Low Orbit Operations of ESA's Gravity Mission GOCE

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The Gravity Field and Steady-State Ocean Circulation Explorer (GOCE) of the European Space Agency was launched on 17th March 2009 with the objective of providing data for establishing a model of the Earth's gravity field with unprecedented accuracy, embarking as payloads an Electrostatic Gravity Gradiometer and a scientific GPS receiver.

During its nominal mission, GOCE was operated by ESA's European Space Operations Centre (ESOC) in an extremely low Earth orbit at an altitude of 260 km.

Owing to the drag environment in which GOCE is operated, the spacecraft is aerodynamically shaped and employs a unique Drag-Free Attitude and orbit Control System (DFACS). The DFACS uses an ion propulsion system and the gradiometer to dynamically measure and counteract the drag caused by the residual atmosphere of the Earth, maintaining the orbit and cancelling out the effects of non-gravitational perturbations on the spacecraft dynamics.

GOCE has already met its nominal mission objectives in 2012 and has contributed to greatly improve the knowledge of Earth's Gravity Field. The satellite is still in very good shape and the low solar activity levels experienced since launch have allowed to save fuel, giving the opportunity to perform a special operations campaign before the end of mission.

Owing to the specifics of the mission with its extraordinary mission profile and technological features –no other spacecraft is flying at such a low altitude and embarking such a sophisticated system for the sensing of gravity field gradients–, the only way of significantly improve the accuracy of the gravity field measurements is to further lower the orbit. Answering a strong recommendation from the scientific community, ESA has planned an extensive lowering of the orbit by 20 km. The mission will be operated at this altitude up to when the satellite runs out of fuel for the ion propulsion, causing a fast re-entry in the Earth atmosphere expected for the second half of 2013.

ESA went through a phase of feasibility study and mission profile re-definition, also supported by the satellite manufacturer, in order to select the target altitude and descent pattern compatible with (i) assumptions on solar activity levels in 2012 and 2013; (ii) the capability of the satellite to fly in presence of drag levels exceeding its design specification; (iii) the power budget re-estimated using flight data; (iv) the increased risks of operating the spacecraft at a significantly lowered altitude.

An important driver for the selection of the new mission profile was the capability of the ground segment to promptly recover from an interruption of drag-free mode. In the presence of high drag levels at low altitudes such an anomaly leads to a quick orbit decay, with ground having to recover before the altitude becomes so low that the ion propulsion cannot deliver enough thrust to prevent the satellite from re-entering. Special measures at ground segment level were put in place to counter the additional risks of operating the spacecraft at the newly selected altitude.

Following the new mission profile, the GOCE altitude was lowered to 251 km in August 2012 and further decreased to 245 km in November 2012. The last manoeuvre to bring the satellite down to 240 km will be executed in early 2013. This step-wise descent profile was selected in order to verify the satellite behaviour as the altitude was lowered and to gradually prepare the Flight Operations Segment for low orbit operations.

Interesting phenomena were experienced linked to the altitude lowering, like spurious simultaneous blindings of the three independent Star Trackers arguably caused by the effects of Auroras, or rapid increases of atmospheric density in presence of geo-magnetic storms, leading to the DFACS not fully compensating the instantaneous peaks in the drag level.

Following an introduction to the GOCE mission and satellite, the paper will discuss the drivers which led to planning a lowering of the GOCE orbit, the studies performed in preparation for this challenging phase, and finally the resulting new mission profile. The paper will also report on the unique flight experience during the descent phase and at the target altitude of 240 Km, with particular emphasis on the Drag Free Attitude and orbit Control System.