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Item 8 of the provisional agenda*
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. In its resolution 70/82, the General Assembly, deeply concerned about the fragility of the space environment and the challenges to the long-term sustainability of outer space activities, in particular the impact of space debris, which was an issue of concern to all nations, considered it essential that States pay more attention to the problem of collisions of space objects, especially those with nuclear power sources, with space debris, and other aspects of space debris. It called for the continuation of national research on that question, for the development of improved technology for the monitoring of space debris and for the compilation and dissemination of data on space debris. The Assembly also considered that, to the extent possible, information thereon should be provided to the Scientific and Technical Subcommittee of the Committee on the Peaceful Uses of Outer Space, and agreed that international cooperation was needed to expand appropriate and affordable strategies to minimize the impact of space debris on future space missions.

2. At its fifty-second session, the Subcommittee agreed that Member States and international organizations with 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 ways in which debris

* A/AC.105/C.1/L.336.

mitigation guidelines were being implemented (see A/AC.105/1088, para. 113), and on this basis an invitation was issued in a note verbale dated 27 July 2015 to provide the reports by 19 October 2015, so that the information could be made available to the Subcommittee at its fifty-third session.

3. The present document has been prepared by the Secretariat on the basis of information received from four Member States, namely Austria, Finland, Germany and Japan, and from the World Meteorological Organization (WMO). The information provided by Japan, which includes pictures and figures related to space debris, will be made available as a conference room paper at the fifty-third session of the Subcommittee.

II. Replies received from Member States

Austria

[Original: English]
[19 October 2015]

National research on space debris

Since 1982, 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. Day and night, seven days a week, this station measures distances to more than 60 retro-reflector equipped satellites, such as geodetic satellites, global navigation satellite system satellites (such as GALILEO, GPS, GLONASS, COMPASS), Earth observation satellites and various scientific and research satellites. The Graz SLR station is still considered one of the most accurate in the world.

In 2012, the Graz laser station started to test laser ranging of space debris objects. New specialized single-photon detectors were developed, and the laser ranging software for space debris tracking was adapted. For the first time, photons diffusely reflected by space debris objects were measured to determine the distance to those objects. Although the accuracy of the measurements is not in the millimetre range, given that the selected debris objects are one to a few metres in size, this approach does allow for significantly better orbit determination.

Additional improvements to orbit determination are possible if other SLR stations are able to detect the diffusely reflected Graz photons. In 2012 the first such experiment was successful; photons emitted in Graz were diffusely reflected by the bodies of satellites and detected at the Zimmerwald SLR station in Switzerland, which for this purpose had been synchronized with the Graz station. This method can be extended without difficulty to several other receive-only stations.

Since 2013, the Graz laser station has been involved in the space situational awareness programme of the European Space Agency (ESA). In the coming years cooperation will be increased at the European and international levels. Since 2014, the station has also been involved in setting up an operational European space situational awareness programme network.

Space law

In 2015, a regulation of the Federal Minister for Transport, Innovation and Technology for the implementation of the federal law on the authorization of space activities and the establishment of a national space registry entered into force. In order to prevent the generation of space debris, in accordance with article 5 of the law, operators must fulfil certain requirements. A report on preventing the generation of space debris during the operation and preventing the breakup of the space object in orbit, in which the internationally accepted guidelines on space debris are taken into account (e.g. the maximum limit of 25 years in orbit), must be approved. The report must include a representation of the measures taken in outer space activities to avoid collisions with other space objects. Furthermore, appropriate documentation is needed to prove that the space object does not contain dangerous or harmful substances that can lead to the contamination of space or adverse environmental changes.

Finland

[Original: English]
[27 October 2015]

Research on space debris is carried out by:

(a) The Finnish Geospatial Research Institute of the National Land Survey;

(b) Oulu University, through the use of European Incoherent Scatter Scientific Association radars.

Finland is preparing the launch of its first satellite, Aalto-1, which is a 3-kg CubeSat. The satellite has a braking device based on the electric sail concept (see www.electric-sailing.fi) that could allow the satellite to be brought down much faster than would be possible without the brake.

Germany

[Original: English]
[19 October 2015]

In Germany, research activities on issues related to space debris are being carried out in all relevant fields, such as space debris environment modelling, observation of space debris, studies of the effects of hypervelocity impact on spacecraft, and protection of space systems from the impact of micrometeoroids and space debris. German experts actively participate in relevant international forums in the field of space debris research, including the Inter-Agency Space Debris Coordination Committee (IADC), and in international standardization activities in the field of space debris mitigation.

For space projects sponsored by the German Aerospace Centre (DLR), space debris mitigation requirements are a mandatory 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 Space Debris Mitigation Guidelines of IADC and the Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space. The general objectives are to limit the creation of new space debris and thus to limit the risk to current and future space missions and the risk to human life. The measures to be adopted in order to achieve these objectives include the conduct of a formal space debris mitigation assessment; the implementation of specific design measures to prevent the release of mission-related objects, fragmentations, malfunctioning and on-orbit collisions; and the adoption of measures pertaining to passivation, end-of-life disposal and re-entry safety.

In order to establish a national space surveillance capability, a country must have the capabilities for generating and utilizing sensor data, for instance to establish a space object catalogue or to perform orbit determination. Such an object catalogue is the backbone of space situational awareness operations. The development of this end-to-end capability requires a coordinated programme of work, covering many different aspects. Such a programme was set up by the DLR Space Administration, and began with the commissioning of the German Experimental Space Surveillance and Tracking Radar (GESTRA) in 2015. GESTRA, which is being developed by the Fraunhofer Institute for High Frequency Physics and Radar Techniques, is an experimental system to determine orbital information in low Earth orbit (LEO); testing is expected to start late in 2017.

Software to simulate sensor measurement data is being developed at the Institute of Space Systems (IRS) at the Technische Universität Braunschweig. On the basis of the simulated data, key functionalities, such as object correlation, orbit determination and implementation of an object database, are implemented. Complementary methods for orbit determination and propagation are being investigated so as to ensure the availability of fast and accurate methods within the process chain of a simulated space surveillance system.

Efforts are under way to develop a network of optical stations set up by the German Space Operations Centre (GSOC) at DLR in close cooperation with the Astronomical Institute of the University of Bern, Switzerland. It is intended for continuous monitoring of the geostationary regions and related orbits to support collision avoidance and scientific research, and its telescopes are operated telerobotically by GSOC at DLR. The data captured will make it possible to track and predict the orbit of geostationary objects larger than approximately 50 cm. The Sutherland Observatory in South Africa has been chosen as the location for the first telescope station, to be set up early in 2016. Several test campaigns have been successful, resulting in a detectable object magnitude of better than 18 mag. In a joint project between the Institute for Simulation and Software Technology and the Space Operations and Astronaut Training department, both at DLR, an orbital database for objects in Earth orbit is being developed. The main research topics are object identification through different sensor observations, orbit determination and orbit propagation, including state vector and state uncertainty. The optical telescope network will provide the first observation data to be processed through the database.

At the Technische Universität Braunschweig, activities to analyse the long-term evolution of the space debris environment are ongoing. One completed project focused on porting propagation methods to graphic processing units to achieve a drastically lower computation time. Furthermore, more detailed simulations of the evolution of the environment have been carried out to investigate the effects of mitigation measures and active debris removal, with a special focus on the associated costs. Additionally, scenarios for the medium Earth orbit and geostationary orbit environment have been investigated. A new activity builds on those achievements to utilize the decreased runtime of long-term simulations, investigate the uncertainties within those, partly within the framework of an IADC activity, analyse the impacts of current trends in space flight, such as the increase in CubeSats, and perform more detailed cost analyses.

Materials on the exterior of spacecraft are exposed to the harsh environment of space, which causes degradation. The main threats are charged particle radiation, ultraviolet radiation, atomic oxygen in LEO, extreme temperatures, thermal cycling and impacts of micrometeoroids and debris. The relative impact of the individual threats depends on the type of mission to be performed, the mission duration, the solar cycles, solar events and the orbit in which the spacecraft will be placed. Sources of degradation particles are the paint applied to upper stages, and the multilayer insulation foil that is used on almost every spacecraft to maintain the operation temperature. The degradation process and the inherent release and generation of particles smaller than 1 mm are simulated on the basis of empirical modelling parameters.

Active removal of space debris is another area of research at IRS. Different approaches using various technologies, such as robotic arms and tethers or nets, are under consideration, and the benefits and challenges of those approaches have been researched. On that basis, last year, Airbus Defense and Space GmbH Bremen and IRS launched a joint project for research into tethered removal of large debris objects; objectives include the development of control algorithms and laws for the stabilization and secure deorbiting of a tethered space system constituting a chaser, a tether and an uncooperative target. IRS determined the influence of orbital perturbations on tethered space systems using the Tether Orbital Perturbations Influence Determinator (TOPID) software tool it created.

Several German companies and research organizations are currently involved in ESA studies addressing the topic of space debris re-entry. The objective of the Characterization of Demisable Materials project is to increase knowledge about material behaviour and demise processes during re-entry in order to reduce the uncertainties of the simulation tools currently used for re-entry risk assessment. The high-enthalpy-flow wind tunnels of DLR in Cologne are used in particular for this purpose. The Rapid Assessment of Design Impact on Debris Generation activity is aimed at developing a new generation re-entry analysis tool with the capability to be used in concurrent engineering facilities and with automatic design optimization features. Design-for-demise 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.

The new In-Orbit Tumbling Analysis tool will provide a long-term, six-degrees-of-freedom propagator, supporting future active debris removal missions with reliable predictions of the tumbling rates of the target objects.

Japan

[Original: English]
[23 October 2015]

1. Overview

Further to the request from the Office for Outer Space Affairs of the Secretariat, Japan submits the following information on its debris-related activities, conducted mainly by the Japan Aerospace Exploration Agency (JAXA).

An overview of the JAXA strategic plan for space debris was included in the note by the Secretariat on national research on space debris, safety of space objects with nuclear power sources on board and problems relating to their collision with space debris (A/AC.105/C.1/107).

In the section below, major advances are presented in the following debris-related activities conducted by JAXA during 2015:

(a) Research on conjunction assessment and on core technology for space situational awareness;

(b) Research on technology for observing objects in LEO and geosynchronous Earth orbit (GEO) and for determining the orbits of such objects;

(c) In situ microdebris measurement system;

(d) Protection from the impact of microdebris;

(e) Development of a propellant tank that easily disintegrates during re-entry;

(f) Active debris removal.

2. Status

2.1. Research on conjunction assessment and on core technology for space situational awareness

JAXA regularly receives conjunction notifications from the Joint Space Operations Center. For example, in September 2015, the number of notifications received was 64, which exceeded a specific conjunction threshold value. Between 2009 and 2015 (September), JAXA executed 15 collision avoidance manoeuvres for LEO spacecraft.

In parallel, JAXA determines the orbit of space objects by using radar and telescope observation data from the Kamisaibara and Bisei spaceguard centres of the Japan Space Forum, predicts close approaches using the latest orbit ephemerides of JAXA satellites, and calculates probability of collision using its in-house methods.

Also, JAXA evaluates the criteria for conjunction assessment and collision avoidance manoeuvres based on its experience. In its evaluations, the trends in conjunction conditions and prediction errors due to perturbations (e.g. uncertainty in air drag) are analysed.

JAXA, through a simplified fragmentation model, succeeded in identifying the origin of GEO fragmentation debris by using the optical-observation data acquired by the Bisei spaceguard centre in its collaborative research with Kyushu University.

2.2. Research on technology for observing objects in low Earth orbit and geosynchronous Earth orbit and for determining the orbits of such objects

Generally, the observation of LEO objects is conducted by radar, but JAXA has been trying to use optical systems instead to reduce the cost of both construction and operation. Arrays of optical sensors are used to cover large regions of the sky. Survey observations using an 18-cm telescope and a charge-coupled device (CCD) camera showed that objects 30 cm or more in diameter were detectable at an altitude of 1,000 km and that 15 per cent of those were uncatalogued. For GEO observation, a field-programmable gate array board that can analyse 32 frames with a resolution of up to 4,096 x 4,096 pixels (commonly referred to as 4K x 4K) in 40 seconds confirmed that objects 14 cm in diameter were detectable by analysing CCD images taken with a one-metre telescope at the Bisei spaceguard centre. Compared with the current size limit for detecting objects in GEO, reported to be 1 metre, this result can be said to show that the technique is effective for detecting small fragments caused by break-ups in the GEO region.

2.3. In situ microdebris measurement system

For microdebris (less than 1 mm in diameter), which cannot be detected from the ground, JAXA is developing an on-board detector for in situ measurement. Its sensor, referred to as the space debris monitor, is the first to apply a sensing principle based on conductive (resistive) lines.

If such sensors were installed on a large number of spacecraft, the data acquired could help to improve the debris environment model. The first such space debris monitor was launched with the H-II Transfer Vehicle Kounotori-5 (HTV-5) on 19 August 2015, for the first microdebris measurement experiment on the International Space Station using conductive (resistive) lines for detection. JAXA is currently conducting an analysis of the data acquired.

Currently, little is known about tiny debris and micrometeoroids in outer space, although having such knowledge is essential for impact risk assessment, for spacecraft survivability analysis and for designing cost-effective protection for spacecraft. It would be very welcome if the world’s space agencies launched such detectors on their spacecraft, shared the data collected and thus contributed to the improvement of the existing debris and meteoroid models.

2.4. Protection from the impact of microdebris

The amount of LEO microdebris (less than 1 mm in diameter) has increased. The impact of microdebris can inflict critical damage on satellites because its impact velocity is, on average, 10 km/s.

To assess the effects of debris impact on satellites, JAXA is conducting hypervelocity impact tests and numerical simulations for structural panels and bumper shield materials. Internal damage to structure panels has also been investigated with the help of numerical simulations.

The results of that research are reflected in the “Space debris protection design manual” (JAXA manual JERG-2-144-HB). The original version of the manual was published in 2009, and it was revised in 2014.

JAXA has developed a debris impact risk assessment tool named Turandot. Turandot analyses debris impact risks using a three-dimensional model of a spacecraft. Turandot has been updated to apply the latest ESA debris environment model, MASTER-2009.

2.5. Development of a propellant tank that easily disintegrates during re-entry

Propellant tanks are usually made of titanium alloys, which are superior because of their light weight and good chemical compatibility with the propellants used. However, their melting points are so high that they would generally not disintegrate during re-entry, and pose a risk of casualties on the ground.

JAXA has conducted research to develop an aluminium-lined tank overwrapped with carbon composites, which will have a lower melting point. As a feasibility study, JAXA has conducted fundamental tests, including one to determine the compatibility of aluminium as a liner material with hydrazine propellant, and an arc heating test. JAXA has produced a prototype for a scale model named Trial 1. Vibration tests were conducted on a propellant management device to confirm its tolerance to the launch environment. The next step is trial production of the full-scale tank and a qualification test. Once it has passed the qualification test, the tank will cost less and have a shorter manufacturing lead time than previous titanium tanks.

2.6. Active debris removal

JAXA is studying a cost-effective active debris removal system that can rendezvous with and capture non-cooperative debris objects in crowded orbits to de-orbit them. Key technologies for realizing active debris removal have been studied, such as non-cooperative rendezvous using image sensors, and capture using extensible booms, harpoons and other approaches. An electrodynamic tether system is promising not only because it can de-orbit debris without any propellant, but also because it is easy to attach to the debris object. A flight demonstration of electrodynamic tethers is planned for the H-II Transfer Vehicle Kounotori-6 (HTV-6), and electrodynamic tether components are being manufactured and tested in 2015.

III. Replies received from international organizations

World Meteorological Organization

[Original: English]
[10 August 2015]

WMO relies on the use of space-based assets for many essential activities, primarily for the observation of atmospheric and other environmental variables in support of weather prediction, climate monitoring, disaster risk reduction and other applications, as well as for telecommunications and satellite-based navigation.

Therefore, the safety and sustainability of the use of space-based systems is an important concern. In this respect, WMO values the efforts of the Office for Outer Space Affairs to foster collaboration and progress on the mitigation of the risk related to space debris. WMO will bring this issue to the attention of the Expert Team on Satellite Systems of the Commission for Basic Systems.