A05

Space Debris Related Activities in Russia

○Vladimir Agapov (Astronomical Scientific Center)

Astronomical Scientific Center (ASC), JSC since 2010 has being developing and operating optical observation network around the globe, including the dedicated network of telescopes for ROSCOSMOS. More than 40 telescopes collect daily about 180-210 thousand of measurements for more than 9000 space objects in GEO, MEO and HEO. ASC analyze those data to identify new objects and maintain the orbits of existing objects for ROSCOSMOS. The network is capable to detect and track objects as faint as 18.5-19th magnitude at GEO distance. It had quickly identified the debris clouds created in three fragmentation of Atlas 5 Centaur R/B in GTO in Aug 2018, Mar and Apr 2019 (see Figure 1). Quality of measurements permits to maintain GEO, HEO and MEO orbits for larger space objects at the accuracy level better than 200-300 m in normal mode and ca. 50-60 m in the special mode. The detail of the network, its outcomes and other space debris related activities in Russia will be discussed in this talk.

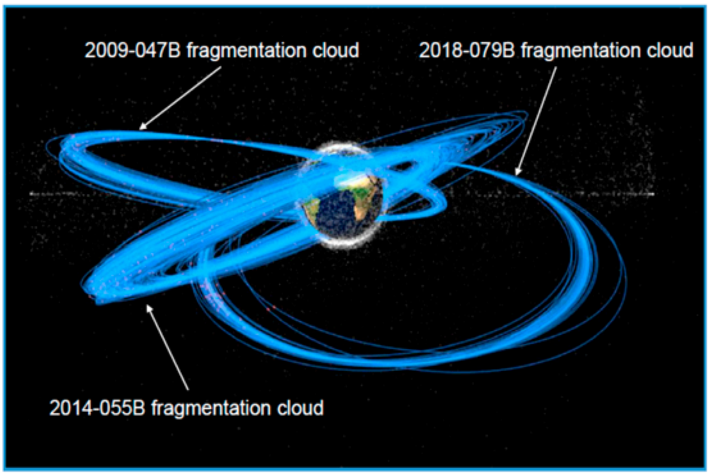


Figure 1. Three debris clouds identified by the Roscosmos optical observation network.

Biography

Vladimir Agapov

Vladimir Agapov is the Senior Research Fellow of Keldysh Institute of Applied Mathematics, Russian Academy of Sciences and Designer General of the Astronomical Scientific Center, JSC. For many years he was working as a leading expert of the Russian delegation on space debris, LTSSA, STM and SSA in COPUOS and other international fora. His research interests are space flight mechanics, SSA, STM and international space law. He is the author of over 150 scientific papers. He is also the member of the Working Group 1 (space debris observation) of the Inter-Agency Space Debris Coordination Committee (IADC)

Space Debris Related Activities in Russia

Vladimir Agapov

Astronomical Scientific Center, JSC

agapov@ancprotek.ru

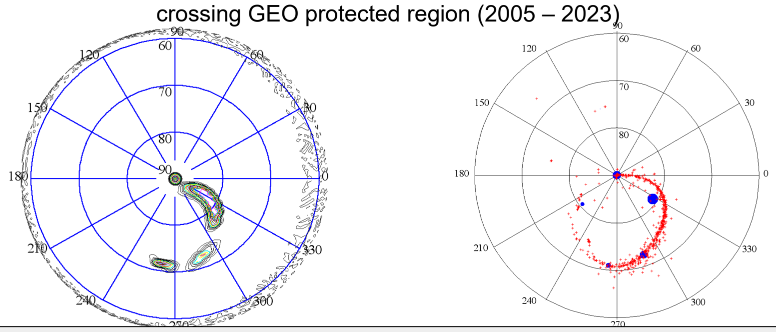
9th Space Debris Workshop
JAXA, 24 Feb 2021

Major Space Debris Related Activities in Russia

- Regulatory and organizational
- **Space debris modeling**
- **Optical and radar observations**
- Protection and mitigation
- Situational awareness
- Space operations support, including conjunction assessment
- Space debris removal

Model of space debris distribution and evolution (research conducting jointly by KIAM and TsNIIMash)

Evolution of direction of normal to orbital planes for space objects residing in or crossing GEO protected region (2005 – 2023)



Statistical approach to description the space debris spatial distribution

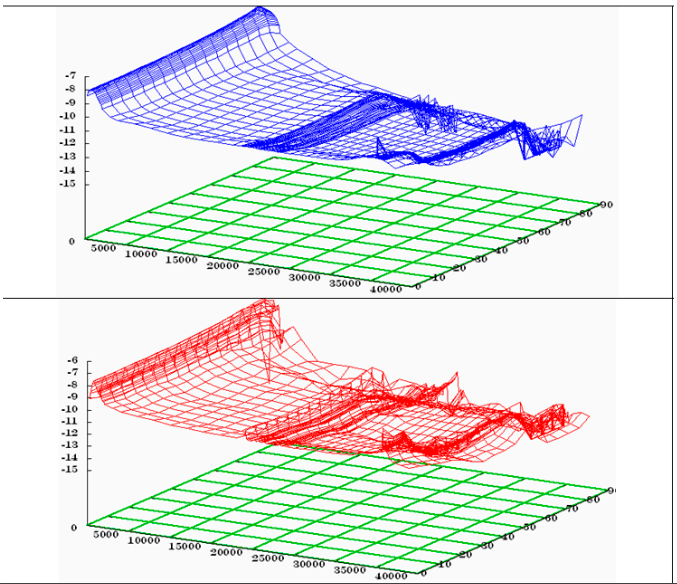
Distribution of valuable parameters represented as normal distributions mixture

$$f(a, e, i, \Omega, \omega, M) \to f(\boldsymbol{r} \times \boldsymbol{v}, a) \to \sum N(q_i, C_i)$$

Advantages of the approach:

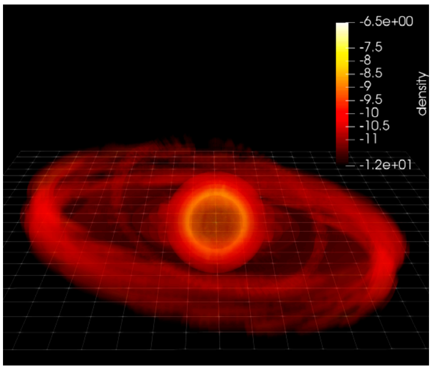
- information on distribution by latitude is preserved (*essential for objects in high orbits*)
- compact description of objects grouping in selected phase space (*independent calculation of flux for each group – components of the mixture*)
- a universal tool for approximating complex distributions of the orbital parameters of space objects

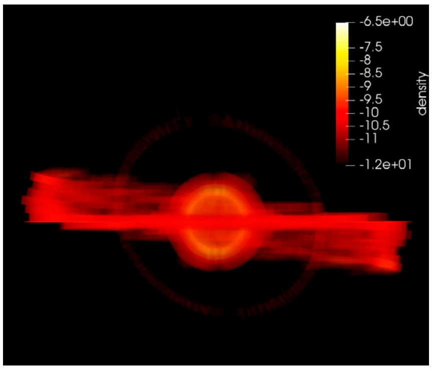
Model of space debris distribution and evolution (research conducting jointly by KIAM and TsNIIMash)



Comparison of distributions provided by the improved model (top) and calculated based on information taken from orbital catalogue (bottom)

Model of space debris distribution and evolution (research conducting jointly by KIAM and TsNIIMash)





Sum of spatial densities of distribution of space objects for each group describes the complete distribution of all space objects

Resulting distribution highly depends of latitude and longitude for objects in high orbits (*due to uneven distribution by Ω, unlike LEO*)

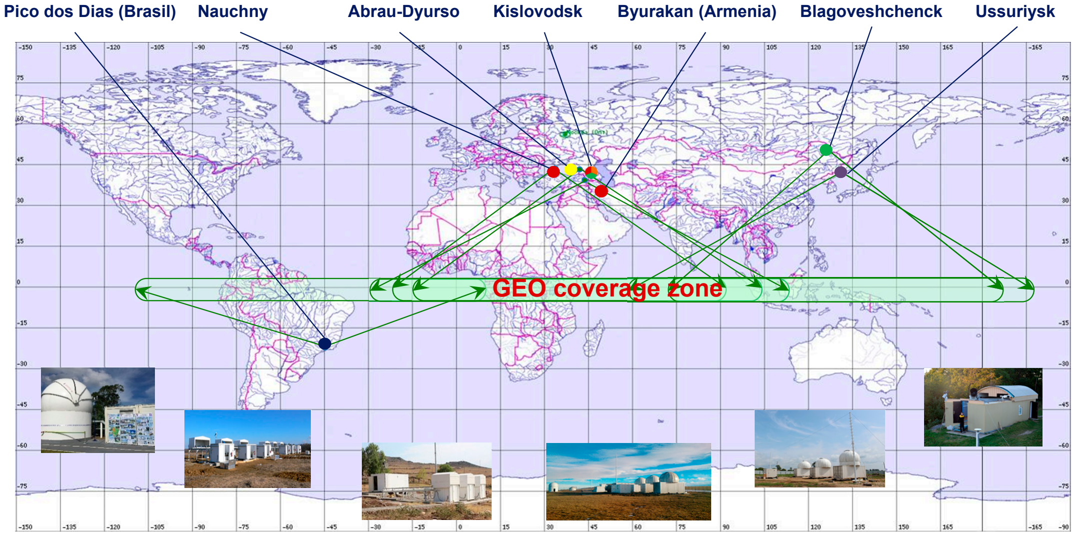
5

Russian Civilian Observation Networks and Facilities

- Automated Warning System on Hazardous Situations in Outer Space (ASPOS OKP) with a network of dedicated optical observation facilities — operated by ASC for ROSCOSMOS
- Network of optical observation facilities owned and operated by Astronomical Scientific Center (ASC)
- Dedicated optical observation facilities operated by various organizations in partnership with KIAM RAS (ISON)
- Observation facilities operated by other scientific institutes (CrAO, INASAN – optical, ISTP RAS – optical and radar) and universities (MSU, KFU – optical) supervised by the Ministry of High Education and Science
- Optical observation facilities operated by industry organizations (Vympel JSC, NPK SPP)

6

Operational network of optical facilities of ASPOS OKP (ROSCOSMOS)



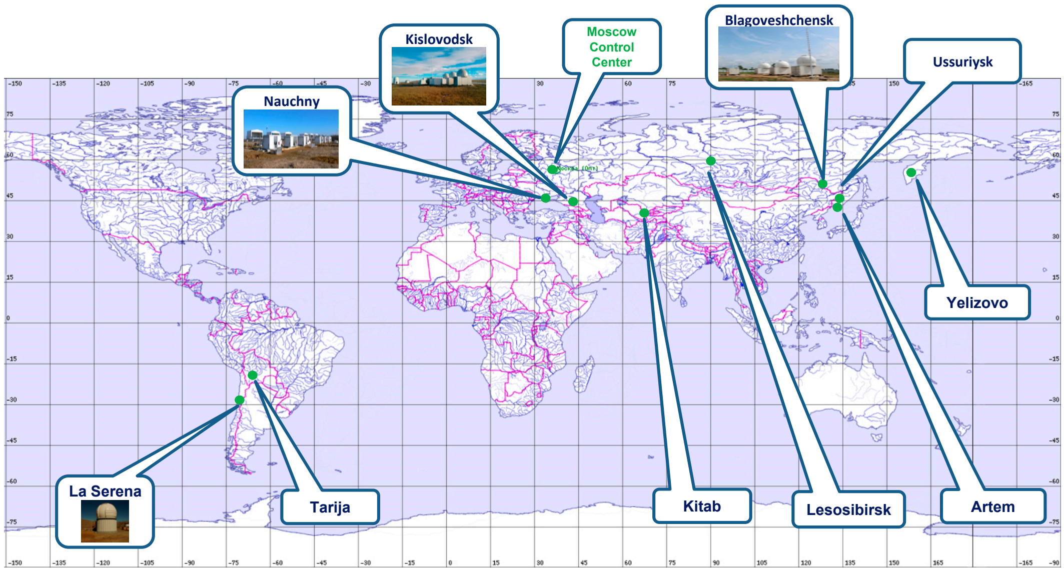
EOP-1 (4 facilities)
Each facility includes
2 telescopes with 19 cm aperture
1 telescope with 25 cm aperture
1 telescope with 40 cm aperture

EOP-2 (2 facilities)
Each facility includes
4 telescopes with 19 cm aperture
1 telescope with 40 cm aperture
1 telescope with 65 cm aperture

OES-50
OES-65
RKS-25
OEK OKM

Total: 22 instruments

ASC Optical Network



Current Catalogue of Tracked Objects in High Orbits

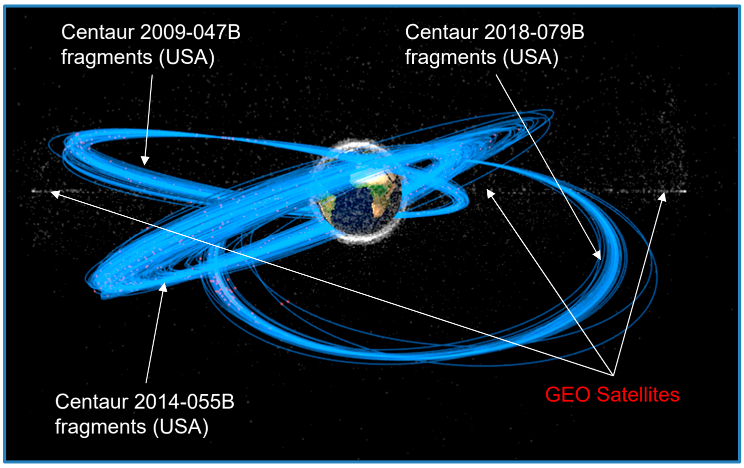
As of Feb 23, 2021

Orbit type	Definition	Number of tracked objects
GEO	1100 <= T <= 2000 min e <= 0.25 i <= 25°	2791
MEO	600 <= T < 1100 min e <= 0.25	433
HEO	Ha >= 3500 km e > 0.25	5373
Other	Not included into the groups above	408
TOTAL		9005

925 new space debris objects in various high orbits were detected in 2020 by Russian civilian optical facilities
Yet more ca. 3000 previously detected and tracked objects in high orbits are considered lost for a while

9

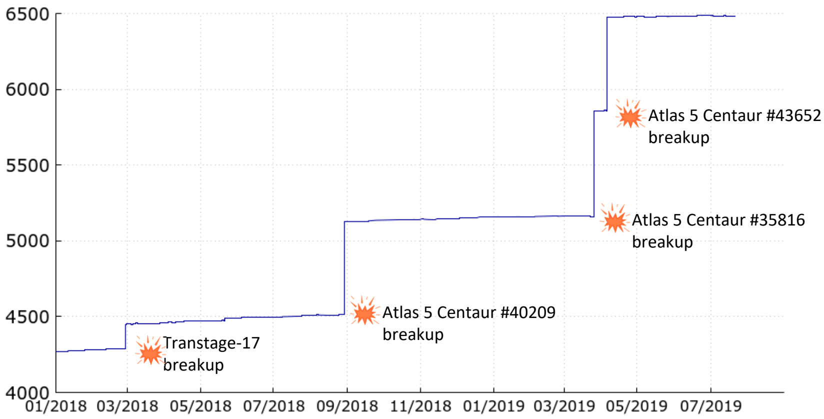
Objects Population Grow in High Orbits. Three Fragmentation Events of 2018-2019 with the Largest Number of Long-Lived Trackable Space Debris Objects Created



10

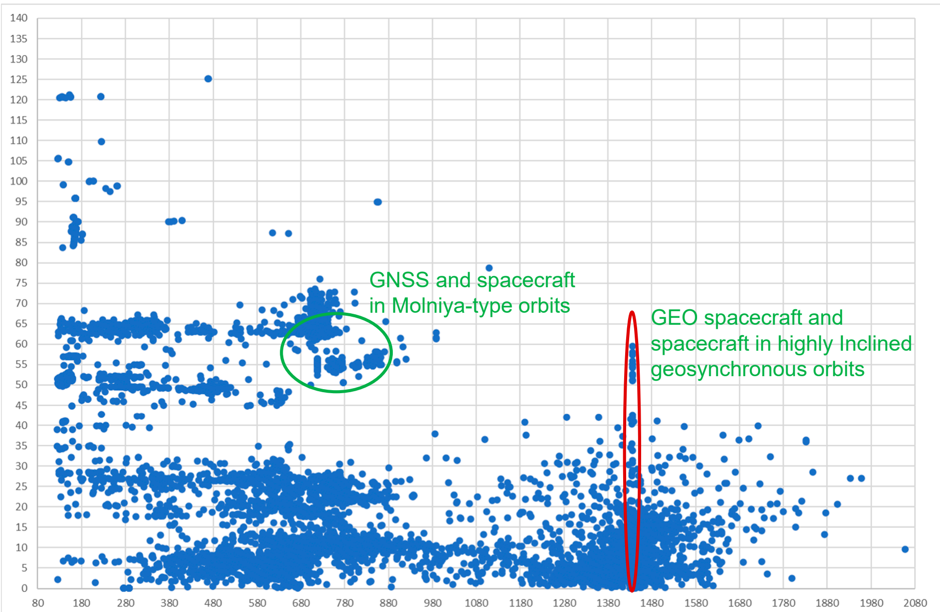
Objects Population Grow in High Orbits

More and more space debris in HEO and GEO



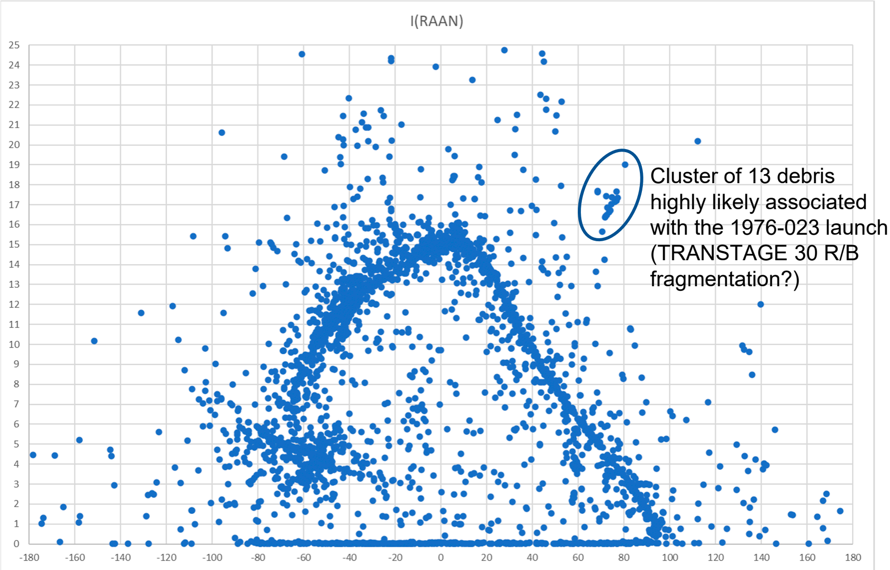
Up to date more than 2100 new fragments of these fragmentations are discovered

Current Distribution of Objects in High Orbits Tracked by Russian Civilian Optical Facilities



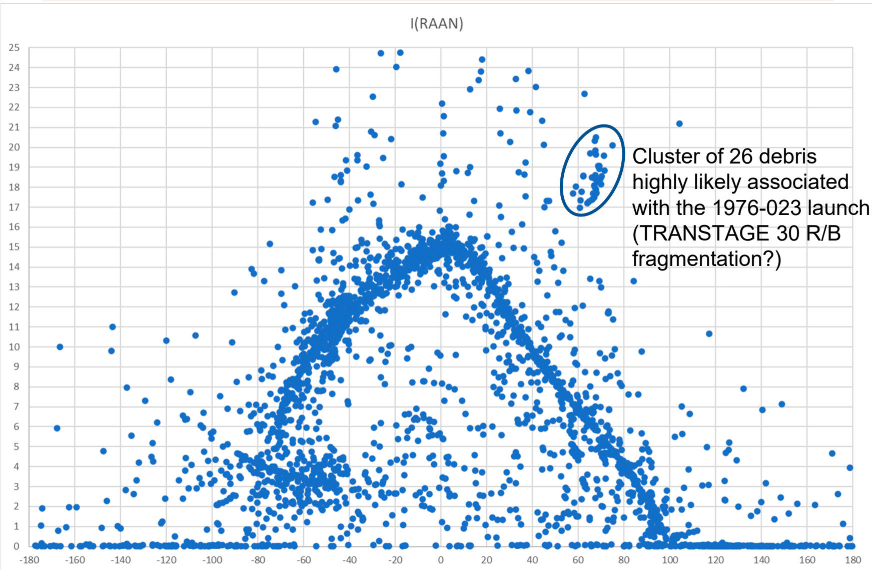
Inclination vs. Period

Distribution of Objects in GEO Region (29.11.2019)



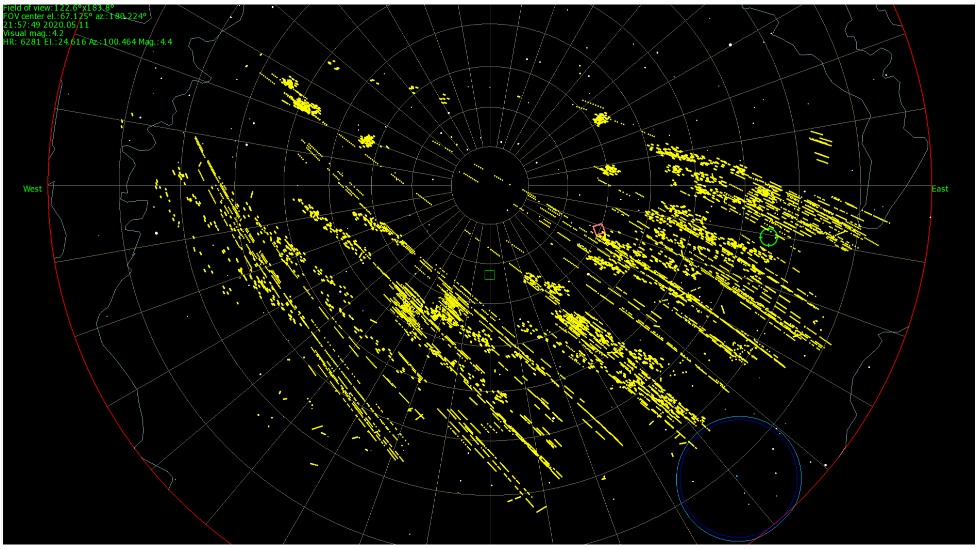
13

Distribution of Objects in GEO Region (23.02.2021)



14

Improved Performance of Telescopes for Observation of Objects in LEO

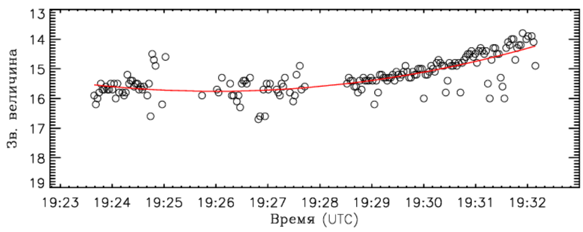


Test observations on May 8, 2020 in the “optical fence” mode.
Debris of Fregat R/B fragmentation (range: 1000…3600 km, estimated size of the smallest observed objects: 5-7 cm)

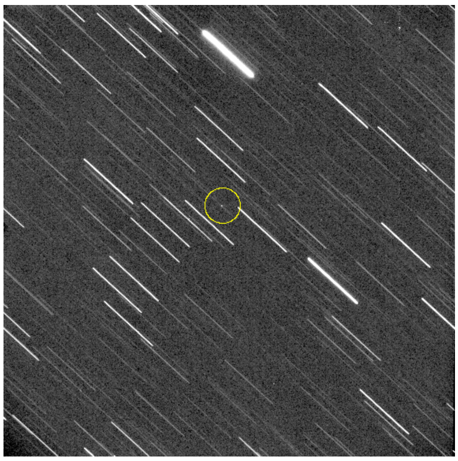
Observations of Small Objects in LEO

Object: SSN 12329 (KYOKKO 1 DEB)
RSC: < 0.0095 m^2

Phase angle: 76.0 – 124.4 deg
Range: 2258 – 4070 km

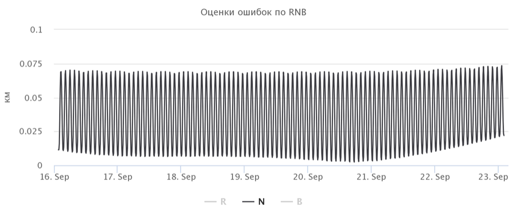


Light curve

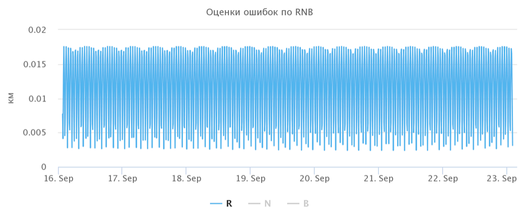


Measured position precision:
1.80 arcsec (1σ)

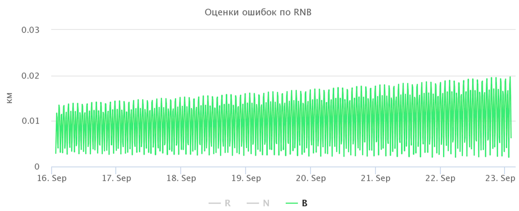
Achieved Precision of OD for LEO Object Using Optical Measurements Only



Along-track (3-75 m)



Radial (3-17 m)



Cross-track (3-20 m)

Object: SSN 12138, 394x1448 km, 84°

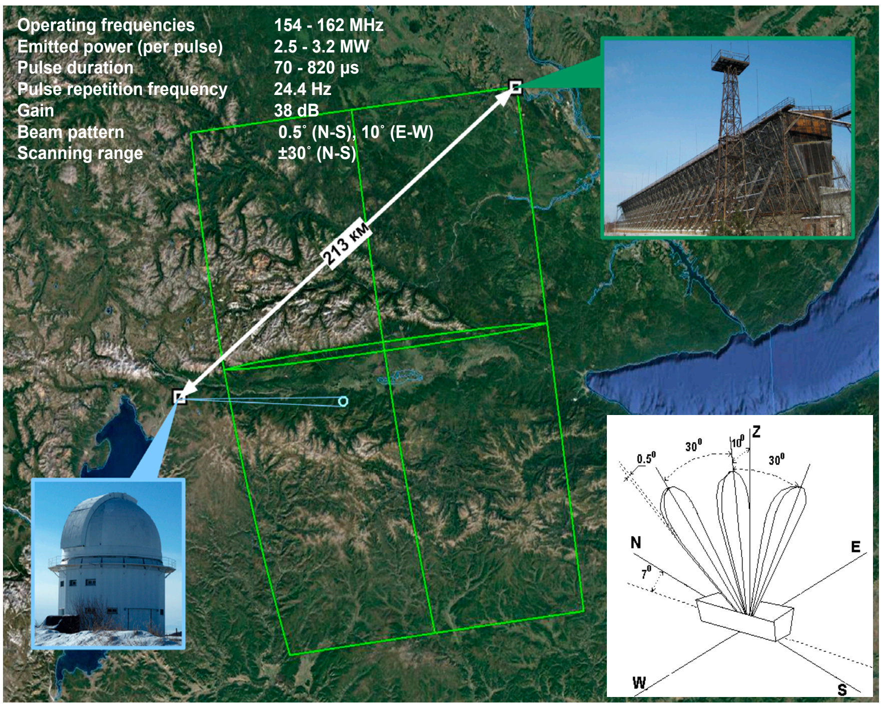
OD fit interval: 7 days

Achieved OD precision: 5-75 m

Raw measurements precision: 0.2-0.3 arcsec (1σ)

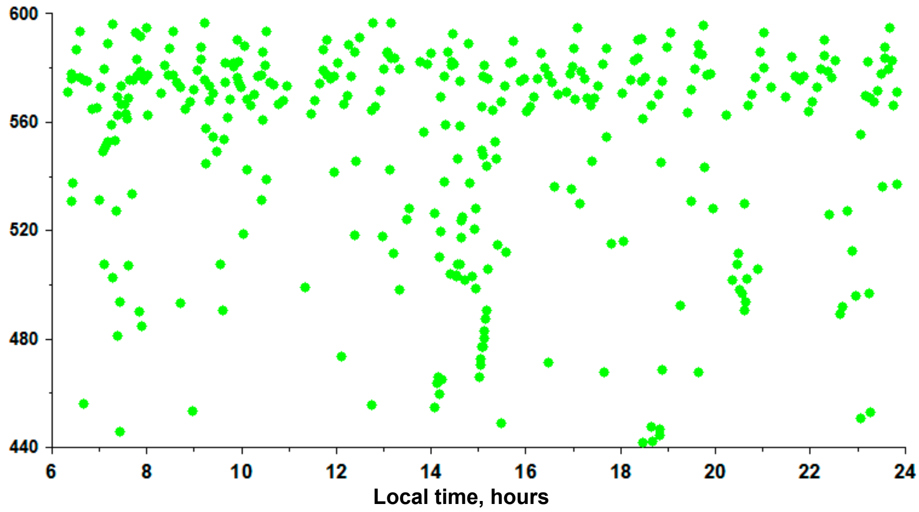
17

Radar and Optical Facilities by ISTP RAS



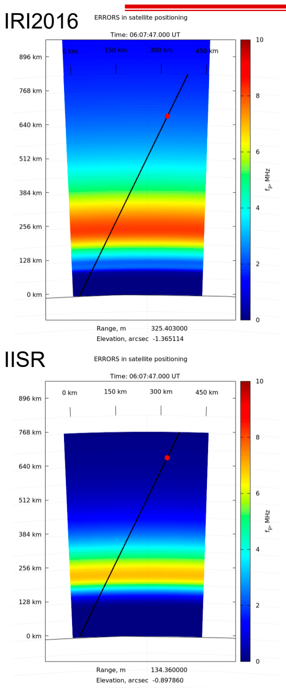
18

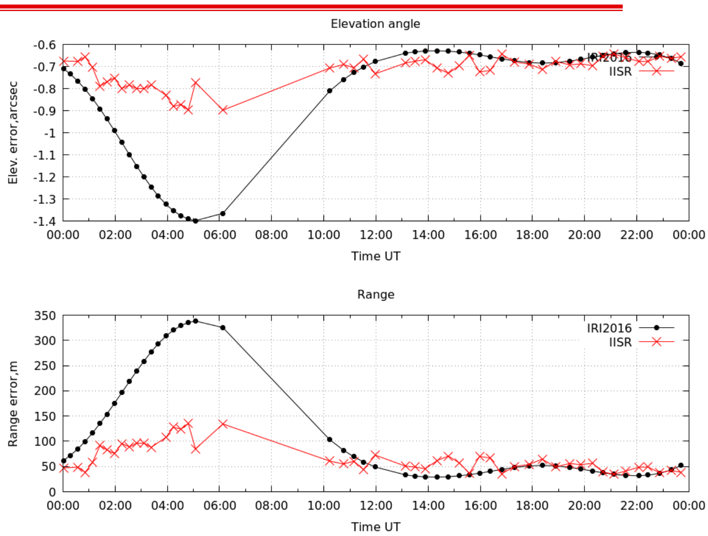
Radar Test Observations on Nov 10,2020



Scanning heights range: 440 – 600 km
Duration of survey: 18 hours
Number of registered tracks: 342

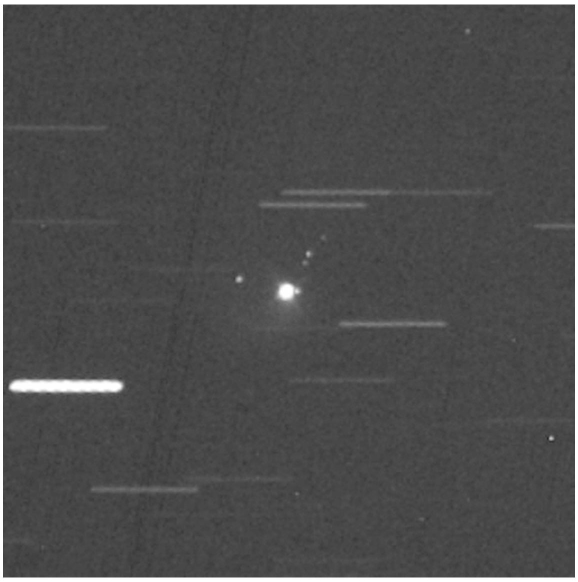
Improved Ionospheric Propagation Error Model





Comparison of IRI2016 and IISR models
Assessment of range and elevation errors during 24 hours for height 670 km [frq 159.8 MHz]

Minor breakup example



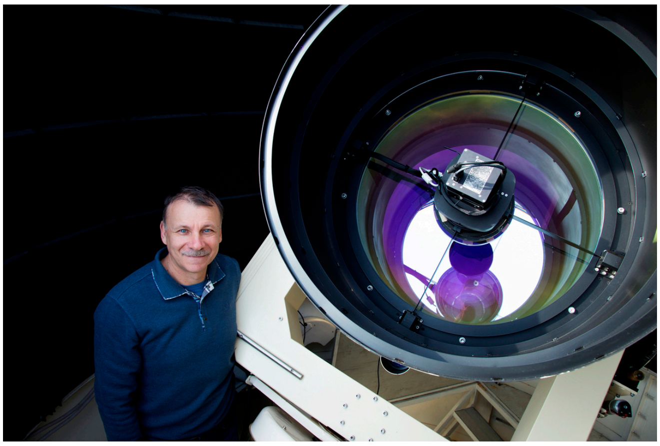
Apr 8 2019 – Intelsat 29E in GEO

Non Space Debris Related Matters

First known for humanity interstellar comet 2I/Borisov was discovered in August 2019 with a 65 cm telescope by a scientist, Gennady Borisov, working for ASC.

He develops modern optical instruments for ASC and supports different observation programs.

Nine comets and several near-Earth asteroids – current score of Gennady's achievements using his own telescope which was built using the same technologies we are using in ASC.



Thank you for your attention!