CURRENT STATUS AND DEVELOPMENTS OF THE ISON OPTICAL NETWORK

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ABSTRACT

International Scientific Optical Network (ISON) represents one of largest systems specializing in observation of space objects. ISON project is continuously developing and is joining now the 33 observation facilities in 14 countries with 60 telescopes of different class (aperture from 12.5 cm to 2.6 m). 5.8 millions of measurements in 850 thousands of tracks are collected for about 3500 objects in 2012. The ISON observations are coordinated mainly by the Center on collection; processing and analysis of information on space debris (CCPAISD) developed and operated on the basis of the Ballistic Centre at the KIAM, Russian Academy of Sciences. The obtained results are used for KIAM orbital archive maintenance and conjunction analysis in interests of the Russian Mission Control Center and Reshetnev Company. Three ISON subsystems are already formed from telescope of different classes - for survey observations of bright objects at GEO-region, ephemerides observations of high-orbit faint fragments and ephemerides observations of bright GEO and HEO objects. One more subsystem for surveying the HEO-objects and extended GEO surveys is in development. Few series of dedicated telescopes with large FOV and automated mounts are elaborated and 40 items are produced for them. Observations of all automatic survey telescopes are centrally scheduled using dedicated planning software.

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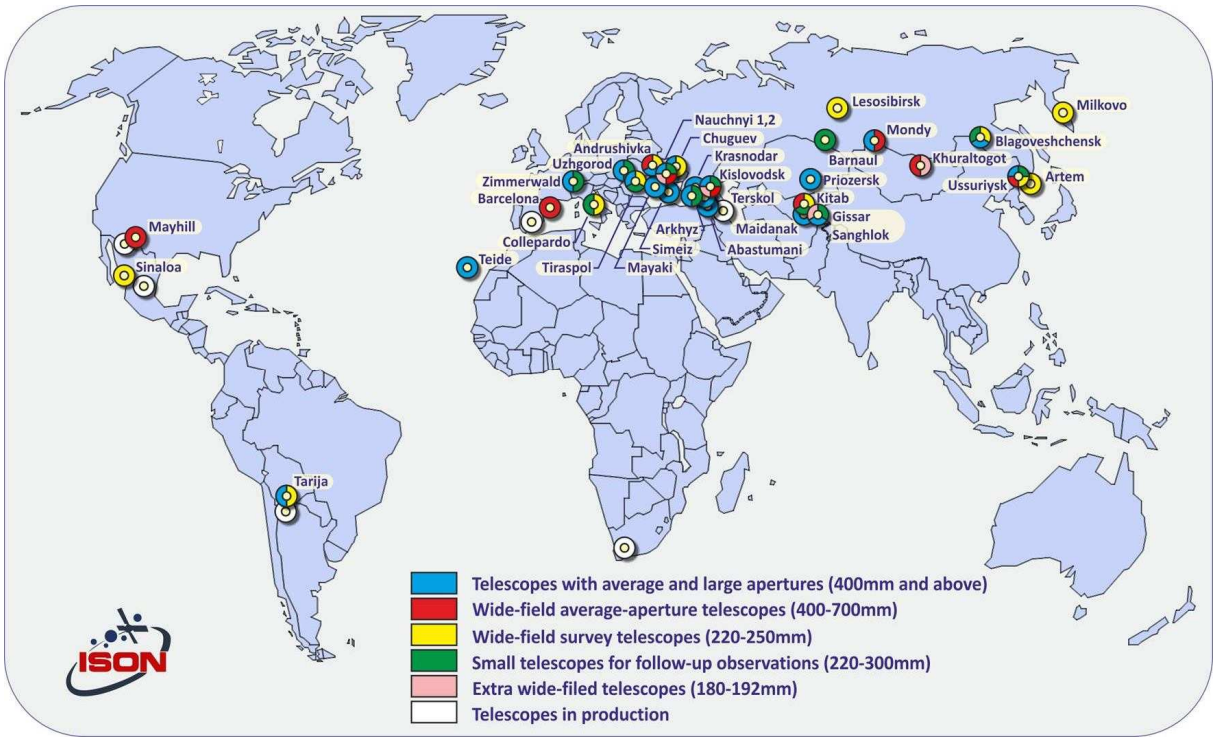

Figure 1. Geographic positions and names of the ISON observatories

1 INTRODUCTION

International Scientific Optical Network (ISON) is an open international non-government project developed to

be an independent source of data about space objects for scientific analysis and spacecraft operators. ISON is concentrated on observations of GEO region mainly providing regular monitoring along full orbit. Observations of HEO objects were started in 2011 only. Other goals of the ISON project are supporting the astronomical observatories of Former Soviet Union (FSU) countries and improving the international collaboration between FSU observatories and scientific organization in other countries. Additional scientific goals of the project are discovery and study of asteroids, comets and gamma-ray burst (GRB) afterglow.

Dates back to early 2000s when the first trial satellite observations were performed in several Russian astronomical observatories, independently of the former Soviet Union space surveillance system and using the existing telescopes, charge-coupled device (CCD) cameras, and custom-made software. At the end of 2004, Pulkovo Cooperation of Optical Observers was established as a mostly self-supporting volunteer project joining together professional and amateur astronomers and engineers, mainly from the post-Soviet space and those having long-standing contacts with Russian astronomers, in order to create an all-purpose independent coordinated worldwide network of optical facilities suitable for various tasks of observational astronomy that may benefit from using a large number of small-aperture but fast-response telescopes with large fields of view (FOV). Now ISON optical network now represents one of largest ground systems specializing in observation of space objects. ISON joins 60 telescopes (with apertures from 19.2 cm to 2.6 m) in 33 observation facilities of various affiliations in 14 countries. Overall coordination is performed by the Keldysh Institute of Applied Mathematics (KIAM) of the Russian Academy of Sciences where the Center on collection; processing and analysis of information on space debris (CCPAISD) is developed and operated on the basis of the Ballistic Centre.

Current locations of optical facilities participating in the project are shown at Fig. 1. Each facility hosts one or more telescopes. Different colors corresponds to telescopes of different class or/and using for different purposes.

2 ISON STRUCTURE

ISON has three supporting groups (electric and software engineering, optical and mount engineering, observation planning and data processing) and five subsets of telescopes (different classes of telescopes are applied for different targets).

Electric and software engineering group has developed: (i) the time keeping hardware for precise determination of CCD frame capture moment, utilizing the trigger mode of the CCD shutter, (ii) full set of software modules for control of all telescope devices under common platform – GPS receiver (AccuTime module), CCD camera (CameraControl module), telescope mount (CHAOS module), (iii) Apex II software package for astrometric and photometric reduction of the CCD frames. All software components can interact with each other. Apex II provides calibration of CCD frames, detection of space objects, differential astrometry and photometry using stellar catalogs, identification of detected space objects using catalog of orbits, checking of the internal accuracy of measurements. A number of improved versions of all modules are issued each year, based on the constantly improving observational experience. A dedicated web site was established for centralized, downloading of new versions from all ISON observatories. In last time a new integrated telescope control system and data acquisition software package FORTE (Facility for Operating Robotic Telescope Equipment) was developed.

About 70 time keeping devices were produced at Pulkovo and installed at all ISON telescopes (ISON standard requires that each telescope has its own time keeping system). Standard software is used already at 50 observatories. Technical support is maintained with each user with help of dedicated board at ISON projects' web site (http://astronomer.ru).

Optical and mount engineering group has developed: (i) a set of dedicated telescopes, (ii) a set of mounts with different weigh capacity, (iii) a set of domes, (iv) lots of individual solutions for automation of the mounts of legacy telescopes that are working with ISON. In the whole, 80 optical telescopes ranging apertures from 80-cm to 12.5 cm are produced (see new 65-cm telescope at Fig. 2), and 10 telescopes of 0.6-0.8-m class are

Figure 2. 65-cm SANTEL-650 telescope of new series.

Figure 3.WS-240, WS-300, WS-500 folk mounts.

refurbishing now. 30 mounts of WS-180 to WS-500 series we elaborated (see Fig. 3).

Observation planning and data processing group develops standard observation modes for telescopes - survey, search scan, ephemeris tracking etc., adjusts new observations techniques with each observatory team, and schedules the survey and ephemerid observations using dedicated KIAM software.

5 telescope subsets are (i) global GEO survey (down to 15.5^m), (ii) tracking of the faint (fainter than 15.5^m) space debris at GEO and GTO, (iii) tracking of bright GEO and HEO objects, (iv) HEO survey and extended GEO survey, (v) asteroids researches.

The ISON GEO survey subsystem for studying of the bright (not fainter than 15.5m) objects in GEO region consists of 12 small survey automated telescopes of 22-25 cm aperture with FOV from 3.3° to 5.5° across the globe (Milkovo, Ussuriysk, Artem, Blagoveschensk, Lesosibirsk, Kitab, Nauchniy-1, Chuguev, Tiraspol, Andrushivka, Tarija and Sinaloa, see example of such telescopes in Fig. 4), and one 50-cm telescope near Barcelona with FOV of 4.4°.

Each survey telescope is surveying visible part of GEO and provides a few thousands measurements for a few hundreds objects per night (duration of tracks is varying between 15 and 40 minutes). These surveys produce measurements for all bright GEO-objects supporting the maintenance of KIAM database. Many uncatalogued fragments and objects of new GEO launches are detecting and many HEO objects are detecting as background ones.

Subsystem for high altitude faint (15.5^m to 18^m) space debris fragments tracking consists of the telescopes with aperture from 40 cm to 2.6 m and includes 64-cm AT-64 telescope in Nauchniy-1, 60-cm Zeiss-600 in Arkhyz, 40-cm ORI-40 in Kitab, 48-cm AZT-14 in

Figure 4.22-cm ORI-22 telescope in Kitab.

Mondy, 80-cm RC-800 telescope in Mayaki (see Fig. 5), 70-cm AZT-8 telescopes in Gissar, 50-cm CHV-500 telescope in Kislovodsk, 50-cm ORI-50 in Ussuriysk, 60-cm S-600 telescope in Andrushivka, 50-cm ORI-50 in Andrushivka. Three last telescopes, having FOV about 2° – 2.5° provides some times the local surveys to cover the fields with the highest density of known fragment trajectories.

The subsystem for tracking of bright GEO and HEO objects provides follow up of bright (brighter 15.5^{m}) objects discovered by the survey sybsystems and consists of 25-cm GAS-250 telescope in Ussuriysk, 25cm BNC-250 telescope in Uzhgorod, 25-cm Sajen-TM telescope in Arkhyz, 25-cm ORI-25 telescope in Blagoveschensk, 25-cm ORI-25 telescope in Tiraspol, 25-cm ORI-25 telescope in Kislovodsk (see Fig. 6), 22-cm PH-1 telescope in Nauchniy-1, 50-cm AZT-28

Figure 5. New 80-cm RC-800 telescope in Mayaki started operations in end of 2012.

Figure 6.New 25-cm ORI-25telescope in Kislovodsk started operations in middle of 2012.

telescope in Priozersk and 25-cm TAL-250 telescope in Barnaul.

Subsystem for extended GEO surveys consists of four 18-19.2 cm automated survey telescopes with FOV of 7°x7° in Khuraltogot, Sanglokh, Kislovodsk and Nauchniy-1. Each telescope is surveying visible part of GEO and provides up to 15 thousands measurements for 500 - 700 objects per night (duration of object tracks is up to a few hours). 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. Many HEO objects are detecting as background ones.

In addition, two telescopes in Nauchniy-1 and Kislovodsk (see Fig. 7) provides the dedicated surveys of HEO orbits.

Figure 7.New twine19.2-cm VT-78a telescope in Kislovodsk started operations in middle of 2012.

3 STATUS OF ISON OBSERVATIONS

Number of measurements collecting by ISON is steadily growing each year (see Fig. 8). This happens both thanks to increasing number of participating instruments as well as improvement of observation scheduling and implementation of more optimal observation techniques.

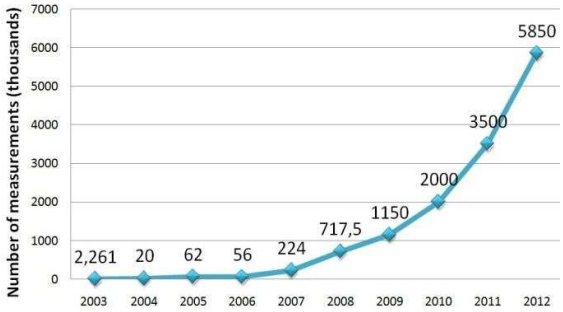

Figure 8.Quantity of optical measurements collected by ISON network for GEO and HEO objects by year.

As of May 2013, about 15 millions of optical measurements obtained by ISON instruments are accumulated in the KIAM/ISON space objects database Each night up to 20 telescopes are working (Fig. 9) providing observations up to 1200 individual objects (see Fig. 10) making possible frequent updates of orbital parameters for nearly all active GEO spacecraft and many of non-active space debris objects at GEO and HEO

Fig. 11 shows real daily GEO coverage by ISON in 2012 (Jan-Jun). One can see that the 30W-160E arc (and even some longitudes further East) is covered through the year almost without significant gaps. Increase of the 40W-140W arc coverage starting May 2012 is explained by the start of operation of a new facility in Mexico.

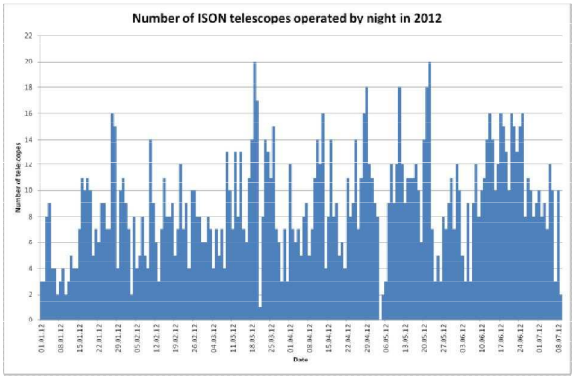

Figure 9. Number of ISON telescopes operated by night in 2012 (from Jan 1 to Jul 8).

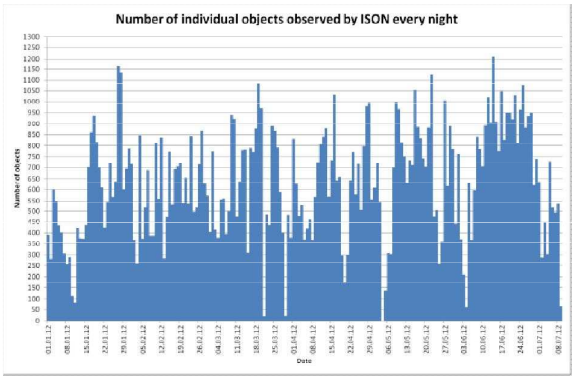

Figure 10.Number of individual objects observed by ISON every night in 2012(from Jan 1 to Jul 8).

As of Feb 1, 2013 the CCPAISD database at KIAM contains information for more than 3200 HEO, MEO and GEO objects with orbits updating using ISON optical measurements and 897 of these objects are newly discovered during 10 years of ISON work (see Fig. 12, the objects discovered by ISON network are marked in red color). 270 HEO and GEO space debris objects are discovered in 2012 (compare to 168 ones discovered in 2011 and 61 – in 2010).

ISON/KIAM is already involved in Roscosmos's ASPOS OKP project (Automated System for Prediction and Warning on the dangerous situations in the near-Earth space) and provides conjunction analysis for Electra-L, Luch-5A and Luch-5B GEO satellites on regular basis.

Surprisingly, number of discoveries of relatively bright GEO debris objects (brighter than 16 magnitude) continues to grow. 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 brighter than 17^{m} exist in the GEO region.

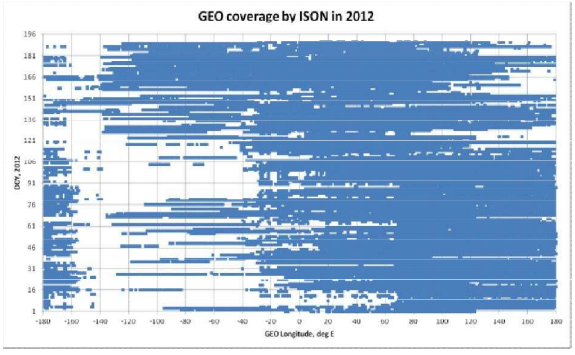

Figure 11. Daily GEO coverage by ISON in the first half of 2012.

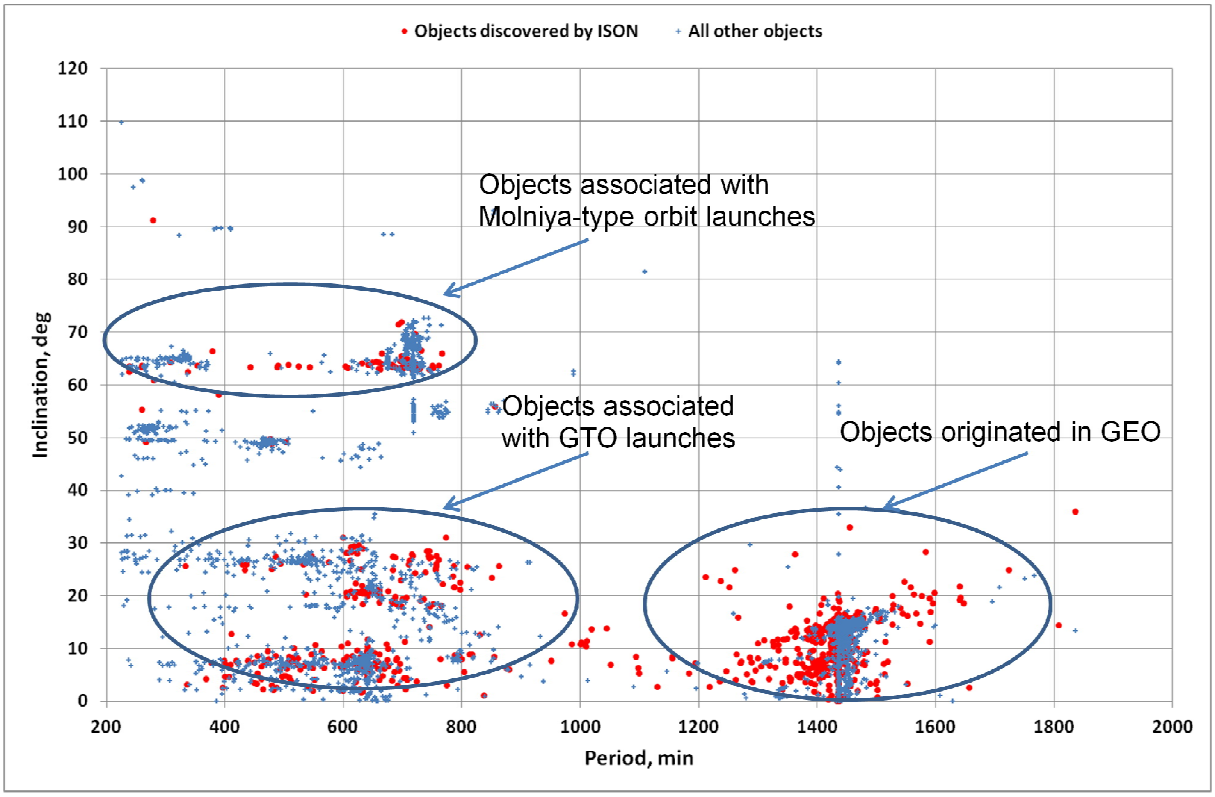

Figure 12. Orbital parameters of 3200 objects in CCPAISD database at KIAM including 897 of these objects are newly discovered during 10 years of ISON work (red color points).

4 CONCLUSIONS AND OUTLINES

Future development of ISON network is connected with installation of the dedicated space debris mini-observatories. 4 EOP-1 (2x19.2 cm. 25-cm and 40-cm telescopes), 2 EOP-2 (4x19.2 cm, 40-cm and 65-cm telescopes) and 3 separate telescopes (25-cm, 50-cm and 60 cm) are produced under three grants of Roscosmos (see part of EOP-2 observatory on Fig. 13).

Figure 13. 4x19.2 cm telescope in dome and observer pavilion of EOP-2 observatory.

First mini-observatory EOP-1 is already installed near Kislovods, North Caucasus and started regular observations since July of 2012 (and discovered comet C/2012 S1 (ISON).

So, first international network for high near-Earth orbits monitoring was created. ISON network collects on routine basis measurements for more than 1800 objects in GEO region and more than 1400 objects at HEO orbits. Unique KIAM database (about 15 millions of measurements) is using for scientific analysis and applied tasks, including spaceflight safety support. Development of ISON continues and everyone is welcome to participate.

Possible forms of collaboration with ISON are (i) joint observation campaigns to exchange the obtained results, (ii) installation of ISON telescopes to share the data, (iii) modernization of non-operational obsolete telescopes, (iv) production of telescope under scientific grants for future joint observations, (v) service on provision of orbital data, (vi) service on conjunction analysis, (vii) participation at UN supported ISON conferences.