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BREAKING THE CYCLE: NOVEL CAPTURE MECHANISMS FOR ACTIVE SPACE DEBRIS REMOVAL

Abstract

Since the launch of Sputnik 1 in 1957, over 6000 rockets and more than 11,300 satellites have been launched into space, resulting in a high number of artificial space debris in orbit around Earth. Of this debris, there are over one million objects between 1 cm and 10 cm in existence. To ensure the feasibility of future space missions, it is crucial to not only mitigate debris creation but actively remove debris from space to prevent a cascade of breakup events. Major space agencies and industries have been involved in developing space debris capture mechanisms, including Astroscale's ELSA- d mission which successfully demonstrated the capture and release of debris in 2021. Despite the large proportion of debris being less than 10 cm, most capture mechanisms in development only address debris greater than 10 cm. Another concern with some existing mechanism concepts is the potential that they could create more debris through impact on capture, adding to the existing problem.

With an aim to facilitate active space debris removal and address some of the gaps in existing technology, this paper presents and compares three conceptual mechanism designs for capture of space debris of three different target sizes. The first mechanism utilises multiple chain link arms housed in extendable brackets which extend and connect to form a closed loop around the debris. The debris is then held up against the payload satellite in a 'hug' configuration. This method is highly adaptable to debris shape and size, and can capture debris between 10 cm to 1 m. The second mechanism is a cable-driven hybrid soft robotic gripper. The design features a rigid skeleton with multiple hinge points and a silicone elastomer covering, allowing the fingers to 'bend' to adapt to the shape of the target debris. Implementation of soft robotics theory and embedded 'soft sensors', aims to mitigate the risk of smaller debris being created upon capture. The mechanism is sized to capture debris of approximately 10 cm; however, it could be scaled up for capture of larger debris. The third mechanism is an origami-inspired deployable scissor grid cylinder, which uses flexible material to allow for adaptation to the size and shape of the debris being captured. This mechanism is designed to capture debris smaller than 10 cm and can be applied to irregularly shaped tumbling debris.