UNITED
NATIONS

A

General Assembly

Distr.
GENERAL

A/AC.105/659/Add.2
14 February 1997

ENGLISH
ORIGINAL: RUSSIAN

COMMITTEE ON THE PEACEFUL
USES OF OUTER SPACE

NATIONAL RESEARCH ON SPACE DEBRIS

SAFETY OF NUCLEAR-POWERED SATELLITES

PROBLEMS OF COLLISIONS OF NUCLEAR-POWERED SOURCES WITH SPACE DEBRIS

Note by the Secretariat

Addendum

1. The Secretary-General addressed a note verbale, dated 19 July 1996, to all Member States, inviting them to provide information on national research on space debris, safety of nuclear-powered satellites and problems of collisions of nuclear-powered sources with space debris.

2. The information on those topics submitted by Member States as of 6 December 1996 is contained in document A/AC.105/659.

3. The information on those topics submitted by Member States between 7 December 1996 and 6 February 1997 is contained in document A/AC.105/659/Add.1.

2. The present document contains information provided in replies received from Member States between 7 February 1997 and 14 February 1997.

CONTENTS

Page

REPLIES RECEIVED FROM MEMBER STATES

Russian Federation*

[Original: Russian]

In the Russian Federation the main priorities set for work aimed at mitigation of the technogenic pollution of circumterrestrial space are as follows:

- Observation of space debris (particles and objects);
- Space pollution modelling and cataloguing of space debris;
- Protection of spacecraft from space debris;
- Measures to mitigate technogenic space pollution;
- Measures to ensure the safety of satellites with nuclear sources on board.

A. Observation of space debris fragments

Observations of space debris at altitudes of up to several thousand kilometres are made principally by radar stations belonging to the Space Monitoring System. In the geostationary orbit (GSO) region, space debris observations are made by the ground-based optical facilities of the Russian Academy of Sciences. Observation data exchange between Russian operators proceeds within the framework of joint research programmes. Where necessary, catalogues of objects constituting space debris are exchanged between the Russian space monitoring system centres and the United States so that they can be compared and supplemented on a reciprocal basis. The possibilities are currently being explored of setting up a single international catalogue of observed space debris.

In the interests of dealing effectively with observation and cataloguing problems, a coordinated programme of studies has been in preparation at the Russian Space Agency with a view to ensuring the safety of space activity from the point of view of technogenic space pollution. In particular, it is proposed under this programme to establish a single hardware-software system (APK) for the collection, storage and efficient use of space debris data by various State agencies in the Russian Federation and, in future - once the requisite legal and regulatory framework is in place - for collaboration with foreign parties. It is planned to use the APK for two main purposes:

(1) To provide prompt information coverage of events involving incidents of uncontrolled space debris entry into the dense layers of the atmosphere, dangerous approaches of orbital systems and operational spacecraft with space debris and accident situations on board space systems and objects caused by collisions with space debris;

(2) To provide a full information service relating to the design and finalization stages of space technology development with a view to protection of operational objects from collisions with space debris and mitigation of the pollution of circumterrestrial space in the course of its utilization.

A number of APK segments are currently undergoing testing and have already been used, in particular, for early forecasting and information supply for the purposes of decision-making both at the time of the incident involving the dangerous approach of the Mir station with the KN-11 satellite on 27 December 1995, and for information coverage of uncontrolled entries into the dense layers of the atmosphere in December 1995 by the Russian satellite Cosmos-398 and in March 1996 by the Chinese satellite FSW-1.

---

* This reply has been reproduced without formal editing.

In both these latter cases procedures were refined, *inter alia*, for information exchange with foreign space agencies and circumterrestrial space tracking centres.

B. Pollution modelling and cataloguing of objects and particles

Statistical models of circumterrestrial space pollution characterizing the distribution of uncatalogued fine particulate debris provide a basis for assessing the risk of collision between space objects and space debris and also for forecasts of the "fragment" situation in circumterrestrial space.

There has now been developed in Russia a sophisticated mathematical model of circumterrestrial space pollution. The model's parameters have been correlated with known experimental data. Its distinguishing feature is the systematic use of a statistical approach in all the main calculations of the orbital dynamics of space debris objects. The model is based on the statistical theory, developed in Russia, of the movement of space objects as an ensemble. Research has been carried out along a variety of lines using this model. Most notably, it has been shown that in order to prevent steady, uniform growth in space pollution, it is necessary to reduce the rate of generation of new debris objects by at least one order of magnitude, especially at altitudes above 1,000 km.

On the basis of the results yielded by modelling the "fragment" situation, a draft Russian standard has been drawn up, scheduled to enter into effect in 1997.

Comparison of the Russian modelling results with the data obtained using existing mathematical models of the space debris situation in circumterrestrial space, i.e. ORDEM 96 (NASA) and MASTER (ESA), has indicated substantial discrepancies (by a factor of four to five times or more) in various areas, a matter which will require further joint investigation.

Areas of further analysis and matching of the models have been identified, which will assist in reducing the existing discrepancies and achieving greater precision in the calculation of technogenic space pollution:

- Critical analysis of the relative importance of the role played by space debris on elliptical orbits (especially with regard to debris with small dimensions and at low altitudes) in overall debris pollution;
- More precise calculation of the spatial density and flux of space objects at altitudes of up to 500 km;
- Analysis of recurrent patterns in the generation and evolution of fine particulate debris at altitudes above 1,000 km;
- Fine adjustment of mathematical models for the purpose of calculating relative velocity values and directions in respect of potential collisions.

D. Protection of space objects from hypervelocity particles

The protection of space objects from the effects of impact with hypervelocity particles involves research in the following main areas:

- Improvement of shield protection for the most probable collision conditions;
- Development of calculation methods relating to the protective properties of shield structures;
- Experimental validation of calculation accuracy.

The most hazardous events are considered to be collisions of orbital systems and space objects with debris particles of millimetre to 10 centimetre size; mass: 0.1–20g and with impact velocities (80% of impacts) of 8-12 km/s.

A further important area of research is the development of active shielding methods, one of which is the manoeuvring of space objects and orbital systems to prevent their collision with observed debris particles. As part of the endeavours to establish the APK high-speed information service, work is under way at the Russian Space Agency to set up and complete the development of a chain of technological facilities for preventing situations involving the risk of collision with space debris particles, for ensuring prompt data coverage of such events and for the control of orbital systems and spacecraft.

Methods have been elaborated and are being further refined for calculating the hypervelocity impact (at particle velocities of 5-15 km/s) of space debris particles with the screens of orbital systems and space objects. Two- and three-dimensional mathematical modelling programmes have been devised. For the purposes of efficient assessment of shield effectiveness and the selection of shield characteristics, calculation methods based on design engineering are being developed. Experimental facilities have been set up in the Russian Federation, where it should be possible, after some modernization, to simulate the entire range of conditions relevant to the modelling of the action of space debris particles on space objects.

E. Measures to mitigate technogenic pollution of circumterrestrial space

The reduction of levels of technogenic pollution of circumterrestrial space is one of the principal factors involved in ensuring space flight safety. Organizations in the space sector are engaged in research to investigate the causes of such pollution. Specialists at the Central Engineering Research Institute (TsNIIMash) and the Software Research Centre (TsPI) under the Russian Space Agency have been collaborating with specialists from the Kaman Sciences Corporation (United States of America) in studies aimed at analysing the causes of the orbital break-up of space objects. As a result of this work, recommendations have been produced for reducing the likelihood of such situations.

A number of methods and means have been proposed and implemented for reducing technogenic space pollution. More specifically, these include the application of new technological solutions designed to preclude the generation of space debris due to technological operations in orbit and to prevent explosions of space objects.

A further proposal is the passivation of spent rocket stages and space objects remaining in orbit, i.e. the freeing from tanks and balloons on rocket stages and space objects of propellant components and gases which could cause the explosion of the tank (or balloon) and break-up of the object even after a considerable period of time has elapsed. It is proposed to fit the DM booster module of the Proton carrier-rocket with equipment of this kind.

The design of the carrier-rocket is currently being modified in the Russian Federation in order to reduce the number of modules which are separated from the carrier-rocket during flight and to have their engine units operate on the main propellant components supplied from the carrier-rocket tanks. This change will make it possible to reduce transfer orbit pollution by the separable modules and will decrease the probability of their exploding as a result of the long-term effects of space conditions.

Work is constantly in progress to improve and refine systems for the separation of carrier-rocket stages from space objects and for opening components of the latter (the trapping of explosive bolts inside devices designed to prevent fragments from their explosion from falling into the space environment; the replacement of pyrotechnical systems by closed mechanical devices, etc.).

On-board power-supply systems are being further developed and improved. In particular, work is being done on the Ekran series of geostationary spacecraft to improve the reliability of the control unit, stabilization of load stress and hermetic leakproofing of the gas-circulation systems. It is planned to introduce these improvements in future generations of spacecraft, which will help to improve their operating safety and to prevent explosions in space, including those caused by prolonged recharging of the buffer chemical batteries of spacecraft.

A variety of types of space object are being modernized with a view to the creation of new systems for disposing of individual components without fragments being released into the space environment and without the object itself breaking up.

Software and diagrammatic aids are being elaborated to enable space objects to be injected into orbit without the separating parts of the final carrier-rocket stages actually reaching this orbit. This is being done by targeting the last rocket stage to fall to the so-called “antipodal point” (i.e. antipodal to the launching site) and for the space object to be inserted into working orbit by means of the booster module or apogee stage.

Work is under way to reduce the periods of time during which objects remain in orbit in passive ballistic mode. In particular, it is planned to fit the modernized Soyuz carrier-rocket with a passive breaking system on its final stage (I unit).

According to estimates by the TsSKB-Progress State Scientific-Production Rocket and Space Centre, the use of passive breaking system should reduce the ballistic periods of the third-stage unit of the Soyuz-2 carrier-rocket (as compared with units without passive breaking) by a factor of five to six for each individual insertion orbit and should prevent the accumulation of spent I units in space.

With regard to spent Molniya objects revolving in high-elliptical orbits, in order to reduce the perigee altitude and to speed up re-entry into the dense layers of the atmosphere, a breaking correction of 16 m/s was introduced at apogee in the final stages of design work on the Molniya series back in 1982.

Measures are currently being undertaken in connection with the controlled removal of spent objects from geostationary orbit with a view to averting the risk of their collision with operating or newly orbited objects and eliminating potential perturbations. Such disposal measures are envisaged for space objects in the Luch, Ekran and Gorizont series through the use of residual propellant in the on-board motors. The operating time of the engine unit is selected according to the criterion of ensuring complete burn-up of the propellant components. Analysis of the statistical data shows that introducing this correction as a function of the residual propellant in the motors makes it possible to increase the altitude of spent objects by 30-400 km. In the development of future Russian geostationary objects and in the case of objects manufactured in the Russian Federation under contract with foreign firms, the introduction of special on-board fuel capacity is envisaged, corresponding to a characteristic velocity of 7.5 m/s, which will make it possible to increase with certainty the altitude of spent objects in the first stage by 200 km in relation to the GSO.

The possibility is being explored of establishing 300 km as the minimum required value for the increase in altitude of spent geostationary objects. In order to reach final agreement on this value, further technical study will be required, together with continued discussion with the representatives of ESA, NASA and other space agencies and organizations operating satellite systems.

In the modernization and development of new booster modules, the requirement is being introduced that they should be removed into orbits so as to prevent possible collisions with space objects still in operation.

In order to prevent space pollution by fine particulate debris, it is proposed to take the following measures:

- Renunciation of the use in space of motor systems powered by types of propellant whose combustion involves the formation of solid particles (a third of the combustion products of solid rocket motor fuels, for instance produce aluminium oxide particles of 0.0001-0.01 mm in size);
- The use in rocket stages and space objects of materials and casings with minimal susceptibility to erosion as a result of the effects of circumterrestrial space conditions.

In future it will be possible to move to fully reusable means of orbiting and retrieving space objects and to the use of space tugs.

In overall terms, “cleaning” circumterrestrial space of space debris presents an array of problems whose resolution will entail a vast outlay of resources. For the odd operation to remove large objects from orbit it is possible to use interorbital tugs with liquid rocket motors or even orbital transport craft of the Buran or Space Shuttle type.

F. Russia’s activity on the Inter-Agency Space Debris Coordination Committee (IADC)

Since 1993 the Russian Space Agency has represented Russia with a casting vote of the Inter-Agency Space Debris Coordination Committee (IADC), whose members comprise the major launching space agencies.

The purpose of the Committee is to elaborate proposals regarding the technical space policy of launching States with respect to space debris; to organize information exchange among participating agencies regarding technogenic space pollution; to coordinate national programmes for minimizing orbital pollution due to space debris; and to conduct joint research on issues relating to the monitoring, tracking and forecasting of technogenic space pollution. The Committee’s work is performed by its Steering Group (its governing body) and four permanent working groups which hold annual sessions.

On 24 February 1993, a meeting was held with ESA specialists at the TsNIIMash, at which matters were discussed relating to the preparation of the first European Conference on Space Debris. In March 1993 the participants in this Conference included Russian scientists working in the field of technogenic pollution of circumterrestrial space. In October 1993, the Committee’s tenth session was held at the TsNIIMash, the work of this session culminating in the adoption of the Committee’s statute in which Russian proposals for the distribution of the working groups’ tasks are reflected.

In May 1994 the Committee’s eleventh session took place in Japan. In March 1995 the twelfth session was held in the USA and a draft regulatory instrument regarding pollution in circumterrestrial space was presented by the Russian Space Agency. In June 1995 the TsNIIMash provided the venue for a meeting with NASA specialists on matters relating to space debris observation and cataloguing. In October 1995 the Russian Space and Energy Software Research Centre held the First International Working Seminar on the topic of technogenic pollution of circumterrestrial space, at which over thirty papers were presented by Russian specialists covering the entire spectrum of issues associated with technogenic pollution.

At forthcoming sessions of IADC Russia proposes that discussion be focused on the following conceptual questions:

- Conduct of studies to identify the causes of discrepancies in the evaluations of circumterrestrial space pollution yielded by Russian and foreign space debris models, and action to eliminate these causes;
- Elaboration of measures to reduce circumterrestrial space pollution using means such as the removal of large fragments from economically advantageous circumterrestrial orbits; location of the fine-particle fraction of space debris; and identification and elimination of its sources and causes of proliferation;
- Definition of the radioactive components of space debris, analysis of the processes responsible for its proliferation and evolution, and hazard posed both to space activity and to life on Earth;
- Development of methods for defining “State ownership” of radioactive space debris;
- Development of technical approaches to the measurement of space debris radiation parameters and elimination of its most hazardous fragments;
- Comparative analysis of existing methods for calculating shield puncturing and experimental verification of shields;
- Elaboration of an international regulatory instrument for space object protection.

G. Proposals for International Cooperation

In view of the global character of problems relating to space debris and their impact on the future course of the conquest of space, it has become a matter of particular urgency to rally the constructive efforts of the major space-faring States in order to tackle the range of scientific and technical problems involved in ensuring the safety of space activity (manned flights, first and foremost) under conditions of technogenic space pollution.

It is the view of Russian specialists that international cooperation efforts should focus on the following main approaches to tackling technogenic pollution:

- Coordination of the observation and surveillance of circumterrestrial space by national space monitoring systems with a view to forecasting hazardous approaches of orbital systems and space objects (including the planned International Space Station, whose assembly in space is scheduled to begin towards the end of 1997) with space debris, as well as the re-entry into the atmosphere of “high-risk space objects”, on the basis of the national space object catalogues maintained by Russian Federation and the United States of America;
- Establishment of a joint database for catalogues and mathematical models of space debris in circumterrestrial space;
- Development of a mathematical model characterizing the fine-particle fraction of the pollution of circumterrestrial space and the GSO, and comparison of the calculation results yielded by existing models;
- Development and experimental fine-tuning of shielding mechanisms for protecting orbital systems from collision with space debris;
- Development of technologies and systems for cleansing the circumterrestrial space environment of space debris.