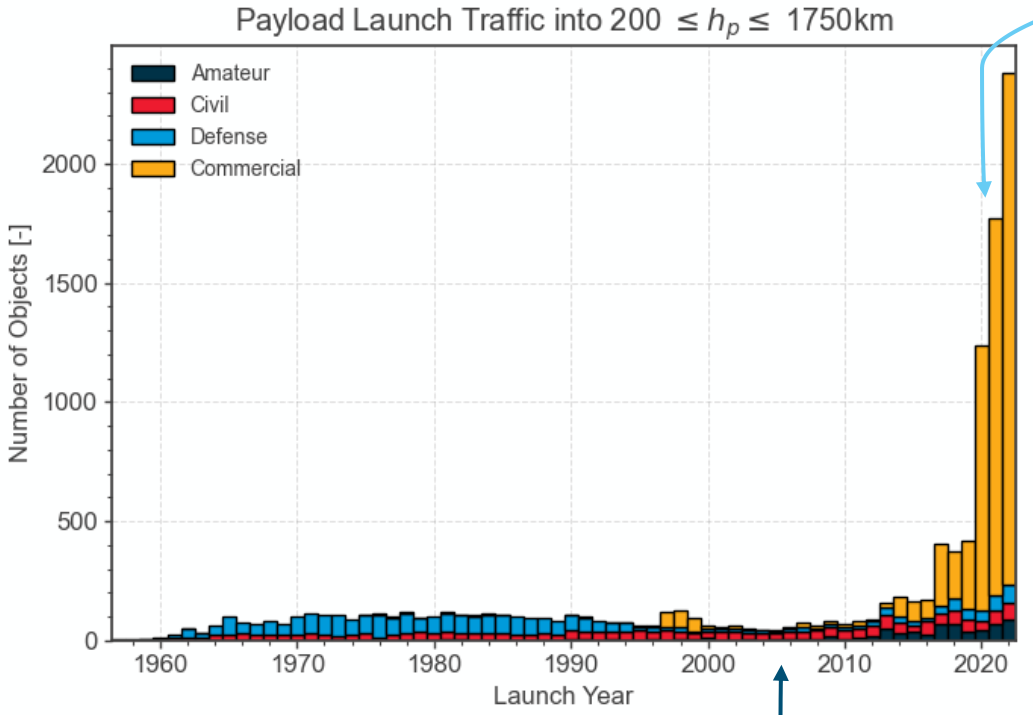
# ESA's Zero Debris Approach: Policy and Requirements

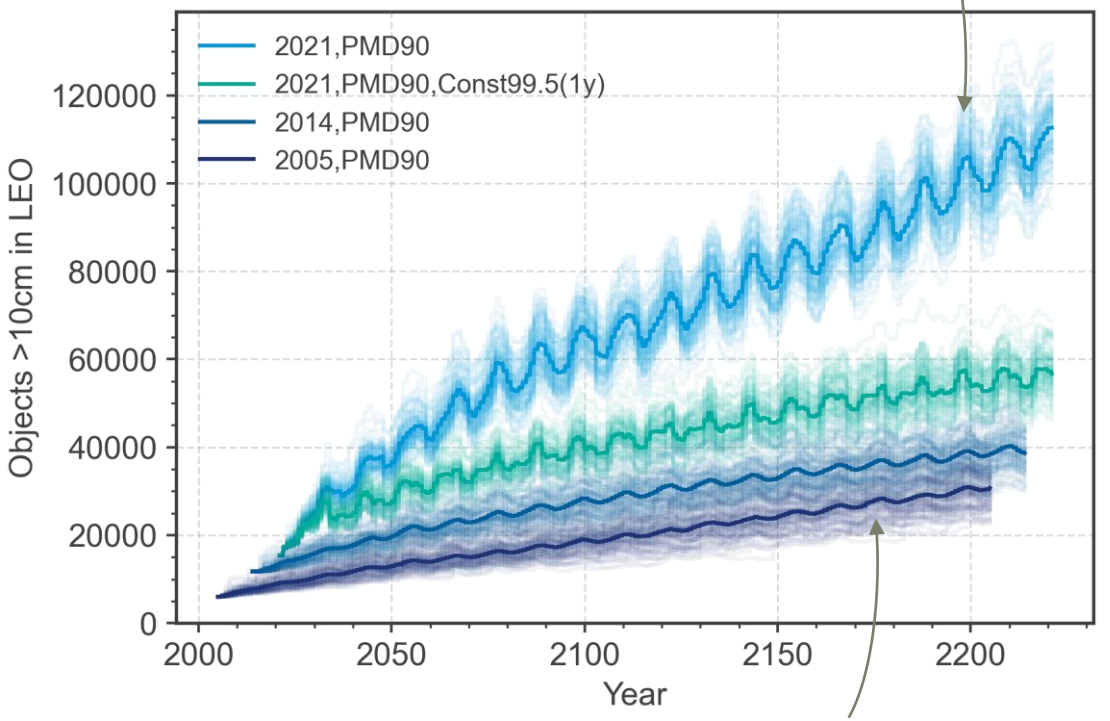
Paloma Villar

24/06/2024

# Why do we need a new approach to mitigation?




What PMD90(25y) means now:
is this acceptable?




What PMD90(25y) meant when
IADC drafted their recommendation

$h_p$: perigee altitude | PMD: Post-Mission Disposal

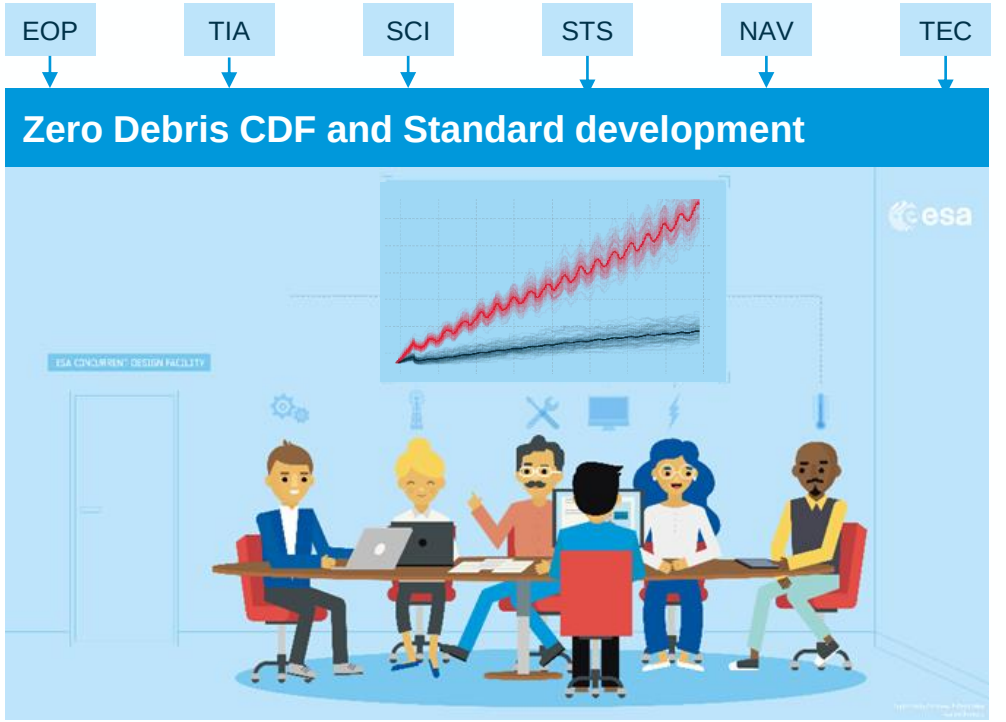
# Zero Debris Approach development

> *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

**Policy update recommendations** considering environmental needs and impact on future missions, informed by an extensive **simulation campaign**

**Roadmap** for technical developments & standards, providing an estimation of the **resources** needed and a **phase-in schedule**



# Zero Debris Scope

Developing ESA Zero Debris approach

Engaging partners, building a community

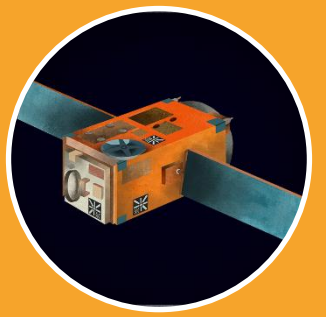
## ESA SDM Policy & Standard

Technical requirements for ESA missions and contributions

## ESA Technical Developments

ESA support to industry's transition and compliance to SDM standards

## Zero Debris Technology Booklet



Crowd-sourced technical solutions to reach Zero Debris targets by 2030

## Zero Debris Charter

Jointly defined principles and targets for long term space sustainability

# ESA Space Debris Mitigation Regulation status

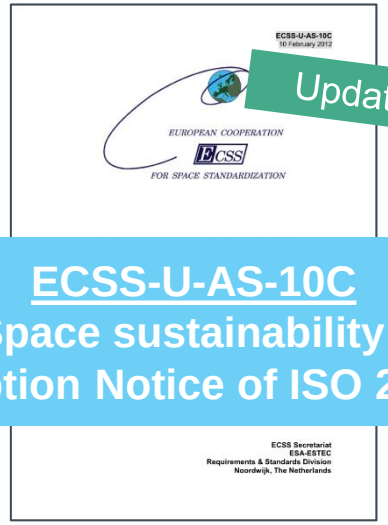

Updated in 2023

**ESA/ADMIN/IPOL(2023)1**
**ESA Space Debris Mitigation Policy**


Born in 2023

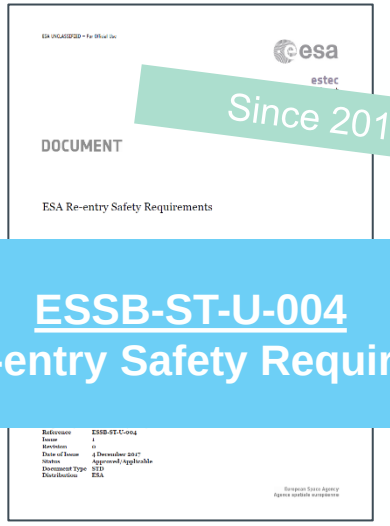
**ESSB-ST-U-007**
**ESA Space Debris Mitigation Requirements**

- Policy
- Standard
- Handbook



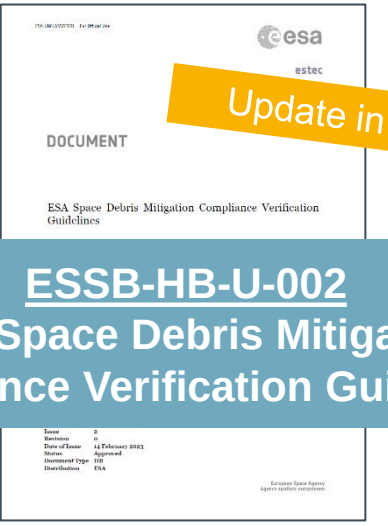

Updated in 2024

**ECSS-U-AS-10C**
**Space sustainability - Adoption Notice of ISO 24113**




Since 2017

**ESSB-ST-U-004**
**ESA Re-entry Safety Requirements**

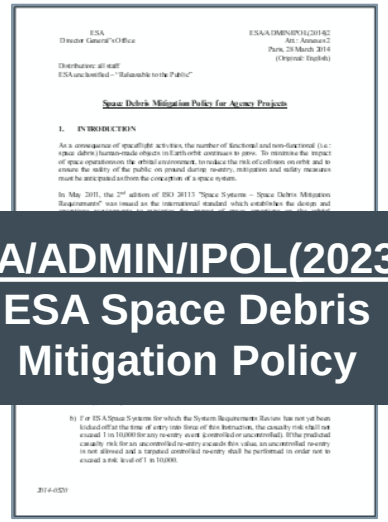



Update in 2024

**ESSB-HB-U-002**
**ESA Space Debris Mitigation Compliance Verification Guidelines**

# ESA’s Space Debris Mitigation Policy

Who?



**ESA/ADMIN/IPOL(2023)1**
**ESA Space Debris Mitigation Policy**

Definition of the perimeter of applicability

ESA space systems, operations under ESA’s responsibility, contribution to international activities, procurement of launch services

Applicable to all missions regardless of their phase

Introduction of the Space Debris Mitigation Assessment Board

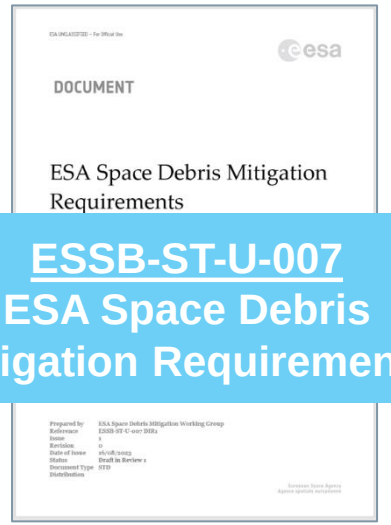
It provides recommendations in case of Mission Extension Reviews, anomalies affecting space debris mitigation measures, and requests for deviations/waivers

https://technology.esa.int/upload/media/ESA-ADMIN-IPOL-2023-1-Space-Debris-Mitigation-Policy-Final.pdf

# ESA's Space Debris Mitigation Requirements

What's new

What?




**ESSB-ST-U-007**
**ESA Space Debris Mitigation Requirements**

## 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

## 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

## Design for removal

+ Preparation for removal for high-risk objects in the protected regions

https://technology.esa.int/upload/media/ESA-Space-Debris-Mitigation-Requirements-ESSB-ST-U-007-Issue1.pdf

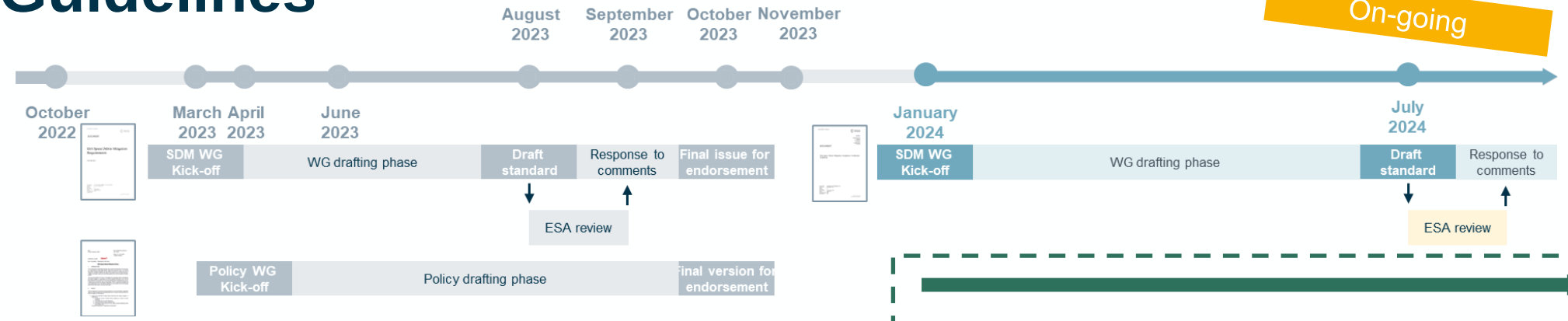
COLA: Collision Avoidance | STM: Space Traffic Management

# ESA's Space Debris Mitigation Compliance Verification Guidelines

On-going

How?


**ESSB-HB-U-002**
**ESA Space Debris Mitigation Compliance Verification Guidelines**




- Guidelines on suitable methodologies for verification
- Indication of what's expected at the different mission phases
- Revision of ESA's available tool for compliance analysis
- Update/coordination of/with related documents

drama

- Update & planned releases to support analyses

ESA's Space Debris Mitigation Toolkit

Design-for-Demise,
Close Proximity Operations

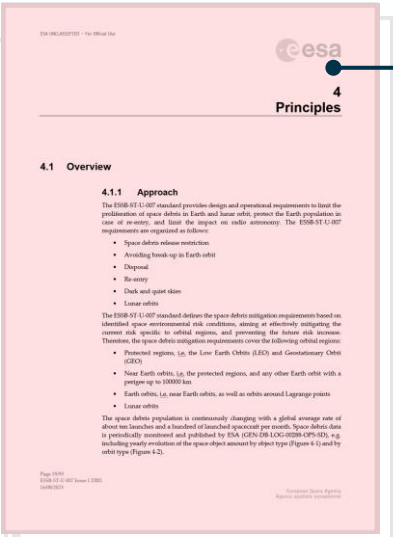
# The Document

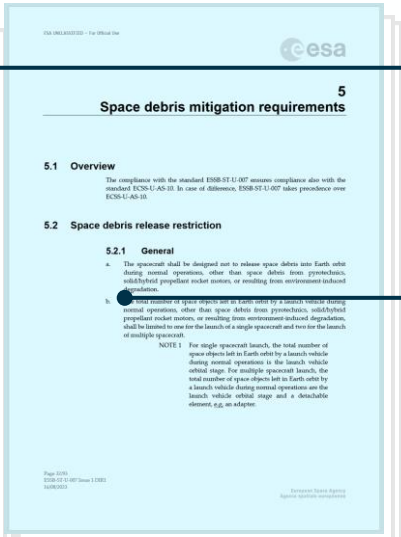
**Frontmatter**
Introduction, scope, definitions

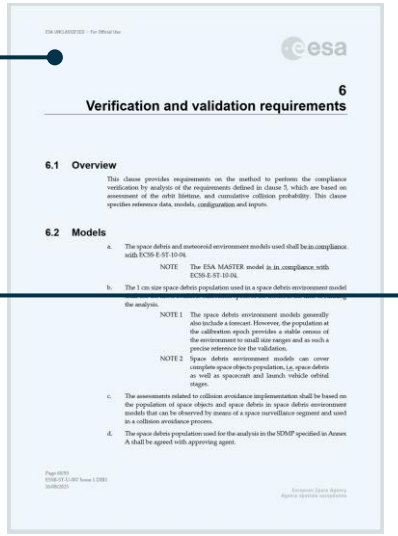
**Verification & Validation requirements**
Indications on key models and data inputs for the required analyses (complementing ESSB-HB-U-002 ESA Space Debris Mitigation Compliance Verification Guidelines)

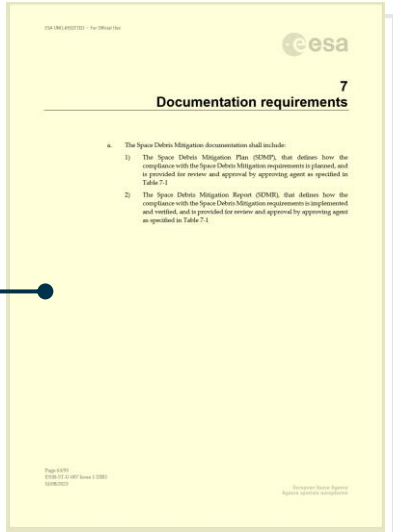
**Documentation requirements**
Including expected content for reporting

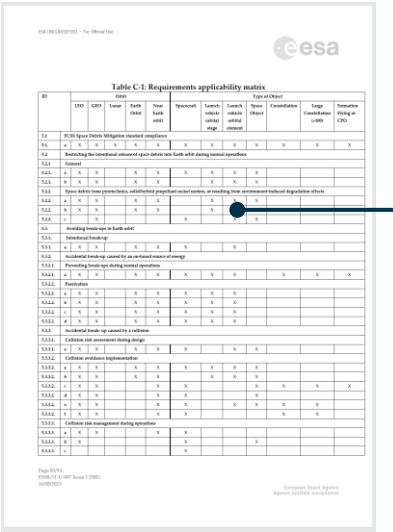


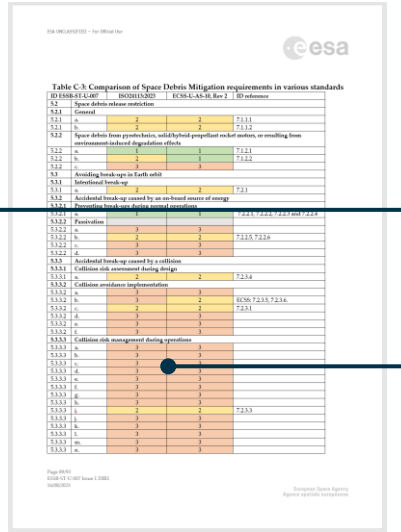



**Principles**
Rationale for each requirement

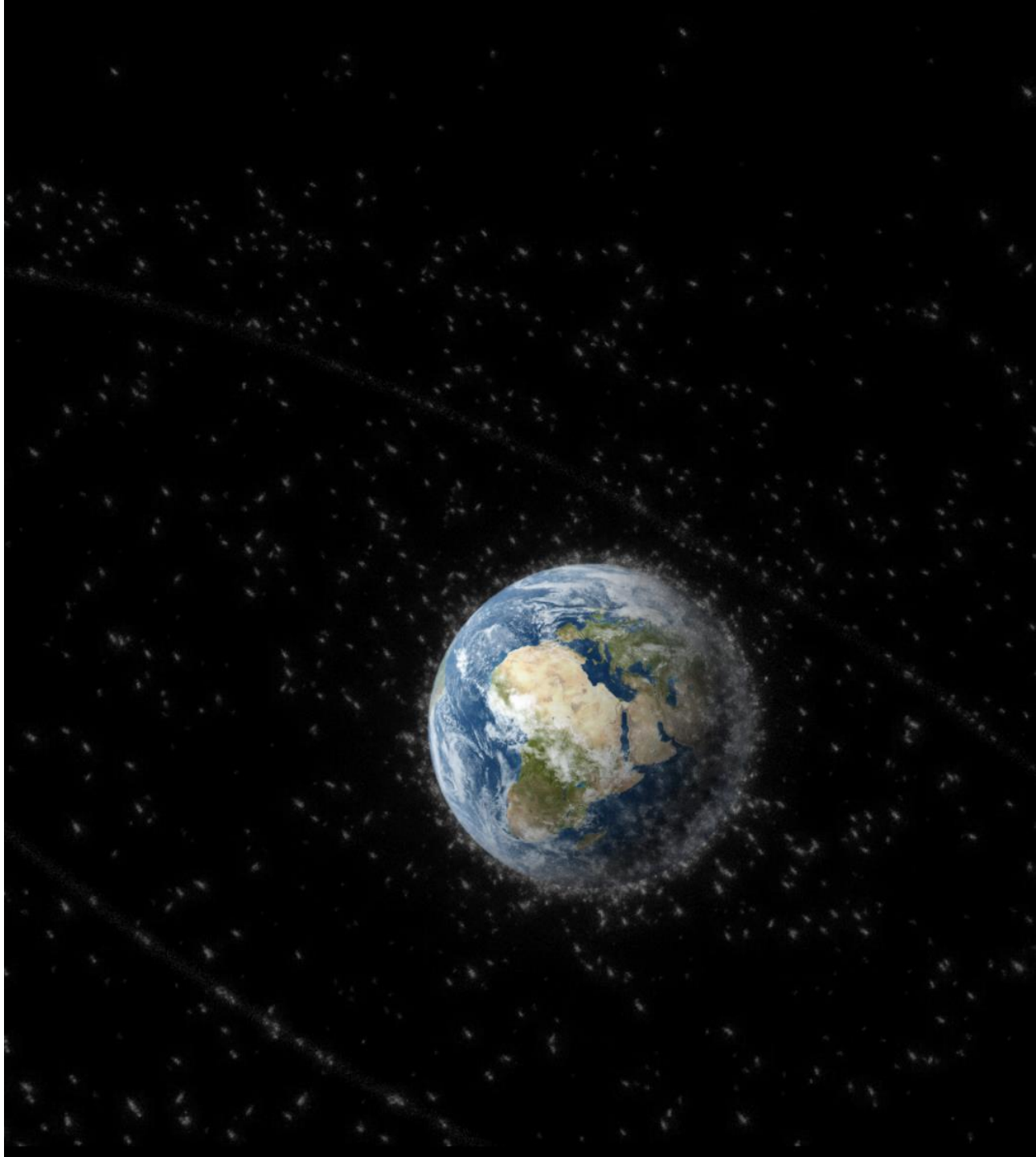
**Space Debris Mitigation Requirements**
Space debris release, Avoid breakups in Earth orbit, Disposal, Re-entry, Dark and quiet skies, Lunar orbits

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

# SPACE DEBRIS MITIGATION REQUIREMENTS

a bit more in detail

BACK UP SLIDES



# 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

**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.

# ESSB-ST-U-007 rationale

LIFETIME

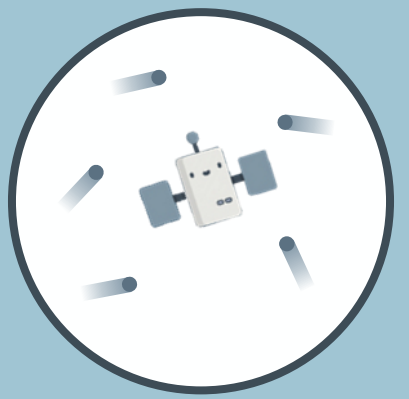
**High risk**
natural orbital decay duration
between 5 and 25 years

**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

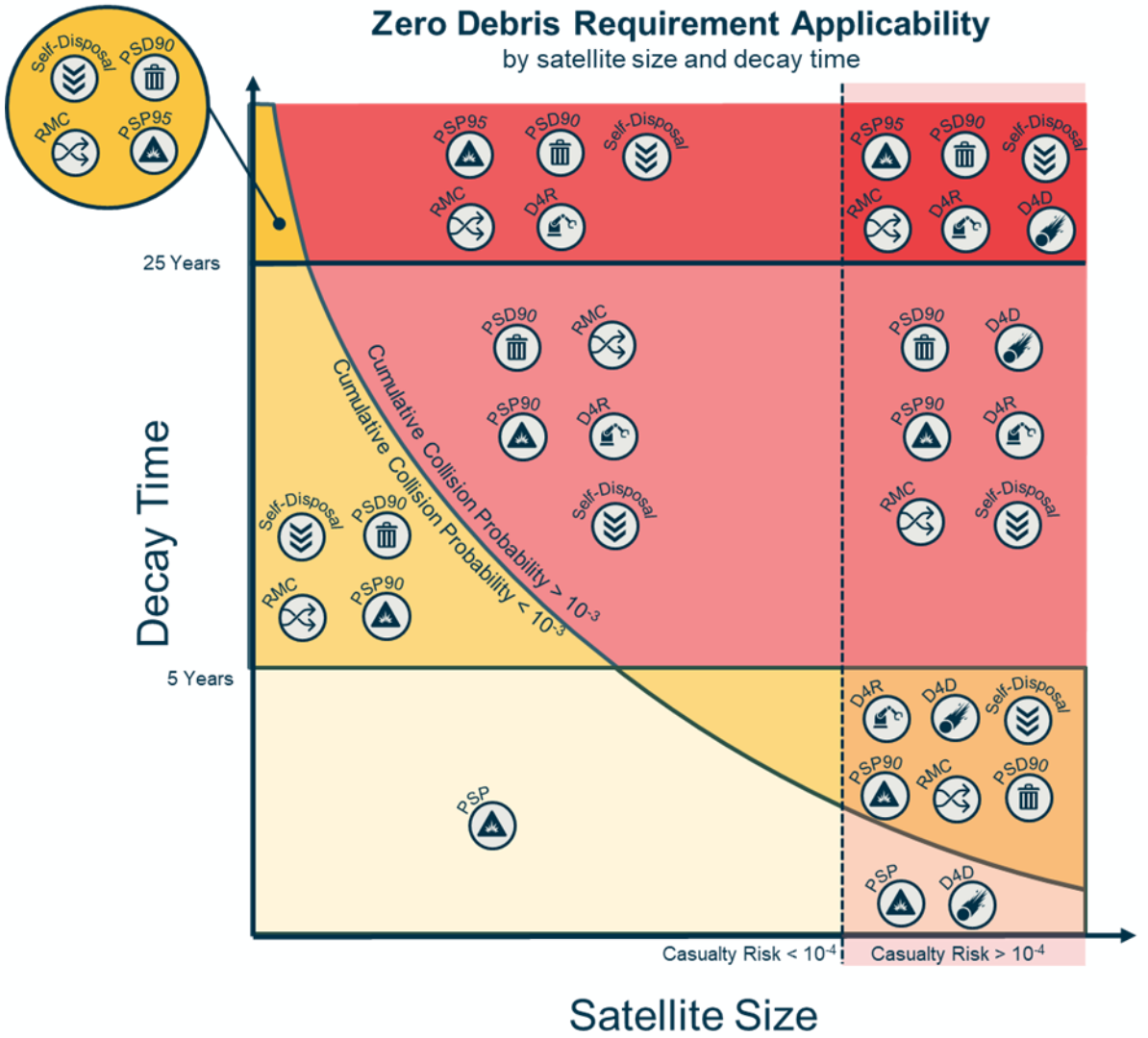
COLLISION PROBABILITY

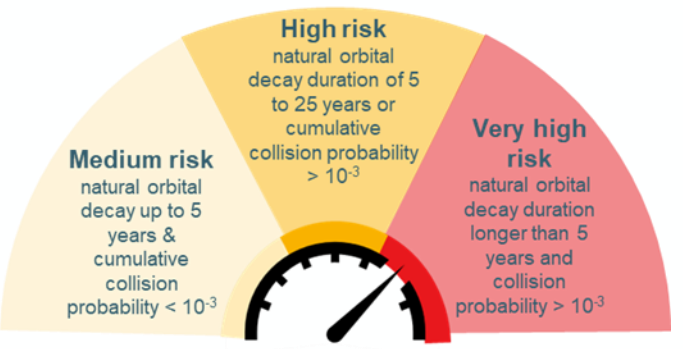
Collision probability with
**space debris** objects
larger than **1 cm**



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**.

# ESSB-ST-U-007 rationale – example for single satellite




**Key**

- PSD90 — Probability of Successful Disposal > 90%
- D4D — Design for Demise
- D4R — Design for Removal
- RMC — Recurrent Manoeuvre Capability
- PSPX — Probability of Successful Passivation > X%
- Self-Disposal — Self-Disposal Capability

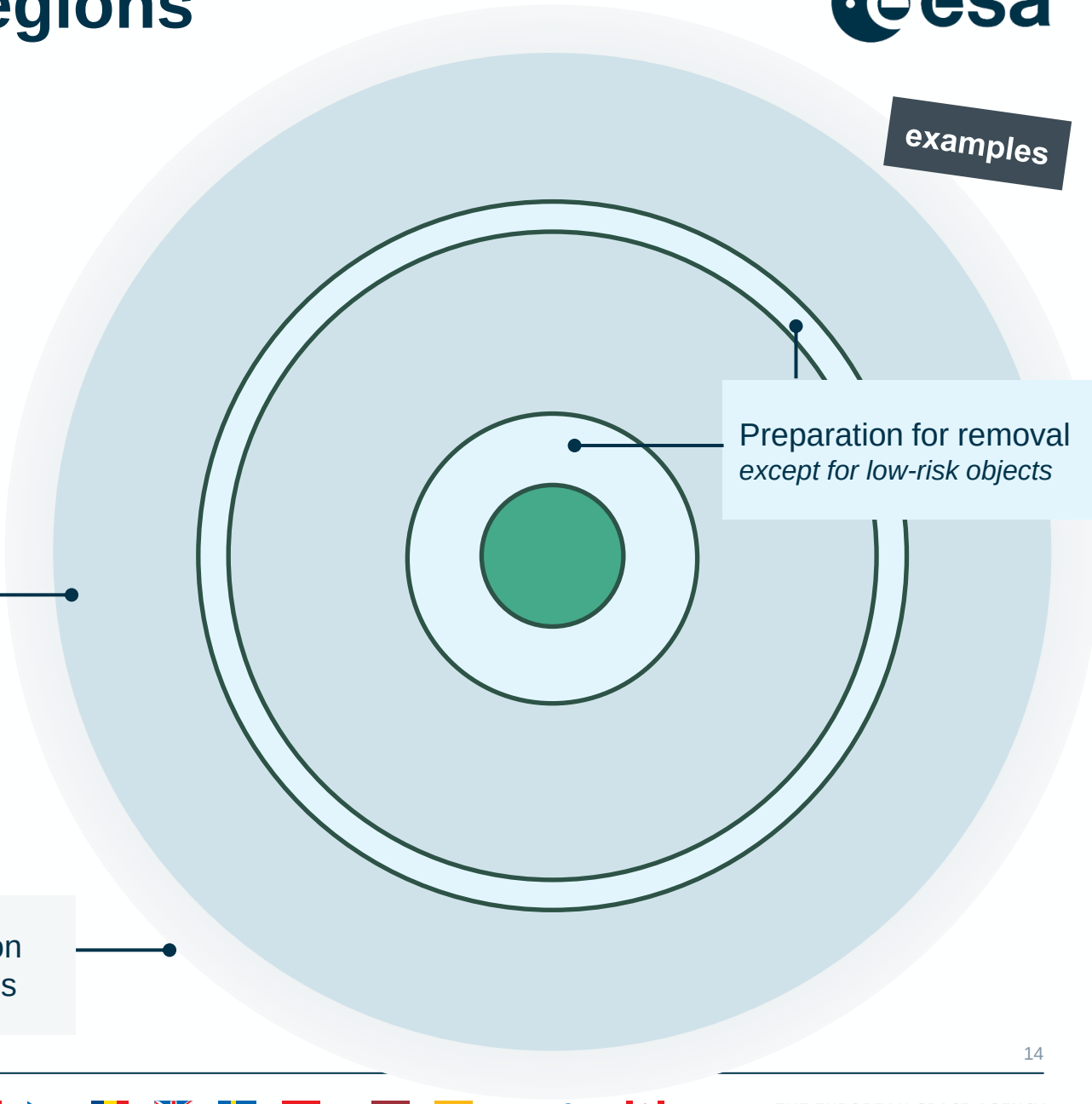
# ESSB-ST-U-007 scope: orbital regions

Protected regions (i.e. LEO and GEO)

Near-Earth orbits (perigee < 100000 km)

Earth orbits (including Libration Point Orbits)

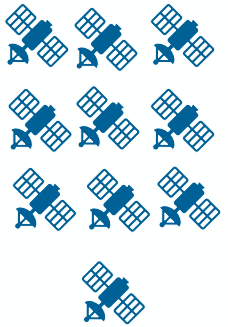
Lunar orbits (including Libration Point Orbits)



# ESSB-ST-U-007 scope: space system type

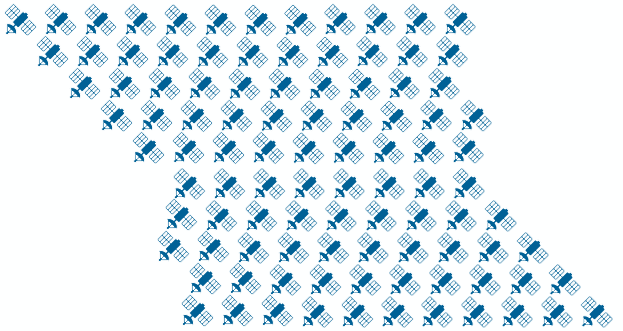
**Single spacecraft**

Request for collision avoidance capability in GEO and LEO if high or very high risk



**Constellation**
(≥ 10 spacecraft)

Request for collision avoidance capability in near-Earth orbit



**Large constellation**
(≥ 100 spacecraft)

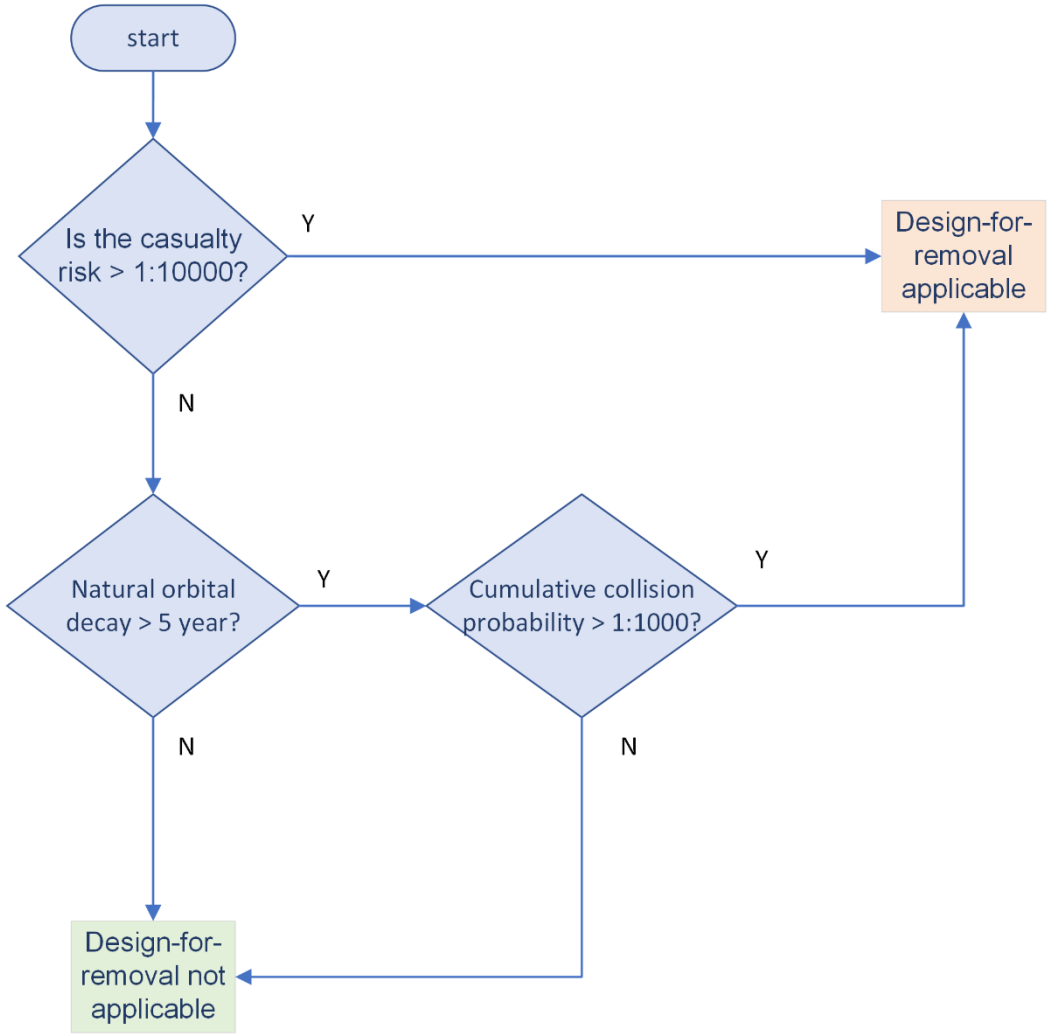
System reliability > 0.95

In LEO, disposal below 375 km and injection orbit with natural decay time < 5 years

Re-entry casualty risk per spacecraft < $1:10^6$

**Launch vehicle**
(including elements, and orbital stages)

# Preparation for removal




The requirements cover several aspects

- Mechanical **interfaces**
- Support to passive **navigation**
- Assessment of long-term **attitude**
- Attitude reconstruction from ground
- Limiting and damping **angular rates**
- **Operations**
- …

# Re-entry

Note to the novelty indicator
Novelty level of the requirement. High novelty does not mean that the requirement is difficult to achieve


The main requirement has not changed:
**re-entry casualty risk < $10^{-4}$**

What's new

Explicit request for a **probabilistic assessment** of the casualty risk

- Uncertainty sources to be considered described in ESA Space Debris Mitigation Compliance Verification Guidelines (ESSB-HB-U-002-Issue 2),
- Modelling guidelines in DIVE - Guidelines for Analysing and Testing the Demise of Man-Made Space Objects During Re-entry (ESA-TECSYE-TN-018311)

# Lunar orbits

No intentional **breakup**

No **release** of space debris during normal operations

Space & ground segment designed to have **ephemerides** available for space traffic coordination

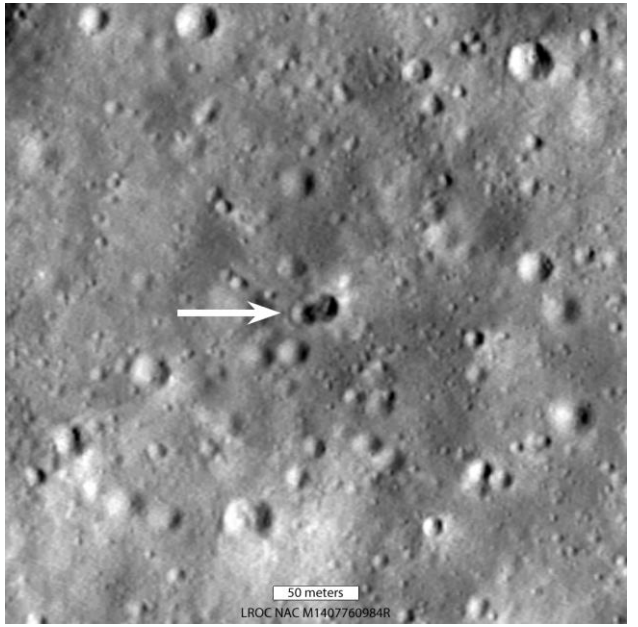
**Disposal** by one of the following means in order of preference:

1. **Heliocentric** orbit
2. Lunar impact, Earth re-entry, or a Lunar graveyard orbit

The free drift trajectories after disposal of a spacecraft or launch vehicle orbital element in lunar orbit shall be analysed for at least 100 years to evaluate:

1. Probability of **Earth re-entry** and its associated impact area
2. Probability of **Lunar impact** and its associated impact area

Double crater created by the impact of a rocket body on the Moon in March 2022.
Credits: NASA/Goddard/Arizona State University




space.debris.mitigation@esa.int

# References and tools

ESA Space Debris Mitigation Requirements

https://technology.esa.int/upload/media/ESA-Space-Debris-Mitigation-Requirements-ESSB-ST-U-007-Issue1.pdf

ESA Space Debris Mitigation Compliance Guidelines

https://sdup.esoc.esa.int/documents/download/ESSB-HB-U-002-Issue214February2023.pdf

ESA Tools (DRAMA)

https://sdup.esoc.esa.int/drama/