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LUNAR DEBRIS MITIGATION: IDENTIFICATION OF STABLE GRAVEYARD ORBITS IN THE CISLUNAR SPACE

Abstract

A growing interest towards cislunar space became evident when the Lunar Gateway proposal was announced. Both national agencies and private companies are now collaborating on lunar missions, which will inevitably increase the number of objects in orbit. Therefore, robust disposal methods will soon be needed: these will have to ensure the sustainability of human activities and the preservation of the lunar environment, anticipating the problem of space debris. One such disposal option is the transfer to graveyard orbits, amply used for Earth-bound orbits for which atmospheric re-entry is not feasible in acceptable times. This paper will transfer this concept to the larger cislunar space, presenting different families of suitable graveyard regions and periodical solutions. The main focus will be on their stability for one hundred years, debris mitigation compliance, and accessibility at the end of a spacecraft's mission.

First, an overview of the cislunar space landscape is provided, browsing the area for potential candidate orbits which exhibit good stability properties over the long period. The results of this scouting operation are obtained in the CR3BP (Circular Restricted 3-Body Problem) model. Following the preliminary overview, the gravitational influence of other bodies is considered in a higher-fidelity model employing accurate celestial bodies' positions. Other perturbations, such as Solar Radiation Pressure (SRP) and gravitation spherical harmonics, can be added to the model to increase its fidelity further. Trajectories are then propagated in this dynamical model for long durations. Uncertainty about the initial position and velocity is addressed with a statistical approach. The results are discussed in terms of the percentage of orbits remaining bounded in a chosen stability threshold, serving as a starting point to the realisation of engineering maps of the cislunar zone. As defined by the Inter-Agency Space Debris Coordination Committee (IADC), interactions with Earth's protected regions will also be quantified. Additionally, the relationship between the long-term residence of objects in the graveyard zone and their physical parameters, such as area-to-mass ratio and optical properties, can be outlined. Finally, a preliminary evaluation of the cost to travel from typical operational orbits to cislunar graveyard orbits is reported.

The feasibility of this disposal solution could impact the way lunar missions are conceived and pave the way to better debris mitigation in the perspective of expanding spacecraft traffic towards the Moon in the coming years.