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GOES 8 TUMBLING SPIN STATE EVOLUTION AND THE IMPLICATIONS FOR GEO DEBRIS MITIGATION

Abstract

While the long-term orbital evolution of defunct satellites in the geosynchronous belt has been studied extensively, much less is known about their rotational motion. In spite of this, many defunct GEO satellites spin rapidly or have highly evolving spin states, with some transitioning between uniform and tumbling motion. It is hypothesized that the observed evolution of some defunct GEO satellites is caused by the Yarkovsky-O'Keefe-Radzievskii-Paddack (YORP) effect and internal energy dissipation. The YORP effect, torques generated by the absorption, reflection, and delayed thermal re-emission of solar radiation, is known to cause secular changes in asteroid spin rates.

One notable defunct GEO satellite is GOES 8, whose significant asymmetry makes it particularly susceptible to the YORP effect. GOES 8 photometric light curves obtained periodically since 2013 show that the satellite's uniform spin period steadily increased after which it began tumbling. Leveraging analytical rigid body dynamics, inertia constraints, Fourier analysis, and ray-traced simulated observations, we obtained plausible rotation states from each light curve. Dynamically linking these together, it appears that GOES 8 spun down due to YORP, began tumbling, and then started spinning up about its minimum inertia (long) axis, the axis most easily accelerated by external torques. Dynamical YORP simulations conducted with a GOES 8 model also exhibited this behavior. During long axis spin up, the light curve spin states suggest that energy dissipation eventually overcame YORP, driving the satellite back towards uniform rotation. This apparent evolution outlines a potentially repeating path in which GOES 8 and other defunct GEO satellites cycle between phases of uniform and tumbling rotation.

Better understanding of this evolution promises to advance GEO debris orbit prediction and mitigation efforts. Improved rotation state knowledge will yield more accurate estimates for attitude dependent solar radiation forces, thereby refining orbit predictions and potentially revealing spin-orbit resonances and long-term orbital drift not predicted by ubiquitous cannonball models. Furthermore, deorbit and servicing missions involving physical interaction with large, non-cooperative GEO satellites will require detailed target spin state knowledge, preferably well before rendezvous. Conducting docking and grappling procedures during phases of slow, ideally uniform, rotation would be optimal. For targets like GOES 8

with highly variable spin states, identifying favorable interaction windows in advance would be extremely advantageous. In general, knowledge of possible target spin states would greatly aid in the design of robust deorbit/servicing spacecraft and operational procedures. So for any such mission, understanding long-term spin state evolution will be crucial.