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# Space systems — Disposal of orbital launch stages

*Systèmes spatiaux — Élimination des étages orbitaux de lanceurs*

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# Foreword

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

# Introduction

A launch vehicle stage plays a critical role in moving a spacecraft toward or into its final mission orbit. Once the spacecraft has been delivered to the desired orbit, the stage can be separated from the spacecraft. If the stage itself is in orbit and is deactivated at this point, it becomes another object added to the growing population space debris – an uncontrolled object that may threaten operating satellites for the remainder of the stage's orbit lifetime. And a launch vehicle stage may also be a source for large numbers of smaller threatening objects if residual propellants, pressure vessels or other sources of stored energy explode or if it is involved in a collision with another object.

This International Standard in one of several standards focused on minimizing the growth of space debris, and removing orbital launch stages from orbit or moving them to non-threatening orbits at the end of their missions is an important component of this strategy. This International Standard provides guidance on how a spacecraft owner and a launch service provider can work together to develop spacecraft deployment options leading to removal of an orbital launch stage either by re-entering the stage into the atmosphere in a short time or by leaving the stage in or moving the stage to an orbit that does not intersect regions of heavy use by satellite missions for a very long time. This International Standard also calls for eliminating all sources of stored energy remaining in the stage prior to its final disposal (except in cases where the stage will execute a controlled re-entry into the atmosphere).

# Space systems — Disposal of orbital launch stages

## 1 Scope

This International Standard focuses on disposal of launch vehicle stages used during launch of spacecraft to be operated in space where the orbital launch stages are left in orbit after the spacecraft are released.

End-of-mission disposal of launch vehicle orbital stages broadly means removing the stages from the protected regions of space (see ISO 24113) so as not to collide or otherwise interfere with the other users of those protected regions in the future. ISO 24113 also requires that "During the disposal phase, a spacecraft or launch vehicle orbital stage shall permanently deplete or make safe all remaining on-board sources of stored energy in a controlled sequence." These "passivation" actions are typically either accomplished in the course of disposal, or immediately follow the disposal operations. In this document, the term "disposal actions" refers to both disposal manoeuvres and to passivation actions (note: passivation actions are not required after the final manoeuvre leading to a controlled re-entry).

ISO 24113 provides six options for spacecraft or orbital launch stage disposal. This International Standard specifies techniques for planning and executing disposal of orbital launch stages that are consistent with ISO 24113 requirements, reflect current internationally accepted guidelines, and consider current operational procedures and best practices.

## 2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

ISO 27852, *Space systems — Estimation of orbit lifetime*

ISO 27875, *Space systems — Re-entry risk management for unmanned spacecraft and launch vehicle orbital stages*

## 3 Terms and definitions

For the purpose of this document, the terms and definitions given in ISO 24113:2011, and the following apply.

**3.1**
**decay orbit**
orbit which will result in the re-entry of the space system within a specified time

**3.2**
**decay phase**
period that begins at the end of the operational phase of a space system, when it has been placed into its decay orbit, and ends when the space system has performed a re-entry

Note 1 to entry: This only applies for space systems performing re-entry.

**3.3**
**deorbit manoeuvre**
action of moving a space system to a new orbit that will cause the space system to re-enter the atmosphere

**3.4**
**controlled re-entry**
manoeuvring a space system in a controlled manner into a targeted re-entry with a well-defined impact footprint on the surface of the Earth to limit the possibility of human casualty

Note 1 to entry: This generally means that the object will re-enter the Earth's atmosphere less than one orbit revolution from the time of initiation of the final deorbit manoeuvre.

**3.5**
**graveyard orbit region**
orbit region outside of protected regions such as LEO and GEO

**3.6**
**orbital launch stage**
launcher orbital propulsive element that is discarded by the time the payload reaches orbit, usually only the last propulsive element

**3.7**
**passivation**
elimination of all stored energy on a space system to reduce the chance of break-up

Note 1 to entry: Typical passivation measures for spacecraft include venting or burning excess propellant, discharging batteries, and relieving pressure vessels (see ISO 16127 for examples).

**3.8**
**uncontrolled re-entry**
re-entry where no specific manoeuvre is used to control the time and location of the re-entry point

Note 1 to entry: Therefore, the re-entry time and location of the space object are random and unknown.

## 4 Abbreviated terms

| | |
|---|---|
| EOMDP | end-of-mission disposal plan |
| GEO | geostationary Earth orbit |
| LEO | low Earth orbit |
| OLSDP | orbital-launch-stage disposal plan |

## 5 Primary requirements

Controlled re-entry is the baseline approach; all other options should only be used if a controlled re-entry is not feasible.

### 5.1 Launch provider/Payload owner coordination

The spacecraft mission designer and the launch provider shall jointly design the launch phase of the mission to enable disposal of the orbital launch stage. Specifically:

a) The spacecraft mission designer shall specify the desired injection conditions to the launch service provider.

b) Using the information provided by the spacecraft mission designer, the launch service provider shall develop a candidate launch and spacecraft injection scenario and for that scenario shall provide the final orbit parameters after final engine cut off and an estimate of the orbit lifetime of all orbital launch stages released during launch and injection of the owner's spacecraft (see ISO 27852).

c) The launch service provider shall estimate the casualty expectation for an uncontrolled re-entry of all orbital stages provided by the launch service provider for which a controlled re-entry is not

planned. The casualty expectation for an uncontrolled re-entry of each launch vehicle stage shall be computed as specified in ISO 27875.

d) The launch service provider and the spacecraft mission designer shall iterate on the payload separation / injection conditions and select separation / injection conditions such that the spent stage can meet an appropriate disposal requirement as specified in ISO 24113. As an example, once the spacecraft mission designer has specified a desired injection orbit, the launch provider may then present options (if available) for orbital launch stage disposal. In some instances, the specified injection orbit may not lead to satisfactory disposal options. The launch provider and the spacecraft mission designer may then explore alternative injection orbits that offer better conditions for disposal of the orbital launch stage. If the spacecraft is to perform significant propulsive manoeuvres subsequent to injection (e.g. orbit raising, inclination change, drift rate change, etc.), then an alternative injection orbit may 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 orbital launch stage disposal.

NOTE Responsibility for the orbital stage disposal remains with the LS-provider.

## 5.2 Selection of disposal option

a) If the orbital launch stage after payload separation will be in an orbit with a perigee altitude of less than 2 000 km and a controlled re-entry is not planned, the casualty expectation for a random re-entry of the launch vehicle stage shall be computed by an acceptable method (e.g. see ISO 27875).

b) For the re-entry of an orbital launch stage (or any part thereof), the maximum acceptable casualty risk shall be set in accordance with norms issued by approving agents.

   1) If the casualty expectation is lower than the value specified, the stage may be placed in a final orbit that will decay within 25 years (see ISO 27852).

   2) If the casualty expectation exceeds the value specified, the stage shall be either directed to re-enter and impact in a well-defined impact footprint on the surface of the Earth to limit the possibility of human casualty via a controlled deorbit manoeuvre or shall be moved to a graveyard orbit region.

c) If the orbital launch stage is to be left in an orbit where disposal by orbit decay or controlled re-entry are not available options, the orbital launch stage shall be left in or moved to a final graveyard orbit region.

In all cases except controlled re-entry, the stage shall be passivated after the nominal decay or sending to the graveyard orbit region is reached. Passivation is not required after successful completion of the final manoeuvre leading to a controlled re-entry. Should there be an anomaly and disposal manoeuvres cannot be accomplished, passivating the upper stage will lower the risk posed to operational systems.

NOTE Some kinds of upper stages have negative temperature balance which is sufficient for passivation.

## 5.3 Disposal manoeuvre planning and documentation

An orbital-launch-stage disposal plan (OLSDP) shall be developed, maintained and updated in all phases of mission and launch system design and shall be included in the overall end-of-mission disposal plan (EOMDP) defined in ISO 24113. The OLSDP shall include:

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

b) a statement of the stage disposal method to be utilized (retrieval, controlled re-entry, uncontrolled re-entry, or sending to the graveyard orbit region) and background information supporting the selection of this method;

c) identity of systems and capabilities required for successful completion of the stage disposal action;

d) estimates of the propellant, power, controllability, and communications required for any stage disposal or re-orbit manoeuvre;

e) verification that the selected mission design leaves the orbital launch stage with sufficient propellant, power, controllability, and communications capability for disposal after payload separation in order to meet the probability of successful disposal requirement specified in 5.4;

f) if controlled re-entry is selected, identification of the geographic area where the stage will re-enter and debris will impact the Earth's surface;

g) if controlled re-entry is selected, a time line for the disposal and re-entry action and a list of those individuals and/or entities to be notified prior to the disposal action and a timeline for notification;

h) the plan and timeline for passivating the orbital launch stage if controlled re-entry is not selected as the disposal option;

i) if a decision is made to move to a graveyard orbit, documentation describing the final orbit and the rationale for its selection, including confirmation of the completion of the disposal actions.

## 5.4 Reliability for disposal

The launch mission and orbital launch stage shall be designed such that the probability of completing the disposal action, which is the conditional probability weighted on the mission success equals or exceeds 0,9 at the nominal time the disposal action is to be executed. Details of the design that provides the basis for the probability estimate shall be included in the OLSDP (see ISO 24113:2011, Annex A for an example of how this probability may be computed).

## 5.5 Criteria for executing disposal action

Orbital launch stage disposal shall be scheduled as soon as practical after completion of its mission.

If it is determined that the impact of executing the disposal action will result in an increased probability of the orbital launch stage causing debris within the protected region, then it shall be acceptable to forego the predefined disposal action. (An example of this is the scenario where, after launch, a problem is identified with the de-orbit propulsion system that is deemed likely to result in a catastrophic loss of the orbital launch stage. In this case, it would be better not to use the propulsion system and hence not to execute the disposal action.) In all cases, if the nominal disposal action cannot be executed, the orbital launch stage should be passivated.

## 5.6 Contingency planning

Should insufficient propellant remain or a system or other failure prevent execution of the primary disposal action, if possible and before critical systems are lost every effort shall be made to

a) select an alternative decay orbit that minimizes the duration of the decay phase, or

b) select an alternative graveyard orbit region that has a low probability of future interference with protected regions such as LEO or GEO as possible.

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

## 5.7 Exceptions

Appropriate authorities may wish to grant exceptions to disposal requirements for pre-existing orbital-launch-stage designs, where incorporation of these requirements into the design of the orbital launch stage is infeasible. Disposal exceptions and their rationale shall be documented in the OLSDP.

# 6 Disposal planning requirements

## 6.1 Determination whether the disposal must be a controlled manoeuvre

If the orbital launch stage has been selected for a re-entry, then determination of whether the disposal must be a controlled manoeuvre shall be in accordance with ISO 27875.

## 6.2 Estimating orbit lifetime

If the orbital launch stage has been selected for an uncontrolled re-entry, then the decay phase duration shall be computed by calculating the orbit lifetime of the initial decay orbit.

## 6.3 Computing the time in graveyard orbit region

If the orbital launch stage has been selected to be sent to the outside of the protected region, the time that the orbital launch stage remains outside of the protected region shall be calculated. The time duration shall be measured from the time at which the manoeuvre to the graveyard orbit region is complete to the first time at which the new orbit enters a protected region such as LEO or GEO.

# Bibliography

[1] ISO 14303, *Space systems — Launch-vehicle-to-spacecraft interfaces*

[2] ISO 15864, *Space systems — General test methods for space craft, subsystems and units*

[3] ISO 16127, *Space systems — Prevention of break-up of unmanned spacecraft*

[4] ISO 17401, *Space systems — Spacecraft interface requirements document for launch vehicle services*

[5] ISO 26872, *Space systems — Disposal of satellites operating at geosynchronous altitude*

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