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ENVIRONMENTAL SUSTAINABILITY OF LARGE SATELLITE CONSTELLATIONS IN LOW EARTH ORBIT

Abstract

The current plans envisaging the deployment of very large constellations in low Earth orbit (LEO), some consisting of thousands of spacecraft, raised a growing concern regarding the long-term sustainability of the near-Earth space environment with the present-day guidelines recommended around the world. Assessing the impact of the proliferation of small satellites and large constellations has therefore been identified as a priority, in order to evaluate if additional, and more stringent, mitigation measures might be needed to preserve the long-term access and utilization of the LEO protected region.

However, this task may be quite complex, because traffic models and constellation deployment plans are, of course, subject to sudden changes, driven by economic and technical issues, and are anyway very uncertain beyond twenty years in the future. The same applies to technological developments and breakthroughs, which could change completely the nature of space systems, as in part is already occurring with the very fast increase of mini, micro and nanosatellites. Therefore, it might be desirable to address the problem avoiding the detailed simulations of complex and highly speculative scenarios, concentrating instead on a simplified and fast analysis, able to provide some preliminary clues and insights, perhaps useful for steering further refinements with more complex and time expensive approaches.

With this goal in mind, during the last few years we developed several analytical expressions, based on reasonable simplifying assumptions, for the assessment of the environment criticality of large constellations and huge numbers of small satellites in LEO. They can provide preliminary quantitative answers to difficult questions, with no need of complex models and computations. Moreover, a specific figure of merit was introduced for gauging the environment criticality of new large constellations: the collision rate percentage increase.

Since 2014, we also developed a LEO criticality index, initially devised to rank potential optimal targets for long-term orbital debris remediation purposes. In this paper, the criticality index was instead applied as a tool for mitigation analysis, in order to evaluate the environmental impact of large constellations as a function of their level of compliance with appropriate end-of-life disposal, including spacecraft failures. The results obtained are therefore compared, for consistency, with the collision rate percentage increases computed with the previous independent approach, through the presentation and discussion of several quantitative examples.