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Next Generation Gravity Mission: a Step Forward in the Earth's Gravity Field Determination

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This paper concerns with the "System Support to Laser Interferometry Tracking Technology Development for Gravity Field Monitoring" study of the European Space Agency, a mission study for monitoring the variations of Earth's gravity field at high resolution (up to harmonic degree 200) over a long time period (>5 years). The mission exploits the use of a heterodyne laser interferometer for the high-resolution measurement of the displacement between two satellites flying at low altitude (around 325 km). More in details, employing a formation of two co-orbiting satellites at 10 km relative distance, a resolution of about 1 nm rms is needed in the inter-satellite distance measurement, and the non gravitational accelerations must be measured with a resolution of about 10-10 m/s2 rms to achieve geoid height variation rate error equal to 0.1 mm/year at degree 200. Starting from the geophysical phenomena to be investigated, a detailed derivation of the mission requirements on the orbit, satellite formation and control, measurement instruments (laser interferometer and accelerometer) was performed using analytical models and numerical simulations, and the satellite GNC (Guidance, Navigation & Control) was approached through different techniques.

A possible solution for the optical metrology suitable for the realization of a Next-Generation Gravimetric Mission has been identified, designed, breadboarded and tested to a level of detail sufficient to assess its feasibility. The main elements of this optical metrology are:

1) a Michelson-type heterodyne laser interferometer for measuring the distance variation between the retro-reflectors installed on two satellites. The innovative feature of the interferometer consists in chopping the laser beam with a frequency related to the satellite distance. This enables its proper functioning with a retro-reflector placed at large distances (around 10 km) from the source;

2) an optical device consisting of three small telescopes endowed with Position Sensing Detectors (PSDs). Basically, the satellite orientation relative to the interferometer laser beam and the lateral displacement of the laser beam axis from the retro-reflector are measured from the position and optical power of the laser beam portions focused on the PSDs.

The lateral displacement information is utilized for driving a "Beam Steering Mechanism" that keeps the laser beam emitted by one satellite pointed towards the retro-reflector on the other satellite. Both the laser interferometer core and the telescope assembly of the angle/lateral metrology have been breadboarded and tested.

This paper will be organized as follows: Section I will introduce the problem of the geoid determination, gravity field retrieval and the prior mission GOCE. Section II will describe the next generation gravity mission, the measurement models and requirements derivation. Section III will give an overview of the laser metrology system design and the metrology proof of concept. Finally, Section IV will be focused on the mission control issues, as the drag-free and the loose formation flying control, the attitude control and the Laser Beam Pointing Control.