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Space systems — Rendezvous and Proximity Operations (RPO) and On Orbit Servicing (OOS) — Programmatic principles and practices

Systèmes spatiaux — Opérations de proximité et de rendez-vous et services sur orbite — Principes et pratiques programmatiques

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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

This document outlines the principles and practices that rendezvous and proximity operations and on-orbit servicing (RPO/OOS) service providers are expected to follow in order to ensure safe operations and to encourage a healthy RPO/OOS industry. International law, treaties, and agreements have been researched for compliance and reference. If additional, more specific requirements are needed for Human Spaceflight (HSF) these can be provided in the future.

This document is intended to be the highest-level standard for the discipline of RPO/OOS for spacecraft systems. As such, there are several places in the document where a requirement is stated, but alternative acceptable methods of verification of compliance exist. Examples include but are not limited to: notification of authorities (4.2.2); certifications of design or operational procedures (5.1.1, 5.1.2, 5.1.3). Clauses 4 and 5 specify programmatic principles and operational practices respectively. Annex A contains information related to Clause 4 (A.1) and Clause 5 (A.2). Annex B outlines notional RPO/OOS mission phases.

Initial drafts were produced by the Consortium for Execution of Rendezvous and Servicing Operations (CONFERS) team, an international team of 26 initial companies promoting standardization for RPO/OOS missions to improve safety and promote development of the RPO/OOS industry. Work was performed over a period of 18 months at six international workshops in the US and Germany. With this issue, the draft has been handed over to ISO TC 20/SC 14 for vetting and processing with the normal ISO standardization processes. In the further development within ISO, parallel commercial and governmental RPO/OOS efforts have contributed to the consensus requirements herein.

CONFERS is an independent, self-sustaining forum created to advocate and promote the spacecraft servicing industry and encourage responsible commercial RPO/OOS. CONFERS collaborates on research, development, and publication of voluntary consensus principles, best practices, and technical and safety standards. CONFERS also engages with national governments and international bodies on policy and oversight of spacecraft servicing activities.

Space systems — Rendezvous and Proximity Operations (RPO) and On Orbit Servicing (OOS) — Programmatic principles and practices

1 Scope

This document establishes guiding principles and best practices at the programmatic level for all participants in the rendezvous and proximity operations (RPO) and on-orbit servicing (OOS) industry. These principles and practices establish the broadest boundaries for behaviour of participants in the RPO/OOS industry and precede more detailed standards. In principle, the document also covers both robotic and HSF missions, but requirements are derived from robotic missions.

This document is applicable to a broad array of RPO/OOS industry participants from spacecraft equipment manufacturers, spacecraft operators, service providers, developers of RPO/OOS simulation, planning and safety tools, and insurers. It helps to establish responsible norms of behaviour for RPO and OOS that industry participants are supposed to achieve and to promote throughout the global industry.

2 Normative references

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 23312, *Space Systems — Detailed space debris mitigation requirements for spacecraft*

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

ISO 27875, *Space systems — Re-entry risk management for unmanned spacecraft and launch vehicle orbital stages*

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
capture
act of establishing a connection between two space objects

3.2
client
organization contracting for the service

3.3
proximity operations control volume
control volume
operations zone
volume of space established for non-interference and to assure relative navigation control while the *servicer spacecraft* (3.15) and *client* (3.2) space object are within close proximity

3.4
client space object
space object being serviced by the *servicer spacecraft* (3.15)

Note 1 to entry: It is property of the *client* (3.2).

3.5
coordinated
active, interactive participation between both *servicer spacecraft* (3.15) and *client space object* (3.4)

Note 1 to entry: The antonym is uncoordinated.

3.6
docking
process wherein a servicing spacecraft's GNC actuators are used to execute a controlled contacting trajectory to a *client space object* (3.4) in such a manner as to align and mesh the interface mechanisms

3.7
on-orbit servicing
OOS
on-orbit activities by a *servicer spacecraft* (3.15) which requires *rendezvous* (3.12) and/or proximity

Note 1 to entry: This may include *servicing operations* (3.16).

3.8
passively safe trajectory
trajectory which does not interfere with a convex envelope, volume, zone or any area defined to avoid contact with sufficient margin of the *client space object* (3.4) when control is lost

3.9
prepared
status of the *servicer* (3.14), *servicer spacecraft* (3.15), *client* (3.2) and *client space object* (3.4) having taken actions to be ready for RPO or OOS

3.10
proximity operations
series of orbital manoeuvres executed to place and maintain a spacecraft in the vicinity of another space object (artificial or natural bodies) on a relative planned path for a specific time duration to accomplish mission objectives

3.11
relocation
<service> operation to change the orbit of the *client space object* (3.4)

Note 1 to entry: See also *re-orbit* (3.13).

3.12
rendezvous
process wherein two space objects (artificial or natural bodies) are intentionally brought close together through a series of orbital manoeuvres at a planned time and place

3.13
re-orbit
operation to change the orbit of the *client space object* (3.4)

Note 1 to entry: See also *relocation* (3.11).

3.14
servicer
organization that provides *on-orbit servicing* (3.7) operations by contract

3.15
servicer spacecraft
spacecraft performing the *servicing operation* (3.16)

3.16
servicing operation
action provided by *servicer spacecraft* (3.15) to the *client space object* (3.4), including but not limited to inspection, *capture* (3.1), *docking* (3.6), *relocation* (3.11), refuelling, repair, upgrade, assembly and release

4 Programmatic principles for rendezvous and proximity operations (RPO) and on-orbit servicing (OOS) missions

4.1 Responsible design and operations

4.1.1 Promote safety and mission success

In order for the industry to flourish, servicers shall ensure their activities are planned and conducted to promote safety and mission success, to include other space assets, their activities, the orbital environment and ground environment.

4.1.2 Space debris

4.1.2.1 Servicer spacecraft manufacturer and servicer shall ensure conformity to ISO 24113.

4.1.2.2 Further, the Servicer shall ensure that both the Servicer spacecraft and the Client Space Object under the Servicer's responsibilities avoid generating space debris during servicing operations.

4.1.2.3 Provisions shall be made in service planning and operations for mitigating the adverse consequences of a close approach, such as a collision that generates space debris.

4.1.2.4 In the case of a mission extension service (e.g. refuelling, relocation/re-orbit or components replacement), the client shall verify that the client space object meets ISO 24113 requirements throughout its extended mission lifetime.

NOTE This explicitly makes ISO 24113 applicable to the client space object, even if it was manufactured or placed into operation prior to the publication of ISO 24113.

4.1.3 Effective communications

During a servicing operation, the servicer and client organizations shall establish and maintain effective communications in support of safe and successful operations.

4.1.4 Liability for damage and insurance

A servicing operation shall be insured to cover the risk of damage to the activity of third parties.

NOTE The liability for damage can be covered by conventional insurance, financial reserves, alternative operational support or other means.

4.2 Transparent operations

4.2.1 General

The servicer and client conducting servicing operations shall work within the principle of transparency to promote safety and trust.

4.2.2 Notification to states

It is presupposed that the servicer and client involved in servicing operations notify the proper state authorities of the intended operations (general nature, timing, locations) and results of servicing operations according to relevant law. See Article XI of the OST[1].

4.2.3 Communications with entities

The servicer and client conducting servicing operations shall take reasonable measures by sufficient communication and coordination with entities not associated with the RPO/OOS activities that have safety concerns, due to proximity, about the intentions or interference by the servicing operation to support safety and avoid harmful interference. See Article IX of the OST[1].

4.2.4 Notification protocols

The servicer and client conducting the servicing operations shall develop and implement a protocol that provides timely public notification of anomalies or mishaps that can have an adverse impact on other entities or the space environment.

4.2.5 Lessons learned

The servicer and client conducting servicing operations shall look for opportunities to share lessons learned from operational successes and anomalies while protecting intellectual property and competition-sensitive information.

4.2.6 Notification of re-entry hazard

4.2.6.1 Assessment of re-entry hazard

If a mission purpose is to capture a client space object and place it into a re-entry trajectory, the servicer shall assess re-entry risk for all spacecraft and objects which will re-enter as a result of service operation.

4.2.6.2 Notification of re-entry event

In the case of re-entry, relevant state actors (e.g. civil aviation, communications or maritime authorities) require the notification of the servicer of anticipated re-entry risk(s). This notification supports notification to the United Nations Office of Outer Space Affairs registration of objects launched into outer space. Re-entry shall be in accordance with ISO 24113 and ISO 27875. See Convention on Registration of Objects Launched into Outer Space (1976)[2].

4.2.7 Registration of orbit

It is presupposed that the initial orbit and subsequent significant orbital changes are registered in accordance with relevant registration regulations.

5 Programmatic practices for rendezvous and proximity operations and on-orbit servicing missions

5.1 Design for mission success

5.1.1 General

For coordinated RPO and OOS, servicers should develop a state-of-the-art/best practices and holistic approach to the system design and verification, and design and verification of operations of their servicing system to enhance safety and mission success.

The system design shall consider risk mitigation and operational safety practices across the layers of control specified in 5.1.2 to 5.1.6.

5.1.2 Formal review of hardware design

Hardware provides essential guidance, navigation and control (including propulsion, attitude control, etc.) and mechanism capabilities for RPO and OOS. This includes but is not limited to a relative navigation sensor system, on- and off -board navigation systems, interfaces in terms of sensor support patterns or docking/capture mechanisms and attitude determination and control subsystems. Modelling, simulation, component and system-level testing, and documentation of as-built hardware are critical to providing a reliable and sustainable system.

The systems involved in OOS shall verify hardware design for system and operational safety. (See ISO 23135 for verification standard requirements).

5.1.3 Resilient software design and verification

Software provides both the ability for varying levels of RPO and OOS automation and autonomy as well as fault detection and corrective logic. Software designs and functionality should be verified using, for example, extensive simulation runs to model sensor inputs to the relative navigation algorithms. Baselining, performance verification, and the ability to update or patch in-flight are key to resilient software design that shall help ensure confidence in mission execution.

The systems involved in OOS shall have software design verified for system and operational safety.

5.1.4 Concepts of operation

Concepts of operations (CONOPS) define the full set of expected and acceptable RPO and OOS scenarios, implementing the elements/components of the expected system architectures, and techniques to be utilized that focus on spaceflight safety. Specific techniques may include passively safe orbits, safety zones, and keep-out spheres or volumes for RPO and OOS activities. For experimental or first use activities, a "crawl, walk, run" approach to assessing capability, verifying functionality and performance while building confidence and experience is an essential prerequisite to implementing in sensitive environments (e.g. geostationary belt or near crewed spacecraft).

The systems involved in OOS shall verify the concept of operations for system and operational safety and a hazard assessment analysis. See ISO/IEC/IEEE 29148 for general CONOPS standard requirements. See ISO 23135 for verification standard requirements.

5.1.5 Approved and proven procedures

Organizationally controlled procedures (i.e. configuration-controlled procedures) along with defined guidelines, constraints and limitations are the foundation to ensure safety and success in baselining the plan to achieve RPO and subsequent servicing. The approved procedures should align with the CONOPS and establish the foundation for the servicer to execute.

Procedures, including operational procedures and instructions as well as flight rules and test and operational Limits, shall be reviewed and tested for completeness, correctness, and safety.

5.1.6 Trained and qualified operators

Servicer spacecraft and client space object operators are critical to safety and enabling mission success. An operations team that is trained, experienced, disciplined and rehearsed is a substantial confidence builder for sustainable and repeatable servicing missions.

Servicer spacecraft and client space object operators shall be trained, experienced and have rehearsed procedures to detect anomalous navigation and control conditions, system health, and mission performance, as well as to manually intervene, if necessary, to limit material safety risks and hazards.