Benefits of SLR Tracking for Galileo Orbit and Attitude Determination

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Satellite laser ranging (SLR) has proven to be a unique and powerful tool for over two decades in the calibration and validation of spacecraft dynamics. The technique's greatest strength—in contrast to microwave measurements—is its ability to provide an independent, unambiguous, and absolute observation of a satellite's orbit. This makes SLR invaluable, especially for global navigation satellite system (GNSS) spacecraft with higher area-to-mass ratios and increased sensitivity to radiation pressure, such as the European Galileo or Japanese Quasi-Zenith Satellite System (QZSS) satellites. As orbit determination strategies have reached unprecedented levels of precision and accuracy, the ultimate question arises of whether SLR measurements can directly contribute to precise orbit determination (POD) of GNSS satellites. In this presentation, we report on the efforts of the European Space Agency's (ESA) Navigation Support Office (NSO) to improve Galileo POD solutions through a careful combination of radiometric and SLR range measurements at the observation level. For this technique to be effective, high-fidelity spacecraft models and quick-look normal point (NP) data have been used from an intense Galileo SLR tracking campaign aptly named SUCCESS. Launched by the European Laser Network (EUROLAS) in mid-May of 2019, the three-week campaign provided an unmatched number of greater than 1000 NPs for two selected Galileo spacecraft: GSAT0102 and GSAT0220. When compared to solutions without SLR data, the precision of the orbits of the two satellites was improved by more than 10 percent. The presentation also discusses the presence of station-specific SLR biases, taking advantage of near-simultaneous tracking of GSAT0102 and GSAT0220 by two or three separate laser sites. Finally, we demonstrate that full rate data from a single SLR kHz system can be used to determine the Galileo satellites' yaw state during an eclipse maneuver with about eight-degree accuracy in terms of the root-mean-square (RMS). This approach takes advantage of the 1.0 m distance between the Galileo laser retroreflector array (LRA) and the spacecraft's rotation axis to estimate the yaw angle in a recursive least-squares algorithm, epoch by epoch. The discussed technique may serve as an interesting alternative to reverse kinematic point positioning, particularly for LRA-equipped satellites without significant transmit antenna phase center offset.