(Tentative translation/For reference purpose only)

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

Guidelines for Collision Avoidance with Satellites, etc.

National Space Policy Secretariat
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1 Introduction

Under Article 20 of the "Act on Launching of Spacecraft, etc. and Control of Spacecraft (Act No. 76 of 2016)," this Guidelines provides concepts and measures for satellites that are capable of transferring orbits around the Earth, to avoid and mitigate a collisions risk with other satellites and space debris that are subject to license related to control of spacecraft.

It is noted that measures for collision avoidance herein may not be suitable for all satellites in the Earth orbit because the situation such as number of and distribution of space objects are not uniform depending on the altitude, and the minimum size of objects detected by ground-based radar also varies.

In addition, there may be adoption of non-traditional schemes for collision avoidance in light of progress in Space Situational Awareness (SSA) capabilities such as radar upgrade, enhanced observation network and data sharing, utilization of in-orbit observations, and also with international collaboration on space traffic management.

Therefore, it is recommended to adopt methods that are appropriate to the satellite in application considering its orbit and operational conditions, from the latest good practices compiled by space agencies, industrial consortia given guidelines herein.

2 Scope of application

It is required for satellite operators that are licensed for control of spacecraft under "Article 20 of the Act on Launching of Spacecraft, etc. and Control of Spacecraft (Act No. 76 of 2016)" and their satellites are capable of transferring in the Earth orbit described in Article 20(2)(iii) of the Act, to have a sufficient capability to execute management plan per Article 22(3) of the Act, and to perform collision avoidance against conjunction event that is considered the one to perform maneuver to avoid collision based on "Regulation for Enforcement of the Act on Launching of Spacecraft, etc. and Control of Spacecraft (Cabinet Office Order No. 50 of 2017) ." For satellites falling under the above, it is assumed to begin collision avoidance management in accordance with this Guideline when stable control is established after separation from Launch Vehicle followed by initial checkout of a satellite.

This Guideline is not intended to be applied to satellites for planetary exploration that may tentatively reach to the Earth to perform the Earth swing-by or reentry from non-Earth orbit because they do not fall under the definition of "operated in the Earth orbit" and do not stable orbit the Earth.

3 Definition of Terms

Unless otherwise specified, terms used in this document shall be in accordance with the examples of terms used in the Act on Launching of Spacecraft, etc. and Control of Spacecraft and the Enforcement Regulations of the Law and related guidelines, and terms and abbreviations used in this document shall mean the following.

Low Earth Orbit

Satellites orbiting the Earth with an average altitude of less than 2,000 km above the Earth's surface and an eccentricity of less than 0.25.

Primary Object

Satellites operating in orbit around the Earth that are subject to collision avoidance control under this Guideline.

Secondary Object

Space objects (e.g., satellites operated by others, space debris, etc.) that may collide with the primary object.

Time of Closest Approach (TCA)

The time when the primary and secondary objects are expected to be closest to each other in three dimensions.

Collision Risk

The probability of a collision between a primary object and a secondary object expressed in terms of possibility, relative distance, etc., and the overall evaluation of the impact on the orbital environment resulting from the collision. However, there are cases where only the former is intended to be used regardless of the impact on the orbital environment.

Collision Probability

Probability of collision between primary and secondary objects. Used to evaluate collision risk.

Conjunction Analysis

To identify secondary objects approaching in proximity to the primary object by comparing orbital ephemeries, etc., and to quantify the collision risk between them.

Conjunction Data Message (CDM)

The messages formatted in CCSDS 508.0 to exchange conjunction data with conjunction analysts, satellite operators (owners), and other parties.

Error Covariance

Uncertainty of the position, velocity, etc. of space objects.

Collision Avoidance Operation

A series of operations to move from a state of high collision risk to a lower risk state.

Collision Avoidance Control

Orbital control to avoid secondary objects that are at collision risk.

Screening

Evaluate the closest distance between the primary object and secondary object(s) and identify secondary objects that intrude within a specific area around the primary object.

Predicted Orbit Ephemeris

The position and velocity information predicted for each time in the object's orbit.

4. Establishment of proper organization and framework for satellite operation

4.1 Dedicated organization and work for operation management

As part of the framework for executing satellite operation, a person in charge of tasks related to the planning and execution of collision avoidance operations shall be established.

[Information to be submitted]

- System of command for operations (positions and main roles)
- Point of contact information for coordination of collision avoidance operation

4.2Recognition of collision risks with space debris and satellites operated by other parties

Satellite operators should be able to identify the collision risk between primary and secondary objects based on SSA provided by those who maintain a reliable catalog of orbiting objects.

[Information to be submitted]

Documents, etc. that certify the use of SSA provided by public organizations or private companies, etc.

4.3Information provision, etc.

4.3.1 Providing information for collision avoidance

In order to reduce the collision risk between the primary and secondary objects, satellite operators should provide information of the primary object to the operators of secondary objects for SSA service, etc., upon request to the extent possible.

[Information to be submitted]

- Describe the above response in the license application.

4.3.2 Providing information on anomalies

In the event of an unexpected accident or malfunction that results in an abnormal condition that interferes with the performance of the Guidelines for primary objects, the highest priority should be given to minimizing damage and taking preventive measures against new accidents, and information should be provided to relevant organizations and potentially affected operators, as necessary.

In the unlikely event that affects a wide range of other satellite operators, such as break-ups or collision accidents, consideration should be given to disclosing information to the public.

[Information to be submitted]

- Identification of the event for which information should be communicated and possible contact information (may be included in the license application).

[Supplemental]

In some cases, such as loss of control in geostationary orbit, there is a possibility of directly harming the operations of other satellites, such as interference with satellites operating in adjacent areas, etc., and in such cases, prompt provision of information is required.

5. Design and operational measures to prevent and avoid collision, etc.

5.1 Selection of operational orbit and design considerations for satellites

5.1.1Selection of operational orbit

To the extent possible to achieve the mission objectives, an orbit should be selected that is as advantageous as possible in preventing or avoiding collisions, etc. The following points should be considered

- Interference with operational orbits of large constellation satellites
- Interference with operational orbit of a manned space station
- Interference with orbits with large amounts of space debris

[Information to be submitted]

- Concept of operational orbit selection (may be included in license application)

5.1.2 Design considerations for satellites

Since the functions used to prevent or avoid collisions are general functions required for satellites to carry out their missions, the Guidelines do not have additional requirements regarding functions and performance of satellites.
The following points, which are good practices compiled by space agencies and international organizations, should be considered as much as possible.

5.1.2.1 Promote Satellite Identification

- The size of the satellite should be large enough to be identified from ground-based radar. For example, a low earth orbit satellite should be at least 10 cm in diameter, and a satellite operating in a higher orbit should be at least 50 cm in diameter. If these are not met, incorporate devices that contribute to identification (Source: NASA Spacecraft Conjunction Assessment and Collision Avoidance Best Practices Handbook).
- For satellites that are launched in a rideshare mission, the collision risk immediately after launch can be reduced by installing devices (beacons, active/passive optical markers, etc.) to identify themselves after separation from the launch vehicle. Especially for satellites with dimensions that are difficult to be identified by a radar, this will also contribute to reducing the collision risk during normal operations (Source: IOAG/SOS WG Issue B).

5.1.2.2 Reliable operation of the satellite

- Maintain sufficient reliability* of critical functions of the satellite throughout its operation and disposal. If the system status changes during operation due to malfunctions, etc., or if the satellite is operated beyond its original design life, the reliability of critical functions should be confirmed again to be sufficiently maintained (Source: NASA Spacecraft Conjunction Assessment and Collision Avoidance Best Practices Handbook).

  *** Supplemental: Although NASA considers it ideal that the reliability of functions related to disposal should be 99% or higher, sufficient reliability data is not provided for consumer parts, etc., and in some cases the calculation itself is impossible. Therefore, there may be no choice but to ensure reliability through qualitative evaluations by checking the actual performance of the same components and conducting screening tests on the ground, or through systemic risk reduction measures such as redundancy design, etc.**

- To avoid a dead-on-arrival (DOA) situation, one or more of the following measures should be taken, especially for newly developed satellites (Source: SSC Best Practices).
  i. For the actual satellite to be launched, rigorous test simulating the launch environment and orbital environment (based on established technical standards, etc.*) will be conducted.
  ii. For satellites that have no on-orbit operational experience for critical functions (necessary for satellite control and collision avoidance), qualification tests with severe conditions than actual environment will be conducted.
  iii. Satellite orbit insertion and initial operations (even if DOA) should be performed in orbits with orbital lifetimes of 25 years or less, or in orbits that are rarely used by other satellites.

  *** Supplement: The satellite design standard (JERG-2-XXX) set by JAXA and industrial standard (ISO), etc., are available to the public.**

5.1.2.3 Promote implementation of collision avoidance operations

- Build a system that can provide predicted orbit ephemeris with sufficient accuracy as required for collision avoidance operations in Section 5.2 (Source: NASA Spacecraft Conjunction Assessment and Collision Avoidance Best Practices Handbook).
- Load a sufficient quantity of propellant to execute collision avoidance operations that are expected to increase with the prescribed operational period and changes of the orbital environment during that period (Source: IOAG/SOS WG Issue B).
- Ensure that mission operations can continue even during collision avoidance operations as much as possible. This is enables collision avoidance operations to be carried out without hesitation (Source: IOAG/SOS WG Issue B).

5.2 Collision Avoidance Operations

This section describes the basic concepts and procedures for collision avoidance operations for low earth orbit satellites, which are generally implemented by space agencies and private companies. If there is a more suitable method for the orbit and operation method of the satellite to be managed, the most appropriate method can be used.

5.2.1Determining decision criteria

The CDM for low earth orbit satellites provided by a typical SSA service are delivered about 5 days before TCA (actually, it depends on the arrangement with SSA service). Since the accuracy of the predicted collision probability is likely to be low at the time of the longer time to the TCA, it is not always necessary to shift promptly to collision avoidance operations even if the probability is high. As the TCA approaches and the prediction error of the secondary object's orbit becomes smaller, it may be necessary to consider shifting to collision avoidance operations depending on the collision probability, but in order to balance mission planning (e.g., imaging of specific point) and collision avoidance, It is desirable to establish a decision criteria suitable for each operator's operation so that a certain degree of flexibility can be maintained with respect to the timing of collision avoidance control.

Supplement: In the "Collision Risk Management Standard for Satellites (JMR-016)" established by JAXA, the risk level is set and managed by combining the number of days to TCA and collision probability, and a threshold value with a wide range is set as the collision avoidance control recommendation so that a flexible decision can be made at the stage before seeking reliable avoidance control rather than automatically implementing collision avoidance control at a specific threshold value.

[Information to be submitted]

- A plan document for collision avoidance operations (or a description of the criteria in the license application)
- Standards, ideas, etc. used as references in setting the decision criteria (For satellites operated in orbits to which other good practices, etc. are not applicable, provide more detailed information on the criteria and concept)

5.2.2 Managing collision risk

To manage the satellite collision risk, a plan for satellite collision avoidance operations should be established, taking into account the series of procedures described in sections 5.2.2.1 through 5.2.2.4.

[Supplemental]

- Consideration shall be given to ensure that the collision risk with a secondary object does not exceed the criteria established in Section 5.2.1 during orbit control performed to change the primary object's orbit or to maintain its orbit.

[Information to be submitted]

- Draft plan for collision avoidance operations in accordance with Sections 5.2.2.1 through 5.2.2.4 (may be included in the license application)

5.2.2.1 Obtaining conjunction data

In order to manage the collision risk, it is necessary to obtain conjunction information of the secondary object from the SSA service as instructed in section 4.2. For this purpose, an appropriate information notification route from the SSA service should be set up so that the appropriate person in charge of the external contact point can receive the CDM in a timely manner.

In addition, information such as launch date, time, orbit, and order of separation (in case of rideshare) should be provided to the SSA service with sufficient time to allow the SSA service to determine the orbit of the primary object as quickly as possible (in some cases, this information may be compiled by the launch operator).

5.2.2.2 Screening

If the collision risk with a secondary object is detected by the conjunction analysis and other evaluations performed by the SSA service, a CDM is sent to the operator of the primary object. The operator of the primary object should respond appropriately to the request for information from the SSA service, such as providing a predicted orbit ephemeris (including error covariance) of the primary object, in order to obtain more accurate conjunction information from the SSA service.

5.2.2.3 Risk Assessment

The necessity of collision avoidance operations is determined in accordance with the assessment criteria established in accordance with section 5.2.1. If it is determined that collision avoidance operations are necessary, perform collision avoidance operations in section 5.2.2.4. If there is time before the TCA and the decision is postponed, set the timing for the next risk assessment.

If the collision risk is judged to be at an acceptable level in the last risk assessment before TCA, or if the collision risk is high but collision avoidance operations cannot be performed for some reason (e.g., malfunction), the primary object's condition should be closely monitored until a sufficient time has passed after TCA, in preparation for information communication in case any anomalies are detected. If any anomaly is detected, the operator should prepare for sharing information of anomaly.

5.2.2.4 Risk Mitigation

When performing collision avoidance operations as a result of section 5.2.2.3, the timing and amount of control for collision avoidance should be promptly reviewed, and if necessary, the

operator should confirm in advance, with the cooperation of the SSA service, that the collision probability with the secondary object after avoidance control will be sufficiently reduced.
It shall also be confirmed that the collision risk with a new secondary object in the orbit after implementation of the collision avoidance control is sufficiently small.
If the secondary object is a satellite in operation and the operator of the secondary object can be contacted, it is desirable to coordinate in advance with the operator of the secondary object on how to proceed with collision risk mitigation before deciding whether collision avoidance control is necessary.

5.2.3 Considerations when performing maneuvers

When the primary object performs orbit control to maintain or change the operational orbit, to provide the SSA service with orbit control plans and other information with sufficient time margin.

[Information to be submitted]

- The above must be taken into account in the draft plan for collision avoidance operations (or may be included in the license application)

5.2.4 Considerations when maneuvering by autonomous functions

When a satellite performs autonomous orbit control without command from the ground, the following considerations should generally be taken into account

- The time, direction, and amount of control to be performed shall be notified to the ground in advance (with sufficient time margin) so that the SSA service can perform conjunction analysis and other evaluations in the same manner as when orbit control is performed by command from the ground. The same shall also apply to the results of orbit control.
- If the screening results predict a collision risk with a secondary object, allow the autonomous function's planned orbit control to be interrupted or cancelled by ground operator.
- Planned orbit controls that have been notified to the ground in advance should be implemented as planned unless there are no updates for interventions by the ground.