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ANALYSIS OF HIGH AREA-TO-MASS RATIO (HAMR) GEO SPACE OBJECT ORBIT DETERIMINATION AND PREDICTION PERFORMANCE

Abstract

Optical surveys have identified a class of high area-to-mass ratio (HAMR) objects in the vicinity of the Geostationary Earth Orbit (GEO) ring [Schildknecht, et al., "Properties of the High Area-to-mass Ratio Space Debris Population in GEO," AMOS Tech. Conf., Wailea, Hawaii, Sept, 2005]. The exact nature of these objects is not well known, though their proximity to the GEO belt implies origins from resident space objects (RSOs) near GEO. These HAMR objects pose a collision hazard as they transit through the vicinity of active GEO satellites. Due to their high area-to-mass ratios (CpA/m), which can range from 0.1-20 m2/kg and higher, the effective solar radiation pressure perturbs their orbits in a significant way due to mismodeling of the (non-conservative) solar radiation pressure accelerations, and results in errors in the orbit determination and prediction. The unknown materials and attitude dynamics result in shorter term errors in the predictions (over 10's of days), whereas the combined solar-lunar gravitation and large non-conservative solar pressure result in longer terms changes (over weeks to years). The dynamic uncertainties, combined with the typically dim magnitudes, result in lost tracks and, hence, a track association challenge.

This paper presents study results that examine orbit determination and prediction performance metrics for two specific GEO RSOs. The first case study examines a dynamically "well-behaved" RSO having stable CpA/m < 1 m2/kg, and tracked with sub-arcsecond angle observations. Simulated observations are generated and validated against estimation and prediction results from similar actual observations. The second case study examines an object having high CpA/m > 1 m2/kg showing evidence of time variation in the CpA/m estimates, also tracked with angles-only observations. The validation of estimations using simulated versus actual observations allows establishment of a baseline for comparing the error sensitivity to the non-conservative force mismodeling. Performance metrics include a Mahalanobis distance metric comparison between estimation results, pre-fit residual comparisons generated from predictions derived from a previous fit to the data, and position, velocity and solar radiation pressure estimation consistency tests [Wright, James, "Optimal Orbit Determination," Analytical Graphics, Inc., AGI internal white paper describing Orbit Determination Tool Kit (ODTK), 2002]. The results (a) quantify comparisons between the simulated and actual data cases, (b) quantify the error sensitivity to un-modeled forces orthogonal to the sun-object line, and (c) provide guidelines for the best estimation strategy (a priori values and uncertainties) in the presence of un-modeled non-conservative forces.

Alternate: Orbital Dynamics (Astrodynamics Symposium)