Considering Space Debris within the LCA framework

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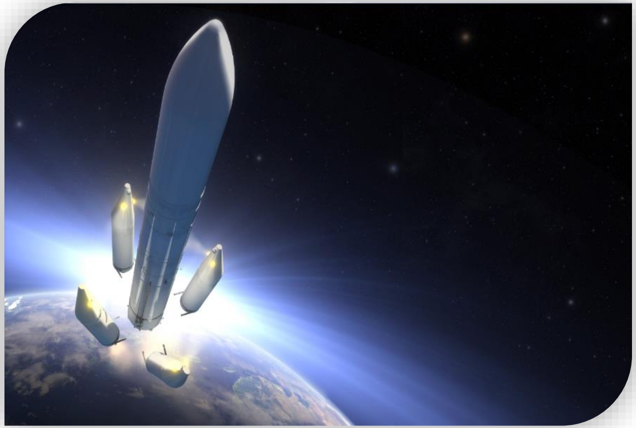
SUMMARY

01

CONTEXT & OBJECTIVES OF THE WORK



ECO-DESIGN IN EUROPEAN SPACE SECTOR

Environmental legislation is evolving fast

- European directives: REACh regulation, RoHS, Critical Raw Materials…
- Evolution of the Legislation:

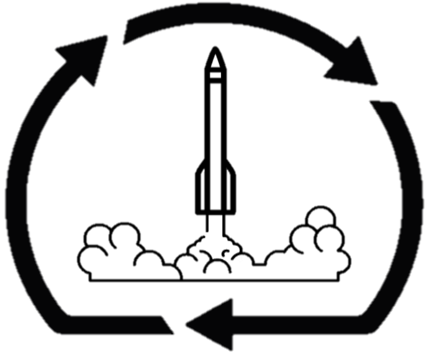
  French Space Operation Act (full entry into force in 2020),

  UNCOPUOS guidelines for the long-term sustainability of outer space activities

↘ LCA has been identified as the most appropriate tool to evaluate and reduce the environmental impact of space activities

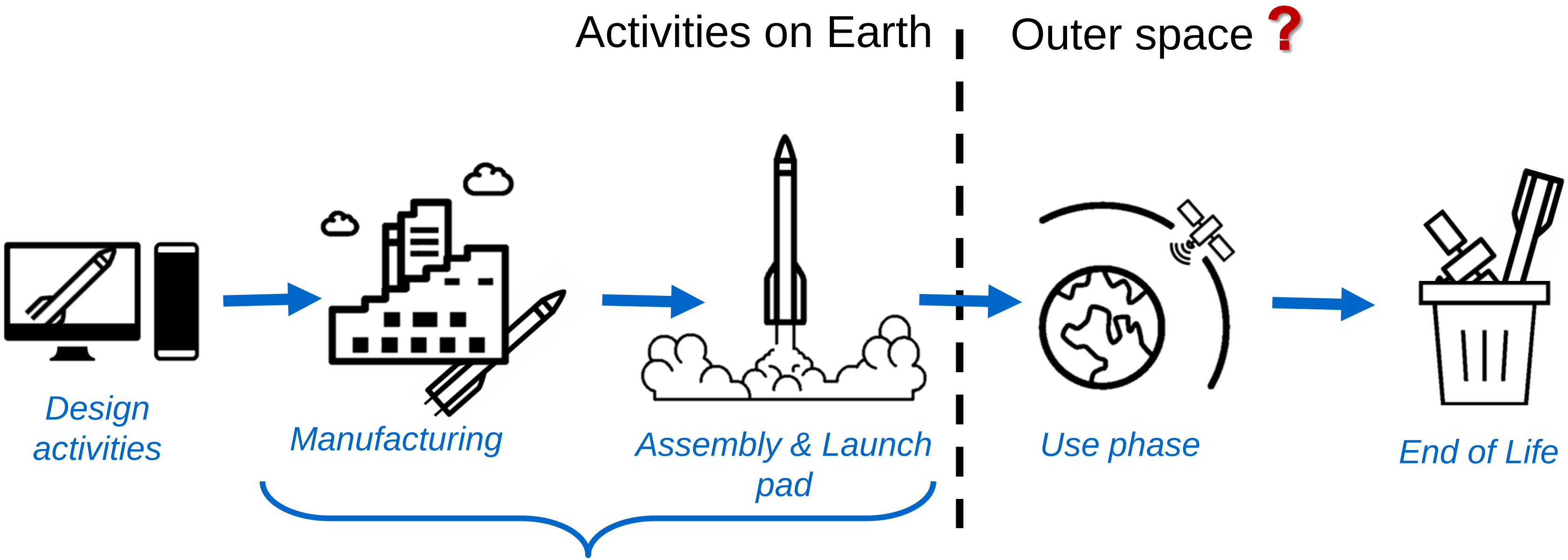
Ariane 6 development – Contractual requirement:

- Perform an LCA of Ariane 6 in exploitation phase
- Compare to A5 ECA



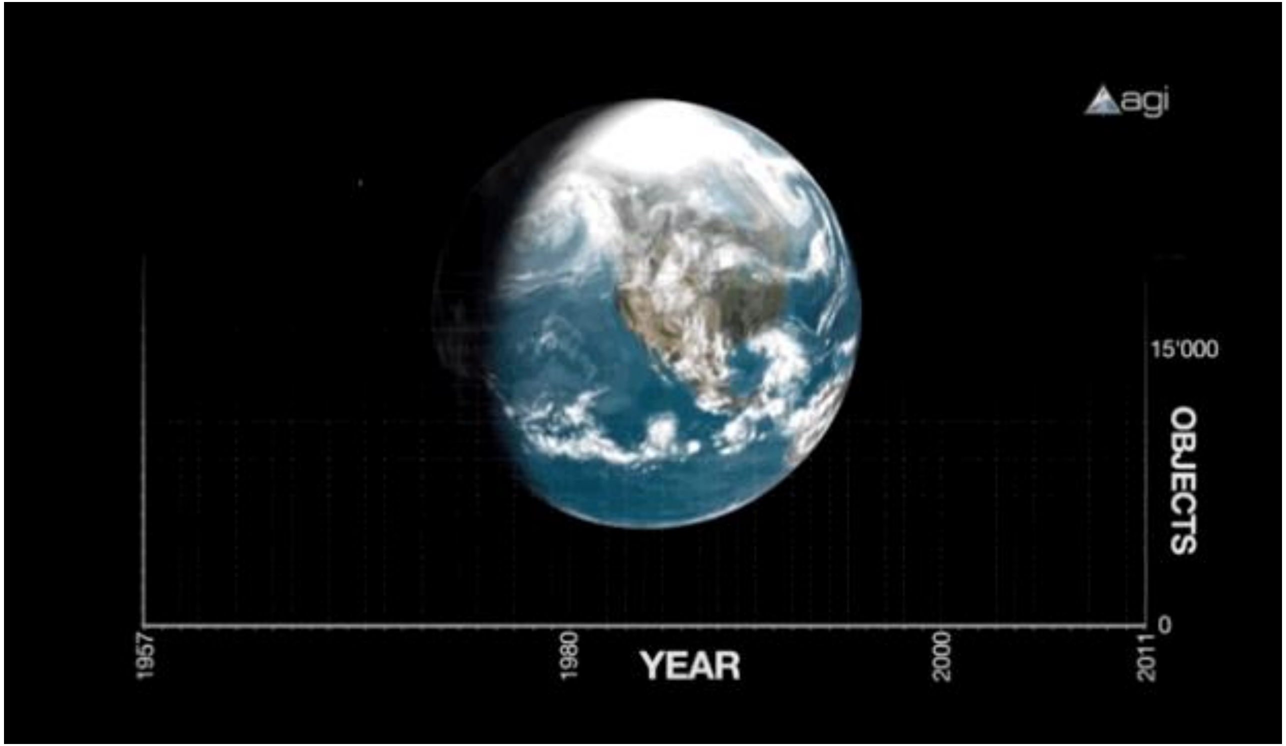
LIFE CYCLE OF SPACE MISSIONS

Ensuring sustainability on both Earth and orbital environment



Current LCA studies do not cover the entire life-cycle

THE GROWING THREAT OF SPACE DEBRIS



94% of the catalogued objects around Earth are **Space Debris**

(dead satellites, parts of launchers, fragments…)

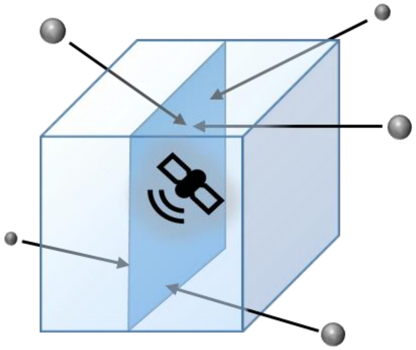
OBJECTIVES OF MY WORK

Make the link between eco-design and Space Debris *via* LCA methodology

Develop & implement an indicator in compliance with the Life Cycle Impact Assessment framework:

- Considering operational orbits as resources that can be depleted by the presence of space debris

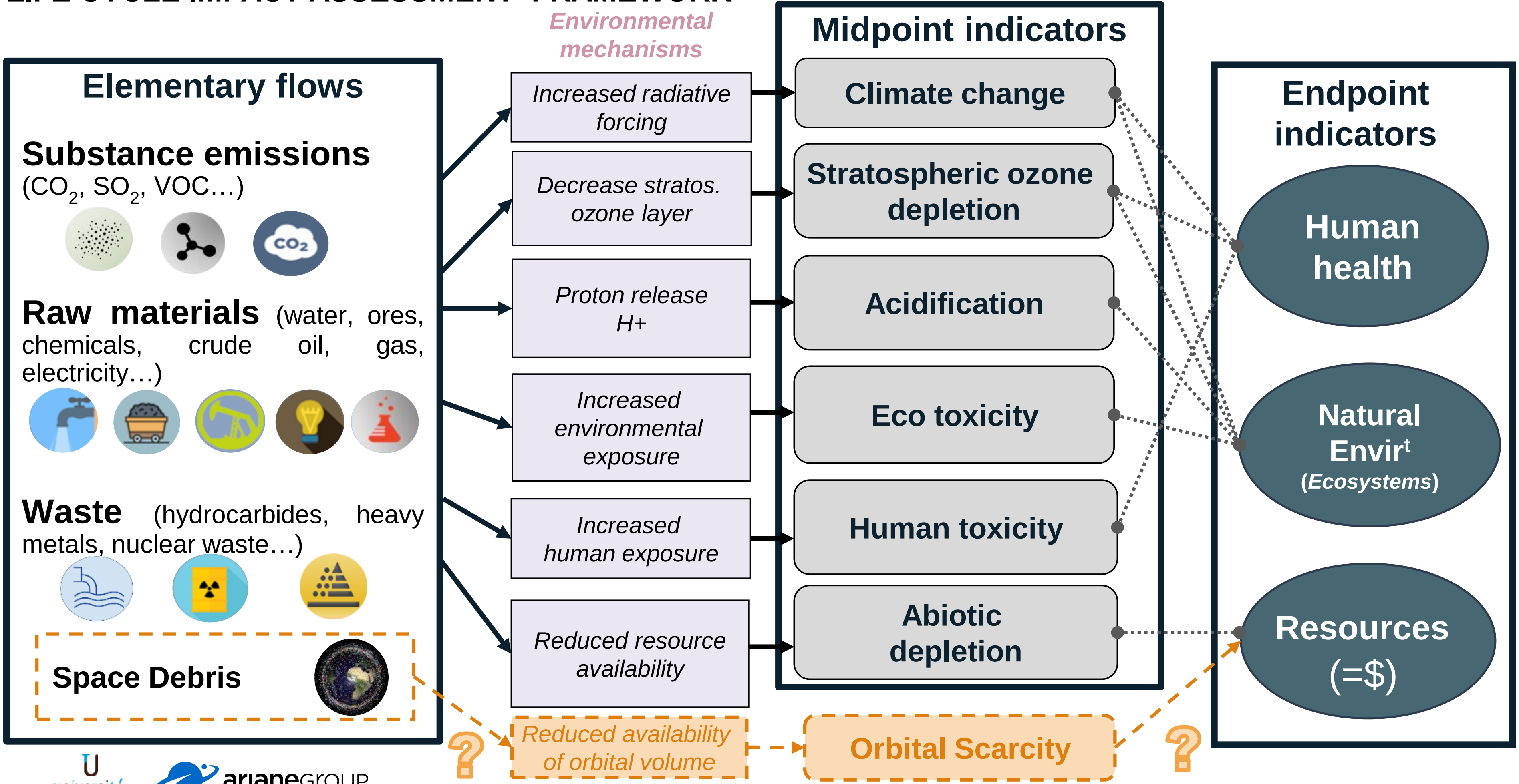
- Comparing several missions & post-mission disposal scenarios to study potential trade-offs *(propellant load vs no end-of-life management)*



02

MATERIAL & METHODS

LIFE CYCLE IMPACT ASSESSMENT FRAMEWORK



RESOURCE APPROACH FOR SPACE DEBRIS RELATED IMPACTS

Definition of Resource use in LCA

- Functional value *(Stewart and Weidema, 2005)*: abiotic resources have only a functional value according to an anthropocentric point of view
- Resource is seen as a support providing services to man-made environment and economy - ***JRC Vision on provisioning capacity*** *based on Dewulf et al. 2015)*

  OECD definition : **"natural resources as natural assets (raw materials) occurring in nature that can be used for economic production or consumption"**

Functional value of orbits :

- Allowing satellite operations and so create economic value
- Operating orbits have to be safeguarded to ensure services on Earth provided by satellites (e.g. data exchange, communication, GPS, earth observations)

↘ **Operating orbits can be included within the Area-of-Protection 'Resources' (Endpoint)**

03

ON-GOING DEVELOPMENT

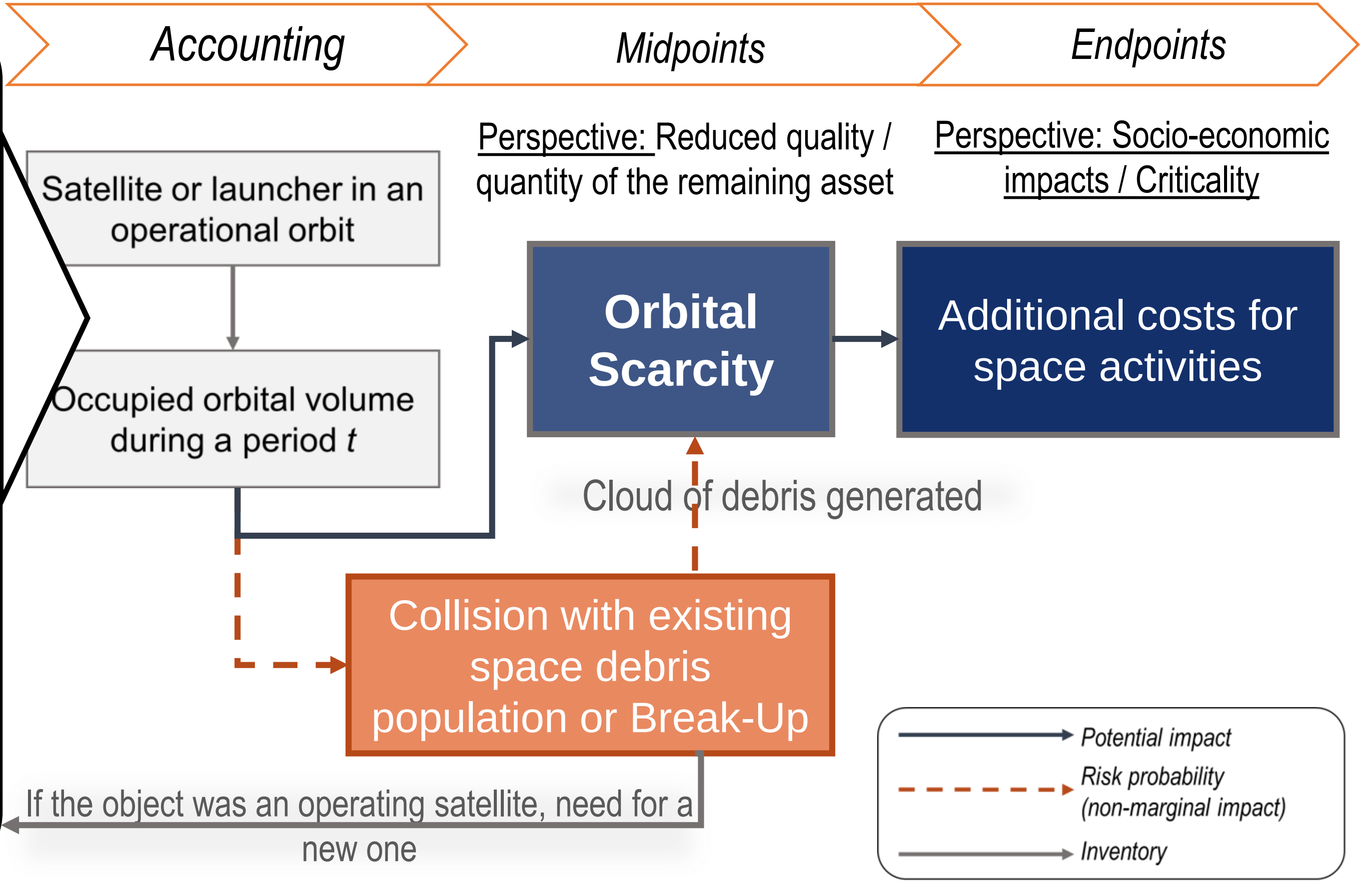
IMPACT PATHWAY PROPOSAL (CAUSE-EFFECT CHAIN)

Space object inventory

Orbital Parameters
- *a: semi-major axis*
- *i: inclination*
- *e: eccentricity*

Design Parameters
- *m: mass*
- *A: Cross Sectional Area*
- *Duration of the mission*
- *Materials & substances on board*

Debris Mitigation Parameters
- *Passivation capacity (Avoiding Break-up)*
- *Collision avoidance capacity*
- *End-of-Life Scenario*



FOCUS ON ORBITAL SCARCITY

Weighting the occupation of the orbit by the 'debris stress'

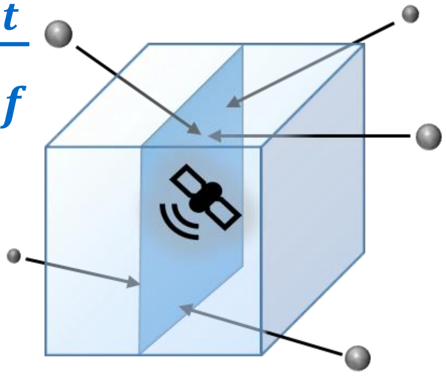
$$\text{Impact} = \text{Inventory} \times \text{Characterisation factor}$$ *(e.g water stress)*

- Within a particular operational orbit ɣ *(inclination; altitude; eccentricity)*

$$I_{ɣ,s/c} = \underbrace{occ.area_{s/c} \times t}_{inventory} \times \boxed{stress_{ɣ}}$$

Flux of debris

$$\frac{\theta_{ɣ,t}}{\theta_{ref}}$$



- During the overall lifetime in orbit

$$I_{global,s/c} = \sum_{ɣ=1}^{n} occ.area \times t_{ɣ} \times stress_{ɣ}$$

04

PERSPECTIVES &
TAKE HOME MESSAGE

PERSPECTIVES

- Develop formula for LCA impact related to catastrophic event – Collision or Break-up *– Second part of the indicator 'Orbital Scarcity'*

- Case study: Application on a theoretical Ariane 6 space mission (comparison with A5 ECA mission)

- Towards a cost analysis at Endpoint Level based on Marginal cost increased

Space debris are only one part of End-of-Life for spacecraft

How to characterize the impacts during the atmospheric reentry ?

……………Water toxicity ?

TAKE-HOME MESSAGE

- Useful orbital volume supporting satellite activities is a non-renewable resource, depleted by the presence of Space Debris

- A dedicated indicator compliant with the LCA framework will be integrated in LCA studies to figure out **complete footprint**

- Complete life-cycle of space missions has to be taken into account in order to addressed potential environmental trade-offs <u>on Earth & Space</u>

Thanks for your attention

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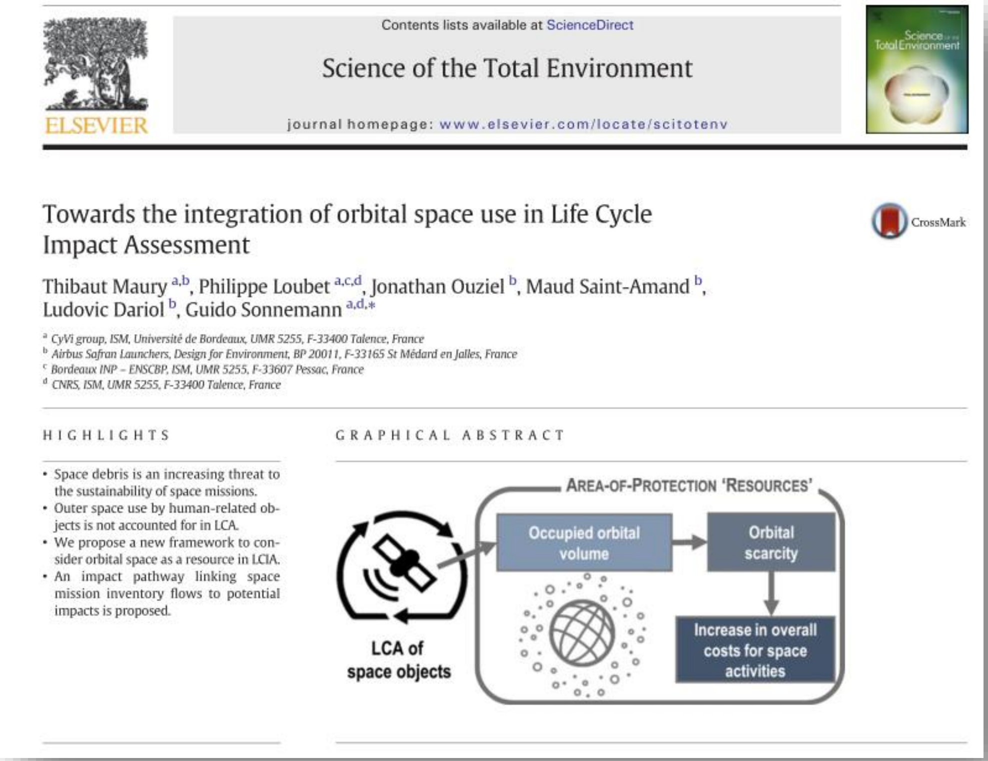
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Towards the integration of orbital space use in Life Cycle Impact Assessment

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HIGHLIGHTS

- Space debris is an increasing threat to the sustainability of space missions.
- Outer space use by human-related objects is not accounted for in LCA.
- We propose a new framework to consider orbital space as a resource in LCIA.
- An impact pathway linking space mission inventory flows to potential impacts is proposed.

GRAPHICAL ABSTRACT