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JAXAスペースデブリ発生防止標準 JMR-003の最新状況

Status on JAXA Space Debris Mitigation Standard JMR-003

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JAXA は 1996 年に最初のスペースデブリ発生防止標準を制定して以降、最新の情報を踏まえて適宜標準の改定を進めている。ISO 24113 スペースデブリ低減要求が出来て以降は、24113 の改定に合わせて JAXA 標準である JMR-003 の改定も実施している。2019 年に ISO 24113 が第 3 版となった。これは近年の軌道環境悪化を反映した新しい規制を含んでおり、これらの新しい要素を JMR-003 に取り込んで改定する検討を実施した。新しい JMR-003 には、宇宙機・ロケット軌道投入段の運用終了後の廃棄成功確率 0.9 以上の達成、デブリ・メテオロイドの衝突確率の評価、ロケット関連規制の強化等の種々の要求を含んでいる。本講演では、JMR-003 に新たに加えられた規制の概要について紹介する。

JAXA has been working on the mitigation of space debris since 1990s, and since the first space debris mitigation standard was established in 1996, the standard has been revised appropriately based on the latest study. After the ISO 24113 space debris mitigation requirement was published, the JAXA space debris mitigation standard JMR-003 has been revised in line with the revision of ISO 24113. In 2019 the third revision of ISO 24113 was published. This includes new regulations reflecting the deterioration of the orbit environment in recent years, and a study was conducted to incorporate these new regulations into JMR-003 and revise them. The new JMR-003 includes various requirements such as achievement of a probability of successful disposal of 0.9 or more after completion of operation of the spacecraft or launch vehicle orbital stage, evaluation of debris/meteoroid collision probability, and strengthening of launch vehicle-related regulations. This presentation includes the explanation of the regulations newly added to JMR-003, the discussion within JAXA when incorporating regulations, and the explanation of the standard revision process within JAXA.

Status on JAXA space debris mitigation standard JMR-003

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1.Background

- ◆In July 2019, ISO 24113:2019 Space systems- Space debris mitigation requirements was published which includes some new requirements.
- ◆A working group for JAXA Space debris Mitigation Standard (JMR-003) which includes Japanese manufacturers and operators discussed how to reflect new requirements of ISO 24113:2019.
- ◆In September 2020, new JMR-003D was published.
- ◆This presentation introduces overview of the JMR-003D.

JMR-003D is available in the following site. (Japanese only)
http://sma.jaxa.jp/TechDoc/

Old version JMR-003C is available in English site.
http://sma.jaxa.jp/en/TechDoc/index.html

2.1 The total number of launch vehicle-related objects

The revised parts are shown in red.

5. Planning and implementation of the space debris mitigation measures
5.1 Minimizing the objects released during normal operations
5.1.1 Limitation of released components, parts and its fragments
(1) As a general rule, the total number of launch vehicle-related objects (launch vehicle orbital stages and other payload support structures, etc.) left in orbit after launch shall be limited to **one for the launch of a single payload** and **two for the launch of multiple payloads**.

[Rationale of update]
Since the launch vehicle-related debris remaining in orbit has a large impact on the orbital environment, the regulation on the number of objects was adopted in accordance with ISO 24113:2019.

[Additional note]
Violation of the number of objects may be acceptable if the on-orbit collision risk and the ground casualty risk is lower than in case of smaller number of objects.

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2.2 SRM slag emission limit in LEO protected region

5.1.2 Suppression of combustion products from pyrotechnics and solid motors
(1) Pyrotechnics, except for solid rocket motors shall be designed and used so as not to release combustion products and fragments larger than 1 mm in their largest dimension into Earth orbit.
(2) Solid rocket motors shall be designed and operated so as not to release slag **larger than 1 mm** into GEO protected region and **LEO protected region**. It is evaluated on a case by case basis when the effect on GEO protected region by released products is limited due to its trajectory such as moon, planetary and other missions with highly elliptical orbit.

Note: The main aim of this requirement is to limit the generation of slag debris ejected into GEO protected region and LEO protected region during the final phase of combustion. Slag debris is potentially hazardous to space operations due to its size, number and orbital lifetime. **This is particularly the case when slag debris is ejected into a high orbital region where it can pose an impact risk for a long period of time**.

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2.2 SRM slag emission limit in LEO protected region

[Rationale of update]

- The requirement was proposed by ISO based on the ESA's space debris environment model (MASTER). This model shows SRM slag is major contributor on space debris population in LEO.
- Besides, NASA standard does not require limitation of SRM slag because their environmental model (ORDEM 3.0) shows different characteristics on SRM slag.
- Although NASA and ESA have different evaluations, JAXA decided that the SRM slag limitation is appropriate and adopted the requirement in accordance with ISO.
- JAXA just started developing slag less solid motor.

[Additional note]
Slag emission is possible if the orbit is sufficiently low (for example, below the inhabited orbit).
If slag emission is beyond the inhabited orbit, the risk should be evaluated each time.

Figure: Spatial density of each debris with respect to altitude (number per km ^ 3), SRM-Slag is a solid motor slag. (Source: ESA Environmental Model MASTER2009)

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2.3 Improvement of visibility from the ground

5.2.3 Prevention of break-ups caused by a collision with orbital objects
5.2.3.4 Improvement of visibility from the ground
Improving the visibility from the ground and improving the orbit determination accuracy is effective for improving the accuracy of conjunction analysis and collision avoidance. For this reason, especially for systems that have potential problems with visibility, should be considered adding optical or radio wave reflection means, or transmission means.

[Rationale of update]
For the conjunction analysis and the preparation of the collision avoidance plan, it is desired that the orbit determination accuracy of both the satellite in operation and the approaching object is high. Specifically, it is conceivable to mount a laser reflector or the like on the system.

This requirement is unique to JAXA not in ISO.

Mt.FUJI (EM model)

(Source: Status Report of Tanegashima SLR Station (GMSL) and Developing Status of JAXA's Next SLR Station, ILRS Technical Workshop 2019)

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2.4 Evaluation of probability of break-ups caused by a collision

5.2.3 Prevention of break-ups caused by a collision with orbital objects
5.2.3.5 Evaluation of the probability that space debris and meteoroid will collide and cause complete break-ups
(1) When determining the orbit, size, mass, etc. of the spacecraft in the early phase of spacecraft development (for example, the conceptual design phase), the spacecraft body and major large components (service module, payload module, solar array paddle, large antenna etc.) shall be evaluated the probability that space debris or meteoroids will collide and cause complete break-ups during operation.
(2) The probability that the high-pressure vessel and propellant tank of the spacecraft will be completely broke by small space debris and meteoroids shall be evaluated, and if necessary, their arrangement and protection design should be considered.

[Rationale of update]
Due to the increase in orbital debris, an evaluation of the break-up probability due to external factors (collision of debris and meteoroids) was adopted.
[Additional note]
The debris flux model is open to the public by ESA (MASTER) and others. JAXA owns a debris damage analysis tool (TURANDOT) that incorporates the flux model and can carry out such an evaluation.

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2.5 The target for the probability of successful disposal

5.3 Removal of space systems from protected orbital regions after the end of mission
5.3.1 Basic requirements
After the end of mission, the space system shall avoid the interference with the protected regions and minimize the possibility of break-ups according to Section 5.2.1. **The target for the probability of successful disposal is 0.9 or higher.** **This goal is considered to be achieved by complying with the requirements of Sections 5.3.1.1 to 5.3.4**.

[Rationale of update]
- The Inter-Agency Space Debris Coordination Committee (IADC) has shown that the probability of successful disposal (PSD) is required 0.9 or higher for sustainable LEO environment.
- In the past version of ISO 24113:2011, the conditional PSD was defined, but changed to the nonconditional in ISO 24113:2019
- ISO 24113:2019 does not provide a specific calculation formula for evaluation.
- Since JAXA cannot define a formula* for calculating the PSD at this time, we aim for reliable successful disposal by listing the possible design and operational measures as requirements.

* In Europe and the US, a **quantitative** evaluation method based on the reliability calculation of the disposal function is implemented, but JAXA does not currently adopt the quantitative evaluation method for several reasons.

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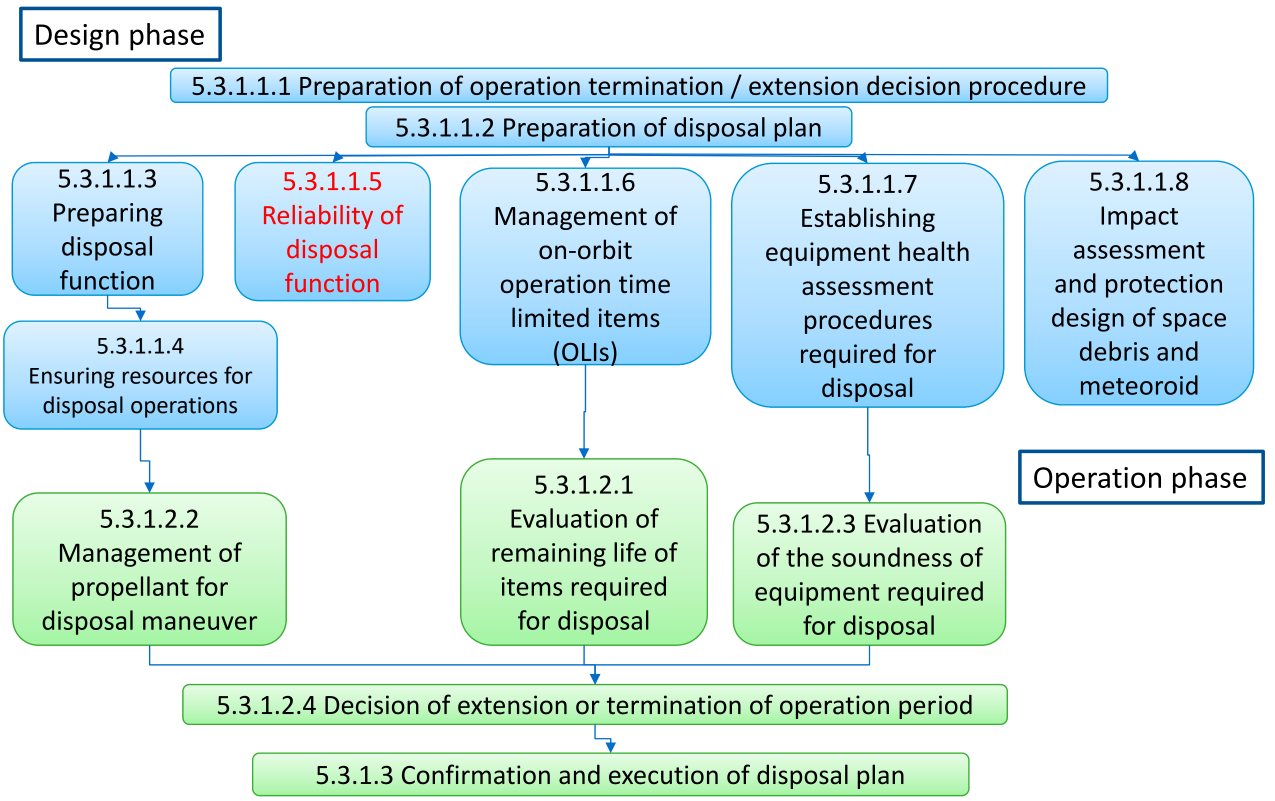
2.5 Framework for requirements for successful disposal



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2.5 Framework for requirements for successful disposal

5.3.1.1.5 Reliability of disposal function

For spacecraft, the reliability of the disposal function at the end of the disposal operation following the planned operation period shall be evaluated in relation to the reliability prediction work based on JMR-004 “Reliability Program Standard”. **The target value shall be the value determined for each project.**

Note 1: The planned operation period is the period guaranteed by the design.
Note 2: If the period from the end of mission to the completion of disposal work is short enough and the reliability is not significantly affected, the reliability prediction value at the end of mission may be used for evaluation.
Note 3: The reliability of the launch vehicle is evaluated in the activities based on JMR-004 "Reliability Program Standard".

- It is not suitable to apply JAXA’s regular reliability calculation method based on MIL-HDBK-217F to PSD evaluation because it is unreasonably conservative for this purpose and not showing realistic prediction.
- JAXA still tackle how to quantitively evaluate the probability of successful disposal based on the reliability. Some option can be considered…
  - Change of calculation condition such as temperature.
  - Change of reliability database such as FIDES.

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3. Conclusion

- ◆A working group of JAXA Space debris Mitigation Standard (JMR-003) discussed how to reflect new requirements of ISO 24113:2019.
- ◆In September 2020, new JMR-003D was published.
- ◆The new requirements in JMR-003D are very challenging because they have some technical issues such as the SRM slag and the probability of successful disposal.
- ◆JAXA will continue to study the reduction of SRM slag and the quantitative evaluation of the probability of successful disposal.

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Information on the 11th IAASS Conference in Osaka

- ➢ The 11th conference of the International Association for the Advancement of Space Safety (IAASS), an academic society whose activities aim to promote international cooperation and technology in the field of space system safety and sustainability, will be held in Asia for the first time since the establishment of the academic society.
- ➢ In the past conference, the participants were mainly in Europe and the United States, but since it will be held in Osaka, participation from Japan and the Asia-Pacific region is also expected.
- ➢ Recent hot topics include space debris mitigation, space situational awareness (SSA), and space traffic management (STM).

19-20-21 October 2021
Osaka International Convention Center (Grand Cube Osaka)
http://iaassconference2020.space-safety.org/

Fees：**Early Registration Presenting Authors $735 (YEN 80000)**
Early Registration non-IAASS members $870 (YEN 95000)
(Early registration include the first day luncheon and the Gala Dinner)

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Thank you for your attention!
And any questions or comments?

Back up

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Monitoring and Managing items (Example)

5.3.1.1.7 Establishing equipment health assessment procedures required for disposal
- -Batteries
- -Generated power from solar array paddle
- -Pressure of gas tank
- -Thrusters
- -Electric power consumption
- -Communication
- -Attitude orbit control
- -etc…

5.3.1.1.6 Management of on-orbit operation time limited items (OLIs)
- -Wheels
- -Thruster valves
- -Batteries
- -Paddle driving mechanisms
- -Other mechanical devices
- -etc…

5.3.1.1.4 Ensuring resources for disposal operations
- - The amount of propellant remaining