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NEW SUBSYSTEM OF THE ISON OPTICAL NETWORK TO IMPROVE THE CONJUNCTION ANALYSIS

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In 2015 quantity of telescopes of 37 observatories that collaborate with ISON project in 17 countries is close to 100 units. These telescopes are combined in 4 main subsystems - for GEO survey, bright and faint objects follow up, and for asteroids (ASPIN). KIAM collected 10.7 million astrometry measurements during 2014 and 9.7 millions to the middle of September 2015. Since 2010, ISON is involving in operations of the Roscosmos Automated system of warning on dangerous situations in space (ASPOS OKP). In this system KIAM is responsible for the daily conjunction analysis at high orbits. To improve the quality of this activity ISON is deploying additional subnetwork for extended GEO surveys from 7 small (18-19.2 cm aperture) automated telescopes with field of view 7x7 degree. Extended surveys of new ISON subnetwork allows to KIAM to determine more precise GEO orbits, to detect maneuvers of active satellites and to help maintain the orbits of GEO objects in clusters. Also it was attempted to form the other new ISON subsystem - for LEO observations from 8 telescopes of 12.5 –cm – 50-cm apertures, but then it was solved to complete with these telescopes already existing follow up subsystems..

I INTRODUCTION

International Scientific Optical Network[1]. (ISON) is an open international project developed to be an independent source of data about space objects for scientific analysis and space situation awareness. Main area of monitoring is GEO, regular surveys of HEO

objects are carried out, observations of LEO objects are started. Keldysh Institute of Applied Mathematics of the Russian Academy of Sciences (KIAM), which coordinates the ISON project and processes ISON measurements, maintains 35% more complete GEO-object database than public TLE data.

ISON promotes enhancing the international collaboration between observatories in developing countries and scientific organization in industrialized countries in the field of optical observation of natural and man-made celestial objects. Currently ISON joins 37 observation facilities of various affiliations with 100 telescopes in 17 countries. Current locations of optical facilities participating in the project are shown at Fig. 1. Each facility hosts few telescopes for different goals. In addition to own telescopes of KIAM and NCT Ltd there is collaboration with few observatories in Spain, Switzerland, Kazakhstan, Georgia and Russia, with networks of Roscosmos/TSNIImash observatories[2], ASC Ltd and JSC Vimpel.

ISON has three supporting groups (electric and software engineering, optical and mount engineering, observation planning and data processing) and four main subsets[3] of telescopes: (i) global GEO survey, (ii) tracking of bright (brighter than 15.5^{m}) GEO and HEO objects, (iii) tracking of the faint (fainter than 15.5^{m}) space debris at GEO and GTO, (iv) asteroids researches (ASPIN project[4]). Most part of the ISON observatories is using standard software package which includes AccuTime module (GPS receiver), CameraControl module (CCD camera), CHAOS module (telescope mount), Apex II module (astrometric and photometric reduction of the CCD frames). In last time a new integrated telescope control system and data acquisition software package FORTE[5] (Facility for Operating Robotic Telescope Equipment) is developed.

Using ISON data KIAM carries out researches in following fields: (i) estimation of real population of space debris at high geocentric orbits, (ii) determination of physical properties of discovered space debris objects, (iii) determination of probable sources of newly discovering space debris fragments, (iv) verification of existing evolution models of space debris distribution (v) high orbit space debris risk assessment, (vi) improvement of technologies of studying of space debris population using optical instruments, (vi) improvement of motion models for space debris objects with complex physical properties.

With this goal KIAM developed space debris data centre based on software complex ADAPS[6].

So, ISON optical network now represents one of largest and powerful ground systems specializing in observation of space objects.

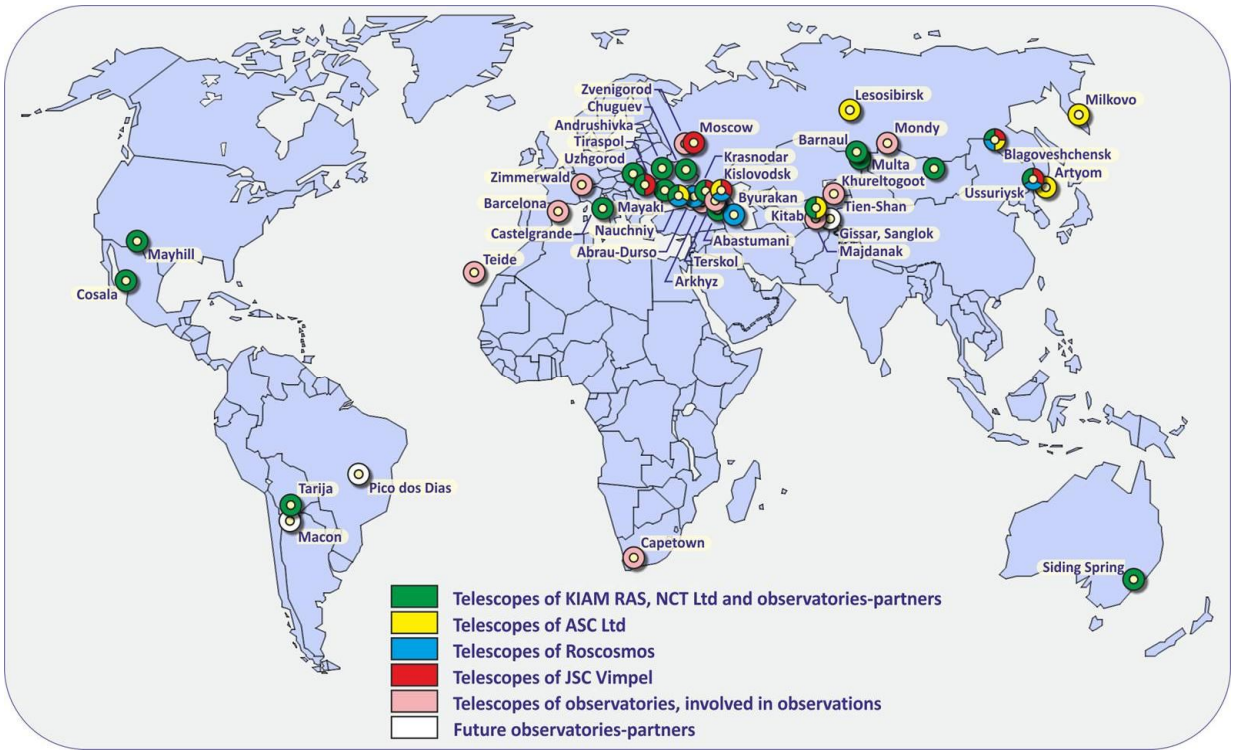

Fig. 1: Map of the ISON observatories.

II. CURRENT STATUS OF DEVELOPMENT

KIAM&ISON are involved into the Roscosmos project "Automated System for Prediction and Warning on the dangerous situations in the near-Earth space" (ASPOS OKP). KIAM is responsible for conjunction analysis and notification at high Earth orbits and create the dedicated service for the daily operations. ISON was a main source of measuring data for this goal, but already first trial operations of ASPOS OKP system clearly displayed that existing data stream is not enough for quality collision risk analysis in high orbits. Therefore KIAM proposed to create a Roscosmos subnetwork of dedicated observation facilities to increase the volume of measurements and orbit determination precision.

The deployment of Roscosmos telescopes dedicated for space debris observations is finished in 2015. Four mini-observatories EOP-1 with 3 telescopes in each: 40-cm, 25 cm and double 19.2 cm apertures, are installed in Kislovodsk (North Caucasus), Buyrakan (Armenia) and Nauchniy-3 (Crimea). Two mini-observatories EOP-2 with 3 telescopes in each: 65-cm (see Fig. 2), 40-cm, 4x19.2 cm apertures are installed in Kislovodsk (see Fig. 3) and Blagoveschensk.

Three separate telescopes – OES-65 (65-cm), OES-50 (50-cm) and OES-25 (25-cm) are installed in Ussuriysk, Kislovodsk and Abrau-Durso.

Originally main goals of Roscosmos telescope subsystem was improving the precision of orbital data for conjunction analysis by means of the improving the regularity of the GEO surveys and the follow up observations of GEO, HEO, MEO and LEO objects predicted to be a candidate for possible conjunction. Addition goals was an expand quantity of tracking objects by means of the regular HEO surveys and local GEO survey for detection of new faint objects.

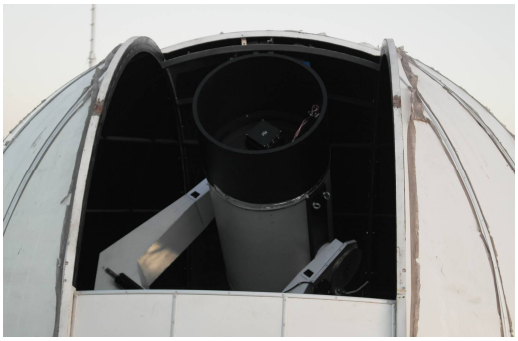

Fig. 2: EOK-65 telescope with 65-cm aperture of EOP-2 mini-observatory. Field of view is 2.2x2.2 degree for 50x50-mm CCD-chip.

Now the work is concentrated on adjusting the follow up observations of discovered objects in quasi-real time and HEO objects surveys.

Moreover set of 8 telescopes (12.5 cm – 50 cm apertures) of JSC Vimlel[7] started the operations in 2015 in Ussuriysk, Blagoveschensk (see Fig. 4), Kislovodsk, Krasnodar and Tiraspol. Originally it was planned for LEO object observations, but then redirected on follow up observations of HEO and GTO objects.

These activities allowed completing two main ISON subsystems - for tracking of bright GEO and HEO objects, and for tracking of the faint space debris at GEO and GTO. Also global GEO survey subsystem was completed – collaboration was restored with Abastumani observatory (Georgia) and Zimmerwald observatory[8] (Switzerland). Also telescope in Italy is refurbishing (it was moved from Colleparo to Castelgrando). Each from these three susbsystems has now 15 telescopes.

Fig. 3: Roscosmos mini-observatories in Kislovodsk: EOP-1 (left), EOP-2 (right), OES-50 (centre).

Fig. 4: VT-53e telescope with 12.5-cm aperture of JSC Vimpel in Blagoveschensk. Field of view is 12.3x8 degree for 36x24-mm CCD-chip.

III. NEW SUBSYSTEMS

Since the EOP-1/EOP-2 observatories are not providing expecting large contribution to the improving of precision of GEO object orbits still, it was solved to continue the development of the additional subsystems for extended GEO-surveys from small telescope with field of view as 7x7 degree. First such telescopes were installed in Khuraltogot (Mongolia), Kislovodsk and Nauchniy-1 (Crimea). During end of 2015 and 2015 additional VT-78a telescopes were installed in Tiraspol (Moldova), Ussuriysk (Far East) and in new observatory at Multa (Altai republic) – see Fig. 5. One more telescope (twine 18-cm VT-52c) is prepared for installation in future observatory at Macon (Argentina) – see Fig. 6.

Each such telescope is surveying visible part of GEO and produces up to 15 thousands measurements for 500-700 objects (with brightness down to 14^m) per night (and up to 1 million measurements per year) providing duration of object tracks is up to few hours – see example of distribution of number of objects by overall measurements arc length in Fig. 8.

These surveys allows to KIAM to determine more precise GEO orbits for conjunction analysis, to detect maneuvers of active satellites and to help maintain the orbits of GEO objects in clusters.

Also the works on local GEO surveys of the areas with the highest density of known GEO fragment trajectories is continued with new 50-cm telescope ORI-50 with field of view 2.2x2.2 degree in Andrushivka (see Fig. 9). Such local surveys allow as detect new faint fragment and obtain measurements for known objects.

Fig. 5: VT-78a telescope with 19.2-cm aperture of NCT Ltd in new observatory at Multa (Altai republic) JSC Vimpel in Blagoveschensk. Field of view is 7x7 degree for 36x36-mm CCD-chip.

Two more similar telescopes will be putted in operations in 2016 – one in Kislovodsk and second – in Nauchniy-3. It is expected that three 65-cm telescopes of Roscosmos in Ussuriysk, Blagoveschensk and Kislovodsk will join to this goal to form additional specialized subsystem.

The surveys of HEO objects are continued with single 18-cm VT-52c telescope in Nauchniy-1. Also similar surveys are in adjusting with twine VT-78a of EOP-1-4 in Nauvhmiy-3. It is planned that two quadruple 19.2 cm VT-78a telescope of EOP-2 in Blagoveschensk and Kislovodsk will join to this goal to form additional specialized subsystem.

Fig. 7: Twin VT-18c telescope with 18-cm aperture for future observatory at Macon (Argentina). Summary field of view is 14x7 degree for two 36x36-mm CCD-chips.

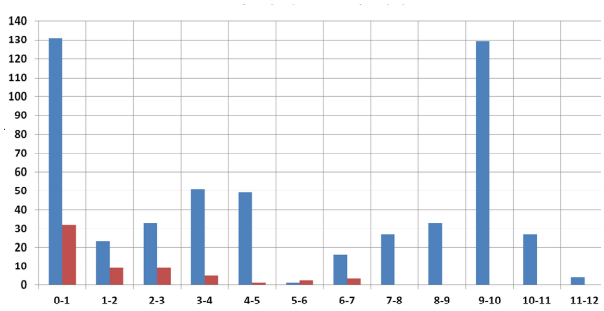

Fig. 8: Example of distribution of number of objects (vertical axis in pieces) by overall measurements arc length (horizontal axis in hours) for 524 GEO object (blue colour) and 61 HEO objects (red colour) detected in single survey with VT-78a.

Number of measurements collecting by ISON is steadily growing each year (see Fig. 10). To middle of September of 2015 it were already received 9.7 million measurements in 1.3 million tracklets, that on 25% more than in 2014.

KIAM database maintains the orbits of 1795 GEO objects and 2205 HEO objects. During 2015 it were discovered 62 new GEO-object and 90 HEO-object, and rediscovered 175 lost objects.

So, number of discoveries of relatively bright GEO debris objects (brighter than 16-17^{m}) continues to grow in spite of already few year meticulous surveys of all GEO ring. This may demonstrate that there is some source of permanent generation of new GEO objects.

Many of newly discovered GEO space debris are crossing or permanently staying in the GEO protected region and increase threat to operational spacecrafts. It is expected that at least several hundreds more of GEO space debris exist in the GEO region.

Fig. 9: ORI-50M telescope with 50-cm aperture in for future observatory in Andrushivka. Field of view is 2.5x2.5 degree for 50x50-mm CCD-chip.

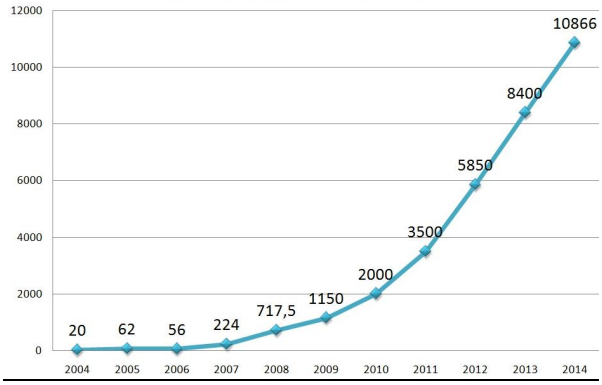

Fig. 10: Number of measurements collected by ISON annually for the 2004 – 2014 period..

IV. CONCLUSION

Completeness of three main subsystems of the ISON network is finished thank to deployment of six Roscosmos EOP-1/EOP-2 observatories and starting of operations of JSC Vimpel telescope set. Global GEO survey subsystem, subsystems for tracking of bright GEO and HEO objects, and for tracking of the faint space debris at GEO and GTO contains of 15 telescopes each.

Development of the additional subsystem for extended GEO-surveys is continued to provide better precision of GEO object orbits for conjunction analysis. 6 telescopes with field of view 7x7 degree are already working. And one more telescope will be installed in Argentina.

There is a plan to form two new subsystems – for local GEO surveys of faint fragments from 50-cm and 65-cm telescope with field of view 2.2x2.2 degree and for surveys of HEO objects with involving of the quadruple 19.2 cm VT-78a telescope of EOP-2 mini-observatories.

KIAM data centre maintains daily operations of the ISON network providing scheduling for ISON and Roscomsos telescopes, collecting and processing up to 90 thousands measurements per day. To middle of September of 2015 it were already received 9.7 million measurements in 1.3 million tracklets that allowed to KIAM maintains the orbits of 1795 GEO objects and 2205 HEO objects, and provides daily conjunction analysis for 50 operational spacecraft within the framework of ASPOS OKP system under requests of TSNIImash, including analysis of motion for co-located GEO active spacecraft operated by non-cooperating entities.

152 new high-orbit objects were discovered and 175 lost objects were rediscovered during 2015.

[1]Molotov I., Agapov, V., Titenko, V. et al. International scientific optical network for space debris research, Advances in Space Research, Volume 41, Issue 7, 2008. p. 1022-1028

[2] Molotov I., Agapov V., Makarov Yu. et al. EOP-1/EOP-2 mini-observatories for space debris observations: characteristics, tasks and first results of operation. Proceedings of the 65th International Astronautical Congress, Toronto, Canada, 29.09-03.10.2014, ISSN 1995-6258, IAC-14,A6,1,4,x23058

[3] Molotov I., Agapov V. Subsystems of the ISON Telescopes for GEO, HEO and LEO Observations. Proceedings of the Advanced Maui Optical and Space Surveillance Technologies Conference, held in Wailea, Maui, Hawaii, September 11-14, 2012, id.28

[4] Molotov I., Krugly Yu., Elenin L. et al. ASPIN: research project on near-Earth asteroid photometry in frame of the ISON optical network. Abstracts of 40th COSPAR Scientific Assembly 2014,B0.4-0027-14

[5] Vladimir Kouprianov. Apex II + FORTE: data acquisition software for space surveillance. Abstracts of the 39th COSPAR Scientific Assembly. Held 14-22 July 2012, in Mysore, India, p .974

[6] Molotov I., Zolotov V., Fakhrutdinov T. et al. ADAPS-new software tool for collection, processing and analysing of ISON astrometric measurements. Program and abstracts of Twelfth International Seminar "Mathematical models & modeling in laser-plasma processes & advanced science technologies. Budva, Montenegro, May 31 - June 7, 2014, p. 66

[7] Garichev S.N., Kolessa A.E., Ignatov Yu.A. University network of optical robotic telescopes. Proceedings of the International Symposium "Research Environments 2013", Larnaka, Cyprus, May 13-17, 2013, p. 70 - 79

[8] Herzog J., Fiedler H., Weigel M., et al. SMARTnet: A Sensor for Monitoring the Geostationary Ring. Proceedings of 24th International Symposium on Space Flight Dynamics, Laurel, Maryland, 2014