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# JAXA 衛星に対するスペースデブリ接近解析の現状

## Current Status of Conjunction Assessment for JAXA satellites

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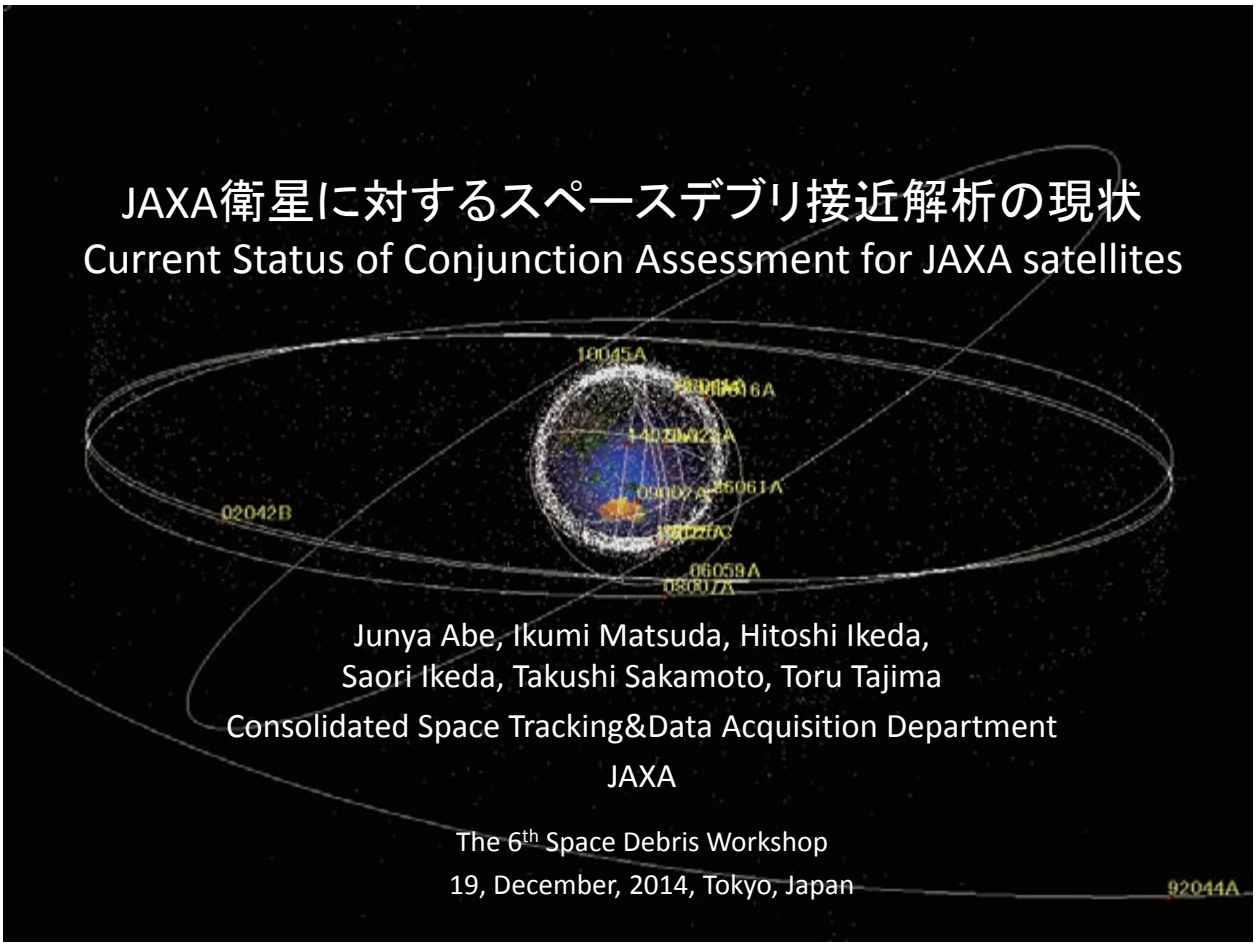
近年、スペースデブリの増加が著しく、人工衛星はスペースデブリとの衝突の危険が高まっている。JAXA では、人工衛星をスペースデブリとの衝突から守るため接近解析を日々実施しており、接近解析によって衝突の危険性が高いと判断した場合には、必要に応じて衝突回避運用を実施している。この衝突回避運用の実施に当たっては、衛星寿命やミッションの成立性を考慮し過剰な実施は避けるべきであり、確度の高い接近解析および効果的な軌道制御運用に取り組む必要がある。本講演では、JAXA によるスペースデブリの接近解析に基づく衝突回避運用の事例を紹介する。

# JAXA衛星に対するスペースデブリ接近解析の現状
## Current Status of Conjunction Assessment for JAXA satellites

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# 1. Introduction

- On-orbit collisions pose deterioration of space environment.
- The activities for collision risk identification and mitigation are necessary to preserve sustainable space development.

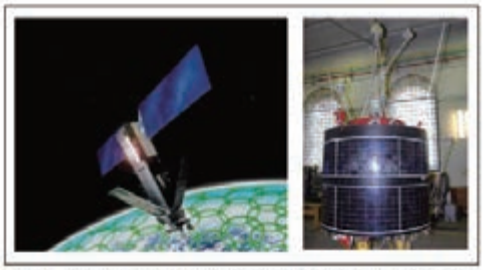


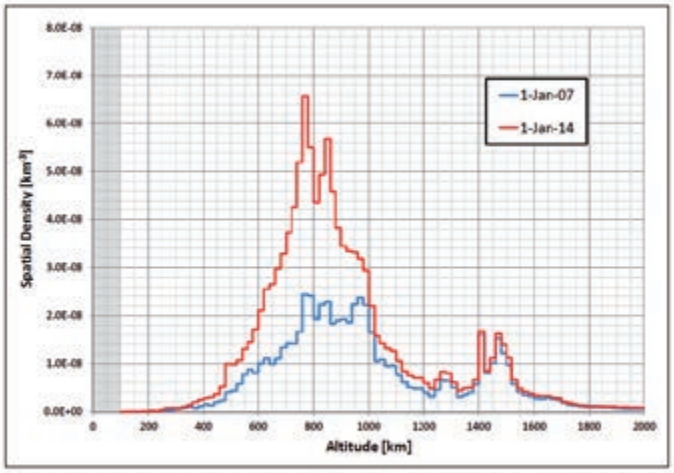
Figure 2. Configurations of an Iridium satellite (left) and the class of Cosmos satellite (right) involved in the collision of 10 February 2009.

Table 1. A summary of recent major breakups (based on the 25 June 2009 catalog data).

| Event | Event Time | Cause | Total Catalogued Fragments* | Number of Catalogued Fragments with RCS data | Number of Catalogued Fragments Remaining In Orbit |
|---|---|---|---|---|---|
| Fengyun-1C | Jan 2007 | Collision (deliberate) | 2680 | 2680 | 2630 |
| Briz-M | Feb 2007 | Explosion | 69 | 69 | 67 |
| Cosmos 2421 | Mar 2008 | Unknown | 506 | 506 | 40 |
| Iridium 33 | Feb 2009 | Collision (accidental) | 349 | 349 | 335 |
| Cosmos 2251 | Feb 2009 | Collision (accidental) | 809 | 809 | 785 |

*some tracked objects have not been added to the catalog.

Ref. ODQN Vol. 13, Issue 3, July 2009




This chart compares the spatial density distributions of the tracked objects in low Earth orbit (LEO) for 1 January 2007 and 1 January 2014. The increase below 1000 km altitude is approximately 115.4%. Fragments generated from the Fengyun-1C anti-satellite test conducted by the People's Republic of China in 2007 and the accidental collision between Iridium 33 and Cosmos 2251 in 2009 account for most of the increase.

Ref. ODQN Vol. 18, Issue 2, April 2014

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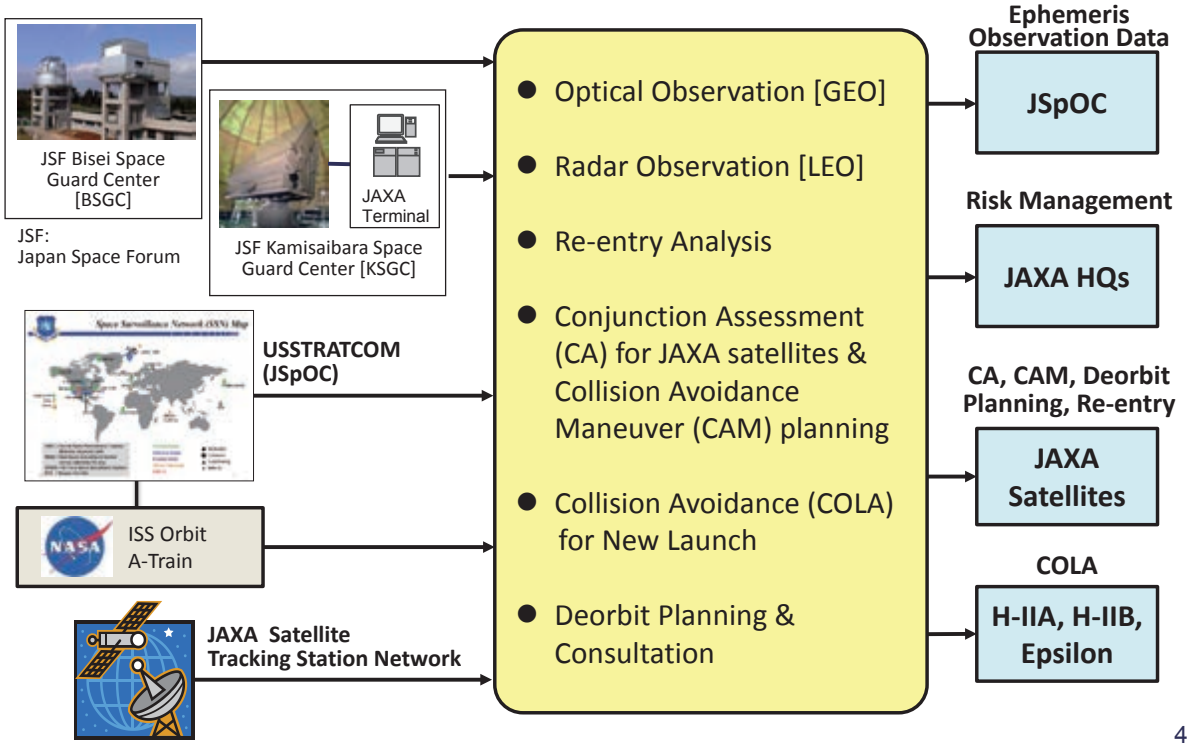
# 2. Overview of JAXA Activities for SSA

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# 3. Conjunction Assessment

## CA History and Practice Summary

- **HISTORY**
  - The 1st generation CA tool validation was accelerated by the IRIDIUM 33 and COSMOS 2251 accidental collision in February 2009
  - The 1st collision avoidance maneuver (ALOS vs. COSMOS 2251 DEB) in July 2009
  - SSA Sharing Agreement in May 2013

- **CA Practice Summary**
  - 3 GEO, 1 QZ, 1 HEO, and 10 LEO JAXA Satellites
    - Maneuverable satellites' orbit information including regular maneuvers has been informed to JSpOC
  - CA and CAM（Collision Avoidance Maneuver)
    - 22 CA notifications with initial evaluation were made within a month.
    - 4 collision avoidance maneuvers were executed in LEO since April 2014

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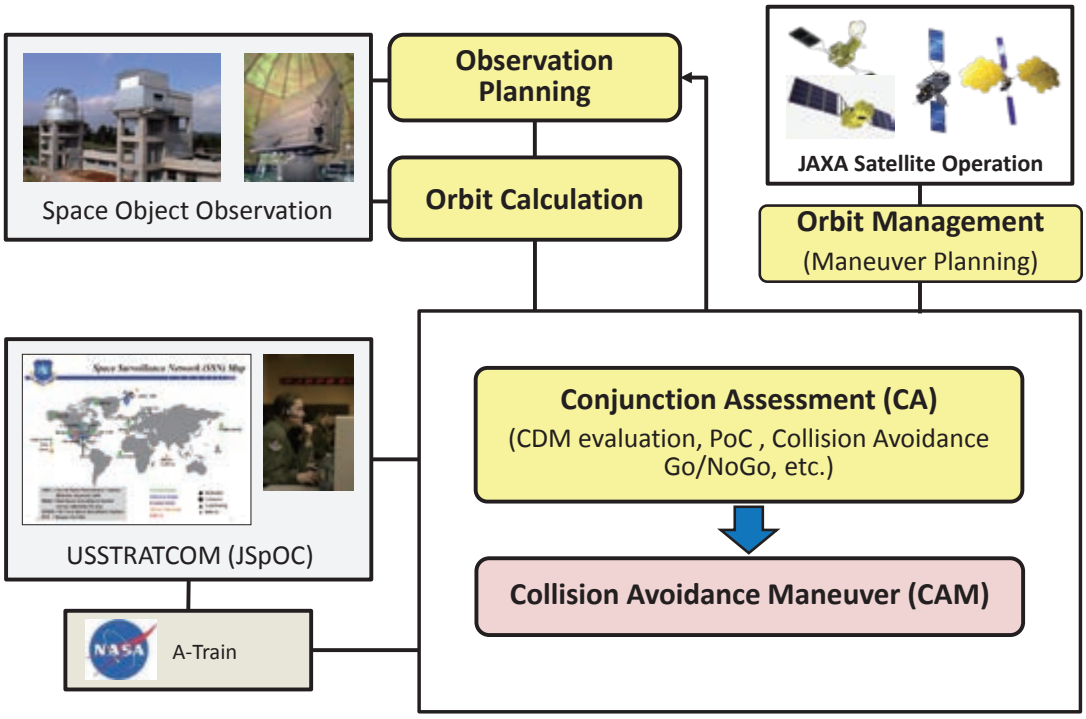
# 3. Conjunction Assessment

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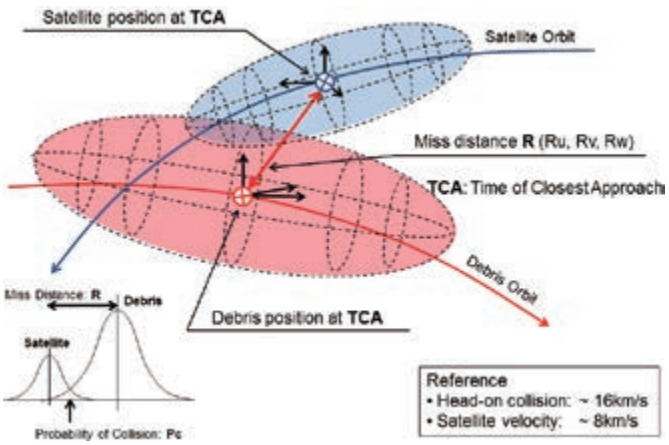
# 3. Conjunction Assessment

Assessment Point for CAM

## ■TCA Information

- Miss distance
- Geometry（Radial, In-track, Cross-track）
- Orbital error covariance
- Collision probability
- Orbit Determination(OD) quality
- Close approach to same objects at other timing
- Close approach to other objects




## ■Operational Capability

- Constraint of orbit keeping
- Feasibility of CAM operation (e.g., operation timeline, tracking station assignment)

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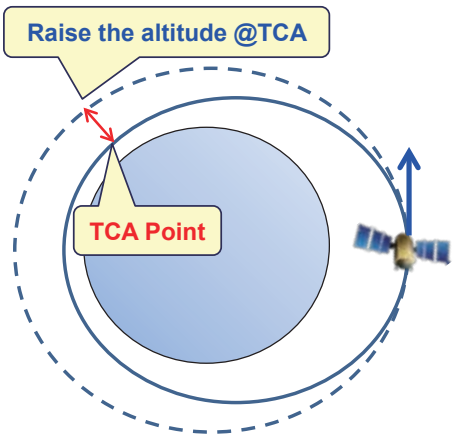
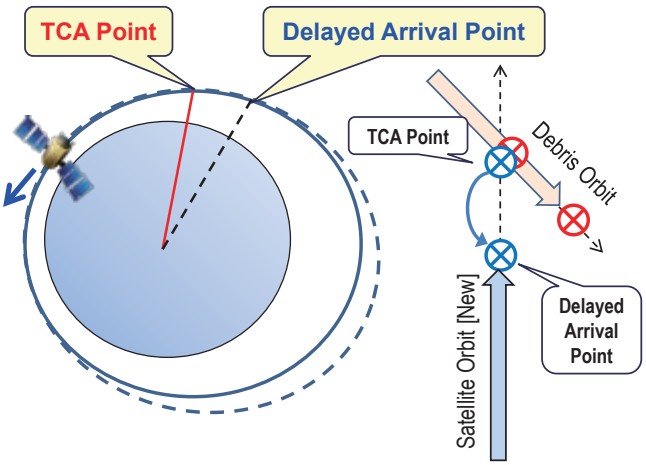
# 4.Collision Avoidance Maneuver

**Altitude Separation**




**Phase Separation**




**Advantage** : can enlarge a miss distance rapidly
**Disadvantage** : need flexible maneuverability for an effective CAM operation

**Advantage** : can accept a constraint of s/c maneuverability (e.g., attitude, direction)
**Disadvantage** : need relatively long duration time to obtain phase separation

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# 4.Collision Avoidance Maneuver

## Strategies for CAM planning

- Risk mitigation to leverage routine Orbit Control Maneuvers (OCMs)
  - Cancel
  - Change an execution timing
  - Adjust a magnitude of ΔV
- Control Autonomous OCMs
  - Figure out planned OCMs calculated by onboard computer to decide following operations
  - Send a Enable/Disable command to ensure a schedule of CAM operation
- Additional OCM Planning
  - In the case of no routine OCMs, additional OCM is planned as CAM
- CA Screening
  - S/C trajectories after a CAM operation (nominal, backup) are also assessed again

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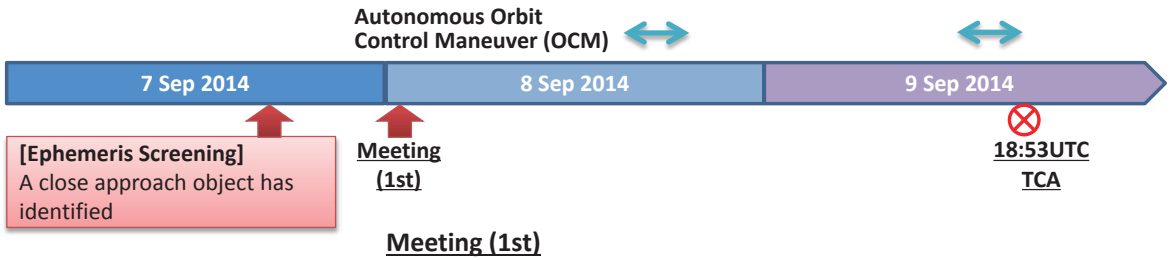
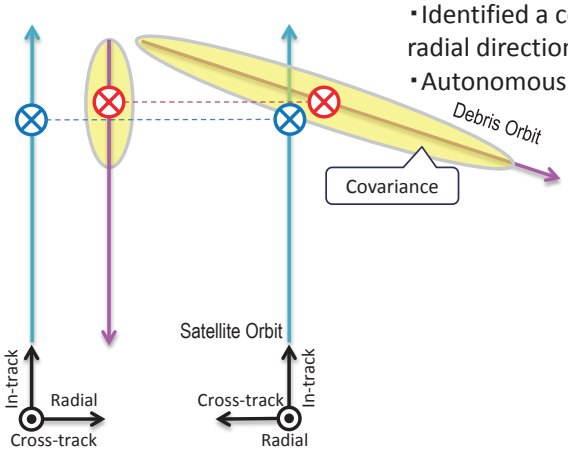
# 5. Practical Example of CAM Operation

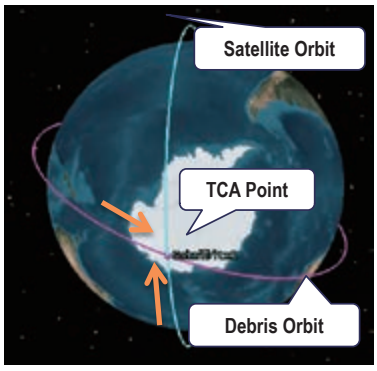



**Meeting (1st)**

・Identified a conjunction: secondary object is located above in radial direction, large prediction error

・Autonomous OCMs had planed to maintain operational orbit.

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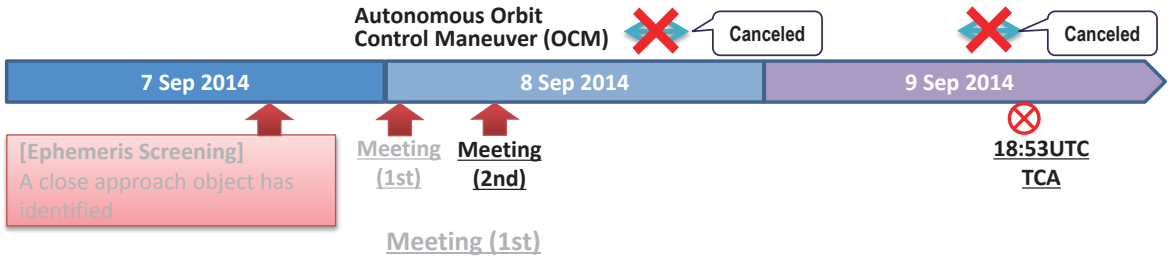
# 5. Practical Example of CAM Operation




**Meeting (1st)**

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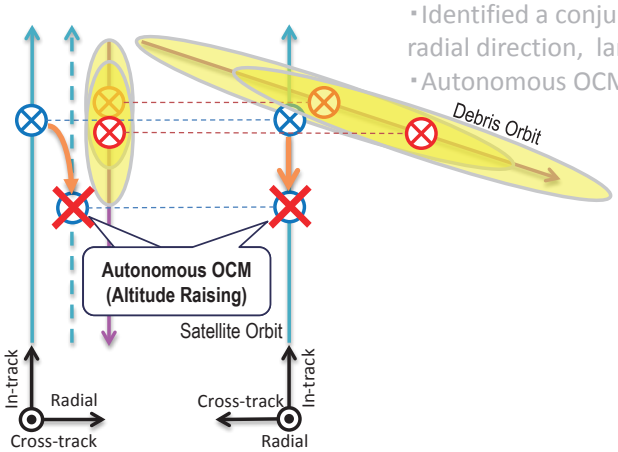


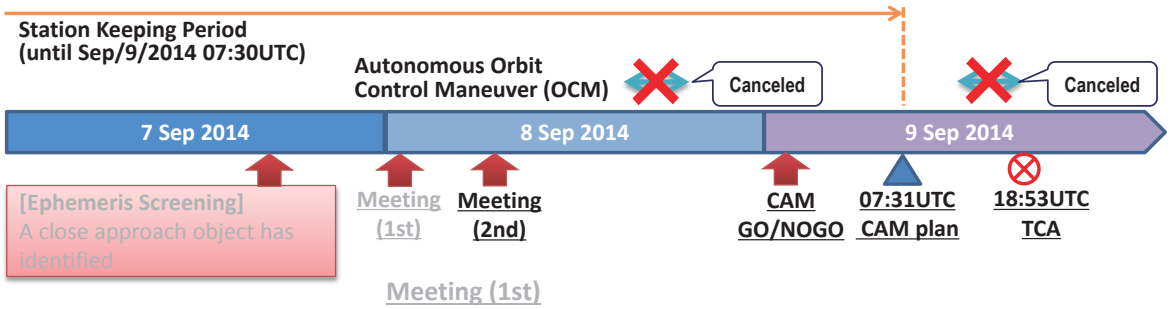

**Meeting (2nd)**

・Radial miss distance are still close and the autonomous OCMs yields increased risk.

⇒ Autonomous OCMs are canceled.



# 5. Practical Example of CAM Operation

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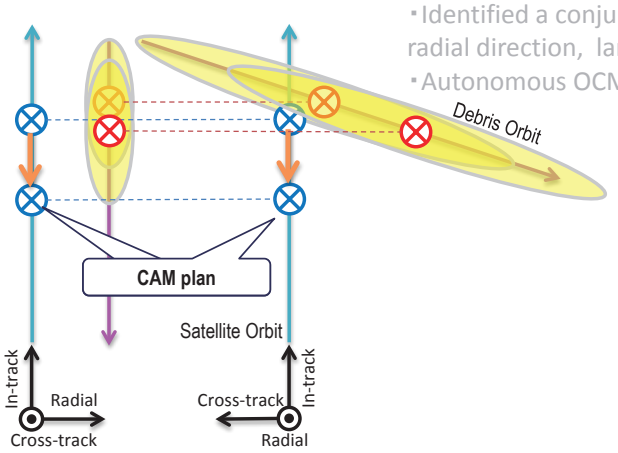



**Meeting (2nd)**

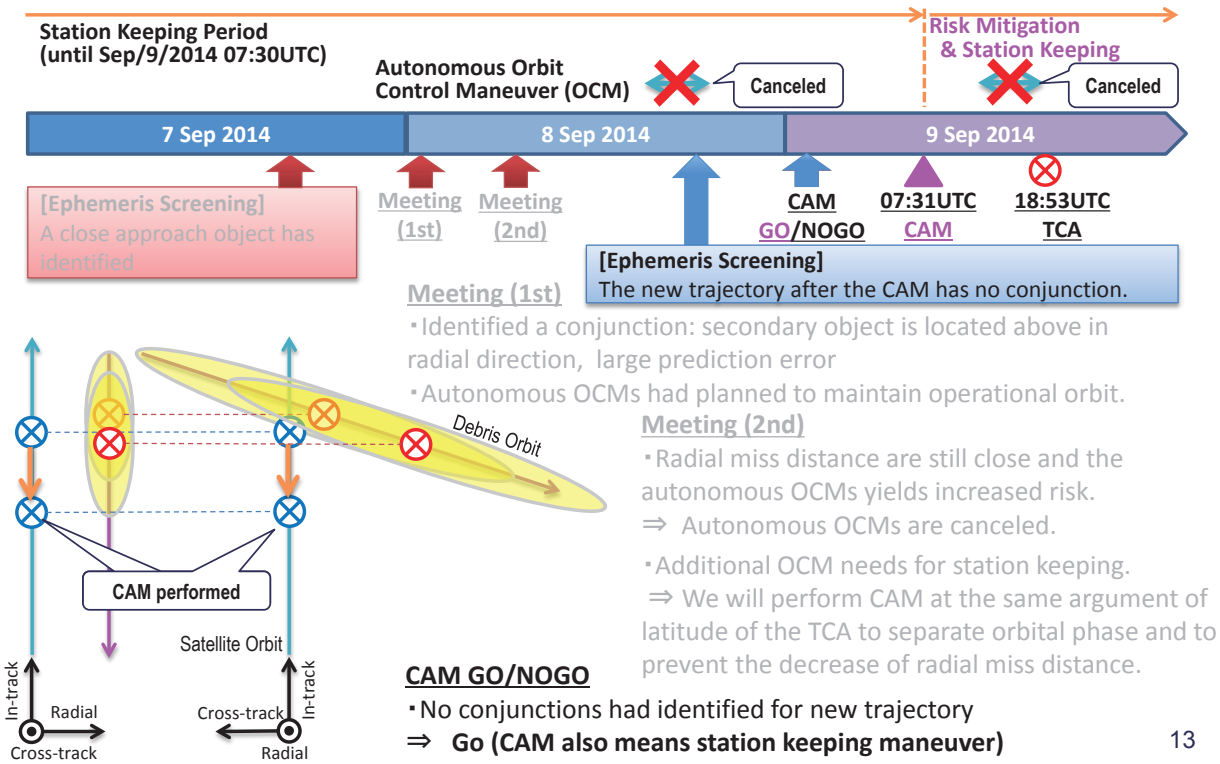
・Radial miss distance are still close and the autonomous OCMs yields increased risk.

⇒ Autonomous OCMs are canceled.

・Additional OCM needs for station keeping.

⇒ We will perform CAM at the same argument of latitude of the TCA to separate orbital phase and to prevent the decrease of radial miss distance.

## 5. Practical Example of CAM Operation




## 6. Summary

- The overview of SSA activities for JAXA satellites are presented.
- Current status of conjunction assessments and collision avoidance maneuver operation are also described with some practical examples.
- The steady CA and CAM operation are necessary to accomplish a sustainable space environments.
- To save the fuel consumption caused by CAM, precision and stable CA techniques are necessary.
- We will continue consistent effort not only to improve accuracy of conjunction assessment but also to perform effective CAM operation.

# Thank you for your attention.

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