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COMMITTEE ON THE PEACEFUL USES OF
OUTER SPACE
Scientific and Technical Subcommittee
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Agenda item 8
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

1. In paragraph 27 of its resolution 60/99 of 8 December 2005, the General Assembly considered that it was essential that Member States pay more attention to the problem of collisions of space objects, including those with nuclear power sources, with space debris, and other aspects of space debris, and called for the continuation of national research on the 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-second session, the Scientific and Technical Subcommittee invited Member States and space agencies to continue 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.105/848, para. 89). In a note verbale dated 24 August 2005, the Secretary-General invited Governments to submit any information on the matter by 31 October 2005 so that that information could be submitted to the Scientific and Technical Subcommittee at its forty-third session.

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3. The present document contains a report received from the United Kingdom of Great Britain and Northern Ireland[1]. Reports received by 31 October 2005 are available in all official languages of the United Nations and have been distributed as document A/AC.105/862.

United Kingdom of Great Britain and Northern Ireland

1. Introduction

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 achieve consensus on the most effective debris mitigation solutions.

Central to this is BNSC's membership of the Inter Agency Space Debris Coordination Committee (IADC), which is an important forum for reaching international agreement on a variety of debris issues (see www.iadc-online.org). BNSC contributes to the 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 2005 the UK participated in the 23rd IADC meeting, which was hosted by the European Space Agency (ESA) in Darmstadt, Germany.

Within Europe, ESA coordinates debris research capabilities through a Space Debris "Network of Centres" (NoC) Group. BNSC is a member of this group together with ESA and three national agencies – the Italian Space Agency (ASI), the French Space Agency (CNES) and the German Space Agency (DLR). The NoC is responsible for the production of an Integrated European Work Plan and Strategy for space debris.

At a national level, BNSC maintains its support of the UK Space Debris Coordination Group, which meets annually to provide a forum for the coordination of all UK debris research and policy activities. The Natural History Museum (NHM) hosted the autumn 2005 meeting with participation from UK government, industry and academia. The meeting discussed the latest international developments, in particular with respect to debris mitigation guidelines and standards, and provided an opportunity to report on recent UK research.

The UK has particularly strong debris research capabilities, which BNSC regularly calls upon for impartial technical support and advice. During the past year, UK organisations have conducted a wide range of activities, some of which are summarised below.

[1] This report has not been formally edited. It will be edited, translated into all official languages of the United Nations and distributed as document A/AC.105/862/Add.1 after the forty-third session of the Scientific and Technical Subcommittee.

2. Observation and Measurement of the Debris Population

2.1. UK participation in IADC "Measurements" Working Group (WG1)

The UK network of Passive Imaging Metric Sensors (PIMS) has been used by the UK partners in BNSC to carry out debris discovery and tracking campaigns in support of the IADC work programme. A principal element of this support has been a long-term trilateral international collaboration with Switzerland and Russia which has helped gain an understanding of the orbital evolution of large area-to-mass ratio debris in higher Earth orbits; such debris is a newly recognised type of debris. Studies have also been carried out by the PIMS prime contractor (Space Insight Ltd.) into space traffic census methods and satellite close-approach forecast accuracies.

2.2. In-situ detectors and analysis of retrieved surfaces

During the past year, staff at the NHM in London have been working on the design of small particle impact residue collectors for the monitoring of the low Earth orbit environment. The design and experimental testing of the Multi Layer Polymer Experiment (MULPEX) has been published in Advances in Space Research. Results from an ESA-funded study of impact damage on the solar cells of the Hubble Space Telescope (in collaboration with ESA, UniSpace Kent and ONERA) have been presented at two conferences and are now published in Advances in Space Research. One important conclusion from this work is that there has been a decline in the flux of micrometre-scale space debris particles from solid rocket motor firings.

Collaborative work with NASA and the University of Kent has yielded important advances in the interpretation of micrometeoroid impacts upon metal surfaces. Evaluation of impact residue analysis techniques is continuing.

3. Debris Environment Modelling

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

3.1. UK participation in IADC "Environment & Database" Working Group (WG2)

IADC WG2 activity has been divided into studies focusing on low Earth orbit (LEO), medium Earth orbit (MEO) and Geosynchronous Earth orbit (GEO). A new study of the LEO debris environment, led by BNSC, compared predictions from a business-as-usual scenario over 100 years using new, 3D-capable environment models, with the UK contributing results from the DELTA model developed at QinetiQ. Good agreement was found between the three models employed (DELTA, SDM and LEGEND). The suitability of semi-analytical orbital propagators for use in the MEO region was investigated in a study conducted at QinetiQ and supported by the University of Southampton's DAMAGE propagator. Results from this study indicated that the semi-analytical propagators routinely used in debris environment models are able to capture

the large growth in eccentricity associated with some navigation satellite disposal orbits, comparing well to high-precision, "force" propagators used operationally. Finally, BNSC led activities in GEO modelling; firstly, to investigate the long-term evolution of GEO disposal orbit eccentricities and, secondly, to investigate the business-as-usual, future evolution of the GEO debris environment.

3.2. Investigation into the response of the space debris environment to thermospheric cooling

This research was undertaken by the University of Southampton in collaboration with QinetiQ and in consultation with colleagues from George Mason University, USA and the Naval Research Laboratory, USA. The work followed on from results published by Emmert et al, in 2004, showing a reduction in atmospheric density due to thermospheric cooling associated with rising greenhouse gases. The new research used the DAMAGE debris environment software with a modified atmospheric model to predict the evolution of the space debris environment over the next 100 years. The results indicated a significant increase in collision activity and a corresponding increase in debris spatial density in low Earth orbit as a result of thermospheric cooling. There was substantial international media interest in the results.

3.3. Modelling the debris environment

QinetiQ is part of a European team undertaking to upgrade the ESA MASTER model to MASTER-2005, under an ESA contract. At QinetiQ, development is nearing completion on a new version of the Debris Environment Long-Term Analysis (DELTA) model, a simulation and analysis tool for the long-term prediction of the space debris environment and its associated mission collision risks. Upon completion of the upgrade, DELTA will be exploited to provide representations of the future environment for MASTER-2005, both including and excluding the implementation of debris mitigation measures.

At the University of Southampton, a new collision probability algorithm has been added to the DAMAGE debris model. The algorithm is based on the 'CUBE' method employed by NASA's LEO-to-GEO model, LEGEND, and represents an improvement in speed and information-capture over existing methods.

4. Spacecraft Debris Protection and Risk Assessment

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

4.1. UK participation in IADC "Protection" Working Group (WG3)

BNSC receives technical support from QinetiQ for protection-related discussions within IADC WG3. A major output of the group has been the development of a Protection Manual containing technical information relating to spacecraft debris risk assessment and

protection. The first public issue of the document (No. IADC-04-03) is now available on the IADC website.

A new study was initiated at the 23rd IADC Meeting in April 2005 to report on the feasibility and options for the design of an impact sensor network that could be fitted onboard 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.

4.2. Satellite survivability modelling and protection optimisation

The University of Southampton (together with subcontractor Deimos Space, Spain) has recently completed a one-year ESA study contract to evaluate an automated modelling process for optimising spacecraft debris protection. The method uses a genetic algorithm to optimise the protection design of a spacecraft, i.e. to maximise its survivability in the space debris environment. In the study a software model called SHIELD was used to assess the viability of the technique when applied to a typical unmanned LEO spacecraft. It was found that significant enhancements to survivability could be achieved simply by improving the layout of equipment to enhance the protection of critical and sensitive items.

QinetiQ is involved in an ongoing ESA contract led by FhG Ernst Mach Institute, Germany to characterise the response of typical spacecraft equipment to debris and meteoroid impacts. An extensive impact test programme is nearing completion and the resulting damage equations will soon be incorporated into the SHIELD software model. With these new equations, it will be possible to provide a more accurate assessment of the survivability of typical unmanned spacecraft.

4.3. Numerical simulation of hypervelocity impacts

Century Dynamics Ltd. 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 impacts. The company continues to be heavily involved in the support of clients worldwide (e.g. ESA, NASA, etc.) in the application of the software to space debris related problems.

Additionally, Century Dynamics participates in space debris research projects for ESA/ESTEC. One ongoing project, in collaboration with FhG Ernst-Mach-Institut, Germany, involves the development of carbon fibre reinforced plastic (CFRP) material models for hypervelocity impact numerical simulations. Previous projects with ESA have concentrated on developing sophisticated models for composite materials. The focus of the current study is to develop model data for a CFRP material using an extensive programme of experimental tests and to validate this data for the numerical simulation of hypervelocity impact events.

4.4. Hypervelocity impact testing

During the past year, space debris research has been an integral part of the overall hypervelocity impact programme at the University of Kent. Impact work using Kent's two-stage light gas gun has been carried out in collaboration with other groups. These include the Natural History Museum, London, which is working on a project to develop a capture cell for possible use on the International Space Station (ISS). Impact tests were also carried out for US collaborators working on an aerogel debris collector, also for the ISS. Finally, the university provides hypervelocity impact research opportunities to MSc students. One student has been manufacturing aerogel monoliths at Kent and using the resultant aerogels in impact tests. Additionally, during the year, another student was awarded an MSc for work on oblique incidence penetration of bumper shields.

5. Debris Mitigation

5.1. UK participation in IADC "Mitigation" Working Group (WG4)

Within IADC WG4, 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 a low orbit eccentricity and an initially sun-pointing perigee are beneficial in preventing the object from re-entering the protected GEO region.

5.2. Debris mitigation standards

The UK 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 (ECSS) and the International Standards Organisation (ISO) where the UK 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 UK experts are coordinated at national level through the British Standards Institute.

5.3. Debris Risk Assessment and Mitigation Analysis (DRAMA) tool

A QinetiQ-led European team has completed development of a Debris Risk Assessment and Mitigation Analysis (DRAMA) software tool for ESA. The tool enables satellite programmes in Europe to assess their compliance with the recommendations in the European Code of Conduct for Space Debris Mitigation. DRAMA is composed of five individual software applications collected under a common graphical user interface. The individual applications have been designed and developed to address different aspects of debris mitigation. They enable an assessment of collision avoidance manoeuvres, collision flux and damage statistics, disposal manoeuvres at end-of-life, re-entry survival and re-entry risk analysis.

5.4. UK satellite licensing process

BNSC is responsible for issuing licenses to confirm that UK satellites are launched and operated in accordance with the UK'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 license. Over the past year, safety evaluations have been performed on two GEO and one LEO spacecraft.

6. Near Earth Objects

The Rutherford Appleton Laboratory (RAL) supported BNSC in its briefing to the UK Government's Natural Hazards Work Group which was established by the Prime Minister following the Indian Ocean tsunami in December 2004. The Working Group reported its findings in 2005 (http://www.ost.gov.uk/policy/bodies/nhwg/index.htm) in which it recognised the potential hazard posed by Near Earth Objects. RAL also completed its work leading the Organisation for Economic Cooperation and Development (OECD) Working Group on the Risk of Near Earth Objects, which reported its findings to the ICSU Workshop on Comet/Asteroid Impacts and Human Society. This work was also reported to, and informed the deliberations of UNCOPUOS Action Team 14, and was the focus of a number of technical presentations at the 42nd Session of the Scientific and Technical Subcommittee. RAL is also organising a European meeting to discuss a way forward on Near Earth Objects under the auspices of the Royal Aeronautical Society in London on 23rd November 2005. In addition RAL is exploring opportunities to discover new comets and asteroids through its development of the Heliospheric Imager (HI) instruments to be launched in 2006 on the NASA Stereo mission.

The University of Southampton is actively involved in research to predict the infrastructure damage and casualty estimates following the terrestrial impact of a Near Earth Object. A software analysis tool is under development to simulate NEO land and ocean impact events, primarily of 'small' sub-kilometre asteroids. This includes the simulation of atmospheric entry, impact and post impact effects. Such objects present a significant threat to humanity due to their relative abundance, and also because of the severity of impact-generated effects such as tsunamis, seismic shock waves, radiation flux and impact debris. These combined effects will influence both coastal and inland populations across the world. This research aims to provide casualty estimates resulting from both land and ocean NEO impacts with a view towards assessing how the impact effects on population might be mitigated.