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Committee on the Peaceful Uses of Outer Space
Scientific and Technical Subcommittee
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Item 14 of the draft provisional agenda*
Long-term sustainability of outer space activities

Long-term sustainability of outer space activities

Note by the Secretariat

The present conference room paper contains the full reports received by the Secretariat from Japan. A summary of the reports is contained in document A/AC.105/C.1/103.

* A/AC.105/C.1/L.310.

II. Replies received from member States

The Experiences and Practices related to the Long-Term Sustainability of Outer Space Activities in Japan (Regarding space debris, space operations and tools to support collaborative space situational awareness)

I. Introduction

In accordance with the provisions of the terms of reference and methods of work of the Working Group on the Long-term Sustainability of Outer Space Activities, adopted by the Committee at its fifty-fourth session (A/66/20, annex II), Japan would like to provide information of its experiences and practices that relate to the long-term sustainability of outer space activities and how Japan envisages work under the topic (A/66/20, annex II, paragraph 23). This paper emphasizes debris related issues. This paper also identifies the problems common in the world to be improved. It is expected that improvements can be made through the activities of the WG.

II. Background information of the orbital environment

Major efforts to limit the generation of debris have been made in most of the countries. However, when looking at the long-term sustainability, we should take into account the following points:

(1) The debris environment is deteriorating in spite of the establishment of UN Debris Mitigation Guidelines and other international or national standards.

(2) The risk of collision cannot be ignored in densely populated orbital regions.

(3) The major source of debris generation in the near future will be a collision among existing objects followed by a chain reaction of collisions.

Under such situation, following risk factors should be considered in addition to the debris mitigation measures:

(1) Protection from debris impact

(a) Protection from collision with large detectable objects
Influence is too large if a numerous number of fragments generated in the orbit.

(b) Protection from collision with undetectable tiny particles
It causes loss of function to perform mission and disposal actions.

(c) Protection from collision with manned spacecraft at launch operation
If it happens, it could cause loss of human life and generate large number of fragments.

(d) Protection from collision with debris cloud generated by break-up
If a launch vehicle or spacecraft enters into the debris cloud, collision risk is very high.

(e) Protection of humans on the ground from the re-entering objects
If it happens, it can also cause loss of human life and environmental pollution.

(2) Preventing from collision among orbital objects

Accumulated debris in the useful and crowded orbital region should be positively removed in the future.

(3) Ensuring the quality and reliability of spacecraft

The mission completion is the best and is a principle requirement to mitigate debris

III. Experiences and practices in Japan

1. General mitigation practices

1.1 Requirements

The importance of the debris issue is clearly stated in the "Basic Plan for Space Policy" published by the Japanese government. Japan Aerospace Exploration Agency (JAXA), which is a core organization that promotes space activities in Japan, has registered the "Space Debris Mitigation Standard (JMR-003)". The standard has following requirements which almost comply with the ISO-24113 "Space debris mitigation requirements", UN Space Debris Mitigation Guidelines, and the IADC Space Debris Mitigation Guidelines.

(1) limiting releases of mission related objects,

(2) preventing break-ups,

(3) removal of mission terminated Geosynchronous satellites from the GEO protected region,

(4) removal of mission terminated space systems passing through the LEO protected region,

(5) ensuring ground safety from the re-entering debris,

(6) preventing collision with large debris,

(7) preventing collision with manned space system at launching phase, and

(8) preventing damage by collision with tiny debris.

1.2 Planning and review

JAXA applies the standard to all of its space projects. To assess the compliance with the standard, JAXA requires contractors to submit the Debris Mitigation Plan for authorization.

During the product lifecycle, the traceability between mitigation plan and actual design and operation plan are reviewed at the end of each design phase, and compliance is verified.

1.3 Compliance and Subjects to be Discussed

The compliance of JAXA projects with the requirements of JMR-003 is shown in the Table-1. As a reference, comparison among JMR-003 and other world Standards and Guidelines are shown in Table-2.

In general, activities in Japan show relatively good compliance with applicable requirements. However the points below have been identified as subjects for improvement.

(1) The micro satellites, which do not have propulsion systems, will be injected to the orbit lower than 600 km to limit their orbital lifetime shorter than 25 years.

(2) The effort to reduce the risk of re-entry by selecting adequate material should be encouraged. Technology to reduce the survivability is being developed. (propellant tank to be demised during re-entry, etc.).

(3) When the collision avoidance manoeuvre is essential, the information of approaching spacecraft is needed, but sometimes it may not be available.

(4) When the break-ups occur, it would be risky to operate spacecraft or launch vehicles through debris cloud. So that break-up event should be informed by operators or on-ground observers immediately after the fragmentation.

(5) It should be noted that, in future, collision among orbital objects will be a major source of the deterioration of the environment.

(6) "Collision Avoidance for new Launch (COLA)" with manned system is expected to be applied in all the world launching operation. But not all the manned systems are providing its orbit and manoeuvring plan. Then COLA is not available for such systems.

(7) Since the world debris environment models do not show good agreement for micro-millimetre objects, excessive heavy mass for shielding tend to be required.

(8) Protection technology is still under development.

Coupling with the risk factors mentioned in section II, above understanding will induce the subjects to be discussed in UN for the sustainability of space activities, which is presented in the next section.

Table-1 Practices and Compliance with JAXA standard

	Requirements	Compliance, Experiences, Practices and Efforts	Further Efforts/Subjects to be discussed
1	Not releasing mission related objects	Every project has complied. 1) Clamp band which ties the spacecraft with the launcher will not be released. 2) Fasteners to hold antenna or paddles have bolt catcher not to release the parts, in spite that they cause loss of performances of antenna and paddles that are being applied in design. 3) In the case of launching multiple payloads, support structures are separated into orbit, but since their orbital lifetime is short, it is allowed in the world. 4) Other pyrotechnic devises would not be released their parts.	There are no major problems.
2	Prevention from break-ups	Every project has complied. 1) During the operation the critical parameters are monitored to detect a symptom of failure. In case of critical failure, operation will be terminated and adequate measures will be taken to prevent break-up. 2) At the end of operation, residual propellants are vented, and battery charging lines will be shut-off. 3) Pressure vessels are applied Leak-Before-Burst design, or have mechanical devices to prevent bursting (example: rupture disk in Lithium battery). 4) Break-up probability during operation is limited to less than 0.001.	There are no major problems.
3	Removal from the GEO protected region	Every project has complied 1) GEO satellites have been sent to disposal orbit regions after the end of operation. It may cause economical loss because the operation period would be reduced about 2 month, but operators put priority on preservation of orbital environment. 2) The eccentricity after disposal is controlled as small as possible (currently, smaller than 0.003). 3) Probability of success for disposal is controlled to be less than 0.9.	There are no major problems.
4	Removal from the LEO protected region	Projects are improving their status. 1) Since the February 2011, a 25 year rule has been strictly applied. Large satellites are complying with that rule. 2) Probability of success for disposal is controlled less than 0.9.	(1) The micro satellites, which do not have propulsion systems, will be injected lower altitude than 600 km to limit their orbital lifetime shorter than 25 years.
5	Ground safety from	Projects are improving their status. 1) Spacecraft are being designed to comply with the	

	the re-entering debris	required casualty expectancy. Some types of materials are refrain from application because of their high melting point or large specific heat. 2) A series of HTV, which is a transfer vehicle for logistics to ISS, is being conducted controlled re-entry. The second stage of H-2B has conducted controlled re-entry experimentally in February 2011. 3) Research and development are being conducted to reduce the re-entry survivability. A composite propellant tank is an example. 4) Re-entry analysis tool and procedure are being improved.	(1) The effort to reduce the risk of re-entry by selecting adequate material should be encouraged in the world.
6	Preventing collision with large debris	To prevent orbital collision all possible effort is conducted. 1) Conjunction assessment will be conducted using available information in the world, then collision avoidance manoeuvre will be planned, if necessary. 2) JAXA satellite (Daichi) conducted a collision avoidance once in 2009. 3) Research and development are being conducted to observe approaching objects as small as possible. 4) Japan is working in ISO to develop standards for data exchanging and general conjunction analysis procedure.	1) When the collision avoidance is essential, the information of approaching spacecraft is needed, but sometimes it may not be available. 2) When the break-ups occur, it is risky to operate spacecraft or launch vehicles through debris cloud. A break-up event should be informed by operators or by on-ground observers immediately after fragmentation. 3) It should be noted that, in future, collision among orbital objects will be a major source of the deterioration of the environment.
7	Prevent collision with manned space system at launching phase	Collision avoidance at new launch (COLA) with manned system is required in the every launching operation. 1) Lift-off time is coordinated not to collide with manned system, International Space Station.	1) COLA with manned system is expected to be applied to all the worlds launching operations. 2) Not all the manned systems are providing orbit characteristics and a manoeuvring plan. In this case COLA is not available for such systems.
8	Preventing damage by collision with tiny debris	Recent large satellites in JAXA adapt protection measures in spite of loss of payload mass. 1) Exposed wire-harness, propellant tanks, and other critical items are shielded against impact of tiny debris. 2) A protection design manual has been developed.	1) Since the world debris environment models do not show good agreement for micro-millimetre objects, excessive heavy masses for shielding tend to be required. 2) Protection technology is still under development.

Table-2 Recommendations/Requirements in Major World Debris Mitigation Standards (1/2)

<table>
<tr><th colspan="2"></th><th>Measures</th><th>IADC Guidelines[a]</th><th>UN Guidelines[b]</th><th>ISO 24113[c]</th><th>NASA (NASA-STD 8719.14)[d]</th><th>US Gov. STD Practice (and NPR 8715.6A)[e]</th></tr>
<tr><td colspan="2" rowspan="4">Mission Related Objects</td><td>Operational Debris</td><td>Addressed in 5.1</td><td>Addressed in Rec-1</td><td>Required</td><td>(1) LEO: >1mm (decay within 25 years, and total < 100 object-years)
(2) GEO: > 5cm (decay - 500km within 25 years)</td><td>> 5 mm (decay within 25 years)</td></tr>
<tr><td>Slag from solid motor</td><td></td><td></td><td>Required</td><td></td><td></td></tr>
<tr><td>Pyrotechnics</td><td></td><td></td><td>Combustion Products < 1 mm</td><td></td><td></td></tr>
<tr><td>secondary ejector</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2" rowspan="3">On-orbital Break-ups</td><td>Intentional Destruction</td><td>Addressed in 5.2.3</td><td>Addressed in Rec-4</td><td>Required</td><td>(1) <100 object-years (for > 10 cm)
(2) Fragments > 1mm shall be limited 1 year
(3) Fragments > 1mm, collision with operating S/C shall be limited < 10^{-6},</td><td></td></tr>
<tr><td>Accident during Operation</td><td>Addressed in 5.2.2 (Monitoring)</td><td>Addressed in Rec-2</td><td>Probability of BU < 10^{-3}</td><td>Probability of BU < 10^{-3}</td><td>Required</td></tr>
<tr><td>Post Mission Break-up</td><td>Addressed in 5.2.1</td><td>Addressed in Rec-5</td><td>Required</td><td>Required</td><td>Required</td></tr>
<tr><td colspan="2" rowspan="2">Collision</td><td>with Large Objects</td><td>Addressed in 5.6</td><td>Addressed in Rec-3 (CAM, COLA)</td><td></td><td>< 0.001 (with > 10 cm)</td><td></td></tr>
<tr><td>with Small Objects</td><td>Addressed in 5.6</td><td></td><td></td><td>probability of accidental collision which prevent disposal success > 0.01</td><td></td></tr>
<tr><td rowspan="3">Post Mission Disposal</td><td rowspan="3">GEO</td><td>Reorbit at EOL</td><td>235 km+ (1,000·Cr·A/m)
e < 0.003</td><td>Addressed in Rec-7</td><td>235 km+ (1,000·Cr·A/m)
e < 0.003
Success Probability > 0.9
100 years' guarantee</td><td>235 km+ (1,000·Cr·A/m)
e < 0.003
Success Probability > 0.9
100 years' guarantee</td><td>>36100 km (> 300km + GEO)</td></tr>
<tr><td>GEO Lower Limit</td><td>-200 km</td><td></td><td></td><td>GEO - 500 km</td><td></td></tr>
<tr><td>Protected Inclination</td><td>-15< latitude <15 deg.</td><td></td><td>-15< latitude <15 deg.</td><td>-15< latitude <15 deg</td><td></td></tr>
</table>

	LEO (MEO)	Reduction of Orbital Lifetime	Addressed in 5.4 (Recommend 25 years)	Addressed in Rec-6	EOL Lifetime < 25years Success Probability >0.9	Lifetime: Total <30 years, EOL <25years, Success Probability >0.9	EOL Lifetime <25years
		Transfer to Graveyard			Required 100 years' guarantee	2,000 km ～ (GEO-500 km) (exclude 19,100 - 20,200 km)	2,000 - 19,700 km 20,700- 35,300 km
		On-orbital Retrieval	Addressed in 5.4			Retrieve within 10 years	Retrieve within 10 years
		Ground Casualty	Addressed in 5.4	Addressed in Rec-6	Required	Ec < 10^{-4}, (Count impact energy> 15 J)	Ec < 10^{-4}

Abbreviations: a: semi-major axis, Cr: solar reflection coefficient, A/m: Area Mass Ratio, Ec: Number of Casualty, e: eccentricity, EOL: End of Operation Life, Rec: Recommendation

Note: "Success Probability" for disposal $P(D|M)$ is a conditional probability expressed by $P(D|M)=\frac{P(M\cap D)}{P(M)}$,

here, P(M) = (mission success probability), and $P(M\cap D)$ = (probability of correctly performing both mission and disposal phases).

Table-2 Recommendations/Requirements in Major World Debris Mitigation Standards (2/2)

		Measures	European Code of Conducts for Space Debris Mitigation[f]	JAXA (JMR-003B[g])	RSA	ESA (April 2008) Space Debris Mitigation for Agency Projects[h]
Mission Related Objects		Operational Debris	Required	Required	Required	Required
Mission Related Objects		Slag from solid motor	Slag < 0.01mm（Changed to 1mm）	Required		Slag < 1mm
Mission Related Objects		Pyrotechnics	Objects < 0.01mm	Combustion Products < 1 mm		Particles < 1mm
Mission Related Objects		secondary ejector	Required (SD-DE-07)		Required	
On-orbital Break-ups		Intentional Destruction	Required (SD-DE-04)	Required	(Allowed just before the impact to the Earth)	Required
On-orbital Break-ups		Accident during Operation	Probability of BU < 10^{-4} (SD-DE-05)	Probability of BU < 10^{-3}	Required	
On-orbital Break-ups		Post Mission Break-up (Passivation, etc.)	Required Inner Press. < 50% of critical Press. Dispose within 1 year Success Probability > 0.9	Required	Required	Required (to be conducted < 2 months)
Collision		with Large Objects	Required	Required（CAM, COLA）	Risk Assessment	Risk Assessment
Collision		with Small Objects	(Recommended by other document）	Required	Risk Assessment	
Post Mission Disposal	GEO	Reorbit at EOL	235 km+ (1,000･Cr･A/m) Success Probability >0.9	235 km+ (1,000･Cr･A/m) e < 0.003 Success Probability > 0.9 100 years' guarantee	235 km+ (1,000･Cr･A/m)	235 km+ (1,000･Cr･A/m) e < 0.005
Post Mission Disposal	GEO	GEO Lower Limit	-200 km	-200 km		
Post Mission Disposal	GEO	Protected Inclination	-15< latitude <15 deg.	-15< latitude <15 deg.		-15< latitude <15 deg.
Post Mission Disposal	LEO (MEO)	Reduction of Orbital Lifetime	EOL Lifetime < 25years Success Probability >0.9	EOL Lifetime < 25years Success Probability >0.9	EOL Lifetime < 25years	EOL Lifetime < 25years
Post Mission Disposal	LEO (MEO)	Transfer to Graveyard	Required	Required		(Excluding Galileo orbit)
Post Mission Disposal	LEO (MEO)	On-orbital Retrieval		Required		

		Ground Casualty	$Ec < 10^{-4}$ (Excluding France)	$Ec < 10^{-4}$	Required (Poisoned material)	$Ec < 10^{-4}$

a) IADC-02-01: IADC Space Debris Mitigation Guidelines, (Revised September 2007, Revision 1),
b) Space Debris Mitigation Guidelines of the COPUOS, United Nations Office (Resolution of 22 December 2007)
c) ISO-24113 Space Debris Mitigation (DIS) (published by the end of 2010),
d) NASA-STD-8719.14: Process for Limiting Orbital Debris (Approved: 2007-08-28)
e) NPR 8715.6A: NASA Procedural Requirements for Limiting Orbital Debris, (Effective 19 February 2008)
f) European Code of Conduct for Space Debris Mitigation (28 June 2004, Issue 1.0)
g) JAXA-JMR-003B: Space Debris Mitigation Standard, (1 February 2011)
h) ESA: Space Debris Mitigation for Agency Projects, ESA/ADMIN/IPOL(2008)2,Director General's Office (1 April 2008)

2. Further risk assessment

As mentioned in section II, the current and prospected future situation indicate that it is not enough just to encourage the limitation of the generation of debris. Protection from the impact of debris and mission success should be emphasized more. The many of the problems that are identified in sub-section 1.3 are also indicated that the protection of space systems and human are subjects to be discussed for sustainability. In short, adding to the current mitigation measures, the following six risks are to be put more emphasis for discussion.

(1) collision with detectable large objects,

(2) impact of undetectable tiny particles,

(3) collision during launch at least with manned spacecraft,

(4) debris cloud generated by break-up,

(5) risk of re-entering debris to the human on the ground, and

(6) insufficient quality and reliability of spacecraft.

This section shows the concept of the approach of the risk assessment, and method to find the vulnerability in current systems to ensure an effective output to the Long-Term Sustainability of Outer Space Activities.

2.1 Risk Identification and assessment

The following table simply shows the result of risks assessment. The influences and probabilities for some items are difficult to define, but we will be able to agree that none of these risks can be ignored.

Table-3 Risk Assessment

	Risk	Influence	Probability	Risk Magnitude
1	Collision with detectable Large objects	Loss of function Break-up, and deterioration of environment	$< 10^{-3} \sim 10^{-5}$	**Risk: Medium** **- Probability: Small** **- Influence: Large** **- Action: Insufficient**
2	Impact of undetectable tiny objects	(1) Loss of function for mission and disposal activities. (2) Break-up	Failure rate is expected to be less than 0.01	**Risk: Medium** **- Probability: Large** **- Influence: Medium** **- Action: Insufficient**
3	Collision during launch	(1) In case of ISS, human casualty	N/A	**Risk: Medium** **- Probability: Large** **- Influence: Medium** **- Action: Insufficient**
4	Debris cloud generated by break-up	Loss of function Delay of launch timing	About 200 break-up events have been observed	**Risk: Large** **- Probability: Large** **- Influence: Large** **- Action: Being promoted**
5	Risk of re-entering debris to the human on the ground	(1) Casualty on the ground (2) Pollution on the ground	Expected to be less than 0.0001.	**Risk: Unignorable** **- Probability: Small** **- Influence: Medium** **- Action: Insufficient**
6	Insufficient quality and reliability of space systems	Loss of function Break-up, and deterioration of environment	N/A (Quality & Reliability differ depending on manufacture)	**Risk: Various** **- Probability: Large** **- Influence: Various** **- Control level is varied**

2.2 Identification of Subjects and Contingency Planning

According to the risk assessment as shown in the table, all of six subjects were submitted to the contingency plan, and identified as subjects to be improved. The concept of contingency planning approach is described in Figure-1. Such approach will clear the current experiences and practices as well as problems to be solved in the future.

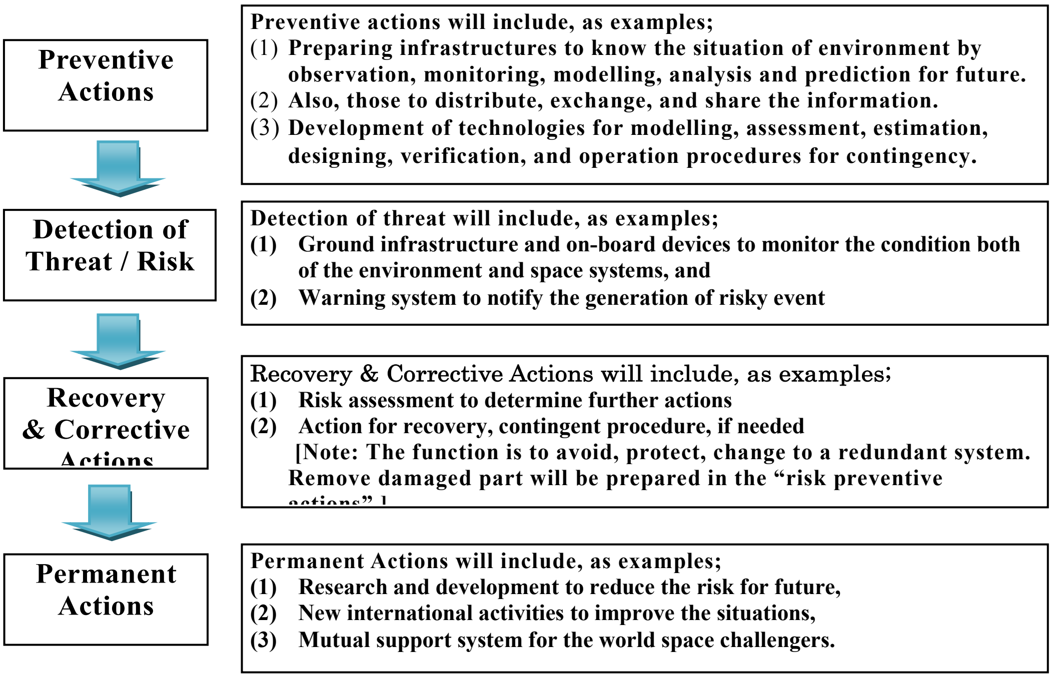

Figure-1 Concept for Contingency Planning Approach

The contingency planning for each subjects are described in Table-4.1~6, which describe current experiences and practices, and also the problems to be solved. The problems seem to be common in the world.

3. Best Practices and International Cooperation

The problems identified in Table-4.1~6, should be discussed. The measures and practices to be solved, are described in Table-5. The WG may create common understanding and develop fundamental philosophy, methods or conceptual procedure as the best practices. However, not all subjects may be solved by the UN framework. There are subjects that can be dealt by other international bodies, such as ISO and IADC, as described in the right side row of Table-5.

Table-4.1 Experiences and Practices Sheet -1

<table>
<tr><td>Sheet No. RA-2-1
Rev: NC</td><td colspan="2">Date: 2011/08/25</td><td>Status: Open / Close, Rejected</td></tr>
<tr><td rowspan="3">Category</td><td colspan="3">Threat: Space Debris</td></tr>
<tr><td colspan="3">Risk Factor: Collision with large Objects</td></tr>
<tr><td colspan="3">Influence to: General Spacecraft</td></tr>
<tr><td colspan="4">Title: Prevention of collision with larger objects (> 10 cm)</td></tr>
<tr><td>Description
(risk scenario, potential problem, etc.)</td><td colspan="3">Collision to operational satellites with large objects (> 10cm) will cause a catastrophic break-up which may deteriorate orbital environment for decades years or longer.
The US provides warning service to the world, but final assessment for avoidance manoeuvre and practices are responsible of owners of spacecraft.</td></tr>
<tr><td rowspan="2">Risk Assessment</td><td colspan="2">Probability: around 0.00001 impact/year/m2</td><td rowspan="2">Risk Magnitude: Unignorable</td></tr>
<tr><td colspan="2">Influence: Large
(generate thousands of debris)</td></tr>
<tr><td colspan="4">Contingency Planning</td></tr>
<tr><td>Step</td><td colspan="2">Status</td><td>Problem</td></tr>
<tr><td>Risk Identification</td><td colspan="2">Large objects (> 10cm) are detected, tracked, and catalogued by the US, and being provided to the world.</td><td></td></tr>
<tr><td>Design Measures</td><td colspan="2">Function and resources for avoidance manoeuvre are incorporated to the systems.</td><td></td></tr>
<tr><td>Operational Measures</td><td colspan="2">Collision avoidance manoeuvre will be planned.</td><td></td></tr>
<tr><td>Detection of Event</td><td colspan="2">Conjunction assessment will be conducted using available information in the world.</td><td></td></tr>
<tr><td>Counter Measures</td><td colspan="2">Conduct collision avoidance manoeuvre with coordination with the counterpart, and return to the original orbit.</td><td>It is not possible to know that the approaching satellites are under operation or not, or who is the operator of the satellites.
The status of space objects (operational or not, etc.) cannot be confirmed in the UN website.</td></tr>
<tr><td>Permanent Measures</td><td colspan="2">(Encouragement of disposal at the EOM.)</td><td></td></tr>
<tr><td colspan="4">Guidance for Best Practices</td></tr>
<tr><td>Problems</td><td colspan="3">The events of launch and termination of operation are to be registered in UN website.
Operation status (operational or EOM) is not necessarily registered.</td></tr>
<tr><td>Guidance for Best Practice</td><td colspan="3">Registration of the operational states is encouraged.</td></tr>
<tr><td>Link to Other Organizations</td><td colspan="3"></td></tr>
<tr><td>Remarks:</td><td colspan="3">Disclosure of every contact point for operation centre will not be welcomed with relation to security aspects.</td></tr>
</table>

Table-4.2 Experiences and Practices Sheet -2

Sheet No. RA-2-2 Rev: NC	*Date:* 2011/08/25	*Status*: Open / Close, Rejected	
Category	*Threat*: Space Debris		
	Risk Factor: Collision with tiny objects		
	Influence to: General Spacecraft		
Title: **Protection from damage caused by collision with tiny debris**			
Description (risk scenario, potential problem, etc.)	Even the collision with tiny debris is risky. Debris smaller than 1mm could penetrate the structure panel, or cause serious damage to power cables exposed to outer space. Yet, the distribution models are hard to be verified to the actual environment, and cost-effective design measures have not been established.		
Risk Assessment	Probability: 1 impact/year/m2 for 0.5 mm debris	Risk Magnitude: Unignorable	
	Influence: Failure rate is expected to be less than 0.001		
Contingency Planning			
Step	*Status*	Problem	
Risk Identification	The debris distribution data is available by models which have been developed by a few space agencies based on the results of orbital experiment conducted decade's years ago.	**Current models for tiny debris have not been verified.**	
Design Measures	Protection design (by shielding, redundancy or location behind hard materials) is applied, and being developed.	**Cost-effective protection design has not been established.**	
Operational Measures	(Basically, no operation measures.)		
Detection of Event	(Detection of impact may be possible.)		
Counter Measures	(Basically, no measures during operation.)		
Guidance for Best Practices			
Problems	- Actual environment is not known. - Cost-effective protection design for tiny debris has not been established.		
Guidance for Best Practice	- Nations will be encouraged to investigate the orbital environment for tiny debris. - Nations will be encouraged to research for risk assessment method and cost-effective protection design. (Now IADC is challenging.)		
Link to Other Organizations	UNCOPUOS is expected to encourage nations to cooperate to monitor the environment, and develop protection design, through IADC or other international academic bodies.		
Remarks:	JAXA is developing a real time monitoring device for tiny debris which is expected to be installed in world satellites.		

Table-4.3 Experiences and Practices Sheet -3

<table>
<tr><td colspan="2">Sheet No. RA-2-3 Rev: NC</td><td>Date: 2011/08/25</td><td>Status: Open / Close, Rejected</td></tr>
<tr><td rowspan="3">Category</td><td colspan="3">Threat: Human Activities</td></tr>
<tr><td colspan="3">Risk Factor: Collision during Launch</td></tr>
<tr><td colspan="3">Influence to: Manned Systems in Orbit</td></tr>
<tr><td colspan="4">Title: Collision avoidance with manned systems during the launch</td></tr>
<tr><td>Description
(risk scenario, potential problem, etc.)</td><td colspan="3">Launch vehicles and other objects released from the vehicle may cause collision with ISS or other manned systems.
Analysis to avoid such collision is not so difficult, and worthy to avoid tragedy and social impact.</td></tr>
<tr><td rowspan="2">Risk Assessment</td><td colspan="2">Probability: Depends on the situation</td><td rowspan="2">Risk Magnitude: Unignorable</td></tr>
<tr><td colspan="2">Influence: Human casualty and system loss</td></tr>
<tr><td colspan="4">Contingency Planning</td></tr>
<tr><td>Step</td><td colspan="2">Status</td><td>Problem</td></tr>
<tr><td>Risk Identification</td><td colspan="2">Usually ISS has a function to avoid collision by manoeuvre, but it is not available for a few days after new launch which would not be recognized by the ISS operators. Lift-off time is controlled not to cause collision.</td><td>There are a few nations to conduct the collision avoidance in launch operation.</td></tr>
<tr><td>Design Measures</td><td colspan="2">N/A</td><td></td></tr>
<tr><td>Operational Measures</td><td colspan="2">Analysis is conducted, and the lift-off time is controlled if the risk is larger than threshold.</td><td></td></tr>
<tr><td>Detection of Event</td><td colspan="2">N/A</td><td></td></tr>
<tr><td>Counter Measures</td><td colspan="2">N/A</td><td></td></tr>
<tr><td>Permanent Measures</td><td colspan="2">N/A</td><td></td></tr>
<tr><td colspan="4">Guidance for Best Practices</td></tr>
<tr><td>Problems</td><td colspan="3">- There are just few nations to conduct the collision avoidance control.</td></tr>
<tr><td>Guidance for Best Practice</td><td colspan="3">- Collision avoidance control with manned system is expected to be encouraged to the world launch service providers.</td></tr>
<tr><td>Link to Other Organizations</td><td colspan="3">- World launch service providers</td></tr>
<tr><td>Remarks:</td><td colspan="3"></td></tr>
</table>

Table-4.4 Experiences and Practices Sheet -4

<table>
<tr><td colspan="2">Sheet No. RA-2-4 Rev: NC</td><td colspan="2">Date: 2011/08/25</td><td>Status: Open / Close, Rejected</td></tr>
<tr><td rowspan="3">Category</td><td colspan="4">Threat: Quality of Space Systems</td></tr>
<tr><td colspan="4">Risk Factor: Break-ups</td></tr>
<tr><td colspan="4">Influence to: orbital Environment</td></tr>
<tr><td colspan="5">Title: Protection from Debris Cloud Generated by Break-up</td></tr>
<tr><td>Description
(risk scenario, potential problem, etc.)</td><td colspan="4">On-orbit break-up might not be detected if it caused in high altitude (GEO, etc.), and it will be more true if the break-up magnitude is not so large.
Just after the event, the debris cloud is risky because the density is high and collision probability is high, and the most of them are not decayed so soon.
New launch planned at that time is better to be postponed until the situation would be cleared, and some of the fragments would be decayed.
The break-up are also caused by collision among debris and the following chain reaction of them.</td></tr>
<tr><td rowspan="2">Risk Assessment</td><td colspan="2">Probability: not known
(more than 200 break-ups in history)</td><td colspan="2" rowspan="2">Risk Magnitude: Unignorable</td></tr>
<tr><td colspan="2">Influence: Depends on situation</td></tr>
<tr><td colspan="5">Contingency Planning</td></tr>
<tr><td>Step</td><td colspan="2">Status</td><td colspan="2">Problem</td></tr>
<tr><td>Risk Identification</td><td colspan="2">The event of break-up will be informed by the US. The fragment distribution models which have been developed in US and Europe may be referred.</td><td colspan="2"></td></tr>
<tr><td>Design Measures</td><td colspan="2">N/A</td><td colspan="2"></td></tr>
<tr><td>Operational Measures</td><td colspan="2">Safe mode operation may be conducted.
Lift-off time may be re-arranged.</td><td colspan="2"></td></tr>
<tr><td>Detection of Event</td><td colspan="2">The US releases orbital characteristics of orbital objects.</td><td colspan="2">If the break-up occurs in high altitude, it may not be recognised by anyone other than the operator.</td></tr>
<tr><td>Counter Measures</td><td colspan="2">(1) Hold the launch operation until the distribution of debris became cleared.
(2) Control the altitude of S/C or retrieve deploying devices.</td><td colspan="2">Distribution of fragments is expected to be notified as soon as possible.</td></tr>
<tr><td>Permanent Measures</td><td colspan="2">Prevent chain reaction of collision by removing existing large objects from crowded orbital region.</td><td colspan="2">Consensus has not been made to remove the existing objects.</td></tr>
<tr><td colspan="5">Guidance for Best Practices</td></tr>
<tr><td>Problems</td><td colspan="4">- On-orbit break-up might not be detected if it caused in high altitude (GEO, etc.), and it will be more true if the break-up magnitude is not so large.
- International consensus has not been made to remove the existing objects.</td></tr>
<tr><td>Guidance for Best Practice</td><td colspan="4">- If the operating satellites cause a break-up, the operator is encouraged to inform the fact to the adequate organization (to be defined) to notify the events.
- To remedy the orbital environment, the framework for further discussion to this matter is necessary.</td></tr>
<tr><td>Link to Other Organizations</td><td colspan="4"></td></tr>
<tr><td>Remarks:</td><td colspan="4"></td></tr>
</table>

Table-4.5 Experiences and Practices Sheet -5

Sheet No. RA-2-5 Rev: NC	*Date:* 2011/08/25		*Status*: Open / Close, Rejected
Category	*Threat*: Re-entering Space Systems		
	Risk Factor: Impact on the ground which posed human casualty or ground pollution		
	Influence to: Human on the ground and the Earth environment		
Title: **Human casualty caused by re-entering space systems**			
Description (risk scenario, potential problem, etc.)	If the re-entering objects cause human casualty, it will not be limited to the tragedy for victims but to expand the social impact leading to re-assessment on the traditional space activities.		
Risk Assessment	Probability: expected to be less than 0.0001		Risk Magnitude: Unignorable
	Influence: human casualty, pollution on the ground		
Contingency Planning			
Step	*Status*		Problem
Risk Identification	Historically almost dozens of space systems have been re-entering every year in average.		
Design Measures	Some of the nations restrict the number of casualties, by controlled re-entry, or selecting adequate materials.		**There are no international guidelines to encourage design measures.**
Operational Measures	N/A		
Detection of Event	The operators can prospect the re-entering event by analyses based on the orbital data. The controlled re-entry and natural re-entry of the high risk objects will be notified to the world.		**High risk objects such as nuclear power sources should be notified with the status and risk.**
Counter Measures	N/A		
Guidance for Best Practices			
Problems	- There are no international guidelines to encourage design measures. - High risk objects (nuclear power source) should be notified. - There are no tools to identify the status (system, orbit parameter, etc.).		
Guidance for Best Practice	- The design and operation for safe re-entry should be encouraged for large systems. - Information system to notify the re-entry of the high risk objects is expected to be prepared. The status of nuclear powered systems is expected to be shared to the world.		
Link to Other Organizations			
Remarks:			

Table-4.6 Experiences and Practices Sheet -6

Sheet No. RA-2-6 Rev: NC	*Date:* 2011/08/25		*Status*: Open / Close, Rejected
Category	*Threat*: Insufficient Quality assurance		
	Risk Factor: Deterioration of orbital environment		
	Influence to: General Space Activities		
Title: **Ensuring the quality of space systems not to be debris easily**			
Description (risk scenario, potential problem, etc.)	The influences of low quality spacecrafts are not limited to the economical loss of its owner but pose the risk to other space users by injecting additional debris as a source of collision risk and potential break-up event. Ensuring the quality is the most basic measures for debris mitigation. Except some nations whose government control them by licensing system, there is no restriction to prevent them.		
Risk Assessment	Probability: N/A-		Risk Magnitude: Unignorable
	Influence: Not known		
Contingency Planning			
Step	*Status*		Problem
Review	(1) A national government is expected to review, control or authorize its domestic activities. (2) A spacecraft with low reliability could be limited to its altitude lower than 600km.		
Design Measures	Basic technologies are disclosed through the international standards to ensure the quality against the natural and induced environments.		
Operational Measures	An adequate operational measures including disposal action would be taken, if any malfunction would be detected.		
Detection of Event	Periodical monitor for the critical parameters.		
Permanent Measures	**Experiences should be accumulated in technical standards (ISO, etc.) which can be obtained by market.**		**Newcomers and students may not have chances to learn the knowledge or experiences.** **The matured technologies are encouraged to be shared through the ISO and other international standards.**
Guidance for Best Practices			
Problems	- New comers and students may not have the chances to gain the knowledge or experience.		
Guidance for Best Practice	- The matured technologies are encouraged to be shared through the ISO and other international standards. - Before to invite the legal framework, every nation is encouraged to strengthen its self-governance.		
Link to Other Organizations	International Standardizing Organization (ISO), other bodies to provide technical standards.		
Remarks:			

Table-5 Subjects to be discussed and potential measures

1. Risk Factors	2. Subjects to be Discussed/ Problems	3. Measures/Efforts	4. Forum for solution
1) Protection from collision with detectable large objects	It is not possible to know that the approaching satellites are under operation or not, or who is operating the satellites.	Following information is to be registered on the UN website. a) Launch event b) Function (Possibility to conduct avoidance manoeuvre) c) Status (Under operation or not) d) Contact point to coordinate collision manoeuvre	Information sharing (by UN framework)
2) Protection from impact of undetectable tiny objects	(1) Current models for tiny debris that have not been verified. (2) Cost-effective protection design is not yet established.	To encourage academic institutes to conduct research for followings; a) Investigate the orbital environment for tiny debris, and improve debris models. b) Research for risk assessment method and cost-effective protection design. (Now IADC is challenging.)	Cooperation with other bodies (Encourage IADC or other academic bodies)
3) Protection from collision during launch	There are few nations to conduct the collision avoidance control.	Collision avoidance control for manned system at launch is expected to be encouraged to the world launch service providers.	Suggestion from UN for international cooperation
4) Protection from debris cloud immediately after break-up	(1) If the break-up occurs in high altitude, it may not be recognised by anyone but the operator. (2) Distribution of fragments is expected to be notified as soon as possible. (3) Consensus has not been made to remove the existing objects by international activities.	a) If the operating satellites cause break-up, the operator will be encouraged to inform the adequate organization (to be defined) to notify the events. b) The authority that has the ability to observe the environment is expected to notify the event to the world. c) To remedy the orbital environment, the framework for further discussion to this matter is necessary.	Suggestion from UN for international cooperation
5) Protection from re-entering debris for the human on the ground	It is not possible to predict impact zone in the case of uncontrolled re-entry. But high risk objects are expected to be notified to the world.	a) The design and operation for safe re-entry should be encouraged for large systems. b) Information system to notify the re-entry of the high risk objects is expected to be prepared. The status of nuclear powered system is expected to be shared to the world.	Suggestion from UN for international cooperation
6) Ensuring quality and reliability	New comers and students may not have chance to learn the knowledge or experiences.	a) The matured technologies are encouraged to be shared through the ISO and other international standards.	Cooperation with other bodies (Encourage ISO or other societies)

Note: The command destruction will be conducted in the ascending trajectory during which the rocket body would be fallen to the ground if the thrust would be terminated. And the nature of destruction is not the complete fragmentation but making holes on the surface of the propellant tanks to evacuate propellants. Then such destruction would not generate orbital debris usually.

IV. Allocation of Subjects According to the Identification in ToR

Section II and III provide the experiences, practices and subjects to be discussed. This section present them with allocating to the titles categorized in ToR.

1. Space Debris

(1) Measures to reduce the creation and proliferation of space debris

(a) The status in Japan and some problems are described in Section III.

Brief summary is described as follows;

- JAXA registered the Space Debris Mitigation Standard (JMR-003) version B in February 2011. All the JAXA projects apply this standard and the compliance with the standard is reviewed by the safety review held at the end of major lifecycle phase.
- The requirements of the standard are almost equivalent to ISO-24113; Space Debris Mitigation Requirements, and other world guidelines.
- The compliance with the standard is well for “mission related objects”, “prevention from break-ups”, “removal from the GEO protected region”. Some subjects presented in sub-section 1.3 in section III and table-1 is identified to be improved.
- In the commercial launch service of H-IIA vehicle, JAXA is responsible for safety review and debris mitigation review. Then not only JAXA’s spacecraft but also those offered by other organizations. Micro satellites offered by the universities are also submitted for review.

(2) Collection, sharing and dissemination of data on functional and non-functional space objects

(a) These subjects are discussed in “Tools to support collaborative space situation awareness”.

(3) Re-entry notifications regarding substantial space objects, and also on the re-entry of space objects with hazardous substances on board

(a) Precise prediction of uncontrolled re-entry is difficult. Risk mitigation design should be encouraged not to use materials which have high melting temperature or specific heat.

(b) JAXA recognizes that the definition of “substantial space objects” has not reached to international consensus even in IADC.

(c) JAXA has conducted controlled re-entry for HTV and the second stage of H-IIB.

(d) JAXA requires in JMR-003B to refrain from using materials which will survive re-entry due to their high melting point or high specific heat. It should be encouraged in the world.

(e) JAXA is evaluating large objects which will re-enter in near future, and predicts their re-entry time. The data sources are the US Space Track-web and the observation data from domestic facilities.

(f) The status of nuclear powered system is expected to be shared to the world.

(4) Technical developments and possibilities regarding space debris removal

(a) With the understanding that the removal of existing large objects from the crowded useful orbital region is essential to ensure the sustainability, Japan conducting research for technologies to remove objects mainly using the electric dynamic tether system.

(b) It would be welcomed that the framework to discuss this matter in the world level in UN or other bodies.

2. Space Operation

(1) Collision avoidance processes and procedures

(a) Conjunction assessment is conducted using available information in the world, and avoidance manoeuvre will be planned, if necessary.

(b) JAXA, based on knowledge and experiences acquired by these activities, participates in CCSDS and ISO forum to establish the standards for conjunction and collision avoidance analysis.

(2) Pre-launch and manoeuvre notification

(a) JAXA provides pre-launch notifications in accordance with Hague Code of Conduct (International Code of Conduct against Ballistic Missile Proliferation).

(b) JAXA analyses the probability of collision with manned system and control launch window. It is expected that the collision avoidance control for manned system at launch is expected to be encouraged to the world launch service providers.

(c) Notification of orbital change of ordinal spacecraft is not easy for its frequency.

(3) Common standards, practices and guidelines

(a) There are several international standards registered or being developed in ISO. JAXA is contributing those activities, such as;

- JAXA Space Debris Mitigation Standard, JAXA-JMR-003, 2004
- IADC Space Debris Mitigation Guideline, 2001
- ISO-24113, Space Debris Mitigation Requirements (published by the end of 2010)
- CCSDS 502.0-B-2, Orbit Data Message, November 2009
- CCSDS 508.0-W-3, Conjunction Data Message, V3, July 2011
- ISO-WD 16158, Avoiding Collisions Among Orbiting Objects, V3, June 2011

3. Tools to support collaborative space situation awareness

(1) Registries of operations and contact information

(a) To assess the risk and plan the avoidance manoeuvre, following information is useful but currently not easy to obtain. It is expected to be obtained timely on the UN website.

- Launch event
- Function (Possibility to conduct avoidance manoeuvre)
- Status (Under operation or not)
- Contact point to coordinate collision manoeuvre

(2) Storage and exchange of information on space objects and operational information

(a) The information of orbital characteristics can be obtained from US space surveillance network, and Japan basically depend on that.

(b) In Japan, to have the ability to detect orbital objects, adding to the optical telescope (detectable ~ 1.0 m size in GEO), and the radar facility, research is being done to detect smaller objects in GEO and LEO.

(c) If the operating satellites would cause break-up, the operator should inform the fact to the adequate organization (to be defined) to notify the events. The authority which has the ability to observe the environment is expected to notify the event to the world.

(3) Guideline of collection, sharing and dissemination of data on functional and non-functional space objects

(a) JAXA complies with the procedure in accordance with Convention on Registration of Objects Launched into Outer Space and Recommendations on enhancing the practice of States and international intergovernmental organizations in registering space objects (UN General Assembly resolution 62/101), so JAXA notifies the United Nations of information when the space object was registered and no longer functional or in Earth orbit.

(b) JAXA publishes satellite launch information and on-orbit operation status as needed.

(c) JAXA intends that sharing of information regarding functional and non-functional space objects is achieved through the usage and improvement of UN OOSA website.

4. Others:

(1) The damage by impact of tiny objects is enough critical for spacecraft:

JAXA is applying the protection design against impact of the tiny debris smaller than 1mm. However the current population models for tiny debris have not been verified. Also Cost-effective protection design has not been established. UN is expected to encourage academic institutes to conduct studying these technologies.

For the purpose to detect and survey the population of tiny objects, on-board detector is being developed in JAXA.

(2) Technical standards, best practices and lessons learned for the successful development and operation of space systems.

(a) Quality and reliability is a principle factor for the debris issue. However new comers and students may not have had the chance to learn, experience and have the knowledge. The matured technologies are encouraged to be shared through the ISO and other international standards.

(b) The command destruction during flight safety ranges would not generate long lived orbital debris. If it should be discussed from the point of sustainability, it can be discussed as a matter of safety management and quality of relevant system and devices.

(3) Rendezvous and proximity operation

(a) JAXA, as a member of ISS program, operates HTV based on internationally agreed rendezvous, proximity operations and the de-orbit operations procedure. The detection, notification and avoidance procedure for close approach of space debris are also specified in the flight rule and the operations interface procedure.

(b) In formation flight operations, operation boxes are allocated and operation will be coordinated among the member bodies.

V. Conclusion

(1) Considering current and future situation in orbital environment, which cannot be recovered with existing Debris Mitigation Standards, 6 items of subjects are identified. The subject, problems and best practices induced from them should be discussed in UN framework.

(2) Emphasis should be put on the protection of operating space systems, and human in orbit and on the ground.

(3) Also, more positive action to remedy the environment will be required to sustain space activities in the near future. The discussion with regards to removing existing large debris cannot be avoided. If the WG can identify the significance, it can be transferred to the next step to improve the situation.

(4) It is not necessary to define that all the best practices shall be implemented in the UN framework. Other international bodies can work for them.

The Experiences and Practices related to the Long-Term Sustainability of Outer Space Activities in Japan (Regarding space weather)

1. Introduction

This report describes Japanese space weather activities related to the Long-Term Sustainability of Outer Space Activities (LTS). It is expected this information will contribute to the activities of the LTS WG.

2. Objective

Space environment that causes satellite anomalies and negative effects to the human activities both in space and on the ground is referred to as space weather.

In order to develop good ways to avoid such risks, it is important to gather existing information on space weather and the practices for mitigating the risks, which are attached to this report.

3. Experiences and practices

3-1) Space-based observation

JAXA (Japan Aerospace Exploration Agency) is now conducting space environment measurement by using 5 satellites (LEO; 2, GEO; 1, QZS; 1 and ISS (International Space Station)/JEM (Japan Experimental Module)). This data has been provided in real time or quasi-real time, depending on the situation via JAXA website.

NICT (National Institute of Information Communication Technology) is also gathering solar wind data by using NICT ground station. Solar wind data has been provided via NICT website in real time.

3-2) Ground-based observation

Ground-based observation has been performed by NICT and SERC (Space Environment Research Center, Kyushu Univ.) NICT conducting solar observations by optical telescope and radio telescope. This data has been provided via NICT website in real time. SERC has deployed magnetometer systems to over 50 places all over the world. This data have been provided via SERC website in real time or quasi-real time.

3-3) Space weather modelling

There are several space weather models in Japan and most of them are being developed in the universities. JAXA also has been developing a space radiation model based on the observation data collected by JAXA satellites. It is an empirical/average model depending on the solar activity. This year, JAXA published a paper which demonstrates a new dynamical mode.

3-4) Space weather forecast tool

NICT has been developing a real time geospace simulator, whose input is real time solar wind information. This year, NICT succeeded to calculate space plasma environment in the vicinity of satellites. The NICT geospace simulation data is open to the public via the NICT website.

3-5) Standard for satellite manufacturing

Space weather effects on the satellite charging and the single event etc. JAXA has been revising the document of the standard for satellite manufacturing.

4. Summary and future task

JAXA has a responsibility of satellite manufacturing and operation, while NICT is in charge of space weather forecast. Issues 3-4) and 3-5) will advance more in these agencies. On the contrary, space weather observation and space weather modelling have a common nature. Hence, it is expected to combine the results of research and development in the universities and other institutions in order to contribute to the long-term sustainability of outer space activities.

Risks raised from Space Weather

	Item	General description	Influence and concern	Measurement in Japan
1	Level and Trend of Solar Activity	Overview proxy of solar activity level based on synoptic observation.	General space environment risk evaluation.	f10.7 radio index (NICT)
2	Solar X-ray Radiation	Total X-ray intensity radiated from the Sun. On the solar flare, the intensity increase rapidly. Long duration event (LDE) on X-ray plot is important because the LDE event sometimes drives disturbance harmful for space systems.	Solar X-ray radiation is the widely used indicator for solar activity level and flare and associating disturbance harmful for space systems.	None
3	Solar High Energy Particle	Ions accelerated to high energy by solar flare and/or CME process including interplanetary disturbance.	Onboard computer malfunction due to upset of semiconductor devices, deterioration of SAP, electric devises, optical sensor etc…	In-situ measurement by satellite sensor (JAXA)
4	Solar Flare and CME Occurrence	Flare and CME information and listings including time, location, scale and associated events are all important pieces of information.	Solar flares and associating CME are a major source of space environment disturbances. Generally, long duration and strong flares are thought to be important for risk evaluation on satellite operation sources of geomagnetic storms. CMEs are the main cause of geomagnetic storms.	Ground-base observation (NICT)
5	Coronal Holes	Coronal hole information and listings include time, location, and scale.	Coronal holes are a major source of high speed solar wind, which produces geomagnetic storm.	Remote measurement by satellite sensor (JAXA)
6	Galactic Cosmic Rays	Highly energetic particles coming from out of the solar system.	Onboard computer malfunction due to upset of semiconductor etc…	Measurement by satellite sensor (JAXA)
7	Solar wind plasma data	Plasma and magnetic field property of interplanetary space. Geomagnetic storms are results of electro-magnetic interaction between solar wind magnetic field and geomagnetic fields.	Precaution of geomagnetic disturbance caused by interplanetary shock. Sub-storms caused by high speed wind stream is the potential cause of satellite malfunction.	Measurement by satellite sensor (JAXA)

8	K-index of geomagnetic field	Horizontal component of geomagnetic field strength observed by ground based observations. Planetary K index (Kp) is convenient to identify geomagnetic sub-storm.	General space environment risk evaluation.	Ground based magnetometer observation network and its real-time data circulation (SERC)
9	Dst-index of geomagnetic field	Horizontal component of geomagnetic field at magnetic equator derived by ground based observations. Dst index is convenient to identify geomagnetic storm.	General space environment risk evaluation.	Ground based magnetometer observation network and its real-time data circulation (SERC)
10	Low energy electrons at GEO	Near GEO, electron population with energy of keV changes with geo-magnetic sub-storm.	KeV electron is considered major driver of satellite surface charging and following discharging. The surface charging and discharging is one of the major cause of GOE satellite malfunction.	None
11	High energy electrons at GEO	Near GEO, electron population is dominant comparing with proton. The electron flux change has a relation with geomagnetic storm and sub-storm.	High energy (>MeV) electron is considered a major driver of satellite charging and following discharging including component and harness inside spacecraft. The charging and discharging is one of the major cause of GOE satellite malfunction.	In-situ measurement by satellite sensor (JAXA)
12	Low energy electrons at LEO	Electron precipitation is dominant in high-latitude auroral region. The electron flux change has a relation with geomagnetic sub-storm.	KeV electron is considered major driver of satellite surface charging and following discharging. The surface charging and discharging is one of the major causes of LEO satellite malfunction.	None
13	High energy protons at SAA	Near SAA (South Atlantic Anomaly) region, high energy proton population is dominant.	Onboard computer malfunction due to upset of semiconductor devices, deterioration of SAP, electric devises, optical sensor etc…	In-situ measurement by satellite sensor (JAXA)
14	Solar EUV proxy index	Atmospheric density change in LEO is caused by solar EUV radiation, which influences air drug to LEO satellite	The proxy called f10.7 is used as solar EUV proxy parameter to deduce satellite drag on satellite orbital analysis. Abrupt increase of the proxy may cause severe trouble due to drastic changes of satellite drag.	None

15	Auroral Electro jet index	Atmospheric density change in LEO is caused by the energy input in the auroral atmosphere, which influences air drug to LEO satellite	The AE is used to atmospheric density model, which leads to satellite drag on satellite orbital analysis. Abrupt increase of AE may cause severe trouble due to drastic change of satellite drag.	Ground based magnetometer observation network and its real-time data circulation (SERC)
16	Ionospheric Disturbances	Plasma density change in the ionosphere is caused by the geo-magnetic storm and sub-storms.	Operation of satellite at various altitude and ground communications by using radio waves are influenced by the ionospheric condition.	Ground based measurement by ionospheric observatory and in-situ measurement by satellite sensor (SERC).