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Space systems — Detailed space debris mitigation requirements for spacecraft

Systèmes spatiaux — exigences détaillées pour la diminution des debris spatiaux relatifs aux satellites

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Foreword

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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).

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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 first edition cancels and replaces ISO 16127:2014, ISO 16164:2015, ISO 23339:2010 and ISO 26872:2019.

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

This document is developed to incorporate the content of ISO 16127, ISO 16164, ISO 23339, ISO 26872 and other detailed requirements relevant to spacecraft related debris mitigation, corresponding to ISO 24113. The purpose of this document is to enable conformance with those high-level space debris mitigation requirements in ISO 24113 that are relevant to spacecraft.

This document acts as one of the supporting technical standards for space debris mitigation, to provide implementation requirements and details for the top-level requirements in ISO 24113.

Space systems — Detailed space debris mitigation requirements for spacecraft

1 Scope

This document defines detailed space debris mitigation requirements and recommendations for the design and operation of unmanned spacecraft in Earth orbit.

This document defines detailed requirements that are applicable to:

a) avoiding the intentional release of space debris into Earth orbit during normal operations;

b) avoiding break-ups in Earth orbit;

c) disposal of a spacecraft after the end of mission;

d) estimating the mass of the remaining usable propellant;

e) developing and maintaining the space debris mitigation plan.

NOTE This document does not cover nuclear power sources on spacecraft.

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 and the following apply.

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

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

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

3.1
acquiring organization
organization that plans and manages the development and acquisition contracts for the space system

Note 1 to entry: The responsibilities of the acquiring organization include the engineering and technical aspects of the space system's design and operations.

3.2
book-keeping method
method for determining fluid consumption by monitoring flow rates and the duration of propellant expenditure periods

3.3
disposal orbit
orbit in which a spacecraft resides following the completion of its disposal actions

3.4
PVT method
method for determining the remaining fluid quantity by estimating the mass of gas by deriving density in a known volume from pressure and temperature measurements

3.5
remaining usable propellant
propellant that remains in the propellant system and that is effective for attitude and orbit control manoeuvres excluding residuals and uncertainty

4 Symbols and abbreviated terms

ΔV	delta velocity or total velocity change
EOL	end of life
EOMDP	end of mission disposal plan
GEO	geostationary Earth orbit
LEO	low Earth orbit
$\dot{m}$	mass flow rate
MLI	multilayer insulation
PVT	pressure, volume, temperature
SDMP	space debris mitigation plan
t	time

5 Avoiding release of space debris into Earth orbit during normal operations

ISO 24113 specifies that a spacecraft shall be designed so as not to release space debris into Earth orbit during normal operations. To satisfy this requirement, as a minimum, the following measures shall be implemented.

a) Any appendage related to spacecraft normal operations shall be designed not to be released.

NOTE 1 Appendages include items such as apogee kick propulsion devices, fasteners of holding and deployment mechanisms, caps, hoods, heat insulation enclosures, springs, explosive bolts and related fragments.

b) Releasing parts essential for mission objectives should be assured not to pose a risk to the safety of operating spacecraft and deteriorate the space environment.

c) Paint, MLI and surface materials that are exposed to the space environment, should be selected and processes applied properly, to avoid flaking off from the spacecraft.

NOTE 2 Following ISO documents could help to assure compliance:

1) ISO 16691, Thermal control coatings for spacecraft — General requirements.

2) ISO 23129, Space systems — Thermal control coatings for spacecraft — Atomic oxygen protective coating on polyimide film.

3) ISO 23230, Space systems — Paint materials — Processes, procedures, requirements.

d) Programs using tethers shall take extra measures to limit the collision risk with resident space objects, and not to be severed with a single impact of debris or meteoroid.

NOTE 3 Potential measure for tethered system is to apply multi-strand tether, to retract the tether in the disposal phase.

6 Avoiding break-ups in Earth orbit

6.1 General

ISO 24113 specifies requirements to avoid the accidental break-up of a spacecraft in Earth orbit both before and after its end of life. 6.2 and 6.3 provide detailed measures to help satisfy these requirements.

6.2 Accidental break-up caused by an on-board source of energy

6.2.1 General measures

6.2.1.1 Spacecraft design

The spacecraft design measures to prevent accidental break-ups caused by on-board source of energy are as follows.

a) The calculations to determine the probability of accidental break-up while in orbit until its end of life shall be performed and assessed with probability levels defined in ISO 24113:2019, 6.2.2.1.

NOTE 1 Annex A provides an example of an acceptable detailed evaluation approach.

b) Measures shall be designed to ensure that all on-board sources of stored energy can be depleted or made safe and permanently deactivated once they are no longer required for the mission operation.

NOTE 2 Source can be residual propellants, batteries, high-pressure vessels, self-destructive devices, flywheels, and momentum wheels.

c) The design of the on-board sources of stored energy shall take into account the following influences:

— the environmental extremes expected to be encountered during the normal operations;

— mechanical degradation during the normal operations;

— chemical decomposition;

— the effect of potential failure modes of the spacecraft during the mission, and

— what effect they would have on the ability to passivate the spacecraft.

d) The robustness of the design shall be confirmed during the design review process, to ensure that adequate reliability and quality control has been performed to inhibit any failure that can lead to a break-up event with a probability worse than specified in ISO 24113.

e) The first issue of passivation procedures shall be established prior to the end of the design phase.

6.2.1.2 Spacecraft operations

The spacecraft in-orbit operation measures to prevent accidental break-ups caused by on-board source of energy are as follows.

a) For the operations of the spacecraft, procedures shall be defined to allow monitoring of the relevant parameters of each subsystem, which has been identified as a potential source of space debris generation, in order to detect malfunctions.

b) The following items, as a minimum, shall be monitored from the ground, if applicable:

— pressure and temperature in the engines, tanks, pressure vessels;

— parameters (temperature and voltage) of batteries to detect failures;

— parameters to detect failure modes of the orbit and attitude control system.

c) Prior to the disposal phase, the passivation procedures shall be updated to take into account any failures that have occurred during the mission and that affect the ability to passivate the spacecraft.

d) At the time when spacecraft operation is concluded either purposefully or due to malfunction and disposal manoeuvres have been finished, passivation shall be performed.

NOTE If a controlled re-entry is to be performed, then passivation is not necessary.

e) In the event of in-orbit malfunctions which can lead to break-up or the loss of operating function, a contingency plan to prevent debris generation should have been studied and, where appropriate, implemented.

6.2.2 Subsystem-specific measures

6.2.2.1 Electrical systems

The specific measures for electrical systems are as follows.

a) The performance of batteries shall be monitored and assessed in accordance with standardized procedures to assure the safety of the mission and post-mission disposal.

NOTE 1 Standardized procedure for health assessment of lithium-ion batteries can be found in ISO/TR 20891.

b) Batteries and/or electrical systems shall be designed and manufactured, both structurally and electrically, to prevent break-ups during all orbital life.

c) Pressure increase in battery cells and assemblies, potentially leading to a break-up, shall be prevented.

NOTE 2 This can be done by mechanical measures for some types of batteries as far as it doesn't decrease the reliability.

d) At the end of operations, take measures to prevent re-charging to batteries, and discharge the stored electric energy with assuring to keep necessary electric energy for following disposal action.

6.2.2.2 Propulsion systems

The specific measures for propulsion systems are as follows.

a) Pressure vessels, such as tanks and high-pressure gas bottles, shall be designed to avoid accidental break-up caused by stored energy sources.

NOTE 1 ISO 14623 and ISO 24638 contain requirements relating to the design of pressure vessels.

b) For a bipropellant propulsion system, especially with hypergolic propellants, tanks and lines should be designed so that any single-point failure does not cause the unplanned mixture or combustion of the propellants.

c) Before end of life, as part of the disposal phase, the spacecraft shall have consumed or vented residual liquid propellants and pressurized fluids, such as cold gas, liquefied gas, and propellant for the fluid-based electric propulsion systems, which are potential sources of break-ups. Any residual liquid propellants and pressurized fluids can be a source of break-ups also for spacecraft drifting outside protected regions after end of life and should be consumed or vented to the maximum extent as possible before end of life.

d) End of venting shall be monitored (or confirmed), if appropriate, by proper means, such as on-board pressure sensors, fluid gauging systems, thermal sensing, attitude sensing, or any other demonstrable means.

e) If it is not possible to vent, a sufficient safety margin to ensure no break-ups under expected post-disposal environmental conditions shall be adopted.

f) The venting system and process shall be designed not to be prevented by the frozen propellants.

g) The venting process should be defined to take into account any potential effects on the spacecraft's attitude or orbit and any ground visibility issues.

h) Solid rocket motors shall only be actuated in the case that there have been no sensor indications of motor degradation due to mission-induced damage or due to adverse environmental conditions.

i) Solid motor should not be allowed if it generates slags in the GEO and LEO protected regions.

6.2.2.3 Pressurized systems such as heat pipes/fluid loops

All pressurized systems which are typically not designed to be vented, such as heat pipes/fluid loops, shall be designed and qualified with safety margins that prevent break-up of the spacecraft when considering thermal effects in orbit.

NOTE Specific venting operations for this kind of pressurized systems are not required in the disposal phase.

6.2.2.4 Rotating hardware

The specific measures for rotating hardware are as follows.

a) All rotating devices, for example flywheels, reaction wheels, and momentum wheels, shall be designed so that failure of the rotating part does not cause the break-up of the spacecraft under nominal mechanical environmental conditions.

b) All rotating parts shall be allowed to de-spin, or stopped by termination of the power supply, at the end of life.

6.2.2.5 Other devices

The specific measures for other devices are as follows.

a) Any other energy sources, such as pyrotechnically operated devices, shall be designed so that they do not cause unacceptable risk of break-up and generate fragments.

b) Where this is unavoidable, the fragments shall be self-contained within the device which is affected by break-up.

6.3 Accidental break-up caused by a collision

6.3.1 Collision avoidance

The spacecraft shall be designed and operated properly to prevent collision with trackable orbital objects before its end of life.

a) During the mission operation, the conjunction assessment shall be conducted periodically against potentially approaching objects based on the reliable orbit data.

b) Exchange of orbital parameters should be encouraged among spacecraft operators or space agencies, to precisely check the close approach distance, and then determine an optimal avoidance manoeuvre strategy for operators.