



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

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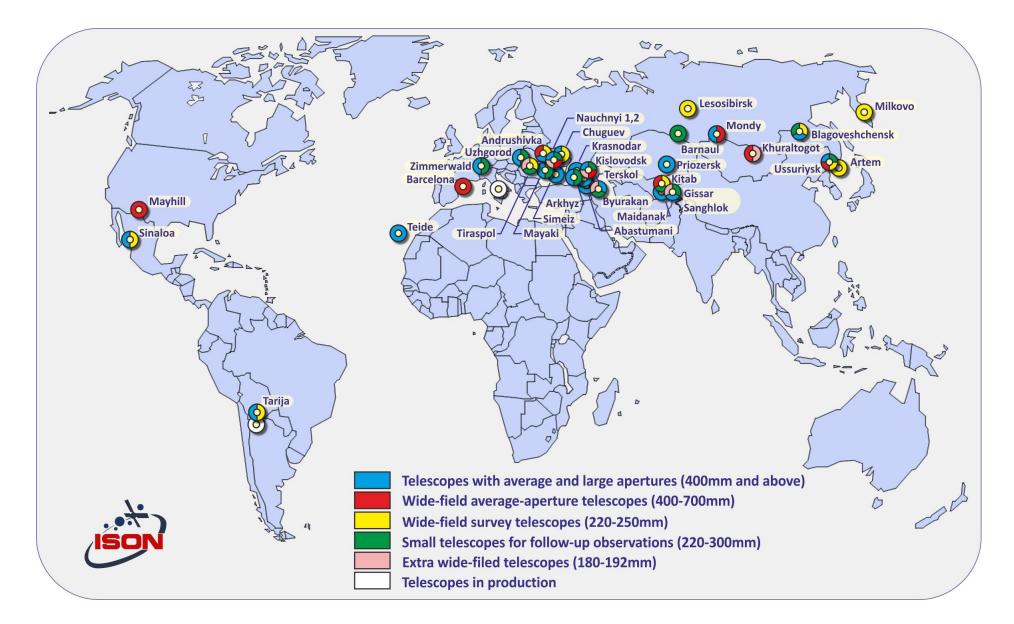
Keldysh Institute of Applied Mathematics RAS

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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



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



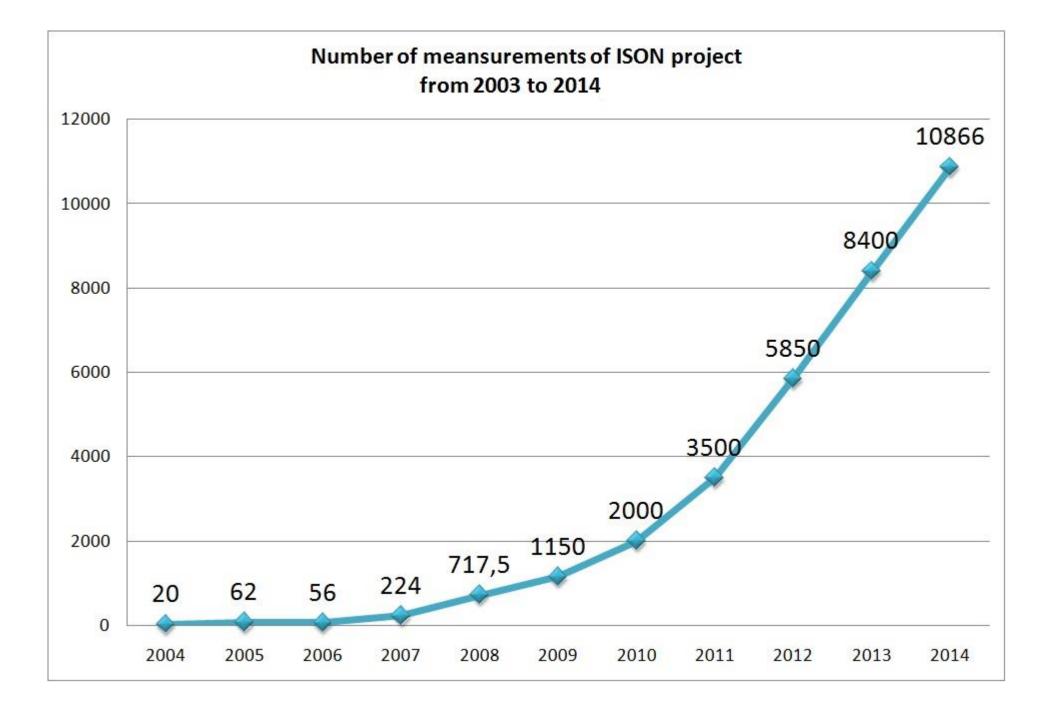


KIAM Space Debris Data Center Overview

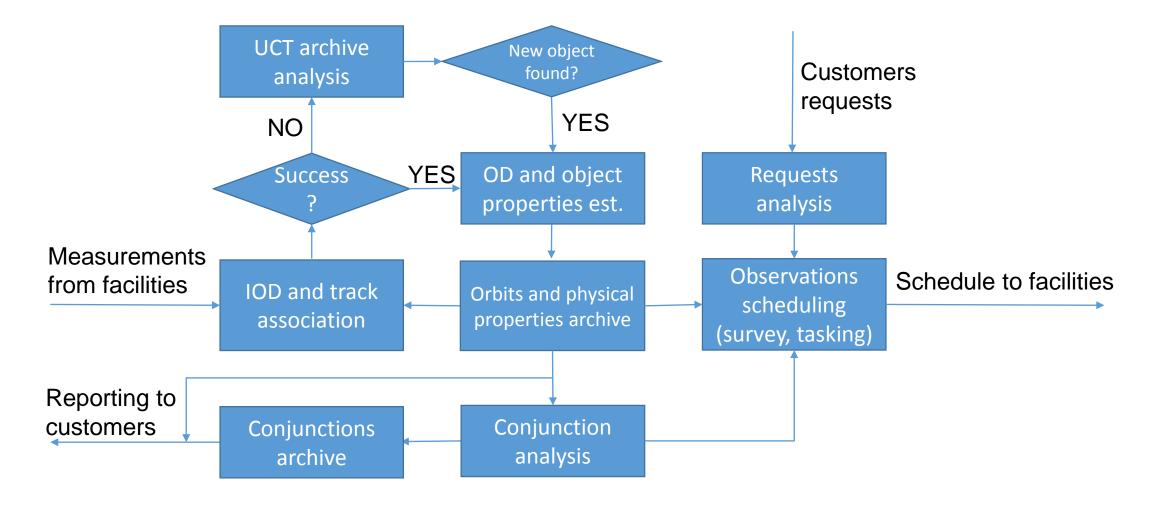
- KIAM space debris data center is established in 2003 as a central information node for space debris research in RAS and to support ISON development and operations
- Key solving tasks
 - Maintenance of the ISON master database on space objects, related events (launches, fragmentations, re-entires etc.), 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	

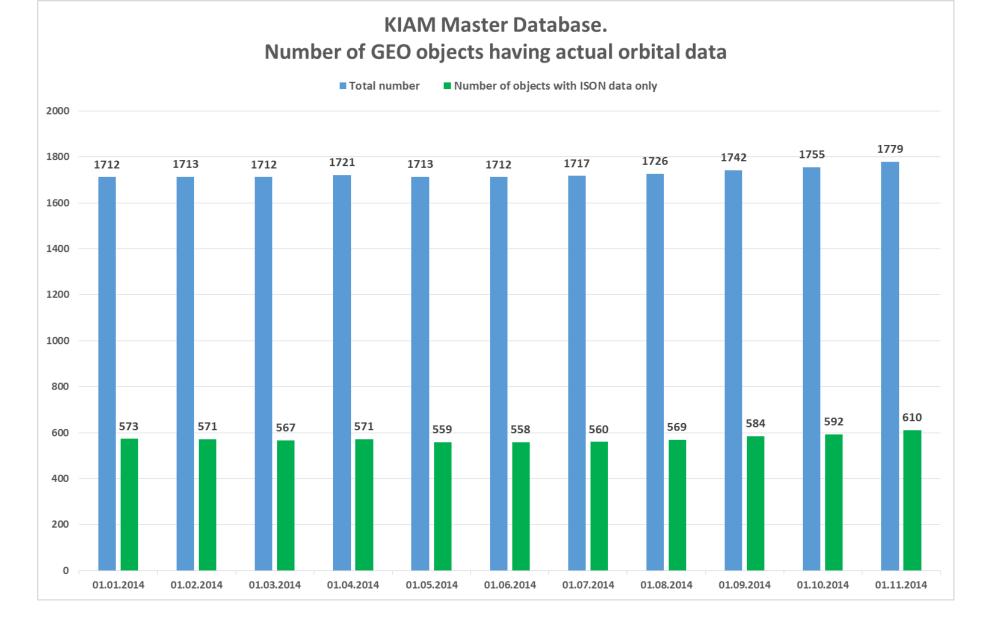


Simplified operational flow of measurement processing and conjunction analysis

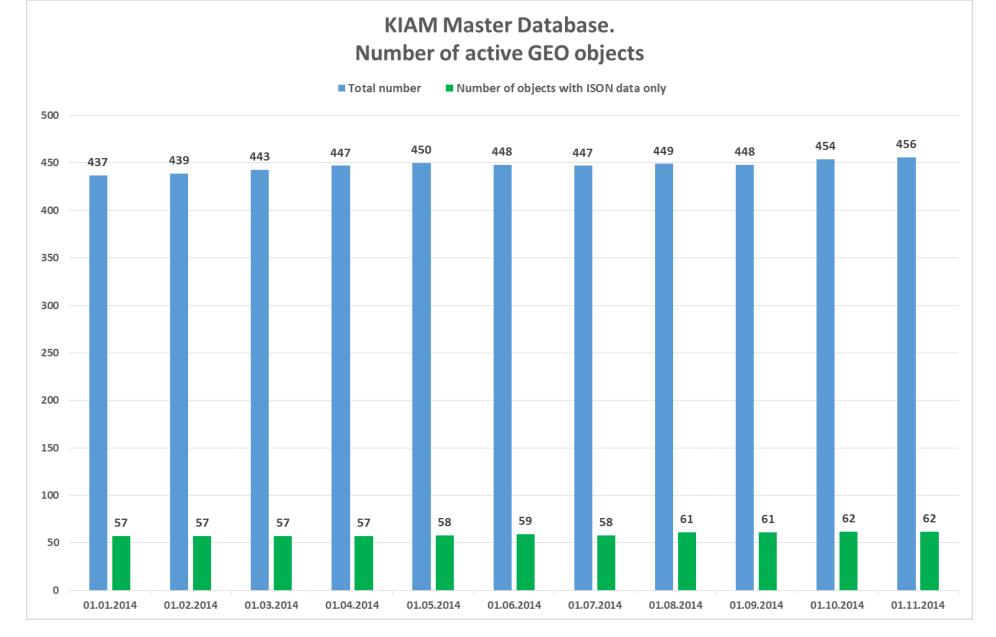


Data Center Current Operational Characteristics

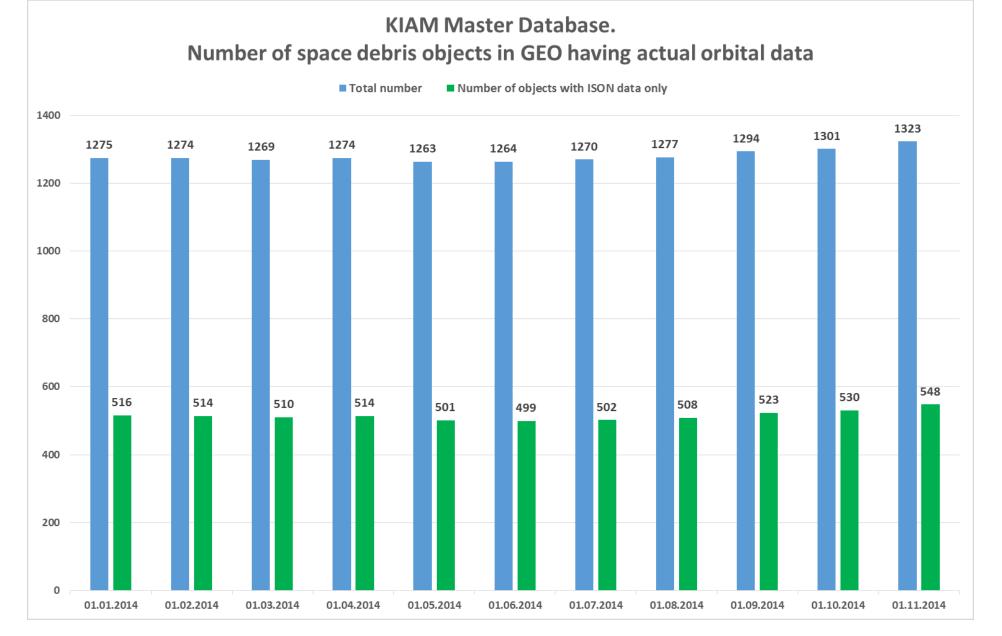
- Daily processing up to 90000 optical measurements
- Daily updating orbital data for nearly 2000 high altitude space objects
- Daily conjunction analysis for >50 operational spacecraft, including analysis of motion for co-located GEO active spacecraft operated by non-cooperating entities
- Daily scheduling 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



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



13.6% of active objects in GEO region have orbital data derived only from ISON measurements



41% of space debris objects in GEO region have orbital data derived only from ISON measurements

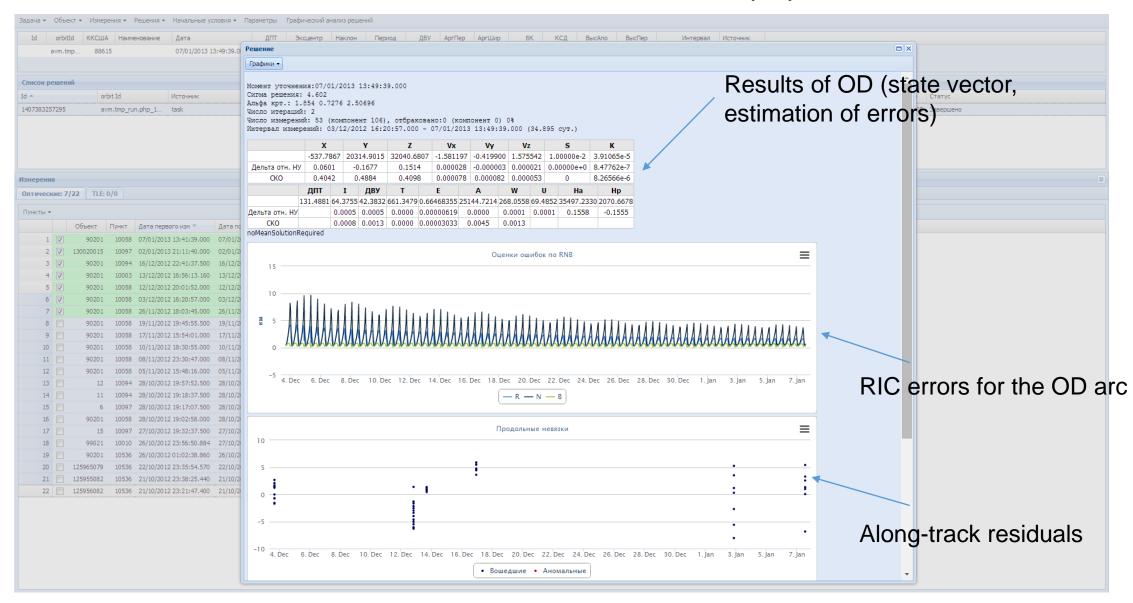
Orbit determination

- 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)

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Orbit determination (3)



Orbit determination (4)

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→ ДПТ → Nmax → KCД

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 вм. М	f. B. Келдыша РАН			Расчет опасных сближе	ений		Closes	st conj	unctio	n on Aug 7
			Инте	рвал понска: 01/08/2014 00:00:00 - 10/	/08/2014 00:00:00			-		-
	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 12 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 вы. В	 В. Келдыша РАН 		Инте	Расчет опасных сближ рвал понска: 01/08/2014 00:00:00 - 10			Close	st conj	junctio	on on A	ug 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)

		Π	араметры сближения	
3	ашишаемый объект		24435 / Экспресс 2 (24435,1996-058A)	
	ближающийся объект		33460 / EUTE 28B (EUTE W2M) (33460,2008-065B)	
	Лин. расстояние, км			
	Годуль отн. скорости, км/с		4.1395 0.706657 Conjunction parameters	
	Iara		07/08/2014 02:03:04.098	
	ероятность		1.866e-14	
	π		Параметры сближающегося объекта	
	Параметры защищаем Официальное наименование	Экспресс 2	Официальное наименование ЕUTE 28В (EUTE W2M)	
	Іомер в кат. КК ВВС США	24435		
	Іомер в кат. ИПМ	24435	Номер в кат. КК ВВС США 33460 Номер в кат. ИПМ 33460 2000 state V Межд. обозначение 2008-065В	lactor
	Лежд. обозначение	1996-058A		CUUI
	ысота на момент сближения, км	35804.2393	ножд околастино Высота на можент сближения км	
	Широта на момент сближения, «	0.0552	Высота на момент сближения, км 35802 2265 Широта на момент сближения, ° 0.055 Components	
	Парота на момент солижения, °	48.1170	Долгота на момент сближения, ° 48.1219	
	изимут напр. на второй объект на момент сближения, °	83.4257	Долгота на момент сближения, ° 48.1219 Азимут напр. на второй объект на момент сближения, ° 83.37 Or each obje	ot
	гол места напр. на второй объект на момент солижения, °	-0.0116	Угол места напр. на второй объект на момент сближения, ° 0.0116	6 1
	тол места напр. на второй объект на момент солижения, поха НУ	05/08/2014 22:33:03.135	Эпоха НУ 03/08/2014 22:19:44.576	
6	поха ну	03/08/2014 22.33.03.133	Siloxa ny 03/08/2014 22.19:44.370	
	Вектор положения защищаемого объекта	на момент сближения в СК Ј2000	Вектор положения сближающегося объекта на момент сближения в СК J2000	
	, км	34880.1331	Х, КМ 34876.4484	
	′, КМ	23721.9102	У, КМ 23723.7489	
(2	, KM	-8.3613	Z, KM -7.9400	
	/х, км/с	-1.682224	Vx, км/с -1.728501	
	<u>v, км/с</u>	2.473325	Vy, км/с 2.541376	
No. 1	Z, KM/C	0.704995	Vz, km/c 0.003146	
	Орбита защишаемого объекта на мо	мент сближения в СК J2000	Орбита сближающегеся объекта на момент сближения в СК J2000	
stions a	Орбита защищаемого объекта на мо fsuappropriate position/	V00001t42159.0618	Большая полуось, км 42164.3520	
	appropriate position/	VGIUGIL Y _{3.2620}		nononto
		0.00055845	Наклонение, ° Missidistance con	iponents
onents i	Rec for each object	171.9324	Аргумент перигея, ° 177.6363	· ·
	ргумент широты, °	359.9505	Аргумент широты, ° 349.5813	
	BY, °	34.2677	ДВУ, ° 44.6431	
	ысота апогея, км	35804.4918	Высота апогея, км 35802.3862	
	ысота перигея, км	35757.4041	Высота перигея, км 35770.0458	
	Іериод, мин.	1435.8072	Период, мин. 1436.0775	
		1 0.077		
	Проекция вектора отн. положения на момент макс. с			
	объектом		R, км (2.0126)	
	, KM	-2.0129	N, KM (3.5932)	
	I, KM	-3.5933	B, KM -0.4172	
	, KN	-0.4145	Vr, KM/C 0.706657	
	r, KM/c	0.701932	Vn, KM/C -0.000143	
	/n, KM/C	0.000143	Vb, km/c -0.000001	
	′b, км/с	0.080907	· · ·	
		0.007.01772	CKO portona corroquing p upoortinu ua OCK cô juricatorio con obtourta	
	СКО вектора состояния в проекции на ОСК защищаемов		СКО вектора состояния в проекции на ОСК сближающегося объекта	
	СКО вектора состояния в проекции на ОСК защищаемог R, км N, км B, км Vr, к 0.663676 1.16294 0.161446 8.680	м/с Vn, км/с Vb, км/с	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 4.8069e-5 2.72011e-5 7.12066e-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