IAF ASTRODYNAMICS SYMPOSIUM (C1)
Mission Design, Operations & Optimization (2) (5)

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ROUND-TRIP TRAJECTORIES BETWEEN EARTH-MOON NRHOS AND HELIOCENTRIC SPACE IN THE EARTH-MOON-SUN SYSTEM

Abstract

Transit between the lunar vicinity and the region near the Sun-Earth libration points presents many interesting opportunities in the near future. The Gateway is the current framework for the NASA development of a space facility near the Moon with an option to return to the Lunar surface. From a baseline orbit in an Earth-Moon L2 Near Rectilinear Halo Orbit (NRHO), the Gateway is intended to serve as a proving ground for deep space technologies and a staging location for missions beyond the cislunar space, as well as a potential transit facility for sample returns before return to Earth. Potential destinations for sample return missions include heliocentric space; for example, various science interests exist at the Sun-Earth L1 libration point, including the possibility of collecting solar wind particles.

In this investigation, sample return transfer trajectories via the Gateway are designed within the context of the Bicircular Restricted 4-Body Problem (BCR4BP). The BCR4BP is a time-dependent, periodic model that includes the gravitational influences of the Earth, the Moon, and the Sun, acting on a spacecraft. Transfer design within the BCR4BP blends natural flow from both the Earth-Moon and the Sun-Earth systems. An advantage of the BCR4BP is that relevant information about the trajectory is available in two frames: the Earth-Moon rotating frame and the Sun-Earth rotating frame. The BCR4BP avoids the added complexity of the higher-fidelity force model while still accurately describing the dynamics of the Earth-Moon-Sun system.

This investigation demonstrates the framework to design trajectories in a dynamical environment that includes the Earth, the Moon, and the Sun. A sample-return mission scenario is discussed. First, a spacecraft departs the NRHO and transits to a Sun-Earth halo orbit. After two years in the Sun-Earth libration point orbit, the spacecraft returns to the NRHO. The presented methodology is effective for transit between any cislunar orbit and the Sun-Earth libration point regions; the framework demonstrates its capability with the NRHOs, which possess complex cislunar dynamics and near-stable properties. The challenges of the trajectory design include the phasing of the trajectory with respect to the Earth, the Moon, the Sun, and Gateway. Various geometries of transfers are presented, and their associated times of flight and energy characteristics are discussed. To demonstrate the validity of the transfer design in the BCR4BP, selected trajectories are transitioned to the higher-fidelity ephemeris model.