UPDATE ON THE ISO SPACE DEBRIS MITIGATION STANDARDS

Hedley Stokes[(1)], Membership[(2)]

[(1)] Convenor, ISO TC20/SC14/WG7 (Orbital Debris Working Group), Email: hedley_stokes@msn.com
[(2)] ISO TC20/SC14/WG7 (Orbital Debris Working Group)

ABSTRACT

An update is provided on the ISO space debris mitigation standards, which have been developed through several editions over the past 20 years. The standards are organised in a hierarchical top-down structure. Primary requirements for different mission types are defined in a top-level standard, ISO 24113. Below ISO 24113 is a collection of lower-level standards and technical reports. These contain detailed requirements, implementation measures or engineering practices to help comply with the requirements in ISO 24113. The framework of standards is described briefly, before discussing each of the standards in turn. Key changes to the scope and technical requirements during the past five years are highlighted. Finally, suggestions are presented for future development of the standards.

1 INTRODUCTION

This paper provides an update on the family of space debris mitigation standards that have been under development within ISO since 2003.

The main purpose of the ISO debris standards is to transform guidelines and best practices from the IADC, the United Nations, spacecraft operators and regulatory bodies into a comprehensive set of debris mitigation requirements that can be used by the entire space industry worldwide. A key objective of the standards is to formulate requirements in such a way that they can be readily implemented in the contractual agreement between a customer and supplier. This helps to avoid differences in interpretation during the procurement of spacecraft or launch services. The ISO standards can also be used as the basis for national regulations on space debris mitigation, or they can be applied voluntarily. It is worth noting that the standards have already been used to guide a number of countries in their space activities, and so they now represent an important contribution in global efforts to address the space debris problem.

This paper discusses the main changes that have occurred in the family of ISO debris standards during the past five years or so and the rationale for the changes. In particular, some new requirements have been introduced into the top-level standard, ISO 24113 [1], in recognition of the rapidly evolving space environment, especially in low Earth orbit. A technical specification has also been published as a first step towards the development of a new standard containing debris mitigation requirements specific to large constellations. And, following industry feedback, the content of several of the lower level implementation standards has been consolidated to produce a smaller, more coherent set of supporting standards.

In terms of the way ahead, the paper discusses the latest thinking within ISO for how the debris mitigation standards might evolve. Aside from the usual considerations regarding the addition of stricter requirements to cope with the growing population of space debris, the possibility of a new framework structure for the standards is also presented. Efforts such as these will ensure that the ISO debris standards remain relevant and broadly applicable. Ultimately, the standards must create a level competitive environment for the entire industry whilst promoting the long-term sustainability of space activities in a fair and equitable manner. That is the key measure of their success.

2 CURRENT FRAMEWORK OF ISO DEBRIS STANDARDS

ISO organises the debris mitigation standards in a hierarchical structure, as shown in Fig. 1. All of the top-level requirements are contained in ISO 24113 the fourth edition of which was published in 2023. This is the most important debris standard. The requirements in ISO 24113 are intended to reduce the growth of space debris by ensuring that spacecraft and launch vehicle orbital stages are designed, operated and disposed of in a manner that restricts them from generating debris throughout their orbit lifetime. The requirements are also intended to reduce the casualty risk on ground associated with atmospheric re-entry of space objects. Below ISO 24113 in the hierarchy there are a number of lower level implementation standards and informative technical reports. These help to support compliance with the requirements in ISO 24113.

Since the publication of a previous update on progress [2], the ISO debris standards have completed a process of consolidation in which the content of five standards was reduced to two new standards, ISO 23312 and ISO 20893. The aim of this exercise was to produce a more concise and coherent set of documents thereby improving their usability and maintainability.

Proc. 9th European Conference on Space Debris, Bonn, Germany, 1–4 April 2025, published by the ESA Space Debris Office
Editors: S. Lemmens, T. Flohrer & F. Schmitz, (http://conference.sdo.esoc.esa.int, April 2025)

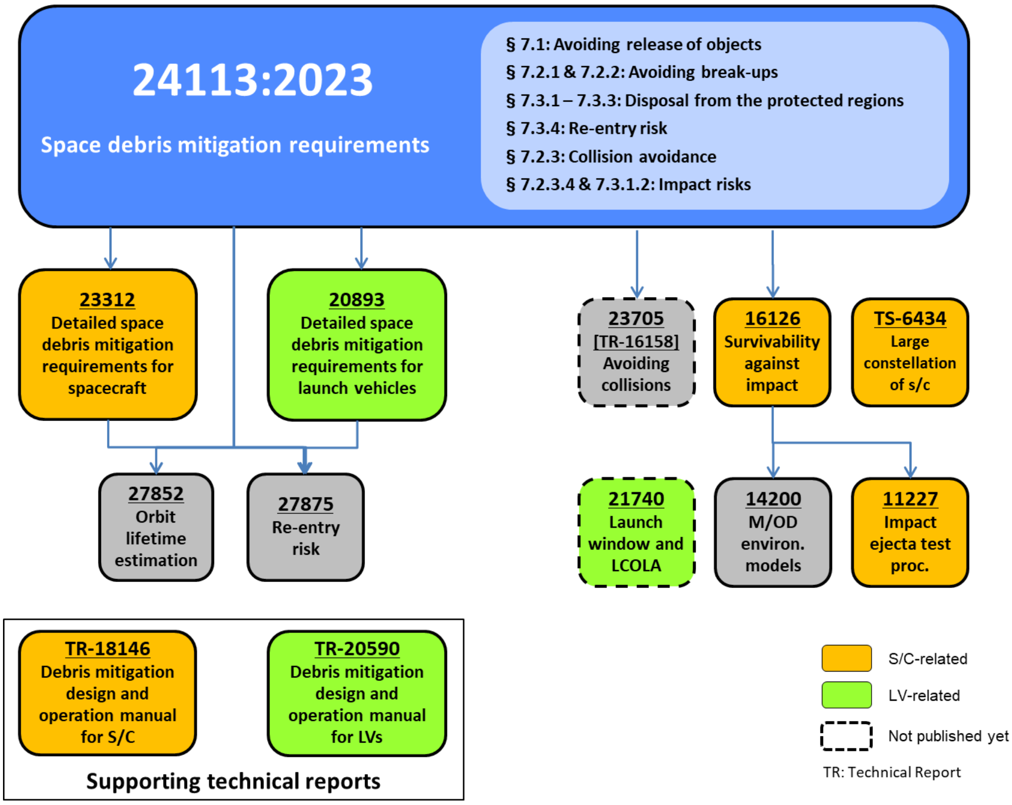

Figure 1. Current Framework of the ISO Debris Standards

3 STATUS OF ISO DEBRIS STANDARDS

This section reviews the status of the ISO debris standards, highlighting any updates to their scope or content during the past five years. The rationale for any changes is also discussed.

3.1 ISO 24113

ISO 24113 defines the primary space debris mitigation requirements applicable to all elements of unmanned systems launched into, or passing through, near-Earth space, including launch vehicle orbital stages, operating spacecraft and any objects released as part of normal operations.

The standard contains an effective and realistic set of measures focused on:

- Avoiding the release of objects during normal operations.
- Prevention of on-orbit break-ups.
- Post-mission disposal of spacecraft and orbital stages.
- Re-entry risk management.

ISO 24113 is the main interface for the user, bridging between the primary space debris mitigation objectives and a set of lower level standards and technical reports that support conformance. The lower-level documents contain detailed requirements and implementation measures associated with the high-level requirements in ISO 24113.

The 4th (2023) edition of ISO 24113 replaced the third edition published in 2019. It is worth noting that this relatively short time between editions is not typical. It is a reflection of the rapid growth occurring within the space economy and the consequential impact on the space environment. Among the changes implemented in the document were the following:

- Modifications to several of the terms and definitions to improve clarity.
- Modification of a clause requiring an assessment of the probability that a debris or meteoroid impact will prevent the successful disposal of a spacecraft; the scope was broadened to be applicable to all spacecraft rather than just those performing disposal manoeuvres.
- Modification of a clause requiring a reassessment of the capability of a spacecraft to perform successful disposal before extending its mission lifetime; it was clarified that the reassessment had to be done prior to any decision to extend the mission lifetime.
- Refinement of a clause requiring a pre-launch assessment of the hazard caused by the ground impact of any objects that are expected to survive re-entry.

- Specification of a 10^{-4} threshold for the expected number of casualties during the re-entry of a spacecraft or launch vehicle orbital stage.

The last change was a particularly important achievement for the document. Consensus on the introduction of a casualty risk threshold has taken approximately 20 years to reach. Overall, the changes between the 2019 and 2023 editions of ISO 24113 were relatively limited in number, but nevertheless continued to move the document in the direction of a stricter set of debris mitigation requirements.

3.2 ISO 23312

ISO 23312 [3] defines detailed space debris mitigation requirements and recommendations for the design and operation of unmanned spacecraft in Earth orbit. In particular, it defines detailed requirements that are applicable to:

- Avoiding the intentional release of space debris into Earth orbit during normal operations.
- Avoiding break-ups in Earth orbit.
- Disposal of a spacecraft after the end of mission.
- Estimating the mass of the remaining usable propellant.
- Developing and maintaining the space debris mitigation plan.

ISO 23312 was developed mainly by incorporating content from ISO 16127:2014, ISO 16164:2015, ISO 23339:2010 and ISO 26872:2019. These four standards were subsequently cancelled when the first edition of ISO 23312 was published in 2022. The consolidation exercise took several years to complete but was considered necessary based on industry feedback.

In summary, ISO 23312 acts as one of the supporting technical standards for space debris mitigation, providing implementation requirements and best practices to satisfy the top-level, spacecraft-related requirements in ISO 24113.

3.3 ISO 20893

ISO 20893, first published in 2021 [4], was developed to support the implementation of the high-level, launch vehicle orbital stage related requirements in ISO 24113. The standard contains a detailed and practical set of space debris mitigation requirements and recommendations relating to the design and operation of launch vehicle orbital stages in Earth orbit. Particular emphasis is placed on:

- Avoiding the release of space debris.
- Passivating a launch vehicle orbital stage after the end of its mission so as to avoid a break-up in orbit.
- Disposing of a launch vehicle orbital stage after the end of its mission so as to minimize interference with the protected regions.
- Safely re-entering a launch vehicle orbital stage.

During the early stage of its development, ISO 20893 incorporated content on the disposal of launch vehicle orbital stages from ISO 16699. Once the information was transferred, ISO 16699 was subsequently cancelled. This activity was part of the previously mentioned consolidation exercise.

3.4 ISO 27852

ISO 27852 [5] describes a process for the long-duration prediction of orbit lifetime for spacecraft and launch vehicle orbital stages in LEO-crossing orbits after the mission phase (including any mission lifetime extensions). Constraining estimated orbit lifetime of human-made objects is increasingly important as the space debris population continues to grow, and as such is one of the central tenets of the global space debris mitigation strategy.

The standard clarifies:

- Modelling approaches and resources for solar and geomagnetic activity modelling.
- Resources for atmosphere model selection.
- Approaches for spacecraft ballistic coefficient estimation.

ISO 27852 is a supporting document to ISO 24113 as well as ISO 23312 and ISO 20893. Its purpose is to provide a common, consensus-based approach to determining orbit lifetime, one that is sufficiently precise and easily implemented for the purpose of demonstrating conformity with ISO 24113, in particular requirements to limit the orbital lifetime. The document offers standardized guidance and analysis methods to estimate orbital lifetime for all LEO-crossing orbit classes.

The orbit lifetime estimation process is represented generically in Fig. 2. There are three basic analysis methods used to perform a long-duration orbit lifetime prediction. Method 1 utilizes a numerical integrator, Method 2 utilizes semi-analytic orbit theory, and Method 3 is simply a tabular lookup or graphical analysis approach.

The third edition of ISO 27852, published in 2024, replaced the second edition from 2016. The main technical changes were as follows:

- Clarified that the document does not apply to non-LEO regions above 2000 km (e.g. GEO).
- Harmonized terms and definitions with those in ISO 24113.

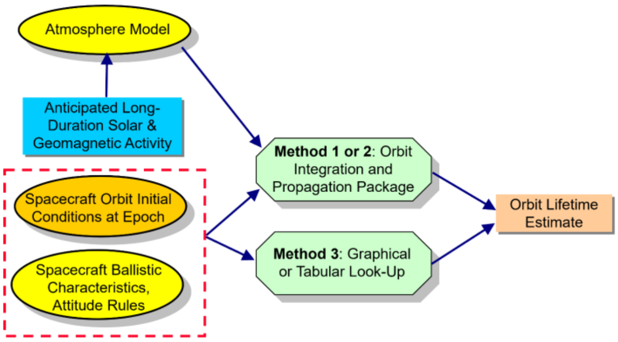

Figure 2. Orbit lifetime estimation process [5]

- Updated to harmonize with IADC and United Nations guidelines.

3.5 ISO 27875

ISO 27875 [6] provides a framework to assess, reduce, and control the potential risks posed by unmanned spacecraft and launch vehicle orbital stages when they re-enter the Earth's atmosphere and impact the Earth's surface. The standard focuses mainly on the estimation of casualty risk and the risk of on-ground pollution. It also presents requirements for when controlled re-entry would be conducted to reduce risk. Controlled re-entry is one of the best practices, upon mission completion, to mitigate both orbital debris and public risk on the ground. It involves the planned re-entry of a vehicle so that all surviving fragments impact a designated and unpopulated area on the surface of the Earth, such as over an ocean, in accordance with a specified probability.

ISO 27875 acts as part of a system safety programme based on ISO 14620-1 [7]. It is intended to be applied to the planning, design, and review of space vehicle missions for which controlled or uncontrolled re-entry is inevitable.

The standard is applicable to:

- Unmanned objects re-entering from orbit in conformance with ISO 24113.
- Launch vehicles (including payloads, other objects separated during the ascent phase, etc.) that are mentioned in flight safety activities under ISO 14620-2 [8].
- Interplanetary spacecraft returning to Earth.

The second edition of ISO 27875 was published in 2019. This was followed a year later by the issue of a minor amendment to the document. Work on the third edition of the standard is now underway with a target publication date of May 2026. A small number of important changes are currently being considered.

3.6 ISO 16126

ISO 16126 [9] defines requirements and procedures for analysing the risk that an unmanned spacecraft fails as a result of a space debris or meteoroid impact. In the first edition, published in 2014, the analysis procedures did not link to any requirements in the top-level standard, ISO 24113. High-level requirements relating to space debris impact risk had not yet been established in ISO 24113 at that time. This situation changed in 2019 with the addition of two such requirements in the third edition of ISO 24113. Thus, the second edition of ISO 16126, published at the end of 2024, provides a significant amount of new content aimed at satisfying the two high-level requirements. Specifically, ISO 16126 aims to:

- Maximise the survival of critical equipment required to perform post-mission disposal of an unmanned spacecraft.
- Limit the possibility of an impact-induced break-up of an unmanned spacecraft.

The analysis procedures in this standard are consistent with those defined in [10] and [11]. Fig. 3 summarises one of the procedures.

To assist users in implementing the procedures, a substantial quantity of background information has been added to a set of annexes in the document. This includes:

- Methods and models for analysing the impact risk from small debris.
- Ballistic limit equations.
- Guidance for implementing impact protection on a spacecraft.
- Examples of advanced shielding for unmanned spacecraft.
- Typical environmental constraints for shield materials.

In principle, this document can also be used to assess the impact survivability of an unmanned spacecraft in support of other mission objectives. However, careful adaptation of the document might be necessary if put to such use.

3.7 ISO 14200

Every spacecraft in Earth orbit is exposed to impacts from micrometeoroids and man-made space debris. Over the past thirty years or so, a number of environment models have been developed to describe the populations of these objects. Such models can be used to estimate the impact fluxes that a spacecraft might experience in a particular orbit. This information

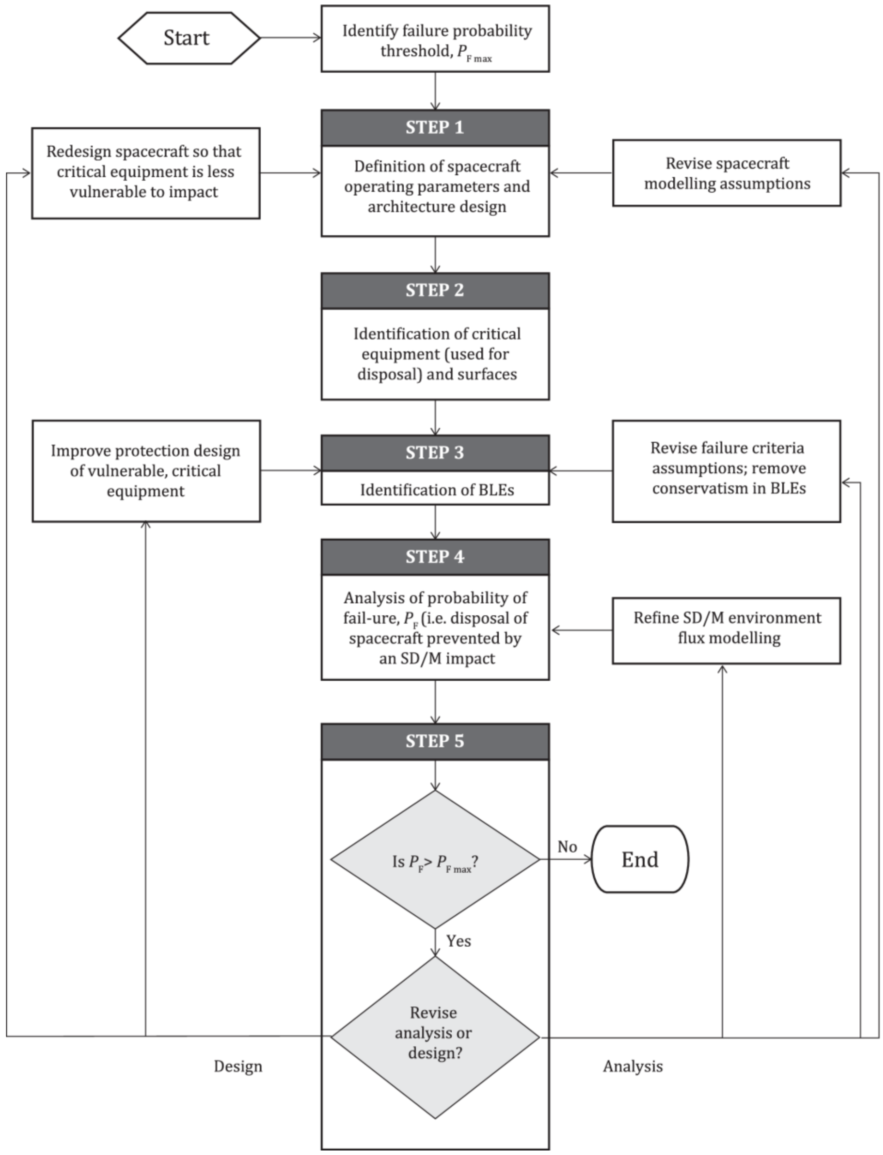

Figure 3. Summary of an impact risk analysis procedure in ISO 16126 [9]

can help with orbit selection, prediction of the frequency of collision avoidance operations, and impact risk analysis and protection design.

The environment models use a variety of different mathematical and physical methods to generate the populations. Whilst there is reasonable agreement between the models, differences do exist and it has not yet been possible to produce a standardised model of the space debris and micrometeoroid environment for use by the space industry. This is a challenge that needs to be addressed. In the meantime, ISO 14200 [12] offers a common process for selecting and implementing micrometeoroid and space debris environment models.

The second edition of ISO 14200 was published in 2021 to replace the first edition (ISO 14200:2012). The main changes were as follows:

- Focus on models that have been developed primarily for assessing impact fluxes that can subsequently be used in impact risk analyses, as described in ISO 16126.
- Updated information on space debris environment models in the annexes.

3.8 ISO 11227

ISO 11227 [13] describes an experimental procedure for assessing the behaviour, under orbital debris or meteoroid impacts, of materials that are intended to be used on the external surfaces of spacecraft and launch vehicle orbital stages. This standard provides a unified method by which to rank surface materials. The ejecta production characteristics of different materials are compared under standardized conditions in which test parameters are fixed to one number.

In particular, ISO 11227 establishes requirements for test methods to characterize the amount of ejecta produced when a surface material is impacted by a hypervelocity projectile. The purpose is to evaluate the ratio of ejecta total mass to projectile mass, and the size distribution of the fragments. These are necessary inputs for modelling the amount of impact ejecta that a surface material might release during its orbital lifetime. The suitability of the material for use in space, in terms of debris ejecta production, can then be quantified.

The first edition of ISO 11227 was published in 2012 and underwent a minor amendment in 2021 to include consideration of oblique impacts on external surfaces. Work on the second edition is ongoing with publication expected in January 2026. This new edition will be a relatively minor revision. Further into the future it would be desirable to enhance the annexes with information on other ejecta models and examples of ejecta data arising from impact tests and models.

3.9 ISO 23705

ISO 23705 [14] is a new standard being developed to replace ISO/TR 16158, which is a Technical Report containing non-normative information on collision avoidance. ISO 23705 provides the workflow and technical requirements for perceiving, evaluating, and avoiding collisions among orbiting objects, and data requirements for these tasks. The document also identifies techniques that can be used to estimate the probability and/or consequence of collision, and provides guidance and requirements for executing collision avoidance manoeuvres.

The process begins with obtaining orbital data from observations provided by spacecraft operators or sensor systems developed for this purpose. Spacecraft orbits can be compared with each other to discern physically feasible approaches that could result in collisions. The trajectories so revealed can then be examined more closely to estimate the probability of collision. Where the possibility of a collision has been identified within the criteria established by each spacecraft operator, the spectrum of feasible manoeuvres is examined.

The avoidance process begins with obtaining the best possible positional information on all potentially conjuncting objects obtained from a combination of spacecraft operator and/or Space Traffic Coordination systems. The format of this content is specified in ISO 26900 [15]. The data can be provided by collaborating spacecraft operators and from entities with the capability to track space objects in certain orbital regions. It is also important to know the nature of each object if possible. This information includes size, mass, geometry, and the operational state (e.g., active or inactive).

Collision probability estimates consider the inevitable imprecision associated with orbit determination and propagation. This information then allows decision makers to take an effective course of action, as shown in the top-level workflow contained in Fig. 4.

ISO 23705 has currently reached the Draft International Standard stage in its development. The target date for publication of the first edition of the document is set at May 2026.

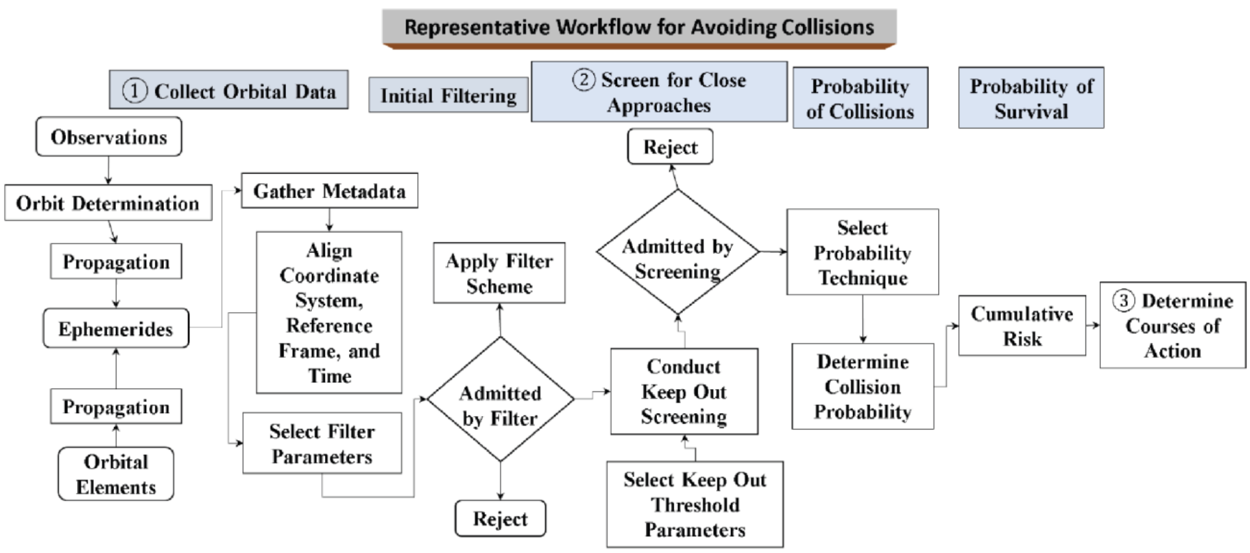

Figure 4. Top-level collision avoidance workflow [14]

3.10 ISO 21740

Human-inhabited and inhabitable space stations and space capsules are exposed to the risk of collision with new launch vehicle stage(s) and spacecraft during their launch and early orbit phase. While such collision hazards also exist during on-orbit spacecraft operations, the launch and early orbit phase is unique in that potential collisions with inhabitable space stations and space capsules can be avoided at minimal cost (i.e. without the expenditure of on-orbit manoeuvring fuel) through the proper selection of suitable launch times.

Consistent with Clause B.5 of the United Nations long term space sustainability guidelines [16], and to protect human missions from the danger of collision with newly launched objects, the LCOLA approving agent may apply launch collision avoidance (LCOLA) methods to assess either collision risk, close approach, or both. If this assessment determines that launch at certain times would incur unacceptable risk to the human missions, the LCOLA approving agent may delay the time of launch.

ISO 21740 [17] establishes the general safety launch collision avoidance (safety LCOLA) requirements for the avoidance of collision between the collection of newly launched objects resulting from a space launch (including launch vehicle stage(s) and payloads or released objects) and human-inhabited or human-habitable space stations and space vehicles. Strictly speaking, the standard is a safety measure rather than a measure against debris generation.

In particular, ISO 21740 specifies the requirements for the analysis of launch times and procedures for identifying safe launch opportunities. Fig. 5 illustrates how the trajectory resulting from a lift-off event is very dependent upon the launch time.

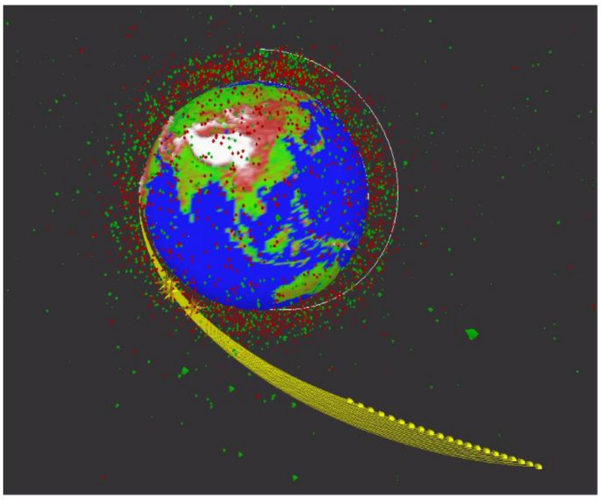

Figure 5. Illustration of how the launch time affects the launch trajectory [17]

ISO 21740 also describes the assessment and constraints for collision avoidance risk evaluation metrics (launch collision probability and standoff distance). Within the document's annexes, supporting information is provided on algorithms, processes, and screening criteria that may be used to conduct assessments for safety LCOLA as well as mission assurance LCOLA.

ISO 21740 is a new standard in development, the first edition of which is due to be published by May 2025.

3.11 ISO/TS 6434

ISO/TS 6434 [18] provides requirements that are either unique or particularly relevant to large constellations of spacecraft operating in the LEO protected region throughout their life cycle, including planning, designing, testing, operating and disposal activities. As such the document has a broader scope than just space debris mitigation, although this is still the focus. The requirements in the document are applicable to large constellation owners or the manufacturers or operators under their responsibility.

A number of large constellations are currently being sent into orbit at a rapid pace and several more constellations are due to follow in the coming years. While space-based services from large constellations can provide societal benefits to humanity, they can also put pressure on the orbital and electro-magnetic environments, introducing mission design, hardware design, launch, operations and disposal challenges to other operating space assets and the long-term sustainability of space activities. ISO/TS 6434 provides a set of standard practices throughout the large constellation life cycle to promote safety on the ground from re-entry hazard and long-term sustainability of space operations.

In developing this document, several external sources of information were considered, including:

- Practices of the existing large constellation programs.
- Consensus in the Space Safety Coalition [19].
- The "Statement on Large Constellations" [20] of the Inter-Agency Space Debris Coordination Committee (IADC).
- The UN "Guidelines for the Long-term Sustainability of Outer Space Activities" [16].

It should be noted that ISO/TS 6434 is a new document; the first edition was published in January 2024. Furthermore, it is a Technical Specification (TS) rather than an International Standard. According to ISO, *a Technical Specification addresses work still under technical development, or where it is believed that there will be a future, but not immediate, possibility of agreement on an International Standard. A Technical Specification is published for immediate use, but it also* *provides a means to obtain feedback. The aim is that it will eventually be transformed and republished as an International Standard.* ISO/TS 6434 falls within the category of a TS as consensus has yet to be reached on several aspects of its content. Some examples of clauses that remain open for discussion are as follows:

- Selection of orbit of constellation considering collision risk with neighbouring constellations. The clause requires that neighbouring constellations avoid interacting with each other, e.g. by radial separation, but no threshold has been agreed yet. Current opinion seems to favour the definition of a collision probability limit rather than a minimum radial separation. This is to avoid the possibility of constellations blocking other users from a particular orbital region.
- Design for post-mission orbital lifetime. The clause limits a constellation spacecraft's post-mission orbital lifetime to be the same as its design life, up to a maximum of 5 years. The long-term environmental consequences of widespread adoption of this requirement are not completely understood. In practice, some constellation operators are aiming to achieve much shorter deorbit lifetimes than this.
- Predicted probability of successful disposal. The clause requires constellation spacecraft to maximize the probability of successful disposal to be greater than 95% with a goal of 100%. Whilst stricter than the 90% threshold specified in ISO 24113, the 95% threshold is somewhat arbitrary and has not been formally endorsed by the IADC. Furthermore, the specification of a 100% goal within a requirement is not entirely meaningful.
- Safe re-entry. It is required that re-entering objects do not pose a significant threat to people, property, or the environment, aggregated over the entire constellation, commensurate with the safety thresholds set by an approving agent. This is a rather weak statement as it is written in a way that is not measurable or verifiable. The question of defining a suitable re-entry casualty risk value, either on a per spacecraft basis or on an aggregated basis, has not yet been settled.
- Test and checkout before injecting into the planned orbit. The clause requires constellation spacecraft to be deployed into a checkout orbit with a natural orbit lifetime shorter than 5 years. This is to confirm the spacecraft is free of initial defects prior to it being raised to its operational orbit. There is some debate about whether it is necessary for every member of a constellation to be placed into a check-out orbit or whether it is only necessary for initial batches of spacecraft to be tested. Also, the clause does not mention the need for a check-out orbit to be chosen in a way that minimises the collision risk with inhabited spacecraft in orbits nearby.

Matters such as these will need to be addressed before ISO/TS 6434 can become a standard. It is also possible that some of the content may be transferred into ISO 24113.

3.12 ISO/TR 18146

ISO/TR 18146 [21] contains information on design and operational practices for spacecraft to support the mitigation of space debris. It is a Technical Report, and so it provides only non-normative information. The document seeks to facilitate the implementation of spacecraft-related requirements in the preceding standards through the provision of debris mitigation activities applicable at system level, subsystem level and component level in all phases of the spacecraft lifecycle.

The second edition of ISO/TR 18146 was published in 2020. Work is currently underway to update the content so that it remains aligned with the latest editions of the ISO debris standards. Publication of the third edition of this document is due by January 2026.

3.13 ISO/TR 20590

ISO/TR 20590 [22] is a very similar document to ISO/TR 18146 but with the focus being on launch vehicle orbital stages instead of spacecraft. The second edition was published in 2021 and is now due to be updated to ensure alignment with the latest editions of the ISO debris standards. Publication of the third edition is expected by January 2027.

4 FUTURE ACTIVITIES

4.1 ISO 24113

With the publication of the 4th edition of the top-level debris standard, ISO 24113, in 2023, attention turned very quickly to consider a range of possible changes that might be included in the next edition. This is a reflection of the fact that the space industry is growing rapidly and, as a result, the Earth orbital environment is becoming increasingly populated and polluted. Normally, a period of several years would pass before commencing such an activity.

Tab. 1 illustrates some of the more interesting and contentious change proposals that are currently being debated within ISO. If consensus can be reached on a reasonable number of these then it is conceivable the 5th edition of ISO 24113 could be published by 2027.

Table 1. Change proposals being considered for the 5th edition of ISO 24113

Clause in ISO 24113	Examples of change proposals under consideration within ISO
Accidental break-up caused by a collision	Extend the requirement for 'GEO spacecraft to have a recurrent manoeuvre capability' to other orbits and classes of spacecraft
	Add a requirement to assess the aggregate probability of collision of non-manoeuvrable spacecraft of a large constellation with trackable debris, and take appropriate mitigation measures if a threshold is exceeded
Provisions for successful disposal	Change the probability of successful disposal threshold from 0.9 to '0.9 with a goal of 1.0'
	Include micrometeoroids and space debris impact risk in the assessment of probability of successful disposal
	Add a requirement for the spacecraft in a LEO large constellation to be placed into a check-out orbit
	Add a requirement for the spacecraft in a LEO large constellation to achieve a probability of successful disposal of at least 0.95
Disposal to minimize interference with the GEO protected region	For spacecraft operating in GEO with a periodic presence, extend the disposal requirement to cater for missions in HEO or inclined GEO
Disposal to minimize interference with the LEO protected region	Reduce the 25-year LEO post-mission deorbit lifetime, e.g. to 5 years
Re-entry	Add a threshold for the re-entry casualty risk of the spacecraft in a LEO large constellation, e.g. aggregated over the entire constellation

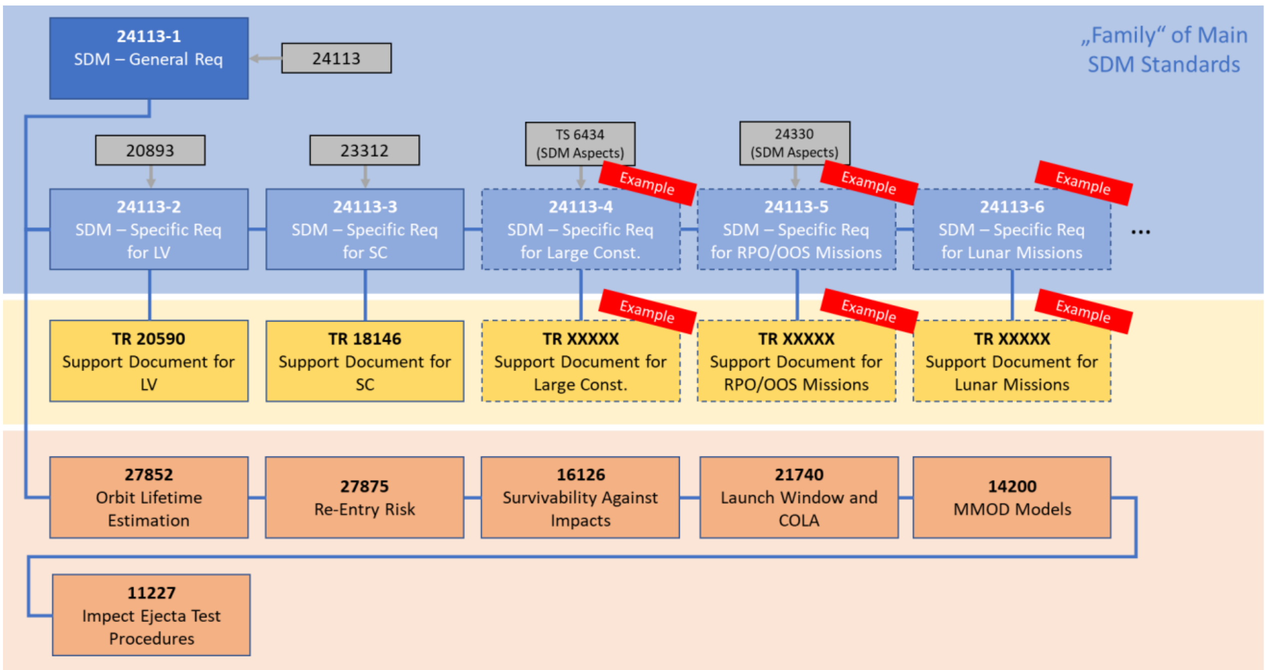

Figure 6. Possible new framework of the ISO debris standards

4.2 Possible Changes to the Framework of ISO Debris Standards

The requirements in the ISO space debris mitigation standards follow a logical top-down structure, as shown in Fig. 1. Recently, there has been a proposal to modify this framework so that ISO 24113 would become a multi-part standard. The idea is to move the existing content of ISO 24113, i.e. the high level requirements, into ISO 24113-1 (Part 1). Similarly the content of the two main supporting standards, ISO 20893 and ISO 23312, would be transferred into ISO 24113-2 (Part 2) and ISO 24113-3 (Part 3), respectively. This process could then be extended to other debris-related standards so that a new framework might be constructed, as depicted in Fig. 6.

There are a number of advantages to this approach, including:

- Making greater use of the existing ISO 24113 "brand awareness". This debris standard is the most well-known and widely used in the industry.
- Providing greater clarity in the relationship between the standards of this family.
- Providing pre-tailoring depending on the mission type, i.e. selecting only the parts you need.
- Specific requirements can be locally developed and maintained whilst keeping the rest of the requirements untouched.
- Improved synchronisation in the scheduling of parts that need to be revised.

A decision about whether to proceed with this proposal is likely to be made prior to formal commencement of work on the 5th edition of ISO 24113.

5 SUMMARY

This paper provides an update on the ISO space debris mitigation standards that have been continually developed over the past 20 years. The paper begins with a brief description of the framework of standards, the organisation of which follows a hierarchical top-down structure. Primary requirements are defined in a top-level standard, ISO 24113. Below that is a collection of lower-level standards and technical reports containing detailed requirements, implementation measures and engineering practices. These provide the ways and means to help comply with the high-level requirements in ISO 24113.

In the main part of the paper the scope and technical requirements in each standard are discussed. Particular emphasis is placed on important changes that have been introduced during the past five years.

Finally, the paper presents suggestions for future development of the standards. These include amendments and additions to the requirements in ISO 24113 and the possibility of turning this document into a multi-part standard.

6 REFERENCES

1. ISO 24113. *Space systems — Space debris mitigation requirements*.
2. Stokes, H., Akahoshi, Y., Bonnal, C., Destefanis, R., Gu, Y., Kato, A., Kutomanov, A., LaCroix, A., Lemmens, S., Lohvynenko, A., Oltrogge, D., Omaly, P., Opiela, J., Quan, H., Sato, K., Sorge, M. & Tang, M. (2019). Evolution of ISO's Space Debris Mitigation Standards. *Journal of Space Safety Engineering*. **7**(3), 325-331.
3. ISO 23312. *Space systems — Detailed space debris mitigation requirements for spacecraft*.
4. ISO 20893. *Space systems — Detailed space debris mitigation requirements for launch vehicle orbital stages*.
5. ISO 27852. *Space systems — Estimation of orbit lifetime*.
6. ISO 27875. *Space systems — Re-entry risk management for unmanned spacecraft and launch vehicle orbital stages*.
7. ISO 14620-1. *Space systems — Safety requirements — Part 1: System safety*.
8. ISO 14620-2. *Space systems — Safety requirements — Part 2: Launch site operations*.
9. ISO 16126. *Space systems — Survivability of unmanned spacecraft against space debris and meteoroid impacts for the purpose of space debris mitigation*.
10. Inter Agency Space Debris Coordination Committee. *Protection Manual*. (2018). IADC-04-03. Version 7.1.
11. Inter Agency Space Debris Coordination Committee. *Spacecraft Component Vulnerability for Space Debris Impact*. (2018). IADC-13-11. Version 1.0a.
12. ISO 14200. *Space environment (natural and artificial) — Process-based implementation of meteoroid and debris environment models (orbital altitudes below GEO + 2 000 km)*.
13. ISO 11227. *Space systems — Test procedure to evaluate spacecraft material ejecta upon hypervelocity impact*.
14. ISO 23705. *Space systems — Identifying, evaluating, and avoiding collisions between orbiting objects*.

15. ISO 26900. *Space data and information transfer systems — Orbit data messages*.

16. United Nations Committee on the Peaceful Uses of Outer Space. *Guidelines for the Long-term Sustainability of Outer Space Activities*. (2021). A/AC.105/C.1/L.366.

17. ISO 21740. *Space systems — Launch window estimation and collision avoidance*.

18. ISO/TS 6434. *Space systems — Design, testing and operation of a large constellation of spacecraft*.

19. Space Safety Coalition. *Best Practices for the Sustainability of Space Operations*. (2021). https:// spacesafety.org/ best -practices.

20. Inter Agency Space Debris Coordination Committee. *IADC Statement on Large Constellations*. (2021). IADC-15-03. Rev1.1.

21. ISO/TR 18146. *Space systems — Space debris mitigation design and operation manual for spacecraft*.

22. ISO/TR 20590. *Space systems — Space debris mitigation design and operation manual for launch vehicle orbital stages*.