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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*

Addendum

Contents

* The present document was prepared on the basis of replies received from the United Kingdom of Great Britain and Northern Ireland and the Committee on Space Research after 30 November 2007.

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I. Replies received from Member States

United Kingdom of Great Britain and Northern Ireland

[Original: English]

1. Introduction

1. The United Kingdom of Great Britain and Northern Ireland, through the British National Space Centre (BNSC), maintains an active role in addressing the space debris problem by encouraging coordination at the national and international levels to reach agreement on effective debris mitigation solutions. Central to this is the membership of BNSC on the Inter-Agency Space Debris Coordination Committee (IADC), which is an important forum for achieving international consensus on space debris mitigation. BNSC contributes to IADC by participating in cooperative research activities and working with other member space agencies to formulate debris mitigation solutions and guidelines. In July 2007, the United Kingdom participated in the twenty-fifth meeting of IADC, which was hosted by the Centre national d'etudes spatiales (CNES) in Toulouse, France.

2. The United Kingdom is also actively involved in the development of spacecraft engineering standards pertaining to the mitigation of space debris. Contributions have been provided by experts in BNSC, industry and academia to the International Organization for Standardization (ISO), of which 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.

3. Within the United Kingdom, BNSC is responsible for issuing licences to confirm that United Kingdom satellites are launched and operated in accordance with the obligations of the United Kingdom under the Outer Space Act 1986. The conformance of satellites and launch vehicles with debris mitigation guidelines and standards is an important consideration in the decision to grant a licence. During the past year, QinetiQ has supported BNSC in evaluating license applications from several space system operators including Paradigm, Inmarsat and SES Satellite Leasing.

4. The United Kingdom space debris community has continued to make notable contributions to measure the debris population and model its long-term evolution, to improve impact protection in spacecraft and to develop debris mitigation solutions. A selection of this work is summarized below.

2. Observation and measurement of the debris population

5. During 2007, the United Kingdom participated in two re-entry prediction campaigns, which were organized by IADC. The first campaign related to Cosmos 1025 (COSPAR ID 1978-067A), which returned to Earth on 9 March 2007; the second campaign related to a Delta 2 rocket body (COSPAR ID 2007-023B), which returned to Earth on 16 August 2007. The technical lead for risk object re-entry prediction in the United Kingdom is Space Insight, which provides support to BNSC on a range of activities related to space situational awareness. That

operational support includes, among other things, information on anticipated re-entries of risk objects and, using the Starbrook space surveillance system, the monitoring of platforms licensed under the United Kingdom Outer Space Act in order to ensure the compliance of the activities of licensees with the obligations of the United Kingdom under the outer space treaties. Figure I[1] shows an example of a Starbrook image. In addition to its national regulatory role, Starbrook is also used to take observations which form the contributions of the United Kingdom to the IADC campaigns to measure the debris population.

6. A United Kingdom team comprising QinetiQ and Space Insight has studied capability gaps for a European space situational awareness system for the European Space Agency (ESA), giving consideration to the present and future needs of operators, Governments and other parties such as insurers with respect to knowledge of the position and the characteristics of orbiting objects. The contribution of QinetiQ to the study included system-level procurement guidance and radar and space-based observation expertise, while Space Insight provided technical requirement analysis and optical expertise.

7. The Open University, in collaboration with United Kingdom consultancy UniSpace Kent, has continued to support the analysis and interpretation of data from the ESA Debris In-Orbit Evaluator (DEBIE) instrument, which is a small, bespoke space-debris impact detector flying aboard the ESA Proba-1 spacecraft. The instrument has returned several years' worth of small-particle data. A similar instrument, DEBIE-2, which also had design and testing input from the Open University and Unispace Kent, will fly to the International Space Station aboard Space Shuttle mission STS-122 of the National Aeronautics and Space Administration (NASA) of the United States of America, in December 2007. DEBIE-2, comprising three sensor units (see figure II), will operate on the European Technology Exposure Facility.

8. Research at the Impacts and Astromaterials Research Centre of the Department of Mineralogy of the Natural History Museum in London has concentrated upon the reliable interpretation of the composition, dimensions, density and internal structure of impacting particles as deduced from residue analysis and the measurement of the three-dimensional morphology for hypervelocity impact features on aluminium alloys and from particles captured in silica aerogel. Most of the effort addressed the nature of cometary dust impacts on the Stardust spacecraft (see figure III), but had subsequent applications for materials subject to micrometeoroid and space debris hypervelocity impacts in low-Earth orbit, including Long Duration Exposure Facility clamps, a Hubble Space Telescope stanchion shroud and a re-entered Salyut 7/Kosmos 1686 titanium tank.

3. Debris environment modelling

9. The contribution of BNSC to IADC Working Group 2 (Environment and Databases) has focused on modelling the future debris populations in low-Earth orbit and geostationary orbit. BNSC led a comparison of the three evolutionary models, Debris Analysis and Monitoring Architecture for the Geosynchronous

[1] The original document submitted by the United Kingdom in English, including the figures referred to in this document, can be found on the website of the Office for Outer Space Affairs of the Secretariat (http://www.unoosa.org/oosa/natact/sdnps/2007/index.html).

Environment (DAMAGE) of BNSC, the LEO-to-GEO Environment Debris model (LEGEND) of NASA and the Space Data Management (SDM) project of the Italian Space Agency (ASI), in a study of the future geostationary orbit environment and concluded that these models are now ready to perform detailed projections of the debris population in geostationary orbit. In addition, the instability of low-Earth orbit debris populations, under a “no new launches” scenario, has been investigated by researchers at the University of Southampton using the DAMAGE model and a new model, called “Fast Debris Evolution” (FADE). The results of that work suggest that the low-Earth orbit environment is approaching a critical point and that an “active debris removal” policy may be required in the future to prevent uncontrolled debris growth. Figure IV shows a snapshot of the debris population in low-Earth orbit, as modelled with DAMAGE.

10. Researchers at the University of Southampton have developed a new risk assessment model for near-Earth object (NEO) impacts. Results from studies conducted in 2007 identify the countries at risk, in terms of number of casualties and loss of infrastructure, from a NEO impact. The United Kingdom appears eighth in the ranking of the ten countries most at risk.

4. Spacecraft debris protection and risk assessment

11. BNSC continues to participate in IADC Working Group 3 (Protection), whose current focus of 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. It is expected that the report will be published in 2008.

12. United Kingdom researchers continue to improve numerical simulation models of the complex interactions between hypervelocity debris/meteoroid particles impacting typical spacecraft structures. The company Century Dynamics has been extending and validating its explicit transient dynamics software, “ANSYS AUTODYN”, to model impacts on carbon fibre reinforced plastic/aluminium honeycomb structures, as shown in figure V. The AUTODYN software is used worldwide on a variety of space debris impact-related problems and now, increasingly, on planetary impact-related problems.

13. The Crashworthiness, Impact and Structural Mechanics Group at Cranfield University has been collaborating with the Los Alamos National Laboratory of the United States and the Ernst-Mach-Institute of Germany to develop the non-linear finite element code, “LLNL-DYNA3D”, for predicting the response of a material to a hypervelocity debris impact. This technique is now coupled with a smooth particle hydrodynamic method to provide improved modelling accuracy. The codes have been used to model impacts on spacecraft structures and fuel tanks, as shown in figure VI.

14. The two-stage light gas gun at the University of Kent continues to be used in support of debris/meteoroid impact protection studies. Work has focused on spacecraft shielding effectiveness and impact detectors for structures for the Return to the Moon project (carried out in collaboration with the United States).

5. Debris mitigation

15. The participation of BNSC in IADC Working Group 4 (Debris Mitigation) has focused on the following activities during the past year: carrying out a worldwide survey of procedures used to estimate the hazards caused by re-entering space objects; reviewing studies related to the long-term presence of objects in the geostationary region; and reviewing and updating the IADC space debris mitigation guidelines.

16. The disposal of satellites at end-of-life is a key recommendation of the IADC guidelines. In accordance with that, Paradigm, on behalf of the United Kingdom Ministry of Defence and with support and advice from QinetiQ, successfully planned and re-orbited the NATO IVA satellite to a graveyard orbit during August/September 2007.

17. Several organizations have been working on the space engineering aspects of space debris mitigation. For example, the Space Research Centre of Cranfield University has studied a drag sail concept for de-orbiting spacecraft from low-Earth orbit (see figure VII) and the design of a space tug satellite to inspect, service and re-orbit spacecraft in geosynchronous orbit.

18. Finally, space debris mitigation will be addressed in a special issue of the Institute of Mechanical Engineers *Journal of Aerospace Engineering* to be published in December 2007. United Kingdom experts have contributed papers on satellite decommissioning, ISO standards, the current legal framework and insurance industry perspectives.

II. Replies received from international organizations

Committee on Space Research

[Original: English]

1. The present report by the Panel on Potentially Environmentally Detrimental Activities in Space (PEDAS) of the Committee on Space Research (COSPAR) covers the timespan from October 2006 to October 2007. It addresses only space debris issues, which represent the current focus of PEDAS activities.

2. Most of the deterministic knowledge on objects orbiting the Earth is obtained from the United States Space Surveillance Network (SSN), which can detect and track objects down to 5 centimetres in diameter in low-Earth orbit altitudes, and objects down to about 30 centimetres in diameter at geostationary orbit altitudes. On 1 January 2007, the SSN catalogue of tracked objects contained a total of about 10,000 items, of which approximately 40 per cent were fragmentation debris and 7 per cent were operational spacecraft. The remaining 53 per cent consisted of non-functional satellites, spent orbital stages and mission-related objects. In 2007, there was a total of 65 launches (compared with 63 launches in 2006).

3. On 11 January 2007, China conducted an anti-satellite test, intercepting the 960-kilogram Fengyun 1C weather satellite with a medium-range missile. The impact on a near-circular, sun-synchronous orbit occurred at an altitude of 864 kilometres. The high-intensity fragmentation produced an orbital population of

about 2,500 additional debris objects that was detected and tracked by December 2007, thus increasing the SSN catalogue population by 25 per cent, making it the worst fragmentation event in space history. Analysts estimate that the event caused a short-term increase in the probability of shield penetration of the manned modules of the International Space Station by more than 50 per cent, and a long-term increase, of 20 per cent to 80 per cent, in the probability of catastrophic collisions with operational spacecraft near the fragmentation altitude.

4. On 19 February 2007, a Russian Briz-M orbital stage exploded after it had failed to deliver ArabSat 4A into its geostationary transfer orbit on 28 February 2006, due to a premature engine shutdown, with an estimated 10 tons of propellant left in its tanks. SSN observed more than 1,100 fragments generated from that event, but few of them were entered in its catalogue, due to the poor observability of the Briz-M orbit, which had a perigee of nearly 500 kilometres and an apogee of nearly 14,700 kilometres. Between October 2006 and October 2007, a total of 10 on-orbit fragmentations were detected. That is more than twice the long-term average of 4.5 fragmentations per year.

5. Several spacecraft operators monitor close fly-bys of catalogue objects near their spacecraft, in order to reduce the probability of high-intensity collisions, which could further deteriorate the debris environment. NASA conducted two collision avoidance manoeuvres in 2007. In June 2007, the spacecraft Terra was manoeuvred to evade a Fengyun 1C fragment, and in July 2007 the spacecraft Cloudsat was manoeuvred to evade the Iranian Sinah 1 satellite.

6. In 2006, 26 additional payloads and 2 orbital stages were launched and deployed into geostationary orbit. A total of 16 geostationary orbit payloads reached their end-of-life. Seven of those were re-orbited according to international guidelines (for example, IADC guidelines), seven were insufficiently re-orbited, and two were left in libration orbits. Of 911 objects in the geostationary orbit region, 354 were controlled spacecraft. Observations of the geostationary orbit region are routinely performed by the United States and Russian space surveillance networks, with resolutions down to 30 centimetres. On an experimental basis, such observations are also carried out by other entities at the national level, or through international cooperation, with resolutions down to 15 centimetres.

7. Today, radar observations of the low-Earth orbit region can detect objects down to 2 millimetres in diameter (Goldstone bistatic radar). Following the Fengyun 1C anti-satellite test, the United States Haystack Observatory radar observed a notable population increase in fragments down to 5 millimetres in size. The European Incoherent Scatter Radar and the radar of the Research Establishment for Applied Science (FGAN) of Germany (serving as a transmitter/receiver), in cooperation with the Effelsberg radio telescope of Germany (serving as receiver) also observed a significant increase in the debris population between 1 and 2 centimetres in size. Such observations, often coordinated within the framework of IADC, can be used to improve the understanding of fragmentation processes and to improve predictions of the space debris environment.

8. To preserve the long-term stability of the space debris environment, the removal (de-orbiting) of mass from the low-Earth orbit region is essential. Initially, this applies to operational payloads and rocket stages after the completion of their mission. Later, this should also include inert objects in orbit, leading to “space

debris remediation". A study on this subject is in progress at the International Academy of Astronautics.

9. Space debris is a global problem requiring international cooperation and coordination for the elaboration and implementation of effective mitigation measures. The leading entity in this respect is IADC. IADC has 11 members from all major space-faring countries. They meet annually to facilitate the exchange of technical information. The twenty-fifth meeting of IADC was held in Toulouse, France, in July 2007, hosted by CNES. The twenty-sixth meeting will be held in Moscow, in April 2008, to be hosted by the Russian Federal Space Agency. In 2007, IADC prepared an update of their *Space Debris Mitigation Handbook*. They also conducted two re-entry prediction test campaigns.

10. Since 1994, space debris has been an item of the agenda of the Scientific and Technical Subcommittee of the Committee on the Peaceful Uses of Outer Space. Several Member State delegations, as well as ESA and IADC, report regularly to the Subcommittee on their space debris activities. At its forty-fourth session, the Scientific and Technical Subcommittee approved space debris mitigation guidelines, which the Committee on the Peaceful Uses of Outer Space, at its fiftieth session, subsequently endorsed as the Space Debris Mitigation Guidelines of the Committee (A/62/20, annex). The Guidelines consist of a set of seven policy-level guidelines that were derived from the IADC space debris mitigation guidelines.

11. Principles on space debris mitigation are also important for the design and operation of spacecraft and launch systems. ISO (through its subcommittee TC20/SC14) is working on a set of standards governing implementation of space debris mitigation measures, which will serve as guidelines for manufacturers and operators of space systems.