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Item 7 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 67/113, the General Assembly recognized that space debris was an issue of concern to all nations; 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; 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-ninth 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.105/1001, para. 91). In a note verbale dated 31 July 2012, the Secretary-General invited Governments to provide by 19 October 2012 reports on

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* A/AC.105/C.1/L.328.

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 fiftieth session.

3. The present document has been prepared by the Secretariat on the basis of information received from three Member States — Germany, Japan and Peru — and from two non-governmental organizations — the Committee on Space Research (COSPAR) and the Secure World Foundation. Information provided by Japan, entitled "Report on space debris-related activities in Japan", which includes pictures, tables and figures related to space debris, 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 fiftieth session of the Scientific and Technical Subcommittee. Information provided by the Secure World Foundation is contained in the note by the Secretariat on information on experiences and practices related to the long-term sustainability of outer space activities (A/AC.105/C.1/104).

II. Replies received from Member States

Germany

[Original: English]
[29 October 2012]

German research activities related to space debris issues carried out in 2012 cover various aspects.

Research activities continued at the Fraunhofer Ernst-Mach Institute to improve a new accelerator facility — the so-called "TwinGun". This facility is used for vulnerability and survivability analysis of spacecraft with regards to impacts of space debris and micrometeoroids. The objective is to be able to experimentally simulate hypervelocity impacts at velocities of up to 10 kilometres/second without changing the physical properties of the projectile during the acceleration.

At the Technical University of Braunschweig, a study is being performed to investigate the economics of the active removal of large objects from sun-synchronous orbits. High-risk collision partners are being identified as candidates for a possible removal. Simulations are conducted to show the influence of the active removal of these objects on the future evolution of the space debris environment.

Scientists at the German Aerospace Centre (DLR) Institute of Technical Physics are currently developing the technology for laser-based tracking of space debris. A successful demonstration on real low Earth orbit (LEO) debris objects was performed in 2012 in cooperation with the Graz satellite laser ranging station (Austria). The technology is aiming at the simultaneous monitoring of highly accurate angular and distance data of orbital objects that can be used for orbit determination.

The collision avoidance system at the German Space Operations Centre (GSOC) has been enhanced with various tools supporting the evaluation and analysis of critical conjunctions. Another system expansion is the reception of Conjunction Summary Messages (CSM) released by the Joint Space Operation Center (JSpOC) as input to the assessment process. A revised conjunction assessment procedure allows the exchange of operational orbital data, including manoeuvre planning and execution. Since the beginning of 2011 (until September 2012), GSOC has analysed 27 critical events (17 in 2011, and 10 in 2012), for which CSM have been received in 24 cases, and executed 6 collision avoidance manoeuvres (3 in 2011, and 3 in 2012) with the satellites controlled by GSOC.

Germany is developing a national competence in space situational awareness and its assessment by using existing resources. The mission of the German Space Situational Awareness Centre (GSSAC) is to produce a recognized space picture in order to contribute to the protection of the space infrastructure, and to security on the ground. To fulfil this mission, GSSAC will acquire, collect, process, analyse and store data from different sources, work in close cooperation with national and international partners, and produce various products and services in order to provide the recognized space picture.

GSSAC was set up in Kalkar/Uedem in 2009 with across-the-board facilities under the management of the German Air Force and a prominent participation of the DLR Space Administration.

Space situational awareness, in addition to its technological relevance, has gained a highly political dimension. In Germany, the Ministry of Defence and the Ministry of Economics and Technology are working closely together to assess national capabilities. Moreover, there are firm plans to increase activities regarding French-German cooperation initiatives. Both countries have the necessary technical equipment and complement each other perfectly.

Japan

[Original: English]
[18 October 2012]

Introduction

Research relating to space debris in Japan, mainly conducted by the Japan Aerospace Exploration Agency (JAXA), has focused on the following areas:

(a) Preventing damage to spacecraft caused by collision with debris and safeguarding mission operations;

(b) 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 in respect of space systems removed from orbit and allowed to fall to Earth;

(c) Promoting research targeting the improvement of the orbital environment by removing existing large debris from orbit.

Accordingly, JAXA defines the fundamental details of its debris-related strategy in the following Space Debris Strategic Plan:

Strategy 1: mission assurance. To apply measures to mitigate debris and ensure mission reliability at a rational cost. This also ensures debris mitigation activities are performed successfully;

Strategy 2: preservation of the orbital environment. To ensure the sustainability of space activities and to mitigate the generation of debris to preserve the environment while balancing cost and reliability;

Strategy 3: safe re-entry. If re-entering objects caused casualties, this would not only be tragic for the victims, but also unfortunate for space users, because it would delay space activities or enforce fundamental changes in the related procedures;

Strategy 4: remediation of the orbital environment. To prevent chain collision reactions among orbital objects, it is crucial to remove a portion of such large objects left in orbit in future. This action will require the collective efforts of multiple countries, hence international cooperation should be encouraged.

Strategy 1: mission assurance

(a) Target of the strategy

The target of strategy 1 is to ensure mission reliability via reasonable and rational measures. The Strategic Plan will stipulate measures to prevent any loss of function and mission performance. Moreover, under international responsibility, it will prevent fragmentation caused by collision and any loss of crucial functions used to conduct disposal actions.

(b) Work breakdown structure

The overall mission assurance measures, induced by the contingency planning approach, consist of preventive measures, detection of the realization of a threat and countermeasures. Collision with detectable large objects (>10 centimetre (cm) or several centimetres in low Earth orbit (LEO)), can be avoided by manoeuvres, while protection from tiny debris (<1 millimetres (mm) or several millimetres) should be provided by design. However, objects within the range from several millimetres to 10 cm are impossible to detect in order to avoid collision and to prevent damage. To reduce related risks, observation technology aims to detect smaller objects, while protection technology targets larger debris as far as possible.

(c) Research and development activities

To support the above measures for mission assurance, the following are identified as research and development work in the Strategic Plan:

(i) Debris environment models, including a function to predict the future environment;

(ii) A conjunction analysis tool and procedure to conduct avoidance manoeuvres;

(iii) Observation of smaller objects in geosynchronous Earth orbit (GEO), and determination of orbital characteristics;

(iv) Observation of smaller objects in LEO using an optical telescope;

(v) Modelling the impact damage characteristics and developing protective measures;

(vi) Surveying and modelling the population of particles.

The following subsection will introduce the above items (iii) to (vi):

(iii) Observation technology to detect smaller objects in GEO

The purpose of this study is to develop technologies to determine orbital characteristics, irrespective of the United States catalogue data, and detect objects smaller than the current world level. (Official limit is 1 metre in GEO in the United States surveillance network.) In JAXA, a 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 extended duration required to analyse data when detecting unseen objects with unknown movement, because the range of likely paths must be assumed and checked. To reduce the analysis time involved in the stacking method, an analysis system applying a Field Programmable Gate Array (FPGA) is being developed. In 2011, the FPGA system was installed at the JAXA Mount Nyukasa optical facility to observe GEO debris, and successfully determined the orbit characteristics of objects which had not been catalogued by the United States. It also succeeded in detecting small fragments (roughly in the 20 cm class) near GEO using a 35-cm aperture optical telescope. This technology will enable the detection of 10-cm class objects and determine their orbit, if applied to larger telescopes available in Japan. (See appendix A of the report on space debris-related activities in Japan, available from www.unoosa.org.)

(iv) Observation technology used to detect smaller objects in low Earth orbit via an optical telescope

Objects in LEO are usually observed via a radar system. However, the use of such a system for detecting objects in the 10 cm class would see the budget far exceeding permissible levels. Accordingly, an optical observation system is being studied instead of radar as a secondary measure due to its lower cost. However, severe restrictions stemming from the lighting conditions of the sun, time (relation with sunshine) and weather conditions apply. Such a system would be cost-effective if its problems could be solved by setting out multiple locations to compensate for this problem due to the lighting of the sun. Using wide-field optics and large high-speed CCD cameras, the detection and orbit determination of compact LEO debris will be possible. To date, feasibility has been positively assessed, and this technology is also expected to be applicable to on-orbit observation systems.

(v) Modelling the impact damage mode and developing protective measures

Historically, protection technologies for manned systems have been studied to protect against the impact of debris smaller than one centimetre or so. However, ordinal satellites remain vulnerable, even to particles smaller than 1 mm. Under this study, the characteristic of impact damage for vulnerable elements of spacecraft, such as the electric harness and the honeycomb sandwich panel, are being studied using the hypervelocity impact test and numerical simulation analysis, as well as some materials for the protection shield. The result of this study is reflected in the JAXA Design Manual to provide the spacecraft project teams with cost-effective protective measures. In the recent orbital environment, it has become crucial to apply a protective design to important spacecraft to ensure the minimum function crucial for disposal actions. (See appendix B of the report on space debris-related activities in Japan, available from www.unoosa.org.)

(vi) *Technology to survey and model the population of particles*

When a protective design against particle impact is applied, the increased mass of the protection shield or bumper may impact on mass management efforts in a manner that must be addressed. Conversely, in risk assessment using current debris environment models, engineers warn that the probability of impact tends to be overestimated beyond their engineering sense, whereupon a more accurate debris population model is required. This study aims to determine the actual debris population using an in situ Micro-Debris Measurement Sensor and to improve the debris population model. Such a sensor should be expected to measure particles of around 100 micrometres to 1 millimetre in size, and should have the advantage of allowing real-time detection while traditional surveys are performed on spacecraft retrieved a few years after impact. The performance of this sensor has been verified using the Bread Board Model to detect objects from 100 micrometres to a few millimetres. It is expected that in future, the sensor would be installed in global spacecraft and data shared to improve global debris population models and contribute to a more cost-effective protective design. Japan hopes to coordinate the above with other space agencies in the Inter-Agency Space Debris Coordination Committee (IADC). (See appendix C of the report on space debris-related activities in Japan, available from www.unoosa.org.)

Strategy 2: preservation of the orbital environment

(a) *Target of the strategy*

The target of strategy 2 is to mitigate debris and thus ensure the sustainability of space activities.

The Strategic Plan will develop technology, infrastructure and a management system to control debris generation in compliance with the Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space as a minimum.

(b) *Activities*

(i) *General*

The technologies involved in general debris mitigation activities, such as limiting the release of mission-related objects or preventing break-up, have almost matured and are not major items promoted for research and development activities. Debris mitigation activities are controlled in systems engineering, design management or operation control with few technical problems remaining to be studied. One exception is the study of a new propellant for solid rocket motors, which would not eject slag.

Subsequently, related works include mainly management work to encourage debris mitigation activities, control projects, avoid engaging in activities which may threaten other space activities, and develop a support system to provide engineers with best practices for sustainable space activities. Internationally, discussion seems focused on how to strengthen voluntary activities to spread to other nations and international organizations worldwide, and establish transparency and confidence-building measures to avoid conflict through mutual understanding. Activities in the framework of the Committee on the Peaceful Uses of Outer Space and the International Organization for Standardization (ISO) are introduced in the following sections as examples.

(ii) Works in the framework of the Committee on the Peaceful Uses of Outer Space

In the framework of the Committee on the Peaceful Uses of Outer Space, a working group of the Scientific and Technical Subcommittee for the agenda item on the long-term sustainability of outer space activities was established. In February 2011 and 2012, the Japanese Government proposed comprehensive work, including risk assessment, identification of subjects using a contingency planning approach, and development of best practices to ensure effective output. The proposal identified current vulnerabilities, and proposed cooperative work for a solution was identified. One of the unique points involved focusing on “Lack of Quality and Reliability Assurance” as one of the risks. Currently, a number of space systems have been prone to break-up just after launch due to accidental or intentional destruction. Moreover, it has been observed that certain spacecrafts tend to lose their functions just after being injected into orbit, ending up as dysfunctional debris. Global debris mitigation guidelines mention the need to refrain from intentional destruction, but do not cover ensuring quality to prevent break-up or the launch of defective systems. The causes may include the use of invalid parts, lack of tests to verify their mechanical or thermal strengths and so on. The situation is expected to improve by establishing proper standards, such as ISO standards.

(iii) Works for ISO/TC20/SC14

Since many debris-related standards are being developed in ISO, engineers must also refer to many of them and utilize all the requirements imposed in the subsystems or components for which they are responsible. Japan has proposed the development of a technical report, entitled “Spacecraft design and operation manual in the debris environment”, which will support the engineers in charge of concept design, system design, subsystem design component design or operations, and help them systematically understand and comply with the technical requirements and recommendations. The manual is being developed in parallel by both JAXA and ISO and is supported by the Japanese space industry. It has the following aims:

(a) Encouraging a debris mitigation design from an early product lifecycle phase;

(b) Encouraging the determination of a philosophy affecting system design (disposal, ground safety, collision avoidance, impact protection etc.);

(c) Providing a list of all the requirements and recommendation affecting system design; and

(d) Providing a checklist for designing and operation planning of associated subsystems and components.

Strategy 3: safe re-entry

(a) Strategic target

The target of strategy 3 involves limiting the re-entry hazard, not only to prevent tragedy for individuals, but also the social and diplomatic impact, which may trigger a reaction halting space activities.

The Strategic Plan will enable the re-entry risk to be properly determined, and provide design measures to minimize risk using specific hardware or technology for controlled re-entry.

(b) Work breakdown structure

The measures for ground safety from re-entry are shown in table 3 of the report on space debris-related activities in Japan, available from www.unoosa.org.

(c) Research and development activities

To support the above ground safety measures, the following are identified as major research and development items in the JAXA Strategic Plan:

(i) Improving the accuracy of re-entry survivability analysis (re-entry survivability analysis tool, and other measures to improve analytical accuracy);

(ii) Developing a composite propellant tank for early demise;

(iii) Mastering technology for controlled re-entry;

(iv) Mastering technology to estimate decay trajectory.

The first two research and development items are introduced in the next subsections.

(i) Improving the accuracy of re-entry survivability analysis

Most global space agencies strive to limit the expected number of casualties (Ec) of re-entering spacecraft and launch vehicle orbital stages to less than 0.0001. Since this criterion is difficult to meet, particularly for launch vehicle orbital stages, which incorporate numerous mechanical and thermal components designed strongly, the calculation of Ec needs careful consideration. JAXA coordinated with NASA to import a tool to analyse re-entry survivability in 2001, and has since improved it by adding functions and support programs. There are now plans to verify the analysis with actual data acquired by on-board sensors, and hence acquire the thermal characteristics of materials for accurate analysis.

(ii) Composite propellant tank

One of the elements increasing the risk of re-entry is the use of pressure bottles and propellant tanks made of titanium alloy. JAXA is studying the development of composite tanks with metal skin overwrapped with carbon fibre-reinforced plastic (CFRP), which are expected to break up during re-entry.

Strategy 4: remedying the orbital environment

(a) *Target of the strategy*

The target of Strategy 4 is to develop cost-effective technology to remove existing large debris from useful orbital regions and thus prevent a chain reaction of on-orbit collisions.

The Strategic Plan will help accelerate international cooperation to remove a certain amount of debris.

(b) *Work breakdown*

Several technical measures have been proposed to remove existing large (system-level) objects from useful orbital regions. These may include traditional propulsion devices, aerodynamic-drag enhancement devices, laser radiation from the ground, and so on. To remove large dysfunctional objects from LEO, at an altitude of roughly 800-1000 kilometres, with light mass devices, JAXA is striving to develop an electrodynamics tether system. This research and development includes technologies for rendezvous with non-cooperative objects, motion/attitude estimation, the installation of tether devices, and so on. However, the task of remedying the orbital environment cannot be accomplished by one country alone. JAXA is proposing that this matter be mentioned in the report of the Working Group on the Long-term Sustainability of Outer Space Activities of the Scientific and Technical Subcommittee. Besides the technical innovation, some subjects remain to be ascertained before initiating the remediation. Firstly, how to obtain with owners consensus on the selection of target objects? Secondly, there are risks of re-entry casualties. These and other non-technical matters are also under discussion in the committee involving the industry side. JAXA is also proposing that IADC discuss the above for future cooperation. (See appendix D of the report on space debris-related activities in Japan, available from www.unoosa.org.)

JAXA is also studying the feasibility to re-orbit large objects from the GEO using ion beam irradiation. This system can be operated without catching target objects, and can thus be applied to a wide range of debris objects, regardless of their shapes or rotations. (See appendix E of the report on space debris-related activities in Japan, available from www.unoosa.org.)

Conclusion

Debris mitigation efforts are crucial to ensure the long-term sustainability of space activities. If this understanding becomes global, the industrial society will welcome these trends to guarantee a fair and competitive business environment. The scope must also include universities, in that they have responsibilities to train their students to master how to join human society.

However, the current orbital environment has deteriorated to such an extent that protective measures are strongly recommended, not only to ensure mission reliability but also under the responsibility to sustain space activities. Under the Strategic Plan introduced above, JAXA will continue to accelerate debris mitigation and protective measures and help develop a global framework for the sustainability of space activities, while taking technical and financial feasibility into consideration.

Peru

[Original: Spanish]
[9 November 2012]

The Asia-Pacific Ground-based Optical Satellite Observation System (APOSOS), a project operated by the Asia-Pacific Space Cooperation Organization (APSCO), has been implementing a system node in Peru.

III. Replies received from international organizations

Committee on Space Research

[Original: English]
[23 October 2012]

The Committee on Space Research (COSPAR) has been addressing the topic of space debris for more than a quarter century. For many years the COSPAR Panel on Potentially Environmentally Detrimental Activities in Space (PEDAS) has held multiple space debris sessions at each biannual COSPAR Scientific Assembly. These sessions address (a) the characterization of the space debris environment through measurements and modelling, (b) risks posed to spacecraft by collisions with space debris, (c) the means to protect spacecraft, and (d) strategies and policies to curtail the creation of new space debris.

Today, the number of individually monitored, man-made objects in Earth orbit exceeds 22,000 and represents a mass of more than 6,000 metric tons. The number of smaller debris that are potentially hazardous to operational satellites is many millions. To date, two identified incidents of collisions between operational spacecraft and space debris have resulted in the damage of one spacecraft and the total destruction of the other. Dozens of collision avoidance manoeuvres are executed each year, including by the International Space Station.

Prior to 2007 more than 95 per cent of all hazardous space debris was created in accidental or deliberate explosions of spacecraft and launch vehicle orbital stages. The major spacefaring nations and organizations recognized the threat that the continued growth of the space debris population posed to the numerous space systems serving vital needs on Earth and adopted first national and then international space debris mitigation policies. The Inter-Agency Space Debris Coordination Committee (IADC) established in 2002 the first consensus set of space debris mitigation guidelines for the world's leading national space agencies. These guidelines were used as the foundation for the United Nations space debris mitigation guidelines of 2007.

Collisions among resident space objects not only can be potentially catastrophic but also can generate large numbers of new debris, which could further degrade the near-Earth space environment. This threat was first espoused in the 1970s, but new studies in 2005 indicated that some parts of the low Earth orbit region, i.e., altitudes below 2,000 kilometres, had already become unstable. In other words, the rate of debris generation by accidental collisions exceeded the natural removal rate by atmospheric drag. Hence, the space debris population in those regimes will continue to increase even in the absence of new satellite deployments. This condition, known as the Kessler Syndrome, is one of the major issues affecting the long-term sustainability of outer space activities.

In the near-term, the greatest threat to operational spacecraft is the very large population of debris with sizes of 5 millimetres-10 centimetres. With very high collision velocities, these small debris carry sufficient energy to penetrate and to damage vital spacecraft systems. For the long-term, the principal threat arises from the collision of larger objects, which in turn will generate significant numbers of new space debris. Even if all newly launched satellites comply with international recommendations for limiting stays in low Earth orbit, the large number of derelict spacecraft, launch vehicle orbital stages, and moderately-sized debris already in orbit will collide among one another with increasing frequency and create new hazardous debris.

Consequently, the removal of existing space debris, both small and large, is of great importance for the preservation of near-Earth space for the use of future generations. Several countries are now evaluating the technical and economic feasibility of a wide variety of space debris removal concepts. These proposals range from conventional space tugs to innovative ideas employing drag augmentation devices, electrodynamic tethers, solar sails and many other imaginative devices.

The challenges of active space debris removal are substantial, but spacefaring nations and international scientific organizations such as COSPAR are devoting considerable efforts to promote the long-term sustainability of operations in near-Earth space for the benefit of all.