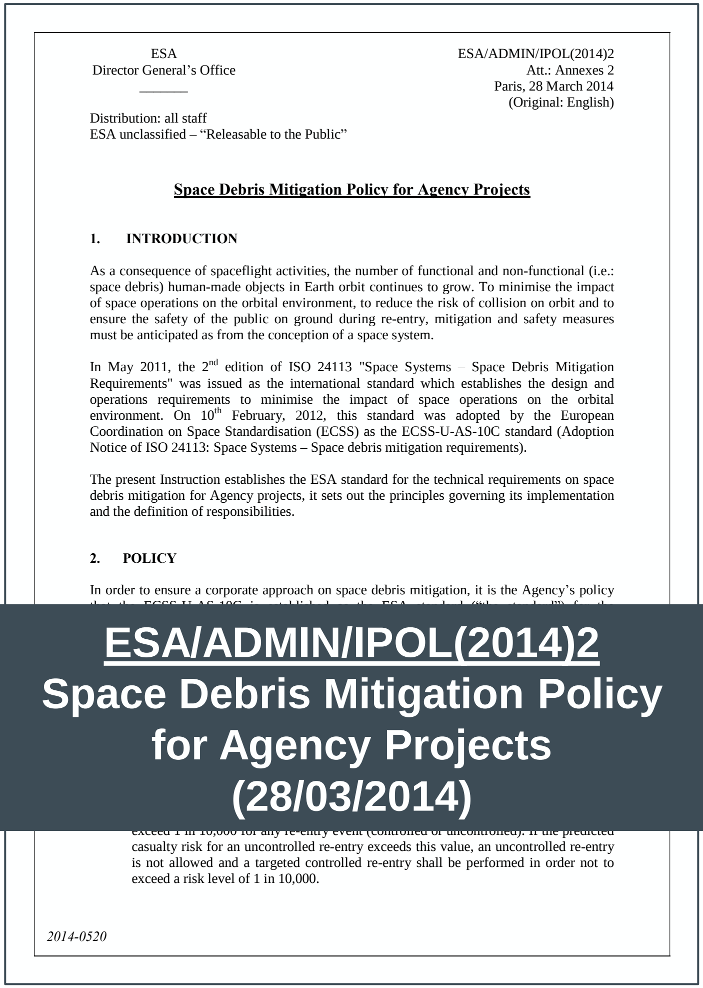
ESA Space Debris Mitigation Standard & Policy

Francesca Letizia

17/10/2023

ESA’s SDM Policy and Requirements – current status



ESA
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ESA/ADMIN/IPOL(2014)2
Att.: Annexes 2
Paris, 28 March 2014
(Original: English)

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Space Debris Mitigation Policy for Agency Projects

1. INTRODUCTION

As a consequence of spaceflight activities, the number of functional and non-functional (i.e.: space debris) human-made objects in Earth orbit continues to grow. To minimise the impact of space operations on the orbital environment, to reduce the risk of collision on orbit and to ensure the safety of the public on ground during re-entry, mitigation and safety measures must be anticipated as from the conception of a space system.

In May 2011, the 2nd edition of ISO 24113 "Space Systems – Space Debris Mitigation Requirements" was issued as the international standard which establishes the design and operations requirements to minimise the impact of space operations on the orbital environment. On 10th February, 2012, this standard was adopted by the European Coordination on Space Standardisation (ECSS) as the ECSS-U-AS-10C 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 principles governing its implementation and the definition of responsibilities.

2. POLICY

In order to ensure a corporate approach on space debris mitigation, it is the Agency’s policy

casualty risk for an uncontrolled re-entry exceeds this value, an uncontrolled re-entry is not allowed and a targeted controlled re-entry shall be performed in order not to exceed a risk level of 1 in 10,000.

2014-0520

ESA/ADMIN/IPOL(2014)2
Space Debris Mitigation Policy for Agency Projects (28/03/2014)

ECSS-U-AS-10C
10 February 2012

EUROPEAN COOPERATION
ECSS
FOR SPACE STANDARDIZATION

Space sustainability

Adoption Notice of ISO 24113: Space systems - Space debris mitigation requirements

ECSS Secretariat
ESA-ESTEC
Requirements & Standards Division
Noordwijk, The Netherlands

ECSS-U-AS-10C – Rev.1
Space sustainability - Adoption Notice of ISO 24113 (12/2019)

Both due for **update** in **2023**

ESA’s SDM Policy

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ESA/ADMIN/IPOL(2014)2
Space Debris Mitigation Policy for Agency Projects (28/03/2014)

2023

Still under preparation

Definition of
- Scope & **applicability**
- **Roles** and **responsibilities** within the Agency

Example:
Space Debris Mitigation Panel
Review in case of
- Mission extensions
- Deviations

ESA’s SDM Requirements

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DOCUMENT

ESA Space Debris Mitigation Requirements

Draft in Review 1

Revision 0
Date of Issue 16/08/2023
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Distribution

European Space Agency
Agence spatiale européenne

ESSB-ST-U-007
ESA Space Debris Mitigation Requirements (2023)

Why an ESA's own standard?

"In ESA we are implementing a policy that by 2030, we have a 'net zero pollution' strategy for objects in space, by consistently and reliably removing them from valuable orbits around Earth immediately after they cease operations.
We need to lead by example here."

Josef Aschbacher
ESA Director General

Lead = own standard where we can **steer** the **process** (content & pace)
Lead ≠ proceed in **isolation**

Intention to flow-back requirements into the ECSS standard in the upcoming years

Process for ESA SDM standard

SDM: Space Debris Mitigation
WG: Working Group

Final Presentation Zero Debris CDF

Operators Workshop

Standard put to vote

October 2022

March 2023

June 2023

August 2023

September 2023

October 2023

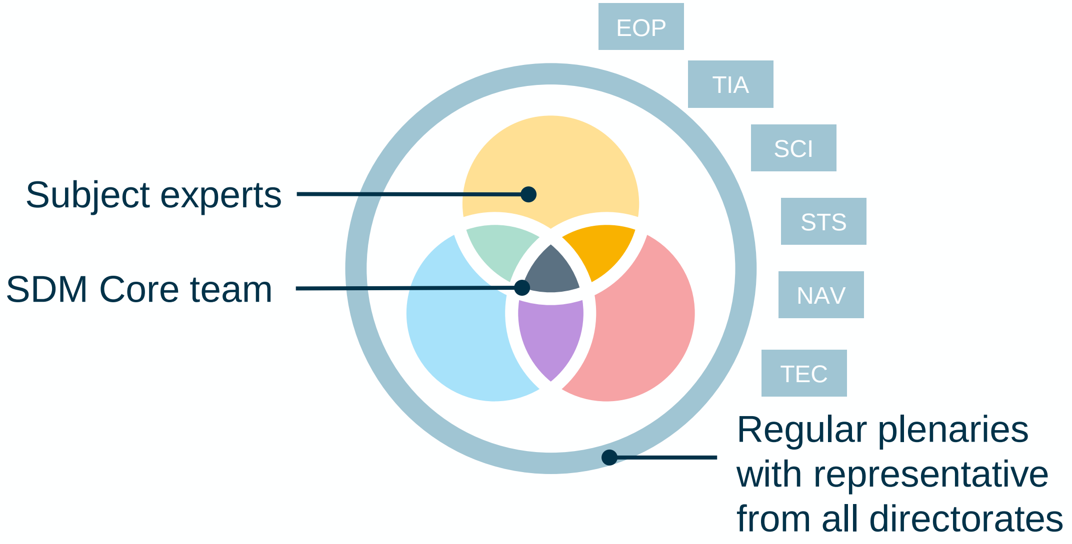
SDM WG Kick-off	WG drafting phase	**Draft standard**	Response to comments	**Final standard**

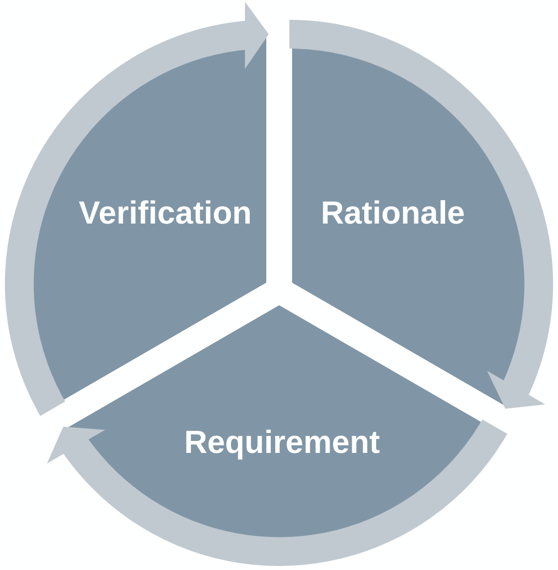
ESA review

ESA personnel not involved in the WG

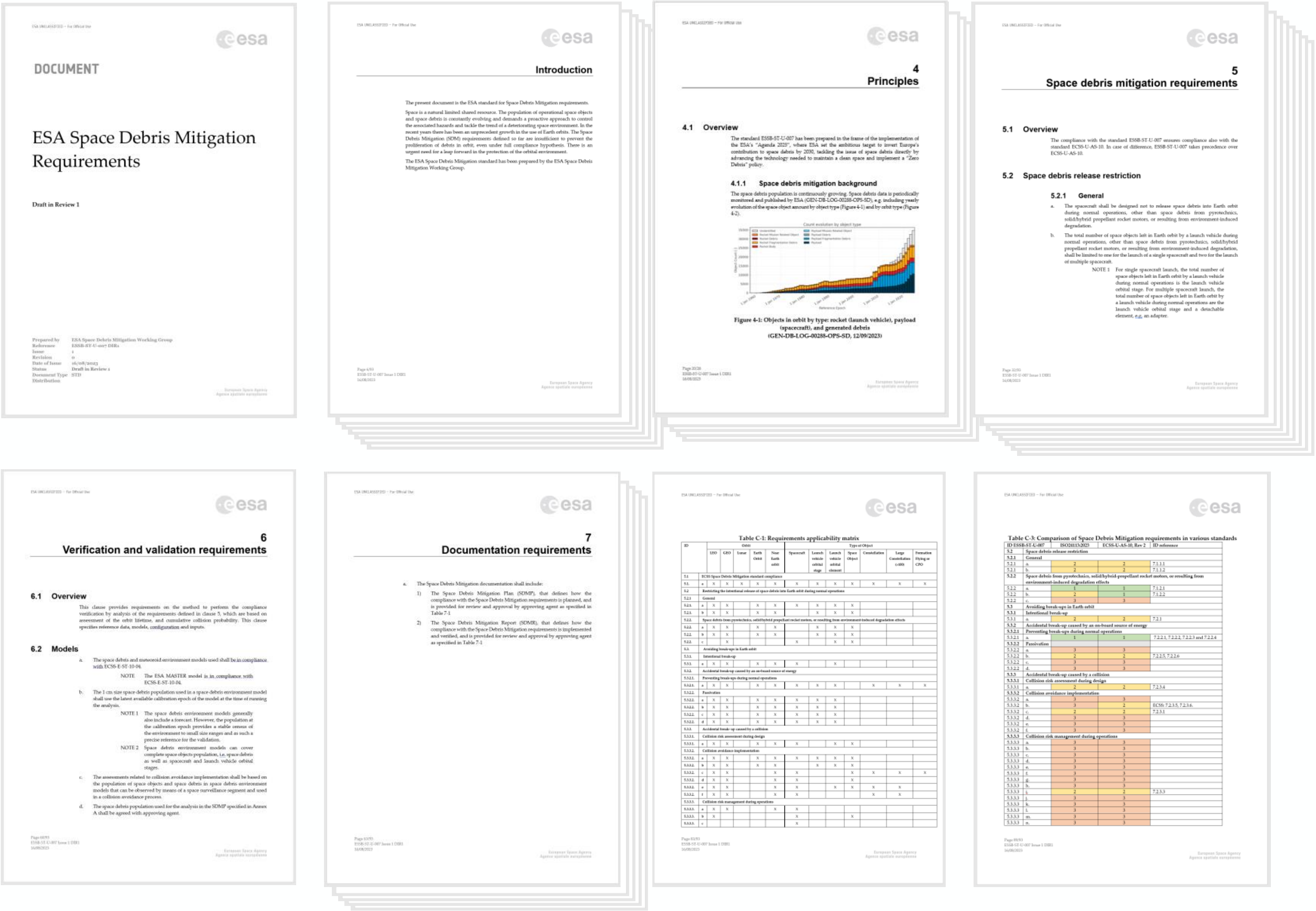
Working group topics & organisation

- Valuable Orbits
- Passivation
- Probability of successful deorbit
- Health Monitoring
- Orbital Clearance
- Collision Risk Assessment
- Collision Risk Minimisation
- Design for Removal
- Re-entry Assessment
- Dark and Quiet Skyes





The Document

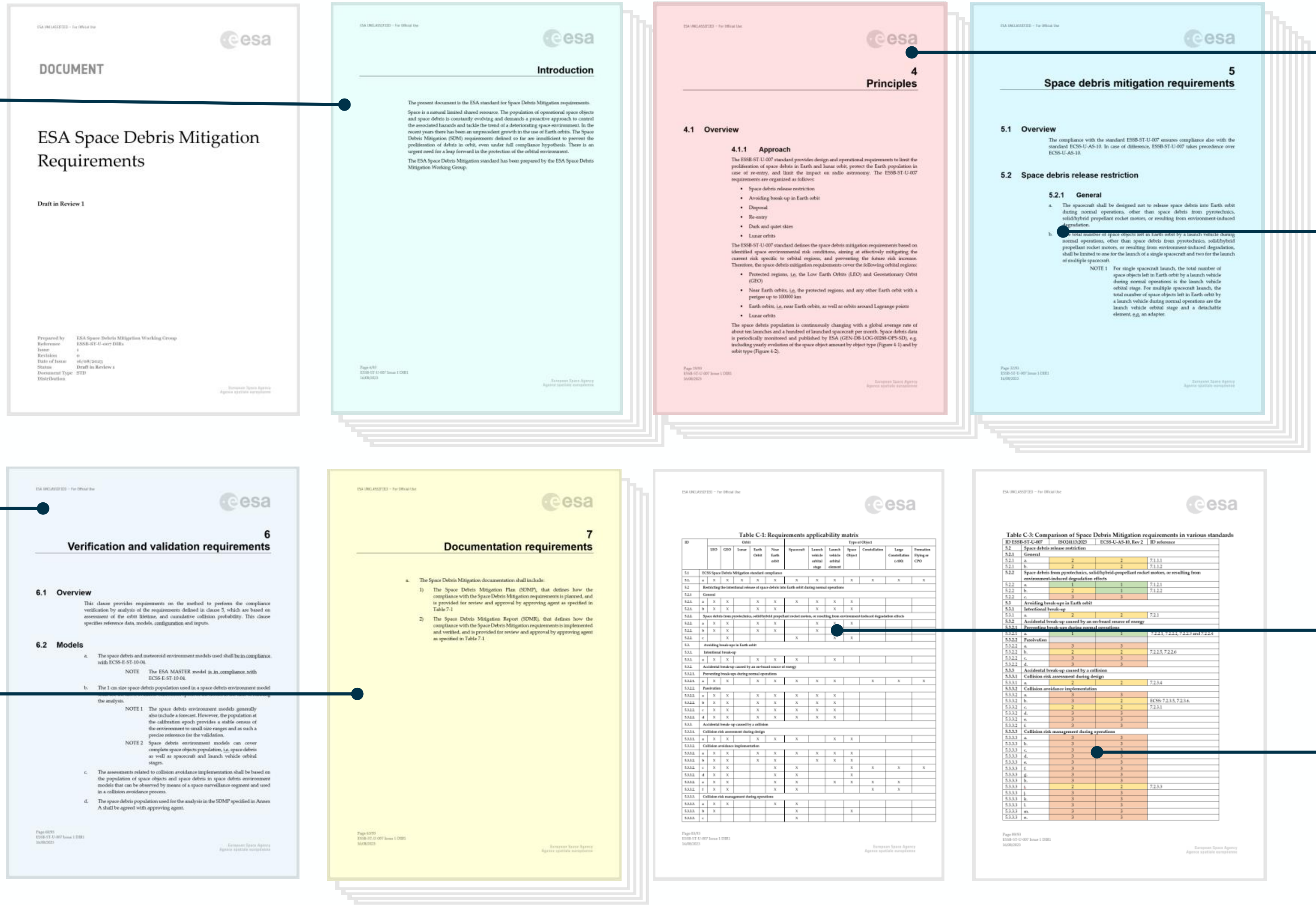


The Document

Frontmatter
Introduction, scope, definitions

Verification & Validation requirements
Indications on key models and data inputs for the required analyses (complementing ESSB-HB-U-002 ESA Space Debris Mitigation Compliance Verification Guidelines)

Documentation requirements
Including expected content for reporting



Principles
Rationale for each requirement

Space Debris Mitigation Requirements
Space debris release, Avoid breakups in Earth orbit, Disposal, Re-entry, Dark and quiet skies, Lunar orbits

Requirement Applicability Matrix
Requirement mapping based on orbital region and object type
Comparison wrt ISO24113:2023 and ECSS-U-AS-10

Requirements

Classical requirements
with specified thresholds/targets

Pyrotechnics shall be designed not to release space debris larger than 1 mm in their largest dimension into Earth orbit.

Intentional break-up of a spacecraft or launch vehicle orbital element shall not be performed.

A spacecraft or launch vehicle orbital stage operating in Earth orbit shall be designed to guarantee a probability of successful passivation through to the end of life of:
1) At least 0,90
2) At least 0,95, when operating in the LEO protected region in an orbit with a natural orbital decay duration longer than 25 years
3) At least 0,95, when operating in the GEO protected region

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Seed requirements
i.e. request of quantification/assessment

During the design, the developer of a spacecraft operating in near Earth orbit with a recurrent manoeuvre capability shall quantify the operational impact during normal operations due to conjunctions.

The developer of a spacecraft or launch vehicle orbital element injected in near Earth orbit shall quantify:

- the expected number of conjunctions at 10^{-4} and 10^{-6} collision probability threshold,
- the estimated number of collision avoidance manoeuvres triggered thereby on other spacecraft

during normal operations and after end of life until re-entry or up to 100 years.

Seed requirements motivations

- Implement lessons learned
- Create awareness on known risks
- Develop quantifiable processes to assess such risks
- Define process towards threshold definition

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Seed requirement - Example

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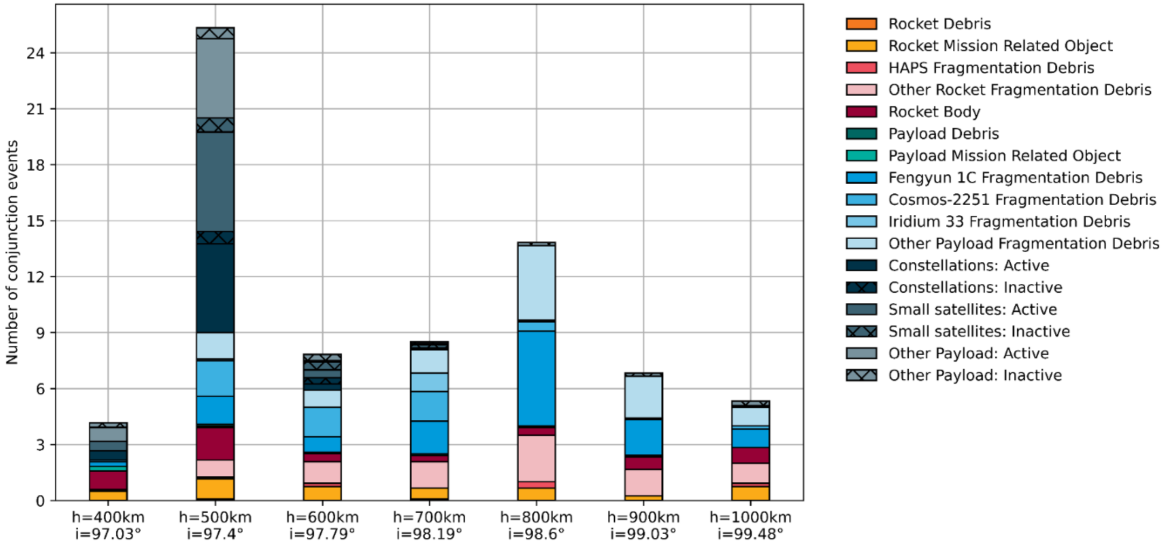
Representative missions in Sun-synchronous orbits vs catalogued objects
Statistics for conjunctions with collision probability above **10^{-6}** over one year (2021)



- Are change of orbits possible to limit the number of conjunctions with other objects?
- Is the space system (space and ground segment) ready to support the expected number of conjunctions?
  e.g. spacecraft design to avoid slew, operational procedures to support conjunction analysis
- In case of conjunctions with active objects, does the mission have the necessary interfaces for coordination?
- …

Approach: orbital regions

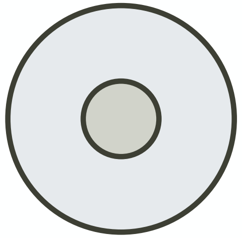
Protected regions (i.e. LEO and GEO)

Near-Earth orbits (perigee < 100000 km)

Earth orbits (including Libration Point Orbits)

Lunar orbits (including Libration Point Orbits)

Evolution from the concept of *valuable orbits* discussed in the Zero Debris CDF (how can we define what's valuable?)
Protection measures for cislunar missions addressed in a dedicated section +
GNSS region addressed in specific requirements (e.g. no disposal into other known constellations)



Approach: risk conditions

LIFETIME

High risk
natural orbital decay duration between 5 and 25 years

Medium risk
natural orbital decay up to 5 years and crossing altitudes above 375 km

Very high risk
natural orbital decay duration longer than 25 years

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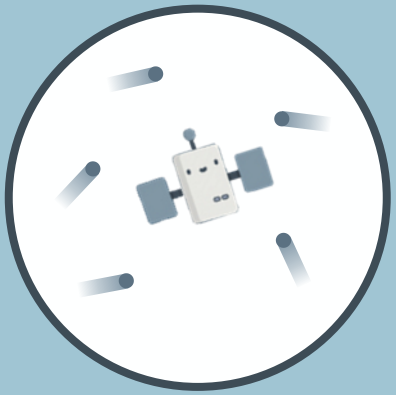
COLLISION PROBABILITY

Collision probability with **space debris** objects larger than **1 cm**



A space object in Earth orbit without capability of performing collision avoidance manoeuvres and with a cumulative collision probability with space objects larger than 1 cm above **1 in 1000** is considered **environmentally hazardous**.

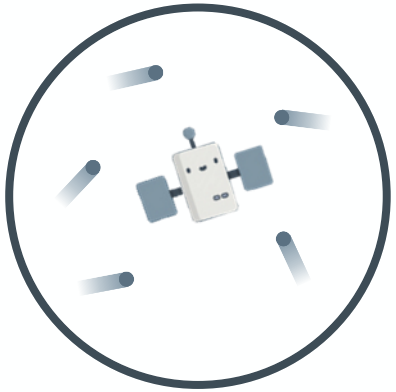
Collision probability criterion

LEO protected region clearance

a. The orbit clearance of a spacecraft or launch vehicle orbital element from the LEO protected region shall satisfy both following conditions:

1) the orbit lifetime is less than 5 years […]
2) the cumulative collision probability from its end of life until re-entry with space objects larger than 1 cm is below 10^{-3}

[…]



How to compute

1. Use **space debris population** only
   - reasonably **calibrated** for 1 cm and above (good above 10 cm, limited validation in GEO for 1 cm)
   - meteorite model (Grün) has a 0.1 – 10 uncertainty
2. Use **calibrated** population (no prediction)
3. Ballistic Limit Equation driven approach (size such that perforation can occur): **1 cm dangerous everywhere**
4. **1/1000** threshold as derived from the **acceptable risk** of not breaking up during the mission

What's new? – some examples

Lunar orbits

+ No MROs
+ Breakup prob. < 1:1000
+ Space traffic coordination
+ Analysis of disposal options

Clearance criteria

+ 5 years in LEO
+ Collision probability threshold
+ Apogee below 375 km for constellations
+ If graveyard, no crossing with known constellations

Probability of successful disposal

+ ≥ 90% considering both internal (reliability) and external (impacts) factors
+ ≥ 95% for large constellations
+ Monitoring and reassessment

Design for removal

+ Preparation for removal for objects at high and very high risk, if cumulative collision probability > 1:1000

COLA & STM

+ Encoding of current best practices (e.g. data sharing)
+ Recurrent manoeuvre capability in GEO, in LEO for high and very high-risk objects, and for constellations
+ Collision probability threshold for action ≤ 1:10000 (single conjunction)

COLA: Collision Avoidance | STM: Space Traffic Management

COLA & STM

Ability to be **unambiguously identified** by a space surveillance segment within **1 day after injection**

Support by space surveillance segment able to provide **daily updated ephemerides** and **on-demand screening**

Use (generation & processing) of orbital produces (ODM, CDM) according to **CCSDS formats**

Operational procedures for the generation and **distribution** of **ephemerides**

Recurrent manoeuvre capability in GEO, in LEO for high and very high-risk objects, and for constellations

Ability to **generate ephemerides** within 1 day after injection

Ability to **perform CAMs** within 2 days after injection

Ability to **plan** a **CAM** if alert received at least 12 hours before TCA

Acceptable collision probability threshold below **10^{-4}** per conjunction.

If a CAM is executed, the probability should be reduced of at least **two order of magnitude**

CAM: Collision Avoidance Manoeuvre | CDM: Conjunction Data Message | ODM: Orbit Data Message | TCA: Time of Close Approach

Next steps

Approval	Training	Update
Finalisation of the internal formal process Plan for the final document to be made publicly available	Development of training material on new ESA's process (internal) Dissemination on expected verification/documentation of new requirements	**2024**: Handbook for verification guidelines **2026**: 2^{nd} update of the SDM Standard **2030**: 3^{rd} update of the SDM Standard

https://technology.esa.int/page/space-debris-mitigation

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