EXPANDING KNOWLEDGE ON REAL SITUATION AT HIGH NEAR-EARTH ORBITS

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ABSTRACT

Vital role of geostationary and other high near-Earth orbits for various space applications is undoubted. Therefore, the issue of safety of space operations in congested areas of near-Earth space like GEO is getting more and more important in view of continuously increasing number of operational satellites at those orbits. The key problem that remained not yet completely resolved is timely availability of reliable information on objects and events (including anticipated ones) in protected GEO region and at MEO orbits used by GNSS. This information should be complete and accurate enough to assist in decision making while planning operations including avoidance manoeuvres. To address properly risks for spacecraft and launch vehicles involved into operations in outer space the State Space Corporation "Roskosmos" have developed and put into operation the Automated Warning System on Hazardous Situations in Outer Space (ASPOS OKP). The system is aimed at collection, processing, analysis, systematization and cataloguing information on objects and events in outer space in order to identify and characterize risks and hazards caused by orbital objects and provide timely information to spacecraft control centres and the management of Roscosmos. Significant amount of optical measurements is gathering every day by the network of dedicated ground telescopes developed for ASPOS OKP. It makes possible to assess virtually any changes of situation caused by new launches, fragmentations, manoeuvres etc. for significant part of the entire GEO belt, as well as to improve significantly our knowledge on objects and events at HEO and MEO orbits.

1 INTRODUCTION

The Automated Warning System on Hazardous Situations in Outer Space have developed within the framework of the Federal Space Program of the Russian Federation under the contracts with Roscosmos.

It represents the system dedicated to solving following key tasks:

- detection and characterization of potentially hazardous objects and events in outer space that may compromise safety of operations of spacecraft under control of Roscosmos (Elektro-L, Luch-5, Meteor-3 and others), Russian Satellite Communication Company and non-governmental Russian satellite operators or may pose a threat to human life and/or property on the ground,
- monitoring operations on re-orbiting of Russian spacecraft and launch vehicle upper stages into disposal orbits, including GEO graveyard orbit and orbits with limited decay time;
- assessment the situation in outer space, including new launches, conjunctions and on-orbit fragmentations;
- verification of compliance of operations in outer space with space debris mitigation guidelines,
- provision of support to the Russian launch service providers while preparing and launching objects at high near-Earth orbits.
- provision information on current situation, objects and events in outer space to spacecraft control centers, Roscosmos and other customers.

The system operates in 24/7/365 mode.

<u>ASPOS OKP key structural units</u>

The system includes following key structural units:

- Main information and analytical centre located at the Mission Control Centre (MCC), Korolyov, Moscow region,
- Detachment at the Keldysh Institute of Applied Mathematics (KIAM) of the Russian Academy of Sciences (responsible for monitoring hazardous situations at high near-Earth orbits), Moscow,
- Detachment at the Pushkov Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation (IZMIRAN) of the Russian Academy of Sciences (responsible for space weather monitoring and forecasts), Troitsk, Moscow region,

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- the network of dedicated optical observation facilities operated by Astronomical Scientific Center JSC.

ASPOS OKP put into regular operations on Jan 1, 2016.

2 OPERATIONAL NETWORK OF DEDICATED OPTICAL OBSERVATION FACILITIES OF ASPOS OKP

The network includes six observation facilities with 21 optical instruments in total:

- Kislovodsk (7 instruments),
- Ussuriysk (1 instrument),
- Byurakan (3 instruments),
- Abrau-Dyurso (1 instrument),
- Blagoveshchensk (3 instruments),
- Nauchny (6 instruments).

Each instrument consists of 1 to 4 telescopes. All but 3 instruments are grouped into mini-facilities of two types:

- Type 1, so called EOP-1, which includes a set of 2 telescopes with aperture 19 cm on a single mount, one telescope with aperture 25 cm and one telescope with aperture 40 cm (Fig. 1),
- Type 2, so called EOP-2, which includes a set of 4 telescopes with aperture 19 cm on a single mount, one telescope with aperture 40 cm and one telescope with aperture 65 cm (Fig. 2).

Figure 1. Type 1 optical observation mini-facility of the ASPOS OKP system.

Figure 2. Type 2 optical observation mini-facility of the ASPOS OKP system.

Major characteristics of instruments are provided in [1].

Location of facilities is shown at Fig. 3.

Figure 3. Location of observation facilities of the ASPOS OKP system.

3 RESULTS OF HIGH ORBITS MONITORING IN 2016

Optical facilities of ASPOS OKP have collected more than 8 million of measurements in 2016 for more than 3400 space objects at high orbits (GEO, MEO, HEO). Instruments of the network have discovered 530 new and re-discovered more than 410 lost GEO and HEO space debris objects during 2016.

Number of observation nights during 2016 for ASPOS OKP optical observation facilities varies between 134 and 257.

Total 3420 high orbit objects have been observed by ASPOS OKP dedicated instruments in 2016. Fig.4 shows the number of observed objects by each facility.

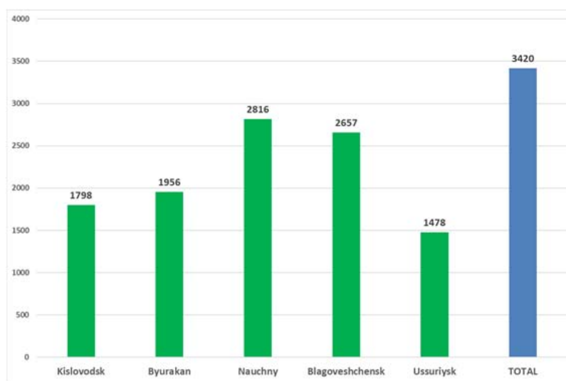

Figure 4. Number of high orbit objects observed by individual ASPOS OKP optical facilities in 2016.

Discovery of new objects and rediscovery of the lost ones is conducting in cooperation between ASPOS OKP and ISON. Thanks to their high automation level optical instruments of ASPOS OKP provides for more than 90% of discoveries of new objects in 2016. Fig. 5 provides information on the cumulative number of GEO and HEO objects discovered (rediscovered) by ASPOS OKP and ISON during the last 7 years.

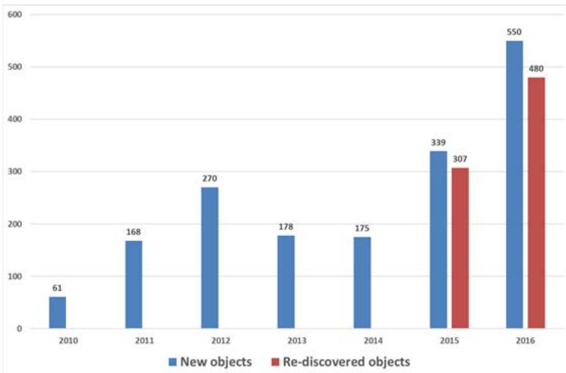

Figure 5. Cumulative GEO and HEO objects discovery statistics (ASPOS OKP and ISON).

As of the end of 2016, 76% of nearly 2300 debris objects discovered by ISON and ASPOS OKP sensors have epoch at the last orbit determination (OD) later than Jan 1, 2016. This is significant improvement over the results achieved by the end of 2015 when there was just 57% of objects having epoch of the latest OD in 2015. ASPOS OKP sensors have provided key input into the maintenance of orbits for increased number of objects. Distribution of OD epochs is shown at Fig. 6.

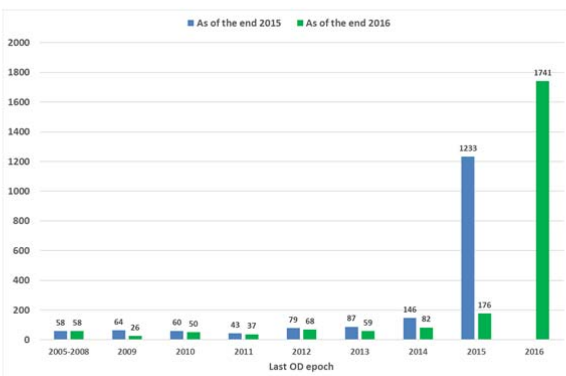

Figure 6. Distribution of the last OD epoch for GEO and HEO space debris objects.

Thanks to significantly increased number of measurements it became possible to maintain accurate orbits for much more objects having high area-to-mass ratio. Distributions of AMR values, as of Jan 1, 2017, are shown at Fig. 7 and Fig. 8 for objects at GEO and HEO orbits respectively. Only objects having AMR>0.5 sq.m/kg and the latest OD epoch in 2016 are considered.

It should be noted that for the first time regular maintenance of orbital parameters in ASPOS OKP database was established for HEO objects having AMR value higher than 30 sq.m/kg. At present the largest AMR value among all tracking objects has a debris at HEO with inclination 53 deg and orbital period 595 min (as of Jan 1, 2017). AMR value for this object is equal to 68 sq.m/kg.

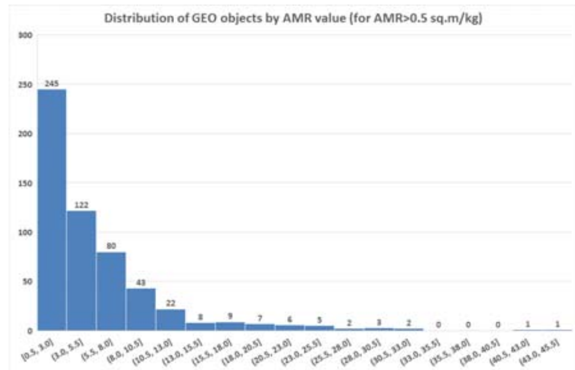

Figure 7. Distribution of GEO objects by AMR value.

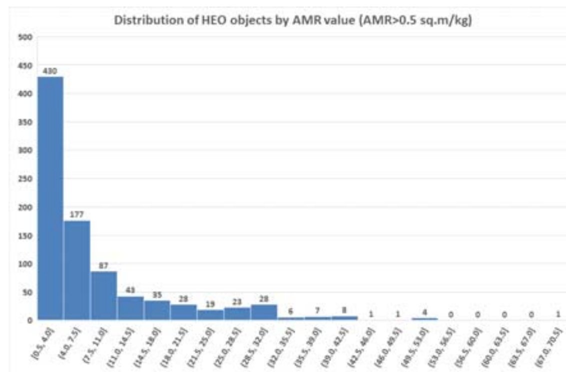

Figure 8. Distribution of HEO objects by AMR value.

Comparison of distribution of GEO objects tracked by ASPOS OKP by inclination and RAAN as of Jan 1, 2017 and Jan 1, 2016 reveals increased number of objects supposedly belonging to clusters of debris related to fragmentations which are not considered yet by space debris community as ‘confirmed’ ones (Fig. 9).

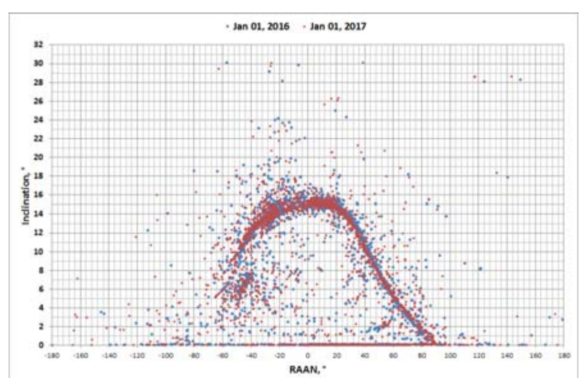

Figure 9. Distribution of GEO objects: comparison for 01 Jan 2016 and 01 Jan 2017.

Clustering of objects is getting obvious if to plot the same diagram leaving only objects having AMR<0.5 sq.m/kg (Fig. 10).

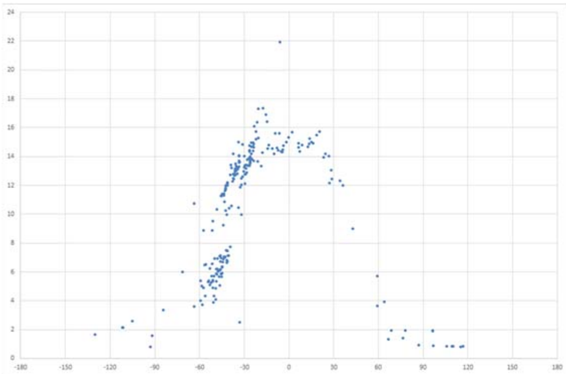

Figure 10. Distribution of GEO fragments having AMR<0.5 sq.m/kg

Comparison of distribution of HEO and MEO objects tracked by ASPOS OKP by period and inclination as of Jan 1, 2017 and Jan 1, 2016 also reveals increased number of objects supposedly belonging to fragmentation-related clusters of debris (Fig. 11).

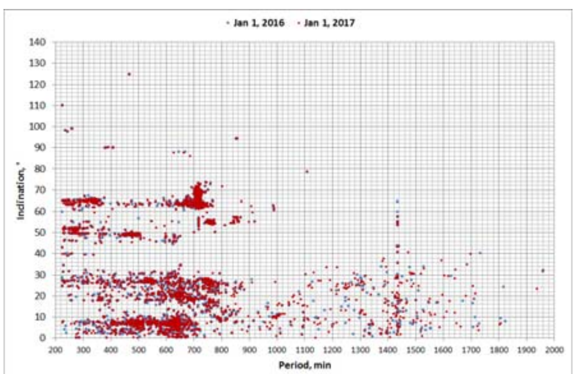

Figure 11. Distribution of HEO and MEO objects: comparison for 01 Jan 2016 and 01 Jan 2017

One of fragmentations have occurred in GEO in January 2016. Breeze-M upper stage (2015-075B), launched on 13 Dec 2015, have suddenly exploded. ASPOS OKP optical facilities have detected and tracked fragmentation debris. ISON telescopes have provided additional follow-up measurements. As a result, following estimations of the fragmentation parameters were obtained:

time – 16.01.2016 03:50:05 UTC

latitude – 0.178° S

longitude – 136.976° W

height – 34928 km

relative velocities of discovered fragments – 19.8-32.0 m/s

Approximate size of fragments is estimated based on brightness measurements analysis and simplified assumptions on the shape and reflectivity of observed debris. Estimated diameter of equivalent specular spheres is varying between 0.23 and 0.56 m for different fragments associated with the Breeze-M explosion.

It is interesting that analysis of backward propagation of orbital motion of debris indicates possibility of more than one explosion (Fig. 12).

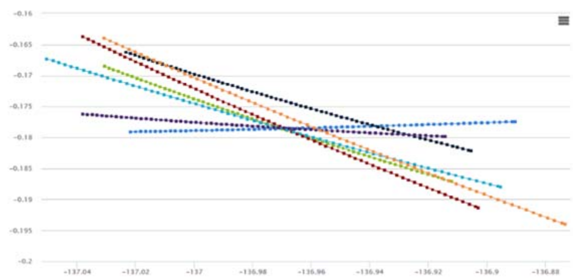

Figure 12. Trajectories of the Breeze-M explosion fragments propagated backward to the time of the event.

4 NEW OPTICAL OBSERVATION INSTRUMENT FOR ASPOS OKP

On Apr 5, 2017, an official ceremony took place on the opening the new optical facility built for ASPOS OKP and deployed in the observatory Pico dos Dias not far from Itajuba city in Brazil.

Figure 13. OEK OKM during the final phase of integration and testing.

The instrument, called OEK OKM (Fig. 13, 14), represents a valuable addition to the network of dedicated optical sensors of ASPOS OKP. This is the first monitoring facility built by Roscosmos in the Western hemisphere. It is expected that this instrument will provide significant input to LEO objects observations in addition to more traditional GEO and HEO regions monitoring.

Figure 14. OEK OKM – close view.

5 CONCLUSION

The Automated Warning System on Hazardous Situations in Outer Space (ASPOS OKP) is providing significant amount of optical measurements for objects at high near-Earth orbits. Sophisticated scheduling system and high level of automation make possible to increase significantly the rate of discovery of new and rediscovery of lost objects. Increased accuracy of orbit determination for various objects in GEO and HEO, including space debris and operational spacecraft, provides for ability to produce more reliable results of conjunction analysis, fragmentation events, manoeuvres etc.

Roscosmos continues to expand the network of dedicated instruments for ASPOS OKP system. The goal is to achieve the level of reliability of information provided to spacecraft operators that would decrease the number of notification on potentially threatening conjunctions to minimum thus making possible to avoid uncertain situations and unnecessary manoeuvres.

6 REFERENCES

Lapshin, A., Agapov, V. & Khutorovsky, Z. (2016). Autonomous detection and follow-up tracking of new objects at high near-Earth orbits. IAC 2016, Guadalajara, Mexico. IAC-16-A6.1.2.