KIAM space debris data center for processing and analysis of information on space debris objects obtained by the ISON network

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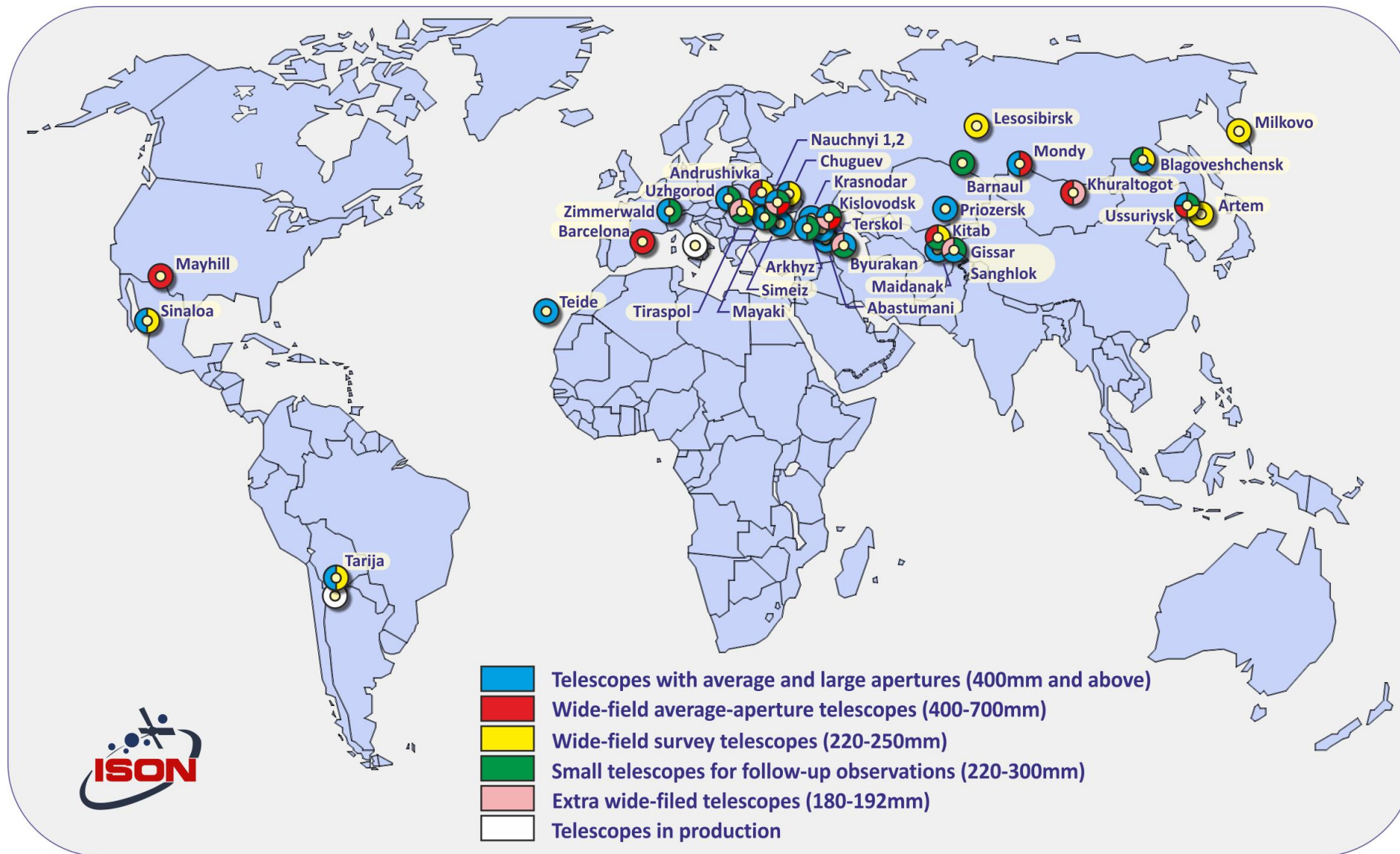*Keldysh Institute of Applied Mathematics RAS*

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International Scientific Optical Network (ISON)

- 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 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

Legend:

- ■ (blue) Telescopes with average and large apertures (400mm and above)
- ■ (red) Wide-field average-aperture telescopes (400-700mm)
- ■ (yellow) Wide-field survey telescopes (220-250mm)
- ■ (green) Small telescopes for follow-up observations (220-300mm)
- ■ (pink) Extra wide-filed telescopes (180-192mm)
- □ (white) Telescopes in production

Locations labeled: Lesosibirsk, Milkovo, Mondy, Blagoveshchensk, Nauchnyi 1,2, Chuguev, Krasnodar, Barnaul, Khuraltogot, Andrushivka, Kislovodsk, Priozersk, Artem, Uzhgorod, Terskol, Ussuriysk, Zimmerwald, Kitab, Barcelona, Gissar, Arkhyz, Byurakan, Sanghlok, Simeiz, Maidanak, Mayhill, Tiraspol, Mayaki, Abastumani, Sinaloa, Teide, Tarija

Network of Roscosomos observatories providing measurements to support ASPOS OKP functions by KIAM Space Debris Center
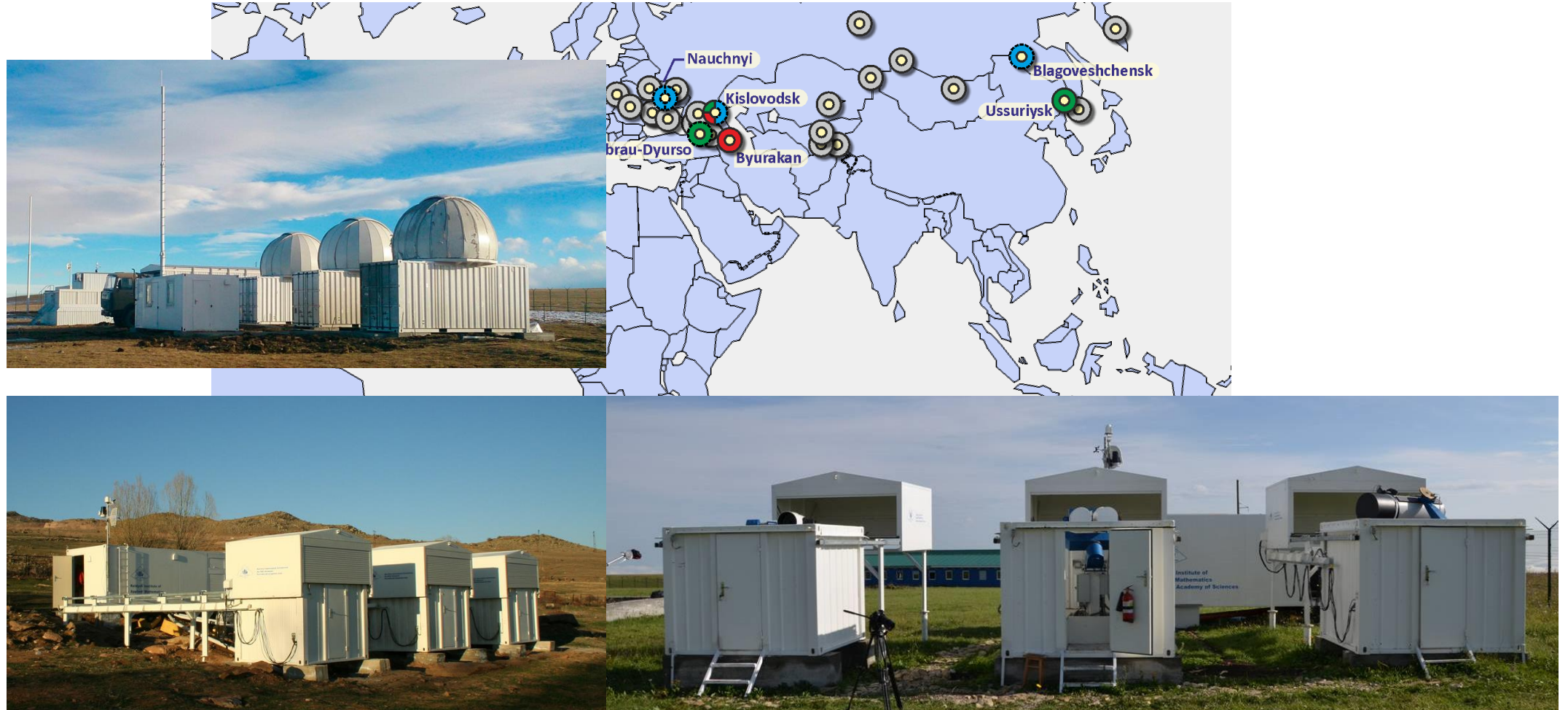
KIAM Space Debris Data Center Overview

- KIAM space debris data center is established in 2003 as a central information node for 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 request and preparing output products (conjunction assessment messages, raw measurements, orbital parameters etc.)

The Center's Master Database

Objects and events	Sensors	Observations and derived data	Customer's data
Master registry of orbital objects	Optical instruments properties	Raw measurements archive	Archive of data on customer's objects
List of space launches	Archive of calibration data	Processed measurements archive	Customer requests archive
List of on-orbit fragmentations	Obs schedules archive (survey, tasking)	Archive of orbits	Output reports archive
Archive of external data on objects and events in space	Archive of data on meteo and sky conditions	Archive of estimated physical properties of objects	
		Conjunctions archive	

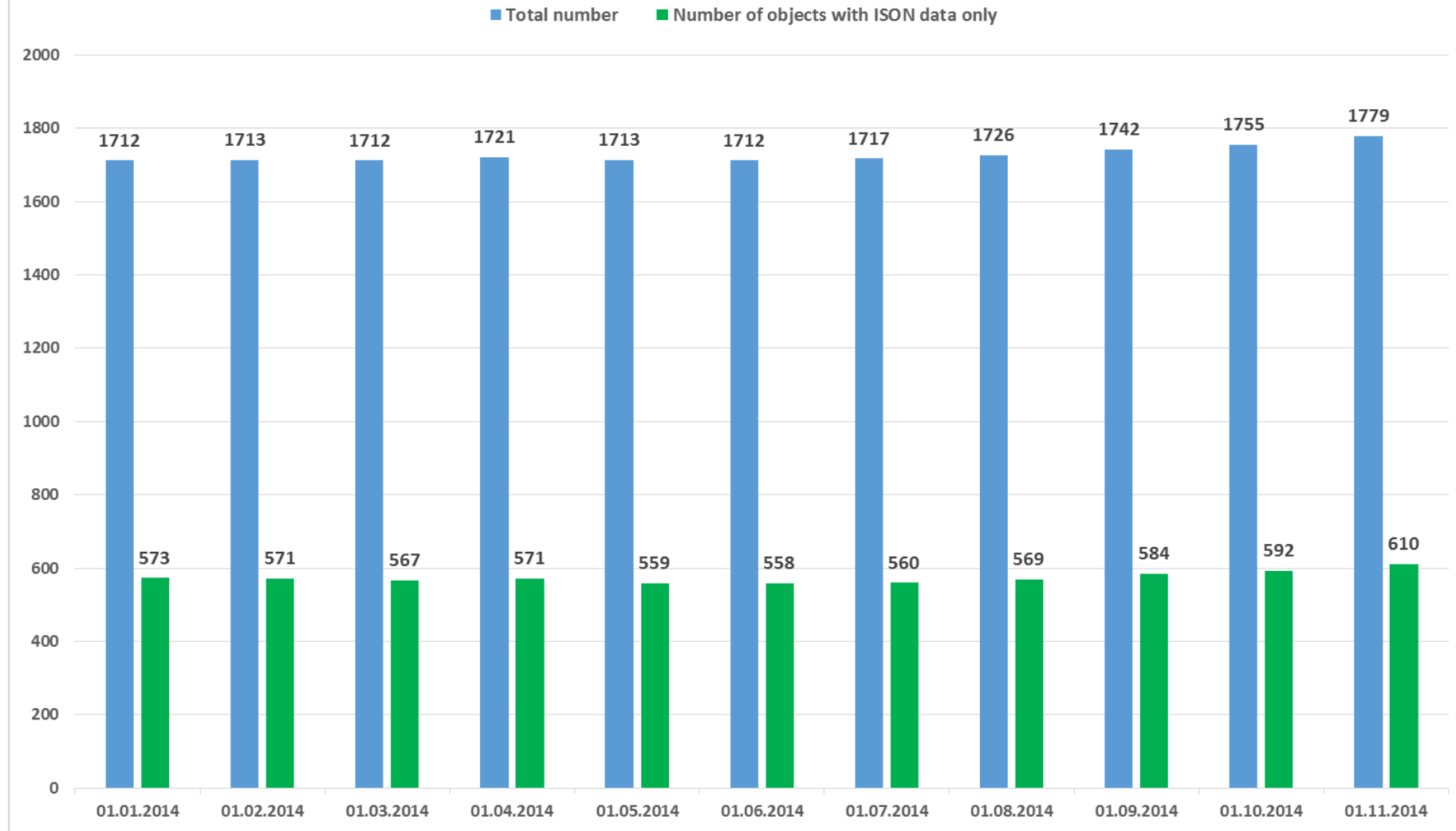Number of meansurements of ISON project from 2003 to 2014
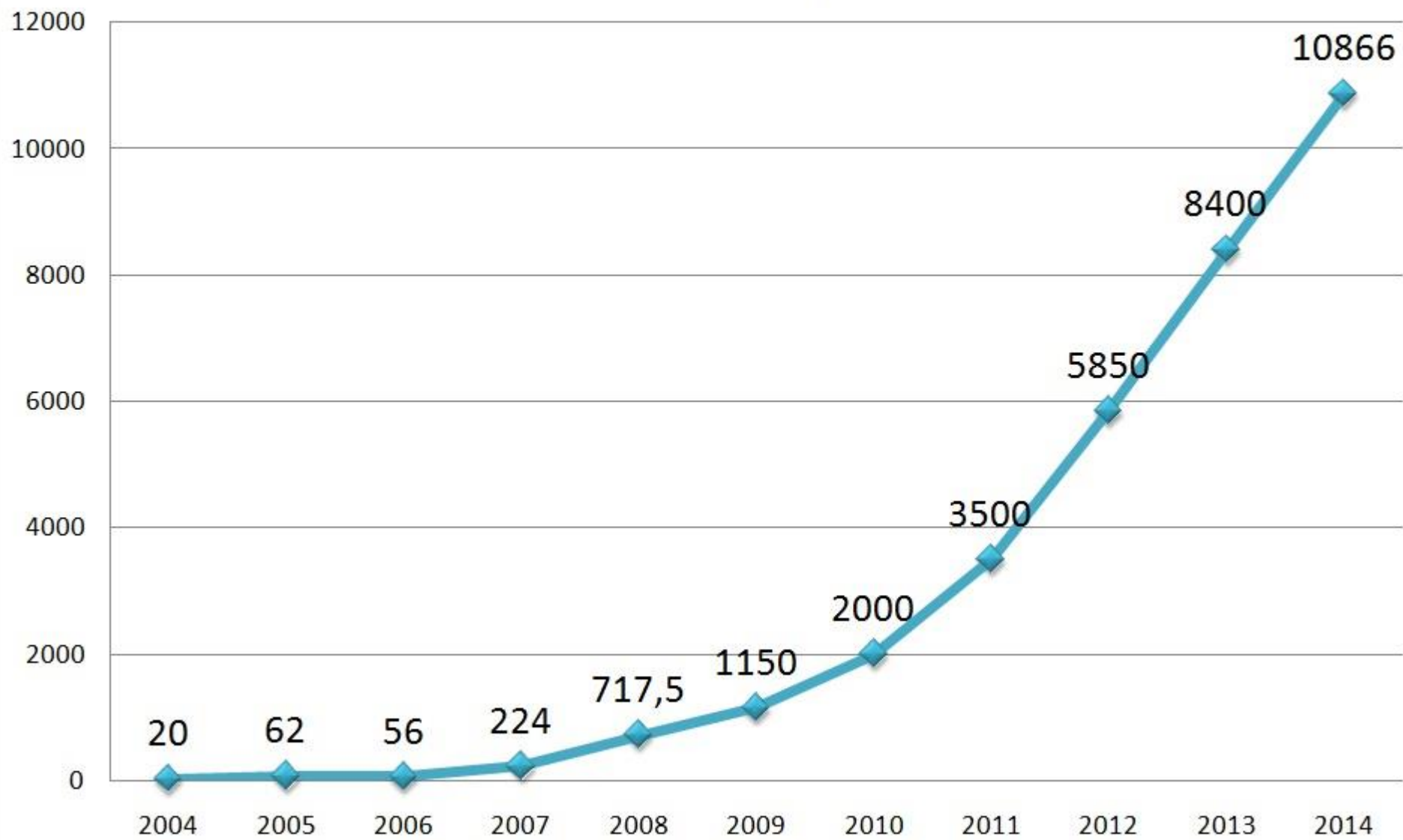
Simplified operational flow of measurement processing and conjunction analysis
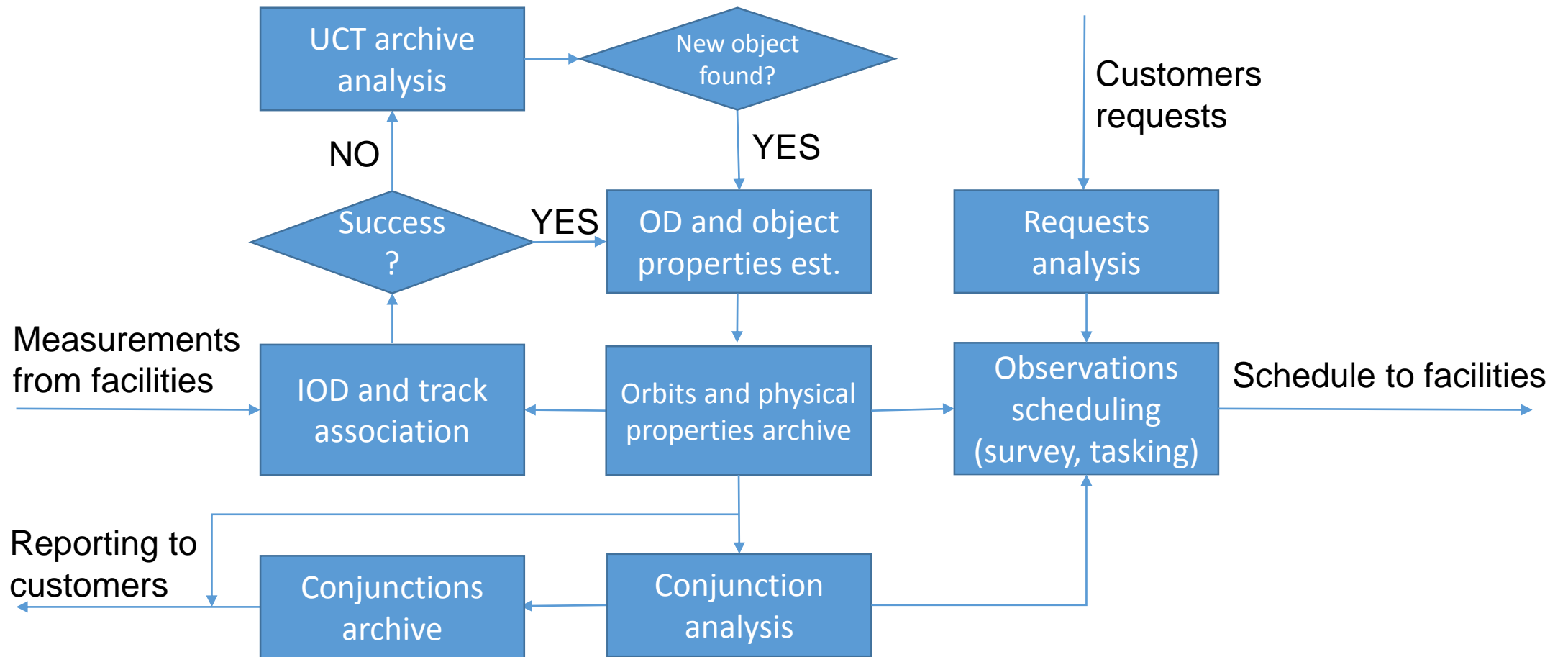
# Data Center Current Operational Characteristics

- 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 20 survey and 15 tasking sensors
- Scheduling and processing dedicated observations of objects as part of on-orbit operations of a new launch (LEO, HEO, GEO)
- Storing original CCD images obtained by ISON instruments
- Required number of personnel for operation – 3 people in a shift

KIAM Master Database.
**Number of GEO objects having actual orbital data**

■ Total number   ■ Number of objects with ISON data only

Date	Total number	Number of objects with ISON data only
01.01.2014	1712	573
01.02.2014	1713	571
01.03.2014	1712	567
01.04.2014	1721	571
01.05.2014	1713	559
01.06.2014	1712	558
01.07.2014	1717	560
01.08.2014	1726	569
01.09.2014	1742	584
01.10.2014	1755	592
01.11.2014	1779	610

34% of objects tracked by ISON in GEO region have orbital data derived only from ISON measurements

KIAM Master Database.
Number of active GEO objects

■ Total number   ■ Number of objects with ISON data only
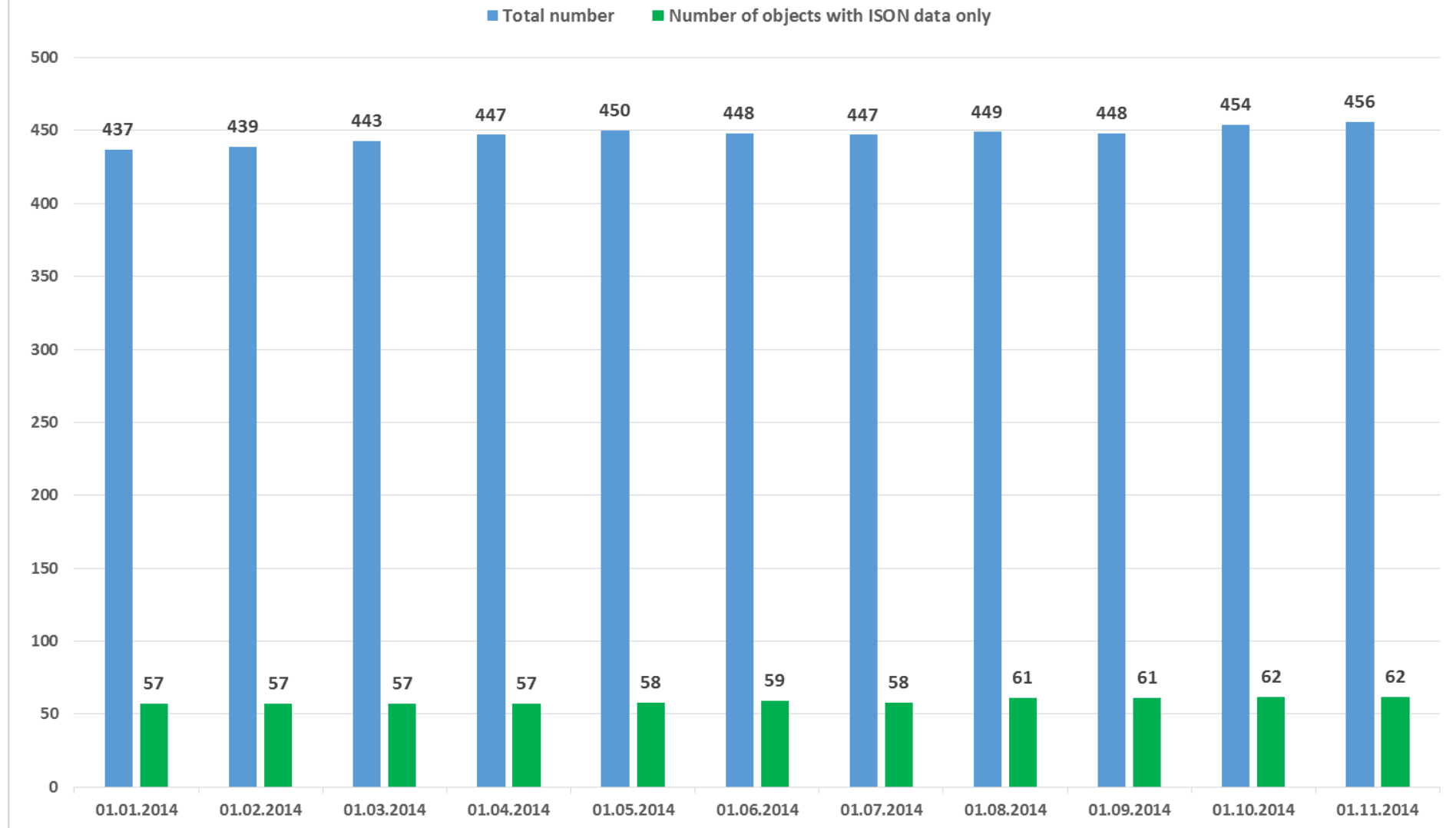
13.6% of active objects in GEO region have orbital data derived only from ISON measurements

KIAM Master Database.
Number of space debris objects in GEO having actual orbital data
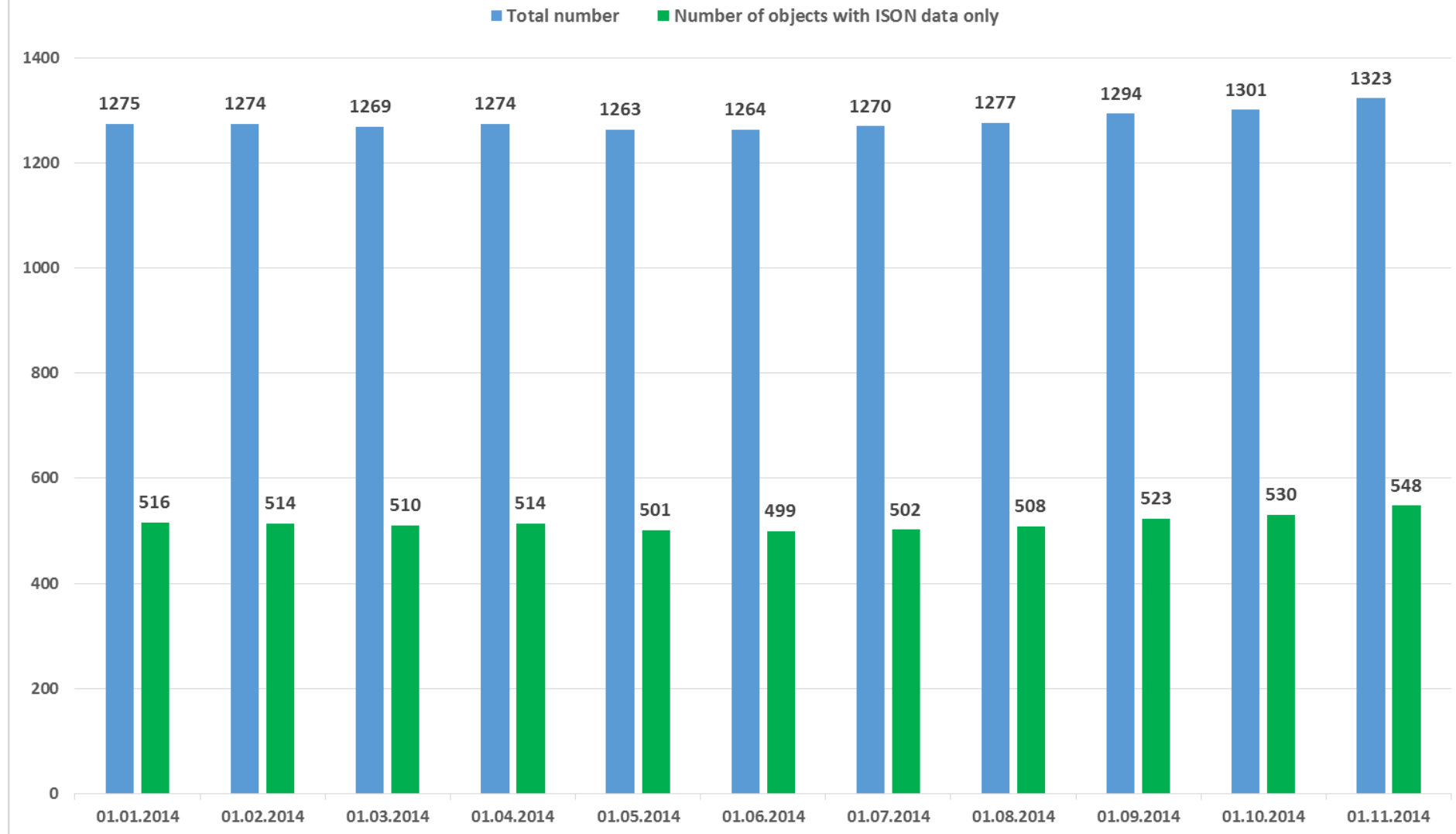
41% of space debris objects in GEO region have orbital data derived only from ISON measurements

Orbit determination

- Numerical propagator taking into account following perturbations (tunable for specific orbit):
  - ➢ Earth gravity (selection of a model possible)
  - ➢ Moon gravity (DE405)
  - ➢ Sun gravity (DE405)
  - ➢ atmosphere (selection of a model possible)
  - ➢ SRP (cylinder or conical Earth shadow)
- Estimation of 6, 7 or 8 parameters (state vector in combination with ballistic coefficient and/or SRP coefficient – decision is making automatically on what combination would be the most appropriate in particular case of OD) + covariance
- Possibility of setting a-priory values for certain orbital parameters
- Automatic selection of measurement arc where motion can be considered as 'passive'
- Automatic filtering of anomalous measurements
- Tools for graphical analysis of results
- Simple criterion (max in-track error within one orbit) to compare quality of different solutions

Orbit determination (2)

Obtained orbital solution

List of tracks associated with the object

Orbit determination (3)

Results of OD (state vector, estimation of errors)

RIC errors for the OD arc

Along-track residuals
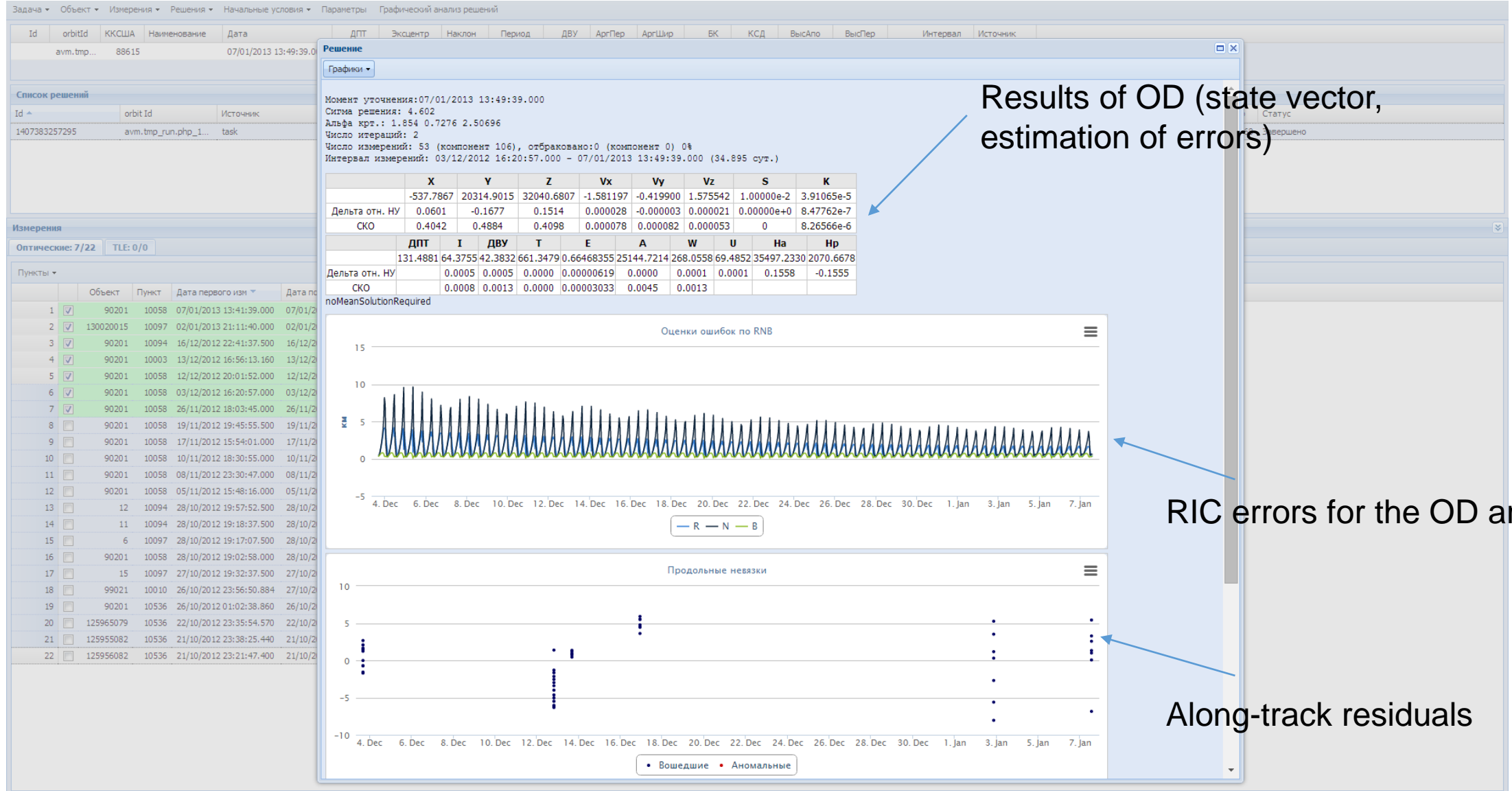
Orbit determination (4)
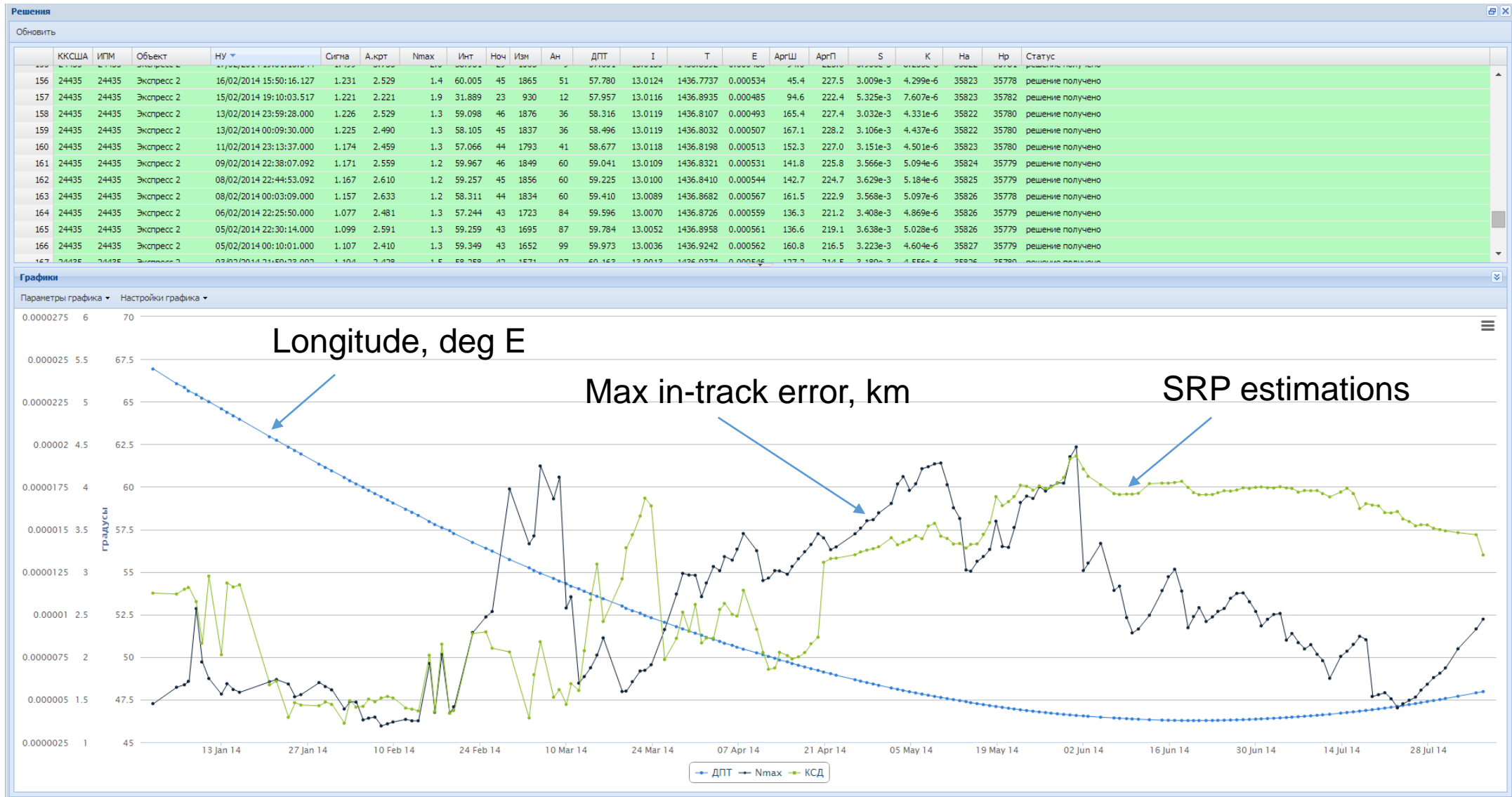
Conjunction analysis

- Only orbits numerically derived from ISON optical measurements are using (including orbit determinations for even those functioning spacecraft for which orbital data are provided by operators)

- If required, additional measurements are collected in order to improve orbit for both objects in conjunction

- 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 ratio of appropriate miss-distance component and estimation of predicted state vector error component)

- Standard conjunction assessment message (in XML format) is sending to a customer

Conjunction analysis (2)

EXPRESS-2 – EUTE 28B case

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

ИПМ им. М. В. Келдыша РАН

Расчет опасных сближений

Интервал поиска: 01/08/2014 00:00:00 - 10/08/2014 00:00:00

Closest conjunction on Aug 7

	Баз.(ВВС США)	Базовый объект	Сбл.(ВВС США)	Сближающийся объект	Dmin	dV	Дата сближения	Пр.баз.	Пр.сбл.	Статус
	24435	Экспресс 2	33460	EUTE 28B (EUTE W2M)	49.478	0.707	06/08/2014 02:07:14.778	0.149	2.158	
	24435	Экспресс 2	33460	EUTE 28B (EUTE W2M)	12.753	0.707	06/08/2014 14:05:10.717	0.647	2.657	
	24435	Экспресс 2	33460	EUTE 28B (EUTE W2M)	4.140	0.707	07/08/2014 02:03:04.098	1.146	3.155	
	24435	Экспресс 2	33460	EUTE 28B (EUTE W2M)	43.024	0.707	07/08/2014 14:00:59.087	1.644	3.654	
	24435	Экспресс 2	33460	EUTE 28B (EUTE W2M)	42.108	0.707	08/08/2014 01:58:52.352	2.143	4.152	

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

ИПМ им. М. В. Келдыша РАН

Расчет опасных сближений

Интервал поиска: 01/08/2014 00:00:00 - 10/08/2014 00:00:00

Closest conjunction on Aug 6

	Баз.(ВВС США)	Базовый объект	Сбл.(ВВС США)	Сближающийся объект	Dmin	dV	Дата сближения	Пр.баз.	Пр.сбл.	Статус
	24435	Экспресс 2	33460	EUTE 28B (EUTE W2M)	42.012	0.709	05/08/2014 14:09:52.660	-0.349	-0.350	
	24435	Экспресс 2	33460	EUTE 28B (EUTE W2M)	34.912	0.708	06/08/2014 02:07:47.281	0.149	0.149	
	24435	Экспресс 2	33460	EUTE 28B (EUTE W2M)	2.632	0.709	06/08/2014 14:05:41.582	0.648	0.647	
	24435	Экспресс 2	33460	EUTE 28B (EUTE W2M)	10.568	0.708	07/08/2014 02:03:35.935	1.146	1.146	
	24435	Экспресс 2	33460	EUTE 28B (EUTE W2M)	44.370	0.709	07/08/2014 14:01:29.533	1.645	1.644	

Conjunction analysis (3)

Параметры сближения	
Защищаемый объект	24435 / Экспресс 2 (24435,1996-058А)
Сближающийся объект	33460 / EUTE 28B (EUTE W2M) (33460,2008-065В)
Мин. расстояние, км	4.1395
Модуль отн. скорости, км/с	0.706657
Дата	07/08/2014 02:03:04.098
Вероятность	1.866е-14

Conjunction parameters

Параметры защищаемого объекта		Параметры сближающегося объекта	
Официальное наименование	Экспресс 2	Официальное наименование	EUTE 28B (EUTE W2M)
Номер в кат. КК ВВС США	24435	Номер в кат. КК ВВС США	33460
Номер в кат. ИПМ	24435	Номер в кат. ИПМ	33460
Межд. обозначение	1996-058А	Межд. обозначение	2008-065В
Высота на момент сближения, км	35804.2393	Высота на момент сближения, км	35802.2265
Широта на момент сближения, °	0.0552	Широта на момент сближения, °	0.0551
Долгота на момент сближения, °	48.1170	Долгота на момент сближения, °	48.1219
Азимут напр. на второй объект на момент сближения, °	83.4257	Азимут напр. на второй объект на момент сближения, °	83.3756
Угол места напр. на второй объект на момент сближения, °	-0.0116	Угол места напр. на второй объект на момент сближения, °	0.0116
Эпоха НУ	05/08/2014 22:33:03.135	Эпоха НУ	03/08/2014 22:19:44.576

J2000 state vector components for each object

Вектор положения защищаемого объекта на момент сближения в СК J2000		Вектор положения сближающегося объекта на момент сближения в СК J2000	
X, км	34880.1331	X, км	34876.4484
Y, км	23721.9102	Y, км	23723.7489
Z, км	-8.3613	Z, км	-7.9400
Vx, км/с	-1.682224	Vx, км/с	-1.728501
Vy, км/с	2.473325	Vy, км/с	2.541376
Vz, км/с	0.704995	Vz, км/с	0.003146

Орбита защищаемого объекта на момент сближения в СК J2000		Орбита сближающегося объекта на момент сближения в СК J2000	
Большая полуось, км	42159.0618	Большая полуось, км	42164.3520
Наклонение, °	3.2620	Наклонение, °	0.0596
Эксцентриситет	0.00055845	Эксцентриситет	0.00038648
Аргумент перигея, °	171.9324	Аргумент перигея, °	177.6363
Аргумент широты, °	359.9505	Аргумент широты, °	349.5813
ДВУ, °	34.2677	ДВУ, °	44.6431
Высота апогея, км	35804.4918	Высота апогея, км	35802.3862
Высота перигея, км	35757.4041	Высота перигея, км	35770.0458
Период, мин.	1435.8072	Период, мин.	1436.0775

Estimations of appropriate position/velocity components in RIC for each object

Miss-distance components, km

Проекция вектора отн. положения на момент макс. сближения в ОСК связанной с защищаемым объектом		Проекция вектора отн. положения на момент макс. сближения в ОСК связанной со сближающимся объектом	
		R, км	2.0126
R, км	-2.0129	N, км	3.5932
N, км	-3.5933	B, км	-0.4172
B, км	-0.4145	Vr, км/с	0.706657
Vr, км/с	0.701932	Vn, км/с	-0.000143
Vn, км/с	0.000143	Vb, км/с	-0.000001
Vb, км/с	0.080907		

СКО вектора состояния в проекции на ОСК защищаемого объекта					
R, км	N, км	B, км	Vr, км/с	Vn, км/с	Vb, км/с
0.663676	1.16294	0.161446	8.68094е-5	4.81733е-5	6.01823е-6

СКО вектора состояния в проекции на ОСК сближающегося объекта					
R, км	N, км	B, км	Vr, км/с	Vn, км/с	Vb, км/с
0.373333	0.533021	0.245401	4.8069е-5	2.72011е-5	7.12066е-6

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

- KIAM Space Debris Data Center is a modern low-cost solution for to maintain up-to-date information awareness on space objects and events at high altitude orbit

- The Center provides full support to the operation of ISON and open for cooperation with all nations

- Orbit determination and conjunction analysis are performing on a routine daily bases

- 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

- Currently The Center's Master Database keeps records on 1300+ space debris objects in GEO that is 41% more that in any other available source