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WAIT, DETECT AND COLLIDE STRATEGY FOR SMALL SPACE DEBRIS REMOVAL IN LOW EARTH ORBITS

Abstract

This study presents a new approach to space debris removal, utilizing a debris removal system (DRS) equipped with a plate structure to intentionally collide with small space debris pieces at low relative velocities. By executing collisions at shallow angles, the debris undergoes sufficient deceleration to reduce its orbital lifetime while minimizing damage to the DRS. This approach eliminates the need for traditional capture or intentional deceleration methods, enabling consecutive removal of small space debris pieces. Analyses conducted using on-orbit object databases demonstrate that the proposed approach can effectively reduce the orbital lifetime of the majority of space debris in Low-Earth Orbit (LEO) to below one month. The study also investigates an orbit design approach to maximize the number of removable space debris pieces, determining an optimal orbital inclination of 87.3deg for the DRS at an 850km altitude in LEO. Notably, the lower rate of change in Right Ascension of the Ascending Node (RAAN) for this optimal orbit, at -0.30deg/day compared to the typical LEO satellite rate of 0.99deg/day, enables the DRS to naturally align for successive debris removal opportunities, eliminating the need for large intentional orbital maneuvers and enhancing operational efficiency. Furthermore, numerical simulations involving six DRSs positioned on optimal orbits with different RAANs every 60deg are conducted to assess the effectiveness of the proposed approach. These simulations consider various factors such as collision criteria, maximum orbital maneuver capabilities, and post-collide perigee altitude of space debris below 300km. Results indicate that with an upper limit of orbital maneuver of 10m/s, 60 debris pieces could be removed within one month with an average orbital maneuver of 5.4m/s, while with an upper limit of 100m/s, 163 pieces of debris were removed with an average orbital maneuver of 33.6m/s within the same timeframe. The range of orbital inclinations for removed debris varied from 70.1 to 100.9deg. Approximately 5200 pieces of space debris within specified altitude and inclination ranges were identified. Assuming a lifetime total V of 3000m/s of a DRS, six DRSs could remove approximately 3300 pieces of debris in 86.8 months with a maximum orbital maneuver of 10m/s, and 530 pieces in 3.4 months with a maximum orbital maneuver of 100m/s. These findings suggest that while a larger maximum orbital maneuver facilitates quicker debris removal, limiting it to a smaller value achieves cost-effective removal over a longer period. Further simulations with detailed scenarios are now underway to be presented at IAC.