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LOW EARTH ORBITAL TRAFFIC MANAGEMENT THROUGH SLOTTING

Abstract

Under the Outer Space Treaty, all nations have a right to make use of space. However, there is finite orbital volume available and use by one actor increases collision risk for others with overlapping orbits, limiting placement of subsequent orbital assets. Numerous mega-constellations have been proposed, typically with orbits carefully designed to minimize self-conjunctions and some with autonomous collision-avoidance systems. However, real-time on-orbit coordination at scale between large numbers of heterogeneous satellites controlled by multiple operators is an open challenge demanding novel solutions.

Slotting is already used at GEO to promote the "rational, equitable, efficient, and economic use" of spectrum and the associated orbital commons. The implementation of a Low Earth Orbit (LEO) slotting system offers one way to substantially simplify the traffic coordination problem in LEO and better achieve these same objectives.

This paper describes progress in work to develop a LEO slotting system architecture using Flower Constellation Theory and specifically Two-Dimensional Lattice Flower Constellations to generate slots that maintain an arbitrary minimum separation from each other at all times. The slotting problem is introduced, several slotting approaches demonstrated, and key implications and limitations of LEO slotting are described: chiefly a need to restrict most traffic to quasi-spherical shells and to a single inclination per shell (to preserve uniform secular drift in the right ascension of the ascending node due to J2). The authors argue that these limitations are acceptable, given the vast majority of satellites operate in near-circular orbits and that layers with different inclinations can be stacked fairly closely. Decisions for policy-makers and system architects are presented.

A study is conducted to demonstrate various common space operations in a densely slotted LEO environment. These include collision avoidance maneuvers between a slotted satellite and a non-compliant resident space object, a launch and string-of-pearls deployment into a slotted orbit, and a J-2 assisted re-deployment of several satellites to an orbit with a different right ascension.

A densely slotted LEO shell is then compared against a non-slotted alternative with similar traffic distribution to demonstrate the significant reduction in high risk conjunctions achievable via slotting.

Further work is proposed, including integration of non-spherical shells, launch window phasing, slot-value aware (as opposed to simply capacity-aware) parameter optimization, studies of robustness to non-compliance/orbital failures, and further comparative analysis using the European Space Agency's debris index to assess slotting's overall impact on system capacity.