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TRANSFERS TO RESONANT QUASI-PERIODIC NEAR-RECTILINEAR HALO ORBITS IN THE EARTH-MOON-SUN ELLIPTIC-CIRCULAR PROBLEM

Abstract

As a major milestone in the future of space exploration, the NASA-led Lunar Gateway will be an integral part of the Artemis program, which aims to return humans to the Moon and to support future manned and robotic interplanetary missions. The Gateway will be placed in orbit around the Moon and will host science and observation missions, visiting astronauts, and act as a communication point with Earth. In that regard, transfer vehicles will play a significant role in transporting cargo and astronauts to the Gateway from Earth. In this context, this paper investigates transfers arising from natural connections between Earth vicinity and lunar quasi-periodic trajectories that are resonant with either the synodic (29.5 days) or the sidereal (27 days) periods. Previous works have looked other transfer possibilities from Earth to Moon vicinity in the Bicircular Restricted Four-Body Problem model, which considers that the Earth and the Moon move in circular orbits about their barycenter and the Sun moves in a circular co-planar orbit around the Earth-Moon barycenter. In this work, we extend these studies by including another major perturbation of the cislunar environment, the Moon's eccentricity. To do so, we make use of the Elliptic-Circular Restricted Four-Body Problem (ECR4BP) dynamical model and apply it to the Earth-Moon-Sun system. This model can be seen as a generalization of the Bicircular model where the Earth and Moon orbit each other in elliptical orbits, and the Sun remains in a circular co-planar orbit about the Earth-Moon barycenter. In the Elliptic-Circular model the Lunar Gateway's planned orbit - a synodic resonant Near-Rectilinear Halo Orbit (NRHO) - is replaced by a two-dimensional synodic resonant quasi-periodic torus. We present the quasi-periodic tori associated with the Gateway's planned synodic resonant orbit and two additional resonances, one synodic and one sidereal resonant quasi-periodic NRHO, due to their proximity and similarity to the baseline trajectory. We then compute their stable and unstable invariant manifolds, finding natural transfer trajectories between the Earth vicinity and these quasi-periodic resonant NRHOs in the Elliptic-Circular system. These trajectories are then translated to an ephemeris model and used as initial guesses for an optimization routine, which produces new solutions that are compared to those arising from previous methods. Our novel approach is highlighted by its increased flexibility in designing real transfer trajectories.