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HOLISTIC MODELING OF LEO CAPACITY AND CONSUMPTION

Abstract

The value of low Earth orbits, both for communications and for sensing, is uncontested. Understanding the capacity of low Earth orbit (LEO) space, and the impact on that capacity from various actions, is critical for sustainability. Launching satellites, deorbiting satellites, losing maneuverability, explosions, collisions, AST, and actively removing non-maneuverable objects (such as derelict rocket bodies) are all actions that impact available capacity. The performance of Space Surveillance and Tracking (SST), Space Situational Awareness (SSA), and Space Traffic Management (STM) alter the impact of these actions. Environmental factors beyond our control, such as the existing debris flux, future solar activity, and future meteorite flux, also impact available capacity. These actions, performances, and factors cannot be evaluated in isolation; a holistic approach is required.

A metric is proposed that accounts for all of the actions, performances, and factors; and is used to evaluate various scenarios. High fidelity models are used to 1) capture the effect of SST, SSA, and STM performance on the collision probability, 2) access the consequences of collisions based on satellite characteristics, and 3) explore the impact of environmental factors. Scenarios evaluated range from the current environment with no further LEO launches to full deployment and sustainment of all large constellations that have been proposed. Each scenario is considered with various combinations of SST, SSA, and STM performances; satellite characteristics; and environmental factors.

A robust metric allows satellite operators, regulators, and space agencies to understand the impacts of their actions on LEO capacity – tailoring their design and mission parameters to minimize that impact. For example, trading constellation size, satellite mass and area-to-mass ratio, and orbits. The metric also allows for more efficient resource allocation, providing insights on the gains achieved by improving the performance of each of SST, SSA, and STM systems. It additionally provides guidance on remediation and debris removal efforts. For example, the relative benefits of removing one particular derelict rocket body compared to removing a different one.

The results demonstrate that there are no hard limits on constellation sizes, satellite characteristics, or orbits. There are numerous options for consuming a given fraction of the capacity. Further, improving SST, SSA, and STM performance and remediation efforts increase the effective capacity. This work builds on existing models and methods to extend our capability for understanding, and trading, the environmental impact of actions effecting LEO.