23rd IAA SYMPOSIUM ON SPACE DEBRIS (A6)
Interactive Presentations - 23rd IAA SYMPOSIUM ON SPACE DEBRIS (IP)

Author: Mr. Kyle Cybul
United States

BEYOND DISPOSAL: A CIRCULAR APPROACH TO POST-MISSION SUSTAINABILITY

Abstract

The current paradigm of post-mission disposal (PMD) and debris removal focuses on deorbiting defunct satellites, leaving them in designated graveyard orbits, or in many cases, leaving them where they are. However, these methods do not address the growing challenge of debris accumulation and fail to leverage the potential of a circular space economy (CSE). As the space sector transitions toward sustainability, an alternative approach - designing for circularity - must be prioritized. This paper explores how improved End-of-Life (EOL) strategies, life extension strategies, on-orbit servicing (OOS), and modular spacecraft architectures can fundamentally transform space operations, reducing reliance on active debris removal (ADR) while enabling long-term orbital sustainability.

Key areas examined include:

- EOL Life Extension Strategies Beyond Disposal: Instead of defaulting to deorbiting, satellites should be designed for capture or extended lifespans through serviceability, refueling, and modular upgrades, minimizing the generation of new debris.
- Active Design for Circularity: Spacecraft should integrate features that facilitate disassembly, recycling, and repurposing, enabling a CSE. The paper will discuss emerging concepts in standards such as docking interfaces, refueling ports, components, and material recycling.
- Challenges in Implementation: Despite its advantages, transitioning to a circular approach presents several hurdles. These include, Technical Barriers - Developing interoperable servicing technologies and ensuring spacecraft are designed for modularity without compromising performance is tricky and costly. Operational Challenges - Coordinating life extension efforts with space traffic management (STM) and mitigating risks of satellite failures in critical orbits. Regulatory Gaps - Unclear frameworks for ownership, liability, and salvage rights for orbital assets. Economic and Industry Adoption - Creating viable business models for OOS and incentivizing manufacturers to shift from single-use spacecraft to reusable architectures.

The paper will also discuss how just-in-time collision avoidance (JCA) and LDTM solutions can complement circularity-driven strategies, ensuring a more adaptive and responsive approach to space traffic management. By integrating these solutions into future mission planning and regulatory frameworks, the industry can transition from a disposable spacecraft model to a sustainable orbital infrastructure, reducing long-term remediation costs and securing the viability of space operations.

To achieve a truly sustainable space environment, PMD must evolve into post-mission resource utilization. This paper presents actionable pathways for implementing circularity in space design and operations, highlighting how proactive solutions can revolutionize how we go about debris remediation while simultaneously setting ourselves up for a more resilient and sustainable orbital ecosystem.