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Space systems — Design, testing and operation of a large constellation of spacecraft

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operations*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

More than a dozen large constellations of spacecraft are planned to be launched in the next several years. While large constellations can provide societal benefits to humanity, they can also put pressure on the orbital and electro-magnetic environments, introducing mission design, hardware design, launch, operations and disposal challenges to other operating space assets and the long-term sustainability of space activities.

This document provides a set of standard practices throughout the large constellation life cycle to promote safety on the ground from re-entry hazard and long-term sustainability of space operations.

In developing this document, the practices of the existing large constellation programs, consensus in the Space Safety Coalition, "Best Practices for the Sustainability of Space Operations,"[1], the "Statement on Large Constellations"[2] of the "Inter-Agency Space Debris Coordination Committee (IADC)", ISO 24113, which specifies space debris mitigation requirements, the "Guidelines for the Long-term Sustainability of Outer Space Activities" COPUOOS June 2021[3] and other effective documents were consulted.

Space systems — Design, testing and operation of a large constellation of spacecraft

1 Scope

This document provides requirements that are either unique or particularly relevant to large constellations of spacecraft (particularly when operating in the LEO protected region) throughout their life cycle, including planning, designing, testing, operating and disposal activities.

The requirements in this document are applicable to large constellation owners. While some are directly applicable to the constellation owners, others are allocated to the manufactures or operators under the responsibility of the constellation owners.

2 Normative reference

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 19389[1)], *Space data and information transfer systems — Conjunction data message*

ISO 24113, *Space systems — Space debris mitigation requirements*

ISO 26900[2)], *Space data and information transfer systems — Orbit data messages*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
large constellation of spacecraft
large constellation
system of a hundred or more spacecraft working together

Note 1 to entry: While providing a specific quantity of spacecraft, the size, mass, complexity and function of the spacecraft also have a bearing.

3.2
latitude range
band of geocentric latitude that spacecraft in two constellations may simultaneously occupy

3.3
radial separation
distance between constellation orbits in the radial direction within a common *latitude range* (3.2), irrespective of right ascension of ascending node and timing (nodal regression and in-track motion)

1) Adoption from CCSDS 508.0-B-1.

2) Adoption from CCSDS 502.0-B-2.

3.4
useful life
operating duration in which a product is claimed to remain suitable and safe for its intended use when used as designed

4 Abbreviated terms

CCSDS Consultative Committee for Space Data System

DoA dead-on-arrival

ITU International Telecommunication Union

LED light emitting diode

LEO low Earth orbit

RCS reaction control system

RFI radio frequency interference

SSA space situational awareness

5 Requirements

5.1 Mission design

5.1.1 Orbit selection of constellation and maintenance to minimise collision risk

5.1.1.1 Selection of orbit of constellation considering collision risk

The orbit of constellation shall be selected to minimise the probability of collision with other space objects.

5.1.1.2 Maintenance of radial separation from other constellations

The constellations shall be designed to maintain adequate radial separation from other large constellations to assure safe operations under both nominal and anomalous vehicle operating conditions.

5.1.2 Intra-constellation collision avoidance

5.1.2.1 Allocation of orbit of member spacecraft to minimise collision risk

Constellations shall be configured to mitigate collision risk between constellation spacecraft according to the threshold defined by approving agent.

5.1.2.2 Allocation of orbit considering the contingencies

Constellations shall be configured such that constituent failures do not significantly elevate intra-constellation collision risk (e.g. by separating the orbit planes and radial profiles to avoid intersection points).

5.1.2.3 Orbit control of spacecraft during operation

Spacecraft insertion, operational and disposal orbits shall be chosen considering collision risk and post-mission orbital lifetime, commensurate with mission objectives and constraints.

5.1.3 Space debris mitigation

A large constellation shall satisfy the space debris mitigation requirements in ISO 24113, except where stricter versions of the requirements are specified elsewhere in this document.

5.1.4 Selection of launch service providers

The launch service provider shall be selected from those that conform to the space debris mitigation requirements in ISO 24113.

5.1.5 Assessment on the long-term evolution of debris environment

When planning to apply a large constellation, an assessment of the aggregate risk to space operations sustainability posed by the mission and constellation design, the individual spacecraft design, operations, and launch services shall be made and approved by the responsible authority.

NOTE 1 Commonly used metrics include risks placed on other operators, expected levels of space debris, likelihood of triggering a Kessler syndrome, etc.

NOTE 2 Such a risk assessment can identify increased levels for post-mission success rate and/or reduced disposal lifetime as described in 5.2 for constellation members and associated launch services.

5.2 Spacecraft design

5.2.1 Reliability design

5.2.1.1 General

Large constellation spacecraft designs shall safeguard against deployment of DoA spacecraft, unintentional termination of operation, accidental break-ups including dew to collision, failure to conduct proper disposal actions conforming to requirements in 5.2.

NOTE 1 For details of a rigorous qualification and testing program, see 5.3, which mentions that all relevant components are examined in the testing program given the mass production of constellation spacecraft.

NOTE 2 For details for the collision avoidance, see 5.4.2.

NOTE 3 For information on a proper disposal, see 5.5.

5.2.1.2 Availability of components and materials that have a limit for useful life

5.2.1.2.1 General

Any components and materials whose useful life (including “operation life” and “storage life”) is limited shall be designed or selected to assure the design life. If the operation is expected to be extended beyond the design life, they shall satisfy the planned extended life.

5.2.1.2.2 Operation time limited items

For components essential for the disposal function which have limited operation time or cycles and whose remaining usable service life is uncertain, an operations log shall be developed and procedurally maintained to enable analysts to assess the component’s residual life to ensure successful post-mission disposal prior to component failure.

5.2.1.2.3 Storage life limited items

If the mission's operational period is extended, the total operation period shall not exceed the "storage life" of any components used for disposal.

5.2.1.3 Critical components in new flight application

All components that are essential for the disposal function (including those required for maintaining spacecraft control and performing active collision avoidance and de-orbiting) shall have either been demonstrated on-orbit, or pass a rigorous testing regimen as specified in 5.3.2.

5.2.1.4 Design for post-mission orbital lifetime

a) Besides the requirement of ISO 24113, the post-mission orbital lifetime of large constellation spacecraft shall be controlled to be within the same duration as the spacecraft was designed to be operational, up to a maximum of five years.

   EXAMPLE If the mission lifetime is 4 years, then the spacecraft is brought down within 4 years after its decommissioning.

b) When disposed to a circular orbit, the selected disposal altitudes should be selected in a manner that avoids creating highly crowded orbit altitudes.

c) When disposing into an eccentric orbit, the disposal apogee should be placed below the constellation's lowest operational orbit radius at the epoch of disposal; and the perigee should be selected to avoid highly crowded orbits.

5.2.1.5 Predicted probability of successful disposal

In the design phase (prior to constellation launch and deployment), large constellation spacecraft shall be designed, configured, and operated to maximize the probability of successful disposal to be greater than 95 % with a goal of 100 %. Assessment of the probability of successful disposal shall apply at least until the end of the disposal manoeuvre. The time period during the passive decay until the end of passivation, when conjunction assessment is continued according to 5.5.4 b), can be excluded from the assessment of the probability of successful disposal on the condition that passivation can be immediately conducted when the symptom of failure is detected.

It is attained with following:

a) allocation and sequestering of propellants for planned disposal manoeuvre(s);

b) reliabilities are assured by the measures defined by the approval agent preferably including the reliability of the disposal function based on the failure rate, the single point failures in the electrical and electronic devises, the limitation of operation / storage life, etc.;

c) in the calculation of reliability, use of reliable electrical and electronic components and circuit design relating to the disposal function drawing upon the latest component failure rate and anomaly data as mandated by the responsible authority;

d) design and operational procedures to ensure that components are used within their designed operational lifetime, accompanied by procedures to identify when components are exhibiting characteristics of degradation, fatigue or imminent failure (see 5.2.1.2);

e) system design to facilitate continuous monitoring of all critical components to assess the health and readiness for proper disposal, etc. (see 5.4.1);

NOTE 1 The probability of successful disposal is required to be 0,9 in ISO 24113, but in the case of a large constellation, such a requirement would allow 10 % of large constellation spacecraft to not be properly disposed, greatly increasing collision risk in an important orbital region. Improvements to