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# Space systems — Detailed space debris mitigation requirements for launch vehicle orbital stages

*Systèmes spatiaux — Exigences détaillées pour la limitation des débris spatiaux relatifs aux étages orbitaux des lanceurs*



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# Foreword

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

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# Introduction

This document was developed to support the implementation of the high-level space debris mitigation requirements in ISO 24113.

This document contains a detailed and practical set of requirements and recommendations to assist the space industry in conforming to the requirements in ISO 24113 which relate to launch vehicle orbital stages.

# Space systems — Detailed space debris mitigation requirements for launch vehicle orbital stages

## 1 Scope

This document defines detailed space debris mitigation requirements and recommendations for the design and operation of launch vehicle orbital stages in Earth orbit.

The requirements defined in this document are applicable for:

— avoiding the release of space debris;

— disposing of 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.

## 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, *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 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/

**3.1**
**decay orbit**
orbit that will result in the re-entry of a launch vehicle orbital stage

**3.2**
**disposal orbit**
orbit in which launch vehicle orbital stage resides following the completion of its disposal maneuvers

## 4 Avoiding the intentional release of space debris into Earth orbit during normal operations

**4.1** ISO 24113 specifies a limit for the total number of launch vehicle orbital stages and space debris objects that a launch vehicle may leave in Earth orbit during normal operations.

NOTE The space debris objects related to the launch include, but are not limited to, protective shrouds, inter-stage elements, clamp bands, jettisonable tanks, jettisonable attitude control or propellant settling systems.

**4.2** If a launch vehicle, by design, leaves two launch vehicle orbital stages in Earth orbit during the launch of a single spacecraft, then at least one of the two stages shall be removed. It is preferred for both stages to be removed from orbit at the end of the launch vehicle's operations.

# 5 Avoiding break-ups in Earth orbit

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

### 5.1.1 General

The following elements of a launch vehicle orbital stage are most likely to cause an accidental break-up:

a) residual propellants in propulsion systems;

b) pressure gasses in vessels including propellant tanks, high-pressure gas bottles, and pressure lines;

c) batteries;

d) range safety system when not decoupled from command chain, ie. computer order and necessary energy.

### 5.1.2 Residual propellants in propulsion systems

**5.1.2.1** Residual propellants shall be vented from a launch vehicle orbital stage as part of its passivation, the timing of such an operation being selected in order not to generate any adverse consequence to the stage or its payloads.

NOTE1 In case residual propellants are vented by combustion from the thrust chamber, the change of mixture ratio inside the chamber is a major factor of break-up risk of the thrust chamber.

NOTE2 In case residual propellants are vented in a sequential mode, without combustion, the pressure gradients of venting of liquid residual propellants are key control variables to avoid either boiling up or the generation of ice particle(debris) which can clog the passivation orifices and valves.

**5.1.2.2** The venting of residual propellants shall be implemented in accordance with the requirements of launch vehicle orbital stage disposal.

NOTE Proper orientation of venting outlets can lower the final orbit and thus reduce the orbit lifetime of a launch vehicle orbital stage.

### 5.1.3 Pressurized gasses in pressure vessels

Pressure vessels shall be designed in accordance with standardised procedures, and made safe by one or more of the following means (in order of preference):

a) relieving the pressurized gasses totally, or

b) relieving the pressurized gasses until the internal pressures are lower than their validated critical values, or

c) designing with safety margins that do not allow rupture when considering thermal effects in orbit.

NOTE 1 Pressure vessels include propellant tanks and high-pressure gas bottles.

NOTE 2 ISO 14623 provides standardised procedures for pressure vessel design.

NOTE 3 Pressure vessel critical value[2][3] is the highest pressure under which an impact does not lead to an explosion, but a simple hole.



 

### 5.1.4 Batteries

**5.1.4.1** The capacity margin of safety of batteries shall be evaluated in accordance with standardised design procedures to ensure mission safety and post-mission disposal.

NOTE ISO 17546 is an example of a lithium ion battery design standard.

**5.1.4.2** Batteries shall be designed and manufactured, both structurally and electrically, to prevent break-up.

### 5.1.5 Range safety systems

**5.1.5.1** The definition and layout of the self-destruct explosive charge on a launch vehicle shall be such that it cannot reach its self-ignition temperature.

**5.1.5.2** The command receiver of a command self-destruct system in a range safety system shall be turned off soon after a launch vehicle has passed through a range safety area.

### 5.1.6 Probability of accidental break-up due to internal causes

ISO 24113 specifies a limit for the probability of accidental break-up, due to an internal cause, that a launch vehicle orbital stage shall be designed to satisfy.

## 5.2 Accidental break-up caused by a collision

**5.2.1** A launch vehicle orbital stage shall be launched to reduce the risk of collision among launch vehicle, injected payloads, mission related objects, and existing orbital objects (at least manned space systems) during ascent and after the injection according to the requirements set by approving agents.

NOTE Some approving agents use $10^{-4}$ as the threshold for the risk of collision.

**5.2.2** Structural materials that generate less debris when impacted, should be preferentially considered in the design of a launch vehicle orbital stage.

# 6 Disposal of a launch vehicle orbital stage after the end of mission so as to minimize interference with the protected regions

## 6.1 Launch service provider — spacecraft mission designer coordination

**6.1.1** The spacecraft mission designer and the launch service provider shall jointly design the launch phase of the mission to enable disposal of the launch vehicle orbital stage.

**6.1.2** Using the information provided by the spacecraft mission designer (e.g. see ISO 14303, ISO 17401), the launch service provider shall estimate the orbit lifetime of all launch vehicle orbital stages, based on the spacecraft injection scenario and final orbit parameters at end of life (e.g. see ISO 27852).

**6.1.3** The launch service provider shall estimate the casualty risk for an uncontrolled re-entry of all launch vehicle orbital stages for which a controlled re-entry is not planned.

**6.1.4** The casualty risk for an uncontrolled re-entry of each launch vehicle orbital stage shall be computed using a standardised method.

NOTE ISO 27875 provides standardised methods for computing the casualty risk.

**6.1.5** The launch service provider and the spacecraft mission designer shall agree on the spacecraft separation and injection conditions, taking into account potential perturbations following spacecraft separation, so that the spent launch vehicle orbital stages can meet the disposal requirements specified in ISO 24113.

NOTE Perturbations can occur during post-separation maneuvers or stage passivation.

**6.1.6** Once the spacecraft mission designer has specified a desired injection orbit, the launch service provider shall present options (if available) for launch vehicle orbital stage disposal.

**6.1.7** In those instances where the specified injection orbit does not lead to satisfactory disposal options, the launch service provider and the spacecraft mission designer may explore alternative injection orbits that offer better conditions for disposal of the launch vehicle orbital stage.

NOTE If the spacecraft is to perform significant propulsive maneuvers subsequent to injection (e.g., orbit raising, inclination change, drift rate change, etc.), an alternative injection orbit can yield equivalent results and be acceptable to the spacecraft mission designer. A typical example would be a trade-off between orbital inclination and perigee altitude for a transfer orbit injection in which the velocity required to achieve the spacecraft final orbit remains unchanged. This type of coordination can lead to mutually beneficial solutions in terms of mission objectives and launch vehicle orbital stage disposal.

## 6.2 Selection of disposal option

### 6.2.1 Disposal to minimize interference with the geostationary Earth orbit (GEO) protected region

**6.2.1.1** The launch vehicle orbital stage shall be left in, or moved to, a disposal orbit, ensuring that it will remain outside of the GEO protected region for a period of at least 100 years.

**6.2.1.2** The time duration in the disposal orbit shall be counted from the instant at which the launch vehicle orbital stage's disposal maneuver is complete to the first instant at which its orbit penetrates the appropriate protected region in accordance with a standardised method.

NOTE ISO 27852 provides standardised methods for computing the time duration.

### 6.2.2 Disposal to minimize interference with the low Earth orbit (LEO) protected region

**6.2.2.1** ISO 24113 specifies the available disposal options for a launch vehicle orbital stage in the LEO protected region (with safe retrieval or controlled re-entry being the preferred options unless they are proved impossible).

**6.2.2.2** A launch vehicle orbital stage shall be directed to re-enter and impact in a safe area on the surface of the Earth via a controlled maneuver or sequence of maneuvers.

**6.2.2.3** If safe retrieval or controlled re-entry is not possible, and the casualty risk for a random re-entry of the launch vehicle orbital stage is lower than the value specified by an approving agent, then a launch vehicle orbital stage may be placed in a decay orbit that has an orbit lifetime of less than 25 years.

**6.2.2.4** The orbit lifetime of a launch vehicle orbital stage's decay orbit shall be calculated in accordance with a standardised method.

NOTE ISO 27852 provides standardised methods for computing the orbit lifetime.

**6.2.2.5** For the re-entry of a launch vehicle orbital stage (or any part thereof), a casualty risk analysis shall be approved by an approving agent.



 

NOTE The common value shared at international level for such casualty risk threshold is $10^{-4}$ per re-entry.

**6.2.2.6** A maneuver which results in the perigee of the disposal orbit of a launch vehicle orbital stage being above the LEO protected region shall be avoided.

## 6.3 Probability of successful disposal

**6.3.1** The launch mission and launch vehicle orbital stage shall be designed so that the probability of successful completing the disposal actions, which is calculated mainly considering remaining propellant, power, controllability, communications, and loss of redundancy, satisfies the probability of successful disposal requirement specified in ISO 24113.

NOTE For the case of a launch vehicle orbital stage in a highly eccentric orbit, such as a geostationary transfer orbit, where there is significant uncertainty in the estimation of orbit lifetime, the amount of propellant for the 25-year disposal can be estimated with a certainty of 0,9. This is independent of the requirement for the probability of successful disposal to be at least 0,9.

**6.3.2** Details of the design that provides the basis for the probability estimate shall be included in the space debris mitigation plan (SDMP).

## 6.4 Contingency planning

In the event that a launch vehicle orbital stage has insufficient remaining propellant, or a system or other failure prevents execution of the primary disposal action, then efforts shall be made to perform one of the following actions before critical systems are lost:

a) select an alternative decay orbit that minimizes its orbital lifetime, or

b) select an alternative disposal orbit that has as low a probability of future interference with the LEO and GEO protected regions as possible.

The rationale for and the results of any such disposal action or inaction shall be documented and included in the SDMP. The final state of the launch vehicle orbital stage shall be included.

# 7 Re-entry

**7.1** The re-entry of launch vehicle orbital stages shall be performed in accordance with a standardised procedure.

NOTE ISO 27875 provides standardised procedures for performing re-entry.

**7.2** Uncontrolled re-entry of a launch vehicle orbital stage should be avoided.

NOTE This is due to the high survivability of launch vehicle debris.

**7.3** The deliberate destruction of a launch vehicle orbital stage performing a controlled re-entry may be permitted if it satisfies the following conditions:

a) it is operated at sufficiently low altitude to avoid injecting fragments into Earth orbit, and

b) it leads to a lower casualty risk than that of the complete stage.

**7.4** During the design of a launch vehicle orbital stage, best efforts shall be made to design for demise during re-entry.

# 8 Planning and documentation

## 8.1 General

**8.1.1** An SDMP shall be developed, maintained and updated in all phases of a launch vehicle's mission and shall be included in the overall SDMP which is defined in ISO 24113.

**8.1.2** The SDMP shall include detailed break-up prevention, disposal, re-entry requirements and plans, including verification either by analysis, simulation, demonstration and, where possible, ground testing to comply with the requirements defined by the approving agent (e.g. see ISO 15864).

## 8.2 Break-up prevention plan

The break-up prevention plan shall include:

a) probabilities of accidental break-up, disposal and re-entry casualty risk with related confidence levels;

b) details of ability of demise during re-entry if intentional break-up is selected;

c) critical pressures of pressure vessels;

d) the plan and timeline for passivating the launch vehicle orbital stage if controlled re-entry is not selected as the disposal option in the design phase or in a go/no go test;

e) a justification of the proper design of the passivation of the launch vehicle orbital stage, including the evaluation of the probability of a successful passivation;

f) details of privileged structural materials for generating less debris.

## 8.3 End of mission disposal plan

The end of mission disposal plan shall include:

a) probabilities of accidental disposal with related confidence levels;

b) details of the nominal orbit where the launch vehicle orbital stage is to be separated from the payload;

c) a statement of the launch vehicle orbital stage disposal method to be utilized (retrieval, controlled re-entry, uncontrolled re-entry, or disposal orbit) and background information supporting the selection of this method;

d) details of the orbital domain aimed at for the disposal orbits of the launch vehicle orbital stages, taking into account separation perturbations and the effects of any passivation actions;

NOTE This can be accomplished with a statistical analysis, such as a Monte Carlo method, that includes the various dispersions impacting the final orbit.

e) identity of systems and capabilities required for successful completion of the launch vehicle orbital stage disposal action;

f) estimates of the propellant, power, controllability, and communications required for any launch vehicle orbital stage disposal or re-orbit maneuver, including dispersions associated to these estimations;

g) the rationale for and the results of contingency plan as well as the final state of the launch vehicle orbital stage.



 