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FORCE AND DISTURBANCE MODELS AFFECTING LUNAR MISSIONS TO NEAR RECTILINEAR HALO ORBITS

Abstract

In the field of space mission design, an increasing interest is being shown towards the Moon as the next objective for international space exploration. As part of the Artemis program, the Lunar Gateway is being developed by the International Space Station partners, with the purpose of achieving sustainable human presence on the Moon and establishing an outpost for Solar System exploration.

This research focuses on quantifying the main perturbations affecting spacecraft operations, orbit maintenance and maneuvers on Near Rectilinear Halo Orbits (NRHOs). The Gateway will be located on one of these orbits, as they offer continuous visibility from the Earth and low-cost transfers to and from the lunar surface. The sources of disturbance considered in the present study are twofold: the non-uniform mass distribution of the Moon - described by the spherical harmonics model of its gravity potential - and the solar radiation pressure (SRP). Perturbations accelerations are integrated in an Earth-Moon Circular Restricted Three Body Problem force model, to estimate their impact over spacecrafts on NRHOs until insertion into escape trajectories. Furthermore, it is of particular interest for rendez-vous and station-keeping purposes to assess the deviations from the reference orbits, as spacecraft operations are highly influenced by all kinds of disturbances. By examining the evolution of the perturbed trajectories' momentum integral, optimization strategies are derived in terms of correction maneuvers timing.

The perturbations accelerations and ΔV that affect a spacecraft trajectory are analyzed in different scenarios: over all relevant perilune altitudes, spacecraft characteristics and environmental parameters such as solar flux and initial propagation date. The variation of the perturbation integral with respect to the aforementioned parameters quantifies the role of the Moon's gravity potential and the SRP in the divergence of NRHOs from their reference trajectories. The number of revolutions before a spacecraft departs from its original NRHO changes mainly with respect to initial date and perilune altitude. Perturbations are first considered acting separately, then their effect is combined. Comparing perturbation integrals in all the considered scenarios allows to draw conclusions on the disturbances' relative intensity. In most cases, the spherical harmonics model is responsible for earlier departure than the SRP, which however does not occur for specific ranges of perilune altitudes. Further investigation is carried out on the possible exploitation of the perturbed dynamics, in order to naturally perform insertion from the original NRHOs into escape or return to Earth trajectories with low fuel consumption.