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Inter-Agency Space Debris Coordination Committee

IADC Space Debris Mitigation Guidelines

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Revision History

Issue	Revision	Date	Reason for Revision
1	0	2002-10-15	Initial Version
1	1	2007-09-01	First revision with clarifications
1	2	2020-03-01	Update section 5.3.2 to include post mission disposal success rate values.
1	3	2021-06-10	Third revision including clarifications and target values on GEO disposal, break-up causes, operational phases, and re-entry risks.

List of Abbreviations

Abbreviation	Description
ASI	Agenzia Spaziale Italiana (Italian Space Agency)
CNES	Centre National d'Etudes Spatiales
CNSA	China National Space Administration
CSA	Canadian Space Agency
DLR	Deutsches Zentrum für Luft- und Raumfahrt (German Aerospace Center)
ESA	European Space Agency
GEO	Geostationary Earth Orbit
GTO	Geostationary Transfer Orbit
IADC	Inter-Agency Space Debris Coordination Committee
ISRO	Indian Space Research Organisation
JAXA	Japan Aerospace Exploration Agency
KARI	Korea Aerospace Research Institute
LEO	Low Earth Orbit
NASA	National Aeronautics and Space Administration
ROSCOSMOS	Russian Space State Corporation
SSAU	State Space Agency of Ukraine
UKSA	UK Space Agency

Foreword

The Inter-Agency Space Debris Coordination Committee (IADC) is an international forum of space agencies, authorized governmental or inter-governmental entities for the coordination of activities related to the issues of human-made and natural debris in space. The primary purpose of the IADC is to exchange information on space debris research activities between member space agencies, to facilitate opportunities for co-operation in space debris research, to review the progress of ongoing co-operative activities and to identify debris mitigation options.

Members of the IADC are the Italian Space Agency (ASI), Centre National d'Etudes Spatiales (CNES), China National Space Administration (CNSA), Canadian Space Agency (CSA), German Aerospace Center (DLR), European Space Agency (ESA), Indian Space Research Organisation (ISRO), Japan Aerospace Exploration Agency (JAXA), Korea Aerospace Research Institute (KARI), National Aeronautics and Space Administration (NASA), Russian State Space Corporation (ROSCOSMOS), State Space Agency of Ukraine (SSAU), and United Kingdom Space Agency (UKSA).

One of its efforts is to recommend debris mitigation guidelines, with an emphasis on cost effectiveness, that can be considered during planning and design of spacecraft and launch vehicles in order to minimise or eliminate generation of debris during and after the missions. This document provides guidelines for debris reduction, developed via consensus within the IADC.

In the process of producing these guidelines, IADC got information from the following documents and study reports:

- Technical Report on Space Debris, Text of the report adopted by the Scientific and Technical Subcommittee of the United Nations Committee on the Peaceful Uses of Outer Space, 1999
- Interagency report on Orbital Debris 1995, The National Science and Technology Council Committee on Transportation Research and Development, November 1995
- U.S. Government Orbital Debris Mitigation Standard Practices, 2001
- Space Debris Mitigation Standard, NASDA-STD-18, March 28, 1996
- CNES Standards Collection, Method and Procedure Space Debris – Safety Requirements, RNC-CNES-Q-40-512, Issue 1- Rev. 0, April 19, 1999
- Policy to Limit Orbital Debris Generation, NASA Program Directive 8710.3, May 29, 1997
- Guidelines and Assessment Procedures for Limiting Orbital Debris, NASA Safety Standard 1740.14, August 1995
- Space Technology Items. General Requirements Mitigation of Space Debris Population. Russian Aviation & Space Agency Standard OCT 134-1023-2000
- ESA Space Debris Mitigation Handbook, Release 1.0, April 7, 1999

- IAA Position Paper on Orbital Debris – Edition 2001, International Academy of Astronautics, 2001
- European Space Debris Safety and Mitigation Standard, Issue 1, Revision 0, September 27 2000
- Space technology items. General requirements for mitigation of space debris population. National standard of the Russian Federation. GOST R 52925-2008
- Stability of the Future LEO Environment, IADC-12-08, Rev. 1, January 2013
- U.S. Government Orbital Debris Mitigation Standard Practices, 2019
- ESA Re-entry Safety Requirements, ESSB-ST-U-004, Issue 1 Revision 0, 2017
- ESA Space Debris Mitigation Compliance Verification Guidelines, ESSB-HB-U-002, Issue 1 Revision 0, 2015.

Introduction

It was a common understanding at the time when the United Nations Committee on the Peaceful Uses of Outer Space (UN COPUOS) published its Technical Report on Space Debris in 1999, that human-made space debris posed limited risk to ordinary robotic spacecraft in Earth orbit, but the population of debris was already growing. The probability of collisions that could lead to potential damage has consequently increased ever since. It has now become common practice to consider the collision risk with space debris in planning a mission. So, the implementation of debris mitigation measures today is still a prudent and necessary step towards preserving the space environment for future generations.

Several national and international organisations of the space faring nations have established Space Debris Mitigation Standards or Handbooks to promote efforts to deal with space debris issues. The contents of these Standards and Handbooks may be slightly different from each other but their fundamental principles are the same:

(1) Preventing explosive and collisional on-orbit break-ups

(2) Removing spacecraft and orbital stages that have reached the end of their mission operations from the useful densely populated orbit regions

(3) Limiting the objects released during normal operations.

The IADC guidelines are based on these common principles and have been agreed to by consensus among the IADC member agencies.

IADC Space Debris Mitigation Guidelines

1 Scope

The IADC Space Debris Mitigation Guidelines describe existing practices that have been identified and evaluated for limiting the generation of space debris in the environment.

The Guidelines cover the overall environmental impact of the missions with a focus on the following:

(1) Limitation of debris released during normal operations,

(2) Minimisation of the potential for on-orbit break-ups,

(3) Post-mission disposal,

(4) Prevention of on-orbit collisions.

2 Application

The IADC Space Debris Mitigation Guidelines are applicable to mission planning and the design and operation of spacecraft and orbital stages that will be injected into Earth orbit.

Organisations are encouraged to use these Guidelines in identifying the standards that they will apply when establishing the mission requirements for planned spacecraft and orbital stages.

Operators of existing spacecraft and orbital stages are encouraged to apply these guidelines to the greatest extent possible.

3 Terms and definitions

The following terms and definitions are added for the convenience of the readers of this document. They should not necessarily be considered to apply more generally.

3.1 Space Debris

Space debris are all human made objects including fragments and elements thereof, in Earth orbit or re-entering the atmosphere, that are non-functional.

3.2 Spacecraft, Launch Vehicles, and Orbital Stages

3.2.1 Spacecraft – an orbiting object designed to perform a specific function or mission (e.g. communications, navigation or Earth observation). During the operational phases, a spacecraft or orbital stage can be considered as functional. 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.)

3.2.2 Launch vehicle – any vehicle constructed for ascent to outer space, and for placing one or more objects in outer space, and any sub-orbital rocket.

3.2.3 Launch vehicle orbital stages – any stage of a launch vehicle left in Earth orbit.

3.3 Orbits and Protected Regions

3.3.1 Equatorial radius of the Earth – the equatorial radius of the Earth is taken as 6,378 km and this radius is used as the reference for the Earth's surface from which the orbit regions are defined.

3.3.2 Protected regions – any activity that takes place in outer space should be performed while recognising the unique nature of the following regions, A and B, of outer space (see Figure 1), to ensure their future safe and sustainable use. These regions should be protected regions with regard to the generation of space debris.

(1) Region A, **Low Earth Orbit** (or LEO) **Protected Region** – spherical region that extends from the Earth's surface up to an altitude (Z) of 2,000 km

(2) Region B, the **Geosynchronous** (or GEO) **Protected Region** – a segment of the spherical shell defined by the following:

lower altitude = geostationary altitude minus 200 km

upper altitude = geostationary altitude plus 200 km

-15 degrees ≤ latitude ≤ +15 degrees

geostationary altitude (Z_{GEO}) = 35,786 km (the altitude of the geostationary Earth orbit)

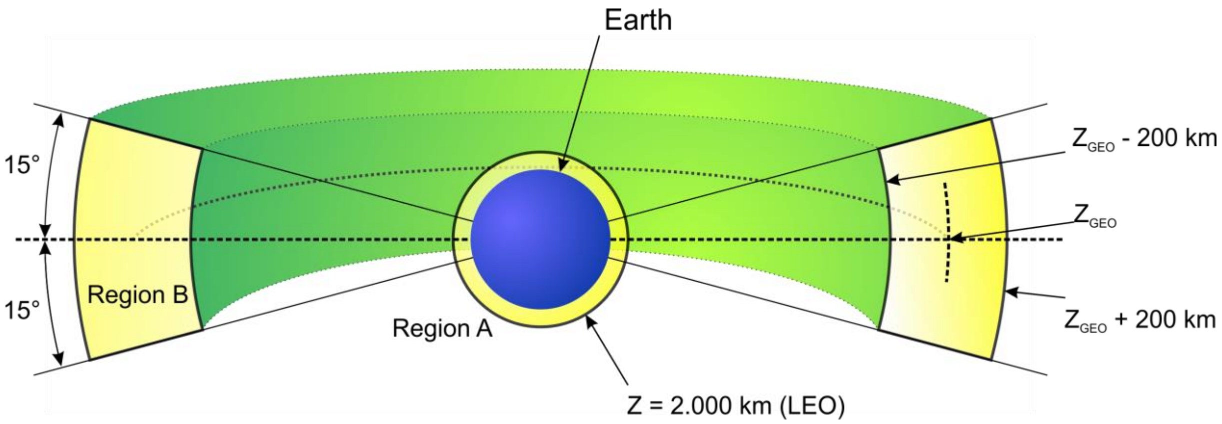

Figure 1: Protected regions

3.3.3 Geostationary Earth Orbit (GEO) – 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.

3.3.4 Geostationary Transfer Orbit (GTO) – an Earth orbit which is or can be used to transfer spacecraft or orbital stages from lower orbits to the geosynchronous region. Such orbits typically have perigees within LEO region and apogees near or above GEO.

3.4 Mitigation Measures and Related Terms

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

3.4.2 De-orbit – intentional changing of orbit for re-entry of a spacecraft or orbital stage into the Earth's atmosphere.

3.4.3 Re-orbit – intentional changing of a spacecraft or orbital stage's orbit.

3.4.4 Break-up – any event that generates fragments, which are released into Earth orbit. This includes:

(1) An explosion caused by the chemical or thermal energy from propellants, pyrotechnics and so on,

(2) A rupture caused by an increase in internal pressure,

(3) A break-up caused by energy from collision with other objects.

However, the following events are excluded from this definition:

- A break-up during the re-entry phase caused by aerodynamic forces.
- The generation of fragments, such as paint flakes, resulting from the ageing and degradation of a spacecraft or orbital stage.

Break-ups related to items (1) and (2) above are referred to as explosive break-ups. Break-ups related to item (3) above are referred to as collisional break-ups.

3.5 Operational Phases

3.5.1 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.

3.5.2 Mission phase – the phase where the spacecraft or orbital stage fulfils its mission. Begins at the end of the launch phase or when released on-orbit as part of the mission phase of another spacecraft, and ends at the beginning of the disposal phase.

3.5.3 Disposal phase – begins at the end of the mission phase for a spacecraft or orbital stage and ends when the spacecraft or orbital stage has performed the actions, if any, to reduce the hazards it poses to other spacecraft and orbital stages. If the spacecraft or orbital stage is on-orbit after its disposal phase, it can be considered space debris.

4 General Guidance

During an organisation's planning for and operation of a spacecraft and/or orbital stage, it should take systematic actions to reduce adverse effects on the orbital environment by introducing space debris mitigation measures into the spacecraft or orbital stage's lifecycle, from the mission requirement analysis and definition phases.

In order to manage the implementation of space debris mitigation measures, it is recommended that a feasible Space Debris Mitigation Plan be established and documented for each program and project. The Mitigation Plan should include the following items:

(1) A management plan addressing space debris mitigation activities.

(2) A plan for the assessment and mitigation of risks related to space debris, including applicable standards.

(3) The measures minimising the hazard related to malfunctions that have a potential for generating space debris.

(4) A plan for disposal of the spacecraft and/or orbital stages at end of mission.

(5) Justification of choice and selection when several possibilities exist.

(6) Compliance matrix addressing the recommendations of these Guidelines.

5 Mitigation Measures

5.1 Limit Debris Released during Normal Operations

In all operational orbit regimes, spacecraft and orbital stages should be designed not to release debris during normal operations. Where this is not feasible any release of debris should be minimised in number, area and orbital lifetime.

Any program, project or experiment that will release objects in orbit should not be planned unless an adequate assessment can verify that the effect on the orbital environment, and the hazard to other operating spacecraft and orbital stages, is acceptably low in the long-term.

The potential hazard of tethered systems should be analysed by considering both an intact and severed system.

5.2 Minimise the Potential for On-Orbit Break-ups

On-orbit break-ups caused by the following factors should be prevented using the measures described in 5.2.1 – 5.2.3:

(1) The potential for break-ups during mission should be minimised.

(2) All space systems should be designed and operated so as to prevent accidental explosions and ruptures after end-of-mission.

(3) Intentional destructions, which will generate long-lived orbital debris, should not be planned or conducted.

5.2.1 Minimise the potential for post mission break-ups resulting from stored energy

In order to limit the risk to other spacecraft and orbital stages from accidental break-ups after the completion of mission operations, all on-board sources of stored energy of a spacecraft or orbital stage, such as residual propellants, batteries, high-pressure vessels, self-destructive devices, flywheels and momentum wheels, should be depleted or made safe when they are no longer required for mission operations or post-mission disposal. Depletion should occur as soon as this operation does not pose an unacceptable risk to the payload. Mitigation measures should be carefully designed not to create other risks.

(1) Residual propellants and other fluids, such as pressurant, should be depleted as thoroughly as possible, either by depletion burns or venting, to prevent accidental break-ups by over-pressurisation or chemical reaction.

(2) Batteries should be adequately designed and manufactured, both structurally and electrically, to prevent break-ups. Pressure increase in battery cells and assemblies could be prevented by mechanical measures unless these measures cause an excessive reduction of mission assurance. At the end of operations battery charging lines should be de-activated.

(3) High-pressure vessels should be vented to a level guaranteeing that no break-ups can occur. Leak-before-burst designs are beneficial but are not sufficient to meet all passivation recommendations of propulsion and pressurisation systems. Heat pipes may be left pressurised if the probability of rupture can be demonstrated to be very low.

(4) Self-destruct systems should be designed not to cause unintentional destruction due to inadvertent commands, thermal heating, or radio frequency interference.

(5) Power to flywheels and momentum wheels should be terminated during the disposal phase.

(6) Other forms of stored energy should be assessed and adequate mitigation measures should be applied.

5.2.2 Minimise the potential for break-ups during operational phases

The IADC has found that observed annual rates of explosive break-ups are not compatible with limiting the space debris environment. During the design of spacecraft or orbital stages, each program or project should demonstrate, using failure mode and effects analyses or an equivalent analysis, that there is no probable failure mode leading to accidental explosive break-ups. If such failures cannot be excluded, the design or operational procedures should minimise the probability of their occurrence. The probability of occurrence during all operational phases should be at least below 10^{-3} in order to have a noticeable effect on the space debris environment.

During the operational phases, a spacecraft or orbital stage should be periodically monitored to detect malfunctions that could lead to a break-up or loss of control function. In the case that a malfunction is detected, adequate recovery measures should be planned and conducted; otherwise disposal and passivation measures for the spacecraft or orbital stage should be planned and conducted.

5.2.3 Avoidance of intentional destruction and other harmful activities

Intentional destruction of a spacecraft or orbital stage, (self-destruction, intentional collision, etc.), and other harmful activities that may significantly increase collision risks to other spacecraft and orbital stages should be avoided. If intentional break-ups cannot be avoided, they should be conducted at sufficiently low altitudes so that orbital fragments are short lived and do not cause a significant collision risk.

5.3 Post Mission Disposal

5.3.1 Geosynchronous Region

5.3.1.1 Objects in a Circular or Near-Circular Orbit Completely within the Geosynchronous Protected Region at the End of the Mission Phase

Launch vehicle orbital stages and spacecraft that have reached the end of their mission phase in a circular or near-circular orbit completely within the Geosynchronous Protected Region should manoeuvre immediately away from GEO so as not to cause interference with operational spacecraft or orbital stages still in that region. A manoeuvre should place such orbital stages or spacecraft in an orbit that remains outside the GEO Protected Region for at least 100 years.

For spacecraft and launch vehicle orbital stages that reach the end of their mission phase in a circular or near-circular orbit within the GEO Protected Region, the IADC and other studies have found that fulfilling the two following conditions at the end of the disposal phase should give an orbit that remains above the GEO Protected Region for a long period of time:

(1) A minimum increase in perigee altitude of:

$$235\,km + \left(1000 \times C_R \times {}^{A}/_{m}\right)$$

where	C_R	is the solar radiation pressure coefficient, typically in the range of about 1.2 to 1.5,
	${}^{A}/_{m}$	is the aspect area to dry mass ratio ($m^2\,kg^{-1}$)
	235 km	is the sum of the upper altitude of the GEO Protected Region (200 km) and the maximum descent of a re-orbited spacecraft due to luni-solar & geopotential perturbations (35 km).

(2) An eccentricity less than or equal to 0.003.

Other options enabling spacecraft to fulfil this guideline to remain above the GEO Protected Region are described in the "Support to the IADC Space Debris Mitigation Guidelines" document. In all cases a trajectory analysis should be conducted to confirm that the disposal orbit will remain above the GEO Protected Region for at least 100 years.

The propulsion system for a spacecraft operating during its mission phase within the GEO Protected Region should be designed not to be separated from the spacecraft. In the case that there are unavoidable reasons that require separation, the propulsion system should be designed to be left in an orbit that is, and will remain for at least 100 years, outside of the GEO Protected Region. Regardless of whether it is separated or not, a propulsion system should be designed for passivation.

5.3.1.2 Objects Passing Through the Geosynchronous Protected Region

Operators should avoid the long-term presence of launch vehicle orbital stages and spacecraft in the geosynchronous region.

5.3.2 Objects Passing Through the LEO Region

Spacecraft or orbital stages that are terminating their operational phases in orbits that pass through the LEO region, or have the potential to interfere with the LEO region, should be de-orbited (direct re-entry is preferred) or where appropriate manoeuvred into an orbit with an expected residual orbital lifetime of 25 years or shorter. The probability of success of the disposal should be at least 90%. For specific operations such as large constellations, a shorter residual orbital lifetime and/or a higher probability of success may be necessary. Retrieval is also a disposal option.

If a spacecraft or orbital stage is to be disposed of by re-entry into the atmosphere, debris that survives to reach the surface of the Earth should not pose an undue risk to people or property. Using 10^{-4} as the upper limit for the expected number of human casualties per re-entry is recommended. This may be accomplished by limiting the amount of surviving debris or confining the debris to uninhabited regions, such as broad ocean areas. Also, ground environmental pollution, caused by radioactive substances, toxic substances or any other environmental pollutants resulting from on-board articles, should be prevented or minimised in order to be accepted as permissible.

In the case of a controlled re-entry of a spacecraft or orbital stage, the operator of the system should inform the relevant air traffic and maritime traffic authorities of the re-entry time and trajectory and the associated ground area.

5.3.3 Other Orbits

Spacecraft or orbital stages that are terminating their operational phases in other orbital regions should be manoeuvred to reduce their orbital lifetime, commensurate with LEO lifetime limitations, or relocated if they cause interference with highly utilised orbit regions.

5.4 Prevention of On-Orbit Collisions

The IADC and other studies have demonstrated that accidental collisions will drive the future space debris population increase in the environment. In developing the design and mission profile of a spacecraft or orbital stage, a program or project should estimate and limit the probability of accidental collision with known objects during the spacecraft or orbital stage's orbital lifetime. If reliable orbital data and conjunction assessments are available, avoidance manoeuvres for spacecraft during all operational phases and co-ordination of launch windows for launch vehicle orbital stages should be considered. After the end of all operational phases of a spacecraft or orbital stage, the integrated collision risk during the remaining orbital lifetime should be minimised commensurate with post mission disposal measures. Spacecraft design should also limit the probability of collision with small debris which could cause a loss of control, thus preventing post-mission disposal.

6 Update

These guidelines may be updated as new information becomes available regarding space activities and their influence on the space environment.