United Nations A/AC.105/888

General Assembly

Distr.: General
14 December 2006

Original: English

**Committee on the Peaceful Uses of Outer Space**

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

**Note by the Secretariat**

Contents



V.06-58964 (E) 291206 291206

# I. Introduction

1. In paragraph 24 of its resolution 61/111 of 14 December 2006, the General Assembly considered that it was essential for Member States to 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, and also considered that, to the extent possible, information thereon should be provided to the Scientific and Technical Subcommittee of the Committee on the Peaceful Uses of Outer Space, and agreed that international cooperation was needed to expand appropriate and affordable strategies to minimize the impact of space debris on future space missions.

2. At its forty-third session, the Scientific and Technical Subcommittee agreed that Member States and space agencies should again be invited to provide reports on research on space debris, safety of space objects with nuclear power sources on board and problems relating to their collision with space debris (A/AC.105/869, para. 96). In a note verbale dated 25 August 2006, the Secretary-General invited Governments to submit any information on the matter by 30 October 2006, so that that information could be submitted to the Scientific and Technical Subcommittee at its forty-fourth session.

3. The present document has been prepared by the Secretariat on the basis of information received from the following Member States: Finland, Japan, Latvia, Poland and the United Kingdom of Great Britain and Northern Ireland.

# II. Replies received from Member States

## Finland

[Original: English]

Finland has several ongoing space debris research activities and applications:

(a) The debris in-orbit evaluator (DEBIE), space debris sensors and data-processing units were launched on board the Project for On-board Autonomy (PROBA) satellite in October 2001;

(b) DEBIE will later fly on the International Space Station in a more operational role;

(c) A low-Earth orbit space debris survey was carried out using European incoherent scatter (EISCAT) radars (demonstrated capability: 1-centimetre and larger objects) in Lapland;

(d) The University of Turku carried out a geostationary orbit space debris survey using the European Space Agency's telescope located in the Canary Islands, Spain.

## Japan

[Original: English]

The research related to space debris in Japan, mainly conducted by the Japan Aerospace Exploration Agency (JAXA) and Kyushu University, has been focused on the following work.

### (a) Ground-based space debris observation

Along with routinely conducted observation of objects in the geosynchronous Earth orbit (GEO) region above Japanese territory and objects in the low-Earth orbit region, research and development is conducted by an automatic detection technique for debris at the geostationary satellite orbit, a signal-stacking method for detection of faint noise-level GEO objects [annex A],* as well as a system to estimate the motion and shape of an object from the time-history of optical intensity.

### (b) Modelling of debris population

A study to predict the long-term evolution of artificial objects in low-Earth orbit, taking into account collisions and explosions, is being conducted by Kyushu University, as described in annex B.

### (c) Hypervelocity impact testing

Hypervelocity impact testing was once conducted to develop the bumper for the Japanese Experiment Module of the International Space Station. The study is being continued by JAXA and the target of the study has shifted to the protection of unmanned spacecraft. Extensive data acquisition has been conducted on the impacts on composite materials and metals using a conical-shaped charge system and gas guns [annexes C and D] and the results are analysed in comparison to the standard break-up model [annex E] of the National Aeronautics and Space Administration (NASA) of the United States of America.

While focusing on the phenomena induced by the debris impact, the paper (annex F) presents the possibility of detecting debris impact with radio-wave emissions, which can be adapted to the International Space Station and other spacecraft.

### (d) Electro-dynamic tether to accelerate orbital decay for post-mission spacecraft

As a method of accelerating orbital decay of post-mission spacecraft and debris that is more efficient from a mass-penalty point of view and by its simplicity, electro-dynamic tether (EDT) is being studied by JAXA and Kyushu University. A system using EDT called the “space debris micro remover”, which has a capability to rendezvous with and capture the target, is being studied and its conceptual design has been prepared [annexes G and H].

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* All annexes referred to in the reply from Japan can be found on the website of the Office for Outer Space Affairs of the Secretariat (www.unoosa.org).

## Latvia

[Original: English]

The Ventspils International Radio Astronomy Centre and the University of Latvia Institute of Astronomy, in cooperation with the Academy of Sciences of the Russian Federation and the National Academy of Sciences of Ukraine, are in the process of joining the 5 GHz frequency band to the radio-location observation network of space debris and near-Earth objects. To date, the corresponding receiver has been designed and tested. A complete incorporation into the observation programme is anticipated in 2007. At present, the researchers of the Radio Astronomy Centre and the Institute of Astronomy of the University of Latvia are processing the data that has already been collected.

## Poland

[Original: English]

No major activities were performed. There is an educational project related to minimizing the creation of space debris. The main goal of the project is to test the technical solutions for the de-orbiting of satellites after the end of their operational life on the low-Earth orbit. The project is led by students from the Warsaw University of Technology.

## United Kingdom of Great Britain and Northern Ireland

[Original: English]

### 1. Introduction

1. The British National Space Centre (BNSC) maintains an active role in addressing the space debris problem by encouraging coordination at national, European and international levels to reach agreement on effective debris mitigation solutions.

2. Central to this is BNSC's membership in the Inter-Agency Space Debris Coordination Committee (IADC), which is an important forum for achieving international consensus on debris mitigation (see www.iadc-online.org). BNSC contributes to IADC in a number of ways: exchanging information on space debris research activities with other member space agencies, facilitating opportunities for cooperation in space debris research, reviewing the progress of ongoing cooperative activities, and identifying debris mitigation options. In April 2006, the United Kingdom participated in the 24th IADC meeting in Japan, which was hosted by the Japan Aerospace Exploration Agency.

3. Within Europe, debris research capabilities are coordinated through a Space Debris Network of Centres group. BNSC is a member of this group, together with the European Space Agency (ESA) and three national agencies: the Italian Space Agency, the Centre national d'études spatiales of France and the German Space

Agency. The Network of Centres is responsible for the production of an Integrated European Work Plan and Strategy for space debris.

4. At the national level, BNSC maintains its support of the United Kingdom Space Debris Coordination Group, which meets annually to provide a forum for the coordination of all debris research and policy activities by the United Kingdom. The Rutherford Appleton Laboratory hosted the 2006 meeting in November, and participation included United Kingdom industry and academia. The meeting discussed the latest international developments, in particular with respect to space debris mitigation guidelines and standards, and provided an opportunity to report on recent research in the United Kingdom.

5. The United Kingdom has particularly strong debris research capabilities, which BNSC regularly calls upon for impartial technical support and advice. During the past year, organizations in the United Kingdom have conducted a wide range of activities, some of which are summarized below.

## 2. Observation and measurement of the debris population

### (a) Participation of the United Kingdom in the Measurements Working Group of the Inter-Agency Space Debris Coordination Committee

6. BNSC undertook medium-Earth orbit (MEO) debris research in support of the IADC work programme using the United Kingdom network of passive imaging metric sensors, a technology demonstration project run by the United Kingdom Ministry of Defence. The research and analysis was carried out by Space Insight Ltd. on behalf of BNSC and was reported at the 24th IADC meeting, in Japan. The results of the MEO study included the first report of the discovery of uncorrelated MEO objects during a search programme targeted on the MEO orbit regime to be presented to the IADC.

### (b) In situ detectors and measurement of retrieved surfaces

7. During 2005 and 2006, researchers at the Natural History Museum and the University of Kent (in Canterbury, United Kingdom) have concentrated on impacts onto silica aerogel and aluminium 1100 substrates in collaboration with NASA; and on preparation for a suite of European experiments to be deployed on the International Space Station in 2008 as part of the United States large area debris collector. In collaborative laboratory work, light gas gun impacts at the University of Kent have been employed to create craters from impacts at 6 km/s. Analytical electron microscopy at the Natural History Museum has been used for crater measurements, giving a robust size calibration for impacting particle size and a wide range of density and composition. New stereometric software has been used to reconstruct and analyse crater morphology in three dimensions. The primary purpose was to support interpretation of cometary grain impacts on the Stardust spacecraft, but the development of techniques for residue composition analyses should also be applicable for recognition of specific micrometeoroid materials in impacts on spacecraft in low-Earth orbit (LEO).

### 3. Debris environment modelling

8. United Kingdom debris researchers remain active in modelling the debris environment, its long-term evolution and the potential risks it causes to possible future space systems.

#### (a) Participation of the United Kingdom in the Environment and Database Working Group of the Inter-Agency Space Debris Coordination Committee

9. BNSC took part in a study with other delegations on the Environment and Database Working Group of IADC to investigate the role of the orientation of the eccentricity vector in relation to the Sun for the long-term evolution of geosynchronous Earth orbit (GEO) disposal orbits. There was good agreement found between the participating delegations, with orbits having a "solstice-pointing" eccentricity vector being identified as the least variable. The conclusion of this work was the insertion of an upper value for disposal orbit eccentricity into the IADC space debris mitigation guidelines.

#### (b) Modelling the debris environment

10. At the Astronautics Research Group at the University of Southampton, work is progressing on studies investigating long-term projections of the LEO and GEO space debris environments. New studies of the LEO debris environment are focusing on the influence of thermospheric cooling and future predictions of solar flux on a variety of scenarios (including business-as-usual, post-mission-disposal and no-future-traffic) over 100 and 200 years using the University's three-dimensional-capable environment model, Debris Analysis and Monitoring Architecture for the Geosynchronous Environment (DAMAGE). Preliminary results from these studies indicate that there is sufficient mass currently on-orbit to maintain collision activity, and so to increase the debris population, without the addition of future traffic. Further, the results show an increased risk of collision in the presence of thermospheric cooling. Further work is ongoing to establish the uncertainty within these results.

### 4. Spacecraft debris protection and risk assessment

11. The assessment of risk to and protection of spacecraft from hypervelocity debris impacts is another research area in which the United Kingdom remains active.

#### (a) Participation of the United Kingdom in the Protection Working Group of the Inter-Agency Space Debris Coordination Committee

12. BNSC continues to participate in protection-related activities within the Protection Working Group of IADC. The current focus of the Group's effort is the production of a report on the feasibility and options for the design of an impact sensor network that could be fitted onto a variety of spacecraft. The purpose of such a system would be to provide operators with real-time data on the occurrence of impacts and their association with spacecraft anomalies or failures. The United Kingdom representative is the lead editor of the report, which should be published in late 2007 or early 2008.

13. Another significant output of the group is the development of a *Protection Manual* containing technical information relating to spacecraft debris risk assessment and protection. The first issue of this document (No. IADC-04-03) was published on the IADC website in 2004. A second issue of the *Protection Manual* is currently being drafted.

**(b) Satellite survivability modelling**

14. The company QinetiQ participated in a recently completed ESA study contract led by the Ernst-Mach-Institut of Germany to characterize the response of typical spacecraft equipment to debris and meteoroid impacts. An extensive impact test programme was performed and damage equations derived. These were embedded into a risk assessment code called "SHIELD" to provide a more accurate predictive capability for determining the survivability of a typical unmanned spacecraft.

**(c) Numerical simulation of hypervelocity impacts**

15. The company Century Dynamics is the developer and supplier of the explicit transient dynamics software "AUTODYN". This is used worldwide for the simulation of non-linear dynamic events, including hypervelocity impact events. The company continues to be heavily involved in the support of clients worldwide (such as ESA, NASA and others) in the application of the software to problems related to space debris and now increasingly on problems related to planetary impact.

16. Furthermore, Century Dynamics continues to participate in research projects for the ESA European Space Research and Technology Centre in relation to space debris. An ongoing project, in collaboration with the Ernst-Mach-Institut, involves the development of carbon fibre reinforced plastic (CFRP) material model data for hypervelocity impact numerical simulations. Previous projects with ESA have concentrated on developing sophisticated models for composite materials. In AUTODYN, orthotropic materials subject to shock wave loading can be simulated with the correct thermodynamic response. Advanced damage modelling capabilities allow prediction of the extent of damage and residual strength of fibre reinforced composite materials after impact, orthotropic non-linear stress-strain response, directional damage initiation, and progressive damage growth. An extensive programme of experimental tests has been completed during the current study from which material model data have been derived. The focus now is to validate this data for the numerical simulation of hypervelocity impact events such as micrometeoroid impact on a CRFP-aluminium honeycomb structure.

**(d) Hypervelocity impact testing**

17. At the University of Kent, work has focused on studying impacts in the laboratory using a two-stage light gas gun to recreate impacts. The gun is fully operational and fires almost every day on a variety of projects. In the past year, it has been used to carry out work for a client on simulating grazing incidence impacts on spacecraft materials. Work has also continued on developing sub-micron dusts for use in electrostatic accelerators as mimics of cosmic dust. These can then be used in laboratory simulations of impacts.

## 5. Debris mitigation

### (a) Participation of the United Kingdom in the Mitigation Working Group of the Inter-Agency Space Debris Coordination Committee

18. Within the Mitigation Working Group of IADC, QinetiQ, on behalf of BNSC, is leading the work towards a firmer understanding of re-orbiting GEO objects at the end of their useful life. The focus of this work is to provide guidance on the initial target orbital parameters for the re-orbited GEO object. In particular, studies have shown that careful consideration of the eccentricity vector is beneficial in preventing the object from re-entering the protected GEO region. Similar work has also been performed for BNSC on the navigation satellite orbits, in particular the Galileo constellation. Studies have begun to consider draft recommendations for disposing of Galileo assets that have reached the end of their operational lifetime, ensuring that the defunct objects do not present a hazard to the remaining operational navigation satellites.

### (b) Debris mitigation standards

19. The United Kingdom continues to be actively involved in work to identify and draft engineering standards related to the mitigation of space debris. Inputs have been provided through the European Cooperation for Space Standardisation initiative and the International Organization for Standardization (ISO), where the United Kingdom chairs a working group charged with coordinating all work on space debris mitigation standards throughout ISO. In drafting the standards, care has been taken to align them, as far as possible, with the IADC guidelines for space debris mitigation. Contributions from United Kingdom experts are coordinated at the national level through the British Standards Institute.

### (c) United Kingdom satellite-licensing process

20. BNSC is responsible for issuing licences to confirm that United Kingdom satellites are launched and operated in accordance with the United Kingdom's obligations under the Outer Space Act 1986. To assist BNSC in the licensing assessment process, QinetiQ uses a specially developed software tool called "SCALP" to evaluate the satellite collision risks and liabilities. This analysis forms part of the overall assessment that allows BNSC to make an informed judgement on whether to grant a licence. Over the past year, safety evaluations have been performed on three GEO spacecraft: AMC14, AMC18 and SESC4 (change of orbital slot).

## 6. Near-Earth objects

21. The Rutherford Appleton Laboratory organized a meeting in London on 23 November 2005 to discuss a way forward on near-Earth objects under the auspices of the Royal Aeronautical Society. The Society endorsed the leadership of ESA for such future activities in Europe through initiatives such as the Don Quijote mission concept.

22. The Astronautics Research Group at the University of Southampton is conducting a significant amount of research into the effects of near-Earth object impacts on the Earth. A software tool was developed in the period 2004-2005 to assess the repercussions of impact-generated effects for the human population and

this was exploited in the last year to analyse particular impact case studies. The first of these was an evaluation of the casualty numbers resulting from ground and sea impacts in the regional neighbourhood of the United Kingdom and the other was a study of the effects on the human population resulting from the potential impact of the asteroid 99942 Apophis in 2036. The results of these studies will be published in the Proceedings of the International Astronomical Union Symposium on Binary Stars as Critical Tools and Tests in Contemporary Astrophysics, held in Prague in August 2006.

23. This work is being further advanced with the development of a more capable software tool, called the near-Earth object impactor, which will be used for global studies of the effects of near-Earth object impact-generated effects on both population and infrastructure. The tool contains sophisticated models of the impact-generated effects for airbursts, ground impacts and ocean impacts. Completion of the research programme, which is funded jointly by the University of Southampton and BNSC, is expected in 2007.