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JAXAのデブリ状況把握・防御技術

Research and Development for Space Debris Situational Awareness and Defense in JAXA

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JAXA研究開発部門ではデブリ対策の一環としてデブリ状況把握・防御技術の研究開発を実施している。本研究開発を実施するにあたりシナリオの検討を現在進めているとことである。また、それと並行して、地上観測、軌道上観測、モデル、防護、衝突接近回避、レーザーレンジングの各要素技術の研究開発を実施している。本講演ではシナリオ検討及び各要素技術の進捗状況を報告する。

Research and Development Directorate of JAXA is carrying out R & D for Space Debris Situational Awareness and Defense. In order to carry out the activities, we are establishing the scenario. We are also developing basic technologies of ground observation, on-orbit observation, modeling, protection, collision avoidance and laser ranging. In this talk, the status of the scenario establishment and progress of each the technology will be presented.

7th Debris Workshop in Chofu

Research and Development for Debris Situational Awareness and Defence in JAXA

Japan Aerospace Exploration Agency

T.Yanagisawa, H.Matsumoto, H.Ueno, K.Kamiya, M.Higashide, T.Hirai, I.Matsuda, K.Akiyama, H.Oda, S.Ikeda, S.Nakamura, T.Mukai, S.Kawamoto, and M.Ohnishi

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Abstract

Research and Development Directorate of JAXA is carrying out R & D for Debris Situational Awareness and Defence. In order to carry out the activities, we are establishing the scenario. We are also developing basic technologies of ground observation, on-orbit observation, modeling, protection, collision avoidance and laser ranging. In this talk, the status of the scenario establishment and progress of each the technology will be presented.

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Scenario construction for R&D

From the bottom-up to the top-down.

1. Effective measures for space debris problem.
2. Effective use of the limited resources.
3. Clear objectives for the researchers.

Issue 1. Situation of the objects which are approaching JAXA satellites are unclear.

Issue 2. Situation of the objects from mm to 10cm which are not protectable and observable are unclear.

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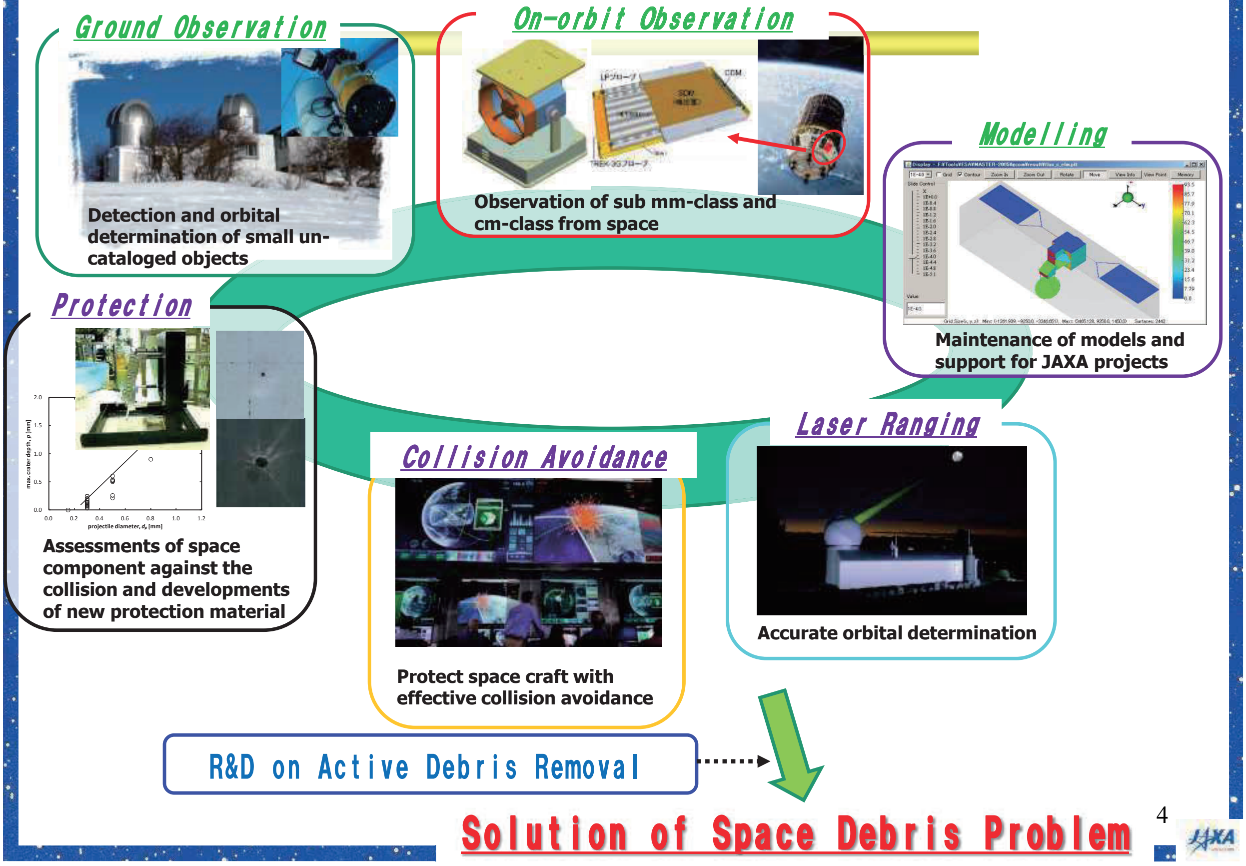
Sub-themes of the R&D



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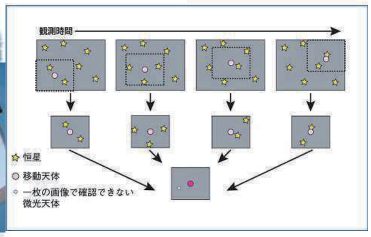
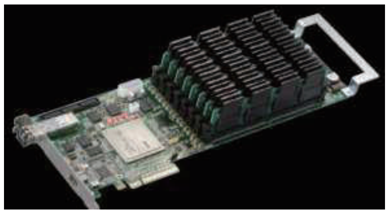
Ground observation

Mt.Nyukasa Optical Facility



Detection algorithm for faint moving objects

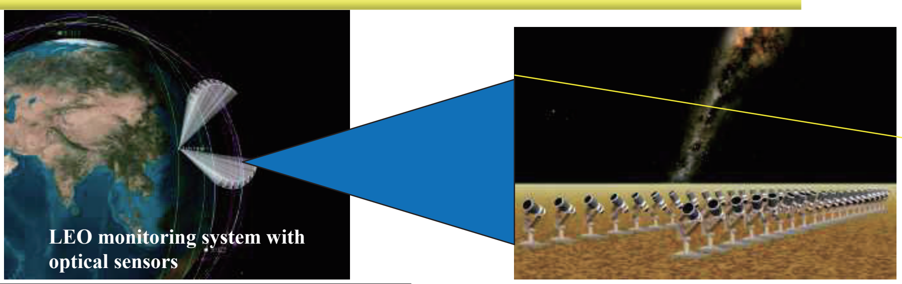


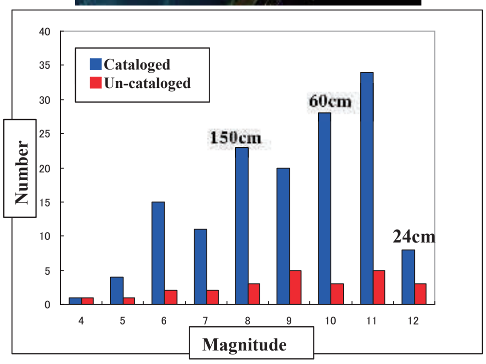
FPGA board for the algorithm

Distribution of un-cataloged GEO objects detected with our technologies

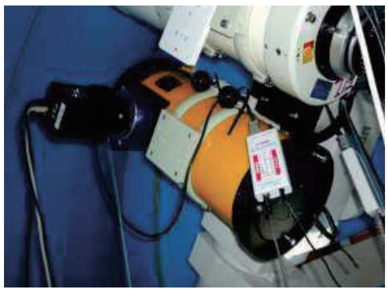
In GEO, the situation of objects less than 1m is not well understood. An image-processing algorithm and the FPGA board designed for the algorithm are being developed to detect faint objects which is invisible under the background noises. Orbit determination and orbit maintenance of detected un-cataloged objects are also carried out under the collaboration with JAXA Space Tracking and Communications Center.

Ground observation





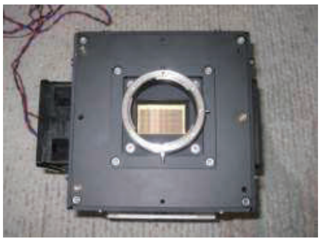
Brightness distribution of detected objects at the 16 days' survey. 15% of them were un-cataloged.



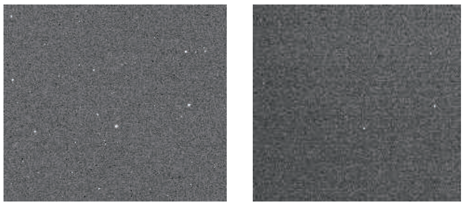
The 18cm telescope and the CCD camera

For LEO, the monitoring system using numerous optical sensor, which covers vast region of the sky is being proposed. Survey result using the 18cm telescope and the CCD camera showed that 30cm LEO objects at 1000km altitude were detectable.

Ground observation

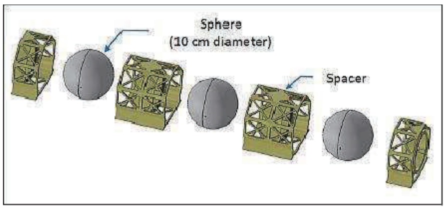


The large CMOS sensor for LEO objects observation.



Performance comparison between the developed CMOS sensor(left) and the conventional CMOS sensor.

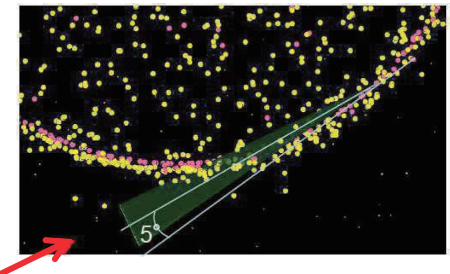
A large CMOS sensor is being developed under the collaboration with Canon. CMOS sensor can read the image 100 times faster than CCD which is convenient for the detection of fast moving LEO objects.

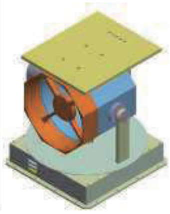


POPACS observation was carried out to assess the possibilities of the CMOS sensor. By analyzing the data with the FPGA system developed for GEO debris detection, POPACS (10cm aluminum sphere) was detected with the magnitude of 12.8.

On-orbit observation

Concept of the on-orbit optical observation



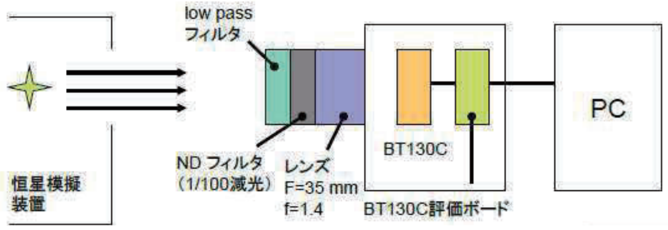


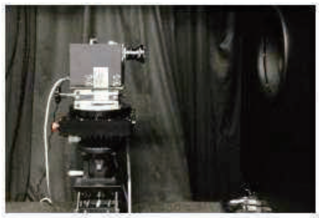
項目	スペック
CCD sensor	Pixel size： 7.1μm×7.1μm Number of pixel： 1024×1024 CCD
Focal length(f) (mm)	50
F number	1.2
F.O.V.	8° ×10°
Diameter	41.6mmΦ
Wave length	450~650nm
transmissivity	0.88
QE(%)	80
S/N(dB)	10(目標 6)
Exposure time	0.1～10sec
Readout noise	2e-
Weight(kg)	3.8

On-orbit system which can detect 1cm GEO objects, determine their orbits and avoid them is being developed. Collaboration with the ground observation system will be considered.

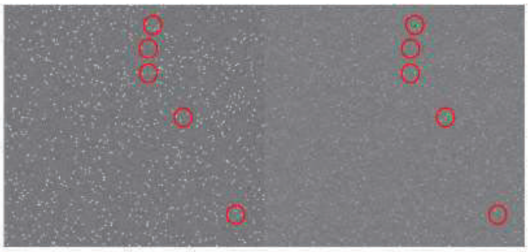
Spec of the sensor

On-orbit observation

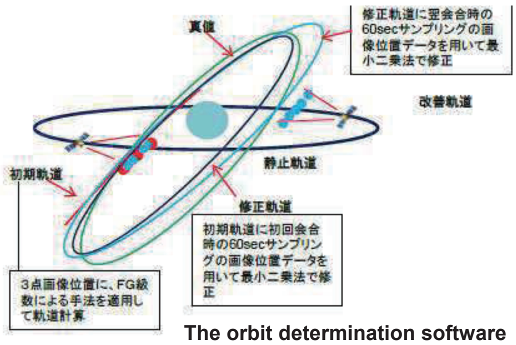




CCD BT130M manufacture by Brookman tech is selected. Its performance was investigated using the star simulation device. Limiting magnitude of the sensor with 33msec exposure was 11 magnitude



The image simulation software. Before field star removal(left) and after the removal.



The orbit determination software

The image simulation software considering the sensor diameter, transmissivity, F number and so on, and the orbit determination one was developed.

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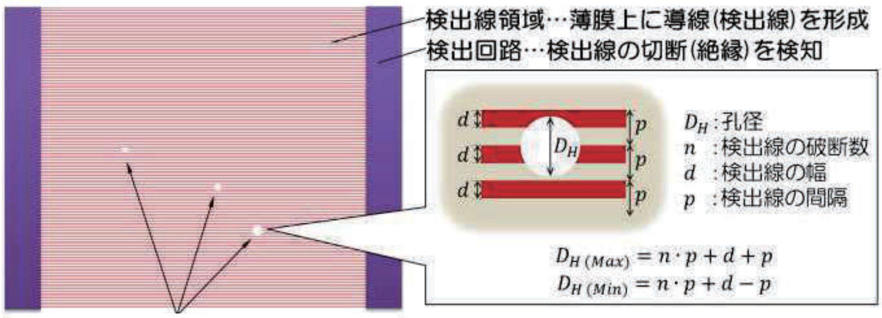
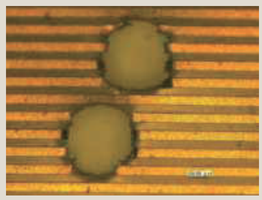
On-orbit observation



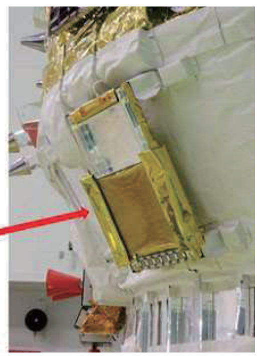
Perforation hole created with debris

Concept of the small debris detection



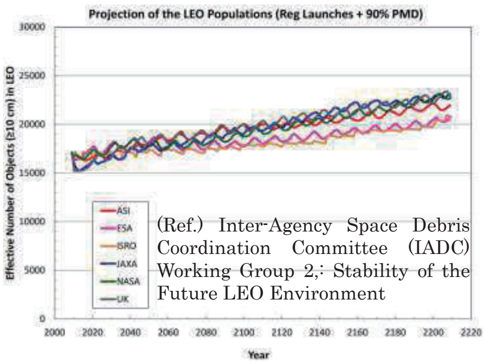
衝突孔の例(衝突試験@ISAS)
- 衝突粒子: SUS 309 μm
- 衝突速度: 5.2 km/s

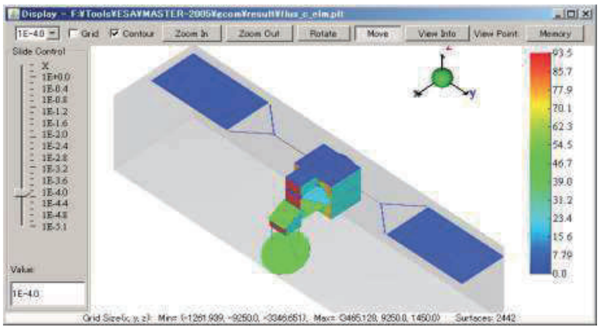
In order to detect sub-mm size debris, The film perforation sensor was developed. We succeeded in the flight experiment using HTV 5. The next step is the measurement of 800km region using the sensor.

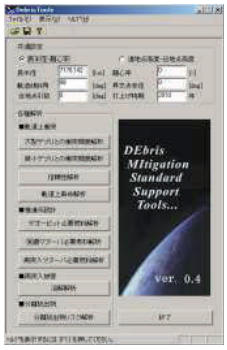


KASPAR (KOUNOTORI Advanced Space Environment Research Equipment) on HTV5

Modelling







NEODEEM　　TURANDOT

Three debris related tools are being developed and maintained. These tools are used to support JAXA projects and the international activities like IADC.

1. NEODEEM: Evolutionary model (collaboration with Kyushu Univ.)

2. TURANDOT: Damage assessment tool.

3. DEMIST: Project support tool to follow the debris mitigation standard.

DEMIST　11

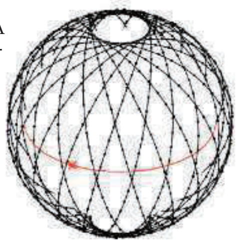
Modelling

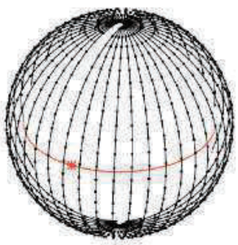
NEODEEM was updated to assess the effect of the mega-constellation. This enables us to join the international discussion like IADC on the issue.

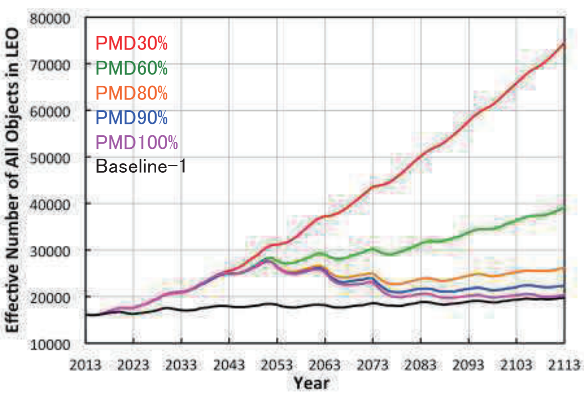
(Ref.) Kitajima, S., Abe, S., et.al: Influences of MEGA Constellations on the Orbital Environment, IAC-16,A6,2,5,x35062.

Scenario example

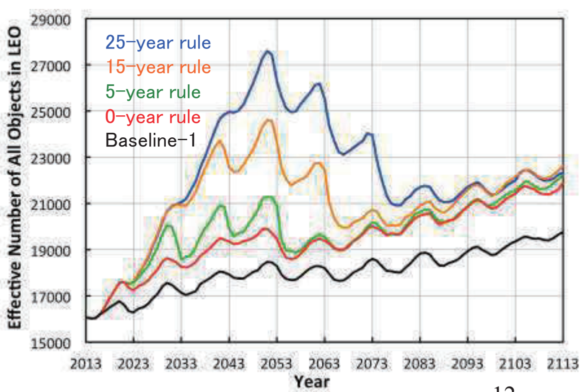
- 1000 satellites with 20 orbital plane.
- Altitude:1200km. Inclination:88 and 75-degree.
- Weight of satellite:150kg. Cross section: 3.0 m^2
- Operation period: 30 years (start from 2020)







Effect of the PMD success rate



Effect of the PMD period

(PMD: Post Mission Disposal)

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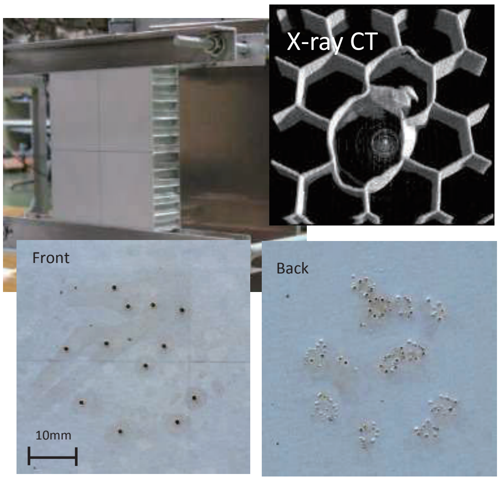
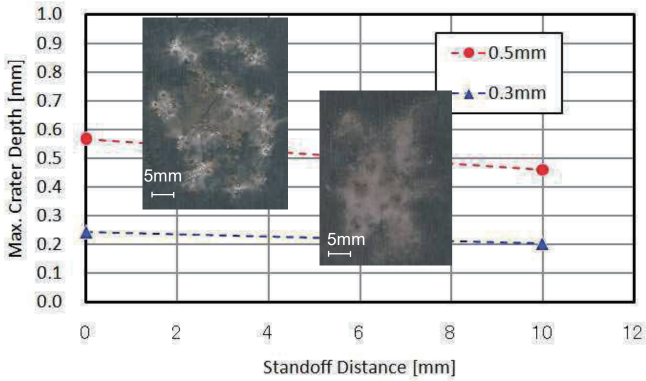
Protection



Resistance assessment of the construction panel(Aluminum honeycomb sandwich panel)



Standoff effect of the damage against the second wall.

Ref. Higashide, et al., Trans. JSASS Aerospace Tech. Japan, 2012

Collision speed of debris reaches 10km/sec. Therefore, 1mm debris causes serious damages on satellites. Since small debris cannot be avoided, satellites themselves need to have resistance. Assessments of space component against the collision and developments of new protection material are being carried out.

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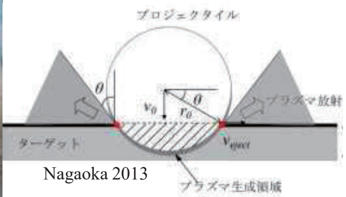
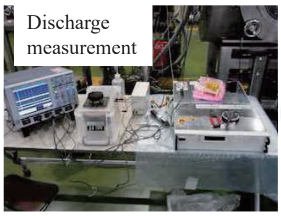
Protection

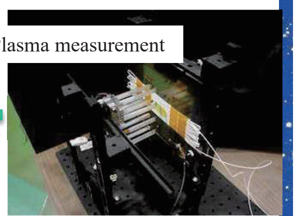
Electrical damage of the harness (Short caused by continuous discharge)

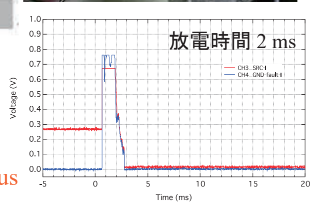
Plasma parameter (Density・Velocity)

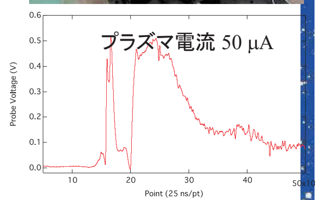


Nagaoka 2013









Risk assessment on physical basis is necessary.

→ Establishment of damage model based on simultaneous measurement of discharge and plasma phenomena.

In addition to the mechanical damage, electrical damage should be considered. Continuous discharging causes serious damages on space crafts. Experimental devices, which can measure both the discharging time and plasma current simultaneously, was established. Some tests were carried out and the data analysis is underway.

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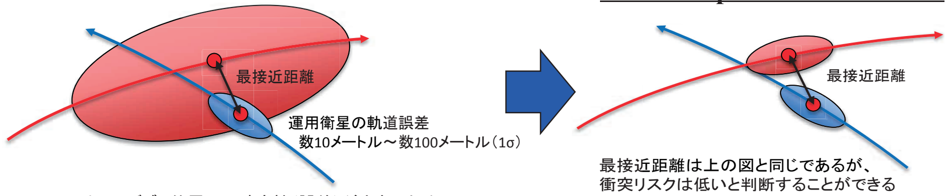
Collision avoidance

- Objective
  - Reduction of operational load by assessing collision risk between space craft and space debris accurately and efficiently.
- Problems of collision avoidance
  1. Since accuracy of orbit determination and prediction is low, collision risk in the future is highly uncertain.
  2. Since accuracy of error of future orbit is low, calculated certainty of collision risk is low.
  3. Since real risk is searched among a large amount of data, operational load is high.
- Themes of R & D
  1. Improvement of orbital determination accuracy and prediction accuracy.
  2. Orbital determination and prediction error modelling based on operational history.

Error of space debris is large

スペースデブリの軌道誤差
数100メートル～数10キロメートル(1σ)

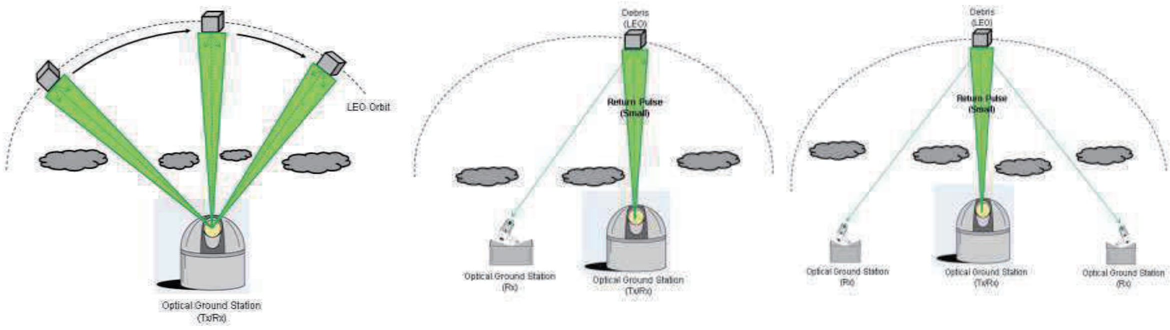
Error of space debris is small



最接近距離は上の図と同じであるが、
衝突リスクは低いと判断することができる

スペースデブリ位置の不確定性(誤差)が大きいために、
衝突リスク(衝突確率)が高いと計算される場合がある

Laser ranging



Monostatic Ranging　　Bistatic Ranging　　Multistatic Ranging

Step by Step

Accurate orbit determination of detected objects with ground and on-orbit observation may be possible using laser ranging. Basic test will be carry out using the existing SLR facility. Networking observation with the combination of passive devices will be the next step. World wide network for the operational collision avoidances will be established in the future.

Summary

Research and Development Directorate of JAXA is carrying out R & D for Debris Situational Awareness and Defence. In order to carry out the activities, we are establishing the scenario. We are also developing basic technologies of ground observation, on-orbit observation, modeling, protection, collision avoidance and laser ranging. In this talk, the status of the scenario establishment and progress of each the technology was presented.