Paper ID: 51544
oral
student

17th IAA SYMPOSIUM ON SPACE DEBRIS (A6)
Post Mission Disposal and Space Debris Removal (1) (5)

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RAPID COMPUTATION OF MEO SATELLITE DEORBIT TIMES USING DOUBLY-AVERAGED DYNAMICS

Abstract

The analysis of medium Earth orbits, MEO, over long time-spans pose unique challenges due to their chaotic dynamics, which arise from the interaction of lunisolar resonances with Earth's gravity field. While precise integrations of the full equations of motion are necessary for specific predictions, they require significant computing power which limits our ability to analyze this regime. The use of averaging techniques can significantly speed up the integration times; however, these methods lead to degraded precision. In this research we characterize the accuracy of doubly-averaged models for long-time prediction of orbits in this regime and show how they can be used to accurately capture their statistical characterization.

MEO in particular is known to have chaotic behavior due to interactions between multiple resonances. The gravitational pull from the Moon and Sun cause orbits to drastically increase eccentricity which can be utilized to deorbit satellites after their end of life. This is done by placing a satellite in a known chaotic area so that the eccentricity increases until the radius of periapsis is lower than an altitude of 120 km and the satellite burns up. Previous work has been done on targeting those areas for this exact purpose [1]. This paper is focused on further analyzing these regions through faster computing methods, namely, looking at how averaged solutions can capture the full dynamics of this system.

Over time spans of 100 years we find that singly averaged dynamics can follow the full solutions almost exactly even in these highly chaotic regions while the doubly averaged solution does not follow as precisely [1]. However, with our focus on debris removal we are not concerned with the exact state, but rather the general trends in orbit evolution. This research seeks to understand the statistical significance in these deviations. We will examine how close neighboring solutions follow precise solutions of the dynamics. By determining if the doubly averaged solution captures general trends in the chaos, we can validate it as a tool.

The use of the doubly averaged solution enables a significant computational speed-up and allows for the chaotic trends in the GNSS region to be characterized. This will help engineers better utilize this region for more cost-effective debris removal practices at orbit altitudes as high as MEO.

[1] M. Pellegrino and D. Scheeres, "Robustness of Targeting Regions of Chaos In the GNSS Regime," *Winter 2019 Spaceflight Mechanics Meeting.*