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BALLISTIC LUNAR TRANSFER DESIGN TO ACCESS CISLUNAR PERIODIC AND QUASI-PERIODIC ORBITS LEVERAGING FLYBYS OF THE MOON

Abstract

In 2020, NASA released the agency's lunar exploration program overview, offering the latest Artemis and Gateway status as well as plans for additional extended lunar missions. To enable these endeavors, efficient path planning in a multi-body dynamical environment is critical. However, the complex dynamics in these regimes present difficulties in preliminary trajectory design from Earth to desired destinations in the lunar vicinity. To overcome these difficulties, missions can benefit from design strategies that leverage structures of multi-body systems.

This investigation focuses on examining ballistic lunar transfer trajectories that leverage solar gravity to access the lunar region within the context of a four-body problem. Specifically, periodic and quasi-periodic orbit destinations in the Bicircular Restricted Four-Body Problem (BCR4BP) are explored. The BCR4BP serves as a useful model for preliminary trajectory design in regimes where the gravitational acceleration of the Sun, Earth, and Moon are significant. The force imparted by these three massive bodies is incorporated into a single model, while reducing the complexity from added perturbations of an ephemeris model. Additionally, Poincaré maps are used to represent information about manifold structures from periodic and quasi-periodic orbits that inform the generation of initial guesses for ballistic lunar transfers. Subsequently, deterministic maneuvers are introduced and families of solutions are computed to expand the available solution space. Lastly, additional constraints are imposed and solutions from the BCR4BP are validated in an ephemeris model to demonstrate a framework for end-to-end design.

The results of this investigation demonstrate how leveraging dynamical structures in the BCR4BP aids in the construction of ballistic lunar transfers. Including the gravitational force of all three bodies in a single model builds intuition during the design process. Exploiting the structured motion reduces the computation time required as compared to larger, less informed grid searches. Families of solutions provide a wider understanding of the dynamical flow for a particular transfer geometry. Furthermore, demonstrating the flexibility of this framework may inform future designs.