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Space debris

National 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-fourth 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 (see A/AC.105/1138, para. 133). Accordingly, a communication dated 26 July 2017 was sent to Member States and international organizations with permanent observer status, inviting them to provide their reports by 16 October 2017 so that the information could be made available to the Subcommittee at its fifty-fifth session.

2. The present document has been prepared by the Secretariat on the basis of information received from four Member States, namely Austria, Brazil, Germany, and Mexico, and from the European Space Agency (ESA). Further information provided by Austria, which includes figures related to space debris, will be made available as a conference room paper at the fifty-fifth session of the Subcommittee.

* A/AC.105/C.1/L.368.

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II. Replies received from Member States

Austria

[Original: English]
[16 October 2017]

According to the Austrian Outer Space Act, one of the conditions for the authorization of national space activities by the Austrian Ministry for Transport, Innovation and Technology is that provision be made for the mitigation of space debris in accordance with the state of the art and in due consideration of the internationally recognized guidelines for the mitigation of space debris (§ 4, subparagraph 1 (4), and § 5 of the Outer Space Act). As evidence of appropriate provisions for the mitigation of space debris, operators must submit a demonstration of measures adopted for the avoidance of space debris and mission residue released during normal operations, for the prevention of on-orbit collisions with other space objects, for the avoidance of on-orbit break-ups of the space object as well as for the removal of the space object from Earth orbit at the end of the space activity, either by controlled re-entry or by moving the space object to a sufficiently high orbit ("graveyard orbit"), while for non-manoeuvrable space objects, the mission orbit must be chosen such that they do not remain in Earth orbit for more than 25 years after the end of their operation (§ 2, subparagraph 4 of the Outer Space Regulation).

The nanosatellite PEGASUS, the third Austrian national satellite, which was successfully launched in June 2017, is the first satellite that underwent an authorization process under the Austrian space legislation. In that connection, the space debris tools developed by ESA, in particular Meteoroid and Space Debris Terrestrial Environment Reference (MASTER) and Debris Risk Assessment and Mitigation Analysis (DRAMA) tools, have proved to be highly useful in evaluating whether a mission fulfils international space debris mitigation standards, such as the space debris mitigation guidelines of the Inter-Agency Space Debris Coordination Committee (IADC) and the Committee on the Peaceful Uses of Outer Space. This includes the assessment of the orbital lifetime, the calculation of the probability of collisions and the analysis of break-up and demise during atmospheric re-entry and the associated risk on the ground. Moreover, the satellite has been registered under the Convention on Registration of Objects Launched into Outer Space and is tracked by the United States Strategic Command, which enables other space actors to consider it in their collision avoidance process.

Austrian research on space debris

Since more than three decades, the Institute for Space Research of the Austrian Academy of Sciences has operated a satellite laser ranging (SLR) station at the Lustbühel observatory in Graz. In addition to tracking more than 150 cooperative targets (equipped with laser retroreflectors), space debris laser ranging is getting an increasing amount of attention. In the recent past, in Austria, within research on space debris, focus has been placed on the three areas described below:

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 SLR station which can be installed at external telescopes. It consists of a transmitting module (15 µJ/1 ns/2 kHz laser, optics, mounted on the telescope) and a detection package (laptop, field-programmable gate array (FPGA)-based control unit, Riga event timer, global navigation satellite system (GNSS) unit, meteorological instruments). The major advantage of such a setup is the reduced alignment effort owing to the avoidance of any Coude-path. The SP-DART system was successfully tested on a 70-cm astronomy telescope owned by Astrosysteme Austria. Overall, during two observation nights, 17 targets were tracked with maximum return rates ranging from >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 SLR station using a compact high-power space debris laser directly mounted on the Graz telescope, successfully ranging to several space debris targets.

Multi-static experiments

Multi-static experiments are complex space debris laser ranging measurements involving at least three different stations measuring the distance to the same space debris target. The Graz SLR station sends photons using its green high power (20W/100Hz) space debris laser, simultaneously the Wettzell SLR station sends photons using its infrared space debris laser to the same space debris target. After diffuse reflection at the space debris target, the photons are spread across Europe. Graz's green photons are now detected by Graz itself and by the Wettzell SLR station. At the same time, Graz, Wettzell and Stuttgart detect Wettzell's infrared photons. An analysis of the data showed that such simultaneous measurements significantly increase orbit prediction accuracy compared to the same number of stations operating in mono-static mode.

Stare and chase

Stare and chase is a method to track and range to space debris targets for which no a priori orbit information is available, by optically determining the pointing direction to such targets. An analogue astronomy camera is equipped with an off-the-shelf 50 mm objective monitoring a field of view of approximately seven degrees of the sky. The camera system is piggyback-mounted on our SLR 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 ninth-order magnitude. From the stellar background, utilizing a plate-solving algorithm, the equatorial pointing direction of the camera centre is determined with an accuracy of approximately 15 arc seconds. Once a sunlit space debris object passes through the field of view, its equatorial coordinates and the current time are stored. From the pointing information a consolidated-prediction-format (CPF) orbit prediction file is generated and used to immediately track the satellite within the same pass. The process from the first detection of the satellite until successful tracking can be completed within less than 2 minutes. As soon as tracking is established, the SLR system starts "chasing" the target with a high power (20 W/100 Hz) space debris laser. Space debris laser ranging to several cooperative and uncooperative (without retroreflectors) targets was successfully achieved using such stare-and-chase predictions.

Brazil

[Original: English]
[16 October 2017]

Research on space debris involves two major areas: (1) atmospheric re-entry (where and when space debris is generated and can re-enter) and (2) the prediction of collision in orbit (probability of collision in orbit) and methodologies to avoid the generation of space debris, forcing its controlled or natural re-entry (de-orbit). Still there is no Brazilian demand for the area of security of space objects with nuclear power.

Regarding problems with space debris, some analyses of collisions with space debris were recently made at the Centre for Satellite Tracking and Control of the National Institute for Space Research (INPE), based on a collision risk alert received from the Xian Satellite Control Centre (XSCC). The analysis consisted of generating reports for a future period of one week for the China/Brazil Earth Resources Satellite 4 (CBERS-4). To achieve that, the satellite tool kit (STK) software was used, since its close-approach module allows the generation of this kind of report. The orbital elements of the debris and other objects in orbit that were necessary for the analysis data were obtained via the North American Aerospace Defense Command (NORAD) site (www.space-track.org). Due to the results obtained with these analyses, the possibility is being considered of periodically generating the same kind of reports for all the satellites operated by INPE (data collection satellites SCD -1 and SCD-2, and CBERS-4).

In addition, in the testing phase at the INPE centre for satellite tracking and control is a software system for prediction of collision of space debris developed in-house. Under the code name CHKDEBRISSGP8, the software provides the probability of collision of any object available through NORAD, currently with almost 17,000 objects catalogued (16,695 as of 29 September 2017), against satellites under the responsibility of Brazil (OSCAR-17, SCD-1, SCD-2, CBERS-1, SACI-1, CBERS-2, NANOSAT-C-BR1 and CBERS-4 and others that are going to be released: CBERS-4A and AMAZONIA/PMM). Other software with numerical model, under the code name CHKDEBRISNUM, performs a more accurate forecast when the CHKDEBRISSGP8 results show the probability of a collision greater than 1 per cent. The alerts are evaluated three times a day and the results are sent to specialists. The whole operation is automated.

In 2016, a dissertation was concluded of the INPE master's course in engineering and management of space systems entitled "Comparative analysis of the process for obtaining alumina α, zirconia-3YTZP and composite alumina α + 18.5 per cent zirconia-3YTZP ceramics for application as satellites impact shield for space debris". The objective of this dissertation was to study and identify possible materials to be used as ceramic pieces in a system of protection against impacts. Thus, a critical mass of debris to be stopped was estimated. The ceramic composite obtained from a mixture of deflocculated powder suspensions showed better mechanical properties. These results classified the composite alumina-zirconia as the best candidate among the studied materials for using as shield for satellites.

In 2017, another dissertation of the INPE master's course in engineering and management of space systems related to space debris was concluded. In this work was studied "From launch to injection in orbit, the areas of impact (fall) of the launcher stages and re-entry of cargo". This work provides support to other research efforts that study the forced re-entry of the last stage of the launcher. The tool developed has direct application in Brazilian launchers.

Germany

[Original: English]
[13 October 2017]

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 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 (IADC), the International Academy of Astronautics (IAA), and in international standardization activities in the field of space debris mitigation. 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.

For space projects of the space administration of the German Aerospace Center (DLR), space debris mitigation requirements are mandatory as part of the product assurance and safety requirements for DLR space projects. These requirements ensure the implementation of internationally recognized mitigation measures including those identified in the IADC Space Debris Mitigation Guidelines and the Space Debris Mitigation Guidelines of the Committee. The general objective is to limit the creation of new space debris and thus to mitigate the risk to other current and future space missions and the risk to human life. The measures to be adopted in order to achieve this objective include the conduct of a formal space debris mitigation assessment, specific design measures to prevent the release of mission-related objects, fragmentations, malfunctioning, and on-orbit collisions, as well as measures pertaining to passivation, end-of-life disposal, and re-entry safety.

Modelling and small-size particles

At the Institute for Space Systems (IRAS) of Braunschweig Technical University analyses of the long-term evolution of the space debris environment are being conducted using long-term propagations of that environment. Such analyses are an important tool for assessing the effectiveness of space debris mitigation measures and are being used in studies by IADC. The studies take into account recently observed changes in the launch rate and mission types, i.e., the increasing number of small satellites and scenarios that include new potential large constellations in low-Earth orbit.

To improve the knowledge regarding small (100 µm<d<cm) but abundant objects in space, a new type of in-situ sensor was developed at DLR. The so-called solar panel based impact detector (SOLID) is a large-area impact sensor that can be placed on a spacecraft in any orbit and can provide measurement data in a real-time manner. The SOLID sensor was integrated into the TechnoSat spacecraft of the Technical University of Berlin and successfully launched on a Soyuz rocket from Baikonur, Kazakhstan, on 14 July 2017 into a 600 km orbit.

Measurements

To establish a national space surveillance competence, capabilities of generating and utilizing sensor data are needed, for instance to establish a space object catalogue or to perform orbit determination. Such an object catalogue is the backbone of space situational awareness (SSA) operations. The development of this end-to-end capability requires a coordinated programme of work, covering many different aspects. Such a programme is running at the DLR space administration, beginning with the development and commissioning of the German Experimental Space Surveillance and Tracking Radar (GESTRA) starting in 2015. This system is being developed by the Fraunhofer Institute for High-Frequency Physics and Radar Techniques. It is an experimental system to survey and determine orbital information in low-Earth orbit. Testing of GESTRA is expected to start in mid-2018.

At the same institute, novel concepts for space surveillance by radar are being studied. Multiple options exist to increase the performance of ground-based surveillance radar measurements of space debris. One option that is currently being studied in detail by Fraunhofer is the use of multiple surveillance radars at separated sites. 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.

An optical space debris observation station near Stuttgart in the south of Germany is operated by DLR for research and development. It has the status of an engineering station, participating at the International Laser Ranging Service (ILRS) network. The station is equipped with a 17-inch Dall-Kirkham telescope and various high-end camera systems. Its time-of-flight laser system is operational and has successfully measured the distance to objects in low-Earth orbit with an accuracy of the order of 1 meter. Optical stare-and-chase procedures were demonstrated successfully, allowing for the tracking of uncatalogued objects. In addition, a transportable container system suitable for laser tracking of space debris is currently being tested in the field and is expected to be ready for use and global deployment soon.

A network of optical telescopes called Small-Aperture Robotic Telescope Network (SMARTnet) consists at present of two telescope stations. These stations are located in Zimmerwald, Switzerland, and near Sutherland, South Africa. In a joint effort, these stations are operated remotely 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 20 cm to 50 cm. This network starts to monitor the geostationary region and related orbits to support research on collision avoidance and other scientific topics. Data will encompass objects larger than approximately 30 cm in geosynchronous orbits. Objects fainter than 18.5 magnitudes were already detected and their positions measured. Also clustered satellites had been resolved unambiguously. Observations will be used to further improve the quality of collision avoidance services.

DLR is also developing an information system for space surveillance. Central to the project is the Backbone Catalogue of Relational Debris Information, an orbital database for objects in Earth orbit. 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 being implemented and tested. All algorithms are programmed such that observation data for up to 100,000 objects can be processed in real time. The orbital database will be used primarily to predict close approaches for purposes of collision avoidance, but it can be expanded for other applications. 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 required accuracy.

IRAS is currently developing a software tool to simulate space debris measurements from different sensor types, including radar and optical sensors. At the same time, key functionalities such as object correlation, orbit determination and an object database are implemented. Once finalized, the software tool can be used to investigate different methods for orbit determination and propagation as well as to ensure the availability of fast and accurate methods within the processing chain of a simulated space surveillance system. Furthermore, the tool will be able to analyse the performance of arbitrary sensor networks. Also, an optical telescope is being installed at a site near IRAS to observe space debris and support research activities.

On-orbit and on-ground risk assessment

A new numerical algorithm based on the discrete-element method is applied to simulate hypervelocity impacts on spacecraft and the subsequent material failure and fragmentation processes. This software, developed at the Fraunhofer Institute for High-Speed Dynamics, has been applied to simulate impact events of small debris particles in the hypervelocity regime. Simulated impact generated debris clouds have been compared with hypervelocity impact experiments. The ultimate objective of the study is to apply the new method for the simulation of complex spacecraft fragmentations resulting from space debris impact and spacecraft collisions.

In order to mitigate the on-ground casualty risk posed by uncontrolled re-entering objects, a new method was developed at DLR to improve the break-up behaviour during the re-entry phase caused by aerodynamic forces. Simulation results show that the total causality area for a typical upper stage can be reduced by a factor of more than five.

Several German companies and research organizations are currently involved in European Space Agency studies addressing the topic of space debris re-entry, recently including a first study on the re-entry of the International Space Station (ISS). Design-for-demise (D4D) studies are focused on innovative engineering solutions for spacecraft components in order to achieve as much demise as possible during re-entry, consequently reducing the on-ground risk. Currently, the focus of theses D4D activities is on intended early break-up of satellites during re-entry and dedicated analyses on the demisability of specific spacecraft components. Within the study “Atmospheric impact of spacecraft demise (ATISPADE)”, the impact of spacecraft demise on the Earth’s atmosphere and climate is investigated. Regarding the evolution of re-entry simulation software, the ESA Debris Risk Assessment and Mitigation Analysis (DRAMA) suite is currently being upgraded.

The University of Stuttgart, in cooperation with a small company named HTG, has started a project to experimentally and theoretically analyse the failure criteria for aerospace structures for re-entry break-up. For this purpose, high-enthalpy wind tunnel facilities are used for dedicated aerothermal testing to determine failure criteria for break-up during uncontrolled re-entry under thermal and mechanical loads. The results will be used to compile break-up criteria for re-entry prediction tools.

Mexico

[Original: Spanish]
[29 September 2017]

Mexico collaborates with the Working Group on the Long-term Sustainability of Outer Space Activities within the four expert groups: expert group A, on sustainable space utilization supporting sustainable development on Earth; expert group B, on space debris; expert group C, on space weather; and expert group D, on regulatory regimes and guidance for actors in the space arena.

In that regard, with respect to national research on space debris, and in accordance with the practice on the elimination of debris, the National Autonomous University of Mexico, through the School of Engineering and its High-technology Centre, has been carrying out work aimed at planning future missions with a focus on sustainability.

That work covers the detection of space particles, the development of mathematical models of debris production, the measurement of that debris and the creation of protection plans. Furthermore, the National Autonomous University of Mexico is working to install a vacuum chamber and an electromagnetic radiation chamber for testing satellites and their capacity to cancel out such interference to reduce the likelihood that they will malfunction during space operations and become space debris. The University is also working to develop electrical power propulsion units in order to ensure that once satellites reach the end of their useful life, they leave their orbit, re-enter the Earth's atmosphere and disintegrate, thus avoiding the production of additional space debris.

With respect to the monitoring of space debris in order to ensure the safety of space infrastructure, the Autonomous University of Sinaloa, through the use of its telescope, has joined international efforts led by the International Scientific Optical Network (ISON). Space debris has been monitored since 2012, and almost a dozen new objects are discovered every year, including fragments and lost satellites that have left their geostationary orbit. The Centre for Research on Physical and Mathematical Sciences of the Autonomous University of Nuevo León, which is part of the international project for monitoring space debris comprising a network of 25 observatories in more than 15 countries under the coordination of the Keldysh Institute of the Russian Academy of Sciences, has also joined those efforts.

All of the aforementioned activities are conducted in accordance with international regulations such as the space debris mitigation guidelines of the Inter-Agency Space Debris Coordination Committee, International Telecommunication Union recommendation ITU-R S 1003 ("Environmental protection of the geostationary orbit"), the standards of the European Code of Conduct for Space Debris Mitigation, and International Organization for Standardization (ISO) 24113 (Space systems: space debris mitigation requirements). Mexico also took part, alongside Canada, Czechia and Germany, in the initiative to create a compendium of space debris mitigation standards, which was presented at the fifty-third session of the Legal Subcommittee of the Committee on the Peaceful Uses of Outer Space. It is the first document to contain direct information for Member States, including Mexico, on regulatory measures to reduce and eliminate space debris (see A/AC.105/C.2/2014/CRP.15, p. 31).

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

With regard to the safety of space objects with nuclear power sources on board, Mexico complies with the relevant principles on the use of nuclear power sources in outer space, and has maintained its position on the non-militarization of outer space and the peaceful use of outer space. It is governed by international instruments such as the Treaty for the Prohibition of Nuclear Weapons in Latin America and the Caribbean (Treaty of Tlatelolco). Mexico is party to the Convention on Nuclear Safety, which addresses the issue of safety as a preventive and systematic endeavour and reflects the importance that the international community attaches to ensuring that the use of nuclear energy is safe, well-regulated and environmentally sound.

Notwithstanding the foregoing, Mexico is party to the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, article IV, paragraph 1, of which states the following:

> "States Parties to the Treaty undertake not to place in orbit around the Earth any objects carrying nuclear weapons or any other kinds of weapons of mass destruction, install such weapons on celestial bodies, or station such weapons in outer space in any other manner."

III. Replies received from international organizations

European Space Agency

[Original: English]
[26 July 2017]

ESA's Annual Space Environment Report, Technical Note GEN-DB-LOG-00208-OPS-GR, rev. 2 (Darmstadt, Germany, ESA Space Debris Office, 2017) is available at https://www.sdo.esoc.esa.int/environment_report/Environment_Report_I1R2_20170427.pdf.