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ASSESSMENT OF TIME SPENT IN THE LEO, GEO, AND SEMI-SYNCHRONOUS ZONES BY SPACECRAFT ON LONG-TERM REENTERING DISPOSAL ORBITS

Abstract

The U.S. Government Orbital Debris Mitigation Standard Practices (ODMSP) released in December 2019 include a disposal option to use orbital eccentricity growth for long-term reentry within 200 years. By allowing the use of natural orbital perturbations for eventual reentry as an alternative to permanent storage orbits, this option promotes environmental sustainability for long-term operational usability of the regions above low Earth orbit (LEO). As a condition for use of this option, the ODMSP specifies a 25-year limit on cumulative time a disposed spacecraft can spend in designated altitude zones that are frequently used by operational spacecraft. These include the LEO zone, the geosynchronous (GEO) zone, and the semi-synchronous zone. The intent of the time limit is to restrict the effective accumulation of disposed objects in these zones. An analysis was performed to determine the time spent by disposed spacecraft in the LEO, GEO, and semi-synchronous zones for several classes of reentering disposal orbits above LEO, including Tundra orbits, near-circular inclined geosynchronous orbits (IGSOs), and GPS orbits. Long-term disposal orbit propagations over 200-years were performed using the Aerospace high-precision integration code TRACE. The methodology for computing time in zone for these time-varying disposal orbits is discussed in detail in the paper. Time in each zone is determined as a function of initial inclination and right ascension of ascending node (RAAN), and as a function of initial argument of perigee and RAAN for cases when initial argument of perigee can feasibly be targeted. The initial semimajor axis and eccentricity of GPS and IGSO disposal orbits are selected to promote eccentricity growth for reentry while retaining a disposal maneuver delta-V cost, similar to that for historical disposal practice. For the GPS case, collision probability with operational satellites in the GPS constellation is also determined in order to quantify the correlation with time spent in the semi-synchronous zone. Results show initial orbit parameter ranges that enable compliance with the 200-year limit on orbital lifetime and the 25-year limit on time in zones for non-operational space vehicles disposal. Tundra disposal orbits are shown to be compliant throughout almost the entire initial orbital parameter range. Near-circular IGSO and GPS disposal orbits have more constrained compliant parameter ranges determined by the nearest zone. For GPS, a linear correlation exists between time in the semi-synchronous zone and collision probability with operational GPS satellites.