

ESA Space Debris Mitigation Standard & Policy

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ESA
Director General's Office

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

Distribution: all staff
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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).

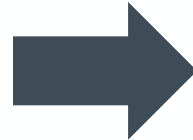
The present Instruction establishes the ESA standard for the technical requirements on space debris mitigation for Agency projects, it sets out the principles governing its implementation and the definition of responsibilities.

2. POLICY

In order to ensure a corporate approach on space debris mitigation, it is the Agency's policy that the ECSS-U-AS-10C is established as the ESA standard ("Standard for the technical requirements on space debris mitigation for Agency projects").

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

2014-0520



2023

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Att.: Annexes 2
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Still under preparation

Space Debris Mitigation Policy for Agency Projects

Definition of

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

Example:
Space Debris Mitigation Panel Review in case of

- **Mission extensions**
- **Deviations**

2014-0520

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

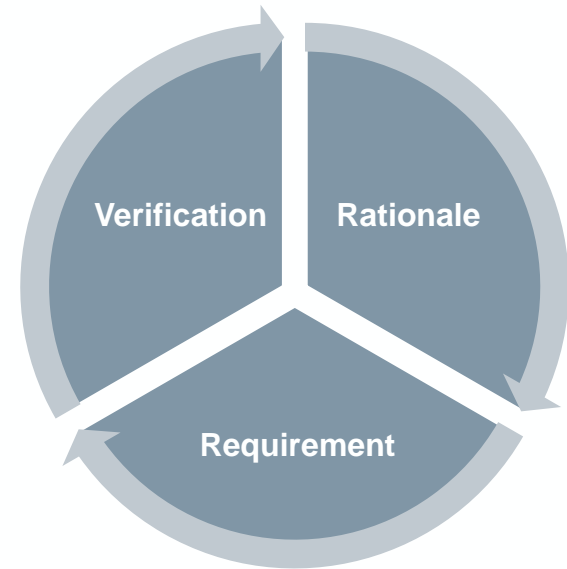
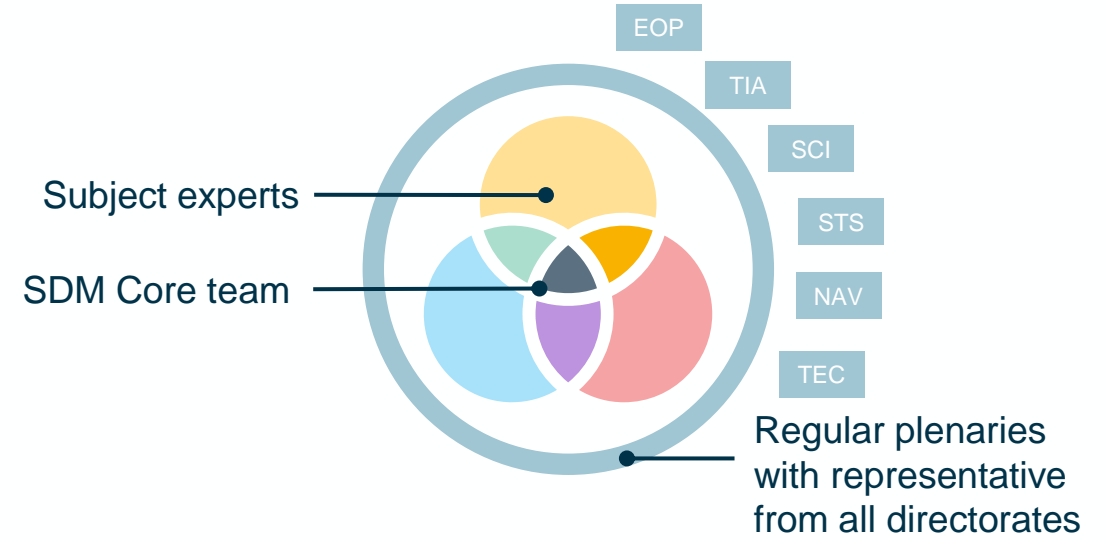


ESA personnel
not involved in
the WG



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



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DOCUMENT

ESA Space Debris Mitigation Requirements

Draft in Review 1

Prepared by: ESA Space Debris Mitigation Working Group
Reference: ESDB-S3-0-user-0004
Issue: 1
Revision: 1
Date of Issue: 01/07/2023
Status: Draft in Review 1
Document Type: WP1
History: See Annex 1
Version: 1.0

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Introduction

The present document is the ESA standard for Space Debris Mitigation requirements. Space is a natural limited shared resource. The population of operational space objects and space debris is constantly evolving and demands a proactive approach to control the associated hazards and reduce the level of a deteriorating space environment. In the recent years there has been an unprecedented growth in the use of Earth orbits. The Space Debris Mitigation (SDM) requirements defined in this document are intended to prevent the proliferation of debris in orbit, even under the compliance hypothesis. There is an urgent need for a long-term plan for the protection of the orbital environment. The ESA Space Debris Mitigation standard has been prepared by the ESA Space Debris Mitigation Working Group.

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Principles

4.1 Overview

The standard ESDB-S3-0-007 has been prepared in the frame of the implementation of the ESA's "Agenda 2027", where ESA set the ambitious target to limit Europe's contribution to space debris by 2030, halting the issue of space debris directly by advancing the technology needed to maintain a clean space and implement a "Zero Debris" policy.

4.1.1 Space debris mitigation background

The space debris population is continuously growing. Space debris data is periodically assessed and published by ESA (ESDB-LOG-0028-OPS-SD), e.g. including newly estimated of the space object amount by object type (Figure 4-1) and by orbit type (Figure 4-2).

Figure 4-1: Objects in orbit by type: rocket (launch vehicle), payload (spacecraft), and generated debris (ESDB-LOG-0028-OPS-SD, 12/09/2023)

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Space debris mitigation requirements

5.1 Overview

The compliance with the standard ESDB-S3-0-007 means compliance also with the standard ESDB-AS-10. In case of difference, ESDB-S3-0-007 takes precedence over ESDB-AS-10.

5.2 Space debris release restriction

5.2.1 General

The spacecraft shall be designed not to release space debris into Earth orbit during normal operations, other than space debris from pyrotechnic, solid/hybrid propellant rocket motors, or resulting from environment-induced degradation.

The total number of space objects left in Earth orbit by a launch vehicle during normal operations, other than space debris from pyrotechnic, solid/hybrid propellant rocket motors, or resulting from environment-induced degradation, shall be limited to one for the launch of a single spacecraft and two for the launch of multiple spacecraft.

NOTE 1: For single spacecraft launch, the total number of space objects left in Earth orbit by a launch vehicle during normal operations is the launch vehicle orbital stage. For multiple spacecraft launch, the total number of space objects left in Earth orbit by a launch vehicle during normal operations are the launch vehicle orbital stage and a detachable element, e.g. an adapter.

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Verification and validation requirements

6.1 Overview

This clause provides requirements on the method to perform the compliance verification by analysis of the requirements defined in clause 5, which are based on assessment of the orbit lifetime and cumulative collision probability. This clause specifies reference data, models, configurations and inputs.

6.2 Models

The space debris and environment models used shall be in compliance with ESDB-E-SE-1016.

NOTE: The ESA MASTER model is in compliance with ESDB-E-SE-1016.

The con-con space debris population used in space debris environment model shall use the latest available collection epoch of the model at the time of running the analysis.

NOTE 1: The space debris environment models generally also include a forecast. However, the population of the collection epoch provides a stable source of the environment to small size regions and as such a precise reference for the validation.

NOTE 2: Space debris environment models can cover complete space object populations, or space debris, as well as spacecraft and launch vehicle orbital stage.

The assessments related to collision avoidance implementation shall be based on the population of space objects and space debris in space debris environment models that can be observed by sensors of a space surveillance system and used in a collision avoidance process.

The space debris population used for the analysis in the SDMP specified in Annex A shall be agreed with approving agent.

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Documentation requirements

The Space Debris Mitigation documentation shall include:

- The Space Debris Mitigation Plan (SDMP), that defines how the compliance with the Space Debris Mitigation requirements is planned, and is provided for review and approval by approving agent as specified in Table 7-1.
- The Space Debris Mitigation Report (SDMR), that defines how the compliance with the Space Debris Mitigation requirements is implemented and verified, and is provided for review and approval by approving agent as specified in Table 7-1.

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Table C-1: Requirements applicability matrix

ID	REQ	SDMP	SDMR	SDMP	SDMR	SDMP	SDMR	SDMP	SDMR	SDMP	SDMR	SDMP	SDMR	SDMP	SDMR	SDMP	SDMR	SDMP	SDMR										
51	SDMP	X																											
52	SDMR		X																										
53	General			X																									
54	Space debris from pyrotechnic, solid/hybrid propellant rocket motors, or resulting from environment-induced degradation stress				X																								
55	Orbiting fragments in Earth orbit					X																							
56	Interorbit fragmentation						X																						
57	Accidental break-up caused by an in-orbit source of energy							X																					
58	Preceding break-up during normal operations								X																				
59	Accidental break-up caused by a collision									X																			
60	Collision risk assessment during design										X																		
61	Collision risk assessment during operations											X																	
62	Collision avoidance implementation												X																
63	Collision avoidance implementation													X															
64	Collision avoidance implementation														X														
65	Collision avoidance implementation															X													
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Table C-3: Comparison of Space Debris Mitigation requirements in various standards

REQ	ESDB-S3-0-007	ESDB-AS-10 Rev 2	IB reference
51	General	2	7.1.1.1
52	Space debris from pyrotechnic, solid/hybrid propellant rocket motors, or resulting from environment-induced degradation stress	2	7.1.1.2
53	Orbiting fragments in Earth orbit	2	7.1.1.3
54	Interorbit fragmentation	2	7.1.1.4
55	Accidental break-up caused by an in-orbit source of energy	2	7.1.1.5
56	Preceding break-up during normal operations	2	7.1.1.6
57	Accidental break-up caused by a collision	2	7.1.1.7
58	Collision risk assessment during design	2	7.1.1.8
59	Collision risk assessment during operations	2	7.1.1.9
60	Collision avoidance implementation	2	7.1.1.10
61	Collision avoidance implementation	2	7.1.1.11
62	Collision avoidance implementation	2	7.1.1.12
63	Collision avoidance implementation	2	7.1.1.13
64	Collision avoidance implementation	2	7.1.1.14
65	Collision avoidance implementation	2	7.1.1.15
66	Collision avoidance implementation	2	7.1.1.16
67	Collision avoidance implementation	2	7.1.1.17
68	Collision avoidance implementation	2	7.1.1.18
69	Collision avoidance implementation	2	7.1.1.19
70	Collision avoidance implementation	2	7.1.1.20
71	Collision avoidance implementation	2	7.1.1.21
72	Collision avoidance implementation	2	7.1.1.22
73	Collision avoidance implementation	2	7.1.1.23
74	Collision avoidance implementation	2	7.1.1.24
75	Collision avoidance implementation	2	7.1.1.25
76	Collision avoidance implementation	2	7.1.1.26
77	Collision avoidance implementation	2	7.1.1.27
78	Collision avoidance implementation	2	7.1.1.28
79	Collision avoidance implementation	2	7.1.1.29
80	Collision avoidance implementation	2	7.1.1.30
81	Collision avoidance implementation	2	7.1.1.31
82	Collision avoidance implementation	2	7.1.1.32
83	Collision avoidance implementation	2	7.1.1.33
84	Collision avoidance implementation	2	7.1.1.34
85	Collision avoidance implementation	2	7.1.1.35
86	Collision avoidance implementation	2	7.1.1.36
87	Collision avoidance implementation	2	7.1.1.37
88	Collision avoidance implementation	2	7.1.1.38
89	Collision avoidance implementation	2	7.1.1.39
90	Collision avoidance implementation	2	7.1.1.40
91	Collision avoidance implementation	2	7.1.1.41
92	Collision avoidance implementation	2	7.1.1.42
93	Collision avoidance implementation	2	7.1.1.43
94	Collision avoidance implementation	2	7.1.1.44
95	Collision avoidance implementation	2	7.1.1.45
96	Collision avoidance implementation	2	7.1.1.46
97	Collision avoidance implementation	2	7.1.1.47
98	Collision avoidance implementation	2	7.1.1.48
99	Collision avoidance implementation	2	7.1.1.49
100	Collision avoidance implementation	2	7.1.1.50

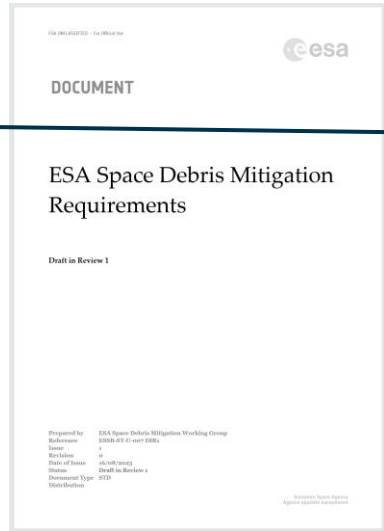
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The Document



Frontmatter
Introduction, scope, definitions



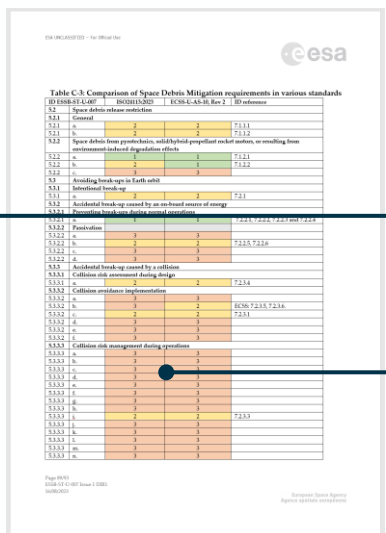
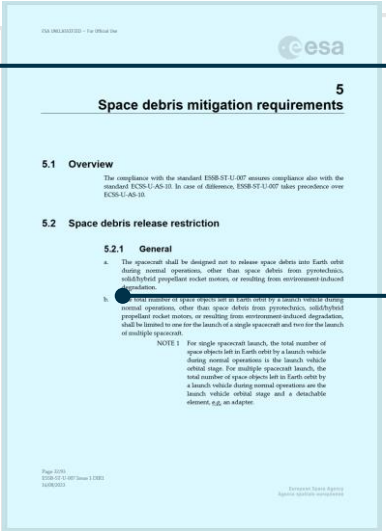
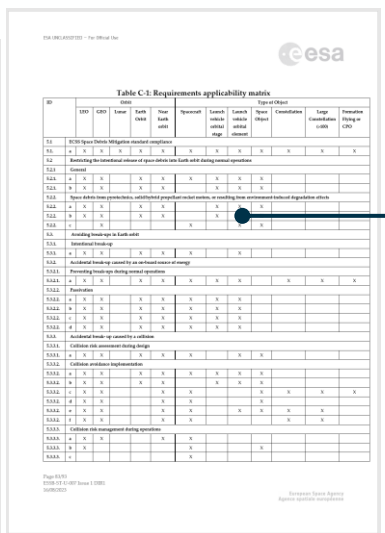
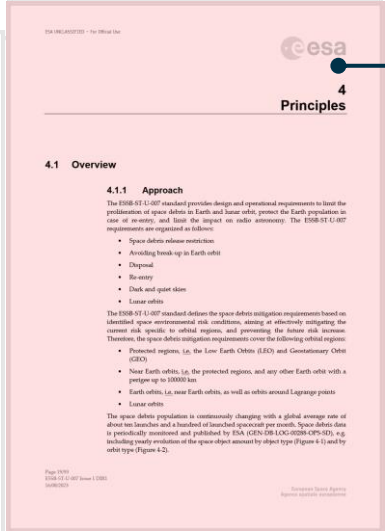
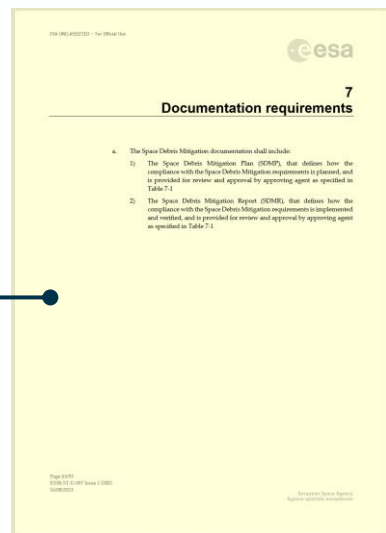
Verification & Validation requirements

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





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



Classical requirements with specified thresholds/targets

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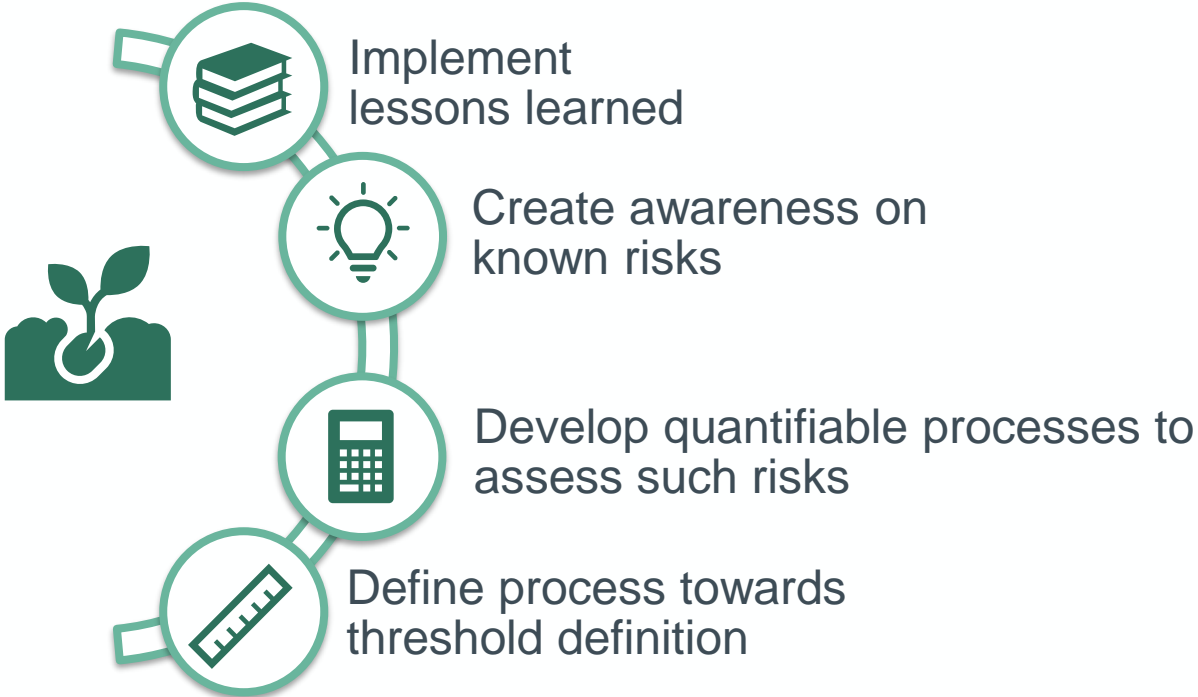
Seed requirements i.e. request of quantification/assessment

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.

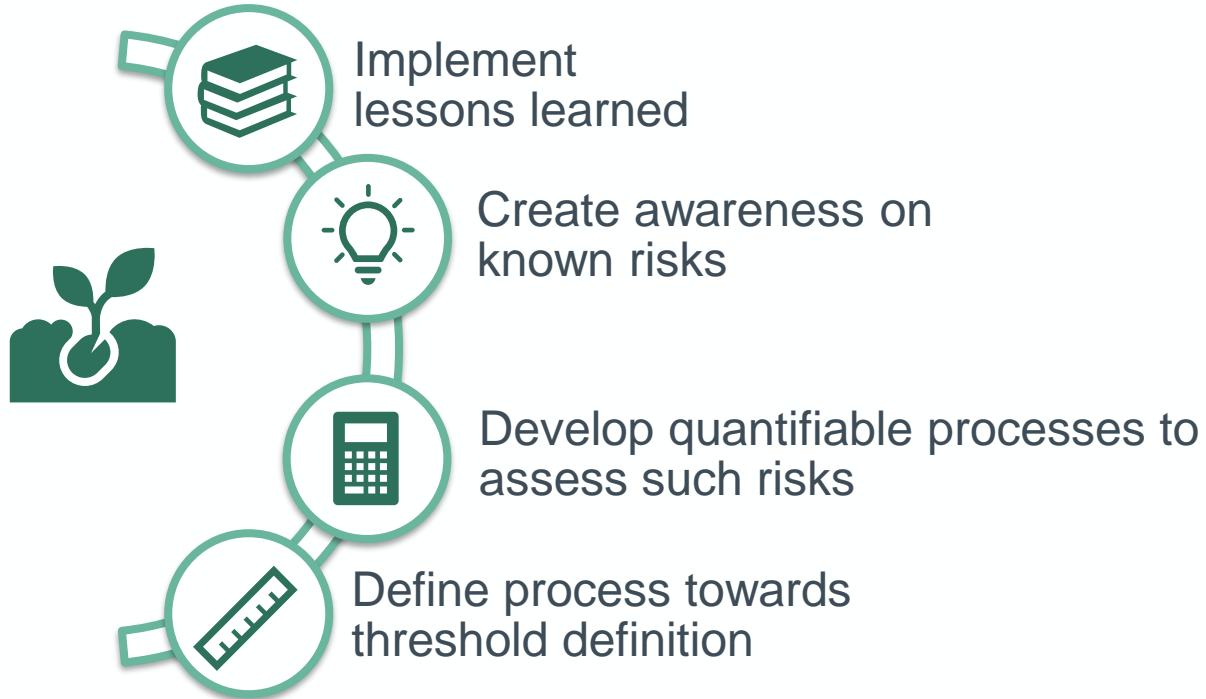
The developer of a spacecraft or launch vehicle orbital element injected in near Earth orbit shall quantify:

- 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



Seed requirements motivations



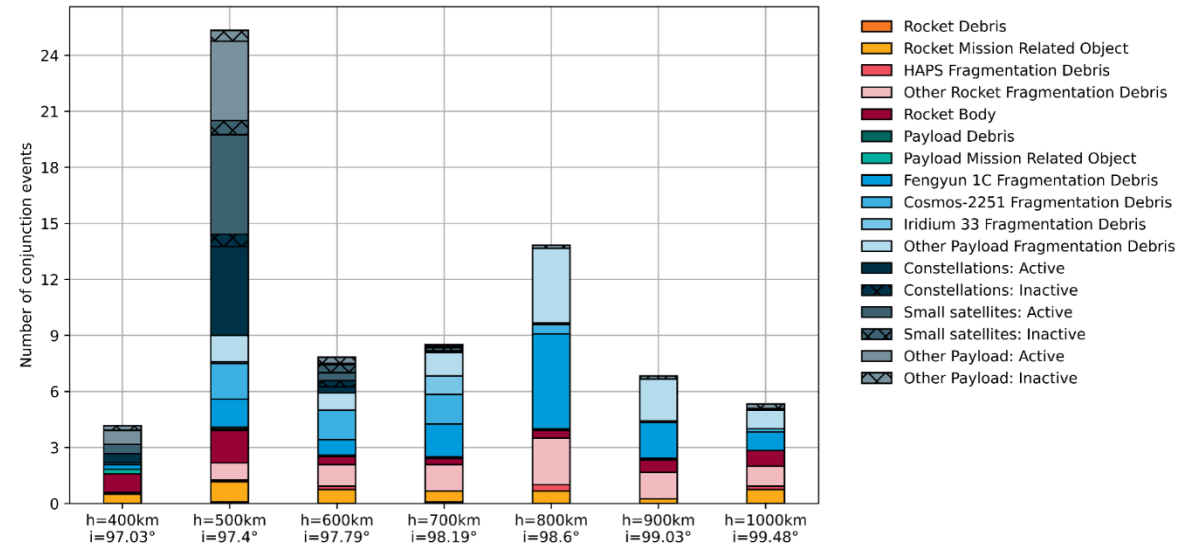
Seed requirement - Example

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.

- 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?
- ...

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



Approach: orbital regions

Protected regions (i.e. LEO and GEO)

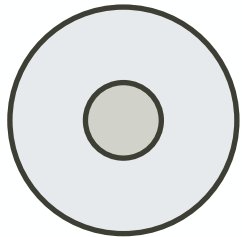
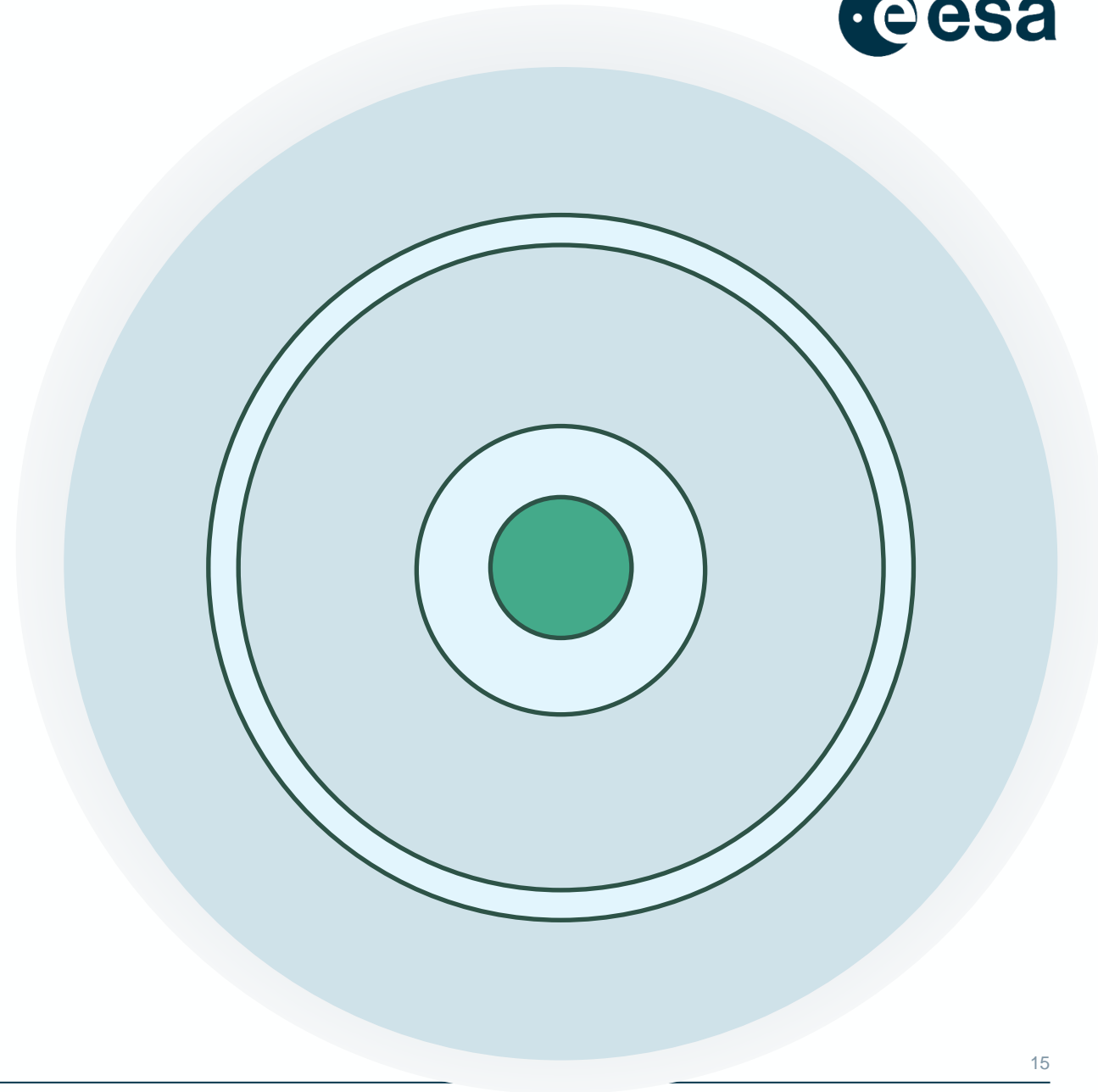
Near-Earth orbits (perigee < 100000 km)

Earth orbits (including Libration Point Orbits)

Lunar orbits (including Libration Point Orbits)

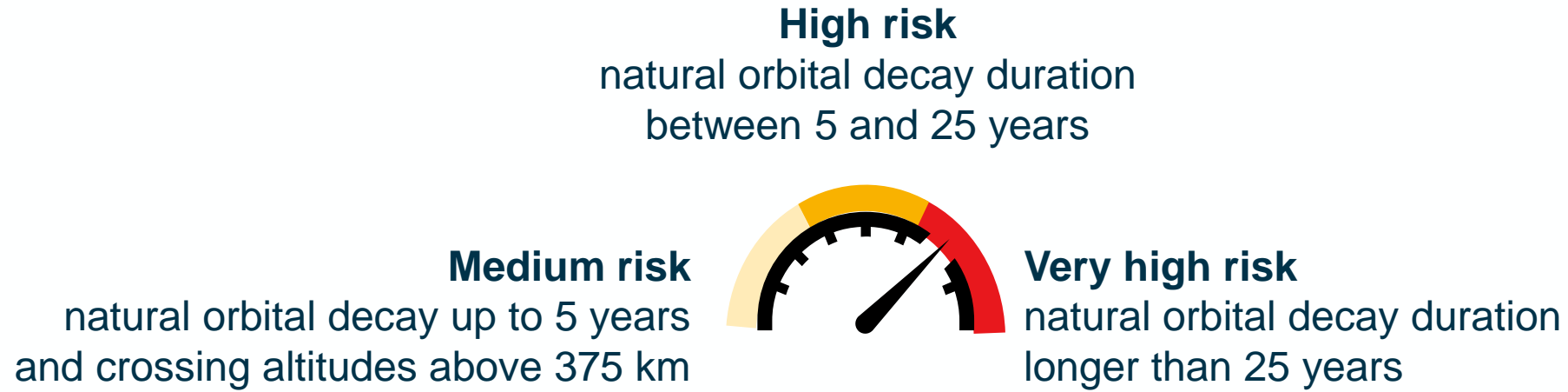
Evolution from the concept of *valuable orbits* discussed in the Zero Debris CDF (how can we define what's valuable?)

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



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

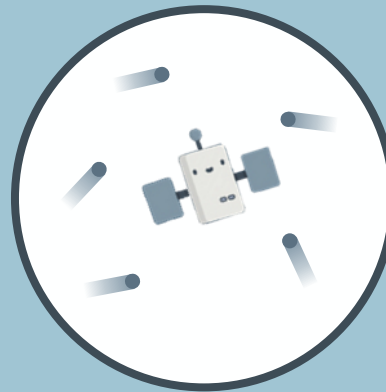


Very high risk

natural orbital decay duration
longer than 25 years

COLLISION PROBABILITY

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



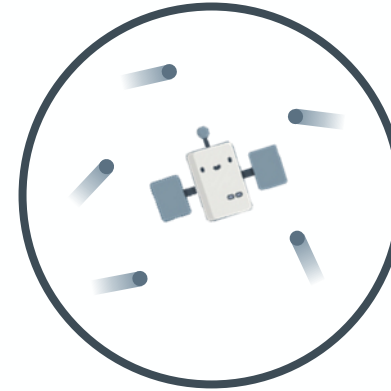
A space object in Earth orbit
without capability of performing
collision avoidance manoeuvres
and with a cumulative collision
probability with space objects
larger than 1 cm above **1 in 1000** is
considered **environmentally
hazardous**.

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}

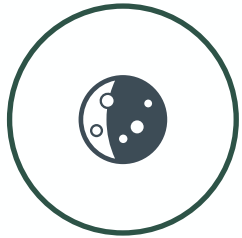
[...]



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



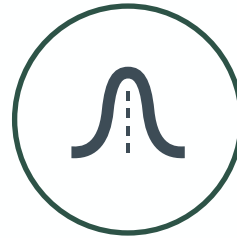
Lunar orbits

- + 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

- + $\geq 90\%$ considering both internal (reliability) and external (impacts) factors
- + $\geq 95\%$ 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 $\leq 1:10000$ (single conjunction)



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

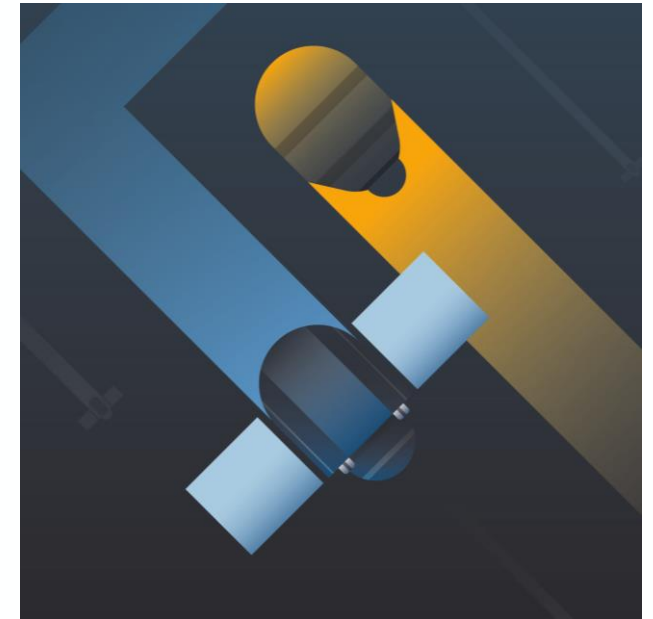
Ability to **generate ephemerides** within 1 day after injection

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

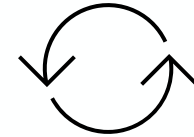
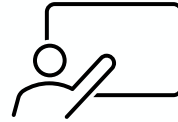
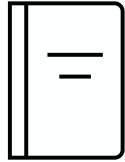
Ability to **plan a CAM** if alert received at least 12 hours before TCA

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**



Next steps



Approval

Finalisation of the internal formal process

Plan for the final document to be made publicly available

Training

Development of training material on new ESA's process (internal)

Dissemination on expected verification/documentation of new requirements

Update

2024: Handbook for verification guidelines
2026: 2nd update of the SDM Standard
2030: 3rd update of the SDM Standard



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

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Space Debris Mitigation and Re-entry Safety Engineer

Independent Safety Office (TEC-QI)

Product Assurance and Safety Department (TEC-Q)

Directorate of Technology, Engineering and Quality (TEC)

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