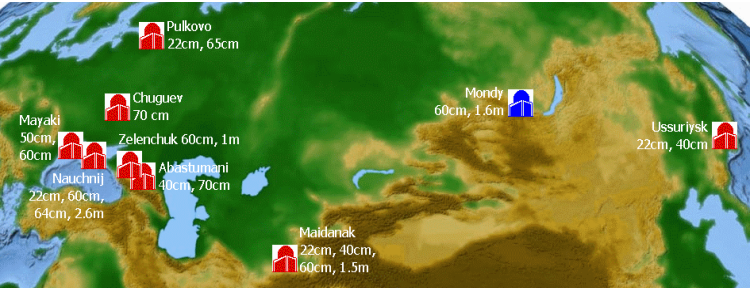


Stages of development of the ISON optical telescope global network

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At the first stage 2005-2007, attempts were made to use the telescopes that remained in observatories since the USSR for observations of space objects. But after the start of regular research, it became obvious that outdated non-automated telescopes with small fields of view (FOV) and insufficient sensitivity are not suitable.

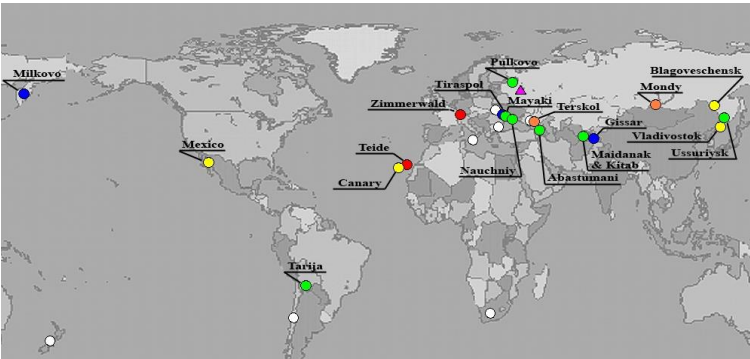


International scientific optical network (ISON) project (www.astronomer.ru) started in 2004 at Pulkovo observatory as open international voluntary project on self-financing basis to be an independent source of data for scientific and applied purposes about natural and artificial space objects. At different stages of the project, as the level of knowledge about space debris, new tasks and problems appeared that required the development of new tools and methods for monitoring the near Earth space.

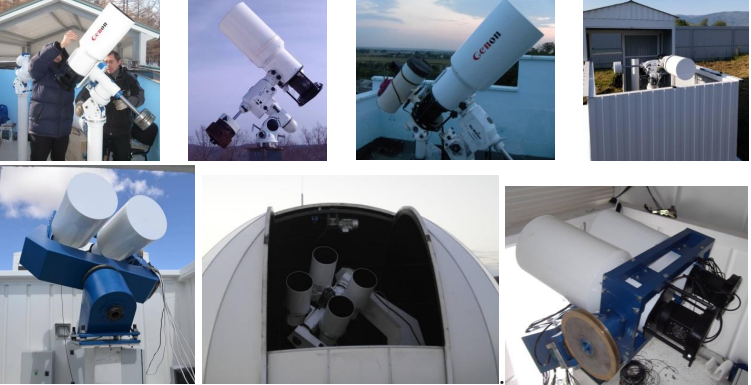
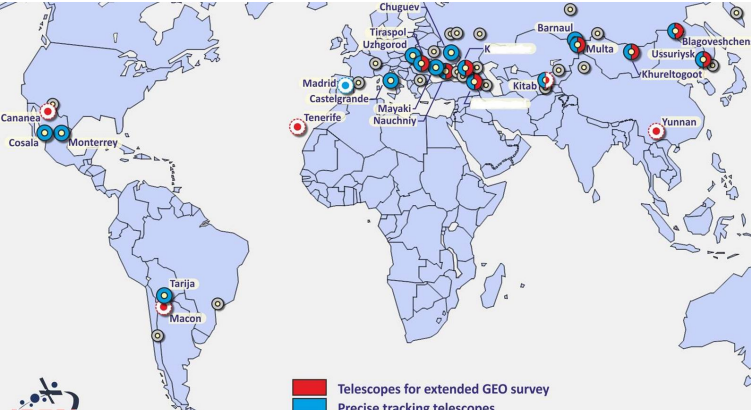
ISON project milestones:

- 2005-2007: Usage of existing obsolete telescopes.
- 2008-2011: Producing the 22-cm telescopes with FOV 4x4 degree for GEO survey.
- 2011-2016: Deployment of the 19.2-cm telescopes and complexes with FOV 7x7, 9x7 and 9x14 degrees for extended GEO surveys and HEO objects (Roscosmos ASPOS OKP project).
- 2017-2019: Subdividing of network on three independent parts - scientific cooperation, Roscosmos and industry organizations.
- 2020-2021: Establishment of refreshed ISON network for scientific and commercial activities under the auspices of Small Innovation Enterprise “KIAM Ballistics-Service”.

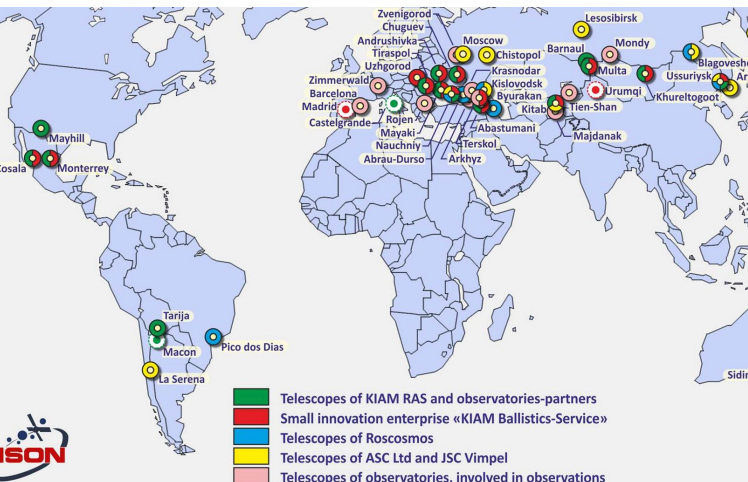
At second stage 2008-2011 the main focus was on small survey telescopes with FOV 4x4 degree that could dig through the entire visible part of the GEO overnight. Initially, they were installed on top of outdated telescopes. This work made it possible to compile and maintain a list of orbits of all bright GEO-objects.



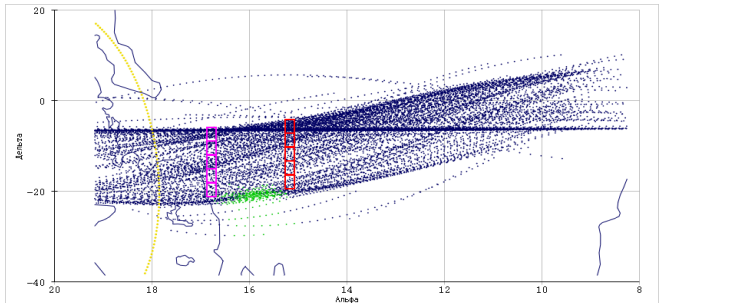
Third stage was realized with involving into work of Roscosmos system on prognosis of dangerous situations. It were elaborated 19.2-cm telescopes with FOV 7x7 degrees and developed the extended surveys, significantly increases the accuracy of the orbits for all bright GEO-objects by multiple scans for the night. Next task was to detect more objects in highly elliptical orbits (HEO). To solve this problem, two-tube and four-tube telescope systems were developed with FOV 9x7 and 9x14 degree.



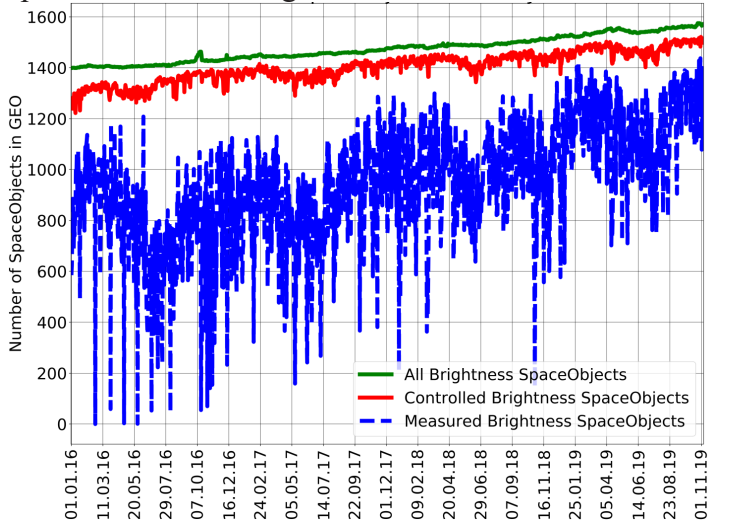
2017-2019: Subdividing of network on three - scientific cooperation (including telescopes of SIE “KIAM Ballistics-Service”), Roscosmos and industry organizations.



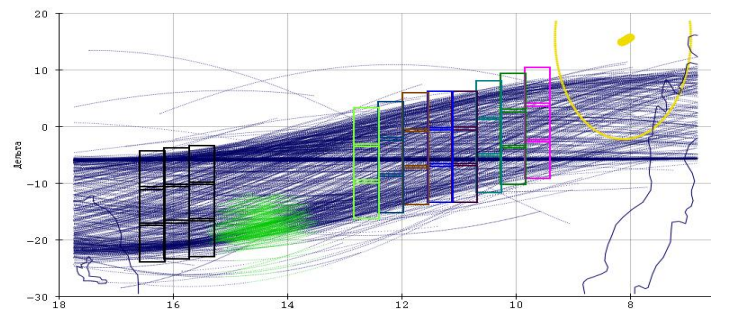
Each subnetwork has own center of scheduling and data analysis, and source of financing.



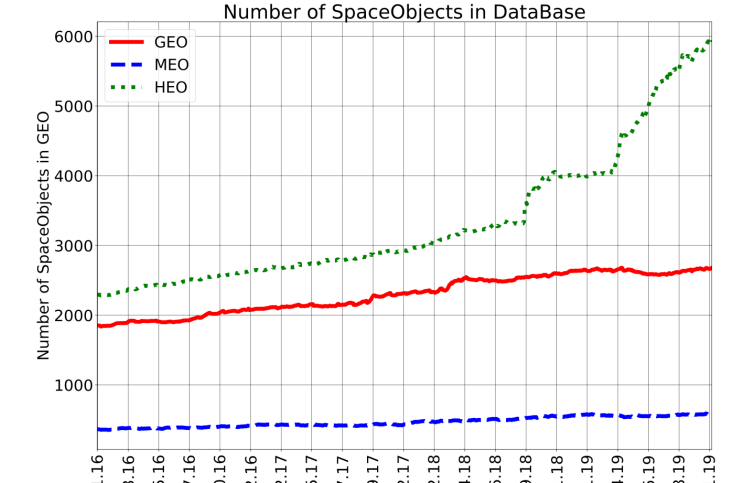
Each 22-cm telescope with FOV 4x4 deg. surveys visible part of GEO in 18 degree width and provides per night a few thousands measurements for a few hundreds objects up to 15.5^m and average arcs from 15 to 40 minutes.



Status of the ISON catalog of bright GEO objects in 2016-2019. Measurements of 90% population of bright objects are regularly obtained, ensuring that accurate orbits are maintained in 98% of the population



Each 19.2 cm telescope with FOV 7x7 deg. and more surveys visible part of GEO and provides per night up to 15 thousands measurements for 500 - 700 objects up to 14^m and average arcs up to a few hours.



Status of the ISON catalog in 2016-2019. Quantity of HEO-objects increased almost 3 times and now the number of HEO-objects is 2 times more than GEO-objects.

Summary and outlook:

ISON project was one of pioneers in CCD sky surveying in Russia. A lot of equipment and software was elaborated: few series of dedicated telescopes, standard set of software for telescope control, image processing and observation scheduling. Global network of the 100 optical telescopes at 42 observatories of 18 countries was arranged. For years the network had provided a leading position in the field of space debris investigation at high orbits. However, it was later divided into several components with its own scheduling center each. Nevertheless ISON is still covering with observations all longitudes of the globe and can provide significant output.

Due to a 15-year series of the observations of space debris by ISON the knowledge about the SD population at the GEO and HEO has reached a fundamentally new level. ISON database contains the orbital information for 9300 objects at high orbits and 23.4% of that have an area-to-mass ratio greater than 1 m²/kg. More than 2,000 new fragments at the HEO were catalogued in last 2 years. For this reason the quality of catalog of faint GEO and HEO objects has decreased due to the percentage of objects with accurate orbits – down to 50%. Number of GEO and HEO fragments constantly changes (periodically decreasing by tens of percent) and first time have a trend to decreasing of quantity. To go further in the study of the space debris population it is necessary to develop fundamentally new tracking tools and realize new approaches to scheduling.

Milestone references:

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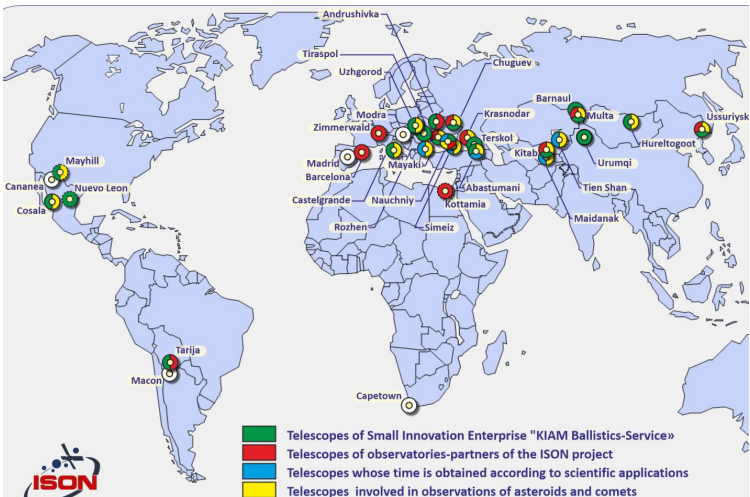
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Refreshed ISON network for scientific and commercial activities under the auspices of Small Innovation Enterprise “KIAM Ballistics-Service” Ltd.



Currently, ISON consists of 53 telescopes at 27 observatories and carries out the investigations of the space debris and asteroids. ISON small survey telescopes cover all GEO orbit and provide the significant contribution to the maintenance of the catalogue’s accuracy for space objects brighter 15.5^m that is important for the conjunction analysis procedure.

There is the scheduling and data analyzing center and works for goals of commercial orders including foreign (supply of raw measurements, orbital data, and conjunction assessment analysis). First foreign customers – GMV, ESA.