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ANALYSIS OF OUTCOMES OF SPACECRAFT FRAGMENTATION ON THE LUNAR GATEWAY ORBIT

Abstract

The Lunar Gateway is to be the first space station beyond Low Earth Orbit (LEO), and is expected to start being built in the coming years. The project assembles space agencies from around the world (NASA, ESA, JAXA, CSA & MBRSC) with the common goal of providing orbital infrastructure for longer stays on the Moon's surface and opening the door to Mars missions in the more distant future. While collision avoidance is common practice and even often automated in LEO, its application for lunar orbits is fraught with complications that may require the development of additional infrastructure to be solved. This fact, together with the currently growing activity in lunar orbit, makes clear how increasingly pressing it is to assess the consequences of the breakup of spacecraft with orbits such as the Gateway's Near-Rectilinear Halo Orbit (NRHO). There are several regions of the Moon's surface around which the consequences of an impact would be particularly calamitous, in particular: mares, swirls, permanently shadowed craters, pits, and anthropogenic objects. This paper aims to estimate the likelihood of fragments impacting these areas of interest using advanced fragmentation models such as the NASA Standard Breakup Model (SBM) in combination with the dynamics of the Circular Restricted 3-Body Problem (CR3BP). First, the outcomes of breakup (escape from the Moon's sphere of influence, continued lunar orbit, impact on the Moon's surface) are determined simply by propagating fragments in a range of retrograde to prograde velocities along the path of the Gateway's orbit. The effects of spread angle are later assessed by imparting a fixed velocity impulse in all directions of space, and the different outcomes are then computed as previously done. In order to focus on more relevant cases, this is done in particular for anomaly values for which it had already been determined that breakup would be more likely to result in impact. Finally, using the probability distributions for the fragments' velocity and numbers given by the NASA SBM, the likelihood of impact in different cases can be estimated. The results provided in this paper should help to determine which sections of the orbit put critical regions of the lunar surface at risk, and which fragmentation cases would be the most catastrophic. Thus, it will be clearer which scenarios are to be paid particular attention to and be avoided by implementing policy or standards for spacecraft operations around the Moon.