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STATISTICAL ANALYSIS OF ON-ORBIT FRAGMENTATION EVENTS

Abstract

To permanently stabilize the current space debris environment an active reduction of the existing in-orbit mass is necessary via active debris removal (ADR). However, for ADR to become a reality a more comprehensive characterization of the space debris environment is needed, including the probability and severity of on-orbit fragmentation events. Such parameters would help limit the exposure of a chaser spacecraft to a possible fragmentation event of a target object during the close-range rendezvous phase of a mission. Past studies on the topic have focused almost exclusively on the statistical analysis of on-orbit failure data of satellites, neglecting space debris. Using a collection of statistical methods (e.g., survival analysis, Pareto principle, box plots) the probability and severity of breakups is analyzed from the sample of the ESA's database of space debris, DISCOS, consisting of 11490 unmanned, catalogued objects having an average observable area-to-mass ratio within the $(0, 0.1)$ m^2kg^{-1} interval. Human spaceflight related objects are excluded from the sample as they would tend to skew the probability results in view of more stringent spaceflight safety measures and reliability characteristics. The resulting survival probability of rocket bodies and payloads is found to be overall high, i.e., there is more than 96% chance that an object, if in orbit, will survive past the 50-year mark without experiencing any fragmentation event. However, rocket bodies collectively do tend to have a bathtub-like hazard curve, mainly due to propulsion related events, characterized by an initial high *infant mortality* and a *wear-out period* between 40 and 50 years in orbit. Payloads on the other hand collectively exhibit a more gradual reduction of the survival probability in time, mainly due to “anomalous events”, as it might be expected for hardware whose purpose is to remain functional in-orbit for a longer period. The *unknown events* of payloads display a bathtub-like hazard curve, hinting at ”active systems” as probable cause, despite their *unknown* classification. The performed statistical analysis of on-orbit fragmentation events provides a step towards a more comprehensive characterization of the space debris environment as well as a more complete understanding of the currently available data with an aim to make the initial planning of future ADR missions easier and more systematic.