Evaluation of post-mission disposal options for a large constellation

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ABSTRACT

Large constellations of satellites in Low Earth Orbit (LEO) aim to provide important communications and broadband internet services to large parts of the world, especially where the necessary terrestrial infrastructure is lacking. At the same time, there is potential for these space systems to adversely impact the sustainable use of the space environment over the long-term and the safety of spaceflight in the short-term unless appropriate plans for orbital debris mitigation measures are incorporated into the design and operation. In particular, recent computer modelling studies have shown that comprehensive observance of the Inter-Agency Space Debris Coordination Committee (IADC) guideline on post-mission disposal is a vital element of debris mitigation plans intended for large constellations in LEO. Although the IADC guideline conveys a preference for direct re-entry, operators can instead maneuver their spacecraft to an orbit with a reduced lifetime where this is appropriate. In general, the IADC has found that a lifetime limit of 25 years is reasonable. Subsequently, operators of spacecraft at altitudes above approximately 600 km, and seeking to address orbital debris concerns, can maneuver to orbits with perigee altitudes below that on reaching the end of their mission. Further, most spacecraft deployed to orbits at altitudes below approximately 600 km will naturally decay within the suggested lifetime limit once reaching the end of their mission. As a consequence, several operators have proposed that this region of LEO could be used to accommodate large numbers of spacecraft without unduly heightening orbital debris concerns. Such proposals are seen as a way to reduce the adverse impacts of large constellations, but they need to be considered alongside the plans of other operators who wish to maneuver their spacecraft to orbits crossing the same region once their missions have ended. Therefore, the objective of a new computer modelling study, using the Debris Analysis and Monitoring Architecture to the Geosynchronous Environment (DAMAGE), was to evaluate deployment and post-mission disposal options for a large constellation in the context of widespread adoption of the so-called “25-year rule” by other operators.

DAMAGE was used to evolve the population of objects > 10 cm in LEO from 1 February 2018 over a 200-year projection period. The simulation of the build-up, replenishment and disposal of a large, complex constellation comprising 10,440 active spacecraft was included. The constellation was assumed to be made up of three fundamental components: 7200 spacecraft in three bands operating near 350 km altitude, 1440 spacecraft in three bands operating near 1200 km, and 1800 spacecraft in a single band at either 1100 km or 550 km altitude. The positioning of the latter constellation component provided the two basic study conditions. For each case, it was assumed that all operators – constellation and background – achieved a high level of success with their post-mission disposal plans. For the constellation, 95% of the spacecraft were maneuvered using electric propulsion to orbits with a perigee altitude of 300 km regardless of their initial, mission altitude. For the background, 90% of spacecraft and rocket bodies were maneuvered where necessary to eccentric orbits with a lifetime of 25 years.

The results showed that positioning the 1800-spacecraft band at 550 km altitude, instead of at 1100 km altitude, did reduce the overall collision hazard associated with the constellation, but the risk of an encounter with another constellation spacecraft or an object from the background population remained, even if at a low level. In addition, collisions involving spacecraft from other parts of the constellation, especially those maneuvered to disposal orbits from mission orbits near 1200 km altitude, continued to account for a relatively substantial number of collision events. This was true even through the residual spacecraft lifetimes were considerably less than 25 years, although some additional mitigation measures could be taken to reduce the number or severity of these events. Consequently, plans to deploy large constellations should continue to be assessed appropriately even if high rates of post-mission disposal are achieved, if residual lifetimes are short, or if spacecraft operate at altitudes where their natural orbital lifetime will be less than 25 years.