Enabling a Space Circular Economy by 2050

A white paper involving contributions from operators, integrators, suppliers, academia, and agencies at the ESA Clean Space Industry Days 2023

Introduction

As part of the Zero Debris Approach for Space for a sustainable and safe space environment by 2050, ESA is encouraging the implementation of a 'circular economy' in space that ensures long-term orbital sustainability through an ecosystem of in-orbit servicing, in-orbit assembly, in-orbit manufacturing, and eventually in-orbit recycling.

Previous studies have identified the advantages and challenges of a space circular economy. Building on these studies and recognising the capabilities and aspirations of European industry to work towards a circular space economy, ESA seeks to build consensus around actions to develop European leadership in building the circular space economy.

General Challenges:

- The business justification needs to be matured.
- Regulatory framework needs to be defined.
- Availability of funding and willingness to support from stakeholders.
- Customers involvement is fundamental in defining future service needs.
- A significant step in the state-of-the-art for the enabling technologies is required (e.g., standardized interfaces, verification approaches, long-term reliability of complex mechanisms).
- Space Circular Economy demands innovative mission concepts and architectures.
- Complexity of operations for circular economy (e.g., waste management in the context of in-orbit recycling).

Motivations:

The implementation of a Space Circular Economy could play an important role in guaranteeing the sustainability of the orbits, maximising the usage of space assets (reduction of costs) and protecting the Earth's environment by limiting the exploitation of raw materials on-ground and lowering the number of satellites launches and re-entries.

ANNEX

The proposed actions in this annex were derived from the contributions made during the session and consolidated following the feedback from participants. The following non-exhaustive list is intended to be only an example of proposed actions.

Examples of proposed actions:

- Define use cases for in-orbit assembly, manufacturing, and recycling - including timeframe, cost, and return on investment (*e.g.,* break-even point).
- Investigate enablers for the space circular economy considering market interest, availability of funding, regulatory pressure, and technological benefits.
- Perform a cost-benefit analysis of the development and deployment of in-orbit assembly, manufacturing, and recycling compared to existing solutions, including metrics such as: impacts on the environment, use of resources, risks, reliability, and effectiveness compared to existing solutions.
- Investigate potential incentive and regulatory schemes to foster an in-orbit assembly, manufacturing, and recycling ecosystem (*e.g.,* reduction of insurance cost when reusable spacecraft parts are used).
- Define the technologies required for the space circular economy, establish their technological readiness, analyse the necessary delta developments, and prepare technology roadmaps.
- Define standardised interfaces for in-orbit assembly.
- Define design principles for in-space manufacturing and recyclable space systems.
- Investigate the long-term reliability of in-space robotic technologies.
- Develop methodologies and technologies for in-orbit verification and validation.
- Investigate the effect of space environment on materials and components assembled, manufactured, and recycled in orbit behaviour.
- Assess impacts on the Earth-space environment (e.g., debris generation) and related liabilities of assembly, manufacturing, and recycling in space.