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Committee on the Peaceful Uses of Outer Space

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 65/97, the General Assembly considered that it was essential that Member States pay more attention to the problem of collisions of space objects, including those with nuclear power sources, with space debris, and other aspects of space debris; 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; 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 forty-seventh session, the Scientific and Technical Subcommittee agreed that research on space debris should continue and that Member States should make available to all interested parties the results of that research, including information on practices that had proved effective in minimizing the creation of space debris (A/AC.105/958, para. 80). In a note verbale dated 13 August 2010, the Secretary-General invited Governments to provide by 22 October 2010 reports on research on space debris, the safety of space objects with nuclear power sources on board and problems relating to the collision of such space objects with space debris, so that the information could be submitted to the Subcommittee at its forty-eighth session.

3. The present document has been prepared by the Secretariat on the basis of information received from the following Member States: Canada, Germany, Japan, Slovakia, Spain, and the United Kingdom of Great Britain and Northern Ireland, and from the following international organization: the Planetary Society. Information

provided by Finland, entitled "National research on space debris, near-Earth objects and the Space Weather Initiative: list of national assets potentially available for the European Space Situational Awareness programme", which includes a list of national assets related to near-Earth objects, will be made available in English only on the website of the Office for Outer Space Affairs of the Secretariat (www.unoosa.org) and as a conference room paper at the forty-eighth session of the Scientific and Technical Subcommittee.

II. Replies received from Member States

Canada

[Original: English]
[9 November 2010]

Canada is actively involved in discussions and projects related to space debris at the national and international levels.

Canadian space debris mitigation research activities

The Canadian Space Agency (CSA) leads space science and technology initiatives related to space debris, working with academic and other Government department stakeholders.

The development of an implosion-driven hypervelocity test facility, which provides a unique capability to accelerate masses to debris velocities, allowing full impact regimes to be investigated, has put Canada in a leading position on this issue.

Canada is now developing fibre-optic-based sensors that will be incorporated into self-healing composites to assess the impact of space debris, while mitigating secondary debris propagation.

CSA has established an internal Orbital Debris Working Group to facilitate the exchange of information and to provide the expertise required for supporting future space debris research activities.

Current operational practices

Throughout 2010, CSA witnessed an increasing number of collision threats to Canadian space assets (Radarsat-1, Radarsat-2, Scisat-1 and MOST), necessitating spacecraft debris collision avoidance manoeuvres. At the same time, there is recent evidence of space debris impacts on the Mobile Remote Servicer Base System and on the Space Station Remote Manipulator System (Canadarm2), two of the three components of the Mobile Servicing System that constitute the advanced robotics contribution of Canada to the International Space Station.

During the first 10 years of operation of Radarsat-1, only one close approach alert was signalled. The situation is now drastically different. Since January 2010, 12 alerts, leading to four collision avoidance manoeuvres and five ground track recovery operations (post-avoidance manoeuvres), have been undertaken. Those alerts included actions taken in avoidance of other active spacecraft and space debris.

Owing to the potential impact on its space assets, CSA has established a detailed procedure to facilitate a timely and systematic reaction to close approach alerts. Avoidance manoeuvre criteria have been established, creating a virtual collision avoidance box. Although close approach alerts are all unique and require special attention, the criteria significantly facilitate the decision-making process.

Decisions are taken on the basis of available information. CSA makes use of information from the Joint Space Operations Center of the United States of America, the German Space Agency conjunction data analysis information, and SOCRATES-LEO data analysis. Information is received twice a day and provides a seven-day forecast summary of potential close approaches. By combining the data received from these sources, CSA is improving its early warning system in support of its spacecraft operations.

Canada recognizes the support received from the Joint Space Operations Center and the active role it plays in providing precise and timely information. It also recognizes the support received from the German Space Agency and SOCRATES-LEO, which is critical for actively planning, managing and mitigating close approach threats.

In 2011, Canada will be launching the NEOSSat spacecraft and, once it is commissioned, will be providing operational data to the Joint Space Operations Center using its High Earth Orbit Space Surveillance Sensor.

In addition, 2011 will see the launch of the national defence satellite Sapphire. Sapphire is a space-based optical sensor that will provide observations of high Earth-orbit objects and contribute to a broader operational awareness of the space domain. Sapphire data will contribute to the United States Space Surveillance Network in order to support efforts to increase safety in space.

International activities

CSA recognizes the important role played by the international community in the coordination and management of space debris research activities and looks forward to working actively with other space agencies as a future member of the Inter-Agency Space Debris Coordination Committee (IADC).

Germany

[Original: English]
[4 November 2010]

Below is a summary of nationally funded research activities carried out in Germany in 2010.

German Space Operations Center collision avoidance system

The German Space Operations Center is developing a collision avoidance system to identify close approaches between the satellites operated by the Center and other space objects, on the basis of the USSTRATCOM two-line elements catalogue. A first basic monitoring system has been operational since November 2009. In case of an alert, the situation is analysed in more detail so that a decision can be taken on whether measures are necessary to avoid a collision. The refinement of the orbit knowledge of the other space object by radar tracking could be required. If the risk of collision is too high, a collision avoidance manoeuvre is implemented. Since the system has been in operation, the Center has analysed 10 critical events and has executed five collision avoidance manoeuvres with its satellites TerraSAR-X and TanDEM-X.

The system is currently being enhanced with various tools that support the evaluation and analysis of critical conjunction events, helping to widely automate the system. The conjunction summary messages released by the Joint Space Operations Center/USSTRATCOM will also be included in the process.

Fraunhofer Ernst-Mach-Institut: improvement of hypervelocity impact test capabilities

The Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institut in Freiburg, is well known for its expertise in conducting vulnerability and survivability analysis for spacecraft with regard to the impact of space debris and micrometeoroids. For the analysis, the Institute performs hypervelocity impact experiments on spacecraft components with two-stage light-gas guns. The guns allow millimetre-sized projectiles to accelerate to speeds greater than 8 kilometres per second, which is the current performance limit of the guns for routine operations. For realistic simulation of encounter scenarios in low-Earth orbit in a laboratory environment, the velocities to be routinely achieved should be above 10 kilometres per second and ideally should approach 15 to 16 kilometres per second.

Currently, there are two ongoing national projects aimed at improving the light-gas gun test facilities at the Institute. Their objectives are to be able to simulate hypervelocity impacts at velocities of about 10 kilometres per second without changing the physical properties of the projectile during the acceleration process, and to reduce the light-gas gun loads in order to reduce experiment costs. For that purpose, an existing light-gas gun is being upgraded to allow it to accelerate millimetre-sized particles to velocities of 10 kilometres per second in a reproducible manner. A new type of high-pressure gun bore has been developed and manufactured, which consists of a carbon-fibre-overwrapped very hard metal matrix composite. Furthermore, a new accelerator concept, based on the light-gas gun acceleration technique, the so-called TwinGun, is being developed at the Institute to accelerate particles smoothly to high velocities. During the reporting period, the gun components were manufactured and the integration of the facility began.

Both new accelerators will help to improve understanding of the physics of impacts in the upper hypervelocity regime and contribute to the development of improved spacecraft components in terms of particle impact threats.

Technical University of Braunschweig: analysis of accumulation of space debris in sun-synchronous orbits and the economics of debris removal

At the Technical University of Braunschweig, a recent analysis of the space debris problem has revealed an accumulation of objects, in particular objects in sun-synchronous orbits. These orbits are important for Earth observation missions, among others. Introducing space debris mitigation measures is a way of allowing long-term use of sun-synchronous orbits. The results show that the debris population close to 900 kilometres will continue to grow. A very effective mitigation measure can be the immediate de-orbiting of spent upper stages and satellites at the end of their lives. In the simulations, the biggest cost savings are obtained if de-orbiting measures are introduced quickly. The analysis showed that immediate de-orbiting has significant advantages in terms of both economics and the evolution of future catastrophic collisions.

A follow-up project has been launched to investigate the economics of the active removal of large objects from sun-synchronous orbits. It will focus on identifying and studying objects with the highest collision risk. To keep the cost of active removal low, the number of removed objects should be limited to those with a high collision risk; a priority list should be established in which the target objects are sorted according to those that present the greatest risk of being involved in a catastrophic collision. A cost and benefit analysis will be made by comparing the cost of satellite damage as a result of debris impact with the expenses of mitigation.

Japan

[Original: English]
[29 October 2010]

Overview

Research relating to space debris in Japan, mainly conducted by the Japan Aerospace Exploration Agency (JAXA), has concentrated on the items below, in conformity with the stance of JAXA on the issue of space debris:

- Preventing damage to spacecrafts caused by collision with debris and ensuring the operation of missions;
- Preventing the generation of debris during the operation of spacecraft and launch vehicles, including by removing mission-terminated space systems from useful orbital regions, and ensuring ground safety from space systems falling to the ground when removed from orbit;
- Promoting research aimed at improving the orbital environment by removing existing large debris from orbit.

Mission assurance

In order to avoid collisions with large debris (larger than 10 centimetres), whose orbital characteristics can be obtained from the database provided by the United States of America, and to minimize the damage from collision with tiny debris (smaller than 1 millimetre), Japan is conducting research and development activities aimed at:

- Improving capability to detect smaller objects, particularly those located in the geostationary orbit above Japan;
- Enhancing technology to assess the risk of collision with tiny debris;

- Developing a detector for tiny debris (smaller than 1 millimetre) to contribute to improving statistical debris models;
- Confirming the vulnerability of critical elements of ordinal satellites and providing protection measures.

Research on observational technologies for space debris in geostationary orbit

The Innovative Technology Research Center of JAXA is undertaking research on observational technologies for space debris in geostationary orbit by developing technologies for detecting uncatalogued debris objects in geostationary orbit and determining their orbits. The stacking method, using multiple charge-coupled device (CCD) images to detect very faint objects that are undetectable on a single CCD image, has been developed since 2000. The only weak point of the stacking method is the time required to analyse the data relating to an unseen object whose movement is not known, because a range of likely paths must be assumed and checked. In order to reduce the time required for the analysis of the stacking method, a field-programmable gate array (FPGA) system is being developed.

The most time-consuming part of the stacking method is calculating the median values of each pixel from the sub-images. As FPGA is a kind of electrical circuit, it shows its power in simple calculations. A more sophisticated and simplified algorithm is required for FPGA. It was discovered that binarizing the sub-images with a proper threshold and then calculating the sum of the binarized sub-images could derive almost the same outcome as the original algorithm of the stacking method. Calculating the sums is much simpler than calculating the median, and it is well suited to FPGA. Moreover, binarization itself reduces the amount of data to one sixteenth, which helps to substantially reduce the analysis time. To execute this algorithm, an FPGA board was developed.

The FPGA board was shown to be able to reduce the analysis time to about one thousandth. The analysis results show the successful work of the FPGA board and its capacity to detect faint objects that are not visible on a single CCD image.

Collision risk analysis tools

A debris collision risk analysis tool has been updated. In addition to assessing debris impact probability for each part of a spacecraft, considering the shielding effect, the tool can now be used to analyse the probability of occurrence of the defined damage mode by setting the ballistic limit equations.

Hypervelocity impact test and analysis

Historically, hypervelocity impact tests have been conducted for manned systems to measure the impact of debris of several millimetres in size. However, since a common satellite can be damaged by debris smaller than 0.3 millimetres, an additional test is needed. Furthermore, as the impact test cannot cover speeds greater than 10 kilometres per second, analytical methods are needed to verify the effects caused by velocities of 12 or more kilometres per second. For example, it was verified analytically that particles as small as 0.3 millimetres in diameter can cause serious damage, such as a sustained arc, to a power supply cable.

JAXA released its Space Debris Protection Design Manual in 2009. The purpose of that document is to specify a procedure for space debris impact risk assessment. The manual contains the results of hypervelocity impact tests and numerical simulations of some components frequently used in satellites. In order to support spacecraft design, the more rigorous document, Standard Procedure for Risk Assessment for Micro-debris Impact, will be released in 2011.

Collision risk avoidance

JAXA has monitored close approaches between its large satellites and other space objects. Orbital information of space objects is received from the United States Space Surveillance Network and provided in the two-line element format. The automated collision risk assessment is performed daily, with seven-day predictions, and the result is sent by e-mail. When conjunctions that meet established criteria are detected, JAXA considers radar observation, as far as possible, in order to receive more accurate orbital information of risk objects. When the collision risk remains high following the precise conjunction assessment, a collision avoidance manoeuvre will be undertaken, if the satellite has a manoeuvring function.

JAXA developed a conjunction assessment tool in 2007. In order to conduct the assessments efficiently, a sequence of processes, as described above, is performed by that tool. The tool has a three-dimensional visualization function to help understanding of the situation.

Preservation of environment and safety assurance on the ground

The importance of the debris issue is clearly stated in the Japanese Basic Plan for Space Policy. JAXA is applying a space debris mitigation standard, in compliance with guidelines of the Committee on the Peaceful Uses of Outer Space.

The debris mitigation plan is required for every project, and compliance with the standard is reviewed at every critical phase in the development lifecycle. The following mitigation efforts are required:

- Refraining from releasing mission-related objects;
- Preventing in-orbit break-ups;
- Re-orbiting mission-terminated geosynchronous satellites from the geostationary orbit -protected region;
- Removing mission-terminated spacecraft passing through the low-Earth orbit protected region;
- Preventing collision with large debris;
- Preventing damage from collision with tiny debris.

When mission-terminated space systems are re-entered to Earth, ground safety should be assessed and ensured. If there is a casualty risk, controlled re-entry should be selected.

JAXA has developed a new safety guideline for controlled re-entry. The H-II Transfer Vehicle (HTV-1) was the first spacecraft to implement the controlled re-entry process on the basis of the guideline.

The HTV-1 re-entry process consisted of several manoeuvres, all of which had been planned and prepared before the spacecraft's departure from the International Space Station. Once it had departed, HTV-1 made descending manoeuvres to the standby orbit. As a result, HTV-1 maintained a healthy condition on both primary and secondary strings at its departure from the Station. HTV-1 implemented the successful final de-orbit manoeuvre on 1 November 2009 (GMT), and all the fragments were expected to be within the planned footprint, based on the real-time monitor.

Improvement of orbital environment

In line with the background information contained in the Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space, and reports of some space agencies, collision among existing orbital objects is expected to be a major source of debris in the future.

Recent studies by various space organizations have revealed that an effective and adequate means of keeping the environment stable would be to remove a mere 100 large objects from the most useful and crowded orbital region.

JAXA is studying an active space debris removal system, which consists of a small spacecraft (a microsatellite capable of a piggyback launch with other payloads) that transfers large debris objects occupying useful orbits to a disposal orbit.

Electrodynamic tether technology is being investigated for a high-efficiency propulsion system for active debris removal in low-Earth orbit. A demonstration flight of electrodynamic tether using a small satellite has been studied, and some key components have been developed. Japan conducted some on-ground tests, such as hypervelocity impact tests for conductive tethers, tether deployment tests and a long-duration test of field emission cathode for electron source.

Slovakia

[Original: English]
[4 November 2010]

The Faculty of Mathematics, Physics and Informatics of Comenius University in Bratislava is undertaking a project on orbital evolution of arbitrarily shaped cometary and asteroidal dust particles.

On the basis of infrared astronomical satellite observations, which indicate that the observed shape of the zodiacal cloud can be accounted for by a combination of asteroidal and cometary dust, it has been noted that the orbital evolution of the realistically shaped and composed dust particles differs significantly, depending on the origin of the particles. This raises a question about the dynamical evolution of such particles in the solar system and their possible capture in orbital resonances with the planets.

The project is aimed at investigating the dynamical behaviour and lifetimes of cometary and asteroidal dust particles and simulating their interactions with the

Earth, in order to verify how inaccurate present models are, based on the assumption of ideally spherical and homogeneous interplanetary dust particles.

Some of the results indicate that the lifetime and the orbital elements of the particles will depend on both the particle topology and morphology. Comparison with the action of other non-gravitational effects influencing orbital evolution is also important.

Spain

[Original: Spanish]
[8 November 2010]

Spain is currently participating in the European Space Agency (ESA) Space Situational Awareness Programme, which is designed to ensure the safe operation of European space assets. The initiative includes activities such as the detection and monitoring of space debris and warnings of possible collisions with space debris.

Under the Programme, Spain is leading the development of a prototype for a monostatic radar, which is needed in order to detect space objects that are to be included in a future catalogue of objects. That catalogue of space objects will form the basis of the collision alert system.

The Programme, which is aimed at improving safety in the space environment, does not, however, include specific activities concerned with studying the problems of nuclear power sources in space.

The Astronomical Observatory of Mallorca, together with Spanish companies such as Deimos, is participating in research and development projects aimed at reutilizing systems for the observation of near-Earth objects in conjunction with tools for autodetection and reduction of observations in order to detect objects in geostationary orbits.

United Kingdom of Great Britain and Northern Ireland

[Original: English]
[1 December 2010]

Introduction

The United Kingdom of Great Britain and Northern Ireland has maintained an active role in addressing the problem of space debris through its continued membership of important international forums such as IADC and the Orbital Debris Coordination Working Group of the International Organisation for Standardisation (ISO). The United Kingdom has contributed to IADC technical studies and discussions that are aimed at providing greater understanding of the evolving space debris population and methods to protect against it. This process is essential for achieving international consensus on future space debris mitigation guidelines. From 9 to 12 March 2010, the United Kingdom, through the British National Space Centre, participated in the 28th IADC meeting, which was hosted by the Indian Space Research Organisation in Trivandrum, India. A representative from the British

National Space Centre has chaired the ISO Working Group, which is tasked with overseeing the development of a set of ISO space debris mitigation standards that are consistent with IADC guidelines, since its inception in 2003. During the past year, the first tranche of international standards on debris mitigation were published and it is expected that they will soon be implemented in space projects around the world.

To meet its obligations under United Nations outer space treaties, the United Kingdom operates a licensing scheme to permit the launch and operation of United Kingdom satellites in outer space. In April 2010, with the replacement of the British National Space Centre by the UK Space Agency, the role of licensing authority passed to the new Agency. As was the case under the British National Space Centre, licences will be granted only following a technical evaluation of applications. The conformance of spacecraft and launch vehicles with international debris mitigation guidelines and standards, such as those described above, is an important consideration in the decision to grant a licence.

Following the collision between the Iridium-33 and Cosmos-2251 satellites in February 2009, the need to improve monitoring of objects in orbit around the Earth is now widely recognized. In this regard, the United Kingdom has confirmed its intention to participate in the ESA Space Situational Awareness system. Monitoring, modelling and analysis of the space environment represent core tasks of the planned system.

Further details on some of the space debris mitigation activities of the United Kingdom are provided below.

Observation of space debris

The UK Space Agency has continued the participation undertaken in previous years by the British National Space Centre in IADC campaigns to predict the re-entry of space objects into the Earth's atmosphere. The technical lead for this activity in the United Kingdom is Space Insight Ltd., which provides support to the UK Space Agency for a range of activities related to space situational awareness. This operational support provides, among other things, information on anticipated re-entries of risk objects and (using Starbrook sensors) monitoring of platforms licensed under the United Kingdom Outer Space Act in order to ensure compliance of licensees' activities with the obligations of the United Kingdom under the United Nations outer space treaties. In addition to their national regulatory role, Starbrook observations underpin the contributions of the United Kingdom to IADC debris population measuring campaigns.

Debris environment modelling

In the IADC Working Group on Environment and Databases, the UK Space Agency is represented by the University of Southampton, which is currently participating in a study using its DAMAGE evolutionary model to assess the stability of the current debris population. This activity will set the baseline for any future investigation of active debris removal. In addition, the impact of changes in the thermosphere, especially during the recent solar minimum, on the effectiveness of active debris removal has been investigated.

Spacecraft debris protection and risk assessment

To support the activities of the IADC Working Group on Protection, the UK Space Agency representative, PHS Space Ltd., has contributed to two tasks in which information has been gathered on current agency/industry approaches to debris impact risk assessment and protection for unmanned spacecraft, and on past spacecraft failures that might be attributed to debris or meteoroid impacts. The purpose of these tasks is to understand whether current procedures for designing impact protection on spacecraft are adequate or if they would benefit from further IADC guidance. Other tasks of the Working Group to which the United Kingdom has contributed include the provision of information for the next issue of the IADC Protection Manual.

Debris mitigation

In March 2010, the UK Space Agency's representative in the IADC Working Group on Debris Mitigation completed the role of Working Group Chair for the customary two-year period. Among the activities of that Group, the United Kingdom participated in the production of a report concerning the long-term presence of objects in the geostationary region and assisted in the drafting of an updated version of the IADC Debris Mitigation Guidelines and supporting documents.

Finally, within the ISO Orbital Debris Coordination Working Group, a major milestone was reached during the past year with the publication of the top-level space debris mitigation standard, ISO 24113. The representative of the United Kingdom in the Working Group played a leading role in the development of that international standard. The standard defines the high-level quantitative requirements applicable to all elements of unmanned systems launched into or passing through near-Earth space, including launch vehicle orbital stages, operating spacecraft and any objects released as part of normal operations or disposal actions. Requirements contained in the standard aim to reduce the growth of space debris by ensuring that spacecraft and launch vehicle orbital stages are designed, operated and disposed of in a manner that prevents them from generating debris throughout their orbital lifetime. Methods and processes to enable compliance with these requirements will be provided in a set of lower-level implementation standards. Of particular importance in this respect are standards relating to the disposal of satellites in low-Earth orbit and the passivation of spacecraft at the end of their lives. Representatives from Surrey Satellite Technology Ltd. are currently leading the development of both of these implementation standards.

III. Replies received from international organizations

Planetary Society

[Original: English]
[15 September 2010]

The Planetary Society supports the attention given to the topic of space debris and the concern about this subject. Space debris can inhibit normal space activities and can pose a hazard to normal space operations. However, the Planetary Society thinks that more attention should be given to sources of space debris and that greater distinction among the different types of debris is required before imposing any constraints on civil satellites. As noted in the ESA report (available from www.esa.int/esaMI/Space_Debris/SEMQQ8VPXPF_0.html), most space debris has come from in-orbit explosions related to residual fuel in spacecraft tanks and rocket fuel lines, plus the single event of an anti-satellite test. Thus, arbitrary imposition of “rules of the road” on small satellites without residual fuel or engaged in anti-satellite tests could lead to unwarranted inhibitions to space operations and actually be counter-productive for efforts to remove or restrict space debris.