Space and the Circular Economy: Exploring Expert Perceptions

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Enrico Stoll, Andreas Hein

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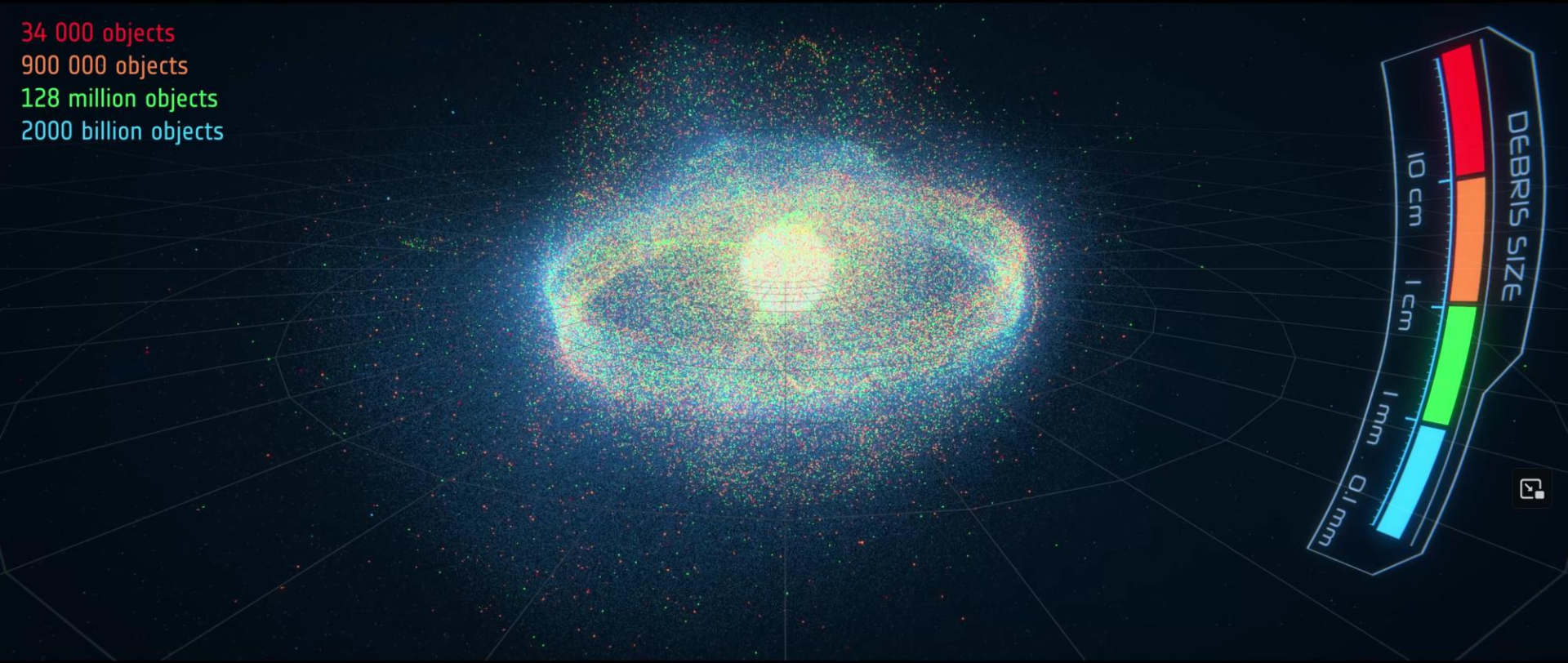
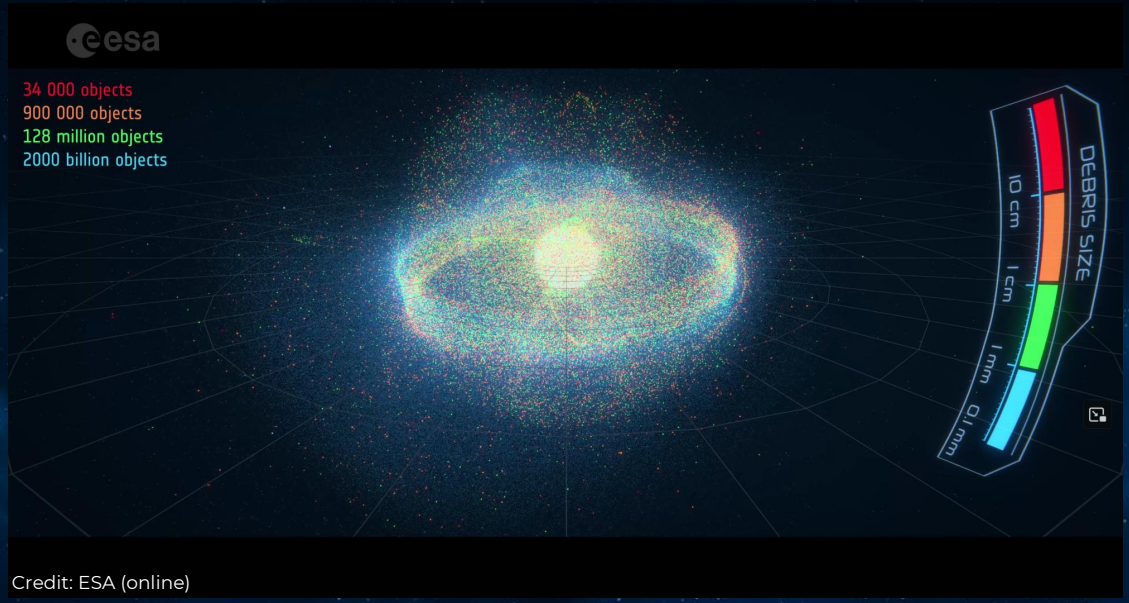
UNIVERSITY OF LUXEMBOURG

Space faces significant sustainability issues



Credit: ESA (online)

Our Problem: Linear Design of Space Activities – „Make, take, waste“



Credit: ESA (online)

Design → Production → Launch → Use → End-of-Life

Our Problem: Linear Design of Space Activities – „Make, take, waste“

Solution: Circular Space Economy – „Waste-free Design“

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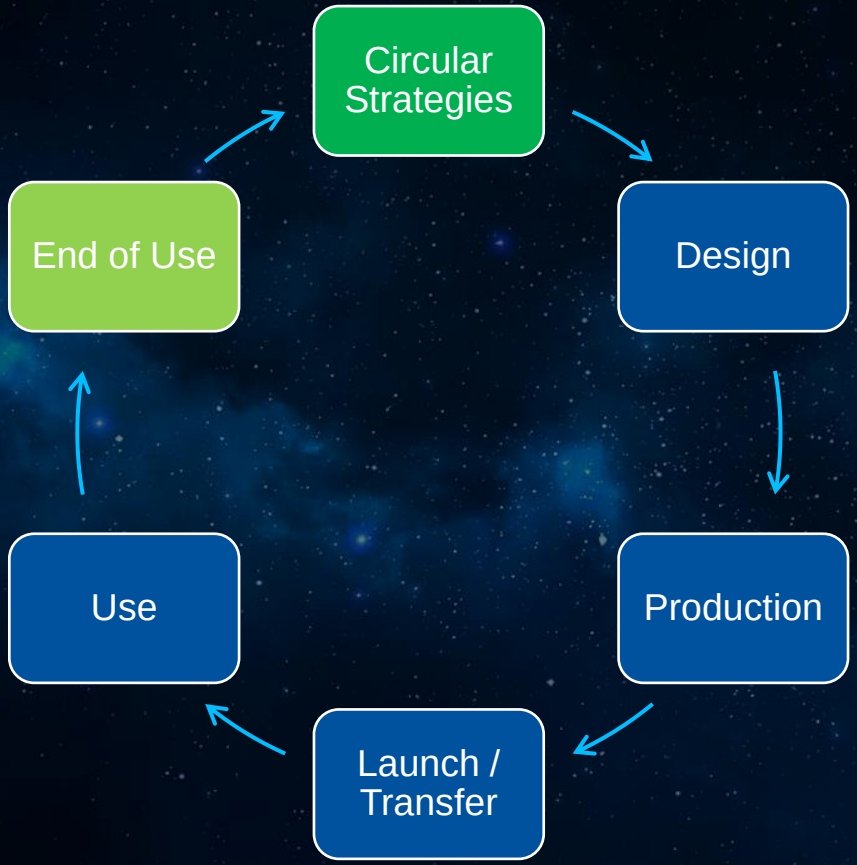


Boundary condition

- Space segment

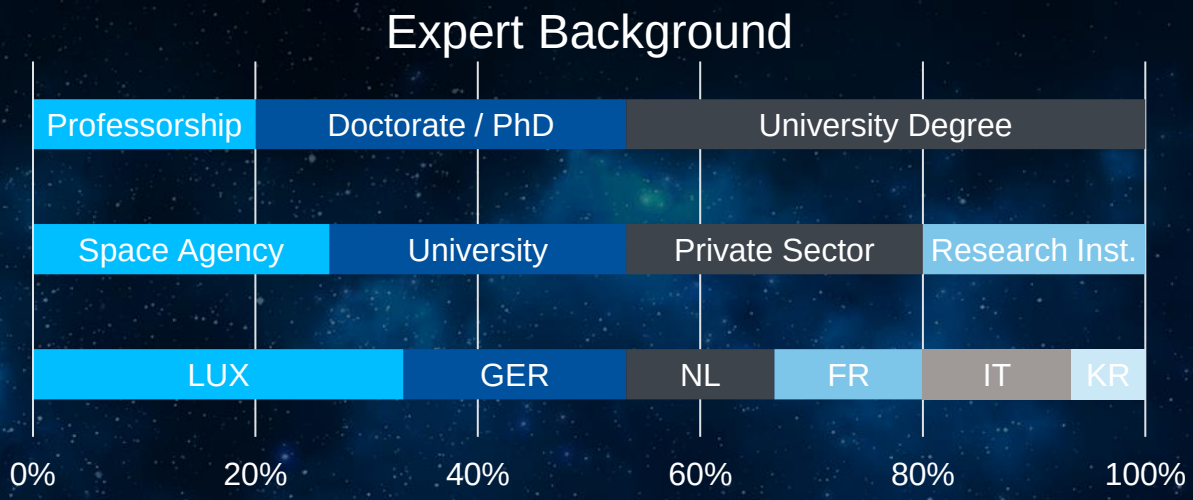
Promises

- Enables increase of space activites & large space structures
- Long-term sustainability of outer space activities (UNOOSA)
- Contributing to sustainability on Earth (e.g., less launches)
- Lower long-term costs through resource efficiency

Credit: Experts 01-15

Study Details and Expert Composition

- Circular economy and space experts
- 60-90 min per interview
- Ongoing study, currently 15 experts
- 215 years of cumulated work experience



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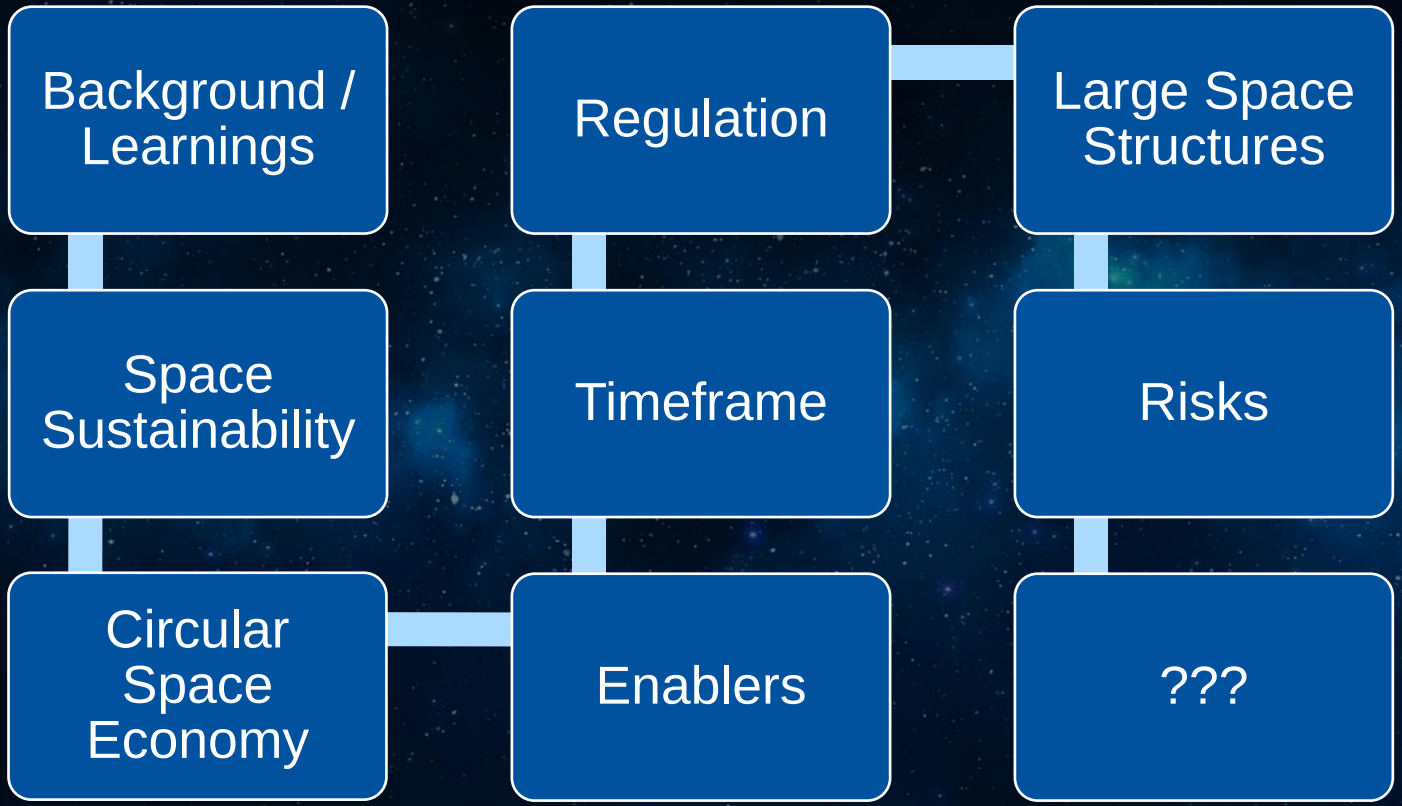
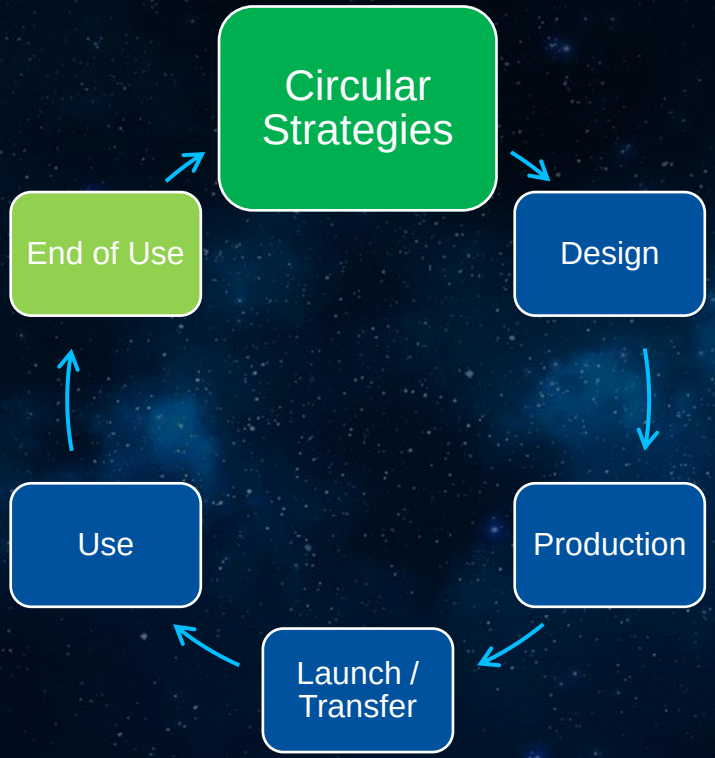
Semi-Structured Interview Guideline



Circular Strategies and Examples



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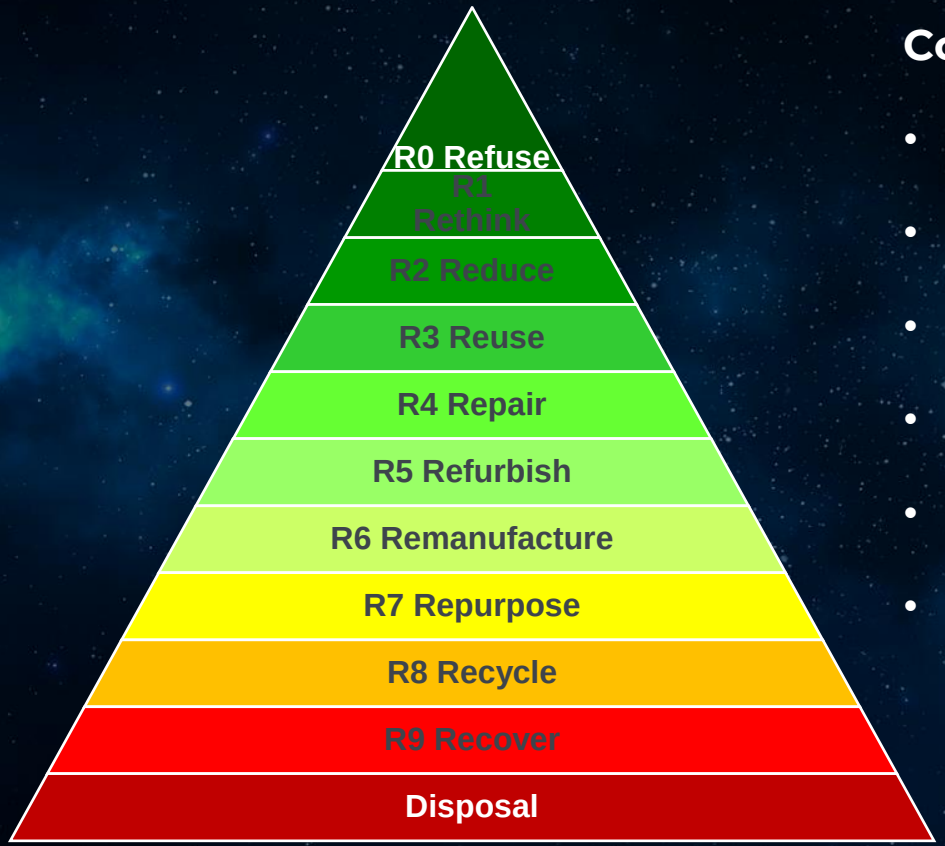

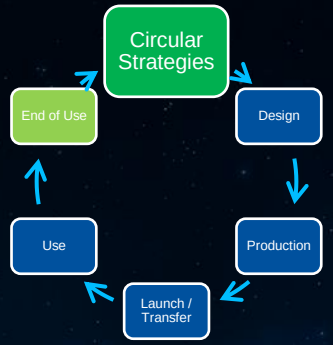

Considerations:

- Complexity of operation
- Energy / Resources involved
- Environmental impact
- Business case potential
- Technical / Biological loop
- Specific loops at system, subsystem, component, material levels

Credit: Experts 01-15; adapted from: Kirchherr et al., M., 2017. Conceptualizing the circular economy: An analysis of 114 definitions. Resources, Conservation and Recycling 127, 221–232.

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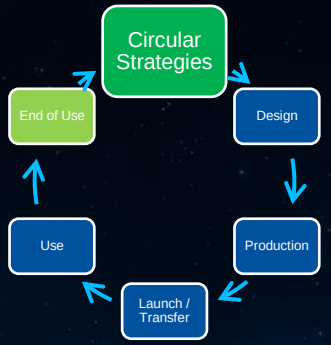

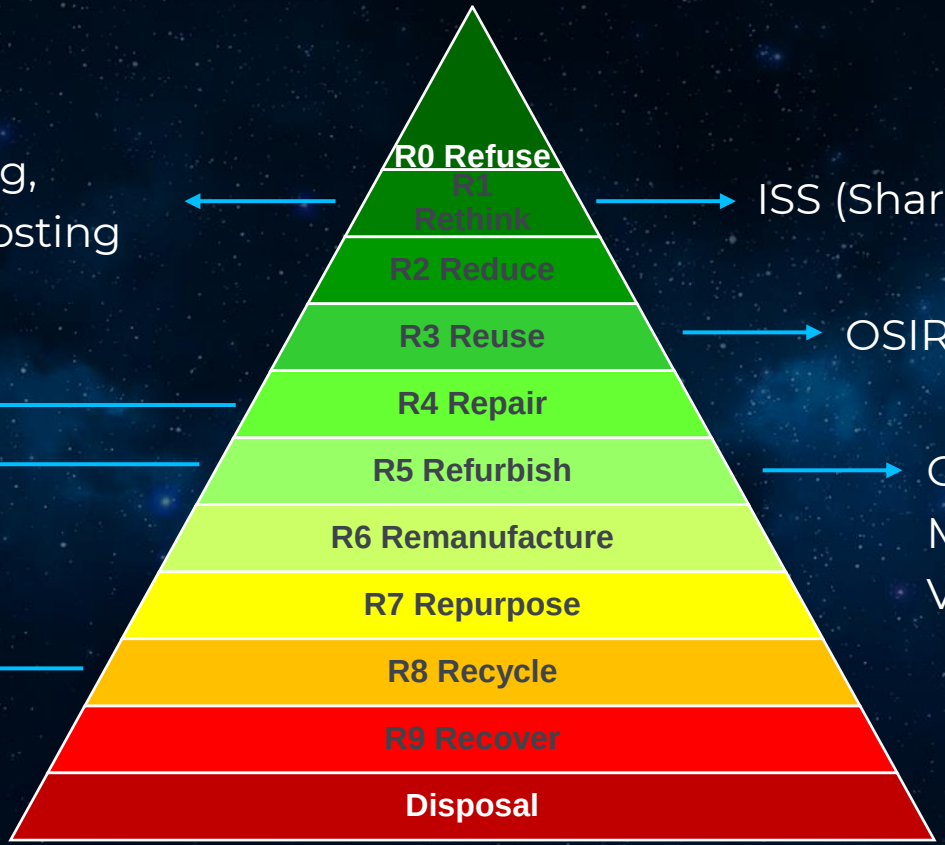

Ridesharing, Payload Hosting

ISS (Sharing)

OSIRIS-REx -> APEX

Hubble

GEO AOCS Takeover; Mission Extension Vehicle (MEV-1 & 2)

ISS (e.g., Water)

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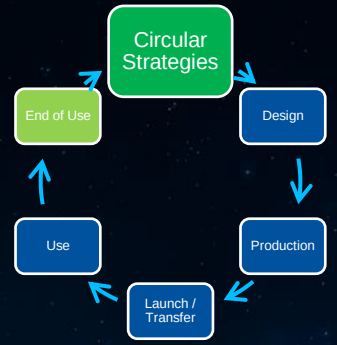

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ISS (e.g., Water)

R0 Refuse
R1 Rethink
R2 Reduce
R3 Reuse
R4 Repair
R5 Refurbish
R6 Remanufacture
R7 Repurpose
R8 Recycle
R9 Recover
Disposal

Credit: Experts 01-15; adapted from: Kirchherr et al., M., 2017. Conceptualizing the circular economy: An analysis of 114 definitions. Resources, Conservation and Recycling 127, 221–232.

Circular Space Economy (CSE) Definition Approach

Focusing on the **space segment**, the CSE replaces the traditional end-of-life concept with an **end-of-use** approach.

It aims to avoid waste creation during all mission phases, providing a **new life by design** for all involved **technical** and **biological resources** after their intended use phase.

CSE serves as a **performance enhancement strategy** to achieve **long-term space sustainability**.

Credit: Experts 01-15

Disclaimer: Long-term space sustainability as defined by UNOOSA.

Enablers I

- Space sustainability issues

- Implementing Circular Strategies in early design phases (step by step approach)

- High system mass
- Modularization
- In-orbit servicing capabilities

- Distance from Earth
- Valuable orbital locations (e.g., GEO, Lagrange Points)

Credit: Experts 01-15

Enablers II

- Sharing data (e.g., disassembly map, IOS instructions)
- Business models
- Cooperation

- Young workforce
- Customer demand

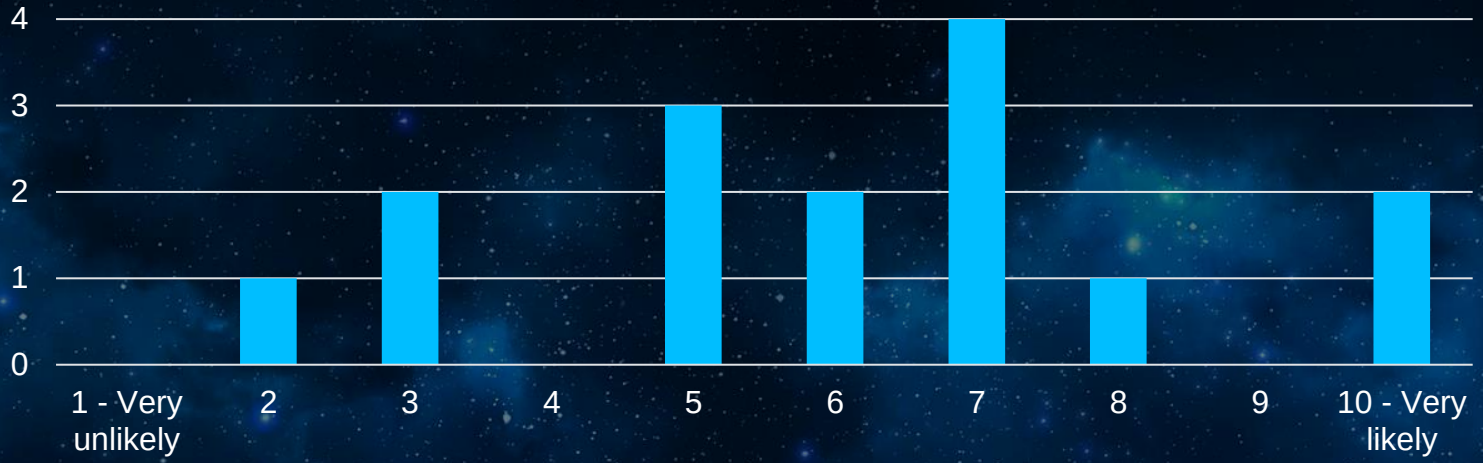
- Global regulation (e.g., by UN COPUOS or ITU)
- Legal frameworks

- Standardization (e.g., ISO)

Credit: Experts 01-15

Timeframe

Q1: How likely do you think is an established CSE by 2050?



Q2: When do you think the CSE will be established, instead?

Credit: Experts 01-15

Timeframe

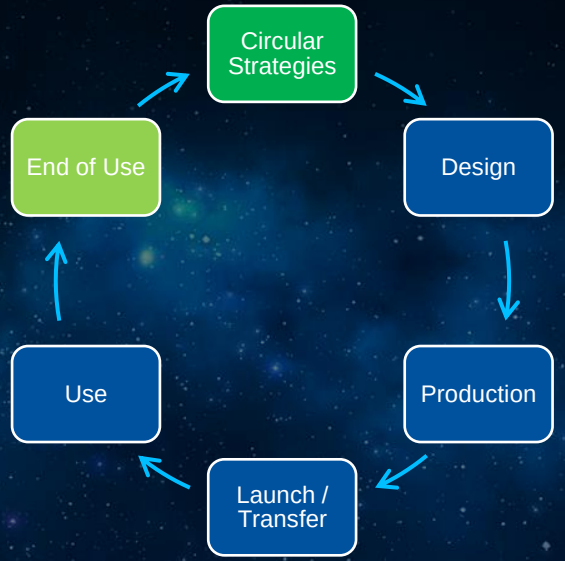
Q2: When do you think the CSE will be established, instead?

2040 2045 2050 2055 2075 2100 2150

Present → Future

Conclusion

- CSE is a performance enhancement strategy for achieving long-term space sustainability
- Circular Strategies have been demonstrated in space
- CSE promises to let us increase our space activities in a sustainable way
- CSE especially viable for high-mass systems and limited orbital locations (e.g., GEO, Lagrange Points)



Credit: Experts 01-15

Outlook

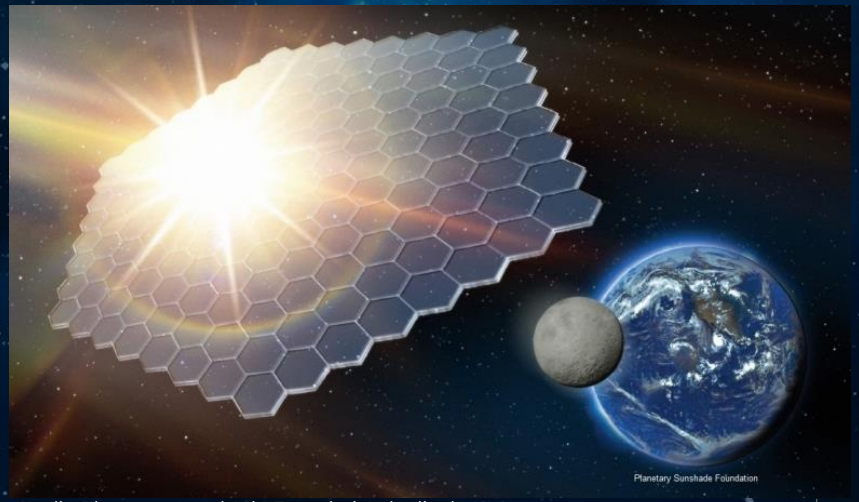
Step 1: Continuing study, widening and deepen scope

Step 2:

CSE+Space-Based Solar Power

Credit: Physicsworld (online)

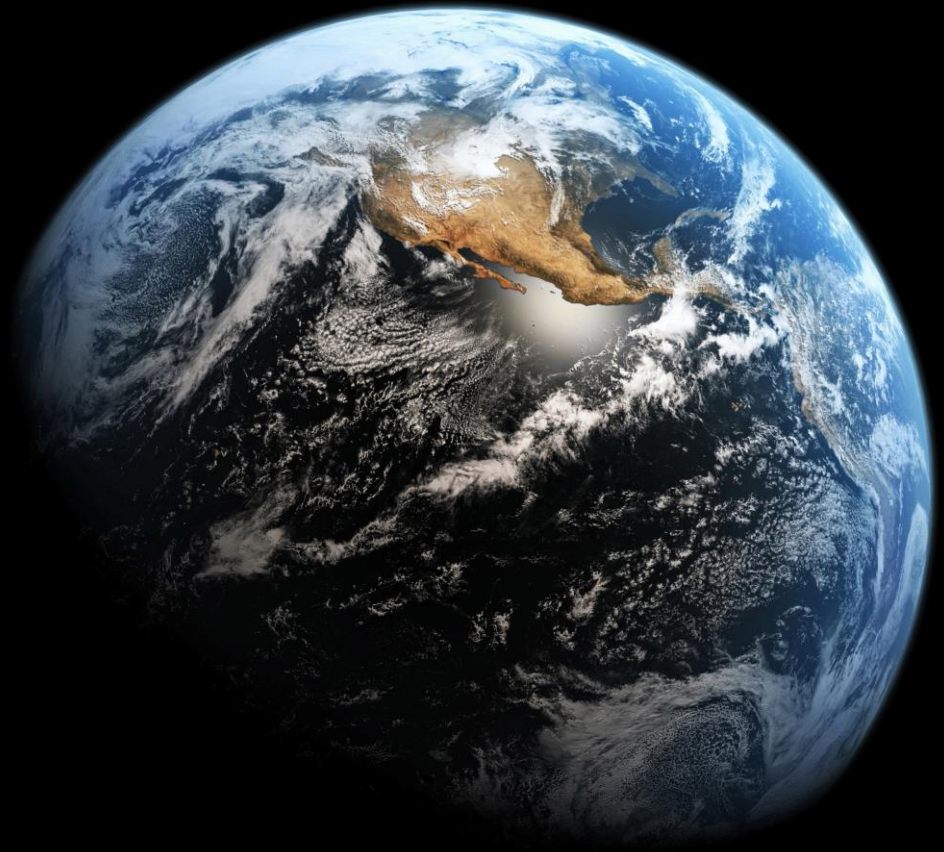
CSE + Space-Based Climate Action



Credit: Planetary Sunshade Foundation (online)

“The dreams of yesterday are the hope of today and the reality of tomorrow.”

Dr. Robert H. Goddard



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SnT

Thanks to all study participants!

Thank you very much for your attention!

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