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EVOLUTION OF THE OUT-OF-PLANE AMPLITUDE FOR QUASI-PERIODIC TRAJECTORIES IN THE EARTH-MOON SYSTEM

Abstract

For decades, the collinear libration points have been viewed as potentially useful locations to support both communications and scientific observations. Since the late 1970's, a number of missions have successfully operated in the vicinity of Sun-Earth collinear libration points including ISEE-3, WIND, SOHO, ACE, MAP, and Genesis. Despite the successes of past Sun-Earth libration point missions, no spacecraft had ever flown in the vicinity of an Earth-Moon libration point until August 2010 when the first ARTEMIS spacecraft inserted into orbit near the Earth-Moon L2 point. Due to the continuing success of the mission, it seems likely that interest in the Earth-Moon libration points will continue to increase.

The ARTEMIS libration point orbit design features Lissajous orbits with z-amplitudes, i.e., excursions normal to the lunar orbit plane that vary greatly over the course of the mission. The evolution of the z-amplitude is highly sensitive to small perturbations in position or velocity and deterministic correction maneuvers are designed as specific point solutions to ensure that the spacecraft trajectory retains the required lunar arrival conditions several months in the future. However, these successfully designed corrections do not yield any useful generalizations about the trajectory behavior at later epochs along the path or for future mission applications. Development of greater intuition concerning the Lissajous trajectory evolution and the potential trade-off relationships in this dynamical environment is essential for effective future spacecraft operations in the Earth-Moon regime. First, it is necessary to understand the underlying dynamical structure that produces the z-amplitude evolution and to explore the sensitivity of this out-of-plane component to changes in lunar eccentricity and solar perturbations. This analysis is accompanied by a comparison of results from numerical simulations in both the restricted three-body model and higher-fidelity Earth-Moon-Sun ephemeris models. Initial studies indicate that lunar eccentricity and solar gravity create a small but non-negligible effect on z-amplitude evolution.

Numerical differential corrections algorithms are also required to both predict and control the evolution of these unstable trajectories via the determination of locations along the trajectory that are best-suited for deterministic maneuvers. This capability is explored by decomposing the path into a series of segments separated by impulsive maneuvers. The total cost is constrained and maneuver placement strategies that meet a total cost requirement are developed. Ultimately, the process translates into specific procedures to ensure that the spacecraft satisfies desired end-of-mission criteria despite the highly sensitive Earth-Moon environment.