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Space carrying capacity assessment and allocation (10-E9.4)

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A STABLE EQUILIBRIUM FOR THE LEO ORBITAL CAPACITY

Abstract

The population of satellites in Low Earth Orbit (LEO) has recently witnessed a significant increase due to the advancements in satellite technology, the reduction of launch costs, and the deployment of large constellations of satellites. This surge in LEO satellite populations raises concerns about the orbital capacity, essentially the ability of the LEO environment to sustain a certain number of satellites without unsustainable levels of risk due to space debris or collisions. The idea of orbital capacity concerns the physical space available along with the sustainability of orbital paths over long evolution times. As more satellites occupy this region, the risk of in-orbit collisions increases, which can generate debris that further complicates space traffic management and increases the risk to operational satellites and human spaceflight missions.

This work leverages an improved version of the MIT Orbital Capacity Assessment Tool - Source-Sink Evolutionary Model (MOCAT-SSEM) to investigate the evolution of the space objects population in LEO and assess the LEO orbital capacity, where multi-shells multi-bins species can be defined, and the debris generated by collisions are deposited into the nearby shells, according to the NASA Standard Breakup Model (SBM). The mechanism for the creation of debris and the dynamics of imparting the change in velocity to each particle is approximated in the SSEM by sampling the stochastic SBM process and averaging the number of objects whose semi-major axis are changed by the change in velocity. This spreading function to the debris population for each shell allows a more realistic representation of the evolution of the space objects population, and adds in a mechanism for a dense lower-altitude regime to increase the density of the shells around it. A constrained nonlinear optimization problem is then formulated to compute the maximum orbital capacity of the low region of LEO, considering stable equilibrium points and the failure rate of satellites as constraints. In this way, we can estimate the maximum number of satellites that it is possible to fit in LEO for a long-lasting stable space environment. The optimal solution is then given as input into MOCAT-MC, the higher-fidelity Monte Carlo version of MOCAT, to prove the effectiveness of the maximum orbital capacity results. To enhance the performance and fidelity of MOCAT-SSEM, a calibration of the model is performed based on the MOCAT-MC output. Preliminary results show an agreement between the maximum orbital capacity equilibrium solution retrieved by SSEM and the MC counterpart.