THE STATUS OF RUSSIAN SPACE DEBRIS MITIGATION STANDARD

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ABSTRACT

Russian Aviation & Space Agency (Rosaviakosmos) approved its Space Debris Mitigation Standard in July 2000. The Standard have been analyzed and compared with the similar Standards of the USA, France and Japan. It has been shown, that basically all recommendations of mentioned Standards had been included in the Russian Standard. There are some differences in boundaries space object burial zones in the GEO region. These differences were discussed of at the 18-th IADC meeting in June, 2000 in Colorado Springs (USA). The terminology in the Russian and other national Standards is different but the functional equivalence was finally recognized. The procedures of introducing the Standard by space vehicle designers and operators are under consideration.

RUSSIAN MITIGATION STANDARD

United Nations Technical Report on Space Debris was prepared two years ago. The Report provides a comprehensive description of the technical issues of space debris. However further efforts are needed to implement of debris mitigation measures. Russia like other space-fairing nations is seriously concerned about the near-earth space artificial debris pollution and intends to consistently undertake measures to mitigate space debris population on the basis of the adopted international agreements. So, Russian 1023-2000 "Space technology items. General requirements. Mitigation of space debris population" (Standard) had come into force in July, 2000. The Standard contains six topics which describe field of application, standard references, terms and definitions, general provisions and general requirements for space vehicles to ensure space debris mitigation.

The field of application of the present Standard extends to launch vehicles and spacecrafts capabilities, reusable space systems, interplanetary stations and vehicles exploring outer space, space vehicles of scientific, socio-economic and commercial designations to include manned space vehicles, excluding military space vehicles. The standard does not cover designs, systems, equipment and devices incorporated in space vehicles and developed before the present Standard is come into force. The Standard requirements are obligatory for all participants of space technology and operation development if references to the present Standard in specifications (technical assignments), state contracts (agreements) and other documents on development, updating and operation of space technology items are available.

Terms and definitions of the Standard were determined in accordance with the same terms used in world practice. The main space debris sources there are submitted in the Standard:

- accidental space object explosions;
- self-destruction of S/C (S/C systems) upon their active life termination or as a result of an emergency situation;

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- ejection of operational elements (springs, push rods, dangerous elements of explosive bolts etc.);
- space launch vehicles (SLV) stages, boost modules (BM) and spacecraft upon their active life termination;
- fragmentations of SO due to their in-orbit collisions with each other or with natural space particles;
- ejection of engine combustion products, non-burnt fuel, liquid and gaseous substances out of S/C and SLV bodies;
- erosion of materials from space vehicle surfaces;
- tether systems separated upon their use;
- ejection of life-support means from orbital stations.

General mitigation requirements for space vehicles are listed in Table 1. For comparing the documents the requirements of another national Standards there are shown in table 1 too. Generalized comparison of Russian, NASA, CNES, and NASDA debris mitigation standards is submitted in table 2. As it follows from the table all the mitigation requirements of Russian Standard are common with another standards except the next differences:

- in contradiction to CNES and NASDA Russian and NASA standards admit self-destruction of space vehicles (and their systems) just before their reentry; this measure may be useful to minimize the risk of large space object fall on the earth surface;
- in Russian Standard GEO objects postmission disposal is defined as it was agreed at the IADC meetings namely: (235 km + add.) above geo. this requirement coincides with CNES Standard, but is lower/higher by comparison with NASA/NASDA requirements;
- Russian Standard provides postmission disposal measures at LEO and MEO when their mission is over; Russian designers and operators will follow common ideas about disposal orbits but quantitative characteristics of these orbits will be incorporated in our standard and validated by future practice.

By comparison with all other documents Russian standard determines the organization requirements additionally. These requirements are directed to realize proposed mitigation measures namely:

- Measures to prevent space debris generation are obligatory for all participants of design and operation of space vehicle in all phases and at all stages of their life cycle. The mitigation requirements to space vehicles should be included in specifications (technical assignments) for them and coordinated in the established order.
- Each event of an accidental explosion in orbit or SO fragmentation because of a collision with other space objects in all phases of their operation should be analysed with clarification of causes of such situations, issuance of recommendations as to how to prevent such events in the future.The given work is being organized by the Russian Aviation & Space Agency. Results will be executed in the form of a separate document by the space vehicle designer and submitted to the Russian Aviation & Space Agency.
- The design documentation materials should contain:
  - a list and description of standard and expected emergency situations giving an information of probable sources of space debris;
  - the description of the SV design and operation peculiarities giving an information of probable sources of space debris (fuel, chemical supplies, pressurized tanks, fuel tanks and pipelines, explosive devices, kinetic energy supplies, payload separation and deployment systems, shielding elements for optical and other devices, most vulnerable to collisions with space debris fragments and sensitive to external effects, life-support systems, coatings, etc.);
  - data on expected amounts of masses, dimensions, shapes, materials of separated operational elements measuring over 1 mm;
  - a list of specific operational and technical measures directed at mitigation of space debris.
- Observing the present standard requirements it is necessary to take into account economic and other expenses on implementation of required measures.
- The fulfillment of the established

space debris is controlled by the Customer of the given space vehicles.

The implication of the Standard to industrial enterprises practice is not yet clear and will require further discussions. Standard development and realization conditions can be determined as follows:

- the mitigation measures should be implemented so as not to cause major disruptions in space activity practice;
- all the measures should be carefully analysed from a position of cost-effectivness criteria;
- any changes in current space practice should be implemented in manner which allows definite variation among the mitigation scenarios;
- the mitigation practice will make sense only when corresponding mitigation measurements will be enforced by international resolutions and be applied by all spaceactive states and organizations.

Summary

- Russian mitigation Standard is prepared and comes into force in July, 2000.
- In general all the mitigation requirements of Russian Standard are common with another world mitigation standards.
- In contrast to world mitigation standards the organization requirements have been included in Russian Standard to make for the success of mitigation practice in space vehicle designing and operating processes.
- Russian Standard realization will be implemented step by step taking into account economic and other expenses on implementation of required measures.

Table 1. Comparison of RASA, NASA, CNES and NASDA Debris Mitigation Standards

s	RASA	NASA	CNES	NASDA
e l n io	1. Limitation of fragment generation during partition and separation of payloads applying explosive locks and push rods of different types, as well as safety covers and springs of spacecraft devices and minimization of ejections of fragments of separation systems based on explosive bolts, extended shaped charges, pyro-knives and pyro-guillotines. 2. Minimization of dangerous fragment number of engine nozzle stoppers and covers. 3. Minimization of the number of dangerous (measuring over 1 mm) solid particles produced by rocket engines by optimization of solid-propellant engine modes of operation. 4. Minimization of material erosion from space vehicles surfaces	1. Limit number, size, and orbit lifetime of debris larger than 1 mm (below 2000 km altitude) – The total area-time product should be no larger than 0.1m2-yr. – The total object-time product should be no larger than 100 object-yr. 2. Limit lifetime of objects passing through GEO – apogee altitude of GTO objects should be no higher than 300 km below GEO altitude within 25 years.	1. Limit the injected object: 1 inserted object in orbit per payload 2. Avoid the release of objects during operations: [lens caps, covers, spin-up mechanisms, packing devices,…] 3. Minimize the production of debris • solid propellant motors, • pyrotechnical devices • reduction of produced debris in case of explosion • ageing of materials	1. Minimize debris release during normal operations. Operational debris in Earth orbit, such as fasteners, should be minimized unless technical or economical problem make it impossible
n- lo-	1. Remaining fuel removal from tanks of S/C, BM and SLV upper stages. 2. Liquid and gas removal from pressurized tanks in case space debris fragments may be generated due to depressurization of these tanks. 3. Chemical battery discharging. 4. Load relief (rotation termination) of flying wheels and gyroscopes.	1. Limit probability of accidental explosion during mission operations 2. Deplete on-board stored energy at end of mission life	1. Deplete all on-board energy sources - Mechanical energy: • pressure lowering in the tanks • pressure gas expelling - Chemical energy: • remaining propellant draining, emptying • discharge of batteries and cells	1. Remove potential causes of accidental breakup: - Deplete residual propellant - High pressure bottles should be equipped pressure relief valves or provide sufficient safety margin for the proposed orbit environment - Batteries should discharged completely - Protect the command destructive change against thermal environment and miscommand - Vent residual propellant from apogee propulsion systems 2. Monitor main functions to take immediate actions in case of failure

Table 1. Comparison of RASA, NASA, CNES and NASDA Debris Mitigation Standards (continued)

Items	RASA	NASA	CNES	NASDA
Intentio-nal breakups	Self-destruction of space vehicles (their systems) just before their reentry to minimize the risk of large space object fall on the earth surface Limitation of the number of self-destroyed spacecraft device fragments in near earth space.	1. Limit number, size, and orbit lifetime of debris larger than 1 mm – the area-time product does not exceed 0.1m2-yr – the object-time product does not exceed 100 object-yr2. 2. Assess risk to other programs for times immediately after a test 3. No assessment of for breakups occurring below90 km altitude	Prohibited	Intentional destruction shoul planned (except to assure safe re
Collisions with large objects	Development of method of orbital maneuvering for avoiding collisions of manned space vehicles with large size SD objects.	Assess probability of collision with intact space systems or large debris	If the collision risk does not meet program objectives, collision prediction is recommended. Avoidance maneuver can be performed if necessary	Avoid interference with spacecr in the same orbit (Orbit should be planned tc adequate distance from other sp
Collisions with small debris	Collision risk of space vehicles under designing with SD should be assessed.	Assess and limit the probability of damage to critical components as a result of impact with small debris	The probability to perform the end life disposal operations shall be greater than 0.99	
Postmis-sion disposal of S/C	Removal of spacecraft upon their service life termination from the GEO region to the burial region. The orbit perigee of S/C removed to the burial region (with due regard for the subsequent evolutions of S/C under the disturbance factor effects) should be higher by over 200 km as compared with GEO radius. Removing especially dangerous space vehicle fragments from orbits their disposal to long-term existence orbits. Reduction of orbital lifetime of S/C at the end of their mission.	Remove space systems from high value regions of space so they will not threaten future space operations 1. Atmospheric reentry within 25 yr 2. Maneuvering to a storage orbit between LEO and GEO: - above 2500 km below 19,900km - above 20,500 km below 35,288 km (500 km below GEO altitude) 3. Direct retrieval within 10 years 4. Maneuvering to a storage orbit above GEO altitude: - 300 km+(1,000 x Cr x A/M)	Remove space systems from useful regions or that cross useful regions of space so they will not threaten future space operations 1. Atmospheric reentry within 25 yr 2. Maneuvering to a storage orbit between LEO and GEO: - above 2500 km below about 35,500 km (500km below GEO altitude). 3. Maneuvering to a storage orbit above GEO altitude: - 235 km + (1,000x Cr x A/M)	Remove spacecraft from high orbit regions so that they will future space operations 1. Atmospheric reentry withi only if ground safety can be g 2. Maneuvering to a storage or LEO and GEO: - above 1700 km (2500km, below 19,900 km - above 20,500 km below (500 km below GEO altitud 3. Direct retrieval by STS 4. Maneuvering to a storage GEO altitude: - 200 km+(0,22 xax Cr x A/M)

Table 1. Comparison of RASA, NASA, CNES and NASDA Debris Mitigation Standards
(continued)

s	RASA	NASA	CNES	NASDA
s- al of	Same as S/C described above	Same as S/C described above	Same as S/C described above	1. L/Vs are expected to be designed to be able to reduce interference with useful orbit after the separation of payloads 2. The flight trajectories of L/V for each mission should be designed to be adequate to comply with the purpose of the Space Debris Mitigation Standard. 3. Apogee altitude of GTO should be decreased to 500 km lower than GEO within 25 yr after the separation of payloads 4. In the case of direct GEO injection by upper stages, the final orbit of upper stages should be higher than GEO altitude, as the distance calculated by the following equation: 200 km (0,22xax Cr x A/M) • a: semimajor axis of orbit after reboost
ns	Pulling-in of spacecraft long tethers (if possible), usage of enhanced strength tethers			
ing y ting ted	Methods of prediction of dangerous space debris fragments reentry should be developed.	Limit number and size of debris fragments that survive uncontrolled reentry (the total debris casualty area for components and structural fragments surviving reentry will not exceed 8 m^2)		1. Predict the reentry risk and guarantee it to be acceptably small 2. Notify the reentry footprint to the authorities for shipping lanes and airline routes 3. Limit the altitude of intentional destruction for safety reentry

Table 2. COMPARISON of RUSSIAN, NASA, CNES AND NASDA DEBRIS MITIGATION STANDARDS

Mitigation Measures	RASA	NASA	CNES	NASDA
jation of Mission Related cts	Required			
ibition of Intentional ruction	Limited		Prohibited	
etion of Residual ellants	Required			
harge of Batteries	Required			
ection of On-board ructive device	Required			
sures for Pressure ease in Tanks & Bottles	Required			
sion Avoidance Maneuver	Recommended			-
sures for Small Debris	Required to assess probability			-
l orbit GEO S/C reorbiting	235km+add	300km+add	235km+add	200km+add
d Interference of R/B in with GEO	-	Required		
oval or Reorbit S/C at LEO	Reorbiting to Disposal Orbit Defined by each Organization or Remove within 25 yr			
er Systems	Required	-	-	-
of Ground Impact	To be assessed	< 8 m^2		