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TOWARDS SUSTAINABLE SPACE EXPLORATION: A COMPREHENSIVE STUDY OF ORBITAL DEBRIS AND ITS IMPLICATIONS FOR SPACE SYSTEMS

Abstract

Orbital debris, or space debris, consists of man-made objects that have been launched into space but no longer serve any useful purpose. This debris, which includes defunct satellites, spent rocket stages, and fragments from collisions or explosions, poses a significant environmental threat in space. Just as pollution damages the natural environment on Earth, the injection and release of orbital debris can be seen as an emission of an environmental stressor that harms the natural resources in space that are vital for supporting space activities. As human exploration and use of space continues to expand, it's essential to address the issue of space sustainability. The international community recognizes the importance of ensuring safe and responsible space exploration and is actively working on developing solutions to this challenge. A key part of this effort involves integrating the impact of debris emissions on orbital resources into the life cycle assessment (LCA) for space systems. This broadens the scope of LCA to consider not just the environmental impact on Earth but also the environmental impact in space. This work proposes a simplified study of the life cycle of space debris. It involves simulating clouds of space debris generated by random explosions, with each particle analyzed individually. This is done within the context of the restricted three-body problem (PRTC), where the mass of each particle is considered negligible compared to the masses of the Earth and the Moon. The analysis employs numerical integrators for temporal orbit propagation and re-entry, with MATLAB being a commonly used tool for this purpose. The study also involves debris risk assessment and mitigation analysis, leveraging tools such as DRAMA (Debris Risk Assessment and Mitigation Analysis) developed by the European Space Agency (ESA). Additionally, the study includes analysis of orbit propagation and collisions, which are critical factors in understanding and managing the risks associated with space debris.