# THE EUROPEAN SPACE DEBRIS SAFETY AND MITIGATION STANDARD

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## ABSTRACT

A standard has been proposed as one of the series of ECSS Standards intended to be applied together for the management, engineering and product assurance in space projects and applications. The requirements in the Standard are defined in terms of what must be accomplished, rather than in terms of how to organise and perform the necessary work. This allows existing organisational structures and methods within agencies and industry to be applied where they are effective, and for such structures and methods to evolve as necessary, without the need for rewriting the standards. The Standard comprises management requirements, design requirements and operational requirements. The standard was prepared by the European Debris Mitigation Standard Working Group (EDMSWG) involving members from ASI, BNSC, CNES, DLR and ESA.

## 1 INTRODUCTION

### 1.1 Background

Existing international treaties relating to outer space clearly identify the responsibilities of those seeking to exploit this unique resource. According to the "Treaty on principles governing the activities of States in the exploration and use of outer space, including the Moon and other celestial bodies", of January 27, 1967, called the "Outer Space Treaty", article I: "*The exploration and use of outer space (...) shall be carried out for the benefit and in the interests of all countries, irrespective of their degree of economic or scientific development, and shall be the province of all mankind.....Outer space (...) shall be free for exploration and use by all States (...)....There shall be freedom of scientific investigation in outer space (...)*". Article IX:"*(...) States Parties to the Treaty shall pursue studies of outer space, including the Moon and other celestial bodies, and conduct exploration of them so as to avoid their harmful contamination (...) and, where necessary, shall adopt appropriate measures for this purpose*". Proliferation of space debris may be interpreted as harmful contamination as referred to in the Outer Space Treaty [1] as the presence of debris in orbit is a change in the existing environment and harmful due to the hypervelocity nature of collisions.

The European Space Debris Safety and Mitigation Standard has been developed from an existing CNES document [2] to represent fundamental safety and mitigation requirements and recommendations related to space debris. The standard specifies measures for the design and operation of a space vehicle that will avoid or minimise the future generation of space debris. In addition the standard proposes measures to protect a space vehicle from the collision hazard posed by space debris. The standard also defines the process to be followed with respect to the application of the specified requirements, in conjunction with the more general safety requirements relevant to a project or space related activity.

### 1.2 Rationale

As space activity can lead to the generation of space debris, there should be a commitment to reduce the future generation of debris in order to ensure the freedom of access to space in perpetuity. The policy in Europe is to design space vehicles in order to prevent the generation of space debris and to encourage the adoption of operational techniques which

will limit the production of space debris during the operational phase, while ensuring consistency and compliance with the operational phase requirements and safety.

Non proliferation of space debris could be achieved by a re-entry requirement imposed on each space vehicle orbiting or intended for orbiting the Earth (including launch vehicles). A space vehicle would be re-entered in a safe manner within a specified time of completion of its operational phase. Although adoption of this re-entry requirement would comply with the spirit and objectives of the Space Treaties, it is neither practicable nor reasonable to require such action at this time because:

1. the energy (and associated fuel budget) would be excessive, and would rapidly become prohibitive (for example, to perform the re-entry of a space vehicle from a geosynchronous orbit);
2. modifications to the design of space vehicles to permit re-ignition of their propulsion systems while still complying with safety constraints would be too technically complicated.
3. some objects injected into space have no propulsive capability, such that subsequent modifications to provide manoeuvre capability would result in the system being commercially unviable.

Although it is an ambitious goal, the rule of a systematic re-entry within a specified time and compliant with safety specifications will ultimately become mandatory in the long term, through international co-operation.

### 1.3 Structure of the Standard

The Standard is presented in seven sections and a set of informative annexes. The sections consider Scope and Applicability, Normative References, Terms and Definitions, Abbreviated Terms, Management Requirements, Design Requirements, and Operational Requirements. The information annexes consider guidelines for verifying and justifying compliance (or otherwise), and guide for implementation, definition of the space debris environment, practical guidance for assessing re-entry risk, the geostationary orbit, orbital lifetimes, potential disposal solutions, the use of nuclear power sources in outer space, and a bibliography.

### 1.4 Applicability of the Standard

The European Space Debris Safety and Mitigation Standard is intended for application by ESA, by national space agencies, by European industry, and by all entities involved in the activities of management, engineering, manufacture, production, operations, and exploitation of a space project conducted in Europe, or by a European entity acting outside of Europe (for example, partners, contractors at all levels, customers, suppliers, etc engaged in such an activity). It is proposed that the Standard be applied to all space vehicles orbiting or intended for orbiting the Earth including launch vehicles and their components (for example, stage, adapter for the launch of multiple payloads). The Standard does not cover the launch phase, for which specific safety rules are defined elsewhere (for example, Launch Site Safety Regulations). It is intended that the Standard should be read in conjunction with the European Space Debris Mitigation Handbook. It is planned that the Standard be incorporated with the ECSS [3] framework. ECSS is a co-operative effort of the European Space Agency, National Space Agencies and European industry associations for the purpose of developing and maintaining common standards.

## 2 REQUIREMENTS OF THE STANDARD

### 2.1 Process and Organisation

In order to demonstrate implementation of the Standard, the contents and status of a space debris mitigation plan will be presented at project reviews to confirm compliance with specified design and operational requirements. The plan should contain the functions and responsibilities of a space debris manager, a management plan for space debris activities including assessment and mitigation of debris risks, measures for minimising debris generation, and ultimately the disposal of the system in question.

There are a number of key roles in the implementation of the standard. The space debris authority (SDA) for a project conducted by a space agency would be the Director General of that agency or his delegated authority. The SDA for project conducted by industry would be nominated by the prime contractor. The space debris manager (SDM) has the delegated authority and responsibility to enforce the space debris mitigation plan during all phases of the project. The SDM verifies that the space project complies with the applicable specifications of the project and

approves decisions made (e.g. in relation to technical options).

### 2.2 Management Requirements

A set of management requirements are developed which are to be applied by the project manager in consultation with the appointed SDM. Tailoring of the space debris requirements is permitted but this must be justified in the space debris mitigation plan, be approved by the SDM, and is subject to a waiver issued by then SDA. Waivers may be issued by the SDA where a requirement proves either to be technically difficult to accomplish, or may have exorbitant costs associated with them resulting in a potential loss of commercial competitiveness. Where a waiver is applied for, the project manager must justify the request on the basis of the impact on the product and record this in the space debris mitigation plan.

### 2.3 Design Requirements

A set of design requirements is also developed within the Standard. These relate to debris prevention measures such as the reduction of mission related objects, fragmentation (accidental or otherwise), the use of solid propellants and pyrotechnics, the application of certain materials and technologies, and the possibility of malfunction leading to the production of debris. End of life measures are also considered such as passivation, de-orbiting to a lower altitude or re-orbiting to a higher altitude. Impact protection measures are also addressed such as measures to ensure or maximise the survivability of a vehicle to debris impact. Safety requirements are also considered, reflecting safety policy and criteria, including the issue of controlled or un-controlled re-entry of objects.

### 2.4 Operational Requirements

A set of operational requirements is presented in the Standard. These address prevention measures that can be applied, end of life measures such as passivation and the disposal of objects at end of life, necessarily reflecting the important issue of protected regions in space. Impact protection measures consider shielding and collision risk reduction while safety requirements again address safety policy and criteria, including the issue of controlled or un-controlled re-entry of objects.

### 2.5 Implementation

An informative annex is provided which links with the ESA Space Debris Mitigation Handbook [4] to provide details for implementing some of the requirements. In particular specific measures are presented for the passivation of a space vehicle, the protection of launch vehicles, the lowering of orbit perigee altitude of a launcher upper stage, fragmentation altitude considerations, selection of environment models for risk analyses, and practical guidance for considering controlled and un-controlled re-entries, disposal of objects from the geostationary orbit, and determination of orbital lifetimes of objects in low Earth orbit. Finally some specific scenarios are considered and potential practical solutions explored.

As an example, for the geostationary orbit and associated disposal of objects at end of life, the Standard presents the specification agreed at the 15th IADC meeting, namely:

*The disposal orbit for a space vehicle in geostationary orbit shall have a minimum perigee altitude ΔH above the geostationary altitude according to the following formula:*

$$\Delta H = \Delta H_{\min} + 1000\, Cr\, S/m$$

*where:*
*ΔH in km*
*$\Delta H_{min}$ = 235 km*
Cr = reflectivity coefficient of the space vehicle at beginning of life
*S/m = ratio of cross-section area (in $m^2$) to dry mass (in kg) of the space vehicle.*

*It is recommended that to avoid undesirable effects due to a lack of accuracy in the determination of the final orbit, or to potential errors during the operational phase, or to the possible failure of the space vehicle, or to its damage over time, an additional margin should be added to the ΔH value calculated.*

### 2.6 Philosophy and Approach

In this standard the concept of a protected region is introduced. This is a region of outer space that is protected in relation to the generation of space debris and where the presence, permanent or periodic, of space debris is limited to 25 years.

Any human activity, which takes place in outer space, should be performed by recognising the unique nature of the following two regions A

and B of the outer space (see Figure 1) to ensure their future safe and sustainable use.

1) Region A extends from the Earth's surface up to an altitude of 2 000 km; it includes low orbit, $Z \leq 2\,000$ km.
2) Region B is the geostationary ring, including the geostationary orbit, defined by the following segment of a spherical shell:
   minimum geocentric radius = geostationary radius minus $\Delta H_{min}$,
   maximum geocentric radius = geostationary radius plus $\Delta H_{min}$,
   -15 degrees ≤ latitude ≤ +15 degrees,
   geostationary radius = 42 164 km.

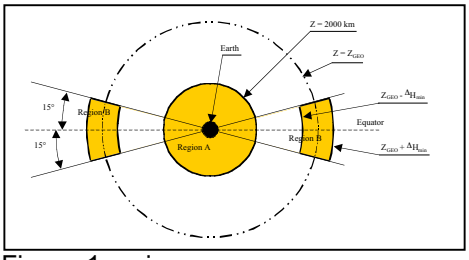

Figure 1 regions

## 3 CONCLUSION

### 3.1 Summary

A standard has been proposed as one of the series of ECSS Standards intended to be applied together for the management, engineering and product assurance in space projects and applications. The requirements in the Standard are defined in terms of what must be accomplished, rather than in terms of how to organise and perform the necessary work. This allows existing organisational structures and methods within agencies and industry to be applied where they are effective, and for such structures and methods to evolve as necessary, without the need for rewriting the standards. The Standard comprises management requirements, design requirements and operational requirements.

### 3.2 Way Forward

Although the Standard was developed to address European requirements for dealing with the space debris problem, the Standard clearly has applicability to a wider audience and environment. Similar standards and guidelines have been developed by other agencies and the IADC is currently developing a similar set of practices and processes to form an international standard. It is hoped that while in the interim a number of guidelines and standards will exist, the establishment of a coherent and consistent set of international standards, applicable to all space activities, should ensure a level playing field for all operators and designers to strive for the minimisation of the future orbital debris hazard.

## 4 REFERENCES

[1] Treaty on principles governing the activities of States in the exploration and use of outer space, including the Moon and other celestial bodies, January 27, 1967.

[2] CNES MPM-51-00-12, Space debris - Safety requirements, 19 April 1999.

[3] ECSS-Q-40A, Space product assurance: Safety, 19 April 1996.

[4] ESA Space Debris Mitigation Handbook, Release 1.0, 7 April 1999.