Future Debris Mitigation Concepts

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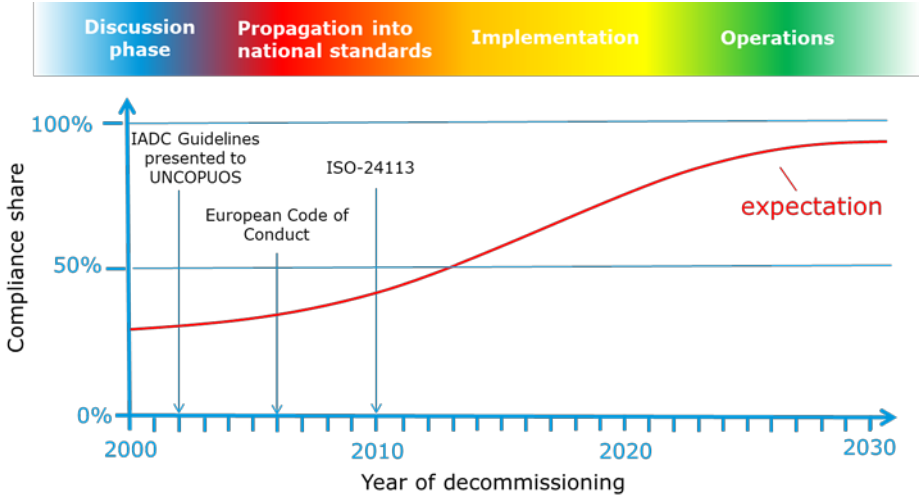
Introduction

- Guidelines and standards are only useful when they are used

- United Nations, *Guidelines for the long-term sustainability of outer space activities (A/AC.105/2016/CRP.17)*, 2016. Guideline 26:
  - Provide a transparent overview of global space activities,
  - Quantify the effect of internationally endorsed mitigation measures aimed at sustainability of the environment,
  - **Estimate the impact of these activities on the space environment.**

Introduction

- Space debris standards are in a phase of maturation:
  - Explicit numerical processes where possible (e.g. orbital lifetime)
  - Objectives where necessary (e.g. pressure release from tanks)
  - Implementation:

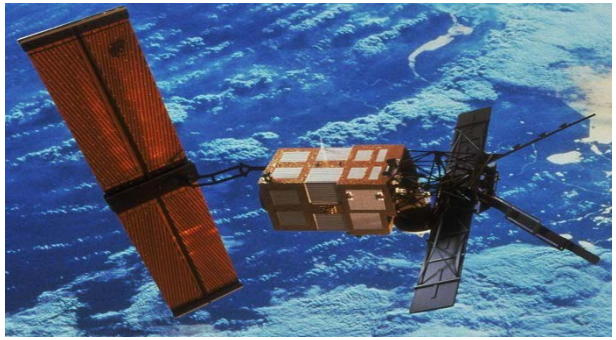


Introduction

- Space debris standards are in a phase of maturation:
  - Explicit numerical processes where possible (e.g. orbital lifetime)
  - Objectives where necessary (e.g. pressure release from tanks)
  - Time to implementation can be significant

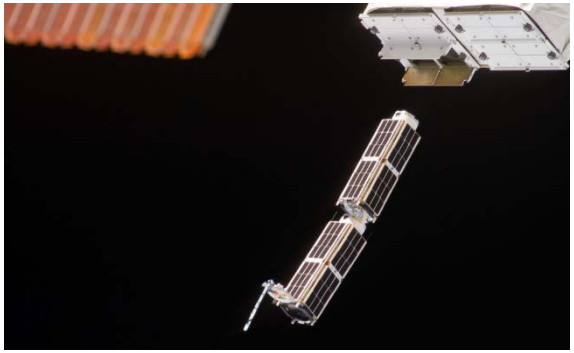
- Standards are still based on guidelines/national objectives from the 90'ies
  - 25 year rule in LEO is based on launch traffic assumption,
  - GEO graveyarding practices do not work for inclined satellites,
  - Collision avoidance is qualitative addressed,
  - Observability questions for surveillance lead to security questions,
  - ...

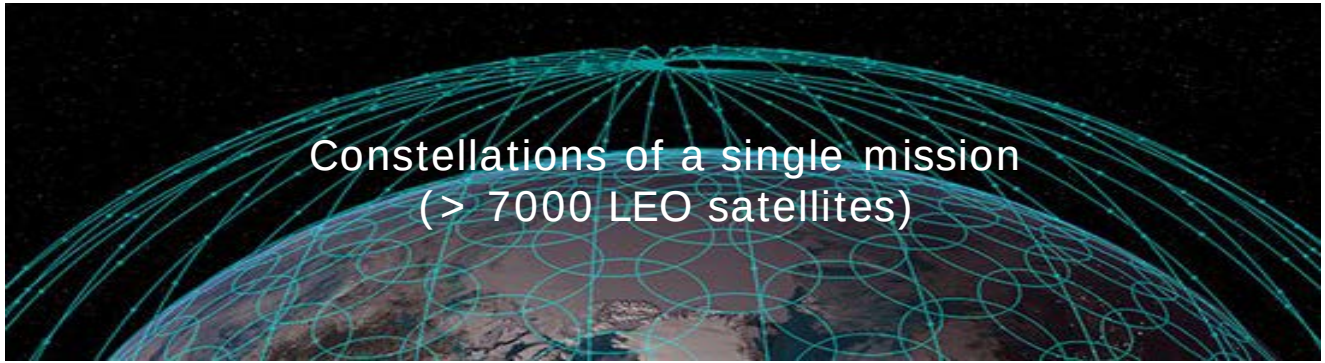
New Space Revolution



Large
Complex,
institutional

Lean,
agile,
commercial

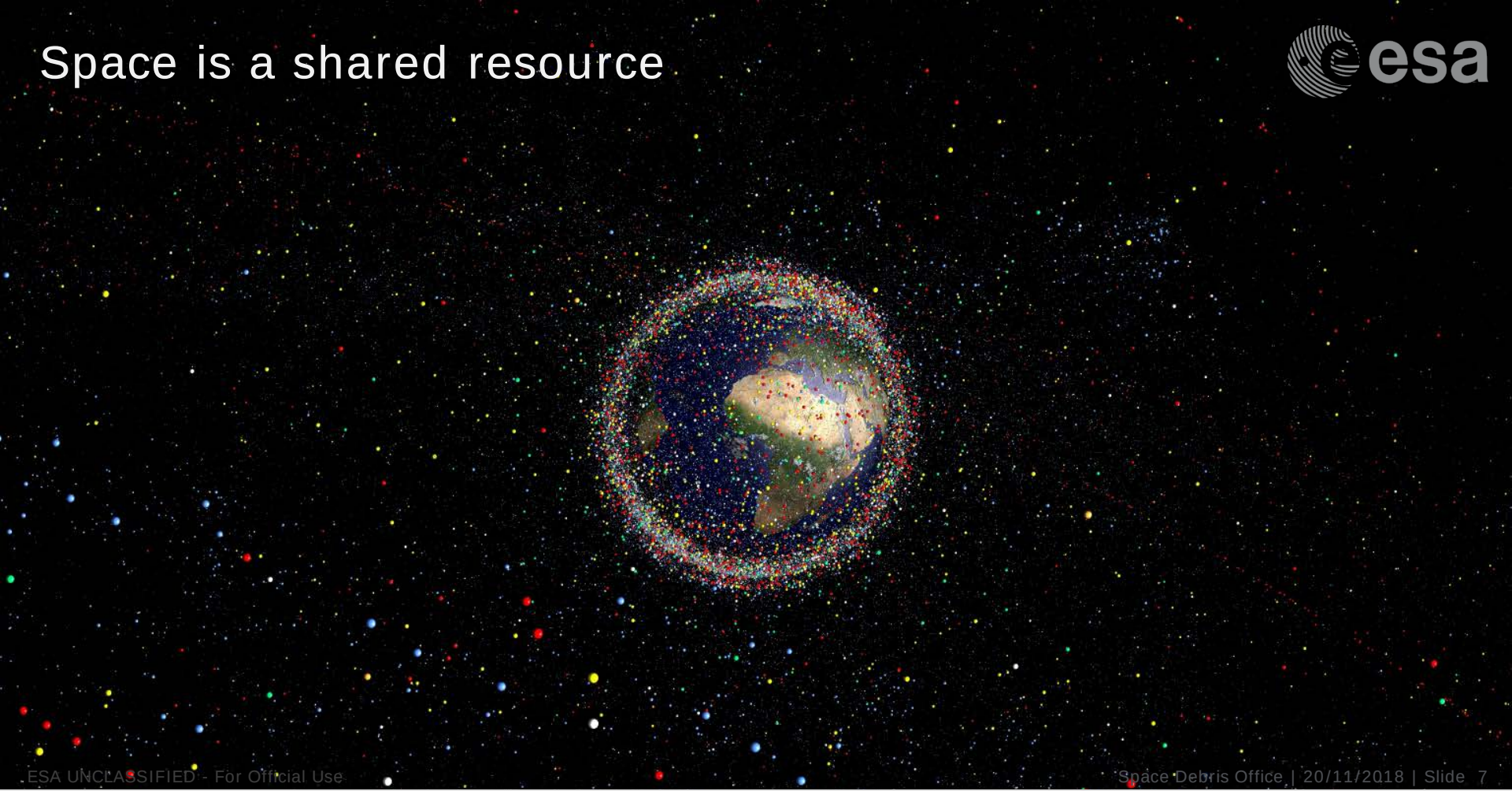




Problem statement

- Complementary to legal issues associated to space debris:
  - Space debris mitigation is about space sustainability
  - Can a technical concept capture the long term sustainability guidelines?
  - The environment is dynamic, so needs to be the standard.
  - Is a standard for each object alone enough?
  - Not all technical solutions to mitigate are equally desirable
  - Can we differentiate?

Space is a shared resource



But how to share the cake?

Problem statement

- “Similar” frameworks in place on Earth:
  - Environmental burden and protection
  - Economic value of a resource

- Space Debris mitigation needs to focus:
  - Liability: Debris causes collisions; Re-entries cause impacts; …
  - Environment: Space needs to be useable and available

All objects, one set of rules

- Broadly compatible **internationally**
- Based on **established** guidelines
- Requirements are **evolving**
- But new space is a **revolution**

ESA Director General's Office — ESA/ADMIN/IPOL(2014)2 — Space Debris Mitigation Policy for Agency Projects

Inter-Agency Space Debris Coordination Committee

IADC Space Debris Mitigation Guidelines

EUROPEAN COOPERATION ECSS

Scientific and Technical Subcommittee of UNCOPUOS

UN Space Debris Mitigation Guidelines

UN Guidelines for the long-term sustainability of outer space activities

INTERNATIONAL STANDARD ISO 24113

Second edition 2011-05-15

Space systems — Space debris mitigation requirements

Systèmes spatiaux — Exigences de mitigation des débris spatiaux

Reference number ISO 24113:2011(E)

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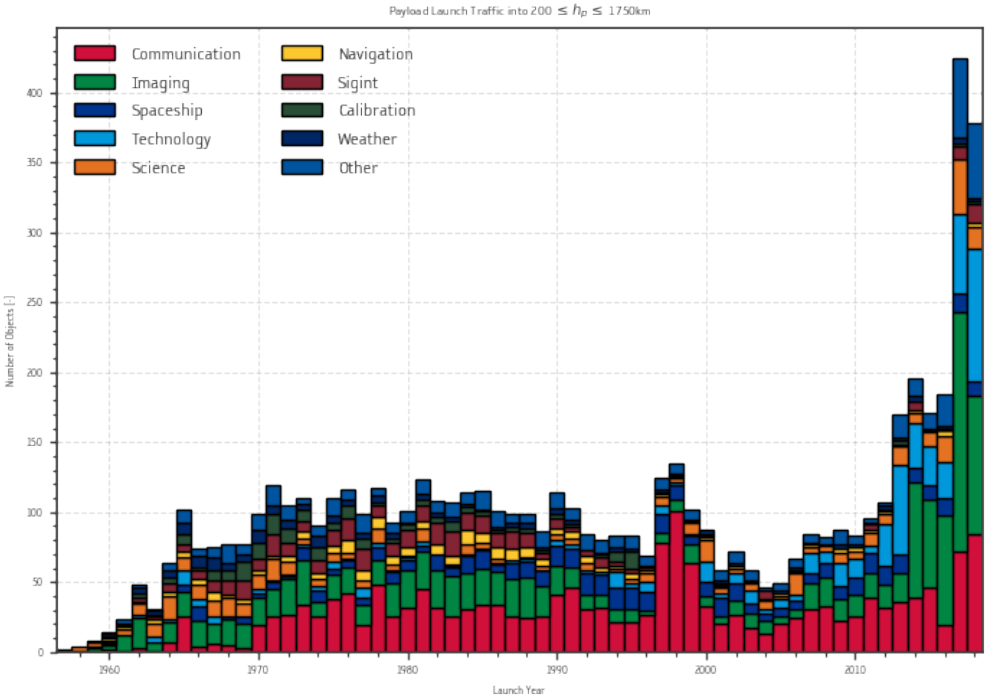
One object, one slot

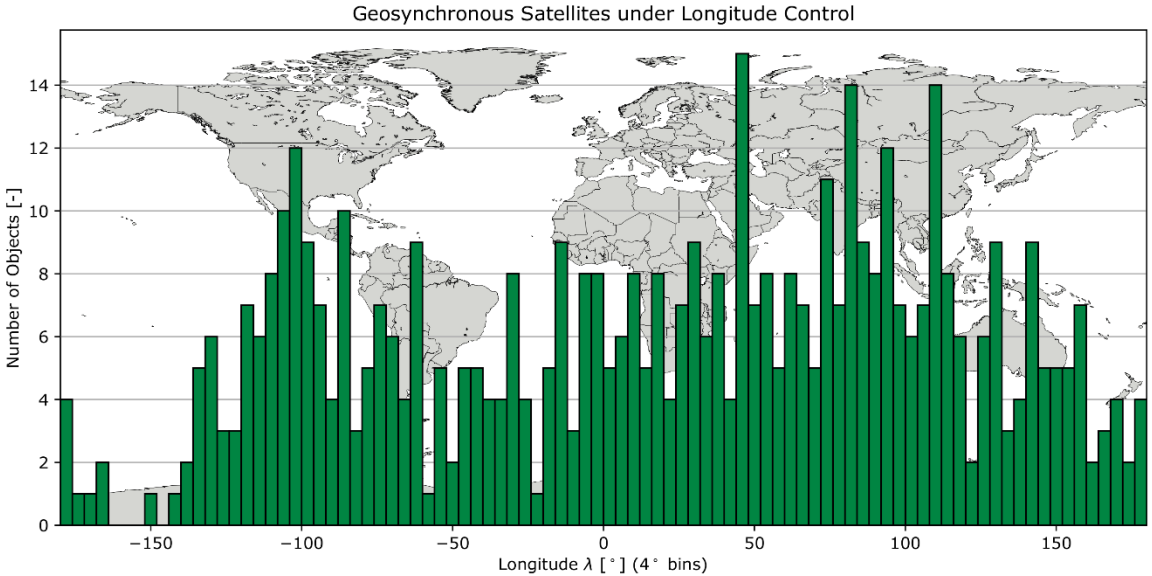


- An upper stage is treated equally independent on how much mass it launches

- A CubeSat based drag sail de-orbit from 1000km in 25 years is as compliant as ERS-2 from 600km.

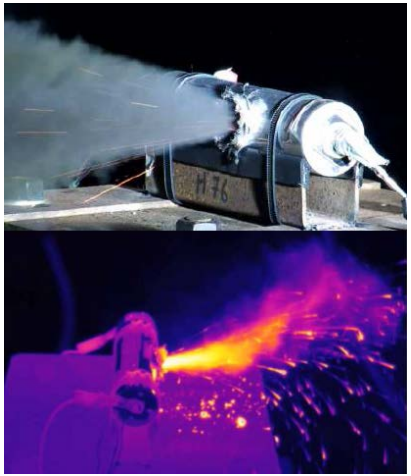
- 100's of re-entries of the same constellation in few given years with a casualty risk of 0.99 * 10^{-4} each is compliant.

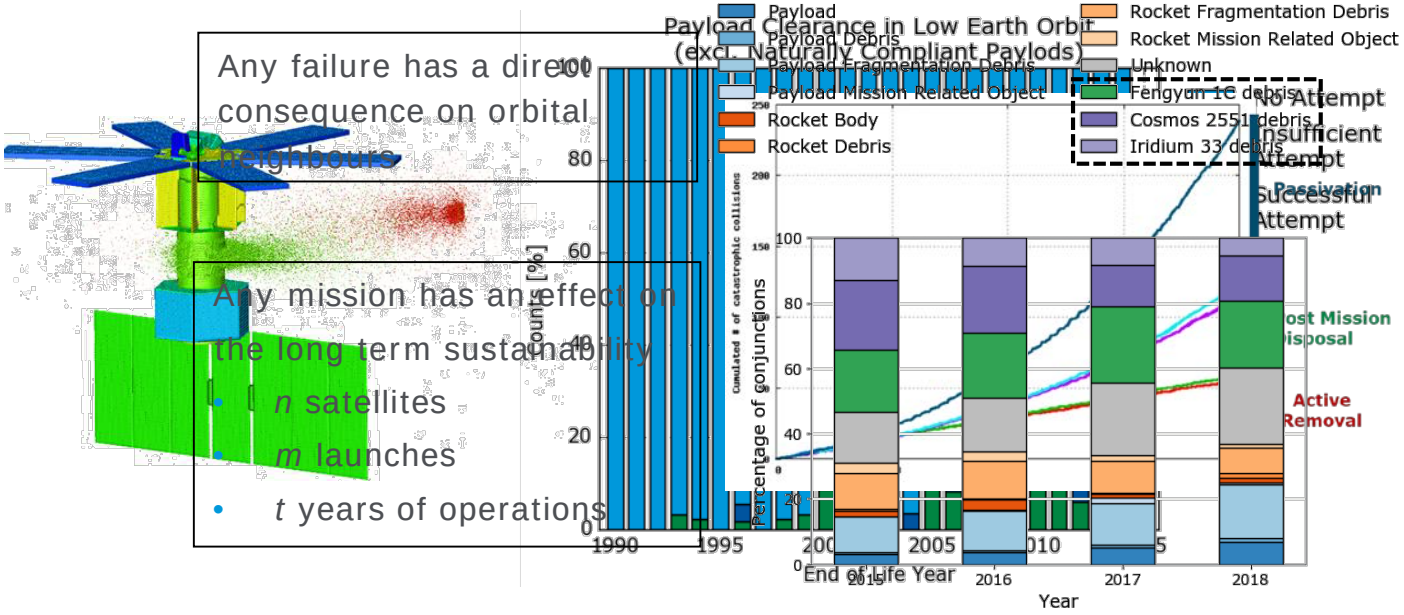
One slot, how many objects?



Satellites in **GEO** share and manage **longitude slots** based on **frequency allocation** to avoided harmful interference (short term)

One slot, how many objects?





Satellites, launch vehicles, and constellations **around Earth** could share and manage **orbits** based on **environment capacity allocation** to avoided harmful interference (short & long term)

One slot, how many objects?

Development of a risk figure, i.e. environment index, to define a capacity:

- **Risk** equals probability times severity
- **Probability**: the likelihood of a catastrophic collision in the year analysed;

With active/operational payloads performing collision avoidance; …

- **Severity**: the resulting in cumulated collision risk on the rest of the LEO population including inactive objects; …

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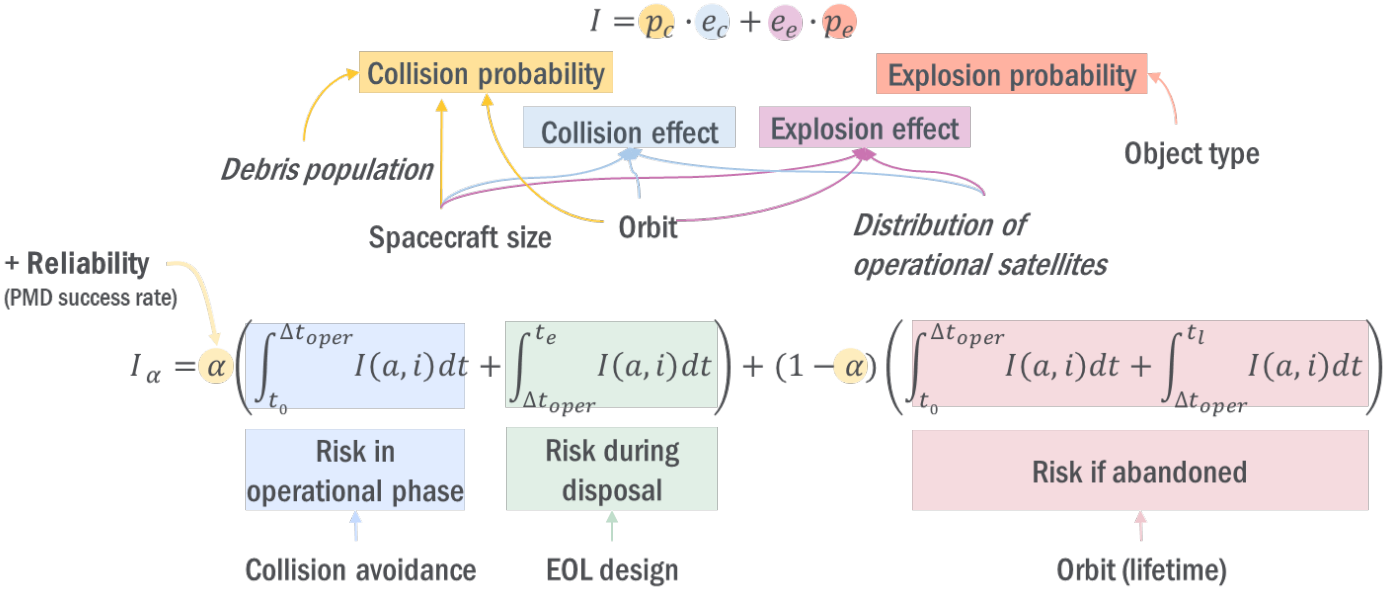

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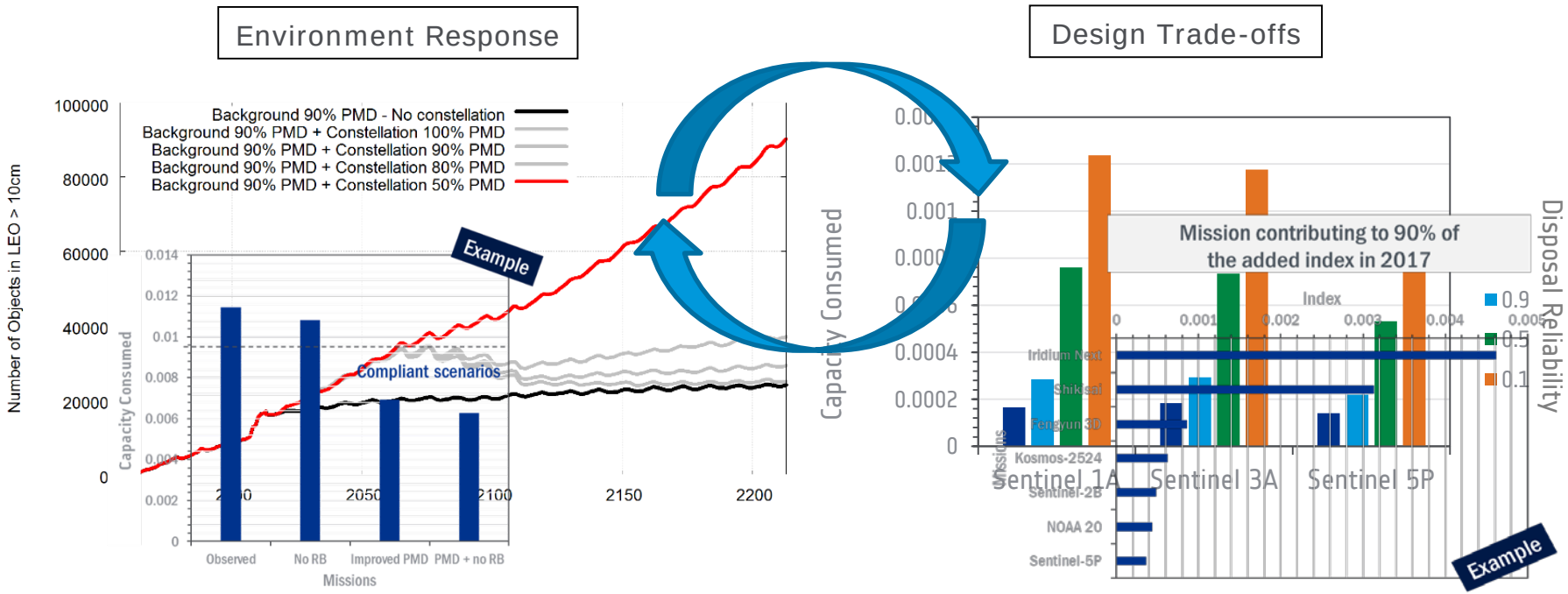
Slots OK, but how to allocate them?



Environment capacity is the **typology & orbital regimes** of artificial space objects compatible with a **stable evolution** of the environment

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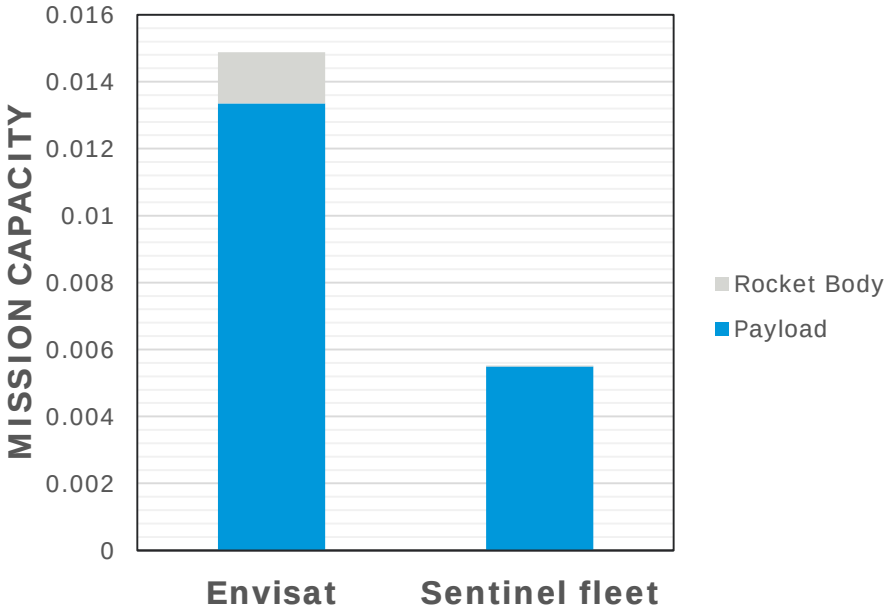
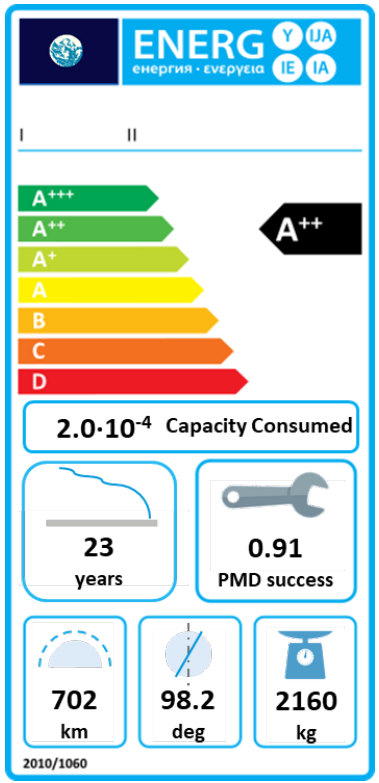


Design Trade-offs

- Single satellite versus fleet
- Sustainable use of launches
- Optimal use of different orbits
- Enables long term allocation

Environment capacity is the **typology & orbital regimes** of artificial space objects compatible with a **stable evolution** of the environment

Slots OK, but what does it bring?



Mitigation guidelines:

"Limit the yearly consumption of environmental capacity"

Standards:

"The environmental impact shall be less than X based on method Y"

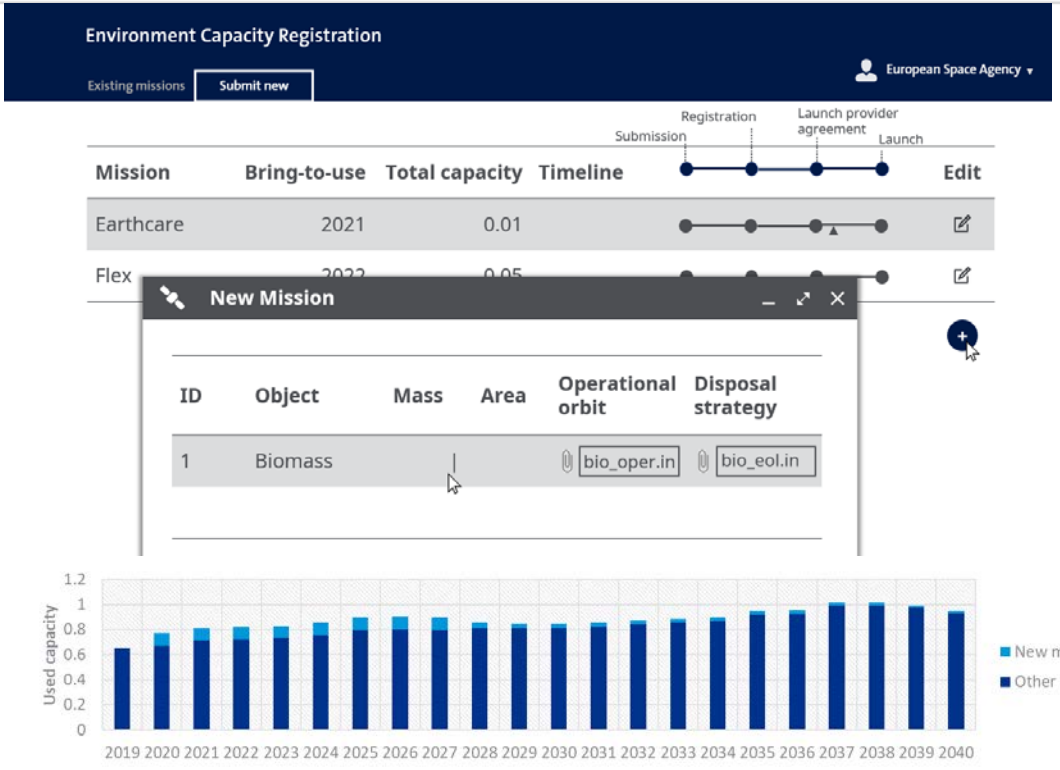
Engineering practice:

"Find the optimal solution which is mission dependent"

Legally:

A handle for flexible target setting

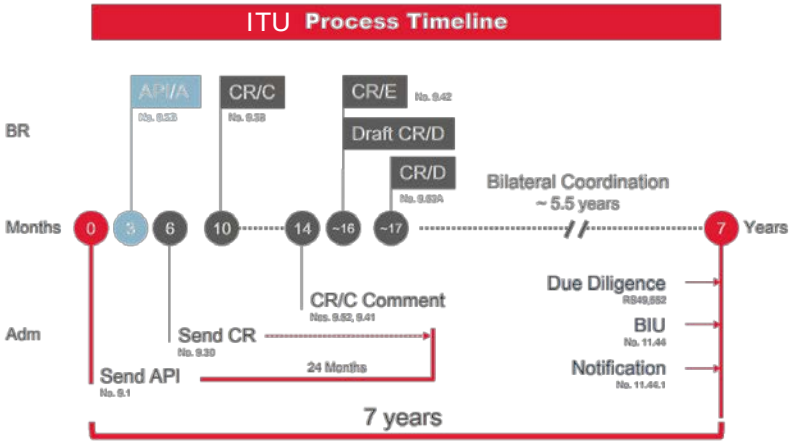
Slots OK, but how to keep track?



Slots OK, but how to keep track?

- ITU-like **process** to request **capacity allocation** (instead of frequencies)

- E.g. First-come first-served
- The consumption of capacity is measured for all the mission duration (operational life + disposal)
- **Book-keeping of capacity-allocation** for the future years
- The status needs to be **re-computed** routinely to **track changes** in the environment



Environment Capacity

- Seeing space as a limited environment allows for:
  - a “natural” inclusion of environmental law concepts, including **damage & harm**. I.e. going in orbit is already a damage done.
  - The notion of space sustainability

- Norms of behaviour are laid out in standards and can further mature
- Under the assumption of space as a “limited” “environment”, a **dynamic strengthening of the norms** becomes possible.
  - Shortening the 25 year disposal rule and higher than 90% post mission disposal success rates (IADC, On Large Constellations of Satellites in LEO, 2017)
  - One can consider missions, instead of objects.

Environment Capacity

- The mission/object index behind environment capacity is a **label**:
  - ADR can have negative impact (i.e. creating more capacity for the rest)
  - One can address common but differentiated responsibility
  - It creates an **incentives** for “low impact” missions, enabling technological differentiations.

- Currently secondary space debris mitigation aspects can still influence it:
  - Tractability enhancers or orbital data sharing.

- Non-adherence will still allow of positive identification of others.
  - Enabling **gradual adoption**

Environment Capacity

Environment capacity is the **typology & orbital regimes** of artificial space objects **compatible with a stable evolution** of the environment.

The use thereof by any mission {should be minimised / shall be of level A/B/C}