## **Passive devices for** **safe deorbiting and reentry of spent upper stages**

Vladimir Aslanov

aslanov\_vs@mail.ru (Samara National Research University)

Dmitry Sizov

dmitriy.sizov@nu.edu.kz (Nazarbayev University)

Spent upper stages of launch vehicles are a very large and dangerous class of space debris since they are prone to spontaneous explosions producing many small objects. This makes old upper stages one of the primary targets for future active space debris removal missions. If the initial attitude motion of the target stage is known, e.g., from in-situ measurements exploiting CubeSats, it is possible to attach a deorbiting device to the stage in order to ensure its safe deorbiting and reentry.

This study proposes concepts of passive devices that can change the character of the attitude motion of the target following two different deorbiting and reentry scenarios, the choice between which depends on the specific mission’s parameters. The first scenario is aimed at minimizing the debris footprint size. In this case, it is necessary to ensure that the stage does not tumble during reentry, i.e. that its longitudinal axis is closely aligned with the velocity vector of the center of mass. To achieve this, the deorbiting device needs to have fins oriented in such a way as to make the stage spin. The second scenario is intended to ensure that the fragments produced by the eventual breakup of the stage do not reach the Earth’s surface. In this situation, the breakup should occur at high altitudes, thus, unlike the previous case, spinning is undesirable, but tumbling is necessary since it provokes large aerodynamic and thermal loads on the stage, forcing its early breakup. To despin the stage in the initial phase of the mission, the deorbiting device can use a yo-yo mechanism, and tumbling can be achieved if the device is equipped with a fin on one side, which is perpendicular to the stage’s longitudinal axis.