UNITED NATIONS

A

General Assembly

Distr.
GENERAL

A/AC.105/542/Add.1
17 February 1993

ORIGINAL: ENGLISH

COMMITTEE ON THE PEACEFUL USES
OF OUTER SPACE

NATIONAL RESEARCH ON SPACE DEBRIS

SAFETY OF NUCLEAR-POWERED SATELLITES

PROBLEMS OF COLLISIONS OF NUCLEAR POWER SOURCES WITH SPACE DEBRIS

Note by the Secretariat

Addendum

The present document contained information provided in replies received from Member States up to 16 February 1993.

CONTENTS

93-09243 3935d (E) 230293 23/02/93

UNITED KINGDOM OF GREAT BRITAIN AND NORTHERN IRELAND

[Original: English]

Study programmes related to space debris within the United Kingdom

Space debris studies within the United Kingdom are focused through the British National Space Centre at two major research centres, the first within the Space Sector of the United Kingdom Defence Research Agency (DRA) and the second at the Unit for Space Sciences at the University of Kent at Canterbury (UNISPACE).

The major objective of the studies carried out at DRA (formerly the Royal Aircraft Establishment (RAE)) is to develop analysis tools which permit the influence of space debris on satellite system survivability to be determined and the impact on the environment of particular missions to be assessed. A primary goal is to be able to evaluate the relative performance of debris mitigation measures.

The objective of the research carried out at UNISPACE is to improve our understanding of the debris population, the primary production and removal mechanisms, and to differentiate between the natural population of meteoroids and artificial debris. This is achieved through the development of new modelling and detection techniques and the interpretation of in-situ measurements.

Since the beginning of the space age, DRA has been compiling the RAE Table of Earth Satellites. 1/ This is a catalogue of satellites and associated hardware that are launched into orbit about the Earth. Monthly updates provide information on launch date, orbital lifetime, shape, size and mass of objects and the associated orbital elements determined by the United States Space Command at a particular epoch. The table is recognized as a valuable reference tool by the tracking community and forms the basis of a number of satellite catalogue databases including the DISCOS 2/ database initiated and maintained by the European Space Agency (ESA).

DRA carried out a re-entry prediction service for risk objects such as the Skylab and Salyut 7/Kosmos 1686 space stations which impacted the surface of the Earth in 1979 and 1991 respectively. The recent re-entry prediction campaign for the Salyut 7 re-entry 3/ provided information to both ESA and a number of European States. Research studies continue in an attempt to improve re-entry prediction models, but the greatest problems that are encountered are still found to be uncertainties in the behaviour of the atmosphere, lack of vehicle attitude, mass and aerodynamic information. Some information can be derived from post re-entry analysis of vehicle trajectories, a recent study 4/ providing valuable information on the aerodynamic behaviour of large space complexes such as Salyut 7. A method pioneered by DRA, and used by many tracking agencies, does not require such information but instead uses observations of the rate of contraction of the orbit to determine the time of re-entry. This was successfully used for the Salyut 7 re-entry predictions and adapted, 5/ to increase its versatility and performance, in order to provide accurate predictions 6/ during the very recent PION satellite tracking campaign coordinated by ESA and NASA. All the techniques used for re-entry prediction rely upon frequently updated orbital elements. The experience of the Salyut 7 and PION re-entry prediction campaigns is that this information is not always distributed in a timely fashion to the user community (especially as the time of re-entry approaches). It appears that the uncertainty in the predicted re-entry time remains on the order of 10 per cent of the remaining orbital lifetime.

Debris mitigation strategies have also been explored at DRA. The probability of collision in space is dependent upon the number of objects in orbit, the collision cross-section (related to size) of objects, the closing velocity between objects and the residence time in orbit of the objects. It is clear that the massive launch vehicle upper stages which are left in high-energy eccentric orbits following deployment of geostationary satellites will represent a collision hazard to vehicles operating in Low Earth Orbit (LEO) for many years following initial orbit injection. A recent study 7/ by DRA explored the strategies available for removing a launch vehicle upper stage from initial injection to geostationary transfer orbit (GTO). Among the techniques considered, which included the use of ballutes (drag augmentation devices) and appropriate choice of launch window to harness lunisolar perturbations to the trajectory to decrease orbital lifetime, the active propulsive de-orbiting of upper stages using either the main propulsive system or a dedicated unit appears to offer the most effective and practical solution to the problem. The cost/performance penalty associated with such measures must be accepted by operators if incidents such as the near misses between STS-48 and STS-49 and Russian launch vehicle upper stages are to be minimized.

DRA is also developing a suite of software termed AUDIT 8/ (Assessment Using Debris Impact Theory) in order to determine the impact of a particular space system design on the debris environment. Using analytic theory, trade-off studies can be carried out to determine the dominant influences on debris production and satellite survivability. AUDIT offers the possibility of defining measures of pollutive impact which can be used in assigned future design criteria for missions launched into Earth orbit. AUDIT has recently been used to determine the impact of LEO satellite constellations on the debris environment and to recommend mitigation measures. 9/

A detailed study 10/ was carried out under contract from ESA on methods for detection and characterization of debris in Earth orbit, in the millimetre and centimetre size ranges, using passive optical systems working in the visible/near IR and thermal IR regions. The research team comprising SIRA Ltd., the Royal Greenwich Observatory and UNISPACE assessed a range of concepts in terms of performance and required resources. The study concluded that, using a small optical instrument carried on a satellite in LEO, it was feasible to detect debris in statistically significant numbers at sizes down to 1 mm diameter. In addition, a ground-based system of moderate size could be operated at a fraction of the space platform option, providing detection of debris down to 8 mm in LEO

UNISPACE has a comprehensive research programme 11/ seeking to determine the sources and characteristics of the measurable particulate population. A number of studies have shown that the Earth's atmosphere at LEO exerts a significant influence on particles of micron dimensions, particularly during periods of high solar activity. The processes of aerocapture and aerofragmentation of meteoroids were shown to be able to enhance significantly the orbital population of artificial debris. 12/, 13/, 14/, 15/, 16/

UNISPACE has enhanced the ability to assess satellite reliability and survivability through the development of a new size-dependent space debris density distribution 17/ and a 3-D numerical model 18/ for space debris and interplanetary dust. Using data on orbit and mass/size distributions derived from the ESA DISCOS database, and meteor observations and in-situ measurements of the interplanetary environment, it is possible to predict impact velocities and fluxes for pre-defined surfaces on spacecraft in LEO. The results compare favourably with LDEF experimental data.

UNISPACE has a strong role in the analysis of surfaces returned from the LDEF satellite. 19/, 20/, 21/ Among the techniques employed is elemental analysis using an energy-dispersive X-ray system in conjunction with a scanning electron microscope. In addition, particle velocity and angle of incidence as well as mass are determined from experiments such as the micro-abrasion package. With appropriate data of the LDEF trajectory the source of the particulate can then be determined.

Notes

1/ King-Hele, D. G. et al. The RAE Table of Earth Satellites 1957-1986 (MacMillan, United Kingdom, 1987).

2/ Klinkrad, H. et al. Retrieval of Space Debris Information From ESA's DISCOS Catalogue. Proceedings of ESA Workshop on Space Environment Analysis, 9-12 October 1990, ESTEC, the Netherlands, ESA WPP-23, 1991.

3/ Crowther, R., Debris Re-entry Prediction: Salyut 7/Kosmos 1686. ESA Special Publication 345, Proceedings of ESA Space Debris Workshop, April 1991.

4/ Crowther, R., Re-entry Aerodynamics Derived From Space Debris Trajectory Analysis. Planetary and Space Science, vol. 40, No. 5, pp. 641-646, 1992.

5/ Crowther, R., Space Debris: Orbit Decay and Re-entry Prediction in Theory and Practice. AAS paper 92-183 presented at the AAS/AIAA Astrodynamics Specialist Conference, Colorado, February 1992.

6/ Crowther, R., Lessons Learnt from the Re-entry Prediction of the Spherical PION Satellites. Paper submitted for presentation at First European Conference on Space Debris to be held at ESOC, Germany, April 1993.

Notes (continued)

7/ Crowther, R., Limitation of Debris in Geostationary Transfer Orbit. ESA Special Publication 326, Proceedings of 3rd International Symposium on Spacecraft Flight Dynamics, Germany, October 1991.

8/ Crowther, R., Orbital Evolution of Space Debris due to Aerodynamic Forces, Paper B.8-M.1.12 presented at World Space Congress, Washington, D.C., September 1992.

9/ Crowther, R., The implications of On-orbit Fragmentations for Satellite Constellation Survivability. Paper submitted for presentation at First European Conference on Space Debris to be held at ESOC, Germany, April 1993.

10/ Lobb, D. et al. Development of concepts for Detection and Characterisation of Debris in Earth Orbit using Passive Optical Instruments. Presented at the World Space Congress, COSPAR, Washington, D.C., 28 August-5 September 1992. For publication in Advances in Space Research.

11/ McDonnell, J. A. M. The Near Earth Particulate Environment. NATO Advanced Study Institute, Pitlochry, 1991. Report in press.

12/ Ratcliff, P. R. and McDonnell, J. A. M. 2-D Dynamical Computation of the Contribution of Natural Material to the Orbital Component of the Near Earth Particle Population. In "Hypervelocity Impacts In Space", proceedings of Symposium, University of Kent, July 1991.

13/ Ratcliff, P. R. and McDonnell, J. A. M. The LEO Microparticle Population: Computer Studies of Space Debris Drag Depletion and of Interplanetary Capture Processes. Presented at the World Space Congress, COSPAR, Washington, D.C. 28 August-5 September 1992. For publication in Advances in Space Research.

14/ McDonnell, J. A. M. and Sullivan, K. Whence the LEO Particulates? LDEF's Data and New Penetration Formulae Reshape the Arguments on the Balance of Sources. Workshop on "Hypervelocity Impacts In Space", University of Kent, 1-5 July 1991, abstract volume 43-44, 1991.

15/ McDonnell, J. A. M. et al. Impact Cratering From LDEF's 5.75 Year Exposure: Decoding of the Interplanetary and Earth Orbital Populations. Proc. Lunar Planet. Sci: 22.185-193, Lunar and Planetary Institute, Houston, Texas, 1992.

16/ McDonnell, J. A. M. et al. Particulate Detection in the Near Earth Space Environment aboard the Long Duration Exposure Facility (LDEF): Cosmic or Terrestrial? In "Origin and Evolution of Interplanetary Dust", Kluwer Acad. Pub. Co., IAU Colloquium No. 126, 3-10, 1992.

/...

Notes (continued)

17/ Zarnecki, J. C. et al. A New Size-Dependent Space Debris Density Distribution. Presented at the World Space Congress, COSPAR, Washington, D.C., 28 August-5 September 1992. For publication in Advances in Space Research.

18/ Deshpande, S. P. and Green, S. F. Can Objects in GTO Affect the Debris Population in LEO? In "Hypervelocity Impacts In Space", proceedings of Symposium, University of Kent, July 1991.

19/ Newman, P. J. and McDonnell, J. A. M. Analysis of the Residues of Hypervelocity Impacts from the Long-Duration Exposure Facility. Presented at the World Space Congress, COSPAR, Washington, D.C., 28 August-5 September 1992. For publication in Advances in Space Research.

20/ McDonnell, J. A. M. LDEF Contribution to LEO Particulate Environment. Presented at the World Space Congress, COSPAR, Washington, D.C., 28 August-5 September 1992. For publication in Advances in Space Research.

21/ Paley, M. A Refinement of Hypervelocity Impact Equations using LDEF Data. Paper IAF-92-0325 presented at 43rd Congress of IAF, World Space Congress, Washington, D.C., 28 August-5 September 1992.
