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RELATIVE DYNAMICS ANALYSIS AND RENDEZVOUS TECHNIQUES FOR LUNAR NEAR RECTILINEAR HALO ORBITS

Abstract

The family of Near Rectilinear Halo Orbits (NRHO) is a promising candidate for future missions to the Moon and to the solar system. Many recent research proved the effectiveness of such orbits as staging locations, thanks to their low station-keeping cost and low access Δv; the family also provides cheap transfer possibilities to lunar surface and low lunar orbits. The paper investigates rendezvous and proximity operations in NRHOs, assuming a reference scenario of a chaser spacecraft that joins a target, controlled but uncooperative, orbiting in a lunar NRHO. The analysis is first conducted under the Circular Restricted Three-Body Problem (CR3BP) assumption, in order to highlight some features of the orbits and to identify dynamical structures, to be exploited for rendezvous operations. A suitable region for rendezvous is identified, by analysing the spectrum of the State Transition Matrix (STM) of the orbit; the analysis underlines how operations should be performed in an arc, near the aposelene, where the eigenstructure of the STM is more regular, while the periselene region should be avoided due to the more chaotic nature of the orbit. The periselene region might anyway be employed for orbit injection, exploiting the cheap manoeuvres offered by the stronger gravitational field. First, phasing trajectories are analyses, to obtain ballistic phases that allow the two object to be in proximity ($\simeq$1000 km). Then, the STM is once again exploited, to identify the central eigenvector, i.e. the direction that guarantees a periodic, bounded motion in the neighbourhood of the target orbit. This central direction is used as a reference state, where the chaser spacecraft shall be injected, to obtain a safe hovering trajectory prior to the final approach. Such eigenvector denotes a direction in the 6-dimensional position-velocity state, so one degree of freedom is left to the analyst to size the amplitude of the hovering motion ($\simeq$100 km). Eventually, the chaser spacecraft is injected into a stable approach trajectory ($\simeq$1 km), employing the stable eigenvector of the STM or a direct transfer, according to time-fuel mission constraints. The CR3BP assumption is then dropped, and some results are provided in a fully perturbed ephemeris model. Here, the spectrum of the STM does not result as well-defined as in the restricted model, thus direct transfers and connection are preferred. The stable and unstable direction are anyway identified, to guarantee good initial guesses and to avoid instabilities in proximity motion.