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SPACE DOMAIN AWARENESS FOR CISLUNAR SPACE: PARAMETRIZATION AND CHARACTERIZATION OF COMMON MISSION SCENARIOS

Abstract

While the detection, identification, tracking and cataloguing of objects in traditional Earth-bound orbits remain a pressing issue, the burgeoning exploitation of cislunar space poses yet another challenge for Space Domain Awareness (SDA). With the Lunar Gateway and increased international efforts to explore and exploit the Moon and xGEO (beyond GEO) space, SDA for this dynamically complex environment necessitates improved understanding of the inherent stability properties of xGEO trajectories, of station-keeping requirements, and of deep-space surveillance. These factors impact viewing geometries and required observation campaigns for proper object identification, tracking, inter alia. It is now necessary to provide: (a) a more complete characterization of the dynamical environment; (b) effective parametrization approaches for orbits and transfers of interest; and (c) quantification of inaccuracies and uncertainties in the orbit determination process with an understanding of how these factors affect the feasibility of cislunar SDA and catalog maintenance.

This study partially addresses such topics through the reassessment of the overlooked applicability of geocentric and selenocentric orbital elements (when within the Moon's Hill sphere) to describe the motion of cislunar objects and to maintain an xGEO catalog. We reproduce, in a high-fidelity ephemeris model, common station-keeping maneuvers, transfers between quasi-periodic Lagrange orbits, lunar mean-motion resonant orbits (such as those of the IBEX and TESS spacecraft), and DROs proposed as parking orbits for interplanetary missions. This work then showcases the utility of orbital elements to parametrize cislunar trajectories and to identify transfer and station-keeping maneuvers, and it assesses how inaccuracies and uncertainties in the orbit determination process affect the orbital-element parametrization and orbit-prediction capabilities. This study thus provides a comprehensive analysis of potential cislunar mission scenarios and supports current efforts to face the apparent challenge of SDA in the soon-to-be-populated cislunar space.