Contribution of ISON and KIAM space debris data center into improvement of awareness on space objects and events in the near-Earth space

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ISON is an open international project developed to be an independent source of data about natural and artificial space objects for scientific and applied purposes.

ISON is a worldwide network coordinated by Keldysh Institute of Applied Mathematics of the Russian Academy of Sciences (KIAM).

ISON is cooperating with 35 optical observatories and observation facilities operating more than 70 telescopes in 15 countries (including emerging spacefaring nations).

ISON promotes enhancing the international collaboration between observatories in developing countries and scientific organization in industrialized countries in the filed of optical observation of natural and man-made celestial objects.
ISON observatories location

- Telescopes with average and large apertures (400mm and above)
- Wide-field average-aperture telescopes (400-700mm)
- Wide-field survey telescopes (220-250mm)
- Small telescopes for follow-up observations (220-300mm)
- Extra wide-filed telescopes (180-192mm)
- Telescopes in production
Network of Roscosmos observation instruments providing measurements to support ASPOS OKP functions by KIAM Space Debris Center

This instrument is providing up to 18500 observations for up to 560 objects per night
Observation tasks currently supported by ISON

• Global surveys of GEO region (full GEO arc coverage is provided)
• Surveys of Molniya-type HEO apogee region over the Northern hemisphere
• Observations of dedicated LEO, HEO, MEO and GEO objects in tasking mode
• Search and observation of objects of new launches, including near-real time provision of measurement data for launch operations
• Follow-up observations of newly discovered objects
Number of observations (in thousands) obtained by ISON for objects on GEO, HEO and MEO orbits
KIAM Space Debris Data Center Overview

• KIAM space debris data center is established in 2003 as a central information node to perform space debris research in RAS and to support ISON development and operations

• Key solving tasks
  • Maintenance of the ISON master database on space objects, related events (launches, fragmentations, re-entires etc.), measurement data and derived products (orbits etc.)
  • Development and implementation of optical observation strategies
  • Daily scheduling of the ISON sensors for routine and special survey and tasking observations of GEO, HEO and MEO regions of the near-Earth space
  • Collecting and processing of the ISON produced optical measurements on objects in the near-Earth space, determination of parameters of orbits and their accuracy estimation for each observed object
  • Evaluation of physical characteristics of observed objects
  • Search and analysis of probable close conjunctions at GEO, HEO and MEO
  • Processing customer’s requests and preparing output products (conjunction assessment messages, raw measurements, orbital data/ephemerides etc.)
Data Center Current Operational Characteristics

- Daily processing up to 90000 optical measurements
- Daily updating orbital data for nearly 2000 high altitude space objects
- Daily conjunction analysis for >50 operational spacecraft, including analysis of motion for co-located GEO active spacecraft operated by non-cooperating entities
- Daily scheduling of 20 survey and 15 tasking sensors
- Scheduling and processing dedicated observations of objects as part of launch operations support (HEO, MEO, GEO)
- Storing original CCD images obtained by ISON instruments
- Required number of personnel for operation – 3 people in a shift
The Center’s Master Database

**Objects and events**
- Master registry of orbital objects
- List of space launches
- List of on-orbit fragmentations
- Archive of external data on objects and events in space

**Sensors**
- Optical instruments properties
- Archive of calibration data
- Obs schedules archive (survey, tasking)
- Archive of data on meteo and sky conditions

**Observations and derived data**
- Raw measurements archive
- Processed measurements archive
- Archive of orbits
- Archive of estimated physical properties of objects
- Conjunctions archive

**Customer’s data**
- Archive of data on customer’s objects
- Customer requests archive
- Output reports archive
Simplified operational flow chart of measurement processing and conjunction analysis

1. **IOD and track association**
   - **Success?**
     - **YES**
     - **OD and object properties est.**
     - **Conjunction analysis**
     - **Conjunctions archive**
     - **UTC archive analysis**
     - **Customers requests**
     - **Requests analysis**
     - **Observations scheduling (survey, tasking)**
     - **Schedule to facilities**
   - **NO**
     - **Measurements from facilities**
     - **Reporting to customers**

2. **Orbits and physical properties archive**
   - **New object found?**
     - **YES**
     - **Conjunction analysis**
     - **Conjunctions archive**
     - **UTC archive analysis**
     - **Customers requests**
     - **Requests analysis**
     - **Observations scheduling (survey, tasking)**
     - **Schedule to facilities**
   - **NO**
     - **Success?**
       - **YES**
         - **OD and object properties est.**
         - **Conjunction analysis**
         - **Conjunctions archive**
         - **UTC archive analysis**
         - **Customers requests**
         - **Requests analysis**
         - **Observations scheduling (survey, tasking)**
         - **Schedule to facilities**
       - **NO**
         - **Measurements from facilities**
         - **Reporting to customers**
34% of objects tracked by ISON in GEO region (defined by following constraints: period between 1100 and 1800 min, eccentricity is less than 0.3, inclination is less than 30°) have orbital data derived only from ISON measurements.
13.6% of active objects in GEO region have orbital data derived only from ISON measurements
63% of all active GEO spacecraft have been observed by ISON more often than once per two days in average.
41% of space debris objects in GEO region have orbital data derived only from ISON measurements.
Number of nights with ISON observations for non-active GEO objects in 2014

- Faint, HAMR, fast drifters
**Orbit determination and analysis**

**List of tracks associated with the object**

**Obtained orbital solution**
Orbit determination and analysis (2)

Results of OD (state vector, estimation of errors)

RIC errors for the OD arc

Along-track residuals
Orbit determination and analysis (3)
Conjunction analysis

• Only orbits numerically derived from ISON optical measurements are used for analysis of conjunctions (including orbit determinations for even those functioning spacecraft for which orbital data are provided by operators).

• If required, additional measurements have been collected in order to improve orbit for both objects in conjunction. Observation sessions have scheduling so that to obtain the best possible accuracy of prediction for the conjunction moment.

• Screening for all conjunctions satisfying given criteria in miss-distance (total, in-track and radial).

• Control of reliability of the result (by means of calculation of ratio of appropriate miss-distance component and estimation of predicted state vector error component).

• Standard conjunction assessment message (in XML format) is sent to a customer.
Conjunction analysis (2)

EXPRESS-2 – EUTE 28B case

Analysis based on orbital solutions before EUTE 28B manoeuvre on Aug 5

<table>
<thead>
<tr>
<th>Баз. (ВВС США)</th>
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Closest conjunction on Aug 7

Closest conjunction on Aug 6
Conjunction analysis (3)

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<td>Miss-distance components, km</td>
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<td>J2000 state vector components for each object</td>
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Estimations of appropriate position/velocity components in RIC for each object
Customers of the KIAM space debris data center

• ASPOS OKP - Automated system of warning on dangerous situations in space developed and maintained by ROSCOSMOS

• Industry entities
  • Vimpel Interstate Corporation
  • Information Satellite Systems – Reshetnev Company
  • Gazprom Space Systems
  • Lavochkin Research and Production Association

• RAS research institutes
Conclusion

• ISON network is providing significant contribution into awareness on objects and events in the near-Earth space

• Nearly 1800 objects in GEO region and nearly 2300 objects at HEO and MEO orbits (orbital period more than 200 min) are observed by ISON in 2014

• At present ISON provides full GEO coverage with revisiting time less than 2 days for 61% of all active GEO spacecraft

• ISON is capable to provide near-real time observations as a part of launch support operations and in a case of expected conjunction between non-cooperative objects in GEO

• ISON project is open for cooperation with all nations
Conclusion (2)

• KIAM Space Debris Data Center is a modern low-cost solution to maintain information awareness on space objects and events at high altitude orbit (MEO, HEO, GEO)

• Using ISON observations the Center’s Master Database currently keeps records on more than 4100 high altitude objects, including 1300+ space debris objects in GEO that is 41% more than in any other available source

• The Center provides full support to the operation of ISON

• Orbit determination and conjunction analysis is performing on a routine daily basis

• The Center is capable to fulfill requests of different customers launching and operating spacecraft at high near-Earth orbits as well as of scientific users studying space debris problem