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Rendezvous and Proximity Operations (RPO) and On Orbit Servicing (OOS) – Programmatic Principles and Practices

WD/CD/DIS/FDIS stage

Contents

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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This document was prepared by Technical Committee ISO/TC 20, Aircraft and Space Vehicles, Subcommittee SC 14, Space Systems and Operations, Working Group 3, Operations and ~~Ground~~ Support Systems.

> **Kommentiert [FS1]:** WG3-1

This is the first edition of this document.

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.

This document is intended to be the highest-level standard for the discipline of RPO/OOS for spacecraft systems. 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 TC20/SC14 for vetting and processing with the normal ISO standardization processes.

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.

There are no patent licensing issues associated with the content of this standard.

Rendezvous and Proximity Operations (RPO) and On Orbit Servicing (OOS) – Programmatic Principles and Practices

1 Scope

The intended scope of this document is to establish 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 behavior of participants in the RPO/OOS industry and precede more detailed standards development. In principle the standard also covers both robotic and Human Spaceflight (HSF) missions. If additional more specific requirements are needed for HSF these can be provided in the future.

This standard is intended to apply 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 is intended to help establish responsible norms of behavior for RPO and OOS that industry participants will 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.

2.1 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (1967) (a.k.a. the "Outer Space Treaty" or "OST")

2.2 Convention on Registration of Objects Launched into Outer Space (1976)

2.3 Recommendation on enhancing the practice of States and international intergovernmental organizations in registering space objects (2007)

2.4 ISO 24113 Space Debris Mitigation Requirements

2.5 ISO/IEC/IEEE 42010 Systems and Software Engineering — Architecture Description

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

> **Kommentiert [FS2]:** JP3-9

2.7 Guidelines for the Long-term Sustainability of Outer Space Activities

3 Terms and definitions

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

3.1
Capture
The act of establishing a mechanical connection between two space objects.

> **Formatiert:** Definition

3.2
Client
An ~~entity procuring~~organization contracting for the service

> **Kommentiert [FS3]:** WG3-3

~~3.2~~3.3

Control Volume
A volume of space ~~necessarily~~ established for non-interference and to assure relative navigation control while the servicer spacecraft and client space object are within close proximity. (Also called Proximity Operations Control Volume or Operations Zone)

> **Kommentiert [FS4]:** WG3-9

> **Kommentiert [FS5]:** JP3-1

~~3.3~~ 3.4

Client Space Object
The space object being serviced by the servicer spacecraft. Property of the Client

~~3.4~~3.5
Docking
When a servicing spacecraft's GNC actuators are used to execute a controlled contacting trajectory to a Client Space Object in such a manner so as to align and mesh the mechanical interface mechanisms.

> **Formatiert:** Definition

3.6
On-Orbit Servicing
On-orbit activities by a servicer spacecraft which requires rendezvous and/or proximity. See 3.13~~8~~ Servicing Operations.

~~3.5~~3.7

Passively Safe Trajectory
A ~~passive safe trajectory is a~~ trajectory which will not interfere with a convex envelope of the client space object when control is lost. ~~The trajectory propagation to be considered shall include all navigation uncertainties and process noise (perturbations).~~

> **Kommentiert [FS6]:** WG3-21

> **Kommentiert [FS7]:** WG3-22

~~3.~~ 3.8
~~6~~
Proximity Operations
Series of orbital maneuvers 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

~~3.7~~3.9
Relocation (as a service)
Operation to change the orbit of the client space object.

> **Kommentiert [FS8]:** WG3-23

> **Formatiert:** Definition

3.10
Rendezvous
~~Process~~Wwherein two space objects (artificial or natural bodies) are intentionally brought close together through a series of orbital maneuvers at a planned time and place

> **Kommentiert [FS9]:** WG3-24

~~3.8~~3.11
Servicer
An ~~entity~~ organization that provides on-orbit servicing operations by contract

> **Kommentiert [FS10]:** WG3-3

~~3.9~~3.12
Servicer Spacecraft
Spacecraft performing the servicing operation.

3.103.13

Servicing Operation(s)

Action provided by servicer spacecraft to the client space object, including but not limited to: inspection, capture, docking, berthing, relocation, refueling, life extension, removal, combined stack control, repair, upgrade, assembly, manufacturing, undock, unberth, 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 and their activities, and the orbital and ground environment.

4.1.2 Space Debris

Servicer spacecraft manufacturer and Servicer shall ensure compliance with ISO 24113.

4.1.2.1 Further they shall ensure that the generation of debris during its mission operation is avoided

4.1.2.2 Provisions shall be made in service planning and operations for mitigating the adverse consequences of close approaches and avoiding collision(s) and generating space debris.

4.1.2.3 In the case of a mission extension service (e.g., refueling or components replacement), the Servicer and/or Client shall verify that the client space object still meets ISO 24113 requirements despite its extension of the operation period.

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 may be covered by conventional insurance, financial reserves, alternative operational support or other means.

4.2 Transparent Operations

Parties conducting commercial servicing operations shall work within the principle of transparency to promote safety and trust.

4.2.1 Notification to States

Servicer and Client involved in servicing operations shall notify the proper state authorities of the intended operations (general nature, timing, locations) and results of servicing operations according to national law. Ref Article XI of the OST

4.2.2 Communications with Entities

Parties conducting servicing operations shall take reasonable measures by sufficient communication and coordination with entities not associated with the RPO/OOS activities that have reasonable concern, due to proximity, about the intentions or interference by the servicing operation to support safety and avoid harmful interference. Re Article IX of the OST

4.2.3 Notification Protocols

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

4.2.4 Lessons Learned

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

4.2.5 Notification of re-entry hazard

4.2.5.1 Assessment of re-entry hazard

If the mission intends to capture the Client's a Client Sspace Ooobjects and place them it into a re-entry trajectory, the Servicer shall assess the re-entry risk for the servicer spacecraft and all client space objects.

> **Kommentiert [FS11]:** WG3-4

4.2.5.2 Notification of re-entry event

In the case of controlled re-entry, the Servicer owner shall notify relevant state actors (e.g., civil aviation or maritime authorities) of anticipated re-entry risk(s), consistent with UN treaties and ISO 24113 and ISO 27875 reentry requirements.

> **Kommentiert [FS12]:** WG#-5
>
> **Kommentiert [FS13]:** JP3-9

4.2.6 Registration of Orbit

The initial orbit and subsequent significant orbital changes shall be registered in accordance with registration regulations of the State or international intergovernmental organization having jurisdiction over the mission.

5 Programmatic Practices for On-Orbit Servicing Missions

5.1 Design for mission success

The system design shall take into account risk mitigation and operational safety practices across the following six five layers of control:

5.1.1   Certified hardware design

Hardware provides essential guidance, navigation and control, propulsion and mechanism capabilities for RPO and OOS. This includes 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. Modeling, 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 have hardware design certified for system and operational safety.

5.1.2   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.

5.1.3   Concepts of operation

Concepts of operations (CONOPS) define expected and acceptable RPO and OOS scenarios, 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 have the Concept of Operations certified for system and operational safety.

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<div style="float:right; border:1px solid #c00; padding:4px;">**Kommentiert [FS15]:** JP3-11, FR-10</div>

5.1.4   Approved and proven procedures

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. Organizationally-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.

5.1.5   Trained and qualified operators

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

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5.1.6   External resources

External resources are capabilities that are not provided by the servicer or client spacecraft but which provide independent and coordinated data and information to plan and inform RPO and OOS activities. These can include external space situational awareness and modeling or simulation capabilities. External resources as appropriate to RPO and OOS shall be used in planning and execution of operations to the extent practicable.

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5.2 Design servicing operations to minimize the risk and consequences of mishaps

5.2.1   Contractual Relationship with Client ~~Space Object~~ Owner

RPO and OOS operations shall be performed for a contracted and cognizant Client.

5.2.1.1   Cases with no known Owner

For cases where no owner can be identified (e.g., space debris objects) perform RPO and OOS operations in a safe and transparent manner. This may include providing adequate public notice and communication of intent to States that may have reasonably been the source of the object.

~~5.2.1.1~~5.2.1.2 Cases with and Owner Identified After Servicing Operations Begin

If the source is identified during/following the service, the relevant States shall be notified. Ref Convention on Registration of Objects Launched into Outer Space (1976)

5.2.2   Communications Discipline

Sufficient communications discipline shall be employed between the Servicer and Client to ensure positive control of both objects during the servicing operation.

5.2.3   Trajectory Practice

5.2.3.1   Passively Safe Trajectories

Except while in or establishing a Proximity Operations Control Volume (See B.7), "passively safe" trajectories shall be used

5.2.3.2   With Other Than Client Space Objects

Close approaches with space objects other than the client space object shall be avoided.

~~5.2.2.1~~5.2.3.3 Propagation Uncertainty

The trajectory propagation to be considered shall include all navigation uncertainties and process noise (perturbations).

~~5.2.3~~5.2.4   Third Party Notification

Servicers shall notify a~~A~~ffected third parties ~~shall be notified~~ in advance of close approaches and information exchanged to support safety of spaceflight (e.g. operator points-of-contact, ephemerides, ability to maneuver, and maneuver plans) while respecting owner/operator intellectual property and proprietary information. Reference 5.2.1 for situations where no owners can be identified.

~~5.2.4~~5.2.5   Servicing Operations

~~Servicing operations shall be designed~~ Tt~~o~~ minimize the likelihood of and adverse consequences from interference, collisions and generating space debris (4.1.2).~~-~~ servicing operations shall be control and define the operations environment.

~~5.2.4.1~~5.2.5.1 Proximity Operations Control Volume

Within the mission phases (Annex B, Section B.7) a Proximity Operations Control Volume is identified.

Kommentiert [FS18]: WG3-5

Kommentiert [FS19]: WG3-4

Kommentiert [FS20]: WG3-39

Kommentiert [FS21]: WG3-22 expanded this section to three parts

Kommentiert [FS22]: JP3-17

Kommentiert [FS23]: JP3-19

Kommentiert [FS24]: WG3-12

5.2.4.1.1 5.2.5.1.1 Operational Definition

Servicers shall reasonably define operations zones to assure the physical safety of rendezvous and servicing objects and that of other non-participatory spacecraft.

NOTE: Safety in this case is related to third party spacecraft passing through the control volume and being affected by the physical or electro-magnetic interference of the servicer spacecraft and client space object as identified in 5.3.

5.2.4.1.2 5.2.5.1.2 Allowed Presence

The Servicer shall ensure that only space objects planned as a part of the operation are in an operating zone while proximity operations are underway and to minimize close approaches with space objects other than the Client Space Object at all times per standard industry practice.

5.2.5 5.2.6 Anomaly Resolution

5.2.5.1 5.2.6.1 Anomaly resolution protocols (often called Contingency Operations Plans) shall be prepared and practiced.

5.2.5.2 5.2.6.2 If anomalies happen, specifically when there is a potential ~~impact~~ effect outside the operating zone such as in break-up or loss of control, servicers shall provide situational notice to the public

5.2.5.3 5.2.6.3 When anomalies occur servicers shall enact contingency actions to minimize the adverse effects on other space users or the orbital environment

5.2.6 5.2.7 On-Orbit Checkout

Initial first-time on-orbit checkout procedures and demonstrations at altitudes that minimize the impact on internationally recognized protected orbital zones shall be performed. Ref 24113.

NOTE: When this requirement is not executable, such as possibly for spacecraft without propulsion, the servicer shall find other means to satisfy the intent of this requirement.

5.2.6.1 5.2.7.1 LEO Checkout Altitude

Checkout and demonstration in Low Earth Orbit (LEO) shall occur at sufficiently low altitudes to comply with the 25-year rule (also referenced in ISO 24113) while also being considerate of human spaceflight activities.

5.2.6.2 5.2.7.2 GEO Checkout Altitude

Checkout and demonstration in geosynchronous Earth orbit (GSO) shall be adequately higher or lower than the geostationary altitude to minimize the consequences from possible debris generation.

5.3 Avoidance of Interference

Servicers and Clients shall avoid physical or electro-magnetic interference during all phases of operations.

5.3.1 Avoiding Physical Interference

Services shall exercise positive control of RPO and OOS activities with client space objects and avoid physical interference with other space activities during all phases of operations See 5.2.2.

5.2.75.3.2 Avoiding Electromagnetic Interference

In addition toSservicers shall also exercise all reasonable measures to avoid physical or electromagnetic interference with other space activities during all operational phases.

5.35.4 Information Sharing

Servicers and Clients shall share information on resolution of spacecraft anomalies/failures and related root cause analysis.

5.3.15.4.1 Development of Anomaly Resolution Standards

Servicers and Clients shall participate in the development of anomaly resolution standards and sharing architectures (per Informative Ref ISO 42010).

5.3.25.4.2 Sharing of Anomaly Information

Servicers and Clients shall, to the extent it is practical, share information among spacecraft servicers and regarding servicing operations (the community involved in spacecraft servicing) on specific examples of anomaly resolution and attribution that could impact the community as a whole.

A   Informative Clauses

A.1   Informative Programmatic Principles Clauses

These are related to Section 4. above.

A.1.1   Consensual Operations

RPO/OOS for on-orbit services with artificial space objects should~~all~~ be conducted via agreements between consenting parties using generally accepted business and contractual practices.

A.1.2   Compliance with Relevant Laws and Regulations

The collaborating parties of both the client space object and servicer spacecraft, as well as any third parties engaged in the activity (e.g., separate contract with an observation spacecraft), ~~shall~~should comply with all appropriate licensing and regulations, of all cognizant national jurisdictions of the involved parties. Moreover, the collaborating parties ~~shall~~should conduct their operations in full compliance with the treaties, such as the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (the "Outer Space Treaty" or "OST") and others listed in Clause 2. Normative Refernces.

A.2   Informative Programmatic Practices Clauses

These are related to section 5. above. Implementing the Programmatic Principles for RPO and OOS in Section 5 above, Servicers and Clients ~~shall~~should begin with developing recommended design and operational practices. It is expected that adopting these practices is an effective way to enhance operational safety and success. The following practices represent lessons learned from prior servicing operations, which have historically been conducted by governments. These practices are intended to evolve based upon experience gained through servicing operations.

A.2.1   Design for Mission Success

Spacecraft servicers should develop a holistic approach to the design and operations of their servicing system to enhance flight safety and mission success.

A.2.2   Design spacecraft to facilitate safe and effective spacecraft servicing

Servicer spacecraft should be designed in such a way as to facilitate the safety and effectiveness of spacecraft servicing activities. Servicer spacecraft and future client spacecraft designs should include methods to improve interface compatibility and the trackability of the spacecraft, among other considerations.

A.2.3   State Cooperation

Work with the proper State authorities to provide notifications of ongoing RPO/OOS operations

A.2.3.1   Notification of RPO/OOS Plan

The plan of the RPO and OOS should be open to the public, including its concept of operations, rough time schedule, responsible organization, relevant systems, affected orbital zones, anticipated benefits and potential risks.

A.2.4 Avoidance of Interference

Servicers should take reasonable measures to ensure that other entities (ie. Entities not associated with the RPO/OOS activities) that may have reason for concern about intentions or interference due to proximity are provided adequate notice. Servicers ~~shall~~should not assume responsibility for the collection and quality of SSA data used to perform RPO and OOS missions but ~~shall~~should advocate for its availability and continuous improvement as an important external resource in line with Section 1.1.1 "External Resources" above.

A.2.5 Information Sharing

Spacecraft anomaly/failure detection, resolution, recovery and attribution are critical to improving the safety, reliability, and transparency of spacecraft operations. Spacecraft servicers and servicing operations (and other stakeholders in the spacecraft servicing community) will benefit from clear anomaly attribution and can also potentially contribute to attribution assessments during their operations. Although competition is essential to a healthy servicing sector, it is also in the best interest of the servicing community to abide by the following practices, all while respecting national export control laws and proprietary business confidential/intellectual property restrictions, to help prevent anomalies and failures that could undermine trust in the servicing community.

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A.2.5.1 Sharing Best Practices

Servicers and Clients ~~shall~~should develop and share best practices for the anomaly attribution processes within the servicing community

A.2.6 Promote Sustainability

Servicers and Clients ~~shall~~should promote the long-term sustainability of space activities. Members of the space community believe that a well-maintained space environment is essential to the success of the industry and that the long-term sustainability of the space environment should be considered at every step. Members should strive to:

A.2.6.1 Comply with Existing Standards

Servicers and Clients ~~shall~~should comply with existing, relevant internationally recognized standards for the long-term sustainability of space activities, including those developed by the International Organization for Standardization (ISO) and the Consultative Committee for Space Data Systems (CCSDS).

A.2.6.2 Collaborate

Servicers and Clients ~~shall~~should collaborate with State authorities and the broader space community to identify emerging space sustainability challenges and participate in the development of future guidelines and standards that enhance space sustainability.

B RPO/OOS Mission Phases (Informative)

B.1 Introduction

This Annex establishes a baseline of mission phases that is intended to describe the functions of all OOS missions. All phases do not apply to all OOS missions, but all OOS missions should find general descriptions of the functions of all of their phases. Functions or phases that are not unique to OOS missions are not included. For example, Collision Avoidance (COLA) procedures are continuously performed for all missions, and hence are not included in this document. Similarly, all phases require diligence in prevention of generating space debris, although some (e.g. servicing phases) more than others. Sometimes phase titles for such phases may be included with a note that explains that there is no content that is unique to OOS missions.

The actions and responsibilities identified herein are assigned to the Servicer and Client organizations. If other organizations are required to fulfill the actions of a phase, it is the responsibility of the Servicer and Client organizations to secure those resources and ensure the required functions are performed.

B.2 Overview Diagram

The following figure is an overview of most of the key mission phases described in the following sections of this document. 2
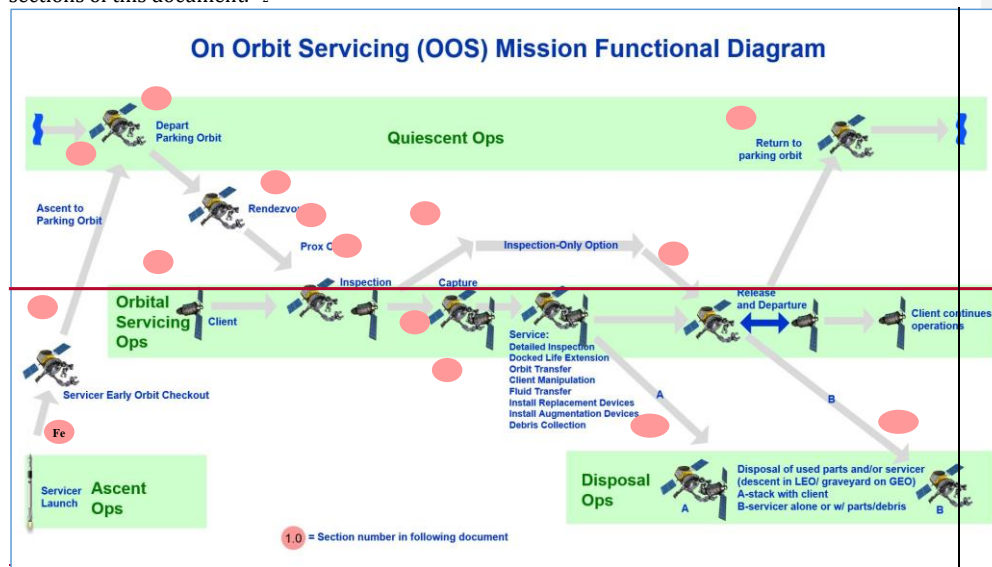

Figure 1: On-Orbit Servicing (OOS) Mission Functional Diagram.

B.3 Pre-Mission

B.3.1 Mission Assessment

Servicer and Client assess mission.

The Servicer and Client assess the needs of the Client Space Object against the capabilities of the Servicer Spacecraft and determine if there is adequate mutual interest to proceed with contracting.

B.3.2   Service Contracting

The Servicer and Client establish servicing agreements and contracts which address, for example, risk assessment, insurance provision, etc.

B.3.3   Perform Compatibility Assessment

The Servicer and Client (and their supporting organizations) collect relevant data (including health of Client Space Object and Servicer Spacecraft) and perform analysis to ensure compatibility between the Servicer Spacecraft and the Client Space Object.

B.3.4   Service Planning

The Servicer and Client exchange and coordinate servicing plans. They develop detailed sequence of events, operational procedures and contingency plans.

B.3.5   Inform and Coordinate with Other Stakeholders as Appropriate

The Servicer and Client ensure necessary regulatory bodies and reasonably affected space actors are informed of the plan and intentions to the level of detail required to provide adequate transparency.

This phase may be executed in a different place of the timeline, for example, by different service providers.

B.3.6   Licensing

The Servicer and Clients coordinate and establish relevant licensing approvals from State Authorities as required.

B.3.7   Insurance

The Servicer and Client ensure adequate insurance is in place for their own interests and those of relevant 3rd parties.

B.3.7.1   Design, Build, Test and Launch Servicer Spacecraft and Operations Systems (as required)

When a new Servicer Spacecraft is required to be developed, the Servicer will design, assemble, and test the Servicering Vehicle Spacecraft according to Recommended Practices.

> **Kommentiert [FS28]:** WG3-32

B.3.7.2   Update Servicer Spacecraft and Associated Operating Systems (as required)

When a Servicer Spacecraft is already on-orbit, the Servicer will (as needed) update Servicer flight software and operational procedure adaptations and tests.

B.3.7.3   Prepare Client Space Object and Associated Operating Systems (as required)

Any required flight software adaptations on the Client Space Object or associated operations systems should be developed, tested and verified.

B.3.8 Train Mission Operations Team

The Servicer and Client will conduct training and mission simulations (standalone or joint) as required.

B.3.9 Servicer Pre-Launch Ground Operations (at the Launch Site)

This phase has no content that is unique to OOS missions. Normal spaceflight/spacecraft processes apply.

B.4 Launch and Prepare Servicer Spacecraft

If using a Servicer Spacecraft that is already in amenable orbit, skip this phase.

This phase consists of three subphases that place a Servicer Spacecraft in a position where it is ready to rendezvous with clients. The subphases are launch, commissioning, and quiescent operations.

B.4.1 Servicer Spacecraft Launch

The Servicer launches a Servicer Spacecraft into an initial orbit. The Servicer monitors systems during ascent.

B.4.2 Servicer Spacecraft Commissioning

The Servicer performs initial activation and checkout of the Servicer Spacecraft and verifies that the Servicer Spacecraft is ready for its mission(s).

B.4.3 Servicer Quiescent Operations

If the Servicer Spacecraft will rendezvous with the Client Space Object immediately, skip this subphase.

Following Servicer Spacecraft Commissioning or after departing a Client Space Object, if the Servicer Spacecraft is not immediately beginning rendezvous operations for its next Client Space Object, then it will enter Quiescent Operations before beginning Rendezvous Operations with the next Client.

A quiescent parking orbit may be any suitable orbit where a Servicer Spacecraft awaits between missions.

When a resupply station is present, the Servicer Spacecraft may rendezvous and dock with the resupply station, following a procedure like the phases that follow for Client Space Objects.

B.5 Client Operations Pre-Servicing

B.5.1 Reposition Client Space Object

If there is no need to reposition the Client Space Object, skip this phase.

The Client Space Object is transferred from its current orbit to the orbit in which it will be serviced by the Servicer Spacecraft. This includes pre-positioning or phasing of the Client Space Object's orbit to achieve the defined proximity operations control volume.

B.5.2 Client Quiescent Operations

The Client Space Object is assumed to be in an initial quiescent state before servicing operations begin.

The Client Space Object control center monitors the Client Space Object's state of health.

B.6 Rendezvous

A In the rendezvous phase is thea series of actions are taken by the Servicer Spacecraft to transition its orbit from the departure of the prior Client Space Object, or from its parking orbit, to the desired rendezvous orbit.

B.6.1 Initiate Rendezvous Action

The Servicer Spacecraft initiates action to rendezvous with the Client Space Object by performing an orbital transfer or phasing maneuver to achieve the desired rendezvous orbit. This action marks the beginning of the Servicer Spacecraft's RPO operations.

B.6.2 Reposition Servicer Spacecraft to Client Space Object Vicinity

The Servicer Spacecraft performs additional orbital transfer and phasing maneuvers to achieve the desired RPO orbit.

This phase ends once the Servicer Spacecraft has achieved the outer limits of a pre-defined Proximity Operations Control Volume and phasing.

B.7 Proximity Operations

In the Proximity Operations phase relative operations are performed between the Servicer Spacecraft and the Client Space Object within a pre-defined Proximity Operations Control Volume. Proximity operations are those relative operations performed between the Servicer Spacecraft and the Client Space Object within a pre- defined Proximity Operations Control Volume. During this phase, separation between the two objects is typically controlled using on-board sensors to provide relative navigation.

Kommentiert [FS29]: US TAG

B.7.1 Approach for Assessment

During this sub-phase, the Servicer Spacecraft may navigate around the Client Space Object, if necessary, to assess the status of the Client Space Object.

At some point during RPO, the Client Space Object will transition from its normal operations mode to a mode in support of servicing by the Servicer Spacecraft.

This phase may be executed in a different place of the timeline, for example, by different service providers.

B.7.2 Verification of Client Space Object Identity

During this phase, the Servicer should verify identity of the Client Space Object (some GEO slots have multiple authorized Resident Space Objects [RSOs], e.g., 19.2°E) which could be located within the proximity operations control volume.

This phase may be executed in a different place of the timeline, for example, by different service providers.

B.7.3 Waypoints

Way points are operational events generally used to:

    a) perform a specific operational function; and/or
    b) reconfigure the spacecraft for the next phase or sub-phase of the rendezvous; and/or
    c) assess status and readiness of the spacecraft for the next phase or sub-phase of the rendezvous

These events generally coincide with either the Servicer Spacecraft attaining a defined orbit relative to the Client Space Object, or freezing its location relative to the Client Space Object, or simply attaining a pre-identified point in time, event, or location. Frequently, such way points are used to coordinate and approve execution of the next phase or sub-phase of the servicing mission between the Servicer and the Client.

Way points may apply to and be performed in other phases as well.

B.7.4   Client Preparation

The Client Space Object may, if necessary and capable, adjust its attitude, its articulations, and its operational configuration in preparation for remote inspection or contact approach and capture.

B.7.5   Remote Inspection and Non-Contact Services

During this sub-phase, the Servicer Spacecraft acquires and records inspection data/images and sends them to the ground. The Servicer and Client ground team performs analysis and (if needed) re-planning based on the data/images. This sub-phase may also constitute a service to the Client by providing the inspection products to the Client. The Servicer may also provide other non-contact services such as wifi or other local communications (e.g. for software upgrades.)

B.7.6   Departure

This sub-phase is the departure from the Client Space Object Proximity Operations Control Volume upon completion of a non-contact Service or if the servicing mission is terminated as a result of new mission information.

B.8   Contact Approach and Capture

If the mission is for remote inspection only, this phase and others following are skipped.

The Servicer Spacecraft makes a final approach to contact the Client Space Object, and the Servicer Spacecraft and the Client Space Object make contact by various means, including docking, grappling, netting, and so forth. This phase includes three sub-phases of approach, capture and stabilization described below.

B.8.1   Approach

The Servicer Spacecraft makes a final approach to contact the Client Space Object. This approach typically will make use of way points in which the Servicer Spacecraft will hold position relative to the Client Space Object while configuration changes or assessments are made to confirm the next step of the approach. Approach concludes once the final command is issued to initiate Capture.

B.8.2   Capture

There are many techniques for achieving capture, each with unique phases and sub-phases and associated risks. Typically, these phases will include some form of initial contact and soft capture followed by rigidization. Prior to or during initial contact, some form of protection against electrostatic discharge between the ~~Servicing~~ Servicer Spacecraft and Client Space Object should be activated, enabled, or otherwise provided.

> **Kommentiert [FS30]:** WG3-33

B.8.3 Post Capture Stabilization

Following rigidization, the new combined vehicle stack will be stabilized either by the ~~Servic~~ering Spacecraft or the Client Space Object, or both. This phase may also include a transition period to achieve a desired servicing attitude and reconfigurations of the Servicing Spacecraft and/or Client Space Object prior to the start of servicing operations.

Kommentiert [FS31]: WG3-33

B.9 Service

If the mission is for remote inspection only, skip this phase.

This phase consists of one or more of the following actions that require contact between the Servicer Spacecraft and the Client Space Object.

B.9.1 Detailed Inspection

During this service, the Servicer Spacecraft acquires and records inspection data/images and sends them to the ground. The Servicer provides the service to the Client by providing the inspection products to the Client.

B.9.2 Docked Life Extension

The Servicer Spacecraft and the Client Space Object remain connected to function as a single vehicle. Operation and control of the mated stack is conducted for a duration per Client and Servicer agreements. Docked operations may continue for the lifetime of the Client Space Object. Various services may supplement Client systems or extend the Client Space Object's life. After this mission, the Servicer Spacecraft may go on to other servicing missions.

B.9.3 Orbit Transfer

In this service, the Servicer Spacecraft may be used to transfer the Client Space Object (or only some of its removed components – see phase **Fehler! Verweisquelle konnte nicht gefunden werden.**) to a new orbit instead of using the Client Space Object's on-board propulsion (if it has any).

Kommentiert [FS32]: WG3-7

This service may be used to assist with decommissioning a Client Space Object (but not the Servicer Spacecraft as discussed in phase **Fehler! Verweisquelle konnte nicht gefunden werden.**). In this case the orbit transfer will be to either a graveyard orbit or a re-entry orbit. Functions include the operation and control of the mated stack and/or captured debris, and release of the Client Space Object/debris to the disposal orbit.

Kommentiert [FS33]: WG3-8

B.9.4 Client Space Object Manipulation

This service includes the manipulating/repositioning of components on the Client Space Object. For example, the Servicer Spacecraft may contact an articulated feature of the Client Space Object that failed to deploy, freeing it to deploy correctly. Functions of this phase may include operation and control of the mated stack, modification of the Client Space Object, or robotic correction of Client Space Object mechanical anomalies.

B.9.5 Fluid Transfer

This service includes transferring fluids (e.g. fuel, water, pressurant, etc.) from one space object to the other. Functions during the service include operation and control of the mated stack, transfer of fluid from the Servicer Spacecraft to the Client Space Object (or vice versa), or a fluid tank exchange. Note that this service may include the Servicer Spacecraft retrieving fuel from the Client Space Object (or a fuel depot).

B.9.6   Installation of Replacement or Augmentation Devices

This service includes the attachment of new components or replacement of components on the Client Space Object. Devices may be launched separately and retrieved by the Servicer as if it were a CSO. Functions during the service include operation and control of the mated stack, removal and stowage of Client Space Object components, addition of new or replacement components on the Client Space Object, and disposal of the removed components. The complete service is then followed by phases 9.3, **Fehler! Verweisquelle konnte nicht gefunden werden.**, 9.3, and disposal of components in a specific orbit (graveyard or reentry).

B.9.7   "Debris" Collection and Removal

This service includes the collection of debris, including non-functioning Client Space Objects. In this case, the RPOC functions are with uncontrolled debris objects (note that these objects may be tumbling, which creates a new technical challenge for the servicer, especially during final approach and capture.) Functions during the service include operation and control of the mated stack, Orbit Transfer (**Fehler! Verweisquelle konnte nicht gefunden werden.**) of the debris, and disposal of the debris in a specific orbit (graveyard or reentry).

B.10 Release and Departure

The Servicer Spacecraft and the Client Space Object demate and separate to a safe distance before resuming independent operations.

B.11 Return to Quiescent Operations

The Servicer Spacecraft may return to quiescent operations.

B.12 Disposal

The Servicer Spacecraft may reposition to a disposal orbit, to dispose itself and any used parts or debris that it carries.

B.12.1 Disposal of Servicer Spacecraft by Re-Entry (may include Client Space Object and/or parts/debris)

In this operation the mated stack of the Servicer Spacecraft including any Client Space Object (and/or parts/debris) are disposed of by reentry. Functions during this phase include operation and control of the mated stack, orbit transfer to the re-entry orbit, reentry operations, and notification to affected states.

B.12.2 Disposal of Servicer Spacecraft in Graveyard Orbit (may include Client Space Object and/or parts/debris)

In this operation the mated stack of the Servicer Spacecraft including any Client Space Object (and/or parts/debris) are disposed of by repositioning to a graveyard orbit. Functions during this phase include operation and control of the mated stack, orbit transfer to the graveyard orbit, reconfiguration of the Servicer Spacecraft and any Client Space Object as appropriate for decommissioning, and notification to affected states.