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DESIGN OF HIGH ALTITUDE INCLINED ORBIT CONSTELLATIONS ACCOUNTING FOR THE EFFECT OF ORBITAL PERTURBATIONS ON MISSION AND DISPOSAL OBJECTIVES

Abstract

High altitude inclined orbits (HAIOs), orbits above LEO and inclined between 50 and 130 degrees, can be designed into a constellation that provides regional coverage to Earth. Three objectives informing overall constellation performance are ground coverage performance, stationkeeping costs, and compliant disposal orbit cost. The orbital perturbations that strongly affect HAIOs, affect all three of these objectives in different ways; they cause constellation coverage region drift, control the orbital drift rate and therefore the total station keeping cost, and enable long-term reentry. In multi-plane constellations, the Earth gravitational and third-body perturbations on each satellite will be different, so a compromise arrangement must be found such that the collective performance is favorable. Natural reentry, one HAIO disposal option, benefits the collective performance due to favorable delta-V costs and collision probability in comparison to alternate disposal according to previous studies. Additionally, natural reentry is a compliant disposal option according to the U.S. government 2019 Orbital Debris Mitigation Standard Practices (ODMSP) if the probability of reentry occurring within 200 years is above a certain threshold, among other requirements.

Cassiopeia is an end-to-end HAIO constellation design workflow and the first of its kind to design constellations that simultaneously achieve the three objectives of sufficient ground coverage, acceptable station keeping delta-V, and acceptable disposal delta-V, employing a genetic algorithm to optimize these competing objectives. A pre-processing step computes HAOI reentry times capped at 200 years for a range of ascending nodes and inclinations that are used within the genetic algorithm to assess reentry time compliance and to perform an efficient reentry probability proxy computation. The genetic algorithm varies the ascending node and inclination and selects optimal constellations minimizing stationkeeping costs, maximizing coverage performance, and minimizing disposal delta-V while maintaining reentry time and probability proxy compliance. Next, the post-processing method computes the reentry probability of the disposal orbits selected by the genetic algorithm and corrects the disposal delta-V result if the genetic algorithm proxy fails.

Results include example optimized 3-satellite HAIO constellations from the Cassiopeia workflow. Additionally, the effectiveness of the proxy reentry probability computation used within the genetic algorithm is analyzed and found to be successful. In one example, 2-fold continuous coverage is achieved for the North America region, with a maximum stationkeeping delta-V of 42 m/s/yr and a disposal delta-V of around 20 m/s for each satellite. Cassiopeia designs novel high-performing constellations, potentially infeasible to develop through previous design methods, through a holistic approach.