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AUTONOMOUS SPACE DEBRIS COLLECTOR SHIP: A SUSTAINABLE SOLUTION FOR MULTI-DEBRIS RETRIEVAL AND REUSABILITY

Abstract

Autonomous Space Debris Collector Ship: A Sustainable Solution for Multi-Debris Retrieval and Reusability The growing accumulation of space debris poses significant risks to satellites and future missions, necessitating an efficient and sustainable removal strategy. This paper introduces a novel Autonomous Space Debris Collector Ship (ASDCS)—a reusable spacecraft equipped with robotic arms and AI-based identification systems to capture multiple debris pieces in a single mission and either return selected materials to Earth for recycling, neutralize hazardous debris, or facilitate in-orbit repurposing.

ASDCS employs AI-driven algorithms, LiDAR, and sensor fusion technologies to autonomously identify, classify, and capture debris while ensuring compliance with international space laws. To address authorization challenges, the system integrates with a Global Space Debris Identification Database (GSDID)—a registry enabling agencies and private entities to pre-authorize debris collection. A Just-in-Time Clearance Model (JCM) ensures real-time verification before retrieval.

Unlike traditional single-use Active Debris Removal (ADR) missions, ASDCS provides a cost-effective multi-debris capture approach. However, not all debris will be returned to Earth. A hybrid strategy is implemented, where only selected, non-hazardous, and reusable debris is retrieved for Earth-based recycling, while other materials are repurposed in orbit. This minimizes reentry risks, reduces fuel consumption, and promotes a circular space economy. The collected debris can be repurposed for manufacturing spacecraft components, in-orbit 3D printing, or constructing new space structures using space-based recycling stations.

For hazardous debris, ASDCS will deploy space-based neutralization techniques such as laser ablation, electromagnetic tethers, or controlled deorbiting to safely eliminate dangerous materials. Large, high-risk debris can be directed toward designated atmospheric reentry zones (e.g., Point Nemo) to ensure safe disintegration. In extreme cases, ASDCS can redirect hazardous debris into deep space using solar sails or ion propulsion, preventing future collisions in Earth's orbit.

This paper details the engineering design, operational workflow, AI-based legal verification, and potential policy frameworks for ASDCS integration. By merging technological innovation with international collaboration, this solution aims to revolutionize space debris removal, paving the way for a safer and more sustainable orbital environment.