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PHASING AND RENDEZVOUS OPERATIONS ON NON-KEPLERIAN ORBITS IN THE EARTH-MOON SYSTEM

Abstract

Recent studies and investigations proved the effectiveness of non-Keplerian orbits as staging location for a lunar orbiting outpost to support future Space Exploration. NASA's Lunar Orbital Platform-Gateway and ESA's HERACLES concepts represent different answers to the outpost architectures settling, both of them looking at Near Rectilinear Halo Orbit (NRHO) family as suitable permanent location for such infrastructure. Moreover the infrastructure, to be effective, shall ensure significant operational flexibility to cope with variable logistics depending on the mission scenarios to support; frequent docking/undocking events of different module classes shall be assumed as one of the primary functionalities an infrastructure in deep space shall provide. At the time being, no proximity manoeuvring has been performed so far in the strongly perturbed non-Keplerian dynamical environment, which is intrinsically challenging. The paper first analyses the different criticalities that arise from such dynamical environment, starting with a discussion on connecting the lunar surface to non-Keplerian orbits. Operational challenges are identified in the connection of parking orbits, belonging to the inertial lunar space, and non-Keplerian trajectories, which are defined in the Earth-Moon rotating frame. The two frames are not directly dependent, and the difference between the apparent forces plays a fundamental role in selecting parking orbits. Furthermore, the strong irregularities in the lunar gravitational field affect the lifetime of such parking orbits, posing an operational challenge in terms of timing the transfer. The investigation then proceeds with the transfer and phasing trajectories analysis, assuming a chaser vehicle to rendezvous with an orbiting infrastructure. The need to drive the transfer design according to the operational constraints is highlighted: whenever possible operational errors are accounted in the trajectory analyses, the cheapest transfers appear as critical for operations, whereas a longer, more expensive trajectory actually gains a Δv saving from an overall perspective which includes Trajectory Correction Manoeuvres (TCM) and both deterministic and stochastic budgets. The case study of a space vehicle, landed on the lunar surface, that shall perform phasing and rendezvous with a vehicle orbits in a NRHO, identifying timing opportunities, different re-phasing possibilities, and investigating stochastic TCMs to take into account manoeuvre and navigation errors is widely discussed in the paper. The effect of the different constraints, including time of flight, surface landing site, and engine limited thrust, is analysed and critically discussed to drive mission analysis requirements.