ASTRODYNAMICS SYMPOSIUM (C1)
Mission Design, Operations & Optimization (1) (4)

Author: Mr. Nicola Sullo
University of Glasgow, United Kingdom, n.sullo.1@research.gla.ac.uk

Dr. Priscilla Sousa Silva
Instituto Tecnológico de Aeronáutica (ITA), Brazil, priandss@ita.br
Prof. Maisa Terra
Instituto Tecnológico de Aeronáutica (ITA), Brazil, maisa@ita.br
Dr. Matteo Ceriotti
University of Glasgow, United Kingdom, matteo.ceriotti@glasgow.ac.uk

OPTIMISATION OF LOW-THRUST AND HYBRID EARTH-MOON TRANSFERS

Abstract

The need to drive the Δv down has led, in recent times, to improve the trajectory models, and take into account the forces that were considered just unwanted perturbations in the past. One of the examples is the exploration and exploitation of multi-body dynamics, to replace the Keplerian two-body problem, from the very initial phases of the trajectory design. Multi-body dynamics allows to exploit families of trajectories that simply do not exist in the two-body problem, at the additional cost of considerably increased the complexity of the design problem. One example is in the Earth-Moon transfer trajectories, where high-energy Apollo-like transfers are possible but highly expensive, as opposed to solutions that make use of the gravitational attraction of the sun, such as weak stability boundary transfers, to reduce the Δv. This paper presents an optimization procedure to generate fast and low-Δv Earth-Moon transfer trajectories. Ideal (first-guess) trajectories are generated at first, using two coupled planar circular restricted three-body problems, one representing the Earth-Moon system, and one representing the Sun-Earth. The two systems are rotating with respect to each other and tilted around a common line of the nodes, to account for the obliquity of the Moon over the ecliptic. The trajectories consist of a first ballistic arc in the Sun-Earth system, and a second ballistic arc in the Earth-Moon system. The two are connected at a patching point on the line of the nodes at one end (with an instantaneous Δv), and they are bounded at Earth and Moon respectively at the other end. Families of these trajectories are found by means of an evolutionary optimization method, with patching Δv of the order of a hundred m/s and transfer time of about 10 days. Subsequently, they are used as first-guess for solving an optimal control problem. At this stage, the full-three dimensional problem is introduced and the patching point is set free, and realistic analytical ephemerides are used. The objective of the optimisation, carried out with pseudo-spectral methods and sequential quadratic programming, is to reduce the total Δv, and the time of flight, together with introducing the constraints of the considered propulsion technology. In this work, we will present a trade-off of different options, including conventional solar-electric low-thrust, chemical high-thrust, and also a hybridisation of the two, envisaging future spacecraft that can carry both systems. A trade-off of the different optimal trajectories and propulsion options will be shown.