TECHNICAL REPORT

ISO/TR 20590

Second edition
2021-04

Space systems — Space debris mitigation design and operation manual for launch vehicle orbital stages

Systèmes spatiaux — Lignes directrices de conception et de manœuvre des étages orbitaux de lanceurs pour réduire les débris spatiaux

Reference number
ISO/TR 20590:2021(E)

Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, 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 (see 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 (see 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 of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operations*.

This second edition cancels and replaces the first edition (ISO/TR 20590:2017), which has been technically revised.

The main changes compared to the previous edition are as follows:

— text has been updated to be aligned with ISO 24113:2019;

— information has been added that the total number of structural elements and orbital stages is limited according to the number of payloads;

— information has been added that the ejection of slag debris from solid rocket motors is limited newly in low Earth orbit in addition to GEO previously;

— information relating to collision avoidance against catalogued space objects has been improved;

— corresponding to the new requirement limiting the total probability of successful disposal to be at least 0,9, the state of the art to confirm the compliance with that taken in the world space industries and national agencies has been added;

— other information relating to the changes in ISO 24113 has been added.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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.

Recently, the orbital environment has become so deteriorated by debris that it is necessary to take actions to mitigate the generation of orbital debris in design and operation of both spacecraft and the launch vehicle orbital stages.

ISO 24113 and other ISO documents, introduced in Bibliography, were developed to encourage debris mitigation activities.

In Clause 5, information about the major space debris mitigation requirements is provided.

In Clause 6, information about life-cycle implementation of space-debris-mitigation-related activities is 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.

This document provides comprehensive information on the requirements and recommendations from ISO documents for the design and operation of the launch vehicles.

Space systems — Space debris mitigation design and operation manual for launch vehicle orbital stages

1 Scope

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

This document provides information to engineers on the requirements and recommendations in the space debris mitigation standards 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.

ISO 24113:2019, *Space systems — Space debris mitigation requirements*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 24113 apply.

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

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

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

4 Symbols and abbreviated terms

CDR	critical design review
CNES	Centre National d'Études Spatiales
COPUOS	Committee on the Peaceful Uses of Outer Space
CSpOC	Combined Space Operations Center (USA)
DAS	debris assessment software (NASA)
DRAMA	debris risk assessment and mitigation analysis (ESA)
E_c	expected number of casualties
EOMDP	end-of-mission (operation) disposal plan
EOL	end-of-life
ESA	European Space Agency

FDIR	failure detection, isolation and recovery
FMEA	failure mode and effect analysis
GEO	geostationary Earth orbit
GTO	geosynchronous transfer orbit
IADC	Inter-Agency Space Debris Coordination Committee
JAXA	Japan Aerospace Exploration Agency
LEO	low Earth orbit
LV	launch vehicle
NOTAM	notice to airmen and notice to mariners
NM	notice to mariners
PDR	preliminary design review
QA	quality assurance
QR	qualification review
S/C	spacecraft
SDMP	space-debris-mitigation plan
SRR	system requirement definition review
STELA	semi-analytic tool for end of life analysis (CNES)
UN	United Nations

5 System-level activities

5.1 General

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

a) Identifying debris related requirements, recommendations, and best practices.

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

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

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

e) Applying appropriate procedures during operation/utilisation and disposal to implement proper space debris mitigation.

This clause provides information useful 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:

— limiting the release of objects into the Earth orbit;

— preventing fragmentation in orbit;

— proper disposal at the end of operation;

— minimization of hazards on the ground from re-entering debris;

— collision avoidance during launch at least for inhabited systems;

— quality, safety, and reliability assurance.

5.2 Design for limiting the release of objects

5.2.1 Intents of requirements in ISO 24113

ISO 24113:2019, 6.1, requires avoiding the intentional release of space debris into Earth orbit during normal operations, including general objects such as fasteners, fragments (larger than 1 mm) from pyrotechnics, slag (larger than 1 mm) from solid rocket motors, etc.

The following objects are concerned:

a) objects released according to the mission requirements (not directly indicated in ISO 24113:2019, 6.1.1.1, though);

b) mission-related objects, such as yo-yo de-spinners, fasteners and other parts (ISO 24113:2019, 6.1.1.1);

c) total number of structural elements in multi-payloads launches and orbital stages. (ISO 24113:2019, 6.1.1.2);

d) fragments and combustion products from pyrotechnic devices (ISO 24113:2019, 6.1.2.1);

e) slag from solid motors (ISO 24113:2019, 6.1.2.2).

ISO 24113 implies that if objects are unavoidably released despite the requirements, the orbital lifetime of such objects in LEO and the interference with GEO is limited as described in ISO 24113:2019, 6.1.1.3 (a typical example is the support structure utilized in a multiple payloads mission).

5.2.2 Work breakdown

Table 1 shows the work breakdown as delineated in ISO 24113 to prevent the release of debris.

Table 1 — Work breakdown for preventing the release of debris

Process	Subjects	Major work
Preventive measures	Identification of released objects and design measures	a) Take preventive design to avoid releasing objects that would turn into space debris. b) Minimise the total number of structural elements in multi-payloads launches, orbital stages, etc. c) If release is unavoidable, designers estimate the orbital lifetime of released objects and check compliance with ISO 24113:2019, 6.1.1.3. d) Apply pyrotechnic device which doesn't eject fragments or combustion product. e) When applying the solid motors, the possibility of generation of slag and its risk posed to environment will be assessed.

Table 1 *(continued)*

Process	Subjects	Major work
Corrective actions	Trouble shooting	Reference: If an object would be released unexpectedly, it is investigated and taken appropriate action to avoid repeating the release in the following missions.

5.2.3 Identification of released objects and design measures

a) Mission-related objects

The following objects are concerned (ISO 24113:2019, 6.1.1.1):

1) nozzle closures for propulsion devices and certain types of igniters for solid motors, which are ejected into space after ignition (particularly if their orbital lifetimes are longer than 25 years);

2) clamp bands that tie the S/C and launch vehicles;

3) structural elements used in multi-payloads launches, fragments and combustion products from pyrotechnic devices, and slag from solid motors are excluded from ISO24113:2019, 6.1.1.1, but are mentioned in ISO24113:2019, 6.1.1.2 and 6.1.2.

b) Structural elements in multi-payloads launches, orbital stages, etc. (ISO 24113:2019, 6.1.1.2)

ISO 24113:2019, 6.1.1.2 requires limiting the total number of orbital stages and “space objects” to one for the launch of a single spacecraft and two for the launch of multiple spacecraft. Generally, “space objects” means structural elements such as payload adaptors.

This requirement seems to prohibit to inject multiple stages in any instance. However, considering the ultimate objective to minimize the number and mass of orbital objects, this requirement can be understood in a slightly different way. For example, in the case that a three-stage LV is designed to leave two stages in orbit during the launch of a single spacecraft, if the second stage has a very short decay life, the third stage is relatively small, and that the total in-orbit collision risk and the total re-entry casualty risk are demonstrably lower compared to the option of leaving one stage in orbit, it is an option worth studying. Careful analysis is needed to confirm the benefit before applying this requirement.

c) Fragments and combustion products from pyrotechnic devices (ISO 24113:2019, 6.1.2.1)

Adequately designed devices are selected to avoid the release of fragments or combustion products. It is possible to apply parts that trap all fragments and combustion products larger than 1 mm inside for segregation.

d) Combustion products from solid motors (ISO 24113:2019, 6.1.2.1)

1) It is preferable not to use an upper-stage with solid propulsion potentially leaving debris in orbit (slag, throat elements), especially if the altitude of the orbit is higher than that of inhabited systems, and if the solid propulsion system conception includes a dead-zone where recirculating gases can concentrate some metalized slag which can be ejected in orbit.

2) It is taken into consideration that if a solid motor is fired to decrease the velocity of the orbital object, to deorbit it for instance, as the particles velocity would increase with that of the orbital object, leading to an increase in apogee of the particles.

e) Estimation of orbital lifetime (ISO 24113:2019, 6.1.1.3)

The orbital lifetime of released objects is assessed as specified in ISO 27852. ISO 27852 designates acceptable analysis methodologies the user employs dependent upon the orbit regime. The available simplified tools that are admissible to estimate the long-term orbital lifetime are introduced in 5.4.3.1.

5.2.4 Monitoring during operation

The released objects, if they are large enough to be detected from the ground, can be confirmed by ground-based space tracking facilities to ensure that they are released as expected and that their orbital lifetimes are sufficiently short. The Space Situation Report provided by the US Combined Space Operations Center (CSpOC https://www.space-track.org/auth/login) provides a good reference.

5.2.5 Preventing failure

If objects are released unexpectedly, the origin of the objects can be identified to help prevent recurrence in future missions. Because such phenomena can indicate a malfunction, the situation is reviewed carefully, and appropriate action is taken to prevent further abnormal conditions.

5.3 Break-up prevention

5.3.1 Break-up caused by intentional behaviour, or stored energy

5.3.1.1 Intents of requirements in ISO 24113

ISO 24113:2019, 6.2 requires the prevention of break-ups caused by intentional behaviour, stored energy, collision with large objects, and impact of tiny debris or meteoroid. This subclause introduces the result of study for the break-ups due to the intentional behaviour, and the stored energy.

While ISO 16127 addresses the prevention of break-ups of S/C, it also provides useful information to the launch vehicle.

5.3.1.2 Work breakdown

Table 2 shows the work breakdown as delineated in ISO 24113 to prevent orbital break-up.

Table 2 — Work breakdown for preventing orbital break-ups

Process	Subjects	Major work
Preventive measures	Identification of sources of breakup	Identify components that can cause fragmentation during or after operation.
	Design measures	1) Preventive designs to limit the probability of accidental break-up during operation no greater than 10^{-3}. Confirm it with FMEA. 2) Providing functions to prevent break-ups after disposal. 3) Preventive design to avoid an unintentional destruction of a self-destruct system caused by miss-command or solar heating.
Risk detection	Monitoring for successful disposal	1) Providing functions to monitor the health of vehicle at the critical events particularly for the decision to proceed to the controlled re-entry. 2) In the case of controlled re-entry, the critical parameters to decide the initiation of re-entry action are monitored. 3) All the cases including the non-controlled re-entry, some parameters to identify the successful execution of critical operation, such as re-ignition, separation of payload, passivation, etc. are being monitored.
Actions in operation phase	Preventive measures for break-up	Energy sources for break-up are removed (residual propellants, high-pressure gas, etc.) or designed to assure safety so as not to cause break-ups after the end of operation.

5.3.1.3 Identification of the sources of break-up

The following launch vehicle subsystem or elements can be potential causes of break-ups:

a) propulsion subsystems and associated components (rocket engines and solid motors, tanks, tank pressurizing systems, valves, piping, etc.);

b) electrical batteries;

c) pressure vessels and other equipment (such as pneumatic control systems);

d) self-destruct systems for range safety.

5.3.1.4 Design measures

Nowadays, the following aspects are incorporated into the design of launch vehicles.

a) Avoiding accidental break-ups during operation

Per ISO 24113, the probability of accidental break-up is no greater than 10^{-3} until its EOL.

ISO 16127 is designed to apply to the S/C, but ISO 16127:2014, Annex A provides adequate instructions to engineers on coping with complicated subsystems such as liquid rocket engines.

To prevent the unintentional explosion of self-destruct charges, the command destruct receivers are turned off after passing through the range safety areas to prevent explosion due to miss-command.

b) Preventing break-ups that occur after the end of operation

The following items are the typical measures to prevent fragmentation for each of the items identified in 5.3.1.3. More detailed information for each subsystem or component is described in Clause 8.

1) Residual propellants in the propulsion systems and associated components

— burning residual propellants to depletion;

— venting residual propellant until its amount is insufficient to cause a break-up by ignition or pressure increase from tanks and lines;

— adequate design of tank. (Historically, some explosion events of the orbital stages and the assist modules were caused by a type of propellant tank design combined fuel and oxygen tanks, separating them only by a common bulkhead.)

2) High pressure fluids

— venting pressurized systems.

3) Range safety systems

— prevention from inadvertent commands, thermal heating, or radio frequency interference.

5.3.1.5 Preventive measures for break-up after mission completion

After separation of payloads, the major sources of break-ups (examples listed in 5.3.1.3) are mitigated (vented or operated in safe mode) according to ISO 16127:2014, 4.4.

Residual propellants and other fluids, such as pressure gasses, are depleted as thoroughly as possible, by either depletion burns or venting, to prevent accidental breakups by over pressurization or chemical reaction. Opening fluid vessels and lines to the space environment, directly or indirectly, at the conclusion of EOM passivation, is one way to reduce the possibility of a later explosion or rupturing,

