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ESCAPE TRAJECTORIES FROM EARTH-MOON AND SUN-EARTH QUASI PERIODIC ORBITS WITH ELECTRIC PROPULSION

Abstract

Optimal low-thrust trajectories for the direct escape from Earth's sphere of influence starting from Sun-Earth or Earth-Moon libration points regions are analyzed with an indirect optimization method. Preliminary escapes from EML2 and SEL2 are employed as tentative solutions for the indirect optimization of escape transfers from Quasi-Periodic Orbits (QPOs), computed with a novel shooting method. Very small propulsive requirements (ΔV ranging from tens to a few hundreds of m/s) are needed to escape from Lagrangian Points on low-energy trajectories with final C_3 below 0.5 $(\text{km/s})^2$. Similar results are found when escapes are transitioned to high-fidelity Lyapunov and Near-Rectilinear Halo Orbits (NRHOs). Different QPOs characteristics, departure points, and epochs are analyzed to evaluate escape performance further.

The dynamic model considers 4-body gravitation (spacecraft subject to Earth, Moon, and Sun gravity), JPL's DE430 ephemeris for the position of the bodies, and solar radiation pressure. Specific techniques and improvements to the method are introduced to tackle the highly chaotic and non-linear dynamics of motion close to Lagrangian points, which challenges the remarkable precision of the indirect method.

Results show that escape trajectories have optimal performance when the solar perturbation acts favorably in both thrust and coast phases. The effects of the Solar and Moon perturbations are more evident for the Earth-Moon L2 region escapes with respect to those from the Sun-Earth L2 region. EML2 escapes have single- or two-burn solutions depending on the trajectory deflection which is needed to have a favorable solar perturbation. The SEL2 escapes, on the contrary, have mainly a single initial burn and a long coast arc, but may need an additional final thrust arc if the required C3 is high. For both the QPOs families, an optimization of the departure point and escape duration further minimizes the propulsive needs. As an application, these results are coupled to the optimization of heliocentric legs for the preliminary design of interplanetary trajectories towards Near-Earth Asteroids.