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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-eighth 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.105/1240, para. 109). Accordingly, a communication dated 11 August 2021 was sent to Member States and international organizations with permanent observer status, inviting them to provide their reports by 11 November 2021 so that the information could be made available to the Subcommittee at its fifty-ninth session.

2. The present document has been prepared by the Secretariat on the basis of information received from five Member States, namely, Austria, Brazil, Germany, India and Japan, as well as from the International Atomic Energy Agency and CANEUS International. Further information provided by Japan and CANEUS International, including figures related to space debris, will be made available as a conference room paper at the fifty-ninth session of the Subcommittee.

* A/AC.105/C.1/L.392.

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II. Replies received from Member States

Austria

[Original: English]
[27 October 2021]

The satellite laser ranging (SLR) station of the Space Research Institute of the Austrian Academy of Sciences is one of the pioneer stations with respect to the tracking of space debris. By using a 16 W laser, the diffuse reflection of defunct satellites or rocket bodies can be detected and the distance can be calculated with an accuracy of approximately 1 m. In bi- or multi-static space debris laser ranging sessions, the SLR station in Graz actively fires the space debris laser and one or more (passive) SLR stations in Europe detect the reflected photons. Such measurements can further improve orbit predictions. During “stare and chase” experiments, space objects with unknown orbits can be detected visually, an orbit is calculated from the pointing directions and the range to the object is measured within the same pass. In parallel to space debris laser ranging, single photon light curves of the sunlight reflected by space debris are recorded. From the space debris laser ranging and light curve data, important conclusions on the spin axis and rotation period can be drawn. In 2020, the Graz SLR station was the first station to successfully measure the range to space debris objects in daylight by visualizing the objects against the blue sky background.

Brazil

[Original: English]
[18 October 2021]

On 16 August 2021, Brazil was accepted as an observer to the Inter-Agency Space Debris Coordination Committee (IADC), a forum in which members exchange information on space debris research activities, facilitate opportunities for cooperation in space debris research, review the progress of ongoing cooperative activities and identify debris mitigation options. The country was given the opportunity to regularly attend the meetings organized by two IADC working groups (working group 2, on the environment and database, and working group 4, on mitigation) for a time frame of two years. However, the Brazilian Space Agency has not yet submitted a list containing the names of the country’s scientists/experts nominated to join those working groups, and it remains a non-member of IADC. The Agency can still forward such a list to ensure the experts’ participation in the next full meeting of IADC, which is scheduled for 6 to 10 June 2022 in the Republic of Korea.

Germany

[Original: English]
[28 October 2021]

Research activities on issues related to space debris are conducted in Germany in all relevant fields. This includes space debris environment modelling, observation of space debris, technology development for observations, studies of the effects of hypervelocity impact on spacecraft, protection of space systems from the impact of micrometeoroids and space debris, as well as design for demise technologies. German experts actively participate in relevant international forums in the field of space debris research and space safety, inter alia, the Inter-Agency Space Debris Coordination Committee and the International Academy of Astronautics, in international standardization activities in the field of space debris, and most recently also in space traffic coordination aspects. German industry and academia are also involved in technology developments to serve the long-term sustainable use of outer space and the protection of the Earth.

Recently, the German Space Agency at the German Aerospace Center (DLR) started an initiative to further improve space debris mitigation in DLR-supported small-satellite projects at universities and research institutes. Internal process changes at the German Space Agency ensure that DLR space debris mitigation requirements are implemented as mandatory requirements in research grants for space missions. Furthermore, a continuous dialogue has been established with the small-satellite initiative of German universities. The aim of that dialogue is to maintain a high level of sustainability for the fast-growing space activities at universities and to support the sharing of knowledge and best practices within the university landscape. The German Space Agency provides support to ongoing projects, has offered online expert workshops related to space debris mitigation topics and has launched a survey on space mission operations at universities in Germany. The first results from the survey are expected at the end of 2021.

Measurements

The development of capabilities for generating and utilizing sensor data is needed to establish a national space surveillance competence, for instance to generate a space object catalogue and to perform orbit determination. Such an object catalogue is the backbone of space situational awareness operations. Therefore, the German Space Agency, through its national programme with funding from the German Federal Ministry for Economic Affairs and Energy, initiated the development of the German Experimental Space Surveillance and Tracking Radar (GESTRA). The system was developed by the Fraunhofer Institute for High Frequency Physics and Radar Techniques. It is an experimental system to survey and determine the orbital information of resident space objects in low Earth orbit. In 2020, the two radar shelters were transported to and commissioned at their operational site, and further integration and test and verification activities have been performed there. The system can be operated fully remotely by the German Space Situational Awareness Centre (GSSAC). GESTRA is also intended to serve as an experimental platform for bi- and multi-static radar operation and to provide data to research institutions in Germany for further research in that area.

A database has been developed and has been hosted and operated by GSSAC since 2019 for the collection and sharing of measurements from the European Union Space Surveillance and Tracking (EU SST) consortium, serving as the main data-sharing platform for EU SST. As a second step, the development of a European precursor catalogue based on that database has been initiated.

Multiple options have been identified to increase the performance of ground-based surveillance radar measurements of space debris. One option is the use of multiple surveillance radars at separate sites working in bi- and multi-static configurations. Such a network of radars is expected not only to increase the size of a surveillance area, but also to result in better measurements of single objects. A study to further analyse such operation modes is currently being conducted through a collaboration between two Fraunhofer institutes.

A network of optical telescopes called the Small-Aperture Robotic Telescope Network (SMARTnet) currently consists of five telescope stations. Those stations are located in Switzerland, the United States, Spain, South Africa and Australia, with DLR operating the ones in South Africa and Australia. The network is organized by DLR in close cooperation with the Astronomical Institute of the University of Bern, Switzerland. The telescope stations consist of several telescopes with apertures ranging from 14 cm to 80 cm. The network monitors the geostationary region and related orbits to support research on collision avoidance and other scientific topics, encompassing data for objects larger than approximately 30 cm in geosynchronous orbits. Objects fainter than a magnitude of 18.5 have already been detected, their positions measured and their orbits calculated. Clustered satellites have also been resolved unambiguously.

DLR is also developing an information system with the Backbone Catalogue of Relational Debris Information, an orbital database for objects in Earth orbit, which is central to this project. Key functionalities, such as object correlation using observations from different sensors (e.g. SMARTnet), providing the first observational data to be processed by the system, orbit determination and orbit propagation, are currently fully operational. The system can process different measurement types, including radar, optical and satellite laser ranging (SLR). The different input data can also be fused and combined for objects to result in a better orbit determination solution. Furthermore, a complete screening algorithm to detect close approaches between objects is in development. All algorithms are programmed such that observation data for up to 100,000 objects can be processed in real time. Currently ongoing research topics include comparison of the accuracy of different orbit propagators, such as numerical and semi-numerical ones, as well as deriving optimum planning from the database for sensors to keep all objects within a specified accuracy.

Another project, at the Technical University of Braunschweig, will evaluate the basic functional fields of a space situational awareness system. The main objective of the project is to gain an understanding of the suitability of selected orbit determination methods. For this purpose, quality criteria for the orbit data catalogue are established. By means of a large number of simulations, the generated catalogue quality will be investigated.

A large Ritchey-Chrétien telescope with a diameter of 1.75 m for the observation and analysis of small space debris objects a few centimetres in size has been installed by DLR in southern Germany. The telescope is equipped with four Nasmyth foci and a Coudé path. In addition, it can be used as a laser transmitter or photon receiver participating in bistatic laser ranging campaigns. In general, the telescope serves as a platform for developing new and innovative laser optical technologies for space safety applications for all Earth orbits, including the very low Earth orbit altitude range. The focus of the laser technology implemented will be in the eye-safe laser wavelength range.

A very compact, automatically operated satellite laser ranging system has been developed by DLR, which provides laser ranging precision down to a few centimetres in the positional data, from satellites equipped with retroreflectors. Such data have numerous applications in geodesy, Earth observation, satellite operation or monitoring decommissioned satellites. A corresponding in-orbit component based on an athermal ceramic retroreflector design has been developed and can be utilized by satellite operators as a solution for laser-based space traffic monitoring.

In the area of very small-sized debris particles, a concept of a low-resource integrated impact detector is being studied by the Fraunhofer Institute for High-Speed Dynamics, Ernst Mach Institute (Fraunhofer EMI) for the European Space Agency (ESA). This in situ detector concept is being developed for collecting on-orbit data of space debris under 0.1 mm, that is, particle impacts that may have significant effects on space systems but are difficult to observe from the ground.

Modelling and on-orbit and on-ground risk assessment

The main objective of a project at the Technical University of Braunschweig was to contribute to the definition of a rating scheme for the sustainable use of the space environment with reference to the increasing collision probabilities on low Earth orbits. Such investigations are of particular importance at present, since the existing mitigation policies are not specially designed to manage the extraordinarily high numbers of objects expected with the introduction of megaconstellations.

Germany also significantly contributes to research on the effects of on-orbit collisions and space debris impacts through Fraunhofer EMI. Experimental simulation of hypervelocity impact is performed using light-gas accelerators and high-speed diagnostics at the current limits of ground testing. Spacecraft components, such as carbon fibre reinforced plastic structures, transparent materials, pressure vessels and de-orbit motor propellants, have recently been tested not only for evaluating damage effects and quantitative design limits but also for deriving models to assess the consequences of space debris impacts at the system level. Impact experiments, mainly performed under ESA contract, are complemented by numerical simulations for extending the parameter range of collision conditions and performing numerical experiments at the spacecraft level. Specialized hydrocodes and discrete element methods are developed and applied for complex simulations of hypervelocity collisions at Fraunhofer EMI. An example of the latter is the ongoing DEM-O project, supported by the German Space Agency. The project demonstrates the suitability of using a discrete element method for simulating hypervelocity impact. Using particle-based models, it is possible to accurately simulate hypervelocity impact scenarios, particularly the fragmentation that results from such impacts. The discrete nature of this method puts it at a distinct advantage for modelling in-orbit satellite fragmentation and break-up when compared to traditional hydrocodes. The current focus is on improving the modelling of secondary impacts that occur within a satellite immediately following a hypervelocity impact event.

The concern about the on-ground risk caused by spacecraft fragments surviving atmospheric re-entry has grown significantly during the past decade, resulting in numerous activities of the space community such as re-entry simulation tool development, improvement and validation, as well as research on design for demise. The purpose of the first group of activities is to increase confidence in numerical re-entry risk predictions, while the aim of the second kind of activities is to develop new spacecraft design techniques which are likely to improve demise behaviour significantly.

One major shortcoming of currently used re-entry simulation tools is the neglection of thermomechanical fragmentation, that is, the break-up of re-entry objects before melting conditions are reached in the structural joints. A recent research activity addressed this topic in an academia-industry cooperation between the University of Stuttgart Institute for Space Systems (IRS) and Hypersonic Technology Göttingen GmbH (HTG). A novel thermomechanical fragmentation model for re-entry analysis tools was developed and implemented by HTG. At IRS, an entirely new set-up to perform plasma wind tunnel tests with controlled additional mechanical loads was invented. Those new experiments were analysed using the recent diagnostic possibilities at IRS (photogrammetry, Echelle spectroscopy) in order to give insight into break-up phenomena when thermomechanical loads are considered. The new finite element-based method developed by HTG can pave the way for an overall thermomechanical analysis to be used in re-entry analysis codes. Test case results show that the strong interaction between mechanical and thermal loads needs to be considered to obtain reliable re-entry simulations.

Another research activity at the Technical University of Braunschweig focuses on the investigation of the scientific judgment capability of an initial analysis of fragmentation events in Earth orbit shortly after detection. Of particular importance is the number of released objects of a given size class and the distribution of debris particles over other orbits. This increases the collision risk for active objects in the corresponding orbital regions, so that the assessment of the risks and their temporal development, that is, the lifetime of the fragmentation particles, are of interest. The goal of the project is to develop a methodology to scientifically analyse a new fragmentation event immediately after it becomes known and to assess the associated risks.

India

[Original: English]
[31 October 2021]

The Indian Space Research Organization (ISRO) has taken up projects to establish observational facilities for the dedicated tracking and monitoring of space objects. A radar and an optical telescope will be established under the Network for Space Object Tracking and Analysis (NETRA) for tracking objects in low Earth orbit and objects in geosynchronous Earth orbit, respectively. Existing facilities such as the multi-object tracking radars in Sriharikota and the telescopes planned under the Satellite Photometry Laser Ranging and Optical Communication initiative will also be utilized for the monitoring of space debris in low Earth orbit and in geosynchronous Earth orbit, respectively.

ISRO has been carrying out research to improve the atmospheric re-entry prediction of space objects and on re-entry fragmentation modelling and analysis. ISRO actively participates in the annual re-entry prediction campaigns of the Inter-Agency Space Debris Coordination Committee. Efforts towards further enhancements of the existing methodologies for the avoidance of collisions of space assets with space debris, namely, space object proximity analysis and launch collision avoidance analysis, are under way.

A control centre has been established under the scope of the NETRA project for the processing of observations from various observational facilities towards building a national catalogue of space debris. Dedicated facilities for research on space debris are planned to be set up in the control centre.

ISRO does not currently have any nuclear-powered space objects that can pose a threat to safety in outer space. If such an object is planned for any future mission, ISRO will address safety issues in line with internationally accepted guidelines.

Japan

[Original: English]
[29 October 2021]

Overview

This report covers debris-related activities mainly conducted by the Japan Aerospace Exploration Agency (JAXA), as requested by the Office for Outer Space Affairs.

The following debris-related activities were conducted by JAXA in 2019 and 2020:

(a) Conjunction assessment results and research on core technology for space situational awareness;

(b) Research on technology to observe objects in low Earth and geosynchronous Earth orbits and determine their orbits;

(c) In situ microdebris measurement system;

(d) Development of a composite propellant tank;

(e) Active debris removal.

Further information is provided in the sections below.

Status

Conjunction assessment results and research on core technology for space situational awareness

JAXA regularly receives conjunction notifications from the Combined Space Operations Center (CSpOC). In 2020, JAXA executed two debris avoidance manoeuvres for low Earth orbit spacecraft. The number of debris avoidance manoeuvres has decreased in comparison to that in 2019, since CSpOC introduced new criteria for identifying high-risk events. As a satellite operator, JAXA has recognized that the conjunction risk posed by space debris remains high, as the space environment deteriorates year after year.

Core technology for space situational awareness

The current analysis system at the Tsukuba Space Center of JAXA determines the orbit of space objects using a radar sensor located at Kamisaibara Space Guard Center (KSGC) and optical sensors located at Bisei Space Guard Center, predicts close approaches using the latest orbit ephemerides of JAXA satellites and calculates the probability of collisions.

At present, a new KSGC radar which is currently being developed can track smaller space debris than the old radar. In particular, the new radar will cover altitudes around 500 to 800 km, at which most of the JAXA low Earth orbit satellites are orbiting. JAXA is also refurbishing its 1.0 m and 0.5 m telescopes to maintain their current capabilities for observations of objects in geosynchronous Earth orbit. In addition, JAXA is developing a new analysis system that will be able to handle more data than the current system and will be able to run by automated processes as much as possible.

Note that the operation of the old KSGC radar was terminated in August 2020 in preparation for the new radar. The new space situational awareness system, including the new KSGC radar, will be available in 2023.

JAXA has also developed tools that help to plan debris avoidance manoeuvres once the Agency receives a conjunction data message from CSpOC. Based on experience, all procedures for debris avoidance manoeuvres have been simplified and workloads reduced. Last March, JAXA released a risk avoidance assist tool named RABBIT free of charge for all satellite operators.

Research on technology to observe objects in low Earth and geosynchronous Earth orbits and determine their orbits

Generally, the observation of objects in low Earth orbit is conducted mainly by radar system, but JAXA has been working to develop an optical system to reduce the cost of both construction and operation. A large complementary metal-oxide semiconductor (CMOS) sensor for low Earth orbit observation has been developed. Analysing the data from the CMOS sensor with field programmable gate array-based image-processing technologies enable the detection of objects in low Earth orbit measuring 10 cm or less. In order to increase the observation opportunities in relation to objects in low Earth and geosynchronous Earth orbits, a remote observation site in Australia was established in addition to the Mount Nyukasa observatory in Japan. One 25 cm telescope and four 18 cm telescopes are available for various objectives. Another remote observation site will be established in Western Australia, which will make it possible to carry out precise orbital determinations and altitude estimation of objects in low Earth orbit using the data from both sites in Australia.

In situ microdebris measurement system

The space debris monitor is an in situ microdebris sensor focusing on micro- to milli-sized debris orbiting at under 1,000 km. A recent flight experience was conducted by H-II Transfer Vehicle Kounotori-5 (HTV-5). Information based on actual measurements of those small debris objects is essential to properly understand the vast amount of small debris orbiting near the Earth, as such debris is becoming a dominant risk factor in orbit.

The unique properties of the space debris monitor are its simple detection system, which does not need any special calibration before flight, and the potential to collaborate easily with other sensors. The monitor 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 measuring from 100 µm to millimetres.

JAXA jointly collaborates with the National Aeronautics and Space Administration (NASA) Orbital Debris Program Office to develop a new in situ microdebris measurement system in order to understand the number of small debris objects orbiting at under 1,000 km.

Development of a composite propellant tank

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

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 manufacture and testing of a shorter engineering model EM-1 tank, JAXA manufactured a full-sized EM-2 tank. The shape of the EM-2 tank is identical to that of the nominal tank, which includes a propellant management device. Using the EM-2 tank, a proof pressure test, vibration test (with wet and dry conditions), an external leak test, a pressure cycle test and a burst pressure test were conducted, and all of them showed good results. Subsequently, the critical design review was completed.

The composite propellant tank has a shorter delivery period and lower cost than a titanium propellant tank. Experimental and analytical evaluation of demisability during re-entry is ongoing.

Active debris removal

JAXA has organized and structured a research programme which is aimed at realizing low-cost active debris removal missions. The research and development of key technology for active debris removal 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 active debris removal on a commercial basis and working to provide these essential key technologies for that purpose.

JAXA is also leading the Commercial Removal of Debris Demonstration programme. The programme comprises two phases and is aimed at conducting the world’s first active debris removal in partnership with private enterprises. During the first phase of the programme, the demonstration of the key technologies, such as non-cooperative rendezvous, proximity operation and inspection of the H-IIA second stage, is planned for Japanese fiscal year 2022. During the second phase, the demonstration of active debris removal and re-entry of the H-IIA second stage is planned after Japanese fiscal year 2025. Astroscale Japan Inc. was selected as a partner company in the first phase through a competition in February 2020.

III. Replies received from international organizations

International Atomic Energy Agency

[Original: English]
[1 November 2021]

The International Atomic Energy Agency (IAEA) provides support to the Working Group on the Use of Nuclear Power Sources in Outer Space of the Scientific and Technical Subcommittee in order to facilitate the implementation of the Safety Framework for Nuclear Power Source Applications in Outer Space, jointly developed by IAEA and the Working Group.

In case of a collision with a spacecraft with a nuclear power source on board, which could potentially result in the re-entry of such sources into the Earth's atmosphere, IAEA has an active programme in the area of preparedness for and response to nuclear and radiological emergencies.

IAEA maintains the International Emergency Preparedness and Response framework, which facilitates the development and maintenance of capabilities and arrangements for preparedness and response to nuclear and radiological emergencies and is based on international legal instruments.

Through the Inter-Agency Committee on Radiological and Nuclear Emergencies, IAEA and the Office for Outer Space Affairs, together with other organizations, maintain the Joint Radiation Emergency Management Plan of the International Organizations (JPLAN), which provides a mechanism for coordination and clarifies the roles and capabilities of the participating international organizations. JPLAN describes a common understanding of how each organization acts during a response and in making preparedness arrangements for a nuclear or radiological emergency.

CANEUS International

[Original: English]
[29 October 2021]

Overview

CANEUS proposes to the Scientific and Technical Subcommittee to initiate system studies to address the problem of the influence of multi-satellite low Earth orbit constellations on traditional tasks both in outer space and from space (within the Committee's mandate).

Based on the results of such studies, which are advisable to carry out, the leading space powers at the national level can be offered real measures to exclude or mitigate the effects of physical and energy interference created by megaconstellations in traditional space systems.

In the short term, this kind of measures may be associated with a number of actions by satellite operators of low-orbit constellations of the micro, nano and pico classes: darkening the surface of satellites, sun shielding and refusing to use non-rigid reflective materials on the nadir-facing parts of the small satellites to reduce glare; changing the orientation of the small spacecraft in order to avoid the projection of light reflected from the on-board equipment, while ensuring the general availability of ephemeris information with the highest possible accuracy.

In the long term, within the institutes and working groups of the Committee on the Peaceful Uses of Outer Space, additional measures can be developed and proposed to eliminate or mitigate the effects of physical and energy interference created by mega-groups to traditional space systems, as well as to reduce the risk of collisions in orbit and the formation of space debris.

Near-term mitigation measures

1. For satellite operators:

   (a) Surface eclipse;

   (b) Sun shielding;

   (c) Adjusting attitude to avoid flares projecting onto major ground-based observatory sites;

   (d) Monitoring satellite control within power constraints to ensure effective reflectivity and maximum prediction of nadir-facing specular surfaces in the direction of ground-based observatories.

2. For observatories:

   (a) Image post-processing to identify, model, subtract and mask affected pixels associated with the satellite trail;

   (b) Maintaining precise ephemerides of entire constellation suites and, for those facilities where it may be practical, closing the shutters of the ground telescopes for the seconds around the predicted satellite passage;

   (c) Pointing avoidance when possible.

Background

Over the past few years, several low Earth orbit multi-satellite constellations have been actively created and deployed mainly by private and government-owned corporations in the United States of America, Great Britain, Canada, China and other countries.

Specific examples include the most widely known constellations of commercial small satellites for broadband communications and space Internet (Starlink and OneWeb), Earth remote sensing (Flock), the Internet of things (SpaceBEE) and automated vehicle identification systems (Lemur-2).

Corporations are placing satellites into orbit at an unprecedented frequency to build “megaconstellations” of communications satellites in low Earth orbit. Some estimates show that more than 100,000 satellites could orbit the planet by 2030.

In general, the current situation with the “population density” of near-Earth orbits was characterized in a recent article by Aaron C. Boley and Michael Byers in *Nature* online scientific reports. Their findings reveal that the number of active and defunct satellites in low Earth orbit increased by over 50 per cent, to about 5,000, in two years (as at 30 March 2021).

SpaceX alone is on track to add 11,000 more satellites as it builds its Starlink megaconstellation, and it has already filed for licences for another 30,000 satellites with the Federal Communications Commission. Others have similar plans, including the Chinese State-owned company Guowang with 13,000 satellites, OneWeb (6,372), Amazon (3,236) and Telesat (Lightspeed network: 298). The current governance (control) system for low Earth orbit, while slowly changing, is ill equipped to handle multi-satellite space systems.

In just a short period, the process will only grow. So, like mushrooms after rain, the aforementioned orbital constellations for broadband Internet, the Internet of things, Earth remote sensing and automatic identification systems have already been appearing in the past two years.

According to a presentation by Canada at the fifty-eighth session of the Scientific and Technical Subcommittee, on space-based photometric measurements of the Starlink orbital constellation collected through the Near Earth Object Surveillance Satellite mission, in the next 10 years, up to 10,000 small (i.e. micro-, nano-, pico- and femto-) satellites are predicted to be in orbit.

Key issues

The emergence of new threats and risks that are directly or indirectly related to the problem of space debris exists in two separate dimensions.

The first dimension is energy (information) interference from low-orbit multi-satellite constellations for routine (day-to-day) space activities, which is associated with the functioning of the satellite systems that ensure strategic stability and international security.

These are, first of all, national (China, Russia, United States) and international (European Union) high-orbit broadband communications and data relay systems, information components of missile attack warning and anti-missile defence systems, as well as the control of near-Earth space, low-altitude strategic intelligence systems (control of compliance with treaties) and special communications in the interests of military and paramilitary departments.

Interference with astronomical observations are carried out from Earth and are directly related to missile attack warnings, missile defence and space control systems since the ground-based optical facilities contribute to the performance of defence tasks.

Therefore, it is impossible to exclude radio interference created by the uninterrupted operation of military and civil satellite communications in the frequency ranges Ka, Ku (from 22 GHz) and V (60 GHz). In addition, a global and poorly controlled threat to physical and information security in the space sector is being created by all the above-mentioned multi-satellite constellations, not limited to telecommunications.

The second dimension is the threat of cascading growth in the population of space debris associated with the observed intensification of the use of small (micro) and ultra-small (nano, pico and femto format) satellites in the context of the use of automated control over them based on micro-/nanotechnologies and artificial intelligence.

Potentially dangerous mutual encounters of such small spacecraft as part of “swarm” constellations at critical distances and the threat of possible collisions as a result of loss or control errors will force (and already have forced) operators of large low-orbit space objects (such as unique and expensive strategic reconnaissance satellites or the International Space Station) to resort to frequent defensive manoeuvring, with all the ensuing consequences, including the disruption of the performance of target tasks or the consumption of the mission’s energy resources.

Related efforts

At the fifty-eighth session of the Scientific and Technical Subcommittee, some delegations expressed their serious concern about the placement of large constellations and megaconstellations of satellites and its implications, and, in that connection, expressed the view that the topic should be treated by the Subcommittee as a priority, with a view to mitigating the creation of space debris (A/AC.105/1240, para. 98).

Considering the fact that the problem of space debris has been considered by the Committee on the Peaceful Uses of Outer Space for many years, including attempts to regulate the debris level in near-Earth orbit by special measures at the national and international levels, the introduction of recommendatory norms and the creation of specialized United Nations institutions to solve the problem of interference and long-term threats to everyday space activities as a result of the emergence of multi-satellite constellations in low orbit seems unlikely to be constructive.

Suggested modifications

Alternatively, in the current, traditional mandate under item 8 of the Subcommittee’s agenda (in accordance with General Assembly resolution 75/92), on research on the problem of space debris, the safety of space objects with on-board nuclear power sources and problems related to their collision with objects of artificial origin, in particular, the phrase "low-orbit multi-satellite constellations" should replace the phrase "with nuclear power sources on board" or be added to the mandate.

Rationale for the proposed modifications

First, space objects with on-board nuclear power sources have not been launched, at least for the past two years. The exception was for radioisotope energy sources used for long-term (usually interplanetary) space missions.

In the short term, such objects do not reflect as obvious a threat as multi-satellite low-orbit constellations, neither from the point of view of collisions in orbit, nor from the point of view of the consequences of such collisions for the ecology of the Earth and space.

Secondly, the problem of the influence of low-orbit multi-satellite constellations both on the efficiency of astronomical observations and routine space activities in its various aspects, including ensuring strategic stability and international security, was not posed by the Subcommittee.

Recent studies of the first component were carried out in the United States by the American Astronautical Society with the support of the National Science Foundation (SATCON1 and SATCON2 workshops, held in July 2020 and July 2021) to minimize the negative impacts of satellite constellations on astronomy and the night sky; however, the second component was ignored in analysts' research.

If specific measures have been proposed to guide both observatories and satellite operators now and in the future (when the international community comes to a more detailed understanding of the impacts of multi-satellite low-orbit constellations on astronomical observations and ways to mitigate such impacts), then in the case of the influence of low-orbit multi-satellite constellations on stabilizing space activities (global communications, relaying, reconnaissance from space, space echelons of missile defence and early warning systems, and space domain awareness), such measures have not been considered in an open format. Moreover, the dominant use of certain orbital regions by a select few countries might also result in a de facto exclusion of other actors from them, violating the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies.

Proposed recommendations

All of the issues and challenges mentioned above could be considered and addressed in a coordinated manner through multilateral law-making only, whether in the United Nations, the Inter-Agency Space Debris Coordination Committee (IADC) or an ad hoc process, rather than in an uncoordinated manner through different national laws.

However, no binding international rules exist on other aspects of megaconstellations. In 2007, IADC, which currently represents 13 space agencies, indicated that direct re-entry at the end of a satellite's operational life was preferred, but it only recommended de-orbiting satellites within 25 years. This is an unacceptable guideline for megaconstellations made up of thousands of satellites with short operational periods. It also overlooks the problem of placement, with satellites at higher altitudes producing relatively high collision probabilities when de-orbiting timescales are too long.

Regardless of the law-making forum, megaconstellations require a shift in perspectives and policies: from looking at single satellites to evaluating systems of thousands of satellites, and doing so within an understanding of the limitations of the Earth's environment, including its orbits.

Thus, based on the above, CANEUS proposes to the Subcommittee to initiate system studies of the problem of the influence of multi-satellite low Earth orbit constellations on traditional solvable problems in outer space and from outer space.