

Requirements on Space Debris Mitigation for ESA Projects

1. SCOPE

The Requirements on Space Debris Mitigation for ESA Projects define a minimum set of requirements for the limitation of space debris, in particular in the LEO and GEO protected areas, and a minimum set of risk reduction measures in the case of re-entries of space-systems or their components into the Earth's atmosphere.

This document addresses three pertinent issues:

- a) Management requirements describing responsibilities for the implementation of space debris mitigation measures, as well as documentation and reporting requirements in the space project life-cycle;
- b) Design requirements to limit the generation of space debris and to minimize the risks associated with space debris generated;
- c) Requirements on the space project prime contractor to define and verify procedures and strategies to limit the generation of space debris, to minimize the risks associated with space debris generated, and to avoid the introduction of space debris in protected orbital regions (see section 5.1).

Implementation and execution of the operational measures defined by the space project prime contractor for ESA projects are outside the scope of responsibility of the space project prime contractor and lies with the operator of the space project. In case of space missions operated by ESA or by a third party under contract with ESA, the operational procedures defined by the space project prime contractor in order to achieve compliance with the requirements described in this document are applicable to the operator and shall be complied with.

In case of space projects undertaken by ESA on behalf of a third party, where the responsibility for the space project operations is not with ESA, the responsibility of the space project prime contractor for the definition of operational procedures and strategies for space debris mitigation remains unchanged. The definition of the operational responsibility for the implementation of these operational measures in such a case is outside the scope of this document and shall be governed by project specific agreements.

2. REFERENCE DOCUMENTS

- [RD-1] European Code of Conduct for Space Debris Mitigation, Issue 1.0, June 28, 2004;
- [RD-2] ADC Guidelines for Space Debris Mitigation, IADC-02-01, Oct. 15, 2002;
- [RD-3] 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, UNCOPUOS, 06 March 2007;
- [RD-4] United Nations Treaties and Principles on Outer Space, ST/SPACE/11, ISBN 92-1-100900-6, New York, 2002.

3. MANAGEMENT REQUIREMENTS

3.1 Implementation of Space Debris Mitigation Measures

MR-01

The prime contractor of the space project shall be responsible for the implementation of space debris mitigation measures as defined in this document. The prime contractor shall deal with these requirements using the same engineering methodology and the same reporting as for all other contractually applicable Agency requirements.

3.2 Specific Responsibilities

MR-02

In order to implement the space debris mitigation measures defined in this document the space project prime contractor shall:

- a) Define derived design requirement specifications at system and sub-system level;
- b) Verify compliance with the design requirements;
- c) Define and verify necessary operational procedures prior to launch;
- d) Document activities and procedures resulting from a, b, and c.

MR-03

Verification of and compliance with the applicable space debris mitigation requirements shall be reported by the space project prime contractor as part of the overall space project verification control up to Flight Acceptance Review.

3.3 Space Debris Mitigation Document

MR-04

The space project prime contractor shall document in a "Space Debris Mitigation Document" the measures put in place to implement and fulfil the applicable requirements. The document shall be part of the Design Justification File.

MR-05

The Space Debris Mitigation Document shall:

- a) Be provided for and reviewed at the space project System Requirements Review;
- b) Be updated for and reviewed at the space project Preliminary Design Review;
- c) Be updated and revised by the space project prime contractor to follow the design evolution of the space project;
- d) Be updated for and reviewed at the space project Critical Design Review.

MR-06

The Space Debris Mitigation Document shall contain as a minimum:

- a) a table of compliance with the requirements in the present document;
- b) a description of design and operational measures put in place to achieve compliance;
- c) a list of objects (mission-related objects or space debris) released as part of the nominal mission. For these objects, the physical characteristics, the orbital characteristics and the predicted on-orbit lifetime shall be provided;
- d) a feared-events list of malfunctions of the space system which have the potential to cause space debris, and a description of the characteristics of the debris so caused.

4. DESIGN REQUIREMENTS

The following design requirements shall be met together with the operational requirements defined in section 5.

4.1 Prevention measures

4.1.1 Mission related objects

DR-01 (launchers)

- a) For the launch of a single payload there shall be at most one additional launch vehicle element (for example the insertion stage) injected into orbit.
- b) For the launch of multiple payloads there shall be at most two additional launch vehicle elements (for example the insertion stage and an adaptation structure for multiple payloads) injected into orbit.

DR-02 (spacecraft)

Spacecraft shall be designed such that objects that must be released as part of the nominal mission are retained and do not become detached from the spacecraft. In cases where this is not possible for technical or operational reasons the following requirements apply:

- a) Mission-related objects and space debris so generated shall remain outside the GEO protected region (see section 5.1);
- b) Mission-related objects and space debris so generated shall not remain in the LEO protected region for more than 25 years after their release;
- c) A justification for the implementation shall be given in the space debris mitigation document (see MR-04, MR-05 and MR-06).

4.1.2 Fragmentation

DR-03

A space system or any of its parts shall not be intentionally destroyed in orbit.

4.1.3 Solid propellants and pyrotechnics

DR-04

Solid rocket motors releasing burn products larger than 1mm into orbit shall not be used.

DR-05

The use of pyrotechnics (for example, pyrotechnic cutters) shall not release into orbit any particles greater than 1 mm.

4.2 Space System End-of Life Measures

DR-06

The space system shall be designed such that the end-of-life measures required in section 5.2 can be fulfilled by the operator.

DR-07

An analysis shall be performed to determine and allocate the amount of propellant needed to perform the required end-of-life manoeuvres.

DR-08

The design shall allow the operator to establish the propellant reserve with an accuracy which is compatible with performing the end-of-life manoeuvres in accordance with requirement DR-10.

DR-09

A space system shall be designed such that it can be permanently passivated at the end of its disposal phase in accordance with requirements OR-04 and OR-05.

DR-10

The reliability of successfully performing the end-of-life disposal and/or

passivation shall not be less than the nominal mission reliability for the operational phase.

5. OPERATIONAL REQUIREMENTS

The following operational requirements apply together with the design requirements.

5.1 Protected Regions

“Protected Regions” in the context of this document are the LEO and GEO orbital regions defined as follows:

- a) The low Earth orbit protected region (LEO region) is the spherical shell region that extends from the Earth’s surface up to an altitude (Z) of 2000 km.;
- b) The geosynchronous protected region (GEO region) is a segment of a spherical shell defined by Figure 1:
 - lower altitude boundary = geostationary altitude minus 200 km,
 - upper altitude boundary = geostationary altitude plus 200 km,
 - latitude sector: 15 degrees South \leq latitude \leq 15 degrees North,
 - geostationary altitude (Z_{GEO}) = 35 786 km.

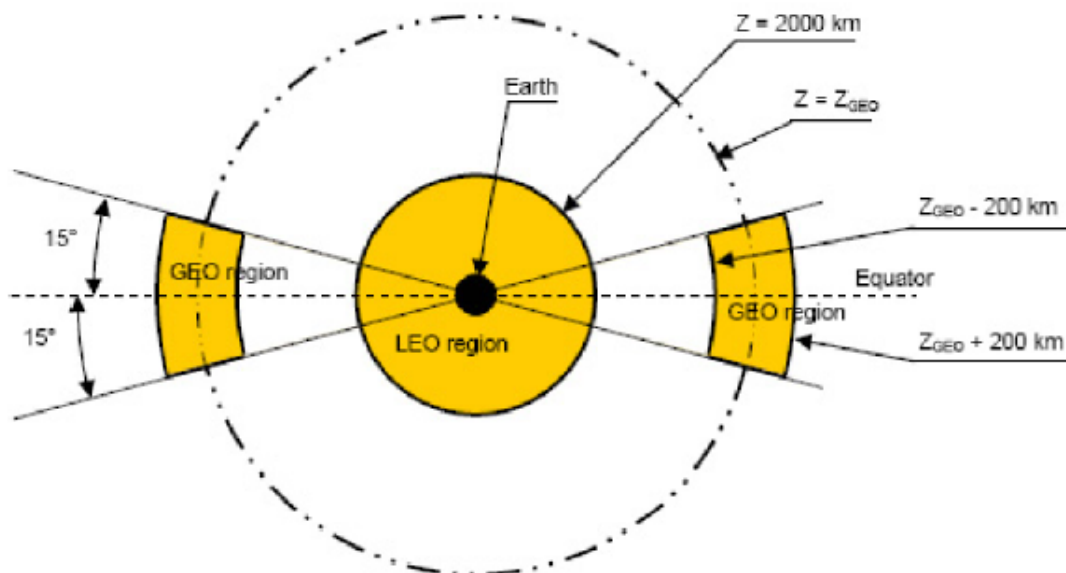


Figure 1 – Protected Regions

5.2 End-Of-Life Measures

5.2.1 Disposal

OR-01

Space systems operating in the LEO protected region shall be disposed of by reentry into the Earth’s atmosphere within 25 years after the end of the operational phase.

OR-02

Space systems operating in the GEO protected region shall be disposed of by permanently removing them from the GEO protected region.

Note: Conformance with the GEO disposal requirement can be ensured by using a disposal orbit with the following characteristics:

- a) *eccentricity ≤ 0.005 ,*
- b) *minimum perigee altitude ΔH above the geostationary altitude according to the following formula:*

$$\Delta H \geq 235 + 1000 * Cr * A/m,$$

Where ΔH is in km, Cr is a dimensionless solar radiation pressure coefficient of the space system at the beginning of its life (0 for completely transparent material, 1 for completely absorbing material, 2 for totally reflecting material), A/m is the ratio of the cross-section area (in m^2) to dry mass (in kg) of the space system.

OR-03

Where practicable and economically feasible, space systems outside the LEO and GEO protected regions shall implement means of end-of-life orbit disposal to avoid long-term interference with operational orbit regions, such as the Galileo orbit.

OR-04

Launcher stages shall satisfy one of the following conditions:

- a) They shall perform a direct re-entry as part of the launcher sequence;
- b) They shall be placed in a LEO orbit where they will re-enter the Earth's atmosphere within 25 years;
- c) They shall be permanently removed from the LEO and GEO protected regions, and from orbits interfering with other operational orbit regions, such as the Galileo orbit.

5.2.2 Passivation

OR-05

Passivation of a space system shall be completed within two months after the end of the operational phase. This includes launcher stages which remain in orbit.

5.2.3 Re-Entry

OR-06

For space systems that are disposed of by re-entry, the prime contractor shall perform an analysis to determine the characteristics of fragments surviving to ground impact, and assess the total casualty risk to the population on ground assuming an uncontrolled re-entry.

OR-07

In case the total casualty risk is larger than 10^{-4} , uncontrolled re-entry is not allowed. Instead, a controlled re-entry must be performed such that the impact footprint can be ensured over an ocean area, with sufficient clearance of landmasses and traffic routes.

TERMS AND DEFINITIONS

Casualty Risk: The probability of serious injury or death.

Direct Re-Entry: The Space System performs the manoeuvres to complete its re-entry phase within a single orbit revolution.

Disposal Phase: Begins at the end of the operational phase of the Space System, and ends when either the Space System has performed a direct re-entry or completed its disposal activities (having reached its disposal orbit and

having completed its passivation).

End of Life: End of the disposal phase.

GEO: Geostationary orbit, of mean altitude 35786 km, with a period of one sidereal day, a near-zero eccentricity, and a near-zero inclination.

IADC: Inter-Agency Space Debris Coordination Committee.

LEO: Low Earth orbit, with an altitude below 2000 km.

Mission-Related Objects: Protection or adaptor structures or mechanisms required for the deployment of one or several payloads into orbit.

Operational Phase: The period during which a space system performs its useful function.

Orbital Lifetime: The length of time that a space system remains on orbit.

Passivation: The elimination of all stored energy on board of a space system.

Re-entry: Comprises the orbital decay, atmospheric capture, and burn up or survival to ground impact of a space systems or parts thereof.

Space Debris: Any man-made space object, including fragments and elements thereof, in Earth orbit or re-entering the Earth's atmosphere, that is non-functional (IADC definition).

Space Object: Any man-made space system, its components, and parts or fragments thereof.

Space System: Spacecraft, launch vehicle stages, and mission-related objects.