(Tentative translation/For reference purpose only)

- Notes in this document are prepared exclusively for the translated version; they do not appear in the original Japanese text.

Supplementary Requirements for a License to Operate a Spacecraft Performing On-Orbit Servicing

Sub-working Group on On-Orbit Servicing

Inter-Agency Task Force on Space Debris

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(Tentative translation/For reference purpose only)

1. Objective

Respecting the need for considerable transparency in licensing on-orbit servicing (OOS) missions, this document provides supplementary requirements for the spacecraft for the purpose of or with the capabilities of rendezvous, proximity operations or OOS by other means to other space objects to satisfy the statutory general requirements prescribed in the licensing criteria[1] for spacecraft operation and its management in general. To this end, this document also provides some tips and sample measures on how to conform with each requirement.

2. Scope

The supplementary requirements are applied to any related procedures, architecture and an operation and management plan of servicer spacecraft which plan and are capable to provide on-orbit servicing in any of the phases listed from (1) through (5) below. They are not applied to the stages before rendezvous (phase (1)), or before servicing (phase (4)) without rendezvous, and after separation (phase (5)), or after servicing (phase (4)) without separation. In addition, the supplementary requirements are not applied to the operation of spacecraft conducted by or under the control of the Government per exemption in the Space Activities Act 2016, including cases for national security purposes or certain civil purposes.

(1) Rendezvous phase
Where a servicer spacecraft approaches a client object by controlling relative position, relative velocity, and other parameters within a designated range.

(2) Proximity operations phase
Where the servicer spacecraft is operated in a very close distance but not coming into contact with the client object. Observing and imaging of the client object are assumed to be performed in this phase.

(3) Final approach and capture phase
Where the servicer spacecraft performs final approach to the client object and captures it.

(4) Servicing phase
Where the servicer spacecraft performs various services (e.g., life extension by orbit maintenance/station-keeping, refueling, ORU replacement, repairs, etc.) for the client object (spacecraft, etc.). If the servicer spacecraft is to be disposed of altogether with the captured client object, the sequence of applicable phases ends here.

(5) Separation phase
Where the servicer spacecraft separates and departs from the client object and returns to its solo operations. (When servicing multiple clients, it shifts to the next rendezvous phase.)

Note that for each service operation performed in the servicing phase (phase (4)), specific safety measures may be required, as appropriate, in addition to these "supplementary requirements"; and that the requirements for servicing operation prescribed here are also applied to

[1] Previously translated as "Review Standards".

the services remotely provided in the proximity operations phase (phase (2)).

3. Terms and definitions

Unless otherwise specified, terms and abbreviations used in this document, other than those based on the definitions in the Space Activities Act 2016, the Cabinet Office directive for its implementation, and the general guidelines, have the following meanings.

(1) General Guidelines
The Guidelines on a License to Operate a Spacecraft (2nd edition, 14 September 2019, National Space Policy Secretariat, Government of Japan)[2].

(2) Space Debris
All human-made objects including fragments and elements thereof, in Earth orbit or re-entering into the Earth’s atmosphere, that are non-functional.

(3) On-orbit servicing (OOS)
An act by a spacecraft to intentionally influence another spacecraft for the purposes of resupply, inspection, replacement, repair, modification and/or augmentation, or to remove either a spacecraft whose mission is terminating or space debris from orbit.

(4) Active debris removal (ADR)
On-orbit servicing that removes either a spacecraft whose mission is terminating[3] or space debris from the current orbit to an orbit for disposal (including orbits for the Earth's atmospheric reentry).

(5) Rendezvous
An act of approaching a client object by controlling the relative positions, relative velocities and other parameters within a designated range.

(6) Proximity operations
Operations performed while two objects are connected or in a very close range.

(7) Rendezvous and proximity operations (RPO)
A general term for rendezvous and proximity operations.

(8) Capture
A sequence of operations to establish a structural engagement between the servicer spacecraft and the client object.

(9) Servicer spacecraft
A spacecraft that provides on-orbit servicing.

(10) Client object
A functioning or non-functioning on-orbit spacecraft or space debris to which on-orbit servicing is provided.

(11) Catalog

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[2] Previously translated as "Guidelines on License Related to Control of Spacecraft".
[3] Thus, the definition of "ADR" here includes end of life servicing.

A database of the identification of space objects (international designation and other relevant information) and of their orbital parameters based on the registration thereof and space situational awareness.

(12) Passively safe trajectory

An approaching trajectory which does not interfere with the client object or its dynamic envelope in near timeframe, even if the servicer spacecraft loses its function.

(13) Collisional trajectory

An approaching trajectory which could interfere with the client object or its dynamic envelope in near timeframe, if the servicer spacecraft loses its function.

(14) Anomaly

Any indication that a spacecraft may not be properly functioning.

(15) Failure mode

A systematic classification of manners in which failure of a system itself or each of its component elements or items is foreseen occuring in light of their specification.

(16) Hazard

A state or a set of conditions, internal or external to a system, that has the potential to cause harm.

4. Requirements regarding purposes, manners, and methods to make the performance of OOS lawful business conduct

4.1. Prevention of infringement of rights related to the client object

4.1.1. Confirmation of title to the client object

Performance of on-orbit servicing must be based on a contract with or consent from an entity having all necessary power and authority to modify the current state of the client object, or to dispose of it.

On-orbit servicing would extend the life of the client object by refueling or change the current state of its form or operation through repairs, modifications, and/or proxy control. In addition, the client object could be damaged or break up by accident even if it is not discarded by ADR.

Therefore, an applicant must confirm, based on registration in accordance with the Convention on Registration of Objects Launched into Outer Space, the entity which holds the proprietary right to the client object. The applicant must then demonstrate that the client party is legitimately entitled, delegated or given the right-holder's consent to order the OOS, and that the applicant would not infringe any rights of third parties by performing it.

Suggested items to present

(1) When an entry for the client object is available in an official registry/register

- Officially registered information related to the client object (proof of the entry in the UN register and/or a national registry).

- A contract with the client party in which the client party represents and warrants to the OOS provider that the client party holds the authority to have the client object serviced as stipulated therein, and has all necessary power and authority to execute and deliver the contract (This is not required when the OOS provider itself has all necessary authority over the client object.).
- Information about the owner and operator of the client object (entity's name, location, etc.).

(2) When an entry for the client object is expected to appear in an official registry/register well before the implementation of the OOS

- Information about the progress of registration procedures in the prospective state of registry.
- A contract with the client party in which the client party represents and warrants to the OOS provider that the client party holds the authority to have the client object serviced as stipulated therein, and has all necessary power and authority to execute and deliver the contract and perform its obligations thereunder (This is not required when the OOS provider itself has all necessary authority over the client object.).
- Information about the owner and operator of the client object (entity's name, location, etc.).

(3) When an entry for the client object is not expected to appear in an official registry/register well before the implementation of the OOS

- A contract with the client party in which the client party represents and warrants to the OOS provider that the client party holds the authority to have the client object serviced as stipulated therein, and has all necessary power and authority to execute and deliver the contract and perform its obligations thereunder.
- Information necessary for the Government to facilitate opportunities for potentially concerned states which may request appropriate international consultations. E.g., information about the launching states of the client object and the nationalities of its owner and operator.

4.1.2. Respect for regulations of the state of registry/license

Foreseeable state of the client object derived or resulted from on-orbit servicing must not conflict with regulations of the state of registry or the state licensing the operation of the client object.

Except for the cases of simple inspection, such on-orbit servicing as resupply for life extension, change of functions or transfer between orbits could bring about some change to the structure or operation of the client object. Thus, depending on the regulations by the state of registry or the licensing state of the client object (hereafter referred to as "the state of registry/license,"), on-orbit servicing could result in the client object being against those regulations, or the licensee thereof being required to take additional steps to have such changes authorized. In particular, an applicant is advised to note that a license to operate a service spacecraft would never substitute for any procedures that the state of registry/license could impose on the client object receiving OOS: such procedures could include obtaining consent of all relevant right-holders as necessary.

Therefore an applicant must obtain information necessary for examining the legal implications of what the OOS would cause the state of the client object in relation to the regulations of the state of registry/license and must demonstrate that there would be no conflicts between them and that, if the regulations have been revised after originally licensed, potential conflicts with the current regulations would be allowed. In addition, if there are any necessary procedures to take regarding the client object, the applicant must demonstrate that they have already been performed or that they will be completed by a time well before the implementation of OOS.

Suggested items to present

- Regulations and conditions of the license imposed by the state of registry/license for the client object (This is not required when Japan is its state of registry.)
- Copies of the application and accompanying documents for the license to operate the client object (This is not required when Japan is its state of registry.)
- A contract with the client party which stipulates who takes all necessary procedures imposed on the client object and in which the client party represents and warrants to the OOS provider that the client party has all necessary power and authority to perform/outsource them
- Responses to inquiries as to whether the client object could lawfully receive the planned OOS, if there are any ambiguities in the interpretation and/or application of the related regulations (The responses could include the guarantee of exemption from potentially conflicting provisions.)
- The implementation plan, if the OOS provider is contracted to perform all or some of the necessary procedures set by the state of registry/license

4.2. Prevention of ex post facto interference caused by the client object

Foreseeable state of the client object resulted from on-orbit servicing must not contradict the purposes and standards of the Act.

The serviced client object connected to a servicer spacecraft would de facto always bring about situations conforming with the requirements by the Act, the cabinet office directive and the criteria during and at the end of on-orbit servicing, because its motion equals that of the servicer spacecraft[4]. However, if the state of registry/license would not be identified or the level of its requirements would not be so strict as those in Japan, the serviced client object could bring about situations conflicting with Sec. 22, Para. 1 of the Act after it is separated from the servicer spacecraft or when it is serviced without being connected at all.

Therefore, an applicant must plan to transfer the client object into an appropriate orbit in order not to interfere with the operation of third-party spacecraft including crewed one when it is moved

[4] The servicer spacecraft is operated by the licensee in accordance with the requirements prescribed in Japan's regulations.

or transferred into another orbit in the process of and/or as a consequence of OOS, even if that movement does not fall under Sec. 23, Para. 1 of the Cabinet Office directive, as in the case[5].

In addition, when a servicer spacecraft performs OOS terminating the operation of the client object or changing either the current state or orbit of the client object discarded before, an applicant must demonstrate that the ADR of the client object is conducted basically in accordance with Sec. 22, Para. 4 of the Act[6]. However, when performing the ADR corresponding to Sec. 22, Para. 4, Item d[7], the servicer spacecraft is just required to transfer the client object into an orbit with substantially shorter lifetime; it does not have to place it into an orbit with a 25-year-long lifetime or less.

It is also required, in relation to Requirement 4.2, that the client object is not fragmented in an orbit other than that with a short lifetime in consequence of the service not involving the connection between the two objects[8].

Suggested item to present

- Operation plan

4.3. Information disclosures for ensured transparency

4.3.1. Notification and reporting of the operation[9]

The licensee must stipulate the means and procedures for providing main features of the operational plan and associated information to the Government and other spacecraft operators, including foreseeable operators.

A servicer spacecraft may transfer among orbits more frequently on a larger scale than conventional spacecraft, and hence its operator needs to give due consideration to information disclosure so as not to threaten the safe operation of third-party spacecraft passing nearby. Besides, it is necessary, in view of the security aspect as well, to inform the international community of the operation in advance, for the capability of the servicer to perform on-orbit servicing could evoke concern that it would harm third-party spacecraft.

Therefore, an applicant must make an operations and management plan stipulating how the OOS provider provides relevant institutions and other parties with information regarding the operation plan and its implementation by such means as a press release to facilitate space traffic management. In particular, the applicant must specify the means, content and timing of the

[5] Sec. 23, Para 1 of the cabinet office directive regulates the OOS involving connection and/or separation in the same way.

[6] The PMD of a servicer spacecraft itself and the client object connected thereto is regulated directly by the general requirements (6.4.1-4.).

[7] Indicated as "ニ" in the original Japanese text.

[8] Sec. 23, Para 1 of the Cabinet Office directive regulates the OOS involving connection and/or separation in the same way.

[9] Procedures and items for notification and reporting are further elaborated in the main report.

following communication which would not disturb operations:

- Notification to the Government SSA center of servicer's ephemeris and other information useful to the Government for monitoring it as a part of law enforcement; and
- Direct reporting to one or more external organizations designated by the Government (e.g., a principal foreign SSA agency) in order to ensure transparency and avoid unnecessary concerns and the risk of approaches or collisions.

In addition, the applicant must establish procedures for timely reporting to the Government with such supplementary and updated information in order that a government announcement can be released for transparency in advance of the implementation of the service. The government announcement referred to above could include the type of on-orbit servicing to be performed, the client object, the entity providing the service, basic orbital parameters, the period of the sequence from rendezvous to separation, SSA organizations to be informed of servicer's ephemeris, and the information disclosure policy in the event of emergency.

It should be noted that stealth technology must not be applied to the servicer spacecraft in view of the prevention of hindrance to the verification of the announcement and to SSA activities monitoring the servicer spacecraft, as is also required by Requirement 5.2, Item (6).

<u>Suggested items to present</u>

- Operation plan
- Plan for providing information to relevant institutions and other parties in accordance with the operation plan above

4.3.2. Providing information in emergencies

The licensee must stipulate the means and procedures for providing the Government and other spacecraft operators potentially affected with information on the operating state of the servicer spacecraft in a timely manner in case of emergency such as the loss of its control.

A servicer spacecraft involves different capabilities and operation from conventional spacecraft, and hence anomalies occurring therein could cause third-party spacecraft relatively grave danger and concern in relation to other spacecraft.

Therefore, the applicant must stipulate necessary notification to relevant institutions and other operators potentially affected in the event that an unexpected accident or anomaly forces an operation clearly deviating from the established operation plan (including prepared response procedures for foreseeable failure modes and other anomalies), or that the control of the servicer spacecraft is lost, while the highest priority must be given to tasks of minimizing damage and preventing secondary disasters.

The applicant must plan an announcement through the press and notification to the public if there is a risk of affecting a wide range of present and forthcoming spacecraft operators due to, for instance, the loss of control in the case of such an event.

<u>Suggested items to present</u>

- Contact information set in advance according to the type of anomaly or accident; and sample contents and format of information provided.
- Means and procedures for providing information according to the type of anomaly or accident, including prompt notification to relevant institutions and public announcement (e.g., criteria for deciding the necessity and scope of disclosure).

5. Requirements regarding architecture and an operations and management plan for safe performance of OOS

5.1. Study of the architecture of and other information on the client object for assurance

The licensee must acquire and study sufficient information on the client object to ensure the safe performance of on-orbit servicing.

To perform on-orbit servicing safely, it is essential that the architecture of and operations plan for the servicer spacecraft be compatible with the state and form of the client object as well as the characteristics of each part thereof.

Therefore, when designing a mission, an applicant must obtain from the client party and ascertain in advance design information related to structure, interfaces and other characteristics of the client object as well as the information necessary for setting up measures to ensure safety such as that on estimated amounts of residual propellant.

For example, the applicant must pay attention to the following items when planning to have the servicer spacecraft approach the immediate vicinity of the client object, or perform capture thereof or docking thereon:

- Layout of propellant tanks, batteries and other energy sources and devices that could disturb safe operations if damaged;
- Structural strength of the parts which would be in contact with or be connected to the servicer spacecraft;
- Presence of radio transmitters, and the frequency and intensity of any RF radiation;
- Presence of devices which could interfere with or otherwise adversely affect the functioning of sensors necessary for approach;
- Sensitivity to heat and electrostatic discharge generated on contact; and
- Layout of thrusters and gas emitter and directions of thrust plumes and gasses.

The applicant must arrange, if sufficient information cannot be obtained in advance, to additionally collect information on the actual on-orbit state of the client object to the extent possible by observation with ground and on-orbit sensors for risk reduction. The applicant, at the same time, must design the mission to tolerate uncertainty due to lack of information by, for instance, selecting the methods of capture and docking and/or operations that will not lead to a destructive accident even if capture fails.

Suggested item to present

- Information on the architecture and other aspects of the client object necessary for verifying whether the architecture and operations plan of the servicer spacecraft conform with the requirements prescribed in Sections 5.2 to 5.4

5.2. Architecture of the servicer spacecraft

It must be verified that the servicer spacecraft is designed to have the capability to perform on-orbit servicing and associated operations.

Each subsystem of the servicer spacecraft must have the functions and capabilities specified in a corresponding paragraph in order to safely execute rendezvous, proximity operation, connection (including capture and that for towing), servicing, separation or maneuvers associated with them (though its subsystems can be categorized differently if necessary). An applicant, in addition, must analyze the minimum requirements for functions and capabilities of other subsystems important, if any, to the implementation of on-orbit servicing than those identified here, and demonstrate the validity of the design.

(1) Power supply subsystem

The subsystem must have sufficient power supply capacity for the assumed operations plan and conditions.

Suggested item to present

- Power resource analysis

(2) Communication subsystem

The subsystem must be capable of establishing communication with the ground stations at the required timing and periods.

Suggested item to present

- Operation plan

(3) Command and telemetry subsystem

The subsystem must be capable of processing commands and telemetries to execute appropriate failure detection, isolation and recovery (FDIR) so as to avoid collisions. In addition, for failure responses that are not achieved by ground commanding, the onboard function must support automated safing response.

Suggested items to present

- Command and telemetry processing policy, its feasibility and the verification results of their function and performance
- Verification results of the performance on FDIR (It is desirable to demonstrate the overview of the algorithm and its processing time.)

(4) Propulsion subsystem

The engines and thrusters must provide necessary performance (thrust, operating time, etc.) for rendezvous and collision avoidance operations.

Suggested item to present

- Verification results of the function and performance of the propulsion system

(5) Attitude and trajectory control subsystem

The subsystem must be equipped with sensors necessary for absolute navigation, relative navigation and final approach, and these sensors must be capable of detection necessary for collision avoidance and other planned operations.

Suggested items to present

- Concept of collision avoidance measures, and verification results of the performance of the guidance and control functions
- Analysis of guidance and control subsystem taking account of possible sensor error (Monte Carlo simulation, etc.)

(6) Thermal control subsystem

The subsystem must be capable of keeping the servicer spacecraft within the specified temperature range facilitating planned operations under the assumed thermal environment and conditions. In addition, paint and thermal insulations applied to the servicer spacecraft must not disable trackability from the ground.

Suggested item to present

- Thermal analysis

(7) Structure

- General

The structure must withstand the loads induced by collision avoidance and other maneuvers.

- A servicer spacecraft in contact with or connecting to a client object

The parts which would be in contact with or be connected to the client object must withstand the associated loads. - A servicer spacecraft performing maneuvers with a client object connected thereto

The structures and connecting parts of both the servicer spacecraft and the client object must withstand the loads induced by maneuvers under connected configuration.

Suggested item to present

- Stress analysis for on-orbit load

5.3. Operations and management plan for servicing spacecraft

5.3.1. Recognizing the on-orbit state of the client object

The operation plan must be executed step-by-step while recognizing information on the in-situational state of the client object so as to ensure the safe performance of on-orbit servicing.

Safe implementation of on-orbit servicing requires the servicer spacecraft to accommodate the current on-orbit state and condition of the client object, as well as its architecture.

Therefore, an applicant must formulate an operation plan to ascertain the position, behavior, state and other characteristics of the client object step-by-step, confirm that the conditions are still met for safe execution, and then carry out the mission per prescribed sequence.

The applicant must properly update the operation plan per the following perspective in the event that there is a wide discrepancy in the current on-orbit state of the client object against assumption and condition baselined for the planned operation, and that predefined safety measures could be no longer applicable:

- To develop and carry out alternative measures; or
- To reconfirm that such dysfunction of the original measures will not give a serious concern on resuming operation per the original plan.

Suggested item to present

- Operation plan
- Flight rules (a set of conditions that should be confirmed step-by-step to continue safe operations), etc.

5.3.2. Space situational awareness of the area where rendezvous and other operations are executed[10]

The licensee must utilize space situational awareness (SSA) data to mitigate the risk of - collision between the servicer spacecraft and the client and/or other space objects; and - harmful interference with third party spacecraft by the servicer spacecraft itself, or any object released or an electromagnetic radiation beamed therefrom.

A servicer spacecraft may change trajectories more frequently on a larger scale, especially in the rendezvous and subsequent phases, than conventional spacecraft. It is also considered that

[10] Planning and performing of collision avoidance based on obtained SSA data have been already stipulated in the general requirements, which are equally applied to any privately operated satellites.

rendezvous and close proximity operation are potentially risky for collision. Moreover, some on-orbit servicing may release/eject an object or beam electromagnetic radiation depending on the type of service.

Therefore, in order to sufficiently reduce the risk of collision or interference caused by trajectories of the servicer spacecraft, separated objects or electromagnetic beams, an applicant must secure SSA service with a reliable catalog of space objects to gain situational awareness for the following areas. The aforesaid SSA service must include information service required for determining the maneuver magnitude and timing to perform necessary orbital/attitude maneuvers as preventive measures.

- Areas where the servicer spacecraft will perform orbital maneuvers in order to approach to, operate in close proximity of, and/or provide servicing to the client object
- Areas within a certain range in the direction in which the servicer spacecraft will separate an object or emit an electromagnetic beams

<u>Suggested item to present</u>

- Agreement with CSpOC on the use of its advanced services or that with other entities including commercial SSA service providers offering equivalent SSA services with equal or higher quality

5.3.3. Basic principle for approaching trajectories

> The servicer spacecraft must take passively safe trajectory to the maximum extent possible even when approaching to the client object.

In the rendezvous and subsequent proximity operations, which are not performed by conventional spacecraft, it is required to manage collisional risk throughout the approach to a client object in addition to the regular conjunction assessment against other space objects.

Therefore, in the aforesaid phases, an applicant must plan approaching trajectories with a lower probability of collision in reference to the regular avoidance criteria, even in the absence of any control functions of the approaching servicer spacecraft.

<u>Suggested items to present</u>

- Operation plan
- Guidance, navigation and control analysis (Monte Carlo simulations, etc.)

5.3.4. Conditions of not taking a passively safe trajectory

> The licensee must stipulate plans for collision avoidance operations and the criteria for determining its implementation if it is necessary to plan the servicer spacecraft to take a collisional trajectory toward the client object for the purposes of final approach, capture and so on.

The basic principle in 5.3.3 above cannot be applicable in phases where a servicer spacecraft performs final approach, capture and docking, and hence it is necessary to take specific measures against each event causing collision and other danger, considering acceptable risk criteria.

For this reason, when planning trajectories tolerating collision under certain conditions and/or those with the probability of collision not meeting the regular avoidance criteria, an applicant must preset acceptable levels for relative position, attitude and velocity, and other parameters, and plan that collision avoidance will be implemented automatically or promptly under persistent monitoring in the event that these conditions are not satisfied. The applicant is advised to note, however, that the servicer spacecraft may collide or be in contact with the client object in a manner fulfilling the specific condition s under which the collision or contact would not bring about any serious damage.

Suggested items to present

- Operation plan
- Guidance, navigation and control analysis (assessment of abort performance)
- Collision analysis (when collision or contact is accepted under certain conditions)

5.3.5. Ensuring of stable operation during capture and docking

The servicer spacecraft must maintain the conditions for safe, stable and continuous operation of itself and the client object under control throughout the sequence of capturing, docking and separating if applicable.

In the process that a servicer spacecraft captures and/or docking with a client object, there is a risk that, for example, a robot arm could experience a malfunction while grappling the client object, and that the servicer spacecraft falls into a situation where neither docking nor separation can be completed.

Therefore, unless adopting a method that is less likely to create such an unstable situation, an applicant must enable the servicer spacecraft to have the client object safely and stably captured or separated, automatically by itself or promptly under persistent monitoring from the ground in the event that a failure or an anomaly could interrupt capture sequence to the stable connection (enough to be operated safely and continuously). The applicant, in either case, must ensure that the servicer spacecraft maintain attitude control and communication with the ground appropriately for the subsequent operations thereof.

In addition, the applicant must consider collision avoidance and other necessary maneuvers of the servicer spacecraft together with the client object connected thereto, when planning to have them connected for a relatively long period of time to provide such services as ADR with docking or capture, or supporting attitude control.

Suggested items to present

- Failure modes and effect analysis (FMEA) for capture and docking operations

- Performance evaluation for docked configuration

5.3.6. Employment of Go/No-go testing at appropriate timings in operations

The licensee must conduct Go/No-go testing at every appropriate timing during the on-orbit servicing so as to continue the operation only when the Go condition is met.

On-orbit servicing usually consists of multiple operational phases including a number of maneuvers in combination, and hence it is more complex by nature than the operations of conventional spacecraft.

Therefore, an applicant must plan to examine at appropriate timings whether the operation can be continued or not, per the following confirmation steps:

- Confirm if the conditions for safe operation are still met in light of foreseeable failure modes and expected environmental conditions;
- Confirm if the servicing operation can be continued; and
- Proceed with the operation.

The applicant is advised to note that Go/No-go testing may not be performed by the ground, and that reasonable methods may be utilized based on what will be confirmed.

<u>Suggested item to present</u>

- Operation plan (nominal response part)

5.4. Identification of failure modes and risk mitigation

The licensee must identify the failure modes and other foreseeable anomalies that pose considerable risk of collision and other harmful consequences and mitigate the risk to a sufficient extent.

Failures and anomalies during an on-orbit servicing operation could lead to hazards such as collision.

Therefore, in planning trajectories and operation plans, an applicant must analyze and identify failure modes and other anomalies causing serious consequences such as collision as well as hazards associated with Sec. 5.3.3. Then, the applicant must assess the likelihood and sensitivity of the identified foreseeable failure modes and anomalies and apply an appropriate architecture to the servicer spacecraft and/or stipulate operational measures in the operations and management plan to sufficiently reduce the risk of the failure modes and anomalies with serious risk.

Particularly, in addition, for what could lead to an accident without prompt response, the applicant must prepare dedicated procedures and/or automated on board sequences for immediate reaction. For failure modes and anomalies not requiring prompt response, meanwhile, the applicant must stipulate in outline the procedures.

It should be noted that an applicant, if possible even in case of accident, may resume performing the rest of mission on condition that the applicant has completed all necessary measures to minimize the damage and prevent further accidents from occurring.

Suggested items to present

- Failure modes and effect analysis (FMEA)
- Operation plan (off-nominal response part)

5.5. Safety measures for specific missions (beaming and the release of objects)

The servicer spacecraft must prevent contact and harmful interference with any space objects other than the client, and also prevent interruption to operations of third-party spacecraft when it releases or ejects a shooting object, or beams electromagnetic radiation.

Even when a servicer spacecraft itself does not involve a risk of collision or interference directly with third party space objects, there is a distinct risk that a third party object could be hit or interfered with by an object ejected at a comparatively large relative velocity or an electromagnetic beam emitted from the servicer spacecraft if any.

Therefore, an applicant must plan not to separate any object nor beam electromagnetic energy while a third-party space object exists in or is passing through the space area where it could be affected by them. To this end, for example, the applicant must adopt a method of defining the affecting volume or area and assessing a risk of their interference with third party objects to ascertain in advance that the risk is sufficiently small.

However, the applicant may adopt instead a method of ascertaining that there is merely a small risk of conjunction between such third-party objects and the specific area containing both the servicer spacecraft and the client object, when it is planned that the both objects would be in sufficiently close proximity and that the released objects and beams would not affect anything outside the aforesaid area.

It should be noted that the applicant must apply an appropriate architecture to the servicer spacecraft and/or stipulate operational measures in the operations and management plan to reduce the risk below by means of an interlock function, monitoring function or operational restrictions, if there are so many spacecraft in operation around the orbit or are of the separation or the irradiation that the spacecraft are very likely to be harmed in the event that an object or a beam is released in an unintended direction or at an unintended timing.

Suggested item to present

- Assessment and analysis of the risk that a released object or an electromagnetic beam would interfere with a third-party space object

5.6. Architecture and an operations and management plan for securing the servicer spacecraft control

The licensee must apply an architecture and operational measures to protect the servicer spacecraft against any unauthorized attempt to use it improperly for harmful interference with third party

spacecraft and/or its operation.

The servicer spacecraft can be used to interfere with third-party spacecraft repeatedly without being damaged by abusing their capability of performing on-orbit servicing. This fact makes a servicer spacecraft an attractive target for those wishing to harm other spacecraft or their operation maliciously and, naturally, it would pose a grave threat to other spacecraft if its control were actually taken over by unauthorized means.

Therefore, in order that the control thereof may not be lost or taken over, an applicant must apply an architecture and operational measures enough to secure the communication and control of the servicer spacecraft with the capability to approach to or operate in the immediate vicinity of non-cooperative objects, or that to harm other spacecraft or interfere with their operation with an object ejected therefrom or electromagnetic beam emitted thereby. In addition, the applicant must establish monitoring functions to timely detect a sign of intervention by an outsider.

Suggested items to present

- Information about standards and guidelines adopted for the architecture and/or security measures (It is not required to present the design of encryption system.)
- An overview of monitoring functions (It is not required to present those detailed information whose disclosure could lead to or aggravate the vulnerability thereof.)
- Overview of the management of security-critical information

6. Organizational structure for responsible operations

The licensee must set up, in the organizational structure for operating the servicer spacecraft, business roles to perform the tasks[11] prescribed in the requirements regarding safety and transparency of the on-orbit servicing as well as the security of the control of the servicer spacecraft.

A servicer spacecraft may transfer among orbits more frequently on a larger scale than conventional spacecraft, and hence there is an increased need for its operator to extensively monitor and disclose information about the situation of its surrounding area in comparison with cases of operating other types of spacecraft. Besides, in phases of rendezvous, proximity operations and servicing, more careful monitoring of the situation is required to avoid a collision with the client object and to prevent any parts and components from breaking off unexpectedly. In addition, owing to the potential capability on interfering with other spacecraft, further transparency and security measures are also required.

Therefore, an applicant must design supplementary business roles to ensure elaborate and credible planning and implementation of operational control as well as international transparency as a part of the organizational structure established for operating the servicer spacecraft based on

[11] The original Japanese version more specifically lists procedural administration, information disclosure, operational control and cyber security as such tasks.

the requirements and guidance prescribed in the General Guidelines.

<u>Suggested items to present</u>

- Command and control structure for operations (positions and primary responsibilities)
- Information on the point of contact for inquiries regarding SSA and transparency

7. Review of the requirements

The specifics of operating servicer spacecraft may evolve due to technological advances, international trends and other factors, and hence the requirements shall be reviewed appropriately in light of future changes in circumstances.