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COMPARISON OF ACTIVE DEBRIS REMOVAL METHODS FOR SUSTAINABLE ON-ORBIT SERVICING AND RECYCLING

Abstract

The growing expansion of activities in cislunar space calls for sustainable solutions to manage space debris and enable the reuse of in-orbit resources. This study evaluates and compares different Active Debris Removal (ADR) technologies—including electrodynamic tethers, Plasma Beam Shepherd (PBS), and mechanical nets—within an In-Space Servicing, Assembly, and Manufacturing (ISAM) framework, aiming to enhance space sustainability.

Electrodynamic tethers facilitate the controlled deorbiting of defunct satellites by interacting with Earth's magnetic field. The Plasma Beam Shepherd, leveraging a directed plasma flow, enables contactless manipulation and repositioning of debris, making it a suitable solution for fine-tuned control of objects without physical interaction. Meanwhile, retractable nets provide a safe method for collecting smaller fragments, minimizing collision risks.

Integrating these technologies into an on-orbit servicing system fosters the repurposing of space materials through additive manufacturing and modular assembly. This strategy marks a significant step toward efficient space resource management, reduced reliance on Earth-based resupply, and improved safety and sustainability for deep-space missions.

To achieve these goals, the study follows a Model-Based System Engineering (MBSE) approach. This research is conducted within the Space Exploration and Development Systems XVI (SEEDS XVII) II Level Master's programme, a collaboration between Politecnico di Torino (PoliTo), Institut Supérieur de l'Aéronautique et de l'Espace (ISAE), and the University of Leicester, with contributions from Agenzia Spaziale Italiana (ASI), Centre National d'Études Spatiales (CNES), European Space Agency (ESA), Thales Alenia Space, and Altec.