General

JERG-2-026(E)

SAFETY STANDARD
FOR ON-ORBIT SERVICING MISSIONS

March 30, 2020

Japan Aerospace Exploration Agency

This is an English translation of JERG-2-026, “SAFETY STANDARD FOR ON-ORBIT SERVICING MISSIONS,” and does not constitute itself. Whenever this document conflicts with the original document in Japanese, the original document takes precedence.

Table of Content

1. Purpose

This standard provides basic requirements for on-orbit servicing to be operated under liability of the Japan Aerospace Exploration Agency (hereinafter referred to as "JAXA"). On-orbit servicing described herein includes Rendezvous and Proximity Operation (hereinafter referred to as “RPO”), physical contact and docking with a client spacecraft/target debris (collectively, hereinafter referred to as "target") by a servicing spacecraft.

This standard intends to avoid any accidents that could potentially give harmful effect on the operation of the unrelated spacecraft due to subsequent orbital environment (e.g. serious space debris generation by a collision).

The requirements and standards referred in the Space Debris Mitigation Standard (JMR-003) shall be applied as far as no duplication, for safety and sustainable orbital environment (including the mitigation of space debris).

2. Scope

This standard shall be applied to on-orbit servicing in order to prevent:

(1) generation of space debris caused by a collision between a servicing spacecraft and a target; and

(2) loss of major functions that are required for a servicing spacecraft and client spacecraft to mitigate the generation of space debris (as referred to "debris mitigation functions" such as necessary functions for post mission disposal). Interferences and interactions between a servicing spacecraft and a client spacecraft could be a major cause.

A loss of mission for both or either spacecraft is out of scope of this standard.

3. Definition of terms

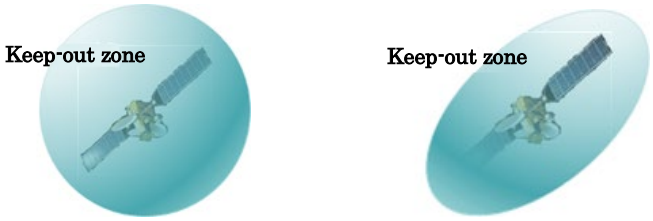
Space debris:	Refer to the definition set out in Space Debris Mitigation Standard (JMR-003). [Non-functional artificial objects existing on orbit, including components and parts separated from a space system, fragments generated from break-up thereof, and a space system after end of life.]
Servicing spacecraft:	Spacecraft providing on-orbit servicing to the other active / inactive spacecraft or space debris.
Client spacecraft:	Active or inactive spacecraft for which a servicing spacecraft provides on-orbit servicing.

Target debris: Unrecoverable out-of-service spacecraft and space debris for which a servicing spacecraft approaches to give on-orbit servicing.

On-orbit service: Intentional interference by a servicing spacecraft with a client spacecraft for refueling, resupplying, adding or replacing functionalities and assisting post mission disposal.
Active debris removal (ADR) for inactive spacecraft / target debris and transportation to/from a space station is also a part of on-orbit servicing.

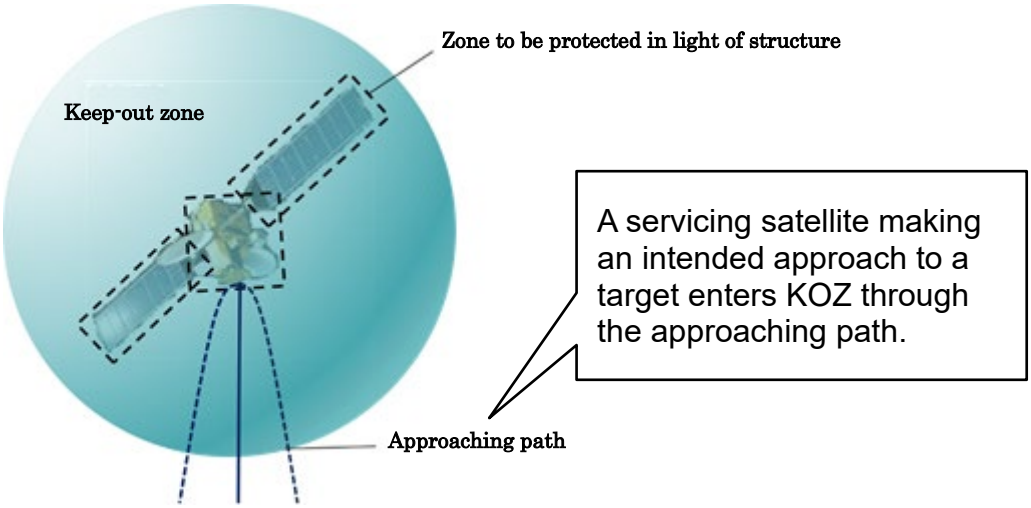
Keep-out zone (KOZ): A zone restricting unintended entry by a servicing spacecraft approaching a target. A keep-out zone is to be defined to encompass a target considering variances on-orbit and attitude determination by available data.

【Keep Out Zone】 *KOZ can take various forms.



Approaching path: A path predefined to prevent a servicing spacecraft from colliding with a target upon making an intentional entry into KOZ to approach the target. An approaching path must not interfere with a protected area (an area involving the risk of collision) in light of the structure of a target.

○ Keep-out zone and approaching path



4. Applicable and Reference documents

4.1. Applicable documents

The following documents shall be applied to the extent that they are referred to in this standard. The latest edition of the applicable documents shall be used.

(1) JMR-001 System Safety Standard
(2) JMR-003 Space Debris Mitigation Standard
(3) Rule No. 16-3 Safety Review Committee Rule

4.2. Reference documents

(1) JERG-2-241 EMC Design Standard
(2) JERG-2-320 Structure Design Standard
(3) JERG-2-330 Mechanisms Design Standard

5. Safety requirements

5.1. Basic requirements

The following measures shall be taken in accordance with 4.1(1).

(1) Unintended generation of debris caused by a collision upon RPO, physical contact and docking with a target as well as the loss of debris mitigation functions are defined as a critical hazard (e.g. serious effect on environment).
(2) Conduct a hazard analysis of the entire system integrating a servicing spacecraft, target and ground system, and take safety measures to address the identified hazards and hazard causes based on fault tolerance.
(3) Additional fault tolerance or equivalent measures are considered when a collision could lead to a catastrophic consequence such as serious threat to the manned spacecraft because of its size, orbit and/or payload properties.

5.2. Specific requirements

Identify hazards and hazard causes taking into consideration the failure modes at least described in the following subparagraphs, but not limited to.

5.2.1. Collision caused by improper orbit and attitude control

In case there is a false detection of trajectory or attitude, or an over/under burn on single or both spacecraft upon final approaching operation, that failure could lead to collision or a loss of debris mitigation functions.

(1) A KOZ shall be defined to determine minimum safety clearance around a target, considering for errors in orbital information, then ensure that the planned trajectory of a servicing spacecraft does not interfere with KOZ, unless it is intentionally planned for final approach.
A servicing spacecraft shall not deviate a predefined approaching path which is designed for intentional entry into the KOZ upon final approaching to a target.
(For an example of a KOZ and approaching path, see Appendix B.)

(2) Single fault tolerance shall be required to prevent an inadvertent entry into the KOZ and deviation from approaching path caused by a false detection of trajectory or attitude, or over/under burn.

(3) In case operational control is necessary for risk mitigation, determine decision making points, process and go/no go criteria. Proper documentation is required so as to execute safety measures in operation (for an example of operational procedures, see Appendix C.)

5.2.2. Failure caused by electromagnetic or optical interference

Electromagnetic or optical interference between a servicing spacecraft and client spacecraft may cause the loss of functions associated with a collision avoidance or a loss of debris mitigation function.

(1) Design in accordance with JAXA's EMC design standard (4.2(1)) or appropriate alternative standards so as to minimize the risk of anomalies due to electromagnetic interference between a servicing spacecraft and client spacecraft.

(2) Conduct an impact assessment if a star tracker and/or sun sensor on a servicing spacecraft and client spacecraft may be degraded by application of a laser on a subsystem like an active light wave sensor. Design a servicing spacecraft to minimize the risk of anomalies due to optical interference if any.

5.2.3. Collision caused by improper robotics operations.

A malfunction or an improper robotics operation may cause a collision or loss of debris mitigation functions while servicing.

(1) Any single fault in electrical or mechanical function during robotics operation shall not cause a collision or a serious impact. Or design to withstand an impact load under a single fault condition to prevent hazardous structural deformation and breakups.

(2) Prior to go for capture a target, examine if all conditions are met such that relative trajectory and attitude are within allowable tolerance. And any single error or false indication of a sensor shall not cause improper engagement between a servicing spacecraft and a target.

(3) Design to withstand maximum load induce by robotics operation with a single fault condition. Or design in accordance with JAXA's mechanisms design standard (4.2(3)) or an appropriate alternative standard.

5.2.4. Structural failure

An inappropriate structural design and/or manufacturing with loads applied upon a servicing spacecraft's capturing, holding, or docking with a target, or a subsequent of the docking, may cause structural failure of the servicing spacecraft and target, resulting in a collision and the loss of debris mitigation functions.

(1) Ensure appropriate structure design and manufacturing of a servicing spacecraft with loads applied upon on-orbit servicing or docking, in accordance with the JAXA's structure design standard (4.2(2)) or an appropriate alternative standard.

(2) For those parts which are incapable of withstanding applicable loads, identify the part as a load sensitive item and operate the spacecraft to avoid contacting the part.

5.2.5. Failure caused by electrostatic discharge

Surface of servicing spacecraft and target are charged by exposure to the space environment. Potential difference between both objects could generate Electrostatic discharge (ESD) upon physical contact and it could cause loss of function of servicing and/or target spacecraft that may lead to a collision and/or the loss of debris mitigation functions.

(1) A risk of functional failure by ESD upon contact between a servicing spacecraft and a target shall be assessed, and the assessment shall be reflected in the design of a servicing spacecraft to minimize a risk on ESD.

5.2.6. Failure caused by thermal incompatibility

Excessive temperature difference between a servicing spacecraft and a target may cause damage or loss of important functions on either or both objects upon contact. That may result in a collision and/or the loss of debris mitigation functions.

(1) Conduct a thermal risk assessment considering the expected maximum temperature difference between a servicing spacecraft and a target. Minimize the risk of failure on sensitive items in case the worst heat transfer may damage them upon contact of the servicing spacecraft and client spacecraft. The assessment shall also consider that the high-temperature or low-temperature may be induced by an anomaly on the electrical system or on a false indication.

(2) For those parts which are incapable of withstanding applicable heat load per assessment, identify the part as a heat sensitive item and operate the spacecraft to avoid contacting the part.

5.2.7. Failure caused by thruster plume and propellant leak

Leaking propellant and/or thruster plume from a servicing spacecraft may contaminate sensors that are necessary for space debris mitigation functions of a client spacecraft. In addition, excessive heat and unintended load given by thruster plume from a servicing spacecraft and/or a client spacecraft to the other may cause serious damage to either or both spacecraft that could lead to generation of space debris as a consequence.

(1) Any single fault in electrical or mechanical function shall not cause an excessive propellant leak and/or irregular firing so as to prevent the pre mentioned consequences.

(2) Design to minimize the risk on a servicing spacecraft and a client spacecraft with respect to contamination on sensors, heat load and other unintended loads induced by thruster plumes.

5.2.8. Inability of separation from or release a client spacecraft

In the event that a servicing spacecraft is unable to separate from or release a client spacecraft, an engaged spacecraft may not keep proper trajectory and attitude control in subsequent operation, including loss of debris mitigation functions such as collision avoidance capability against debris.

(1) Any single fault in electrical system shall not lose power supply to separation or release mechanisms.

(2) Design in accordance with JAXA's Mechanisms Design Standard (4.2(3)) to show equivalency to single fault tolerance or appropriate alternative standards so as to minimize the risk of mechanical failure that disables separation or release function.

5.3. Compliance with interface requirements

In addition to the compliance with the requirements in 5.1, ensure the compliance with interface requirements between a servicing spacecraft and client spacecraft/target debris.

6. Review of compliance with these standards and approval

Compliance with these standards is to be reviewed and approved by the Safety Review Committee referred to in 4.1(3).