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TRAJECTORY TOUR OF THE TROJAN ASTEROIDS GENERATED VIA AN OPTIMAL LOW-THRUST ALGORITHM

Abstract

Asteroids in the vicinity of the Sun-Jupiter equilateral equilibrium points, commonly termed "Greek" or "Trojan" asteroids, offer insight into the primordial composition of the solar system. An increasing number of studies examine transfers to Near Earth Objects and to the equilateral Lagrange points, but comparatively little investigation of transfers within the neighborhood of the L4 and L5 points has been conducted. Because of the dynamical stability and comparatively low relative velocities of orbits near the equilateral libration points, low-thrust systems are particularly attractive for long-term missions in these regions. Low-thrust orbit transfers that are optimized in terms of propellant potentially offer years or even decades of mission lifetime while simultaneously ensuring a large number asteroid encounters. Conservation of propellant is also a critical objective for sample return missions from the vicinity of the Sun-Jupiter Lagrange points.

Given the potential of this unexplored region of the solar system, this investigation considers the addition of a variable specific impulse (VSI) engine into a primer vector-based, optimal transfer and rendezvous strategy. A multiple shooting procedure with analytical gradients yields rapid solutions and generates a framework for an investigation into the trade space between flight time and consumption of propellant mass. The primer vector, propellant-minimizing multiple shooting formulation, when combined with parameter optimization schemes, comprises an extremely useful hybrid optimization approach. This type of algorithm readily allows for the application of path constraints at node points along the transfer arc, where constraints are formulated to satisfy mission requirements or engine operation limitations. Transfers between periodic orbits in the planar circular restricted three-body problem (CR3BP) are initially investigated, but the methodology for the computations is not limited by the dynamical regime and is readily extendable to the quasi-periodic paths representing various asteroids as well as three-dimensional examples. Numerical simulations incorporate VSI engine operation and predict the propellant consumption and the thrust durations for a variety of transfer and rendezvous trajectories, while combinations of coast and thrust arcs offer Pareto optimal trade-spaces for multiple asteroid encounters. Additionally, the results from the VSI engine simulations offer insight into the optimal placement of conventional impulsive maneuvers to seed other types of design options. The symmetry in the CR3BP ensures that solutions in the vicinity of the L4 point are easily translated to initiate investigation of the L5 region as well.