H5

地上光学観測装置を利用した衝突回避運用の可能性

Collision Avoidance Using Ground Optical Observation Data

○柳沢俊史、黒崎裕久、向井達也（JAXA）
○Toshifumi Yanagisawa, Hirohisa Kurosaki and Tatsuya Mukai（JAXA）

宇宙デブリによる低軌道環境の悪化に伴い運用中の衛星に対するリスクも増加する傾向にある。JAXA 衛星においては、米国国防総省戦略軍統合宇宙運用センター（JSpOC）からの接近警報をもとに回避運用をすることにしているが、当該警報の情報のみでは回避運用を実施するか否かの判断が非常に難しくなっている。本講演ではJAXA衛星に接近する宇宙デブリの精度良い軌道決定のための一手法として光学観測装置を利用した軌道決定手法を提案する。光学観測データは背景の天体の位置情報から非常に高い精度で観測対象の位置を決定することが可能であり、軌道決定精度向上に大きく貢献すると思わる。

The effectiveness of the ground optical observation for the collision avoidances were investigated using STK and ODTK software. The simulations showed that propagated errors of the orbital determination calculated with a few passes taken at two separate sites were small enough to decide the maneuver properly. The ground optical observation will contribute the efficient collision avoidances at the low earth orbits in the near future.

7th Debris Workshop in Chofu

Collision Avoidance Using Ground Optical Observation Data

Japan Aerospace Exploration Agency(JAXA)

T.Yanagisawa, H. Kurosaki, T. Mukai

1

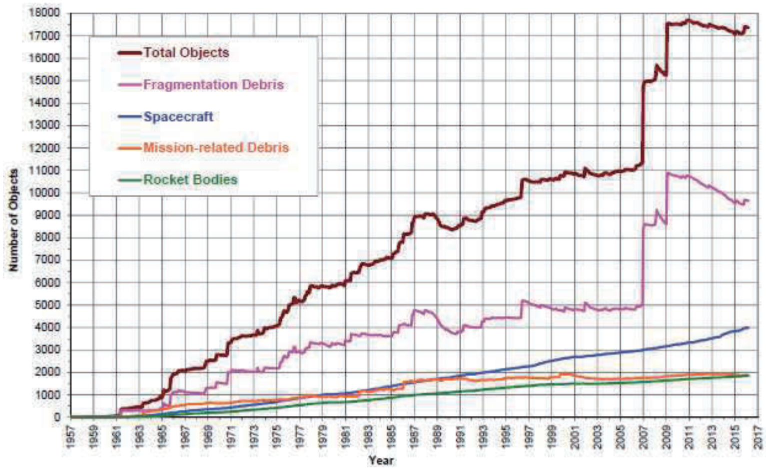
Abstract

The effectiveness of the ground optical observation for the collision avoidances were investigated using STK and ODTK software. The simulations showed that propagated errors of the orbital determination calculated with a few passes taken at two separate sites were small enough to decide the maneuver properly. The ground optical observation will contribute the efficient collision avoidances at the low earth orbits in the near future.

2

Background

Monthly Number of Objects in Earth Orbit by Object Type



- Space environment is deteriorating recently. (ASAT test and the collision of satellites.)
- Number of objects approaching JAXA satellites are increasing.
- JAXA only reply on the information from JSpOC for these objects.
- Large errors make the decision of the collision avoidances difficult.

JAXA should have own means for the collision avoidances.

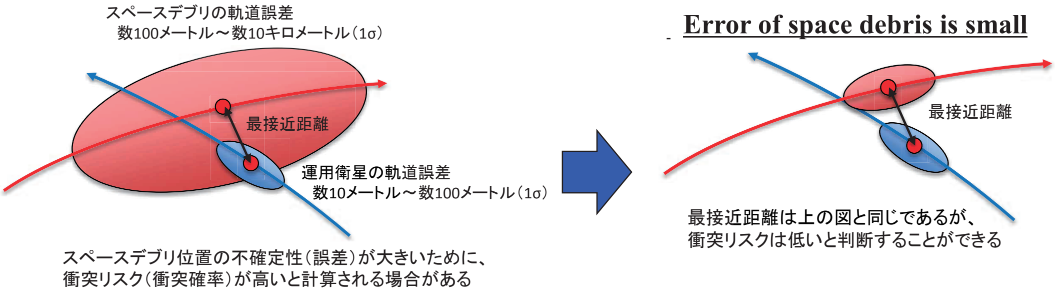
3

Objective

Investigate the possibilities of accurate orbital determination of the objects approaching JAXA satellites using optical equipment. Optical observations and orbital determination are simulated using STK and ODTK and the accuracy of orbital determination is investigated.

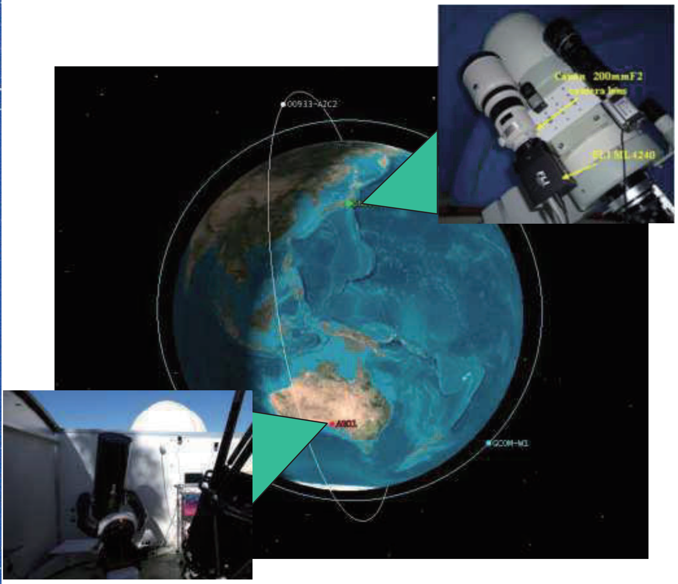
Advantages of optical equipment: High position accuracy. (order of a few arc seconds)
Cost effective. (a lot of commercial items are available)

Error of space debris is large | Error of space debris is small



4

Simulation of observations



Passes of JAXA satellite GCOM-W and Scout X-4 R/B, and optical telescopes which will be used for actual observation.

Investigation of the objects approaching JAXA satellites using SOCRATES

↓

Scout X-4 R/B is approaching JAXA satellite GCOMS-W1 within 46.649 km at 11:57:26.789 UT on 2015/Oct/30

↓

Observation data at Japan and Australia from 4 days before the closest approach are generated using STK. Orbital determinations are carried out by ODTK using these data, and assess the error at the closest approach by propagating the error of the orbital determination.

※artificial position errors are added to the observation data in order to simulate the actual observation.

5

Simulation of observations

Actual observation data. Consecutive images taken with the camera lens of 200mm and CCD camera. 50msec exposure and 1.5sec interval.

6

Simulation of observation

3 cases of observation data are estimated. Orbital determinations are carried out using these data and the errors at the closest approach are evaluated.

Visible passes from both sites

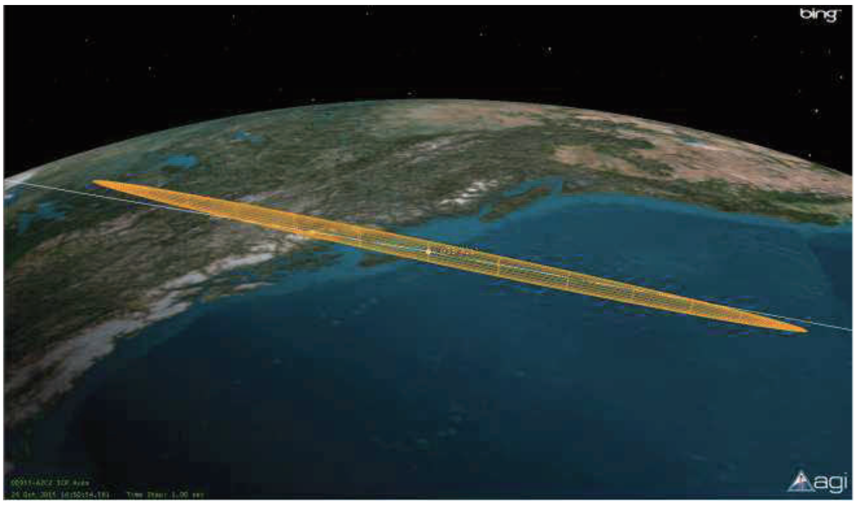
Date	Time(UT)	site	case①	case②	case③
2015/Oct/26	08:26:59 – 08:30:19	Australia	○	○	○
	08:46:35 – 08:48:41	Japan	○	○	○
	10:19:42 – 10:25:09	Australia	○	○	○
	10:37:29 – 10:44:54	Japan	○	○	○
	20:31:12 – 20:50:16	Japan		○	
2015/Oct/27	08:52:26 – 08:59:24	Australia			
	09:10:43 – 09:18:22	Japan			○
	11:07:12 – 11:10:01	Japan			
	19:07:00 – 19:19:18	Japan			
	20:58:28 – 21:00:50	Japan			
2015/Oct/28	09:19:11 – 09:26:51	Australia			
	09:37:02 – 09:46:10	Japan			
	19:32:44 – 19:49:30	Japan			
	20:00:41 – 20:11:33	Australia			
2015/Oct/29	09:46:44 – 09:53:12	Australia			
	10:04:23 – 10:13:14	Japan			
	19:59:22 – 20:18:12	Japan			
2015/Oct/30	08:38:29 – 08:46:05	Japan			
	10:32:59 – 10:39:24	Japan			

Closest approach 2015/Oct/30 11:57:27 Above the south pole

7

Results of the simulations

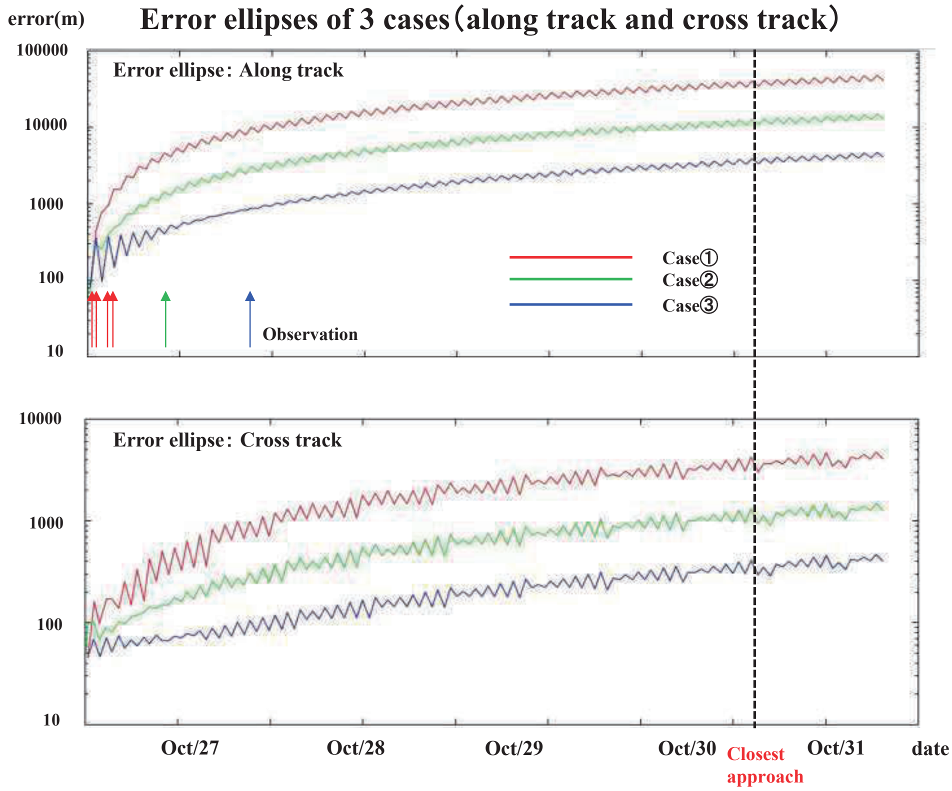
Sets of covariance extracted from the orbital determination using simulated data of 3 cases are propagated to the closest approach.



Propagation of error ellipse after the orbital determination. The figure shows the ellipse of 6 hours propagation for case ①

8

Results of the simulations



9

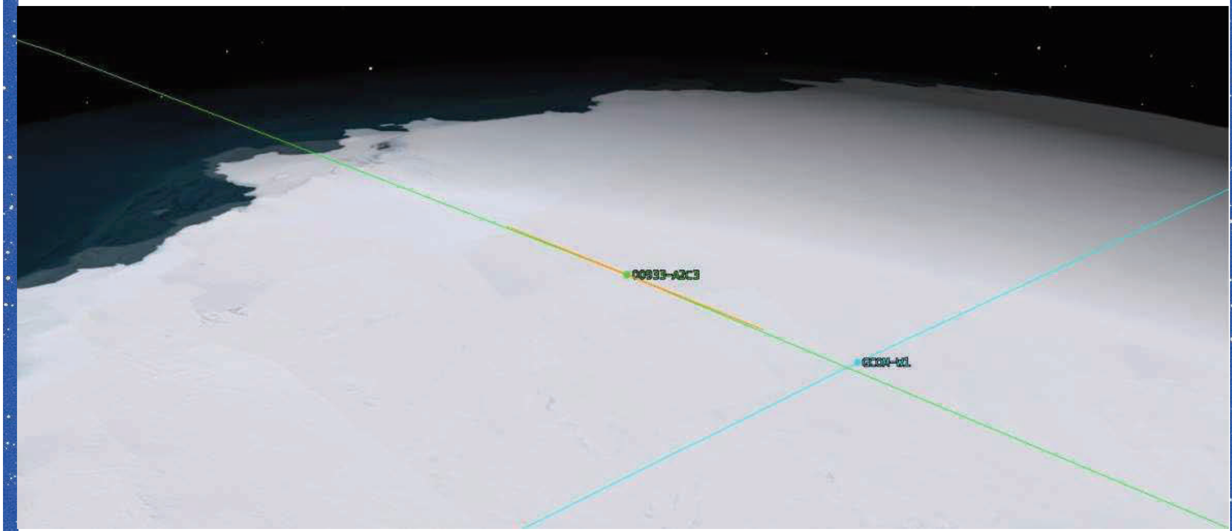
Results of the simulations

Error ellipse of case ① at the closest approach

10

Results of the simulations

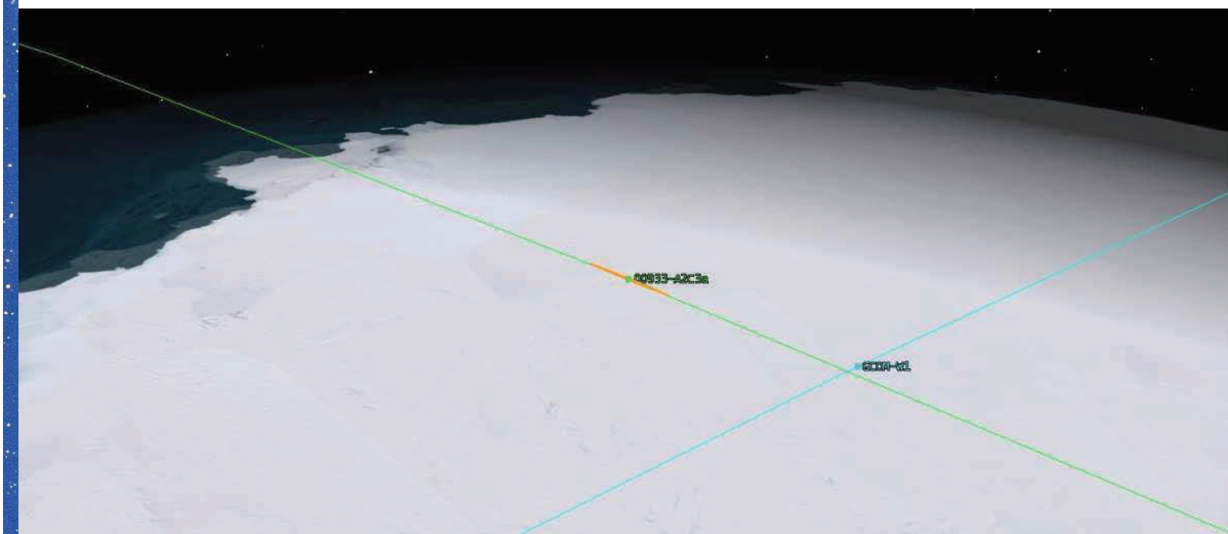
Error ellipse of case ② at the closest approach



11

Results of the simulations

Error ellipse of case ③ at the closest approach



12

Discussion

We can judge the collision risk at the closest approach by orbital determination using data taken 4 days before the approach with 12-24 hours interval.

Future tasks

Another cases should be tested.

Investigation using actual observation data.

Actual operation with numerous sites considering lighting and weather conditions.

R&D for faint object detection.

Global LEO monitoring system not only for objects approaching JAXA satellites using ground and on-orbit equipment.

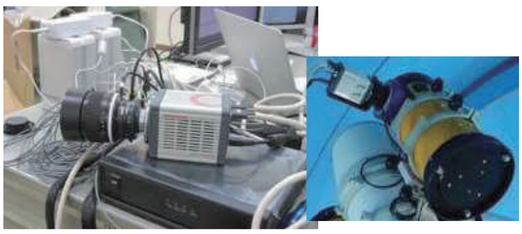
Current Status of R&D

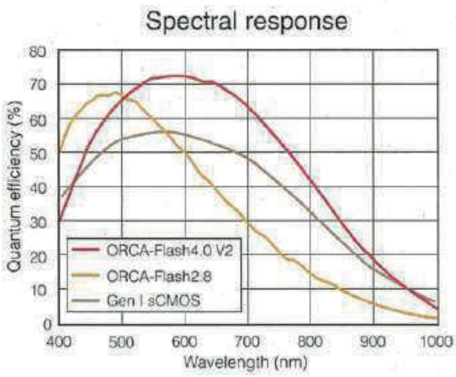
LEO observation technologies using CMOS sensor

CMOS sensor: Hamamatsu ORCA-Flash4.0v2

Modified for LEO observation by Nobuo Electronics (GPS time stamp, interval observation)

FOV : 1.5×1.5-degree with Takahashi ε180ED





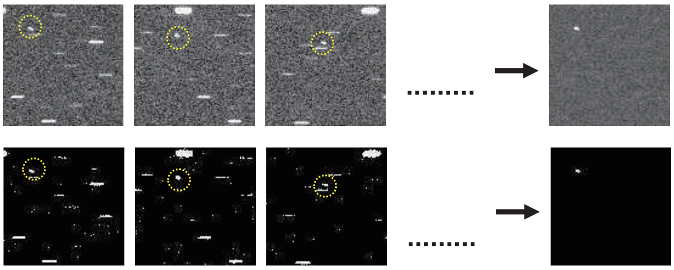
Product number		C11440-22CU
Imaging device		Scientific CMOS sensor FL-400
Effective number of pixels		2048(H) × 2048(V)
Cell size		6.5 μm × 6.5 μm
Effective area		13.312 mm × 13.312 mm
Full well capacity (typ.)		30 000 electrons
Readout time	Standard scan (at 100 frames/s)	10 ms
	Slow scan (at 30 frames/s)	33 ms
Readout noise	Standard scan (at 100 frames/s, typ.)	1.6 electrons rms (1.0 electrons median)
	Slow scan (at 30 frames/s, typ.)	1.4 electrons rms (0.8 electrons median)
Dynamic range (typ.)*2		37 000:1
Quantum efficiency		Over 70 % at 600 nm and 50 % at 750 nm

Much larger CMOS sensor was developed under the collaboration with Canon. Test observations are being carried out.

Current Status of R&D

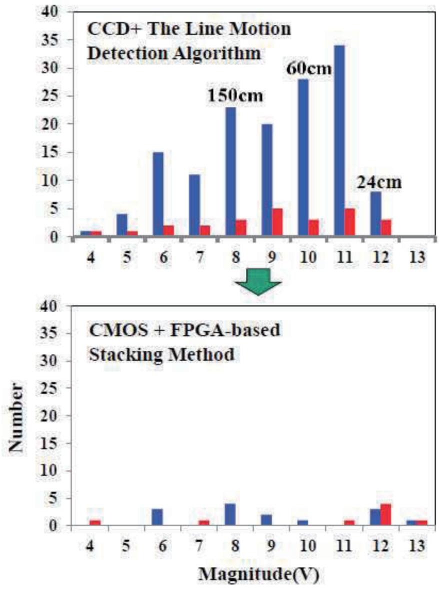
LEO observation technologies using CMOS sensor

Image-processing algorithm, which analyze a lot of data taken with CMOS sensor within realistic time and detect LEO objects of 10cm, are being developed.



(upper) The algorithm which can detect faint objects under the noise level. (bottom)The new algorithm for fast analysis.

FPGA board specially designed for the algorithm.
The board is manufactured by Soliton systems.

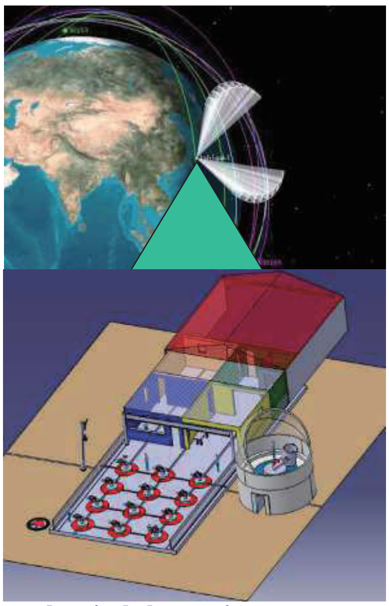


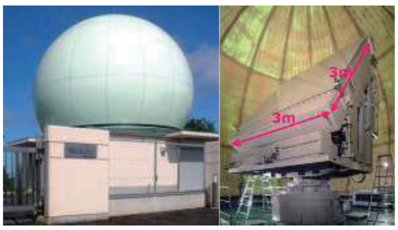
Brightness distribution of the detected objects. CMOS and FPGA can detect fainter objects than CCD and the conventional algorithm

Current Status of R&D

Global LEO monitoring system using numerous optical sensors

LEO monitoring system using numerous optical sensors is proposed. By combining radar, laser and on-orbit optical observation, a global LEO monitoring system will be established.





Radar

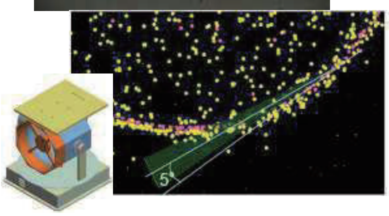
Good: Not effected by the lighting and the weather conditions

Bad: Cost

Laser

Good: Accurate orbital determination. Not effected by lighting condition.

Bad : Cost. Effected by the weather condition.



On-orbit optical observation

Good: Detection of small size objects. Not effected by the weather condition.

Bad: Cost

Ground optical observation

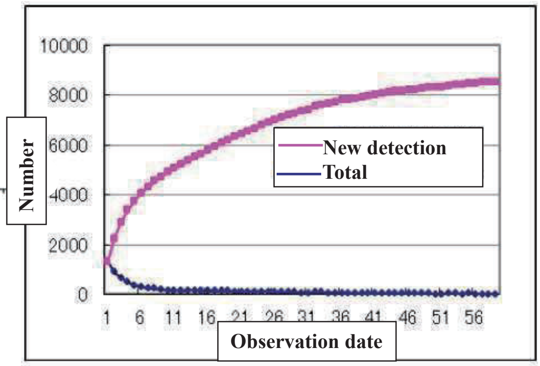
Good: Accurate orbital determination. Cost effective. Objects not detected with radar are detectable.
Bad: Effected by lighting and weather conditions.

16

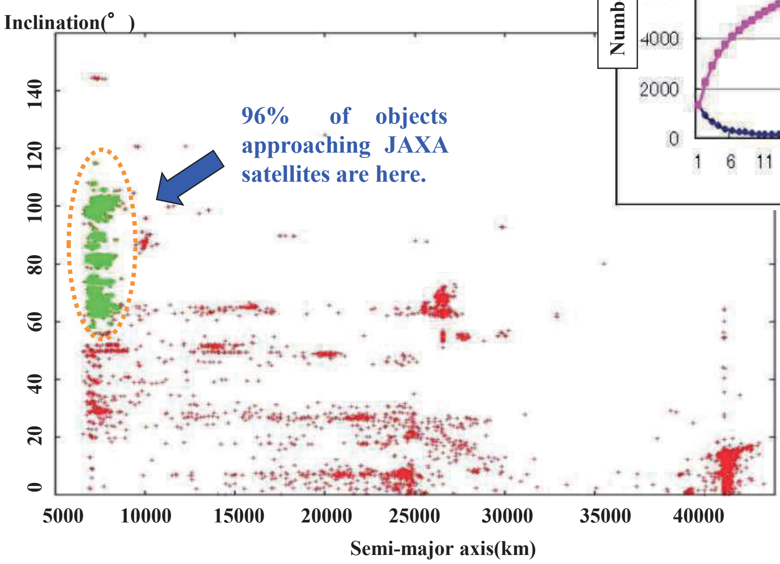
Current Status of R&D

Global LEO monitoring system using numerous optical sensors

60% of TLE objects are detected and orbit-determined using the proposed system in 4 months (weather effect is not included).
96.6% of the objects approaching JAXA satellites are detectable.



Number of the objects orbit-determined with the proposed system.



Objects in semi-major axis vs inclination space. Red and green represent all TLE objects and the objects detected with the proposed system, respectively.

17

Summary

The effectiveness of the ground optical observation for the collision avoidances were investigated using STK and ODTK software. The simulations showed that propagated errors of the orbital determination calculated with a few passes taken at two separate sites were small enough to decide the maneuver properly. The ground optical observation will contribute the efficient collision avoidances at the low earth orbits in the near future.

18