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FRAMEWORK FOR MINIMIZING ORBITAL DEBRIS RISK DURING SATELLITE MISSION PLANNING

Abstract

Space sustainability faces a growing threat from increasing orbital debris. This challenge is amplified by the rise of small satellite technologies, enabling academia and amateur enthusiasts to join governmental and private organizations in launching satellites at an unprecedented rate. While these advancements propel us towards a new era of connectivity, innovation, and exploration, they also aggravate the critical issue of space debris management. The growing number of space debris poses a significant threat to existing and future satellites. Collisions with even small debris can damage critical components or cause complete satellite failure, adding up further to space debris. This necessitates effective strategies to address space debris, ensuring the long-term sustainability of space exploration and utilization. Several guidelines provide quantitative and qualitative recommendations for mitigating orbital debris. These include comprehensive technical standards like NASA-STD-8719.14C, which outlines historically accepted practices for satellite programs to assess their potential debris generation throughout their lifecycle. Additionally, documents like the US Government Orbital Debris Mitigation Standard Practices (ODMSP) and the Inter-Agency Space Debris Coordination Committee (IADC) guidelines offer further guidance. These documents apply to all space operations but also address specific considerations for small satellites as a unique category. This research proposes a strategy for analyzing compliance with space debris mitigation requirements during satellite mission planning and orbit design. This strategy incorporates a conjunction analysis to identify potential close encounters between the planned satellite and existing objects in orbit. Threat volumes are generated around each object, and potential conjunction events are evaluated using analytical methods for collision probability assessment, as proposed by F. Kenneth Chan. Additionally, the strategy considers orbital lifetime requirements. Satellites in Low Earth Orbit (LEO) must comply with a 25-year orbital lifetime limit which is determined by orbital lifetime analysis. The European Space Agency's (ESA) Debris Risk Assessment Mitigation Analysis (DRAMA) software suite is then employed to assess the likelihood of meteoroid collisions. And subsequently, DRAMA's Spacecraft Entry Survival Analysis (SARA) code is used to evaluate the satellite's survivability during atmospheric re-entry. This research methodology can empower academic, industrial, and governmental space agencies to proactively assess debris risks during mission planning. By integrating debris mitigation considerations early in the design phase, this strategy contributes to the long-term sustainability of the space environment, ensuring the continued benefits of space exploration and utilization for all stakeholders.