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European Code of Conduct

for Space Debris Mitigation

Signature :

ASI

BNSC

CNES

DLR

ESA

FOREWORD

Towards the end of the third decade of the space age, it became apparent that a new particulate environment was beginning to dominate the background meteoroid environment in all but the millimetre size regime. This man-made, orbital debris population was growing rapidly, the direct consequence of launching and operating space systems during the previous 3 decades. Man-made orbital debris poses a significantly increased collision hazard to man-made satellites, and as we become more dependent upon space-based systems for remote sensing, communications and navigation, it is important to understand the nature of the threat and the steps that we must take to ensure the sustainable development of near Earth space. The European Code of Conduct for Space Debris Mitigation has been developed co-operatively amongst responsible space agencies in Europe to identify those practices which will serve to minimise the impact of space operations on the orbital environment that will be encountered by future space systems.

The measures in this document 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 to be applied where they are effective, and for the structures and methods to evolve as necessary.

Coherence of the application of this Code of Conduct should be guaranteed by co-ordination, at least annually, of those persons responsible for space debris issues at agency level.

This Code of Conduct is accompanied by a “Support to Implementation” document:

- Code of Conduct for Space Debris Mitigation

The elements of this Code of Conduct are consistent with the IADC Debris Mitigation Guidelines while providing greater detail and rationale. This document can be used by projects to assist in the early consideration of measures to reduce space debris while also giving an insight into necessary future practices. The Code of Conduct has been adopted by ASI, BNSC, CNES, DLR, and ESA, upon signature by their Directors General and will be used to help manage the space debris hazard.

- Support to Implementation

The "Support to Implementation" document is a supporting document which aims to direct those involved in the management, design, operation, and mission control to appropriate sources of information and tools to assist in implementing the Code of Conduct. The "Support to Implementation" document is not submitted for approval, and will be updated from time to time as needed. Its release will be agreed by the co-operating agencies.

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CONTENTS

Foreword 2
1 Introduction 1
2 Scope and applicability 2
2.1 Scope 2
2.2 Applicability 2
3 Management MEASURES 3
3.1 Applicability 3
3.2 Space Debris Manager 3
3.3 Space debris mitigation plan 3
3.4 Project reviews 4
4 Design MEASURES 5
4.1 Prevention measures 5
4.1.1 Mission related objects 5
4.1.2 Fragmentation 5
4.1.3 Solid propellants and pyrotechnics 6
4.1.4 Materials and technologies 6
4.1.5 Malfunction 6
4.2 End-of-life measures 6
4.2.1 Passivation 6
4.2.2 De-orbiting 7
4.2.3 Re-orbiting 7
4.3 Impact protection measures 7
4.4 Re-entry safety measures 7
4.4.1 Safety policy 7
4.4.2 Re-entry 7
5 Operational MEASURES 8
5.1 Prevention measures 8
5.2 End-of-life measures 8
5.2.1 Passivation 8
5.2.2 Protected regions 8
5.2.3 Disposal 9
5.3 Impact protection measures 10
5.4 Re-entry safety measures 10
5.4.1 Safety policy 10
5.4.2 Re-entry 10

Annex 1 Guidelines for verifying and justifying the compliance (or not) with the elements of the Code of Conduct 11
Annex 2 Terms and definitions 12
Annex 3 Abbreviations 15

1 INTRODUCTION

According to the UN "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 (…).»

According to the Outer Space Treaty, 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.»

Due note is also taken of the UN "Convention on International Liability for damage caused by space objects ", of March 29, 1972, called the Liability Convention.

Since activity in space 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 referred to in the Outer Space Treaty.

The European space debris policy is to design space systems in such a way as to minimise 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.

The primary objectives of the European Code of Conduct for Space Debris Mitigation are:

- prevention of on-orbit break-ups and collisions,
- removal and subsequent disposal of spacecraft and orbital stages that have reached the end of mission operations from the useful densely populated orbit regions,
- limitation of objects released during normal operations.

2 SCOPE AND APPLICABILITY

2.1 SCOPE

The European Code of Conduct for Space Debris Mitigation (hereafter referred to as the Code of Conduct) presents fundamental mitigation and safety measures related to space debris. This Code of Conduct specifies measures for the design and operation of a space system that will avoid or minimise the generation of space debris. In addition the Code of Conduct proposes measures to protect a space system from the hazard posed by space debris. The Code of Conduct also defines the process to be followed with respect to the application of specific mitigation measures in conjunction with the more general safety requirements relevant to the project or related activities.

This Code of Conduct is consistent with European space debris policy as presented in document ESA/IRC(2000)14. The aims of the measures and recommendations presented in the Code of Conduct are to preserve outer space from the uncontrolled growth of space debris in the future, and to protect space systems from the hazard due to existing debris generated by past space activities.

This Code of Conduct does not cover the launch phase safety, for which specific rules are defined elsewhere (e.g. Doctrine de Sauvegarde for launches from CSG).

2.2 APPLICABILITY

The application of the Code of Conduct for Space Debris Mitigation is voluntary and should be applied by the European Space Agency, by national space agencies within Europe and their contractors. It is also recommended for application by any other space project conducted in Europe, or by a European entity acting outside Europe, including operators.

The Code of Conduct contains provisions that may be given binding effect by means of legal instruments between contracting parties.

It is intended that this Code of Conduct be applied to all space systems orbiting, or intended for orbiting, the Earth including launch vehicles and their components (for example, stage, adapter for the launch of multiple payloads) associated with the activities described in the preceding paragraph.

Where relevant, the measures drawn up in this Code of Conduct should be considered at each stage, and within each level, of a space project.

3 MANAGEMENT MEASURES

The following measures should be applied as appropriate by the Project Manager in consultation with the Space Debris Manager (see section 3.2).

3.1 APPLICABILITY

SD-MM-01
Each space project should use the Code of Conduct as an applicable document.

3.2 SPACE DEBRIS MANAGER

SD-MM-02

a) Each space project should appoint a Space Debris Manager.
b) The Space Debris Manager should have the authority and responsibility to enforce the space debris mitigation plan (see section 3.3) during all phases of the project.
c) The Space Debris Manager should verify that the space project complies with the applicable space debris specifications of the space project.
d) The Space Debris Manager should approve the decisions by the space project with regard to space debris activities.
e) The Space Debris Manager should co-ordinate the space debris activities and should ensure that they are consistent with the safety and quality activities.

3.3 SPACE DEBRIS MITIGATION PLAN

SD-MM-03
Each space project should establish a space debris mitigation plan.

The space debris mitigation plan permits the Project Manager to demonstrate that:

1) the space system complies with the design measures specified in chapter 4, and
2) operations will be carried out in compliance with the measures specified in chapter 5.

SD-MM-04
During the identification and definition of the space debris tasks, any space project should determine:

a) whether the potential of its products for generating space debris during nominal operation and degraded modes (for example, malfunction) is reduced to the maximum extent possible,
b) whether the potential of its products for generating space debris after an orbital collision with man-made or natural objects is reduced to the maximum extent possible,
c) whether the potential of its products for generating space debris due to an accidental explosion or destruction is reduced to the maximum extent possible,
d) the evolution of its product during the disposal phase,
e) potential harm at the Earth's surface or damage to the environment caused by the re-entry of its product.

SD-MM-05

The space debris mitigation plan for a space project should contain as a minimum:

a) the list of all applicable safety regulations,
b) the functions and responsibilities of the Space Debris Manager for each phase of the project,
c) the management plan of space debris activities,
d) the plan for assessment and mitigation of risks related to space debris,
e) the measures minimising the hazard related to malfunctions which have a potential for generating space debris,
f) the plan for the space system disposal,
g) justification of choice and selection when several possibilities exist,
h) contents and justifications for non-compliance with this Code of Conduct and associated consequences,
i) the compliance matrix given in Annex 1,
j) the risk assessment analysis concerning space debris.

SD-MM-06

A space project, which cannot comply with an element of this Code of Conduct, should:

a) justify the non-compliance, and
b) record the non-compliance and the associated justification in the space debris mitigation plan.

3.4 PROJECT REVIEWS

SD-MM-07

a) During space project reviews, the Space Debris Manager should present the contents and the status of the space debris mitigation plan.
b) The final report of the space debris mitigation plan should be presented during the Flight Readiness Review of the space project.
This final report should include the commitment of the operator(s) for complying with the applicable disposal measures of the space project.

SD-MM-08

a) During space project reviews, the Space Debris Manager should present the space debris mitigation plan to the person responsible for space debris in the concerned agency.
b) The space debris responsible will then issue recommendations to the project review board.

4 DESIGN MEASURES

The following design measures are to be considered together with the operational measures (see chapter 5 and the "Support to Implementation" document).

4.1 PREVENTION MEASURES

4.1.1 Mission related objects

SD-DE-01

a) For the launch of a single payload, there should be only one element (for example, stage) of the launch vehicle injected into orbit, excluding the payload.

b) For the launch of multiple payloads, there should be at most two elements (for example, stage, adaptation structure for multiple payloads) of the launch vehicle injected into orbit, excluding payloads.

SD-DE-02

a) For payloads, mission related components (for example, attachments of electrical wiring, devices retaining antennas, apogee boost motor heat shields, solid propellant thruster nozzle blanks, observation instruments protections, explosive bolts, springs, belts) should be designed so that released parts are retained.

b) Devices, which by design release objects other than payloads into orbit, should be avoided (for example, "yo-yo" device).

When a) or b) cannot be fulfilled, potential space debris should be identified (number, size, orbit parameters, orbit evolution, orbital lifetime, etc.) and included in the space debris mitigation plan.

SD-DE-03

Any suborbital space object (for example, launch vehicle stage, adaptation structure for a launch of multiple payloads) should not generate long-lived space debris.

4.1.2 Fragmentation

SD-DE-04

Intentional destruction of a space system or any of its parts in orbit is prohibited.

SD-DE-05

The accidental destruction probability of a space system due to an internal origin of any stored energy element (AOCS, propulsion, pressurised parts, energy storage elements - batteries, fuel cells, etc.) shall be lower than or equal to 10^{-4} for the operational phase of the space system.

4.1.3 Solid propellants and pyrotechnics

SD-DE-06

Solid propellants likely to generate space debris in the form of particles greater than 10 microns should be avoided.

The use of pyrotechnics (for example, pyrotechnic cutters) in orbit should not generate any particle of size greater than 10 microns.

4.1.4 Materials and technologies

Depending upon the materials or technologies used, the influence of the environment on objects in space can generate a large amount of additional debris.

SD-DE-07

The materials, their application, and the design (structures, tanks, propellant, equipment, surface materials, etc.) should not generate space debris during the orbital phase of any space system.

Recommendation: Where the generation of space debris due to the materials and basic technologies cannot be avoided, the number, size, and lifetime of debris generated should be minimized.

Recommendation: The materials and basic technologies selected for space systems should be qualified accordingly (for example, qualification plans should include tests - radiation, shock, etc. - demonstrating minimal space debris production).

4.1.5 Malfunction

Recommendation: Elements of a space system whose malfunction can lead to a hazardous event likely to generate space debris (AOCS, propulsion, pressurised parts, energy storage elements - batteries, fuel cells, etc.) should be designed to reduce the corresponding risk.
Such measures should be included in the space debris mitigation plan.

4.2 END-OF-LIFE MEASURES

4.2.1 Passivation

SD-DE-08

a) Any space system should be passivated at the end of its disposal phase and should remain passivated.

When a) cannot be fulfilled, the space system should comply with b) and c):

b) When the residual pressure in propellant and pressurisation tanks cannot be removed, this pressure should be lower than 50% of the critical pressure of the tank concerned. The critical pressure of a tank is the maximum pressure under which a penetrating impact does not cause an explosion, but will result in a leak.

c) When the remaining propellants cannot be drained, the design should comply with all the following conditions:
- no explosive reaction of the propellant should occur as a result of a penetrating impact;
- no exothermal dissociation of the propellant should occur due to tank heating;
- no leak should occur that may cause the mixture of hypergolic propellants;
- design of tanks (for example, leak before burst design) and the efficiency of thermal protection should inhibit pressure build-up that may cause tank explosion.

d) Passivation measures should be taken into account in the design of the space system.

4.2.2 De-orbiting

SD-DE-09

According to the operational mitigation measures SD-OP-03, SD-OP-05 and SD-OP-06, the de-orbiting measures should be taken into account in the design of the space system.

4.2.3 Re-orbiting

SD-DE-10

According to the operational mitigation measures SD-OP-03, SD-OP-04, SD-OP-05 and SD-OP-06 the re-orbiting measures should be taken into account in the design of the space system.

4.3 IMPACT PROTECTION MEASURES

A space debris risk assessment should be included in the space debris mitigation plan. Some recommendations for impact protection are stated in the “Support to Implementation” document.

4.4 RE-ENTRY SAFETY MEASURES

4.4.1 Safety policy

SD-DE-11

The re-entry phase of a space system, if any, should not result in harmful contamination of the Earth environment (for example, ionising radiation, hazardous biological or chemical products).

4.4.2 Re-entry

SD-DE-12

a) A space project should limit the risk from re-entering space debris to a safe level.

b) The end of life operations should take into account the applicable on ground safety rules, which depend on the launching state.

c) The casualty risk on ground should not exceed 10^{-4} per re-entry except when France is the launching state where the criteria presented in the CNES “Doctrine de Sauvegarde” are applicable.

For safety regulations, see “Support to Implementation” document, annex "Bibliography".

It should be understood that for any re-entry the UN Liability Convention applies.

Practical guidance for re-entry is provided in the “Support to Implementation” document.

5 OPERATIONAL MEASURES

The following operational measures are to be considered together with the design measures (see chapter 4 and the "Support to Implementation" document).

5.1 PREVENTION MEASURES

> ***SD-OP-01***
> The operational procedures should comply with the design and operational elements of the Code of Conduct.

5.2 END-OF-LIFE MEASURES

5.2.1 Passivation

> ***SD-OP-02***
> The passivation process should be completed within 1 year after the end of the disposal phase, and its probability of success should be higher than 0.9.

5.2.2 Protected regions

Any human activity which takes place in outer space should be performed while recognising the unique nature of the LEO region and the GEO region of outer space (see Figure 1), to ensure their future safe and sustainable use. These regions are considered as protected regions with regard to space debris. They are defined below.

1) The low Earth orbit region (LEO region) is the spherical shell region that extends from the Earth's surface up to an altitude (Z) of 2 000 km.

2) The geosynchronous region (GEO region) is a segment of spherical shell defined by:
lower altitude = geostationary altitude minus 200 km,
upper altitude = geostationary altitude plus 200 km,
-15 degrees $\leq$ latitude $\leq$ +15 degrees,
geostationary altitude (Z_{GEO}) = 35 786 km (the altitude of the geostationary orbit).

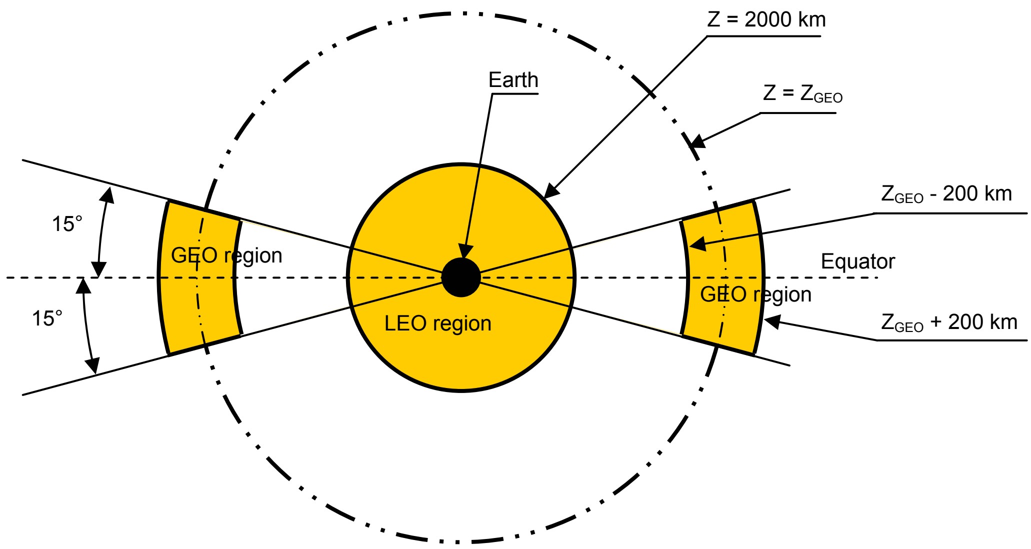

Figure 1 - Protected regions

5.2.3 Disposal

For the disposal of a space system, end-of-life measures avoiding or reducing the generation of space debris are defined below.

SD-OP-03

a) The operator of a space system should perform disposal manoeuvres at the end of the operational phase to limit the permanent or periodic presence of its space system in the protected regions to a maximum of 25 years.
This can be achieved, in decreasing order of preference:
- either by performing a direct re-entry of the space system;
- or by limiting the orbital lifetime of the space system to less than 25 years after its operational phase;
- or by transferring the space system to a disposal orbit.

b) These measures should be in compliance with the applicable safety rules.

c) Compliance with this end-of-life measure should consider all significant perturbations to the trajectory.

Examples to develop potential solutions are provided in the "Support to Implementation" document.

SD-OP-04

At the end of its operational phase a space system in the geostationary orbit should be re-orbited into a disposal orbit with a minimum perigee altitude ΔH above the geostationary altitude according to the following formula:

$$\Delta H = 235 + 1000 \times Cr \times S/m$$

where:

ΔH in km,

Cr = solar radiation pressure coefficient of the space system at the beginning of its life (beginning of orbital phase),

0 for completely transparent material,

1 for completely absorbing material,

2 for totally reflecting material.

S/m = ratio of cross-section area (in m^2) to dry mass (in kg) of the space system.

Recommendation: An additional margin in ΔH should be considered to take into account uncertainties in fuel estimate, effective ΔV and orbit determination.

Recommendation: The eccentricity of the disposal orbit should be minimised.

SD-OP-05

The probability of successful disposal of a space system which can still be operated to fulfil SD-OP-03 or SD-OP-04 at the end of its operational phase should be higher than 0.9.

SD-OP-06

When disposal manoeuvres of a space system are performed using allocated propellants, the following measures should apply.

a) The remaining propellant should be estimated with a level of confidence to fulfil SD-OP-05.

b) This quantity should be assessed according to a method defined during the space system design, using design data (characteristics of propellants, structure and architecture of tanks, etc.) and operational data (careful monitoring of the condition of the space system in orbit, etc.).

c) The operational phase of the space system should cease at such a time point that the quantity of propellants necessary to perform disposal manoeuvres is compliant with SD-OP-05.

d) During the disposal manoeuvres, the resulting presence of the space system in the protected regions should be minimised (for example, multi-burn strategy for re-orbiting with high-thrust systems).

5.3 IMPACT PROTECTION MEASURES

Recommendations on protection measures can be found in the IADC Protection Manual, and in the ESA Space Debris Mitigation Handbook.

5.4 RE-ENTRY SAFETY MEASURES

5.4.1 Safety policy

SD-OP-07

Before the re-entry phase, any space system with nuclear reactors or nuclear power sources onboard should be compliant with the United Nations' resolution on Principles relevant to the use of nuclear power sources in outer space.

5.4.2 Re-entry

SD-OP-08

Before re-entering a space system, the appropriate launching state should apply the relevant air traffic and maritime traffic regulations (e.g. to inform the corresponding authorities on the re-entry time and trajectory, and the associated ground area).

Annex 1

Guidelines for verifying and justifying the compliance (or not) with the elements of the Code of Conduct

Any space project can use the following table to:

1) prove that it complies with the measures specified in this Code of Conduct,
2) or justify that it cannot comply with the measures specified in this Code of Conduct.

	Keywords		Compliance (Yes or No)	Applicability	Justification (notes references, , etc.)
SD-MM-01	Applicability				
SD-MM-02	Space Debris Manager				
SD-MM-03	Space debris mitigation plan				
SD-MM-04	Space debris tasks of any space project				
SD-MM-05	Space debris mitigation plan description				
SD-MM-06	Space debris mitigation compliance				
SD-MM-07	Project reviews				
SD-MM-08	Project reviews reporting				
SD-DE-01	Simple/multiple payload(s) launch				
SD-DE-02	Retain released parts				
SD-DE-03	Suborbital space object				
SD-DE-04	Intentional destruction				
SD-DE-05	Accidental destruction (internal origin)				
SD-DE-06	Solid propellant and pyrotechnics use				
SD-DE-07	Materials & technologies selection				
SD-DE-08	Passivation				
SD-DE-09	De-orbiting				
SD-DE-10	Re-orbiting				
SD-DE-11	Safety policy				
SD-DE-12	Safe re-entry on ground				
SD-OP-01	Operational procedures				
SD-OP-02	Passivation				
SD-OP-03	Disposal (general)				
SD-OP-04	Disposal of geostationary spacecraft				
SD-OP-05	Disposal probability success				
SD-OP-06	Allocated propellant use				
SD-OP-07	Nuclear reactor & power sources				
SD-OP-08	Re-entry and traffic regulation				

Annex 2

Terms and definitions

For the purposes of this European Code of Conduct, the terms and definitions given in European Standard ECSS-P-001, *Glossary of terms*, and the following definitions apply.

Casualty risk

The probability of serious injury to or death of a single person due to the re-entry of a space system.

Damage

Loss of human life, personal injury or other health impairments, occupational illness, total or partial loss of property, or deterioration caused to the aforesaid property or to environment.

De-orbiting

Deliberate or forced re-entry of a space system into the Earth's atmosphere by applying a retarding force, usually via a propulsion system.

Direct re-entry

The space system performs the manoeuvres to complete its re-entry phase within a single orbit revolution.

Disposal orbit
Synonym: Graveyard orbit

Earth orbit remaining outside the protected outer space regions even under the influence of perturbations.

Disposal phase

Begins at the end of the operational phase of a space system, and ends when either the space system has performed a direct re-entry or completed activities to enable it to reach its disposal orbit and has been passivated.

End-of-life

End of the disposal phase.

End of mission

Completion of the scheduled mission of the space system, or mission stop due to a space system failure or to a voluntary decision.

Geostationary Orbit

Earth orbit having zero inclination and zero eccentricity, whose orbital period is equal to the Earth's sidereal period; the altitude of this unique circular orbit is close to 35 786 km.

Geostationary Transfer Orbit

An Earth orbit which is or can be used to transfer space systems from lower orbits to the geosynchronous region; such orbits typically have perigees within LEO region and apogees near or above GEO.

Geosynchronous region (GEO region)

The space region close to and including the Earth orbit with an orbital period equal to one sidereal day.

Hazardous event

An unplanned event or series of events resulting in damage or potential for damage.

Launch phase

Begins when the launch vehicle is no longer in physical contact with equipment and ground installations that made its preparation and ignition possible (or when the launch vehicle is dropped from the carrier-aircraft, if any), and continues up to the end of the mission assigned to the launch vehicle.

The launch phase ends when the launch vehicle has achieved an Earth orbit or an interplanetary trajectory or, if not, when it is in physical contact with the ground again.

Launch vehicle
See "Space system".

Launching state
(UN Liability Convention definition)

(i) A State which launches or procures the launching of a space object;
(ii) A State from whose territory or facility a space object is launched.

Low Earth Orbit
Orbit with apogee altitude lower than 2 000 km.

Low Earth Orbit region (LEO region)
The spherical region that extends from the Earth's surface up to an altitude of 2 000 km.

Operational phase
Part of the orbital phase of a space system starting as the orbital phase and ceasing at the end of mission.

Operator
Any citizen of a nation in which he is performing space activities, or any organisation existing under the laws of a nation or under an international governmental agreement in order to perform space activities or any worker of such an organisation when he is duly authorised by that organisation.

Orbital lifetime
The length of time a space object remains in Earth orbit.

Orbital phase
Starts when a space system is in orbit separated from the launch vehicle and ends when it re-enters the Earth's atmosphere.

Passivation
The elimination of all stored energy on a space system to reduce the chance of break-up.Typical passivation measures include venting or burning excess propellant, discharging batteries and relieving pressure vessels.

Prevention measure
Any measure which decreases the potential for generating space debris, or reduces the associated risk.

Protection measure
Any measure reducing the effective damage caused by space debris.

Re-entry phase
Begins when the space object comes into the Earth's atmosphere, and continues until either the intact object or its surviving parts come to rest on the Earth's surface or when the object and all of its parts have disintegrated.

Re-orbiting
Intentional changing of a space system's orbit.

Safety
All the arrangements intended to control safety risks stemming from activities contributing to the flight of a manned or unmanned space system, in order to ensure the protection of people, public and private property, and the environment, against any damage caused by such activities.

Space debris
Synonym: orbital debris
Synonym: 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.

Space object

Any man-made space system and any of its components or fragments.

Space system

Spacecraft, launch vehicle, and launch vehicle orbital stage are defined as space systems within this document.

Spacecraft : an orbiting object designed to perform a specific function or mission (e.g. communications, navigation or Earth observation). A spacecraft that can no longer fulfil its intended mission is considered non-functional. (Spacecraft in reserve or standby modes awaiting possible reactivation are considered functional.)

Launch vehicle : any vehicle constructed for ascent to outer space, and for placing one or more objects in outer space, and any suborbital rocket.

Launch vehicle orbital stage : any stage of a launch vehicle left in Earth orbit.

Suborbital

Not completing one full orbital revolution.

Annex 3

Abbreviations

AOCS	Attitude and Orbit Control System
ASI	Agenzia Spaziale Italiana
BNSC	British National Space Centre
CNES	Centre National d'Etudes Spatiales
CSG	Centre Spatial Guyanais (French Guiana Space Center)
DLR	Deutsches Zentrum fuer Luft- und Raumfahrt
ESA	European Space Agency
ESA/IRC	European Space Agency / International Relations Committee
GEO	GEostationary Orbit
IADC	Inter-Agency space Debris co-ordination Committee
LEO	Low Earth Orbit
SD-DE	Space Debris, DEsign
SD-MM	Space Debris, ManageMent
SD-OP	Space Debris, OPeration
UN	United Nations
Z	Current altitude (in km, with respect to spherical Earth with a radius of 6378 km)
Z_{GEO}	Geostationary Earth orbit altitude (in km, with respect to a spherical Earth with a radius of 6378 km)