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GENERAL PERTURBATIONS METHODS FOR ORBIT PROPAGATION WITH PARTICULAR APPLICATION TO SPACE DEBRIS MITIGATION COMPLIANCE

Abstract

The average number of spacecraft launched per year has recently and rapidly increased, a trend largely the result of the increased use of small and micro-satellites, platforms such as the CubeSat. This growth trend is unlikely to reverse in the near-term. To mitigate the risk that spacecraft pose to the availability and accessibility of the space environment, debris mitigation standards currently recommend that spacecraft be removed from low-Earth orbit within 25 years of end-of-mission. In order to prove compliance with these standards, spacecraft operators must demonstrate the evolution of their spacecraft's orbit through the use of orbit propagation software. A new general perturbation method for orbit lifetime analysis has been derived, including a new analytical model for atmospheric mass density with an integrated solar activity model. When combined with the derived general perturbations method for orbit propagation, validation against historical data shows an improvement in orbit lifetime estimates from an average error of 50.44 percent with a standard deviation of 24.96 percent, to an average error of 3.46 percent with a standard deviation of 3.25 percent. Furthermore, the new method with applied atmospheric and solar activity models is found to compare favourably against other general and special perturbations methods, including third party, and commercial software, the most accurate of which was found to have an average error of 6.63 percent and standard deviation of 7.00 percent. There are many applications for such a method, however the most notable result presented herein is in collision risk analysis. A popular de-orbit concept due to its simplicity is drag augmentation, the use of a deployable surface to increase atmospheric friction. Such concepts have received notable attention, with various funding bodies and licensing authorities supporting technology and flight demonstrations, as well as in the specialist and popular media. However, studies lack a full analysis of the implications of increasing projected area on collision risk, focusing principally on time to de-orbit and assuming a direct correlation with collision risk. Using the volume swept (equivalent to area-time product) during de-orbit as a metric for collision risk it is shown that, contrary to the widely held belief, drag augmentation typically increases collision risk. It is shown that if applied in the worst-case scenario, specifically at the wrong time during the solar activity cycle, drag augmentation can increase the collision risk by an order of magnitude.