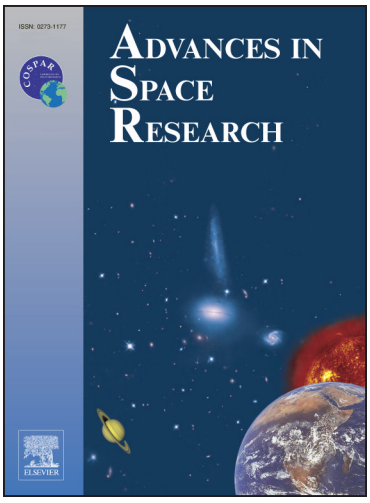

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A Deployable Mechanism Concept for the Collection of Small-to-Medium-Size Space Debris

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Abstract

Current efforts in active debris removal strategies and mission planning focus on removing the largest, most massive debris. It can be argued, however, that small untrackable debris, specifically those smaller than 5 cm in size, also pose a serious threat. In this work, we propose and analyze a mission to sweep the most crowded Low Earth Orbit with a large cupola device to remove small-to-medium-size debris. The cupola consists of a deployable mechanism expanding more than 25 times its storage size to extend a membrane covering its surface. The membrane is sufficiently stiff to capture most small debris and to slow down the medium-size objects, thus accelerating their fall. An overview of the design of a belt-driven rigid-link mechanism proposed to support the collecting cupola surface is presented, based on our previous work. Because of its large size, the cupola will be subject to significant aerodynamic drag; thus, orbit maintenance analysis is carried out using the DTM-2013 atmospheric density model and it predicts feasible requirements. While in operation, the device will also be subject to numerous hyper-velocity impacts which may significantly perturb its orientation from the desired attitude for debris collection. Thus, another important feature of the proposed debris removal device is a distributed array of flywheels mounted on the cupola for reorienting and stabilizing its attitude during the mission. Analysis using a stochastic modeling framework for hyper-velocity impacts demonstrates that three-axes attitude stabilization is achievable with the flywheels array. MASTER-2009 software is employed to provide relevant data for all debris related estimates, including the debris fluxes for the baseline mission design and for assessment of its expected performance. Space debris removal is a high priority for ensuring sustainability of space and continual launch and operation of man-made space assets. This manuscript presents the first analysis of a small-to-medium size debris removal mission, albeit finding it to not be economically viable at the present time.

Keywords: space debris, deployable mechanism, active debris removal, small size, cupola device
PACS: 91.10.Sp, 95.40.+s