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MINIMUM COST RELATIVE DYNAMICS IN CISLUNAR ENVIRONMENT

Abstract

The last decade has been characterized by a renewed interest in human exploration of the solar system, which brought to the creation of a thorough roadmap for the next Moon and Mars manned missions. The Artemis program represents the first step towards that goal, aiming at bringing the humankind back on the Lunar surface by 2024, and laying the foundations for the future exploration and colonization of Mars. Among the objectives, the program started developing a station orbiting around the Moon (Gateway), to serve as home base for astronauts expeditions and as infrastructure for Moon and deep space science. The station will orbit on a Nearly-Rectilinear Halo Orbit (NRHO), generated by the Earth-Moon binary system gravity, that exposes the spacecraft to lunar proximity as well as to deep space environment. The selected trajectory provides several advantages, such as accessibility to various deep space destinations, continuous visibility from Earth, and low orbital maintenance costs. Nevertheless, the complexity and long-term instability of the multibody environment requires a detailed study on the dynamics in the surroundings of the target orbit. In particular, the Gateway will pose the challenge of performing relative maneuvers around the station, to allow approach and departure of spacecraft. The paper explores the topic of relative orbital transfers around NRHO, in the framework of the Three-Body Problem, through the parametrization of quasi-periodic orbits around the station. By leveraging the invariant tori formulation, quasi periodic orbit families are collected in terms of distance from the NRHO and associated orbital frequencies. Then, tori surfaces are exploited to develop relative transfers through homoclinic connections, by departing from the surface and returning to it at the desired location. First, stable and unstable manifolds are developed to find feasible transfers which exploit natural motion. Then, powered maneuvers are explored to provide more versatile solutions applicable in any location along the orbit. Finally, cost maps are drawn to identify cheapest transfers, and their relations with relative positions of spacecraft are identified to provide a basis for the development of a guidance strategy. Transfers will be initially developed in the framework of the Circular Restricted Three-Body Problem (CRTBP), then tested in more complex environments, by including the effects of Moon orbit's eccentricity, and perturbations such as solar radiation pressure, to assess the limits of applicability of the collected results.