# Space Environment Capacity at the European Space Agency

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# Outline

- Motivation behind the approach
- Main idea behind the concept
- Operational status

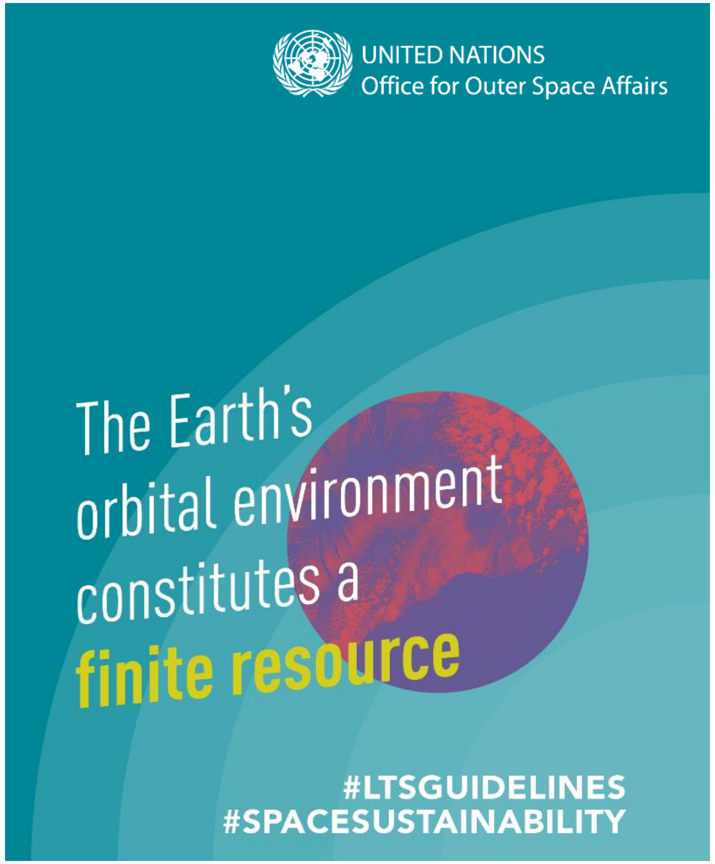
# What do we mean with Space Sustainability?

The remarkable change in the use of the LEO region has prompted several studies into the **sustainability** of space operations

Definition:
equitable access to safe operations in space, now and in the future

Compliance to **existing guidelines** often used as proxy for sustainability, but no longer adequate for today

Idea:
Is it possible to define **reference targets** (~2° for climate change)?
How do we carry out more **robust assessments** of the environment?

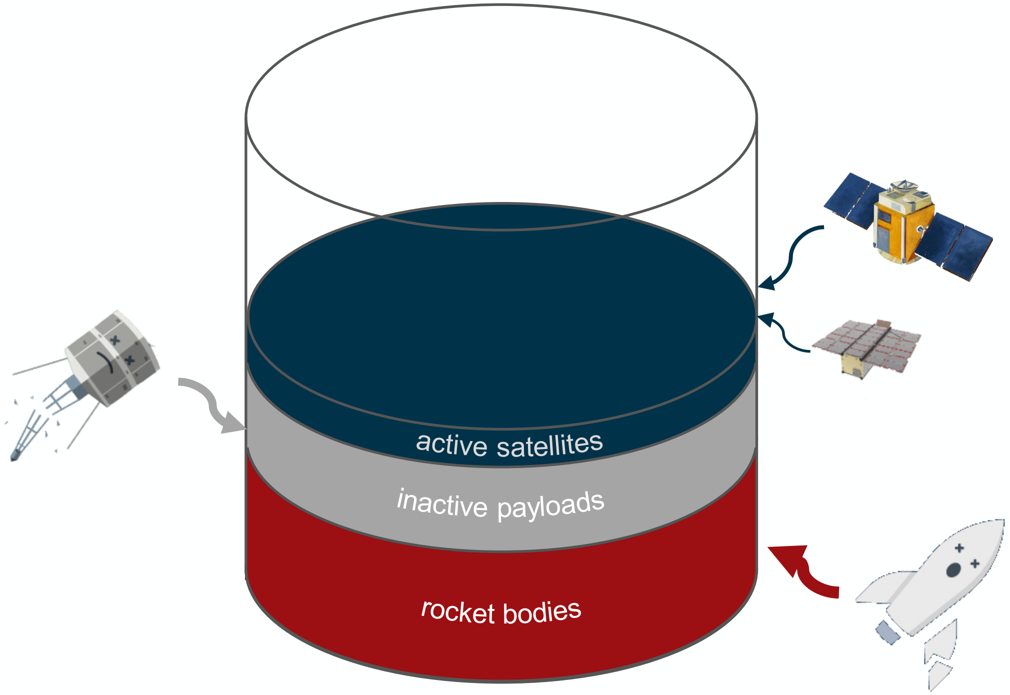


# Earth's orbits as a finite resource

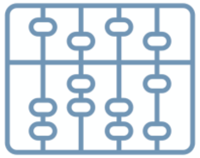
ESPI,
Space Environment Capacity,
2022

Earth's orbital environment as a **common-pool resource**:

- **Universally accessible** and **not excludable**, i.e. the exclusion of users is difficult by nature
- **Rival**, i.e. the use of an orbit by one user decreases resource benefits for other users




**Lessons** from resources management



you cannot manage what you cannot measure ⇨ you cannot measure what you cannot define

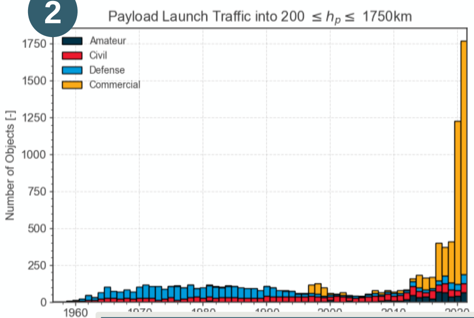
less-than-perfect systems can provide immense value for international collaboration

Space Environment Capacity

# Technical drivers for our approach

## Missing links of current guidelines

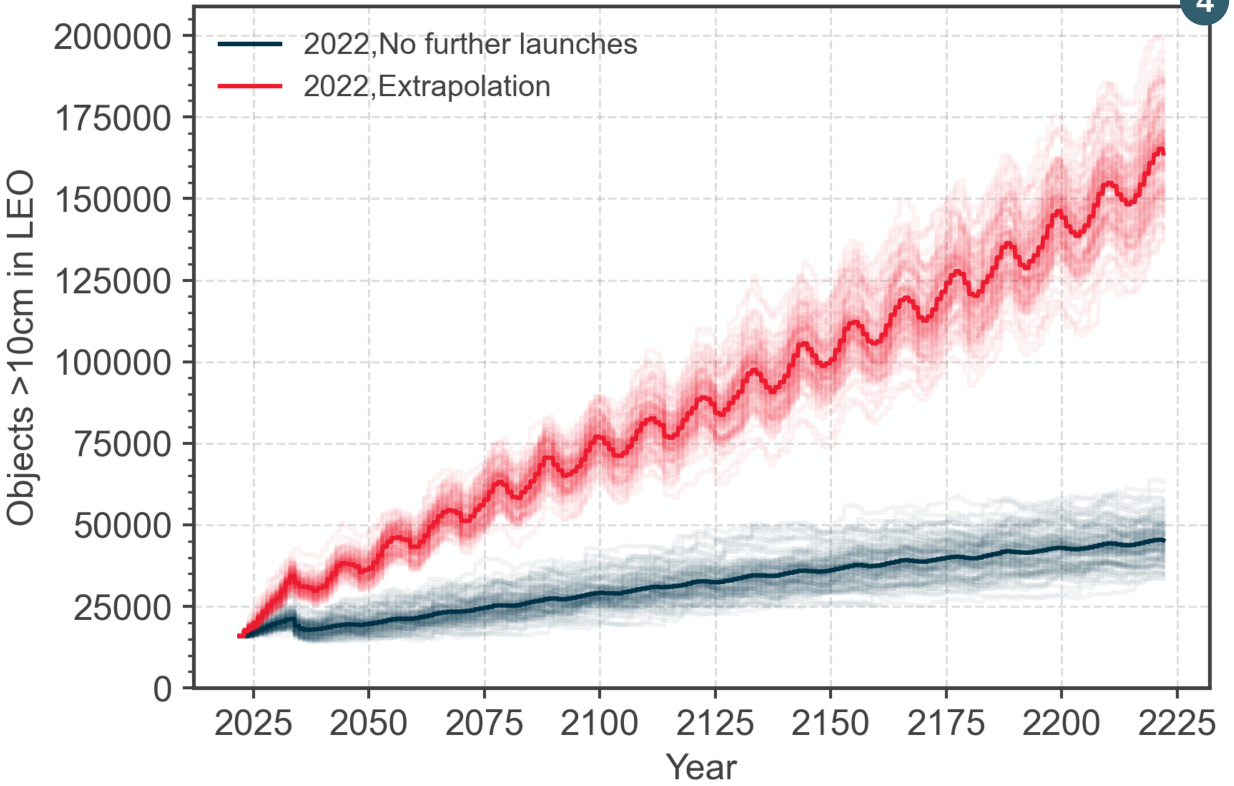
1 The different ways of being compliant




2 The dynamics of the space environment

3 The objective of sustainable spaceflight

## Implementation of guidelines

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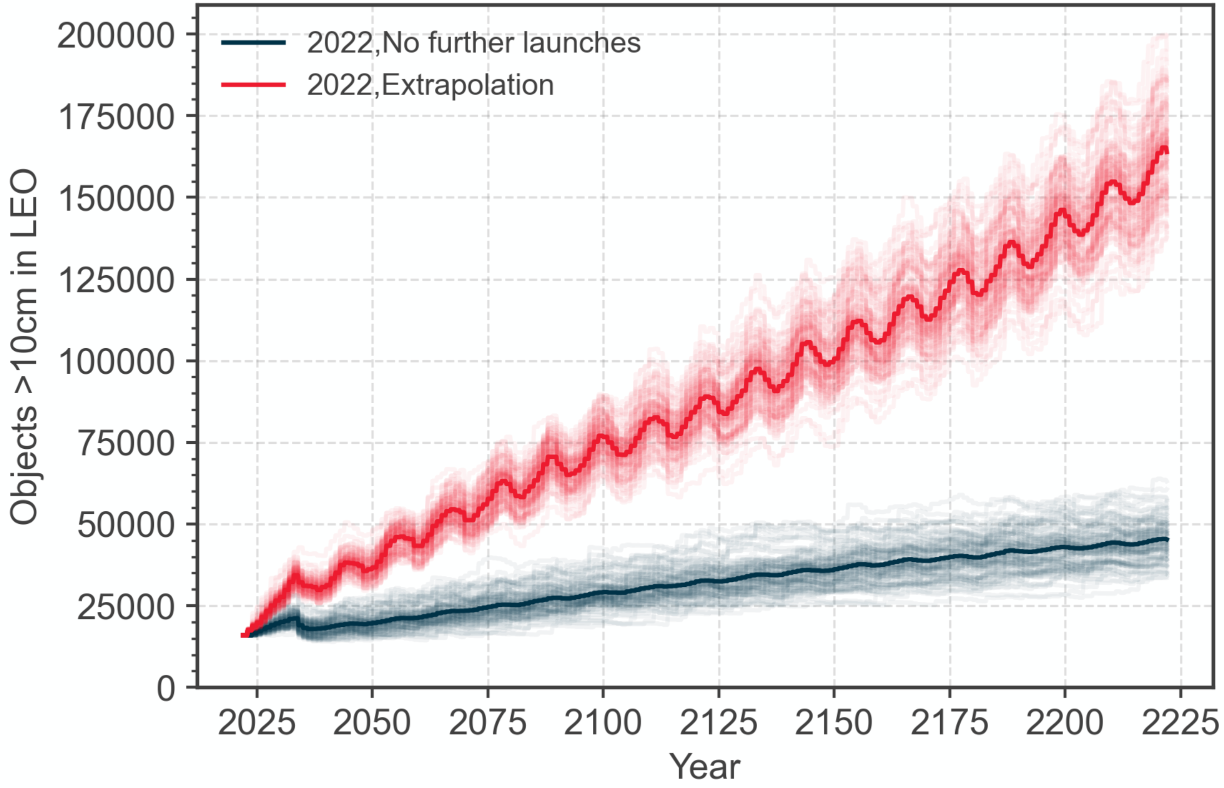
ESA's Space Environment Report, 2022

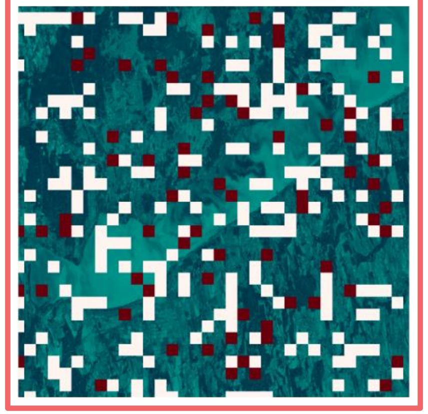
# What does it mean?

=1 year

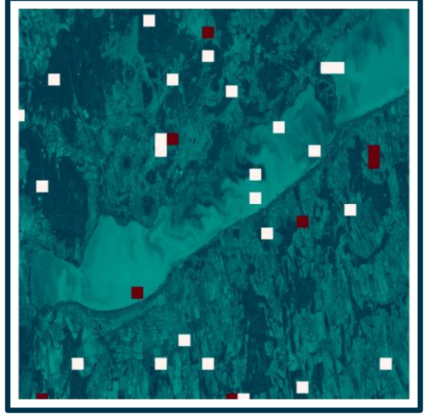
- ■ CAM (Collision Avoidance Manoeuvre)
  visualised as an 8-hour outage of operations
- □ Escalated event
  i.e. monitored conjunction notified to the mission team that did not result in a CAM



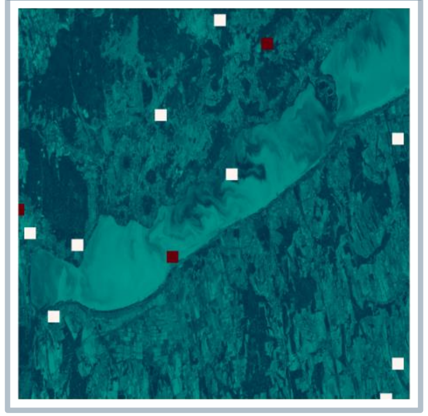

Extrapolation



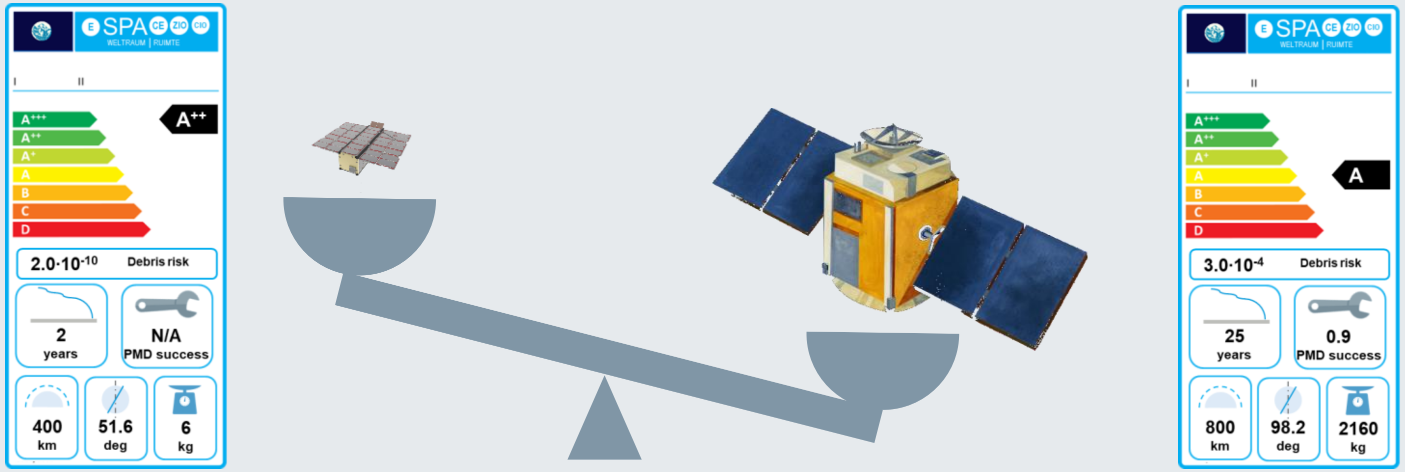
No further launches



Current status



# Towards space environmental impact assessments

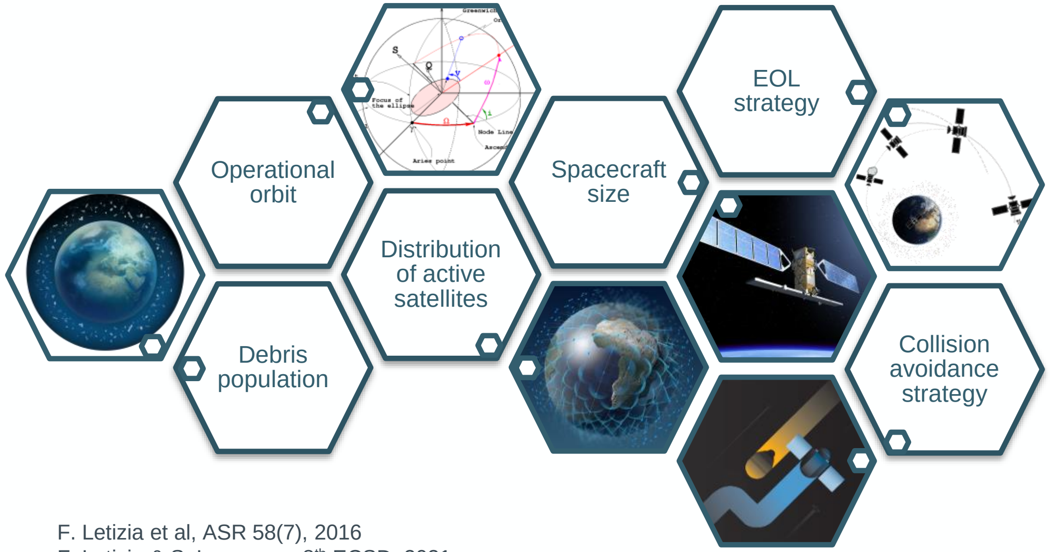



Missions **compliant** with space debris mitigation guidelines can still have significant different **risk levels** in terms of potential **debris generation** and **debris environment impact**

We want to measure for each mission

- How detrimental is it to its **orbital neighbours**? (short-term)
- How does it contribute to the **Kessler syndrome**? (long-term)

Use of a **risk metric** at single mission level




**EOL**: End-Of-Life

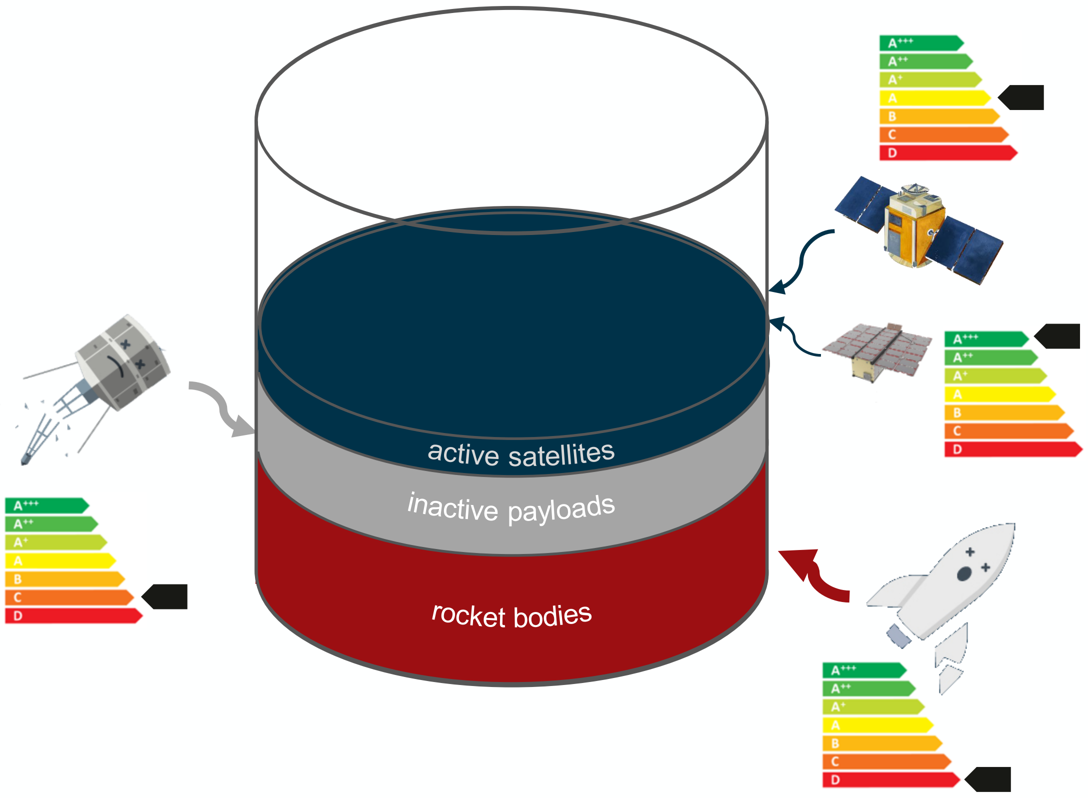
F. Letizia et al, ASR 58(7), 2016
F. Letizia & S. Lemmens, 8th ECSD, 2021

# Space Environment Capacity - concept

number & type of missions compatible with the stable and low risk evolution of the environment

H. Krag, S. Lemmens, F. Letizia, 1st ICSSA, 2017

The space debris risk is **additive**: a population is evaluated summing the contribution of all its members




| | |
|---|---|
| Capacity consumed by non-functional objects | Changes dynamically with the evolving environment |
| Capacity available for new&active missions | Could use allocation mechanism |
| Envelope (total aggregated risk) | Can be defined through long-term simulations of the environment |

# Space Environment Capacity - example

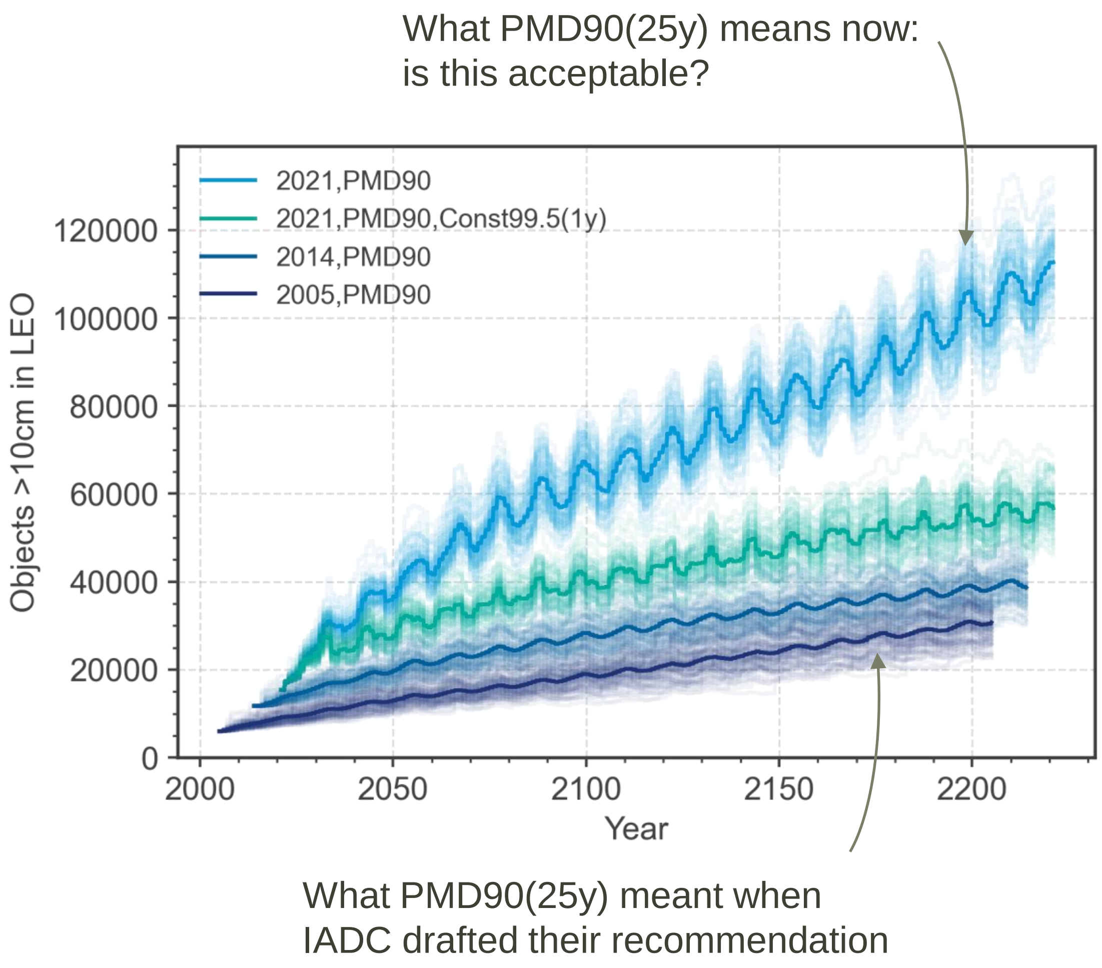
Long-term (200 years) simulations on the environment to quantify the impact of parameters such as

- Launch traffic
- Explosion rate
- Disposal approach

Approach used to derive the **25-year rule**, by comparing it to alternative disposal options

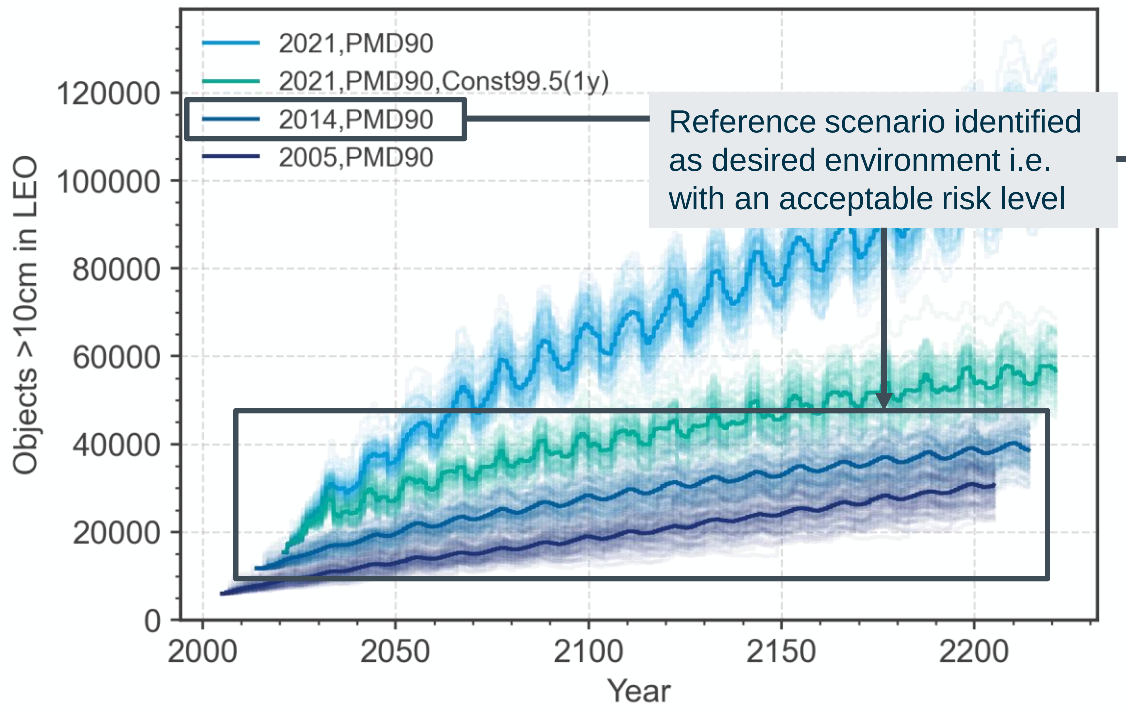
What does this rule mean now for the environment?

Results show the evolution of the environment using different years as starting point for the simulations, extrapolating respective levels for launch traffic and considering a disposal success rate of 90%

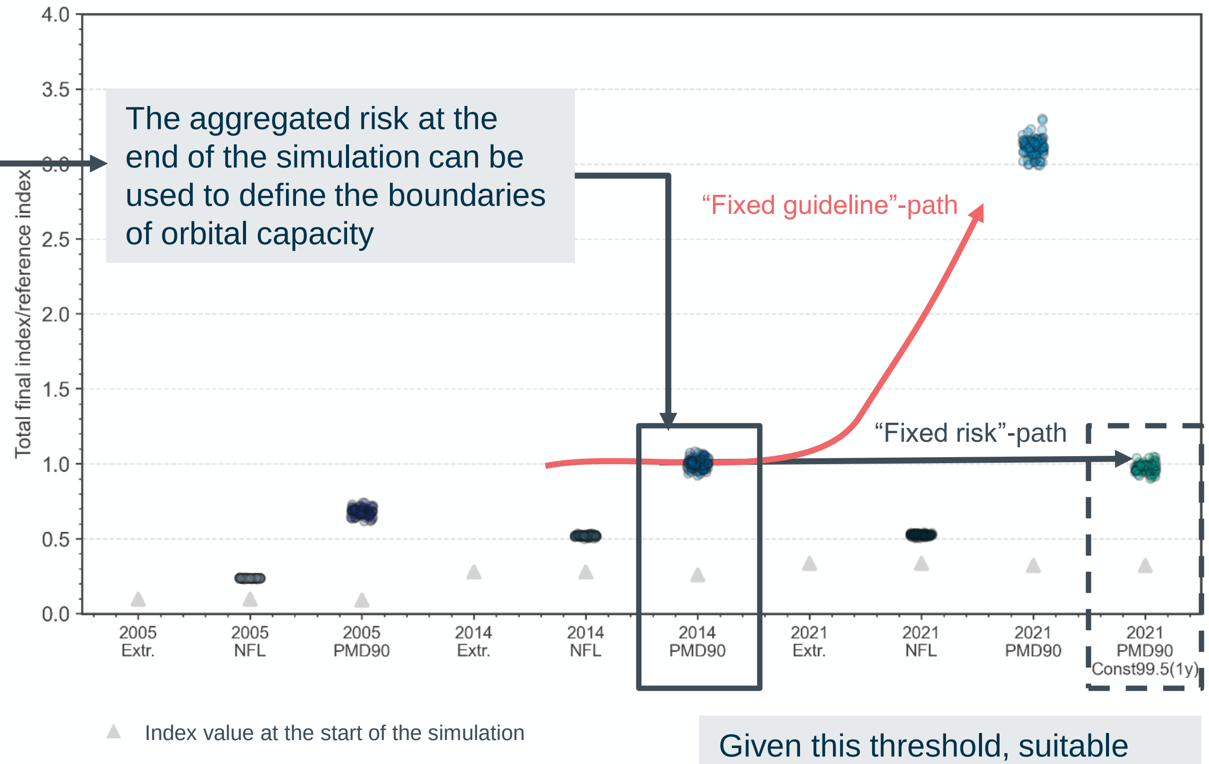


# Derivation of a threshold-based model

## Number of objects




## Aggregated risk metric




Given this threshold, suitable mitigation strategies, matching the observed launch traffic and disposal rates, can be identified

F. Letizia et al, ASR, 2022, 10.1016/j.asr.2022.06.010

# Zero Debris is focused on limiting the risk

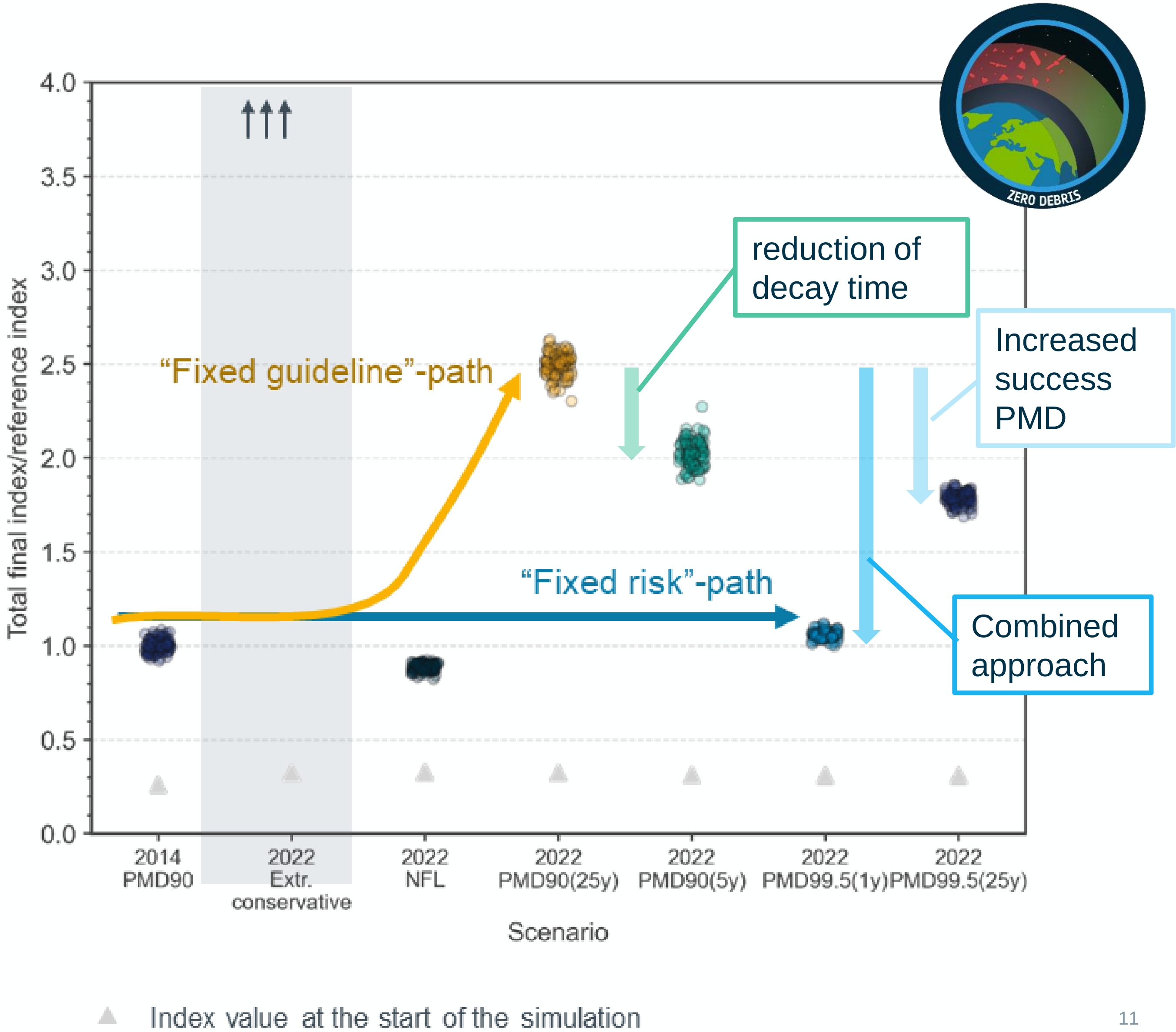
**1** One of the **Zero Debris principles** aims at developing debris mitigation requirements **beyond** proxies as **lifetime limitation**

**2** **Zero Debris** aims at setting a **risk limit** for future missions

**3** This is only feasible through a **combined approach**:

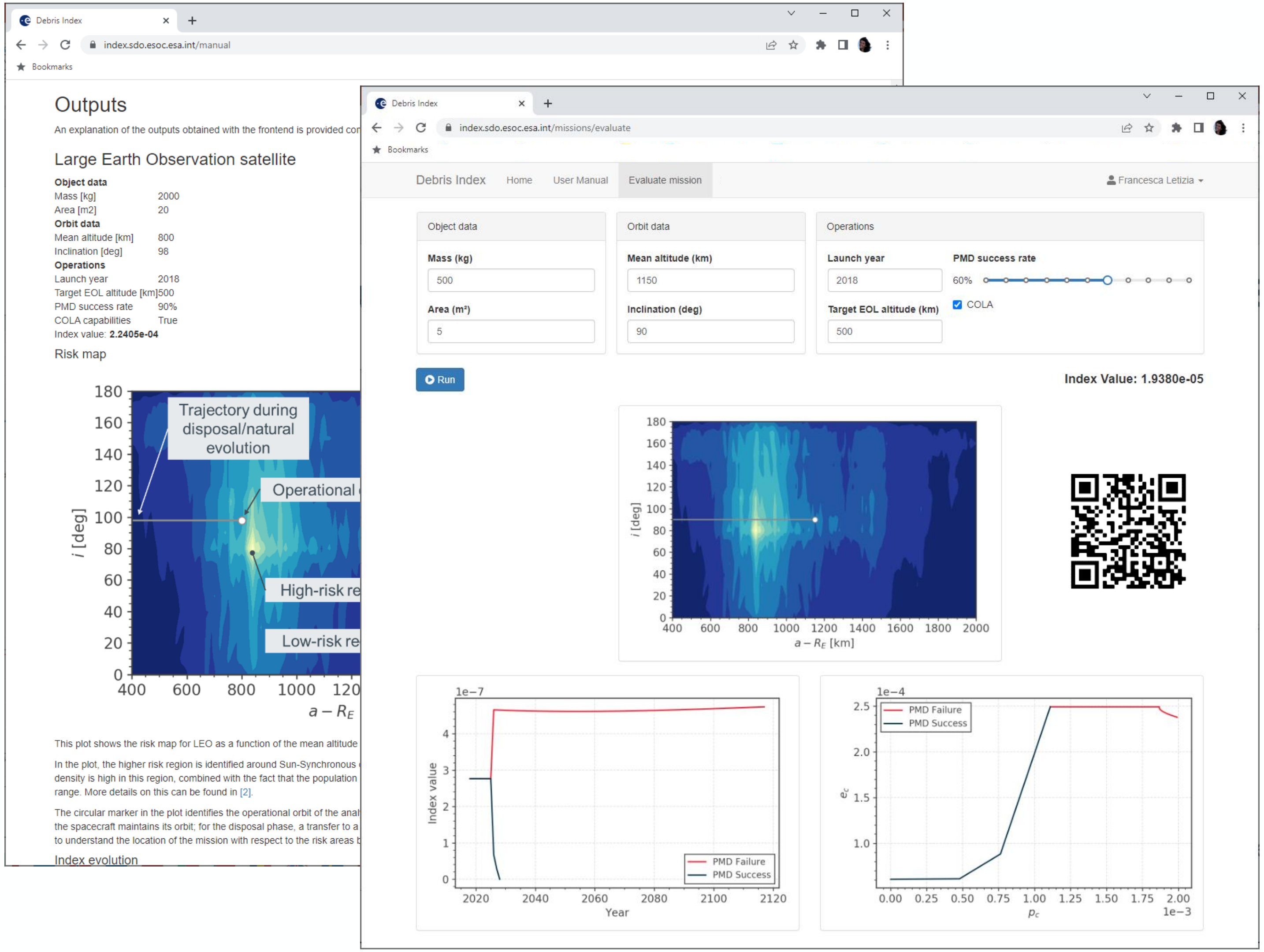
1) Improving the **probability of post mission disposal**: going towards ~100% where needed

**2) Improving the orbital clearance:** reduced time and collision risk threshold



# Operational status: index frontend

https://index.sdo.esoc.esa.int/




Access requires

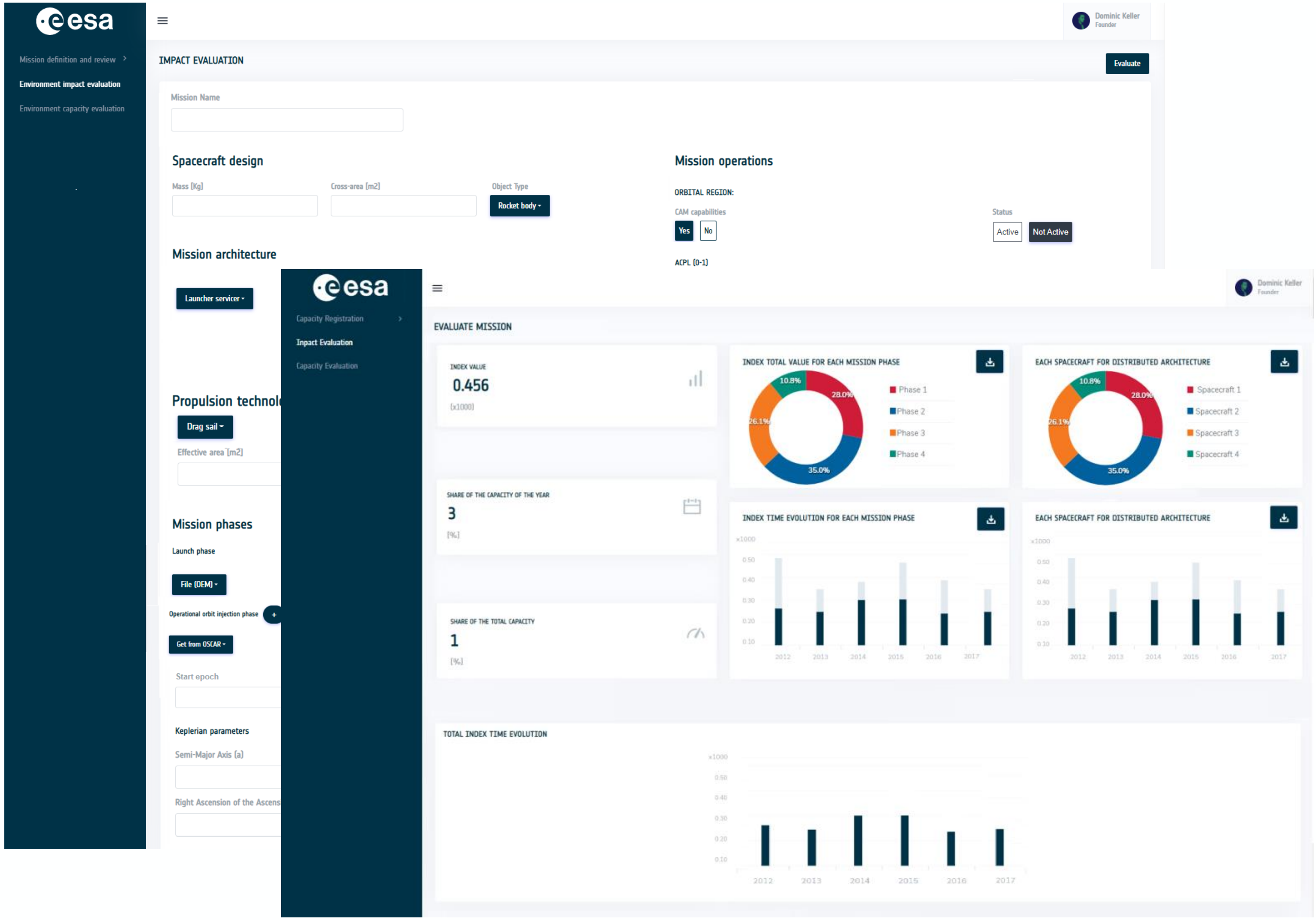
- a (ESA) **space debris user account** (same as for other ESA's tools, e.g. DISCOS, DRAMA, etc)
- **specific request** to space.debris.support@esa.int

Computation restricted to **LEO**, **simplified orbit evolution** and mission architecture

**Ad-hoc support** can be requested at space.debris.support@esa.int

# Operational status: THEMIS

Developed by Politecnico di Milano and DEIMOS




Multi-year activity through ESA's **Space Safety Program** to create a **software infrastructure**, fully integrated in ESA's tool ecosystem and with augmented analysis capabilities (e.g. any orbital regime, complex mission architectures)

Activity to be concluded in **2023**, with planned release of the computation **frontend**, where users can define, store and assess their missions

Open research questions on managing (and trading) mechanisms

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