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ON THE REFINEMENT OF LOW-ENERGY EARTH–MOON TRANSFER FAMILIES INTO AN EPHEMERIS MODEL

Abstract

Interest in the exploration of our natural satellite is growing exponentially, with space agencies and industries working to soon return humans to the Moon. This is a crucial step towards establishing outposts in farther reaches of the solar system.

Designing efficient interplanetary trajectories remains a complex endeavor. Spacecrafts motions are influenced by the simultaneous gravitational pulls of celestial bodies, which make the space environment dynamically rich and of difficult interpretation. However, this intrinsic complexity allows for the design of low-energy Earth–Moon transfers, albeit with longer travel times. Preliminary analyses often utilize simplified dynamic models to identify efficient transfer options, leveraging unique dynamic structures enabled by these frameworks. Notwithstanding, refinement into an ephemeris model, representative of the true environment, is essential to ensure flyability in realistic scenarios.

A database of locally optimal two-impulse Earth–Moon transfer trajectories was previously processed to label transfers as interior, exterior, or mixed depending on their geometries in the Earth–Moon synodic frame. Their motions respect the dynamics prescribed by the planar Earth–Moon, Sun-perturbed bi-circular restricted four body problem. Clustering techniques automatically identified common transfer families. As a natural continuation of that study, this research focuses on the refinement of trajectories into an ephemeris model. Understanding how intricate trajectories evolve during refinement in chaotic environments is critical to ease the design process of future lunar missions.

This study examines the process of smoothly refining a transfer belonging to a certain family towards its more realistic counterpart. The destination dynamics is described by the Earth–Moon roto-pulsating ephemeris model, which includes the attraction of all most relevant celestial bodies and the solar radiation pressure. Depending on the family of belonging, the pulsation of the primaries and the real solar attraction most significantly affect the deviation of the trajectories from their original paths. Therefore, a rule for identifying suitable departure epochs ensures refined trajectories preserve key features of their original seeding ones. We investigate the underlying relationships between transfers properties before and after the refinement process, exploring how these relationships vary across different cluster families. The importance of this work lies in enhancing understanding of the dynamic rules governing two-impulse low-energy lunar trajectories, thereby enabling more informed design practices for future missions.