Future Debris Mitigation Concepts

Stijn Lemmens, Francesca Letizia

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Introduction

• Guidelines and standards are only useful when they are used

  • 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

Constellations of a single mission
(> 7000 LEO satellites)

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
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 $0.99 \times 10^{-4}$ 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 avoid harmful interference (short & long term).

Any failure has a direct consequence on orbital neighbours.

Any mission has an effect on the long term sustainability:
- \( n \) satellites
- \( m \) launches
- \( t \) years of operations
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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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.
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.

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