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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

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I. Introduction

1. In paragraph 32 of its resolution 57/116 of 11 December 2002, the General Assembly considered it 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, 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 thirty-ninth session, the Scientific and Technical Subcommittee invited Member States to continue to provide reports on national 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.105/786, para. 113). In a note verbale dated 8 August 2002, the Secretary-General invited Governments to submit any information on the matter by 15 November 2002 so that that information could be submitted to the Scientific and Technical Subcommittee at its fortieth session. The present document has been prepared by the Secretariat on the basis of information received from Member States.

II. Replies received from Member States

Finland

[Original: English]

Finland has several ongoing space debris research activities and applications:

(a) DEBIE space debris sensors and data-processing units were launched on board the 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 (LEO) space debris survey was carried out using European incoherent scatter (EISCAT) radars (demonstrated capability: 1-cm and larger objects) in Lapland;

(d) The University of Oulu/Sodankylä Geophysics Observatory carried out a contract study for the European Space Operations Centre (ESOC) of the European Space Agency (ESA) to measure small-sized space debris;

(e) The University of Turku carried out a geostationary orbit space debris survey using the ESA telescope in the Canary Islands.

Iran (Islamic Republic of)

[Original: English]

Owing to the effects of humankind's aerospace activities on the environmental health of the Earth, space debris has emerged in recent decades as a problem seriously threatening the survival of orbiting spacecraft, space platforms and astronauts carrying out space walks in LEO. The orbital debris team of the Aerospace Research Institute of the Space Standards and Law Research Group is working on a variety of subjects, such as categorization, characteristics, tracking and laws relating to orbital debris. Mathematical simulation, collision probability functions and hazard analysis are possible subjects for study by the group.

Ukraine

[Original: Russian]

1. The National Space Agency of Ukraine (NSAU) shares the concern regarding the danger of man-made space debris and regards the problem of removing space debris from near-Earth space as of the utmost urgency. Aware of the global nature of the problem, the Agency is actively participating in measures being taken by the Inter-Agency Space Debris Coordination Committee (IADC).

2. In compliance with the recommendations of the eighteenth session of IADC, Ukraine is conducting a series of studies on space debris issues, the results of which were presented at the Third European Conference on Space Debris and at the regular session of IADC, held in March 2001.

3. Measures are envisaged to prevent debris creation in near-Earth space by launch vehicles that are currently in use or being modernized or designed in Ukraine, notably the Zenit-2, Zenit-3SL, Dnieper-1, Dnieper-M, Tsyklon-3 and Tsyklon-4M launch vehicles.

United Kingdom of Great Britain and Northern Ireland

[Original: English]

I. Introduction

1. The continued commitment of the British National Space Centre (BNSC) to addressing the space debris issue is outlined in its *UK Space Strategy report (1999-2002)*. A key objective is to coordinate with other agencies that are also working on the threat posed by space debris. In that regard, BNSC coordinates activities in the United Kingdom of Great Britain and Northern Ireland through the United Kingdom Space Debris Coordination Group and ensures that those activities are harmonized with those of the ESA and its member States via the ESA network of centres coordinating group on space debris. Through its membership of IADC, BNSC is actively pursuing broader international agreement on a variety of space debris issues. It also supports the related programme of work in the Committee on the Peaceful Uses of Outer Space.

2. National meetings provide a forum for the coordination of all debris research activities in the United Kingdom and enable researchers to exchange information and ideas and, where possible, foster collaborative opportunities. The United Kingdom. Space Debris Coordination Group has met twice during the past year—in November 2001 and September 2002—with most research groups in industry and academia in the United Kingdom participating, including Astrium Ltd., the British Geological Survey (Geomagnetism Group), Century Dynamics, the Ministry of Defence, Observatory Sciences, the Open University, Oxford Brookes, QinetiQ Ltd., Surrey Satellite Technology Ltd., University College London and the Universities of Cranfield and Southampton.

3. ESA coordination of space debris is now managed by a network of centres for space debris involving the Italian Space Agency (ASI), BNSC, the Centre national d'études spatiales of France and the German Aerospace Center (DLR), with participation open to all ESA members active in the area of space debris.

4. IADC is an international forum for cooperation on all aspects of the debris problem. In particular, efforts within the group are focused on achieving agreement on recommended mitigation practices based on sound technical analysis of the debris problem. Within the last year, the United Kingdom participated in the 20th IADC meeting, which was hosted by BNSC at Surrey University in April 2002. The 21st IADC meeting will be hosted by the Indian Space Research Organization in Bangalore, India, in March 2003.

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 the research and development activities outlined below.

II. Observation and measurement of the debris population

A. Debris observation campaign

6. The Ministry of Defence, supported by Observatory Sciences Ltd., participated in the 2001-2002 IADC debris search campaign, which involved carrying out a survey and a study into the utility of simultaneous searches for debris using geographically dispersed telescopes. Both tasks focused on deep-space and geostationary orbits and used the network of passive imaging metric sensor (PIMS) telescopes. Objects detected by the PIMS telescopes during the campaign had their orbits submitted to the IADC campaign coordinator. The study showed that exploiting the parallax in observations from geographically dispersed telescopes significantly improved the accuracy of orbits determined from brief sightings of debris (typical of survey work) and was a positive contribution towards creating a more detailed catalogue of deep-space and geostationary-orbit debris.

B. DEBIE in-situ space detector

7. Launch of the DEBIE detector in late 2001, developed jointly by the Open University, ESA and Finavitec, has provided an opportunity for assessment of the micro-particle environment in polar orbit. Two detectors on the PROBA satellite have been commissioned and data analysis by the Open University has commenced. Further work, through Unispace-Kent, has been subcontracted to eta_max Germany,

within an ESA contract. Characterization of the detector response will be performed to better relate the data to particle parameters and hence update models of the space environment.

C. *Hypervelocity impact facilities*

8. A novel two-stage light gas gun has entered its assembly phase following the completion of the new Hypervelocity Impact Laboratory at the Open University. The facility accelerates millimetre-sized projectiles to velocities typical of space debris and is used for detector response and debris damage assessment. It can launch in horizontal and vertical mode, suited to regoliths and fluid targets. The facility complements the micro-particle facilities in the same laboratory where the Van de Graaf generator formerly at the University of Kent is now housed and is undergoing refurbishment and commissioning. The simulation of meteoroid impacts on micro-debris detectors such as the Cassini instrument has previously been performed with a second Van de Graaf generator and, following recommissioning, the facility will be used to mimic anomalous signals detected in geostationary orbit by GORID aboard EXPRESS II. Such detections could represent a highly charged particulate environment and dust streams related to vehicle launch.

D. *Meteoroid and debris discrimination*

9. Over the past year, several retrieved surfaces exposed to the LEO environment have been examined in collaboration with Oxford Brookes University to study the effects of hypervelocity impact and to further characterize the micro-particle populations. That work has notably included the first detailed investigation of a composite fibreglass and polymer blanket that had been exposed on Mir. In addition, the two institutions have been involved in the research and development of a low-cost, reusable passive particle collector and in the analysis of laboratory-impacted surfaces simulating potential impact events upon the XMM-Newton X-ray Observatory. In collaboration with the Imperial College of Science, Technology and Medicine, recent studies have focused on the use of new analytical techniques to assist in the better discrimination and interpretation of preserved projectile fragments that result from hypervelocity collisions. Throughout the year, there has been active participation in both national and international meetings to bring knowledge gained to the attention of the worldwide debris community.

III. Debris environment modelling

10. Modelling of the debris environment, its long-term evolution and the potential risks it causes to possible future space systems continues as a major activity among debris researchers in the United Kingdom. The effect of regularly introducing new assets into near-Earth space, and therefore the consequences for the debris environment, is also a key research area.

A. *Support to the IADC Environment and Database Working Group*

11. QinetiQ continues to provide active national participation in the IADC Environment and Database Working Group, on behalf of BNSC. That participation involved chairmanship of the Working Group for the 20th IADC meeting and significant input to cooperative international studies on the post-mission disposal of

space systems in LEO and on debris issues relating to small satellites. As a result of those studies, general consensus has been reached on the recommended post-mission lifetime of objects in LEO and on long-term environmental impact of small satellite swarms.

B. Upgrade of the ESA MASTER model

12. The ESA DELTA long-term debris evolution model has undergone further upgrades by QinetiQ, performed as part of the ESA MASTER model development project. The DELTA model was employed to provide MASTER with predictions of the future debris population for a number of different future spaceflight scenarios. Exploitation of those population predictions has given MASTER a new capability to assess the future evolution of debris impact risk for any user-defined space mission over the next 50 years. During the project, the QinetiQ team made a number of key improvements in the fidelity and accuracy of the ESA DELTA model. The most significant was the extension of the high-resolution four-dimensional model of the future debris flux environment in LEO to the higher altitude regions of medium-Earth orbit and geosynchronous orbit. Other highlights included the incorporation of solid rocket motor ejecta particles as a future debris source and an update of the satellite break-up model to the latest and most accurate available. The latter development prompted an improved comparison of the DELTA long-term debris population projections with those produced by other long-term debris evolution models.

C. Modelling the geostationary orbit region

13. In the period 2001-2002, a main focus of research at QinetiQ has been the debris environment in the geostationary orbit region. A tool has been developed to aid in the licensing process for national geostationary satellites, under the Outer Space Act 1986, by assessing the collision hazard posed by the satellite, permitting liability risk assessments. An international team consisting of QinetiQ, ESYS, OHB-System and Dutch Space, has received an ESA contract to study commercial and government-centred business cases for robotic spacecraft to remove hazardous objects from geostationary orbit. The project, entitled Robotic Geostationary Orbit Restorer (ROGER), includes an analysis to characterize the use and occupancy of the geostationary orbit and a tool to assess the impact of future satellite operations on the geostationary environment. Under the auspices of the ESA ROGER project there has also been some preliminary investigation of a space-based telescope to observe the small-sized geostationary orbit debris population. The recently upgraded IDES model (Ministry of Defence of the United Kingdom) has undergone further test and validation procedures, in collaboration with the University of Southampton, and has been used to examine the long-term evolution of the debris environment throughout Earth orbit.

14. During the last year the University of Southampton has continued to develop its long-term environment model, the Debris Analysis and Monitoring Architecture for the Geosynchronous Environment (DAMAGE), under the sponsorship of the Engineering and Physical Sciences Research Council. Some of the key components of DAMAGE have been finalized and validated. Those components include a semi-analytical orbital propagator, a break-up model and future event models for explosions and launch traffic. Further, work is ongoing to establish an efficient and

precise collision risk algorithm. It is anticipated that present-day and future environment predictions by DAMAGE will be available over the course of the next year.

15. Over the same period, the University of Southampton has continued work on the development of a novel space debris cloud propagator, aimed at vastly increasing the speed of propagating debris clouds in high-Earth orbits and in particular in geostationary orbit. The fast cloud propagator (FCP) works by propagating the debris cloud as a whole, rather than the more commonly used method of propagating the summation of a number of fragments or pseudo-fragments. The FCP method accurately recreates the debris cloud for a number of different break-up scenarios, as modelled by a number of widely used break-up models. It can be applied to a wide range of orbit types and has been tested for up to 100 years of propagation time. The computational efficiency increases with the number of fragments being propagated as well as the propagation time. The typical speed increase for a 100-year propagation of a debris cloud generated by a low-speed impact in geostationary orbit (generating around 6,000 fragments) is around 75 times that of a conventional propagator. Work is currently under way to improve the speed and accuracy of the model. The work was presented at the World Space Congress in Houston, United States of America, in October 2002.

D. Modelling the interaction of space tethers with the debris environment

16. Another strand of research at the University of Southampton during the last year has been in the area of space tethers and their interaction with the orbital debris environment. Work has focused on developing a new tether risk assessment program (TRAP), which studies the interaction between space tethers and the self-induced debris environment. The model makes use of the probabilistic continuum dynamics (PCD) method that allows an accurate method for determining the collision and sever probabilities of space tethers. The research was also reported in a paper presented at the World Space Congress in October 2002.

IV. Spacecraft debris protection, risk assessment and collision avoidance

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

A. Support to the IADC Protection Working Group

18. QinetiQ continues to provide active national participation in the IADC Protection Working Group on behalf of BNSC. That participation involves chairmanship of the Working Group for the next two years (which encompass the 21st and 22nd IADC meetings). A major ongoing activity of the Working Group is the publication of a protection manual, which will contain technical information and guidance relating to spacecraft debris risk assessment and protection. The Working Group chairman is currently leading that activity.

B. Satellite survivability modelling

19. QinetiQ continues to use the SHIELD software model to evaluate the survivability of unmanned spacecraft designs in the debris environment and to recommend appropriate cost-effective protection strategies. In particular,

simulations have been performed to quantify the debris impact, penetration and failure risks on a representative three-dimensional model of the MetOp spacecraft, which is due to be launched in 2005. That assessment has enabled the identification of the most vulnerable elements of the spacecraft design, thus indicating where additional protection may be most beneficial.

20. A current limitation in SHIELD is the accuracy of its damage assessment algorithms, owing to the lack of available data in the literature. However, it is expected that the issue will be addressed through QinetiQ's involvement in a recently awarded ESA contract, which is being led by the Ernst Mach Institute in Germany. The focus of the contract is to characterize the response of typical spacecraft equipment to debris and meteoroid impacts. An extensive impact test programme will be performed, from which damage equations can be derived and incorporated into SHIELD. With those new equations, SHIELD will be able to provide a more accurate assessment of the survivability of typical LEO spacecraft.

C. Numerical simulation of hypervelocity impacts

21. Century Dynamics continue to sell and provide support for the AUTODYN hydrocode software to the worldwide space community. Customers using AUTODYN for space debris studies include the National Aeronautics and Space Administration of the United States, ESA, the National Space Development Agency of Japan, Alenia, the European Aeronautic Defence and Space Company and the Traunhofer Institute for High-Speed Dynamics. A large study conducted for ESA and Alenia has been completed in the past year; this involved using AUTODYN to validate the ballistic limit of the Columbus shield design.

22. A new research project has been started for ESA that aims to improve further the composite material models for hypervelocity impact modelling. Century Dynamics is also conducting three studies for ESA and BNSC/Astrium using AUTODYN. Those studies relate: (a) to impacts on honeycomb satellite structures; (b) to impacts on carbon (carbon fibre reinforced plastics (CFRP))-based satellite structures; and (c) to very oblique impacts (85 and 89 degrees) on the mirror of the XMM-Newton mission.

23. Century Dynamics has also recently helped University College London conduct studies using AUTODYN into asteroid impact effects on Earth.

D. Hypervelocity impacts on materials

24. Astrium has been working on the response of spacecraft materials to hypervelocity impact. This has included unmanned shield design. The work has been carried out in conjunction with Century Dynamics, the University of Kent, the University of Cambridge, the Open University, Oxford Brookes University and Cranfield University.

25. The University of Kent continues to operate its light gas gun, which can now fire projectiles at speeds of up to 7.5 kilometres per second. As a function of impact speed, the research has examined hypervelocity penetration through thin metal films and how the resulting material spreads out as a cloud behind the target.

E. Collision risk and avoidance

26. Astrium is also modelling collision risk and avoidance for spacecraft operating in LEO, geostationary orbit, geostationary transfer orbit and Sun-synchronous orbit (SSO) spacecraft.

V. Debris mitigation

A. Update of the ESA Space Debris Mitigation Handbook

27. A significant emphasis of debris research activities at QinetiQ during 2001-2002 has been on the production of the second edition of the *ESA Space Debris Mitigation Handbook*, in collaboration with ESA/ESOC and eta_max in Germany. QinetiQ provided significant updates to the chapters on the future space debris environment; the long-term effectiveness of space debris mitigation measures; the long-term prediction of collision risk to space missions; review of mitigation standards and guidelines; post-mission de-orbiting of space systems; and spacecraft protection. Numerous new studies of the long-term evolution of the debris environment in LEO and geostationary orbit were conducted using the ESA DELTA model. The resulting analyses led to the definition of a cost-effective and robust set of debris mitigation measures for LEO and an evaluation of the IADC guideline for the re-orbiting of space systems above the geostationary ring. The sensitivity of the long-term debris population projections to changes in the model assumptions has also been investigated. These particular topics will be published in papers presented at the 34th Committee on Space Research Scientific Assembly at the World Space Congress in October 2002.

B. Debris mitigation guidelines and standards

28. The production of a “mitigation guidelines” document has been a major activity within IADC over the past year. BNSC and QinetiQ have played an active role in that work and will be presenting the document to the Scientific and Technical Subcommittee of the Committee on the Peaceful Uses of Outer Space at its fortieth session.

29. BNSC is also a leading contributor to the formulation of the European Space Debris Safety and Mitigation Standards. QinetiQ, Astrium and Surrey Satellite Technology Ltd. have all participated in that process during the past year by providing an industry perspective to the draft standards. Having achieved a large measure of agreement between European space agencies, the ongoing work will now be focused by the needs of industry and the European and international standards bodies.

30. Additionally, at Astrium, debris mitigation work has focused on the development of a set of engineering implementation standards.