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SPACE DEBRIS CLOUD EVOLUTION IN LOW EARTH ORBIT

Abstract

The Earth is surrounded by inoperative objects created by past space missions; as the orbital speed is very high, the impact with a very small fragment, down to 1 cm, can be catastrophic for operating satellites. Therefore, it is important to assess the collision risk due to space debris; this requires a reliable picture of the debris environment and a deep understanding of its evolution.

In this work, an analytical approach is used to describe the evolution of a debris cloud created by a collision in Low Earth Orbit. In contrast to traditional approaches, which follow the trajectory of single fragments, here the cloud behaviour is studied globally. This reduces the computational time needed to estimate the consequence of a collision and allows simulating several what-if scenarios to understand which objects, in case of fragmentation, are more likely to pose an hazard to operational spacecraft.

The NASA Break-up model is used to describe fragments dispersion in terms of characteristic length, area-to-mass ratio (A/M) and velocity. From the velocity distribution the fragment spatial dispersion is derived, through an estimation of the time after which the fragments create a ring around the Earth . The cloud density is expressed by a distribution function that depends on altitude and A/M, to highlight the effect of A/M on orbit evolution. The distribution function fully describes the debris cloud and so it is set as initial condition for the orbit propagation. Based on an analytical approach proposed in the literature for interplanetary dust and spacecraft swarms, the fragment cloud evolution in time is derived through the continuity equation. In this application, the continuity equation describes the variation of debris density considering Earth's gravity and atmospheric drag . Changes in the Earth's atmosphere due to the solar cycle are considered through a simplified model, while a numerical model of density as a function of altitude is used. An assessment of the consequent collision probability for operating satellites is then computed, by filtering the spacecraft orbits which cross the debris cloud. It will be also shown how the newly generated cloud can be easily superimposed to the space debris historical population.

The long-term cloud evolution is validated through numerical integration and the method's accuracy estimated. A number of fragmentation scenarios are simulated, considering different altitudes and energy levels for the event. Finally, we assess the consequent collision probability for operating satellites.