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LUNAR TRANSFER TRAJECTORIES TO QUASI-STABLE DISTANT RETROGRADE ORBITS USING INDIRECT OPTIMIZATION METHOD

Abstract

This research focuses on identifying optimal trajectories for inserting satellites into Distant Retrograde Orbits (DROs) around the Moon with minimum propellant usage, contributing to cost-effective strategies and enabling heavier payloads for future cislunar missions. This study is motivated by the growing interest in establishing a scientific presence in cislunar space, with initiatives aiming to position orbital stations on such orbits, or to utilize lunar resources and create a launchpad for missions to Mars and beyond. NASA's Artemis program is heading in this direction. Among potential locations, Quasi-Periodic Orbits around Lagrangian Points, including DROs and Near-Rectilinear Halo Orbits (NRHOs), present promising options. DROs, in particular, offer significant advantages due to their stability, reducing maintenance costs and prolonging mission lifespans.

To optimize DRO insertion trajectories, a Multi-point Boundary Value Problem approach is employed, designed to enhance solution convergence due to the chaotic gravitational dynamics between Earth and the Moon. The approach utilizes an iterative shooting procedure with a bang-bang thrust control law based on an optimal control indirect method formulation. Predefining thrust and coast arcs aids in the numerical method's convergence, with the Pontryagin's Maximum Principle providing a basis for ensuring the optimality of control solutions.

DROs are initially computed within the framework of the Circular Restricted Three-Body Problem (CR3BP) and are subsequently transitioned to a higher fidelity n-body model. This dynamic model incorporates the gravitational influence of Earth, Moon, and Sun, and uses JPL's DE440 ephemeris to account for the positions of these celestial bodies over time. Solar radiation pressure is also considered, impacting both the injection trajectory and the quasi-stable DROs.

Results indicate that two-burn trajectories present the most efficient means for achieving DRO insertion, effectively exploiting the lunar gravitational interaction during swingbys. Additionally, variations in departure dates and the influence of lunisolar gravitation are shown to significantly impact trajectory evolution, revealing diverse behaviours based on the relative positions of celestial bodies.