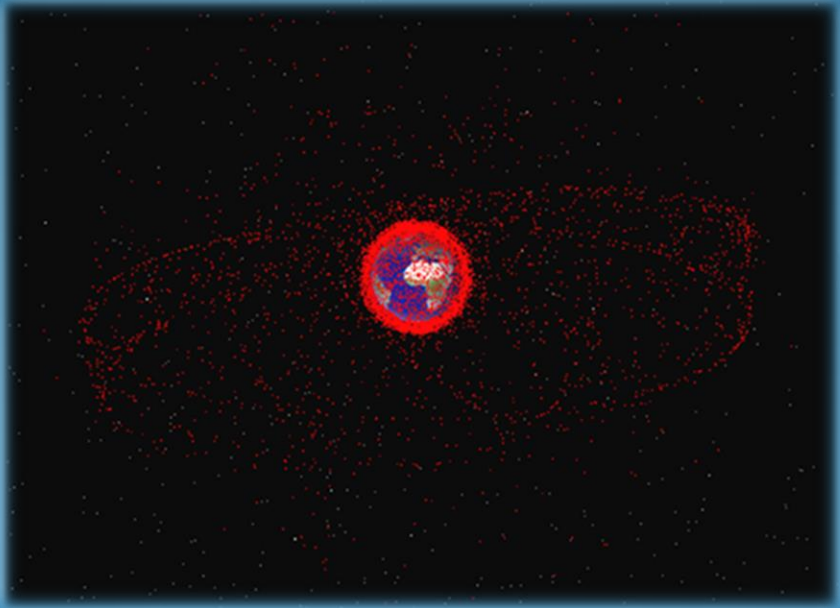
Federal State Unitary Enterprise

Central Research Institute for Machine Building

SPACE DEBRIS IN GNSS OPERATIONAL ORBITS

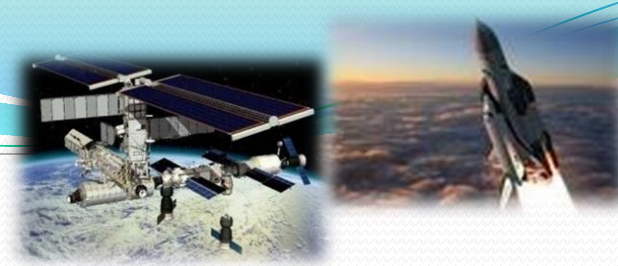


Igor Usovik, Eugeny Ignatovich, Sergey Kaplev

6 November, 2016

Provider's Forum Meeting

Sochi, Russian Federation



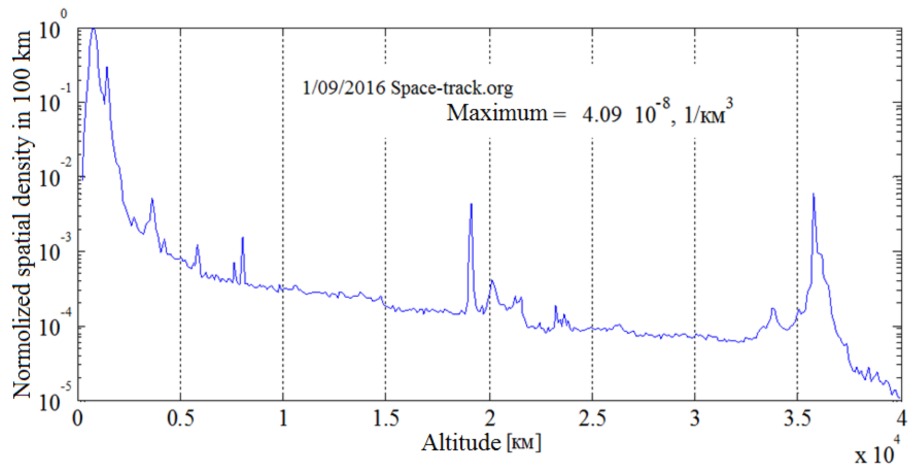
Cataloged Objects in GNSS Operational Orbits

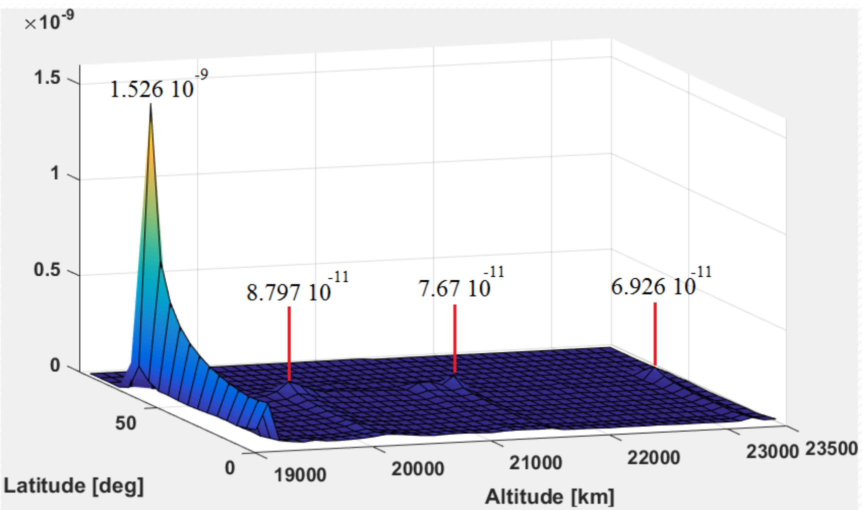
Altitude of GNSS operational region is 19000-23500 km.

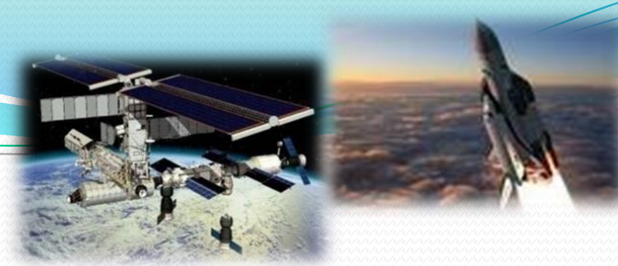
The graphs to the right is:

- normalized spatial density of cataloged space objects
- spatial density dependency on altitude and latitude for GNSS operational region

Spatial density of cataloged space objects for GNSS operational region is significantly less than in the protected LEO region and especially in the protected GEO region

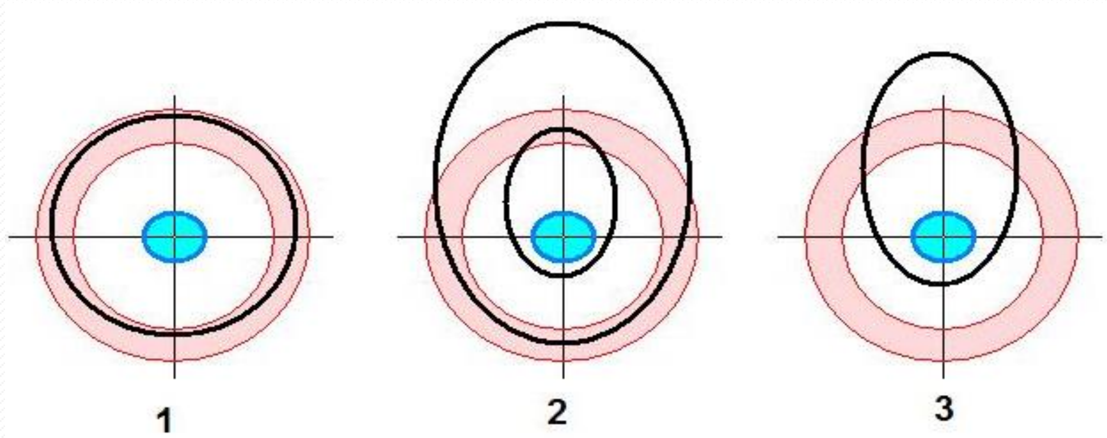






Orbits Crossing GNSS Operational Region

H_{min} [km]	H_{max} [km]
19000	23500



Month.Year	Type	1	2	3	Total
09.2016	Crossing the region	279	134	1240	1653
	Average	279	41	141	461

Estimated collision probability in GNSS operational region is of 3×10^{-7}

GNSS Constellations

Constellation	Number of sats	Altitude [km]	Period [hour, min]	Inclination [degrees]
GLONASS	24(3 pl×8)	19100	11h15m	64.8
GPS	30(6 pl×5)	20200	11h58m	54.7
Beidou	27(3 pl×9)	21215	12h40m	56
Galileo	27(3 pl×9)	23616	14h22m	56

Prediction for the Number of Space Objects in GNSS Operational Region

Constellation	Before 2020 [num/Year]	2020-2050 [num/Year]	2020 [num]	2050 [num]
GLONASS	8…9	2…3	300	370
GPS	1	1	72	100
Galileo	3…6	1…2	40	70
Beidou	3…4	1…	27	60
Total			440	600

Evaluation is made for the evolutionary development of GNSS constellations (constellations' architecture, satellite lifetime)

There is a slight increase in the risk of collision in the near future

Long-term Orbital Evolution

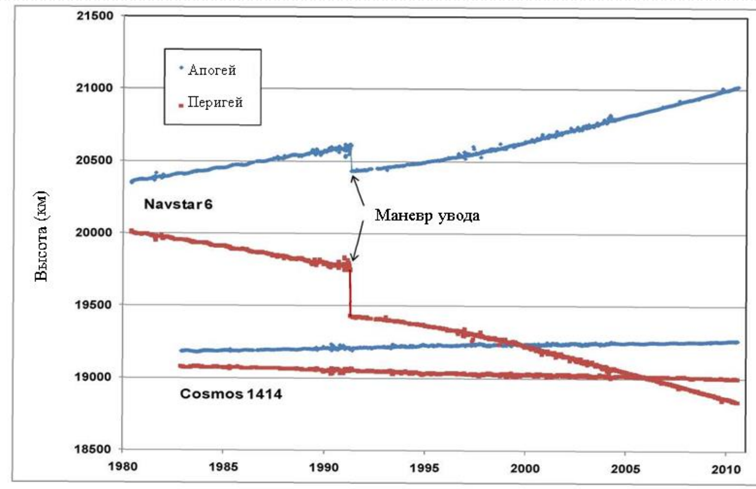
- the biggest problem is the gradual change of orbit eccentricity, which can lead to the intersection of the altitudes of orbits of operational GNSSs.

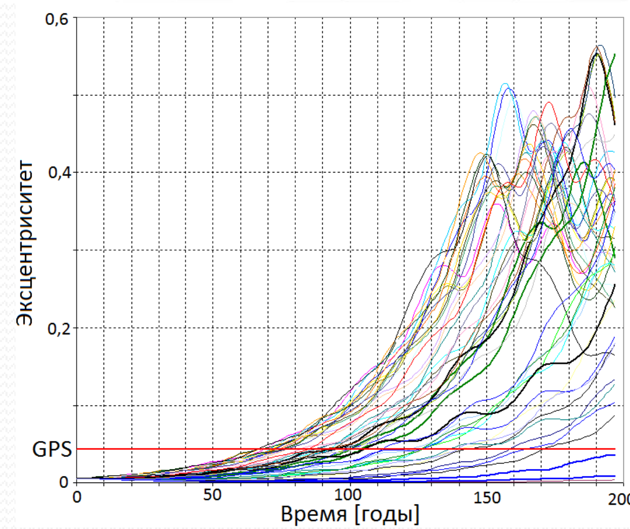
The intersection of GLONASS Sats with orbits of:

GPS – after 40…100 years

Galileo - after 150…200 years

- two critical areas with i1 ~ 56° and i2 ~ 63°, where eccentricity growth has resonance character
- there are inclinations (51-52°, 58.5-60.5°), where eccentricity growth rate is significantly lower
- for Galileo and GPS for several combinations of orbital parameters eccentricity growth can result in satellite re-entry in 500 and more years
- the smaller the initial eccentricity is, the less the degree of its evolution. We can choose the initial orbit parameters in which the evolution is minimum and lies in a bounded region for centuries






Space Debris Mitigation Measures in GNSS Operational Region

Mitigation measures

- Re-orbiting to graveyard orbits
- Monitoring, prevention of dangerous situations
- Prevention of space debris formation

Three ways of reducing space debris (SD) in GNSS operational region:

Technical - defined by the technical characteristics of a SV during its operation, and technical mitigation measures prior to decommissioning of a SV from the system;

Orbital - related to the choice of orbits at the terminal phase of a SV life ("disposal orbits");

Informational - monitoring near-earth space with radio, laser, optical and other means (for possible correction of the orbital parameters of an operational SV , in case of danger).

Mitigation Measures for GLONASS Satellites

1. Minimizing post-mission break-up potential resulting from stored energy:

- GLONASS SVs have rotation wheels, batteries, propulsion system, etc.
- Upon termination of a SV operation in the absence of control from the ground rotation wheels quickly stop due to the internal deceleration
- Upon termination of a SV operation its batteries are discharged and locked
- Residual hydrazine in a SV propulsion system is a source of danger of tank explosion. The most acceptable solution is disposal of a SV with parallel depletion burn

2. Limitation of debris released during nominal operation. Avoidance of intentional break-ups and other dangerous actions:

Separation systems of future generations Glonass SVs, mechanisms used for deploying SV's elements, etc. are designed not to release any elements into near-earth space

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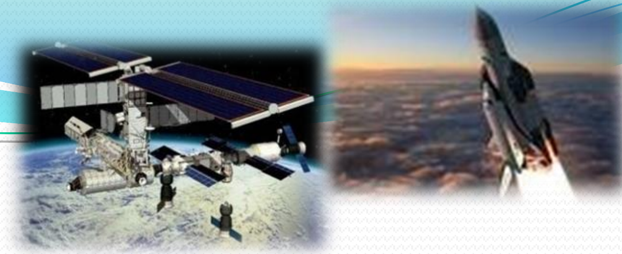
Mitigation Measures for GLONASS Satellites

Next generation Glonass-K satellites after 2020 will be moved into disposal orbit **120 km lower** with the eccentricity of **0.001**. The Delta-V cost for this maneuver is **10 to 15** m/s.

This measure prevents disposed Glonass-K satellites from entering areas where other GNSS satellites operate for 70…100 years provided the optimal choice of perigee and ascending node of disposal orbit

Estimation demonstrates this measure will lead to 2.2×10^{-7} collision probability (as compared to current 3×10^{-7})

Next generation Glonass-K satellites are being designed to meet the requirements of the GOST R 52925-2008 standard which complies with the UN COPUOS Space Debris Mitigation Guidelines and IADC Space Debris Mitigation Guidelines



Mitigation Measures for Upper Stages

Minimizing the potential for on-orbit break-up resulting from stored energy and transfer to safety orbit

- DM upper stage performs braking due to the discharge of pressurizing gas and residual propellant through a special nozzle
- Breez-M upper stage performs depletion burns while transferring from the GLONASS operational orbit
- Since 2011 Fregat upper stage is transferred into the orbit of ~ **25800 to 25880 km** and eccentricity of ~ **0.005 to 0.01**
- Fregat-MT upper stage is transferred into the orbit of **~ 400 km** above the nominal height of GLONASS orbit

Orbital parameters for next generation Glonass-K upper stages

Upper stage	Apogee [km]	Perigee [km]	Eccentricity	α (SMA)
Breez-M	19136	16896	0.046	24387
Fregat	19643	19298	0.0067	25841

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International Organizations involved in Development of Space Debris Mitigation Measures and Space Debris Studies

- ***COPUOS***

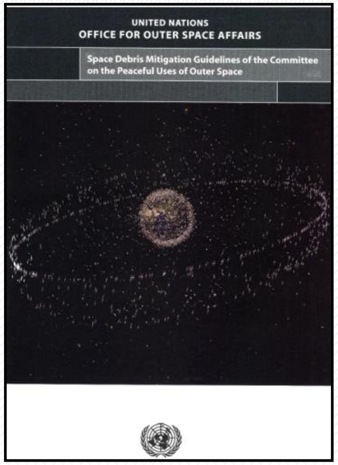
UN Space Debris Mitigation Guidelines

- ***IADC***

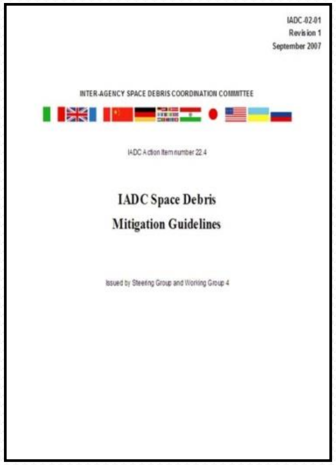
IADC Space Debris Mitigation Guidelines

- ***ISO***

ISO 24113



UNITED NATIONS
OFFICE FOR OUTER SPACE AFFAIRS
Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space



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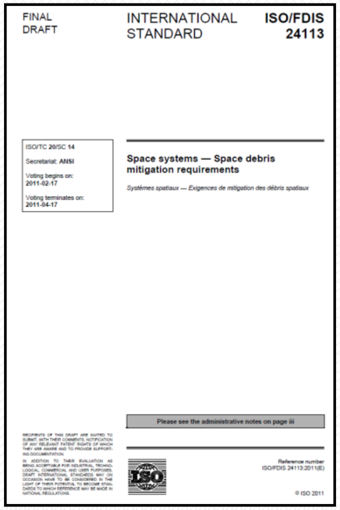
INTER-AGENCY SPACE DEBRIS COORDINATION COMMITTEE

IADC Action Item number 22.4

IADC Space Debris Mitigation Guidelines

Issued by Steering Group and Working Group 4



FINAL DRAFT
INTERNATIONAL STANDARD
ISO/FDIS 24113

ISO/TC 20/SC 14
Secretariat: ANSI
Voting begins on: 2011-02-17
Voting terminates on: 2011-04-17

Space systems — Space debris mitigation requirements

Systèmes spatiaux — Exigences de mitigation des débris spatiaux

Please see the administrative notes on page iii

Reference number ISO/FDIS 24113:2011(E)

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Conclusions

- GNSS operational region is different from the protected LEO and GEO regions in volume of space objects and collision risk probability
- Next gen GLONASS being developed in compliance with space debris mitigation measures of the GOST R 52925-2008, UN COPUOS Space Debris Mitigation Guidelines IADC Space Debris Mitigation Guidelines
- Analysis of the current and future GNSS operational region environment shows the region is unlikely to become the protected region next 100 years


Conclusion

- Space Debris is widely discussed in many international fora (STSC UN COPUOS, IADC and ISO)
- Discussion of space debris issue in GNSS operational region is in the scope of: UN, IADC, ISO
- Space debris in GNSS operational orbits is not viewed as having such a high relevance as compared to LEO and GEO

Providers are recommended to form links with their experts working in these organizations and keep an eye and stay aware of issues being discussed related to MEO

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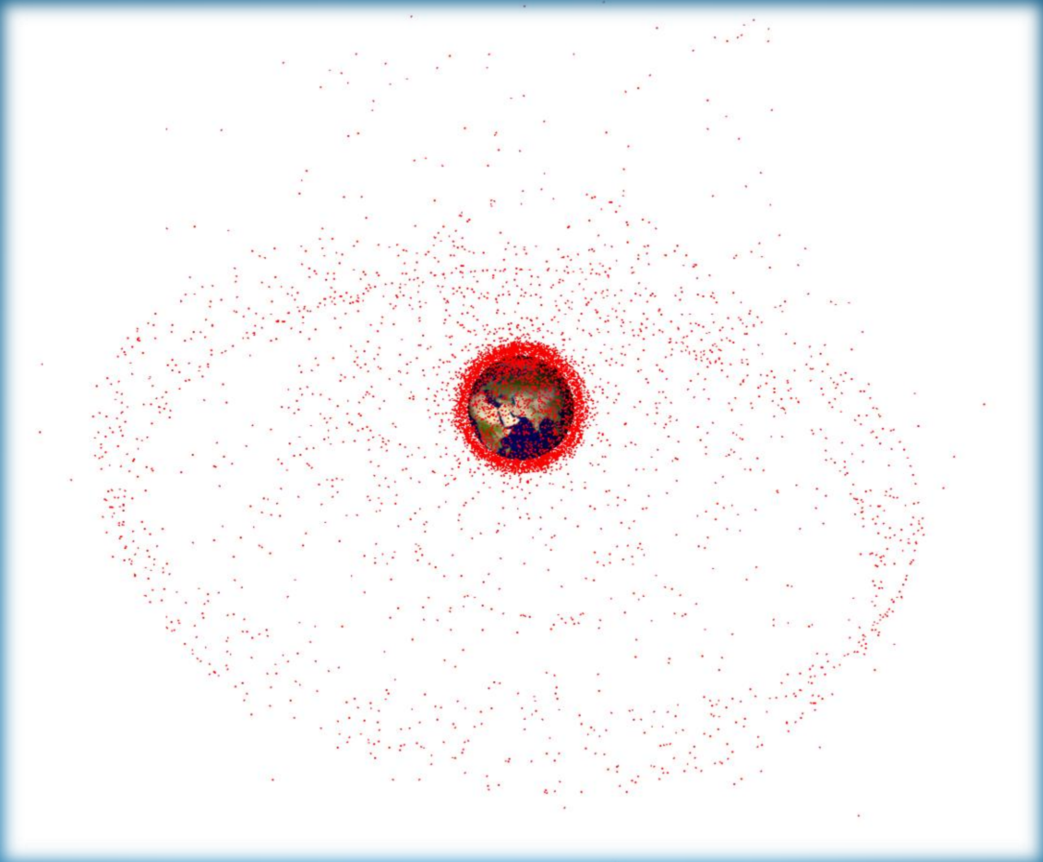

Thanks for your attention!