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Item 8 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

Note by the Secretariat

I. Introduction

1. At its fifty-sixth session, the Scientific and Technical Subcommittee of the Committee on the Peaceful Uses of Outer Space agreed that Member States and international organizations having permanent observer status with the Committee should continue to be invited to provide reports on research on space debris, the safety of space objects with nuclear power sources on board, problems relating to the collision of such space objects with space debris and the ways in which debris mitigation guidelines were being implemented (A/AC.105/1202, para. 143). Accordingly, a communication dated 15 July 2019 was sent to Member States and international organizations with permanent observer status, inviting them to provide their reports by 21 October 2019 so that the information could be made available to the Subcommittee at its fifty-seventh session.

2. The present document has been prepared by the Secretariat on the basis of information received from seven Member States, namely Austria, Denmark, India, Indonesia, Italy, Pakistan and Slovakia, as well as from the International Organization for Standardization and the International Space University. Further information provided by the International Organization for Standardization, which includes figures related to space debris, will be made available as a conference room paper at the fifty-seventh session of the Subcommittee.

* A/AC.105/C.1/L.383.

II. Replies received from Member States

Austria

[Original: English]
[18 October 2019]

In addition to tracking more than 150 cooperative targets (equipped with laser retroreflectors), space debris laser ranging is getting an increasing amount of attention at the satellite laser ranging station in Graz, Austria.

Single-photon detection, alignment and reference tool

The single-photon detection, alignment and reference tool (SP-DART) developed in Graz works as a tiny mobile satellite laser ranging station that can be installed on external telescopes. It consists of a transmitting module (15 µJ/1 ns/2 kHz laser and optics, mounted on the telescope) and a detection package (laptop, field programmable gate array-based control unit, Riga event timer, global navigation satellite system (GNSS) unit and meteorological instruments). The major advantage of such a set-up is the reduced effort required for alignment because of the system's avoidance of any Coudé path. The SP-DART system was successfully tested on a 70-cm astronomy telescope located in Sandl, Austria, and owned by ASA Astrosysteme Austria. Overall, during two observation nights, 17 different targets were tracked with maximum return rates ranging from more than 30 per cent for low Earth orbit satellites to 0.2 per cent for Compass-I5. This innovative approach was recently applied at the Graz satellite laser ranging station using a compact high-power space debris laser directly mounted on the Graz telescope, successfully ranging several space debris targets.

Multi-static experiment

Multi-static experiments are complex laser ranging measurements of space debris that involve at least three stations measuring the distance to the same space debris target. The Graz satellite laser ranging station sends photons using its green high power (20W/100Hz) space debris laser. Simultaneously, the Wettzell satellite laser ranging station in Germany sends photons using their infrared space debris laser to the same space debris target. After their diffuse reflection at the space debris target, the photons spread across Europe. The green photons from the Graz station are then detected by the Graz and Wettzell stations. At the same time, the stations in Graz, Wettzell and Stuttgart detect the infrared photons from the Wettzell station. Analysis of the data shows that such simultaneous measurements significantly increase the accuracy of orbit prediction compared with the same number of stations operating in monostatic mode.

Stare and chase

"Stare and chase" is the name given to a method to track and range space debris targets for which no a priori orbit information is available by optically determining the pointing direction to these targets. An analogue astronomy camera is equipped with an off-the-shelf 50 mm lens to monitor a field of view of approximately 7 degrees of the sky. The camera system is mounted piggyback on the satellite laser ranging telescope and roughly aligned with the optical axis. The telescope is then moved to an arbitrary position "staring" into the sky and displaying stars up to the ninth order of magnitude. From the stellar background, using a plate-solving algorithm, the equatorial pointing direction of the camera centre is determined with an accuracy of approximately 15 arc seconds. When a sunlit space debris object passes through the field of view, its equatorial coordinates and the observation time are stored. From the pointing information, a consolidated orbit prediction file is generated and used to immediately track the satellite within the same pass. From the first detection of the satellite to successful tracking, the process can be completed in less than 2 minutes.

As soon as tracking is established, the satellite laser ranging system starts “chasing” the target with a high power (20W/100Hz) space debris laser. Space debris laser ranging of several cooperative and uncooperative (i.e., without retroreflectors) targets has been successfully achieved using such “stare and chase” predictions.

Daylight space debris observations

A precise knowledge of the orbit of space debris objects is essential for the implementation of removal strategies and for re-entry predictions. Satellite laser ranging provides highly accurate distance and attitude measurements of tumbling objects. However, owing to the inaccurate two-line element-based predictions, it is necessary to identify space debris objects visually. Currently, space debris laser ranging is limited to a few hours after sunset and before sunrise, when the object is in sunlight and it is dark at the observing site. A method to visualize space debris targets in broad daylight has been developed that significantly extends the potential observation time. The gathered image of the space debris object is analysed, correcting inaccurate orbit predictions in real time. After centring the target in the field of view, the standard laser ranging search routine is started.

Simultaneous space debris laser ranging and light curve measurements of a large re-entering upper stage

The upper stage of the Long March 3B rocket body (NORAD 38253) re-entered in August 2017. One month before re-entry, light curves were recorded using single photon avalanche diodes while simultaneously taking distance measurements by means of space debris laser ranging. Based on a simple cylindrical model of the upper stage, simulated light curves and satellite laser ranging residuals were calculated. A comparison of experimental results with the simulations makes it possible to draw conclusions on the parameters of the rotation of the rocket body. From the simulations, the spin period was calculated to be 118 seconds, and the astronomical coordinates of 69 degrees of declination and 224 degrees of right ascension were determined to be the most probable direction of the rotation axis.

Space debris laser mounted on astronomy telescope

In 2015, the Graz satellite laser ranging station presented the SP-DART method for improving an astronomy telescope to make it a fully functional satellite laser ranging station. Two compact lasers (532nm, 15µJ@2kHz; and 1064nm, 30µJ@2kHz) including beam expansion optics were directly mounted on an astronomical telescope. Such a set-up offers the great advantage of making any Coudé path (a number of mirrors reflecting the laser from the laboratory to the telescope) unnecessary. As well as having lower costs, that set-up makes alignment much easier, and pointing is more exact. A compact control unit handles the interaction with the two detectors and handles event timing, range gate generation, GNSS time and clock reference and meteorological data. The system was successfully installed at several satellite laser ranging stations and on astronomy telescopes and can also be used as a reference tool. The method will be used to mount a picosecond laser on the telescope at the new European Space Agency satellite laser ranging station on Tenerife, Spain. As more compact and powerful lasers continue to be developed, the method is now being applied to lasers for tracking space debris. The laser head of a new space debris laser (532nm/80mJ or 1064nm/160mJ@200Hz) was directly mounted on the telescope of the Graz satellite laser ranging station. The cooling unit and the power supply have been installed at the base of the telescope, and cooling liquid and power supply cables were run through the altitude and azimuth axes of the telescope.

Denmark

[Original: English]
[7 October 2019]

Mapping of space debris

In the field of mapping space debris, the National Space Institute of Denmark (DTU Space) works on the development and verification of autonomous debris detection from spacecraft with a view to using this method for selected space missions to demonstrate its efficiency and range.

A fully fledged mapping effort is being discussed with the European Space Agency with a view to starting a systematic effort, using existing space infrastructure in the short term (starting in 2020).

Finally, it is planned to create a full-scale profile of natural debris ranging in size from 0.8 to 5.2 AU (1 AU = 149,597,871 km) using the Juno mission of the National Aeronautics and Space Administration (NASA) of the United States of America to demonstrate the methodology.

Active removal of space debris

DTU Space conducts the following:

(a) Studies on natural orbit decay mechanisms, performing the development, launch, operations and verification of highly autonomous target detection, tracking and rendezvous to an accuracy of 7 cm;

(b) The development and verification of autonomous formation flight sensors for non-cooperative targets;

(c) Studies on capture mechanisms;

(d) Studies on directed energy de-orbiting technology.

Technology for the self-removal of spacecraft

Aalborg University and GomSpace conduct research in technology for the self-removal of spacecraft, a project funded by the Horizon 2020 European Union framework programme for research and innovation. The project started on 1 February 2016 and ended on 31 March 2019.

This technology uses a universal post-mission disposal module to be carried into orbit by any spacecraft to ensure its proper disposal at the end of its service lifetime, whether planned or unscheduled, owing to spacecraft failure. The module is to be independent of the spacecraft.

Safety of nuclear power sources on board and problems relating to their collision with space debris

In 2018, Denmark did not conduct any research at the national level on the safety of space objects with nuclear power sources on board and problems relating to their collision with space objects.

India

[Original: English]
[21 October 2019]

The Indian Space Research Organisation (ISRO) has been carrying out research on atmospheric re-entry prediction, fragmentation and break-up modelling and analysis and participates actively in the annual re-entry prediction campaigns of the Inter-Agency Space Debris Coordination Committee (IADC). Models and software

tools for statistical analysis and evolution of the space debris environment have been developed in India. ISRO has also initiated preliminary studies on active debris removal and spacecraft shielding.

Over the years, ISRO has built the capability for collision avoidance analysis with a view to safeguarding its space assets. Collision avoidance manoeuvres are performed for operational satellites in case of the close approach of another space object. All routine manoeuvre plans are also subject to analysis for conjunction assessment and cleared for execution accordingly.

Since 1996, ISRO has been an active member of IADC. Several measures in line with the Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space and those of IADC are implemented in ISRO launch vehicles and spacecraft projects to limit the creation of debris. All polar and geostationary satellite launch vehicles are passivated at the end of their mission. Presently, all ISRO operational spacecraft in geostationary orbit have post-mission disposal capability. After completion of their mission life, satellites in geostationary orbit are re-orbited into higher orbits and then passivated. A set of ISRO debris mitigation guidelines has been framed and is expected to be published and implemented in all ISRO projects and programmes in the near future.

Currently, ISRO does not have any nuclear-powered space objects that can pose a threat to safety in outer space.

The Directorate of Space Situational Awareness and Management was set up at ISRO headquarters in 2018 to devise strategies for space situational awareness, establish supporting infrastructure and develop an effective operational mechanism to protect Indian space assets in a space debris environment by ensuring coordination between ISRO and Department of Space centres, along with the necessary policy interventions.

ISRO has established a multi-object tracking radar at Sriharikota, India, commissioned in 2015, to detect and track low Earth orbit objects. ISRO is also establishing optical telescopes at Mount Abu, Rajasthan State, and Ponmudi, Kerala State, for the observation of objects in geostationary orbit that are expected to be operational by the end of 2019.

In order to cope up with an increasing number of launches and a growing debris population, current capabilities of space debris observation are planned to be enhanced and augmented by establishing additional observation facilities. The Network for Space Object Tracking and Analysis project has been approved by the Government of India as a first step towards achieving this goal. A control centre for centralized operation, analysis and research of all areas related to space debris and space environment has been proposed within the ambit of this project, which is expected to be completed within three years.

Indonesia

[Original: English]
[18 October 2019]

According to the law on space activities, the National Institute of Aeronautics and Space of Indonesia (LAPAN) has an obligation to conduct the monitoring and mitigation of artificial space objects that fall on Earth, especially on the territory of Indonesia. In this regard, Indonesia has been conducting space debris-related research and observations that include observation, modelling and mitigation. Under this law, Indonesia is mitigating the fall of space debris by developing an online monitoring system based on data obtained from Space-Track. The monitoring is automatic, providing information on falling artificial objects that have the potential to crash on the Indonesian territory.

To strengthen the monitoring of space debris, LAPAN is building a new observation facility in eastern Indonesia, in the province of East Nusa Tenggara. Construction started in 2017, and the facility is scheduled to start operating in 2021. The facility is expected to accelerate space debris observation activities in Indonesia and could also be used in cooperation with other countries to contribute to the observation and mitigation of the impact of falling space debris on Earth. The national observatory will be equipped with several telescopes and optical telescopes. The main telescope will be built as a collaboration between LAPAN and Kyoto University. Kyoto University will design the optical telescope with a diameter of 3.8 m. As part of the National Observatory development plan, representatives of the LAPAN human resources have attended training at the Department of Astronomy of Kyoto University.

Currently, LAPAN is supporting the National Disaster Mitigation Agency in preparing a risk assessment for a draft law on a multi-hazard early warning system. To that end, LAPAN provides input for a decision support system for space debris. The system is also being developed for the LAPAN strategic plan for the period 2020–2024.

Italy

[Original: English]
[21 October 2019]

Italy has a strong history of observing and investigating the space debris population and associated hazards. In 2019, the technical expertise provided by the Italian scientific and technological communities has allowed for the promotion of activities along two parallel lines:

(a) Participating in the Space Surveillance and Tracking Consortium of the European Union, which is developing European space surveillance services, such as collision avoidance, re-entry and in-orbit fragmentation of space objects;

(b) Coordinating research and development initiatives at the national and international levels.

The Consortium carries out its regular operations through the federation of member States assets and centres. The Italian Space Agency acts as the Italian national entity participating in the Consortium, together with the Italian Ministry of Defence and the National Institute for Astrophysics. Within this framework, the Italian space surveillance and tracking operations centre, the Italian national centre for space debris operations, has been appointed by the Consortium as the nominal reference centre for re-entry and in-orbit fragmentation services. As such, it participated in and coordinated two major fragmentation events that occurred during the year, namely, the break-up of ATLAS 5 Centaur R/B and MICROSAT-R, on 24 and 27 March 2019, respectively. In particular, the Italian BIRALES bistatic radar system, comprising the National Institute for Astrophysics “Northern Cross” radio telescope, located near the town of Bologna, Italy, and a multi-frequency Doppler radar, located in Sardinia and operated by the Ministry of Defence, detected several fragments during the above-mentioned fragmentation events, fully validating its performance as a special surveillance radar. The experience gained has allowed ISOC to identify the areas that need improvement in terms of quality of services.

The results of the European Commission Horizon 2020 ReDSHIFT project, coordinated by the Institute of Applied Physics of the Italian National Research Council, were presented in 2019. The outcome of the project has been extremely successful. Mapping the dynamical routes characterizing the near-Earth space has allowed a complete characterization of the de-orbiting and atmospheric re-entry options for the end-of-life disposal of a spacecraft. Novel techniques (e.g., 3D printing) for creating sustainable spacecraft infrastructure (design for demise) have been investigated to minimize the consequences of re-entering spacecraft and make predictions easier, in order to improve safety on the ground.

From 7 to 10 May 2019, Italy hosted, on the premises of the Italian Space Agency, the thirty-seventh annual meeting of the Inter-Agency Space Debris Coordination Committee (IADC). For the first time in many years, all 13 space agencies were represented, in recognition of the growing interest worldwide in the space debris problem and in view of the future space traffic management regulations.

More than 100 participants actively contributed to the working group discussions on cutting-edge technical issues, such as developing a space sustainability ranking system, developing innovative medium Earth orbit disposal strategies, managing the hazard posed by large constellations and identifying potential targets for active debris removal missions.

The IADC Space Debris Mitigation Guidelines, which provide recommendations for national and international governmental institutions on space policy, were updated for the first time in 12 years, and it was recognized that a fast approval cycle was needed to meet with the increasing challenges of space traffic management.

Pakistan

[Original: English]
[28 October 2019]

Pakistan is deeply concerned about the sustainability of outer space activities given the ever-increasing number of objects being launched into orbit, and the foreseen and unforeseen risks associated with this practice, such as the increasing risk of collision and interference with the operations of outer space objects. These issues are more pronounced at the low Earth orbit level. The Space Debris Mitigation Guidelines prepared by the Scientific and Technical Subcommittee of the Committee on the Peaceful Uses of Outer Space need to be implemented at the national and international levels through appropriate mechanisms and administrative measures.

Pakistan is currently operating four satellites. Communication satellites in geostationary orbit have efficient orbit maintenance and control mechanisms. They will be de-orbited to graveyard orbit at the end of their mission lives, and the necessary safety measures will be taken to avoid the creation of space debris. The two other remote sensing satellites, namely, PRSS-1 and PakTES-1A, are operating in low Earth orbit, and proper maintenance of the orbit parameters, debris mitigation and collision avoidance manoeuvring shall be performed. Satellite de-orbit manoeuvring shall also be performed at the end of their respective service lives in line with the Space Debris Mitigation Guidelines. Pakistan has not yet used any nuclear power source in outer space nor plans to use it in future.

Research related to space debris is being conducted, in particular for space debris analysis and mitigation measures in accordance with the Space Debris Mitigation Guidelines. After eight years of negotiations, the Guidelines for the Long-term Sustainability of Outer Space Activities were adopted. Pakistan sees this as a great achievement and is hopeful that the newly created three-year working group on the Guidelines will achieve its objectives and contribute significantly to future space activities.

With regard to activities related to the observation of near-Earth objects, a project was launched in April 2019 to install a telescope with a resolution three times greater (50 cm aperture versus 15 cm aperture) than the existing telescope. This is in addition to the three existing 15 cm telescopes installed at Sonmiani, Pakistan. It will help to achieve unified scheduling and automatic control and will enhance the capability for observing smaller (fainter) objects in low Earth, medium Earth and geostationary orbits with precision. The observatory is connected with the International Asteroid Warning Network for the monitoring and cataloguing of asteroids. Pakistan has also joined the Space Mission Planning Advisory Group (SMPAG) and supports the SMPAG workplan to prepare an international response to

a near-Earth object impact threat through documentation and the implementation of preventive measures.

Pakistan believes that space is the final frontier and that all measures should be taken by all States to mitigate space debris. This is a shared responsibility of all spacefaring nations. However, the criteria and procedures for the active removal or intentional destruction of space objects, either functioning or non-functioning, need to be thoroughly discussed under the auspices of the United Nations. That will guarantee the effectiveness of the measures and ensure acceptability by all stakeholders. Many of the orbital debris that exist in outer space are the result of the past operations of major spacefaring nations. The major spacefaring nations should accept the moral responsibility of assisting less developed spacefaring nations, both technically and financially, in ensuring space debris mitigation. Otherwise, the new entrant countries would be unable to claim their right to the common province of humankind, which would be in contravention of the General Assembly resolutions.

Pakistan believes in the non-militarization of outer space and has serious concerns about the deployment of advanced military technologies and nuclear power sources that are a threat to the security and long-term sustainability of outer space activities. Pakistan is of the view that the use of on-board nuclear power sources for deep-space missions needs to be reviewed and should be restricted through an international legally binding agreement to only those missions that essentially require a nuclear power source. Pakistan believes that there is a need to address gaps in international space law with a view to ensuring that no one threatens peaceful activities and the applications of space technologies for socioeconomic development. In the absence of strong legal instruments, other States could follow suit. Pakistan and the Russian Federation have signed a joint statement on “No first placement of weapons in outer space”, which is a reflection of our joint commitment to refraining from the threat of use of force or use of force in outer space activities. Pakistan encourages other responsible spacefaring nations to follow this example.

Pakistan has always supported a safety paradigm to assist human endeavours in space. Pakistan seeks the protection of operational satellites from space debris in the interest of all States participating in space enterprises.

Slovakia

[Original: English]
[21 October 2019]

The Faculty of Mathematics, Physics and Informatics of Comenius University in Bratislava develops and improves the hardware and software of its 0.7 m Newton telescope as an activity of the Plan for European Cooperating States of the European Space Agency (ESA). The system is dedicated to space debris tracking and research. A fully operational system will also support space debris cataloguing efforts under ESA, the European Union and the International Laser Ranging Service.

Development of a Slovak optical sensor for space debris satellite laser ranging tracking support, objects cataloguing and research

The Division of Astronomy and Astrophysics, which is part of the Faculty of Mathematics, Physics and Informatics, is developing and improving the hardware and software of its 0.7 m Newton telescope (AGO70) through the ESA Plan for the Slovak programme. The primary goal is to develop a space debris research instrument and space surveillance and tracking sensor able to observe objects placed in all orbital regions, from low Earth orbits to geosynchronous orbits. The current ESA Plan activity, which is carried out in collaboration with the Slovak private sector, the Astronomical Institute of the University of Bern (Switzerland), the Austrian Academy of Sciences and the satellite laser ranging station in Graz (Austria), focuses primarily on the development of interfaces between the AGO70 optical passive sensor and active satellite laser ranging sensors.

Public catalogue of apparent rotation properties of space debris extracted from photometric measurements

Since 2017, the Faculty of Mathematics, Physics and Informatics has been collecting photometric data for non-active objects, such as spacecraft and upper stages located in high orbits. These data are scientifically processed and made publicly available. By the end of 2019, Comenius University had collected more than 300 light curves for more than 250 individual objects. The information that has been obtained, such as the apparent rotation period and light curve amplitude, is available to the wider scientific community for further processing.

Application of the Slovak all-sky meteor network for re-entry events monitoring and debris characterization through spectroscopy

The Faculty of Mathematics, Physics and Informatics is investigating the possibility of using its automatic meteor orbit system cameras for space debris re-entry measurements and the characterization of debris objects through spectroscopy. This system is used for meteor automatic detection, orbit determination and spectrum extraction. Comenius University has developed and is now operating 14 automatic meteor orbit system cameras in total, of which 5 are situated in Slovakia, 3 in the Canary Islands (Spain), 3 in Chile and 3 in Hawaii (United States of America). The system can support the modelling of re-entry events by monitoring fragment trajectories in the atmosphere and analysing the spectral analysis of the fragments. It can observe reflectance spectra from specular glints, information which is used for the surface characterization of space debris situated in low Earth orbit.

III. Replies received from international organizations

International Organization for Standardization

[Original: English]
[6 September 2019]

International Organization for Standardization background

The International Organization for Standardization, or ISO, was established 72 years ago to promote standards for international trade, communications and manufacturing. ISO is an independent, non-governmental organization made up of members from the national standards bodies of 163 countries. These bodies facilitate and manage standards development for their respective countries. Working collaboratively with and within ISO, the national bodies identify stakeholders and subject matter experts, coordinate stakeholder inputs and receive requests for new standards. ISO is the world's largest developer of international standards.

Also established in 1947, ISO Technical Committee 20 is one of the most prolific ISO technical committees in international standardization. With more than 600 published standards developed under its broad umbrella and that of its subcommittees, the Committee maintains a significant, relevant presence in the aerospace industry. Within the Committee, the two subcommittees developing space standards are Subcommittee 13 and Subcommittee 14:

(a) Subcommittee 13 develops international space data message standards. It is functionally equivalent to the Consultative Committee for Space Data Systems and comprises 11 space agencies globally. Of particular relevance to the long-term sustainability of space activities are space data message standards assembled by its Navigation Working Group. The sharing of space data, such as orbital information, close approach parameters, tracking data, attitude data, re-entry data and sensor pointing parameters, is enabled by the Navigation Working Group standards of the Subcommittee. The orbit data messages standard is the most widely downloaded Subcommittee 13 standard today;

(b) Subcommittee 14 develops standards that capture best practices for space systems and operations. All disciplines covered by the Subcommittee's seven working groups are relevant to space safety and the long-term sustainability of space activities.

Research on space debris

ISO draws heavily upon its 100,000 global subject matter experts and the research that many conduct to support the development and evolution of its 22,000 active international standards. ISO subject matter experts include members of the Inter-Agency Space Debris Coordination Committee (IADC), academic institutions, national space administrations, Governments and the civil and commercial space industry.

Shortly after the publication of the first edition of the IADC Space Debris Mitigation Guidelines, in 2002, ISO set up a working group to transform guidelines and best practices from IADC, the United Nations, spacecraft operators and regulatory bodies into a comprehensive set of international space debris mitigation standards.

Safety of space objects with nuclear power sources on board and collision risk

Regarding the general safety of nuclear power, ISO has adopted more than 200 standards related to nuclear power,[1] some of which may be helpful.

In addition to space debris mitigation requirements and guidelines (see next section), there are Subcommittee 14 standards addressing the general topics of risk and safety management, including: ISO 31000, on risk management; ISO 11231, on space systems – probabilistic risk assessment; and ISO 14620, on space systems – safety requirements – part 1: system safety.

There are also Subcommittee 14 standards addressing the safety of parts and materials (the 14624 series and ISO/TS 16697, on the safety and compatibility of materials; and the 22538 series, on oxygen safety), and there are also new standards currently under development within the Subcommittee that will address space traffic management (22639, on space systems – design guidelines for multi-geostationary orbit satellites collocation; and 24330 on space systems – rendezvous and proximity operations).

In addition, a number of Subcommittee 14 subject matter experts are actively involved in safety studies at the levels of space agencies, the Inter-Agency Space Debris Coordination Committee and other entities.

Ways in which space debris mitigation guidelines are being implemented

Space systems offer huge economic and societal benefits today, but we must be careful to protect the precious region around the Earth for generations to come. Orbital debris mitigation standards, such as those that ISO develops and publishes, strive to maintain the delicate balance between the competing needs of a rapidly changing space industry and the need to ensure space environment sustainability. As a consequence, the standards will likely continue to evolve as our use of space increases and as we learn more about the space debris population.

Since 2010, many ISO Technical Committee 20/Subcommittee 14 standards relevant to space debris mitigation have been issued. The standards have already been used to guide a number of countries in their space activities, and they now constitute an important contribution to global efforts to address the space debris problem.

Following feedback from industry, Subcommittee 14 is now working to consolidate these standards in a smaller, more coherent set of documents. The supporting implementation standards, listed below, set out the ways and means to achieve compliance with ISO 24113.

[1] See www.iso.org/search.html?q=nuclear&hPP=10&idx=all_en&p=0.

Table
Standards and technical reports

ISO number	*Publication date*	*Title*
11227	2012	Space systems – Test procedure to evaluate spacecraft material ejecta upon hypervelocity impact
14200	2012	Space environment (natural and artificial) – Guide to process-based implementation of meteoroid and debris environmental models (orbital altitudes below GEO + 2,000 km)
16126	2014	Space systems – Assessment of survivability of unmanned spacecraft against space debris and meteoroid impacts to ensure successful post-mission disposal
16127	2014	Space systems – Prevention of break-up of unmanned spacecraft
TR/16158	2013	Space systems – Avoiding collisions with orbiting objects
16164	2015	Space systems – Disposal of satellites operating in or crossing low Earth orbit
16699	2015	Space systems – Disposal of orbital launch stages
TR/18146	2015	Space systems – Space debris mitigation design and operation manual for spacecraft
TR/20590	2017	Space systems – Space debris mitigation design and operation manual for launch vehicle orbital stages
23339	2010	Space systems – Unmanned spacecraft – Estimating the mass of remaining usable propellant
24113	2011	Space systems – Space debris mitigation requirements
26872	2010	Space systems – Disposal of satellites operating at geosynchronous altitude
27852	2016	Space systems – Estimation of orbit lifetime
27875	2019	Space systems – Re-entry risk management for unmanned spacecraft and launch vehicle orbital stages

Of particular significance, ISO 24113[2] was newly updated in 2019 to incorporate significant changes to several of the top-level requirements concerning space debris mitigation. These updates have become necessary in the face of mounting data about the projected growth of orbital debris in the low Earth orbit and geostationary satellite orbit protected regions. Most notably, the requirement for a spacecraft or orbital stage to exceed a specified threshold to achieve the required probability of successful disposal has been made more demanding. It is clear from long-term debris environment studies that space objects must now be disposed of with a very high degree of likelihood of success during their post-mission phase. Widespread adoption of measures such as these by spacecraft manufacturers and operators should go a long way towards mitigating the growth in orbital debris.

[2] Available at www.iso.org/standard/72383.html.

International Space University

[Original: English]
[17 July 2019]

Below is a list of the most recent International Space University student team project reports concerning the topic of space debris. Links are provided to the corresponding library record for each, where an executive summary and the full report in PDF format are available.

Active debris removal and mitigation

In recent years, the number of satellites which have been launched into orbit has been constantly growing. In the event that new concepts, such as megaconstellations in low Earth orbit, are commercially successful, the number of satellites launched annually will increase further. In the absence of specifically dedicated mitigation or remediation activities, the safe operation of spacecraft in these orbits may become impossible in the near future. This project aims to clean orbital space in an eco-friendly manner on Earth. These aims are based on the Clean Space initiative of the European Space Agency.

https://isulibrary.isunet.edu/index.php?lvl=notice_display&id=10462

Space debris

The Earth's orbital environment has become polluted with man-made space debris. The goal of this report is to propose a way forward that addresses these aspects by recommending a preferred technical solution and by suggesting amended or new political, legal and financial frameworks. The report summarizes these proposals in a multi-year road map.

https://isulibrary.isunet.edu/index.php?lvl=notice_display&id=8414

Space traffic management

Space is no longer the vast emptiness that is was at the birth of the space age in 1957. Orbits are becoming congested as a result of an increase in the number of objects in space – both operational satellites and, most significantly, orbital space debris. Moreover, currently, it is not technologically feasible to remove debris from orbit.

This report focuses on space traffic rules which would reduce the probability of debris causing collisions and thus enable space activity to continue to increase more efficiently for all actors. The report uses the *Cosmic Study on Space Traffic Management* of the International Academy of Astronautics as a starting point and tackles several of its key recommendations.

https://isulibrary.isunet.edu/index.php?lvl=notice_display&id=311