TECHNICAL REPORT

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Space systems - Debris mitigation design and operation manual for launch vehicle orbital stages

Systèmes spatiaux - Conception pour l'attenuation des débris et manuel d'utilisation à étages orbitaux pour les véhicules de lancement

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Foreword

The International Organization for Standardization (ISO) is a worldwide federation of national standards bodies (ISO member bodies). International Standards are generally prepared by ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to represent that committee. International organizations, both governmental and non-governmental, in liaison with ISO, also take part in the work.

ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to the conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT).

The committee responsible for this document is ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operations*.

Introduction

Coping with debris is essential to preventing the deterioration of the orbital environment and ensuring the sustainability of space activities. Effective actions can also be taken to ensure the safety of those on the ground from re-entering objects that were disposed of from Earth orbit.

ISO 24113 “Space debris mitigation requirements,” and other ISO documents, introduced in Clause 4, were developed to encourage debris mitigation. Table 1 shows those requirements together with the recommendations in the United Nations Space Debris Mitigation Guidelines and the Inter-Agency Space Debris Coordination Committee (IADC) Space debris guidelines referred to in the United Nations (UN) guidelines.

Table 1 lists the main debris mitigation requirements defined in the standards and compares them to equivalent recommendations published by the UN and the IADC.

In Clause 5, the main space debris mitigation requirements are reported and analyzed.

In Clause 6, the guidance for life-cycle implementation of space debris mitigation related activities are provided.

In Clause 7, the system level aspects stemming from the space debris mitigation requirements are highlighted; while in Clause 8, the impacts at subsystem and component levels are detailed.

In this document, where the content is not directly required by existing ISO Standards but considered relevant to launch vehicle orbital stages operations or design and debris mitigation, it is labelled as “[Information].”

Table 1 — Comparison of ISO debris-related documents with UN and IADC space debris mitigation guidelines

	Measures		ISO Standards (or Technical Reports)	UN Guidelines	IADC Guidelines
Limiting debris generation	**Released objects**	General measures for avoiding the release of objects	**ISO 24113, 6.1.1**	Recommendation-1	5.1
		Slag from solid motors	**ISO 24113, 6.1.2.2, 6.1.2.3**	--	--
		Combustion products from pyrotechnics	**ISO 24113, 6.1.2.1** (Combustion Products < 1 mm)	--	--
	On-orbital break-ups	Intentional destruction	**ISO 24113, 6.2.1**	Recommendation-4	5.2.3
		Accidental break-ups during operation	**ISO 24113, 6.2.2** (Probability < 10^{-3})	Recommendation-2	5.2.2 (Monitoring)
		Post-mission break-up (Passivation, etc.)	**ISO 24113, 6.2.2.3** (Detailed in ISO 16127)	Recommendation-5	5.2.1
Disposal at end-of-operations	**GEO**	Reorbit at end of operation	**ISO 24113, 6.3.2** (Detailed in ISO 26872) 6.3.2.1: General Requirement 6.3.2.2: 235 km+ (1 000•Cr•A/m), e < 0,003 6.3.1: Success Probability > 0,9	Recommendation-7 (No quantitative requirements) Note: ITU-R S.1003-1 recommends; 235 km + 1,000 *Cr*A/M* Here, A[m^2], M[kg], Cr[-]	5.3.1 235 km+ (1 000•Cr•A/m), e < 0,003
	LEO	Reduction of orbital lifetime	**ISO 24113, 6.3.3** (Detailed in ISO 16164, 16699) 6.3.3.1: Orbital lifetime after end of operation < 25 years 6.3.1: Success Probability > 0,9	Recommendation-6 (No quantitative requirements)	5.3.2 (Recommend 25 years)
		Transfer to out of protected region	**ISO 24113, 6.3.3.2 (f)** (Guarantee 100 years of non-interference)	Mentioned in Recommendation-6	5.3.2
		Other options	**ISO 24113, 6.3.3.2 (a) ~ (e)**	--	5.3.2
Re-entry		Avoidance of ground casualties	**ISO 24113, 6.3.4** (Detailed in ISO 27875)	Included in Recommendation-6	5.3.2
Collision avoidance for large debris			**ISO/TR-16158** (for assessment only)	Recommendation-3	5.4
Protection from the impact of micro-debris			**ISO 16126** (for assessment only)	--	5.4

Space systems - Debris mitigation design and operation manual for launch vehicle orbital stages

1 Scope

This document contains non-normative information on the design and operational practices for launch vehicle orbital stages for mitigating space debris.

This document can be used to guide engineers in the application of the family of space debris mitigation standards (see 4.2) to reduce the growth of space debris by ensuring that launch vehicle orbital stages are designed, operated, and disposed of in a manner that prevents them from generating debris throughout their orbital lifetime.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 10795:2011 and the other standards listed in 4.2, 4.3, and 4.4 apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

4 Related documents and abbreviated terms and symbols

4.1 Overview of ISO debris-related standards

The requirements, recommendations, and best practices for mitigating debris generation and preventing other debris related problems are examined in this clause.

Figure 1 shows a general diagram of major ISO documents related to debris.

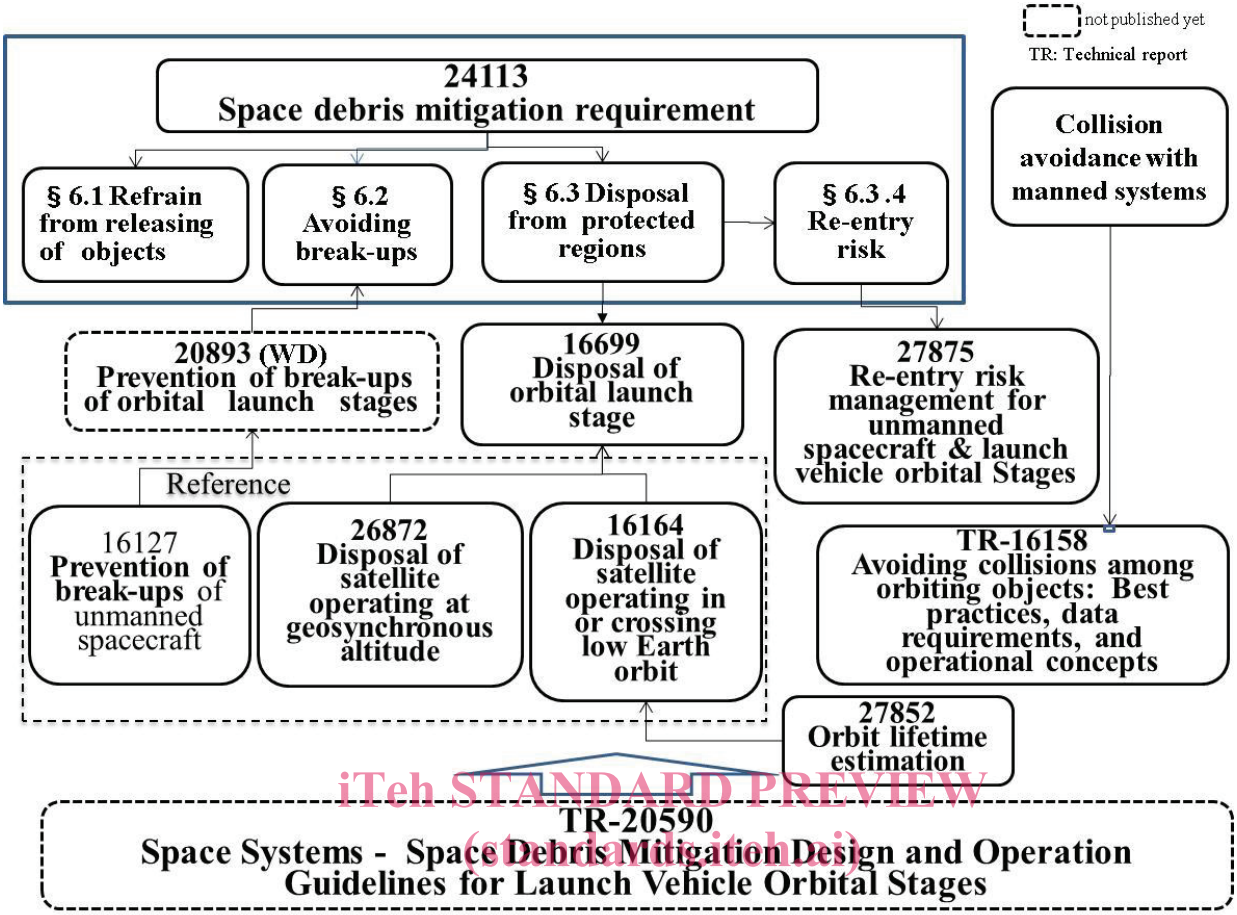

Figure 1 — Structure of major debris related standards for orbital stages

4.2 ISO debris-related standards for launch vehicles as of 2016

The following ISO Standards have been developed to address space debris mitigation. Readers are expected to confirm the most up to date list of ISO standards (available at http://www.iso.org/iso/store.htm. Also for 4.3 – 4.5).

(1) ISO 24113:2011, *Space systems — Space debris mitigation requirements*

(2) ISO 27852:2011, *Space systems — Estimation of orbit lifetime*

(3) ISO 16699:2015, *Space systems — Disposal of orbital launch stages*

(4) ISO 20893, *Space systems — Prevention of break-up of orbital launch stages*

4.3 Spacecraft related ISO standards

(1) ISO 16127:2014, *Space systems — Prevention of break-up of unmanned spacecraft*

(2) ISO 16164:2015, *Space systems — Disposal of satellites operating in or crossing LEO*

(3) ISO 26872:2010, *Space systems — Disposal of satellites operating at geosynchronous altitude*

4.4 Other ISO standards

The following ISO Standards are not specific to space debris mitigation. However, they are considered pertinent:

(1) ISO 27875:2010, *Space systems — Re-entry safety control for unmanned spacecraft and launch vehicle orbital stages*

(2) ISO 14300-1:2011, *Space systems — Programme management – Part 1: Structuring of a project*

(3) ISO 14300-2:2011, *Space systems — Product assurance — Policy and principles*

(4) ISO 14623:2003, *Space systems — Pressure vessels and pressurized structures - Design and operation*

(5) ISO 27025:2010, *Programme management —Quality assurance requirements*

(6) ISO 10795:2011, *Space systems – Programme management and quality –Vocabulary*

(7) ISO/TR 16158:2013, *Space systems — Avoiding collisions among orbiting objects: Best practices, data requirements, and operational concept*

4.5 Other documents

The following documents are referenced to understand the background of the ISO documents:

(1) *Space Debris Mitigation Guidelines of the Scientific and Technical Subcommittee of the Committee on the Peaceful Uses of Outer Space*, Annex IV of A/AC.105/890, 6 March 2007, endorsed by the United Nations General Assembly under Resolution A/RES/62/217

(2) *IADC Space Debris Mitigation Guidelines*, IADC-02-01, Revision 1, September 2007, available at http://www.iadc-online.org/index.cgi?item=docs_pub

(3) *Support Document to the IADC Space Debris Mitigation Guidelines*, IADC-04-06, Issue 1, 5 October 2004, available at http://www.iadc-online.org/index.cgi?item=docs_pub

4.6 Abbreviated terms

A/m	Area-to-Mass Ratio
CDR	Critical Design Review
CFRP	Carbon-Fiber-Reinforced Plastic
CNES	Centre National d'Etudes Spatiales
COPUOS:	Committee on the Peaceful Uses of Outer Space
Cr	Solar Radiation Pressure Coefficient
DAS	Debris Assessment Software (NASA)
DRAMA	Debris Risk Assessment and Mitigation Analysis (ESA)
e	Eccentricity
Ec	Expected number of casualties
EOMDP	End-of-Mission (Operation) Disposal Plan
EOL	End-of-Life

ESA	European Space Agency
FMEA	Failure Mode and Effect Analysis
GEO	Geosynchronous Earth Orbit
GTO	Geosynchronous Transfer Orbit
IADC	Inter-Agency Space Debris Coordination Committee
ISO	International Organization for Standardization
JAXA	Japan Aerospace Exploration Agency
JSpOC	Joint Space Operations Center (USA)
LEGEND	LEO-to-GEO Environment Debris model
LEO	Low Earth Orbit
MASTER	Meteoroid and Space Debris Terrestrial Environment Reference
MEO	Medium Earth Orbit
MMOD	Micro-Meteoroid Orbital Debris
NOTAM	Notice To Airmen
NM	Notice to Mariners
NSS	NASA Safety Standard
ORDEM	Orbital Debris Engineering Model
PDR	Preliminary Design Review
QA	Quality Assurance
QR	Qualification Review
S/C	Spacecraft
SDR	System Definition Review
SDMP	Space-Debris-Mitigation Plan
STELA	Semi-analytic Tool for End of Life Analysis (CNES)
STSC	Scientific and Technical Subcommittee (UNCOPUOS)
USSTRATCOM	United States Strategic Command
TR	Technical Report (a type of ISO document)
UN	United Nations

5 Requirements in ISO Standards and system-level methodologies for complying with the requirements

5.1 General

To accomplish comprehensive activities for debris mitigation work, the following steps are considered:

(1) Identifying debris related requirements, recommendations, and best practices.

(2) Determining how to comply with requirements, recommendations, and best practices.

(3) Applying debris mitigation measures early and throughout development and manufacturing to assure sound debris mitigation capability in the final product.

(4) Applying appropriate QA and qualification programs to ensure compliance with debris mitigation requirements.

This clause provides methodologies for taking comprehensive action at the system level. More detailed information for action at the subsystem and component levels is provided in Clause 8. The following specific subjects are emphasized:

(1) Limiting the release of objects into the useful orbital regions.

(2) Preventing fragmentation in orbit.

(3) Proper disposal during the end of operation.

(4) Minimization of hazards on the ground from re-entering debris.

(5) Collision avoidance for manned or man-able systems.

(6) Quality, safety, and reliability assurance.

5.2 Refrain from releasing objects

5.2.1 Requirements

ISO 24113, 6.1, requires avoiding the intentional release of space debris into Earth orbit during normal operations:

(1) General;

a) S/C and launch vehicle orbital stages shall be designed so as not to release space debris into Earth orbit during normal operations.

b) Space debris released into Earth orbit as part of normal operations, other than as covered by (2), shall remain outside the GEO protected region, and its presence in the LEO protected region shall be limited to a maximum of 25 years after release.

(2) Combustion-related products;

a) Pyrotechnic devices shall be designed so as to avoid the release into Earth orbit of products larger than 1 mm in their largest dimension.

b) Solid rocket motors shall be designed and operated so as to avoid releasing solid combustion products into the GEO protected region.

c) In the design and operation of solid rocket motors, methods to avoid the release of solid combustion products that might contaminate the LEO protected region shall be considered.