Paper ID: 86811
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IAF ASTRODYNAMICS SYMPOSIUM (C1)
Interactive Presentations - IAF ASTRODYNAMICS SYMPOSIUM (IPB)

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REACHABLE SET OF INVARIANT MANIFOLD WITH LOW THRUST

Abstract

Earth-Moon liberation point orbits (LPOs) are viable options for scientific exploration. Increasing attention has been paid on Earth-LPO transfers using low-thrust propulsion due to its benefits on saving fuel expenditures. The invariant manifold provides a dynamical corridor to LPOs. No further maneuvers are needed to reach LPO when the spacecraft is inserted into the stable manifold. However, solving optimal low-thrust Earth-LPO trajectories by leveraging the stable manifold is time-consuming. It is necessary to develop an efficient method to assess the feasibility of Earth-LPO trajectories with the given mission parameters.

In this work, the reachable set of the stable manifold with low thrust is studied. First, the high-dimensional reachable set is projected to the planar one depicted on the Tisserand-Poincare (T-P) graph. To reach the LPO from an Earth orbit, the spacecraft must traverse several resonance regions in the phase space of the Earth-Moon three-body problem. The resonance region is characterized by the ratio between the spacecraft and the Moon's orbital periods. Since a simple relationship exists between the resonance ratio, perigee and apogee of the trajectory, the T-P graph whose coordinate axes are the perigee and apogee is employed. Another advantage of the T-P graph is that it can illustrate the relationship of the resonance and the varying Jacobi constant of the low-thrust trajectory.

Second, the multi-objective optimal control problem that minimizes the perigee and apogee of the low-thrust trajectory is established. With the given transfer time and the thrust-to-mass ratio, the lower boundary of the reachable region is solved by using the multi-objective genetic algorithm. The adjoint control transformation is used to connect physical variables to initial costates. The corresponding resonance of the lower boundary denotes the innermost resonance that can be reached by the controlled trajectory. Lower boundaries for different mission parameters are illustrated and compared on the T-P graph, which can be used to assess the transfer feasibility without solving optimal Earth-LPO trajectories.