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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 68/75, the General Assembly expressed its concern 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 is an issue of concern to all nations; considered that it was essential that 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; 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 fiftieth 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

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on practices that had proved effective in minimizing the creation of space debris (A/AC.105/1038, para. 104). In a note verbale dated 16 July 2013, the Secretary-General invited Governments and international organizations with permanent observer status with the Committee to provide by 14 October 2013 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 fifty-first session.

3. The present document has been prepared by the Secretariat on the basis of information received from five Member States — Canada, Mexico, Switzerland, Thailand and the United Kingdom of Great Britain and Northern Ireland — and from three non-governmental organizations with permanent observer status with the Committee — the Committee on Space Research (COSPAR), the Secure World Foundation and the Space Generation Advisory Council. Information provided by Thailand, entitled "Thailand space debris management (2013)", 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 fifty-first session of the Scientific and Technical Subcommittee.

II. Replies received from Member States

Canada

[Original: English]
[4 November 2013]

Space debris threatens the long-term sustainability of space activities of all nations. Canada remains convinced of the importance of the international community's work in the coordination of space debris research activities, and will continue to actively work with its partners.

In February 2013, Canada launched its first dedicated defence satellite, Sapphire, as a contributing sensor to the United States space surveillance network. Sapphire is a space-based, electro-optical sensor designed to track man-made space objects in high Earth orbit in order to improve Canada's space situational awareness. On the same day, the Canadian satellite NEOSSat was launched to further contribute to the detection of orbital debris and asteroids. The capacities of NEOSSat include the monitoring and tracking of both satellites and debris, where ground-based telescopes have difficulty detecting and tracking.

Inter-Agency Space Debris Coordination Committee

Since joining the Inter-Agency Space Debris Coordination Committee (IADC) in 2011, the Canadian Space Agency (CSA) has been collaborating and exchanging information with IADC members to facilitate cooperation in space debris research and activities. IADC is an international governmental forum composed of 12 member agencies for the worldwide coordination of activities related to the issues of man-made and natural debris in space. Canada's priorities as a member of IADC are to share information on space debris issues, to establish cooperative activities in space debris research (e.g., high-velocity impact research) and to consider debris mitigation options. Canada hosted the thirtieth meeting of IADC in Montreal in 2012 and, as such, also chaired the Steering Group from April 2012 to April 2013. CSA contributes actively to the Steering Group and its working groups, and is the Vice-Chair of Working Group 3, on Protection.

Canadian space debris mitigation research activities

Working with academia and other government departments, CSA leads space debris science and technology initiatives within Canada. The development of an implosion-driven hypervelocity test facility, providing a unique capability to accelerate masses to debris velocities allowing full impact regimes to be investigated, has put Canada in a leadership position in this domain. Canada is now developing fibre-optic-based sensors that will be incorporated into self-healing composites to assess the impacts of space debris as they occur, while mitigating secondary debris propagation. Canada will also participate in the European Union ACCORD survey on orbital debris covering spacecraft design and spacecraft operations.

In 2013, Canada and the Czech Republic, with the support of the German Aerospace Center, initiated the development of a compendium of standards adopted by States and international organizations to mitigate the creation of space debris. That activity is a contribution to the space debris-related initiatives pursued by the Committee on the Peaceful Uses of Outer Space. It is expected that the compendium will be presented under the agenda item “General exchange of information and views on legal mechanisms relating to space debris mitigation measures” of the Legal Subcommittee at its fifty-third session, in 2014, for the review and information of all members of the Committee.

Current operational practices

Throughout 2013, CSA continued to witness an increasing number of collision threats to Canadian space assets necessitating further analysis and, when applicable, spacecraft debris collision avoidance manoeuvres. The CSA Space Debris Centre of Expertise has developed a number of procedures related to close approaches of space debris and links with satellite operators in Canada, providing value-added analysis within minutes of reception of close-approach warnings. Close collaboration with the Department of National Defence Canadian Space Operations Cell has been established in the context of space debris threat analysis, whereby critical space enablers are provided to strategic partners within the Canadian Government, in close cooperation with Canada’s allies around the world.

On 29 March 2013, Canada’s first Earth observation satellite, RADARSAT-1, experienced a major technical anomaly. An extensive investigation was conducted, which concluded that the satellite could not recover from the problem, as a consequence of which it is no longer operational. During its 17 years of exceptional service, RADARSAT-1 provided hundreds of thousands of images to more than 600 users in Canada and in 60 countries worldwide. It provided images to assist in relief efforts during 244 disaster events, and literally mapped the world, providing complete coverage of the world’s continents, continental shelves and polar icecaps.

Among its many accomplishments, RADARSAT-1 conducted two Antarctic Mapping Missions, in 1999 and 2000, and delivered the first-ever high-resolution maps of the entire frozen continent. It also delivered the first stereo-radar coverage of the planet’s landmass and the first high-resolution interferometric coverage of Canada, and produced complete single-season snapshots of all continents. Canada will continue to perform space debris threat assessments with the support of our international partners, and recently initiated internal debris-related investigations on the satellite.

Mexico

[Original: Spanish]
[14 October 2013]

National research on space debris, the safety of space objects with nuclear power sources on board and problems relating to their collision with space debris

Space debris

Mexico is deeply involved in the question of the sustainability of space activity, one of the main aspects of which is space debris. The complexity of the topic is such that it will be difficult to find short-term solutions. Mexico is represented in the four expert groups of the Working Group on the Long-term Sustainability of Outer Space Activities of the Committee on the Peaceful Uses of Outer Space.

It should be noted that the National Autonomous University of Mexico is conducting a study into a satellite re-entry procedure. The relevant document has been submitted to the Committee.

Our country’s space activities started in 1985, with the launch of the geostationary satellites Morelos I and Morelos II. There are currently five satellites in operation, and it is hoped that two others will be launched in the same orbit in 2014 and 2015.

In accordance with the practice on the elimination of space debris, Mexican policy on the orbit of geostationary satellites has consisted in retaining enough fuel to ensure that, at the end of its lifespan, the satellite will automatically de-orbit. This is the procedure used in Satmex 5.

All the procedures referred to above take into account the Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space and the regulations issued in this regard by various countries with significant space programmes.

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

This topic is covered in the Guidelines. In accordance with the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer

Space, including the Moon and Other Celestial Bodies, Mexico has maintained its position on the non-militarization of outer space and the peaceful uses of outer space. The use of nuclear power sources does not form part of any space programme in our country. Their use is governed by the regulations issued by the International Atomic Energy Agency. It is therefore implicitly understood that, in everything involving the use of nuclear sources of power, the safety of human beings in outer space and the space environment is of fundamental importance.

In that regard, the Guidelines provide an essential framework as regards safety.

Neither the Principles Relevant to the Use of Nuclear Power Sources in Outer Space nor the Guidelines are binding. A measure of protection, albeit relative, is provided by article IV of the Outer Space Treaty.

Switzerland

[Original: English]
[14 October 2013]

The Astronomical Institute of the University of Bern (AIUB) continues its research efforts to better understand the near-Earth space debris environment. AIUB uses its 1-metre telescope ZIMAT and a small robotic telescope ZimSMART, both located at the Zimmerwald Observatory, near Bern, to discover and physically characterize small-size debris. A major result of this research is a unique catalogue of high area-to-mass ratio debris in geostationary and highly elliptical orbits, which is built up and maintained in collaboration with the European Space Agency (ESA) and the Keldysh Institute of Applied Mathematics in Moscow. The latter operates the International Scientific Optical Observation Network (ISON), with which AIUB has been sharing observation data in the context of a scientific collaboration for many years. ISON has recently started cooperating with the Basic Space Science Initiative of the Office for Outer Space Affairs. Recent studies of AIUB focused on deep surveys for small debris objects in highly elliptical orbits, including geostationary transfer, and Molniya-type orbits. First results indicate a substantial population of “unknown” objects in those orbital regions, i.e. objects that are not contained in any of the publicly available orbit catalogues. Characterizing those objects will be of great importance in order to identify the sources of the debris and eventually design efficient and economically viable mitigation measures. In support of the discussion on the active removal of large objects from low Earth orbits, AIUB has started an observation programme to assess the tumbling rates of large debris objects in orbits of an altitude of 700 to 1,000 kilometres by means of optical light curves.

The Swiss Space Center at the Federal Polytechnic Institute of Lausanne (EPFL) and its partners have continued research and development in the area of active debris removal under its Clean-mE programme. The recent focus has been on the development of capture mechanisms and technologies (purely mechanical or with advanced soft dielectric elastomer grippers). As part of that programme, the CleanSpace One project is aimed at de-orbiting the SwissCube satellite. The recent activities focused mainly on increasing the fidelity of the mission and remover satellite design. Funding for the mission has recently been secured. In 2013 EPFL also participated in European studies funded by the Centre national d’études spatiales of France to evaluate mission and campaign architectures, debris remover designs and costs associated with removing 5 to 10 large debris objects per year. In this context, EPFL designed a tool for evaluating the architecture and technology of active debris removal missions. The publication of the results is pending.

Thailand

[Original: English]
[14 October 2013]

Thailand Earth Observation System space debris monitoring

The Thailand Earth Observation System (THEOS) ground station has two sources of space debris surveillance: the Joint Space Operations Center (JSpOC) and the Space Data Association (SDA). JSpOC has provided notifications for space debris approaches to THEOS with a miss distance of less than 1 kilometre, while SDA has given notifications for any space debris coming within 5 kilometres of THEOS.

Thailand Earth Observation System close approaches

THEOS has experienced several close approaches, since it has been operated at an altitude of 822 kilometres, where space debris density is the highest. There are two criteria the THEOS ground station uses to consider the necessity of a collision avoidance manoeuvre:

(a) Radial miss distance < (primary object error in radial) + 3 (secondary object error in radial) + primary object radius + secondary object radius;

(b) Radial miss distance < 100 m, in-track miss distance < 300 m, and cross-track miss distance < 100 m.

Thailand Earth Observation System experiences in collision avoidance manoeuvres

So far, three manoeuvres have been performed to avoid collision, once for IRIDIUM 33DEB and twice for COSMOS 2251 DEB.

An unanticipated or collision avoidance manoeuvre has two impacts on a THEOS operation: propellant usage and operation interference. Once the altitude adjustment has been executed so as to avoid the collision, the controlled parameter (ground track error) tends to evolve beyond defined windows at a greater rate. Therefore, altitude correction has to be done sooner than it was supposed to be, which leads to the use of more propellant.

Thailand Earth Observation System de-orbit plan

There are two possible reasons for an increase in the number of space debris objects: satellite self-explosion and collision between satellites that are no longer used.

For this reason, 24.1 kilogrammes of propellant has been reserved for de-orbiting THEOS when its operation is terminated. In order not to create more space debris, the THEOS semi-major axis will be decreased from 7,200 km to 7,030 km, which not only will allow THEOS de-orbitation within 25 years, according to the low Earth orbit disposal standard, but will also remove the satellite from an altitude congested with space objects, thereby reducing the risk of collision with other space objects later on.

In the example depicted in the conference room paper to be made available at the fifty-first session of the Subcommittee, a distance of 7,040 kilometres for the semi-major axis does not allow a de-orbitation of the spacecraft within 25 years. Therefore, a 7,030-kilometre semi-major axis is a good compromise that satisfies the de-orbitation requirements while using as little propellant as possible.

In order to reach this target orbit, $\Delta a = 170$ kilometres will be needed, for which $\Delta V = 87.8$ m/s is required. As the specific impulse at end of life is 210.6 seconds, the corresponding mass decrement, or Δm, is 24.1 kilogrammes. All of the propellant will be depleted during de-orbitation in order to prevent self-explosion of the satellite, which could lead to an increase in the number of space debris objects.

Based on the remaining propellant, 46 kilograms, THEOS operation can be supported for more than 16 more years.

Research and projects related to collision avoidance

THEOS collision avoidance software

The development of software for illustrating the conjunction between space objects in 3-D is aimed at facilitating the close-approach analysis. It enables the satellite operators to make a better decision on whether or not a collision avoidance manoeuvre is required, helping to avoid wasting propellant, unnecessary manoeuvres and risk of collision.

Space environment surveillance system

The future project for enhancing the capabilities of THEOS collision avoidance software focuses on two segments:

In-house space debris monitoring software

At present, since the THEOS ground station has been relying on other space debris surveillance systems, we plan to develop our own redundant one. The monitoring software will retrieve two-line elements for space debris from the North American Aerospace Defense Command, then propagate their positions with respect to time and determine the miss distance.

Improved collision avoidance manoeuvre criteria and develop methodology for conjunction analysis

The current criteria are quite sensitive; three collision avoidance manoeuvres have already been performed in the past five years of operation. The new criteria may take international criteria for robotic spacecraft into consideration (if the probability of collision is greater than 10^{-4}, a collision avoidance manoeuvre should be performed), along with the concrete direction of conjunction analysis.

United Kingdom of Great Britain and Northern Ireland

[Original: English]
[14 October 2013]

Introduction

Many countries have reflected their obligations under the outer space treaties through the enactment of national legislation. When the outer space treaties were developed, there was no understanding of space debris. However, the treaties and national regulations are flexible enough to address the issue in an effective manner, relying upon best practice and codes and principles to encourage the adoption of space debris mitigation measures.

A number of standards and guidelines for minimizing debris production and protecting spacecraft now exist at both the national and the international level. The importance of such mitigation measures is recognized by all spacefaring nations. This is a key step in managing the future evolution of the orbital environment in a fair and equitable manner, as there is a cost associated with many mitigation practices. To ensure that their application will not penalize operational competitiveness, such mitigation measures must be recognized and applied by all users of space in a coordinated manner. To be effective, mitigation practices will need to become an intrinsic and consistent element of in-orbit operations rather than a piecemeal, ad hoc practice. If these practices can be embodied within national legislation, then operators will be obliged to consider space debris mitigation during all phases of a mission, from initial definition and feasibility to final disposal. The Outer Space Act is the basis for licensing the activities of United Kingdom nationals in space, and technical assessments have recently been adapted to include consideration of space debris mitigation practices when deciding whether to issue a licence to an applicant.

United Kingdom Outer Space Act

The Outer Space Act 1986 is the legal basis for the regulation of activities in outer space (including the launch and operation of space objects) carried out by persons connected with the United Kingdom. The Act confers licensing and other powers on the Secretary of State, acting through the United Kingdom Space Agency. The Act ensures compliance with United Kingdom obligations under the international conventions covering the use of outer space to which the United Kingdom is a signatory. Those conventions are:

(a) The Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and other Celestial Bodies, 27 January 1967 (Outer Space Treaty);

(b) The Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space, 22 April 1968 (Rescue Agreement);

(c) The Convention on International Liability for Damage Caused by Space Objects, 29 March 1972 (Liability Convention);

(d) The Convention on Registration of Objects Launched into Outer Space, 14 January 1975 (The Registration Convention).

Under the legislation of the Outer Space Act, the Secretary of State shall not grant a licence unless he is satisfied that the activities authorized by the licence will not jeopardize public health or the safety of persons or property, will be consistent with the international obligations of the United Kingdom and will not impair the national security of the United Kingdom. Further, the Secretary of State requires the licensee to conduct its operations in such a way as to prevent the contamination of outer space or adverse changes in the environment of the Earth, and to avoid interference with activities of others in the peaceful exploration and use of outer space.

The Secretary of State requires the licensee to insure itself against liability incurred in respect of damage or loss suffered by third parties, in the United Kingdom or elsewhere, as a result of the activities authorized by the licence. Further, the licensee shall indemnify Her Majesty's Government in the United Kingdom against any claims brought against the government in respect of damage or loss arising out of activities carried on by the licensee to which the Act applies.

The Outer Space Act provides the necessary regulatory oversight to consider public health and safety, and the safety of property; to evaluate the environmental impact of proposed activities; to assess the implications for national security and foreign policy interests; and to determine financial responsibilities and international obligations.

Licensing process and technical evaluation

Safety evaluation is aimed at determining whether an applicant can safely conduct the launch of the proposed launch vehicle or vehicles and any payload. Because the licensee is responsible for public safety, it is important that the applicant demonstrate an understanding of the hazards involved and discuss how the operations will be performed safely. There are a number of technical analyses, some quantitative and some qualitative, that the applicant must perform in order to demonstrate that the commercial launch operations will pose no unacceptable threat to the public. The quantitative analyses tend to focus on the reliability and functions of critical safety systems, the hazards associated with the hardware and the risk those hazards pose to public property and individuals near the launch site and along the flight path, to satellites and to other on-orbit spacecraft. The qualitative analyses focus on the organizational attributes of the applicant, such as launch safety policies and procedures, communications, qualifications of key individuals, and critical internal and external interfaces.

The launch of a payload into orbit and the hazards associated with such an operation can be categorized into the general mission phases of:

(a) Pre-launch;

(b) Launch;

(c) Orbit acquisition;

(d) Re-entry.

In the technical submissions for a licence under the Outer Space Act 1986, an applicant must provide an assessment of the risk to public safety and property, covering each phase of the mission relevant to the proposed operations and licensed activity. That assessment should include:

(a) Discussion of possible vehicle and payload failures that could affect safety (including the safety of other active spacecraft);

(b) Estimation of the likelihood of their occurrence, supported by vehicle reliability data, both theoretical and historical;

(c) Consideration of the effects of such failures.

As appropriate, the assessment should address:

(a) Launch range risks;

(b) Risk to downrange areas owing to the impact of discarded mission hardware;

(c) Overflight risks;

(d) Orbital risks, including the risk of collision and/or debris generation, owing to intermediate and final orbits of vehicle upper stages and payloads;

(e) Re-entry risks of vehicle upper stages and payloads.

This risk assessment is then used as a basis for the review conducted by assessors to determine if the applicant's proposed activities are compliant with the requirements of the Outer Space Act. The qualitative and quantitative criteria used for that evaluation are based on standards and practices employed by a variety of formal bodies. In each case, the assessor seeks to understand the approach proposed by the licence applicant, to judge the quality of that process, to check the degree of consistency within the project, to consider the effectiveness of the proposed technology or process and to establish its conformance with industry or Agency norms, and the requirements of the Outer Space Act.

Space debris mitigation and interpretation within the Outer Space Act

In developing the technical evaluation framework to reflect space debris mitigation issues, the particular issues of physical interference and contamination referred to in the Outer Space Act are employed. Although the problem of space debris was not recognized when the Outer Space Act was enacted in 1986, the Act is flexible enough to allow interpretation to cover this aspect in the technical evaluation. Thus, "physical interference" is used to address the probability of collision with other objects in orbit and "contamination" to address safe disposal at end of life. As regards the actual measures that are used to evaluate a licence application, use is made of the growing number of guidelines, codes and standards that are being developed to deal with space debris mitigation. The IADC Space Debris Mitigation Guidelines and the Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space provide qualitative and quantitative measures that are used to assess the compliance of licence applicants' proposed activities and measures with recognized best practice within the community. The most common licence that the UK Space Agency processes is a payload licence. In the case of a payload licence, the safety assessors check the satellite platform's specifications (e.g. attitude control system, orbit, power storage mechanism, launcher interface and separation mechanism) and the safety processes (plans and procedures) to assess their effectiveness at space debris mitigation. Examples are given below:

Attitude control system. Initial determination of the nature of a system and whether it is fit for purpose. Is the technology cold gas thrusters or reaction/momentum wheels, is there a potential for stored energy at end of life? If so, consider the likelihood of fragmentation occurring and if so, recommend passivation measures at end of life.

Orbit. Basic understanding of the orbital elements of the proposed trajectory. Consider natural lifetime, stability of orbit under the influence of natural perturbations, degree of crowding at a particular altitude, any unique aspects of orbit configuration.

Power storage mechanism. General review of technology and suitability. Is it physical (flywheel) or electric, are fuel cells standard technology, are there any unique or exotic elements (e.g. radioisotope thermal generator), is the system scaled for platform power requirements and charge cycles (account for eclipse characteristics), is there a potential overcharge problem at end of life, passivation consideration?

Launcher interface and separation mechanism. Understand the nature of the coupling and ejection process. Is the interface dictated by the launcher or payload, is the launch environment very demanding, is the launch environment well understood, specified and payload-qualified? How many objects are introduced into orbit in addition to the upper stage and payload, does the separation process minimize debris production?

Safety processes and procedures. Determine the existence and consideration of safety issues. Where relevant to the launch phase, consider safety implications of the payload for the launcher: are there unique risks associated with the payload, if a multiple payload launch, does payload deployment pose a risk to others?

With regard to contamination of the environment, the impact on both the debris and radiation environment is assessed (for example, frequency interference).

Impact on the debris environment. Safety assessors consider the likelihood of collision of the payload with other operational payloads and general debris environment. This is determined by orbital configuration, orbital lifetime, physical size and spatial density of objects at the proposed altitude.

De-orbit or re-orbit plans. Regarding the operator's ability to comply with safety requirements, the applicant is asked about its de-orbit/re-orbit plans, whether plans exist to remove the satellite from the operational orbit should an irrecoverable failure occur, whether such capability is available, etc. Safety assessors need to understand whether plans exist and if so, whether they are effective. Has the issue been considered, at what altitude is operational orbit, is disposal necessary, is re-orbit to a higher altitude or de-orbit to a lower altitude planned, are disposal orbits effective, do they comply with existing standards and guidelines (e.g. use of IADC re-orbiting formula for geostationary Earth orbit satellites, 25-year maximum disposal orbit lifetime below 2,000 km), what is feasible with platform technology, extent of autonomy on board to conduct de-orbit or re-orbit without ground intervention, what criteria are used to determine end of life? Are operational procedures agreed or will they be put in place prior to regular operations?

Summary

The United Kingdom has implemented space debris mitigation measures in its evaluation of licence applications under the United Kingdom Outer Space Act 1986 to ensure compliance with the established outer space treaties and conventions and the emerging set of guidelines, codes and standards. In addition to setting the requirements for compliance, the United Kingdom performs compliance monitoring activities, including the use of ground-based space surveillance systems such as the Starbrook optical telescope to monitor the position of United Kingdom-licensed satellites in orbit.

III. Replies received from international organizations

Committee on Space Research

[Original: English]
[8 October 2013]

The Committee on Space Research (COSPAR) has been addressing the topic of space debris for more than a quarter of a 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. Those 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.

In 2012 the theme of the PEDAS sessions was “Space debris — steps towards environmental control”. At the fortieth COSPAR Scientific Assembly, in 2014, the theme of the PEDAS sessions will be “Space debris — responding to a dynamic environment”. Four half-day sessions will address advances in ground- and space-based observations and methods for their exploitation, in situ measurement techniques, debris and meteoroid environment models, debris flux and collision risk for space missions, on-orbit collision assessment, re-entry risk assessments, debris mitigation and debris environment remediation techniques and their effectiveness with regard to long-term environment stability, and national and international debris mitigation standards and guidelines.

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 of the continued growth of the space debris population to the numerous space systems serving vital needs on Earth and adopted first national and then international space debris mitigation policies. In 2002 IADC established the first consensus set of space debris mitigation guidelines for the world’s leading national space agencies. Those guidelines were used as the foundation for the Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space of 2007.

Collisions among resident space objects can not only be potentially catastrophic, but can also generate large numbers of new debris objects that could further degrade the near-Earth space environment. This threat was first discussed in the 1970s, but new studies in 2005 indicated that some parts of the low Earth orbit region, i.e. altitudes below 2,000 km, 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 is known as the Kessler syndrome and 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 mm to 10 cm. With very high collision velocities, those small debris objects 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 objects. 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 moderate-sized debris objects already in orbit will collide with one another with increasing frequency and create new hazardous debris.

Consequently, the removal of existing space debris objects, 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 potential of a wide variety of space debris removal concepts. Those 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 promoting the long-term sustainability of operations in near-Earth space for the benefit of all.

COSPAR continues to be a leader in promoting a better understanding of the nature and risks of the space debris environment and in encouraging spacefaring nations and organizations to act responsively in space through each mission phase, including deployment, operations and disposal.

Secure World Foundation

[Original: English]
[18 October 2013]

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 2013, the Secure World Foundation completed a two-year series of international events on issues of on-orbit satellite servicing and active debris removal. On-orbit satellite servicing and active debris removal are part of an emerging category of future on-orbit activities that are critical for taking the next leap in our use of Earth orbit and could play a critical role in mitigating orbital debris and preventing collisions between orbital debris and active satellites. Those activities also raise a host of diplomatic, legal, safety, operational and policy challenges that need to be tackled for that future to be possible. Working with partners, SWF organized a series of international events to bring in the perspectives and viewpoints of all stakeholders on non-technical challenges of active debris removal and on-orbit satellite servicing.

The series of events began with a scenario-based workshop in Washington, D.C., on 5 November 2012, which convened experts from United States government agencies, the private sector and civil society to examine the national regulatory challenges of active debris removal and on-orbit satellite servicing across four different scenarios of possible future private sector activities. On 30 October 2012, in partnership with the French Institute of International Relations, SWF held a public conference on on-orbit satellite servicing and active debris removal in Brussels in order to engage the European community. Specific topics that were addressed included the dual-use nature of on-orbit satellite servicing and active debris removal technologies, norms of behaviour for conducting on-orbit satellite servicing and active debris removal activities, and transparency and confidence-building measures to reduce the risk of such activities being seen as threats. On 19 February 2013, SWF held another active debris removal and on-orbit satellite servicing scenario workshop in Singapore. Attendees included experts in the fields of space policy, space law and space operations from Australia, Canada, China, Germany, India, Japan, Switzerland and the United States. On 20 February 2013, SWF held a full-day public conference in partnership with the Singapore Space and Technology Association. The conference was a continuation of the discussions previously held at the conferences in Belgium and the United States.

The overall conclusion from the discussions at those events was the importance of one or more active debris removal or on-orbit satellite servicing demonstration missions for tackling legal and policy challenges. Ideally, such demonstration missions would involve more than one country and both government and private sector actors. The demonstration missions would provide concrete examples of such activities with specific legal and policy challenges. The demonstration missions would force the relevant actors to resolve those challenges, and in doing so lay the groundwork for establishing the mechanisms, transparency and confidence-building measures, and norms necessary for future active debris removal and on-orbit satellite servicing activities to be carried out in a safe, secure and sustainable manner.

All of the participants in those discussions noted that much more dialogue and work were needed to addresses the challenges of active debris removal and on-orbit satellite servicing. There was consensus that those activities would be a key part of future human activities in space. Addressing the legal and policy challenges that those activities pose is critical not only for enabling them but also for ensuring that they contribute to the safety, security and long-term sustainability of the space domain instead of detracting from it.

In September, the International Aeronautical Federation Young Professional Programme invited the next generation of aerospace professionals to a reception about space debris as part of the 64th International Astronautical Congress, in Beijing. That event was sponsored by SWF and the Federal Polytechnic Institute of Lausanne. Over 100 delegates listened to experts discussing the threats of space debris and the challenges to mitigating them and brought their own opinions to the table by asking questions and providing comments.

Space Generation Advisory Council

[Original: English]
[15 October 2013]

Design of an active space debris removal mission based on priority targets

With more than 93 per cent of the catalogued in-orbit population consisting of space debris, the safety of operational spacecraft, including those with on-board nuclear power sources, is threatened by possible collisions that could result in structural damage or complete disintegration. Several research programmes have assessed the current and future state of the space environment, with studies indicating the urgent need for active debris removal programmes to ensure long-term space sustainability. In order to design an effective active debris removal mission, high-priority targets for future active debris removal missions need to be first identified on the basis of deterministic data of top conjunction objects from daily satellite conjunction alerts. The accurate representation of high-risk objects and regions in space allows for the continual development and implementation of active debris removal solutions that are capable of remediating space debris in low Earth orbit.

Design of technically feasible active debris removal missions

While international efforts to mitigate the current situation and limit the creation of new debris are useful, recent studies predicting debris evolution have indicated that they will not be enough to ensure humanity's access to and use of the near-Earth environment in the long term. Rather, active debris removal must be pursued if we are to continue benefiting from and conducting space activities. A programme capable of approaching the debris object through a close-range rendezvous, establishing physical contact, stabilizing its altitude and finally de-orbiting the object is recommended. Research undertaken at the Space Generation Advisory Council (SGAC) has shown that a modified launch vehicle upper stage equipped with the addition of an electrodynamic tether system could be used to de-orbit large debris objects from polar orbit while also delivering an acceptable payload to orbit. The feasibility of the proposed concept allows the upper stage of the launch vehicle to act as a "hunter system" after delivery of its primary payload.

Measures relating to an economically, legally and politically viable active debris mission

While the concept of active debris removal is not new, there are a host of economic, legal, regulatory and political issues associated with debris remediation. An international, cooperative, public-private partnership concept can address many of these issues and be economically sustainable, while also driving the creation of a proper set of regulations, standards and best practices. A method of objective evaluation based on a scorecard with criteria in each of these non-technical areas is proposed to make a multidisciplinary assessment of active debris removal concepts in a Space Safety and Sustainability Project Group paper presented at the 64th International Astronautical Congress, in Beijing. The scorecard method is a strategic performance tool that is used to keep track of criteria considered important to the performance of the system, based on a project's effectiveness in a specific field, including legal, policy, technical and economic frameworks.

In order to fully comprehend the extent of the space debris issue, help to avoid collisions and eventually manage active debris removal, continual research into a framework for international debris removal efforts is crucial. The Space Safety and Sustainability Project Group, on behalf of SGAC, encourages active participation among students and young professionals in space safety and sustainability-related debates and activities to expand on the current knowledge in order to minimize the risk of orbital collisions.