ASTRODYNAMICS SYMPOSIUM (C1)
Mission Design, Operations & Optimization (2) (7)

Author: Dr. Mauro Pontani
Sapienza - University of Rome, Italy

OPTIMAL LOW-THRUST HYPERBOLIC RENDEZVOUS FOR INTERPLANETARY MISSIONS

Abstract

In recent years, the scientific community has shown a strong interest toward both robotic and human interplanetary missions, and some space agencies are planning to carry out a human mission to Mars within the next three decades. Several criticalities accompany the design of a similar mission, which will require a spacecraft considerably more massive than those already employed for robotic exploration. Cycler mission architectures consider the use of a large space vehicle that cycles continuously between the Earth and Mars, describing a near-ballistic path that includes flybys at the two planets. While this large spacecraft can be equipped with the life support system appropriate for a long interplanetary flight with a crew, taxi vehicles of reduced size are sufficient to ensure the connection between the interplanetary vehicle and each planet. In view of the establishment of a permanent base on Mars, the same architecture can be employed in order to ensure periodic refurnishing from the Earth. The cycling spacecraft employs a negligible propellant amount and describes a hyperbolic trajectory within the spheres of influence of Earth and Mars. In order to transfer a crew or an inert payload from the Earth to Mars, taxi vehicles are needed in two phases: (a) rendezvous with the cycling spacecraft while the latter travels in the proximity of the Earth, and (b) transfer from the cycler hyperbolic trajectory to a suitable Mars orbit. In both cases the orbit transfer is very challenging, due to the cycler hyperbolic velocity. This research addresses the determination of the optimal finite-thrust transfer trajectories for a pair of taxi vehicles involved in phases (a) and (b). The problem is solved through the indirect heuristic method, which uses the necessary conditions for optimality together with a heuristic technique, i.e. the particle swarm algorithm. In this context, a reduced parameter set, mainly composed of the unknown initial values of the adjoint (costate) variables, suffices to transcribe the optimal control problem into a parameter optimization problem. The use of the indirect heuristic approach for low-thrust paths may be affected by hypersensitivity with respect to the initial values of the costate. This phenomenon is mitigated through a judicious choice of the equations of motion that govern the spacecraft dynamics. In the end, through the indirect heuristic method the optimal low-thrust trajectories are determined, for taxi vehicles aimed at transferring a payload from and toward a large Earth-Mars cycling spacecraft.