PERFORMANCE ANALYSIS OF THE LARGE SPACE DEBRIS TRACKING TELESCOPE IN THE NORTH CAUCASUS AFTER THE SECOND FIRST LIGHT

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ABSTRACT

A relatively large new telescope has just started to work in the International Scientific Optical Network (ISON). This instrument, initially installed at a good observing site, was renovated as a tracking telescope, and it is in operation now. Moreover, probation of the instrument is currently going as well as a process of gathering information for its further modification. Nevertheless, even now this telescope is an inherent part of the ISON project, contributing to the observation efficiency of faint objects in a geosynchronous orbit (GEO) and in a highly elliptical orbit (HEO), and improving the accuracy of the entire catalogue of these objects. Instrument specifications and statistics of space debris observations are presented, latest principal developments within the ISON project are mentioned as well.

Key words: ISON project; space debris tracking; optical range; telescope renovation.

1. INTRODUCTION

While the majority of space debris observations in a low Earth orbit (LEO) occur using radar or lidar facilities, current development of optical system design, detectors, and digital image processing enables to indicate substantial advantages in terms of a cost-effective means for monitoring increasing debris population in GEO and HEO, using small and medium aperture ground-based passive optical systems. Corresponding instruments could be based on amateur equipment for mass production or limited production batch for own purposes. In addition to reducing total cost, this utilitarian approach provides yielding of homogeneous data from different or similar observing sites, that is, certainly, useful for space debris pinpointing, tracking, and its photometric study. Present solution leads to rapid deployment of optical facilities network worldwide which sweeps all objects in the geostationary region with completeness depending on the average aperture of telescopes, their specification, detectors, observation schedule program, and, assuredly, processing toolkit. It is also possible to use observational data taken by medium and larger-sized telescopes within scientific and technical cooperation for the database enrichment with faint space junks objects, in particular through the substantial modernization of previously out-of-use and outmoded instruments.

2. THE ISON PROJECT OVERVIEW

The ISON project is one of the top near-Earth technogenic object (NETO) surveillance systems in the world, whose catalogue is regularly updated with observations from the globally distributed network of optical tracking systems (see Figure 1). ISON is coordinated by the Keldysh Institute of Applied Mathematics of the Russian Academy of Sciences (KIAM) that maintains space objects database and also provides conjunction analysis for GEO satellites. ISON project is continuously developing—new observatories are joining, new telescope subsystems are forming, and KIAM database is upgrading: 38 observation facilities in 16 countries comprising 90 telescopes from 12.5 cm up to 2.6 m aperture are involved in the ISON project. Additionally, the number of preparatory works on new observational sites in 8 countries is being implemented at the moment. ISON provides continuous monitoring of the GEO object population, tracking and surveying of objects in GEO, LEO, and in Molniya and other HEO orbits [1][2].

The process of deployment, commissioning and development of small survey follow-up telescopes was actively carried out in 2014, that insignificantly reduced the space debris discovery rate due to coordination issues. A large number of 40–80-cm aperture telescopes have been commissioned for NETOs tracking in 2015 and 2016.

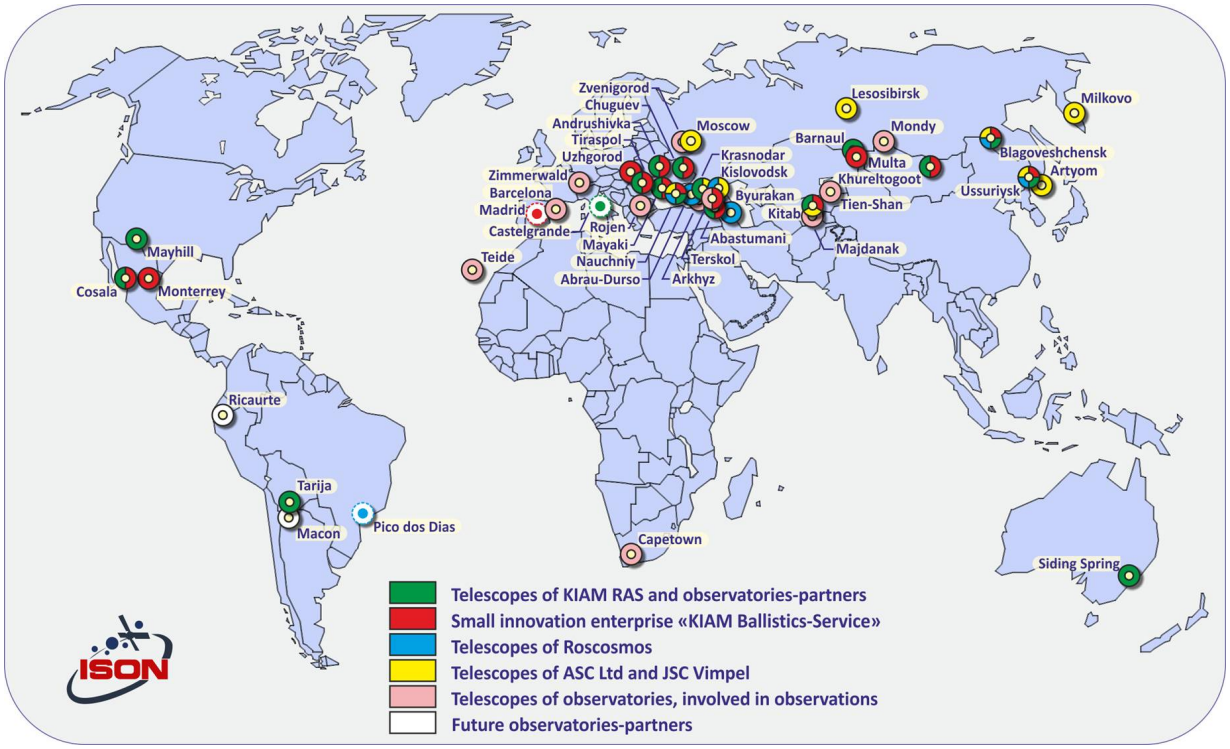

Figure 1. Location map of facilities affiliated with the ISON project

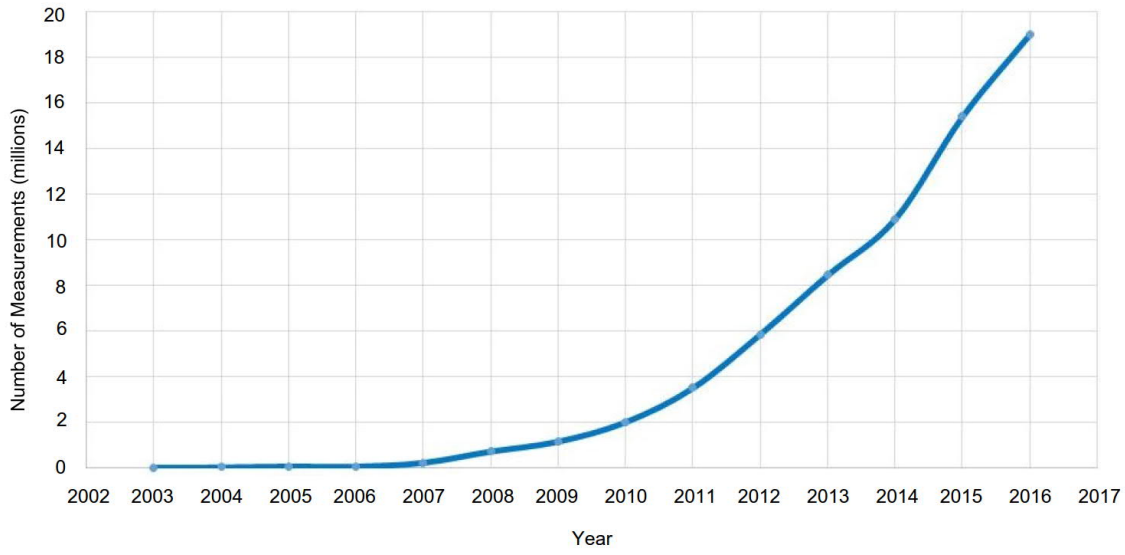

Figure 2. The number of optical measurements obtained by ISON telescopes

There are among renewed telescopes: 80-cm K-800 in the North Caucasus and 60-cm Zeiss-600 in Bolivia [3]. Simultaneously the technique of new space objects quick identification and follow-up has been improved in the number of the ISON observatories, that has increased the GEO and HEO space debris discovery rate significantly.

As a result of the recent developments, 2.4 million tracklets comprising 19 million measurements obtained by ISON in 2016, the general trend from 2013 shown in Figure 2. Orbit determination and conjunction analysis for GEO and HEO are performing on a routine daily basis. Thus, orbital elements of approximately 6150 objects (2040 GEO and 4110 HEO) in the KIAM database are regularly updated at the moment.

Moreover, 550 new objects have been discovered and 480 previously lost objects have been rediscovered in 2016—corresponding quantities increased by about half compare with 2015. It should also be noted that regular optical observations of the dedicated LEO object subset have been started by ISON under remote control of the Vimpel corporation.

Pursuing the collection of data about natural and artificial NEOs, ISON as an open science project provides data for a large variety of purposes. The ISON (KIAM) orbit list of NETOs, some of which are unique non-TLE GEO and HEO objects, has conditionally free access within the diverse forms of cooperation. These orbital parameters partially provided on the Vimpel corporation dedicated website (spacedata.vimpel.ru).

3. THE K-800 TELESCOPE

3.1. Description

The relatively large aperture optical telescope for routine debris monitoring has been recently repaired and renovated in the North Caucasus after the long period of inactivity. The instrument placement at an altitude of 3100 meters provides pristine seeing conditions during on an average 1000 hours per year. This 80-cm telescope K-800, initially Cassegrain, was rebuilt for the observations in the prime focus with CCD technique due to the joint efforts of the ISON project and the Astronomical Observatory of Odessa I. I. Mechnikov National University (Figure 3).

Presently, the instrument with a 228 cm focal length, provided by the large-format 3k$\times$3k CCD camera with 12μm pixel pitch, has enlarged 55 arc minutes field of view. It is able to detect up to magnitude 19 GEO and HEO objects using few second exposures in binning readout mode—telescope has unique specifications for its longitude (42° 30′ E), that aids to fill potential GEO coverage gaps by faint objects.

Mostly, if possible, K-800 is employed in follow-up tracklets, although conventional design, entire massive

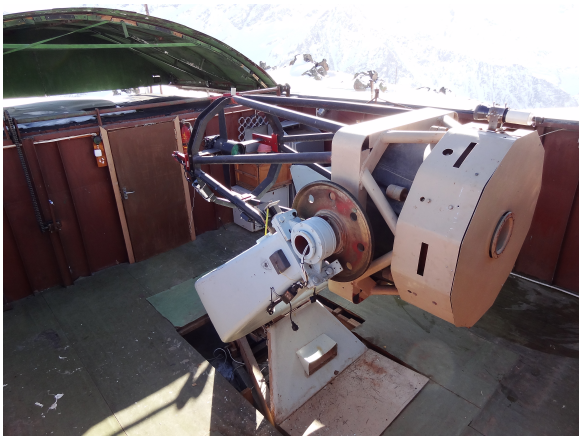

Figure 3. The K-800 telescope in earlier 2017

structure moves sufficiently smoothly and precisely with the fixed spin limitation in both equatorial coordinates of 1 degree per second—excess tracking inaccuracies are eliminated after snapshot processing according to identified stars. During the 2016 fall one-month probation term feasibility of using the instrument for monitoring space debris in GEO was evaluated, almost one thousand proper object follow-ups involved in the statistics, the object distribution has maximum about magnitude 17, according to optimistic estimates it matches half of meter chunks of debris in GEO. Apparently, the significant amount of smaller object can also be observed according to this assessment.

At the same time, the K-800 telescope is still under rebuilding, thus further enhancement is expected: installation of new 2k$\times$2k CCD camera having 24μm pixels for the dimmer object registration, using a photometric filter wheel for space junk models development, the telescope complete control system renewal, and stepper motors replacement by DC motors with encoders for better object pinpointing also. It is expected that similar instruments could be used for the GEO and HEO space debris model development, and although less debris density compared with meteoroids, it can still be valuable in some cases, e. g. for objects with perigee at LEO altitudes.

3.2. Routine Work

Unfortunately, during ongoing instrument development a highly qualified employee is needed for purposes of semi-automatic operation control and technical maintenance. Nevertheless, observations themselves are carrying out mostly in the automatic mode according to an individual script as an integral part of the whole ISON schedule. The observation plan directly related to the latest available information about NETOs and continuously adjusted by the KIAM database to meet the demands of the high efficiency of operational time using. Image processing can be made using the APEX software toolkit [4] either semi-manually or automatically, depending on the

Table 1. The K-800 observation statistics in the second half of 2016

Month	Observing Nights	Tracklets	Measurements	New and Re-found Objects
July	5	86	929	0
August	20	812	9580	19
September	11	806	7579	13
October	4	498	4336	4
November	7	676	5784	2
December	12	739	6628	2
Total	**59**	**3617**	**34836**	**40**

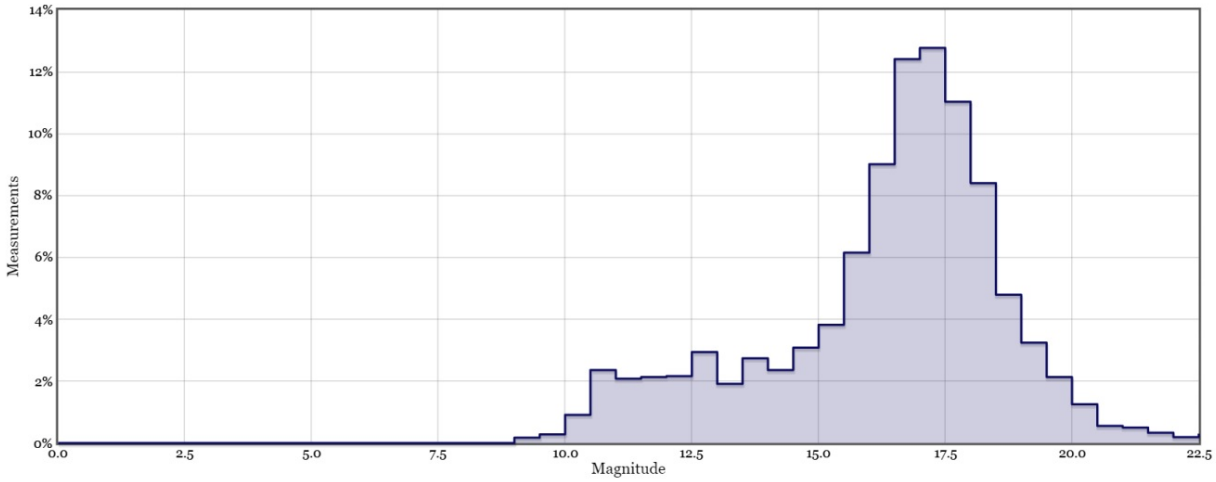

Figure 4. Percentage distribution of magnitude of GEO and HEO objects that have been observed using the K-800 telescope in the second half of 2016

tasks. About one thousand of tracklet apparent places for a single good night of observations are postprocessed in-situ in less than an hour and promptly sent to the KIAM database for orbit determination and conjunction analysis. Semi-annual statistics of the K-800 operation presented in Table 1 and Figure 4.

4. SUMMARY

Existing observational sites can be widely used for purposes of a space debris surveillance network. Even though possible modest weather conditions or obsolete equipment, it could be more beneficial than in individual project, and allows to save resources within interdepartmental or international cooperation.

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