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CubeSat tracking and precise orbit validation using Satellite Laser Ranging

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Satellite Laser Ranging (SLR) to Low Earth Orbiters (LEO) provides optical distance measurements with mm-level precision. The range measurements can be used as a unique technique to validate satellite orbits derived from GNSS microwave observations. Furthermore, both observation types can be combined and processed together to mitigate the systematic errors of the generated satellite orbit. With the increasing popularity of miniaturized satellites in recent years, the need for an adapted Precise Orbit Determination (POD) payload for CubeSat arises. We have developed a small-size versatile payload board using commercial off-the-shelf low-cost multi-GNSS receivers with extremely small weight (1.6 g), size (12.2 x 16.0 x 2.4 mm) and power consumption (100 mW). A small array of three laser retroreflectors has been designed and mounted at the nadir side of the satellite enabling satellite orbit validation with SLR. In collaboration with the company Astrocast, the GNSS board and the laser retroreflector array have been successfully launched onboard 3-Unit CubeSats.

The goal of the POD payload development is to investigate CubeSat orbit determination in real-time and in post-processing based on low-cost multi-GNSS receivers onboard the satellite, and to demonstrate the benefit of a satellite constellation by validating the orbits with SLR measurements. The SLR retroreflector array consists of three small corner cubes with a diameter of 10 mm and a height of 7.5 mm, forming a triangular shape, inclined 20° from the nadir direction and the rear two corner cubes rotated by +30° and -30° outward compared to the anti-flight direction to increase the footprint on the ground. They are very efficient instruments, small, light-weight, passive, and do not require any power. Tracking of the Astrocast satellites is only required during several concentrated time periods of few days. With the support of the International Laser Ranging Service (ILRS), two SLR Campaigns for tracking the CubeSats have been performed and selected SLR stations tracked the two precursor satellites. In total 204 normal points from 8 satellite passages were generated and officially released by the European Data Center (EDC).

The GNSS receiver firmware enables multi-constellation Navigation Solutions (NAVSOL) and raw data output in space. The independent SLR measurements with high accuracy were used to validate the CubeSat orbits obtained by the onboard GNSS receivers. The differences between measured and modeled ranges serve as a quality indicator for the assessment of orbits derived by radiometric tracking techniques. The results show a good agreement between SLR orbit validation and the 3D RMS of a daily orbit fit through the NAVSOL data of the two precursors collected onboard, and an accuracy of about 5 m has been achieved in real-time positioning despite errors caused by the ionospheric refraction. The recording of GNSS raw

data using onboard receivers was enabled for some orbit arcs. SLR measurements are used here as well to validate the precise orbits derived in post-processing and to investigate systematic orbit errors. It is shown that SLR validation of LEO satellites is not only able to detect radial but also along-track and cross-track offsets.

We will present the design of the dedicated retroreflector array and the quality test in a laboratory on ground, the orbit prediction, satellite visibility and link budget simulation for the SLR campaigns, and the results of orbit validation using SLR measurements.