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CHARACTERIZATION OF ABANDONED ROCKET BODY FAMILIES FOR ACTIVE REMOVAL

Abstract

Most of the cross-sectional area and mass in orbit are concentrated in intact objects, of which approximately 80% are constituted by abandoned spacecraft and rocket bodies. In low earth orbit, the abandoned objects and the associated mass are not evenly distributed, but quite often concentrated in relatively narrow altitude-inclination bands, where the probability of catastrophic collision is significantly above the average. This clustering pattern frequently involves a substantial number of nearly identical objects, as upper stages of a few basic models. Therefore, even though upper stages account for about 50% of the abandoned mass in low earth orbit, such a 50% is concentrated in a relatively small number of rocket body families. It seems then quite reasonable that any plausible orbital debris remediation scheme, if and when deemed necessary, should start considering the active removal of abandoned mass from crowded regions, and the targeting of upper stages in particular would offer a lot of advantages, because they are usually easier and safer to grab, more robust from a structural point of view, less secretive, and have simpler and more symmetrical shapes, mass distributions, structures and rotational motions. In addition, the targeting of very similar objects belonging to a few types would make possible many removal missions with basically the same hardware and procedures. This paper characterizes the most relevant rocket body families present in low earth orbit in terms of mass, orbit, residual lifetime and catastrophic debris collision probability. Just six general types of rocket bodies account for approximately 70% of the overall mass stored in upper stages abandoned below the altitude of 2000 km. Through the definition of a simplified ranking scheme based on reasonable and easy to apply assumptions, the results obtained are used to evaluate and prioritize the most relevant families of objects, and the single objects belonging to each family, in order to find the most appropriate potential targets for active debris removal as a function of mass to be de-orbited, average altitude, inclination and node distribution (being the latter information of relevance for multiple removal approaches). The details provided aim to be useful for active removal mission preliminary design, dimensioning and analysis.