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USING DISTANT RETROGRADE ORBITS AS FUTURE SPACECRAFT GRAVEYARDS

Abstract

In the coming years, the Gateway will be the first long-term manned station in the vicinity of the Moon. As a chaotic environment, the lunar space must remain free from debris, to ensure the safety of future missions. Therefore, a safe disposal solution for future cargo or satellites is essential. Among several possibilities, graveyard orbits are of particular interest because they allow the tracking and the potential refurbishing of disposed-off spacecraft. The presence of both the Moon and the Earth's gravitational fields shapes complex orbits in this environment simulated within the Circular Restricted Three-Body Problem (CR3BP) in Python with the SEMpy package. This environment allows the existence of unique orbits, such as the Near Rectilinear Halo Orbit (NRHO) family and the Distant Retrograde Orbit (DRO) family. However, the complexity of this model gives the opportunity to create new disposal strategies, using lunar DROs as graveyard orbits. The high linear stability of those orbits allows the design of multiple-impulse disposal strategies for spacecraft.

After giving a brief state-of-the-art overview of transfers from the Gateway's NHRO orbit to various DROs, this paper assesses the suitability of a graveyard orbit chosen according to its stability indices. The injection precision necessary to stay in orbit is then studied, in a full Ephemeris model propagator, by monitoring the associated Poincaré map. To provide end-of-life mitigation solutions from the Gateway's orbit to this DRO, various two-impulse transfer families are constructed using a simple grid search exploration of the search space. With a cost of 400 m/s and a duration of up to two weeks, those fast transfer solutions could have potential applications for manned missions. The optimization problem for Lambert transfers in the CR3BP is complex because the cost function is implicitly defined and expensive to evaluate. It also presents various local minima and discontinuities that prevent gradient-based method from finding global minimum. To circumvent this issue, a genetic optimization algorithm is developed for the SEMpy environment and allows the design of long duration transfers relying on NRHO's unstable manifolds to depart the Gateway's orbit at low cost. Intermediate planar Lyapunov orbits are also investigated, as an heteroclinic connection between their stable manifolds and the NRHO's unstable ones is possible at low cost. A single-impulse transfer to the graveyard is then possible by selecting a tangent DRO. Those increasingly complex solutions greatly reduce the transfer cost, at the expense of an increased time of flight.