GOCE MISSION AND *EUPOS®* CONTRIBUTION

GOCE MISIJA UN *EUPOS®* DEVUMS

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At the International Symposium GGG2000 in Banff, Canada, Tscherning, Visser, Rummel, Balmino and other scientists [1,2] explained the idea on the low Earth orbiter (LEO) named GOCE as the first Earth Explorer Mission to fly in the framework of the Living Planet Programme of European Space Agency (ESA). At this time the **G**ravity Field and Steady State **O**cean **C**irculation **E**xplorer (GOCE) was foreseen to launch in the year 2004. The GOCE is dedicated to measuring the Earth's gravity field and modelling the geoid with extremely high accuracy and spatial resolution. A precise model of the Earth's geoid is crucial for deriving accurate measurements of ocean circulation, sea-level change and terrestrial ice dynamics – all of which are affected by climate change.
However, the payload equipment construction problems appeared too complicated. As a result just in 2007 the work has been completed [3] and the final test procedures are carried out in the Netherlands now. The launch has been postponed and currently it is scheduled in spring 2008 [4].

Geoid research teams waiting for GOCE.

During past 8 years since GGG2000 Symposium the research in gravity, geoid modelling and geodynamics has achieved remarkable results. A lot of new data and new solutions has been obtained in TOPEX/Poseydon, Jason, CHAMP and GRACE missions. The 3rd International GOCE User Workshop was held in ESA-ESRIN Frascati Rome, Italy, 6-8 November 2006 where the related achievements were reported. We had an opportunity to take part at this meeting and therefore we are presenting a short overview of Workshop and on some of the papers.
High quality new global geoid models were developed in German and French space research centres [5]. Precise high-resolution global mean gravity field models are

needed in various geodetic-geophysical applications such as precise orbit determination of Earth satellites, GPS levelling, determination of ocean surface currents, etc. For such a models the satellite tracking data used to determine the long-wavelength components but surface gravity data providing the short wavelength. In GFZ Potsdam (GeoForschungsZentrum) and GRGS Toulouse (Groupe de Recherche de Geodesie Spaciale) has been determined several global gravity geoid models. Produced in the framework of EIGEN (European Improved Gravity model of the Earth by New techniques) processing activities. Further improved EIGEN combination models will be used for the upcoming GOCE mission [5].
The anticipated accuracy of the combination of NASA/GFZ Gravity Recovery and Climate Experiment (GRACE) mission results and GOCE mission measurements will give unprecedented accuracy of 1 cm rms of a geoid undulations and sea level variations. The GRACE and GOCE gravity missions will provide the unique improvement of the presentation of gravity spectrum. Integrating the data from both GRACE and GOCE jn a complementary fashion NASA and German scientists getting ready to enhance the time-variable gravity recovery including signals of land hydrology, ocean tides and surface ice mass variations [6].
GOCE Level 3 research programme is supported by German Research Foundation "Mass Transport and Mass Distribution in the Earth System" [7]. This programme aims at an interdisciplinary study of mass related processes and signals based on data from CHAMP, GRACE AND GOCE and satellite altimetry. It includes projects on global and regional ocean circulation, on structure and dynamics of mantle and crust, on temporal mass variability and mass exchange [7].
Within the framework of the GOCE - GRAND II project a regional GOCE validation and combination project is realized in Germany [8]. Absolute gravity observations with a recently developed portable absolute gravimeter, deflections of the vertical measured by using zenith telescope, and GPS/levelling data – they all together employed as independent data sets and they will be used for the validation of global GOCE geopotential models [8].
Italian scientists are preparing to exploit the GOCE data for a local estimate of gravity field and geoid in the Regione Piemonte Area (Northen Italy) and to make a special geological GIS [9]. There are also other ideas how to combine the GOCE and ground data [10].

Ocean research teams waiting for GOCE

After more then 10 years of satellite altimetry the present day accuracy of ocean mean dynamic topography (MDT) estimates rms from 4 to 19 cm at spatial scales of 1˚, reducing to 3-8 cm for larger scales [11]. The Sea level rise has been recognized at 1-2 mm/year during the last century [12].
Intensive research has been carried out by Danish, Norwegian, UK, Canadian people in Arctic region and by German, Italian, French and Spanish scientists over the Mediterranean Sea. Improved knowledge on the gravimetric field in the Arctic is a key to the utilization of satellite altimetry to determine sea-ice thickness and MDT [13]. The satellite based lidar data from ICE Sat has been utilized at the Arctic Gravity Project. Obtained data will be combined with GOCE data for the research extension. The OCTAS project has been developed by Norwegians [14], GOCINA by Denmark [15], and MDT in the Mediterranean and Black sea estimated by joint German and Netherlands team,[16], the South oceans by Taiwan and US research

people [17]. All the mentioned above and many other institutions are ready to acquire the GOCE data and to use them for new achievements studies of the Earth and oceans.

GOCE launch is still ahead.

An improved knowledge of gravity anomalies will contribute to a better understanding of the Earth's interior, such as the physics and dynamics associated with volcanism and earthquakes and also further our knowledge of land uplift due to post-glacial rebound.
ESA GOCE Project Manager, Danilo Muzi highlighting the role of industry in this very challenging satellite's development, said: "Forty-five companies distributed over 13 European countries have been working with ESA on the design of the satellite since 2001. The development of the GOCE satellite represents genuine European industrial cooperation" [3]. GOCE has been designed to fly in a particularly low orbit - at an altitude of just 250 km. The newly developed primary instrument - the gravity gradiometer - measures the terrestrial gravitational field thanks to a set of six ultra-sensitive capacitive sensors. In order to attain the required sensitivity, the gradiometer is combined with a precise GPS-based Satellite-to-Satellite Tracking Instrument to provide accurate three-dimensional positioning of the satellite along its orbit [3]. The spacecraft and gradiometer will undergo the final integration and environmental testing programme to make sure everything is in order to withstand the rigours of launch and the hostile conditions it will experience in space. In spring 2008, GOCE will be launched on a Rockot launcher from the Plesetsk Cosmodrome in north-western Russia, under the responsibility of the German-Russian launch operator Eurockot [3,4].

GOCE at Thales Alenia Space [3], July 2007

GOCE mission objectives:

- To determine the gravity-field anomalies with an accuracy of 1 mGal (where 1 mGal = 10^{-5} m/s^2).
- To determine the geoid with an accuracy of 1-2 cm.
- To achieve the above at a spatial resolution better than 100 km.

GOCE m**ission elements**

- Single rigid octagonal spacecraft of approximately 5 m long and 1 m in diameter with fixed solar wings and no moving parts.
- Gradiometer – 3 pairs of 3-axis, servo-controlled, capacitive accelerometers (each pair separated by a distance of 0.5 m).
- 12-channel GPS receiver with geodetic quality.
- Laser retro reflector enabling tracking by ground-based lasers.

GOCE will carry a 12 channel dual frequency GPS receiver for high accuracy precise orbit determination for the use to accurately geolocate the observations obtained by the primary science instrument – the gradiometer [15]. In addition, the orbit solutions will provide complimentary data for the long-wavelength gravity field part. The GPS receiver has been manufactured by AAS-I Milan plant [18]. GPS receiver has a RIMS antenna made in Spain and is calibrated (Geo++). Receiver will work on the 1 sec regime. The quick look coordinates with an accuracy of 30 m will be determined using only L1 frequency. Post processing coordinates (L1, L2) with accuracy 1-2 cm will be determined using the IGS reference network as bases [19]. GPS data processing will be carried out at the ESA European Space Operation Centre (ESOC), Darmstadt, Germany. To relate the GOCE gradiometer data to the actual Earth models of IERS (International Earth Rotation Service) ESOC can provide a direct link between the GOCE orbit reference frame and the ITRF (International Terrestrial Reference Frame) via simultaneous solutions for the GOCE orbit, the GPS satellite orbits and a substantial network of ITRF ground stations [20, 21].

EUPOS® **Proposal**

The proposal was initiated and discussed at the 3rd GOCE Users Workshop with some of the ESA GOCE project authors in November 6-8, 2006. and was recommended to submit to ESA together with a confirmation that a funding for proposal is not requested from ESA (deadline was 8 December 2006). At the end of November the proposal was discussed in ***EUPOS®*** community [28]. 13 partners from 12 countries sent by email their agreement to participate in project "*EUPOS®* contribution to GOCE mission": Berlin, Bulgaria, Bosnia and Herzegovina, Czech Republic, Estonia, Hungary, Latvia (LATPOS and *EUPOS-RIGA),* Lithuania, Poland, Romania, Slovakia, Ukraine. On the 8 December 2006 the Project proposal was submitted to ESA and on the 6 March 2007 Principal investigator J,Balodis did receive the Final acceptance from ESA.

Objective of the project

- Contribute to high accuracy coordinate determination of the GOCE satellite in order to achieve the highest accuracy geoid over the territories of *EUPOS®* countries.
- Obtain from ESA for the scientific use of *EUPOS®* countries the final product – improved geoid model the result of GOCE mission.

EUPOS® activities

1. Determine the homogeneous post processing coordinates of *EUPOS®* reference stations within the framework of IGS/EPN reference network regularly for periods when the GOCE satellite will pass over the corresponding *EUPOS®* country.
2. Receive from ESA raw GPS observations of GOCE satellite over the territories of *EUPOS®* countries regularly.
3. Determine the post processing coordinates of GOCE satellite on each flight over the corresponding territories of *EUPOS®* countries with respect to the coordinates of the *EUPOS®* reference stations.
4. Present the post processed coordinates of the *EUPOS®* reference stations and GOCE satellite to ESA.
5. Receive the final geoid model for scientific use from ESA after the GOCE mission.
6. The *EUPOS®* reference stations should be tied to the national 1-2 order levelling network.
7. It is preferable to use the homogeneous computation scheme of GOCE coordinates. Therefore the use of GNSMART or Burmese software software recommended.
8. The coordination of activities by *EUPOS®* International Steering Committee (ISC) will be performed.

Activities in 2007

After the ***EUPOS®*** Riga meeting on the March 30, 2007 the working group Janis Balodis, Gerhard Wubbena. Jaroslav Šimek and Tamas Horvath discussed on the activities necessary to perform in April. The following issues have been agreed:

- The subset of stations of National ***EUPOS®*** network should be selected which are based on a most stable monuments where the 1-2 order levelling benchmarks are not far.
- The height determination of those antennas should be performed.
- The site evaluation according the SQII instructions should be performed.
- The coordinate calculation of those stations should be processed within the network of surrounding IGS stations.

After preliminary overview of the *EUPOS®* network the conclusion was done that actually all the *EUPOS®* countries are working continuously within the framework of EUREF. Our colleague from Czech Republic Jaroslav Šimek is a member of the Technical Working Group of EUREF. Geodetic Observatory Pecny is one of the IGS Analyses Centres [22]. Hopefully, Jaroslav Šimek and Geodetic Observatory Pecny will play an important role in "*EUPOS®* contribution to GOCE mission." Many other representatives of the *EUPOS®* countries are high level specialists in geodetic network development. The EUREF activities continuously directed to achieve the common European network. *EUPOS®* countries are active participants in EUREF projects. The number of EPN/IGS stations one can see the Table 1. Herewith we can conclude that there are reasonable grounds to believe that in each country *EUPOS®* network is tied in common IGS network. The "*EUPOS®* contribution to GOCE mission" will show also the strength and quality of the common *EUPOS®* network as well as of the each country individually. . GOCE belongs to the Low Earth Orbiters (LEO) and it will fly at an altitude of 250 km. Other LEO satellites were on the higher orbits: CHAMP – 400km, GRACE – 500 km. The analyses of LEO orbital data has achieved very high accuracy [23] and it serves also as a control tool for ground based reference station network [24]. The IGS stations were invited to take part in Pilot project for real-time LEO satellite positioning in time span 2007-2010 [25]. It will be more professional pilot project comparing with EUPOS. First IGS pilot project of LEO positioning commenced in 2001 [26]. However, the "*EUPOS®* contribution to GOCE mission" will have more dense network over East European territory. Of the other tracking data sets Satellite laser ranging (SLR) is usually considered as the most reliable indicator of LEO orbit precision.

Table 1. List of the EPS/IGN stations in *EUPOS®* countries [23, 25].

#	Country	EPN	IGS	
1	Berlin	1	1	**Germany: 15; 7**
2	Bolgaria	1	-	
3	Bosnia and Hercegovina	1	-	
4	Czech Republic	3	1	
5	Estonia	1	-	
6	EUPOS-RIGA	1	1	**Riga (Univ.of Latvia)**
7	Hungary	4	1	
8	Latvia	1	1	**The same Riga**
9	Lithuania	1	-	
10	Poland	10	6	
11	Romania	5	1	
12	Slovakia	3	1	
13	Ukraine	8	7	
	Total	**39**	**19**	

This is partially because of the high precision of the SLR data itself, and partially because the data is in most cases too sparse to introduce major dependencies in the Precise orbit determination solution. The main objective of SLR retroreflectors on LEO satellites is to provide an independent observation of the orbit. Both for CHAMP and JASON, the SLR data forms the main source of information on orbit precision [27,28].

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Balodis J., Silabriedis G. GOCE Mission and EUPOS® Contribution. *The short overviw on the 3rd GOCE User's Workshop has been presented. The objectives and the elements of GOCE mission has been described. The project "**EUPOS®** contribution to GOCE mission" has been shortly described.*

Balodis J., Silabriedis G. GOCE misija un EUPOS® devums. *Sniegts īss pārskats par 3.GOCE lietotāju darbnīcu. Apskatīti GOCE misijas mērķi un tās elementi. Sniegts īss apraksts par projektu "**EUPOS®** kontribūcija GOCE projektam."*

Балодис Я. Силабриедис Г. Миссия ГОЦЕ и вклад ЭУПОС®. *Дан краткий обзор пользователей проекта ГОЦЕ3. Рассмотрены цели миссии данного проекта и ее элементы. Кратко охарактеризованы активитеты проекта ЭУПОС® и вклад его в проект ГОЦЕ.*