Conceptual analysis for a technology demonstration mission of the Ion Beam Shepherd

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Abstract:

With the increased commercialization of space, uncontrolled debris or defunct satellites pose a major hindrance to the launch of new missions. Low Earth Orbit is particularly constrained by the increasing number of satellites, increasing collision risks that might lead to major losses in technological advancement. Hence, it is imperative to develop techniques for ensuring sustainable development and exploration of outer space. Active Debris Removal (ADR) describes strategies employed to preserve the usability of the space environment surrounding Earth over long timescales. In particular, they are concerned with actively removing uncooperative objects which pose a collision threat.

A promising ADR technique consistent with contactless operation constraints, which is undergoing rapid development, is known as the Ion Beam Shepherd (IBS). This revolves around using a highly collimated ion beam to continuously exert a force at a close range on the debris to achieve a highly controlled deorbiting. However, to date, no demonstration mission has proven this concept in space.

Here we show a roadmap and comprehensive analysis of the current state-of-the-art of the required technologies for the development of an ADR demonstration mission for small satellites with an IBS system, along with an assessment of their most critical risks and challenges.

This paper presents a survey of the main research works in the subject of IBS ADR missions along with multiple comparative analyses between alternative architectures for an in-orbit demonstration mission that could potentially increase the technology readiness level (TRL) of IBS capabilities for small satellites in LEO. Particular attention is given to the mission critical elements, such as state-of-the-art electric propulsion, techniques for collision avoidance, methods for the reconstruction of the dynamics of non-cooperative targets, and hazardous effects connected to IBS. The most critical risks are investigated in this paper and discussed in detail. Thruster misalignment resulting in tumbling of the target, contamination risk, problems with acquiring the target based on the visual sensor inaccuracy, attitude control error in the approaching phase, and electric propulsion reliability are studied here from different angles.

This analysis will pave the way for future similar ADR missions in orbit by becoming a reference point of pre-existing research on IBS and presenting a guideline for feasibility studies on IBS implementation in future missions.