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Concept of an Active Debris Removal 2-step capturing system for small satellites in Low Earth Orbit

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Abstract

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Space debris brings up two main critical issues: not only a non-sustainable space environment for satellite missions, with orbit saturation, but also the creation of an unsafe place for human-related space missions.

Despite being extremely challenging, catching autonomously and harmlessly an uncooperative object tumbling at high velocity demand reliability, compliance, and robustness. Grasping an object in microgravity means having control during the impact, but also keeping the link between the chaser satellite and the debris secure enough to handle the deorbiting phase. Supposing that the GNC installed tackles the synchronization with the debris rotation, so that only a linear translation is necessary to capture, three main problems can occur.

The first problem can occur at the impact between the servicer and the debris. Due to the motion-reaction law, the debris could be pushed away if the capturing system does not prevent that motion. Besides, a high stiffness of the system, added to an unexpected strong impact, could damage either the servicer and/or the debris, resulting in a mission failure. Moreover, the need for a secure attach is required to go-on with the deorbit phase without losing the debris.

That's why, thanks to the fruitful collaboration between industry and academia (Spacety Luxembourg - SpaceR research group at the University of Luxembourg), a cutting-edge concept of a two-step capturing mechanism is being designed. Data analysis of trackable objects in LEO reveals an abundant number of CubeSat-shaped satellites, that future constellations might also take advantage of. Consequently, the concept presented is focusing on capturing these, at their end of life.

A first 'soft capture' ensures that the debris is received softly while dampening any vibrations generated. A gecko-inspired adhesive surface will first receive the debris, preventing it from being pushed away. The property of such dry adhesive is that they do not require a high preload to stick to the surface, while having a very strong adhesion. To absorb most of the vibrations or movements due to the first impact, a compliant mechanism will be integrated behind the adhesive part. To that extent, if the alignment is not perfect, the system has some degrees of freedom, so that no damage can be generated. This compliant and sticky system would prevent the first main two issues of capturing an uncooperative target in microgravity. Then, a 'hard capture' secures the debris so that it would be deorbited without being released on the way. This part of the system would either gently squeeze the debris, using controlled adhesive flexible arms, or encircle it, and would be designed in compliance of ESA guidelines for demise.

A two-step capturing mechanism is here proposed, taking advantage of bio-inspired dry adhesive technology, and compliant mechanisms, while having ESA guidelines in mind. Bringing the advantage of removing a vast range of objects in orbit, it also allows a reliable capturing, removing risks of generating more debris. Later works would bring attention to architecture that would fit more than a box shape.