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CONSTRAINT ANALYSIS FOR SERVICING CO-LOCATED SATELLITES

Abstract

As Geostationary Earth Orbit (GEO) operators add more satellites into a single GEO slot, the Rendezvous and Proximity Operations (RPO) problem for potential satellite servicing missions become more difficult. Current co-location schemes may have up to six client satellites less than 10 kilometers from each other, causing increased difficulty for the Serving Vehicle (SV). This paper presents a new start-time-invariant method of RPO trajectory constraint analysis that allows trajectory designers and operators to assess a trajectory's effectiveness in servicing a co-location scheme. Three GEO constellation co-location specific constraints are analyzed: 1) collision avoidance via 3-sigma position dispersions, 2) client visual distinction via co-located satellites not passing within a search window radius of the SV camera boresight, and 3) SV radio shadowing of the other co-located satellites' nadir-pointing radio emissions. Two different co-location schemes are simulated based off existing literature: co-location option A) maximizes safety and minimizes radio shadowing between six homogeneous co-located satellites, while co-location option B) maximizes radial distance between all pairs of co-located satellites when they have the same out-of-plane distance, with a firm zero radio shadowing requirement between three of five satellites. These constraints and co-location schemes are analyzed with two different rendezvous trajectories, which both satisfy typical RPO requirements such as client lighting condition and free-drift safety. Stochastic analysis is used to find the worst case perturbations (from sun/moon gravity, solar radiation pressure, and station-keeping thrust imperfections) and the metrics are compared to the nominal case for each constraint. This allows the trajectory to be assessed against each constraint for each possible phase. The analysis results are used to select a baseline trajectory based on performance, optimized over fuel expenditure, relative navigation uncertainty or other mission metrics across all phases (during design) or to align the operation start time to the feasible set of phases for that trajectory (during operations). The results show that trajectory design needs to account for different co-location schemes. In some cases, constraint violation will always occur when approaching from a given direction, and the trajectory design must balance violation duration with fuel and timing concerns. In conclusion, this paper's contribution is a structured methodology to analyze a trajectory against fuel, time, and co-location specific constraints, which allows trajectory designers and operators to make informed trade-offs when executing more complex servicing missions.