ACTIVITY OF THE RUSSIAN FEDERATION ON SPACE DEBRIS PROBLEMS

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ABSTRACT

Research of space debris problems in the Russian Federation is carried out in following aspects 1) observation, 2) modelling, 3) protection and 4) mitigation. The Russian Federation is devoted to the international efforts on space debris problem resolution and is already implementing practical steps on space debris mitigation on a voluntary basis within its own national mechanisms taking into account the COPUOS UN and IADC Space Debris Mitigation Guidelines.

ARTICLE

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

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.

Within several last years the Russian Federation is leader in launches of spacecrafts. In 2012 the Russian Federation launched 24 launch vehicles (~32%), taking into account launches under programs Sea Launch and "Soyuz" in the Kuru" it's increase to 29 (more then 38 %) (Fig. 1, Tab. 1).

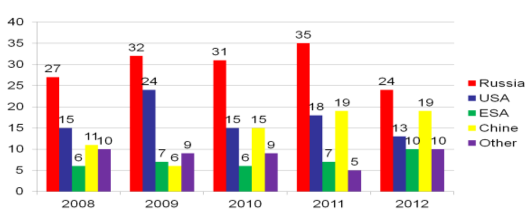

Figure 1. Dynamics of launches in Russia and in other states and organizations

Table 1. Russian Federation launches, 2012

	Type of Launcher	Type of Booster	Number of Launches	Type of Orbit
1	Soyuz-2.1 A	Fregat	1	High elliptical orbit
2	Soyuz-2.1 A	Fregat	1	Circular NEO
3	Soyuz-FG	-	4	Circular NEO
4	Soyuz-U	-	5	Circular NEO
5	Soyuz-ST-B	Fregat-MT	1	Circular MEO
6	Soyuz-ST-A	Fregat-MT	1	Circular NEO
7	Soyuz-FG	Fregat	1	Circular NEO
8	Proton-M	Briz-M	10	GEO
9	Proton-K	DM-2	1	GEO
10	Rokot	-	1	GEO
11	Zenit-3SL	DM-SL	3	GEO
		Total:	29	

As a result in 2012 34 spacecrafts were orbit-inserted, 22 of them is Russian, among them: 4 manned SC Soyuz-TMA, 4 cargo SC Progress-M, 2 SC Cosmos, 2 SC Gonetc-M, etc.

The activity of Roscosmos on space debris mitigation is being carried out within the framework of conventional international documents. They are COPUOS UN and IADC Space Debris Mitigation Guidelines. The National Standard GOST R 52925-2008 "Space technology items. General requirements for mitigation of near-earth space debris population" is the way of realisation of measures of space debris mitigation principles in the Russian Federation; it was put in force in 2009.

Annually analysis of implementation of requirements of the UN Space Debris Mitigation Guidelines is carried out according to the Russian space-rocket industry.

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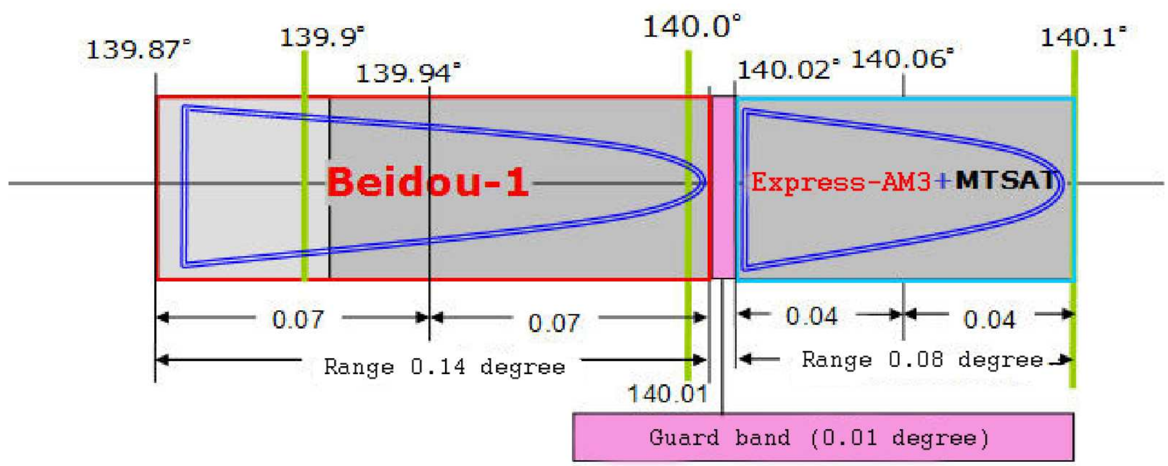
There are some main space debris mitigation actions performed on Russian launch vehicles, boosters and spacecrafts [1]:

- releasing of pressure and fuel in fuel tanks of Proton and Soyuz launch vehicle stages;
- possibility of destructions during mission operation is minimized on the DM-2 booster due to controlled initiation of cruise engine and instruction issue on off-line breakdown switch with remote control in case of contingency, and also due to presence of safety venting valves on fuel tanks and vessels;
- submersion in ocean of Fregat boosters after injection of payloads on orbit;
- there isn't small-size operating elements remaining in the near-earth space after Briz-M booster separation; releasing of residual fuel and gas into the near-earth space environment after separation of additional fuel tank from the Briz-M booster; mission profile of Briz-M booster contains two impulses for its disposal from operational orbit;
- termination of rotation of flywheels, gyroscopes and other mechanical devices, removal of the residues of fuel under the big pressure and discharge of chemical sources of a current are provided on spacecraft Gonets-M for minimization of possibility of destructions caused by the energy residues after the mission termination.

Design documentation of development and modification of space-rocket enterprises products in 2012 (SC Electro-M, Gamma-400, etc.) contains requirements on space debris mitigation.

Collocation (keeping in close orbital position) of spacecrafts is one of the main approaches in space debris mitigation in GEO region. Collocation of several GEO spacecrafts allows to excluding their destruction in a result of mutual collisions. Collocation of three operational spacecrafts: Chinasat-32, MTSAT-1R and Express-AM3 in orbital position 140º±0.1º is an example of the successful decision of this problem. The separate longitudinal zone from 139.9º to 140.01º from a general keeping zone was allocated to Chinasat-32, because operator of Chinasat-32 hasn't exchanged orbital data at a collocation. The guard band at 0.01º is established between longitudinal zones for prevention of dangerous approaching of spacecraft Chinasat-32 with two other spacecrafts. MTSAT-1R and Express-AM3 were in the zone 140.02º-140.1º simultaneously. There was carried out I-E collocation between them. Disposition of zones and spacecrafts is shown in Fig. 2. The average minimum distance between MTSAT-1R and Express-AM3 since 2009 to 2012 was about 15 kilometers. Such strategy has demanded additional expenses of fuel from operators of MTSAT-1R and Express-AM3, but it has allowed preventing collision of spacecrafts (Fig. 2).



Division of longitudes with guard band
Beidou-1:
Longitude deviation: ±0.06 °:139.94 ° E
Possible scope: 139.87-1.01 ° E: ±140.07 °

Express-AM3 + MTSAT:
Shift on a longitude: 140.0 ° +0.06 °
Possible scope:140.02-140.1 ° E (± 0.04 ° from the zone centre)

- Express-AM3 and MTSAT carry out a collocation, using E-I method of division.
- The exchange of the standardized files is carried out for check of conditions of collocation.
- The guard zone (0.01) takes places between zone of Beidou1 and (Express-AM3+MTSAT).
- Beidou-1 data is available, when the Chinese spacecraft approach close to zone border.

Figure 2. Disposition of keeping zones of Chinasat-32, MTSAT-1R and Express-AM3 on a longitude

The scheme of interaction of satellite operators at pair launch spacecrafts Yamal-300K and Luch-5B, in November, 2012 is another example of prevention of accidental collisions in GEO region.

Data exchange was carried out during preparation for launch and at the initial phase of mission for coordination of actions with other spacecraft operators with whom probably dangerous approach. Cooperation included following works:

1) 20-30 days prior to launch, a communication establishment on e-mail with spacecraft operators;
2) 10 days prior to launch, informing of spacecraft operators on prospective date of launch and nominal parameters of spacecraft orbit at the moment of separation;
3) 2-5 days prior to launch, inquiry at spacecraft operators of parameters of an orbit of their spacecrafts in the first days of spacecraft mission taking into account prospective corrections in these dates;
4) after start, an operative exchange with spacecraft operators in actual orbit parameters of again launched spacecraft and plans of corrections.

Data exchange was carried out during preparation for launch and during 5 days after launch with other spacecraft operators, they are:

- INTELSAT-702 (int. № 94034A), spacecraft operator - Intelsat;
- INSAT-3E (int. № 03043E), spacecraft operator - ISRO Satellite Centre;
- GSAT-8 (int. № 11016B), spacecraft operator - ISRO Satellite Centre;
- BONUM-1 (int. № 98068A), spacecraft operator - Russian Satellite Communications Company.

Disposal of spacecraft Express-A3 that has been carried out in June - August, 2009 is example of successful disposal of GEO spacecraft. Longitude operational position of Express-A3 was 11° W longitude on the west bound of Russian ground station visibility. Spacecraft was out of a visibility range of the Russian stations of tracking already during carrying out of disposal maneuver in case of application of the scheme of direct disposal of spacecraft from an orbit on necessary altitude. That did not allow performing termination operations with the spacecraft. Therefore at first the orbit altitude has been reduced, the spacecraft has made drift in east direction, after that the altitude increase has begun. Such sequence of operations guaranteed finding of Express-A3 in a zone of visibility of the Russian space communication center during necessary time after the termination of disposal maneuver.

Thus, the program of Express-A3 disposal included following actions (Fig. 3):

1) decrease of an orbit altitude within 1 day in order to provide spacecraft shift to the East;
2) passive drift of spacecraft on the East within 50 days to a point with a (36-38)° east longitude, 1° per day;
3) increase of an orbit altitude within 6 days for disposal of spacecraft on altitude above GEO approximately on 380-400 km. Rate of spacecraft displacement on the West has made nearby 5° per day.
4) the satellite visibility from ground station after de-orbiting maneuver cut-off was 9-10 days. Rate of spacecraft displacement on the West has made nearby 5° per day.

Possibility of disposal of Russian GEO spacecrafts being on the western border of a visibility range of the Russian stations of tracking to graveyard orbit is shown on example of disposal of Express-A3.

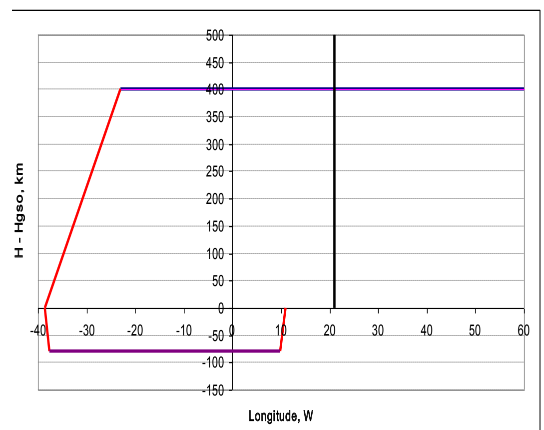


Figure 3. Scheme of Express-A3 disposal

Researches on realization of disposal from near Earth space protected regions of large-sized fragments of space debris utilizing unused power resources of launch vehicle upper stages, that consist in the liquid rests of propellant and in the rests of gas of pressurization, are carried out in Russia. [2]

Russian researches are carried out on developing of ion beam system for de-orbiting large-size space debris fragments.

Improvement of parameters of GEO space debris population is important aspect of space debris activity. With that end in view Keldysh Institute of Applied Mathematics (Russian Academy of Sciences) organized the international cooperation of observers - International Scientific Optical Network (ISON). Utilization of this cooperation has allowed providing registration of objects on all extent of a geostationary orbit. Currently ISON is the largest network in the world for supervising a geostationary orbit area. There was another stage of modernization of this network in 2012. Two more countries have joined project ISON: Mexico and Mongolia. Three new observatories have opened: in Kosala (Mexico), in Kislovodsk (the North Caucasus, Russia) and in Hyraltogot (Mongolia). 11 new telescopes have started up. Development of all five ISON subsystems proceeds: the review of GEO area, monitoring of bright objects, monitoring of faint fragments, monitoring of higheleptical objects, an searching subsystem of the asteroids approaching with the Earth. One comet, one asteroid approaching with the Earth and about 100 asteroids of the main belt were detected by using facilities of this searching subsystem.

The Russian experts continue to improve protection methods and facilities of spacecrafts from influence of particles of space debris and micrometeoroids. Calculations of ability against impact on protective screen of existing and perspective developed modules of ISS Russian segment, the spacecrafts Progress-M and Soyuz-TMA are carried out taking into account increase of space debris population of the ISS orbit. The unified protective screen is developed. Efficiency of this protective screen is investigated on using for protection of the Small research module Rassvet which is the part of Russian ISS segment since 2010. Results of testing of such protective screen are resulted in Fig. 4.

We can see, that the exterior screen of assemblage was punched out by a particle, intermediate screen of assemblage was punched out by the cloud of splinters of the particle and the obverse screen. As a result the protected wall wasn't punched out; the dent from influence of splinters of the particle and the obverse screen was formed only.

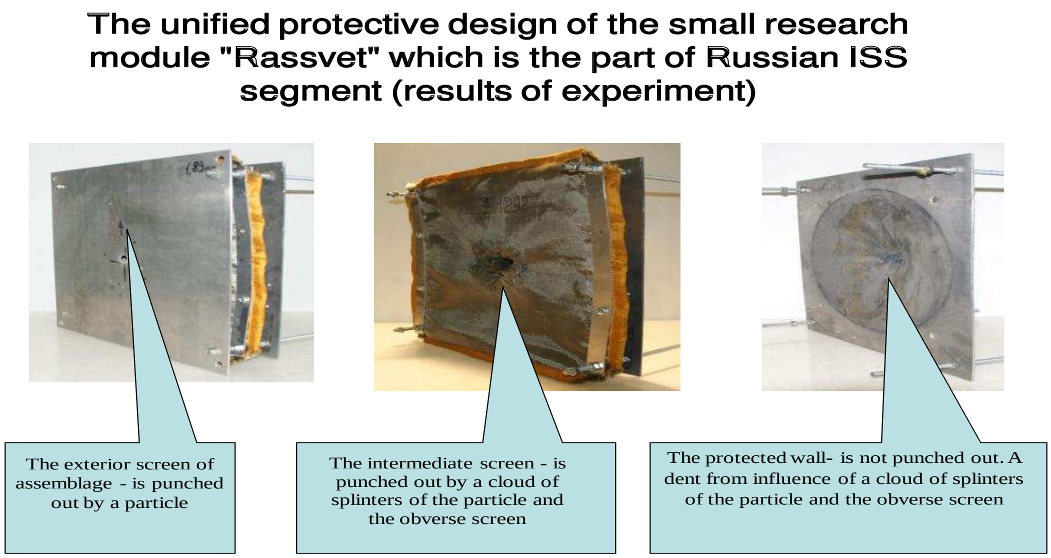


Figure 4. Results of testing of the unified screen protective design for protection of small research module Rassvet of Russian ISS segment. Projectile - Al pellet of 9,13 mm in diameter, velocity ~ 6,93 km/s, impact angle 0°.

Activity on strengthening of protection of the Russian ISS segment from impact of high-speed particles of space debris and meteoroids proceed in Russia. In 2012 five additional protective screens has been installed on small diameter working compartment of service module Zvezda.

Activity on modeling of space debris population proceeds in Russia. The technique of modeling of altitude distribution of fragments of spacecrafts destruction as a result of explosions and collisions is developed with use of experimental data about collision between Cosmos-2251 and Iridium-33.

Mutual collisions of not catalogued objects are the basic source of formation of small fragments of space debris. The contribution of this source to formation of fragments of space debris in the size range from 1mm to 1cm exceeds 10 times the contribution of mutual collisions of catalogued space objects (space objects bigger than 20cm). [2]

Results of researches are implemented in the new version of the Russian space debris model SDPA (Space Debris Prediction and Analysis) as software program. The program allows to predict anthropogenic conditions in near Earth space with the account of mutual collisions of space debris fragments with the size more than 1cm. The prediction of the space debris environment, based on new version of SDPA, shown that avalanche process of self-reproduction of space debris, so-called "Kessler syndrome", already starts.

Qualitative increase of level of operative monitoring of anthropogenic conditions and the prediction of dangerous situations in near Earth space is one of the basic directions of maintenance of safety of space activity.

Creation and development of The Russian Hazard Alarm System (ASPOS) is proceeded in the Russian Federation. The main developer of ASPOS is MCC (Central research institute for machinery building - TsNIImash). Keldysh Institute of Applied Mathematics (Russian Academy of Sciences) and IZMIRAN and other enterprises also take part in this system.

In 2012 ASPOS provided collection and analysis of the information about space objects, analysis, ballistic support of dangerous situations in near Earth space, etc.

The prediction of hazardous approaching of spacecrafts (from the list of "protected" SC) with space debris fragments is carried out every day. Results of prediction are sent to spacecrafts operators and to the Central information office of ROSCOSMOS.

Besides, every day activity is carried out to detection of "risk" objects falling, to control and to track of them, to predict time and falling area.

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Thus, research of space debris problems in the Russian Federation is carried out in following aspects: 1) observation, 2) modeling, 3) protection and 4) mitigation. The Russian Federation is devoted to the international efforts on space debris problem resolution and is already implementing practical steps on space debris mitigation on a voluntary basis within its own national mechanisms taking into account the COPUOS UN and IADC Space Debris Mitigation Guidelines.

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