

# Future Debris Mitigation Concepts

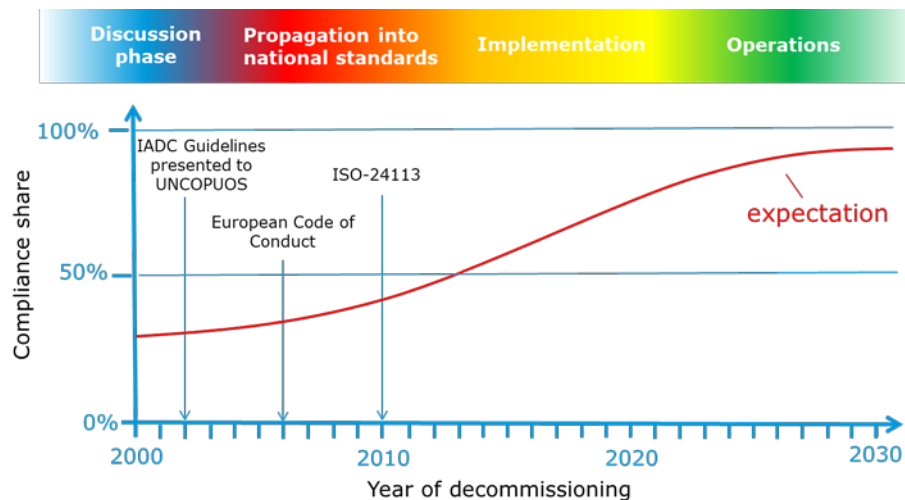
Stijn Lemmens, Francesca Letizia

2019-03-20 ESA ECSL Workshop - Standards

- 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:



- 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,
  - ...

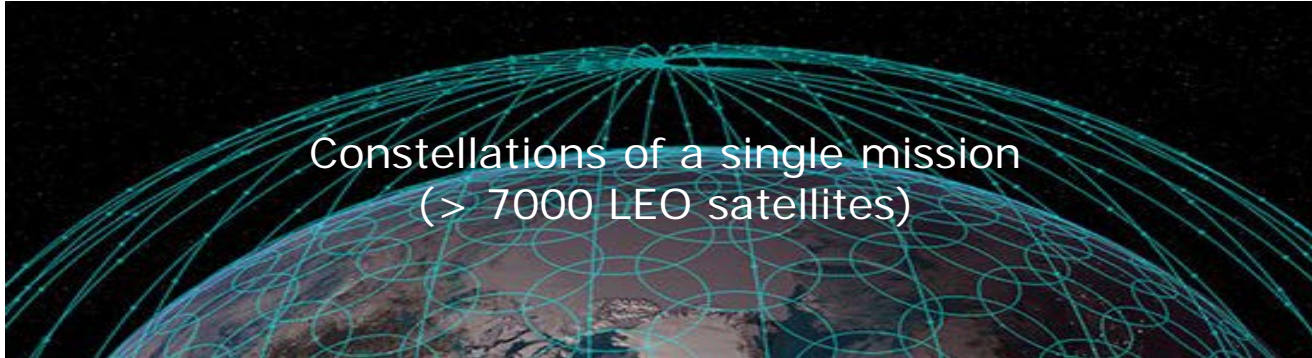
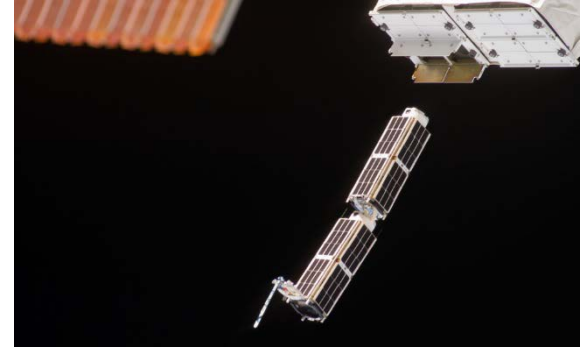
# New Space Revolution



Large  
Complex,  
institutional



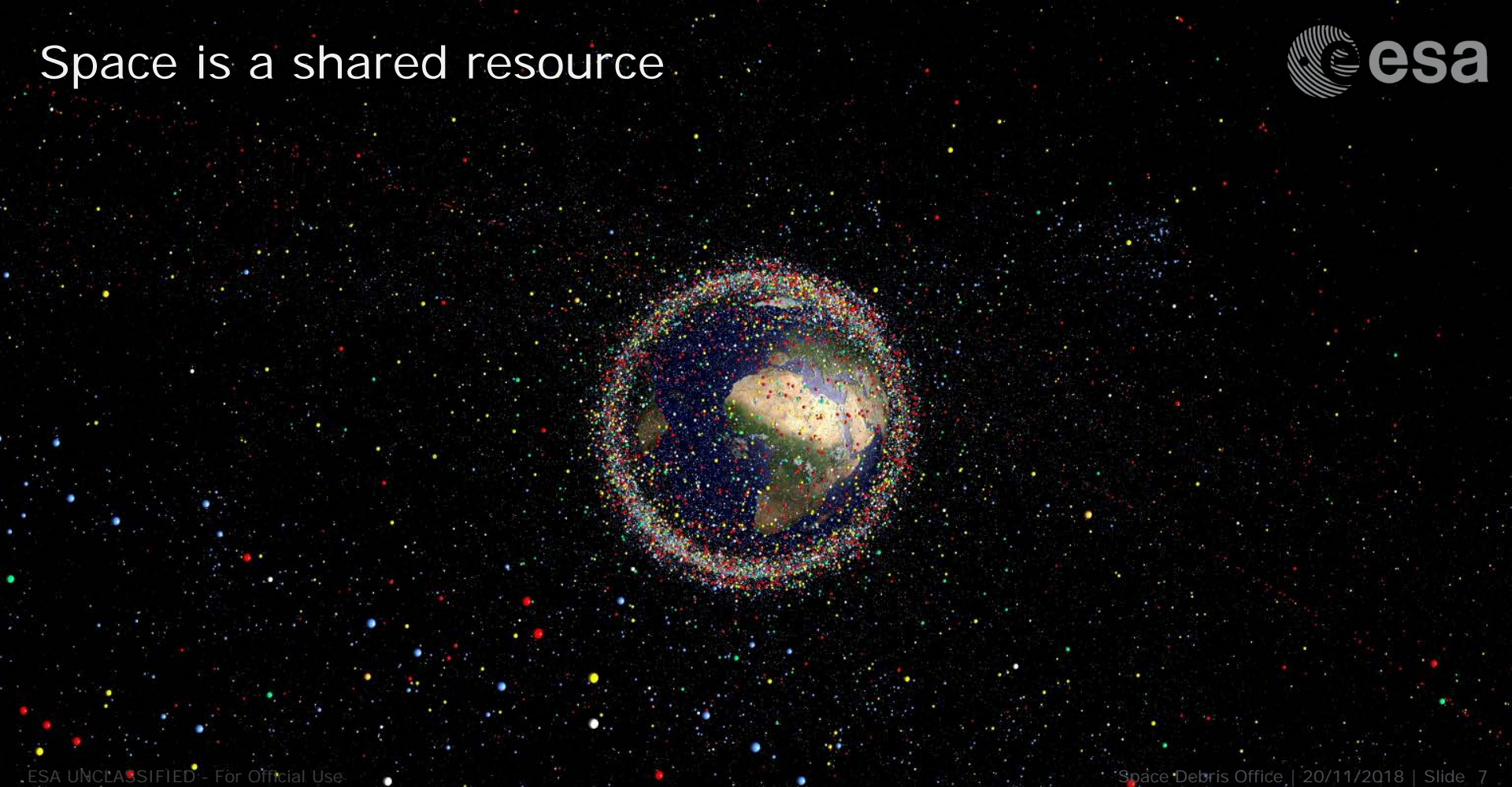
Lean,  
agile,  
commercial



- 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?





- “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  
Dariafouze 41164  
ESA website: "Interim Rules for the Rules"

ESA/EDM/NP/DC (2014)02  
Rev. 1.0  
Paris, 28 March 2014  
(Original English)

**1. INTRODUCTION**

As a consequence of spaceflight activities, the number of functional and non-functional objects in space is increasing rapidly. To ensure the long-term sustainability of space activities, it is essential to establish a set of common rules that will govern the operation of a space system.

In May 2011, the 2<sup>nd</sup> edition of ISO 24113 "Space Systems — Space Debris Mitigation Requirements" was issued as the international standard which establishes the design and operational requirements in order to limit space operations on the orbital environment. On 17 February 2012, this standard was adopted by the European Commission on Space Standardisation (ECSS) as the ECSS-EAS-14C standard (Adoption Notice of ISO 24113: Space Systems — Space debris mitigation requirements).

The present instruction establishes the ESA standard for the technical requirements on space debris mitigation for Agency projects, it sets out the principle governing its implementation and the details of regional details.

**2. POLICY**

As the standard does not in cases of necessity the maximum acceptable residual risk level as determined by the approving agency, it is the Agency's policy to set that the maximum acceptable residual risk level of 1E-05 per object per year (OPEY) for the Agency projects.

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The ECSS Space Systems for which the System Requirements Review has been held level held off at the time of entry into force of this instruction, residual risk assessment shall be implemented on a least effort basis and demonstrated in the Space Debris Mitigation Report.

b) For ESA Space Systems for which the System Requirements Review has not yet been held off at the time of entry into force of this instruction, the residual risk shall not exceed 1 in 10,000 per object per year (OPEY) and, if the product is not certified, the maximum residual risk shall be no greater than 1 in 10,000 per object per year (OPEY) and, if the product is not certified, the maximum residual risk shall be no greater than 1 in 10,000 per object per year (OPEY).

2014-2030

**Inter-Agency Space Debris Coordination Committee**

**IADC Space Debris Mitigation Guidelines**

EUROPEAN COOPERATION

**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**

Systemes spatiaux — Exigences de mitigation des debris spatiaux

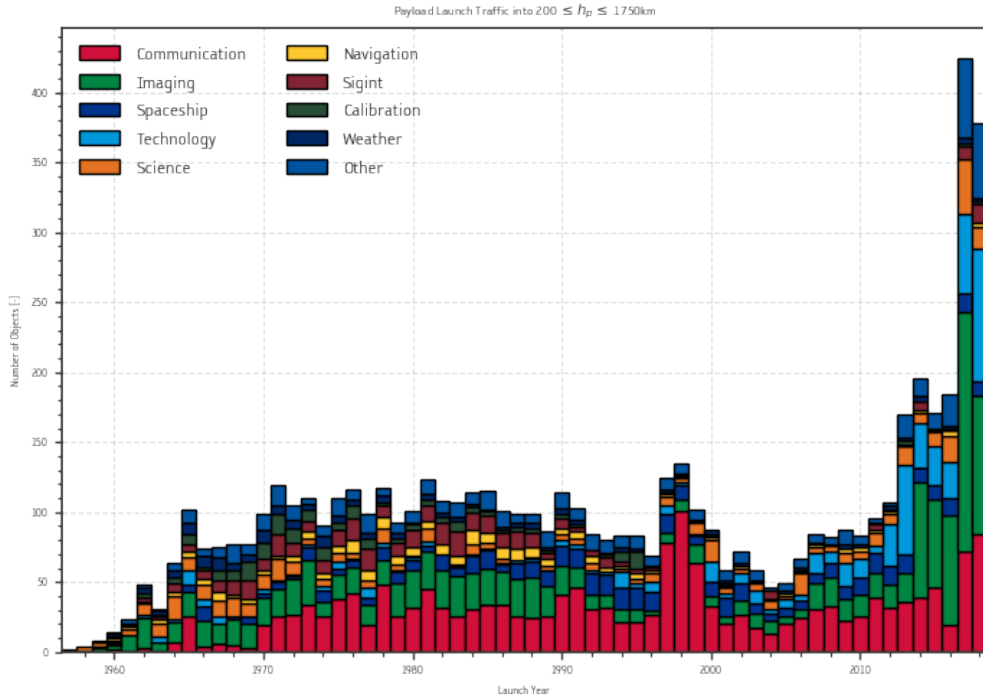
Reference number  
ISO 24113:2011(E)

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ESA ECSS/EAS/ST/Space/ST/DC/2013/0-28/24 PDF

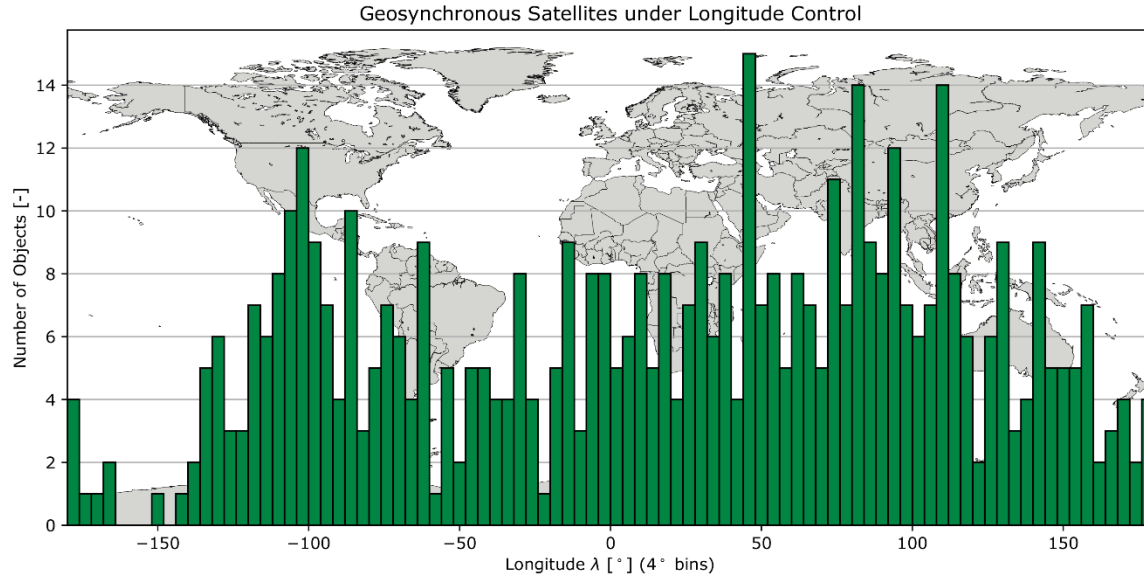


# One object, one slot



- 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.

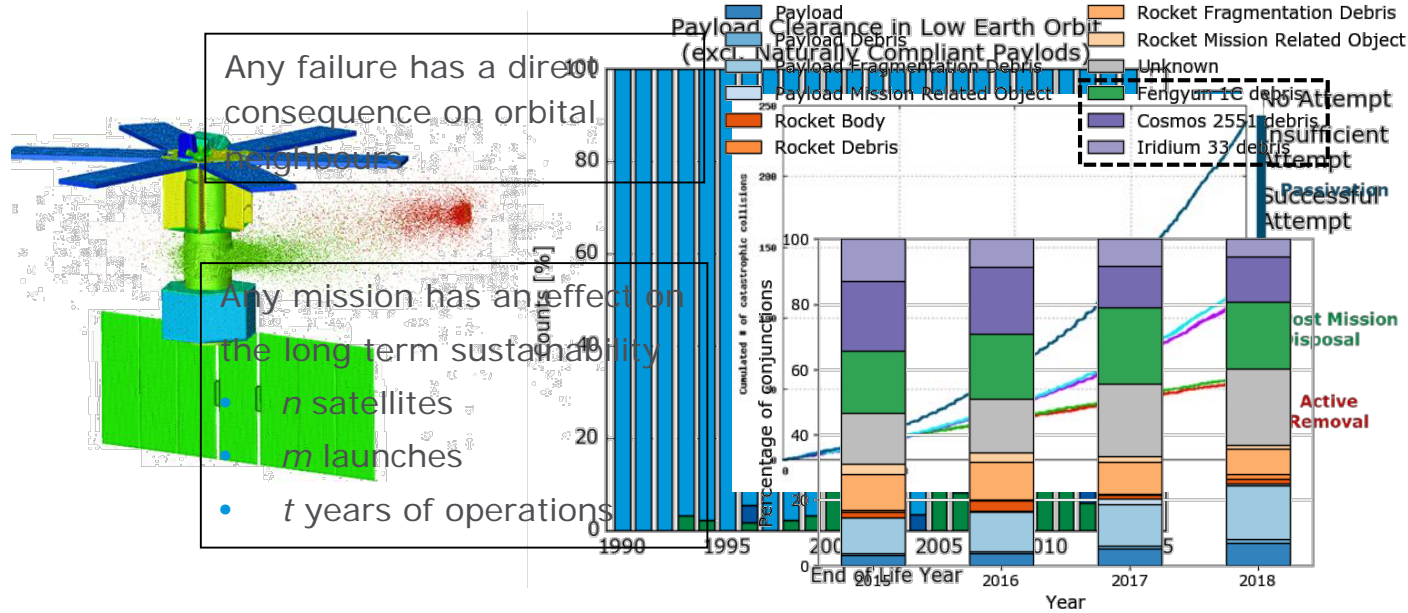
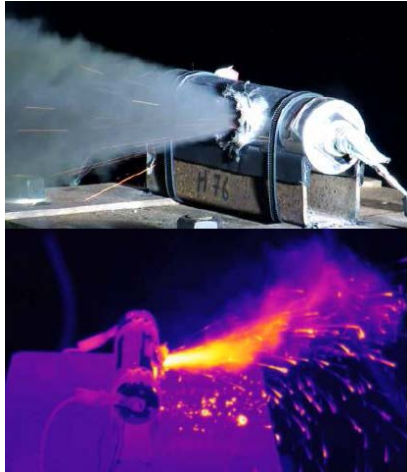
# One slot, how many objects?



Satellites in **GEO** share and manage **longitude slots** based on **frequency allocation** to avoid 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?



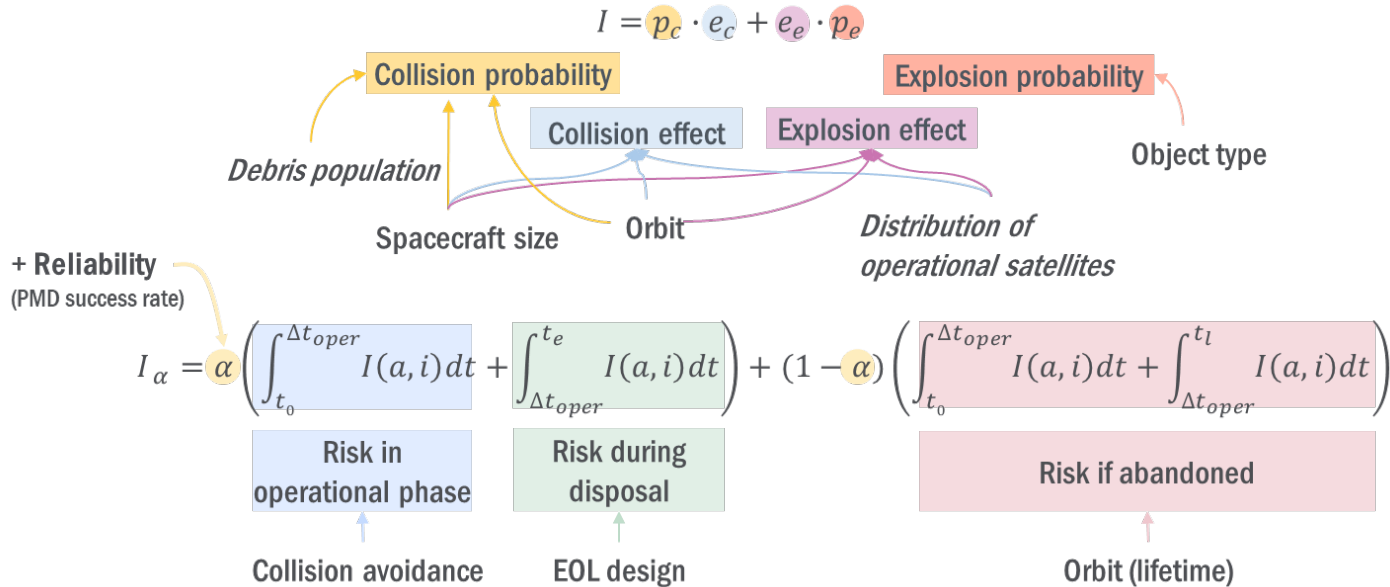
Development of a risk figure, i.e. environment index, to define a capacity:

- **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; ...

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



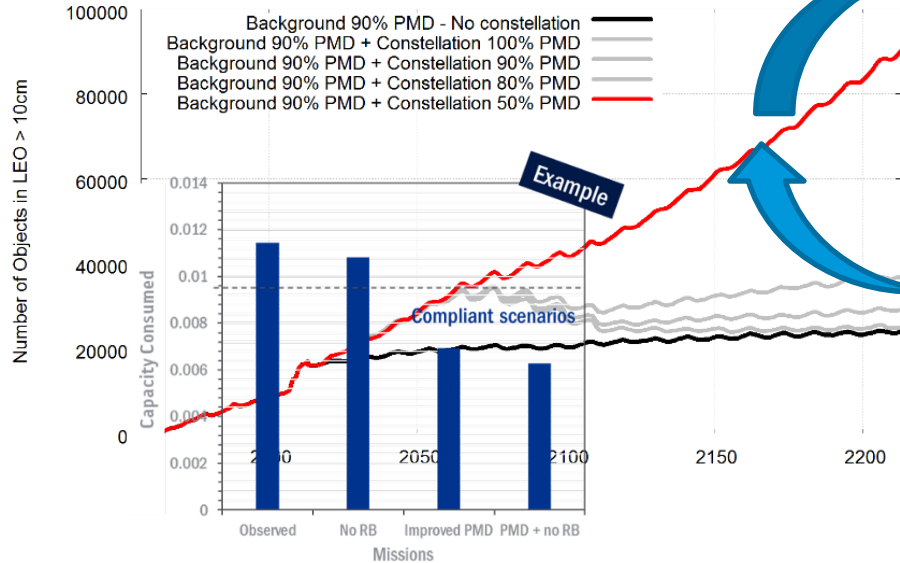
# One slot, how many objects?



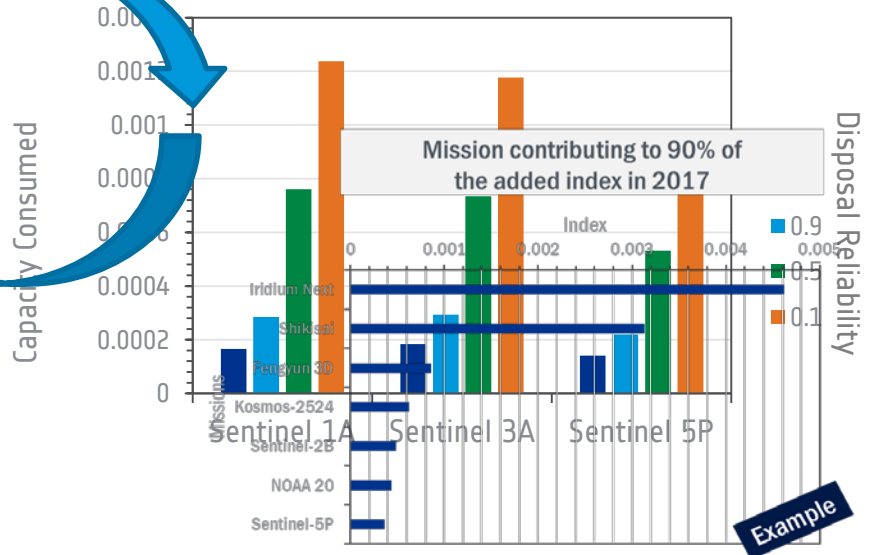
Satellites, launch vehicles, and constellations **around Earth** could share and manage **orbits** based on **environment capacity allocation** to avoided harmful interference (short & long term)

# Slots OK, but how to allocate them?

Environment Response



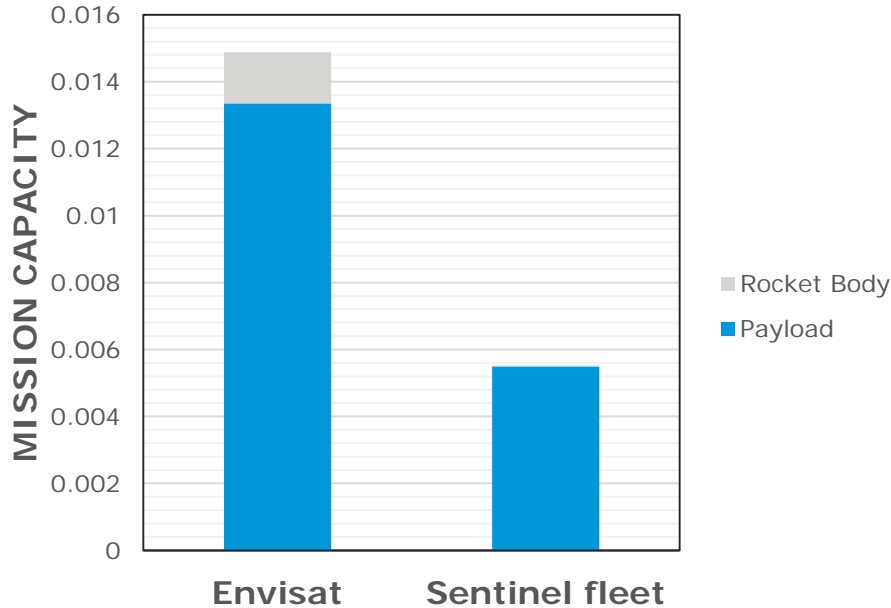
Design Trade-offs



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



# Slots OK, but how to allocate them?

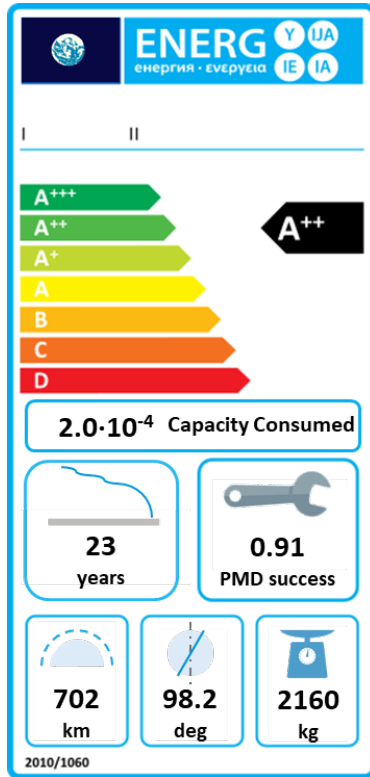


## Design Trade-offs

- 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?

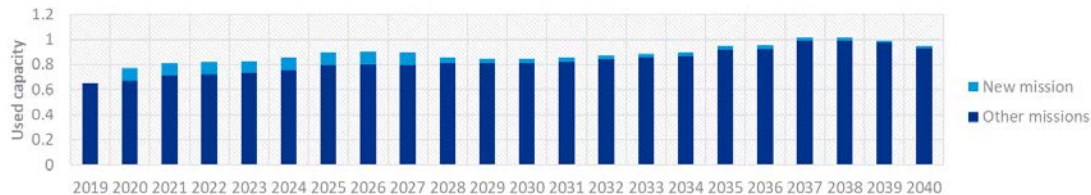
Environment Capacity Registration

Existing missions **Submit new** European Space Agency

Mission	Bring-to-use	Total capacity	Timeline	Registration	Launch provider agreement	Launch	Edit
Earthcare	2021	0.01					
Flex	2022	0.05					

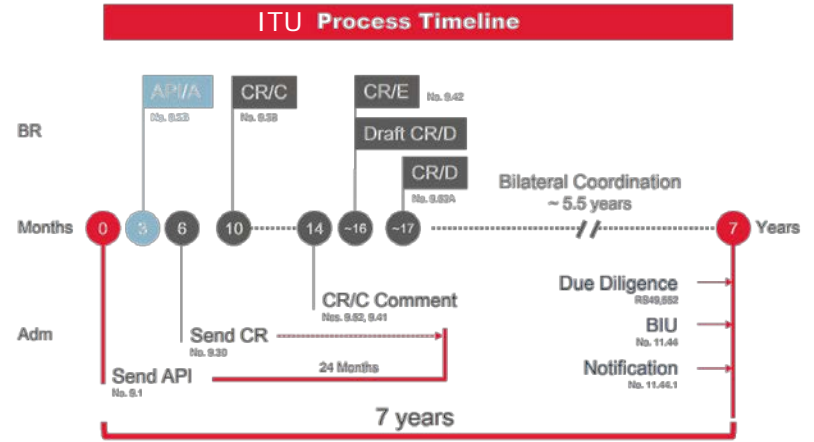
**New Mission**

ID	Object	Mass	Area	Operational orbit	Disposal strategy
1	Biomass			bio_oper.in	bio_eol.in



# 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





- 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.

- 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** 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}