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DATABASE APPROACH FOR SYNTHESIZING A BALLISTIC OTV FLIGHT SEQUENCE CONNECTING LUNAR NRHO TO SEL2 SMALL HALO ORBIT

Abstract

One of the key technologies for sustainable deep space exploration is the realization of a space port and the on-orbit service provided by a reusable orbital transfer vehicle (OTV). In the light of the growing interest in the exploration of the Moon and beyond, an efficient pathway connecting the Gateway and the space port would be highly demanding. This paper explores low-energy OTV transfer between a 9:2 synodic resonant lunar near rectilinear halo orbit (NRHO) and an artificial small halo orbit around the Sun-Earth L2 point. The small halo orbit was proposed by one of the authors as an outpost toward deep space, the unique orbital characteristics of which poses a challenge in realizing fuel- and time-efficient transfer. Specifically, the large energy gap between the orbits and the weak instability of them cause the issue.

The Sun-Earth-Moon system offers useful options for low-energy transfer leveraging the multi-body gravitational environment. We make use of the solar tidal force and lunar swing-bys to fill the energy gap and adopt pseudo-manifold trajectories to shorten the flight time. To systematically design such complicated trajectories, this paper proposes the use of a precomputed database of three-dimensional, Sun-perturbed, Moon-to-Moon transfer trajectories. The trajectories are computed in a circular restricted three-body problem that models the Sun-Earth system and ignores the lunar gravity. A comprehensive search is conducted to generate trajectories starting from and ending up at the center of the Moon. When exploiting the database, the lunar swing-by is modeled as the instantaneous rotation of the v-infinity vector. This enables the separation between the database generation and the individual mission analysis, where the current work targets the Moon from the NRHO and the small halo orbit and systematically patches them together with favorable phasing orbits. The division of a trajectory lowers the sensitivity and the precomputable feature of the database reduces the computational burden in the mission analysis. The synthesized trajectory is optimized in a bicircular model including the lunar gravitational effect. The obtained solutions are near-ballistic multi-flyby trajectories leveraging the solar tidal force. One promising example achieves the transfer with flight time of 313 days and total delta-v of 55 m/s, more than half of which is consumed for accelerating departure and arrival. The results also reveal the trade-off among delta-v, flight time, and practical criteria such as the orbital complexity near the Gateway and the size of phasing orbits around Earth.