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GUIDANCE STRATEGIES TO DEPLOY A LUNAR SATELLITE CONSTELLATION FROM GATEWAY

Abstract

In recent years, lunar constellation design and deployment has attracted a strong interest from the scientific community and some major space agencies. In fact, a similar space infrastructure will represent a valuable asset for navigation and telecommunications purposes, useful to many robotic and human activities on the lunar surface. This study focuses on the analysis, design, and testing of three different feedback guidance strategies for the deployment of a lunar constellation, starting from Gateway. Orbit dynamics is modeled in a high-fidelity framework that employs planetary ephemeris and includes all the relevant orbit perturbations, i.e. the gravitational attraction due to Earth and Sun and several harmonics of the selenopotential. A constellation composed of 6 satellites is considered. They travel two distinct frozen, lunar elliptic orbits, with proper mutual phasing. The first deployment strategy assumes that each satellite uses high-thrust propulsion to enter its operational orbit, with correct phasing. To do this, a new, pre-optimized, iterative Lambert-based algorithm is proposed as an effective real-time guidance technique, capable of determining all the (modest) intermediate correction maneuvers, to drive each satellite toward the desired position. The second deployment strategy assumes again the use of high thrust, while including two distinct phases: (a) orbit acquisition and (b) phasing. Specifically, in phase (a) three satellites are arranged as a cluster and travel toward their orbit, leveraging the iterative Lambert-based guidance. In phase (b), each vehicle performs phasing maneuvers, to get its correct position. A simple and effective approach is described that avoids leaving the operational orbital plane, in spite of perturbations, and the tradeoff between phasing duration and propellant expenditure is characterized. The third deployment strategy includes again two phases: (a) low-thrust orbit acquisition and (b) phasing. In phase (a), the satellites are clustered and embarked onboard two cargo spacecraft, equipped with a low-thrust propulsion system. Nonlinear orbit control allows identifying a saturated feedback law for the low thrust magnitude and direction, and is shown to be effective as a guidance technique for each cargo vehicle. The closed-loop dynamical system at hand is proven to enjoy quasi-global stability properties, leveraging the Lyapunov stability theory. In phase (b), each satellite performs again phasing maneuvers, as in the preceding strategy. The three deployment strategies are evaluated in both nominal and nonnominal flight conditions, with the intent of showing their effectiveness while comparing their performance, in terms of propellant consumption and overall deployment duration.