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METRICS FOR DEFINING PROBABILITY OF COLLISION FOR ON-ORBIT ASSETS

Abstract

There are more than 500,000 objects orbiting the Earth, consisting of operational and retired satellites, rocket bodies, debris, and the colloquial "space junk." The recognition of space as an operational domain requires spacecraft to contend with an increasingly congested environment at various orbital altitudes, and an evolving counterspace threat landscape. Overall, the U.S. space enterprise must contend with the prospect of ensuring on-orbit safety of spacecraft, especially with respect to collisions with either other on-orbit systems, or debris generated through unintended breakups or destructive counterspace engagements. Although multiple agencies around the world have guidelines for mitigating the creation of space debris and track both space debris and active satellites on-obit, the determination of collision risks between resident space objects remains a somewhat uncertain proposition. New metrics will be developed after conducting a survey of current tools, such as the ESA's MASTER (Meteoroid and Space Debris Terrestrial Environment Reference) and DRAMA (Debris Risk Assessment and Mitigation Analysis). Currently, NASA's Office of Orbital Debris maintains Orbital Debris Engineering Model and LEGEND, software that creates an evolutionary model of space debris propagation and makes predictions for how much space debris is created each year. The U.S. Air Force, the United Nations Office for Outer Space Affairs (UNOOSA), and the North American Aerospace Defense (NORAD) Command all track objects launched into space, their status, and their associated orbits. AGI software developers created SOCRATES (Satellite Orbital Conjunction Reports Assessing Threatening Encounters in Space) which uses unclassified NORAD TLEs to calculate minimum distance between all payloads and put potentially hazardous conjunctions in STK. This wealth of information and different software packages has not yet been integrated or fine-tuned to give meaningful risk assessments. This paper will discuss a plan for integrating these systems, specifically to display the level of risk for decision making purposes. Histogram analysis using binning of columns of TLE data will be explored. A methodology to weight different risks will also be developed, considerations given to parameters such as the size of orbital debris, and whether or not both satellites in question can perform orbit maneuvers. These metrics will enhance the space operations efforts which seek to increase the autonomy and maneuverability of space systems. A set of safety metrics for on-orbit collisions will provide constraints for the multi-objective optimization of spacecraft trajectories, whether they are designed for orbit injection, orbit modification, or rendezvous and proximity operations.