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GOCE L1B PRODUCTS USER HANDBOOK

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		Para. 3.3.1.2 Sentence Corrected
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1 INTRODUCTION

1.1 Purpose

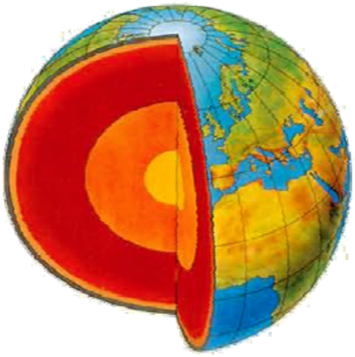
The purpose of this document is to provide a detailed description of the GOCE Level 1b products generated by the Instrument Processing Facility (IPF1) and distributed to GOCE users. The document describes everything required to make use of the Level 1b products for the processing or application and is a self-standing document for what regards Level 1b products user.

For a complete review of GOCE products, please refer also to GOCE Level 2 Data Handbook.

2 GOCE USER GUIDE

2.1 *Scientific Background*

2.1.1 Towards a better understanding of the Earth



This section presents a short description of the scientific applications having lead to the development of the GOCE mission. For a more accurate description of such applications, please refer to the "*GOCE Level 2 Data Handbook*" [RD-2].

The Earth is a dynamic system constantly undergoing changes. For a better understanding of both surface and deep phenomena which are related to the interior structure of the Earth and its temporal evolution, it is necessary to significantly improve the current models of the Earth's gravitational potential, both in resolution and precision - if not its temporal variations induced by the afore mentioned phenomena.

Thus, the gravity field plays a dual role in Earth sciences.

On the one hand, by comparing the real field with the field of an idealized body (e.g. an ellipsoid in hydrostatic equilibrium) one defines gravity anomalies which characterize deviations from a state of internal equilibrium (that is non-radial density variations), which constitutes one method of sounding our planet's interior. The gravity analysis approach is unique in providing direct information on the density field. A significant part of this information is, at present, provided by seismology, by tomographic analysis, but still suffers from uncertainties due to hypothesis on which such inversions are based. The combination of both types of data (seismic velocities and gravity anomalies) is a powerful tool to get a better picture of the interior and to make progress in the understanding of several phenomena for instance the accumulation of stresses and triggering of earthquakes.

On the other hand, the geoid is used as the reference for defining and measuring the altitudes on the continents but also under the oceans or over the ice caps. The geoid is a particular equipotential surface of the gravity potential (the sum of the gravitational and centrifugal potentials) which may be viewed, in oceanic areas, as the surface of an ocean at rest. The irregularities of the geoid characterize the density field variations in a way similar to the gravity anomalies.

A detailed geoid surface when combined with satellite altimetry yields sea surface topography, the quasi-stationary deviation of the ocean surface from its hypothetical surface of rest. Under the assumption of geostrophic balance, ocean topography can be directly translated into a global map of surface ocean circulation. Thus, ocean surface circulation can become directly measurable.

The fields of application of the gravity analysis approach can be differentiated as follows:

Marine Geoid and its Impact on Ocean Circulation – The absolute value of the ocean dynamic topography requires the determination of the 'hypothetic' ocean at rest, i.e. the marine geoid. This is the basic requirement for modelling ocean circulation and interpreting satellite altimeter data. Unfortunately, current geoid uncertainties and their impact on the absolute dynamic topography are large, particularly at shorter wavelengths less than 2000 km. Given the continuing need to study and predict climate variation and climate change by the combined use of altimetry, global ocean circulation models, and high-quality global in-situ data, it is thus essential to significantly reduce errors in our knowledge of the geoid, in particular, at shorter wavelength. A similar requirement also applies to the growing field of operational oceanography for which radar altimetry is an important data source. This could be achieved once and for all through a single dedicated gravity field mission.

Gravity Field and Solid Earth Processes – Specific issues to be addressed by an accurate and detailed determination of the gravity field includes discrimination between active and passive models of rifting; identification of anomalous mass which may drive basin subsidence; and determination of the deep density structure beneath the continents and of the mechanical strength of the continental lithosphere.
The GOCE gravity field models are provided in terms of a set of dimensionless coefficients of a spherical harmonic series up to a maximum degree of the gravity potential. These coefficients are the result of the gravity field determination process.

The gravitational potential spherical harmonic series is defined by (see e.g. eq. 3.89 p. 70 in [RD-8]):

$$V(r,\theta,\lambda) = \frac{GM}{r} \times \sum_{n=0}^{N_{\max}} \left(\frac{a}{r}\right)^n \times \sum_{m=0}^{n} \left(\overline{C}_{nm}\cos(m\lambda) + \overline{S}_{nm}\sin(m\lambda)\right) \times \overline{P}_{nm} \times \cos(\theta) \qquad \text{(eq. 1)}$$

where:

V	gravitational potential at computation point
GM	gravity constant times total mass of Earth
a	equatorial radius of the Earth ellipsoid
n	degree of spherical harmonic coefficient
N_{max}	maximum degree of spherical harmonic series
m	order of spherical harmonic coefficient
r	radial distance of computation point from geocentre
θ	geocentric co-latitude of computation point
λ	geocentric longitude of computation point
$\overline{P}_{nm}$	normalized associated Legendre functions of degree n and order m
$\overline{C}_{nm}, \overline{S}_{nm}$	coefficients of spherical harmonic series to be determined

In this equation

(r, θ, λ)	are the spherical coordinates of the spacecraft
r=a+h	h being a elevation of the spacecraft above the Earth
$\left(\frac{a}{r}\right)^n$	describes the field attenuation with altitude

The maximum degree N_{max} of the spherical harmonic series determines the corresponding spatial-scale D, half wavelength given in km by the following formula:

$$D = \frac{20000}{N_{\max}} \qquad \text{(eq. 2)}$$

For GOCE, N_{max} is set to a value of 300 leading to an expected spatial-scale of approximately 66 km and with an attached error shown in Figure 1. In this figure, the vertical axis of the triangle refers to the spherical harmonic degree n (on the left scale) or to the spatial-scale D (on the right), the horizontal axis refers to the order m of the coefficients, with the C_{nm} coefficients on the right and the S_{nm} coefficients on the left. The colour code refers to the number of decimal digits (significant digits) to which the individual coefficients can be resolved. For example, two (2) significant digits mean a determination of coefficients with only 1% uncertainty [**RD-1**].

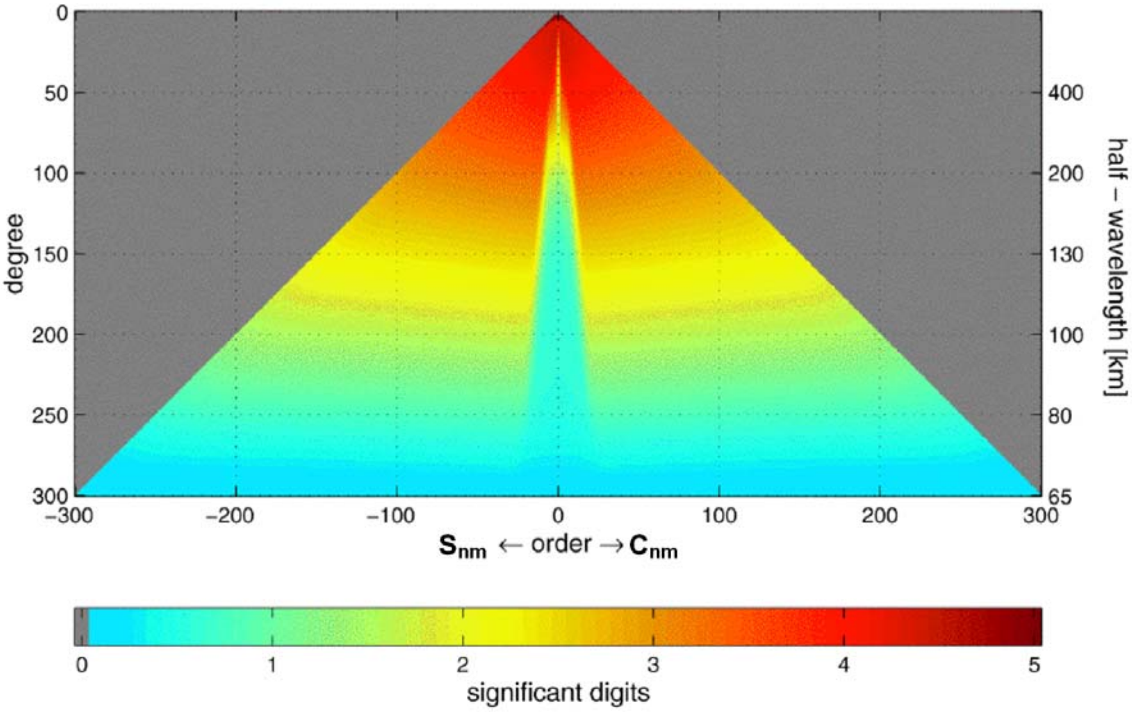


Figure 1 - GOCE spherical harmonic error spectrum.

The expected RMS errors on the geoid height and gravity anomalies at various resolutions are given in Table 1.

Spatial resolution D (half-wavelength)	Maximum degree N (correspond to D)	Geoid height (mm)	Gravity anomaly (mgal)
1000 km	20	0.4	0.0006
400 km	50	0.5	0.001
200 km	100	0.6	0.03
100 km	200	2.5	0.08
65 km	300	~45	~2

Table 1 - Expected errors in geoid height and gravity anomalies.

Understanding of mantle processes, in particular convection patterns, and of post-glacial mass readjustment, will greatly benefit from improved and more detailed knowledge of the Earth's gravity field. Moreover, the accurate and detailed determination of the anomalous gravity field plays a key role in advancing understanding of the dynamics of the continental lithosphere. It is also necessary to identify the contribution of post-glacial rebound to sea level change, and the impact of Solid Earth processes on the global ocean. Further progress in the understanding of these processes and improvement in geopotential models require global determination of the gravity field, at a spatial resolution down to half wavelengths of between 50 and 400 km.

Geodesy – With a high resolution and precise geoid ellipsoidal heights, as provided by GPS, can be directly translated into orthometric (pseudo-levelled) heights, a perspective of high relevance for cartography, mapping, surveying, navigation and exploration. At present, the different orthometric height systems (national datum) differ by the order of decimetres between islands and between islands and continents, over distances of a few 100 km. Between continents these differences may be as large as a metre. Sea level in one part of our planet can therefore not be properly compared with sea level in other parts, nor can changes be precisely separated into sea level rise and vertical land uplift or subsidence respectively. One of the key objectives in geodesy is therefore to improve and unify the different orthometric height systems using high quality gravity field data.

2.1.2 Satellite gradiometry principles

Explanation given here is extracted from **RD-11** (courtesy Radboud KOOP).Consider two proof masses situated in two nearby points A and B (see Figure 2). The gravitational acceleration in point A due to the attraction is $\overrightarrow{a(A)}$. This vector is directed along the line of force going through point A, perpendicular to the equipotential surface through A. The gravitational acceleration in point B is $\overrightarrow{a(B)}$. Suppose A and B are located on the same equipotential surface. Without any support and without any force appearing, the two proof masses will fall towards the Earth. Since the gravitational field of the Earth is almost a perfect central force field, the distance between the two proof masses will decrease while falling towards the Earth due to the convergence of the lines of force. The change in distance between the two proof masses is a measure of the difference in gravitational acceleration in A and B.

Now consider the two proof masses situated on the same line of force but on different equipotential surfaces (see Figure 3). The proof mass in B is closer to the Earth as the one in A and is therefore pulled harder. If the proof masses are dropped and are falling towards the Earth along the same line of force, the distance between them will increase. Again, the change in this distance is a measure for the difference in gravitational acceleration between the two proof masses.

Let put the two proof masses inside a satellite around its gravity centre O. A circular orbit of this satellite will produce a centrifugal acceleration that will compensate the gravitational acceleration at O. The two proof masses are kept at a fixed position with respect to O by means of a electrostatic suspension hardware (see the cages in Figure 7 that are also symbolised in Figure 2 or Figure 3). Proof masses constrained in this way can be seen as accelerometers. The outputs of these accelerometers are the forces needed to keep the proof masses in these fixed positions with respect to O and thus with respect to each other. They are measures for the acceleration difference between the two points and O and can therefore be used as observations to measure the gravitational field of the Earth.

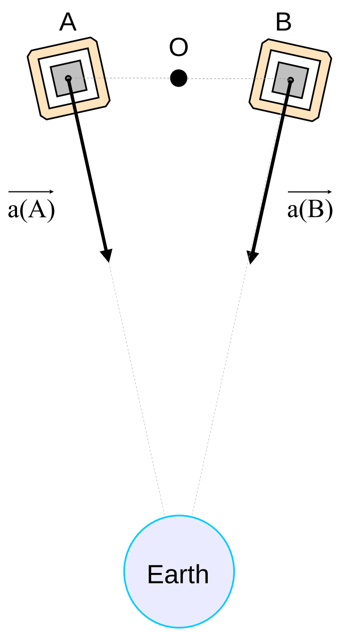


Figure 2 - Proof mass on the same equipotential surface.

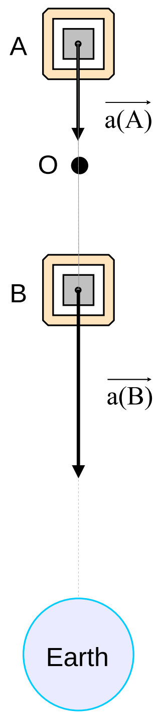


Figure 3 - Proof mass on the same line of force.

Satellite gradiometry is the measurement of acceleration differences, ideally in all the three spatial directions, between the test-masses of an ensemble of accelerometers inside one satellite. The measured signals correspond to the gradients of the component of gravity acceleration or, in other words, to the second derivatives of the gravitational potential.

Non-gravitational acceleration of the spacecraft (for example due to air-drag) affects all the accelerometers inside the satellite in the same manner and ideally drops out when taking the differences. Rotational motion of the satellite does affect the measured differences, but can be separated from the gravitational signal by separating the measured 5x3 matrix of second derivatives into a symmetric and an anti-symmetric part [**RD-1**].

The physical justification and equations are given in section 3.2.1.1.

Advantages of gradiometry principles towards single-accelerometer or inter-satellite tracking are discussed comparing the GOCE mission with the CHAMP and GRACE missions (see section 2.4).

2.2 GOCE Mission Description

The Gravity-field and steady-state Ocean Circulation Experiment (GOCE) is the first Earth Explorer Core Mission selected in the context of ESA's Living Planet Programme. The GOCE satellite, to be launched in 2008, carries onboard a gravity gradiometer and a GPS receiver with the objective of producing high accuracy global measurements of the Earth's static gravity field for being used in a wide range of geophysical applications.

In order to achieve the above scientific objectives two observations concepts are used:

Electrostatic Gravity Gradiometry (EGG) is employed for the derivation of the medium /short wavelength part of the gravity field.

Satellite-to-Satellite Tracking (SST) in high-low (hl) mode is used for the orbit determination and for retrieval of the long-wavelength part of the gravity field. This is accomplished by means of the GPS receiver.

The techniques of gradiometry and SST are complementary (see Figure 4) in that SST-hl allows derivation of the long and medium wavelength part of the gravity field, while gradiometry is especially sensitive to the short-wavelength part. The point of overlap between the gravity retrieval capabilities of SST-hl and gradiometry begins at around degree and order L = 15, or the equivalent of 1300 km resolution. The SST-hl overlaps the gradiometer capability up to at least L = 60, or the equivalent of 330 km resolution.

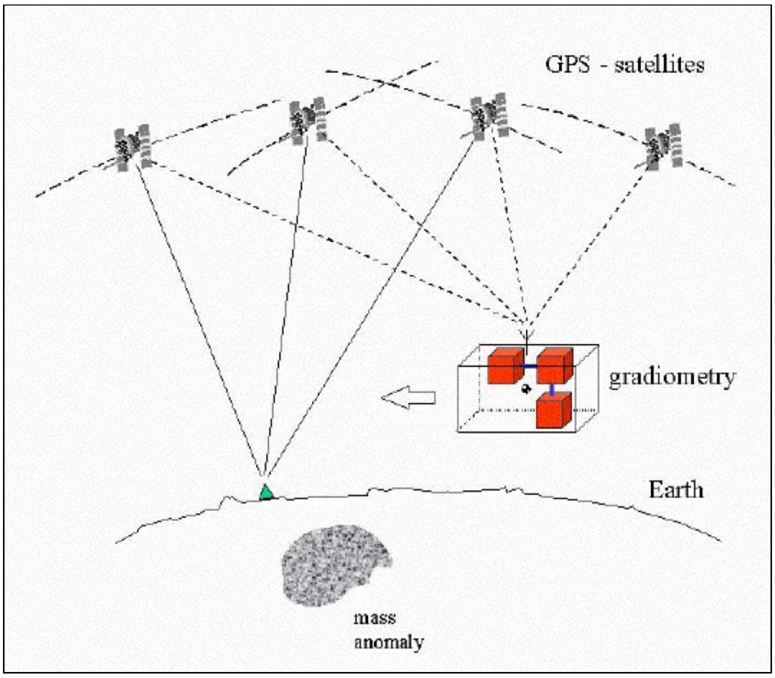


Figure 4 - Schematic illustration of the combined electrostatic gravity gradiometer (EGG) and satellite-to-satellite (high-low) tracking (SST) mission concepts.

In a dawn-dusk Sun-synchronous orbit at altitude below 300km, eclipses are detrimental to the satellite operation because of the thermoelastic disturbances at shadow crossings and the enhanced electrical energy storage requirements of the ion propulsion [**RD-1**].

As shown in Figure 5, the GOCE mission has been phased to avoid periods during which one observes long eclipse durations. During these periods, GOCE will be set in hibernation.

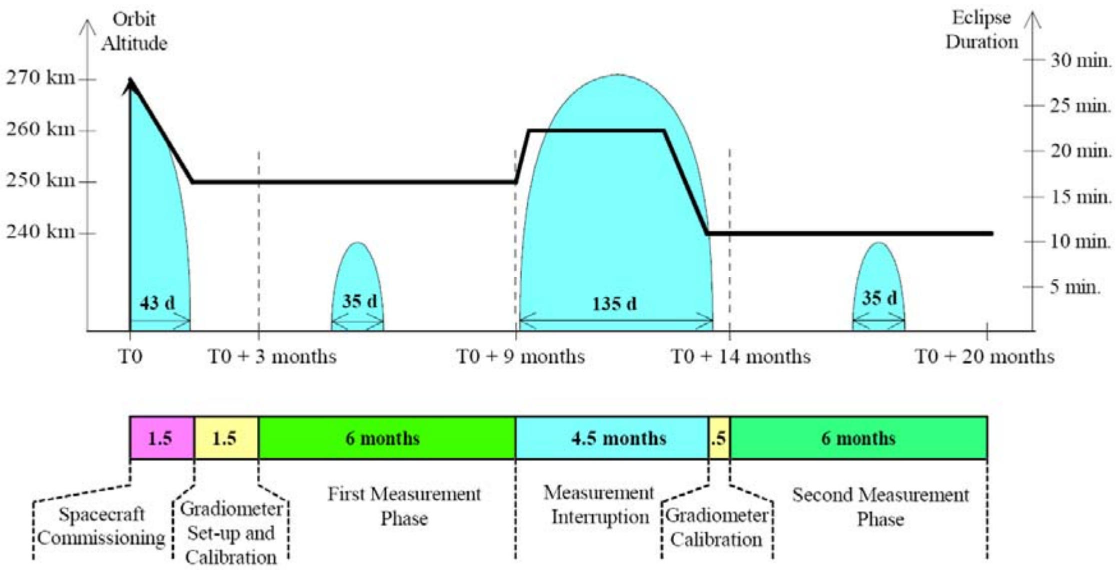


Figure 5 - GOCE mission phases.

2.3 GOCE Instruments

2.3.1 EGG - Electrostatic Gravity Gradiometer

2.3.1.1 Instrument Description

GOCE will employ a three-axis electrostatic gravity gradiometer (see Figure 6) that will allow gravity gradients to be measured in all spatial directions for the first time. It is designed specifically for determining the stationary gravity field. The measured signal is the difference in gravitational acceleration at the test-mass location inside the spacecraft (see Figure 7) caused by gravity anomalies from attracting masses of the Earth.

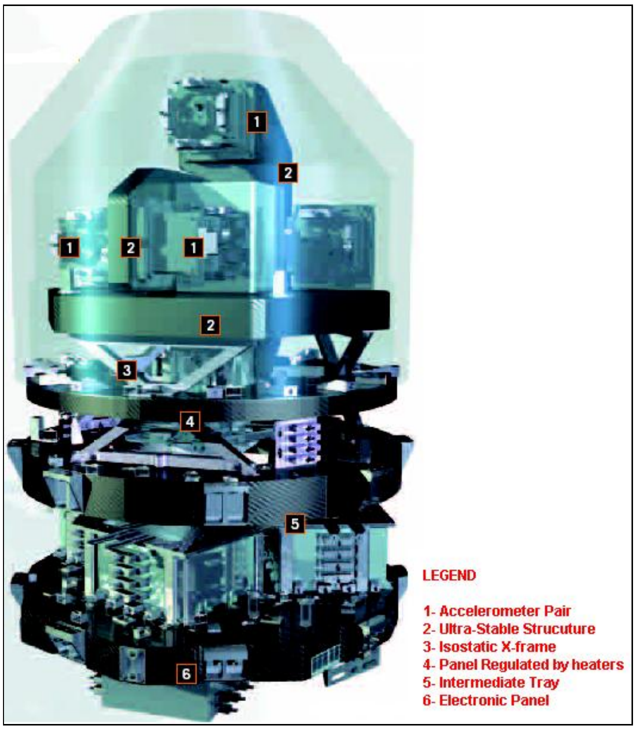


Figure 6 - EGG Instrument excluding harness.

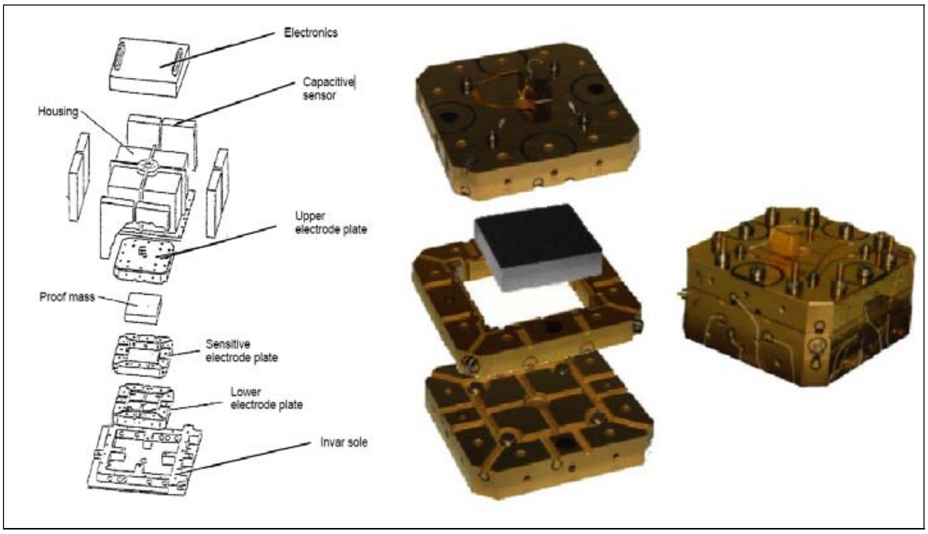


Figure 7 - Schematic and actual views of one accelerometer.

2.3.1.2 Instrument characteristics and performance

The three gradiometer arms are mounted orthogonally to one another one aligned with the satellite's trajectory, one perpendicular to the trajectory, and one pointing approximately towards the centre of the Earth (see Figure 8). The gradiometer baseline of each pair is about 50 cm.

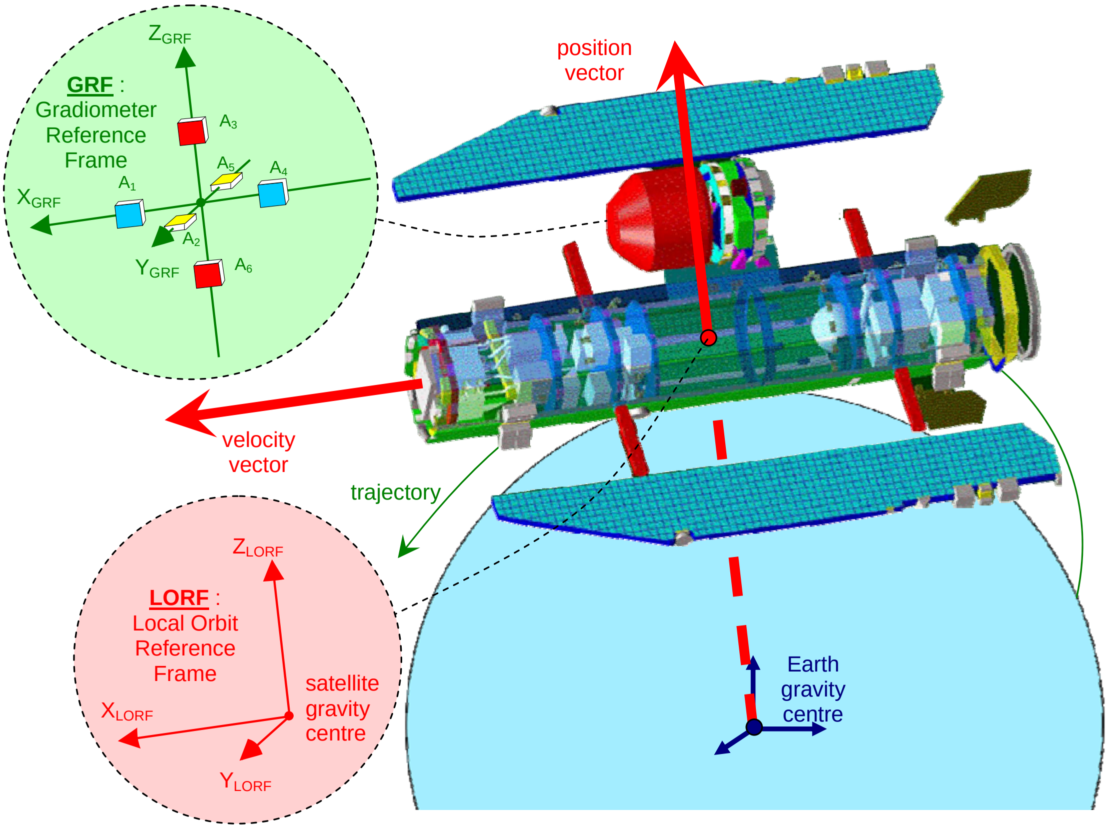


Figure 8 - Trajectory and reference frames.

The approximate accelerometer precision is $2.10^{-12}\,\frac{m}{s^2}\Big/\sqrt{Hz}$ along the ultra sensitive (US) axis and $1.10^{-10}\,\frac{m}{s^2}\Big/\sqrt{Hz}$ along the less sensitive (LS) axis. Each accelerometer is three dimensional with two directions of highest precision and one axis slightly deteriorated. Ideally, the accelerometers of each pair should be perfect twins.

The gradiometric performance is not only a function of the gradiometer but of the whole satellite and the environment, so the gradiometric budget includes all satellite and Level 0 to Level 1b processing errors. The specified GOCE gravimetric mission goal is to provide, after Level 0 and Level 1a/1b ground processing data that conform to the so-called 'trace' requirement. The trace (see eq. 10), or residual Earth gravity gradient tensor (GGT) measurement error should not exceed a pre-specified residual level within the measurement bandwidth (MBW = 5 mHz to 100 mHz) in the gradiometer reference frame (GRF) (for definition of the GRF refer to Section 5.1.3). The following Table 2 lists the EEG Instrument characteristics (see also http://www.esa.int/esaLP/ESAHTK1VMOC_LPgoce_0.html).

Payload: Gravity gradiometry	
	Three-axis diagonal gradiometer based on three pairs of electrostatic servo-controlled accelerometers
Design Measurement Bandwidth (MBW)	5.10^{-3} to 10^{-1} Hz
Approximate Baseline length	0.5 m
Sensitivity (detection noise) • Measurement bandwidth	$<$ US axis precision approx. $2.10^{-12}\,\frac{m}{s^2}\Big/\sqrt{Hz}$; $<$ LS axis spec $1.10^{-10}\,\frac{m}{s^2}\Big/\sqrt{Hz}$
• Extended bandwidth (10^{-5} to 1 Hz)	$<$ US axis precision approx. $2.10^{-12}\,\frac{m}{s^2}\Big/\sqrt{Hz}$; $<$ LS axis spec $1.10^{-10}\,\frac{m}{s^2}\Big/\sqrt{Hz}$
Proof-mass positioning error	$6.10^{-8}\,m/\sqrt{Hz}$
Absolute / relative scale factors	10^{-3} / 10^{-5}
Absolute / relative misalignment	10^{-3} rad. / 10^{-5} rad.

Table 2 - EGG Instrument Characteristics.

2.3.2 SST - Satellite-to-Satellite Tracking

2.3.2.1 Instrument Description

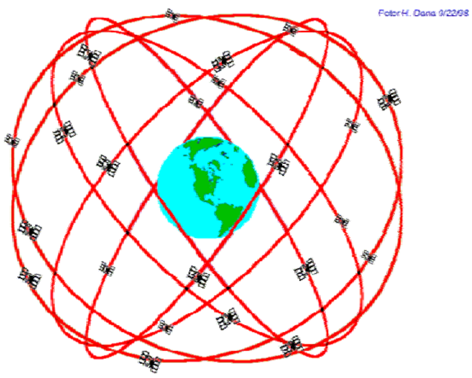
The principle of Satellite-to-Satellite Tracking provides knowledge of the precise (geodetic quality) position of the spacecraft measured relative to a constellation of reference satellites such as the US GPS system. This information is used to extract gravity information through orbit perturbation analysis. The technical specifications for the Receiver are:

- Multi-channel receiver with codeless tracking capability
- Dual frequency for compensation of ionospheric delays

2.3.2.2 GPS constellation

These two sections explaining the GPS behaviour have been extracted from the site of Peter H. DANA, University of Texas (Copyright © 1999).

The nominal GPS Operational Constellation consists of 24 satellites, also called Space Vehicles (SV), that orbit the earth in 12 hours. There are often more than 24 operational satellites as new ones are launched to replace older satellites. The satellite orbits repeat almost the same ground track (as the Earth turns beneath them) once each day. The orbit altitude is such that the satellites repeat the same track and configuration over any point approximately each 24 hours (4 minutes earlier each day). There are six orbital planes (with nominally four SVs in each), equally spaced (60 degrees apart), and inclined at about fifty-five degrees with respect to the equatorial plane. This constellation provides the user with between five and eight SVs visible from any point on the Earth.



GPS Nominal Constellation
24 Satellites in 6 Orbital Planes
4 Satellites in each Plane
20,200 km Altitudes, 55 Degree Inclination

2.3.2.3 GPS signal

The space vehicles (SV) of the GPS constellation transmit two microwave carrier signals. The L1 frequency (1575.42 MHz) carries the navigation message and the Standard Positioning Service (SPS) code signals. The L2 frequency (1227.60 MHz) is used to measure the ionospheric delay by Precise Positioning Service (PPS) equipped receivers.

Three binary codes shift the L1 and/or L2 carrier phase.

- The C/A Code (Coarse Acquisition) modulates the L1 carrier phase. The C/A code is a repeating 1 MHz Pseudo Random Noise (PRN) code. This noise-like code modulates the L1 carrier signal, "spreading" the spectrum over a 1 MHz bandwidth. The C/A code repeats every 1023 bits (one millisecond). There is a different C/A code PRN for each SV. GPS satellites are often identified by their PRN number, the unique identifier for each pseudo-random-noise code. The C/A code that modulates the L1 carrier is the basis for the civil SPS.
- The P-Code (Precise) modulates both the L1 and L2 carrier phases. The P-Code is a very long (seven days) 10 MHz PRN code. In the Anti-Spoofing (AS) mode of operation, the P-Code is encrypted into the Y-Code. The encrypted Y-Code requires a classified AS Module for each receiver channel and is for use only by authorized users with cryptographic keys. The P (Y)-Code is the basis for the PPS.
- The Navigation Message also modulates the L1-C/A code signal. The Navigation Message is a 50 Hz signal consisting of data bits that describe the GPS satellite orbits, clock corrections, and other system parameters.

Data Bit Demodulation and C/A Code Control - The receiver PRN code start position at the time of full correlation is the time of arrival (TOA) of the SV PRN at receiver. This TOA is a measure of the range to

SV offset by the amount to which the receiver clock is offset from GPS time. This TOA is called the *pseudorange*.

2.3.2.4 Instrument characteristics and performance

Reconstruction of the gravity field from the effect it has on the satellite trajectory requires the precise orbit determination (POD) from the 1 Hz satellite to satellite tracking instrument (SSTI) data. Orbit determination by the High level Processing Facility (HPF) is undertaken in two steps. First, the reference trajectory of the GOCE spacecraft, or Rapid Science Orbit (RSO) is determined using reduced dynamic (RD) and kinematic (KI) techniques, as part of the Quick-look (QL) processing within the HPF, and shall be accurate to a few decimetres. The GPS data, together with this reference orbit, will then subsequently be used in both reduced dynamic and kinematic techniques to determine the precise science orbit (PSO) with errors reduced to centimetre level.

Kinematic POD does not need as input the non-conservative forces on the spacecraft, thus the achievable accuracy in the determination of the position of the satellite centre of mass (CoM) depends mainly on the following contributions:

- SSTI measurement noise.
- SSTI ground station coordinates error.
- SSTI ephemeris error.
- Troposphere correction error.
- Phase centre location error of the GPS antenna.
- The error in the location of the spacecraft CoM relative to the GPS antenna.

For dynamic POD, errors on the measurement of the non-conservative linear accelerations of the satellite CoM, and in the knowledge of the gravity field, must be added to the above list. The performance specifications for the SSTI measurements are:

- Carrier phase noise on L1 less than 0.001 m.
- Carrier phase noise on L2 less than 0.001 m in the absence of anti-spoofing and less than 0.0049 m in presence of anti-spoofing.
- C/A code pseudo-range noise on L1 less than 0.5 m.
- P(Y)-code pseudo-range noise on L1 and L2 less than 0.25 m (in absence of anti-spoofing).

The requirement is 1.5 m in presence of anti-spoofing. The expected multi-path effect (due to signal reflection off the satellite structure prior to arrival at the GPS antenna) is less than 0.004 m, while the contribution of multi-path to the code error is expected to be lower than 0.15 m (RD-3). All these requirements are applicable to GPS satellites above 15^{o} elevation, as seen by the GOCE spacecraft.

2.4 Previous missions – CHAMP – GRACE

To improve our knowledge of the Earth gravitation field, four fundamental criteria for dedicated satellite gravity should be satisfied :

1. Uninterrupted tracking in three spatial dimensions.

2. Measurement or compensation of the effect of non-gravitational forces.
3. Orbit altitude as low as possible.
4. Measurement of gravity gradient.

Three techniques are available:

SST-hl With the orbits of the high-orbiting GPS and GLONASS satellites assumed to be known with high accuracy, SST-hl corresponds to an 'in situ' 3-D position, velocity or acceleration determination of a low orbiting (LEO) satellite.

SST-ll The principle corresponds to the line-of-sight measurement of the range, range rate or acceleration difference between the two low-orbiting satellites.

SGG For satellite gradiometry, the measurement is of acceleration differences in 3-D over the short baseline of the gradiometer instrument.

As shown in the sections below:

- CHAMP makes use of SST-hl and has satisfied the criteria 1 and 2.
- GRACE makes use of SST-ll coupled with SST-hl and has satisfied criteria 1, 2 and partially 4.
- GOCE will make use of SGG coupled with SST-hl and will satisfy all the criteria.

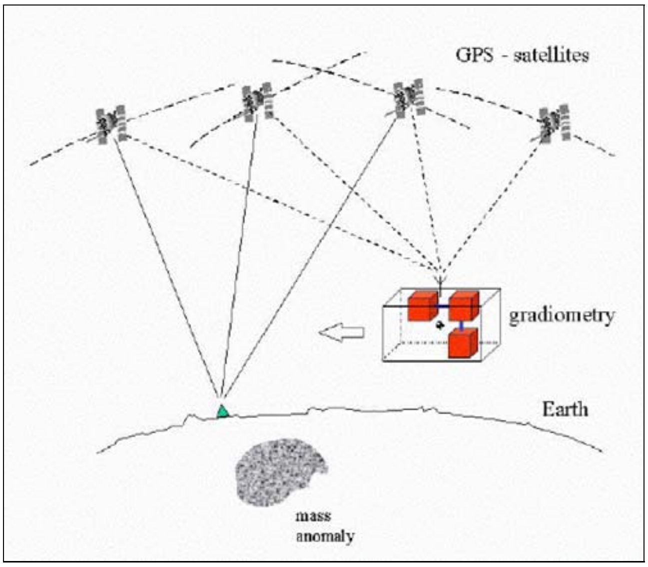


Figure 9 - Concept of satellite gravity gradiometry (SGG) coupled with SST-hl.

2.4.1 CHAMP

The CHAMP (CHAllenging Minisatellite Payload) mission has been designed to measure the gravity and magnetic fields of the Earth. As the satellite's orbit is influenced by gravity field disturbances, the analysis of the orbit data can provide information about the structure of the gravity field. Thus the satellite positions represent the primary observable for the task of gravity field determination. This primary measurement principle is known as satellite-to-satellite tracking in the high-low mode (hl-SST), as the orbit of the low flying CHAMP satellite is determined by the higher-flying GPS satellites. Additionally, CHAMP is equipped with an on-board accelerometer to account for non-gravitational forces acting on the satellite such as atmospheric drag, solar radiation, and Earth albedo, which influence the orbit as well. Star cameras provide high precision attitude information.

Launch date	15/07/2000
Status	Still in service
Orbit	Near circular, inclination 87°
Altitude(s)	454 km 340 km (after 7 years operation)

Table 3 - Characteristics of CHAMP mission.

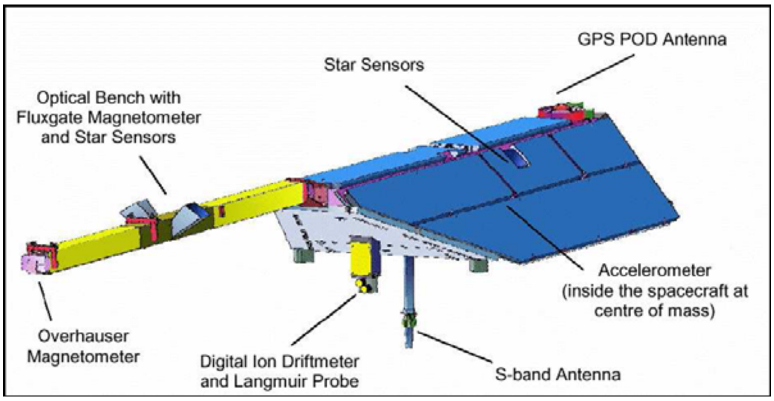


Figure 10 - CHAMP satellite (source GFZ Postdam).

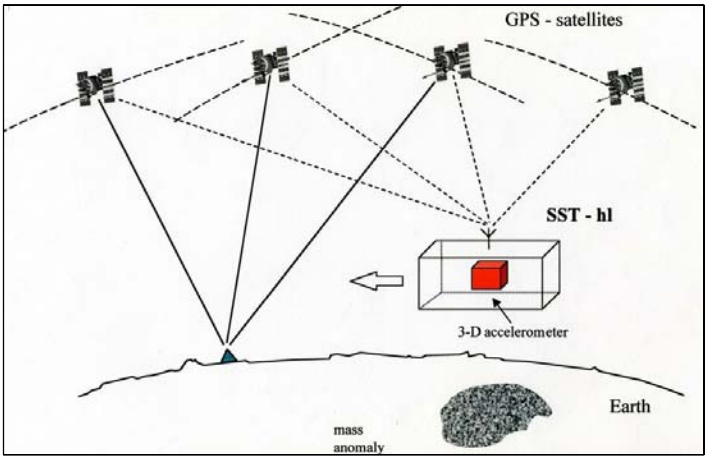


Figure 11 - CHAMP - Concept of satellite-to-satellite tracking in the high-low mode (SST-hl).

For more information regarding the CHAMP mission, please refer to the following Web sites:

- http://www.gfz-potsdam.de/pb1/op/champ/index_CHAMP.html
- http://isdc.gfz-potsdam.de/index.php

2.4.2 GRACE

GRACE is a twin satellite mission consisting of two identical satellites following each other in the same orbit separated by a distance of about 220km.. Both satellites are equipped with an inter-satellite ranging system that establishes the connection by a microwave link enabling the measurement of relative motion (range, range-rate, and range-acceleration) between the two satellites with high accuracy. This K-band ranging system is the key instrument of GRACE and is capable of measuring the dual one-way range between both satellites with a precision of about 1 μm. This kind of inter-satellite gravity measurement principle is known as low-low satellite-to-satellite tracking (ll-SST).

Like CHAMP, each satellite carries a GPS receiver to measure its position, thus enabling observations of the type high-low satellite-to-satellite tracking (hl-SST) as well. In addition, the onboard accelerometer accounts for non-gravitational forces such as atmospheric drag, solar radiation, and Earth albedo, which act on the surface of the satellite and disturb the satellite's orbit.

Launch date	17/03/2002
Status	Still in service
Orbit	Near circular, inclination 89.5°
Altitude(s)	500 km 450 km (after 6 years soft drift)

Comment [SR1]: 465 km ? see http://www.csr.utexas.edu/grace/operations/configuration.html

Comment [SR2]: Data to be verified

Table 4 - Characteristics of GRACE mission.

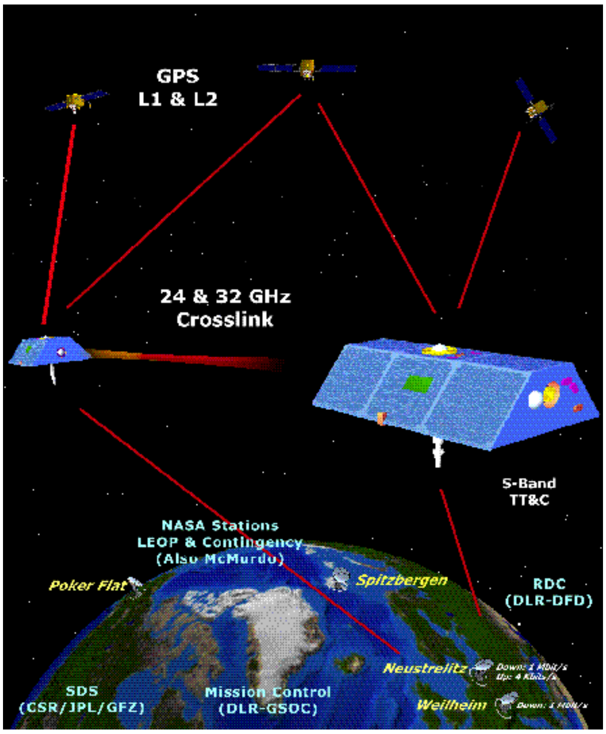


Figure 12 - GRACE satellites (source GFZ Postdam).

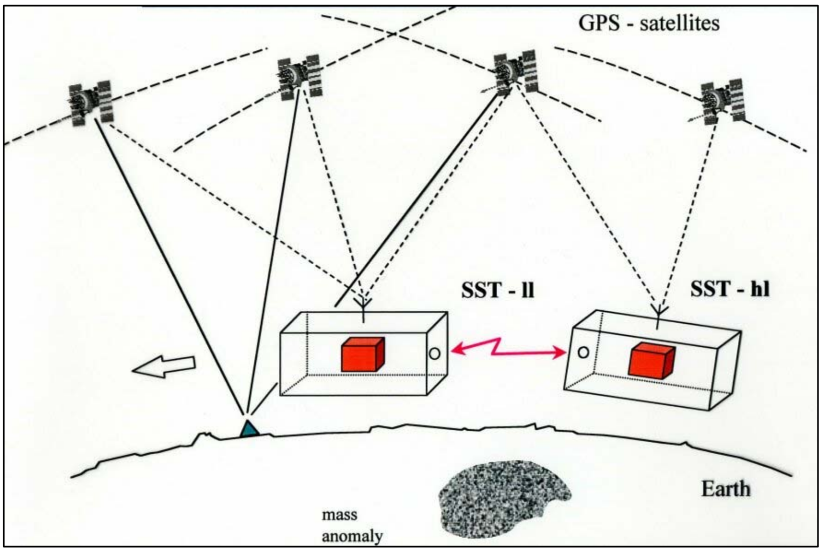


Figure 13 - GRACE - Concept of inter-satellite link (SST-ll) coupled with SST-hl.

For more information regarding the GRACE mission, please refer to the following Web sites:

- http://www.csr.utexas.edu/grace/
- http://www.gfz-potsdam.de/grace/index_GRACE.html

3 GOCE PRODUCTS AND ALGORITHMS

3.1 Introduction

The three basic levels of data products to be produced by the ground segment are briefly described in the following.

3.1.1 Level 0

Level 0 data consists of the time-ordered science and housekeeping raw data produced by the instruments and by the platform. Each of these data streams are needed to produce the Level 1b data products and to check their quality.

Level 0 products include :

- satellite and instrument housekeeping data and ancillary data (such as attitude quaternions measured by the star trackers at 2 Hz),
- output of the 6 accelerometers along their 3 measurement axes at 1 Hz (more precisely at 1/0.999360 Hz),
- SSTI data at 1 Hz

3.1.2 Level 1b

The Level 0 to Level 1b processing carried out by the Instrument Processing Facility (IPF) converts the ordered L0 time series into engineering units and performs the calibration, correction and geolocation of data along the orbit.

L1b products include :

- gravity gradients in GRF together with the GRF to Inertial Reference Frame (IRF),
- frame transformation matrices,
- linear accelerations and angular rates and accelerations,
- SST measurements and derived positions and reconstructed satellite orbits in Earth-Fixed Reference Frame (also available in RINEX format),
- attitude and orbit data (position, velocity and time).

3.1.3 Level 2

Level 2 products are generated by the High Level Processing Facility, a distributed system developed and operated by the European GOCE Gravity-Consortium (EGG-C).

Level 2 products include :

- Pre-processed, externally calibrated, and corrected gravity gradients in both Gradiometer Reference Frame and Terrestrial Reference Frame.

- Rapid and precise orbits.
- Gravity field solutions including variance-covariance matrix and derived quantities (geoid heights, gravity anomalies, and geoid slopes).

For a detailed description of the Level 2 Products, please refer to [RD-2].

3.2 Level 1b Products and Algorithms

The GOCE L1b products are:

- The **nominal SST product (file type SST_NOM_1b)**, containing the raw observables from GPS, corrections and orbit solutions. A complete description of this product is in Section 4.3.
- The **SST RINEX product (SST_RIN_1b)**, containing GPS raw measurements in RINEX format (see Section 4.4).
- The **nominal EGG product (EGG_NOM_1b)**, containing the raw measurements from the accelerometer, instrument-calibrated and corrected and the gravity gradients in the instrument reference frame (see Section 4.5).

In the following, the physical justification and the algorithm description for each of these products are detailed.

3.2.1 Satellite to Satellite Tracking Instrument (SSTI)

3.2.1.1 Physical justification

From the GPS receiver measurements, the orbit trajectory is computed to within ten (10) meters accuracy. As the spacecraft is kept in an almost drag-free mode (at least along track and within an extended measurement bandwidth) the orbit motion is purely gravitational.

The SST technique uses satellites to track other satellites. The GPS receiver sees twelve or more GPS and GLONASS satellites at any time. Their ephemerides are determined very accurately by the large network of ground stations that participate in the International GPS Service (IGS). Taking their orbits and the SSTI GPS measurements, the GOCE orbit can be monitored to centimetre-precision in L2 processing, without interruption, and in three dimensions.

3.2.1.2 Algorithm description

The on-ground processing flow is summarised in Figure 14.

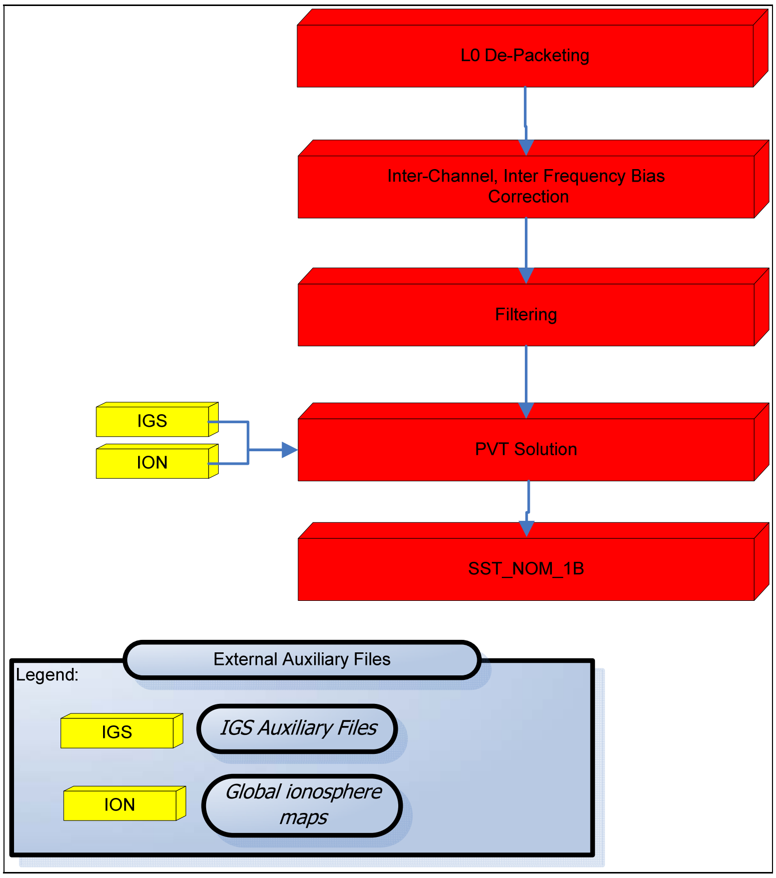


Figure 14 - SST_NOM Algorithm overview.

3.2.1.2.1 L0 De-Packeting

In this processing step the raw instrument data is converted into engineering units and packaged into individual data sets.

3.2.1.2.2 Inter Channel, Inter Frequency Bias Correction

This processing step consists in the correction of the raw code measurements for the inter-channel bias and the correction of the raw phase measurements the temperature dependent inter-frequency bias. From this data the RINEX format output of the measurements is corrected.

3.2.1.2.3 Filtering and Outlier detection

The corrected code measurement data is fitted by a 3rd order polynomial with a data span of 5 elements in order to identify and flag outliers and to produce a smoothed pseudorange together with an estimate of the pseudorange measurement noise.

Cycle slips in the phase measurements are identified and flagged. The receiver wrapping of the phase measurements is removed.

3.2.1.2.4 PVT (Position, Velocity and Time) Solution

In this processing step only the code (pseudorange) measurements are used.

Th processing step consists of three sub-steps :

1. Derivation of a ionosphere-free pseudorange measurement

   The effect of the ionosphere is corrected by either forming the ionosphere free linear combination of the measurements on L1 and L2 or, in case the L2 measurement is not available, by using ionosphere maps to estimate the TEC (Total Electron Content) and correct the L1 measurement for it.

2. Position and clock error determination

   The pseudorange measurements corrected for the effect of the ionosphere are then used to derive the GOCE position and the GOCE SSTI receiver clock error by a least squares adjustment. Inputs from the IGS are the orbits of the GPS satellites.

3. Velocity determination

   The velocity of GOCE is determined by fitting a 4th order polynomial to the derived positions and taking the 1st derivative.

3.2.1.3 Products (SST_NOM_1b, SST_RIN_1b)

The **SST_NOM_1b** product is the nominal Level 1b product of the SSTI. It contains :

- Carrier phase and pseudorange measurements from TM packets.
- On-board navigator solution.
- Inter-frequency bias estimation results.
- Carrier phase measurements IFB corrected.
- Pseudorange measurements, ICB corrected.
- Noise of pseudorange measurements.
- Carrier phase measurements, flagged for cycle slips.
- Pseudorange corrected for ICB, flagged for outliers.
- Smoothed pseudorange.
- Solution vector PVT.
- GDOP, PDOP, TDOP.
- Sigma on PVT elements.

- Covariance matrix.
- PVT solution sigma and residuals.
- Time correlation measurements.
- Position and Velocity of the GPS satellites used for the derivation of PVT.
- Total number of the outliers in the P1, P2, C/A code and L1, L2 phase measurements.

The SST_RIN_1b product [RD-4] contains a subset of SST_NOM_1b data related to processed code and phase observations.

3.2.2 Electrostatic Gravity Gradiometer (EGG)

3.2.2.1 Physical justification

The principle of operation of the gradiometer relies on measuring the forces that maintain a 'proof mass' at the centre of a specially engineered 'cage'. Servo-controlled electrostatic suspension provides control of the 'proof mass' in terms of linear and rotational motion. Three pairs of identical accelerometers, which form three 'gradiometer arms', are mounted on the ultra-stable structure as depicted in Figure 20. The difference between accelerations measured by each pair of accelerometers is the basic gradiometric datum, where half the sum is proportional to the externally induced drag acceleration (common mode measurement).

As indicated in section 2.3.1.2, the three gradiometer arms are mounted orthogonally to one another: one aligned with the satellite's trajectory, one perpendicular to the trajectory, and one pointing approximately towards centre of the Earth. The gradiometer baseline of each pair is about 50 cm.

The approximate accelerometer precision is $2.10^{-12} \frac{m}{s^2} \Big/ \sqrt{Hz}$ along US axis and $1.10^{-10} \frac{m}{s^2} \Big/ \sqrt{Hz}$ along LS axis. Each accelerometer is three dimensional with two directions of highest precision and one axis slightly deteriorated. Ideally, the accelerometers of each pair should be perfect twins. Then all linear accelerations acting on the accelerometers would be perfectly removed when taking the difference between the readings of the two along the same axis.

By combining the differential accelerations, it is possible to derive the gravity gradient components as well as the perturbing angular accelerations

In reality, a common mode rejection ratio (CMRR) of 10^{-5} is attained here. The gradiometer will reach a precision of about $1-3\, mE/\sqrt{Hz}$ over the measurement bandwidth (5.10^{-3}Hz – 0.1Hz). Although the gradiometer is highly accurate, it is not possible to map the complete gravity field at all spatial scales with the same quality. To overcome this limitation the position of the GOCE satellite is tracked by GPS relative to GPS satellites at an altitude of 20 000 km. This procedure is known as satellite-to-satellite tracking (SST).

The gradiometer is used to measure high-resolution features of the gravity field whilst GPS is used to obtain low-resolution data.

From the analytical point of view, gravity gradients are the second order derivatives $\partial^2 V/\partial x_i.\partial x_j = V_{ij}$ of the gravitational potential $\underline{V}$. They form a second-rank tensor with nine components, also called *gravity gradient tensor* or *Eötvös tensor* (see eq. 3.68 of [RD-8]) :

$$V_{ij} = \begin{pmatrix} V_{xx} & V_{xy} & V_{xz} \\ V_{yx} & V_{yy} & V_{yz} \\ V_{zx} & V_{zy} & V_{zz} \end{pmatrix} \qquad \text{(eq. 3)}$$

Values of the gravity gradient tensor can be found in the following MDS:

- 4.5.3.1.13 - Gravity Gradient Tensor in the GRF MDS Record (EGG_GGT_1i)

This [3 x 3] matrix must be symmetrical (∇V is a curl-free vector field) and in empty space (density $\rho = 0$) its trace must be zero (Laplace equation) :

$$V_{xx} + V_{yy} + V_{zz} = 0 \qquad \text{(eq. 4)}$$

Thus, in each point only five of the nine components are independent.

An accelerometer with three axes senses e.g. the acceleration :

$$a_i = -\frac{\partial V(0)}{\partial x_i} - V_{ij}(0).dx_j + \Omega_{ik}.\Omega_{kj}.dx_j + \dot{\Omega}_{ij}.dx_j - b_i(0) \qquad \text{(eq. 5)}$$

Where $b_i(0)$ is the sum of all non-gravitational accelerations acting on the satellite along the i-axis at the centre of mass.

These acceleration values can be found in the following MDS:

- 4.5.3.1.6 - Nominal Linear & Angular Accelerations MDS Record (EGG_NLA_1i)

In the case of GOCE the gravity gradients are derived from the difference of the measured accelerations a_i along e.g. the i-axis of one couple A and B of the accelerometers, separated by a distance Δx_j along the j-axis of the diamond configuration. Then it is [RD- 8] and [RD-10] :

$$\frac{a_i(B) - a_i(A)}{\Delta x_j} = \underline{\underline{\Gamma}}_{ij} = -\underline{\underline{V}}_{ij} + \underline{\underline{\Omega}}_{ik}\underline{\underline{\Omega}}_{kj} + \dot{\underline{\underline{\Omega}}}_{ij} \qquad \text{(eq. 6)}$$

It is worth noting that the components V_{ij} are not observable directly but only their combination with two other terms. These two express the effect of centrifugal acceleration ($\Omega\Omega$) and angular acceleration ($\dot{\Omega}$). They are caused by the measurement in a moving frame fixed to the satellite. Closer inspection shows that $\Omega_{ik}\ \Omega_{kj}$ like V_{ij} is symmetric, whereas $\dot{\Omega}_{ij}$ is antisymmetric. It is in detail :

$$\Gamma_{ij} = \begin{pmatrix} V_{xx} - (\omega_y^2 + \omega_z^2) & V_{xy} + \omega_x\omega_y + \dot{\omega}_z & V_{xz} + \omega_z\omega_x - \dot{\omega}_y \\ V_{yx} + \omega_x\omega_y - \dot{\omega}_z & V_{yy} - (\omega_x^2 + \omega_z^2) & V_{yz} + \omega_z\omega_y + \dot{\omega}_x \\ V_{zx} + \omega_z\omega_x + \dot{\omega}_y & V_{zy} + \omega_z\omega_y - \dot{\omega}_x & V_{zz} - (\omega_x^2 + \omega_y^2) \end{pmatrix} \qquad \text{(eq. 7)}$$

Thus, a separation into symmetric and antisymmetric part yields :

$$\frac{1}{2}\left(\Gamma_{ij} + \Gamma_{ji}\right) = V_{ij} + \Omega_{ik}\Omega_{kj} \qquad \text{(eq. 8)}$$

and:

$$\frac{1}{2}\left(\Gamma_{ij} - \Gamma_{ji}\right) = \dot{\Omega}_{ij} \qquad \text{(eq. 9)}$$

In addition, one finds:

$$trace(\Gamma) = \Gamma_{xx} + \Gamma_{yy} + \Gamma_{zz} = -2\left(\omega_x^2 + \omega_y^2 + \omega_z^2\right) = -2\omega^2 \qquad \text{(eq. 10)}$$

In the above one should keep in mind that ω_y, the angular velocity about a vector perpendicular to the orbital plane, is much greater than ω_x and ω_z. It represents the once-per-revolution rotation of the Earth pointing satellite: $\omega_y \gg \omega_x$, ω_z.

By resuming the above considerations:

- Ideally, when differencing the accelerations a_i, all non-gravitational accelerations b_i (0) drop out, as well as the gravitational accelerations $\partial V(0)/\partial x_i$.
- The gravitational gradients cannot be sensed in isolation. They are mixed with centrifugal and angular acceleration terms.
- The angular accelerations can be isolated and, after integration and double integration, be employed for the angular control of the spacecraft.
- One time-integration of the angular accelerations yields angular velocities which are used to isolate V_{ij} from $\Omega_{ik}\ \Omega_{kj}$.
- For GOCE, with one axis of each accelerometer weaker than the two others, the arrangement of the six 3-D accelerometers is chosen such as to permit precise determination of ω_y, whereas ω_x and ω_z are not determined as well. Consequently, only V_{xx}, V_{yy}, V_{zz} and V_{xz} can be reproduced with highest precision.
- The sum, i.e. the common mode accelerations $a_i\ (A) + a_i\ (B)$, are a measure of the non-gravitational accelerations

  $$a_i(A) + a_i(B) = -2b_i(0) \qquad \text{(eq. 11)}$$

  if the accelerometers are arranged symmetrically with respect to the centre of mass of the spacecraft, for then $\partial V(0)/\partial x_i \approx 0$. They are then employed for drag-free control (together with the GPS orbits).

3.2.2.2 Algorithm description

3.2.2.2.1 EGG Processing Description

For deriving the gravity gradients from the EGG accelerometers voltages, the following steps are undertaken (see Figure 15).

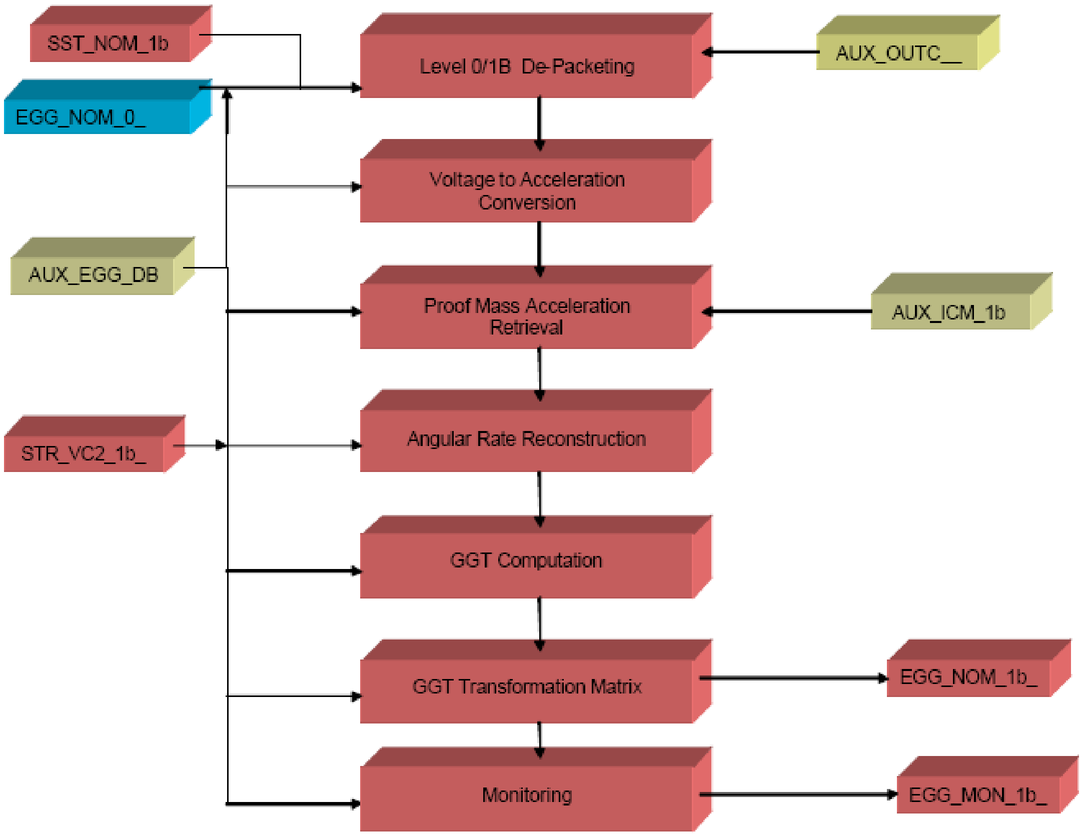


Figure 15 - EGG_NOM Algorithm overview.

Voltage to acceleration conversion: The control voltages applied to the eight electrodes surrounding each proof-mass are corrected from noise (gain attenuation and phase delay) and for the non-linearities introduced by transfer function of the digital filter. Then they are transformed in several sets of acceleration figures (linear acceleration and differential acceleration).

Proof Mass Acceleration Retrieval: The common-mode (C) and differential acceleration (d) of each accelerometer pair (a_i and a_j, ij=14, 25, and 36) is transformed respectively into common-mode and differential acceleration of each accelerometer pair (a_{ij}) by applying the inverse calibration matrices to be found in the AUX_ICM_1b auxiliary file.

The common-mode and the differential-mode accelerations for the OAG1 (accelerometer pair A_1, A_4), OAG2 (accelerometer pair A_2, A_5) and OAG3 (accelerometer pair A_3, A_6) are obtained as follows in below **:**

$$a_{C,ij,X} = \frac{1}{2}\left(a_{i,X} + a_{j,X}\right), \quad a_{C,ij,Y} = \frac{1}{2}\left(a_{i,Y} + a_{j,Y}\right), \quad a_{C,ij,Z} = \frac{1}{2}\left(a_{i,Z} + a_{j,Z}\right), \quad (ij = 14,25,36)$$
$$a_{d,ij,X} = \frac{1}{2}\left(a_{i,X} - a_{j,X}\right), \quad a_{d,ij,Y} = \frac{1}{2}\left(a_{i,Y} - a_{j,Y}\right), \quad a_{d,ij,Z} = \frac{1}{2}\left(a_{i,Z} - a_{j,Z}\right), \quad (ij = 14,25,36) \qquad \text{(eq. 12)}$$

Where: $a_{C,ij,X/Y/Z}$ are the common mode accelerations (see also eq. 11), $a_{d,ij,X/Y/Z}$ are the differential mode accelerations (see also eq. 6) and $a_{i/j,X/Y/Z}$ are the single accelerations for each proof mass (see eq. 5).

These common mode and differential accelerations can be found in the following MDS:

- 4.5.3.1.5 - Nominal Common & Differential Accelerations MDS Record (EGG_NCD_1i)
- 4.5.3.1.9 - Calibrated Common and Differential Accelerations MDS Record (EGG_CCD_1i)

From the differential-mode accelerations, the three angular accelerations of the Gradiometer (see 4.5.3.1.7) about the X, Y, Z axes of the GRF are obtained as follows in below equation:

$$\dot{\Omega}_X = -\frac{a_{d,36,Y}}{L_Z} + \frac{a_{d,25,Z}}{L_Y}, \quad \dot{\Omega}_Y = -\frac{a_{d,14,Z}}{L_X} + \frac{a_{d,36,X}}{L_Z}, \quad \dot{\Omega}_Z = -\frac{a_{d,25,X}}{L_Y} + \frac{a_{d,14,Y}}{L_X} \qquad \text{(eq. 13)}$$

These angular accelerations of the Gradiometer can be found in the following MDS:

- 4.5.3.1.7 - Nominal Gradiometer Angular Accelerations MDS Record (EGG_NGA_1i)
- 4.5.3.1.10 - Calibrated Angular Accelerations MDS Record (EGG_CGA_1i)

Angular Rate Reconstruction: This step computes both the inertial angular rates of the Gradiometer in the GRF and the quaternion defining the attitude of the GRF in the IRF (see 4.5.3.1.11).

The fist step is to compute the inertial angular rates (ω_X, ω_Y, ω_Z) of the Gradiometer about the axes of the GRF, from the angular accelerations of the Gradiometer about the axes of the GRF and from the quaternions (q_1, q_2, q_3, q_4). Then, compute the quaternions ($q_{G,1}$, $q_{G,2}$, $q_{G,3}$, $q_{G,4}$) defining the attitude of the GRF in the Inertial Reference Frame.

The angular rate estimate is obtained merging the inertial angular acceleration (obtained from the Gradiometer measurements) and inertial attitude quaternion (measured by the star sensor) decimated at 1 Hz frequency, knowing the time delay ΔTSTR between the two time series.

The angular rate reconstruction process is based on the following considerations :

- Inside the Gradiometer measurement bandwidth (MBW: 5 to 100 mHz) the best available measures come from the Gradiometer itself. The attitude measurements from star tracker are too noisy, to be derived and used. So the angular rate reconstruction is obtained by proper integration of angular accelerations.
- For frequencies significantly below MBW, the gradiometer drifts are too large and the angular rate is obtained by "*derivation*" of the attitude measurements coming from star tracker.
- The equivalent hybridisation frequency is below the MBW and has different values for each axis.
- The star tracker noise must be attenuated in such way to results negligible with respect to Gradiometer noise inside MBW.

Inside bandwidth, the angular rate is reconstructed only by the numerical integration of angular acceleration measures. The attitude measures are used to recovery from angular rate initial value uncertainty, to compensate the effects of EGG low frequency noise, and to delete the drift of the numerical integration of angular accelerations.

These considerations are at the base of the following algorithm :

1. To reconstruct the angular rate uses as much as possible the measure coming from the EGG. These means:
   - to interpolate the acceleration values coming at 1Hz with an interpolator;
   - to solve in a closed form the integral of the interpolated signal in order to obtain the angular rate.
2. To correct the acceleration coming from the EGG using the star-tracker measures below a given frequency (named *hybridization frequency*) where the acceleration obtained deriving two times the attitude information is better than that obtained by EGG

Gravity Gradient Tensor (GGT) Computation: The GGT computation algorithms will compute the 6 independent components of the GGT in the Gradiometer Reference Frame (GRF), from the calibrated differential-mode accelerations and from the reconstructed inertial angular rates of the Gradiometer about the axes of the GRF. The Figure 16 depicts the algorithm data-flow.

The 6 independent components of the GGT in the GRF are obtained as follows in :

$$U_{G,XX} = -2\frac{a_{d,14,X}}{L_X} - \omega_Y^2 - \omega_Z^2, \quad U_{G,YY} = -2\frac{a_{d,25,Y}}{L_Y} - \omega_X^2 - \omega_Z^2, \quad U_{G,ZZ} = -2\frac{a_{d,36,Z}}{L_Z} - \omega_X^2 - \omega_Y^2 \qquad \text{(eq. 14)}$$

and:

$$U_{G,XY} = -\frac{a_{d,14,Y}}{L_X} - \frac{a_{d,25,X}}{L_Y} + \omega_X \omega_Y$$
$$U_{G,XZ} = -\frac{a_{d,14,Z}}{L_X} - \frac{a_{d,36,X}}{L_Z} + \omega_X \omega_Z \qquad \text{(eq. 15)}$$
$$U_{G,YZ} = -\frac{a_{d,25,Z}}{L_Y} - \frac{a_{d,36,Y}}{L_Z} + \omega_Y \omega_Z$$

Where: $a_{d,ij,X/Y/Z}$ are the differential mode accelerations (see eq. 12) and ω_i the angular rates.

The GGT transformation is implemented by computing the rotation matrix from the GRF to the Inertial Reference Frame from the Gradiometer inertial attitude quaternions. The following Figure 16 shows the GGT Tensor Computation Algorithms overview.

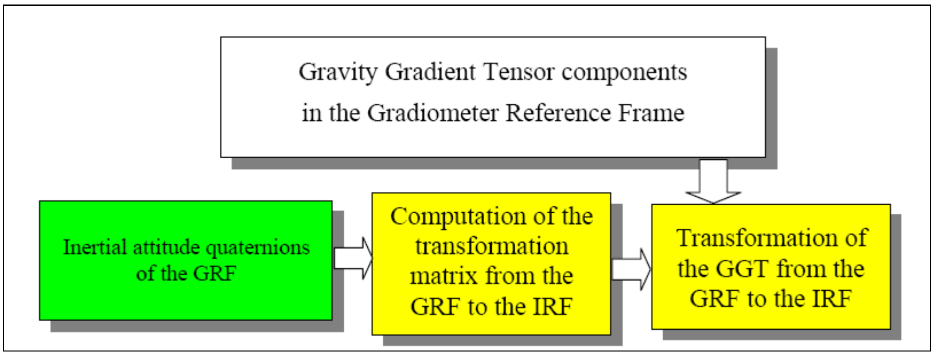


Figure 16 - Gravity Gradient Tensor (GGT) Computation Algorithm overview.

3.2.2.3 Products

The **EGG_NOM_1b** product is the nominal Level 1b product of the Gradiometer. It contains :

- EGG control Voltages
- EGG polarisation Voltages
- Nominal linear and angular accelerations
- Nominal common and differential accelerations
- Corrected Control Voltages
- Calibrated common and differential accelerations
- Calibrated angular accelerations
- Gradiometer angular rates
- Gradiometer inertial attitude quaternions

- Gravity gradient tensor GRF system
- Transformation matrix from GRF to IRF

4 GOCE PRODUCTS FORMATS

This section has been edited with reference to the "GOCE Product Specification Format" (reference GO-ID-ACS-0109 issue 3.3) and shall remain valid with regard to the version of the processors listed in the Table 5 here below. The version of the processor is to be found :

- as the field #7 "Software_Ver" in the Main Product Header (MPH),
- as the field "PGM" in the RINEX file header.

Processor name	Software version
STR_VC2	VV.rr
STR_VC3	VV.rr
GRF_LOR	VV.rr
DFC_F01	VV.rr
DFC_F10	VV.rr
AUX_NOM	VV.rr
EGG_NOM	VV.rr
EGG_MON	VV.rr
EGG_ICM	VV.rr
DFC_Anw	VV.rr
EGG_K2F	VV.rr
EGG_TRC	VV.rr
SST_NOM	VV.rr
SST_MON	VV.rr
SST_ICB	VV.rr
SST_AUX	VV.rr
SST_L1NOM	VV.rr

Table 5 - Version of the processors.

4.1 Naming conventions

The name of the SST_NOM_1b and EGG_NOM_1b products follows the naming convention :

```
0123456789012345678901234567890123456789012345678901234
GO_CCCC_TTTTTTTTTT_yyyymmdd_hhmmss_YYYYMMDD_HHMMSS_vvvv
```

where:

- `GO` is the Mission ID indicating "GOCE" (fixed string).
- **`CCCC`** is the File Class. Allowed values are :
  1. **OPER** for "Operational" files.
  2. **CONS** for consolidated files.
  3. **RPRO** for reprocessed files.
- **`TTTTTTTTTT`** is the File Type (10-characters).
- **`yyyymmdd_hhmmss`** is the start of the time interval covered by the file. It corresponds to the start of the retrieval time window specified in the request.
- **`YYYYMMDD_HHMMSS`** is the end of the time interval covered by the file. It corresponds to the end of the retrieval time window specified in the request.
- **vvvv** is the file version number. It starts from 0001 and increases by 1 every time a new version of the same file is generated.

The GPS RINEX file follows a different convention, which is compliant with the RINEX naming convention (see [RD-4])

```
012345678901
GOCEdddf.yyO
```

Where:

- `ddd` day in year
- `f` relative orbit number of the day
- `yy` year
- `O` file type, fixed, set to observation

4.2 General structure of GOCE L1b Products

The Level-1b files produced by the IPF subsystem are ASCII files structured following the Earth Explorer Standard. Each level-1 product is composed of :

- Earth Explorer Header
- Data Block

The Earth Explorer Header is composed of a Fixed Header plus a Variable Header containing :

- a Main Product Header (MPH)

- a Specific Product Header (SPH) which includes Data Set Descriptors for Reference external input files and Measurement Data of the Product

The Data Block contains meaningful instrument's data organized in Measurement Data Set (MDS). The Figure 17 represents the general structure of an L1b product.

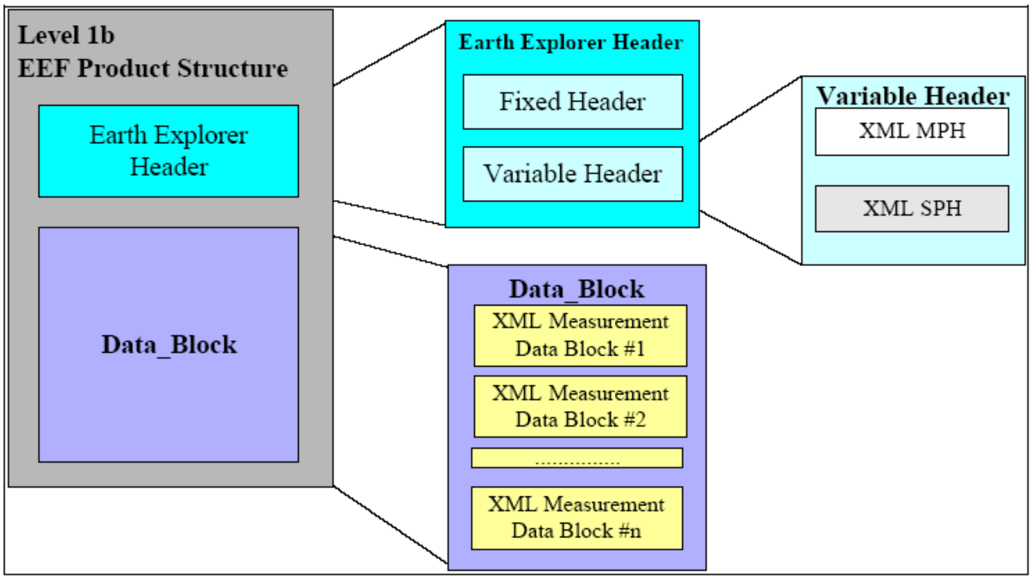


Figure 17 - L1b Files Structure.

4.2.1 Product Header

4.2.1.1 Data types and syntax

The Standard GOCE Header is completely ASCII and based on XML syntax and conventions proposed in **[RD- 7]**.

The fixed header fields are specified in the following tables. Note that the **format** string notation is:

%[+][*width*][.*precision*]*type*

Where '+' Forces to precede the result with a sign (+ or -) if signed type. (by default only - (minus) is printed), and type is one of the following :

d	Signed decimal integer
ud	Signed decimal integer (unsigned)

f	Decimal floating point
uf	Decimal floating point (unsigned)
c	Character
s	String of characters
uc	Unsigned Character

Table 6 - Data types.

4.2.1.2 Level 1 product identifiers

The following table provides the Product ID for each product generated by the IPF1.

Product ID	Description
EGG_NOM_1b	EGG Nominal Level 1b
EGG_MON_1b	EGG Monitoring Level 1b
EGG_TRC_1b	EGG Trace one day Level 1b
EGG_ICM_1b	EGG Calibration Level 1b
STR_VC2_1b	Star Tracker Quaternions Level 1b from VC2
STR_VC3_1b	Star Tracker Quaternions Level 1b from VC3
DFC_F01_1b	DFAC linear acceleration at 1 Hz
DFC_F10_1b	DFAC linear acceleration at 10 Hz
SST_NOM_1b	SSTI Nominal Level 1b
SST_MON_1b	SSTI Monitoring Level 1b
DFC_AnW_1b (n =1,..6) (W = X,Y or Z)	EGG Quadratic Factors Single shaking Calibration Level 1b
EGG_K2F_1b	EGG Quadratic Factors Calibration Level 1b
EGG_ICM_1b	EGG Inverse Calibration MatrixLevel 1b
GRF_LOR_1b	CDMU Rotation angles Level 1b
SST_ICB_1b	SSTI inter-channel bias calibration Level 1b
SST_AUX_1b	SSTI Ancillary data level 1b
AUX_NOM_1b	Auxiliary level 1b
SST_RIN_1b	SSTI Rinex product

Table 7 - Level-1 products list

4.2.1.3 Fixed Header (Standard GOCE Header)

Field #	Description	Units	Format
#1	**File_Name**	Tag	
	Product File Name without the extension		55uc
#2	**File_Description**	Tag	
	This field shall contain a description of file product.		
#3	**Notes**	Tag	
	This field shall be always empty		
#4	**Mission**	Tag	
	This field shall be always GOCE		4uc
#5	**File_Class**	Tag	
	This field is part of the File Name and indicates the type of processing. Possible values are: • OPER (for Routine Operations) • TEST (for Test product) • REPR (for Reprocessed product) • CONS (for Consolidated product) • LTA_ (for Long Term Archive product)		%s
#6	**File_Type**	Tag	
	This field is part of the File Name and shall correspond to one of the Product ID listed in Section 5.1		10uc
#7	**Validity_Period**	Tag	
#7.1	**Validity_Start**	Tag	
	This field correspond to: • Start Time of the nominal L1B product, in UTC format, referred to the predicted ANX time (this time is computed using the Earth Explorer library). • For the Calibration product, is the Start Time of the calibration activity. • For the Auxiliary Level1b Product is the Start Time of the Auxiliary Level0.		UTC=yyyy-mm-ddThh:mm:ss

#7.2	**Validity_Stop**	Tag	
	This field correspond to: • Stop Time of the nominal L1B product, in UTC format, referred to the predicted ANX+1 time (this time is computed using the Earth Explorer library). • For the Calibration product, is the Stop Time of the calibration activity. • For the Auxiliary Level1b Product is the Stop Time of the Auxiliary Level0.		UTC=yyyy-mm-ddThh:mm:ss
#8	**File_Version**	Tag	
	This field is version number of the generation of the product. It shall start from 0001 and increased by one anytime the same product shall be regenerated.		%4d
#9	**Source**	Tag	
#9.1	**System**	Tag	
	Name of the Ground Segment component creating the product. It shall be always set as: PDS		3uc
#9.2	**Creator**	Tag	
	Name of the Ground Segment tool creating the product. It shall be set as: IPF1		12uc
#9.3	**Creator_Version**	Tag	
	This field gives the version of the creator tool as **VV.rr**		5uc
#9.4	**Creation_Date**	Tag	
	This field gives the UTC date of the generation of the file		UTC=yyyy-mm-ddThh:mm:ss

Table 8 - Level 1b Fixed Header.

4.2.1.4 Variable Header (Product Header)

4.2.1.5 XML Main Product Header (XML MPH)

Field #	Description	Units	Format
#01	**Product**	tag	
	Product File Name		See section 4.1.
#02	**Proc_Stage**	tag	
	Processing stage code: T = Test O = Operation R = Reprocessing C = Consolidation		%c
#03	**Ref_Doc**	tag	
	Reference Document describing the product		23*uc
#04	**Acquisition_Station**	tag	
	Acquisition Station ID		20*uc
#05	**Proc_Center**	tag	
	Processing Center ID code		PDS
#06	**Proc_Time**	tag	
	Processing Time (Product Generation Time)	UTC	UTC=yyyy-mm-ddThh:mm:ss.uuuuuu
#07	**Software_Ver**	tag	
	Processor name, up to 8 characters, and software version number followed by trailer blanks if any.		14*uc ProcessorName/VV.rr
#08	**Sensing_Start**	tag	
	UTC start time of data sensing. This is the UTC start time of the first measured record in the L1b product. This time is computed from the GPS time of the first measured record in the product For the Auxiliary File this time is the Start Time of the first record contained into the Auxiliary Level0 product.		UTC=yyyy-mm-ddThh:mm:ss.uuuuuu

#09	**Sensing_Stop**	tag	
	UTC stop time of data sensing. This is the UTC stop time of the last measured record in the L1b product. This time is computed from the GPS time of the first measured record in the product. For the Auxiliary File this time is the Stop Time of the last record contained into the Auxiliary Level0 product.		UTC=yyyy-mm-ddThh:mm:ss.uuuuuu
#10	**Phase**	tag	
	Phase Code: phase letter (A, B, …) For GOCE always set to X		%c
#11	**Cycle**	tag	
	Cycle number. If not used set to 0000		%04d
#12	**Rel_Orbit**	tag	
	Relative Orbit Number at sensing start time. If not used set to 000000		%06d
#13	**Abs_Orbit**	tag	
	Absolute Orbit Number at sensing start time. If not used set to 000000		%06d
#14	**State_Vector_Time**	tag	
	UTC state vector time It is filled properly in case of usage of FOS Predicted Orbit information otherwise it shall be empty.	UTC	UTC=yyyy-mm-ddThh:mm:ss.uuuuuu
#15	**X_Position**	tag	
	unit	m	
	X position in Earth Fixed Reference. It is filled properly in case of usage of FOS Predicted Orbit information otherwise it shall be set to +0000000.000	m	%+012.3f
#16	**Y_Position**	tag	
	unit	m	

	Y position in Earth Fixed Reference It is filled properly in case of usage of FOS Predicted Orbit information otherwise it shall be set to +0000000.000	m	%+012.3f
#17	**Z_Position**	tag	
	unit	m	
	Z position in Earth Fixed Reference It is filled properly in case of usage of FOS Predicted Orbit information otherwise it shall be set to +0000000.000		%+012.3f
#18	**X_Velocity**	tag	
	unit	m/s	
	X velocity in Earth Fixed Reference It is filled properly in case of usage of FOS Predicted Orbit information otherwise it shall be set to +0000.000000	m/s	%+012.6f
#19	**Y_Velocity**	tag	
	unit	m/s	
	Y velocity in Earth Fixed Reference It is filled properly in case of usage of FOS Predicted Orbit information otherwise it shall be set to +0000.000000		%+012.6f
#20	**Z_Velocity**	tag	
	unit	m/s	
	Z velocity in Earth Fixed Reference It is filled properly in case of usage of FOS Predicted Orbit information otherwise it shall be set to +0000.000000		%+012.6f
#21	**Vector_Source**	tag	
	Source of Orbit State Vector Record. It shall be set to FP (FOS Predicted) in case of usage of FOS Predicted Orbit information otherwise it shall be empty		2*uc

#22	**Product_Err**	tag	
	Product Error Flag set to 1 if errors have been reported in the product otherwise 0		%d
#23	**Tot_Size**	tag	
	Unit	bytes	
	Total size of the product		%021d
#24	**SPH_Size**	tag	
	Unit	bytes	
	Length of the SPH		%+011d
#25	**Num_DSD**	tag	
	Number of all Data Set Descriptors.		%+011d
#26	**DSD_Size**	tag	
	unit	bytes	
	Length of each DSD. For GOCE this field **must be empty.**		%+011d
#27	**Num_Data_Sets**	tag	
	Number of attached Data Sets (note that not all the DSDs have a DS attached).		%+011d
#28	**CRC**	tag	
	Cyclic Redundancy Code computed as overall value of all records of the Measurement Data Set. If not computed it shall be set to -00001.		%+06d

Table 9 - XML MPH Description.

4.2.1.6 XML Specific Product Header (SPH)

The Specific Product Header (SPH) is an ASCII header. The SPH structure is as follows.

Field #	Description	Units	Format
#1	**SPH_Descriptor**	tag	
	ASCII string describing the product. Product ID Specific Header. See Product ID in section 4.2.1.2.		28*uc

#2	**Start_GPS_Time**	tag	
	GPS time of the first record in the Main MDS of the product Note: The time is represented as follow: 10 digits for seconds, 9 digits for nanoseconds separated by '.'.	[s][ns]	%20.9uf
#3	**Stop_GPS_Time**	tag	
	GPS time of the last record in the Main MDS of the product Note: The time is represented as follow: 10 digits for seconds, 9 digits for nanoseconds separated by '.'.	[s][ns]	%20.9uf
#4	**Abs_Orbit_Start**	tag	
	Absolute Orbit Number at Product Start Time		%06d
#5	**Rel_Time_Asc_Node_Start**	tag	
	unit	s	
	Relative time since crossing ascending node time relative to start time of data sensing	s	%011.6f
#6	**Abs_Orbit_Stop**	tag	
	Absolute Orbit Number at Product Stop Time		%06d
#7	**Rel_Time_Asc_Node_Stop**	tag	
	unit	s	
	Relative time since crossing ascending node time relative to stop time of data sensing		%011.6f
#8	**Equator_Cross_Time_Start**	tag	
	unit	[s][ns]	
	Time of Equator crossing at the ascending node of the sensing start time (GPS time) Note: The time is represented as follow: 10 digits for seconds, 9 digits for nanoseconds separated by '.'.		%20.9uf

#9	**Equator_Cross_Time_Stop**	tag	
	unit	[s][ns]	
	Time of Equator crossing at the ascending node of the sensing stop time (GPS time) Note: The time is represented as follow: 10 digits for seconds, 9 digits for nanoseconds separated by '.'.		%20.9uf
#10	**Equator_Cross_Long**	tag	
	unit	10^{-6} degE	
	Longitude of Equator Crossing at the ascending node of the sensing start time (positive East, 0 = Greenwich) referred to WGS84.		%+011d
#11	**Ascending_Flag**	tag	
	Orbit Orientation at the sensing start time. A= Ascending D= Descending		uc
#12	**Start_Lat**	tag	
	unit	10^{-6} degN	
	WGS84 latitude of the first record in the Main MDS (positive north)		%+011d
#13	**Start_Long**	tag	
	unit	10^{-6} degE	
	WGS84 longitude of the first record in the Main MDS (positive East, 0 = Greenwich)		%+011d
#14	**Stop_Lat**	tag	
	unit	10^{-6} degN	
	WGS84 latitude of the last record in the Main MDS (positive north)		%+011d
#15	**Stop_Long**	tag	
	unit	10^{-6} degE	

	WGS84 longitude of the last record in the Main MDS (positive East, 0 = Greenwich)		%+011d
#16	**L0_Proc_Flag**	tag	
	Processing errors significance flag (1 or 0). 1 if the percentage of instrument packets free of processing errors is less than the acceptable threshold		uc
#17	**L0_Processing_Quality**	tag	
	unit	10^{-2} %	
	Percentage of quality checks successfully passed during the SP processing (max allowed +10000).		%+06d
#18	**L0_Proc_Thresh**	tag	
	unit	10^{-2} %	
	Minimum acceptable percentage of quality threshold that must be passed during SP processing (max allowed +10000)		%+06d
#19	**L0_Gaps_Flag**	tag	
	Gaps significance flag (1 or 0). 1 if gaps (either caused by extraction or alignment failures) were detected during the SP processing		%d
#20	**L0_Gaps_Num**	tag	
	Number of gaps detected during the SP processing (no gaps indicated as +0000000)		%+08d
#21	**Op_Mode**	tag	
	Operative Mode:		15*uc
#22	**L1b_Prod_Status**	tag	
	Complete/Incomplete Product Completion Flag (0 or 1). 1 if the Product is incomplete.		%d
#23	**L1b_Proc_Flag**	tag	
	Processing errors significance flag (1 or 0). 1 if the percentage of Data Set Record (DSR) free of processing errors is less than the acceptable threshold.		%d

#24	**L1b_Processing_Quality**	tag	
	unit	10^{-2}%	
	Percentage of quality checks successfully passed during Level 1B processing (max allowed +10000).		%+06d
#25	**L1b_Proc_Thresh**	tag	
	unit	10^{-2} %	
	Minimum acceptable percentage of quality threshold that must be passed during Level 1B processing (max allowed +10000)		%+06d
#26	**List_Of_K2Accelorometers**	tag	
	Counter		
#26.1	**K2Accelerometer**	tag	
#26.1.1	**Accel_Id**	tag	
	Identifier of the accelerometer under calibration Possible value 1, 2, 3, 4, 5, or 6		%d
#26.1.2	**Axis**	tag	
	Axis under calibration Possible value : X,Y,Z		uc

Table 10 - XML Specific Product Header description.

The DSD Section contains information on Reference files and on Measurement Data Sets of the product. The 'Summary Quality of DSR' is filled only for the Measurement Data Sets. The general structure of a DSD is shown in Table 11.

Field #	Description	Units	Format
27	**List_of_DSDs**	tag	
27.1	**DSD**		
27.1.1	**Data_Set_Name**	tag	
	Name describing the Data Set		28*uc
27.1.2	**Data_Set_Type**	tag	
	Type of Data Set. It can be: M = Measurement R = Reference		uc

27.1.3	**Filename**	tag	
	Name of the Reference File. Used if DS_TYPE is set to "R". The file name shall be without the extension.		62*uc
27.1.4	**Num_DSR**	tag	
	Number of Data Set Records.		%+011d
27.1.5	**MDS_Proc_Thresh** Minimum acceptable percentage of quality threshold that must be passed during the processing of the MDS.	tag	%+06d
27.1.6	**Perc_Good_Record** Percentage of good record passed during the processing of the MDS	tag	%+06d

Table 11 - Generic DSD Description.

A variable number of DSDs will compose the SPH. Variability in fact depends most on the number of measurement data sets included into the Level 1b. For convenience Measurement DSDs (1 or more) appear first in the list, followed by the Reference DSDs.

For the Reference DSDs the possible "Data_Set_Name" are hereafter listed. For a given "Data_Set_Name" one or more "Reference DSDs" may be in the final layout of the DSD if more than one file was used to generate the product. Identification of the specific file will be possible through the field #3 Filename of the "Generic DSD Description".

Data_Set_Name for Reference DSD (R)	
CONSTANTS_FILES	Constants File
Proc_Config_Params_File	Processor Configuration Parameters File
Level_0_file	EGG/SST/DFC/STR Attitude Error (GRF_LOR) LEVEL 0 nominal/Calibration File from which the product was created
SST_Level_1b_File	SSTI Nominal Level 1b File
SST_Auxiliary_L1b_file	SSTI Auxiliary File
Star_Tracker_L1b_file	Star Tracker Level 1b File
AUX_Level_0_File	Auxiliary Nominal Level0 File
Auxiliary_OBT_UTC_Correlation_file	Auxiliary OBT-UTC Time correlation File
EGG_Single_shaking_L1b_file	EGG proof-mass shaking Level0 Product

Inverse_Calibration_Matrix_file	EGG Inverse Calibration Level 1B File
EGG_Auxiliary_Database_file	EGG Auxiliary Database file
SST_Auxiliary_Database_file	SST Auxiliary Database file
Auxiliary_Calibration_K2_file	Auxiliary Quadratic factor file
Auxiliary_Predicted_Orbit_file	Auxiliary Predicted Orbit file
DFACS_L1b_file	DFCAS 1Hz Level1B File
Inter_channel_bias_calibration_file	ICB Level1b File
IONEX_file	Global Ionosphere Maps File
Antenna_Off_Sets_file	Antenna Off-sets of GPS Satellite
IGS_GPS_Precise_Orbits_Clocks_file	GPS Satellites positions and clocks given as IGS Rapid Orbits (sampling interval 15 minutes)
EGG_Monotoring_File	Monitoring Level1b
IGS_Station_Satellite_Clocks_file	Station and Satellite clocks (sampling interval 5 minutes)
IGS_Satellite_Navigation_file	GPS Navigation messages

Table 12 - Data Set Names for Reference DSDs.

4.3 SST_NOM_1b

4.3.1 Naming convention

The name of the L1b products follows the naming convention described in section 4.1.

4.3.2 Product Packaging

The SST_NOM_1b product is distributed on a single physical file (extension EEF), “tarred” and “gzipped”. That is, the extension of the files delivered to users is “.TGZ”.

4.3.3 Product Structure

The high-level structure of this product is described in section 4.2. The detailed description of the data block is described in the following paragraph.

4.3.3.1 Data Block

The Data Block contains the following data organized in Measurement Data Sets (see Figure 18). The following table reports all MDSs contained in the SST_NOM_1b product:

MDS Name	Description of contents
SST_RNG_1i	Carrier phase and pseudorange measurements from TM packets
SST_NAV_1i	On-board navigator solution
SST_IFB_1i	Inter-frequency bias estimation results
SST_CPM_1i	Carrier phase measurements IFB corrected
SST_PRM_1i	Pseudorange measurements, ICB corrected
SST_CPN_1i	Noise of pseudorange measurements
SST_CPF_1i	Carrier phase measurements, flagged for cycle slips
SST_PRF_1i	Pseudorange corrected for ICB, flagged for outliers
SST_SRG_1i	Smoothed pseudorange
SST_POS_1i	Solution vector PVT
SST_GPT_1i	GDOP,PDOP,TDOP
SST_SIG_1i	Sigma on PVT elements
SST_COV_1i	Covariance matrix
SST_SRS_1i	PVT solution sigma and residuals
SST_TCT_1i	Time correlation measurements
SST_GPS_1i	Position and Velocity of the GPS satellites used for the derivation of PVT
SST_OUT_1i	Total number of the outliers in the P1, P2, C/A code and L1, L2 phase measurement

Table 13 - SST_NOM_1b product Measurement Data Set.

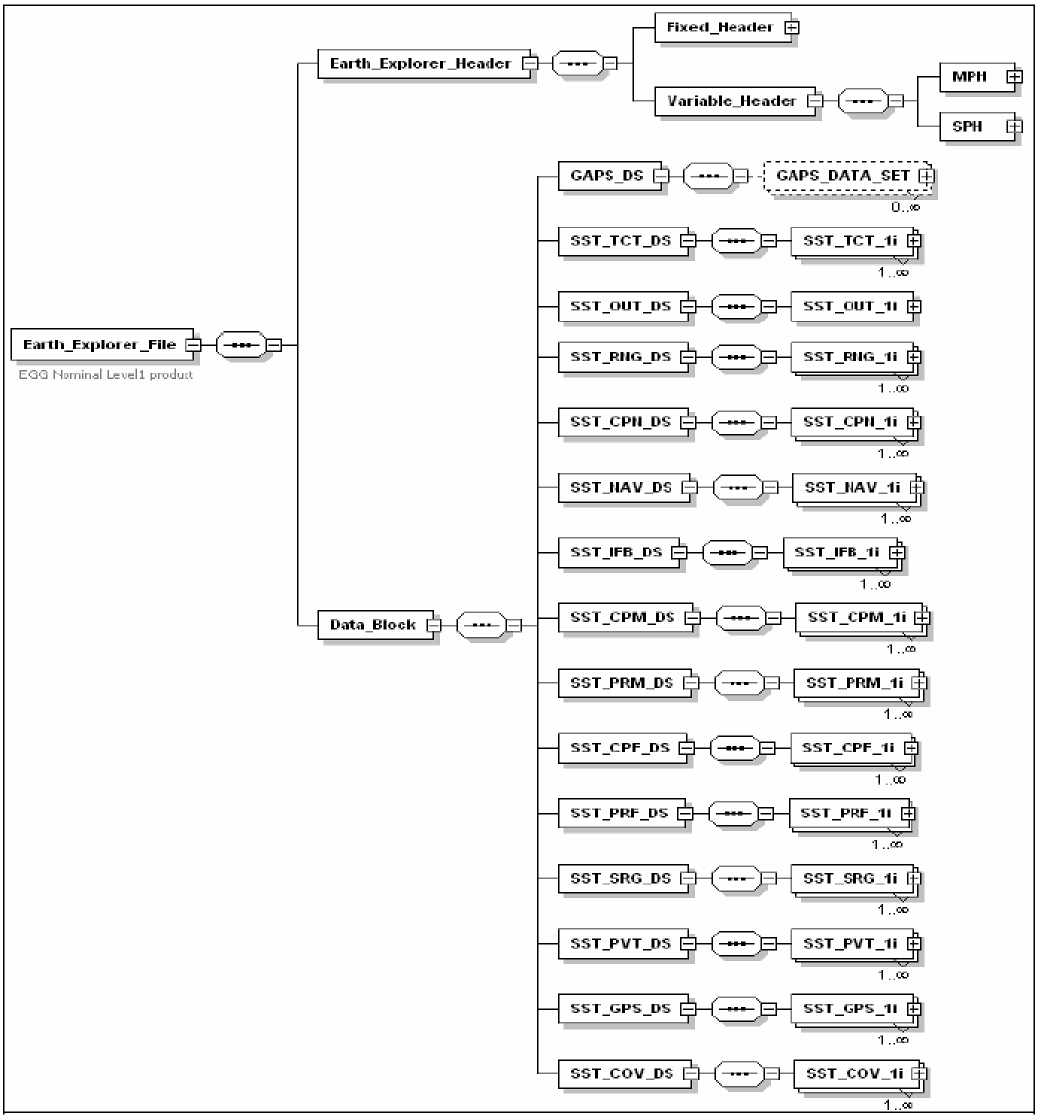


Figure 18 - SST_NOM_1b Product XML Structure.

4.3.3.1.1 GAPS Data Set

The GAPS Data Set contains the start and stop time of the detected gaps. For Gaps that occur across the ANX, as in the picture below, the start time of the first gap will coincide with the ANX time (i.e. equal to the Start Time of the product), for the gap across the ANX+1 the stop of the gap will be the ANX +1 time (i.e. equal to the Stop Time of the product).

The format is detailed in the following table.

Field #	Description	Units	Type/Format
GAPS DATA MDS (GAPS_DATA_SET)			
#1	**Missing_Line**	tag	
	Number of missing lines for the first detected gaps. Value from 1 to N		Int %3d
#2	**Start_Time**	tag	
	GPS Time of the last measured packet before the gap. In case the gap starts exactly at the ANX the gap start time is the ANXtime. Note. The time is represented as follow: 10 digits for seconds, 9 digits for nanoseconds separated by '.'.	[s][ns]	Int[2] %20.9uf
#3	**Stop_Time**	tag	
	GPS Time of the first measured packet after the gap. In case the gap stop exactly at the ANX+1 the gap stop time is the ANX+1 time. *Note:* The time is represented as follow: 10 digits for seconds, 9 digits for nanoseconds separated by '.'.	[s][ns]	Int[2] %20.9uf
	Fields 1 to 3 are repeated for each detected gap.		

Table 14 - SST GAPS DATA MDS.

4.3.3.1.2 Time correlation Table MDS Record (SST_TCT_1i)

This MDS contains the OBT from the SST Level 0, the difference between receiver GPS time and OBT, GPS Time and a flag indicating how the TT_GPS is computed.

The detailed description of data records is reported in following table.

Field #	Description	Units	Type/Format
Time Correlation Table MDS (SST_TCT_1i)			
#1	**Tt_Obt**	tag	
	Time Tag in LOBT from the GOCE GPS receiver. Note: The time is represented as follow: 10 digits for seconds, 9 digits for nanoseconds separated by '.'.	[s][ns]	Int[2] %20.9uf
#2	**Tt_Rx_GPS**	tag	
	Time Tag in GPS time as supplied by the GOCE GPS receiver. This time has to be corrected for the receiver clock error derived during the PVT solution to get GPS system time. Note: The time is represented as follow: 10 digits for seconds, 9 digits for nanoseconds separated by '.'.	[s][ns]	%20.9uf
#3	**Dif_Obt_GPS**	tag	
	Difference between OBT and GPS system time. To determine the difference, This difference is corrected with the estimated clock error of the PT solution to get the correct offset between OBT and GPS system time Note: The time is represented as follow: 10 digits for seconds, 9 digits for nanoseconds separated by '.'.	[s][ns]	%20.9uf
#4	**Tt_GPS**	tag	
	Time Tag in GPS system time. This time is computed after PVT solution determination Note: The time is represented as follow: 10 digits for seconds, 9 digits for nanoseconds separated by '.'.	[s][ns]	%20.9uf
#5	**UTC_Corr**	tag	
	UTC Time corrected for leap seconds.	[s]	Double %20.9uf

#6	**Flag_Origin_GPS**	tag	
	Flag indicating the origin of Tt_GPS (This time is tagged in the [SST-DPM] document as Tt_GPS) GPS system time: 1 = from PVT solution 2 = from Navigation solution (RECV_CLKB_NAV) 3 = from AUX_0UTC 4 = no correction applied		%d
	Fields 1 to 5 are repeated for all the measurements in the product.		

Table 15 - SST Time Correlation Table MDS

4.3.3.1.3 Outliers MDS Record (SST_OUT_1i)

This MDS contains the total number of outliers in the P1, P2, C/A code measurements and the L1, L2 phase measurements. The detailed description of data records is reported in following table.

Field #	Description	Units	Type/Format
	Outliers (SST_OUT_1i)		
#1	**Enum_Cs_L1**	tag	
	Counter for the number of cycle slips in the phase measurements on L1 for current product.		Int %5d
#2	**Enum_Cs_L2**	tag	
	Counter for the number of cycle slips in the phase measurements on L2 for current product.		Int %5d
#3	**Enum_Ol_C_A**	tag	
	Counter for the number of outliers in the C/A Code for current product.		Int %5d
#4	**Enum_Ol_P1**	tag	
	Counter for the number of outliers in the P Code on L1 for current product.		Int %5d

#5	**Enum_Ol_P2**	tag	
	Counter for the number of outliers in the P Code on L2 for current product.		Int %5d

Table 16 - SST Outliers MDS

4.3.3.1.4 Carrier Phase and Pseudorange measurements MDS Record (SST_RNG_1i)

This MDS contains the phase and pseudorange measurements data from the GPS visible satellites obtained from the de-packing and sorting algorithm applied to the Level 0 product.

The detailed description of data records is reported in the following table.

Field #	Description	Units	Type/Format
	Carrier Phase & Pseudo-Range Measurements (SST_RNG_1i)		
#1	**Tt_GPS**	tag	
	Time Tag in GPS system time. This time is computed after PVT solution determination. Note: The time is represented as follow: 10 digits for seconds, 9 digits for nanoseconds separated by '.'.	[s][ns]	Int[2] %20.9uf
#2	**N_Sv**	tag	
	Number of observed GPS satellites		Int %2d
#3	**Sv_Identifier**	tag	
	PRN-number of the observed satellites, the sequence of PRNs shall be consistent with the sequence of CHANNEL_ID so that the satellite with SV_IDENTIFIER[1] is tracked on CHANNEL_ID[1]. Array of integer values, size = N_Sv. The values are separated by blank character.		Int[N_Sv] %2d

#4	**Channel_Id**	Tag	
	Receiver channel numbers of the tracked satellites. (Bits 5 to 2 of the Channel_ID field of the science telemetry). Array of integer values, size = N_SV. The values are separated by blank character.		Int[N_Sv] %2d
#5	**Recv_Sig_Stat**	tag	
	Signal status of the corresponding receiver channel.		
#5.1	**TS0**	tag	
	L1 Code lock. Set to 1 when L1CA code DLL is locked. Array of integer values, size = N_Sv. The values are separated by blank character		Int[N_Sv] %d
#5.2	**TS1**	tag	
	L1 Carrier lock. Set to 1 when L1CA carrier PLL is locked. Array of integer values, size = N_Sv. The values are separated by blank character		Int[N_Sv] %d
#5.3	**TS2**	tag	
	Data Bit lock. Set to 1 when data bit intervals have been located. Array of integer values, size = N_Sv. The values are separated by blank character		Int[N_Sv] %d
#5.4	**TS3**	tag	
	L1 signal lock . Set to 1 when L1 P code loop is locked. Array of integer values, size = N_Sv. The values are separated by blank character.		Int[N_Sv] %d

#5.5	**TS4**	tag	
	L2 signal lock. Set to 1 when L2 Code and Carrier loops are locked. Array of integer values, size = N_SV. The values are separated by blank character.		Int[N_Sv] %d
#6	**Car_Phase**	tag	
	Phase measurement for all the satellite in visibility.	Cycles	Double[N_Sv] %17.6f
#6.1	**L1**	tag	
	Phase measurement at L1 for all the satellites in visibility Array of double values, size = N_Sv. The values are separated by blank character.		Double[N_Sv] %17.6f
#6.2	**L2**	tag	
	Phase measurement at L2 for all the satellites in visibility. Array of double values, size = N_SV. The values are separated by blank character		Double[N_Sv] %17.6f
#7	**Pseudo_Range**	tag	
	Pseudorange	m	
#7.1	**CA**	tag	
	Pseudorange C/A code at L1 for all the satellites in visibility. Array of double values, size = N_Sv. The values are separated by blank character		Double[N_Sv] %17.6f
#7.2	**L1**	tag	
	Pseudorange P code at L1 for all the satellites in visibility. Array of double values, size = N_Sv. The values are separated by blank character		Double[N_Sv] %17.6f

#7.3	**L2**	tag	
	Pseudorange P code at L2 for all the satellites in visibility. Array of double values, size = N_Sv. The values are separated by blank character		Double[N_Sv] %17.6f
#8	**Synch_Pulse**	tag	
	Status of synch pulse This value represents the status of Synch Pulse extracted by the SST_NOM_0_		Int %3d
#9	**Channel_Stat**	tag	
	Channel Status Array of integer values, size = N_Sv. The values are separated by blank character This array contains the values stored into the Channel_status (one byte) extracted by the Level 0 product, for each satellite in visibility.		Int[N_Sv] %3d
#10	**Inst_Dopp**	tag	
	Instantaneous Doppler measurements. Array of double values, size = N_Sv. The values are separated by blank character.	Hz	Double[N_Sv] %17.6f
#11	**Sig_Stat_Full**	tag	
	Total content of the signal status byte from the SST_NOM_0. It is used in the Calibration and Monitoring Facility (CMF) for monitoring Array of integer values, size = N_Sv. The values are separated by blank character This array contains the values stored into the Signal status (one byte) as extracted by the Level 0 product, for each satellite in visibility.		Int[N_Sv] %3d

#12	**Channel_Id_Full**	tag	
	Total content of the channel id byte from the SST_NOM_0. It is used in the CMF for monitoring. Array of integer values, size = N_Sv. The values are separated by blank character.		Int[N_Sv] %3d

Table 17 - SST Carrier Phase & Pseudo-Range Measurements

4.3.3.1.5 Noise measurement MDS Record (SST_CPN_1i)

This MDS contains the noise of carrier phase and pseudorange measurements for the L1, L2 and C/A channels. The detailed description of data records is reported in following table.

Field #	Description	Units	Type/Format
	Code/Phase Noise (SST_CPN_1i)		
#1	**Tt_GPS**		
	Time Tag in GPS system time. This time is computed after PVT solution determination. Note: The time is represented as follow: 10 digits for seconds, 9 digits for nanoseconds separated by '.'.	[s][ns]	Int[2] %20.9uf
#2	**N_Sv**	tag	
	Number of GPS satellites on visibility		Int %2d
#3	**Sv_Identifier**	tag	
	PRN-number of the observed satellites, the order shall be consistent with the receiver channels, so that the first satellite with SV_IDENTIFIER[1] is tracked on receiver channel 1, satellite with SV_IDENTIFIER[2] on channel 2 and so on. Array of integer values, size =N_Sv The values are separated by blank character.		Int[N_Sv] %2d
#4	**Noise_Prm**	tag	
	Noise on Pseudo-Range-Measurements for all the GPS satellites in visibility	m	

#4.1	**CA**	tag	
	Noise of the C/A-Code Pseudo-Range-Measurements for the N_Sv GPS satellites Array of double values, size =N_Sv The values are separated by blank character		Double[N_Sv] %17.6f
#4.2	**L1**	tag	
	Noise of the Pseudo-Range Measurements (P-Code) for all GPS satellites at L1. Array of double values, size =N_Sv The values are separated by blank character		Double[N_Sv] %17.6f
#4.3	**L2**	tag	
	Noise of the Pseudo-Range Measurements (P-Code) for all the first GPS satellites at L2 Array of double values, size =N_Sv The values are separated by blank character		Double[N_Sv] %17.6f

Table 18 - SST Code/Phase Noise MDS

4.3.3.1.6 Navigator data MDS Record (SST_NAV_1i)

This MDS contains the on-board navigation solution data. The detailed description of data records is reported in following table.

Field #	Description	Units	Type/Format
Navigation Solution data (SST_NAV_1i)			
#1	**Tt_GPS**	tag	
	Time Tag in GPS system time. This time is computed after PVT solution determination. Note: The time is represented as follow: 10 digits for seconds, 9 digits for nanoseconds separated by '.'.	[s][ns]	Int[2] %20.9uf
#2	**Recv_Sol_Type**	tag	
	Solution type: 0=SPS 1=NKF		%c

#3	**Pos_Nav**	tag	
	Position of the GOCE satellite based on the raw-data navigation solution OR the Kalman filtered navigation solution of the Receiver		
#3.1	**X**	tag	
	X position element	m	Double %+17.6f
#3.2	**Y**	tag	
	Y position element	m	Double %+17.6f
#3.3	**Z**	tag	
	Z position element	m	Double %+17.6f
#4	**Vel_Nav**	tag	
	Velocity of the GOCE satellite based on the raw-data navigation solution OR the Kalman-filtered navigation solution of the Receiver		
#4.1	**X**	tag	
	X velocity element	m/s	Double %+17.6f
#4.2	**Y**	tag	
	X velocity element	m/s	Double %+17.6f
#4.3	**Z**	tag	
	Z velocity element	m/s	Double %+17.6f
#5	**Recv_Clkb_Nav**	tag	
	Clock bias of the GOCE GPS receiver with respect to GPS time, derived within the on-bard navigation solution	m	Double %+17.6f

Table 19 - SST Navigation Solution data MDS

4.3.3.1.7 Inter-Freq. Bias estimation results MDS Record (SST_IFB_1i)

This MDS contains the Inter-frequency bias as a function of the temperature. The detailed description of data records is reported in following table.

Field	Description	Units	Type/Format
	Inter Frequency Bias estimation (SST_IFB_1i)		
#1	**Tt_GPS**	tag	
	Time Tag in GPS system time. This time is computed after PVT solution determination. Note: The time is represented as follow: 10 digits for seconds, 9 digits for nanoseconds separated by '.'.	[s][ns]	Int[2] %20.9uf
#2	**Ifb_Corr**	tag	
	IFB correction as applied to the L2 phase measurements	Cycles	Double %20.9uf

Table 20 - SST Inter Frequency Bias estimation

4.3.3.1.8 Carrier Phase Measurements, Inter-Freq. Bias Corrected MDS Record (SST_CPM_1i)

This MDS contains the carrier phase measurements corrected for inter-frequency bias. The detailed description of data records is reported in following table.

Field #	Description	Units	Type/Format
	Carrier Phase IFB Corrected (SST_CPM_1i)		
#1	**Tt_GPS**	tag	
	Time Tag in GPS system time. This time is computed after PVT solution determination. Note: The time is represented as follow: 10 digits for seconds, 9 digits for nanoseconds separated by '.'.	[s][ns]	Int[2] %20.9uf
#2	**N_Sv**	tag	
	Number of satellites in visibility		Int %2d

#3	**Sv_Identifier**	tag	
	PRN-number of the observed satellites, the sequence of PRNs shall be consistent with the sequence of CHANNEL_ID so that The satellite with SV_IDENTIFIER[1] Is tracked on CHANNEL_ID[1] Array of integer values, size = N_Sv The values are separated by blank character.		Int[N_Sv] %2d
#4	**Channel_Id**	tag	
	Receiver channel numbers of the tracked satellites (Bits 5 to 2 of the Channel_ID field of the science telemetry) Array of integer values, size = N_SV. The values are separated by blank character.		Int[N_Sv] %2d
#5	**Recv_Sig_Stat**	tag	
	Signal status of the corresponding receiver channel.		
#5.1	**TS0**	tag	
	L1 Code lock Set to 1 when L1CA code DLL is locked Array of double values, size = N_SV The values are separated by blank character.		Int[N_Sv] %d
#5.2	**TS1**	tag	
	L1 Carrier lock Set to 1 when L1CA carrier PLL is locked Array of double values, size = N_Sv The values are separated by blank character.		Int[N_Sv] %d
#5.3	**TS2**	tag	
	Data Bit lock Set to 1 when data bit intervals have been located Array of double values, size = N_Sv The values are separated by blank character.		Int[N_Sv] %d

#5.4	**TS3**	tag	
	L1 signal lock Set to 1 when L1 P code loop is locked. Array of double values, size = N_Sv The values are separated by blank character.		Int[N_Sv] %d
#5.5	**TS4**	tag	
	L2 signal lock Set to 1 when L2 Code and Carrier loops are locked. Array of double values, size = N_Sv The values are separated by blank character.		Int[N_Sv] %d
#6	**Corr_Phase**	tag	
	Carrier Phase measurement corrected for inter-frequency bias for all the satellites on visibility.	Cycles	Double[N_Sv] %17.6f
#6.1	**L1**	tag	
	Corrected Carrier Phase measurement at L1 for all the satellites in visibility. Array of double values, size= N_Sv. The values are separated by blank character.		Double[N_Sv] %17.6f
#6.2	**L2**	tag	
	Carrier Phase measurement at L2 corrected for inter-channel bias for all the satellites on visibility. Array of double values, size= N_Sv. The values are separated by blank character.		Double[N_Sv] %17.6f

Table 21 - Carrier Phase IFB Corrected.

4.3.3.1.9 Pseudorange Measurements, Inter Channel Bias Corrected MDS Record (SST_PRM _1i)

This MDS collect the pseudorange values corrected by ICB. The detailed description of data records is reported in following table.

Field #	Description	Units	Type/Format
Pseudo-Range measurements, Inter Channel Bias Corrected (SST_PRM_1i)			
#1	**Tt_GPS**	tag	
	Time Tag in GPS system time. This time is computed after PVT solution determination. Note: The time is represented as follow: 10 digits for seconds, 9 digits for nanoseconds separated by '.'.	[s][ns]	Int[2] %20.9uf
#2	**N_Sv**	tag	
	Number of satellites in visibility.		Int %2d
#3	**Sv_Identifier**	tag	
	PRN-number of the observed satellites, the sequence of PRNs shall be consistent with the sequence of CHANNEL_ID so that The satellite with SV_IDENTIFIER[1] Is tracked on CHANNEL_ID[1]. Array of integer values, size = N_Sv. Values are separated by blank character.		Int[N_Sv] %2d
#4	**Channel_Id**	tag	
	Receiver channel numbers of the tracked satellites (Bits 5 to 2 of the Channel_ID field of the science telemetry) Array of integer values, size = N_Sv Values are separated by blank character.		Int[N_Sv] %2d
#5	**Recv_Sig_Stat**	tag	
	Signal status of the corresponding receiver channel for all the satellites in visibility.		
#5.1	**TS0**	tag	
	L1 Code lock Set to 1 when L1CA code DLL is locked Array of integer values, size = N_Sv Values are separated by blank character		Int[N_Sv] %d

#5.2	**TS1**	tag	
	L1 Carrier lock Set to 1 when L1CA carrier PLL is locked Array of integer values, size = N_Sv Values are separated by blank character.		Int[N_Sv] %d
#5.3	**TS2**	tag	
	Data Bit lock Set to 1 when data bit intervals have been located. Array of integer values, size = N_Sv Values are separated by blank character.		Int[N_Sv] %d
#5.4	**TS3**	tag	
	L1 signal lock Set to 1 when L1 P code loop is locked. Array of integer values, size = N_Sv Values are separated by blank character.		Int[N_Sv] %d
#5.5	**TS4**	tag	
	L2 signal lock Set to 1 when L2 Code and Carrier loops are locked. Array of integer values, size = N_Sv Values are separated by blank character.		Int[N_Sv] %d
#6	**Corr_Pseudo_Range**	tag	
	Pseudorange measurement corrected for inter-channel bias for all the Satellites in visibility.	m	
#6.1	**CA**	tag	
	C/A code Pseudorange measurement corrected for inter-channel bias. Array of double values, size = N_Sv Values are separated by blank character.		Double[N_Sv] %+17.6f

#6.2	**L1**	tag	
	Pseudorange measurement on L1 corrected for inter-channel bias. Array of double values, size = N_Sv Values are separated by blank character.		Double[N_Sv] %+17.6f
#6.3	**L2**	tag	
	Pseudorange measurement on L2 corrected for inter-channel bias. Array of double values, size = N_Sv Values are separated by blank character.		Double[N_Sv] %+17.6f

Table 22 - SST Pseudo-Range measurements, Inter Channel Bias Corrected.

4.3.3.1.10 Carrier Phase measurement flagged for cycle slips MDS Record (SST_CPF_1i)

This MDS contains the values of the carrier phase measurements corrected for inter-frequency bias flagged for occurrence of cycle slips.

The detailed description of data records is reported in following table.

Field #	Description	Units	Format
	Carrier Phase measurements flagged for cycle slips (SST_CPF_1i)		
#1	**Tt_GPS**	tag	
	Time Tag in GPS receiver time (is the time related to CPM_CORR_L1, CPM_CORR_L2 measurements). Note: The time is represented as follow: 10 digits for seconds, 9 digits for nanoseconds separated by '.'.	[s][ns]	Int[2] %20.9uf
#2	**N_Sv**	tag	
	Number of observed GPS satellites		%2d

#3	**Sv_Identifier**	tag	
	PRN-number of the observed satellites, the sequence of PRNs shall be consistent with the sequence of CHANNEL_ID so that The satellite with SV_IDENTIFIER[1] is tracked on CHANNEL_ID[1]. Array of integer values, size = N_Sv Values are separated by blank character.		Int[N_Sv] %2d
#4	**Channel_Id**	tag	
	Receiver channel numbers of the tracked satellites. (Bits 5 to 2 of the Channel_ID field of the science telemetry) Array of integer values, size = N_Sv Values are separated by blank character.		Int[N_Sv] %2d
#5	**Corr_Phase**	tag	
	Carrier Phase measurement IFB corrected.	Cycles	
#5.1	**L1**	tag	
	Carrier Phase Measurements from all GPS satellites at L1, corrected for inter-frequency bias. Array of double values, size = N_Sv Values are separated by blank character.		Double[N_Sv] %+17.6f
#5.2	**L2**	tag	
	Carrier Phase Measurements from all GPS satellites at L2, corrected for inter-frequency bias. Array of double values, size = **N_Sv** Values are separated by blank character.		Double[N_Sv] %+17.6f
#6	**Flag**	tag	
	Flag for cycle slip occurred on L1/L2, set to 1 if measurement at considered epoch is identified as an outlier otherwise set to 0.		

#6.1	**L1**	tag	
	Flag for cycle slip occurred on L1. Array of integer values, size = N_Sv Values are separated by blank character.		Int[N_Sv] %d
#6.2	**L2**	tag	
	Flag for cycle slip occurred on L2. Array of integer values, size = N_Sv Values are separated by blank character.		Int[N_Sv] %d

Table 23 - SST Carrier Phase measurements flagged for cycle slips MDS

4.3.3.1.11 Pseudorange measurement flagged for outliers MDS Record (SST_PRF_1i)

This MDS is generated after the filtering and outliers function. It contains the values of pseudorange flagged for outliers.

The detailed description of data records is reported in following table.

Field #	Description	Units	Type/Format
	Smoothed pseudorange measurements (SST_PRF_1i)		
#1	**Tt_GPS**	tag	
	Time Tag in GPS receiver time (is the time related to PRM_CORR_C_A, PRM_L1, PRM_L2 measurements). Note: The time is represented as follow: 10 digits for seconds, 9 digits for nanoseconds separated by '.'.	[s][ns]	Int[2] %20.9uf
#2	**N_Sv**	tag	
	Number of observed GPS satellites.		Int %2d
#3	**Sv_Identifier**	tag	
	PRN-number of the observed satellites, the sequence of PRNs shall be consistent with the sequence of CHANNEL_ID so that The satellite with SV_IDENTIFIER[1] is tracked on CHANNEL_ID[1]. Array of integer values, size = N_Sv Values are separated by blank character.		Int[N_Sv] %2d

#4	**Channel_Id**	tag	
	Receiver channel numbers of the tracked satellites. (Bits 5 to 2 of the Channel_ID field of the science telemetry) Array of integer values, size = N_Sv Values are separated by blank character.		Int[N_Sv] %2d
#5	**Corr_Pseudo_Range**	tag	
	Pseudo-Range-Measurements from the all GPS satellites, corrected for the inter-channel bias.	m	
#5.1	**CA**	tag	
	C/A-Code Pseudo-Range Measurements at L1 corrected for the inter-channel bias. Array of double values, size = N_Sv Values are separated by blank character.		Double[N_Sv] %+17.6f
#5.2	**L1**	tag	
	Pseudo-Range Measurements (P-Code) from all GPS satellites at L1, corrected for the inter-channel bias. Array of double values, size = N_Sv Values are separated by blank character.		Double[N_Sv] %+17.6f
#5.3	**L2**	tag	
	Smoothed Pseudo-Range Measurements (P-Code) from all GPS satellites at L2, corrected for the inter-channel bias. Array of double values, size = N_Sv Values are separated by blank character.		Double[N_Sv] %17.6f
#6	**Flag**	tag	
	Flag for outlier for all GPS satellites.		
#6.1	**CA**	tag	
	Flag for outlier in P code on C/A code, set to 1 if measurements at considered epoch are identified as an outlier otherwise set to 0. Array of integer values, size=N_Sv Values are separated by blank character.		Int[N_Sv] %d

#6.2	**L1**	tag	
	Flag for outlier in P code on L1, set to 1 if measurements at considered epoch are identified as an outlier otherwise set to 0. Array of integer values, size = N_Sv Values are separated by blank character.		Int[N_Sv] %d
#6.3	**L2**	tag	
	Flag for outlier in P code on L2, set to 1 if measurements at considered epoch are identified as an outlier otherwise set to 0. Array of integer values, size = N_Sv Values are separated by blank character.		Int[N_Sv] %d

Table 24 - SST Smoothed pseudorange measurements MDS.

4.3.3.1.12 Smoothed Pseudorange MDS Record (SST_SRG _1i)

This MDS is generated after the filtering and outliers function. It contains the values of the smoothed pseudorange.

The detailed description of data records is reported in following table.

Field #	Description	Units	Type/Format
Smoothed pseudorange measurements (SST_SRG _1i)			
#1	**Tt_GPS**	tag	
	Time tag in GPS system time. Note: The time is represented as follow: 10 digits for seconds, 9 digits for nanoseconds separated by '.'.	[s][ns]	Int[2] %20.9uf
#2	**N_Sv**	tag	
	Number of observed GPS satellites.		Int %2d

#3	**Sv_Identifier**	tag	
	PRN-number of the observed satellites, the sequence of PRNs shall be consistent with the sequence of CHANNEL_ID so that The satellite with SV_IDENTIFIER[1] is tracked on CHANNEL_ID[1]. Array of integer values, size = N_Sv Values are separated by blank character.		Int[N_Sv] %2d
#4	**Channel_Id**	tag	
	Receiver channel numbers of the tracked satellites. (Bits 5 to 2 of the Channel_ID field of the science telemetry) Array of integer values, size = N_SV Values are separated by blank character.		Int[N_Sv] %2d
#5	**Sm_Pseudo_Range**	tag	
	Smoothed Pseudo-Range Measurements from all GPS satellite, corrected for the inter-channel bias.	m	
#5.1	**CA**	tag	
	Smoothed C/A-Code Pseudo-Range-measurements at L1 from all GPS satellites, corrected for the inter-channel bias. Array of double values, size = N_Sv Values are separated by blank character.		Double[N_Sv] %17.6f
#5.2	**L1**	tag	
	Smoothed Pseudo-Range measurements (P-Code) from first GPS satellite at L1, corrected for the inter-channel bias. Array of double values, size = N_Sv Values are separated by blank character.		Double[N_Sv] %17.6f

#5.3	**L2**	tag	
	Smoothed Pseudo-Range measurements (P-Code) from first GPS satellites at L2, corrected for the inter-channel bias. Array of double values, size = N_Sv Values are separated by blank character.		Double[N_Sv] %17.6f
#6	**Flag**	tag	
	Flag for outlier for all GPS satellites.		
#6.1	**CA**	tag	
	Flag for outlier in P code on C/A code, set to 1 if measurements at considered epoch are identified as an outlier otherwise set to 0. Array of integer values, size=N_Sv Values are separated by blank character.		Int[N_Sv] %d
#6.2	**L1**	tag	
	Flag for outlier in P code on L1, set to 1 if measurements at considered epoch are identified as an outlier otherwise set to 0. Array of integer values, size=N_Sv Values are separated by blank character.		Int[N_Sv] %d
#6.3	**L2**	tag	
	Flag for outlier in P code on L2, set to 1 if measurements at considered epoch are identified as an outlier otherwise set to 0. Array of integer values, size=N_Sv Values are separated by blank character.		Int[N_Sv] %d

Table 25 - SST *SRG MDS*

4.3.3.1.13 Solution vector PVT, MDS Record (SST_POS_1i, SST_SRS_1i, SST_SIG_1i and SST_GPT_1i)

This MDS contains the PVT solution in ITRF2000, the sigma on the PT solution, the Residuals and the GDOP, PDOP and TDOP values. The SST_POS_1i, SST_SRS_1i, SST_SIG_1i, and SST GPT_1i are grouped in one MDS record SST_PVT_1i.

The detailed description of data records is reported in following table.

Field #	Description	Units	Type/Format
	SST_PVT_1i *PVT solution, sigma & GDOP-PDOP-TDOP* *(SST_POS_1i, SST_SRS_1i, SST_SIG_1i and SST_GPT_1i)*		
#1	**Tt_GPS**	tag	
	Time Tag in GPS system time. This time is computed after PVT solution determination. Note: The time is represented as follow: 10 digits for seconds, 9 digits for nanoseconds separated by '.'.	[s][ns]	Int[2] %20.9uf
#2	**UTC_Corr**	tag	
	UTC Time corrected for leap second.	s	Double %20.9uf
#3	**N_Sv**	tag	
	Number of tracked GPS Satellites.		Int %2d
#4	**Iono_Type**	tag	
	Type of ionospheric correction applied to the measured pseudorange. 1 if P-code on L1 and L2 are available 2 if P-code on L1 is available and IONEX data has been used for correction 3 if only C/A code is available and IONEX data has been used for the correction Array of integer values, size = N_Sv Values are separated by blank character.		Int[N_Sv] %1d
#5	**SST_Pos**	tag	
	Position of GOCE satellite, output of the least-squares adjustment and receiver clock error. Array of double values, size = 4 [X,Y,Z] Values are separated by blank character.		
#5.1	**Position**	tag	
	Position of GOCE satellite, output of the least-squares adjustment.	m	Double[3] %+17.6f

#5.2	**Rec_Clock_Err**	tag	
	Receiver clock error output of the least-squares adjustment	s	Double %+17.6f
#6	**SST_Vel**	tag	
	Velocity of GOCE satellite, output of the least-squares adjustment. Array of double values, size =3 [X,Y,Z] Values are separated by blank character.	m/s	Double[3] %+17.6f
#7	**Sigma_P**	tag	
	Sigma on Position solution. Array of double values, size =3 [X,Y,Z] Values are separated by blank character.	m	Double[3] %+17.6f
#8	**Sigma_V**	tag	
	Sigma on Velocity solution. Array of double values, size =3 [X,Y,Z] Values are separated by blank character.	m/s	Double[3] %+17.6f
#9	**Sigma_T**	tag	
	Sigma on clock error solution.	s	Double %+17.6f
#10	**Sol_Sigma_Pt**	tag	
	Sigma for PT Solution.		Double %+17.6f
#11	**Res_Sol_Pt**	tag	
	Solution Residuals, containing the residuals of all satellite pseudoranges from the PT solution. Array of double values, size = N_Sv Values are separated by blank character.	m	Double[N_Sv] %+17.6f
#12	**Sol_Sigma_V**	tag	Double %+17.6f
	Sigma for Velocity solution.		

#13	**Res_Sol_V**	tag	
	Solution Residuals containing the residuals to MPV Positions from the Velocity solution**.**	m	
#13.1	**X**	tag	
	Array of double values, size = MPV Values are separated by blank character.		Double[MPV] %17.6f
#13.2	**Y** Array of double values, size = MPV Values are separated by blank character.		Double[MPV] %17.6f
#13.3	**Z** Array of double values, size = MPV Values are separated by blank character.		Double[MPV] %17.6f
#14	**G-P-TDOP**	tag	
	GDOP – PDOP – TDOP value Array of double, size = 3 Values are separated by blank character.		Double[3] %+17.6f

Table 26 - PVT solution, sigma & GDOP-PDOP-TDOP MDS

4.3.3.1.14 GPS MDS Record (SST_GPS_1i)

This MDS contains the position and velocity of the tracked GPS satellites used for the derivation of PVT solution. The table below details the MDS format.

Field #	Description	Units	Type/Format
GPS measurements (SST_GPS_1i)			
#1	**Tt_GPS**	tag	
	GPS system Time. Note: The time is represented as follow: 10 digits for seconds, 9 digits for nanoseconds separated by '.'.	[s][ns]	Int[2] %20.9uf
#2	**N_Sv**	tag	
	Number of tracked GPS Satellites.		Int %2d

#3	**Sv_Identifier**	tag	
	PRN-number of the observed satellite, the order shall be consistent with the receiver channels, so that the first satellite with SV_IDENTIFIER[1] is tracked on receiver channel 1, satellite with SV_IDENTIFIER[2] on channel 2 and so on. Array of integer values, size = N_Sv Values are separated by blank character.		Int[N_Sv] %2d
#4	**Channel_Id**	tag	
	Receiver channel numbers of the tracked satellites Array of integer values, size = N_Sv Values are separated by blank character.		Int[N_Sv] %2d
#5	**Pos_GPS**	tag	
	Position of the tracked GPS satellites.	m	
#5.1	**X**	tag	
	X element. Array of double values, size = N_Sv Values are separated by blank character.		Double[N_Sv] %+17.6f
#5.2	**Y**	tag	
	Y element. Array of double values, size = N_Sv Values are separated by blank character.		Double[N_Sv] %+17.6f
#5.3	**Z**	tag	
	Z element. Array of double values, size = N_Sv Values are separated by blank character.		Double[N_Sv] %+17.6f
#6	**Vel_GPS**	tag	
	Velocity of the GPS satellite, needed for the consideration of the Sagnac effect.	m/s	

#6.1	**X**	tag	
	X velocity element. Array of double values, size = N_Sv Values are separated by blank character.		Double[N_Sv] %+17.6f
#6.2	**Y**	tag	
	Y velocity element. Array of double values, size = N_Sv Values are separated by blank character.		Double[N_Sv] %+17.6f
#6.3	**Z**	tag	
	Z velocity element. Array of double values, size = N_Sv Values are separated by blank character.		Double[N_Sv] %+17.6f

Table 27 - SST GPS measurement MDS

4.3.3.1.15 Covariance Matrix MDS Record (SST_COV_1i)

This MDS contains Covariance Matrix of the Position and Time solution [4X4], the Covariance Matrix for the Velocity solution [3x3]. The format is specified in the following table.

Field #	Description	Units	Type/Format
Covariance Matrix measurements (SST_COV_1i)			
#1	**Tt_GPS**	tag	
	Time Tag in GPS system time. This time is computed after PVT solution determination. Note: The time is represented as follow: 10 digits for seconds, 9 digits for nanoseconds separated by '.'.	[s][ns]	Int[2] %20.9uf
#2	**UTC_Corr**	tag	
	UTC time corrected for leap seconds.	s	Double %20.9uf

#3	**SST_Cov_Pt**	tag	
#3.1	**Row1**	tag	
	4 elements of the first row of the covariance position/time matrix. Values are separated by blank character.		Double[4] %+17.6f
#3.2	**Row2**	tag	
	4 elements of the second row of the covariance position/time matrix. Values are separated by blank character.		Double[4] %+17.6f
#3.3	**Row3**	tag	
	4 elements of the third row of the covariance position/time matrix. Values are separated by blank character.		Double[4] %+17.6f
#3.4	**Row4**	tag	
	4 elements of the fourth row of the covariance position/time matrix. Values are separated by blank character.		Double[4] %+17.6f
#4	**SST_Cov_V**	tag	
#4.1	**Row1**	tag	
	3 elements of the first row of the covariance velocity matrix. Values are separated by blank character.		Double[3] %+17.6f
#4.2	**Row2**	tag	
	3 elements of the second row of the covariance velocity matrix. Values are separated by blank character.		Double[3] %+17.6f
#4.3	**Row3**	tag	
	3 elements of the second row of the covariance velocity matrix. Values are separated by blank character.		Double[3] %+17.6f

Table 28 - SST Covariance Matrix measurements MDS

4.4 SST_RIN_1b

The RINEX product is a subset of the data of the Level 1b product contained in SST_NOM_1b, relating to code and phase observations.

4.4.1 Naming Convention

The name of the L1b products follows the naming convention described in Section 4.1.

4.4.2 Product Packaging

The RINEX product is distributed on two separate physical files : -a header file (extension ".HDR") and -a data block file (extension ".DBL"). The 'HDR' file contains the Fixed Header and the Variable Header as detailed in sections 4.2.1.3 and 4.2.1.4 respectively. The "DBL" file is completely compliant with the RINEX specification.

4.4.3 Product Structure

The high-level structure of this product is described in section 4.2. The detailed description of the data block is described in the following paragraph.

4.4.3.1 Header

The general format of the RINEX is defined in [RINEX-LEO]. Using the terminology defined in [RINEX-LEO], the header fields are populated as follows:

Field Name	Description	Units/Value
Rinex Version	File format version	2.20
TYPE	File type fixed	OBSERVATION
SATELLITE SYSTEM	Satellite system, fixed	GPS
PGM	Processor name and version	SST_L1NOM_P
RUN BY	Processing centre ID code, fixed	PDS
DATE	Product generation time	
MARKER NAME	Mission ID	GOCE
MARKER TYPE	Receiver location	SPACEBORN
OBSERVER	Acquisition station	KIRUNA
AGENCY	Agency	ESA

RECEIVER NUMBER	RECEIVER NUMBER	MAIN
RECEIVER TYPE	RECEIVER TYPE	LABEN
RECEIVER VERSION	RECEIVER VERSION	2.0.9
ANTENNA NUMBER	ANT_ID_GOCE, identify. Of GOCE antennae	0-2-4
ANTENNA TYPE	Antenna type	RYMSA
ANTENNA DELTA X/Y/Z	ANT_PC_GOCE the antenna phase centre offset	[m]
ANTENNA B.SIGHT XYZ	Boresight	[m]
INTERVAL	Interval between records	1.000s
WAVELENGTH FACT L1/2	Wavelength factor used for all frequencies	1 1
TYPES OF OBSERV	Number and specification of the observables in the main part of the RINEX file	6 L1 L2 C1 P1 P2 S1 S2 CH
TIME OF FIRST OBS	GPS time stamp of first observation	GPS

Table 29 - RINEX Products Header Structure

4.4.3.2 Data Block

For each epoch, the RINEX file contains the following records:

Field Name	Description	Units/Value
EPOCH	GPS receiver time stamp	GPS
EVENT FLAG	Not used	0
NUMBER OF GPS	Number of observed GPS	
PRN	List of PRN	
RECEIVER CLOCK OFFSET	Receiver clock offset from the onboard navigation solution	[s]
L1	Phase on L1 corrected from inter-freq. bias	[cycles]

L1LLI	Loss of lock identifier for L1 LLI=1 if cycle slip detected	
L2	Phase on L2 corrected from inter-freq. bias	[cycles]
L2LLI	Loss of lock identifier for L2 LLI=1 if cycle slip detected	
C1	C/A code measurements corrected from Inter-channel bias	[m]
P1	P1 code measurements corrected from Inter-channel bias	[m]
P2	P2 code measurements corrected from Inter-channel bias	[m]
S1	SNR on L1	
S2	SNR on L2	
CH	Channel number	

Table 30 - RINEX Products Data Block Structure.

4.5 EGG_NOM_1b

4.5.1 Naming convention

The name of the L1b products follows the naming convention described in Section 4.1.

4.5.2 Product Packaging

The SST_NOM_1b product is distributed on a single physical file (extension "EEF"), tarred and gzipped. That is, the extension of the files delivered to users is ".TGZ".

4.5.3 Product Structure

The high-level structure of this product is described in section 4.2. The detailed description of the data block follows.

4.5.3.1 Data Block

The Data Block contains the following data organized in Measurement Data Set (see Figure 11)

MDS Name	Description of contents
EGG_CTR_1i	EGG control Voltages
EGG_POL_1i	EGG polarisation Voltages
EGG_NLA_1i	Nominal linear and angular accelerations
EGG_NCD_1i	Nominal common and differential accelerations
EGG_NGA_1i	Nominal gradiometer angular accelerations
EGG_CCV_1i	Corrected Control Voltages
EGG_CCD_1i	Calibrated common and differential accelerations
EGG_CGA_1i	Calibrated angular accelerations
EGG_GAR_1i	Gradiometer angular rates
EGG_IAQ_1i	Gradiometer inertial attitude quaternions
EGG_GGT_1i	Gravity gradient tensor GRF system
EGG_GIM_1i	Transformation matrix from GRF to IRF

Table 31 - EGG_NOM_1b product Measurement Data Sets

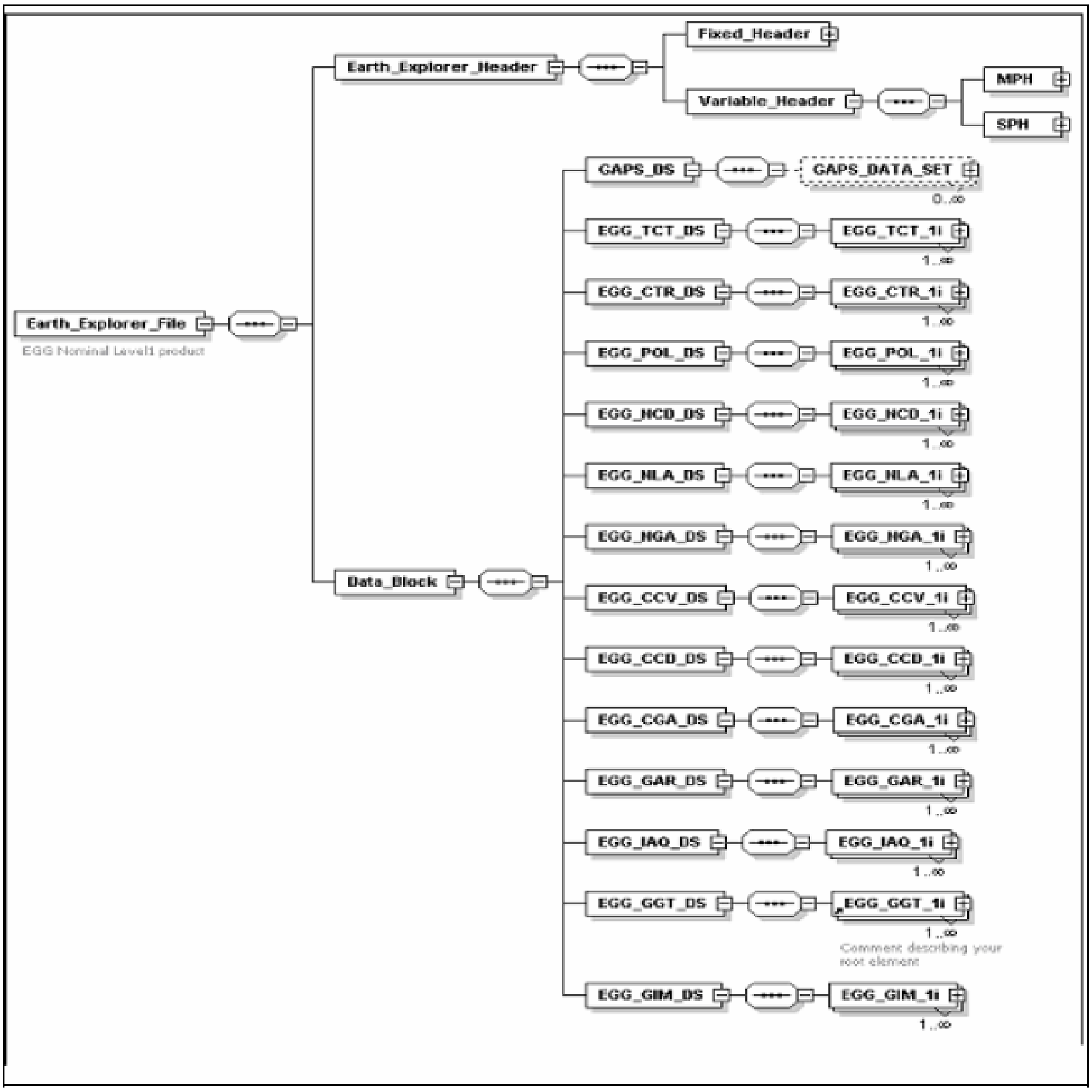


Figure 19 - EGG_NOM_1b XML File Structure.

4.5.3.1.1 GAPS Data Set

See section 4.3.3.1.1 for the format description.

4.5.3.1.2 Time correlation Table MDS Record (EGG_TCT_1i)

This MDS contains the EGG on-board time, the GPS time, difference between GPS time and OBT, and the flag indicating how the Tt_GPS is computed derived from the SST_TCT_1i.

The detailed description of data records is reported in the following table:

Field	Description	Units	Type/Format
	Time Correlation Table MDS (EGG_TCT _1i)		
#1	**Tt_EGG_Obt**	tag	
	OBT Time tag in GPS system time. Note: The time is represented as follow: 10 digits for seconds, 9 digits for nanoseconds separated by '.'.	[s][ns]	Int[2] %20.9uf
#2	**Tt_GPS**	tag	
	Computed Time in GPS system time. Note: The time is represented as follow: 10 digits for seconds, 9 digits for nanoseconds separated by '.'.	[s][ns]	Int[2] %20.9uf
#3	**Dif_EGG_Obt_GPS**	tag	
	Difference between EGG OBT and GPS system time, derived through linear interpolation from SST_TCT_1i. Note: The time is represented as follow: 10 digits for seconds, 9 digits for nanoseconds separated by '.'.	[s][ns]	Int[2] %20.9uf
#4	**UTC_Corr**	tag	
	UTC Time corrected for leap seconds, extracted from AUX_OUTC.	[s]	Double %20.9uf

#5	**Flag_Origin_GPS**	tag	
	Flag indicating the origin of Tt_GPS derived from SST_TCT_1i of SSTI nominal product. 1 = from PVT solution 2 = from Navigation solution (RECV_CLKB_NAV) 3 = from AUX_0UTC 4 = no correction applied		%1d

Table 32 - EGG Time Correlation Table MDS

4.5.3.1.3 EGG Control Voltages MDS Record (EGG_CTR_1i)

This MDS contains the time series of proof mass control voltages applied to the eight pairs surrounding the proof mass of the accelerometer A_i (i=1..6) and two flags: the Detector health status (DHS_i) and Detector saturation status (DSS_i).

The format is detailed in the following table.

Field #	Description	Units	Type/Format
	EGG Control Voltages MDS record (EGG_CTR_1i)		
#1	**Tt_GPS**	tag	
	Time in GPS system time. Note: The time is represented as follow: 10 digits for seconds, 9 digits for nanoseconds separated by '.'.	[s][ns]	Int[2] %20.9uf
#2	**Proof_Mass_Contr_Voltages**	tag	
	Proof Mass Control Voltages for all accelerometers.	V	
#2.1	**X1**	tag	
	Control voltages Vx1 applied to the X1 electrode of all the accelerometers. Array of double values, size = 6. The values are separated by blank character.		Double[6] %±15.8e

#2.2	**X2**	tag	
	Control voltages Vx2 applied to the X2 electrode of all the accelerometers. Array of double values, size = 6. The values are separated by blank character.		Double[6] %±15.8e
#2.3	**X3**	tag	
	Control voltages Vx3 applied to the X3 electrode of all the accelerometers. Array of double values, size = 6. The values are separated by blank character.		Double[6] %±15.8e
#2.4	**X4**	tag	
	Control voltages Vx4 applied to the X4 electrode of all the accelerometers. Array of double values, size = 6. The values are separated by blank characters.		Double[6] %±15.8e
#2.5	**Y1**	tag	
	Control voltages Vy1 applied to the Y1 electrode of all the accelerometers. Array of double values, size = 6. The values are separated by blank character.		Double[6] %±15.8e
#2.6	**Y2**	tag	
	Control voltages Vy2 applied to the Y2 electrode of all the accelerometers. Array of double values, size = 6. The values are separated by blank character.		Double[6] %±15.8e
#2.7	**Z1**	tag	
	Control voltages Vz1 applied to the Z1 electrode of all the accelerometers. Array of double values, size = 6. The values are separated by blank character.		Double[6] %±15.8e

#2.8	**Z2**	tag	
	Control voltages Vz2 applied to the Z2 electrode of all the accelerometers. Array of double values, size = 6. The values are separated by blank character.		Double[6] %±15.8e
#3	**DHS**	tag	
	Detector Health Status given for all the accelerometers. Array of integer values, size = 6. The values are separated by blank character.		Int[6] %d
#4	**DSS**	tag	
	Detector Saturation Status given for all the accelerometers. Array of integer values, size = 6. The values are separated by blank character.		Int[6] %d
#5	**Flag_Ctr_Fail**	tag	
	Flag that indicates the failure of a readout-branch of an accelerometer.		
#5.1	**X1**	tag	
	X1 electrode of all the accelerometers. Array of integer values, size = 6. The values are separated by blank character.		Int[6] %d
#5.2	**X2**	tag	
	X2 electrode of all the accelerometers. Array of integer values, size = 6. The values are separated by blank character.		Int[6] %d
#5.3	**X3**	tag	
	X3 electrode of all the accelerometers. Array of integer values, size = 6. The values are separated by blank character.		Int[6] %d

#5.4	**X4**	tag	
	X4 electrode of all the accelerometers. Array of double values, size = 6. The values are separated by blank character.		Int[6] %d
#5.5	**Y1**	tag	
	Y1 electrode of all the accelerometers. Array of integer values, size = 6. The values are separated by blank character.		Int[6] %d
#5.6	**Y2**	tag	
	Y2 electrode of all the accelerometers. Array of integer values, size = 6. The values are separated by blank character.		Int[6] %d
#5.7	**Z1**	tag	
	Z1 electrode of all the accelerometers. Array of integer values, size = 6. The values are separated by blank character.		Int[6] %d
#5.8	**Z2**	tag	
	Z2 electrode of all the accelerometers. Array of integer values, size = 6. The values are separated by blank character.		Int[6] %d
#6	**Flag_Acc_Fail**	tag	
	Flag that indicates the failure of an accelerometer. Array of integer values, size = 6. The values are separated by blank character.		Int[6] %d
#7	**K2_Status_Flag**	tag	
	Calibration K2 Status. Always set to 0.		Int

Table 33 - EGG Control Voltages MDS.

4.5.3.1.4 EGG Polarization Voltages MDS Record (EGG_POL_1i)

This MDS contains the time series of proof mass polarization and detection voltages applied to the proof masses of the accelerometers belonging respectively to the OAG1 (A_1, A_4), OAG2 (A_2, A_5), and the OAG3 (A_3, A_6).

The format is described in the following table.

Field#	Description	Units	Format
EGG Polarization Voltages MDS record (EGG_POL_1i)			
#1	**Tt_GPS**	tag	
	Time in GPS system time. Note: The time is represented as follow: 10 digits for seconds, 9 digits for nanoseconds separated by '.'.	[s][ns]	Int[2] %20.9uf
#2	Acc_Det_Voltages	tag	
	Proof Mass Detection Voltages.	V	
#2.1	**Pm_Dv**	tag	
	Proof Mass Detection Voltages. Array of double values, size = 6. The values are separated by blank character.		Double[6] %+15.8e
#3	**Acc_Pol_Voltages**	tag	
	Proof Mass Polarization Voltages.	V	
#3.1	**Pm_Pv**	tag	
	Proof Mass Polarization Voltages. Array of double values, size = 6. The values are separated by blank character.		Double[6] %+15.8e

Table 34 - EGG Polarization Voltages MDS.

4.5.3.1.5 Nominal Common & Differential Accelerations MDS Record (EGG_NCD_1i)

This MDS contains the common-mode accelerations and the differential-mode accelerations of the accelerometers pairs A_i,A_j (ij=14,25,36). The structure of this MDS record is described in the following table:

Field #	Description	Units	Format
Nominal Common & Differential Acceleration MDS record (EGG_NCD_1i)			
#1	**Tt_GPS**	tag	
	Time in GPS system time. Note: The time is represented as follow: 10 digits for seconds, 9 digits for nanoseconds separated by '.'.	[s][ns]	Int[2] %20.9uf
#2	**Acc_Ncm**	tag	
	Unit	m/s^2	
	Nominal Common Acceleration component for each accelerometer pair and each degree of freedom.		
#2.1	**X**	tag	
	Vector of Pair_1_4, Pair_2_5 and Pair_3_6 along X axis. Array of double values, size = 3. The values are separated by blank character.		Double[3] %+15.8e
#2.2	**Y**	tag	
	Vector of Pair_1_4, Pair_2_5 and Pair_3_6 along Y axis. Array of double values, size = 3. The values are separated by blank character.		Double[3] %+15.8e
#2.3	**Z**	tag	
	Vector of Pair_1_4, Pair_2_5 and Pair_3_6 along Z axis. Array of double values, size = 3. The values are separated by blank character.		Double[3] %+15.8e
#3	**Acc_Ndm**	tag	
	Nominal differential mode acceleration for each accelerometer pair and each degree of freedom.	m/s^2	
#3.1	**X**	tag	
	Vector of Pair_1_4, Pair_2_5 and Pair_3_6 along X axis. Array of double values, size = 3. The values are separated by blank character.		Double[3] %+15.8e

#3.2	**Y**	tag	
	Vector of Pair_1_4, Pair_2_5 and Pair_3_6 along Y axis. Array of double values, size = 3. The values are separated by blank character.		Double[3] %+15.8e
#3.3	**Z**	tag	
	Vector of Pair_1_4, Pair_2_5 and Pair_3_6 along Z axis. Array of double values, size = 3. The values are separated by blank character.		Double[3] %+15.8e

Table 35 - Nominal Common & Differential Acceleration MDS.

4.5.3.1.6 Nominal Linear & Angular Accelerations MDS Record (EGG_NLA_1i)

This MDS contains for each accelerometer A_i (i=1..6) the three linear acceleration in the ARF. The format of this MDS record is described in the following table:

Field	Description	Units	Format
Nominal Linear & Angular Acceleration MDS record (EGG_NLA_1i)			
#1	**Tt_GPS**	tag	
	Time in GPS system time. Note: The time is represented as follow: 10 digits for seconds, 9 digits for nanoseconds separated by '.'.	[s][ns]	Int[2] %20.9uf
#2	**Acc_Nl**	Tag	
	Nominal Linear Acceleration for each accelerometer and each degree of freedom in the ARF.	m/s^2	
#2.1	**X**	Tag	
	Linear Acceleration X component for all accelerometers. Array of double values, size = 6. The values are separated by blank character.		Double[6] %+15.8e

#2.2	**Y**	Tag	
	Linear Acceleration Y component for all accelerometers. Array of double values, size = 6. The values are separated by blank character.		Double[6] %+15.8e
#2.3	**Z**	Tag	
	Linear Acceleration Z component for all accelerometers. Array of double values, size = 6. The values are separated by blank character.		Double[6] %+15.8e
#3	**Acc_Na**	tag	
	Nominal Angular Acceleration for each accelerometer and each degree of freedom in the ARF.	rad/s^2	
#3.1	**X**	Tag	
	Angular Acceleration X component for all accelerometers Array of double values, size = 6. The values are separated by blank character.		Double[6] %+15.8e
#3.2	**Y**	Tag	
	Angular Acceleration Y component for all accelerometers Array of double values, size = 6. The values are separated by blank character.		Double[6] %+15.8e
#3.3	**Z**	Tag	
	Angular Acceleration Z component for all accelerometers Array of double values, size = 6. The values are separated by blank character.		Double[6] %+15.8e

#4	**Acc_Rec**	tag	
	Accelerations per degree of freedom (three linear and three angular components) and per accelerometer. The values are derived through the recombination of the corrected accelerations of the electrodes given in AESRF system.	m/s^2	
#4.1	**A1**	tag	
	Six values for accelerometer 1.		Double[6] %+15.8e
#4.2	**A2**	tag	
	Six values for accelerometer 2.		Double[6] %+15.8e
#4.3	**A3**	tag	
	Six values for accelerometer 3.		Double[6] %+15.8e
#4.4	**A4**	tag	
	Six values for accelerometer 4.		Double[6] %+15.8e
#4.5	**A5**	tag	
	Six values for accelerometer 5.	tag	Double[6] %+15.8e
#4.6	**A6**	tag	
	Six values for accelerometer 6.		Double[6] %+15.8e

Table 36 - Nominal Linear & Angular Acceleration MDS.

4.5.3.1.7 Nominal Gradiometer Angular Accelerations MDS Record (EGG_NGA_1i)

This MDS contains the nominal gradiometer angular accelerations. The detailed description of data records is reported in following table.

Field	Description	Units	Type/Format
Nominal Gradiometer Angular Acceleration (EGG_NGA_1i)			
#1	**Tt_GPS**	tag	
	Time in GPS system time. Note: The time is represented as follow: 10 digits for seconds, 9 digits for nanoseconds separated by '.'.	[s][ns]	Int[2] %20.9uf
#2	**Grad_Ang_Acc**	tag	
	Nominal Gradiometer Angular acceleration.	rad/s²	
#2.1	**N_Gaa**	tag	
	Nominal Gradiometer angular acceleration X, Y and Z components. Array of double values, size = 3. The values are separated by blank character.		Double[3] %+15.8e

Table 37 - Nominal Gradiometer Angular Acceleration MDS

4.5.3.1.8 Corrected Control Voltages MDS Record (EGG_CCV_1i)

This MDS contains the corrected control voltages for phase delay and gain attenuation for each accelerometer A_i (i=1..6).

The format is described in the following table.

Field #	Description	Units	Type/Format
Corrected Control Voltages (EGG_CCV_1i)			
#1	**Tt_GPS**	tag	
	Time in GPS system time. Note: The time is represented as follow: 10 digits for seconds, 9 digits for nanoseconds separated by '.'.	[s][ns]	Int[2] %20.9uf
#2	**V_Corr**	Tag	
	Corrected Control Voltages for each accelerometer and for each electrode.	V	

#2.1	**X1**	Tag	
	Electrodes X1 for all accelerometers. Array of double values, size = 6. The values are separated by blank character.		Double[6] %±15.8e
#2.2	**X2**	Tag	
	Electrodes X2 for all accelerometers. Array of double values, size = 6. The values are separated by blank character.		Double[6] %±15.8e
#2.3	**X3**	Tag	
	Electrodes X3 for all accelerometers. Array of double values, size = 6. The values are separated by blank character.		Double[6] %±15.8e
#2.4	**X4**	Tag	
	Electrodes X4 for all accelerometers. Array of double values, size = 6. The values are separated by blank character.		Double[6] %±15.8e
#2.5	**Y1**	Tag	
	Electrodes Y1 for all accelerometers. Array of double values, size = 6. The values are separated by blank character.		Double[6] %±15.8e
#2.6	**Y2**	Tag	
	Electrodes Y2 for all accelerometers. Array of double values, size = 6. The values are separated by blank character.		Double[6] %±15.8e
#2.7	**Z1**	Tag	
	Electrodes Z1 for all accelerometers. Array of double values, size = 6. The values are separated by blank character.		Double[6] %±15.8e

#2.8	**Z2**	Tag	
	Electrodes Z2 for all accelerometers. Array of double values, size = 6. The values are separated by blank character.		Double[6] %±15.8e

Table 38 - Corrected Control Voltages MDS

4.5.3.1.9 Calibrated Common and Differential Accelerations MDS Record (EGG_CCD_1i)

This MDS contains the calibrated common and differential accelerations of the accelerometers pairs A_i,A_j (ij=14,25,36).

The format of this data set is detailed in below table.

Field #	Description	Units	Type/Format
Calibrated Common & Differential Acceleration MDS record (EGG_CCD_1i)			
#1	**Tt_GPS**	tag	
	Time in GPS system time. Note: The time is represented as follow: 10 digits for seconds, 9 digits for nanoseconds separated by '.'.	[s][ns]	Int[2] %20.9uf
#2	**Acc_Ccm**	tag	
	Calibration Common Acceleration component for each accelerometer pair and each degree of freedom.	m/s^2	
#2.1	**X**	tag	
	Vector of Pair_1_4, Pair_2_5 and Pair_3_6 along X axis. Array of double values, size = 3. The values are separated by blank character.		Double[3] %±15.8e
#2.2	**Y**	tag	
	Vector of Pair_1_4, Pair_2_5 and Pair_3_6 along Y axis. Array of double values, size = 3.		Double[3] %±15.8e

#2.3	**Z**	tag	
	Vector of Pair_1_4, Pair_2_5 and Pair_3_6 along Z axis. Array of double values, size = 3		Double[3] %±15.8e
#3	**Acc_Cdm**	tag	
	Calibrated differential mode acceleration for each accelerometer pair and each degree of freedom.	m/s^2	
#3.1	**X**	tag	
	Vector of Pair_1_4, Pair_2_5 and Pair_3_6 along X axis. Array of double values, size = 3		Double[3] %±15.8e
#3.2	**Y**	tag	
	Vector of Pair_1_4, Pair_2_5 and Pair_3_6 along Y axis. Array of double values, size = 3.		Double[3] %±15.8e
#3.3	**Z**	tag	
	Vector of Pair_1_4, Pair_2_5 and Pair_3_6 along Z axis. Array of double values, size = 3.		Double[3] %±15.8e

Table 39 - Calibrated Common & Differential Acceleration MDS.

4.5.3.1.10 Calibrated Angular Accelerations MDS Record (EGG_CGA_1i)

This MDS contains the calibrated angular accelerations of the gradiometer about the axes of the GRF.

The format of this data set is detailed in the table here below.

Field #	Description	Units	Type/Format
	Calibrated Gradiometer Angular Acceleration (EGG_CGA_1i)		
#1	**Tt_GPS**	tag	
	Time in GPS system time. Note: The time is represented as follow: 10 digits for seconds, 9 digits for nanoseconds separated by '.'.	[s][ns]	Int[2] %20.9uf

#2	**Cal_Grad_Ang_Acc**	tag	
	Calibrated Gradiometer Angular acceleration.	rad/s²	
#2.1	**CGA**	tag	
	Calibrated Gradiometer Angular acceleration X, Y and Z components. Array of double values, size = 3. The values are separated by blank character.		Double[3] %+15.8e

Table 40 - Calibrated Gradiometer Angular Acceleration MDS.

4.5.3.1.11 Gradiometer Angular Rates MDS Record (EGG_GAR_1i)

This MDS contains the three components of the corrected estimated angular rate at epoch time *'i'*. The format of this data set is detailed in the table here below.

Field #	Description	Units	Type/Format
	Gradiometer Angular Rates (EGG_GAR_1i)		
#1	**Tt_GPS**	tag	
	Time in GPS system time. Note: The time is represented as follow: 10 digits for seconds, 9 digits for nanoseconds separated by '.'.	[s][ns]	Int[2] %20.9uf
#2	**Corr_Est_Ang_Rate**	tag	
	Corrected estimated Inertial Angular rate relative at epoch i.	rad/s	
#2.1	**Iar_Est**	tag	
	Angular Rate X, Y and Z components. Array of double values, size = 3. The values are separated by blank character.		Double[3] %±15.8e

Table 41 - Gradiometer Angular Rates MDS.

4.5.3.1.12 Gradiometer Inertial Attitude Quaternions MDS Record (EGG_IAQ_1i)

This MDS contains the Corrected quaternions synchronous with the gradiometer.

The following table details the MDS structure.

Field#	Description	Units	Type/Format
Corrected Quaternions (EGG_IAQ_1i)			
#1	**Tt_GPS**	tag	
	Time in GPS system time. Note: The time is represented as follow: 10 digits for seconds, 9 digits for nanoseconds separated by '.'.	[s][ns]	Int[2] %20.9uf
#2	**Corr_Quat**	tag	
	Corrected quaternion synchronous with the gradiometer measurements.		
#2.1	**Q_Grad**	tag	
	Array of double values, size = 4. The values are separated by blank character.		Double[4] %±15.8e

Table 42 - Corrected Quaternions MDS.

4.5.3.1.13 Gravity Gradient Tensor in the GRF MDS Record (EGG_GGT_1i)

This MDS contains six independent components of the gravity gradient tensor in the Gradiometer Reference Frame (GRF).

The detailed description of data records is reported in following table.

Field #	Description	Units	Type/Format
Gravity Gradient Tensor in GRF (EGG_GGT_1i)			
#1	**Tt_GPS**	tag	
	Time in GPS system time. Note: The time is represented as follow: 10 digits for seconds, 9 digits for nanoseconds separated by '.'.	[s][ns]	Int[2] %20.9uf
#2	**Gravity_Grad_Tensor**	tag	
	Gravity gradient tensor	$1/s^2$	

#2.1	**U_G**	tag	
	Gravity gradient tensor (XX, YY, ZZ, XY, XZ, YZ) components. Array of double values, size = 6. The values are separated by blank character.		Double[6] %+15.8e
#3	**Qual_Flag**	tag	
#3.1	**Flag**	tag	
	Quality Flag on Proof Mass Control Voltages **Qual_Flag_Ctr**. Quality Flag on Acceleration for DFACS **Qual_Flag_Dfc.** Quality Flag on Proof Mass Polarization Voltages **Qual_Flag_Pv.** Quality Flag on Proof Mass Detectection Voltages with threshold **Qual_Flag_Dv.** Quality Flag coming from the check on the Nominal Angular Acceleration and Nominal Gradiometer Angular Acceleration **Qual_Flag_Acc_Nga.** Quality Flag on Nominal Angular Acceleration **Qual_Flag_Na.** Quality Flag coming from the check on Nominal Common Accelerations with threshold. **Qual_Flag_Dfc_Ncm.** Quality Flag coming from the check on Nominal Common Accelerations with threshold **Qual_Flag_Acc_Ncm.** Quality Flag on Trace_GGT with threshold **Qual_Flag_Ggt.** These flags are computed into the monitoring function. Values: 0 – if quality test passed. 1 – if quality test failed. Array of integer values, size = 9. The values are separated by blank character.		Int[9] %d

Table 43 - Gravity Gradient Tensor in GRF MDS

4.5.3.1.14 Transformation Matrix GRF → IRF MDS Record (EGG_GIM_1i)

This MDS contains the nine elements of the transformation matrix from the GRF to IRF.

The detailed description of data records is reported in following table.

Field #	Description	Units	Type/Format
	Transformation Matrix GRF → IRF (EGG_GIM_1i)		
#1	**Tt_GPS**	tag	
	Time in GPS system time. Note: The time is represented as follow: 10 digits for seconds, 9 digits for nanoseconds separated by '.'.	[s][ns]	Int[2] %20.9uf
#2	**R_GRF_IRF**	tag	
	Rotation Matrix from GRF to IRF.		
#2.3	**Row1**		
	First row of transformation matrix GRF to IRF. Array of double values, size = 3. The values are separated by blank character.		Double[3] %+15.8e
#2.4	**Row2**	tag	
	Second row of transformation matrix GRF to IRF. Array of double values, size = 3. The values are separated by blank character.		Double[3] %+15.8e
#2.5	**Row3**	tag	
	Third row of transformation matrix GRF to IRF. Array of double values, size = 3. The values are separated by blank character.		Double[3] %+15.8e

Table 44 - Transformation matrix GRF → IRF MDS

5 DEFINITIONS AND CONVENTIONS

5.1 *Reference Frames*

The reference frames involved in the Level 0 to Level 1b processing are defined hereafter. These definitions are also given in the "GOCE Standards" document [RD-9] with an other formalism.

5.1.1 Accelerometer Reference Frame (ARF)

This is the reference frame in which the components of the acceleration of the proof mass relative to the cage are measured by the sensor. It is defined in a different way for three accelerometer pairs belonging to the three one-axis gradiometers (OAGs), so that the corresponding axes of all the ARFs are nominally aligned when the six accelerometers are installed in the Three-Axis Gradiometer (see the "diamond configuration" shown in Figure 20).

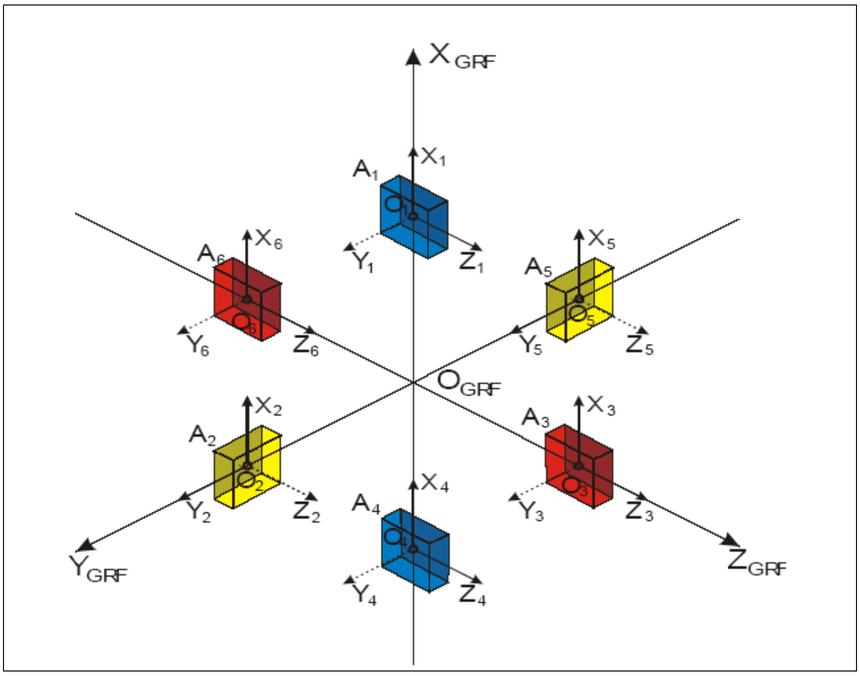


Figure 20 - EGG Accelerometers Configuration.

For all accelerometers A_i:

- Origin, O_i, located at the centre of the accelerometer A_i.

For the accelerometers A_1, A_4 belonging to OAG1 :

- X_i axis parallel to the accelerometer ultra sensitive axis nominally aligned with the OAG1 baseline, positive from the location of A_4 to the location of A_1.
- Z_i axis = $X_i \otimes L$, where X_i is the unit vector of the axis X_i and L is unit vector normal to the internal wall of the lower plate of the ULE^{TM} cage positive in the opposite direction of the sole plate. Z_i is nominally parallel to the second ultra-sensitive axis of the accelerometer.
- Y_i axis parallel to $Z_i \otimes X_i$, with the same sign of $Z_i \otimes X_i$. Y_i is nominally parallel to the less sensitive axis of the accelerometer.

For the accelerometers A2, A5 belonging to OAG2 :

- Y_i axis parallel to the accelerometer ultra sensitive axis nominally aligned with the OAG2 baseline, positive from the location of A_5 to the location of A_2.
- X_i axis = $Y_i \otimes L$, where Y_i is the unit vector of the axis Y_i and L is unit vector normal to the internal wall of the lower plate of the ULE^{TM} (Ultra Low Expansion) cage, positive in the opposite direction of the sole plate. X_i is nominally parallel to the second ultra-sensitive axis of the accelerometer.
- Z_i axis parallel to $X_i \otimes Y_i$, with the same sign of $X_i \otimes Y_i$. Z_i is nominally parallel to the less sensitive axis of the accelerometer.

For the accelerometers A_3, A_6 belonging to OAG3 :

- Z_i axis parallel to the accelerometer ultra sensitive axis nominally aligned with the OAG3 baseline, positive from the location of A_6 to the location of A_3.
- X_i axis = $L \otimes Z_i$, where Z_i is the unit vector of the axis Z_i and L is unit vector normal to the internal wall of the lower plate of the ULE^{TM} cage, positive in the opposite direction of the sole plate. Xi is nominally parallel to the second ultra-sensitive axis of the accelerometer.
- Y_i axis parallel to $Z_i \otimes X_i$, with the same sign of $Z_i \otimes X_i$. Y_i is nominally parallel to the less sensitive axis of the accelerometer.

5.1.2 One-Axis Gradiometer Reference Frame (OAGRF)

This is the reference frame in which the components of the gravity gradient tensor are measured by the OAG, and is defined as follows (see Figure 21).

For OAG1 :

- Origin, $O1_{OGR}$, located in the mid point of the straight line joining the origin O_4 of ARF_4 to the origin O_1 of ARF_1
- $X1_{OGR}$ axis parallel to the line joining O_4 to O_1, oriented from O_4 to O_1.
- $Y1_{OGR}$ parallel to and with the same versus of the vector $\underline{Y} = \frac{\underline{Y}_1'}{\left|\underline{Y}_1'\right|} + \frac{\underline{Y}_4'}{\left|\underline{Y}_4'\right|}$ where $\underline{Y}_1', \underline{Y}_4'$ are the projections of the vectors Y_1 and Y_4 on the plane perpendicular to $X1_{OGR}$.
- $Z1_{OGR}$ parallel to $X1_{OGR} \otimes Y1_{OGR}$, with the same sign of $X1_{OGR} \otimes Y1_{OGR}$.

For OAG2 :

- Origin, $O2_{OGR}$, located in the mid point of the straight line joining the origin O_5 of ARF_5 to the origin O_2 of ARF_2.
- $Y2_{OGR}$ axis parallel to the line joining O_5 to O_2, oriented from O_5 to O_2
- $Z2_{OGR}$ parallel to and with the same versus of the vector $\underline{Z} = \frac{\underline{Z}_2^{'}}{\left|\underline{Z}_2^{'}\right|} + \frac{\underline{Z}_5^{'}}{\left|\underline{Z}_5^{'}\right|}$ where $\underline{Z}_2^{'}, \underline{Z}_5^{'}$ are the projections of the vectors Z_2 and Z_5 on the plane perpendicular to $Y2_{OGR.}$
- $X2_{OGR}$ parallel to $Y2_{OGR} \otimes Z2_{OGR}$, with the same sign of $Y2_{OGR} \otimes Z2_{OGR}$

For OAG3 :

- Origin, $O3_{OGR}$, located in the mid point of the straight line joining the origin O_6 of ARF_6 to the origin O_3 of ARF_3.
- $Z3_{OGR}$ axis parallel to the line joining O_6 to O_3, oriented from O_6 to O_3
- $Y3_{OGR}$ parallel to and with the same versus of the vector $\underline{Y} = \frac{\underline{Y}_3^{'}}{\left|\underline{Y}_3^{'}\right|} + \frac{\underline{Y}_6^{'}}{\left|\underline{Y}_6^{'}\right|}$ where $\underline{Y}_3^{'}, \underline{Y}_6^{'}$ are the projections of the vectors Y_3 and Y_6 on the plane perpendicular to $Z3_{OGR}$.
- $X3_{OGR}$ parallel to $Y3_{OGR} \otimes Z3_{OGR}$, with the same sign of $Y3_{OGR} \otimes Z3_{OGR}$

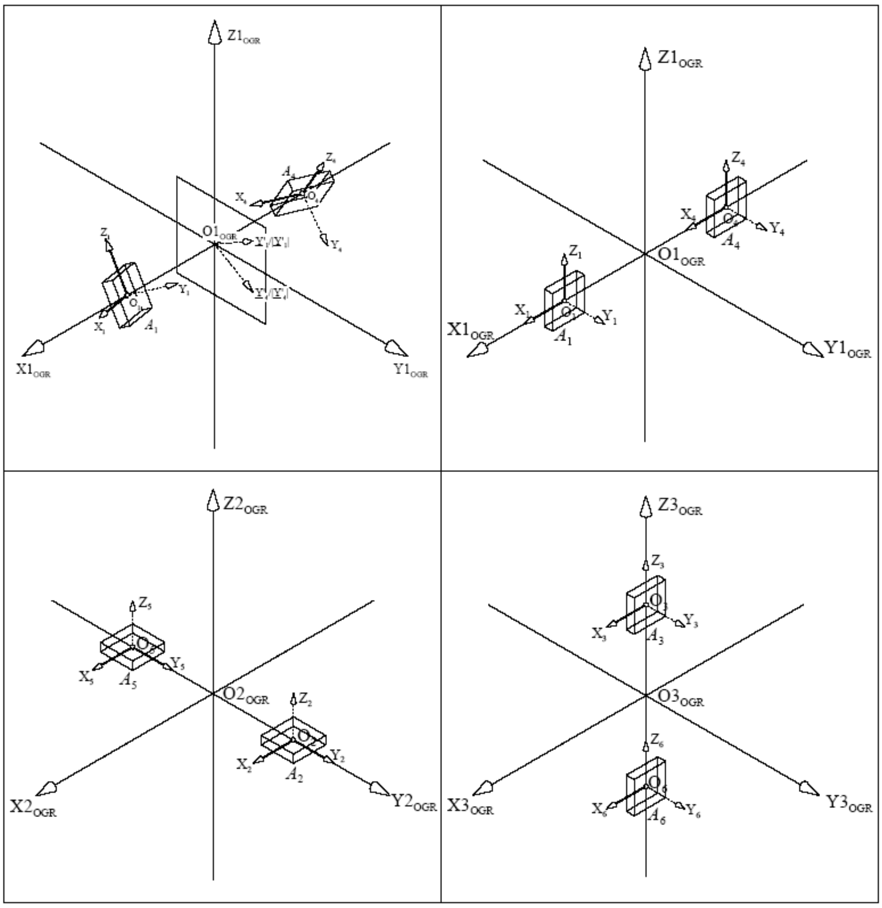


Figure 21 - One-Axis Gradiometer Reference Frame definition for the accelerometer pair A1, A4 (top left) and nominal orientation of the ARF1, ARF4 in the OAGRF1 (top right), of the ARF2, ARF5 in the OAGRF2 (bottom left) and of the ARF3, ARF6 in the OAGRF3 (bottom right).

5.1.3 Gradiometer Reference Frame (GRF)

GRF is the coordinate system in which the components of the gravity gradient tensor are measured by GOCE. The GRF represents the Three-Axis Gradiometer common reference for the mutual positioning and alignment of the three One-Axis Gradiometers and for the positioning and orientation of the whole instrument with respect to external reference frames (see Figure 3). Nominally the origins of all one-axis gradiometer reference frames (OAGRF) coincide in one intersection point. The corresponding axes of each of the 3 OAGRF's are parallel and point in the same directions. The corresponding 6 accelerometer reference frames (ARF) are parallel and point in the same direction.

5.1.4 Inertial Reference Frame (IRF)

The fundamental inertial reference frame of the mission is realized by the J2000 Equatorial Reference Frame (JERF). It is defined as follows (see Figure 22):

- Origin, OJ2000, located at the centre of the Earth.
- XJ2000 axis at the intersection of the mean ecliptic plane with the mean equatorial plane at the date of 01/01/2000 and pointing positively towards the vernal equinox.
- ZJ2000 axis orthogonal to the mean equatorial plane at the date 01/01/2000.
- YJ2000 axis completing a right-handed orthogonal reference frame.

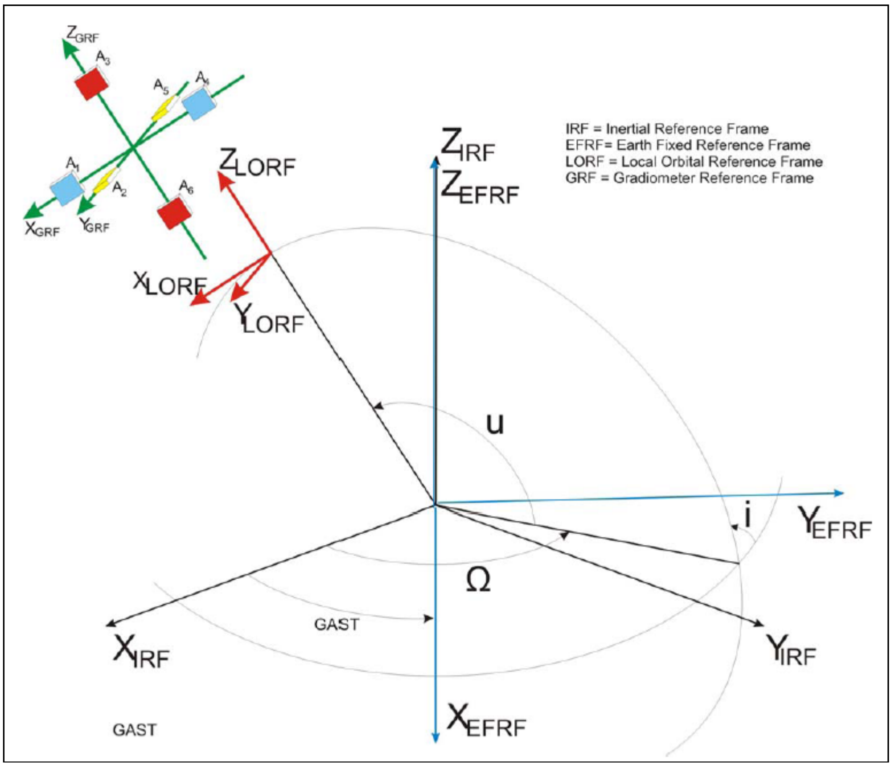


Figure 22 - Definition of fundamental Reference Systems for GOCE.

5.1.5 Time Reference for GPS

The timing diagram in Figure 23 shows the relations between the different timings involved in the SST receiver.

- *GPS System Time* : this is the GPS System Time reference maintained by the GPS master control station. It is offset from the UTC by an integer number of leap seconds that are periodically kept updated. Conversion between GPS time and UTC may be performed by the receiver using coefficients transmitted by GPS SVs in their navigation message.
- *GPS i^{th} satellite clock* : the GPS satellite clock drifts in time with respect to the time reference and can be corrected at each PVT solution by the receiver, using a set of polynomial coefficients transmitted by the GPS satellite within the navigation message. Polynomial correction is defined by the "Navstar ICD" document **[RD-5]**.
- *Receiver internal clock* : the receiver internal clock drifts with respect to the reference time and can be corrected by the "clock bias" value calculated within the PVT solution. The calculated clock bias accuracy is in the order of 80 nsec. with respect to the GPS reference time. The main contributor to this error is from the navigation solution itself.
- *Integration Epoch* : this signal is independent for each channel allocated to an SV and once the channel is tracking this signal is synchronous with the C/A code epoch.
- *Measurement Epoch* : this signal is internally generated by the receiver (one for all channels) with a period of 20 msec. and is maintained synchronous with the receiver PPS.

The *GPS week number reference* is the week #0 starting from January 6, 1980. The count of seconds begins at the midnight, which begins each Sunday morning. The rollover of the GPS week (max number 1024) was in August 1999. The LAGRANGE receiver week, if not differently specified, is evaluated as:

$$\text{Internal WN} = \text{actual WN} + 1024 \qquad (\text{eq. } 16)$$

Where *actual WN* is the WN set by the GPS SVs. GPS time differs from UTC by a variable integral number of seconds.

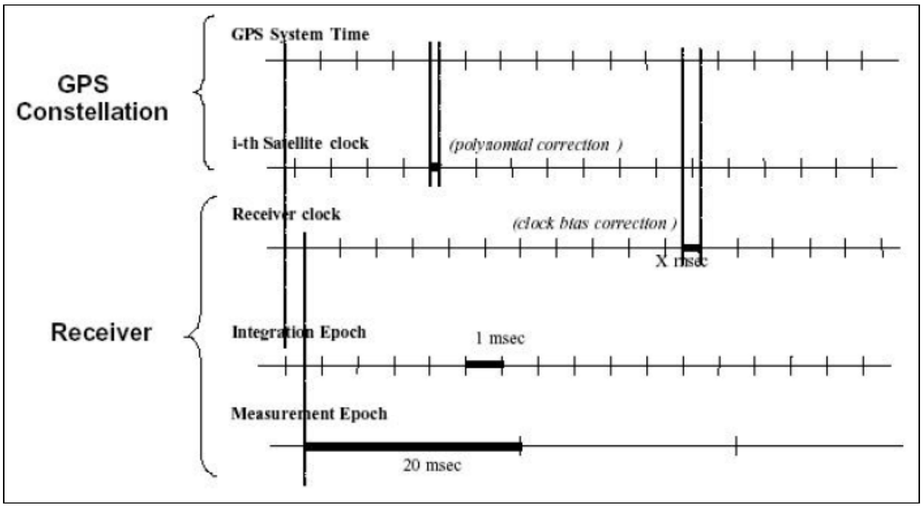


Figure 23 - GPS Timing Reference.

5.2 Basic Measurement Units

5.2.1 Gravity (g)

The symbol for the average acceleration produced by gravity at the Earth's surface (sea level) is *g*. The actual acceleration of gravity varies from place to place, depending on latitude, altitude, and local geology. The symbol *g* is often used informally as a unit of acceleration.

5.2.2 Galileo (Gal or gal)

The Gal unit is used in making measurements of local variations in the acceleration of gravity g. Variations in the acceleration of Earth's gravity (i.e. gravity anomalies) are typically measured in milligals (mGal). One Gal is approximately 0.0010197g, so a milligal (or mGal) is a very small acceleration, of about 10^{-6}g (or 10^{-5}m.s^{-2}). The mean Earth gravity is about 981 000 mGal (the well-known 9.81 m/s^2), varies from 978,100 mGal to 983,200 mGal from Equator to pole due to the Earth's flattening and rotation. Variations, due to density inhomogeneities, mountain ridges, etc., range from tens to hundreds of milligals. The unit is named after the Italian astronomer and natural philosopher Galileo Galilei, who lived from 1564 until 1642. Galileo proved that all objects at the Earth's surface experience the same gravitational acceleration.

5.2.3 Eötvös (E)

The Eötvös unit is used in geophysics to measure the rate of change, or gradient in the acceleration of gravity with horizontal distance. One Eötvös equals 10^{-7}Gal per metre or 10^{-4}Gal per kilometre. In proper SI units, the Eötvös unit equals 10^{-9} per second squared (s^{-2}). The largest component is the vertical gravity gradient, being about 3000 E on Earth (gravity changes by 3.10^{-6}m/s2 per metre of elevation). The horizontal components are approximately half this size; mixed gradients are below 100 E for the normal field. Gravity-gradient anomalies can be much larger and reach 1000 E in mountainous areas. This unit is named after the Hungarian physicist Roland von Eötvös who lived from 1848 until 1919.

5.2.4 Hertz (Hz)

Hertz is the SI unit of frequency, equal to one cycle per second. The hertz is used to measure the rates of events that happen periodically in a fixed and definite cycle. Multiples of the hertz are common: the frequencies of radio and television waves are measured in kilohertz (kHz), megahertz (MHz), or even gigahertz (GHz), and the frequencies of light waves in terahertz (THz). The unit is named after the German physicist Heinrich Rudolf Hertz (1857-1894), who proved in 1887 that energy is transmitted through a vacuum by electromagnetic waves.

6 REFERENCES

6.1 Acronyms and abbreviations

ANX	Ascending Equator Crossing Node
ARF	Accelerometer Reference Frame
AS	Anti-Spoofing (GPS signal)
C/A	Coarse Acquisition
CHAMP	CHAllenging Minisatellite Payload
CMF	Calibration and Monitoring Facility
CoM	Centre of Mass
CPF	Central Processing Facility or Carrier Phase measurement
DFACS	Drag-Free and Attitude Control System
DOP	Dilution Of Precision
DPM	Detailed Processing Model
DSR	Data Set Record
ECSS	European Cooperation for Space Standardization
EFRF	Earth Fixed Reference Frame
EGG	Electrostatic Gravity Gradiometer
EGG-C	European GOCE Gravity Consortium
EME2000	Equinox and Mean Equator of J2000
EO	Earth Observation
ESA	European Space Agency
GDOP	Geometric Dilution Of Precision
GFZ	GeoForschungsZentrum Potsdam
GOCE	Gravity field and steady-state Ocean Circulation Explorer
GPS	Global Positioning System
GRACE	Gravity Recovery And Climate Experiment
GRF	Gradiometer Reference Frame
GS	Ground Segment
HPF	High level Processing Facility

HW	Hardware
ICB	Inter-Channel Bias
ICD	Interface Control Document
IERS	International Earth Rotation and Reference Systems Service
IFB	Inter-Frequency Bias
IGS	International GNSS Service
IPF1	Instrument Processing Facility level 1
IRF	Inertial Reference Frame
LEO	Low Earth Orbit
LORF	Local Orbital Reference Frame
LS	Less Sensitive
MBW	Measurement Bandwidth
MPH	Main Product Header
MPV	Number of elements used for polynomial fit for derivation of GOCE velocities
NA	Not Applicable
OAG	One-Axis Gradiometer
OAGRF	One-Axis Gradiometer Reference Frame
OBT	On-Board Time
PCD	Product Confidence Data
PDOP	Position Dilution Of Precision
PDS	Payload Data Segment
PT	Position and Time
PVT	Position, Velocity and Time
PF	Processing Facility
POD	Precise Orbit Determination
PPS	Precise Positioning Service
PRN	Pseudo Random Noise
RD	Reference Document
RERF	Radial Earth-pointing Reference Frame
S/C	Spacecraft
SGG	Satellite Gravity Gradiometer
SI	Système International (*International system*)

SP	Science Processing
SPH	Specific Product Header
SST	Satellite-to-Satellite Tracking
SSTI	Satellite-to-Satellite Tracking Instrument
SV	Space Vehicle (in GPS constellation)
TDOP	Time Dilution Of Precision
ULE™	Ultra Low Expansion
US	Ultra Sensitive
UTC	Universal Time Coordinated
XML	eXtensible Markup Language

6.2 Reference documents

Document Title	**Identifier**	**[RD-ID]**
Gravity Field and Steady-State Ocean Circulation Mission	ESA-SP-1233 (1)	**[RD-1]**
GOCE Level 2 Data Handbook	GO-MA-HPF-GS-0110	**[RD-2]**
GOCE Calibration & Validation Plan for L1b data Products	EOP-SM/1363	**[RD-3]**
RINEX Modifications to Accommodate Low Earth Orbiter Data - Issue 2.20	IGSMAIL-3281	**[RD-4]**
NAVSTAR GPS Space Segment / Navigation User Interfaces, Rev. C, Release 004, 12 April 2000	ICD-GPS-200C	**[RD-5]**
Rummel, Balmino et al. Dedicated gravity field missions, Journal of Geodynamics, N. 33, 2002		**[RD-6]**
Earth Explorer Ground Segment File Format Standard	PE-TN-ESA-GS-0001	**[RD-7]**
Torge, W., *Geodesy 3rd edition*, Ed. de Gruyter, Berlin, 2001.	ISBN 3-11-017072-8	**[RD-8]**
GOCE High Level Processing Facility – GOCE Standards http://esamultimedia.esa.int/docs/GOCE_Standards_Document.pdf	GO-TN-HPF-GS-0111	**[RD-9]**
Satellite Gravity Gradiometry with GOCE Rummel, R., J. Müller, H. Oberndorfer, N. Sneeuw (Institut für Astronomische und Physikalische Geodäsie) in *Towards an Integrated Global Geodetic Observing System (IGGOS)* IAG Section II Symposium, Munich October 5-9, 1998		**[RD-10]**

R. Rummel, H. Drewes, W. Bosch, H. Hornik (eds.), IAG symposium 120, pp. 66–72, Springer		
Global Gravity Field Modelling Using Satellite Gravity Gradiometry 1993, Radboud KOOP New Series, Number 38 Nederlandse Commissie Voor Geodesie, Thijsseweg 11, 2629 JA Delft, The Netherlands.	ISBN 90-6132-246-4	**[RD-11]**

6.3 Web links

- *ESA – The Living Planet Programme – GOCE Data Products*
  Last update: 3 October 2006
  http://www.esa.int/esaLP/ESA4HK1VMOC_LPgoce_2.html
- *Basic measurement units*
  Last update: 3 October 2006
  http://www.esa.int/esaLP/ESAK4XZK0TC_LPgoce_0.html
- *Gravity field quantities*
  Last update: 3 October 2006
  http://www.esa.int/esaLP/ESANYVZK0TC_LPgoce_0.html