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

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ORBITAL CARRYING CAPACITY METRICS, CALCULATIONS, AND REGULATION

Abstract

Low Earth orbit (LEO) is a finite resource and "rivalrous" (each consumer reduces the amount available to others), yet available to all, incentivizing a "tragedy of the commons". Current trends of satellite deployments risk overloading LEO (exceeding carrying capacity). Orbiting satellites increasingly are at risk of being fragmented by collisions, creating debris. Increasing collision risk in LEO is one of the most pressing threats to the safety and sustainability of space exploitation.

Three steps for addressing this problem are: 1) defining orbital carrying capacity metrics, 2) implementing tools to holistically evaluate these metrics, and 3) developing a regulatory approach that will reduce risk of overloading LEO. We define several carrying capacity metrics, use a high-fidelity Monte Carlo simulation to evaluate each over a range of assumptions, and propose an approach to risk mitigation.

Several carrying capacity metrics are explored, including a) the point at which the rate satellites are consumed by collisions is equal to a specified fraction of the constant rate at which satellites would be launched to maintain a constellation, b) debris size density masks, that limit the numbers of debris of various sizes in various orbits, and c) net growth rates of non-maneuverable payloads and of debris in various orbits.

The Monte Carlo simulation propagates all objects discreetly using semi-analytic methods. It is initialized with payloads, derelict rocket bodies, and trackable debris from existing catalogs. Additionally, non-trackable, debris are initialized from models. Fragmentation events are modeled using the EVOLVE 4.0 NASA Standard Breakup Model (SBM) suitably modified to conserve mass. Sufficient Monte Carlo trials are generated in the cloud to provide high, 95

The simulation is used to evaluate each of the carrying capacity metrics over a 100-year timeframe. Mitigations, such as Space Surveillance and Tracking (SST), Space Situational Awareness (SSA), and Space Traffic Management (STM) are modeled in the simulation. Environmental factors beyond our control, such as future solar activity, are modeled stochastically. This methodology enables comparing holistic global contributions to the metrics as a function of specific system characteristics and deducing the incremental impact of individual systems and characteristics.

Simulation results demonstrate that, independent of the carrying capacity metric used, orbital admittance control and minimum satellite reliability standards (i.e., using license conditions to limit the number of satellites, mass, and cross-sectional area; and requiring minimum satellite reliability standards) are needed to mitigate risk of exceeding carrying capacity.