ABOUT RUSSIAN FEDERATION ACTIVITY ON SPACE DEBRIS PROBLEM

Loginov. S[(1)], Yakovlev. M.[(1)], Mikhailov. M.[(1)], Makarov. Y.[(2)], Popkova, L.[(1)]
Gorlov. A.[(1)], Bulynin. Y.[(3)]

[(1)] *Central Research Institute of Machine Building, Pionerskaya Str., 4, Korolev, Moscow Region, Russian Federation, Email: popkova@tsniimash.ru*

[(2)] *Federal Space Agency, Schepkina st., 42, Moscow, Russian Federation*

[(3)] *JSC "Information Satellite Systems" Reshetnev Company, Zheleznogorsk-2, Krasnoyarsk Region, Russian Federation, Email: bulinin@iss-reshetnev.ru*

The space activity the world community conducts results in the growth of the near-earth space pollution with artificial space debris fragments and as a consequence in the space mission safety diminishing.

The Russian Federation shares the concern of the World community associated with the danger presented by the near-earth space man-made debris pollution first of all for the International Space Station (ISS) and manned space missions. We have encountered many times with hazardous situations when there was a risk of ISS collision with space debris fragments or a situation dangerous for the earth population and ground objects when large space objects enter the upper atmosphere subsequently impacting the ground.

Measures for solving the space debris mitigation problems are included in the relevant sections of Russia's Federal Space Program 2006 – 2015.

In 2008 the Russian Federation launched 27 space launchers among them:

- 3 Soyuz-FG SLVs of which one with a Fregat booster,
- 5 Soyuz-U SLVs,
- 1 Soyuz-2.1B SLV,
- 7 Proton-M SLVs+Briz-M booster (one of them partially successful with AMC-14 SC insertion in an unpredicted orbit),
- 2 Proton-M SLVs+DM-2 booster,
- 1 Proton-K SLV+DM-3 booster,
- 3 Kosmos-3M SLVs,
- 2 Dnepr SLVs,
- 1 Zenit 3SLB SLV,
- 1 Rokot SLV+Briz-KM booster,
- 1 Molniya-M SLV.

As a result 43 space vehicles were orbit-inserted of them 21 Russian vehicles:

- 2 manned Soyuz-TMA series spacecraft (Soyuz-TM-12 and Soyuz-TM-13),
- 4 Progress-M cargo space vehicles (Progress *M*-63, -64, -65, -01*M*»),
- 6 Glonass-M SCs and others.

Among the main measures to mitigate the space debris generation level implemented in 2008 onboard Russian SLV stages and boosters the following measures are worth noting:

- Proton and Soyuz SLV stages propellant tank pressure release and fuel depletion;
- No structure elements separated from the DM-3 booster remaining on orbit; after booster separation from the SLV the medium adaptor is jettisoned in open reference orbit; the booster is safely removed from the spacecraft to exculde accidental in-orbit collisions; residual propellant and pressurization gas
- depletion from the propellant tanks and sustainer pipelines after SC orbit insertion; helium release from the sustainer submerged cylinders; onboard storage battery discharge after mission completion;
- No small-size operating elements remaining in the near-earth space after Briz-M booster separation; release of residual fuel and gases from the

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additional propellant tank at its separation from the Briz-M booster into the near-earth space environment;

- The Dnepr SLV upper stage structure prevents pollution of the near-earth space with small-size operating elements (explosive bolts, separation system elements and elements of other fittings remain inside the stage); at the end of a mission propellant components are burnt out for passivation*a*;
- The Kosmos-3M SLV upper stage SC separation pushoff springs have been modified in order to prevent ejection of fragmemnts generated at their operation into the near-earth space environment.

The Russian Federation is governed while implementing the space activity by the UN Guidelines on Space Debris Generation Mitigation. It may be exemplified by the efforts we undertake to limit SC long-term existence in the GSO vicinity after the SC scheduled lifetime termination as applied to the GSO Express-A spacecraft. Currently the guaranteed 7-year service life of two out of the three Express-A spacecraft has expired. These are: Express-A2 (#2000-013A) launched March 12 2000 and Express-A3 (#2000-031A) launched June 24 2000. The two GSO spacecraft will be deorbited after their replacement with the new-generation Express-AM satellites. The propulsive mass reserve for deorbiting would enable to raise the orbit perigee by at least 200 km as prescribed by the international requirements. A special procedure for deorbiting the Express-A3 SC (#2000-031A) has been developed. Since this spacecraft is kept on the western boundary of the Russian control stations visibility zone (in its orbital position 11^0 W) it will be moved at first to the east to be within the Russian control stations visibility zone, then its orbit will be corrected for perigee elevation. Such a strategy would enable to complete the finishing passivation operations after deorbiting in compliance with the 5th guiding principle of the document “Minimization of Probability of Fragmentations Generation caused by Energy Budget after Mission Implementation”.

An important point in the space debris problem solution is *updating of the near-earth space man-made space debris pollution***,** especially it concerns the geostationary orbit region. To this end the M.V.Keldysh Institute of Applied Mathematics of the Russian Academy of Science organized an International Cooperation of Observers who helped register the objects along the whole GSO length. The year of 2008 witnessed as well the development of the Scientific Optical Instruments Network for astrometry and photometry tracking of space debris fragments Currently the Network integrates 18 observatories, 25 telescopes, over 50 observers and researchers.

In 2008 the Network underwent an ordinary modification thus enabling to organize three specialized subsystems – a GSO and GSTO objects surveillance subsystem, a high orbit small-size space debris fragments detection and tracking subsystem, a LEO and high elliptical orbit objects observation subsystem. In 2008 the Scientific Observation Network performance enhanced by 2.5 times as compared with 2007 and today it is a powerful capability for observing high orbit space objects. So the number of known GSO objects increased by 35% due to deployment of the Scientific Optical Instruments Network (SOIN).

The issue of protecting spacecraft against meteoroidal and man-made fragments becomes especially acute in connection with the further ISS buildup and operation. The ISS project scale (the total area of the pressurized shell of ISS modules ~1000 m^2, crew – up to 6 man) sets higher requirements to the safety bearing in mind the probability of ISS depressurization as a result of its collision with pace debris fragments.

The MIR orbital station operation experience has shown that despite absence of emergencies associated with the pressurized shell breakthroughs by meteoroids and man-made fragments the station’s structure external elements were exposed to multiple impacts of fragments of the size close to critical which was fraught with pressurized shell breakthroughs.

At present the ISS structure elements are protected against fragments or micrometeorites by passive shielding structures. The protected compartment is divided into zones taking into account their structural features and fragment impact conditions. Shield types and their structure configurations are selected individually for each zone.

Russia has developed a concept for using the protective shielding structures, procedures for their designing, calculating, development testing and performance evaluation. Specialists of TSNIIMASH and Energia RSC have developed shielding structures for the ISS Russian Segment. A unified shielding structure with high impacts resistance properties and mass perfection has been designed. Procedures for designing, calculating, development testing of the shielding of the ISS RS modules have been developed. Protective shielding structures with front shields made of pulverulent heavy metal compositions, small-cell steel fabric and shaped structures have been developed. Tests have shown that theprotective shielding structures with front shields of the mentioned types have the impact resistance level surpassing the resistance level of protective shielding structures of the NASA-developed MOD-1 type similar in geometry, mass expenditure and protected wall thickness.

At the same time while working on enhancing the spacecraft safety level in terms of possible pressurized shell damages caused by high-velocity fragment impacts the Russian specialists came to a conclusion that the currently applied protective shielding structures are approaching the physical limit of their capabilities and their further improvement would demand an inaccessible high mass expenditure.

According to the Russian specialists enhancement of the future SC safety would demand utilization of pressurized shells capable of restoring pressurization after damage along with passive protective structures. One of the methods is to use "self-pressurizing" shells in which mechanical devices or chemical reagents would stop the hole made by a high-velocity fragment.

Russia continues *space debris modeling* works. In 2008 the input parameters of the space debris model GOST R 25645.167-2005 were updated applying the accessible test data: "Space Environment (Natural and Artificial)".). Model of Spatial & Temporal Distribution of Technogenic Substance Flows Density in Space".

We continued works to establish an *Inter-Industry Automated Information & Analytical System for Short- and Long-Term Prediction and Warning of the emergency situations* presenting danger to orbital SC groupings and ground objects and caused by man-made space debris objects with the aim to manage the emergency risk.

Works are underway to support prevention of ISS impacts with large space debris fragments. We regularly analyze the circumstances of close approaches of such objects with ISS and other spacecraft and assess the collision risks. On average the Russian MCC receives monthly 2-3 notifications on close approaches of uncontrolled space objects with ISS which are then strictly controlled. After thorough analysis of the hazardous situation if the collision probability doesn't reduces a set of maneuvers to avoid the dangerous space object is fulfilled by ISS. Lately the number of alarm messages on dangerous close approaches received by the Russian MCC has sharply grown. In 2008 we received 48 messages informing on space debris fragment intrusions in the ISS safety zone therewith the safety corridor critical boundaries (the so called "Red Threshold") were breached 8 times. After a thorough analysis of the situations one decision to make an avoidance maneuver by ISS was made and realized on August 27 2008. Worth noting is the situation with the Soyuz TMA-12 launched on April 8 2008 to dock with ISS. This space vehicle could collide with a fragment of the American USA-193 spacecraft (#2006-057A) which broke in February 2008.

The Russian MCC tracks the objects entering the upper atmosphere in cooperation with other organizations. In this case special attention is paid to the so called space objects of risk (bulky, large-size space objects or hazardous substance containing objects). We operatively tracked descending spent upper stages of the Soyuz-type medium-weight SLVs remaining on LEO after PL orbit injection (with the life time of several days).

In 2008 we monitored the process of deorbiting totally 8 spent SLV upper stages. The Russian MCC made from 7 to 12 decisions on ascertaining the orbit parameters and predicting the time and place of service life termination for each controlled object.

In 2008 we conducted operations on monitoring the flight of the failed American SC «USA-193» (#2006-057*A*) applying data acquired by the Russian space object tracking stations.

In 2008 we analyzed the deorbiting space objects in order to define the candidate for a target object to be used by the 10th IADC Test Campaign. The American «EAS» (the Early Ammonia Servicer, # 98067BA) became an international test object for the period from October 22 to November 3. The Russian Space Monitoring System took the task of tracking this object individually. For the test campaign time the IADC database received from Roscosmos 19 orbital data packages (TLE), formatted by the Russian Space Monitoring Center and 27 formal decisions of MCC containing the space object ground impact time prediction. The values of the EAS SC ground impact place and time obtained by the Russian MCC specialists are as follows:

time: – 03.11.2008 at 05:05 UTC (08:05 DMT),

place: – 19.8° S, 190.5° E.

The values are in good agreement with the official data which determine November 3 2008, 04:58 UTC to be the EAS SC service life termination time.

In 2008 the National Standard of the Russian Federation GOST P 52925-2008 “Space Technology Items. General Requirements to Space Assets on Mitigation of Near-Earth Space Pollution with Man-Made Space Debris” was duly approved and put in force. The Standard requirements have been harmonized with the requirements of the UN Guidelines on Space Debris Generation Prevention.

The Russian Federation participates in ISO works on developing international standards for near-earth space man-made space debris pollution mitigation.

26-th session of IADC has been held in Moscow in 2008. During discussions the most actual problems of a space debris were discussed.

On the whole we may note that Russia pays much attention to solving the near-earth technogenic pollution problems. The works in this area are conducted within the framework of the national effective space activity laws of Russia with due regard for the dynamics of implementing the appropriate measures by other space agencies and organizations.