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Space debris

Inter-Agency Space Debris Coordination Committee space debris mitigation guidelines

1. In its resolution 57/116 of 11 December 2002, paragraph 16 (b) (iv), the General Assembly endorsed the recommendation of the Committee on the Peaceful Uses of Outer Space that the Committee's Scientific and Technical Subcommittee consider an item on space debris, in accordance with the work plan adopted by the Subcommittee at its thirty-eighth session (A/AC.105/761, para. 130). According to this work plan, the Inter-Agency Space Debris Coordination Committee (IADC) was invited to present its proposals on debris mitigation, based on consensus among the IADC members, to the fortieth session of the Subcommittee.

2. IADC has submitted the following proposals on debris mitigation in response to this invitation. Under the work plan, Member States will review the IADC proposals on debris mitigation and discuss the means of endorsing their utilization.

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Annex

IADC space debris mitigation guidelines

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Foreword

1. The Inter-Agency Space Debris Coordination Committee (IADC) is an international forum of governmental bodies for the coordination of activities related to the issues of man-made and natural debris in space. The primary purpose of IADC is to exchange information on space debris research activities between member space agencies, to facilitate opportunities for cooperation in space debris research, to review the progress of ongoing cooperative activities and to identify debris mitigation options.

2. Members of IADC are the British National Space Centre (BNSC), Centre national d'études spatiales (CNES) of France, the China National Space Administration (CNSA), the European Space Agency (ESA), the German Aerospace Center (DLR), the Indian Space Research Organisation (ISRO), the Italian Space Agency (ASI), Japan, the National Aeronautics and Space Administration (NASA) of the United States of America, the National Space Agency of Ukraine (NSAU) and the Russian Aviation and Space Agency (Rosaviakosmos).

3. IADC efforts include recommending debris mitigation guidelines, with an emphasis on cost-effectiveness, that can be considered during the planning and design of spacecraft and launch vehicles in order to minimize or eliminate the generation of debris during operations. This document provides guidelines for debris reduction, developed via consensus within IADC.

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

Technical Report on Space Debris, report adopted by the Scientific and Technical Subcommittee of the Committee on the Peaceful Uses of Outer Space, 1999 (United Nations publication, Sales No. E.99.I.17) (A/AC.105/720).

Interagency Report on Orbital Debris 1995, National Science and Technology Council Committee on Transportation Research and Development, November 1995.

U.S. Government Orbital Debris Mitigation Standard Practices, December 2000.

Space Debris Mitigation Standard, NASDA-STD-18, 28 March 1996.

CNES Standards Collection, Method and Procedure Space Debris—Safety Requirements, RNC-CNES-Q-40-512, Issue 1-Rev.0, 19 April 1999.

Policy to Limit Orbital Debris Generation, NASA Program Directive 8710.3, 29 May 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 and Space Agency Standard OCT 134-1023-2000.

ESA Space Debris Mitigation Handbook, Release 1.0, 7 April 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, 27 September 2000.

Introduction

5. It has been a common understanding since the Committee on the Peaceful Uses of Outer Space published its *Technical Report on Space Debris* (A/AC.105/720) in 1999, that man-made space debris today poses little risk to ordinary unmanned spacecraft in Earth orbit, but the population of debris is growing, and the probability of collisions that could lead to potential damage will consequently increase. It has, however, now become common practice to consider the collision risk with orbital debris in planning manned missions. So the implementation of some debris mitigation measures today is a prudent and necessary step towards preserving the space environment for future generations.

6. Several national and international organizations 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:

(a) Preventing on-orbit break-ups;

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

(c) Limiting the objects released during normal operations.

7. 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) Minimization 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 (defined here as space systems) that will be injected into Earth orbit.

Organizations are encouraged to use these guidelines in identifying the standards that they will apply when establishing the mission requirements for planned space systems.

Operators of existing space systems 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" refers to all man-made objects, including fragments and elements thereof, in Earth orbit or re-entering the atmosphere, that are non-functional.

3.2 Space systems

Spacecraft and orbital stages are defined as space systems within this document.

3.2.1 Spacecraft

A spacecraft is 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.)

3.2.2 Launch vehicle

A launch vehicle is 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

A launch vehicle orbital stage is 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 recognizing the unique nature of the following regions (A and B), of outer space (see figure), 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 (LEO) Region—the spherical region that extends from the Earth's surface up to an altitude (Z) of 2,000 km;

(2) Region B, the Geosynchronous Region—a segment of the spherical shell defined by the following:

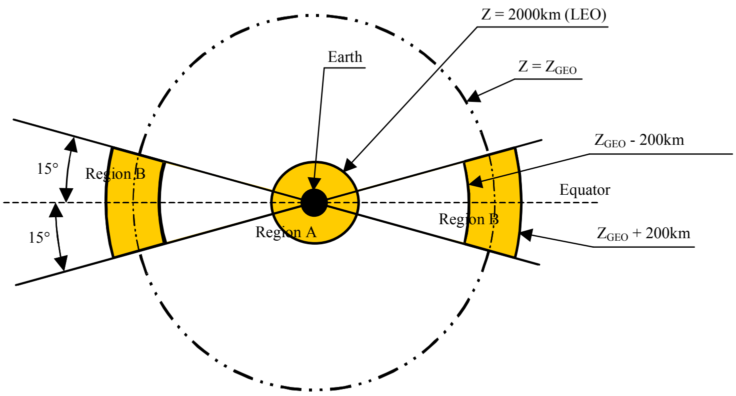
lower altitude = geostationary altitude minus 200 km

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).

Protected regions



3.3.3 Geostationary Earth orbit

A geostationary Earth orbit (GEO) is an 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

A geostationary transfer orbit (GTO) is 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 the LEO region and apogees near or above GEO.

3.4 Mitigation measures and related terms

3.4.1 Passivation

Passivation is 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.

3.4.2 De-orbit

De-orbiting is intentional changing of orbit for re-entry of a space system into the Earth's atmosphere to eliminate the hazard it poses to other space systems, by applying a retarding force, usually via a propulsion system.

3.4.3 Re-orbit

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

3.4.4 Break-up

A break-up is any event that generates fragments that 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:

(1) A break-up during the re-entry phase caused by aerodynamic forces;

(2) The generation of fragments, such as paint flakes, resulting from the ageing and degradation of a space system.

3.5 Operational phases

3.5.1 Launch phase

The 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 mission phase is the phase where the space system fulfils its mission. It begins at the end of the launch phase and ends at the beginning of the disposal phase.

3.5.3 Disposal phase

The disposal phase begins at the end of the mission phase for a space system and ends when the space system has performed the actions to reduce the hazards it poses to other space systems.

4. General guidance

During an organization's planning for and operation of a space system, it should take systematic actions to reduce adverse effects on the orbital environment by introducing space debris mitigation measures into the space system's life cycle, 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 programme 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 minimizing the hazard related to malfunctions that have a potential for generating space debris;

(4) A plan for disposal of the space system 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, space systems should be designed not to release debris during normal operations. Where this is not feasible, any release of debris should be minimized in number, area and orbital lifetime.

Any programme, 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 space systems, 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 Minimize 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 minimized;

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

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

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

In order to limit the risk to other space systems from accidental break-ups after the completion of mission operations, all on-board sources of stored energy of a space system, such as residual propellants, batteries, high-pressure vessels, self-destructive devices, flywheels and momentum wheels, should be depleted or “safed” (made inactive) 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, as follows:

(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-pressurization or chemical reaction;

(2) Batteries should be adequately designed and manufactured, both structurally and electrically, to prevent break-ups. Pressure increases 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 deactivated;

(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 pressurization systems. Heat pipes may be left pressurized if the probability of rupture can be demonstrated to be very low;

(4) Self-destruct systems should be designed not to cause unintentional destruction owing to inadvertent commands, thermal heating or radiofrequency 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 Minimize the potential for break-ups during operational phases

During the design of a space system, each programme or project should demonstrate, using failure mode and effects analyses or an equivalent analysis, that there is no probable failure mode leading to accidental break-ups. If such failures cannot be excluded, the design or operational procedures should minimize the probability of their occurrence.

During the operational phases, a space system 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 system should be planned and conducted.

5.2.3 Avoidance of intentional destruction and other harmful activities

Intentional destruction of a space system (self-destruction, intentional collision etc.) and other harmful activities that may significantly increase collision risks to other systems should be avoided. For instance, intentional break-ups should be conducted at sufficiently low altitudes so that orbital fragments are short-lived.

5.3 Post mission disposal

5.3.1 Geosynchronous region`

Spacecraft that have terminated their mission should be manoeuvred far enough away from GEO so as not to cause interference with space systems still in geostationary orbit. The recommended minimum increase in perigee altitude at the end of re-orbiting, which takes into account all orbital perturbations, is:

$$235 \text{ km} + (1{,}000 \cdot C_R \cdot A/m)$$

where C_R: Solar radiation pressure coefficient (typical values are between 1 and 2),

A/m: Aspect area to dry mass ratio [m^2/kg]

235 km: Sum of the upper altitude of the GEO protected region (200 km) and the maximum descent of a re-orbited space system owing to luni-solar and geopotential perturbations (35 km).

The propulsion system for a GEO spacecraft 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, outside of the protected geosynchronous region.

Regardless of whether it is separated or not, a propulsion system should be designed for passivation.

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

5.3.2 Objects passing through the LEO region

Whenever possible, space systems 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 a reduced lifetime. Retrieval is also a disposal option.

A space system should be left in an orbit in which, using an accepted nominal projection for solar activity, atmospheric drag will limit the orbital lifetime after completion of operations. A study on the effect of post-mission orbital lifetime limitation on collision rate and debris population growth has been performed by IADC. This IADC and some other studies and a number of existing national guidelines have found 25 years to be a reasonable and appropriate lifetime limit. If a space system 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. 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 minimized in order to be accepted as permissible.

In the case of a controlled re-entry of a space system, 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

Space systems 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 utilized orbit regions.

5.4 Prevention of on-orbit collisions

In developing the design and mission profile of a space system, a programme or project should estimate and limit the probability of accidental collision with known objects during the system's orbital lifetime. If reliable orbital data is available, avoidance manoeuvres for spacecraft and coordination of launch windows may be considered if the collision risk is not considered negligible. Spacecraft design should 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.