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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 66/71, 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-eighth 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.105/987, para. 88). In a note verbale dated 9 August 2011, the Secretary-General invited Governments to provide by 31 October 2011 reports on research on

* A/AC.105/C.1/L.310.

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-ninth session.

3. The present document has been prepared by the Secretariat on the basis of information received from four Member States — Japan, Switzerland, Turkey and the United Kingdom of Great Britain and Northern Ireland — and from two international organizations — the Asia-Pacific Space Cooperation Organization and the Secure World Foundation. Information provided by Japan, entitled "Report on space debris-related activities in Japan", which includes pictures 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 forty-ninth session of the Scientific and Technical Subcommittee.

II. Replies received from Member States

Japan

[Original: English]
[31 October 2011]

Overview

The research relating to space debris in Japan, conducted mainly by the Japan Aerospace Exploration Agency (JAXA), has concentrated on the areas described below. The principal aims of JAXA with regard to the debris issue are:

(a) To prevent damage to spacecraft caused by collision with debris and ensure mission operation;

(b) To prevent 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;

(c) To promote research aimed towards the improvement of the orbital environment by removing existing large debris from orbit.

The JAXA strategic plan on space debris defines the following research and development areas:

(a) Observation and modelling:

(i) Technology to observe objects in geosynchronous Earth orbit (GEO) (10-cm class);

(ii) Optical observation for objects in low-Earth orbit (LEO);

(iii) Dust sensor to detect sub-millimetre-sized debris;

(iv) Propagation model to predict future population;

(b) Protection:

Hypervelocity impact testing and analysis to estimate damage from the impact of tiny debris, and development of shielding methods;

(c) Re-entry:

(i) Research on and development of a propellant tank that demises upon re-entry;

(ii) Improvement of re-entry analysis tool;

(d) Remediation:

Active debris removal system that employs electrodynamic tethers;

(e) Other measures:

Slagless solid motor propellant.

The text below presents the status of several research and development items and related work.

Debris mitigation requirements and compliance with them

The JAXA space debris mitigation standard requires or recommends the following:

(a) Refraining from releasing mission-related objects;

(b) Preventing in-orbit break-ups;

(c) Re-orbiting mission-terminated geosynchronous satellites from the GEO protected region;

(d) Removing mission-terminated spacecraft passing through the LEO protected region;

(e) Preventing collisions with large debris;

(f) Preventing damage from collisions with tiny debris.

In February 2011, the standard was revised to be equivalent to the International Organization for Standardization (ISO) space debris mitigation requirements (ISO 24113). The major changes resulted in the following requirements:

(a) Pyrotechnic devices shall not generate combustion products larger than 1 mm;

(b) The eccentricity of a geosynchronous orbit satellite after re-orbiting shall be less than 0.003;

(c) Break-up probability during operation shall be less than 0.001;

(d) Conditional success probability for re-orbit manoeuvre shall be greater than 0.9;

(e) The orbital lifetime of objects passing through LEO (lower than 2,000 km) shall be shorter than 25 years after the end of operation.

The compliance of each project with the requirements is reviewed in the safety review held at the end of each design phase.

Research on observational technologies for space debris in geosynchronous Earth orbit and low-Earth orbit

The innovative technology research centre of JAXA is developing technologies for the detection of uncatalogued GEO debris and the determination of 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 under development since 2000. The only weak point of the stacking method is the time required to analyse the data when detecting an unseen object whose movement is not known, because a range of likely paths must be assumed and checked. In order to reduce the analysis time of the stacking method, JAXA is developing the field programmable gate array system. This year, JAXA has installed that system in the Mount Nyukasa optical facility for GEO debris observation.

JAXA is also trying to develop an optical observation system for LEO debris. Using wide-field optics and a large high-speed CCD camera, the detection and orbit determination of small LEO debris will be possible.

Development of an in situ micro-debris measurement system

JAXA has been developing the micro-debris measurement system. The objective of the system is to measure small debris (between 100 micrometres and several cm). The distribution and flux of debris of small size are not well understood. Micro-debris is difficult to observe from the ground, although the impact risk cannot be ignored. For the measurement system, the combination of an optical sensor and a dust detector is under study by JAXA. The in situ measurement is useful for: (a) verifications of meteoroid and debris environment models, (b) verifications of meteoroid and debris environment evolution models and (c) real-time detection of unexpected events, such as explosions and collisions in an orbit. At present, the in situ optical observation system is under conceptual study, and a dust sensor is already in the breadboard model phase. The dust sensor, especially to monitor the size range from 100 micrometres to a few mm, must have a large detection area, while the constraints of a space environment deployment require that the systems be low in mass, low in power and robust, and have low telemetry requirements. JAXA has been developing a simple in situ sensor to detect dust particles ranging from a hundred micrometres to several millimetres. Multitudes of thin, conductive strips (copper) are formed with fine pitch (100 m) on a thin film of nonconductive material (12.5 micrometres, polyimide). A dust particle impact is detected when one or more strips are severed by the perforation hole. The sensor is simple to produce and use and requires almost no calibration, as it is essentially a digital system. The breadboard model was manufactured successfully with the application of printed wiring board product technology. The sensor area of the model is 35 cm x 35 cm, and thermal-strain experiments and hypervelocity impact experiments on the model were performed.

Debris modelling and analysis tools

An orbital debris evolutionary model developed in collaboration with Kyushu University has been updated. The effective number of objects in LEO predicted by the model, under some assumptions set for study to investigate the stability of the LEO debris environment, is shown in the original document submitted by Japan, which can be found on the website of the Office for Outer Space Affairs of the Secretariat (www.unoosa.org). In that document, it is shown that even with a good implementation of the commonly adopted mitigation measures, the LEO debris population is expected to increase in the next 200 years, which agreed well with other agencies' results. A debris collision risk analysis tool called Turandot has also been updated and used for evaluating JAXA projects.

Investigation of impact damages

Historically, debris impact damages have been investigated for manned systems to confirm the impact of debris of several millimetres in size. However, since a usual satellite tends to be damaged even by debris smaller than 1 mm, additional data are needed. Debris impact damages of satellites are investigated by hypervelocity impact experiments, and then damage-limit equations are developed. As the impact experiment can hardly cover speeds higher than 10 km per second, numerical simulation is essential to verify the effects caused by velocities of 10 km per second or higher. To incorporate the experiment and numerical simulation data in satellite design, the Space Debris Protection Design Manual was published in 2009, and it has been updated. Moreover, JAXA is developing a standard of micro-debris impact risk assessment.

Controlled re-entry of the second stage of the H-IIB launch vehicle

The H-IIB launch vehicle was developed to launch the H-II Transfer Vehicle (HTV) to the International Space Station, and to satisfy various customers' needs for a heavy launch. For its second flight, JAXA and Mitsubishi Heavy Industries Ltd. added a new function to the second stage of H-IIB to perform controlled re-entry.

The design changes include:

(a) A new helium bottle to repressurize the liquid hydrogen tank;

(b) Thermal protection for several components to withstand the thermal effect resulting from the longer ballistic phase;

(c) Modification of the avionics system to receive a de-orbit command from ground stations;

(d) A new algorithm for guidance control to send an engine cut-off command during the de-orbit burn; it also optimizes the burn duration in real time to minimize the impact footprint.

The second flight of H-IIB was conducted on 22 January 2011. The flight was very consistent with the pre-flight simulation, and successfully inserted HTV into its planned orbit. After the payload separation, the stage circled the Earth once and performed a de-orbit manoeuvre as planned. The performance of a low-thrust-level burn of the LE-5B-2 engine was close to the pre-flight predicted value. The event timeline was very consistent with the prediction analysis.

Consequently, all acquired flight data indicated that the controlled re-entry of the second stage of H-IIB was conducted as planned.

Research on and development of an easily demisable propellant tank

A propellant tank is usually made of titanium alloy, which is superior because of its light weight and good chemical compatibility with propellant. But its melting point is so high that a propellant tank would not demise during re-entry, and that presents one of the major risks of ground casualty. JAXA is conducting research to replace the titanium tank with the demise tank upon re-entry for hazard prevention. The targeted specifications, including mass, volume, maximum expected operating pressure, propellant expulsion efficiency and propellant storage life, are determined. The compatibility test with the propellant hydrazine and the arc heating test are being planned.

Remediation of orbital environment

The amount of space debris has been increasing, and many evolutionary models predict that it would increase even if new satellite launches were stopped, because of collisions between existing objects. In such a case, debris mitigation measures, such as explosion prevention and end-of-mission de-orbit, will be inadequate and active debris removal will be needed to preserve the space environment. JAXA is therefore studying an active removal system that can rendezvous with and capture non-cooperative debris objects in crowded orbits to de-orbit them. The propellant requirements of conventional propulsion systems make their use for transferring multiple objects infeasible, and instead the electrodynamic tether is considered to be one of the most promising propulsion systems for de-orbiting debris in LEO. As a first step towards realizing active debris removal, a flight demonstration, using a small satellite to demonstrate some key technologies, such as non-cooperative rendezvous and electrodynamic tethers, is being studied.

Switzerland

[Original: English]
[27 October 2011]

The population of space debris has increased drastically in recent years through explosions of deactivated satellites and collisions. The situation is particularly critical in the low-Earth orbit (LEO). Long-term predictions show a risk of a self-feeding collision cascading effect, called Kessler syndrome, if no measures are taken.

On the basis of the recommendations of scientific groups stating that removing 5 to 15 large objects per year from critical orbits would be necessary to stabilize the situation, the Space Center at the Swiss Federal Institute of Technology in Lausanne (EPFL) started an activity called Clean-mE in 2010. That activity is aimed at integrating existing technologies with new research developments in order to demonstrate a system that will enable the collection and removal of orbital debris in LEO. The Clean-mE project started with a conceptual design and system study of a small satellite whose goal was to remove 1 to 10 pieces of orbital debris with sizes greater than 10 cm. During the study, existing and needed new technologies were identified. Contacts with major international space agencies were made. A preliminary version of system requirements was established to guide technology developments. Those technology developments, building on expertise in EPFL laboratories, are focusing on autonomous robotics and vision system aspects. The Space Center brings to bear mission and system engineering expertise to create a complete ground demonstrator (hardware and software), which could later be the foundation for a flight demonstration. The EPFL Space Center recognizes the need for international collaboration in the activity and wishes to continue its developments in coordinated programmes at the international level.

Given the critical situation described above, accurate observation and monitoring of space debris are also crucial. The Astronomical Institute of the University of Bern (AIUB) continues to monitor the small-debris environment at high altitude using its one-metre telescope, ZimLAT, and a small robotic telescope, ZimSMART, located at the Zimmerwald observatory near Bern. AIUB maintains a unique catalogue of high area-to-mass ratio debris in geostationary and highly elliptical orbits, in collaboration with the European Space Agency and the Keldish Institute of Applied Mathematics in Moscow. Recent studies focused on the physical characterization of such objects in order to assess their nature and their origin. In 2010 a study to find small debris in the region of the navigation satellite constellations was conducted. That study was the first of its kind in that orbit region. The results show no indication of a breakup of a larger object in the current navigation satellite constellations.

Turkey

[Original: English]
[10 November 2011]

The Space Technologies Research Institute (TÜBITAK UZAY) is involved in a European Commission-funded project called Prediction, Protection and Reduction of Orbital Exposure to Collision Threats (P^2-ROTECT), which is aimed at assessing the risks associated with the space debris (both trackable and untrackable) and at recommending possible solutions (better prediction, better protection or action on the debris environment) to reduce the vulnerability of future space missions to in-orbit collisions (see www.p2rotect-fp7.eu/index.html). The project started in March 2011 and will last for 30 months.

United Kingdom of Great Britain and Northern Ireland

[Original: English]
[15 November 2011]

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 the Inter-Agency Space Debris Coordination Committee (IADC) and the Orbital Debris Coordination Working Group within the International Organization for Standardization (ISO). For IADC, the United Kingdom has contributed to technical studies and discussions aimed at providing greater understanding of the evolving space debris population and methods to protect against it. That process is essential for achieving international consensus on future space debris mitigation guidelines. From 11 to 14 April 2011, representatives of the UK Space Agency participated in the twenty-ninth meeting of IADC, which was hosted by the German Aerospace Centre (DLR) in Berlin, Germany. Regarding the Orbital Debris Coordination Working Group, which is tasked with overseeing the development of a set of ISO space debris mitigation standards that are consistent with the IADC guidelines, the United Kingdom has contributed to the process by providing a combination of technical expertise and leadership of the Working Group.

As part of its commitment to meet its obligations under United Nations outer space treaties, the United Kingdom operates a statutory licensing scheme to permit the launch of its satellites and their operation in outer space. The new UK Space Agency formally took over the responsibility for issuing the licences in April 2011. As was the case under the British National Space Centre, the former licensing authority, licences will be granted only after the applications have been technically evaluated. The conformance of spacecraft and launch vehicles with United Nations debris mitigation guidelines and standards is an important consideration in the decision to grant a licence.

Further detail on these and other United Kingdom debris mitigation activities is provided below.

Observation of space debris

The United Kingdom has continued its participation in the IADC campaigns to predict the re-entry of objects into the Earth's atmosphere. This year's campaign targets were the National Aeronautics and Space Administration Upper Atmosphere Research Satellite and the German Aerospace Centre Roentgen satellite. The United Kingdom technical lead for that activity is Space Insight Ltd., which provides support to the UK Space Agency on a range of activities related to space situational awareness. That 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 with obligations under the United Nations outer space treaties.

Debris environment modelling

During the past year, the University of Southampton's Debris Analysis and Monitoring Architecture for the Geosynchronous Environment tool has been used to improve understanding of the effectiveness of space debris mitigation and remediation. That work has supported the European Union (EU) Seventh Framework Programme project called Alignment of Capability and Capacity for the Objective of Reducing Debris (ACCORD), which commenced in December 2010, and the IADC Working Group on environment and database study of the future low-Earth orbit (LEO) environment. Results have suggested the need for remediation to stabilize the LEO debris population, and the existence of a synergy between the IADC space debris mitigation guidelines and remediation measures, which are aimed at removing large, intact objects from the environment to prevent their involvement in future collisions. In addition, preliminary results from the ACCORD project show the capacity of individual IADC mitigation measures to constrain the growth of the debris population in the long term. Those results will provide a focus for ongoing discussions within the IADC Working Group on environment and database, as they highlight both effective and less effective measures. Other activities at the University of Southampton in the space debris area have included an investigation of the benefits of "cloud computing" for space situational awareness and exploring space debris remediation issues.

Spacecraft debris protection and risk assessment

As a member of a consortium on an EU Seventh Framework Programme project called Reducing the Vulnerability of Space Systems, which is investigating design solutions to reduce the vulnerability of future LEO satellites to small debris, PHS Space Ltd. has used its proprietary software to perform detailed, novel impact risk assessments of two representative satellites. That analysis is an essential precursor for the next step in the study, i.e. the identification and development of new shielding techniques.

Debris mitigation

The United Kingdom has continued its participation in the IADC Working Group on debris mitigation. Among the various activities of the Working Group, the United Kingdom has assisted in the production of a report on the long-term presence of objects in the geostationary region.

Within ISO, a second edition of the top-level space debris mitigation standard, ISO 24113, was published in May 2011. That standard, whose development was led by PHS Space Ltd., specifies high-level measures for 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 those measures are being provided in a set of lower-level implementation standards. Of particular importance in this respect are standards relating to (a) the disposal of satellites in low-Earth orbit and (b) the passivation of spacecraft at the end of their life. Technical experts from Surrey Satellite Technology Ltd. are currently leading the development of both of those implementation standards.

At Cranfield University, work is under way to develop a de-orbit device for the United Kingdom technology demonstration satellite (TechDemoSat-1) due for launch in 2012. That device is a deployable drag sail sized to achieve re-entry within the 25-year post-mission lifetime recommended by the IADC debris mitigation guidelines. The main design objectives are rapid delivery (less than a year to design, test, manufacture and deliver), low cost compatible with small satellites, minimal risk to the host spacecraft and good de-orbit capability. The University has also been pursuing research into other debris-related topics such as active debris removal and collision modelling.

III. Replies received from international organizations

Asia-Pacific Space Cooperation Organization

[Original: English]
[24 October 2011]

The Asia-Pacific ground-based Optical Space Observation System is a prioritized project whose feasibility study was completed in 2010 and approved in the last week of January 2011. The project will facilitate the detection, tracking and identification of space objects, orbit determination and cataloguing, collision early warning, re-entry prediction, technical consultation and training. The first phase of the project, on the basis of the existing resources of the member States of the Asia-Pacific Space Cooperation Organization, is under implementation and is expected to be completed by the end of May 2012, after which regular operation will start. Phase two of the project will commence subsequently.

Secure World Foundation

[Original: English]
[30 August 2011]

The Secure World Foundation (SWF) has a keen interest in the long-term sustainability of the space environment, and considers space debris mitigation to be an important topic. In 2011 the Foundation continued conducting and sponsoring research on space debris topics, including addressing some of the legal and policy concerns with regard to actively removing space debris from orbit and cooperative governance mechanisms for using space in a sustainable manner. SWF developed a website that serves as a publicly accessible database of global space situational awareness sensors, in part to foster data-sharing and collaboration. In October, SWF co-organized the 2011 Beijing space sustainability workshop with Beihang University, which brought together international experts to discuss issues related to space debris mitigation, removal, safe space operations and space weather.