S5: The Zero Debris Community Effort Lessons Learned

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Multiple Channels for Interaction and Exchange

Image credits: SpaceX / NSF DOE Rubin Observatory

International

- UNCOPUOS: Group of Friends for the Dark and Quiet Skies for Science and Society
- ITU (e.g. Equivalent Power Flux Density method for studying constellation impact)
- IAU CPS (I&T Hub, Astronomer Guides, SatHub observing campaigns)
- **Zero Debris Charter + Technical Booklet (ESA + 180 signatories)**
- EU Space ACT / CRAF / Space Label…

National

- United States imposes coordination with NSF to obtain FCC license
- Licensing conditions for operators in South Africa (ongoing discussions)
- UK Earth Space Sustainability Initiative
- Switzerland Space Sustainability Rating / Spacetalk
- US AIAA Space Sustainability WG / AAS COMPASSE
- NRAO / Rubin Observatory / SKAO / NOIRLab …

Challenges to Action

Awareness

Technology

Motivation

Acknowledging the Problem: ESA Zero Debris Requirements

esa

CPS

IAU NOIRLab SKAO

- Applicable orbits

- Guarantee successful disposal

- Improve orbital clearance

- Avoid in-orbit collisions

- Avoid internal break-ups

- No intentional release of space debris

- Limit on-ground casualty risk

- Guarantee dark and quiet skies

Assessment and mitigate impacts on ground astronomy

Zero Debris: A Space Community Approach

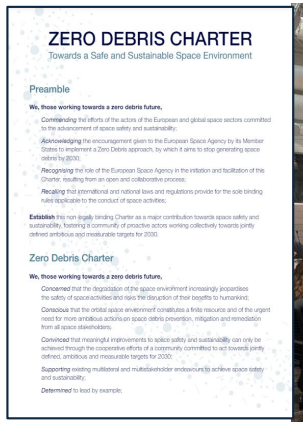
Where we want to be by 2030?

Zero Debris Charter

Published in
Oct 2023

Signature ceremonies
ongoing

182 signatories
as of September 2025


ZERO DEBRIS CHARTER
Towards a Safe and Sustainable Space Environment

Preamble

We, those working towards a zero debris future,

Contending that efforts of the actors of the European and global space sectors committed to the advancement of space safety and sustainability;

Acknowledging the encouragement given to the European Space Agency by its Member States to implement a Zero Debris approach, by which it aims to stop generating space debris by 2030;

Recognising the role of the European Space Agency in the initiation and facilitation of this Charter, resulting from an open and collaborative process;

Recalling that international and national laws and regulations provide for the sole binding rules applicable to the conduct of space activities;

Establish this non-legally binding Charter as a major contribution towards space safety and sustainability, fostering a community of proactive actors working collectively towards jointly defined ambitious and measurable targets for 2030.

Zero Debris Charter

We, those working towards a zero debris future,

Concerned that the degradation of the space environment increasingly jeopardises the safety of space activities and risks the disruption of their benefits to humankind;

Conscious that the orbital space environment constitutes a finite resource and of the urgent need for more ambitious actions on space debris prevention, mitigation and remediation from all space stakeholders;

Convinced that meaningful improvements to space safety and sustainability can only be achieved through the cooperative efforts of a community committed to act towards jointly defined, ambitious and measurable targets for 2030;

Supporting existing multilateral and multistakeholder endeavours to achieve space safety and sustainability;

Determined to lead by example;

Zero Debris: A Space Community Approach

Where we want to be by 2030?

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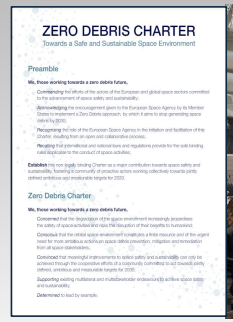

ZERO DEBRIS CHARTER
Towards a Safe and Sustainable Space Environment
Preamble
Zero Debris Charter

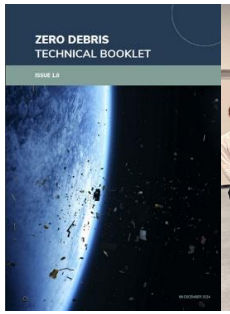
How to get there?

Zero Debris Technical Booklet

How can the booklet be useful?
As a support for

- Defining **sustainability strategy** and **priorities**
- Engaging with the community for **collaboration**
- Identifying **contributions** and **needs**

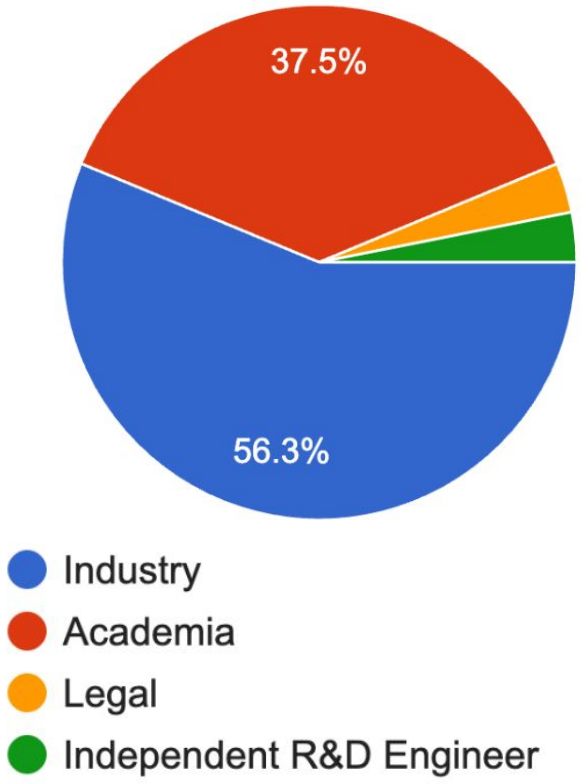
1st issue released on **15 January 2025**


ZERO DEBRIS
TECHNICAL BOOKLET
ISSUE 1.0

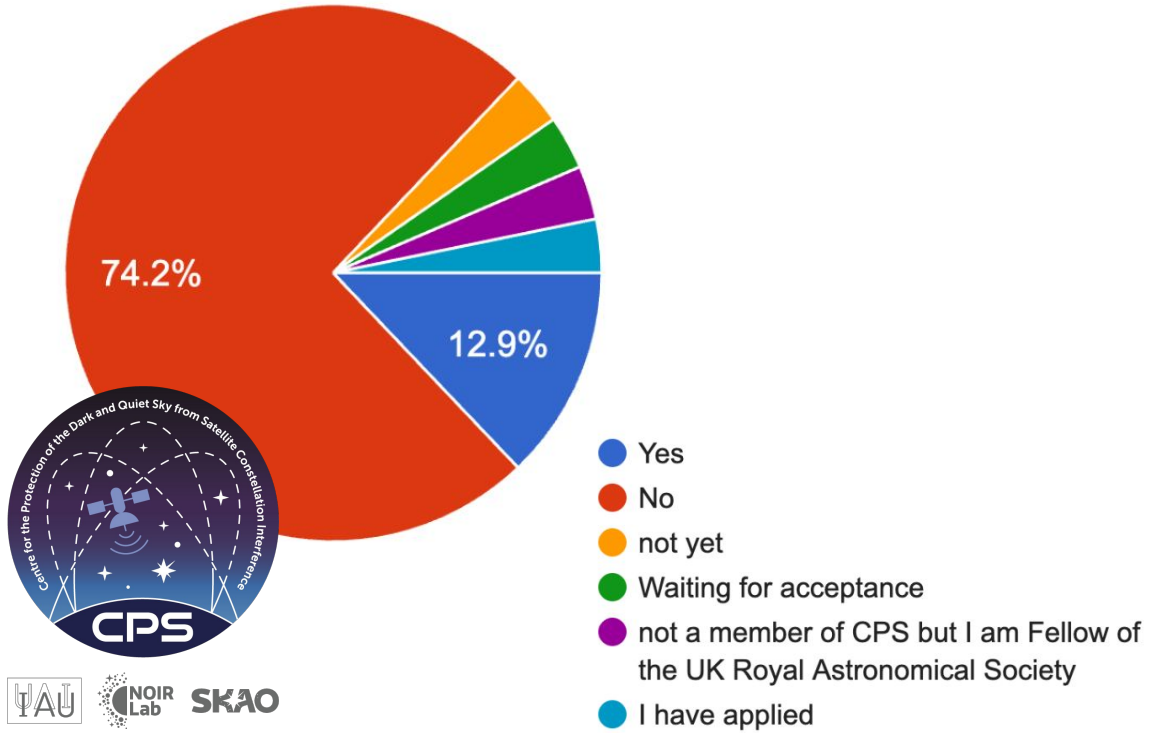
ZD Week – June 2025

Zero Debris Technical Booklet Community

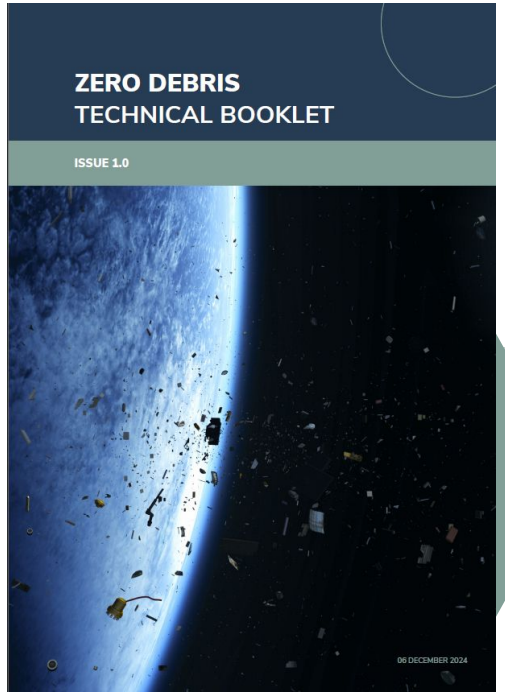
Primary Affiliation



Member of the IAU CPS?

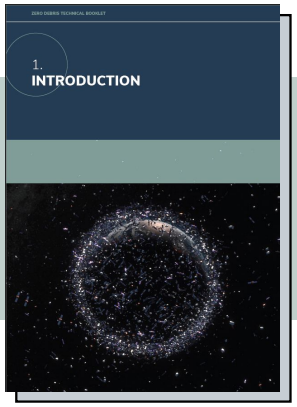


The Zero Debris (ZD) Technical Booklet



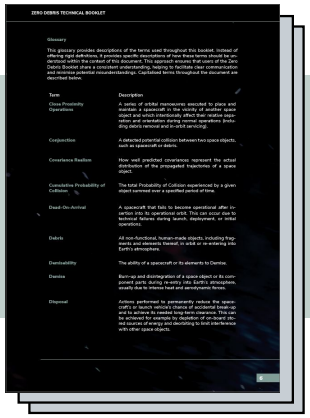
- The Booklet serves as a **resource to support the Zero Debris Community** in directing its resources **towards research and future technology developments**.
- The Booklet is **technically focused**, **non-binding**, and **collaborative**.
- **Not "owned" or written by ESA**, and participation is not restricted to European space actors

Introduction



- Background
- Scope

Glossary



- Description of terms used

Technical Chapters

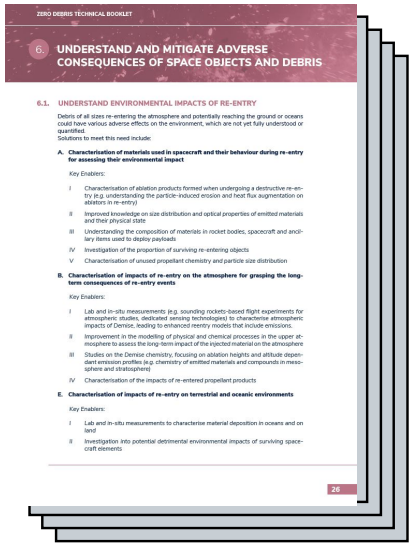
- Needs, Key Enablers and Solutions for Zero Debris by 2030

Vision for a Circular Economy in Space

- Long-term Vision

ZD Technical Booklet Chapter 6

6. UNDERSTAND AND MITIGATE ADVERSE CONSEQUENCES OF SPACE OBJECTS AND DEBRIS


ZERO DEBRIS TECHNICAL BOOKLET

6. UNDERSTAND AND MITIGATE ADVERSE CONSEQUENCES OF SPACE OBJECTS AND DEBRIS

6.1. UNDERSTAND ENVIRONMENTAL IMPACTS OF RE-ENTRY

Debris of all sizes re-entering the atmosphere and potentially reaching the ground or oceans could have various adverse effects on the environment, which are not yet fully understood or quantified.
Solutions to meet this need include:

A. **Characterisation of materials used in spacecraft and their behaviour during re-entry for assessing their environmental impact**

Key Enablers:

I Characterisation of ablation products formed when undergoing a destructive re-entry (e.g. understanding the particle-induced erosion and heat flux augmentation on ablators in re-entry)

II Improved knowledge on size distribution and optical properties of emitted materials and their physical state

III Understanding the composition of materials in rocket bodies, spacecraft and ancillary items used to deploy payloads

IV Investigation of the proportion of surviving re-entering objects

V Characterisation of unused propellant chemistry and particle size distribution

B. **Characterisation of impacts of re-entry on the atmosphere for grasping the long-term consequences of re-entry events**

Key Enablers:

I Lab and in-situ measurements (e.g. sounding rockets-based flight experiments for atmospheric studies, dedicated sensing technologies) to characterise atmospheric impacts of Demise, leading to enhanced reentry models that include emissions.

II Improvement in the modeling of physical and chemical processes in the upper atmosphere to assess the long-term impact of the injected material on the atmosphere

III Studies on the Demise chemistry, focusing on ablation heights and altitude dependant emission profiles (e.g. chemistry of emitted materials and compounds in mesosphere and stratosphere)

IV Characterisation of the impacts of re-entered propellant products

E. **Characterisation of impacts of re-entry on terrestrial and oceanic environments**

Key Enablers:

I Lab and in-situ measurements to characterise material deposition in oceans and on land

II Investigation into potential detrimental environmental impacts of surviving spacecraft elements

26

6.2. PROTECT DARK AND QUIET SKIES

A. Prediction and mitigation of the **unintended emission** from space objects and debris to protect the integrity of astronomical observations

B. Prediction of **interference** caused **by intended emissions**

Select Key Enablers:

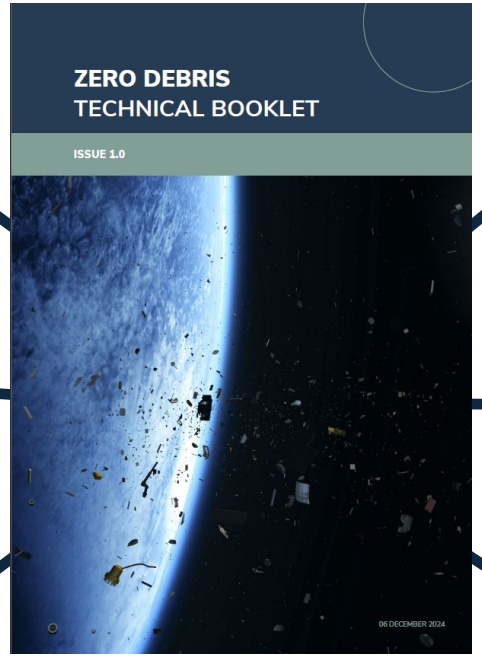
- *Development of a set of **technical guidelines** for the design, manufacturing and operation of spacecraft based on the **recommendations of the IAU***
- ***Sharing of Operational data** such as brightness data, antenna diagrams, orbital profiles, and predicted, real-time, and historical orbital elements*
- ***Assessment and modelling** of unintended electromagnetic emissions during all project phases*
- ***Development and choice of materials,** technologies and operational concepts minimizing unintended emissions of spacecraft*
- *Solutions to **maintain trackability** while reducing unwanted spacecraft emission*
- *Characterization of potential radio **interference into protected radio astronomy bands** from adjacent transmissions*

The ZD Technical Booklet Issue 2.0

Authorship
Imprint with list of contributing organizations

Metrics
How to track progress on the Booklet

Outreach
Raising awareness and increasing uptake

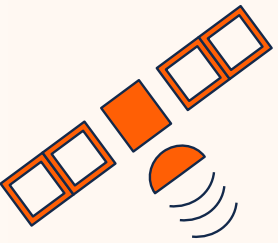


Database
Online library of needs, solutions, and key enablers

Prioritization
What is most urgent to work on first?
Upcoming task

Mapping
Who is working on what?
Current focus

Technology Examples for Impact Mitigation

 Dielectric Mirrors	Non-reflective Materials	Operational Data Sharing: Satellite Attitude Modification + EM Silencing
 Satellite Impact Assessment	Satellite Brightness and EM Emission Modeling	Operational Data Sharing: Observatory Satellite Dodging

Zero Debris Technical Booklet

Lessons Learned

- Many industry partners want to take action
- Some mitigations methods are successful / some constellations very close to IAU recs.
- Some are (still) not aware of the problem
- Most do/did not know how to get started
- Frequent communication between astronomers and space industry is crucial to developing solutions

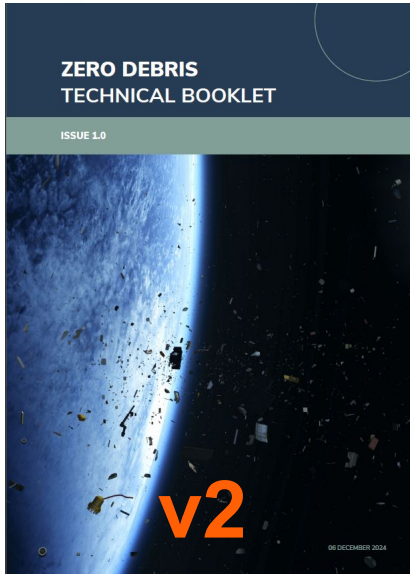
Voluntary Industry Action on Dark and Quiet Skies

Motivation is Key

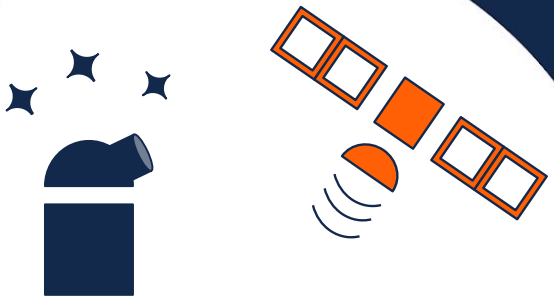
- The EU Space Act has so far been most successful in engaging industry
- ESA funding also helped
- Ensures industry is proactive in understanding and solving problems
- Levels playing field
- Regulations do not have to be “static”

(Prospect of) Regulatory Action

Thank you!



Identify Existing Technology + Tech Gaps



Enable Coexistence