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FINDING THE UPPER THRESHOLD OF LEO ACTIVITY THAT MAKES LONG-TERM SPACE OPERATIONS UNSUSTAINABLE

Abstract

As an increasing number of space-faring nations and commercial operators continue to populate LEO with large constellations, a looming question emerges: "What is the upper threshold of LEO activity at which point the orbital regime becomes unsustainable for permanent residents and transients passing through on their way to other orbital regimes?" This study addresses this question using the Aerospace Debris Environment Projection Tool (ADEPT) to examine the evolution of dozens to hundreds of possible future orbital environment scenarios to quantify the effects on several aspects of space operations. These scenarios span a variety of parameters including the amount of launch traffic, number and placement of large constellations, debris mitigation and post-mission disposal practices, accidental explosion rate, accuracy of space surveillance data for collision avoidance, and size range of objects that can be tracked. Future sustainability projections consider how the orbital environment will evolve based on the above parameters and interactions between objects, accidental collisions, debris generation, and feedback loops.

The definition of what constitutes conditions that are unacceptable or unsustainable for space operations is complex, containing both technical and political components. A number of operational characteristics are examined to provide a comprehensive view of space operations effects of the different future environments modeled. These characteristics include satellite collision and loss rates due to debris, stability of the debris environment with respect to the "Kessler Syndrome" of self-perpetuating debris growth, collision avoidance frequencies for operational satellites, rates of launch window closure due to launch collision avoidance, and interactions between space surveillance system characteristics and the above operations.

The different operational effects are examined and quantified for the range of scenarios analyzed. This provides a range of operations effects that can be used to identify unacceptable or unsustainable conditions. The multi-characteristic examination of the effects is needed to provide insight into the full range of operations impacts that will affect space usability. Each of these characteristics is presented as a relative measure comparing the individual scenario to a baseline scenario, which represents a close approximation to the current state of space traffic. This approach allows for assessing the sustainability characteristics as compared to current operations by identifying what inputs lead to order-of-magnitude

degradation of those characteristics over time. The results provide a high-level graphical reference for policy-makers to evaluate decisions that affect long-term space operational sustainability.