Considering Space Debris related impacts into the LCIA framework

LCIA method developments in a global perspective
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SUMMARY

1 CONTEXT & OBJECTIVES

2 MATERIALS & METHODS

3 RESULTS

4 CASE STUDY

5 CONCLUSION

Ariane 5 Ariane 6

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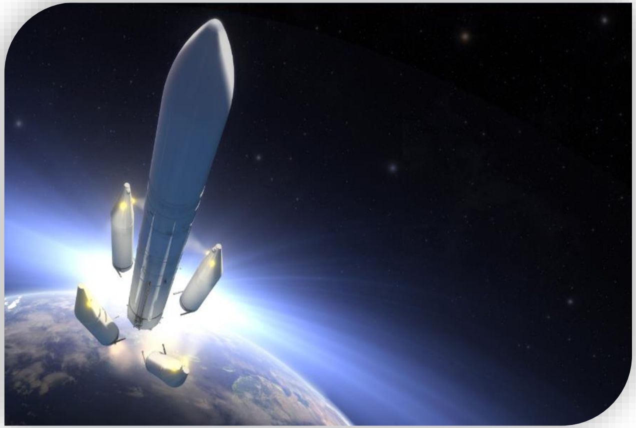
CONTEXT & OBJECTIVES OF THE WORK



ECO-DESIGN IN EUROPEAN SPACE SECTOR

Environmental legislation is evolving fast

- European directives: REACh regulation, RoHS, Critical Raw Materials…

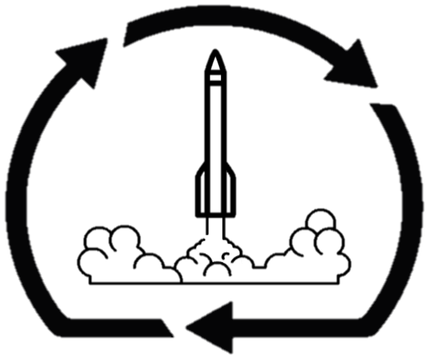
French Space Operation Act (full entry into force in 2020),

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

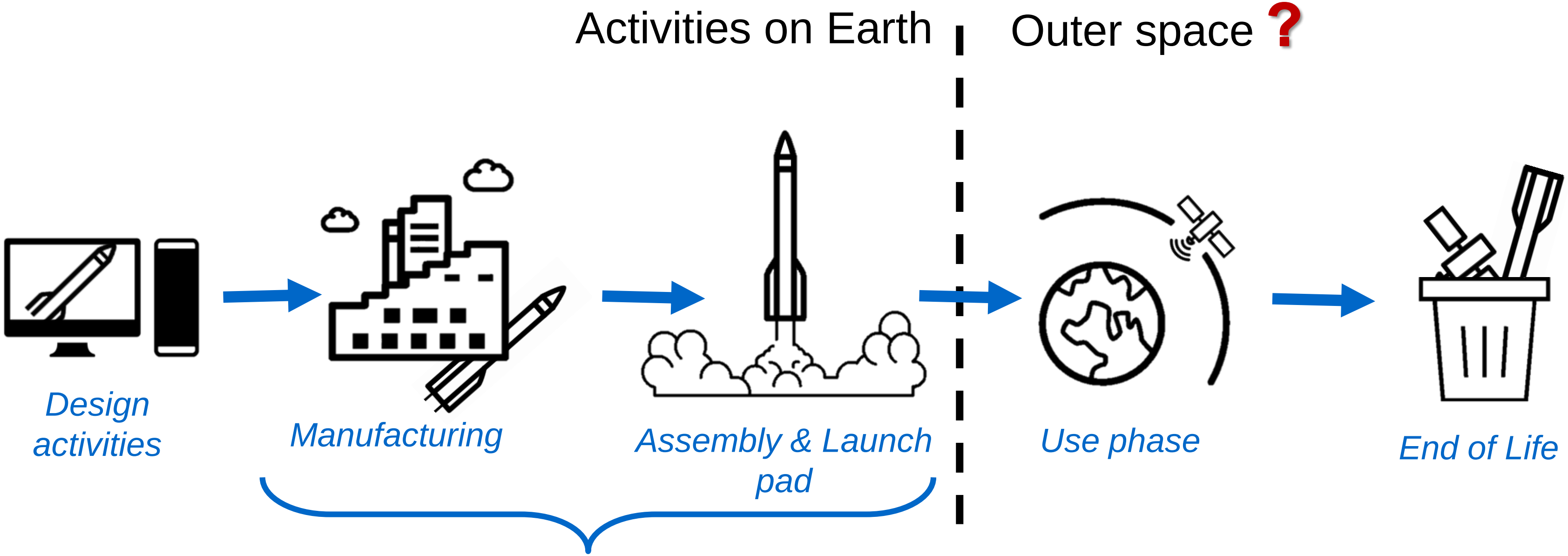
Ariane 6 development – Contractual requirement:

- 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

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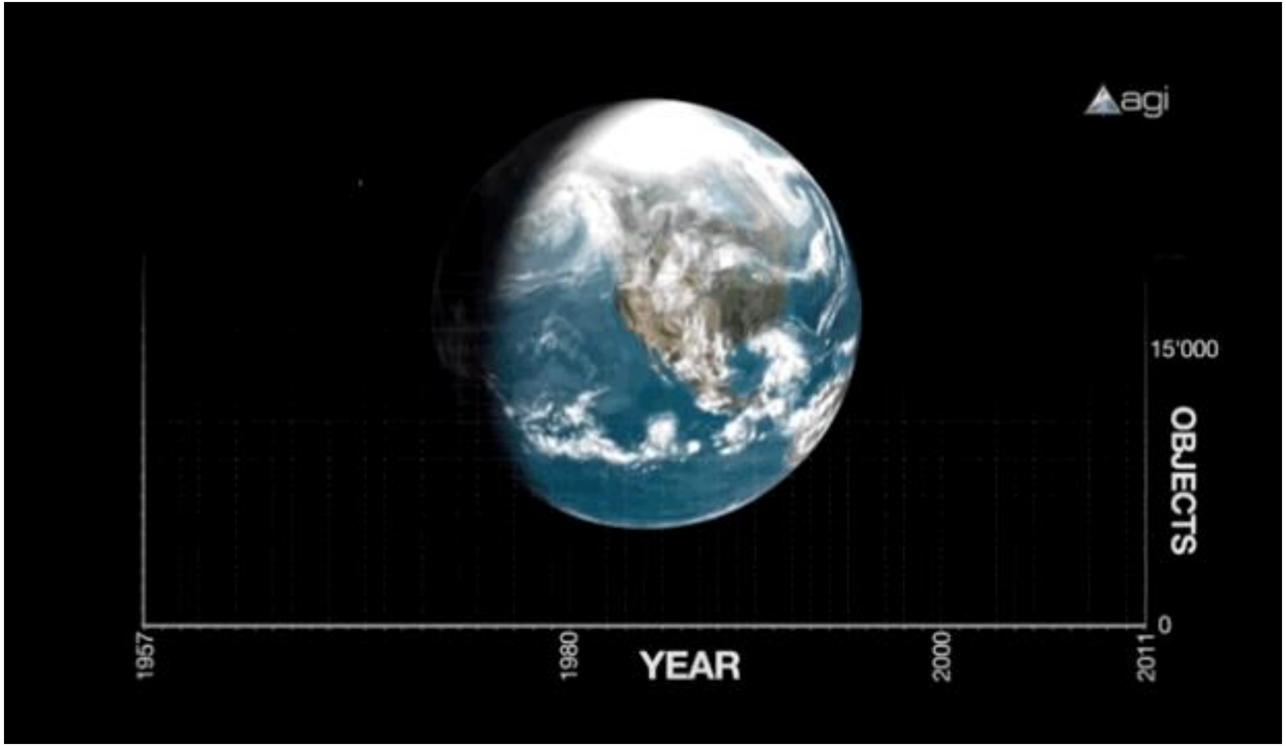
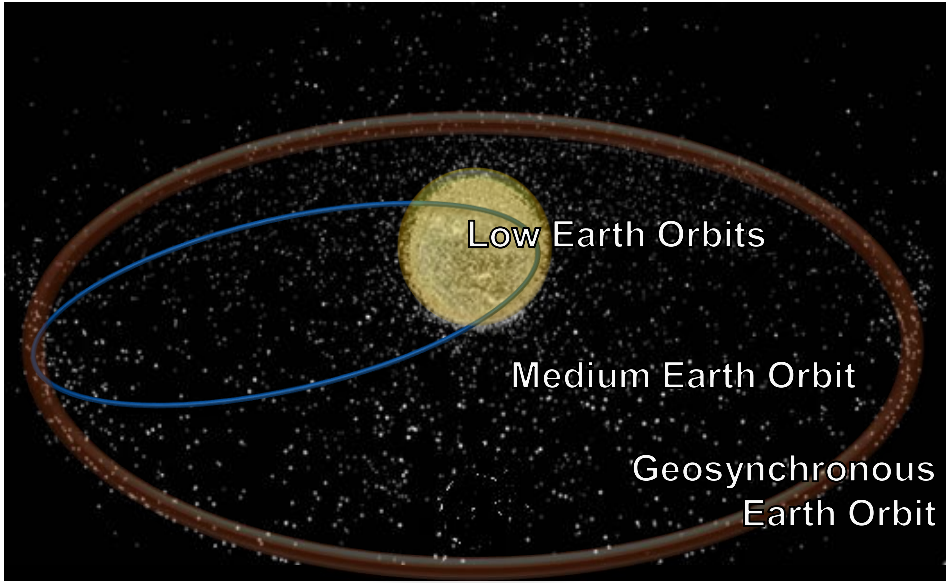
THE GROWING THREAT OF SPACE DEBRIS



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

(dead satellites, parts of launchers, fragments…)

SPACE DEBRIS DISTRIBUTION



Orbital Region	% earth orbital volume	% of the catalogued population
LEO *(200 – 2000km)*	0,30%	75%
MEO *(2.000 – 36.000km)*	> 95%	~17-20%
GEO *(~ 36.000km)*	3%	~ 5-8%

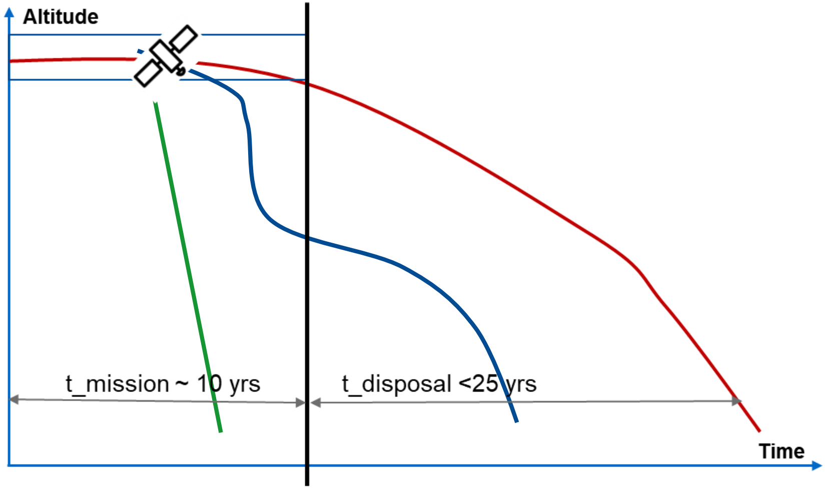
OBJECTIVES OF THE WORK

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

- Development of Characterization Factors (CF) assessing potential impacts of space mission on orbits

- Application of the CF on 3 post-mission disposal scenarios in LEO to study potential trade-offs with different dwelling time

  - *No management of the End-Of-Life*
  - *Delayed Re-entry (< 25 yrs)*
  - *Direct Reentry (< 1 yr)*



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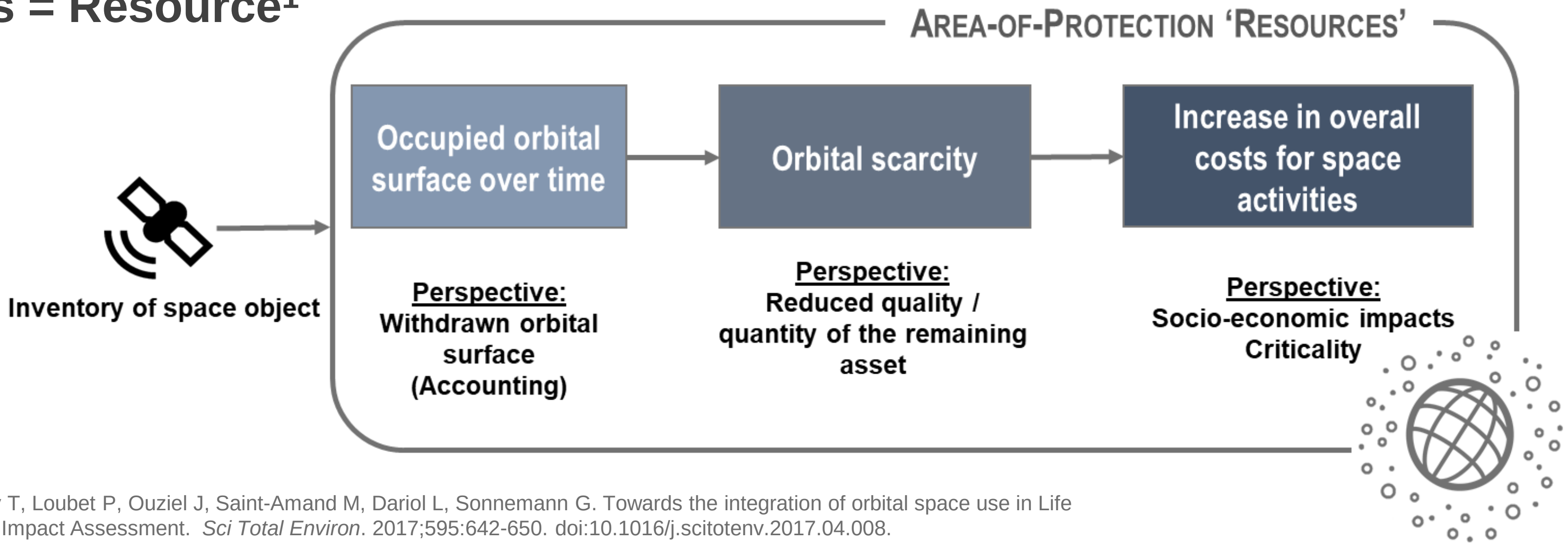
MATERIAL & METHODS

RESOURCE APPROACH FOR SPACE DEBRIS RELATED IMPACTS

Definition of Resource use in LCA

- 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)*

Orbits = Resource[1]



1. Maury T, Loubet P, Ouziel J, Saint-Amand M, Dariol L, Sonnemann G. Towards the integration of orbital space use in Life Cycle Impact Assessment. *Sci Total Environ*. 2017;595:642-650. doi:10.1016/j.scitotenv.2017.04.008.

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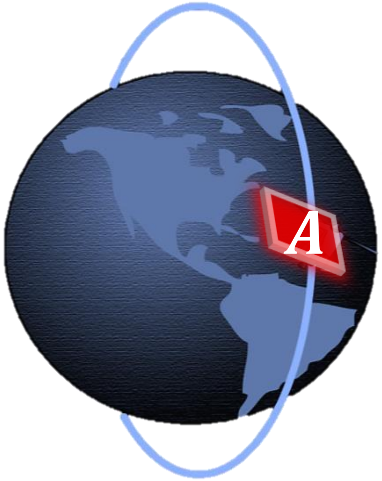
LIFE CYCLE INVENTORY

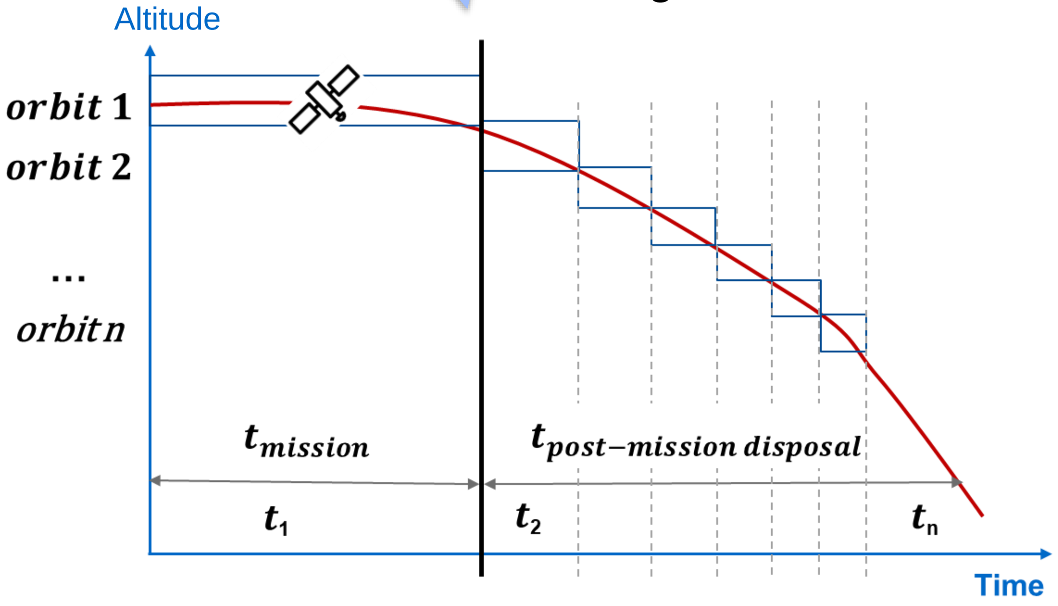
$$Accounting = A \cdot \sum_{Orbits} t_i$$

$[m^2]$ $[yr]$

Dwelling time

Cross sectional area



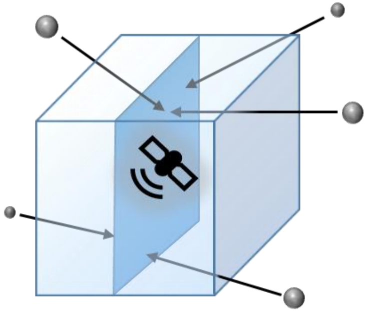


CHARACTERISATION FACTORS

Debris related impacts

Each orbit presents a different state of scarcity which allows to classify and differentiate them

$$Impact = Accounting \cdot CF$$



We decide to characterize orbital scarcity with the average **flux of debris** crossing the target orbits

$$Impact = A \cdot \sum_{Orbits} t_i \cdot \overline{\Phi_i}$$

$[\#_{debris}]$ $[m^2]$ $[yr]$ $[\#_{debris}.m^{-2}.yr^{-1}]$

Calculated impact: avg. number of debris crossing the target surface during the dwelling time of the spacecraft

CHARACTERISATION FACTORS : Φ_i

MASTER-2009 Model

Orbital environment

Debris Population > 1cm

Launch and mission related objects (1,2%)
Explosion (62,4%) / Collision fragment (26,4%)
Sodium Potassium (NaK) droplets (6,8%)
Solid Rocket Motor (SRM) slag (2,7%)
…

$$\Phi_i = Density \cdot \Delta v_p$$

[#.m^{-3}] [m.yr^{-1}]

MASTER 2009
Meteoroid and Space Debris Terrestrial Environment Reference Model

- We assume circular target orbits
- The flux is calculated for a period of 35 years in a business as usual perspective
- All the LEO region is characterised: [200-2.000] km & [0-180°] inclination

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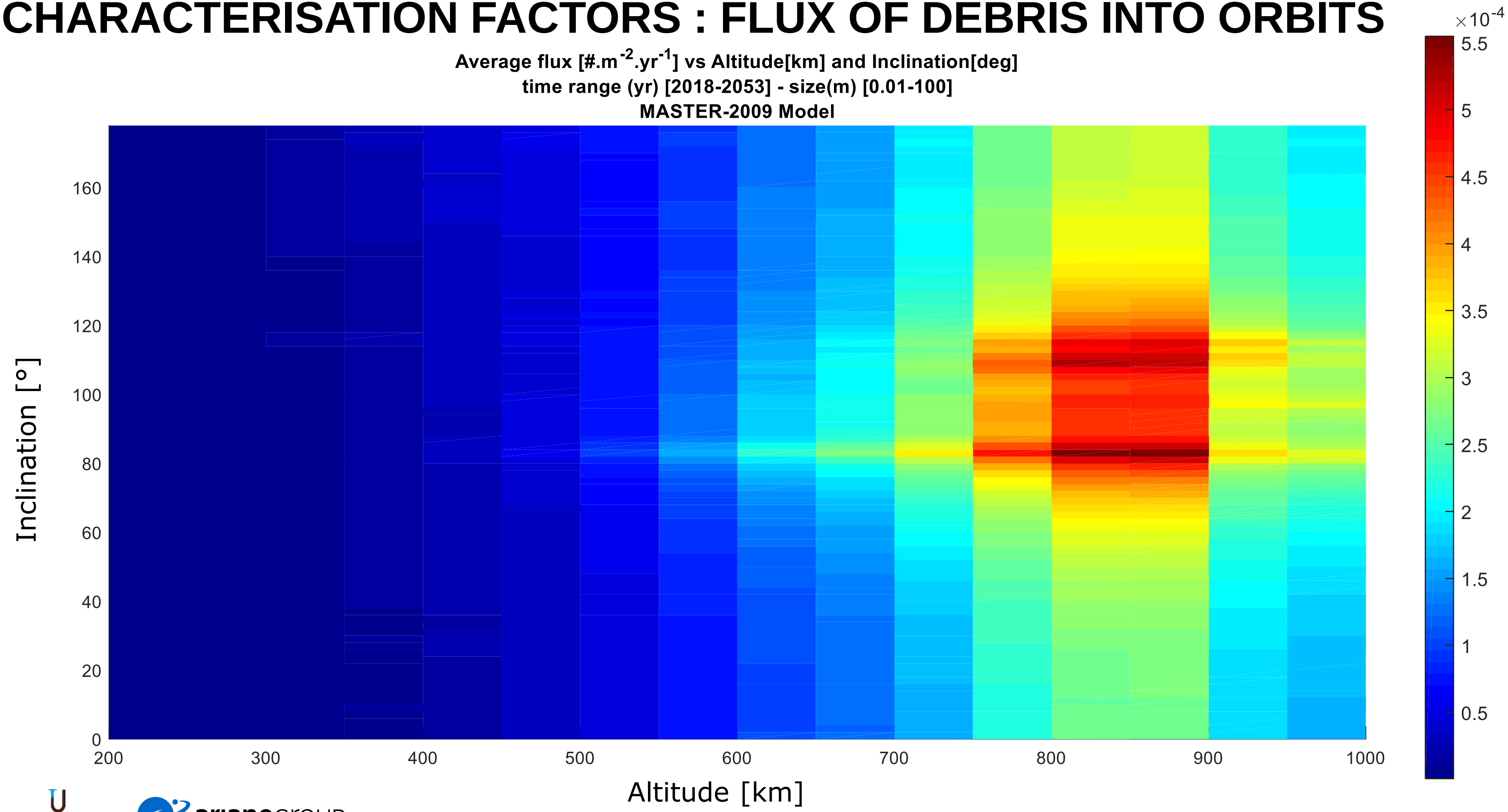
RESULTS

CHARACTERISATION FACTORS : FLUX OF DEBRIS INTO ORBITS



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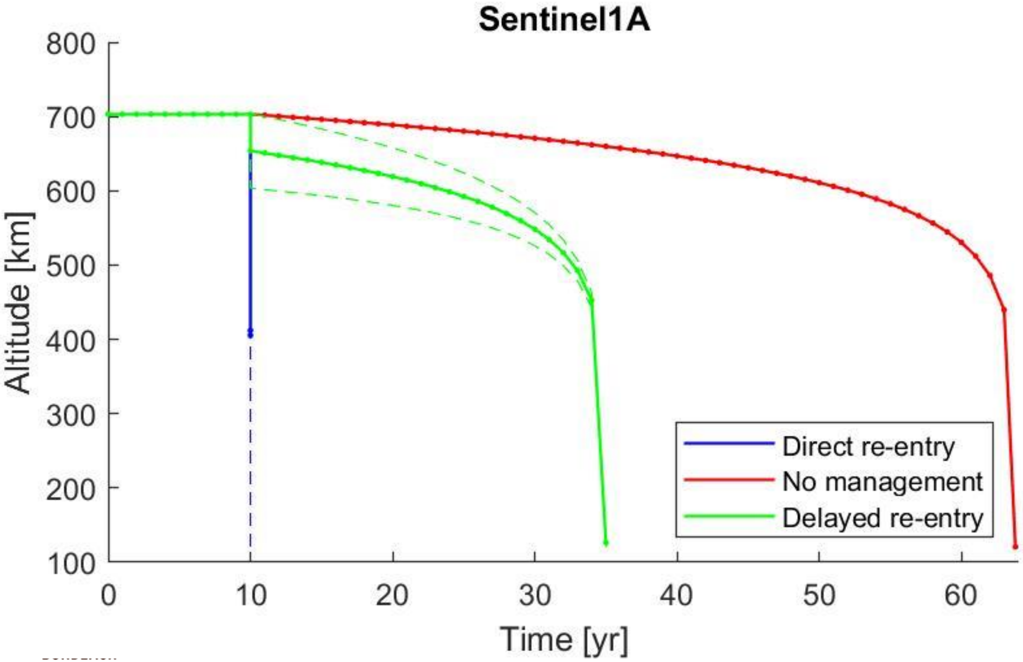
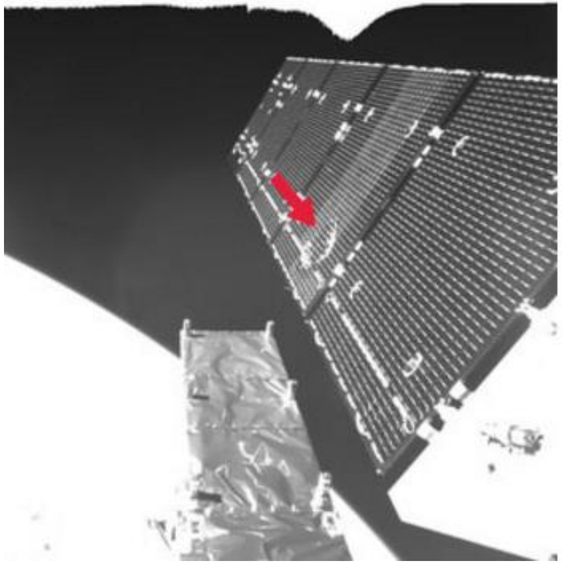
CASE STUDY

SENTINEL 1-A

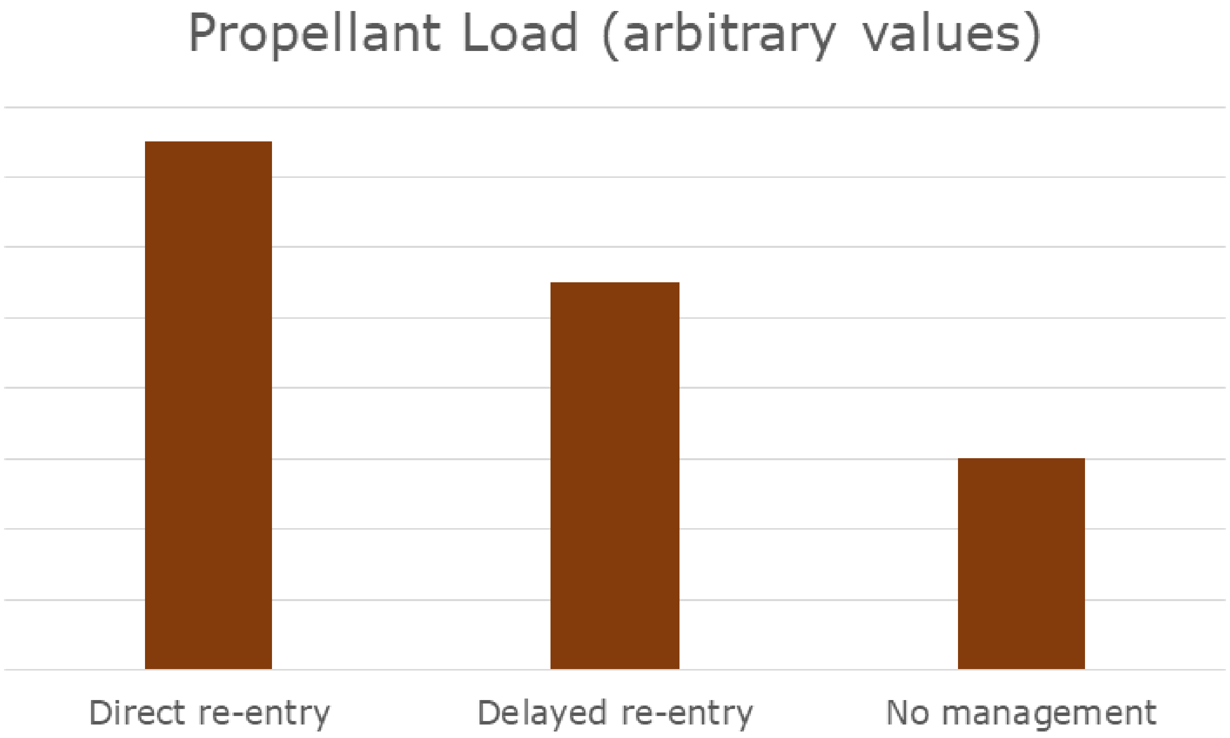
SENTINEL 1-A





Assessing different EOL scenarios

SENTINEL 1-A
Impact results



But…
Possible burdens shifting

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CONCLUSION

TAKE-HOME MESSAGE

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

- A dedicated set of characterisation factors has been developed to characterize the orbital stress into the LEO region [<2,000km] & [0-180°]

- The indicator is suited to compare EOL scenarios as shown with the Sentinel 1-A case study.

- This indicator will be applied to the Heavy Launcher Ariane 6 (Currently in design phase)

Thanks for your attention

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