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REVIEW OF PAST ON-ORBIT COLLISIONS AMONG CATALOGED OBJECTS AND EXAMINATION OF THE CATASTROPHIC FRAGMENTATION CONCEPT

Abstract

The intentional and accidental collisions involving artificial satellites in recent years have captured worldwide attention well outside the borders of the orbital debris community, raising a growing interest in topics like sustainable space activities, possible exponential growth of the fragments able to destroy intact objects, and active debris removal. The increasing awareness and concern led to a number of policy, research and operational initiatives at UN, international and national levels. It is certainly a fact that during the last three decades, in spite of a progressively broader adoption of mitigation measures, the number of objects tracked around the Earth has grown by a factor 4.5. Part of this increase (1/4) was due to the improving sensitivity of the space surveillance sensors, but most of it (3/4) represented a real proliferation of objects, of which approximately 50% were generated in just two catastrophic collisions, one intentional and one accidental. It is also true, from a mathematical point of view, that the debris population in LEO above 700 km is intrinsically instable, due to collisional dynamics and to the relative inefficacy of air drag in removing intact objects and fragments. However, from a practical point of view, the evaluation of the time scale(s) characterizing the expected pace of debris growth is of fundamental importance to factor in the operational impact, the technological advances, the economic consequences, and the need of remediation measures. Apart from the uncertainty of future launch traffic and space technology, the predictions of the current long-term evolutionary models are strongly affected by a number of critical assumptions concerning the definition of catastrophic collision, the fragmentation threshold, the collision geometry, and the mass, area and velocity distributions of the fragments. Any change in this set of hypotheses might have significant consequences on the time scale(s) of debris growth and this explains the current renewed interest in satellite breakup tests carried out on the ground. Even if the numbers involved are still too low, some insight can also be derived by revisiting the documented collisions already occurred in orbit. For instance, it is intriguing to remark that among the four accidental collisions recorded so far among cataloged objects, only one was truly catastrophic, but involved a maneuverable spacecraft, so it was, at least in principle, avoidable. This paper will address the definition and expected relative frequency of catastrophic collisions and the other hidden uncertainties of long-term evolutionary model forecasts.