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RAPID TRAJECTORY DESIGN IN THE EARTH-MOON EPHEMERIS SYSTEM VIA AN INTERACTIVE CATALOG OF PERIODIC AND QUASI-PERIODIC ORBITS

Abstract

With the increasing complexity of space missions, there is significant interest in a trajectory design approach that requires fewer resources and delivers results sustainable over long term scenarios. Such goals may be achieved by leveraging the natural dynamical structures in the Earth-Moon system to guide the selection of a baseline trajectory. A well-informed trajectory design process may be particularly beneficial for several upcoming mission concepts including exoplanet observatories, in situ exploration of asteroids as well as redirect concepts, and lunar cubesat missions. To supply a framework for incorporating knowledge of the dynamical accessibility in the Earth-Moon system, Purdue University and NASA Goddard Space Flight Center have been developing an interactive adaptive design process exploiting a reference catalog of periodic and quasi-periodic orbits to enhance efficient trajectory design in such complex environments.

The design of a baseline trajectory is nontrivial in a dynamically sensitive environment. In fact, in a higher-fidelity multi-body regime, the comparison of a large set of candidate solutions demands significant, and often prohibitive, time and computational resources. However, the well-studied Circular Restricted Three-Body Problem (CR3BP) can provide a reasonable approximation to the actual dynamical environment. In this simplified model, periodic and quasi-periodic orbits govern the underlying dynamics and are approximately retained in higher-fidelity models. Characterization of various families of periodic orbits facilitates an initial trade analysis within the global solution space. Quasi-periodic motion, which inherits the behavior of a nearby periodic orbit, further expands the set of design options, thereby allowing identification of trajectories that may satisfy the mission requirements when transitioned to an ephemeris model.

This investigation demonstrates the utility of a ‘dynamic’ catalog of fundamental structures in the CR3BP to guide the design of trajectories in an Earth-Moon ephemeris model. Within this interactive environment, periodic and quasi-periodic solutions are characterized by parameters to aid trajectory design and selection. Through a graphical interface, users may interactively filter and define trade spaces to explore the orbital options. Following selection of the desired solution behavior from an initial trade, families of periodic and quasi-periodic orbits can be explored in further detail. Any orbits that may, potentially, satisfy the mission requirements are then exported for use in an end-to-end adaptive trajectory design suite that incorporates a higher-fidelity dynamical model. As demonstrated through sample mission

concepts, the trajectory characteristics rapidly selected using a ‘dynamic’ catalog of periodic and quasi-periodic solutions in the CR3BP are approximately retained in the Earth-Moon ephemeris system.