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Author: Mr. Masaki Kakoi
Purdue University, United States

Prof. Kathleen Howell
Purdue University, United States
Mr. David C. Folta
National Aeronautics and Space Administration (NASA), Goddard Space Flight Center, United States

ACCESS TO MARS FROM EARTH-MOON LIBRATION POINT ORBITS: MANIFOLD AND DIRECT OPTIONS

Abstract

Within the context of both manned and robotic spaceflight activities, orbits near the Earth-Moon L1 and L2 libration points could support lunar surface operations and serve as staging areas for future missions to near-Earth asteroids and Mars. In fact, an Earth-Moon L2 orbit has been proposed as a potential hub for excursions to Mars as well as activities in support of planetary exploration. Yet, the dynamical environment within the Earth-Moon system is complex and, consequently, trajectory design in the vicinity of Earth-Moon L1 and L2 is nontrivial. Routine transfers between an Earth-Moon L1/L2 facility and Mars also requires design strategies to deliver trajectory arcs that are characterized by a coupling between different multi-body gravitational environments across two-, three- and four body systems.

This investigation is focused specifically on transfers from Earth-Moon L1/L2 libration point orbits to Mars. Initially, the analysis is based in the circular restricted three-body problem to utilize the framework of the invariant manifolds. The dynamics in the vicinity of the Earth are modeled in terms of the Sun-Earth-Moon system by coupling the Earth-Moon system and the Sun-Earth system. For example, unstable Earth-Moon L2 manifolds are employed to depart libration point orbits, and the dynamical model is then shifted to the Sun-Earth system, far from the Moon, to incorporate the solar gravity for departure to Mars. Various departure scenarios are compared, including arcs that leverage manifolds associated with the Sun-Earth L1 and L2 orbits as well as non-manifold trajectories. For the manifold options, ballistic transfers from Earth-Moon L1/L2 libration point orbits to Sun-Earth L1 and L2 halo or Lissajous orbits are first computed, assuming an inclined lunar orbit and three-dimensional libration point orbits. Hyperplanes, i.e., surfaces of section, are employed to project trajectory states and to develop the no-cost transfer arcs. This autonomous procedure applies to both departure and arrival between the Earth-Moon and Sun-Earth systems. Departure times in the lunar cycle, amplitudes and types of libration point orbits, manifold selection, and the orientation/location of the section all contribute to produce a variety of options. Non-manifold trajectories are incorporated into the end-to-end design as significant arcs along the path or as a ‘stand-alone’ transfer concept. As the destination planet, the ephemeris position for Mars is employed throughout the analysis. The complete transfer is transitioned to the ephemeris model after the initial design phase. Results for multiple departure/arrival scenarios are compared.