Paper ID: 71017
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student

IAF SPACE COMMUNICATIONS AND NAVIGATION SYMPOSIUM (B2)
Advances in Space-based Navigation Technologies (1)

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LUNAR GATEWAY AUTONOMOUS ORBIT DETERMINATION AND TIME SYNCHRONIZATION BY THE USE OF ONE OR TWO SMALL ORBITERS

Abstract

The Lunar Gateway is intended to serve as a communication hub, science laboratory, and short-term habitation module and is planned to be deployed in a highly elliptical seven-day Near-Rectilinear Halo Orbit (NRHO) around the Moon. Having a precise Orbit Determination of the Gateway can open the way to many possibilities, such as the integration in a future Lunar Navigation System or, more in general, it could assume the function of anchor point for any localization measurement from other spacecraft.

In this work, we propose to use one or two additional orbiters, in the same orbit and close to the Gateway, for a precise autonomous orbit determination without the use of any Earth-based tracking system. The autonomous orbit determination exploits the particularity of the three-body problem, i.e. Earth, Moon, spacecraft. In fact, due to the strong asymmetry of the three-body force field, a spacecraft in a NRHO can track a second spacecraft and determine their absolute positions and velocities simultaneously, exploiting only scalar satellite-to-satellite tracking data, such as inter-satellite range measurements.

Once having a precise orbit determination, by exploiting the orbiters, the Gateway (and orbiters) can also be synchronized with the Earth exploiting only the reception of a GNSS signal. Having the satellites' absolute position, the time synchronization is based on the measurement and comparison of the pseudorange with the expected known distance, without the limitations due to the inversion of an ill-conditioned navigation problem or to the very high Dilution Of Precision usually experimented by a lunar GNSS user. Finally, due to the proximity of the orbiters to the Getaway and the simplicity of the range measurements system the additional orbiter(s) can be very simple, small and with low cost.

In the paper, different simulations are performed using an orbit determination algorithm based on a sliding window weighted least squares approach in an unperturbed Circular Restricted Three-Body Problem. The results show that precise orbit determination can be obtained even by introducing only one additional orbiter. For example, sub-meter accuracy is obtained exploiting inter-satellite range measurements every 120 minutes accumulated for 3 orbital periods. In the case of two additional orbiters, it is possible to achieve the same level of performance accumulating the measurements for only 2 orbital periods. Furthermore, it has been demonstrated that there is no need for large angular separation between the orbiters and the Gateway and the GNSS time synchronization error is maintained below few nanoseconds.