIBRATED DATA, TEMPERATURE CORRECTED, ECLIPJ2000/CSEQ-COORDINATES, n SECOND-AVERAGE, VALUE IS GIVEN IN NANOTESLA
QUALITY	QUALITY FLAG, cf. EAICD chapter 3.3

4.8 Generation of LEVEL_H Data

LEVEL_H data are Reaction Wheel (RW) and LAP disturbance corrected data. As input the LEVEL_C data are taken. Thus the data represent the magnetic field in the celestial system of the related LEVEL_C data: Mainly ECLIPJ2000 coordinates for the precomet phase and the CSEQ frame at the comet are used.

During the ROSETTA mission the reaction wheels, which control the attitude of the s/c, turned out to create a magnetic disturbance signature. The dynamically changing rotation frequencies of the four wheels cause magnetic AC disturbances. They occur not at the original rotation frequencies but they are folded down into the measurement frequency range according to the Nyquist sampling theorem. Thus it is an effect of aliasing. The disturbance amplitude is in the order of about 1 to 2 nanotesla and can be eliminated, as the reaction wheel frequencies are known at any time. Elimination is only reasonable for the primary sensor (OB) data in BURST mode (20 vectors/s) as only here the disturbance emerges significantly from the background signal/noise.

Besides this also the LAP instrument generates disturbances of fixed but mode dependent (LAP operation mode) disturbances lines in the frequency spectrum. These lines are eliminated by the reaction wheel disturbance purging algorithm as well. Data generation Procedure:

- Provide the Reaction wheel frequency data from the DDS (binary coded) or the Imperial college data server (SCHK7.TXT files, ASCII)
- For each time the needed the measurement mode dependent disturbance frequency, which occurs in the data, has to be calculated. This has to be done according to the folding theorem and the actual used sampling- and resulting Nyquist frequency.
- Fourier-transform the magnetic field data into the frequency domain and generate a dynamic spectrum (day by day).
- For each time interval localize the 4 actual disturbed frequencies in the spectrum. In stripes of width Δf around the regarded local frequencies f the amplitudes have to be set to the values which occur in the original spectrum just below or above the regarded stripe. Add some appropriate noise to the substituted amplitudes. After having processed all data in this way, the originally clearly identifiable disturbance lines should not be visible anymore. Instead of them slightly noisy values of the neighborhood of those lines should substitute them and only the background should be visible.
- The LAP disturbance is eliminated in a similar way: LAP generates horizontal lines in the frequency spectrum (constant frequency). The elimination is done by substituting the actual amplitudes of these line (i.e a stripe of width Δf around this lines) by the noisy background value.

- Fourier-transform the dynamic spectrum back to the time domain to create the purged time series of LEVEL_H data.

REMARK: All the MAG data processing, inclusive the the RW and LAP signature correction algorithm works on a daily base. Thus all data (primary sensor) available for a specific day are processed in one instance. The main trick to get rid of the disturbing RW signatures is to operate in frequency domain rather than in time domain. The transformations into frequency domain and back to time domain are executed by a complex FFT and an inverse complex FFT respectively. After several attempts of achieving the best results it turned out, that the pure FFTs without any extra windowing gave the best results. As we were not interested in further use of the calculated spectra but just wanted to ensure having a lossless pair of transformations available, we just did it this way. We tested this pure pair of transformations and came to the conclusion that the data transition between consecutive days stays smooth and does not generate any phase problems.
Every day is separated into several time intervals of 1024 data points each. These intervals overlap by 25 % to ensure a reasonable coverage and a stable phase transition at the edges of the single time intervals. The complete set of all Fourier-transformed data in all these time intervals yield the dynamic spectrum of a single day which can then be purged from the occurring reaction wheel signatures by the means described above. The width Δf of the manipulated frequency band around the disturbed freq f is chosen automatically in dependence of the instrument sampling frequency. For Burst mode we use $\Delta f = 0.06$ Hz. The bandwidth values have been empirically determined, to result in the cleanest spectra. An optical inspection of each purged spectrum, reveals any possibly problems left and provides finally confidence to the used method.

WARNING: All LEVEL_H data have been automatically generated, which in general led to good results. Nevertheless it can happen that artificial structures appear in the LEVEL_H data, which are not present in the LEVEL_C source data. This will mainly happen during observations of steep transitions or high level magnetic fields.**Especially between Spring 2015 and Spring 2016 the environmental magnetic conditions are complex leading to potential failures in the described data cleaning. Therefore, in case of using LEVEL_H data, we highly recommend to compare these data to the original LEVEL_C data, and to check the existence of any artificial structures.**
The data producers are grateful to be informed about any data peculiarities.

LEVEL_H data are delivered in the the following structure.

Data	Description
TIME_UTC	UTC TIME OF OBSERVATION: YYYY-MM-DDTHH:MM:SS.FFFFFF
TIME_OBT	S/C CLOCK AT OBSERVATION TIME, SECONDS SINCE 00:00 AT 1.1.2003: SSSSSSSSS.FFFFF
POSITION_X	SPACECRAFT POSITION, X COMPONENT, ECLIPJ2000/CSEQ VALUE IS GIVEN IN KILOMETER
POSITION_Y	SPACECRAFT POSITION, Y COMPONENT, ECLIPJ2000/CSEQ VALUE IS GIVEN IN KILOMETER
POSITION_Z	SPACECRAFT POSITION, Z COMPONENT, ECLIPJ2000/CSEQ VALUE IS GIVEN IN KILOMETER
BX	MAGNETIC FIELD X COMPONENT, CALIBRATED DATA; TEMPERATURE, REACTION WHEEL AND LAP DISTURBANCE CORRECTED; ECLIPJ2000/CSEQ-COORDINATES, VALUE IS GIVEN IN NANOTESLA
BY	MAGNETIC FIELD Y COMPONENT, CALIBRATED DATA; TEMPERATURE, REACTION WHEEL AND LAP DISTURBANCE CORRECTED; ECLIPJ2000/CSEQ-COORDINATES, VALUE IS GIVEN IN NANOTESLA
BZ	MAGNETIC FIELD Z COMPONENT, CALIBRATED DATA; TEMPERATURE, REACTION WHEEL AND LAP DISTURBANCE CORRECTED; ECLIPJ2000/CSEQ-COORDINATES, VALUE IS GIVEN IN NANOTESLA
QUALITY	QUALITY FLAG, cf. EAICD chapter 3.3

A Abbreviations

Item	Meaning
a_i	Fit coefficients for temperature dependent offset
ADC	Analog Digital Converter
ATNR	Attitude file provided by FDT
$\underline{B}^c$	Magnetic calibration field generated by coil system
$\underline{B}^c_s$	Calibrated Magnetic field measured by sensor s
$\underline{B}^{off}$	Offset of the magnetometer [nT]
$\underline{B}^{off}_k$	Polynomial Fit coefficients for the sensor offset vs. temperature
$\underline{B}^m$	Measured magnetic field raw data, offset & residual field corrected [nT]
$\underline{B}^{or}$	$= \underline{B}^{off} + \underline{B}^{res}$, Offset + Residual field at CoC [enT]
$\underline{B}^r$	Magnetic field raw data
$B^r_{0^\circ}$	Magnetic raw data, measured in normal position (0°)[enT]
$B^r_{180^\circ}$	Magnetic raw data, measured in turned position (180°)[enT]
$\underline{B}^{res}$	Residual field of the coil system
e°C	Engineering degrees centigrade units
$\underline{B}^s_{ECLIP}$	Magnetic field measured by sensor s in ECLIPJ2000 coordinates
$\underline{B}^s_{s/c}$	Magnetic field measured by sensor s in s/c- coordinates
$\underline{B}^s_{URF}$	Magnetic field measured by sensor s in Instrument coordinates
c_0, c_1, c_2, c_3	Fit coefficients of the sensor thermistor
CoC	Center of Coil system
CSO	Cometo-centric solar orbital coordinates
DDS	Data Distribution System
DPU	Digital Processing Unit
enT	Engineering NanoTesla units
	applicable after nominal conversion of ADC counts
ESB	Earth Swing by
$\underline{\underline{F}}$	$=\underline{\underline{SOR}}$, Transfer Matrix
FGM	Fluxgate Magnetometer
FDT	Flight Dynamics Team of ESOC
FM	Flight Model
FS	Flight Spare Unit
FSDPU	Flight Spare Digital Processing Unit
GSE	Geocentric Solar Ecliptic coordinates
HGA	High Gain Antenna
HK	Housekeeping data
i	component x | y | z
IB	Inboard Sensor
$\underline{\underline{K}}$	Geometric correction Matrix for alignment angles
k_i	Geometric correction factors for sensitivities
λ, μ, ν	Euler rotation angles
LAP	RPC instrument: Langmuir Probe

Item	Meaning
MCF	Magnetic calibration Facility
MSO	Mars centered solar orbital coordinates
$\underline{\underline{O}}$	Orthogonalisation matrix
OASW	Orbit and Attitude Software, provided by ESA
OB	Outboard Sensor
OBDH	Onboard Data handling system
$\underline{\underline{\omega}}$	$= \underline{\underline{O}}^{-1}$, Inverse orthogonalisation matrix
ORER	Orbit and Position file (related to EARTH) provided by FDT
ORHR	Orbit and Position file (related to SUN) provided by FDT
ORMR	Orbit and Position file (related to MARS) provided by FDT
$P_3(T)$	3rd order Fit-polynomial of Temperature
$p_{s,k,i}$	fit coefficient of sensor s, order k and component i
$\underline{\underline{\phi}}$	$= \underline{\underline{F}}^{-1}$, Inverse Transfer Matrix
PIU	Power interface unit
$\underline{\underline{R}}$	Rotation matrix of sensor vs. coil system
$\underline{\underline{\rho}}$	$= \underline{\underline{R}}^{-1}$, Inverse rotation matrix
$\underline{\underline{S}}$	Sensitivity matrix
s	Sensor index $s = \{\text{IB} \mid \text{OB}\}$
$\underline{\underline{\sigma}}$	$= \underline{\underline{S}}^{-1}$, Inverse sensitivity matrix
$\sigma_{k,i}$	Polynomial Fit coefficient for sensitivity vs. temperature. Coefficient of order k for the sensor component i
T	Temperature
T_i	Temperature of measurement i
TLM	Telemetry
T_s^O	Additional Temperature offset of sensor Thermistor s
T_s^c	Temperature of sensor s, calibrated data [°C]
T_s^r	Temperature of sensor s, raw data [e°C]
s	Sensor IB | OB
s/c	spacecraft
URF	Unit Reference Frame, Instrument–Coordinates
$U_{\text{T, IB}}$	IB–Temperature data [V], measured
$U_{\text{T,OB}}$	OB–Temperature data [V], measured
uvw	Instrument coordinate axes
ξ_{ij}	Temperature dependent alignment angle (ij component)
$\xi^0_{k,ij}$	Polynomial Fit coefficient for misalignment angle vs. temperature. Coefficient of order k for the angle ij

B Ground Calibration files

B.1 IB Sensor

The file RPCMAG_GND_CALIB_FSDPU_FMIB.ASC contains the ground calibration result for the FM IB sensor operated with the FS DPU.

```
***** File GND_CALIB_FSDPU_FMIB.TXT

# File automatically generated by FGM_CAL.PRO
# Final Calibration Coefficients for
# DPU: FS
# SENSOR: FM IB
#
# OFFSET COEFFICIENTS
A_0       114.3      -119.8       494.0
A_1      -0.565       0.731      -1.673
#
#
#
# TEMPERATURE COEFFICIENTS
T_0  -368.61072
T_1   458.49304
T_2  -356.02890
T_3   180.00644
T_OFF      -1.5
#
#
# SENSITIVITY COEFFICIENTS
SIGMA_00     1.09070     1.09434     1.09413
SIGMA_01  -1.42E-005  -9.30E-006  -8.55E-006
#
#
# ALIGNMENT COEFFICIENTS
#
XI_10     90.0348     89.9587     89.9433
XI_11   8.54E-005   3.71E-005   1.20E-004
#
K_0     1.00000    -0.00017     0.00031
K_1     0.00000     1.00000    -0.00008
K_2     0.00000     0.00000     1.00000
#
```

B.2 OB Sensor

The file RPCMAG_GND_CALIB_FSDPU_FMOB.ASC contains the ground calibration result for the FM OB sensor operated with the FS DPU.

```
***** File GND_CALIB_FSDPU_FMOB.TXT

# File automatically generated by FGM_CAL.PRO
# Final Calibration Coefficients for
# DPU: FS
# SENSOR: FM OB
#
# OFFSET COEFFICIENTS
A_0       214.5       -79.9       384.7
A_1      -1.053       0.073      -1.657
#
#
#
# TEMPERATURE COEFFICIENTS
T_0  -368.61072
T_1   458.49304
T_2  -356.02890
T_3   180.00644
T_OFF      -2.7
#
#
# SENSITIVITY COEFFICIENTS
SIGMA_00     1.09100     1.09352     1.09289
SIGMA_01  -1.18E-005  -8.21E-006  -6.97E-006
#
#
# ALIGNMENT COEFFICIENTS
#
XI_10     90.0666     90.0366     90.0370
XI_11  -6.04E-005  -1.11E-004  -8.12E-005
#
K_0     1.00000    -0.00010     0.00028
K_1     0.00000     1.00000    -0.00038
K_2     0.00000     0.00000     1.00000
#
```

B.3 Boom Alignment Parameter from Ground Measurements

The file RPCMAG_SC_ALIGN.ASC contains the measured mounting information of the RPC-MAG sensors on the MAG boom. The matrices reflect the static rotations between the Unit reference systems (U,V,W) and the s/c-coordinate systems for the stowed and deployes boom configurations.

```
***** File SC_ALIGN.TXT  ******
#
#       Stowed [MAGinSC] measured
#                          SC_X                      SC_Y                 SC_Z
OB_U_STOWED        -0.999996321               -0.00253212          0.000973021
OB_V_STOWED        -0.002528122               0.999988449          0.004087938
OB_W_STOWED        -0.000983361               0.004085463         -0.999991171
#
IB_U_STOWED        -0.999986718              -0.001887027          0.004796146
IB_V_STOWED        -0.001868169               0.999990519           0.00393335
IB_W_STOWED        -0.004803523               0.003924337         -0.999980763
#
#
#
#       Deployed [MAGinSC] measured
#                          SC_X                      SX_Y                 SC_Z
OB_U_DEPLOYED    0.219768642967342     0.961446688834391    -0.165293702534850
OB_V_DEPLOYED    0.793133605262099    -0.077436608300837     0.604104838499749
OB_W_DEPLOYED    0.568014812986632    -0.263863290785682    -0.779573816904796
#
IB_U_DEPLOYED    0.215741971645595     0.963435635624521    -0.158893604903554
IB_V_DEPLOYED    0.792516208990562    -0.077708877352077     0.604879648250715
IB_W_DEPLOYED    0.570415164733284    -0.256423685312912    -0.780303423965860
```

C Offset Correction Data for the Actual Inflight Calibration

C.1 Offset Jump Correction of OB Data

The file `INFLIGHT_PARA_OB_20180305_009.ASC` contains all jump times and used jumps for the OB offset. These corrections are subtracted in the pipeline software.

The n-th line of "OFFSET_JUMP" contains the time interval for which the related lines in the "JUMP_SUM_OB_X", "JUMP_SUM_OB_Y", "JUMP_SUM_OB_Z" fields represent the actual correction values, to be subtracted from the original data component.

The "EXTRA_OFFSET" contain additional manually set shifts. The format is jump-time, Bx-,By-,Bz-component. All magnetic field corrections have to be done in instrument coordinates.

This outputfile of the LABVIEW Offset-Determinator S/W is formatted that way, that IDL can read it directly.

```
OFFSET_JUMP= [['2004-03-02T00:00:00',  '2004-09-06T19:15:00'],$
              ['2004-09-06T19:15:01',  '2004-09-07T00:47:39'],$
              ['2004-09-07T12:26:01',  '2004-09-07T23:52:39'],$
              ['2004-09-20T16:02:01',  '2004-09-21T02:02:43'],$
              ['2004-09-21T20:19:53',  '2004-09-29T14:05:07'],$
              ['2004-09-30T04:32:00',  '2004-10-10T13:55:28'],$
              ['2004-10-13T01:12:00',  '2004-10-14T01:47:16'],$
              ['2005-10-03T16:57:37',  '2005-10-03T21:17:37'],$
              ['2006-07-04T00:02:00',  '2006-07-08T23:54:44'],$
              ['2006-11-23T09:12:00',  '2006-11-25T14:15:02'],$
              ['2006-11-27T16:40:00',  '2006-12-04T23:52:54'],$
              ['2006-12-09T00:03:14',  '2006-12-10T05:58:04'],$
              ['2006-12-10T16:38:04',  '2006-12-20T20:53:00'],$
              ['2006-12-21T07:45:00',  '2007-02-27T02:18:36'],$
              ['2007-09-28T22:32:00',  '2007-09-28T23:55:39'],$
              ['2008-01-07T22:36:00',  '2008-01-08T03:07:57'],$
              ['2008-07-20T12:17:00',  '2008-07-20T15:48:33'],$
              ['2008-09-01T00:02:00',  '2008-09-03T23:53:03'],$
              ['2008-09-07T00:02:54',  '2008-09-10T05:57:58'],$
              ['2009-01-31T19:53:00',  '2009-01-31T23:56:49'],$
              ['2009-11-09T19:42:00',  '2009-11-12T23:53:27'],$
              ['2009-11-14T00:03:21',  '2010-07-09T23:53:24'],$
              ['2010-07-07T00:00:00',  '2010-07-13T15:58:20'],$
              ['2014-03-23T22:02:00',  '2014-03-27T04:58:04'],$
```

```
                    ['2014-05-09T15:12:00',  '2014-05-20T11:23:08'],$
                    ['2014-05-23T14:47:00',  '2014-06-03T10:18:30'],$
                    ['2014-06-06T03:33:00',  '2014-06-17T09:27:36'],$
                    ['2014-06-20T02:32:00',  '2014-07-01T08:17:57'],$
                    ['2014-07-04T02:37:00',  '2014-07-08T08:17:47'],$
                    ['2014-07-11T02:43:00',  '2014-07-12T23:53:04'],$
                    ['2014-07-15T00:00:00',  '2014-07-15T02:18:09'],$
                    ['2014-07-18T02:37:00',  '2014-07-22T02:18:12'],$
                    ['2014-07-25T02:37:00',  '2014-08-05T23:53:05'],$
                    ['2014-10-01T14:45:00',  '2014-10-01T14:46:00'],$
                    ['2014-10-02T08:20:00',  '2014-10-02T08:20:05'],$
                    ['2014-11-12T08:26:41',  '2014-11-12T08:26:43'],$
                    ['2014-11-12T08:35:00',  '2014-11-12T23:59:59'],$
                    ['2015-04-20T16:23:33',  '2015-05-04T20:58:54'],$
                    ['2015-05-07T07:35:18',  '2015-06-05T07:33:48'],$
                    ['2015-07-07T06:40:24',  '2015-09-16T02:04:09'],$
                    ['2015-09-16T14:08:17',  '2015-09-17T04:38:12'],$
                    ['2015-11-14T07:12:04',  '2015-11-25T19:01:28'],$
                    ['2015-11-27T04:22:27',  '2016-10-01T00:00:00']]

JUMP_SUM_OB_X= [ $
                 29.23,$
                 43.74,$
                 27.63,$
                 20.04,$
                 30.57,$
                 44.78,$
                 29.18,$
                 4.27,$
                 2.38,$
                 2.29,$
                 -0.46,$
                 -0.87,$
                 -4.69,$
                 -2.98,$
                 -1.12,$
                 5.14,$
                 0.08,$
                 -6.28,$
                 -11.02,$
                 -1.28,$
                 4.78,$
                 0.71,$
                 2.22,$
                 1.60,$
                 -1.76,$
```

```
                  -5.39,$
                  -4.23,$
                  2.66,$
                  4.00,$
                  3.53,$
                  4.74,$
                  -7.08,$
                  -6.10,$
                  9.70,$
                  9.70,$
                  2.70,$
                  2.70,$
                  -0.03,$
                  -0.64,$
                  4.79,$
                  10.64,$
                  6.65,$
                  7.20]

JUMP_SUM_OB_Y= [ $
                  20.61,$
                  16.56,$
                  21.51,$
                  18.23,$
                  19.06,$
                  21.12,$
                  19.79,$
                  -1.86,$
                  0.08,$
                  -4.35,$
                  -2.66,$
                  -1.07,$
                  -4.46,$
                  2.63,$
                  5.41,$
                  3.12,$
                  -2.03,$
                  -2.41,$
                  -1.81,$
                  -0.36,$
                  1.48,$
                  4.45,$
                  3.62,$
                  0.32,$
                  4.94,$
                  0.36,$
```

```
                 1.13,$
                 1.17,$
                 1.12,$
                 0.52,$
                 0.97,$
                 4.61,$
                 0.24,$
                 3.62,$
                 3.62,$
                 2.62,$
                 -11.38,$
                 -4.69,$
                 -4.28,$
                 -8.13,$
                 -7.70,$
                 -12.58,$
                 -6.67]

JUMP_SUM_OB_Z= [ $
                 30.79,$
                 25.04,$
                 31.94,$
                 35.11,$
                 36.25,$
                 36.36,$
                 31.56,$
                 6.02,$
                 15.80,$
                 1.79,$
                 4.60,$
                 3.11,$
                 5.32,$
                 5.20,$
                 0.18,$
                 -1.69,$
                 -1.07,$
                 -1.04,$
                 1.86,$
                 -6.98,$
                 0.97,$
                 -1.45,$
                 -2.07,$
                 -3.96,$
                 -3.72,$
                 -3.23,$
                 -3.27,$
```

```
                -3.33,$
                -3.30,$
                -3.31,$
                -2.53,$
                -2.27,$
                -2.03,$
                3.22,$
                3.22,$
                -3.78,$
                -0.28,$
                -1.04,$
                0.72,$
                0.52,$
                2.22,$
                -0.90,$
                -0.57]



JUMPS_OB_X= [ $
                29.23,$
                14.51,$
                -16.12,$
                -7.58,$
                10.53,$
                14.21,$
                -15.60,$
                -24.91,$
                -1.88,$
                -0.09,$
                -2.74,$
                -0.42,$
                -3.82,$
                1.71,$
                1.86,$
                6.26,$
                -5.05,$
                -6.36,$
                -4.74,$
                9.74,$
                6.06,$
                -4.06,$
                1.51,$
                -0.63,$
                -3.35,$
                -3.63,$
```

```
                1.16,$
                6.89,$
                1.34,$
                -0.47,$
                1.21,$
                -11.82,$
                0.99,$
                15.79,$
                0.00,$
                -7.00,$
                0.00,$
                -2.72,$
                -0.61,$
                5.43,$
                5.85,$
                -3.99,$
                0.55]

JUMPS_OB_Y= [ $
                20.61,$
                -4.05,$
                4.95,$
                -3.28,$
                0.83,$
                2.06,$
                -1.33,$
                -21.65,$
                1.94,$
                -4.43,$
                1.69,$
                1.59,$
                -3.40,$
                7.10,$
                2.78,$
                -2.29,$
                -5.14,$
                -0.38,$
                0.60,$
                1.46,$
                1.83,$
                2.98,$
                -0.84,$
                -3.29,$
                4.62,$
                -4.57,$
                0.77,$
```

```
                0.04,$
                -0.05,$
                -0.60,$
                0.44,$
                3.65,$
                -4.38,$
                3.39,$
                0.00,$
                -1.00,$
                -14.00,$
                6.69,$
                0.41,$
                -3.84,$
                0.43,$
                -4.88,$
                5.91]

JUMPS_OB_Z= [ $
                30.79,$
                -5.75,$
                6.90,$
                3.17,$
                1.15,$
                0.11,$
                -4.80,$
                -25.54,$
                9.78,$
                -14.01,$
                2.81,$
                -1.49,$
                2.21,$
                -0.12,$
                -5.02,$
                -1.87,$
                0.61,$
                0.03,$
                2.90,$
                -8.84,$
                7.95,$
                -2.42,$
                -0.62,$
                -1.89,$
                0.24,$
                0.49,$
                -0.04,$
                -0.06,$
```

```
                0.04,$
                -0.01,$
                0.78,$
                0.26,$
                0.24,$
                5.25,$
                0.00,$
                -7.00,$
                3.50,$
                -0.76,$
                1.77,$
                -0.21,$
                1.70,$
                -3.12,$
                0.33]


P_MODEL_OB_X= [ $
                991.73486282,$
                -21.86608991,$
                0.13241412,$
                -0.00024916]

P_MODEL_OB_Y= [ $
                431.73832941,$
                -6.46379419,$
                0.03008538,$
                -0.00004488]

P_MODEL_OB_Z= [ $
                -212.10952378,$
                -3.10693170,$
                0.03180377,$
                -0.00007150]



EXTRA_OFFSET= [
2004-05-07T00:00:00  2004-05-09T23:59:59     18.1      -6.8       12.1
2004-05-10T00:00:00  2004-05-10T23:59:59      6.9       4.0        2.2
2004-09-21T20:00:00  2004-09-21T23:00:00    -12.0       6.0        0.0
2004-09-21T23:00:00  2004-09-22T03:00:00     -5.0       6.0        0.0
2004-09-30T00:00:00  2004-09-30T23:59:59      3.1      -0.6        1.2
2005-03-01T00:00:00  2005-03-07T23:59:59     -7.3      -5.8       +0.0
2005-06-21T00:00:00  2005-06-21T23:59:59    -43.4     -19.5      -23.2
2006-03-07T00:00:00  2006-03-07T23:59:59      1.8       0.9        4.8
```

```
2006-08-29T00:00:00  2006-08-29T23:59:59    -31.9      7.0     -20.9
2007-05-22T00:00:00  2007-05-22T23:59:59      5.0     -1.8      -3.4
2007-11-07T00:00:00  2007-11-08T23:59:59     14.0     -4.9       5.7
2007-11-12T00:00:00  2007-11-20T23:59:59     11.0     -1.5       6.0
2008-01-07T00:00:00  2008-01-08T23:59:59      1.0     -2.0      -2.0
2008-07-19T00:00:00  2008-07-19T10:59:59      1.0     -8.0       1.0
2008-07-19T11:00:00  2008-07-19T23:59:59      1.0     -4.0       6.0
2008-07-26T00:00:00  2008-07-26T23:59:59    -42.8      5.1     -14.2
2009-10-01T00:00:00  2009-10-02T23:59:59     14.0     -4.0       9.0
2010-02-24T00:00:00  2010-02-24T23:59:59      1.0     -2.5      -0.2
2010-03-14T00:00:00  2010-03-15T23:59:59     -2.9      0.0       2.6
2010-04-27T00:00:00  2010-04-27T23:59:59    -16.4      0.1      -1.9
2010-12-06T00:00:00  2010-12-06T23:59:59    -18.6     -5.9      -5.6
2014-04-16T00:00:00  2014-04-17T23:59:59     -6.2      4.8       2.5
2014-09-15T00:00:00  2014-10-01T23:59:59     19.0      4.0       0.0
2015-01-15T00:00:00  2015-02-27T23:59:59      0.0      0.0       0.0
2015-02-28T00:00:00  2015-03-17T10:59:59      0.0      0.0       0.0
2015-03-17T11:00:00  2015-03-29T23:59:59      0.0      0.0       0.0
2015-04-02T00:00:00  2015-04-24T07:00:00      0.0      0.0       0.0
2015-04-25T00:00:00  2015-04-28T22:00:00      0.0      0.0       0.0
2015-04-29T00:00:00  2015-05-03T18:00:00      0.0      0.0       0.0
2016-03-17T18:00:00  2016-05-29T00:00:00      0.0      0.0       0.0
2016-06-17T06:00:00  2016-06-22T12:00:00      0.0      0.0       0.0
2016-06-30T00:00:00  2016-09-30T23:59:59      0.5      0.4       0.3
]
```

C.2 Offset Jump Correction of IB Data

The file `INFLIGHT_PARA_IB_20180305_009.ASC` contains all jump times and used jumps for the IB offset. These corrections are subtracted in the pipeline software.

The n-th line of "OFFSET_JUMP" contains the time interval for which the related lines in the "JUMP_SUM_IB_X", "JUMP_SUM_IB_Y", "JUMP_SUM_IB_Z" fields represent the actual correction values, to be subtracted from the original data component.

The "EXTRA_OFFSET" contain additional manually set shifts. The format is jump-time, Bx-,By-,Bz-component. All magnetic field corrections have to be done in instrument coordinates.

This outputfile of the LABVIEW Offset-Determinator S/W is formatted that way, that IDL can read it directly.

```
OFFSET_JUMP= [['2004-03-02T00:00:00',  '2004-09-06T19:15:00'],$
              ['2004-09-06T19:15:01',  '2004-09-07T00:47:39'],$
              ['2004-09-07T12:26:01',  '2004-09-07T23:52:39'],$
              ['2004-09-20T16:02:01',  '2004-09-21T02:02:43'],$
              ['2004-09-21T20:19:53',  '2004-09-29T14:05:07'],$
              ['2004-09-30T04:32:00',  '2004-10-10T13:55:28'],$
              ['2004-10-13T01:12:00',  '2004-10-14T01:47:16'],$
              ['2005-10-03T16:57:37',  '2005-10-03T21:17:37'],$
              ['2006-07-04T00:02:00',  '2006-07-08T23:54:44'],$
              ['2006-11-23T09:12:00',  '2006-11-25T14:15:02'],$
              ['2006-11-27T16:40:00',  '2006-12-04T23:52:54'],$
              ['2006-12-09T00:03:14',  '2006-12-10T05:58:04'],$
              ['2006-12-10T16:38:04',  '2006-12-20T20:53:00'],$
              ['2006-12-21T07:45:00',  '2007-02-27T02:18:36'],$
              ['2007-09-28T22:32:00',  '2007-09-28T23:55:39'],$
              ['2008-01-07T22:36:00',  '2008-01-08T03:07:57'],$
              ['2008-07-20T12:17:00',  '2008-07-20T15:48:33'],$
              ['2008-09-01T00:02:00',  '2008-09-03T23:53:03'],$
              ['2008-09-07T00:02:54',  '2008-09-10T05:57:58'],$
              ['2009-01-31T19:53:00',  '2009-01-31T23:56:49'],$
              ['2009-11-09T19:42:00',  '2009-11-12T23:53:27'],$
              ['2009-11-14T00:03:21',  '2010-07-09T23:53:24'],$
              ['2010-07-07T00:00:00',  '2010-07-13T15:58:20'],$
              ['2014-03-23T22:02:00',  '2014-03-27T04:58:04'],$
              ['2014-05-09T15:12:00',  '2014-05-20T11:23:08'],$
              ['2014-05-23T14:47:00',  '2014-06-03T10:18:30'],$
              ['2014-06-06T03:33:00',  '2014-06-17T09:27:36'],$
```

```
                 ['2014-06-20T02:32:00',  '2014-07-01T08:17:57'],$
                 ['2014-07-04T02:37:00',  '2014-07-08T08:17:47'],$
                 ['2014-07-11T02:43:00',  '2014-07-12T23:53:04'],$
                 ['2014-07-15T00:00:00',  '2014-07-15T02:18:09'],$
                 ['2014-07-18T02:37:00',  '2014-07-22T02:18:12'],$
                 ['2014-07-25T02:37:00',  '2014-08-05T23:53:05'],$
                 ['2014-10-01T14:45:00',  '2014-10-01T14:46:00'],$
                 ['2014-10-02T08:20:00',  '2014-10-02T08:20:05'],$
                 ['2014-11-12T08:26:41',  '2014-11-12T08:26:43'],$
                 ['2014-11-12T08:35:00',  '2014-11-12T23:59:59'],$
                 ['2015-04-20T16:23:33',  '2015-05-04T20:58:54'],$
                 ['2015-05-07T07:35:18',  '2015-06-05T07:33:48'],$
                 ['2015-07-07T06:40:24',  '2015-09-16T02:04:09'],$
                 ['2015-09-16T14:08:17',  '2015-09-17T04:38:12'],$
                 ['2015-11-14T07:12:04',  '2015-11-25T19:01:28'],$
                 ['2015-11-27T04:22:27',  '2016-10-01T00:00:00']]

JUMP_SUM_OB_X= [ $
                29.23,$
                43.74,$
                27.63,$
                20.04,$
                30.57,$
                44.78,$
                29.18,$
                4.27,$
                2.38,$
                2.29,$
                -0.46,$
                -0.87,$
                -4.69,$
                -2.98,$
                -1.12,$
                5.14,$
                0.08,$
                -6.28,$
                -11.02,$
                -1.28,$
                4.78,$
                0.71,$
                2.22,$
                1.60,$
                -1.76,$
                -5.39,$
                -4.23,$
                2.66,$
```

```
               4.00,$
               3.53,$
               4.74,$
               -7.08,$
               -6.10,$
               9.70,$
               9.70,$
               2.70,$
               2.70,$
               -0.03,$
               -0.64,$
               4.79,$
               10.64,$
               6.65,$
               7.20]

JUMP_SUM_OB_Y= [ $
               20.61,$
               16.56,$
               21.51,$
               18.23,$
               19.06,$
               21.12,$
               19.79,$
               -1.86,$
               0.08,$
               -4.35,$
               -2.66,$
               -1.07,$
               -4.46,$
               2.63,$
               5.41,$
               3.12,$
               -2.03,$
               -2.41,$
               -1.81,$
               -0.36,$
               1.48,$
               4.45,$
               3.62,$
               0.32,$
               4.94,$
               0.36,$
               1.13,$
               1.17,$
               1.12,$
```

```
                0.52,$
                0.97,$
                4.61,$
                0.24,$
                3.62,$
                3.62,$
                2.62,$
                -11.38,$
                -4.69,$
                -4.28,$
                -8.13,$
                -7.70,$
                -12.58,$
                -6.67]

JUMP_SUM_OB_Z= [ $
                30.79,$
                25.04,$
                31.94,$
                35.11,$
                36.25,$
                36.36,$
                31.56,$
                6.02,$
                15.80,$
                1.79,$
                4.60,$
                3.11,$
                5.32,$
                5.20,$
                0.18,$
                -1.69,$
                -1.07,$
                -1.04,$
                1.86,$
                -6.98,$
                0.97,$
                -1.45,$
                -2.07,$
                -3.96,$
                -3.72,$
                -3.23,$
                -3.27,$
                -3.33,$
                -3.30,$
                -3.31,$
```

```
                -2.53,$
                -2.27,$
                -2.03,$
                3.22,$
                3.22,$
                -3.78,$
                -0.28,$
                -1.04,$
                0.72,$
                0.52,$
                2.22,$
                -0.90,$
                -0.57]


JUMPS_OB_X= [ $
                29.23,$
                14.51,$
                -16.12,$
                -7.58,$
                10.53,$
                14.21,$
                -15.60,$
                -24.91,$
                -1.88,$
                -0.09,$
                -2.74,$
                -0.42,$
                -3.82,$
                1.71,$
                1.86,$
                6.26,$
                -5.05,$
                -6.36,$
                -4.74,$
                9.74,$
                6.06,$
                -4.06,$
                1.51,$
                -0.63,$
                -3.35,$
                -3.63,$
                1.16,$
                6.89,$
                1.34,$
```

```
                 -0.47,$
                 1.21,$
                 -11.82,$
                 0.99,$
                 15.79,$
                 0.00,$
                 -7.00,$
                 0.00,$
                 -2.72,$
                 -0.61,$
                 5.43,$
                 5.85,$
                 -3.99,$
                 0.55]

JUMPS_OB_Y= [ $
                 20.61,$
                 -4.05,$
                 4.95,$
                 -3.28,$
                 0.83,$
                 2.06,$
                 -1.33,$
                 -21.65,$
                 1.94,$
                 -4.43,$
                 1.69,$
                 1.59,$
                 -3.40,$
                 7.10,$
                 2.78,$
                 -2.29,$
                 -5.14,$
                 -0.38,$
                 0.60,$
                 1.46,$
                 1.83,$
                 2.98,$
                 -0.84,$
                 -3.29,$
                 4.62,$
                 -4.57,$
                 0.77,$
                 0.04,$
                 -0.05,$
                 -0.60,$
```

```
                  0.44,$
                  3.65,$
                  -4.38,$
                  3.39,$
                  0.00,$
                  -1.00,$
                  -14.00,$
                  6.69,$
                  0.41,$
                  -3.84,$
                  0.43,$
                  -4.88,$
                  5.91]

JUMPS_OB_Z= [ $
                  30.79,$
                  -5.75,$
                  6.90,$
                  3.17,$
                  1.15,$
                  0.11,$
                  -4.80,$
                  -25.54,$
                  9.78,$
                  -14.01,$
                  2.81,$
                  -1.49,$
                  2.21,$
                  -0.12,$
                  -5.02,$
                  -1.87,$
                  0.61,$
                  0.03,$
                  2.90,$
                  -8.84,$
                  7.95,$
                  -2.42,$
                  -0.62,$
                  -1.89,$
                  0.24,$
                  0.49,$
                  -0.04,$
                  -0.06,$
                  0.04,$
                  -0.01,$
                  0.78,$
```

```
                 0.26,$
                 0.24,$
                 5.25,$
                 0.00,$
                 -7.00,$
                 3.50,$
                 -0.76,$
                 1.77,$
                 -0.21,$
                 1.70,$
                 -3.12,$
                 0.33]


P_MODEL_OB_X= [ $
                 991.73486282,$
                 -21.86608991,$
                 0.13241412,$
                 -0.00024916]

P_MODEL_OB_Y= [ $
                 431.73832941,$
                 -6.46379419,$
                 0.03008538,$
                 -0.00004488]

P_MODEL_OB_Z= [ $
                 -212.10952378,$
                 -3.10693170,$
                 0.03180377,$
                 -0.00007150]



EXTRA_OFFSET= [
2004-05-07T00:00:00  2004-05-09T23:59:59      18.1      -6.8       12.1
2004-05-10T00:00:00  2004-05-10T23:59:59       6.9       4.0        2.2
2004-09-21T20:00:00  2004-09-21T23:00:00     -12.0       6.0        0.0
2004-09-21T23:00:00  2004-09-22T03:00:00      -5.0       6.0        0.0
2004-09-30T00:00:00  2004-09-30T23:59:59       3.1      -0.6        1.2
2005-03-01T00:00:00  2005-03-07T23:59:59      -7.3      -5.8       +0.0
2005-06-21T00:00:00  2005-06-21T23:59:59     -43.4     -19.5      -23.2
2006-03-07T00:00:00  2006-03-07T23:59:59       1.8       0.9        4.8
2006-08-29T00:00:00  2006-08-29T23:59:59     -31.9       7.0      -20.9
2007-05-22T00:00:00  2007-05-22T23:59:59       5.0      -1.8       -3.4
2007-11-07T00:00:00  2007-11-08T23:59:59      14.0      -4.9        5.7
```

```
2007-11-12T00:00:00  2007-11-20T23:59:59    11.0    -1.5     6.0
2008-01-07T00:00:00  2008-01-08T23:59:59     1.0    -2.0    -2.0
2008-07-19T00:00:00  2008-07-19T10:59:59     1.0    -8.0     1.0
2008-07-19T11:00:00  2008-07-19T23:59:59     1.0    -4.0     6.0
2008-07-26T00:00:00  2008-07-26T23:59:59   -42.8     5.1   -14.2
2009-10-01T00:00:00  2009-10-02T23:59:59    14.0    -4.0     9.0
2010-02-24T00:00:00  2010-02-24T23:59:59     1.0    -2.5    -0.2
2010-03-14T00:00:00  2010-03-15T23:59:59    -2.9     0.0     2.6
2010-04-27T00:00:00  2010-04-27T23:59:59   -16.4     0.1    -1.9
2010-12-06T00:00:00  2010-12-06T23:59:59   -18.6    -5.9    -5.6
2014-04-16T00:00:00  2014-04-17T23:59:59    -6.2     4.8     2.5
2014-09-15T00:00:00  2014-10-01T23:59:59    19.0     4.0     0.0
2015-01-15T00:00:00  2015-02-27T23:59:59     0.0     0.0     0.0
2015-02-28T00:00:00  2015-03-17T10:59:59     0.0     0.0     0.0
2015-03-17T11:00:00  2015-03-29T23:59:59     0.0     0.0     0.0
2015-04-02T00:00:00  2015-04-24T07:00:00     0.0     0.0     0.0
2015-04-25T00:00:00  2015-04-28T22:00:00     0.0     0.0     0.0
2015-04-29T00:00:00  2015-05-03T18:00:00     0.0     0.0     0.0
2016-03-17T18:00:00  2016-05-29T00:00:00     0.0     0.0     0.0
2016-06-17T06:00:00  2016-06-22T12:00:00     0.0     0.0     0.0
2016-06-30T00:00:00  2016-09-30T23:59:59     0.5     0.4     0.3
]
```

C.3 Offset Temperature Correction of OB Data

The file INFLIGHT_OFF__OB_20180305_009.ASC contains the inflight temperature model for the correction of the OB offsets. These corrections are subtracted in the pipeline software. The relevant values are the "TEMP(K)", "Model_x (nT)", "Model_y (nT)", "Model_z (nT)" which contain the Temperature and the related offset model components to be subtracted from the data.

Only an excerpt is listed here due to huge size of the file.

```
# TEMP (K)    Model_x (nT)   Model_y (nT)  Model_z (nT)
  131.00  -163.91    -2.75  -225.89
  131.01  -163.91    -2.76  -225.88
  131.02  -163.91    -2.77  -225.86
  131.03  -163.91    -2.77  -225.84
  131.04  -163.91    -2.78  -225.83
  131.05  -163.91    -2.79  -225.81
  131.06  -163.91    -2.80  -225.80
  131.07  -163.91    -2.81  -225.78
  131.08  -163.91    -2.82  -225.77
  131.09  -163.91    -2.83  -225.75
  131.10  -163.91    -2.84  -225.74
  ....
  237.83   -57.58    -7.62  -113.70
  237.84   -57.60    -7.62  -113.70
  237.85   -57.62    -7.62  -113.71
  237.86   -57.64    -7.62  -113.71
  237.87   -57.66    -7.62  -113.71
  237.88   -57.67    -7.62  -113.72
  237.89   -57.69    -7.61  -113.72
  237.90   -57.70    -7.61  -113.72
  237.91   -57.71    -7.61  -113.72
  237.92   -57.73    -7.61  -113.72
  237.93   -57.74    -7.60  -113.72
  237.94   -57.75    -7.60  -113.72
  237.95   -57.76    -7.60  -113.73
  237.96   -57.77    -7.60  -113.73
  237.97   -57.78    -7.60  -113.73
  237.98   -57.80    -7.59  -113.73
  237.99   -57.81    -7.59  -113.73
  238.00   -57.81    -7.59  -113.73
```

C.4 Offset Temperature Correction of IB Data

The file `INFLIGHT_OFF__IB_20180305_009.ASC` contains the inflight temperature model for the correction of the OB offsets. These corrections are subtracted in the pipeline software. The relevant values are the "TEMP(K)", "Model_x (nT)", "Model_y (nT)", "Model_z (nT)" which contain the Temperature and the related offset model components to be subtracted from the data.

Only an excerpt is listed here due to huge size of the file.

```
# TEMP (K)    Model_x (nT)   Model_y (nT)  Model_z (nT)
  136.00    52.64   188.98  -263.92
  136.01    52.66   188.98  -263.90
  136.02    52.68   188.98  -263.88
  136.03    52.70   188.98  -263.86
  136.04    52.71   188.98  -263.84
  136.05    52.73   188.98  -263.82
  136.06    52.75   188.98  -263.80
  136.07    52.77   188.97  -263.78
  136.08    52.79   188.97  -263.76
  136.09    52.80   188.97  -263.73
  136.10    52.82   188.97  -263.71
  ....
  226.82    89.77   132.66  -133.47
  226.83    89.81   132.69  -133.45
  226.84    89.84   132.73  -133.43
  226.85    89.88   132.76  -133.41
  226.86    89.92   132.79  -133.39
  226.87    89.95   132.82  -133.38
  226.88    89.99   132.85  -133.36
  226.89    90.02   132.88  -133.34
  226.90    90.05   132.91  -133.33
  226.91    90.08   132.93  -133.31
  226.92    90.11   132.96  -133.30
  226.93    90.13   132.98  -133.29
  226.94    90.16   132.99  -133.27
  226.95    90.18   133.01  -133.26
  226.96    90.20   133.02  -133.25
  226.97    90.22   133.04  -133.24
  226.98    90.24   133.05  -133.23
  226.99    90.26   133.06  -133.21
  227.00    90.26   133.06  -133.21
```

D Boom Alignment Improvement Parameter from Inflight Measurements

The file `RPCMAG_BOOM_ALIGN_CORR_EF1.ASC` contains the fitted extra rotation angles of the two RPCMAG sensors mounted on the deployed boom, which are needed to minimize the difference between measured RPCMAG data during the first Earth swing-by in March 2005 and the POMME Earth Magnetic Field Model provided by GFZ Potsdam.

```
#
#    ADDITIONAL ROTATIONS FOR THE OB SENSOR (IN DEGREES)
#
ROTATION_X_OB    0.084
ROTATION_Y_OB   -0.326
ROTATION_Z_OB   -0.094
#
#
#   ADDITIONAL ROTATIONS FOR THE IB SENSOR (IN DEGREES)
#
ROTATION_X_IB   -0.438
ROTATION_Y_IB   -0.244
ROTATION_Z_IB   -0.287
#
```