The GOCE Gravity Field Space Mission as an Important Step for the Exploration of our Planet

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Abstract. As an integral response to its mass distribution, the structure of the Earth's gravitational field represents an important source of information about our planet. Its knowledge is therefore important for the Earth as a system and for geodesy, solid Earth physics, and oceanography in particular.

For the first time in space geodesy, dedicated gravity field missions are being realized during this decade. The three missions are based on different observation concepts but they have one element in common: GPS-based high-low satellite-to-satellite tracking (SST). A second dedicated on-board sensor makes the three missions focus on different aspects of the Earth's gravity field: the determination of the static field with utmost precision and resolution by gravity gradiometry (GOCE mission) versus the monitoring of the temporal variable field with reduced spatial resolution by inter-satellite range measurements (GRACE mission).

The two sensors of the GOCE mission (GOCE = Gravity field and steady-state Ocean Circulation Explorer) combined will deliver a global gravity field with unprecedented accuracy and resolution. The GOCE derived gravity field, if combined with satellite altimeter data, will allow the precise determination of the absolute ocean circulation on a global scale. Considering the interchange between ocean and atmosphere, the results of the GOCE mission have the potential of substantially contributing to the further improvement of climate research. When combined with seismic data, the GOCE mission will enable a significant advance in the understanding of the dynamics of the Earth's interior and will contribute to a better understanding of processes such as plate tectonics, volcanism, and earthquake phenomena. Finally, the GOCE mission will provide a global height reference at the centimetre level, which is of paramount importance for positioning and navigation.

The paper provides an overview of the GOCE satellite gravity field mission in terms of mission parameters, goals, instruments and products and describes in more details the sensor and processing systems. Special emphasis is given to the interaction between the various sub-systems in space and on ground, which are required in order to successfully operate mission and exploit its data.

Introduction to the GOCE Mission

Mission Goals. GOCE is the acronym for „Gravity field and steady-state Ocean Circulation Explorer mission“. It is the first core satellite mission of the newly defined ESA "Living Planet" programme (see ESA, 1999a). The objective of GOCE is the determination of the stationary part of the Earth gravity field and geoid with highest possible spatial detail and precision. The gravity and geoid model derived from the GOCE mission will serve science and application in the fields of solid Earth physics, oceanography, geodesy and glaciology, compare for example (ESA, 1999b; Johannessen et al, 2003; Le Grand, 2003). An overview of the fields of application is shown in Figure 1.

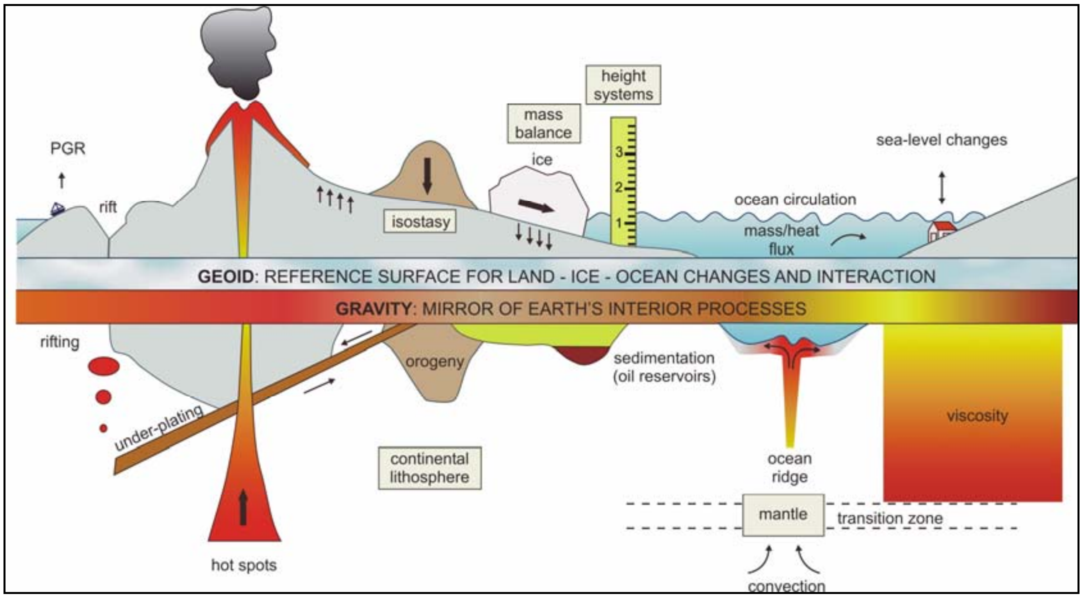

Figure 1: Application fields of GOCE gravity field mission and products (Courtesy ESA1999b).

Two main applications can be distinguished. Firstly, the spatial variations of gravity and geoid are directly related to density anomalies in lithosphere and upper mantle, respectively, and consequently to interior stresses and ultimately to mass motion. In this respect GOCE provides important new information to studies of continental and oceanic lithosphere and upper mantle. Its information is complementary to that of seismic tomography, magnetic field models, geo-kinematic studies and laboratory results. Secondly, a detailed geoid surface when combined with satellite altimetry yields ocean topography, the quasi-stationary deviation of the actual mean ocean surface from its hypothetical surface of rest. Under the assumption of geostrophic balance the sea surface topography can be directly translated into a global map of ocean surface circulation. Thus, ocean surface circulation becomes directly measurable, globally and uninterruptedly. In conjunction with higher resolution ocean models and in-situ measurements, GOCE is expected to improve significantly estimates of global mass and heat transport in the oceans (see Le Grand, 2003). Furthermore, the global geoid will permit height systems to be connected globally with almost cm-precision. Sea level variations in Australia, or East Asia will become directly comparable to those measured in Europe or America. These and other expected scientific benefits from GOCE gravity and geoid models demonstrate that this mission represents an important element of global observation of mass anomalies, mass transport and mass exchange. The science goals and the requirements on the mission performance are summarized in Table 1. To reach the specified science goals, precondition is that GOCE can determine gravity and geoid with a precision of $10^{-6}\cdot g$ (corresponding to 1 mgal) and 1-2 cm, respectively, with a spatial resolution of better than 100 km half wavelength and that these results are achieved free of long wavelength systematic errors. The mission performance depends on the gravity sensor system on-board GOCE.

Table 1: Science Goals and Mission Requirements of GOCE

Application	**Accuracy**		**Spatial Resolution** (half wavelength – D in km)
	Geoid [cm]	Gravity [mgal]	
SOLID EARTH			
Lithosphere and upper mantle density structure		1-2	100
Continental lithosphere:			
▪ Sedimentary basins		1-2	50-100
▪ Rifts		1-2	20-100
▪ Tectonic motions		1-2	100-500
Seismic hazards		1	100
Ocean lithosphere and interaction with asthenosphere		0,5-1	100-200
OCEANOGRAPHY			
▪ Short scale	1-2		100
	0.2		200
▪ Basin scale	≈0.1		1000
ICE SHEETS			
▪ Rock basement		1-5	50-100
▪ Ice vertical movements	2		100-1000
GEODESY			
▪ Levelling by GPS	1		100-1000
▪ Unification of worldwide height systems	1		100-20000
▪ Inertial navigation system		≈1-5	100-1000
▪ Orbits		≈1-3	100-1000
SEA LEVEL CHANGE	Many of the above applications, with their specific requirements, are relevant to studies of sea-level change.		

Mission Concept. The gravimetric concept of GOCE consists of two sensor systems. The first follows the high-low satellite-to-satellite tracking concept (hl-SST). The satellite positions are observed with cm precision by the on-board GPS receiver. These observations between the GPS satellites at high altitudes and the GOCE satellite at very low altitude can be used to determine the long wavelengths of the Earth gravity field by analyzing the orbit variations (the satellite can be regarded in free-fall). The second and completely new element of the GOCE satellite mission is the direct measurement of the anomalous static gravity field by pairs of accelerometers forming a 3-D gravity gradiometer (SGG: Satellite Gravity Gradiometry). By observing differential accelerations in three directions in a drag-free environment and at very low altitude it will become possible to determine the gravity field globally to a much higher spatial resolution than with any satellite mission flown before. The gravity gradiometer, due to its short baseline between the accelerometers and due to its band limitation will not be able to observe the long wavelength part of the Earth gravity field with sufficient accuracy. The two measurement concepts therefore provide complementary information. Figure 2 shows the general mission concept of the gravity field sensor system.

Mission Parameters. In order to determine the Earth gravity field from space with high accuracy and high spatial resolution the mission has to fulfil specific conditions. First of all the ground track coverage of the satellite orbit has to be sufficient in order to reach a spatial resolution of at least 100 km globally. This is ensured by the chosen orbit parameters and by the fact that GOCE mission control will keep the satellite during operational phases in an orbit where no short repeat periods on ground will occur. Nevertheless, due to power consumption constraints the satellite has to fly in a sun-synchronous orbit with an inclination of 96.7 degrees.

This implies that the polar areas cannot be observed completely and that there is a polar gap of 6.7 degrees in the Northern and Southern hemisphere. The definition of the operational phases is also driven by power consumption constraints. This means that the satellite can only be operated in the chosen altitude during direct sun-light and using electric energy from batteries during short eclipse phases. During long eclipse phases the solar energy is not sufficient to fully operate the satellite and its instruments in the science measurement mode. Therefore, for GOCE we have measurement phases interrupted by a so-called hibernation phases during the long eclipse period. A final driving parameter for definition of the mission altitude is the sensitivity of the instrument compared to the expected signal. The strength of the gravity field decreases by the square of the distance from the attracting body (Earth). This means, in order to enable highly precise gravity field determination by means of satellite observations the altitude has to be low enough and/or the instrument sensitivity has to be high enough, respectively. In other words the optimal configuration will be a compromise of both factors using the best possible instrument at lowest possible satellite altitude. The results of this compromise are the selected mission parameters as summarized in Table 2 for a launch date in August 2008. Depending on the actual launch date the mission profile might have to be adapted.

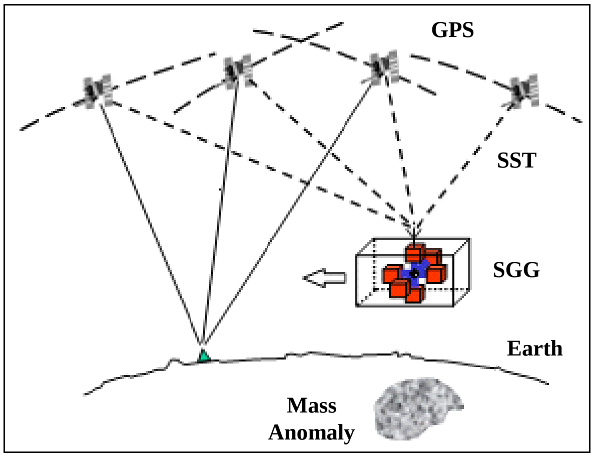

Figure 2: GOCE Mission Concept (SST and SGG)

Table 2: Summary of GOCE Mission Profile

Launch	August 2008
Inclination	96.7 degree
Mean Altitude	260-270 km
Commissioning & 1st Calibration Phase	3 months
1st Measurement Phase	5 months
1st Hibernation Phase	5 months
2nd Calibration Pase	1 month
2nd Measurement Phase	6 months
2nd Hibernation Phase	5 months
3rd Calibration Phase (optional)	1 month
3rd Measurement Phase (optional)	6 months

Products. The GOCE ground segment prepares a set of products tailored for the different application areas. Within the ground segment there exist different facilities, which are responsible for processing of GOCE data on different product levels. According to ESA terminology these levels are:

- Level 0: Raw data from the science instruments extracted from the telemetry data.
- Level 1: Pre-processed raw data per instrument as time series in physical units. For this processing step a combination of different instruments is sometimes required.
- Level 2: Geophysical products computed from the level 1 data. These are corrected and externally calibrated gravity gradients in different coordinate systems, precise science orbits and final gravity field solutions. Specifically the latter two products require a thorough processing in order to combine all relevant input data sets. A summary of the level 2 products is provided in Table 3.

While level 0 and level 1 products are generated by processors implemented at ESA facilities, level 2 products generation is performed by the High Level Processing Facility (HPF), which is formed by a consortium of 10 European institutes and research facilities. More details on this are described in the subsequent chapters.

Table 3: Overview of final GOCE Level 2 Products

Product Name	**Product Definition**
Gravity Gradients	
EGG_NOM_2_	Gravity gradients in observed reference frame with corrections: • Externally calibrated and corrected gravity gradients • Corrections to gravity gradients due to temporal gravity variations • Flags for outliers, fill-in gravity gradients for data gaps with flags • Gravity gradient error estimates
EGG_TRF_2_	L2 gravity gradients in local North oriented reference frame with corrections: • Externally calibrated gravity gradients in local north oriented frame including corrections to gravity gradients due to temporal gravity variations • Flags for outliers, fill-in gravity gradients for data gaps with flags • Gravity gradient error estimates
Orbits	
SST_PSO_2_	Precise science orbits • Reduced-dynamic and kinematic precise science orbits • Rotation matrices between inertial and Earth-fixed reference frames • Variance-covariance information for kinematic positions • Quality report for precise orbits
Gravity Fields	
EGM_GOC_2_	Final GOCE gravity field model • Spherical harmonic series including error estimates • Grids of geoid heights, gravity anomalies and deflections of the vertical • Propagated error estimates in terms of geoid heights • Quality report for GOCE gravity field model
EGM_GVC_2_	Variance-covariance matrix for the final gravity field in terms of spherical harmonic series
SST_AUX_2_	Time variable gravity field due to non-tidal mass variations. 6-hourly time series of gravity field spherical harmonic series.

The GOCE Space Gravity Sensor System

Instruments. Figure 3 shows the satellite structure and the location of the instruments. The main instruments and elements of the satellite are (the numbering scheme follows the numbers in Figure 3.):

1. Solar array wing: Launch configuration is chosen such that the solar arrays always look into the direction of the sun. This is required in order to exploit as much as possible solar energy.
2. Body mounted solar panels.
3. Stabilizer tail fin.
4. Gravity Gradiometer (SGG) located in the centre of mass of the satellite.
5. Ion-thruster Assembly required to keep the satellite in drag-free mode. The satellite is oriented in space such that the thrust direction always is close to flight direction (satellite body cross section towards flight direction). By permanent thrust, the non-gravitational forces due to air drag and solar radiation pressure and others are compensated such that the satellite can be regarded to fly in free-fall in the gravity field.
6. S-band antenna for ground communication.
7. GPS antennas for satellite-to-satellite tracking in high-low mode.
8. Star trackers (not shown in Figure 3). The three star trackers provide information about the

orientation of the spacecraft in the inertial space.

9. Magneto-torquers (not shown in Figure 3): Three magneto-torquers are used for attitude control of the spacecraft. Rotational forces are applied in order to keep the spacecraft in its nominal orientation.
10. Cold gas thrusters (not show in Figure 3): Cold gas thrusters are used for calibration purposes. Known shaking is applied in order to calibrate the gravity gradiometer in space.
11. Magnetometers (not shown in Figure 3): Measuring the magnetic field required to apply angular control by magneto-torquers.

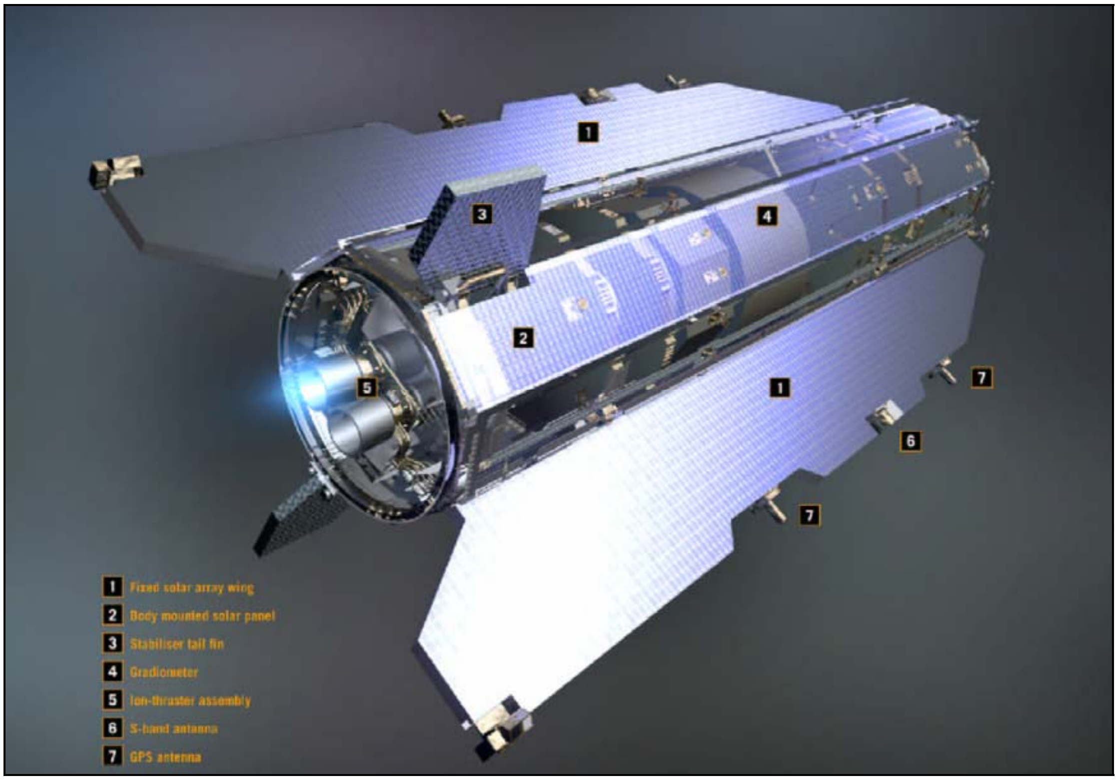

Figure 3: GOCE and its Instruments (Courtesy ESA).

Sensor System. Core instrument on-board GOCE is a three axis gravity gradiometer. It consists of three orthogonally mounted pairs of 3-axis accelerometers, i.e. an orthogonal arrangement of three one-axis gradiometers (see Figure 5, e.g. the blue marked accelerometers form a one-axis gradiometer). The gradiometer baseline of each pair is about 50 cm long. The accelerometer precision is $10^{-12} m/s^2 \sqrt{Hz}$ along two axes with the third axis less sensitive due to constructional reasons. From the measured gravitational acceleration differences the three main diagonal terms of the gravitational tensor can be determined with high precision. The extremely high gradiometric performance of the instrument is confined to the so-called measurement bandwidth (MBW). This means that the gradiometer does only provide valuable information in the medium to short wavelengths. In addition, the gradiometer yields the required information of the angular acceleration about the out-of-plane axis (pitch) of the gradiometer. This information in combination with the angular rates as derived from the star sensor readings and from magnetometers is used as control signal for angular control of the spacecraft by magneto torquers. The use of magneto torquers in the Earth magnetic field implies that three-axis active angular control is possible only over part of each orbit revolution. In order to prevent non-gravitational forces acting on the spacecraft to "sneak" into the measured differential accelerations as secondary effect, the satellite is kept "drag-free" in along track direction by means of a pair of ion thrusters. The necessary control signal is derived from the available "common-mode" accelerations (=mean accelerations) along the three orthogonal axes of the accelerometer pairs of the gradiometer. Ideally, if the centre of the satellite and that of the gradiometer coincide common mode accelerations represent non-gravitational accelerations (e.g. air drag, solar radiation pressure). The non-gravitational accelerations are primarily due to residual air drag. They are compensated in along-track direction by the ion-thruster assembly accelerations, a so-called drag-free system. The gradiometric and angular signal part of the common mode acceleration, which is a result of the imperfect symmetry of the gradiometer relative to the spacecraft centre of mass has to be modelled during data analysis. The gradiometric sensor system and its coupling with drag and angular control systems is illustrated in Figure 4.

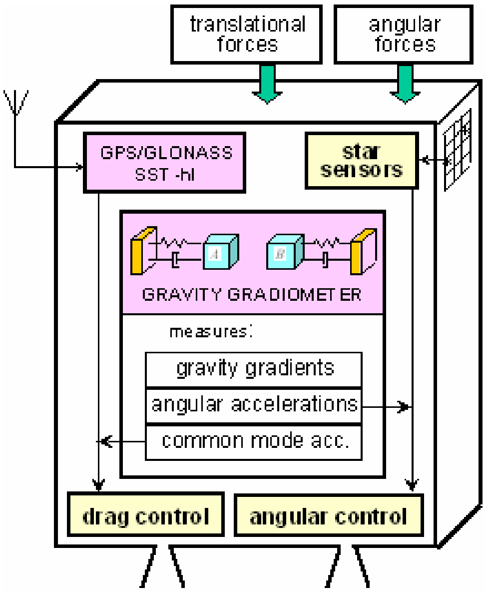

Figure 4: GOCE Sensor System

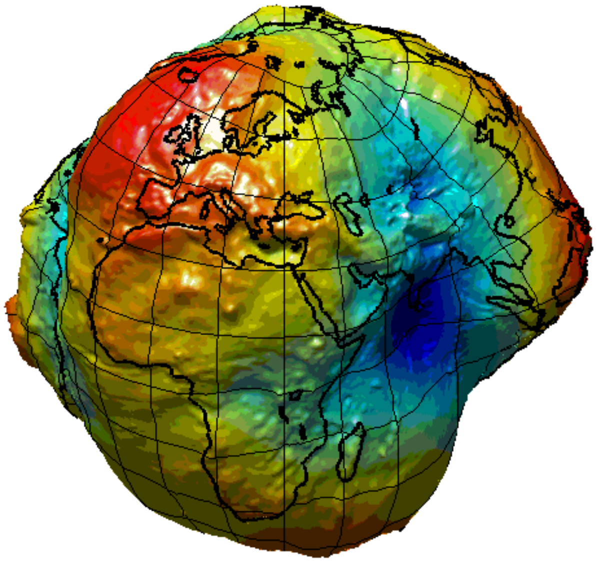

Figure 5: The Earth gravity field in terms of heights with respect to a reference ellipsoid (range -100 m to +100 m, illustrated with large scaling factor).

The second gravity sensor device is a newly developed GPS receiver. From its measurements the orbit trajectory is computed to within a few centimetres, either purely geometrically by a so-called kinematic orbit determination, or by the method of reduced dynamic orbit determination. 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 observations from the GPS receiver complement the measurements of the gravity gradiometer. They provide high quality information about the long wavelength gravity field, below and at the lower end of the measurement bandwidth of the gradiometer. By a joint analysis of data from both gravity field sensors, the final GOCE gravity field models are determined. An example for a pre-GOCE gravity field is shown in Figure 5.

In summary, GOCE is a technologically very complex and demanding mission. The gravitational field sensor system consists of a three-axis gravitational gradiometer and a GPS receiver as core instruments. An extreme low orbit is maintained by a drag control system. Orientation in inertial space is derived from star sensors, angular rates are deduced from the gradiometer. Common mode accelerations from the gradiometer are used for drag-free control with ion thrusters, magneto-torquers provide angular control. The whole satellite together with its instrument forms the sensor system and requires sophisticated control loops in orbit and common data analysis from the different components on ground. This means, that in contrast to many other space missions, the science instruments and the platform systems have close relations and cannot be regarded independently.

The GOCE Ground Processing System

Ground Segment. As described above GOCE instrument data are processed on different levels. For each processing level a sub-system of the overall ground segment is responsible. Figure 6 shows an overview of the GOCE ground segment and the interactions between the different sub-systems.

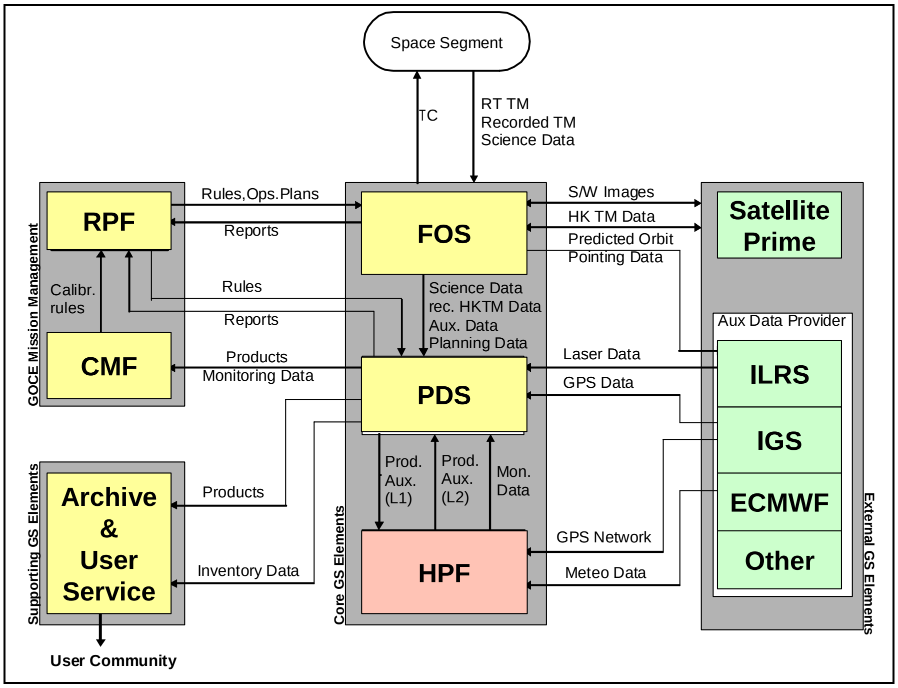

Figure 6: The GOCE Ground Segment

The sub-system elements have the following tasks:

- FOS: Flight Operations System: Control and Tele-commanding of satellite, reception of real-time and recorded telemetry and science data. The sub-system consists of the flight operations control centre and the ground stations for communication with the satellite. The FOS receives the satellite raw data and extracts the relevant data required for further processing. Housekeeping data and operation reports are forwarded to the satellite prime contractor and the RPF in order to check the system and plan for example on-board software updates or setup specific operational procedures. Extracted level 0 science and housekeeping data are given to the PDS in order to further process them to level 1 products.
- RPF: Reference Planning Facility: Performs system checks and sets up operational rules and decisions. Rules and operational plans are given to the FOS for setting up the relevant

operational procedures.

- Satellite Prime Contractor: For initial system check and in case of problems with elements of the space segment, specialists from the satellite prime contractor are available as support to the ground segment.
- PDS: Payload Data System: Reception of level 0 data from FOS and preparation of level 1 products. Acquisition of required auxiliary data from external sources. Single access point to the archive for all mission data and products. The PDS prepares various level 1 data products for different purposes. All products contain results from all intermediate steps in order to enable full analysis of the processing sequence. The PDS provides the needed products to the CMF for calibration and monitoring and to the HPF for generation of level 2 products.
- CMF: Calibration and Monitoring Facility: Estimation of calibration parameters. Monitoring of instruments by analysis of level 1 data products. The CMF provides calibration rules to the RPF and reports about the status of the instruments and products. It supports the RPF for all decisions to be made.
- HPF: High-Level Processing Facility: Generation of intermediate and final level 2 products from level 1 products and required ancillary data. The HPF provides quick-look and regular level 2 products to the PDS. Quick look products are further used in the CMF for monitoring purposes. Various ancillary data from external sources are required to generate the level 2 products. More details about the HPF sub-system are provided in the sequel.
- Archive & User Service: Long-term archiving of all products of all levels. Single access point for all users to order GOCE products.
- Ancillary Data Providers: Specifically for level 2 processing several ancillary data and products are required in order to enable level 2 products generation. Major data providers are the International Laser Ranging Service (ILRS), the International GNSS Service and the European Centre for Medium Range Weather Forecast (ECMWF).

All ground segment elements are in close interaction in order to systematically monitor and process the GOCE data to products for the user community.

High Level Processing Facility (HPF). The HPF is designed, developed, implemented, tested and operated by the European GOCE Gravity consortium (EGG-c) under ESA contract, complemented by significant national and institutional support. EGG-c consists of ten European university and research institutes from seven countries (see Figure 7). These ten groups are:

- AIUB Astronomical Institute of the University of Bern, Switzerland
- CNES Centre Nationale d'Études Spatiale, GRGS, Toulouse, France
- FAE/A&S Faculty of Aerospace Engineering, Technical University Delft, The Netherlands
- GFZ GeoForschungsZentrum Potsdam, Germany
- IAPG Institute of Astronomical and Physical Geodesy, Technical University Munich, Germany
- ITG Institute for Theoretical Geodesy, University of Bonn, Germany
- POLIMI Politecnico di Milano, Italy
- SRON Netherlands Institute for Space Research, The Netherlands
- TUG Institute of Navigation and Satellite Geodesy, Technical University Graz, Austria
- UCPH Department of Geophysics, University Copenhagen, Denmark

The HPF is managed by IAPG and SRON. Six of the ten groups hold responsibility for a main work-package, namely CNES, FAE/A&S, IAPG, POLIMI, SRON and TUG. The heritage of EGG-c is to be found in the cooperation activities between most of the groups that already started during the time of the Aristoteles gradiometer mission proposal, continuing with the four CIGAR studies (1989-1996) on precise gravity field determination methods and mission requirements, followed by two studies under the title “From Eötvös to Milligal (2000-2002). Before the actual HPF development started, the EGG-c performed a study under ESA contract between mid 2001 and mid 2003 aimed at the definition of the high-level architecture for GOCE Level 2 processing. The ten groups in the EGG-c have a long-standing experience in the field of geodetic orbit and gravity field modeling and related data processing. Actually, the EGG-c is characterized by the fact that there is a strong internal overlap of expertise on the one hand, and a complementary expertise on the other. The latter ensures that all relevant subjects required for GOCE data processing are covered by EGG-c, while the former implies that HPF has intrinsically the capabilities for independent validation and – if necessary – back-up scenarios. The expertise and software already available within EGG-c has been re-used in the HPF and adapted and upgraded wherever necessary. On the other hand, novel approaches that have specifically been developed in the last decades aimed at high-accuracy gravity field modeling from satellite measurements, are included in HPF as well. Some specific tasks, in particular related to processing steps that are dedicated and tailored to GOCE, like the pre-processing, external calibration and certain filtering processes, have been developed and implemented from scratch. As a result, HPF constitutes a unique combination of consolidated and promising novel techniques for GOCE Level 2 data processing.

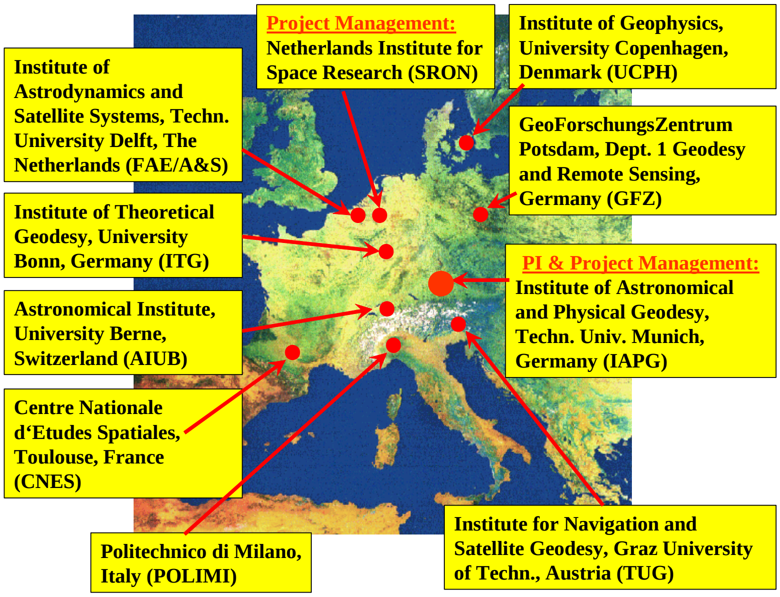

Figure 7: The European GOCE Gravity Consortium

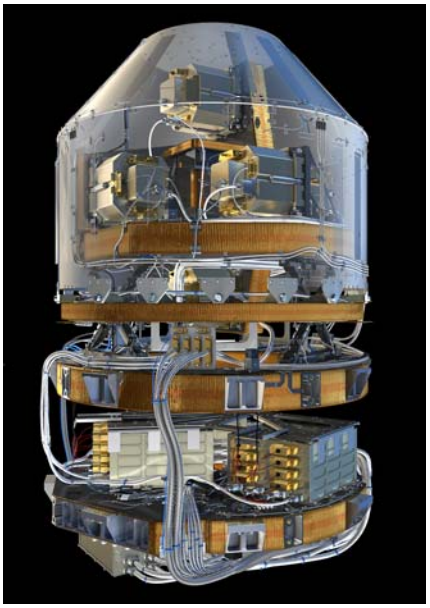

Figure 8: The GOCE Gradiometer (Courtesy ESA)

The top part of Figure 9 shows the high-level interfaces between the HPF and the other elements of the GOCE Ground Segment (compare also to Figure 6). The figure furthermore illustrates the internal high-level architecture of the HPF. The main building blocks of the HPF, which are further discussed below are:

- Central Processing Facility,
- Scientific Pre-processing and External Calibration,
- Orbit Determination,

- Gravity Modeling,
- Product Validation and Selection of Final Products.

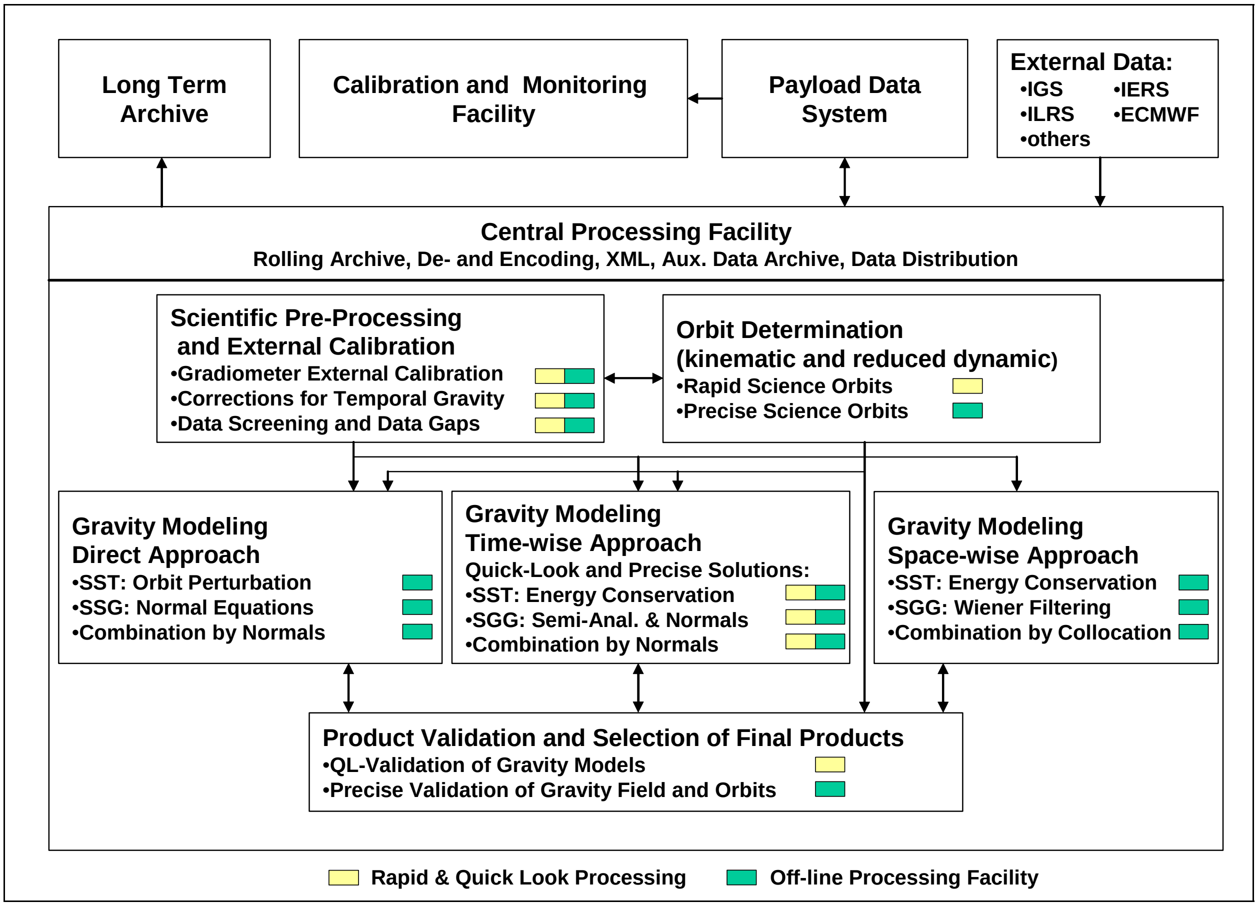

Figure 9: HPF High-level Architecture

Central Processing Facility: The GOCE HPF has been implemented as a distributed facility meaning that actual processing takes place at different sub-processing facilities (SPF's). Nevertheless, HPF has only one interface with the PDS, for which the so-called CPF (Central Processing Facility) has been developed and implemented. The CPF, implemented at SRON, is furthermore the central facility for data distribution within the HPF, for which ten internal interfaces have been defined and implemented. All Level 1b input and Level 2 output products are distributed and collected by the CPF. In order to keep the internal data network as simple as possible no direct interfaces between the SPF's are in operation. The CPF is a dedicated GOCE-HPF data facility which has been developed and implemented from scratch, and which has no direct interface to the end-users.

Scientific Pre-processing and External Calibration: The challenging gradiometer in-flight calibration procedure contributes strongly to the high performance of this novel instrument in the gradiometer measurement band (MB), between 5 and 100 mHz. This in-flight calibration procedure, however, constitutes a "relative" calibration, where the individual accelerometers are calibrated against each-other, mainly to determine a common and differential scale factor and to determine miss-alignments between the axes of the accelerometers and the gradiometer. What is needed in addition is a kind of "absolute" calibration to establish the correct physical dimension of the gradients by determining a scale factor from comparison of the observations with existing and validated external gravity data. Before the gradients are externally calibrated, possible outliers, remaining after the PDS processing, will be detected and flagged, as well as data gaps. For these cases, fill-in values will be provided from interpolation. Furthermore, the gradients are corrected for temporal gravity effects, since GOCE will be used to estimate the stationary gravity field. These temporal corrections include ocean and solid earth tides and non-tidal ocean and atmosphere effects. The outcome of the scientific pre-processing and external calibration are the level 2 gravity gradient products as specified in Table 3.

Orbit Determination: The accurate GOCE SSTI (Satellite-to-Satellite Tracking Instrument, see Figure 5) observations are used both for accurate reconstitution of the orbit, as well as for long-wavelength gravity field modeling. The ultra-low orbit of GOCE poses specific constraints on precise orbit determination from GPS observations, for which existing well-established processing software has been tailored. HPF provides on a routine basis both Rapid Science Orbits (RSO) as well as Precise Science Orbits (PSO), the former of which with a shorter latency, the latter of which being made available to the end-user. Actually, for both RSO and PSO two POD techniques have been implemented in HPF, namely kinematic and reduced-dynamic orbit determination.

Gravity Field Determination: Gravity gradients have never been measured before from a satellite. In view of the final realization of a mission like GOCE, major progress has been made in the last decades in the field of updated and novel processing strategies for such observations. Furthermore, the extreme performance requirements of GOCE make it necessary to revisit "classical' approaches in satellite geodesy. Even in the field of processing GOCE GPS tracking observations special attention is required due to the low orbit and strong performance requirements. Three different processing strategies were proposed at the start of HPF and since one cannot predict which method is the best before the real GOCE data becomes available, it was decided to implement all three methods in parallel in the HPF processing chain, also for reasons of acknowledging the significant progress that has been achieved in novel methods specifically designed for GOCE. As a result, the gravity modeling block of the HPF now consists of the following tasks:

- Direct gravity field modeling approach, based on updated and improved "classical" methods for gravity field determination from satellite measurements.
- Time-wise gravity field modeling approach; this is a novel approach, never been used for real data processing, but taking advantage of the homogeneous and continuous data stream from GOCE by a method that takes the whole data set as a time-series along the orbital track.
- Space-wise gravity field modeling approach, in which the GOCE data is gridded and advantage is taken from fast spatial techniques and elegant theoretical models.

Each of the three methods has its own characteristics in terms of filtering, regularization, processing strategies for huge data sets, solutions of large systems of equations, assumptions and approximations, etc., and each method can be especially tuned to the peculiarities of the real GOCE data.

Product Validation: One of the strongest features of the HPF is that the whole spectrum of state-of-the-art gravity field and orbit modeling is included in the processing chain, building on long-standing expertise available at the EGG-c teams and exploiting consolidated and new scientific ideas and methods. This is reflected in the fact that two alternative POD techniques and three gravity modeling methods are present, which not only can be used to validate each-other but also can be seen as back-up scenarios. Since the ultimate goal of the HPF is to provide for the end-user only one (the "best") GOCE gravity field model and precise orbit, the HPF has implemented an extensive evaluation procedure of the alternative products, as well as a selection of the final product. This validation procedure will result in an extensive quality report, on the basis of which the final (best) GOCE gravity model will be selected.

Quick-Look Processing: In order to support a fast performance monitoring of GOCE in terms of Level 2 products, HPF has implemented a quick-look chain, delivering several quick-look products available for analysis by the participants in the GOCE ground segment. These products are generated by applying certain simplifications in order to keep a short latency. In particular, HPF provides quick-look orbits (the RSO), quick-look corrected and calibrated gravity gradients and quick-look gravity field solutions based on subsets of Level 1b data. Quality reports of the quick-look products will be delivered as well.

Summary and Conclusions

The GOCE gravity field space mission shall provide the global gravity field and geoid with unprecedented accuracy and resolution. This is needed for various applications in Earth sciences and oceanography. The main instrument is a newly developed gravity gradiometer observing acceleration differences in space caused by variations of the gravitational attraction of the Earth due to mass inhomogeneities. Due to their complexity, the satellite system in space as well as the processing system on ground have to be regarded as a system. This is reflected in the satellite instrument configuration with its control loops applied in the space segment as well as in the system layout of the ground segment elements. All together the mission itself and the data analysis is very complex and requires sophisticated techniques in order to reach the mission goals. All elements are in place, extensively tested and ready for the launch.

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Biography

Dr. Thomas Gruber studied Geodesy at the Technical University of Munich. After his diploma in 1989 he started his career at the German Geodetic Research Institute (DGFI), Munich as research scientist in satellite altimetry. From 1992 to 2001 he worked at the GeoForschungsZentrum Potsdam (GFZ), where he was in charge for the science data system of the US/German GRACE gravity field mission. In 2000 he achieved his doctoral degree (Dr.-Ing.) from the Technical University Munich. Since 2001 he works as permanent staff member at the Institute of Astronomical and Physical Geodesy at Technical University Munich, where he is responsible for the GOCE projects. Apart from that he gives lectures in different course programmes and runs research projects related to mass transport in the system Earth.