Paper ID: 14884
oral
student

ASTRODYNAMICS SYMPOSIUM (C1)
Mission Design, Operations and Optimisation (1) (4)

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HIGH AREA-TO-MASS RATIO HYBRID PROPULSION EARTH TO MOON TRANSFERS IN THE CR3BP

Abstract

This paper examines the design of transfers that are useful to micro or nano spacecraft with high area-to-mass ratio, propelled by a simple propulsion engine (such as chemical with a specific impulse ca. 100 to 300 s or arcjet/resistojet), and possessing relatively small solar reflective panels to provide power and a small thrust due to solar radiation pressure. This type of transfer is becoming of greater interest as advances in structures, materials, and small spacecraft design propulsion are made. Such a hybrid design especially offers possibilities of cheaply exploring the Moon using multiple vehicles. With this small hybrid design, interior transfers in the circular restricted 3-body problem between the pair of primary and secondary masses (e.g. the Earth and Moon) can be attempted using solar radiation pressure and multiple small impulses. The source of the outside solar radiation pressure is modeled using an external source rotating about – and in the plane of – the co-rotating set of primary and secondary masses. Starting from a circular starting orbit or GTO about the primary mass a multiple shooting optimization method is used to achieve the transfer, where the segments are patched together using ideally small maneuvers. The spacecraft coasting arcs are controlled by a number of locally optimal control laws to optimize performance while minimizing computational cost. The goal is to hop onto a stable invariant manifold leading to the system's Lagrange L1 point after successive small maneuvers and coasting arcs. The course of the manifolds themselves can be slightly altered using the solar perturbation and control laws to find conditions on the various Poincaré sections that are more suitable for connection between the initial starting point at the Earth and the natural evolution of the manifold towards a periodic L1 orbit. Following connection with a manifold and subsequent arrival at a periodic orbit at L1, temporary or permanent capture around the Moon can be attempted using the remaining resources at hand.