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DEBRIS MITIGATION AND ATMOSPHERIC DEORBITING ANALYSIS FOR LUNAR L2 NRHO DEPARTING SPACECRAFT

Abstract

In recent decades, there has been a desire to establish permanent human settlements on the Moon, leading to the proposal and development of the Lunar Orbital Platform-Gateway (LOP-G), the first cislunar orbital laboratory, stationed on a L_2 Near Rectilinear Halo Orbit (NRHO). This project will result in a significant increase in the number of spacecraft in the cislunar space in the near future. To comply with new space debris regulations, e.g. the recent FCC 5-year deorbit rule to avoid the pollution of cislunar space, proper disposal of spacecraft in such region of space is necessary and advisable. However, most past missions have been directed to impact the lunar surface, which may not be a sustainable long-term solution. Therefore, this paper aims to propose an alternative strategy for debris mitigation of satellites, which involves transferring them from NRHO to Low-Earth Orbits (LEOs) and performing a controlled re-entry.

The departure location is the reference LOP-G orbit, designed on an Earth-Moon Lagragian Point L_2 (EML2) southern NRHO with 9:2 synodic resonance, computed using a three-body dynamic model that takes into account the lunar eccentricity at epoch from JPL's DE432s ephemerides. Five departure dates spanning over a whole lunar month allow for the analysis of the effect of departure date on performance to reach the parameterized LEOs, given the epoch-dependent oscillations of EML2 and the resulting periodic NRHOs.

The analysis is completed by evaluating end-of-life disposal strategies via a direct de-orbiting controlled re-entry from such Earth's target LEOs. Current directives require the risk of causality on the ground to be lower than 1 in 10,000. The main goal of the re-entry analysis is to perform simulations using the ESA DRAMA software to determine the on-ground risk caused by surviving fragments from spacecraft re-entering the Earth's atmosphere. These analyses were conducted with different inputs (solar activity, apogee, targeted perigee, assumed break-up altitude) to assess the variability of the impact footprint of all surviving fragments for different initial parameters. The target area for re-entry is the uninhabited South Pacific Ocean, and the spacecraft is modeled using the CROC (Cross Section of Complex Bodies) tool.