A Party for Everyone?

Analysing international efforts in space debris mitigation

ESPI European Space Policy Institute

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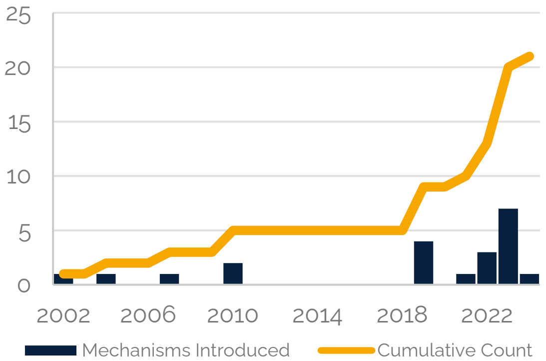
The Analysis

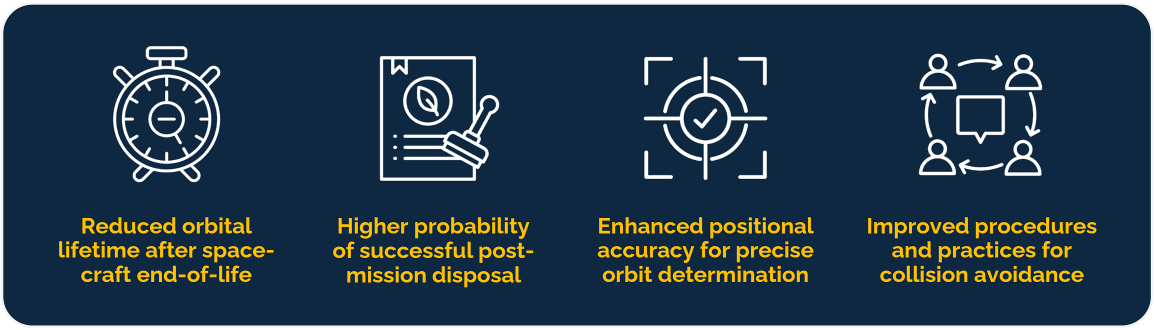
A growing global ambition and shared effort

In recent years, the proliferation of space debris and related issues of space safety and sustainability have gained new global attention, including in non-space communities, such as media, entertainment, high-level policy fora and the general public. In the space sector, stakeholders are increasingly demonstrating a shared global **effort** to addressing these challenges. This momentum is particularly visible in the past 5 years, with two concurrent dynamics at play:

1. **Existing frameworks and newly developed instruments are expanding their scope** (e.g. special requirements for LEO constellations, or increasing inclusion of additional issues, debris removal or dark & quiet skies agenda) **and increasing stringency** (see the visual below);
2. **There is a sharp increase in non-state led initiatives** (NGOs & Industry), which, while offering novel and innovative ways of engaging with this challenge, may also complexify the global space debris mitigation landscape.



Evolution of international space debris mitigation instruments (excl. new releases of existing instruments)



Increasing stringency of international space debris mitigation instruments

The Way Ahead

Consolidating and deepening the consensus

Despite broad involvement, space sector stakeholders **often take action within parallel frameworks,** and **without alignment on concrete implementation pathways.** The analysed mechanisms frequently contain a variety of principles, however, many of them often fall short in providing concrete requirements (e.g. in traffic coordination), especially when compared to other domains (e.g. aviation). In addition, when noting the increasingly proliferated landscape of international instruments, one could question the added value of new mechanisms. Could "less" be "more"?

Different courses of action are in the perimeter of public actors. On one side, **the growing stringency of space debris mitigation instruments solidifies the pathway towards stricter regulatory landscapes.** The progress in international instruments coupled with national policy development increasingly prioritising space safety and sustainability create a credible critical mass to inform regulations that can ensure a more sustainable future in space.

In this light, it is essential to also **strike a balance so that industry competitiveness is not stifled**. Regulatory evolution should mitigate increasing entry barriers to new market actors. Public actors should also enable technology development pipelines to ingest regulatory requirements into future missions and systems, Ultimately, together with regulation, **public sector should deploy additional programmatic resources** to develop the required space solutions.

Shifting the narrative towards positive and enabling outlook

Scopes of space debris mitigation instruments largely remain at technical and operational level. Fostering a conducive environment for enhancing space safety and sustainability entails also communication and perception in a wider audience. **The broader narrative surrounding space debris has been often pessimistic,** highlighting worst-case scenarios such as collisions and the eventual inaccessibility of space, spurring a negative perception of space even beyond the space community. However, **it is critical to shift this narrative towards a more positive outlook**, accentuating the socio-economic benefits of space and the positive effect of developing the foundations, which require space safety and sustainability for space to develop its full benefit to economy and society.

Seizing the opportunity for Europe's global leadership

The absence of global consolidation offers a **unique opportunity for Europe to lead on the global stage**, leveraging the momentum accelerated by broader policy appetite and initiatives across the R&D, capability, and regulatory landscape (e.g. ZDC, EU Space Law, EUSST, ESA S2P, national policies and regulations). This ambition should go beyond regulatory or diplomatic action. To enable all this, **a stronger political will is needed**, translating the rhetoric into impactful policy and programmatic action for economic benefit.

In this broader context of European leadership on space sustainability at large, **Europe could be inspired to promote a Europe-led international programmatic effort**. Such effort can build on successful models of international cooperation, such as the Intergovernmental Agreement (IGA) governing the ISS, to address space safety & sustainability challenges. A similar collaborative framework could unify global efforts in ambitioning a landmark achievement (e.g. debris removal mission) and deepen global consensus on space safety and sustainability guidelines. In this regard, the example of the Intergovernmental Panel on Climate Change (IPCC) is a relevant model for Europe to follow in future space safety and sustainability efforts.

The ESPI Contribution

In line with the vision set forth in the **ESPI2040: Space for Prosperity, Peace and Future Generations** policy vision and ESPI's mandate to promote European space policy globally, provide independent policy advice and raise public awareness, ESPI commits to:

- **Promote the awareness of European decision-makers and citizens** on space safety and sustainability issues and the role of Europe therein, accentuating a narrative of the wider benefit of space on other sectors of policy and economy.
- **Set up and operate the Centre of Excellence for Space and Sustainability (CESS)** with the support of the Austrian government, to support decision-makers by providing knowledge, recommendations, and advice on sustainability issues.
- **Promote international dialogue and the role of European stakeholders therein,** leveraging ESPI's international engagement agenda, including initiatives such as the **Vienna Space Diplomat** platform.
- **Support Europe's ambitions for global leadership in space safety and sustainability**, contributing to large-scale federative initiatives, in line with the vision of a strong Europe as a partner to the world.

2 INTRODUCTION

2.1 Background and Rationale

Space infrastructure has become an indispensable asset, integral to numerous policies, economic sectors and daily life. Without a safe and sustainable space operational environment, Europe (and international community at large) cannot fully develop and utilise the immense value of space for the broader society and economy.

This growing reliance highlights the imperative to safeguard our space infrastructure against various risks, notably the escalating concern of proliferation of space debris.

As use of space becomes increasingly democratised and utilised, the orbital environment faces unprecedented pressures. The proliferation of space debris presents a critical challenge, threatening not only the operational integrity of spacecraft but also increasingly posing hazards upon re-entry.

Notably, the escalating collision risks, could further amplify the debris problem and compromise vital services, highlighting the persisting need for effective debris mitigation strategies. Recognising this, countries, international bodies and private actors increasingly seek solutions to improve space debris mitigation efforts.

Among the **array of responses and solutions, a growing variety of international initiatives have been developed**. These range from the Inter-Agency Space Debris Coordination Committee's (IADC) Space Debris Mitigation Guidelines to recent frameworks like the Zero Debris Charter initiated by the European Space Agency (ESA).

Increased Policy Momentum for Space Safety and Sustainability

In September 2023, ESPI published a report on "Space Safety and Sustainability Momentum".[1]

The report identified a **growing prioritisation of space safety and sustainability in national policies** and international fora, amidst increasing private sector engagement in parallel.

Building on these findings, the report offered four distinct policy considerations to European decision-makers:

1. The risk for Europe of widening the capability gap vis-à-vis other space powers.
2. Greater opportunities & appetite to leverage commercial solutions and services.
3. The challenge of translating political awareness into funding.
4. Need to re-consider risk assessments considering emerging concepts and activities, including beyond GEO.

These efforts embody a **collective resolve** to address the space debris proliferation and related safety & sustainability challenges head-on, aiming to preserve the Earth orbit environment for the benefit of current and future generations.

Building upon the current momentum, producing an increasingly diverse and saturated landscape of different initiatives, ESPI has ambitioned to conduct a comprehensive mapping and comparative analysis of the various instruments and initiatives dedicated to mitigating space debris, to assess how they evolve over time, in areas such as inclusiveness, scope or stringency.

[1] ESPI. Space Safety and Sustainability Momentum. ESPI. https://www.espi.or.at/reports/space-safety-and-sustainability-momentum/ (Accessed: 10 March 2024).

2.2 Objectives and Scope

Acknowledging the breadth of space debris mitigation instruments at various levels[2], **the study focuses exclusively on instruments of international nature.** The study's principal aims are:

1. Evaluation of space debris mitigation instruments

- Mapping and Landscaping: In the mapping section, ESPI research identifies 15 key instruments, complemented by listing of other notable mechanisms outside our main scope to broaden the context and suggest future research directions.
- Assessment and Comparison: This section provides a comprehensive evaluation of space debris mitigation instruments across three overarching criteria—Purpose and Activities, Structure, and Representation—encompassing 10 main sub-criteria, each with individualised assessment.

2. Identification of new trends and concepts, including numerical requirements

- Trend Analysis: Focuses on new or unique concepts that aim to limit debris proliferation, offering insights into innovative approaches and identifying potential gaps in current instruments.
- Spotlight on numerical requirements: Instruments with specific, concrete, and quantifiable provisions are particularly scrutinised to identify measurable actions intended for debris mitigation.

3. Formulation of Policy considerations

- Identification of key takeaways to support future policy-making in the domains of space safety and sustainability.

By delivering a **panoramic analysis** establishing a clear comparison and cataloguing of initiatives, the study enhances our collective understanding of the effectiveness and scope of existing space debris mitigation efforts and contributes to the global discourse on space sustainability.

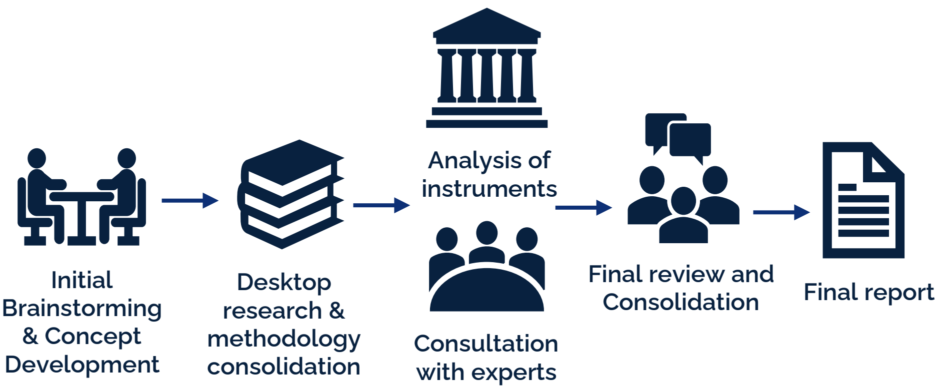


Figure 1: Methodology outline of the study

[2] In this regard, the national legal and regulatory dimension provides for another major set of space debris mitigation instruments. As showcased OECD research (Link, page 30), the number of national regulatory measures integrating debris mitigation provisions has been growing steadily, with varying levels of detail, legal status and scope.

3 Analysis and Comparison of International Mechanisms on Space Debris Mitigation

The mapping exercise identified a multitude of international instruments with goals related to space debris mitigation. In line with the ambition of the study, the study offers the following:

- **A comparative analysis of 15 selected instruments** (Chapters 2.1 and 2.3), using a standardised approach and 10 specific assessment criteria.
- **Identification and categorisation of further mechanisms in support of space debris mitigation** (Chapter 2.2), excluded from the scope of comparative analysis).

The initial **observations and insights** on the dataset and research include several key points:

The **proliferation** of international space debris mitigation instruments has become **particularly visible in the past five years, characterised by the diversification** of frameworks and the involvement of various actors, including a notable rise in private sector engagement, including through driving the development of new initiatives.

Despite a growing global concern among stakeholders with unique (or diverging) interests, these international instruments often involve **incomplete engagement across different actor types**, such as space agencies being present in certain documents, while industry and NGOs more represented in other frameworks.

The analysis suggests that the accelerated international discourse on space debris mitigation and related challenges has produced a body of knowledge which **enjoys a global consensus, but the scope of this consensus remains limited to primarily goals and principles** and to a lesser extent focuses on concrete measures in the practical Implementation by different stakeholders,

The research noted two overarching types of instruments:

1. **Instruments containing actionable requirements, and detailed provisions, often quantifiable**. Examples include the IADC Guidelines, ISO 24113, ESA Space Debris Mitigation Requirements, the Space Safety Coalition's Best Practices, or the Zero Debris Charter.
2. **Instruments serving as collective commitments or statements of goodwill.** Examples include the Paris Peace Forum's Net Zero Space Declaration, the G7 Communiqué, SIA Principles, or the GSOA Code of Conduct.

The study of different space debris mitigation instruments should **consider the broader context and avoid analysing these instruments in isolation**. In several cases, the research highlighted extensive referencing in between documents (in particular to the IADC Guidelines or to the ISO 24113 standard). Additionally, some instruments are directly linked with complementary documents defining their implementation (ESA SDM Requirements & ESA SDM Policy).

International space debris mitigation instruments **are increasing in their ambition**. This is noticeable through their expanding scope (e.g. introduction of various new concepts and measures – see Chapter 3.2) and increased stringency of principles, best practices, guidelines and other provisions (see Chapter 3.1).

3.1 Overview of 15 selected instruments in support of space debris mitigation efforts

1. IADC Space Debris Mitigation Guidelines

Released in 2002, latest updated version in 2021


Inter-Agency Space Debris Coordination Committee

IADC Space Debris Mitigation Guidelines

Main actors: ~~Governments~~ **Agencies** ~~Industry~~ ~~Academia~~ ~~NGOs~~

Established in 1993, the Inter-Agency Space Debris Coordination Committee coordinates efforts of space agencies on space debris research, risk assessment, and mitigation. The widely recognised IADC's key product, the IADC Space Debris Mitigation Guidelines, form the basis for numerous national and international mechanisms, including through incorporation by reference. The IADC guidelines offer a comprehensive approach to debris mitigation, aiming at preventing on-orbit explosions & collisions, facilitating post-mission removal of spacecraft and stages, and limiting debris from normal operations. The 3rd revision in 2021 included updates on GEO disposal, break-up causes and re-entry risks.

2. European Code of Conduct for Space Debris Mitigation

Released in 2004


European Code of Conduct

for Space Debris Mitigation

Main actors: ~~Governments~~ **Agencies** ~~Industry~~ ~~Academia~~ ~~NGOs~~

The European Code of Conduct for Space Debris Mitigation, formulated in 2004 by ESA and four national space agencies, establishes voluntary guidelines for mission design and operation. The Code emphasises flexibility and desired outcomes, enabling adaptability in sustainable space operations. Endorsed by major European space agencies, it aligns with international standards and offers deeper insights. The Code recommends annual coordination among agencies and is geared toward all European space projects, promoting responsible and innovative space missions.

3. Space Debris Mitigation Guidelines of the UN COPUOS

Endorsed by UN General Assembly in 2007


OFFICE FOR OUTER SPACE AFFAIRS

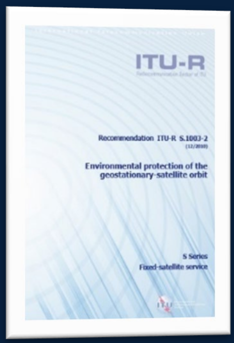
Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space

Main actors: **Governments** ~~Agencies~~ ~~Industry~~ ~~Academia~~ ~~NGOs~~

Adopted in 2007, the guidelines built on the foundation on the IADC's Space Debris Mitigation Guidelines and can be perceived as their stakeholder expansion. The Working Group noted that the UN guidelines were to be "based on the technical content and the basic definitions of the IADC space debris mitigation guidelines," but also "taking into consideration the UN treaties and principles on outer space." The guidelines focus on limiting debris released during normal operations, minimising the potential for break-ups during operational phases, limiting the probability of accidental collisions in orbit, and avoiding intentional destruction and harmful activities.

4. Recommendation ITU-R S.1003-2 Environmental Protection of the Geostationary-Satellite Orbit

Published in 2010



Main actors: **Governments** ~~Agencies~~ ~~Industry~~ ~~Academia~~ ~~NGOs~~

Recommendation ITU-R S.1003-2, published in 2010 by the ITU Radiocommunications Assembly, addresses communication satellites in geostationary orbits (GSO). It emphasises that GSO satellites manoeuvre out of this region at the end of their lifespan to prevent orbital crowding. Though not legally binding, these globally respected guidelines advise to minimise the release of debris, shortening debris lifetime in transfer orbits near GSO altitude, and moving geostationary satellites to an orbit at least 200 km above GSO before their propellant is exhausted. More broadly, as of 2024, it is noticeable that the ITU is increasingly addressing the issue of space sustainability with additional engagement and initiatives.

5. International Standard "Space Systems – Space Debris Mitigation Requirements" [ISO 24113]

Originally published in 2010, latest updated version released in 2023

Main Actors: ~~Governments~~ **Agencies** **Industry** ~~Academia~~ ~~NGOs~~

Though not legally binding, standards by the International Organisation for Standardisation are widely recognised and provide common frameworks in a multitude of domains. Including space debris mitigation. Most notably the top-level standard ISO 24113, updated in May 2023 outlines requirements covering definitions, protected regions, technical specifications, and planning needs, offering a comprehensive overview of the issue and necessary actions for compliance. Additionally, ISO has introduced standards for space safety and sustainability, such as 19389 for conjunction data messages (2014), 23312 for space systems (2022), and 24330 for Rendezvous, Proximity Operations, and On-Orbit Servicing (2022). Other standards on collision avoidance, space traffic coordination, and spacecraft constellation design are in development.

6. UN COPUOS Guidelines for Long-Term Sustainability of Outer Space Activities

Adopted by UN COPUOS in 2019

Main actors: **Governments** ~~Agencies~~ ~~Industry~~ ~~Academia~~ ~~NGO~~

The LTS guidelines, formulated by COPUOS' LTS Working Group in a decade-long process, are voluntary measures ensuring the safety and sustainability of outer space activities. Although not legally binding, they serve as an internationally agreed baseline, covering policy, safety, technical, and cooperation aspects for both governmental and non-governmental entities. LTS Guidelines have a wider scope compared to 2007 UN SDM Guidelines, addressing also issues such as space weather, spectrum or link to national laws and regulations). Alongside standard mission planning and design considerations, the LTS guidelines aim to strengthen international dialogue and cooperation and call for measures encouraging scientific and technical R&D.

7. SIA Principles of Space Safety for the Commercial Satellite Industry

Released in 2019

Main actors: ~~Governments~~ ~~Agencies~~ **Industry** ~~Academia~~ ~~NGOs~~

The predominantly U,S.-driven Satellite Industry Association (SIA) released the Principles of Space Safety, presenting the commitment of its members "to responsible space operations that ensure the long-term sustainability of the space domain". Key elements include open communication on Space Situational Awareness (SSA), 24/7 availability of collision avoidance PoCs, efficient tracking of GSO and NGSO satellites, preventing both intentional and inadvertent debris creation, and maintaining constant availability of PoCs to address space flight safety hazards and potential conjunctions.

8. Space Safety Coalition's (SSC) Best Practices for the Sustainability of Space Operations

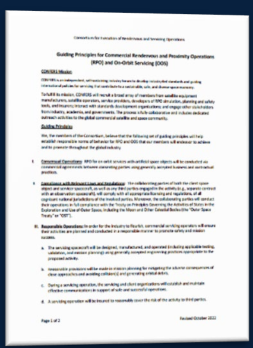
First released in 2019 and latest update in 2023

Main actors: ~~Governments~~ ~~Agencies~~ **Industry** ~~Academia~~ **NGO**

The SSC is a global ad-hoc coalition of private space companies and other private entities aimed at developing and updating a set of voluntary best practices, which were originally developed under the Global VSAT Forum framework. SSC's Best Practices for Sustainability of space operations (first released in 2019 and updated in 2024) are applicable to all spacecraft, regardless of physical size, orbital regime, and constellation size. The best practices for space safety present a comprehensive and concise categorisation of practices to be conducted and followed. It presents a concrete approach for operators.

9. CONFERS Recommended Design and Operational Practices

Issued in 2019, last revised in October 2022



Main actors: ~~Governments~~ ~~Agencies~~ **Industry**[3] ~~Academia~~ ~~NGO~~

In October 2017, DARPA (U.S.) created CONFERS, which became an independent, self-sustaining industry consortium in December 2022. CONFERS develops industry-led standards and international principles to foster a sustainable, safe, and diverse space economy. It supports satellite servicing, including maintenance, repair, assembly, manufacturing, and inspection, from low-earth orbit to cislunar space. The Recommended Design and Operational Practices provide guiding principles for commercial satellite servicing, focusing on Rendezvous, Proximity Operations (RPO), and On-Orbit Servicing (OOS). These guidelines ensure operational safety and mission success, promoting space sustainability while allowing companies flexibility in implementation

[3] While aimed at industry best practices, there is government, academic, and NGO representation through an observer status. Because observers cannot actively contribute, only the industry has been considered as the primary type of actor.

10. Paris Peace Forum's Net Zero Space Initiative

Released in 2021

Main Actors: **Governments** **Agencies** **Industry** **Academia** **NGO**

At the 4th edition of the Paris Peace Forum in 2021, various public and private stakeholders united in a new commitment towards achieving sustainable use of outer space for the benefit of all humankind by 2030. The initiative is semi-centralised, with the Paris Peace Forum acting as a secretariat. The commitments are non-binding, and accession is relatively simple. The document calls for a global commitment to achieving sustainable use of outer space for the benefit of all humankind by 2030. It recommends avoiding the further generation of hazardous space debris and remediating existing hazardous space debris.

11. G7 Science and Technology Ministers' Communique (2023)[4]

Released in 2023

Main actors: **Governments** ~~Agencies~~ ~~Industry~~ ~~Academia~~ ~~NGO~~

Issued during the G7 meetings in May 2023 in Japan, the communique from the Science and Technology Ministers outlines a non-binding commitment to adhere to COPUOS, COPUOS LTS, and IADC Space Debris Mitigation Guidelines. The G7 countries pledged to share best practices on mitigation and Space Situational Awareness (SSA) and support identifying new guidelines in relevant forums. The communique reaffirms the promotion and pledge towards guidelines developed by entities like COPUOS and IADC. Additionally, it emphasises sharing experiences on national orbital debris mitigation through UNCOPUOS and IADC and highlights the importance of addressing ASAT testing as a source of space debris.

12. WEF's Space Industry Debris Mitigation Recommendations

Released in 2023

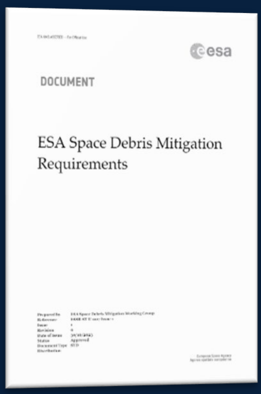
Main actors: ~~Governments~~ **Agencies** **Industry** ~~Academia~~ **NGOs**

The Space Industry Debris Mitigation Recommendations document was announced with 27 space sector signatories by the World Economic Forum in June 2023. Echoing previous instruments, the document puts forward several distinct recommendations, introducing specific quantifiable criteria. Notably, it calls for a 90-95% success rate for post-mission disposal, the completion of disposal no more than five years after the end of each satellite's mission, and the ability to actively manage an orbit for missions with an altitude of 375km or above. Looking towards the 2030 landscape, the document emphasises operational space traffic coordination and active debris removal systems.

[4] The "challenge of orbital debris" was explicitly reiterated also in the 2024 edition of the same G7 Communiqué. The 2024 text also explicitly addressed "the protection of the dark and quiet sky".

13. ESA Space Debris Mitigation Requirements (2023)

Released in 2023



Main actors: ~~Governments~~ **Agencies** ~~Industry~~ ~~Academia~~ ~~NGO~~

As part of ESA's Zero Debris approach, the Agency has updated two fundamental documents that regulate its space missions: the new Space Debris Mitigation Policy and Space Debris Mitigation Requirements. The policy clarifies how the Space Debris Mitigation Requirements, remarkably detailed, apply to all ESA missions. The new requirements reduce the disposal phase duration in low-Earth orbit, mandate a high probability of successful disposal, and introduce collision avoidance and space traffic coordination standards. These documents, effective November 2023, must be read together, as they collectively represent ESA's commitment to reducing space debris and promoting space sustainability.

14. GSOA Code of Conduct on Space Sustainability

Released in 2023

Main actors: ~~Governments~~ ~~Agencies~~ **Industry** ~~Academia~~ ~~NGO~~

Recognising the significant benefits space provides to societies and economies, the Code of Conduct of Global Satellite Operators' Association emphasises the importance of timely action to preserve these benefits amidst the increasing utilisation of space. GSOA recommends practices such as mitigating the risk of in-orbit collisions and non-trackable debris, preserving human life in space, and limiting impacts on optical astronomy. By promoting responsible behaviour and fostering collaboration, GSOA aims to drive better practices in space sustainability, ensuring that the satellite industry can continue to provide vital connectivity and services responsibly.

15. Zero Debris Charter

Announced in 2023

Main actors: **Governments** **Agencies** **Industry** **Academia** **NGO**

The Zero Debris Charter, announced at the Paris Air Show in June 2023 by ESA and industry leaders, promotes a global commitment to space sustainability. In line with the ESA Zero Debris approach endorsed by Member States in 2022, it aims for debris neutrality by 2030. Facilitated by ESA's 'Protection of Space Assets' Accelerator, the Charter, created by 40 space actors, sets high-level principles and specific targets. It unites a diverse global community, including industry, government agencies, and academia, to address the growing threat of space debris. Developed through an open process, including a draft, comments, and workshops, the Charter is a collective effort to ensure sustainable space operations.

3.2 Further mechanisms in support of space debris mitigation

In addition to the 15 space debris mitigation instruments selected for primary assessment in the study, **it is essential to underline the existence of numerous additional mechanisms**, which (while taking various forms, including those without a "guiding document"), address space debris mitigation and promote the sustainability of space activities.

Notable examples of such mechanism include:

Complementary instruments within major frameworks

These are developed within frameworks and platforms previously listed and offer crucial support to the primary instruments.

- **Related IADC Documents:**
  - ***Support to the IADC Space Debris Mitigation Guidelines:*** This document provides additional insights and guidelines to enhance the implementation of the primary IADC Space Debris Mitigation Guidelines.
  - ***IADC Statements:*** These include statements on large constellations and active debris removal, addressing specific challenges and providing strategic direction.
- **Complementary ISO Standards:**
  - ***Lower-Level Standards beneath ISO 24113:*** Several lower-level standards below ISO 24113 provide more detailed requirements and implementation measures, offering specific guidelines for different aspects of space debris mitigation.

Rating Schemes and Labels

These mechanisms promote responsible behaviour in space activities through evaluation and recognition systems.

- **Space Sustainability Rating (SSR):**
  - Launched in 2022, the SSR fosters responsible behaviour in space activities through a detailed rating system, encouraging adherence to sustainability practices.

Platforms for Coordination, Information Sharing, and Service Provision

These initiatives facilitate collaboration and information exchange among stakeholders.

- **Space Data Association's Space Data Centre:**
  - Provides a platform for data sharing and coordination among satellite operators which are members of SDA, to enhance space situational awareness and collision avoidance.
- **European Union's Space Surveillance and Tracking (EUSST) Partnership:**
  - Facilitates the tracking of space objects and space surveillance by pooling and sharing of resources of the participating EU member states and providing dedicated services to registered organisations.

Major International Legal Frameworks and UN Instruments

These frameworks establish the legal foundation for the conduct of space activities and overarchingly promote international cooperation or peaceful uses of outer space.

- **UNGA Resolutions:**
  - ***Annual PAROS Resolution:*** Aims to prevent an arms race in outer space, contributing indirectly to the mitigation of space debris.
  - ***2022 DA-ASAT Test Ban Resolution:*** Bans destructive anti-satellite tests, which significantly reduce the creation of new space debris.
- **International Legally Binding Mechanisms:**
  - ***UN "space treaties", in particular the Outer Space Treaty (OST) of 1967:*** The cornerstone of international space law, which includes provisions relevant to the mitigation of space debris and the responsible use of outer space.

Supplementary International Standardisation

These standards and frameworks provide additional technical guidelines to support the safe conduct of space activities.

- **Consultative Committee for Space Data Systems (CCSDS) Standards,** such as:
  - ***Conjunction Data Messages (CDMs):*** a widely used format for sharing conjunction assessment information, aiding in collision avoidance.
- **European Cooperation for Space Standardization (ECSS)** initiative with international and multi-stakeholder footprint, aiming to develop a coherent, single set of user-friendly standards (including related to space debris mitigation), for use in all European space activities.

Supporting Collective Statements

These statements, proliferated in the past few years and endorsed by various types of stakeholders, reinforce the commitment to responsible space activities.

- **Statement for a Responsible Space Sector (2022):** Endorsed by multiple organisations to promote sustainable practices in the space sector.
- **AIAA Satellite Orbital Safety Best Practices (2022):** Released jointly with 3 companies – Iridium, OneWeb and SpaceX and addressing primarily best practices LEO operations
- **Astra Carta Framework (2023):** Unveiled by the UK monarch, this framework outlines principles for the responsible use of outer space.
- **ESSI Memorandum of Principles (2023):** Launched to establish fundamental principles for sustainable space activities.
- **Lisbon Declaration for Outer Space (2024):** A recent declaration aiming to enhance international cooperation and sustainability in outer space activities.

3.3 Comparative Evaluation

The criteria for evaluating the space debris mitigation instruments are grouped into three overarching categories: **Purpose and Activities, Structure, and Representation**. These categories include 10 specific criteria, each with a unique assessment and scoring approach:

Note on colour coding: The addition of colour coding to the analysis below was chosen to provide additional insights on the added value of each instrument, Light blue – indicates assessment that is closest to highest value in terms of addressing gaps and key effectiveness criteria (clarity, precision, inclusivity), Dark blue denotes partial or semi-satisfactory fulfilment and Orange denoting absent or minimal fulfilment.

Selected Mechanisms (incl. date of first release)		Content				Structure			Representation		
		I. Design & Architecture	II. Collision avoidance	III. Orbital Clearance	IV.Compliance & Monitoring	V. Type of commitment	VI. Centralisation degree	VII. Adaptability & Evolution	VIII. Number of partners	IX. Type of partners	X. Ease of access
IADC Space Debris Mitigation Guidelines	2002	Yes	Yes	Yes	No	Imprecise	Decentralised	Flexible	Internal	Public	Accessible
European Code of Conduct for Space Debris Mitigation	2004	Yes	Yes	Yes	No	Concrete	Decentralised	Partial	Internal	Public	N/A
UN COPUOS Space Debris Mitigation Guidelines	2007	Yes	Yes	Yes	No	Imprecise	Partial	Partial	High	Public	N/A
Rec ITU-R S.1003-2 (Geostationary)	2010	No	No	Yes	No	Concrete	Centralised	Partial	High	Public	Undefined
ISO 24113 Space debris mitigation requirements	2010	Yes	Yes	Yes	Yes	Imprecise	Centralised	Flexible	High	Pub.-priv	Accessible
UN LTS Guidelines	2019	Yes	Yes	Yes	Partial	Imprecise	Partial	Partial	High	Public	N/A
SIA Principles of Space Safety	2019	Yes	Yes	Yes	No	Imprecise	Partial	Partial	High	Private	Accessible
Space Safety Coalition's Best Practices	2019	Yes	Yes	Yes	No	Imprecise	Decentralised	Partial	High	Private	Undefined
CONFERS' Recommended Design & Practices	2019	Partial	Partial	No	Partial	Imprecise	Partial	Flexible	High	Pub.-Priv.	Undefined
PPF's Net Zero Space Initiative	2021	Partial	Partial	Partial	No	Imprecise	Decentralised	Flexible	High	Pub.-Priv.	Accessible
G7 Science and Technology Ministers' Communiqué	2023	Partial	Partial	Partial	No	Generic	Decentralised	Partial	Internal	Public	N/A
WEF's Space Industry Debris Mitigation Recommendations	2023	No	Yes	Yes	No	Concrete	Decentralised	Partial	Low	Private	Accessible
ESA Space Debris Mitigation Requirements	2023	Yes	Yes	Yes	Yes	Concrete	Centralised	Flexible	Internal	Public	N/A
GSOA Code of Conduct on Space Sustainability	2023	Yes	Yes	Yes	Partial	Imprecise	Decentralised	Flexible	High	Private	Accessible
Zero Debris Charter	2023	Yes	Yes	Yes	Partial	Concrete	Decentralised	Partial	High	Pub.-Priv.	Accessible

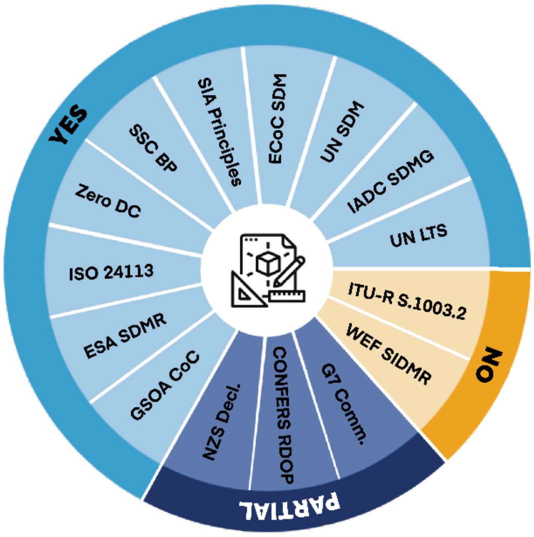
Content criteria

This first category assesses the instrument's overall purpose, focusing on its effectiveness in preventing the generation of new debris. Criteria within this category assess measures for minimising debris creation through satellite design & mission architecture, during operations (including collision avoidance and provisions for the safe and efficient disposal of satellites or spacecraft after their operational life).

I. Design & Architecture

This criterion evaluates whether an instrument addresses satellite design or mission architecture in

view of minimising the risk of debris generation. ESPI has integrated the qualitative assessment of each objective with a tailored scoring mechanism (described on the outer circle of the pie chart). The scoring spectrum includes "Yes" if the instrument fully addresses and integrates comprehensive measures to minimise collision impacts, break-ups, and malfunctions within the satellite design or mission architecture, "Partial" if it addresses some aspects but does not comprehensively integrate these into satellite design or mission architecture, and "No" for no measures addressed.



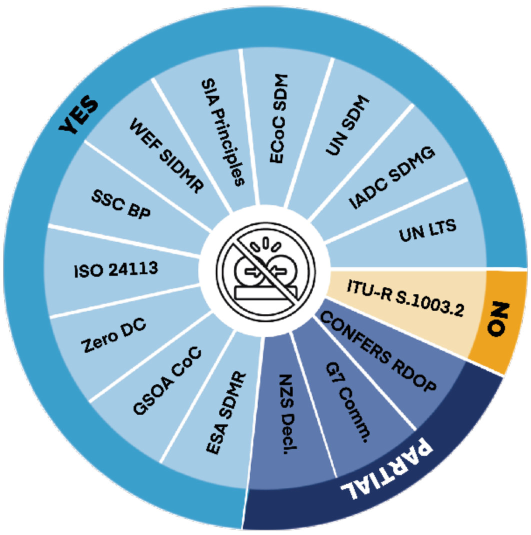
The key observations include the following:

- **Prevailing Emphasis on design measures:** Most instruments contain a more specific focus on how spacecraft and mission profiles should be designed to prevent debris generation. This trend demonstrates the perceived importance of pre-emptive measures in mitigating debris generation, by integrating prevention strategies from the design phase onwards.

II. Collision Avoidance & Operations

This criterion evaluates whether procedures and technologies are in place to

avoid collisions with existing space debris or other operational assets. The scoring spectrum includes "Yes" if comprehensive measures like manoeuvring capabilities through on-board propulsion, transparency requirements, and communication protocols are fully addressed and integrated; "Partial" if some measures are addressed but not comprehensively integrated; and "No" if no measures are addressed.



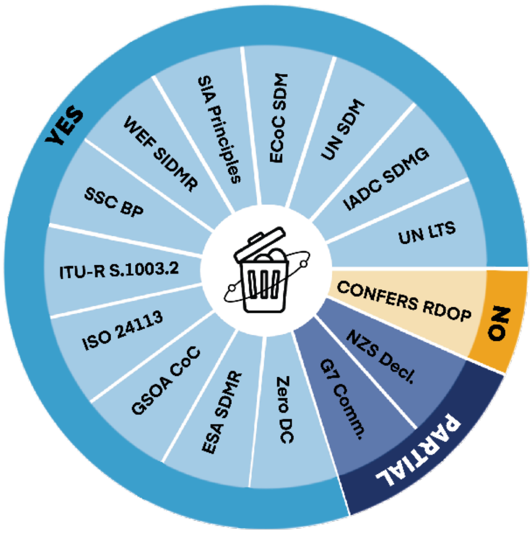
The key observations include the following:

- Most of the analysed initiatives do commit to addressing best practices, norms, design measures, and other commitments to reduce collision risks.

- Space debris mitigation instruments are placing **increasing focus on managing collision risks**, reflecting growing safety concerns.
- There is a stronger emphasis on **coordination between operators**, including data exchange, process development, and positional accuracy improvements.
- However, many **coordination measures remain generic, lacking concrete** and enforceable requirements, unlike those in traffic or aviation standards.

III. Orbital Clearance

This criterion measures the provisions for safe and efficient disposal of satellites or other spacecraft after their operational life, including post-mission disposal and satellites that go defunct during their mission. The scoring spectrum includes "Yes" if comprehensive measures for orbital clearance are fully addressed and integrated, "Partial" if some measures are addressed but not comprehensively integrated, and "No" if no measures are addressed.



The key observations include the following:

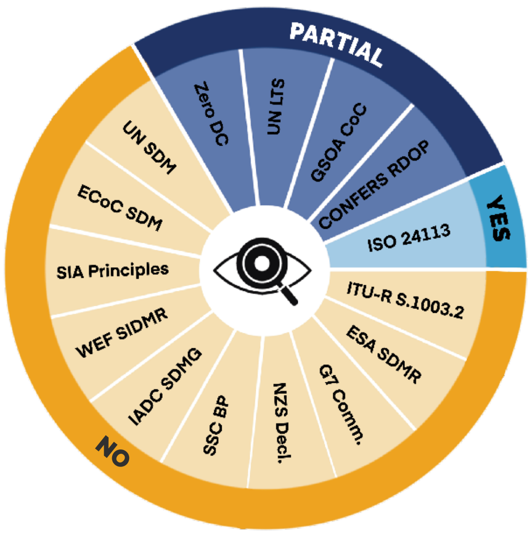
- **Largely recognised backbone of space debris mitigation**: Measures aiming to reduce presence of human-made in orbit, in the protected regions, are widespread in the analysed instruments. Such provisions have been also historically addressed through quantifiable thresholds, which, particularly for LEO, appear to be evolving to more stringent requirements (i.e. 5 years).

Structure criteria

This category examines the nature and weight of commitments made under the instrument. Criteria in this category evaluate whether the commitments include specific targets or are more general in nature. Additionally, the level of centralisation in the instrument's management and implementation is assessed, along with its ability to adapt and evolve over time.

IV. Compliance & Monitoring

This criterion deals with the degree to which entities adhere to the established benchmarks, and how effectively this compliance with the benchmarks is monitored and enforced. The scoring spectrum includes "Clear Provisions for Monitoring," where the instrument features robust, well-defined mechanisms such as comprehensive tracking systems, regular audits, and protocols ensuring consistent adherence. "Partial Monitoring" indicates the presence of provisions like information or data sharing that aid monitoring but do not create a comprehensive system, leading to gaps in enforcement. "No Monitoring Mechanisms" signifies an absence of formal systems to track compliance.

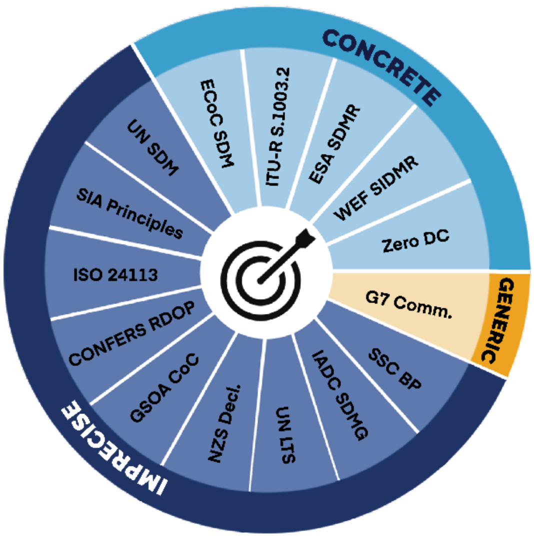


The key observations include the following:

- **Voluntary Nature**: Given the international nature of the analysed dataset, it is no surprise that most of the instruments lack substantive mechanisms for compliance verification. There are, however, relevant situations where the notion of compliance, verification or enforcement is integrated but through other means.
    - **Example**: The ISO system is built on certification and can be scrutinised via an audit; however, a negative outcome has no direct impact beyond the potential loss of certification. Nevertheless, this can realistically have grave consequences on a given entity but implemented by other actors. These can be national regulatory or supervisory authorities in charge of space activities (which may require adherence to ISO standards as a requirement to obtain or hold a required licence).
- The monitoring of the ESA Space Debris Mitigation Requirements (ESA SDMR) is governed by a different document: the ESA Space Debris Mitigation Policy. This document outlines the applicable requirements and clearly defines the roles and responsibilities involved. Although the ESA SDMR does not specifically mention procedural aspects, this document must be read in conjunction with the ESA SDM Policy to fully understand the implementation.
- In the overarching absence of robust internal monitoring schemes, transparency and requiring "proof of work" approach for assessing successful implementation remains infrequent.

V. Type of Commitment

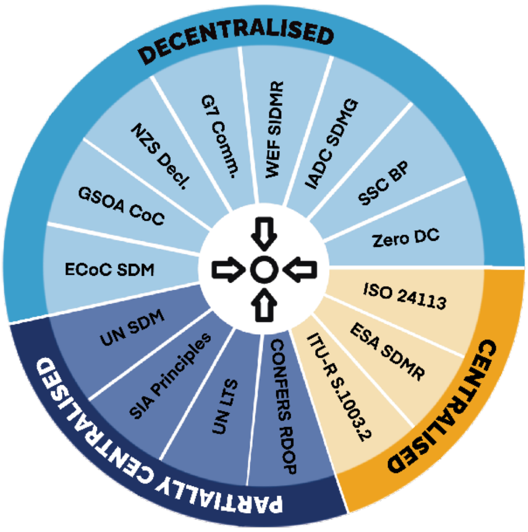
This criterion evaluates the nature and strength of commitments made under the instrument, specifically questioning whether they include specific targets or are more general commitments. The scoring spectrum ranges from "Open and Generic," where commitments are broad and non-specific, allowing for a wide interpretation and minimal accountability, to "Concrete and Defined," where commitments are clear and specific, including detailed targets and timelines for enhanced accountability. The "Somewhat Imprecise" score captures commitments that are not entirely vague but still contain ambiguities that may affect their interpretation and execution.



The key observations include the following:

- **Diverse Subjects of Commitments**: There is substantial diversity in the subjects of commitments across different initiatives. These can range from technical design considerations and operational norms to the establishment of specific guidelines and practices.
    - **Example**: The PPF Net Zero Space Declaration allows endorsees to define their commitments in support of Initiative's implementation themselves in view of shaping a diverse and engaged community.
- **Binding is Rare**: Most commitments are non-binding and lack an enforcement or built-in accountability mechanism.
    - There is a broad spectrum of commitment types, from very specific mandates to broad, flexible guidelines. This diversity of commitments likely reflects the need for flexibility and adaptability in addressing the evolving challenges of space debris.

VI. Degree of Centralisation

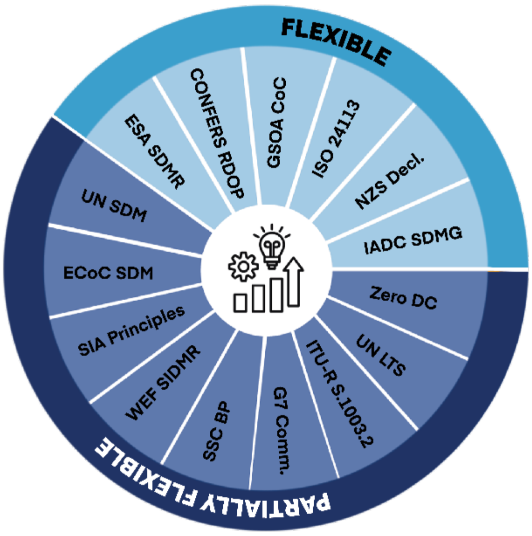


This criterion assesses the level of centralisation of the instrument's management and implementation. The scoring spectrum includes "Highly Centralised," where a single entity generally controls most aspects, indicating a top-down approach to management; "Highly Decentralised," which reflects a more distributed, multi-stakeholder approach allowing for broader input generation and diversity in decision-making; and "Partially Centralised," where there is a mix of centralised control and decentralised participation, balancing between a single authoritative body and shared active involvement.

The key observations include the following:

- At one end of the spectrum, there are **highly centralised mechanisms which rely on a mandated authority for decision-making and oversight of implementation**. On one hand, this generally provides uniformity, consistency, and efficient communication, however but the flexibility and adaptability to the rapidly changing space environment might be challenged as well as the generation of greater stakeholder participation, due to potential reservations of subscribing to mechanisms, which can be considered "owned" or managed by one key entity.
- On the other end, different mechanisms adopt a more **decentralised approach, relying on individual action from multiple participants, without a single overseeing authority.** This allows for a wide range of potentially unique strategies to be employed, encouraging innovation and adaptability to local contexts. However, the challenge is to maintain coherence and coordination among involved actors and to maximise impact beyond the declaratory level.

VII. Adaptability & Evolution



This criterion evaluates the instrument's ability to adapt to changing circumstances and evolve over

time, focusing on how it is set up in order to be able to be updated in response to new technology, increased knowledge, or changes in the space environment. The scoring spectrum is defined as "Flexible," where the instrument demonstrates high adaptability with mechanisms that readily incorporate new insights and technologies; "Inflexible," where the instrument shows little flexibility, lacking mechanisms to adjust to emerging changes; and "Partial," where the instrument exhibits some adaptability but may be limited in scope or slow to integrate changes.

The key observations include the following:

- Most initiatives entail the capability for recurrently updating their framework and provisions. Such adaptation often:
  - relies on the existence of internal processes recurrently gathering involved entities (e.g. annual meetings of endorsees, working groups)
  - comes in the form of major revisions and re-issues (IADC SDM Guidelines, or ISO 24113),

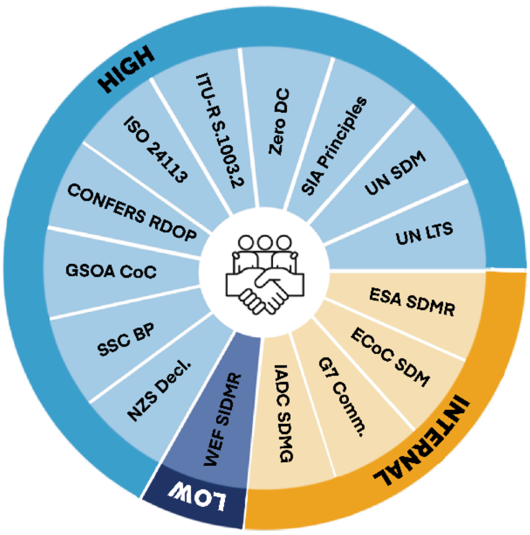
- A handful of initiatives in the research sample have been constructed through an ad-hoc approach, their adaptability appears less flexible, however, the emergence of such processes is not explicitly ruled out and may happen, similarly in an ad-hoc set-up.

Representation criteria

The Representation category focuses on the entities involved in the instrument. Criteria within this category measure the number and diversity of partners participating in the instrument, indicating the broad acceptance and impact it may have. The ease of access for new entities to join or for existing members to use and familiarise themselves with the instrument is also considered.

VIII. Number of Partners

This criterion evaluates the volume of entities participating in the instrument relative to the total amount of possible partners that could be part of the mechanism. It assesses whether a higher number of partners indicates broader acceptance and potential impact, while also considering the challenges it might present in coordination and decision-making. The scoring spectrum includes "High Fraction," where a significant proportion of possible partners are participating, indicating extensive buy-in; "Low Fraction," with a smaller proportion of partners involved, suggesting restricted acceptance or interest; and "Internal-Exclusive," where participation is almost entirely from specific exclusive groups, potentially limiting broader collaboration and diversity.



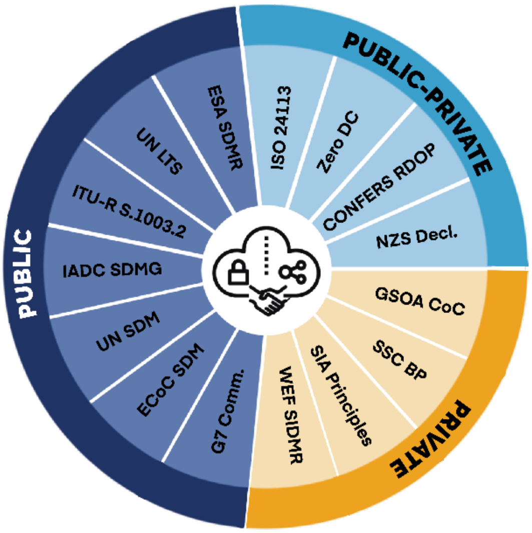
The key observations include the following:

- The number of partners involved in these initiatives varies significantly, pointing towards different strategies for engaging and managing stakeholder groups in space debris mitigation.
- Due to the multilateral framework under which they were developed, several initiatives feature broad global representation, Nevertheless, it is common that the development process is driven by just a handful of the most active actors.
- Frameworks targeting rather small partnership circles or groups constrained in their size (e.g. geographically) are relatively rare. This may reflect the global nature of space debris mitigation and remediation efforts, which, for the time being, necessitates a wide-scale, multi-participant strategy, paired with organisation-specific implementation, to be effective.

IX. Type of Partners

This criterion evaluates the diversity of entities involved in the instrument, considering whether partners are primarily national space agencies, private companies, international organisations, or a mix of these categories. The scoring spectrum is defined as "Public," where the primary participants are national space agencies or public sector entities; "Private," where the major contributors are private companies; and "Public-Private," where there is a balanced mix of public agencies and private companies, reflecting a collaborative approach between different sectors.

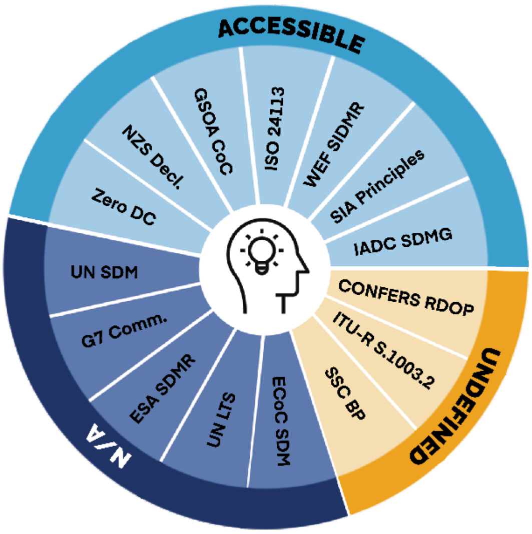
The key observations include the following:



- **Growing prevalence of a blend of public and private participation**. Most space debris mitigation instruments allow for some form of involvement of different stakeholder groups. Interestingly, this includes several cases where the decision-making process is strictly in the hands of public actors, but the respective frameworks enable formal generation of input and involvement also from private representatives (e.g. applicable both to IADC Space Debris Mitigation Guidelines and ISO 24113).
- **Emergence of Private "Self-Regulation":** Initiatives that are built primarily on private sector participation have been historically less common. This could be the effect of the historical role of governments in space activities, and their continued influence in setting standards and guidelines. However, several such mechanisms emerged lately and continue to attract new supporters.

X. Ease of Access

This criterion assesses the ease with which new entities can join or existing members can use and familiarise themselves with the instrument. It considers factors such as the clarity of guidelines, accessibility of information, and the process for joining. The scoring spectrum is categorised as "Clear," where guidelines are well-documented and information is easily accessible, simplifying the process for new members to join and for existing members to engage; "Undefined," where the guidelines and processes are poorly defined or inconsistently applied, making it challenging for members to understand or follow; and "Not Applicable," where the criterion of ease of access and usability does not apply possibly due to the instrument's nature or design.



- Most space debris mitigation frameworks do not have explicit or straightforward processes for potential participants to directly join. The issue of accessibility can pose a barrier to widespread adoption and compliance, potentially hindering the overall effectiveness of these initiatives in achieving their objectives.
- This analysis suggests an opportunity for improving accessibility through transparent, simplified pathways for participants.
    - **Example:** The Zero Debris Charter exemplifies best practice in this criterion. According to paragraph 3.2 of the Charter, "any entity demonstrating a strong commitment to advancing space safety and sustainability" can sign the Charter and join the Zero Debris Community "without requiring the agreement of existing partners."
- At the same time, actions to facilitate accessibility may also require strengthened scrutiny of new signatories and their commitment**.**

4 Temporal perspective - Insights on the evolution of debris mitigation provisions

The recent accelerated development of international instruments for space debris mitigation has significantly advanced beyond the foundational instruments of the early- to mid-2000s. Newer mechanisms have updated numerical requirements and introduced new concepts. The table below shows the evolution of numerical requirements in selected instruments, including the 2019-updated U.S. Orbital Debris Mitigation Standard Practices. The boxes highlighted in **yellow** indicate an evolution towards greater stringency, either in the overall context or regarding the evolution of an individual instrument.

Selected Mechanisms		Numerical Requirements											
		I. LEO Collision Probability	II. GEO Collision Probability	III.GEO Disposal Lifetime	IV. LEO Disposal Lifetime	V. Passivation Success Rate	VI. Casualty Risk (Re-entry)	VII. Accidental break-up probability	VIII. Propulsion Systems & Pyrotechnics	IX. Probability of successful disposal	X. Positional knowledge / accuracy	XI. Altitude requiring active maneuverability or COLA	XII. Operators' availability for Space Traffic Coordination
Original version of the IADC SDM Guidelines	2002			N/A ***100 years in the 2021 update***	25 years		≤0.0001			≥90			
European Code of Conduct for SDM	2004			25 years	25 years	≥90%	≤0.0001		Solid propellant/pyrotechnics >10µm avoided	>90%			
First issue of ISO 24113 Space debris mitigation requirements	2010			100 years	<25 years **Parallel call for reducing orbital lifetime significantly below 25y in the 2023 update**		<0.0001	<0,001	Pyrotechnics/ rocket debris >1 mm avoided	≥90%			
First release of Space Safety Coalition's Best Practices	2019	<0,00001 for non-GSO spacecraft above 400km		100 years	25 years	≥90%	<0.0001	<0,001		**95% GEO 95% LEO w/in 5y 99% LEOw/in 25y**	48h-predicted Knowledge within 500m in both LEO, MEO, and GEO	400km	...should exchange inform. on operator PoCs, ephemerides, ability to maneuver, and maneuver plans
SIA Principles of Space Safety	2019												24/7 PoC, timely sharing of SSA data
WEF's Space Industry Debris Mitigation Recommendations	2023				**≤5 years**					**95-99%**		**375km**	operators must answer all reasonable and legitimate requests … in timely manner
Updated ESA's Space Debris Mitigation Requirements	2023	≤0,0001 cumulated after end of life	≤0,0001 cumulated after end of life		**5 years max. depending on risk profile**	≥90%	<0.0001 *<0,000001 for spacecraft in const.*	<0,001	Pyrotechnics/ rocket debris >1 mm avoided	≥90%	higher than 100m / LEO Higher than 1000m / GEO	Required for spacecraft with natural decay > 5 years in LEO	Underlines operator's coordination e.g. "through the availability of PoCs"
Zero Debris Charter	2023, (targets for 2030)	**<0,001, over whole lifetime in orbit**	**<0,001, over whole lifetime in orbit**	Timely clearance	Timely clearance		<0.0001	<0,001, over whole lifetime in orbit		**≥99%**			
Updated U.S. Gov. Orbital Debris Mitigation Standard Practices	2019	<0.001 for objects 10cm and larger	<0.001 for objects 10cm and larger	100 years	25 years, **while preferring immediate removal**	should be depleted or safed when they are no longer required	<0.0001			≥90% with a goal of 99% or better			

4.1 Evolution of Numerical Requirements

The table above offers a categorisation of the numerical requirements identified within the various instruments evaluated in this study. It breaks down the quantified commitments for space debris mitigation, highlighting the specific measures proposed across different guidelines.

Recalling that the primary objective of this research is to identify key high-level evolutions in space debris mitigation measures, it shall be noted, that the **comparison is necessarily simplified due to numerous technical details and nuances** in wording often present in these instruments.

With that context in mind, below are the key observations on the **evolution of numerical requirements** for space debris mitigation:

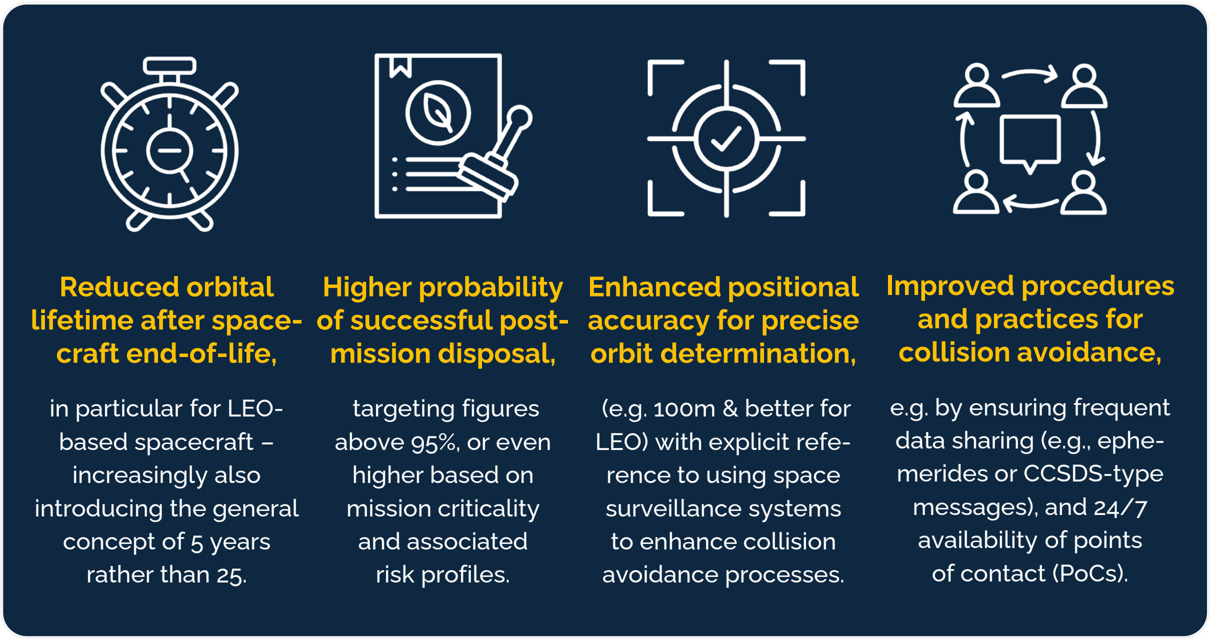


Figure 2: Key evolutions of numerical requirements in int. space debris mitigation instruments

Adding to this, it is noteworthy that most of the provisions appear to be expressed in probabilities, often around **10^{-3} or 10^{-4}**. This statistical outlook suggests that while the risk of an individual event is low, the **cumulative risk** could become significant if an increasing amount of spacecraft is deployed.

There may emerge a need to further **revise these probabilities** and aim for even lower risk levels, to ensure safety levels, should the space traffic continue to grow.

In understanding the details of provisions of individual mechanisms, it is important to consider the **temporal specificities of each instrument**. In this regard, while most of the instruments do not specifically address this aspect, the Zero Debris Charter took a unique approach to defining targets for a specific timeframe in the future (2030).

The widely acknowledged **25-year rule** for de-orbiting defunct satellites is notably evolving into **a significantly shorter timeframe (i.e. 5 years)**, likely soon reaching the status of a ***de facto*** standard, and producing reputational impacts. This calls upon actors engaged in international discourse, to consider, how the individual approaches might be harmonised or improved.

The growing presence of provisions related to positional accuracy highlights the continuous challenge of **detecting and tracking of space objects, especially small objects** (functional, nonfunctional or debris pieces). This challenge is poised to magnify with further deployment of very small satellites (e.g. CubeSats). Given the low manoeuvrability of most such satellites, there is a pressing need for measures that address this specific challenge, now and in the future.

Regarding the concept of **protected regions**, the classification of **Low Earth Orbit (LEO)** might require further refinement, potentially based on orbital parameters. Certain orbits within LEO are becoming "riskier" than others, warranting a more nuanced categorisation and possibly rules for different parts of the LEO environment.[5]

The overall tightening of provisions and elaboration of new requirements is also noticeable in updated releases of existing instruments, which has been the case in both:

- IADC Space Debris Mitigation Guidelines (e.g. explicit integration of 100-year rule for GEO disposal in its 2021 revision) and
- ISO Standard 24113 (comprehensive list of updates, including with stronger language in its latest 2023 release).

Interestingly, the analysis also reveals that new or updated instruments include **provisions that somewhat hint towards a measurable criterion but remain imprecise in doing so**, e.g. by using terms such as "timely" or "significantly below" a certain number. On one side, this clearly demonstrates a growing ambition, reflecting complex trade-offs and negotiations. On the other hand, it leaves major room for implementation, limiting the depth of global consensus.

4.2 New Trends and Concepts

Complementary to the evolution of specific numerical debris mitigation measures, the research also **identified major trends, recent developments and newly introduced concepts** in international soft law on space debris mitigation.

The emergence of these novel qualitative measures adds extra layers of protection and emphasises increasingly comprehensive approaches for effectively mitigating space debris. ESPI's key observations include:

1. **Emergence of special requirements and regimes for specific types of activities or technologies.** Notable examples include:
   a) **Tailoring of space debris mitigation requirements based on risk profiles** depending on a combination of criteria related to space mission design, under a philosophy that higher-risk missions are subject to stricter space debris mitigation requirements.
   b) **Tailoring of requirements based on capability of active manoeuvrability**, in particular in relation to orbital altitude, such as incorporating specific measures related to collision avoidance or post-mission disposal.
   c) **Specific rules for deployment and operation of large satellite constellations**, such as identifying disposal orbits below certain altitudes and setting specific requirements for recurring manoeuvrability capabilities.
   d) **Indications of new protected regions in the future**, such as lunar orbits[6], in response to the increasing activity in cis-lunar space and on the lunar surface.[7]

[5] As space traffic evolves, comparable need may arise in mid- to long-term future also for other orbits (MEO, HEOs).

[6] In similar reasoning, the Lagrange points in the Earth-moon system or the Sun–Earth system, could also be subject to such reflection.

[7] In this regard, the recent discussion at the 6th Summit for Space Sustainability, about increasing occurrence of collision warnings in lunar orbits, comes particularly relevant. For more information, please see Link.

2. **Laying of groundwork towards debris removal activities,** with a particular spotlight for cases including execution with the involvement of **external providers.**

3. **Emphasis on the preparation of different forms of "sustainability plans".**
These plans underscore the need to embed sustainability requirements right from the design phase to the operations and eventual disposal of satellites.

4. **Expansion of scope in debris-related instruments to encompass additional issues,** such as:
    a. **Environmental sustainability** of the space industry, in relation to its harmful environmental effects on Earth's environment,
    b. The **dark and quiet skies** agenda, addressing the impact of space infrastructures on science enabled by astronomical observations,
    c. Integration of **security-driven provisions** in space debris mitigation alongside safety and sustainability measures increases - this includes improved hardware and software design and enhanced resilience to consider the possibility of intentional threats.

In addition to these general trends, some particular examples can be mentioned such as CONFERS' emphasis on resilient design and anomaly resolution, ISO 24113's focus on comprehensive Space Debris Mitigation Planning and the Net Zero Space Initiative's push towards a circular space economy. Furthermore, the Space Safety Coalition and SIA underscore the importance of testing, protection, contact maintenance, and global standards.

Looking ahead – ESPI considerations about concepts to be further developed in international space debris mitigation efforts

While the scope of space debris mitigation instruments is increasingly comprehensive, this research also underlines the continuous need for effective foresight and horizon scanning activities, to ensure an effective further evolution of space debris mitigation efforts, including with Europe at the forefront of such actions.

In that light, ESPI outlines a **few themes and concepts**, which are not yet addressed in detail in the current body of international space debris mitigation instruments, **but which may increase in significance** in discourse related to space debris, as a result of trends within and beyond the space sector:

The place of military actors in space debris mitigation efforts, noting the increasingly profound security & defence dimension of space activities. This drives the growth of military space infrastructures, which may fall out of the scope of usual debris mitigation provisions, given inherent ties to national security.

Greater focus on incentivisation towards responsible space behaviour by policy and regulatory actions (in particular in the context of space activities conducted by commercial actors), to work hand in hand with "restrictive regulation".

Adaptation of space debris mitigation principles, practices and rules to the future of space exploration, in particular in relation to destinations and celestial objects foreseen to be subject to greater space traffic (as already evidenced by recent example of growing need of strengthened space safety in lunar orbits).

5 KEY TAKEAWAYS

5.1 Research Summary – Main Insights

In the light of continued safety & sustainability challenges posed by the proliferation of space debris, this study has demonstrated that:

1. There are strong indications of an expanding **globally shared effort** to address the risks and hazards posed by the proliferation of space debris, in view of broader ambitions towards preserving the utility and accessibility of the space environment.
2. This international **momentum is notably growing in ambition** as evidenced by **expanding scopes** of various instruments and the **increasing stringency** of their provisions, indicating the need to evolve to reflect contemporary realities.
3. While all stakeholder types (governments, agencies, industry, academia, and NGOs) are engaged in space debris mitigation (private actors visibly more in the past five years), they often act **within parallel frameworks and initiatives.**
4. In addition, while the **global consensus expands** in terms of participation, horizontal scope and stringency, **there is an outstanding need for its deepening** towards alignment on concrete implementation pathways.

Next to the study's primary focus on international instruments, **significant progress can be observed at the national level** in numerous countries in technology, regulation, and diplomacy. Additionally, with the exception of Europe, regional efforts are not widespread globally.

5.2 Towards Europe's leadership in space safety and sustainability: Three Final Considerations

Building on this analysis and complementary ESPI research on space safety and sustainability, this study puts forward three key considerations:

1. The accelerating adoption of more stringent space debris mitigation guidelines solidifies the pathway towards stricter regulatory landscapes.

As public actors continue to play a central role in space debris mitigation, with key mandates in regulating space activities, the substantial international progress in these efforts provides a credible critical mass to inform regulations at the national level. It can be anticipated that this will be further stimulated by a growing prioritisation of safety & sustainability themes in national space strategies (evidenced by complementary ESPI research) and Europe's policy ambitions in and beyond the space sector, to lead international rulemaking efforts in new tech fields based on "green" rationales.[8]

In encouraging space sustainability in future policy, regulatory and diplomatic actions, European actors will need to consider developing measures **without discouraging investment and reducing industrial competitiveness** in global comparative outlook.

More broadly, there is an outstanding question, in particular for the expert community on space safety & sustainability, on **how to build a narrative that puts this theme and related developments in a more positive light** (i.e. new developments enabling greater use of space and thus strengthening socio-economic benefits on Earth), rather than excessively accentuating concerns or warnings, spurring a negative perception of space even beyond the space community.

[8] Including in space-related policymaking at the EU level.

A paradigm shift towards stricter enforcement of environmental regulations

Both within and beyond the space sector, there appears to be a growing commitment of public actors to enforce various requirements related to "environmental issues". This can have a **sizeable impact on the evolution of space law and regulations** as the volume of court rulings related to questions of space law has remained limited, with low number of legal precedents. In terms of specific examples, this trend is exemplified by:

- FCC's fine against DISH for violating space debris mitigation rules. Remarkably, this is the first time such enforcement has been executed, creating a precedent with impact easily transcending national regulatory boundaries.
- The recent European Court of Human Rights' (ECHR) ruling that weak climate policies violate human rights is also significant in this context. While not directly applicable to space debris mitigation, it shows a broader trend towards rigorous enforcement of environmental protection at both national and international levels,

2. While the increasingly proliferated space debris mitigation landscape remains without comprehensive global consolidation, this situation offers leadership opportunities for Europe on the global stage.

The remarkable momentum for collective action on space sustainability remains disperse, and fragmented. Achieving alignment among different stakeholder groups, and translation into policy action remain critical tasks for more impactful space debris mitigation. For Europe, leadership in this area **must be substantiated by programmatic action,** ensuring that efforts are backed by concrete initiatives that drive meaningful progress.

In moving towards efficient and impactful consolidation of this diffused landscape, ESPI perceives **Europe as well positioned to take a more prominent and concerted action on the international scene**. This is primarily based on a credible policy momentum Europe currently has on the issues of space safety and sustainability, as evidenced by the following examples:

Policy, Programmatic, Operational	Best Practice, Regulatory, International
Enlargement of ESA's Space Safety Programme at CM19 and CM22, incl. with new missions (i.e. debris removal).	Growing international endorsement of the **Zero Debris Charter**, complemented by development of the **Zero Debris Technical Booklet**.
Continuous growth of the **EU SST Partnership's membership**.	Ongoing development work on an **EU-wide space law**.
Elaboration of an **EU approach to space traffic management.**	**Updating of national regulations** (e.g. the French Space Operations Act) with greater weight to safety & sustainability considerations.

While embracing the diversity of Europe's space ecosystem, the effort to shape and drive international agenda would greatly benefit from concerted European action. In the vision of advancing Europe's global leadership, there is an **opportunity for European stakeholders to strengthen collective buy-in in common initiatives**. Out of these, the seemingly deepening reach of the Zero Debris Charter, with recognised European handwriting, creates a **credible platform to act on this opportunity globally**, in synergy with other concurrent European initiatives. This study recognises the ongoing reflection in multiple states about the decision to sign or not sign the Charter, in the light of all perceived impacts (positive or negative). The "international positioning" element ought not to be diminished in these reflections.

3. Future international efforts can benefit from a multi-actor model, effectively integrating different stakeholder groups and producing credible impact on policy making.

The accumulation of space debris poses a significant challenge to space activities, akin to the global struggle against climate change and its induced effects on societies and economies. This global recognition spurred a formulation of credible international instruments and platforms.

One of them, the Intergovernmental Panel on Climate Change (IPCC) has demonstrated the power of scientific consensus in guiding policy and action on climate change. Its approach emphasises scientific integrity, inclusivity, policy integration, and global cooperation, providing a credible blueprint for space debris mitigation efforts.

Lessons learned from a collaborative model deployed by the IPCC

Like the IPCC, which has guided climate action since 1988 with scientifically backed reports, platforms such as the Zero Debris Charter cab offer an opportunity to expand this ambition towards uniting the global space community in achieving a zero debris future. Developed through inclusive workshops, it engages government agencies, industrial players, and academic institutions and its future development can follow some of best practices and success stories of the IPCC model and work.

Acknowledging the particularities of objectives in IPCC and ZDC efforts, the approach of the IPCC offers relevant lessons for tackling space debris, emphasising e.g.:

- **Building policy advice on the basis of scientific input with a rigorous review process**: IPCC Implements a multi-stage review system to ensure the credibility and transparency of information used to address policymakers.
- **Inclusivity and mandate empowered through a UN context:** The IPCC set-up benefits from a purpose and institutional context set forth by WMO and UNEP, promoting diverse input and broad participation in the governance scheme and work streams.
- **Recurrent productisation strengthened by a detailed approval procedure,** where key outputs (i.e. Reports from the recurrent assessment cycles) are reviewed and approved collaboratively in regular plenary sessions,
- **Enabling of responsive technical support** next to standing Working Groups (i.e. IPCC Task Forces), to ensure the capability to generate credible input on themes and issues suddenly increasing in importance.
- **Integrating communications and outreach functions** at local levels through national focal points, dedicated outreach activities towards a wider audience and formulation of specific guidelines on communicating IPCC work.

One of the main features underpinning the IPCC impact relies on a **functioning structure integrating the functions above**. Paragraphs 3.2 and 3.5 of the Zero Debris Charter can give it the competence to establish a similar structure. Paragraph 3.2 invites partners to regular exchanges, which can facilitate ongoing dialogue and review processes. Paragraph 3.5 encourages all partners to collaborate on the next steps beyond 2030, promoting a unified and continuous approach to tackling space debris.

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