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Scientific and Technical Subcommittee
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Item 7 of the provisional agenda*
Space debris

Research on space debris, safety of space objects with nuclear power sources on board and problems relating to their collision with space debris

The present document has been prepared by the Secretariat on the basis of information provided by Japan on 12 November 2020 and by the International Organization for Standardization on 6 November 2020, and contains figures and pictures related to space debris, not included in A/AC.105/C.1/119. The document is issued without formal editing.

* A/AC.105/C.1/L.387.

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Japan

Report on Space Debris Related Activities in Japan

1. Overview

Corresponding to request from the UNOOSA, Japan reports the debris relating activities mainly conducted by the Japan Aerospace Exploration Agency (JAXA).

The following debris related activities conducted by JAXA during 2019 and 2020 are selected as major progresses to introduce in the next section:

(1) Conjunction Assessment (CA) results and research on core technology for Space Situational Awareness (SSA).

(2) Research on technology to observe LEO and GEO objects and determine their orbits.

(3) In-situ micro-debris measurement system.

(4) Development of composite propellant tank.

(5) Active debris removal.

2. Status

2.1 Conjunction Assessment (CA) results and research on core technology for Space Situational Awareness (SSA)

JAXA receives conjunction notifications from the Combined Space Operations Center (CSpOC). JAXA has executed 3 debris avoidance manoeuvres (DAM) for low earth orbit (LEO) spacecraft in 2019.

Core technology for space situational awareness (SSA)

JAXA determines the orbit of space objects using radar sensor at Kamisaibara Space Guard Center (KSGC) and optical sensor at Bisei Space Guard Center (BSGC), predicts close approaches using the latest orbit ephemerides of JAXA satellites and calculates probability of collisions.

At present, JAXA is developing a new radar that can track smaller space debris than the present radar. Especially, altitude around 500 to 800 km will be covered where most of the JAXA's LEO satellites are orbiting. JAXA is refurbishing the 1.0 m and 0.5 m telescopes to maintain their current capabilities. The new analysis system will be able to handle more data than the current system. JAXA also automates most of processes as much as possible.

JAXA developed tools to help planning DAMs, once JAXA received CDM (conjunction data message) from CSpOC. Based on experience, all procedures toward DAM were simplified and reduced workload.

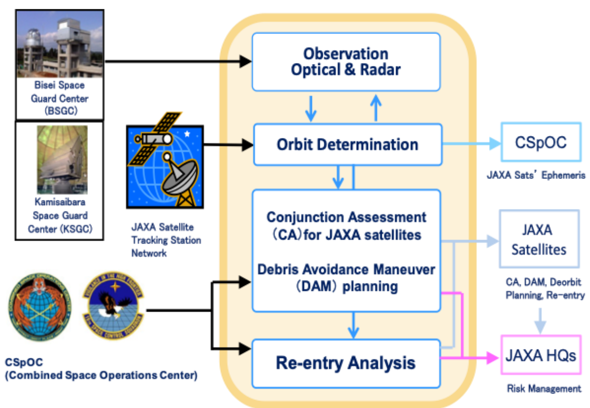


Fig. 1 Activity for the SSA in JAXA

2.2 Research on technology to observe LEO and GEO objects and determine their orbits

Generally, the observation of LEO objects is mainly conducted by radar system, but JAXA has been working to apply the optical system to reduce the cost for both construction and operation. A large CMOS sensor for LEO observation was developed (Fig. 2). Analyzing the data from the CMOS sensor with the FPGA-based image-processing technologies developed in JAXA enable us to detect 10 cm or less LEO objects. In order to increase the observation opportunities of LEO and GEO objects, a remote observation site in Australia (Fig. 3) was established in addition to the Mt. Nyukasa observatory in Japan. One 25 cm telescopes and four 18 cm telescopes are available for various objectives.

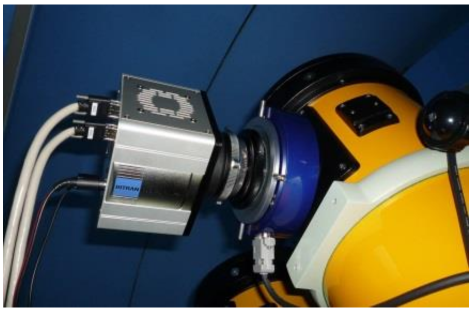


Fig. 2 The CMOS sensor manufactured by Bitran which can detect 10 cm LEO objects analyzing the data with FPGA-based image-processing technologies.

Fig. 3 The remote observation site in Australia. The left figure shows the sliding roof where all the observation devices are installed. One 25 cm telescope and four 18 cm telescopes (the right figure) are available for various objectives.

2.3 In-situ micro-debris measurement system

The space debris monitor (SDM) is an in-situ micro-debris sensor focusing on micro to milli sized debris under 1000 km orbit. The recent flight experience was conducted by H-II Transfer Vehicle “KOUNOTORI” (HTV) 5. Information based on actual measurements on these small debris is essential to properly understand the current situation of vast amount of small debris orbiting near our earth because they are becoming a dominant risk factor on orbit.

The unique properties of the SDM are its simple detection system which does not need any special calibrations before flight and the potential to collaborate easily with other sensors. The SDM consists of a debris-detection area and circuit areas. The debris-detection area is made of very thin polyimide film and there are thousands of 50 µm-wide conductive grid lines capable of detecting the diameter of collided debris sized from 100 µm to millimeters.

JAXA jointly collaborates with NASA Orbital Debris Program Office (ODPO) to develop new in-situ micro-debris measurement in order to grasp the situation of small debris on orbit under 1,000 km.

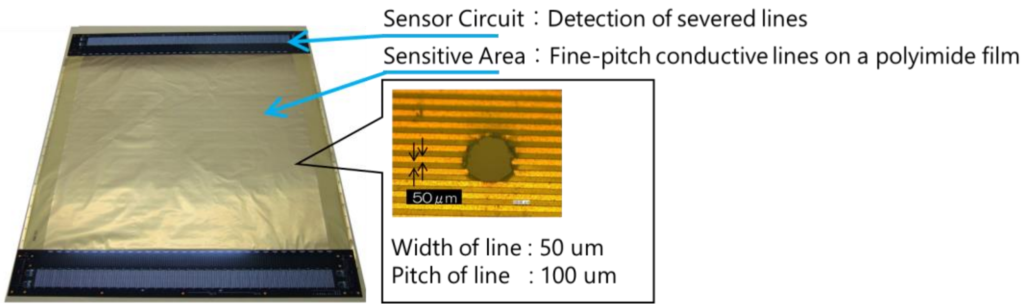


Fig. 4 Conductive grid sheet of SDM Bread Board Model

2.4 Development of composite propellant tank

A propellant tank is usually made of titanium alloy which is superior because of light weight and good chemical compatibility with propellant. But its melting point is so high that such a propellant tank would not demise during re-entry, and it would pose the risks of ground casualty.

For several years, JAXA conducted research to develop an aluminium-lined, carbon composite overwrapped tank with a lower melting temperature. As a feasibility study JAXA conducted fundamental tests including a liner material aluminium compatibility test with hydrazine propellant and an arc heating test.

After the manufacturing and test of shorter size EM#1 tank, manufacturing of full-size EM#2 tank was conducted. The shape of EM#2 tank is same as the nominal tank which includes PMD. Using this EM#2 tank, proof pressure test, vibration test (with wet and dry condition), external leak test, pressure cycle test, and burst pressure test were conducted and all of them showed good results. The critical design review was completed.

This composite propellant tank has a shorter delivery period and lower cost compared to a titanium propellant tank. About the demisability during atmospheric re-entry, experimental and analytical evaluation is ongoing.

Fig. 5 EM#2 tank

Fig. 6 Evaluation Tests by Arc Heating Wind Tunnel

2.5 Active Debris Removal

JAXA has organized and structured a research program which aims at realization of low-cost Active Debris Removal (ADR) missions. As shown in Fig. 7, the ADR key-technology R&D has three major themes: non-cooperative rendezvous, capture technology for non-cooperative targets, and de-orbiting technology to remove massive intact space debris. JAXA is cooperating with Japanese private companies to realize low-cost ADR on a commercial basis and working to provide these essential key-technologies for the purpose.

JAXA also conducted the Commercial Removal of Debris Demonstration (CRD2) program. As shown in Fig.-8, this program has two phases aiming at the world's first ADR in partnership with private enterprises. As the phase one, demonstration of the key technologies such as non-cooperative rendezvous, proximity operation and inspection of H2A 2nd stage is planned launch in the fiscal year 2022. In the phase two, demonstration of the active debris removal and re-entry of the H2A 2nd stage is additionally planned no earlier than the fiscal year 2025. As a partner company of phase one, Astroscale Japan Inc. was selected thorough competition in February 2020.

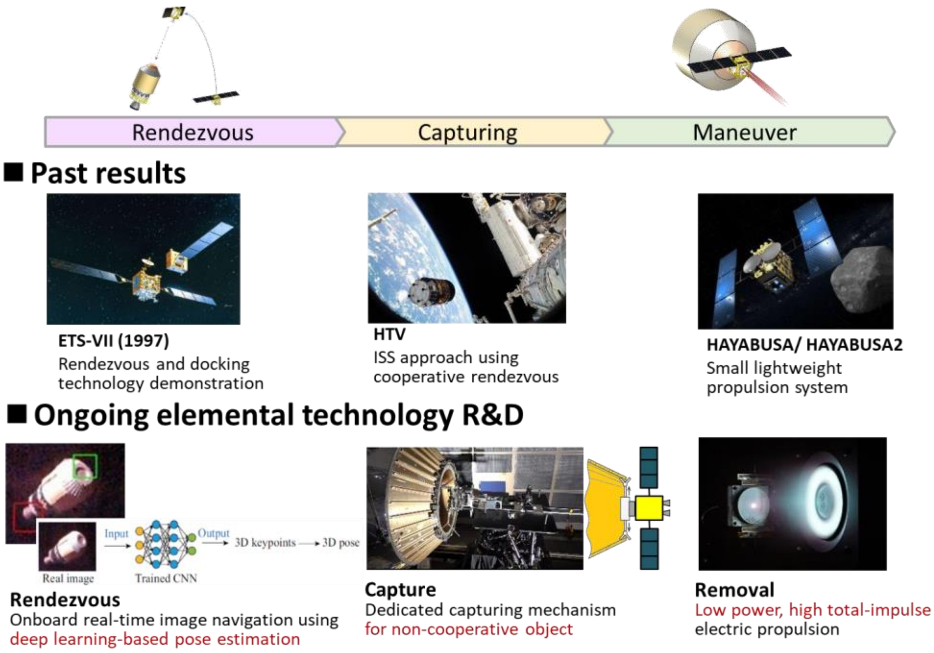


Fig. 7 Active Debris Removal research activities

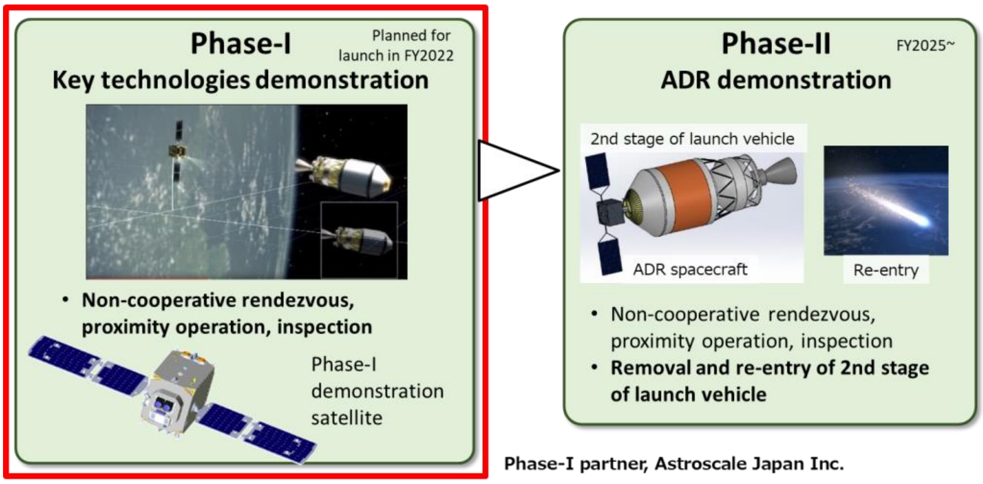


Fig. 8 Demonstration of the removal of large-sized debris in two phases

International Organization for Standardization

International standards for safe and efficient space operations

In today's increasingly complex space environment, it is more important than ever to ensure a better global approach for space operations, safety and sustainability across all space sectors (civil, commercial, government, academia, etc.). Space standards fulfil a key role in providing a global approach, by reducing duplication of effort and leveraging expertise in the associated communities.

Working Group 3 (WG3) of ISO/TC20/SC14 provides an international focus for addressing all aspects of ground operations, launch and space flight operations, and their supporting systems and equipment. WG3 coordinates and develops synergies with international, regional, and national organizations and industry involved with space systems and operations, including space traffic management (STM).

A standards framework for sustaining resilient space operation

One of WG3's key objectives is to ensure that internationally accepted standards exist for operation, maintenance and disposal of components, equipment and space systems, including space vehicles, their attendant ground systems, and the information transfer and data communication systems networks that are embedded within them. Additionally, WG3 seeks to facilitate commerce and safety in all aspects of space activity by developing standards and practices to the space enterprise and achieving international consensus for those standards and practices.

Photo credit: Airbus DS, NASA/Joel Kowsky.

ISO space operations and support systems standards

The structure of ISO's space operations and support systems standards is shown in the overleaf. The principal topic areas are:

- Data exchange and scheduling,
- Launch and flight operations, including Space Traffic Management,
- Launch and flight safety, including Space Traffic Management,
- Ground, launch and space support.

Standards in these areas contain, or incorporate by reference, an effective and realistic set of measures that can be adopted voluntarily, specified via commercial contract, or mandated by national regulations. Qualitative benefits:

- Common verification requirements and reporting formats to ensure wide acceptance of qualification tests,
- Enhanced safety of operations,
- Interoperability through common taxonomies and data formats that enable efficient exchange among international partners and agencies,
- Interoperable ground and space support equipment,
- Preserving and protecting the space environment for future commerce.

WG3 future standards development initiatives

WG3 welcomes your participation to help develop and maintain space system standards in the following areas:

- Cyber protection and cyber security
- Human habitation in space
- Space traffic management
  - Autonomous navigation and station keeping
  - Collocation
  - Inclined Geosynchronous Orbit operations
  - Launch collision avoidance
  - On-orbit servicing
  - Operations scheduling and mission planning
  - Rendezvous and proximity operations
  - Space domain awareness
  - Suborbital flight safety and flight operations

ISO TC20/SC14-WG3 (Nov-2020)

Structure of ISO Space Systems – Operations and Support Systems Standards

Data Exchange & Scheduling	Launch & Flight Operations	Launch & Flight Safety incl. Space Traffic Management	Ground, Launch and Space Support
26900 (CCSDS 502) Orbit Data Message (ODM)	11233 Orbit Determination & Est.	14620 series Safety – Launch site & Flight	14625 Ground Support Equipment
19389 (CCSDS 508) Conjunction Data Message (CDM)	14619 Space Experiments	24113 framework Space debris mitigation	15389 Flight-to-Ground Umbilical
CCSDS (ISO/TC20/SC13) Space Data Messages Attitude Data Message Events Message Fragmentation Data Message Launch Data Message Navigation Data Message Re-entry Data Message Tracking Data Message	14711 Unmanned Mission Operations	16158 Avoiding collisions	15860 Gas Contamination Field Test Measurements
	14950 Unmanned S/C Operability	16164 * S/C Disposal Operating at LEO	16159 Launch Site Failures Analysis
	16679 Relative Motion LV/SC Separation	16699 * Disposal of orbital Launch Stages	16458 Unmanned S/C Transportation
	19473 Orbit Elements LV/SC Separation	23339 * Residual propellant mass estim.	17400 Launch & Integration Site Test Rqmts
	22639 Multiple-S/C at GEO Collocation	26872 * S/C Disposal Operating at GEO	22108 Non-Flight Items Identification and Control
	23041 Unmanned Operating Procs.	27875 Re-entry Risk Management	26870 Launch Site Ops Documentation
	24330 RPO & On-Orbit Servicing	N1823 Space Traffic Coordination STCM	
	27852 Orbit Lifetime Estimation	PWIs Large Spacecraft Constellations Launch Collision Avoidance LCOLA	

Co-developed (shaded: 14620 series, 24113 framework)

New Work Item (dashed: N1823, PWIs)

Published ISO standards can be obtained from www.iso.org

(*) *will be consolidated within the ISO 24113 framework (ISO 23312, ISO 20893)*

ISO TC20/SC14-WG3 (Nov-2020)

Space debris mitigation standards

Private and public actors involved in space operations are increasingly aware of the threat of space debris. Some of these organizations have been applying measures to mitigate debris generation for many years. However, the population of debris continues to grow, and the probability of potentially-damaging collisions is increasing correspondingly. Because remediating the space environment is challenging with existing technologies, the most effective way to ensure the long-term sustainability of space activities at present is to standardize the implementation of debris mitigation measures, including collision avoidance. Standardization will have a major role in the coming years to help regulatory bodies and operators create and apply, in an efficient manner, appropriate space debris regulations and best practices. ISO TC20/SC14, a "space systems and operations" standards committee comprising representatives from industry, academia and institutional organizations, has the skills necessary to meet this challenge. Responsibility for the preparation of debris mitigation standards is shared between all seven of SC14's working groups and is overseen by WG7 (Orbital Debris Working Group).

An international approach to space debris mitigation

Since 2003 ISO has been transforming guidelines and best practices from across the space industry into a comprehensive set of international standards on space debris mitigation. Recommendations published by organizations such as the Inter-Agency Space Debris Coordination Committee (IADC), the International Telecommunication Union (ITU), the United Nations (UN), and regulatory bodies have been at the heart of this activity. A key objective of the ISO debris mitigation standards is to formulate these recommendations in such a way that they can be readily applied in the contractual agreement between a customer and supplier. This helps to avoid differences in interpretation during the procurement of spacecraft or launch services. The standards can also be used as the basis for national regulations on space debris mitigation, or they can be adopted voluntarily. Therefore, within an international context, adoption of ISO debris standards will help to foster fair competition and promote long-term sustainability of space activities.

The ISO space debris mitigation standards framework

The main aim of the ISO debris mitigation standards is to specify measures which when implemented in the design, operation and disposal of a spacecraft or launch vehicle orbital stage will prevent the generation of space debris. The standards are organized in a hierarchical structure, as shown overleaf. All of the high-level debris mitigation requirements are contained in a top-level standard, ISO 24113 (Space systems – Space debris mitigation requirements), the third edition of which was published in 2019. This is the most important debris standard. It contains an effective and realistic set of measures focused on:

- Avoiding the release of objects during normal operations.
- Post-mission disposal of spacecraft and orbital stages from the LEO and GEO protected orbital regions.
- Prevention of on-orbit break-ups.
- Re-entry risk assessment.

Below ISO 24113 in the hierarchy there are a number of lower-level implementation standards which define detailed measures, procedures and practices to support compliance with the requirements in ISO 24113.

The following implementation standards are currently available:

- *ISO 11227* describes an experimental procedure for acquiring data to characterize the ejecta released when spacecraft materials are impacted by hypervelocity projectiles representative of space debris and meteoroids. Such data contribute to informed decisions being made with regard to the selection of suitable materials for external surfaces on spacecraft.
- *ISO 14200* specifies a process for implementing meteoroid and debris environment models in the impact risk assessment of spacecraft and launch vehicle orbital stages. Guidance is provided for selecting and using the models and ensuring their traceability throughout the design of a spacecraft or launch vehicle orbital stage.
- *ISO 16126* defines requirements and a procedure for assessing the survivability of an unmanned spacecraft against space debris and meteoroid impacts to ensure the survival of critical components required to perform post-mission disposal.
- *ISO 27852* describes a process for the estimation of orbit lifetime for satellites, launch vehicles, upper stages and associated debris in LEO-crossing orbits. It also clarifies modelling approaches and resources for solar and geomagnetic activity modelling, resources for atmosphere model selection, and approaches for spacecraft ballistic coefficient estimation.
- *ISO 27875* provides a framework to assess, reduce and control the potential risks that spacecraft and launch vehicle orbital stages pose to people and the environment when those space vehicles re-enter the Earth's atmosphere and impact the Earth's surface.

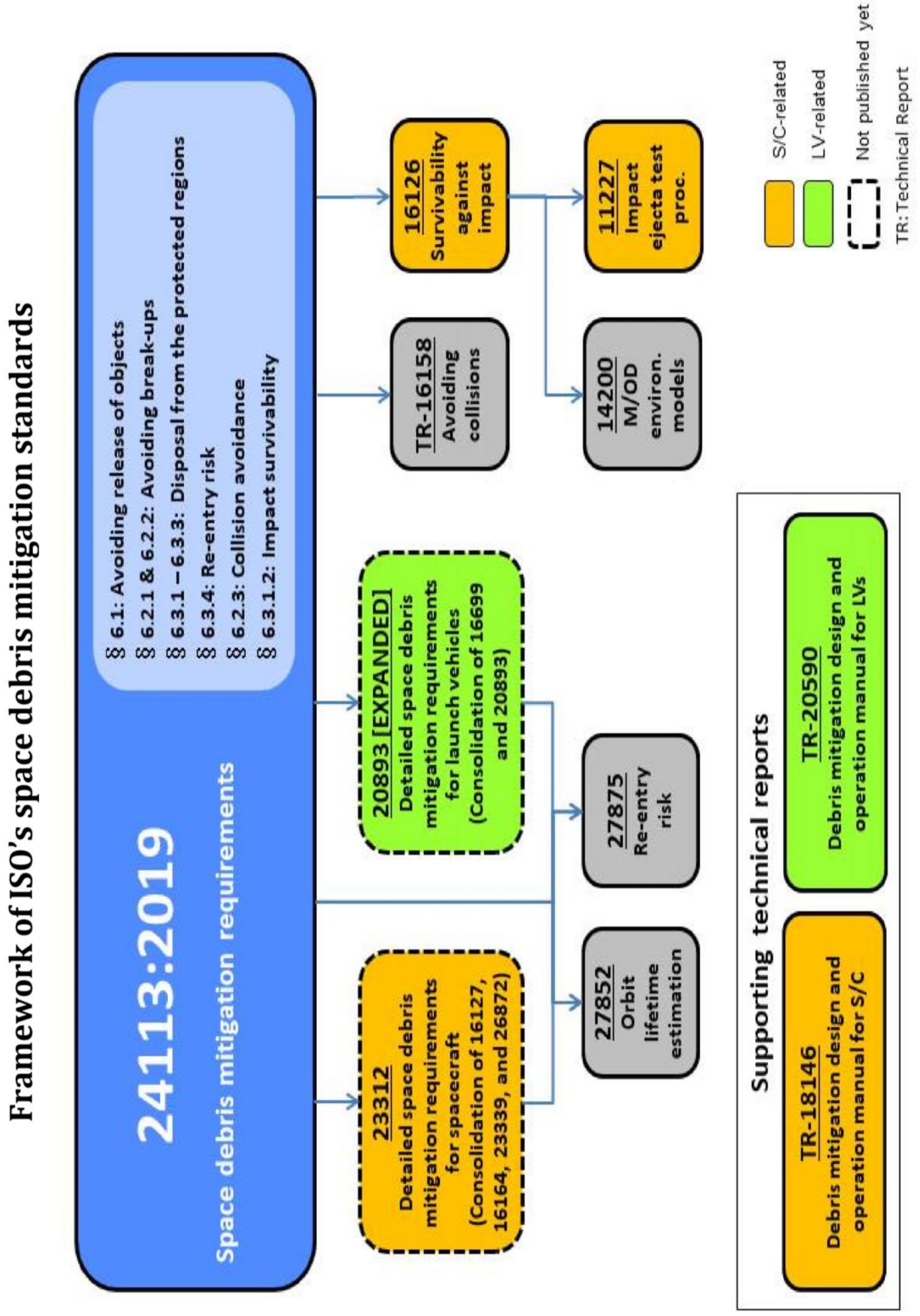
....And the following implementation standards will be published soon:

- *ISO 20893* and *ISO 23312* will define detailed space debris mitigation requirements and recommendations for the design and operation of launch vehicle orbital stages and spacecraft, respectively.

ISO has also published several non-normative Technical Reports for additional guidance:

- *ISO/TR 16158* describes some widely used techniques for perceiving close approaches, estimating collision probability, estimating the cumulative probability of survival, and manoeuvring to avoid collisions.
- *ISO/TR 18146* and *ISO/TR 20590* systematically guide engineers in the implementation of debris mitigation measures during all phases of the design and operation of spacecraft and launch vehicle orbital stages, respectively.

Published ISO standards can be downloaded from www.iso.org
Please use them!


Framework of ISO's space debris mitigation standards
24113:2019
Space debris mitigation requirements
§ 6.1: Avoiding release of objects
§ 6.2.1 & 6.2.2: Avoiding break-ups
§ 6.3.1 – 6.3.3: Disposal from the protected regions
§ 6.3.4: Re-entry risk
§ 6.2.3: Collision avoidance
§ 6.3.1.2: Impact survivability
23312
Detailed space debris mitigation requirements for spacecraft (Consolidation of 16127, 16164, 23339, and 26872)
20893 [EXPANDED]
Detailed space debris mitigation requirements for launch vehicles (Consolidation of 16699 and 20893)
TR-16158
Avoiding collisions
16126
Survivability against impact
27852
Orbit lifetime estimation
27875
Re-entry risk
14200
M/OD environ. models
11227
Impact ejecta test proc.
S/C-related
LV-related
Not published yet
TR: Technical Report
Supporting technical reports
TR-18146
Debris mitigation design and operation manual for S/C
TR-20590
Debris mitigation design and operation manual for LVs