# THE EUROPEAN GOCE GRAVITY CONSORTIUM (EGG-C)

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## INTRODUCTION

GOCE is a very ambitious mission, and many conditions for its success lie at the level of the processing of its data, which for a large part is going to be new to everyone. This implies that special and dedicated care of the data processing be taken, to ensure that the best Earth's gravity field model can be delivered to the scientific users. One highly important phase, the computation of the gravity model parameters from the pre-processed sensor measurements, requires the participation of the best experts in this advanced domain of satellite geodesy, in applied mathematics and computer science. Such experts exist in several research groups in Europe and they are able to cover all facets of this phase. Many of them have already worked together for years in the preparation of the methods to be used for the model parameter derivation from GOCE. A large, sustained and well organized effort is now required, which is proposed to be undertaken by teams working as a consortium. A well structured organization is necessary for ensuring :

- the quality of the data and reliability of products and model for subsequent scientific works,
- the efficiency of the data flow (which also requires proper management, equipment and network),
- good connection and inter-action with the ESA project management team, the users, and adequate public awareness and outreach.

Consequently the **European GOCE Gravity Consortium, EGG-C**, has been established. We first put it in perspective of the other GOCE mission components. Then we present its structure, we give its terms of reference, an overview of the GOCE data usage and a short description of the different tasks which we have identified. Finally the composition of the consortium is announced.

## EMBEDDING OF EGG-C AND OF THE SCIENCE TEAM INTO THE OVERALL GOCE STRUCTURE

The GOCE data processing from level 1a/1b to 2 is a task beyond the classical ESA expertise. Therefore it is proposed to perform this task by a consortium that comprises all the necessary expertise in Europe. Its products will be an official gravity and geoid model together with quality measures and other desirable gravity products. It will be provided to the users (level 3) as GOCE geodetic data records (GGDRs). In order to understand the role and the place of the consortium it is presented here together with the other bodies that constitute the GOCE project. These are :

- **ESA GOCE project team**: its responsibility is the management of the GOCE development and the organization and development of the on-board data processing (from level 0 to level 1a/1b) and of the ground segment.
- **GOCE industry team**: it is concerned with the realization of the GOCE satellite system as a joint effort of an industry consortium.
- **GOCE Mission Advisory Group (GOCE-MAG):** it advises ESA in all matters concerning the realization and scientific use of the GOCE mission and forms the link between ESA and the science community. The **GOCE Project Scientist,** appointed by ESA, coordinates the **MAG** and is in charge of the interface between the project team and the consortium.
- **EGG-C**: its responsibility is the determination of the **geodetic GOCE gravity products**, i.e. the processing from level 1a/1b to level 2. It will also assist ESA in linking to level 3.
- **Science data users** (level 3): these are the users of GOCE products in solid earth physics, oceanography, ice research, geodesy and sea level research.

## STRUCTURE OF THE EUROPEAN GOCE GRAVITY CONSORTIUM (EGG-C)

The consortium is proposed to be organized similar to the structure that was adopted for the HIPPARCOS FAST consortium [1].

- Members: the consortium is composed of a selected number of European institutes. They are called **members.** Their participation rests on a written and accepted commitment. The participating institutions will comprise many of those which contributed to the definition and selection of the GOCE mission, and obviously the European groups in which lies the greatest expertise - which will be required in order to warrant the high quality of geodetic data products of a new kind.

- Team leader and managers: the program of the consortium is coordinated by a **team leader** assisted by two managers; one is the **program manager** and the other the **software and data manager.**

- Tasks: the program is structured according to **tasks**. There are **core tasks**; they comprise the (minimum) work that is necessary in order to produce a complete set of geodetic data products (including feed back to level 1, validation and interface with level 3). The core tasks are complemented by a set of **off-line tasks**. They include add-on products that are highly desirable. An example is regional high resolution solutions that were identified by the science users and the MAG as particularly desirable. For the execution of each task according to agreed upon procedures there exists a commitment of one or several **members**.

- Task leader: each task (core and off-line) is lead by a **task leader**. A significant part of the core tasks should be carried out under ESA contract and financing. The ESA part should be complemented by contracts/financing agreed upon bilaterally with **members** and their respective national funding agencies.

- Technical Committee: the coordination of the work of the consortium is the responsibility of a **technical committee**. It is lead by the **team leader** assisted by the **program manager**. Members of the committee are the **task leaders**.

- Software Advisory Group: consistent software engineering and control is the responsibility of the **software advisory group**. Its chairman is the **team leader** assisted by the **software and data manager**. Each core task group appoints a *software expert* who is member of the committee. Off-line task groups may also appoint a software expert to this committee as deemed necessary.

- Steering Committee: finally there is a **steering committee**. Its purpose is to act as an independent advisory body and a link to the national agencies. Members are representatives of those national organisations which participate and financially contribute to the work of the consortium, plus the **team leader** ex-officio.

**TERMS OF REFERENCE OF THE GOCE GRAVITY CONSORTIUM (EGG-C)**

The **team leader** is coordinating the work of the **task leaders** and is responsible to ESA for the overall management of all tasks. The **team leader** is the official contact of the consortium with ESA. He is member of the GOCE-MAG. He is assisted in technical and organizational matters by the **program manager** and in data and software matters by the **software and data manager**

The **task leaders**, under the chairmanship of the **team leader**, together constitute the **technical committee.** The tasks of the **technical committee** are:

- to discuss and decide on the main scientific and technical methods to be implemented;
- to take the necessary actions if any hardware or software modifications should become necessary, for example, at the request of ESA;
- to discuss and agree upon the calibration and/or simulation procedures;
- to ensure the proper internal communication between the various members of the consortium;
- to ensure compatibility between the inputs and outputs of the various tasks, and to resolve any type of interface problem;
- to prepare and discuss reviews of the progress of the tasks.

Each **task leader** is in charge of a well defined portion of the whole work. He distributes the work among the members (working on the respective task) and coordinates their activities. Each **task leader** is responsible for the interfaces with the other tasks and for the correct and timely completion of the task

The **software advisory group** is composed of a representative of all the tasks contributing to the ultimate core software to be run on an agreed upon computer platform or network of computers (i.e. the core or on-line tasks). It is chaired by the **team leader** with the **software and data manager** as secretary. Its main tasks are:

- to approve the standards of software development and adoption of existing software;
- to discuss and approve the global architecture of the reduction process and interfaces between the processing chains;
- to participate in the elaboration of test, integration and implementation plans,
- to evaluate software documentation of the project;
- to prepare the operational phase of the real data processing.

The main tasks of the **Steering Committee** are:

- to review the progress of the work of the consortium;
- to suggest actions to the **team leader** that would improve the efficiency or the quality of the work;
- to act, through its members, as a link between the consortium and the national agencies;
- to advise the **team leader** on any problem of general interest to the consortium;

- to take all steps to ensure that the responsibilities within the consortium are met.

## OVERVIEW OF THE GOCE DATA PROCESSING

As explained in the Granada II report, chapter 7 [2], data processing is divided into three consecutive stages:

(1) Quick-look real time orbits from GPS/GLONASS and determination of gravity gradients, common mode accelerations and attitude information (e.g. orientation and angular velocities) from a combined analysis of all sensors (accelerometers, GPS/GLONASS, star sensors, attitude and drag control);

(2) Based upon (1) determination of the best possible set of spherical harmonic coefficients of the Earth's gravity field and precision orbits, including quality parameters (error std. dev.) for orbit and for the set of coefficients. In addition –as derived products, a geoid model, gravity anomaly model and geoid slope model are determined globally as well as in selected regions ; these products are provided to the users as geodetic GOCE data records (**GGDR**s);

(3) The GGDRs produced under (2) serve as input for the further fields of science and application, such as solid earth physics, oceanography, ice research, geodesy and sea level studies. Besides, GGDRs consisting of, for example, calibrated gravity gradients or a high resolution gravity/geoid model in a selected region, will be directly used in some scientific investigations, both in forward and inverse modeling.

The following division of responsibilities seems appropriate:

**To 1** : Stage (1), which is level 0 to level 1b, will be full ESA responsibility since, in the case of GOCE, all satellite sensors and control elements form so-to-say one instrument. This activity will involve –under contract, groups which have expertise with this complex system and with real time GPS processing. The International GPS Service (IGS) must also be involved. In addition, the activity will also benefit from quick-look analysis tools provided by the consortium in the second stage.

**To 2** : Stage(2) requires highest expertise in a large number of special areas, ranging from a new type of precision orbit determination, modeling of ocean and solid earth tides, reference systems, reduction for other time-variable gravity effects, three principal approaches to global gravity field recovery (time-wise method, space-wise method, brute force) and regional methods, numerical mathematics (e.g. solution of very large ill-conditioned systems of equations), etc. It requires a multi-disciplinary entity to be formed, which is to be the **European GOCE Gravity Consortium (EGG-C),** working with and under the umbrella of ESA. EGG-C is born from the previous consortium-like structures CIGAR [3, 4, 5, 6, 7] and E2mG [8], which enabled many European teams to work in synergy over several years in the preparation of the GOCE mission as one candidate of the ESA Earth Explorer Programme. The responsibilities of the consortium are detailed in the next section.

**To (3)** : The consortium produces for ESA the official data products, or **GGDR**s (gravity model parameters, grids of related functionals and error estimates) to be disseminated to the users in all relevant research areas of geodesy and geophysics, and validates the gravity gradient data which will be used as such in some investigations.

## THE DETAILED ROLE OF THE CONSORTIUM

From previous activities carried out by the E2mG teams, and using the same terminology, we have identified the following tasks

**TASK 1: Standards.** Define all standards for the processing and preprocessing phases –in cooperation with the preprocessing teams. Pay attention to the currently used standards in other gravity and altimetry missions (ERS, ENVISAT, TOPEX/POSEIDON, JASON, CHAMP and GRACE, ICESAT, CRYOSAT) in relationship with the scientific goals (e.g. continuity is strongly advocated in oceanography, where reprocessing decades of past altimetry data is very costly). Link with IGS for identifying those standards which may have an impact on the GOCE recovered orbit ; find, if necessary, how to cope with this (changing IGS standards vs. correcting GOCE orbit) . Define and develop required algorithms for the implementation of the adopted GOCE standards.

**TASK 2: Data Bases (archiving, formats, data dissemination and distribution).** Develop the interface with the level 1b data base, and specific data bases with information relevant to all approaches, and develop the data base containing the level 2 products. Assist ESA in distributing the level 2 products on ad hoc media with pertinent documentation.

**TASK 3: Aid to Preprocessing (data validation, effect of temporal variations).** Aid to preprocessing phase (level 0 to level 1b), by designing algorithms and providing tools (software) for: (i) quick-look control of some quantities derived from measurements, data editing, quality assesment of level 1b products; (ii) handling time variable gravitational signals (as reductions i.e. a priori modeling of the variations) - link with the GRACE mission community to possibly take advantage of their findings in this domain.

**TASK 4 : Precise kinematic or/and reduced dynamic orbit determination.** Analysis of critical issues in precise orbit determination (POD) at level 1 and 2, such as: use of accelerometer data outside the gradiometer measurement bandwidth, use of ground support tracking (IGS, with special attention to the sampling requirements), use of satellite attitude data. Determination and provision of a precise kinematic or/and reduced dynamic orbit as input to some approaches in task 5 and to task 9. Independant quality assessment of this orbit.

**TASK 5: Global Gravity Model** ([determination of a gravity model with two or three independent methods). Several alternative methods for the determination of a gravity model have been developed in the course of the CIGAR and E2mGal studies. It is proposed to design, for each chosen approach, software enabling the processing of the data from level 1b to level 2. Some characteristic distinctions are : time-wise global method in orbit parameters ; time-wise global method in space parameters ; space-wise global method ; direct, i.e. brute force global method ; methods employing symmetries ; regional recovery methods with similar distinctions as the global methods. Regional solutions to be obtained by the last type of approach is the subject of Task 9. However it is envisaged to also derive a global model from the patching of regional solutions.

For each approach which EGG-C will decide to implement, one or two software packages should be developed, either from existing ones, or (re-) written from scratch. The trade-off between these two options will be carefully evaluated by the software advisory group in terms of history (existing elaborate material, " cleanliness ") and expertise, development schedule, validation procedures (thorough comparisons of software when two are developed in parallel, at all levels : reference systems, kinematics, dynamics, observable handling, observation equations, solutions), and resources (realistic man-power to be available in each team) ; existing software to be augmented will be carefully reviewed and new software to be built will all have to meet rules and standards established by EGG-C.

Process the data by all selected methods, with all developed software ; for each one (especially the direct global recovery methods) either share the computations between several teams, or conduct all computations in parallel (both strategies assume that comparisons have been absolutely satisfactory –to a prescribed level of agreement) – adopting one policy against the other will depend on the amount of support available at each team.

**TASK 6: Validation of solutions.** Evaluate the global solutions derived by different methods, from the SST, SGG data separately and in combination (by means of inter-comparisons, comparison with ground-truth and with previous high-resolution gravity models, tests against CHAMP/GRACE results, etc.). Make a proposal on the official (i.e. with ESA label) level 2 products to be delivered. Advise also on the level 1b products to be delivered to level 3 (link with task 7 for development of data user manual for proper direct use of such products by the scientists).

**TASK 7: Communication, Documentation, Publication and Public Relation.** Develop and update a consortium Web site for communication and transfer of information (e.g. project milestones, updates on activities) between EGG-C and ESA, the GOCE Science Team, the scientific community and industry, also for public outreach. Document, present, publish and publicize widely the obtained results, make sure all procedures are documented.

**TASK 8: Interface to Science Use (level 3).** Provide GOCE gravity products, as well as complementary data sets, error measures, signal and error covariance models, detailed user handbook, and ancillary software tools, all in a form which is useful and understandable to the science users.

**TASK 9: Regional solutions.** Take taylored approach for high resolution regional gravity field recovery.

## COMPOSITION OF THE CONSORTIUM AND TASK ASSIGNMENT

The long history of the GOCE project preparation (and of its predecessors) has reached a point where the creation of the consortium is the natural culmination of all the efforts. EGG-C was established in November 2000.

**Composition**:

Members have been identified. They are ten teams from eleven major European organisations of which the list is given in Table 1. This composition has been based on the involvement of European groups in the preparation of the GOCE mission in the recent past, and on the expertise of space geodesy groups in gravity field model recovery. Additional competences exist in other groups which could become associate to EGG-C. The members will sign a letter of **Agreement on their participation in EGG-C**. This letter may be followed by a **Memorandum of Understanding** between the national organisations to which the members belong, in order to guarantee their necessary support to them for the EGG-C activities in complement to the resources which are expected to come from ESA.

**Responsibilities and distribution of tasks :**

Starting from the consortium composition as given in Table 1, the major competences in each participating organisation - with respect to GOCE/level 2, was identified. The distribution of tasks also tried to take account of the following considerations :

- necessary parallel developments and overlaps for quality control
- safety (redundance) in the operational phase
- sharing of activities in some tasks - ensuring parts of the two first points

- involvement in other space missions vs. work-load of some teams in the 2001-2007 time frame.
- desirable expansion of smaller teams
- past involvement in support to GOCE
- past cooperation between groups
- expected provision of national funding to GOCE teams (official commitment to be obtained)
- national balance (political considerations).

Table 1. The EGG-C Members

| **Name of team/organisation** | **Country** | **Acronym** | **Group leaders** |
|---|---|---|---|
| Inst. of Theor. Geodesy - Technical Univ. Graz/Austrian Space Centre | A | TUG/ASC | Hans Sünkel |
| Inst. of Astron. and Physical Geodesy/ Techn. Univ.Munich | D | IAPG/TUM | Reiner Rummel |
| Inst. of Theoretical Geodesy/Univ. of Bonn | D | UNIBONN | Karl-Hans Ilk |
| Division 1/GeoForschungsZentrum | D | GFZ | Christoph Reigber |
| Astron.Institute/ Univ. of Bern | CH | AIUB | Gerhard Beutler |
| Dept. of Geophysics/Univ. of Copenhagen and National Survey and Cadastre | DK | UCPH + KMS | Christian Tscherning |
| Groupe de Recherches de Geodesie Spatiale/ CNES | F | GRGS | Georges Balmino & Richard Biancale |
| DIIAR/ Politecnico di Milano | I | POLIMI | Fernando Sanso |
| Delft Inst. of Earth Oriented Space research | NL | DEOS | Roland Klees & Pieter Visser |
| Space Research Organisation Netherlands | NL | SRON | Avri Selig |

Then it was found logical and highly desirable that some teams be paired to contribute to some of the tasks, for instance for task 5 : TUG/AAS and GFZ + GRGS (continuation of long lasting cooperation), IAPG/TUM and DEOS, UCPH + KMS and POLIMI. The partners also considered that it was not desirable that a given team undertakes, with formal responsibilities, the recovery of a gravity model (task 5) by several methods because of the implied and expected workload.

Based on these facts, the agreed assignment of tasks, also of task leadership, resulted in the following:

- Task 1 : **Standards.** GRGS : leader, GFZ
- Task 2 : **Data base, archiving, formats, distribution.** GFZ : leader, TUG/ASC
- Task 3 : **Aid to preprocessing.** SRON : leader, TUG/ASC, UCPH + KMS, POLIMI, DEOS
- Task 4 : **Precise Orbit**
    - 4.1. **Kinematic/Reduced dynamic orbit computation:** DEOS : leader, GFZ, AIUB
    - 4.2. **Orbit quality assessment:** AIUB : leader, IAPG/TUM
- Task 5 : **Global gravity model**
    - 5.1. **Direct/brute force method:** GRGS: leader, GFZ, TUG/ASC + UNIBONN
    - 5.2. **Time-wise method:** IAPG/TUM : leader, DEOS
    - 5.3. **Space-wise method:** POLIMI : leader, UCPH + KMS
- Task 6 : **Evaluation of global solutions.** UCPH + KMS : leader, GFZ
- Task 7 : **Communication, documentation, publication, public relations.** TUG/ASC : leader, IAPG/TUM
- Task 8 : **Interface to Science ( to level 3).** IAPG/TUM : leader, POLIMI, DEOS
- Task 9 : **Regional solutions.** UNIBONN : leader, UCPH + KMS.

Finally, **Hans Sünkel** (TUG-Austrian Academy of Sciences, Director of the Austrian Space Center,and Vice-President of the Graz Technical University) was chosen as **Team leader of EGG-C**.
**Other components of the consortium :**
The Program Manager, Software and data Manager and Software Experts will be appointed at a later stage.

## REQUIRED RESOURCES

The different types of resources which will be necessary to obtain in order to carry on the level 2 activities within the consortium are : manpower (including management), computer facilities, travel expenses. A large part is likely to be covered by national organisations. A significant contribution is expected from ESA.

## RECOMMENDATIONS FOR A FUTURE GOCE-GRACE COMBINED SOLUTION

At a later stage the scientific community should expect some international team to work at producing another global gravity field model (with both static and time-varying parts) from a combination of GOCE and GRACE information. The EGG consortium should therefore link with the GRACE community in some phases of its work to ensure maximum compatibility and therefore minimum reprocessing in the future. The consortium has provided its view to the MAG on how to engage in and undertake the activities in this domain.

## References

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