General

JMR-016(E)

Standard for Spacecraft Collision Risk Management

December 27, 2022

Japan Aerospace Exploration Agency

This is an English translation of JMR-016 and does not constitute itself.
Whenever this document conflicts with the original document in Japanese, the original document takes precedence.

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1. General

1.1. Purpose

The purpose of this standard is to avoid collisions between satellites owned by the Japan Aerospace Exploration Agency (hereinafter referred to as "JAXA") and other space objects. This standard specifies requirements for operations to be performed by the operation organization responsible for collision avoidance operations (hereinafter referred to as the "Organizations in charge"). This standard specifies only general requirements independent of satellites specification.

1.2. Background

This section presents the background of the establishment of this standard.

Since the Soviet Union launched Sputnik 1 in 1957, artificial satellites began to exist in orbit. Satellites and rocket bodies that have completed their missions remain in orbit for long periods and are recognized as one of the main obstacles to sustainable space development in the future. When centimeter-sized space debris collides with a primary object, the primary object is partially or destroyed, and even millimeter-sized space debris has the power to shut down an operational satellite if it collides with a critical point for satellite operation. Such collisions have occurred and have been summarized by NASA (Reference Document (12)).

To prevent collision accidents, each space agency conducts conjunction assessment and collision avoidance operations. NASA has established a handbook (Reference Document (1)) that defines best practices for conjunction assessment and collision avoidance, which is available to the public.

To protect the primary object from secondary objects that may collide with the primary object, the Space Tracking and Communication Center (STCC) in JAXA provides support for Conjunction Assessment and Collision Avoidance operations. The STCC has developed management guidelines for space debris collision risk (hereinafter referred to as "the STCC Management Guidelines"). Since FY 2017, the STCC has been conducting conjunction assessment and collision avoidance operational support using a probability of collision as an indicator of collision risk based on the STCC Management guidelines and has confirmed the effectiveness of the guidelines.

On the other hand, in 2019, the United Nations Committee on the Peaceful Uses of Outer Space adopted the "Guidelines for the Long-Term Sustainability of Outer Space (hereinafter referred to as "LTS Guidelines"). Compliance Document (1)" was adopted. JAXA needs to demonstrate its implementation of "B.4 Perform conjunction assessment during all orbital phases of controlled flight" of the 21 items adopted in the LTS

Guidelines, and appropriate collision risk management. The risk of collision with an object on a JAXA-owned satellite, if manifested, could have a serious impact on JAXA and could develop into a crisis requiring an agency-wide response. Based on the need to stipulate standard requirements to be implemented by the organizations involved in on-orbit operations for the management of collision risk for satellites owned by JAXA, and the effectiveness of the STCC management guidelines, a general standard for primary objects will be established as a JAXA standard.

1.3. Application

For satellites developed by JAXA and operated in Earth orbit, this standard shall be called out and applied to development and operation documents, etc., to manage the risk of collision during operations from the time when the orbital accuracy required for screening is confirmed after separation from the launch vehicle until the satellite is terminated. In addition, this standard shall be applied to the counterparty of the contract, etc., as necessary.

1.3.1. Tailoring

The requirements of this standard may be applied by selecting and modifying the requirements in consideration of various conditions, such as the characteristics and properties of the primary object and the information handled in the primary object.
If necessary, the organization responsible for conducting conjunction assessment and collision avoidance operations (see Section 5.1.1.2) may tailor the requirements by consulting with the JAXA Safety and Mission Assurance Department, describing them in a collision avoidance operation management plan, and obtaining approval from the JAXA Safety Review Board.

2. Related documents

2.1. Compliant documents

The existing codes and standards upon which this standard is based are as follows.

(1) Committee on the Peaceful Uses of Outer Space, *Guidelines for the Long-term Sustainability of Outer Space Activities*, 27 June 2018.
(2) Regulations about space debris information management (Decision No. 16-1 by the Director of the Tracking and Network Technology Center)
(3) JMR-011, Risk Management Handbook

2.2. Applicable documents

The following documents are applicable to this standard and form part of this standard. In principle, the latest version should be applied.

(1) JERG-2-026, Safety Standards for On-orbit Service Missions
(2) AAX-03014, Crisis Management Office Operations Manual

2.3. Reference documents

The reference documents for this standard are as follows.

(1) NASA, NASA Spacecraft Conjunction Assessment and Collision Avoidance Best Practices Handbook, December 2020.
(2) QNX-160020, Management Procedure for Space Debris Impact Risk (supplemental manual)
(3) QNX-160019, Management Procedure for Space Debris Impact Risk (main text)
(4) QNX-160021, Probability of collision used to calculate space debris collision risk
(5) JJX-2011023, Information communication response for debris avoidance maneuvers, etc.
(6) François LaPorte, “Operational Management of Collision Risks for LEO Satellites at CNES”, Space Operations Communicator, Vol. 5, No. 4, 2008.
(7) J. Beaumet, "CNES operational feedbacks in collision avoidance for LEO satellites", ISSFD 2009.
(8) T. Flohrer, V. Braun, H. Krag, K. Merz, S. Lemmens, B. Bastida Virgili, and Q. Funke, “Operational Collision Avoidance at ESOC”, Deutscher Luft- und Raumfahrt-kongress 2015.
(9) H. Krag, K. Merz, T. Flohrer, S. Lemmens, B. Bastida Virgili, Q. Funke and V. Braum, “ESA’s Modernised Collision Avoidance Service”, SpaceOps 2016.
(10) The Consultative Committee for Space Data Systems, Conjunction Data Message (Blue Book).
(11) JERG-1-011, Basic Requirements for Flight Safety of Satellite Launch Vehicles
(12) NASA, History of On-Orbit Satellite Fragmentations, 15th edition, July 2018.

3. Definitions

3.1. Definition of terms

The definitions of terms used in this standard are as follows.

(1) Collision avoidance maneuver
A trajectory maneuver to avoid secondary objects that are at risk of collision.
(2) Collision avoidance operations

The sequence of operations from transition to Collision Risk Level 1 to release of Collision Risk Level 2 or 3.

(3) Probability of collision

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

(4) Conjunction Assessment

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

(5) Earth orbit

Orbit with the earth as the central celestial body.

(6) Final decision meeting

A meeting to determine whether to execute collision avoidance maneuvers.

(7) Low Earth Orbit Satellite

A satellite orbiting the earth at an average altitude of lower than 2000 km above the earth's surface with an eccentricity of less than 0.25.

(8) Primary decision-making meeting

A meeting to determine the transition to collision avoidance operations.

(9) Primary object

Operational satellites around the Earth to be protected from collisions by this standard.

(10) Secondary objects

A space object that may collide with the primary object.

(11) Space Systems

It is a generic term for satellites and systems that carry out missions outside the atmosphere, such as satellites and launch vehicles.

3.2. Definition of abbreviations

The definitions of abbreviations used in this standard are as follows.

(1) ISS (International Space Station)

(2) TCA (Time of Closest Approach)

4. A basic approach to conjunction assessment and collision avoidance operation

4.1. Requirements for development phase

The following points shall be considered during development.

(1) During the mission review process, consideration shall be given to selecting an operational orbit in an orbit area with the lowest possible conjunction frequency.

(2) Consideration shall be given to the addition of a collision avoidance function, based on (1) and the importance of the mission.
(3) If a collision avoidance function is added based on the study in (2), the propellant required for collision avoidance maneuver shall be considered.
(4) For systems that potentially cause visibility problems (e.g., satellites not equipped with GPS receivers, satellites covered with materials with good radio absorption characteristics, tethers and other propagation ends, and microsatellites), consideration shall be given to improving visibility from the ground to improve orbit determination accuracy by providing optical or radio reflection and transmission means.

4.2. Requirements for operation phase

Collision avoidance operations are performed to reduce the risk of collision of the primary object with a secondary object. To reduce the risk of collision, it is desirable to provide the primary object with a collision avoidance maneuver capability. However, since some satellites do not have a collision avoidance maneuver capability, this standard specifies that the collision risk shall be assessed regardless of whether a collision avoidance maneuver capability is provided.

According to the compliant document (3), to assess the risk, it is specified that the magnitude of the risk is determined by combining two items: "likelihood of occurrence" and "expected severity". However, when it comes to collision events between objects whose orbits are known (both with object radii of several centimeters or more), once a collision occurs, it not only causes loss of the primary object's function but also seriously affects the space environment, so the expected severity of risk in the event of any collision exceeds the acceptable level. Therefore, in effect, only the "likelihood of occurrence (probability of collision)" indicator is used to evaluate collision risk.

If risk management based on the probability of collision is not necessarily suitable such as in the case of geostationary satellites, a collision avoidance operation policy shall be determined in coordination with the conjunction assessment and collision avoidance operation support organization using methods such as conjunction assessment and appropriate relative distances, etc.

5. General requirements

5.1. Basic requirements

When planning and executing conjunction assessment and collision avoidance operations, the organizations in charge indicated in Section 5.1.1.2 shall develop and implement

effective measures to minimize the risk of collision of the primary object with the secondary object.

The organizations in charge shall include each of the following items in their activities.

(1) Efforts to reduce the risk of collisions between primary and secondary objects. To demonstrate such efforts, the collision avoidance operational management shown in Section 5.1.1 shall be implemented.

(2) Establishment of a management system to accurately reflect the efforts described in (1) above in each operational phase. To implement the development of such a management system, the requirements in 5.1.2 through 5.1.4 shall be applied based on the collision avoidance operational management shown in Section 5.1.1.

5.1.1. Collision avoidance management

5.1.1.1. Overview

The organizations in charge as specified in Section 5.1.1.2 shall ensure that an effective conjunction assessment and collision avoidance operation plan is prepared before the pre-launch phase and that the results are systematically managed for review.

5.1.1.2. Organizations in charge

The following organizations in charge shall assign a person in charge of managing the risk of collision between primary and secondary objects.

(1) The organization that conducts collision avoidance operations

The organization that conducts collision avoidance operations (hereinafter referred to as “COLA team”) shall assign a person in charge of conducting collision avoidance operations.

The COLA team basically refers to the satellite project team or the satellite applications and operations center.

The person in charge of collision avoidance operations (hereinafter referred to as “COLA operator”) is the person who performs collision avoidance operations in the COLA team.

(2) The organization that conducts conjunction assessment and collision avoidance operational support

The organization that conducts conjunction assessment and collision avoidance operational support (hereinafter referred to as “CA team”) shall assign a person in charge of implementing conjunction assessment and collision avoidance operational support.

The CA team basically refers to the STCC. However, this does not apply when there

is a separate person designated to implement conjunction assessment and collision avoidance operational support.

The person in charge of conjunction assessment and collision avoidance operation support (hereinafter referred to as "CA analyst") means the person in charge of conjunction assessment and collision avoidance operation support in the CA team.

(3) The crisis management office

The crisis management office (hereinafter referred to as "CMO") shall assign a person in charge of crisis management related to collision avoidance operations (hereinafter referred to as "CMO staff"). The CMO staff related to the CA consist of personnel who will communicate with the CA analyst and the COLA operator, as well as the assistant of the CMO director (hereinafter referred to as "CMO assistant") per reference document (2).

5.1.1.3. Collision avoidance management plan

The COLA team shall prepare a feasible collision avoidance operation and management plan[1] that applies this standard in consultation with the CA team and the Safety and Mission Assurance Department, and obtain approval from the JAXA Safety Review Board. The collision avoidance operation and management plan shall include the following

(1) Conformity with the requirements of this standard.

(2) A series of operational procedures related to collision avoidance operations with secondary objects (e.g., how to obtain conjunction information, conjunction assessment timeline, and how to implement collision avoidance maneuver).

(3) A list of relevant documents, such as documents to be prepared to satisfy the requirements of this standard, application documents, etc.

(4) A description of tailoring items, if any, to this standard and the rationale for such tailoring.

5.1.2. Requirements for the COLA team

The COLA team shall perform the following tasks

- Implementation decisions regarding satellite operations, including collision avoidance operations
- Information communication regarding the above implementation decisions
- Satellite control operations for collision avoidance operations

[1] It corresponds to the conventional "Space Debris Avoidance Control Operating Procedures.

5.1.3. Requirements for the CA team

The CA team shall perform the following tasks

- Identification of secondary objects that may collide with the primary object and calculation of collision risk
- Notification of close approach events with high collision risk
- Planning for collision avoidance maneuvers
- Operation of tracking network facilities for collision avoidance operations

5.1.4. Requirements for the CMO

The CMO shall perform the following tasks

- Collect information related to risk management and assess the situation (including safety confirmations after collision avoidance)
- Decide on an agency-wide response to detected risks (if a response is deemed necessary, discuss and set up countermeasures).

6. Detailed requirements

6.1. Basic requirements

The organizations in charge described in section 5.1.1.2 shall implement the following to minimize the risk of collisions with secondary objects.

(1) Collision risk assessment

(2) Response according to collision risk level

For low earth orbit satellites, the satellite operation shall be based on Section 6.2.

For other than low earth orbit satellites, the satellite operation shall be based on a risk assessment method using geometrical distance at the time of closest approach, etc., which is separately determined for each satellite[2].

6.2. Collision risk assessment

6.2.1. Collision risk assessment indicators

As an indicator to define the collision risk, the "probability of collision (Pc)," which is calculated by considering the orbital position error and the size of the objects, shall be used in principle. The closest approach distance and separation distance in the altitude direction shall be treated as optional information for evaluating collision risk. The calculation method of Pc is specified in Reference Document (4). For the relationship

[2] For other than low earth orbit satellites, JAXA plan to add the information to this standard once the procedures for collision avoidance operations have matured.

between collision risk and Pc, refer to Section 4 and ANNEX A.

6.2.2. Collision risk level

To prepare for the risk of collision between primary and secondary objects, collision avoidance operations shall be performed corresponding to the collision risk levels shown below. In principle, the collision risk level is defined by two parameters: Pc and urgency (remaining time until TCA).

6.2.2.1. Level 1 (MONITOR)

A state in which a possible high collision risk between the primary and secondary objects is detected, but there is sufficient time to implement a collision avoidance maneuver before reaching TCA. At this collision risk level, the CA team shall report the latest conjunction information to the COLA team and the CMO, and each organization shall keep a close watch on the collision risk trend. Even primary objects that do not have maneuver capabilities fall under this collision risk level if they meet the following conditions.

- Level 1 Conditions
  - Period: 5 days before TCA[3] to first acquisition of signal (hereinafter referred to as "AOS") after TCA
  - Probability of collision: 1.0E-5 or higher

6.2.2.2. Level 2 (URGENT)

A state in which the collision risk between the primary and secondary objects is still high, and a collision avoidance maneuver need to be prepared and, if necessary, implemented. At this collision risk level, the CA team shall report the latest approach status to the COLA team, and the COLA team shall prepare for collision avoidance operations and implement a collision avoidance maneuver if necessary. The COLA team shall give priority to reducing the risk of collision for the primary object. If the contact information of the secondary object operator is included in the conjunction information (Reference Document (10)), the CA analyst shall contact the secondary object operator as much as possible to coordinate collision avoidance operations. In addition, the report distributed by the CA analyst shall include maneuver information on the secondary object.

- Level 2 conditions (only applicable to primary objects with maneuver capability)

[3] The remaining time until TCA is less than 120 hours.

- Period: Primary decision time (see below) to first AOS after TCA
- Probability of collision: In principle, Table 1 will be applied to decide the Level 2 transition. Even if the preparation or implementation of a collision avoidance operation is canceled as a result of a decision made by the COLA team, it will still fall under this collision risk level if it meets this criterion.

Table 1　Definition of Level 2 (URGENT)

Primary Decision Time (N days before TCA)[4]	Probability of collision
N ≦ 2	1.0E-4 or higher
N ＞ 2	1.0E-5 or higher

Guideline for setting the primary decision-making meeting

If the COLA team decides to prepare for the collision avoidance operation in the primary decision meeting, the time required for preparation of trajectory control for collision avoidance (planning of collision avoidance maneuver, conjunction assessment based on the controlled trajectory, securing ground stations for uplink/downlink, making command plans, etc.) differs for each COLA team, so it is necessary to set a time that takes these factors into account. Therefore, it is necessary to set the time in consideration of these factors. The specific values for N in Table 1 shall be described in the collision avoidance management plan (Section 5.1.1.3).

Criteria for deciding whether to implement collision avoidance maneuver (at the time of the final decision meeting)

The decision criteria for the implementation of the collision avoidance maneuver are shown in Table 2. In addition to the criteria below, a comprehensive decision on the implementation of the collision avoidance maneuver shall be made by considering the status of the satellite system of the primary object at the time of the collision (i.e., whether there is any risk from the implementation of the collision avoidance maneuver). The probability of collision to be targeted in the collision avoidance operation shall be described in the collision avoidance management plan (Section 5.1.1.3).

Table 2　Criteria for implementation of collision avoidance maneuver

Probability of Collision	Description

[4] Refers to a condition where the remaining time until TCA is less than N x 24 hours.

1.0E-3 or higher	The COLA team shall prioritize the implementation of collision avoidance maneuvers over the continuity of mission operations if the primary object has maneuver capability.
1.0E-4 to less than 1.0E-3	The COLA team shall implement collision avoidance maneuvers considering the continuity of mission operations if the primary object has maneuver capability.

Guideline for setting the final decision meeting

The time between the final decision meeting and the execution of the collision avoidance maneuver depends on each COLA team and the assignment status of available ground stations. In addition, it is desirable to set the time as close to the TCA as possible to make decisions on collision avoidance maneuvers using the latest approach information. The final decision meeting shall be set at a time that takes these factors into account.

6.2.2.3. Level 3 (CRITICAL)

A state in which the risk of collision between the primary and secondary objects is very high, but satellite operations to reduce the collision risk (e.g., collision avoidance maneuver) cannot be implemented. Because the collision risk cannot be reduced at this risk level, it is truly a high-risk condition, and the COLA team shall take the maximum possible action.

- Level 3 conditions (applicable to primary objects with maneuver capability)
  - Period: After the final decision meeting to first AOS after TCA
  - Probability of collision: 1.0E-3 or higher
  - Only when satellite operations to reduce the risk of collision (e.g., collision avoidance maneuver) cannot be implemented

- Level 3 conditions (applicable to primary objects without maneuver capability)
  - Period: 2 days before TCA[5] to first AOS after TCA
  - Probability of collision: 1.0E-3 or higher

6.2.3. Collision risk level transitions

A matrix of collision risk levels according to collision risk and urgency for primary objects is shown in Figure 1. For primary objects with maneuver capability, the level shifts from

[5] A condition in which the remaining time until TCA is less than 48 hours.

Level 1 to Level 2 after the primary decision time. If the probability of collision is 1.0E-3 or higher and satellite operations to reduce the collision risk cannot be implemented, the risk level moves to Level 3. On the other hand, the risk level for the primary object without maneuver capability moves to Level 3 only when the probability of collision is 1.0E-3 or higher at the time two days before the TCA.

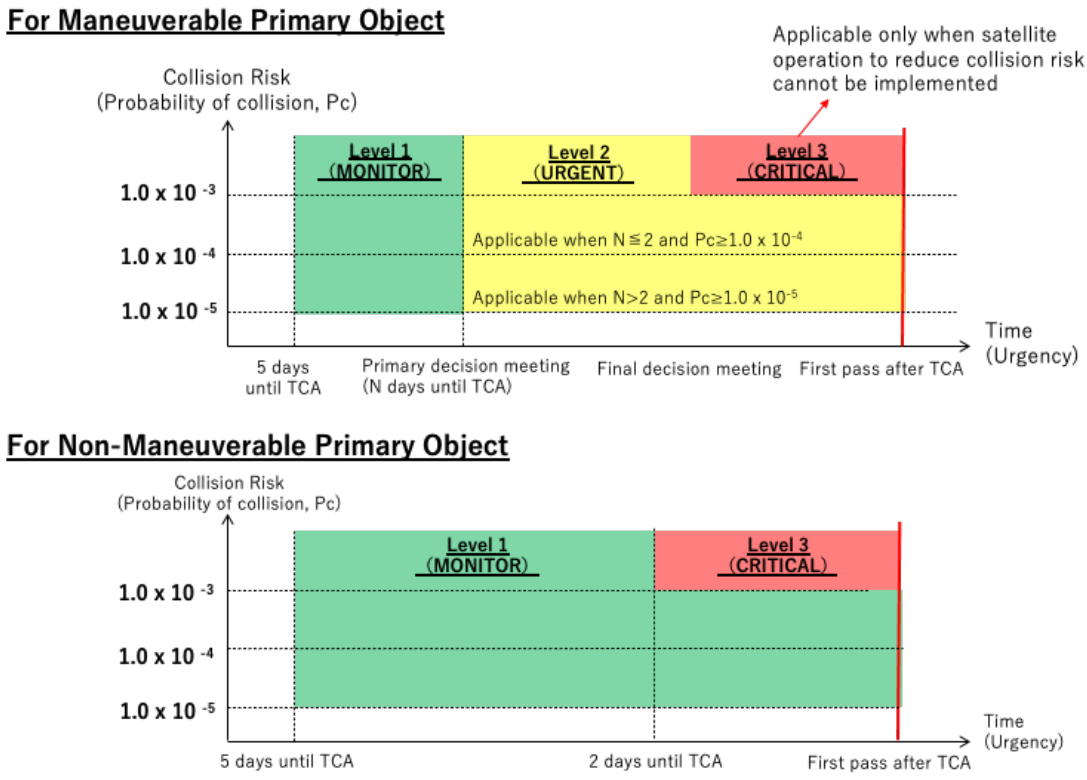

Figure 1 Transition diagram of collision risk levels

6.3. Actions according to the collision risk level

It is necessary to perform collision avoidance operations corresponding to the collision risk levels specified in 6.2.2 and to communicate and share information with relevant organizations. This section defines the information communication flow and the type of information to be communicated (sender, receiver, contents, and timing) for each collision risk level. The basic method of "notification" is e-mail, while "communication" and "coordination" can be handled appropriately by telephone, etc. in addition to e-mail.

This standard describes only the communication flow between the organizations in charge of JAXA, and the procedures for communicating within an organization (including the director in charge) shall follow the procedures established for each

organization. In addition, the crisis management office shall communicate necessary information per the applicable document (2).

6.3.1. Primary object with maneuver capability

Figure 2 shows the information communication flow at each collision risk level. The types of information to be communicated at each collision risk level (sender, receiver, content, and timing of transmission) are specified in ① through ⑥ below.

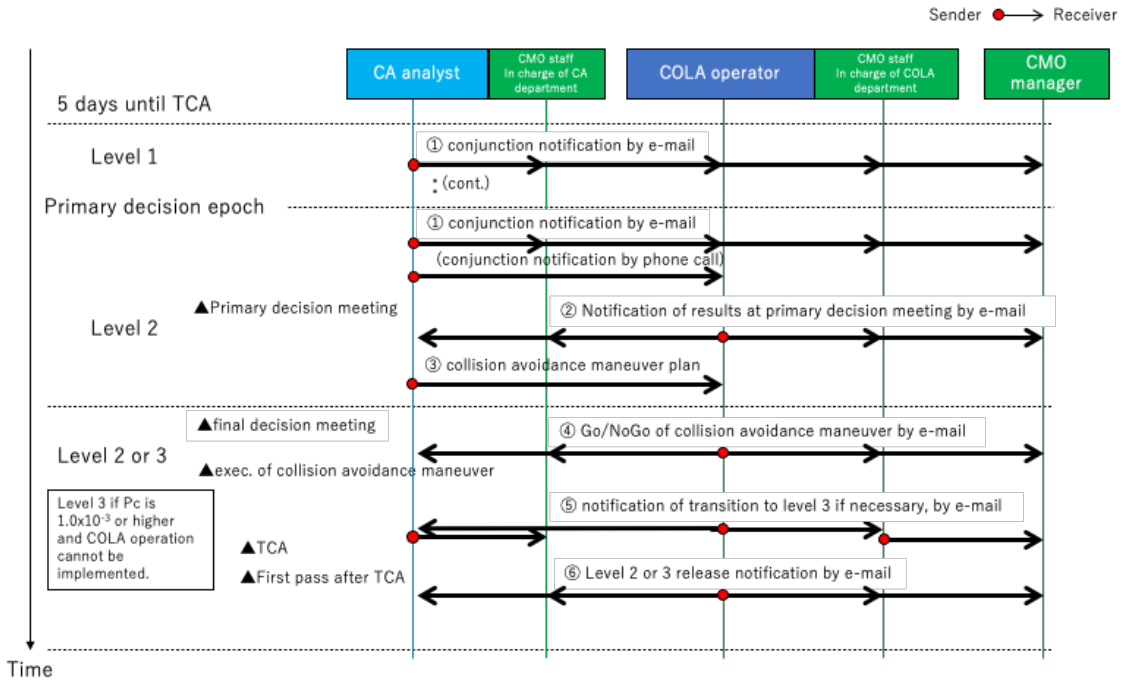

Figure 2 Information communication flow for a primary object with maneuver capability

① Notification of conjunction status

The CA analyst shall notify the COLA operator and the crisis management office of the latest conjunction status as indicated below. In principle, notification shall be made during the day shift when information is updated.

In addition, when the CA analyst detects a conjunction event that meets the definition of collision risk level 2, the CA analyst contacts the CMO staff in charge of the CA team via e-mail (The address of the emergency mobile phone for the person in charge of crisis management shall be added to the e-mail shown in Figure 2 ①. [6]) In addition, the CA

[6] Once added as a recipient, it shall not be removed until there is no longer a risk of relevant conjunction.

analyst shall phone the COLA operator to coordinate the schedule for the primary decision meeting.

Subject: [Notification (or update)] Secondary object approach notification (primary object name x secondary object name, TCA)

(1) Secondary object: OBJECT number, name
(2) TCA: year, month, day, hour, minute, second UTC
(3) Relative date and time: X days later
(4) Probability of collision: X (no unit)
(5) Closest approach distance: X m
(6) Distance of separation in altitude direction : X m
(7) Orbital position error: primary and secondary objects, respectively
(8) Others: the existence of a maneuver plan, simulation results, etc.

② Notification of decision on whether to shift to collision avoidance operations

After the primary decision meeting, the COLA operator shall notify the CA analyst and the crisis management office of the results of the decision on whether to shift to collision avoidance operations.

Subject: [Notification] Result of the decision to shift to collision avoidance operation

(1) Result of the decision to transition to collision avoidance operations (GO/NOGO)
(2) The rationale for the transition decision
(3) Secondary object: OBJECT number, name
(4) TCA: year, month, hour, minute, second UTC
(5) Probability of collision: X (no unit) *Optional
(6) Closest approach distance: X m *Optional
(7) Date and time of the final decision meeting (if GO)

③ Notification of collision avoidance maneuver plan

The CA analyst shall notify the COLA operator of the planned collision avoidance maneuver values. Note that this notification is not required if the collision avoidance maneuver plan has been determined at the time of the primary decision meeting.

Subject: [Notification (or Update)] Issue (or Update) collision avoidance maneuver plan

(1) Maneuver epoch: year, month, hour, minute, second UTC
(2) Maneuver quantity: X m/s

(3) Secondary object: OBJECT number, name
(4) TCA after avoidance: year, month, hour, second, UTC
(5) Probability of collision after avoidance: X (no unit)
(6) Closest approach distance after avoidance: X m

④ Notification of decision to implement or not to implement collision avoidance maneuver

After the final decision meeting, the COLA operator shall notify the CA analyst and the crisis management office of the results of the decision to implement or not to implement the collision avoidance maneuver.

Subject: [Execution (or Cancellation)] Result of the decision to implement collision avoidance maneuver

(1) Result of the decision to implement collision avoidance maneuver (execution/cancellation)
(2) Rationale for decision
(3) Maneuver epoch: year, month, hour, minute, second UTC
(4) Maneuver quantity: X m/s *Optional
(5) Secondary object: OBJECT number, name
(6) TCA after avoidance: year, month, hour, second, UTC *Optional
(7) Probability of collision after avoidance: X (no unit) *Optional
(8) Nearest approach distance after avoidance: X m *Optional
(9) Timing when a collision avoidance maneuver result can be confirmed (time of first AOS)

⑤ Notification of transition to Level 3 (CRITICAL)

If it is found that satellite operations to reduce the risk of collision (collision avoidance maneuver, etc.) cannot be implemented, and the operation is shifted to collision risk level 3, the COLA operator shall call the CA analyst and the CMO staff in charge of the COLA team, to that effect. Thereafter, the CA analyst shall notify the CMO staff in charge of the CA team, and the CMO staff in charge of the COLA team shall notify the CMO assistant by phone call that the collision risk level has been shifted to Level 3. When notified by phone call, the timing when the satellite status can be confirmed after the closest approach shall also be notified.

⑥ Level 2 (URGENT) or Level 3 (CRITICAL) release notification

The COLA operator shall notify the COLA operator and the crisis management office of the results of the implementation of the collision avoidance maneuver and the status of the primary object after the closest approach time has passed. If the collision risk level cannot be released due to a collision or other reason, the COLA operator shall inform the crisis management office to that effect and take action per the applicable document (2).

Subject: [Notification] Result of status confirmation after closest approach (Satellite name)

(1) Results of collision avoidance maneuver implementation
(2) Status of the primary object after the TCA
(3) The release of a Level 2 or Level 3 crisis management

6.3.2. Primary object without maneuver capability

Figure 3 shows the information communication flow at each collision risk level. The types of information to be communicated at each collision risk level (sender, receiver, content, and timing of transmission) are specified in ① through ④ below.

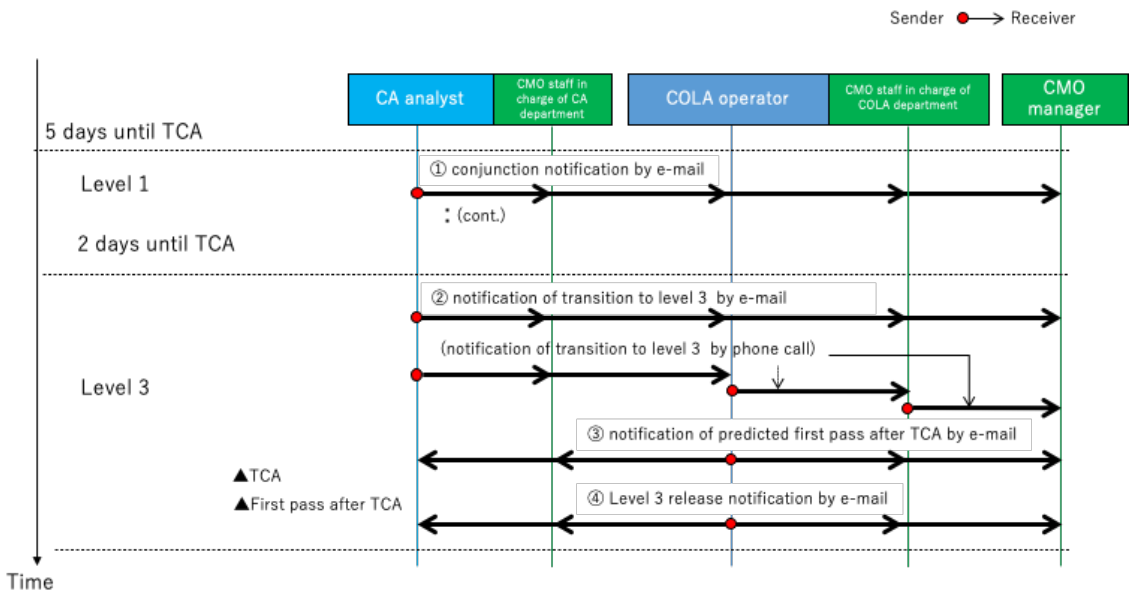

Figure 3 Information communication flow for a primary object without maneuver capability

① Notification of conjunction status

The CA analyst shall notify the COLA operator and the crisis management office of the latest conjunction status. In principle, notification shall be made during the day shift

when information is updated. The information to be communicated shall be per Section 6.3.1 (1).

② Notification of transition to Level 3 (CRITICAL)

When a conjunction event that meets the definition of collision risk level 3 is detected, the CA analyst shall notify the COLA operator and the CMO staff via e-mail that a conjunction that meets collision risk level 3 exists, along with the latest conjunction status.

The CA analyst shall also inform the COLA operator and the CMO staff in charge of the CA team, to that effect by phone call. Thereafter, the COLA operator shall notify the CMO staff in charge of the COLA team, and the CMO staff in charge of the COLA team shall notify the CMO assistant by phone call that the collision risk level will be moved to Level 3.

Subject: [Notification] Notification of transition to collision risk level 3 (primary object name x secondary object Name, TCA)

(1) A statement that the conjunction falls under level 3 (CRITICAL)
(2) Secondary object: OBJECT number, name
(3) TCA: year, month, hour, second, UTC
(4) Relative date and time: X days later
(5) Probability of collision: X (no unit)
(6) Closest approach distance: X m
(7) Distance of separation in altitude direction: X m
(8) The reason why collision avoidance operations cannot be performed

③ Notification of operation pass information after TCA

The COLA operator shall secure an operation pass to check the status of the primary object after TCA, and shall notify the CA analyst and the crisis management office of the information regarding the operation pass for checking the status of the primary object.

Subject: [Notification] Operation pass after closest approach (Satellite name)

(1) Secondary object: OBJECT number, name
(2) TCA: year, month, hour, minute, second UTC
(3) Operation pass time and station name after the TCA

④ Level 3 (CRITICAL) release notification

The COLA operator shall notify the CA analyst and the crisis management office of the status of the primary object after the TCA. If the collision risk level cannot be released due to a collision or other reason, the action shall be taken per the applicable document (2).

Subject: [Notification] Result of status confirmation after closest approach (Satellite name)

(1) Status of the primary object after the TCA
(2) The release of a Level 3 crisis management

7. Contact for inquiries

In the Metadata section of the Conjunction Data Message (Reference Document (10)), which contains the conjunction information, there is a form to provide contact information to the satellite operations organization. To respond to inquiries about conjunction events with external organizations, the CA team publishes the contact information in the Conjunction Data Message so that the contact information is listed in the conjunction information.

ANNEX A. Effectiveness of collision risk assessment using a probability of collision

As candidate indicators to define the likelihood of occurrence of collision risk, the approach distance and the separation distance in the altitude direction at the TCA were used in space debris collision avoidance operations until FY 2016. However, as examples (a) and (b) in Figure 4 show, even if the closest approach distance is small, if the magnitude of the orbital position error is extremely large or small relative to the closest approach distance, the collision risk may be judged to be small, reducing unnecessary collision avoidance operations.

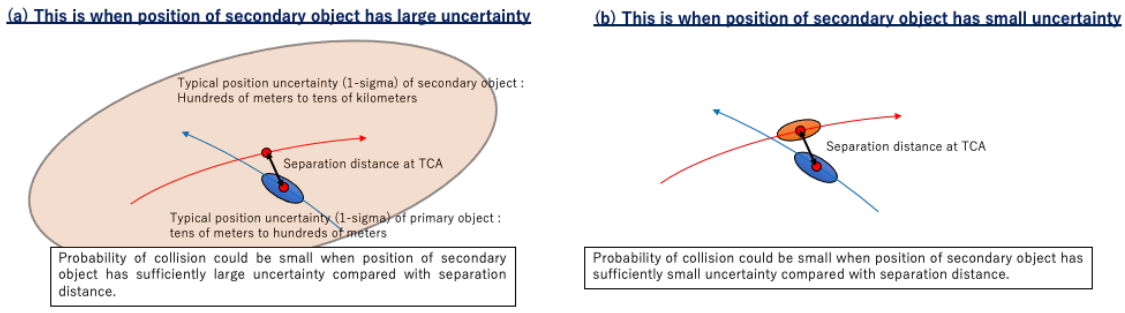

Figure 4 Relationship between orbital error and collision risk between satellites (primary objects) and space debris (secondary objects)

ANNEX B. Comparison with collision avoidance criteria of other space agencies

For collision avoidance operations for other space agencies and the ISS, several thresholds for the probability of collision, as indicated in Sections 6.2.1 and 6.2.2, have been established and examples are given below.

- The criteria for implementing collision avoidance maneuver on the ISS is when the probability of collision is 1.0E-4 or higher (red light level). However, if the probability of collision becomes smaller than 1.0E-4 after the detailed maneuver plan is prepared, the decision to abort can be made with the consent of the flight director two orbits (approximately three hours) before the maneuver. (Reference Document (5))

- The criteria for implementing collision avoidance maneuver in NASA is when the probability of collision is greater than 1.0E-4 or the closest approach distance is less than the Hard-Body-Radius (sum of the radii of the primary and secondary objects). Then, for avoidance operations, it is recommended to reduce the probability of collision to 1.5 times the logarithmic ratio (=probability of collision 3.2E-6). In this case, the probability of collision with another object should be lower than 1.0E-4. (Reference Document (1))

- The criteria for implementing collision avoidance maneuver in CNES are "when radar observation of a secondary object is available and the probability of collision is 1.0E-3 or higher" or "when radar observation of a secondary object is not available but the probability of collision is 1.0E-2 or higher". An alert is issued when the maximum probability of collision is 1.0E-4 or higher, and a detailed analysis is conducted when the probability of collision is 1.0E-3 or higher. (Ref. (6)(7))

- The criteria for implementing collision avoidance maneuver in the ESA is when the probability of collision is 1.0E-4 or higher at the time of the final decision (usually within TCA-1 day). This probability of collision threshold is a value set from the trade-off between "the rate of reduction of collision risk during the satellite operation period" and "the number of alerts issued and collision avoidance maneuvers performed per year". (Ref. (8)(9))

Considering the above situation, the thresholds are set in the range of 1.0E-4~1.0E-2

for the probability of collision in each agency's decision to implement collision avoidance maneuver, and the criteria for judging the implementation of collision avoidance maneuver set in this standard (Table 2) are also consistent with international standards.