Japan’s View on
“the Long-Term Sustainability of Outer Space Activities of the STSC”

10 February 2012
Japan
1. Major Threats for Space Activities

Natural Environment

If accident would occur, orbital environment would be deteriorated.

Space Debris

Artificial Environment
- Induce Environment during launch & orbital Operation (vibration, heat cycling, etc.)
- Electric charging

Large Benefit

re-entry risk, etc.

Human Factors
- Lack of Quality & Reliability Assurance
2. Natural Environment (Factors, Effects, Counter Measures)

- Radiation particles
  - High-energy particles
  - Galactic cosmic ray
- Neutral particle
- Ultraviolet rays
- X rays
- Meteoroid
- Electrification
- Ionizing damage
- Transformation damage
- SEU
- Drag
- Surface deterioration
- Collision

- Electromagnetic pulse
- Output decrease in power supply
- Damage
- Deterioration of an electric circuit
- Deterioration of optical parts
- Deterioration of a solar cell
- Data error
- Image noise
- System hung
- Circuit damage
- Torque
- Orbit fall
- Deterioration in the thermal, electric, and optical characteristic
- Deterioration of structure
- Structure damage
- Decompression

Modeling, Monitoring, Forecasting, Warning, Design measures, Operational actions, etc.
**Fig. 1: Contingency Plan for Natural Environment**

- **Preventive Actions**
  - **Modeling, Monitoring, Forecasting**: Models of natural environment are being developed in ISO and other organizations. Some satellites have monitoring sensors. Research is being done to forecast with higher precision.
  - **Design Measures**: Design standards, radiation hardness design for example, are being applied, and need to be developed more.

- **Detection of risk**
  - **Monitoring Detection Sending Alert / Warning**: Monitoring and warning services are available by the ISES. Provide space weather forecasting and send alert / warning if needed. They are expected to be developed more.

- **Corrective Action**
  - **Risk Avoidance**: In case of warned situation, operation mode will be shifted to safe-mode. Space crew will hide behind shielded area.

- **Permanent Action**
  - **Monitoring, Analysis**: On-ground and in-orbit monitoring and sharing of observation data are encouraged.
  - **Failure Analysis**: In-orbit failures should be analyzed for their causes, and if they were induced by the natural environment, design standards will be modified.

- **Subject to be Discussed in EG-C**: It is expected that the "International Space Warning Service" will be continued and improved.
Conclusion for EG-C

The “International Space Warning Service” is expected to be continued and improved.

Efforts are still needed for modeling, monitoring, forecasting, warning, design measures, and operational actions against risks stemming from the natural environment.
3. Space Debris

3.1 Typical Causes of Debris Generation and Basic Mitigation Measures

- Spent Launch Vehicles: 11%
- Fragments: 64%
- Spacecraft (operational or not): 20%
- Separated Parts: 5%

Remove mission terminated spacecraft from the protected orbital regions.

(1) Refrain from releasing parts
(2) Prohibit destruction
(3) Prevent accidental break-up
(4) Avoidance of collision

Fragments are increasing (Percentage of number of objects observable from the ground)
<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Operational Debris</td>
<td>○</td>
<td>○ (Rec-1)</td>
<td>○</td>
<td>○ -1mm</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Slag from solid motor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Slag: 1mm</td>
<td></td>
</tr>
<tr>
<td>Pyrotechnics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Combustion products: 1mm</td>
<td></td>
</tr>
<tr>
<td>Intentional Destruction</td>
<td>○</td>
<td>○ (Rec-4)</td>
<td>○</td>
<td>100 object-years</td>
<td>○ (SD-DE-04)</td>
<td>○</td>
<td></td>
</tr>
<tr>
<td>Accident during Operation</td>
<td></td>
<td>○ (Rec-2)</td>
<td>Break-up rate &lt;10⁻³</td>
<td>Break-up rate &lt;10⁻³</td>
<td>Break-up rate &lt;10⁻⁴</td>
<td>Break-up rate &lt;10⁻⁵</td>
<td>○</td>
</tr>
<tr>
<td>Post Mission Break-up (Passivation, etc.)</td>
<td>○</td>
<td>○ (Rec-5)</td>
<td>○</td>
<td>Required</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>with Large Objects</td>
<td>○</td>
<td>○ (Rec-3) (CAM COLA)</td>
<td>○</td>
<td>define by other document</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Collision</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Risk assessment</td>
<td></td>
</tr>
<tr>
<td>with Small Objects</td>
<td>○</td>
<td>○ (Rec-6)</td>
<td>○</td>
<td></td>
<td></td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>GEO Post-Mission disposal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>GEO Lower Limit</td>
<td>-200 km</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>GEO - 500 km</td>
<td>-200 km</td>
</tr>
<tr>
<td>Reduction of Orbital Lifetime</td>
<td></td>
<td>○ (Rec-6)</td>
<td>Orbital lifetime 25 years Success rate -0.9</td>
<td>Total orbital lifetime 30 years post mission lifetime 25 years Success rate -0.9</td>
<td>post mission lifetime &lt; 25 years Success rate &gt;0.9</td>
<td>○</td>
<td></td>
</tr>
<tr>
<td>Transfer to Graveyard</td>
<td>No mentioning</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>○ (2,000 km ~ (GEO-500 km) exclude 19,100 - 20,200 km)</td>
<td>○</td>
</tr>
<tr>
<td>Ground Casually</td>
<td>○</td>
<td>○ (Rec-6)</td>
<td>○</td>
<td>○ (Ec 10⁻⁴)</td>
<td>○ (Ec 10⁻⁴)</td>
<td>○ (Ec 10⁻⁴)</td>
<td>○ (Ec 10⁻⁴)</td>
</tr>
</tbody>
</table>
Table-2 Compliance with Debris Mitigation Standard in JAXA to illustrate the relatively good compliance with requirements.

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Situation in Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Not releasing mission related objects</td>
<td>Good compliance</td>
</tr>
<tr>
<td>2 Prevention from break-ups</td>
<td>Good compliance</td>
</tr>
<tr>
<td>3 Removal from the GEO protected region</td>
<td>Good compliance</td>
</tr>
<tr>
<td>4 Removal from the LEO protected region</td>
<td>(1) Since February 2011, 25-year-rule has been strictly applied.</td>
</tr>
<tr>
<td></td>
<td>(2) Large satellites are complying with this rule.</td>
</tr>
<tr>
<td>5 Ground safety from re-entering debris</td>
<td>(1) JAXA conducted controlled re-entry for HTV and H-2B orbital stage.</td>
</tr>
<tr>
<td></td>
<td>(2) R&amp;D for the composite propellant tank is being conducted for easy demising.</td>
</tr>
<tr>
<td>6 Protection from collision</td>
<td>(1) Collision avoidance will be done if needed.</td>
</tr>
<tr>
<td></td>
<td>(2) Protection design is applied for tiny debris.</td>
</tr>
<tr>
<td></td>
<td>(3) Launching vehicle is coordinated not to collide with manned systems.</td>
</tr>
</tbody>
</table>
3.2 Risk of Debris in Need of Further Attention

(1) Risk of Collision with Large Objects
(with other spacecraft, manned space systems, and other large debris)

(2) Risk of Collision with tiny debris

(4) Risk on Ground due to Re-enter

(3) Risk of Collision when diving into Debris Clouds = Fragments from Break-up

(5) Risk of Debris Increase due to lack of Quality & Reliability Assurance
1. **STEP-1:** Assess the risk by its probability and influence, and identify the items for which risk magnitude is not small.

2. **STEP-2:** For each major risk, review the contingency plan, and identify the subjects to be improved.

3. **STEP-3:** Assess the subjects to be developed as best practices.
3.3 Concept of Contingency Planning Approach

Preventive Actions

- (1) Monitoring and Detection of risk
- (2) Exchange and sharing of information,
- (3) Risk Analysis and Risk Preventive design

Detection of Threat / Risk

- (1) Monitoring and Detection of risk
- (2) Warning

Recovery & Corrective Actions

- (1) Confirmation of Risk, and Risk Analysis
- (2) Determination for Immediate and Adequate Action

Permanent Actions

- Removal of large objects from protected orbital regions
3.4 Typical Contingency Planning for Collision Risk

with subjects to be discussed

Risk Avoidance Design
(1) Protection Shield
(2) Collision Avoidance function

Detection of Risk Conjunction Analysis

Collision Avoidance Planning of avoidance

Removal of Debris as a permanent action

Modeling of Population of Debris

Orbital Characteristic Data of Space Objects

Need Cost effective Protection design

Need Taking into Manned System

Need Cooperation for
(1) Consensus
(2) Technology

Need information of approaching satellites
(1) Operational status
(2) Point of contact

Need immediate warning of break-up

Need improvement of models for tiny debris.
3.6 Typical Contingency Planning for Re-entry Risk with subjects to be discussed

- **Risk Avoidance Design**
  1. Avoid materials to be survived or hazardous
  2. Controller re-entry

- **Detection of Risk**
  1. Prediction of re-entry
  2. Estimation of risk

- **Permanent Measures**
  1. Encouraging controlled re-entry for risk objects.
  2. Develop components to be demised easily.

- **Re-entry survivability analysis tool**

- **Orbital Characteristics Data of Space Objects**

**NOTE:**
- Prediction of impact time and location is not easy.
- Need information of hazard of re-entering objects.
  (NOTE: Criteria of risk object is not clear.)
3.7 Typical Contingency Planning for Lack of Quality

with subjects to be discussed

Quality and Reliability Control
(1) Management system
(2) Matured technologies
(3) Reliability design
(4) Verification, Qualification

International Standards
(1) Quality control standards
(2) Technical standard
(3) Lessons learned

Detection of malfunction
(1) Periodical monitoring
(2) Warning if detected

Immediate Actions
(1) Recovering
(2) Disposal action before loss of function or break-up

Experiences are expected to be accumulated in technical standards (ISO, etc.) which can be obtained on the market.

Need to ensure the quality
3.8 Subjects and Candidates for Best Practices for Debris Issue

Collision with large objects
1. The operational status shall be reported according to the international treaty, and it shall be registered immediately on the web site.

Impact of tiny debris
1. Survey tiny debris, and improve the models.
2. Cost-effective protection design method should be established.

Collision with manned systems
1. Launch windows should be controlled to avoid collision with manned space systems at the least.

Debris cloud
1. Immediate warning when detecting break-up.
2. Debris distribution data should be provided timely.
3. Prevention of a chain reaction of collisions (in future)

Re-entry hazard
1. Encouraging a risk reducing design for safe re-entry.
2. High risk object shall be opened for its characteristics

Lack of Quality and Reliability
1. Encouragement of quality control.
2. It should be encouraged that matured technologies are shared through the international standards (ISO, etc.).
3.9 Prospected Work Sharing after the LTS activities to be considered presently

**UN/COPUOS**

- Long Term Sustainability

**Member Countries**

- Self Control
- Contribution
- OGA

**International Academic or Other Bodies for Specific Fields**

**Technologies (IADC, etc.)**

a) Removal of debris and remedy of the environment
b) Research and improvement of debris models

d) notification of break-up

e) orbital data of fragments

**Standardization (ISO, etc.)**

a) Technical & Management Standards in ISO, etc. (as a means of technology transfer)

**Intelligence & Information Sharing (multi-lateral cooperation)**

a) operational situation
b) risk of re-entry
c) environment information
d) notification of break-up
e) orbital data of fragments

**Other Fields**

a) Technical support (ISO)
b) Fair business environment (ISO)

**Is expected for support**

- Common understanding
- Mutual Communication
- Encourage Self-Control
- Intelligence tool for sharing
3.10 Conclusion for EG-B

A) Considering the current and future situation in the orbital environment, which can not be recovered with existing debris mitigation standards, 6 items (*collision avoidance in orbit and during launch, protection from impact, debris cloud, re-entry safety, quality control*) were identified to be discussed.

B) The discussion to remove existing large debris can’t be avoided. If the WG identifies its significance, it can be transferred to other bodies for the next step to improve the situation.

C) Identified subjects should be submitted to the next discussion in EG-B to develop Best Practices.
Appendix-A

Contingency Plan for
① Fig.-A-1 Collision with Large Objects
② Fig.-A-2 Collision with Tiny Debris
③ Fig.-A-3 Collision during Launch
④ Fig.-A-4 On-orbit Break-up
⑤ Fig.-A-5 Re-entering Objects
⑥ Fig.-A-6 Lack of Quality and Reliability
<table>
<thead>
<tr>
<th>Identification of Objects</th>
<th>Large objects are catalogued, and being provided to the world.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design &amp; Operation Measures</td>
<td>Function and resources for avoidance maneuver will be prepared to the systems.</td>
</tr>
<tr>
<td>Monitoring &amp; Warning</td>
<td>Warning will be sent to both sides of operators.</td>
</tr>
<tr>
<td>Risk Assessment</td>
<td>Operator shall assess the risk of collision. The status of objects (operational or not) should be cleared.</td>
</tr>
<tr>
<td>Risk Avoidance</td>
<td>State shall report the operational status according to the international treaty. The information shall be registered immediately on the web site.</td>
</tr>
<tr>
<td>Remove Large Objects</td>
<td>Conduct collision avoidance maneuver coordinating with counter part, and return to the original orbit.</td>
</tr>
</tbody>
</table>

- (1) State shall report the operational status (operational or not, etc.) according to the international treaty.
- (2) Above information shall be registered immediately in web site.

**Fig. A-1 Contingency Plan for Collision with Large Objects**
Preventive Actions

Detection of risk

Corrective Action

Permanent Action

Modeling

The debris distribution models have been developed by the US and Europe based on the results of orbital experiment.

International cooperation is expected to improve models for tiny debris.

Design & Operation Measures

Protection design (by shielding, redundancy or location behind hard materials) is recommended.

Protection design is encouraged, but technology has not been established.

other measures

No effective measures for detection of risk, counter measure, or permanent actions.

Subject to be Discussed in EG-B

(1) Survey tiny debris, and improve the models.
(2) Technologies for cost-effective protection design should be established.

Fig.-A-2 Contingency Plan for Collision with Tiny Debris
Launch event will be registered according to the “International CoC against Ballistic Missile Proliferation”

Launch windows should be controlled to avoid collision with manned space systems.

Detection or Warning is impossible for a few days after the lift-off. (If the SSA operation center will track and determine the orbit of newly launched objects, it will send warning to the manned system operation center.)

Collision avoidance is impossible for both sides of the launch provider and S/C operators.

Subject to be Discussed in EG-B

(1) Launch windows should be controlled to avoid collision with manned space systems at the least.

Fig.-A-3 Contingency Plan for Collision during Launch
**Preventive Actions**

- **Modeling**
  - Models has been developed to estimate the effect of break-up.

- **Design & Operation Measures**
  - Break-up preventive design will be applied.
  - Periodical monitoring of the critical parameters to detect symptom of break-ups, and to prevent break-up.

- **Detection of Break-up & warning**
  - Once the operator detects the break-up, the operator should notify the world.
  - Break-up may not be recognized by the other entities.

- **Risk Avoidance**
  - (1) Hold the launch operation until the distribution of debris is cleared.
  - (2) Control the attitude of S/C or retrieve deploying devices.
  - Fragment distribution data is expected to be provided as immediately as possible.

- **Avoid break-up and collision**
  - Break-up can be prevented by design to some extent.
  - Prevent chain reaction of collision by removing existing large objects from crowded orbital region.

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Subject to be Discussed in WG

(1) Immediate warning when detecting break-up.
(2) Fragment distribution data should be provided timely.
(3) Prevention of a chain reaction of collisions (in future)

**Fig.-A-4 Contingency Plan for On-orbit Break-up**
<table>
<thead>
<tr>
<th>Preventive Actions</th>
<th>Survivability Analysis</th>
<th>Risk reducing design should be encouraged.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detection of Risk</td>
<td>Design &amp; Operation Measures</td>
<td>Survivability of re-entering object is analyzed, and casualty expectancy is assessed.</td>
</tr>
<tr>
<td>Permanent Action</td>
<td>Estimation of Risk</td>
<td>Re-entry time and location will be estimated. Impact footprint will be estimated. Ground pollution will be estimated.</td>
</tr>
<tr>
<td></td>
<td>Warning</td>
<td>Responsible organization should open the situation for its re-entry event, if the risk is large.</td>
</tr>
<tr>
<td></td>
<td>Permanent Action</td>
<td>Encouraging controlled re-entry for risk objects. Develop components to be demised easily.</td>
</tr>
</tbody>
</table>

Subject to be Discussed in EG-B

(1) Encouraging a risk reducing design for safe re-entry.
(2) High risk object shall be opened for its characteristics.

**Fig. A-5 Contingency Plan for Re-entering Objects**
Detection of Risk of Preventive Actions

Design & Operation Measures

The most principle measure for debris mitigation is to ensure the quality and reliability. [Matured technologies are being opened with international standards.]

Corrective Action

Operation Measures

(1) A national government is expected to review, control or authorize its domestic activities.
(2) A spacecraft with low reliability could be limited in its altitude to lower than 600km.

Permanent Action

Feedback to Design with Design Standards

In case of malfunction, disposal measures and break-up prevention measures will be taken.

Subject to be Discussed in EG-B & D

Encouragement of quality control. It should be encouraged that matured technologies are shared through the international standards (ISO, etc.).

Fig. –A-6 Contingency Plan for Lack of Quality and Reliability