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JAXA 衛星に対する衝突リスク評価と デブリ回避制御手順について

Conjunction Assessment of Space Debris and Processes for Debris Avoidance Maneuver

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JAXA 追跡ネットワーク技術センターでは、現在 14 機の衛星に対して追跡管制運用を行っており、それらの衛星に対して米国国防総省戦略軍統合宇宙運用センター (CSpOC) から提供される接近情報 (CDM) に基づき、スペースデブリとの衝突リスクの分析を実施している。

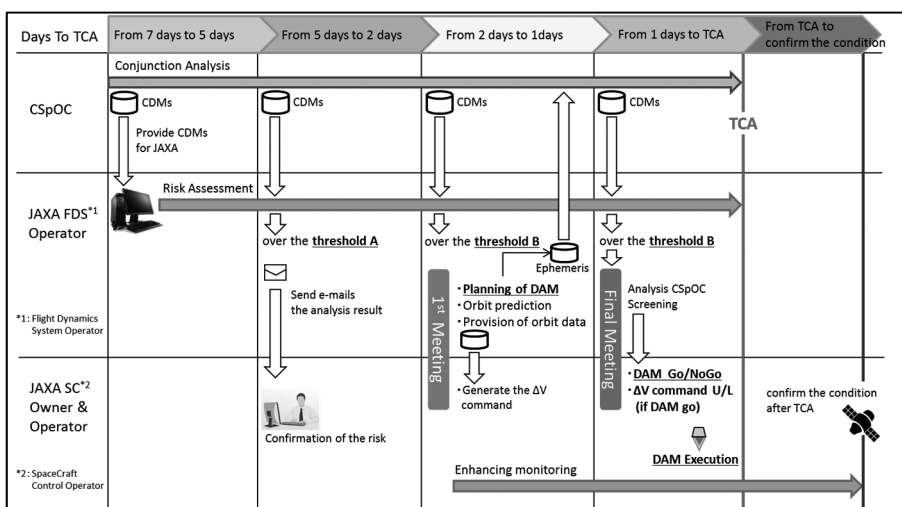
JAXA 運用衛星はそれぞれ異なるミッションを有しており、各ミッションの衛星制約に合わせて衛星毎にスペースデブリ衝突回避制御 (DAM) 運用手順書を策定し、DAM 運用を行っている。

本講演では、JAXA で行っているスペースデブリとの衝突リスク分析の手法と DAM 運用手順の説明、これまで JAXA で実施した DAM 運用の事例およびその課題について報告する。また、DAM 運用の実績を踏まえ、DAM 運用に対する提言事項について報告する。

We operate the 14 satellites in JAXA Space Tracking and Communication Center, and we analyze their collision risks based on conjunction data messages(CDM) which are provided from Combined Space Operations Center(CSpOC).

JAXA Satellites each has different mission, we prepare Space Debris Avoidance Maneuver (DAM) process manuals considering the limitations of each satellite, and perform DAM operations.

In this presentation, we report on methods of risk analysis, processes for DAM operations, practices of DAM operation and problems. In addition, we report a proposal matter for DAM operation.





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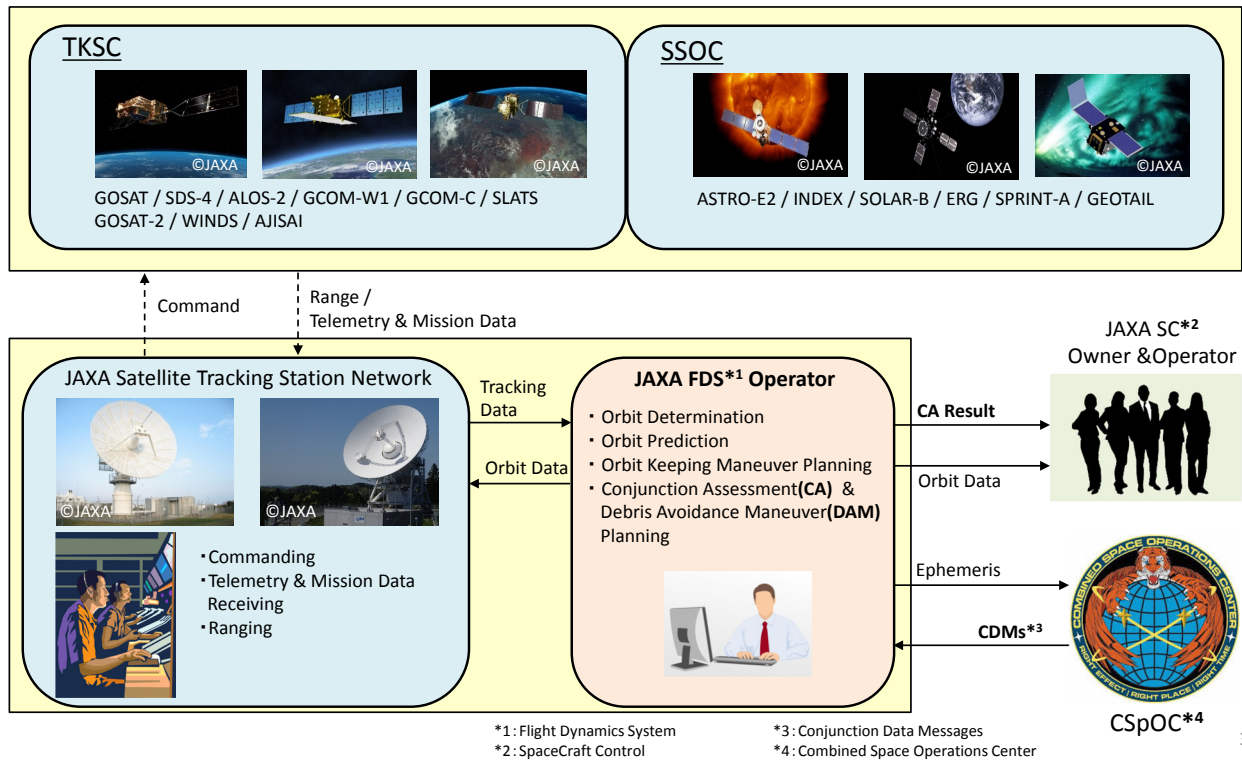
The 8th Space Debris Workshop
5, December, 2018, Tokyo, Japan

Abstract



1. Introduction: JAXA Flight Dynamics System
2. Conjunction assessment
3. Methods of risk analysis for JAXA satellites
4. Processes for Debris Avoidance Maneuver (DAM)
5. Practical examples of DAM operation
6. Summary

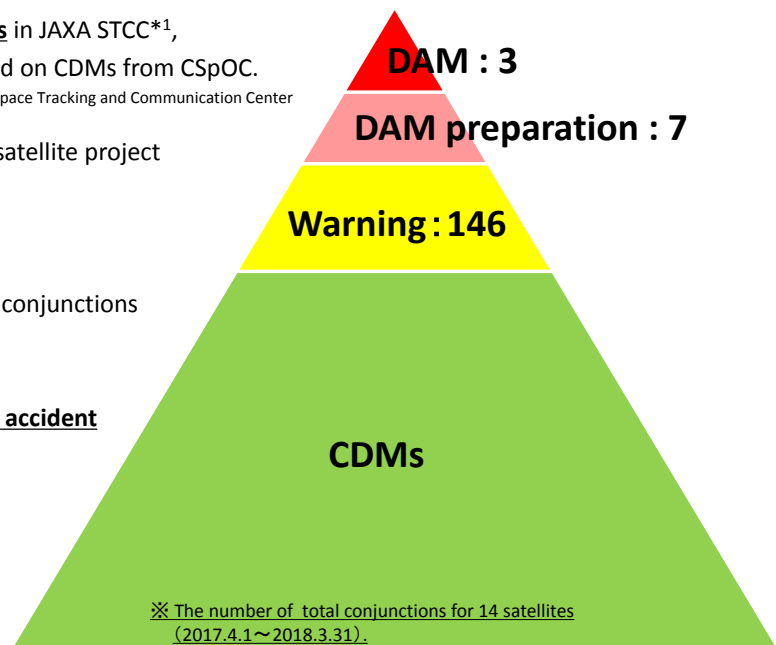
1. Introduction: JAXA Flight Dynamics System



2. Conjunction assessment



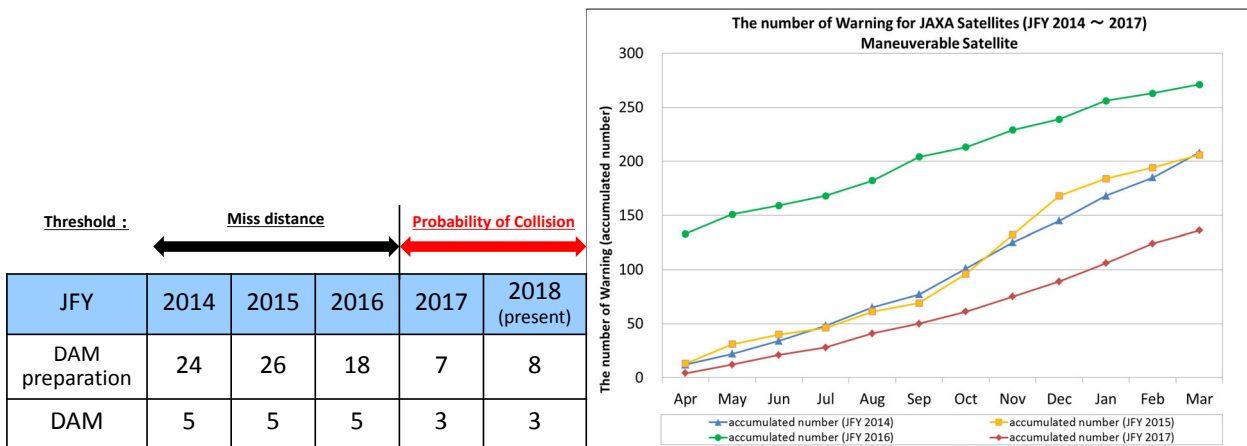
- We operate **11 LEOs, 1 GEO and 2 HEOs** in JAXA STCC*¹, and we analyze their collision risks based on CDMs from CSPOC.
*1: Space Tracking and Communication Center
- If high risk of collision exists, we alerts satellite project with the CA information.
We prepare for and execute DAM.
- The right figure shows the numbers of conjunctions and DAMs in last year.
- **We have never experienced a collision accident with space debris in JAXA satellites.**





2. Conjunction assessment

- 21 DAMs were executed in JAXA satellites since 2014.
- From 2014 to 2016, we had assessed risks by the miss distance, but changed to probability of collision since 2017.
- **We have three thresholds of conjunction assessment using probability of collision and days to TCA*1.** *1: Time of Closest Approach



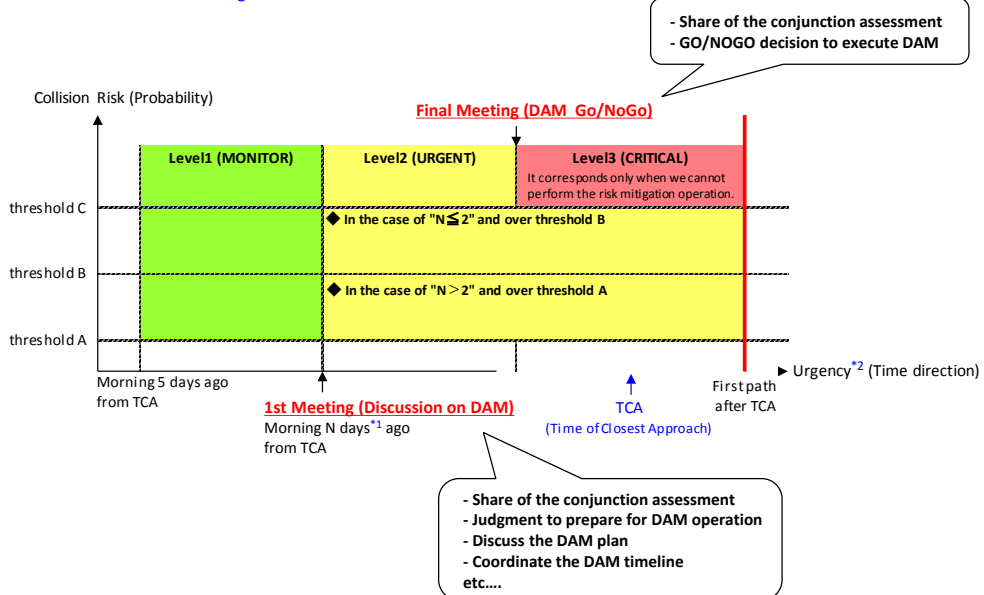
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3. Methods of risk analysis for JAXA satellites



- MONITOR** : Warning notice
- URGENT** : Discussion with satellite project on DAM & Enhancing monitoring
- CRITICAL** : Enhancement against satellite project of a risk management system

*1: Each satellite project determines "N days" in consideration of necessary time in preparation for DAM.
 *2: The urgency is defined in time from the CDM generation time to TCA.

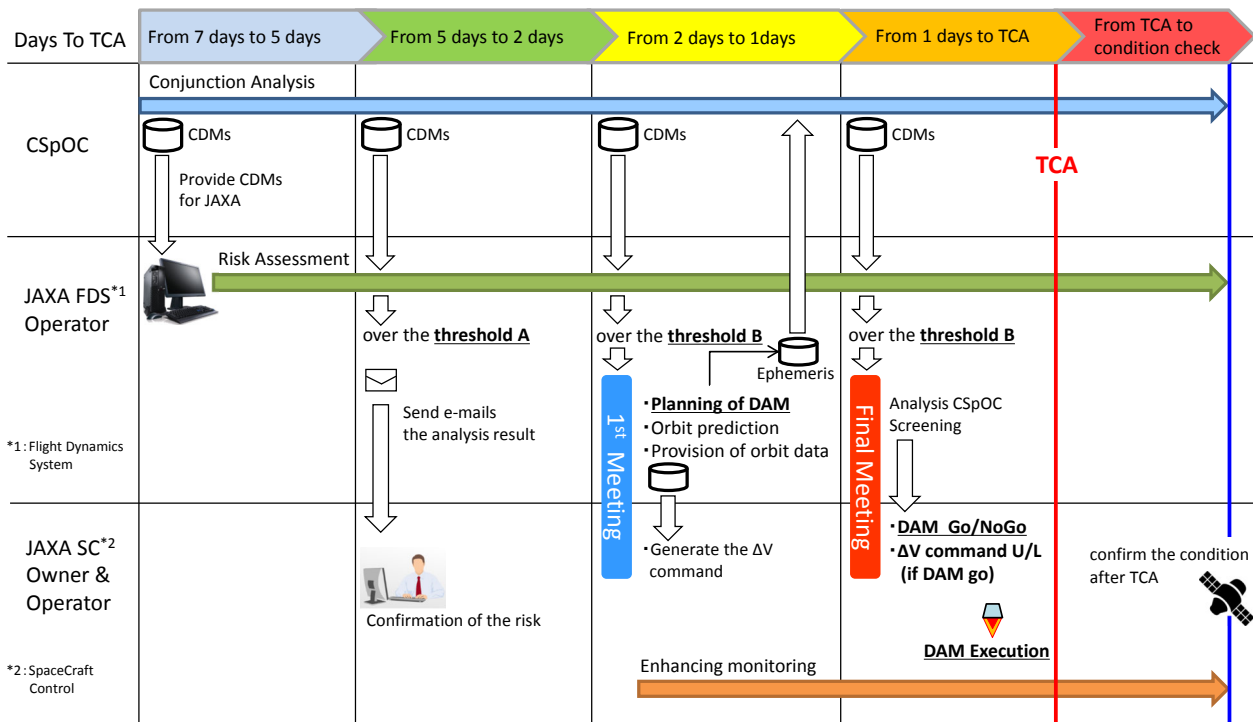


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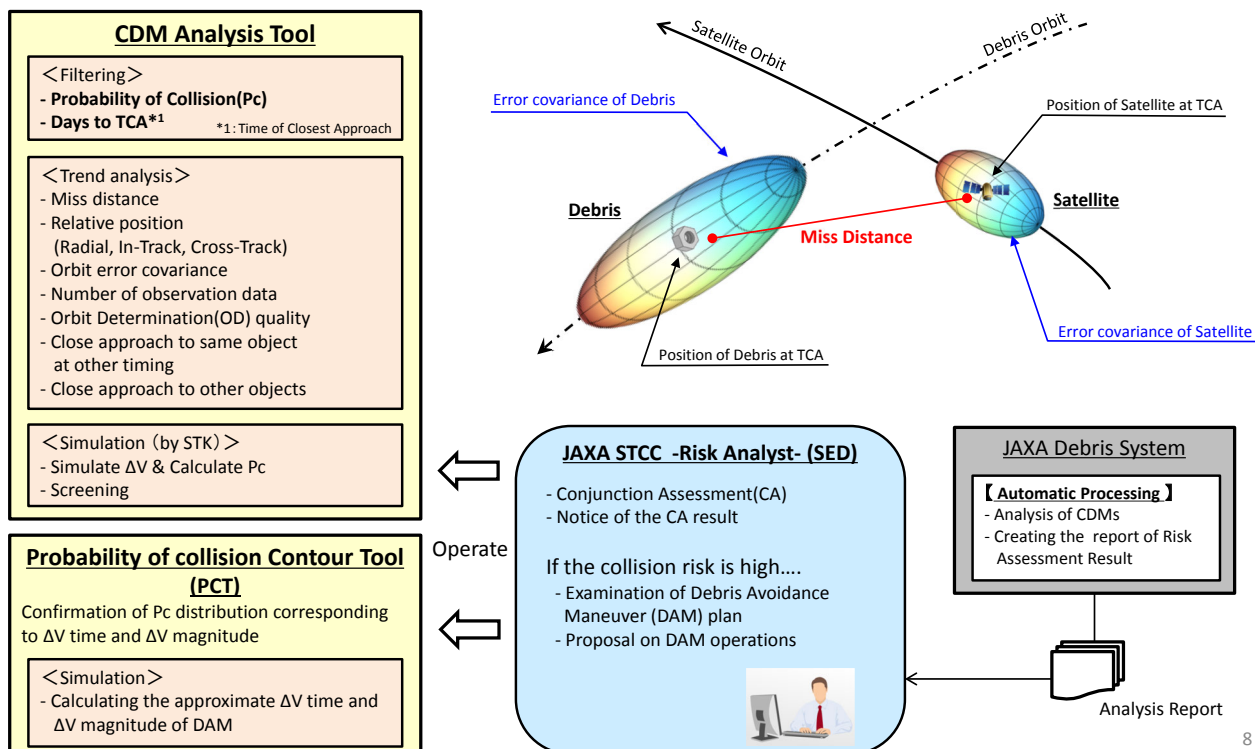
3. Methods of risk analysis for JAXA satellites



Timeline of DAM operations



3. Methods of risk analysis for JAXA satellites



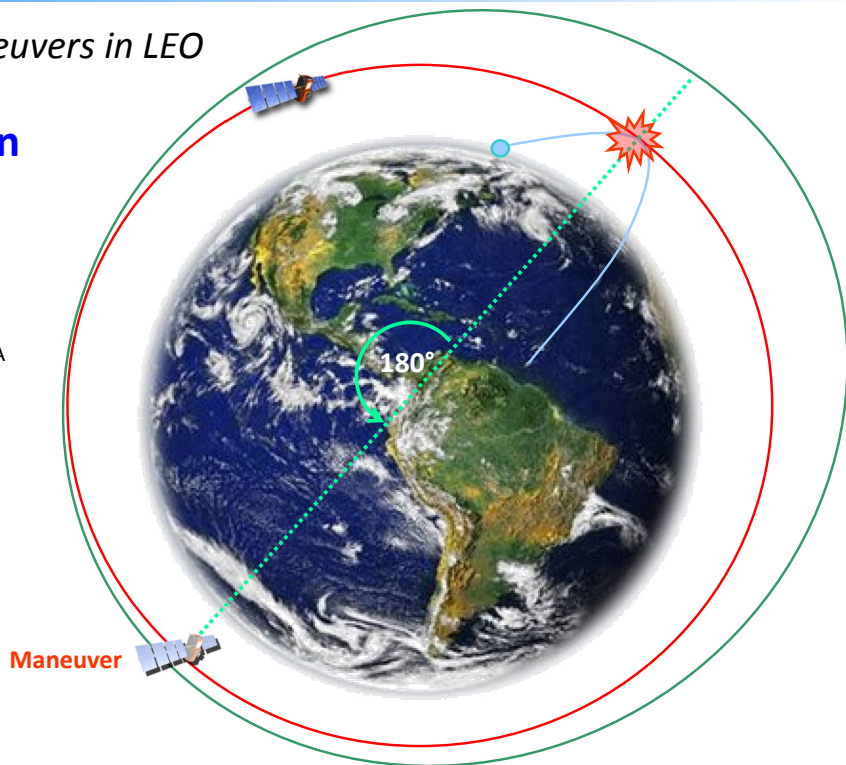
4. Processes for Debris Avoidance Maneuver (DAM)

Debris Avoidance maneuvers in LEO

Radial separation

Tangential maneuver is performed at the opposite side (= 180deg) before TCA

Magnitude order : 50 m Da



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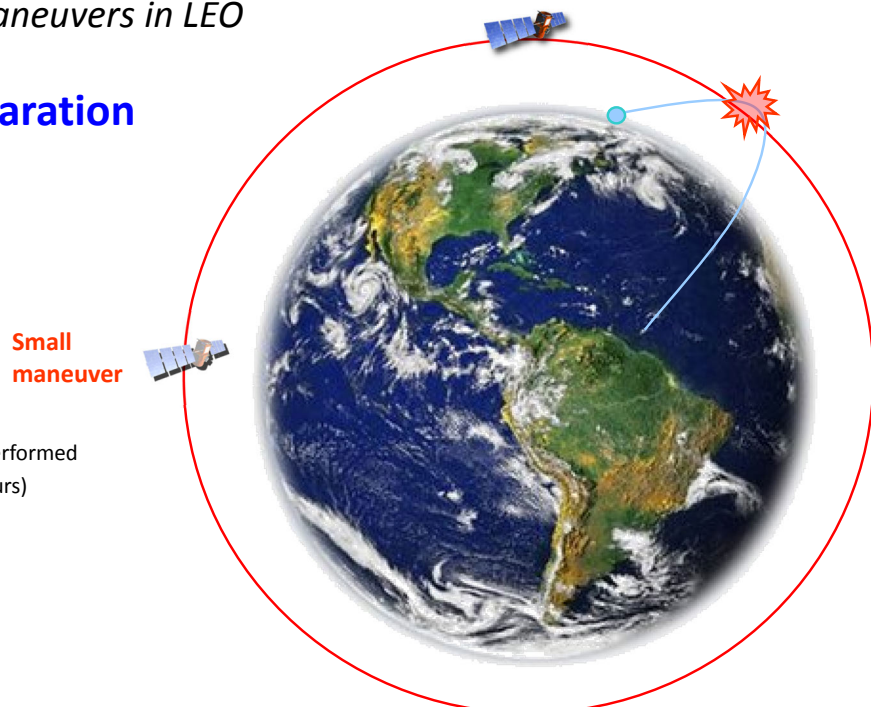
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Debris Avoidance maneuvers in LEO

Along-track separation

A small tangential maneuver is performed a long time before TCA (many hours)

Magnitude order : 20 m Da



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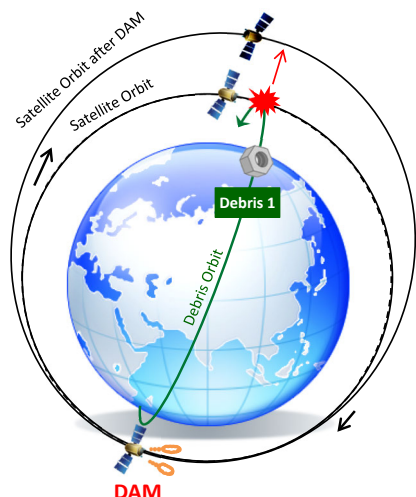
5. Practical examples of DAM operation



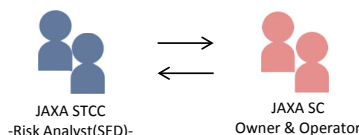
■ (Ex.1) Execute DAM in backup plan instead of nominal plan



Detection of the high risk collision approach for Debris1



□ 1st Meeting (Discussion on DAM)



- ✓ **Share of the conjunction assessment**
 - Debris1 was located below the satellite in the radial direction.
 - Time to TCA was short.
- ✓ **Discuss the DAM plan & Coordinate the DAM timeline**
 - DAM in **nominal plan**
 - <Radial Separation>
 - Maneuver timing : The opposite side(= 180deg) of argument of latitude at TCA
 - DAM in **backup plan**
 - <Radial Separation + Along-track separation>
 - Maneuver timing : 1 revolution earlier than the maneuver timing of the nominal plan

For other risks after DAM, JAXA prepare for backup plan.

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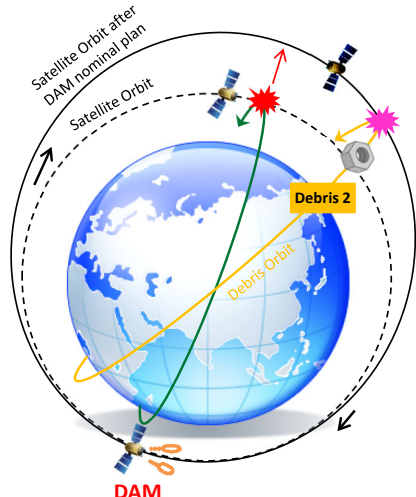
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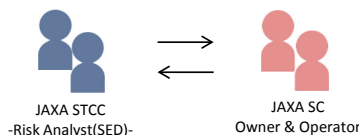
■ (Ex.1) Execute DAM in backup plan instead of nominal plan



Detection of the high risk collision approach for Debris1



□ Final Meeting (DAM GO/NOGO)



- ✓ **Analysis result considering DAM plan by CSpOC screening**
 - Collision risk against "Debris1" was low.
 - Detection of close approach to other "Debris 2" in case of DAM nominal plan.
- ✓ **DAM GO/NOGO**
 - No conjunctions had identified for new orbit in case of DAM backup plan.

➔ **DAM GO (Backup Plan)**

➔ **The satellite condition after TCA was normal**

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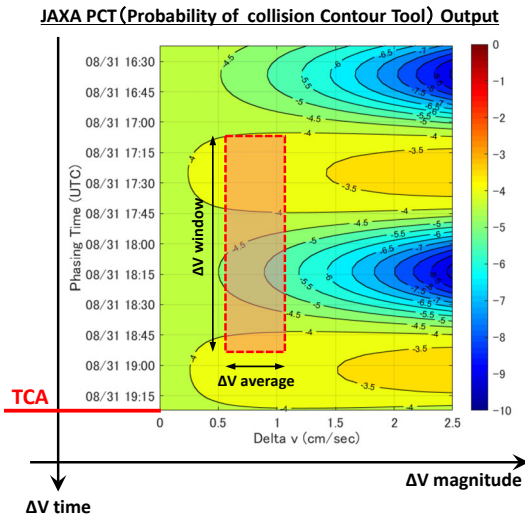


5. Practical examples of DAM operation

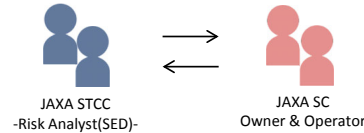
■ (Ex.2) DAM of satellite with OCM(Autonomous Orbit Control Maneuver)



Detection of the high risk collision approach for Debris1



□ 1st Meeting (Discussion on DAM)



- ✓ **Sorting of high-risk approach**
 - Execution of OCM was predicted before TCA.
 - Δv window and Δv magnitude of autonomous OCM were unknown until just before OCM.
 - Conjunction assessment using the "JAXA PCT" is shown on the left figure.

- ✓ **Conjunction Assessment by PCT**

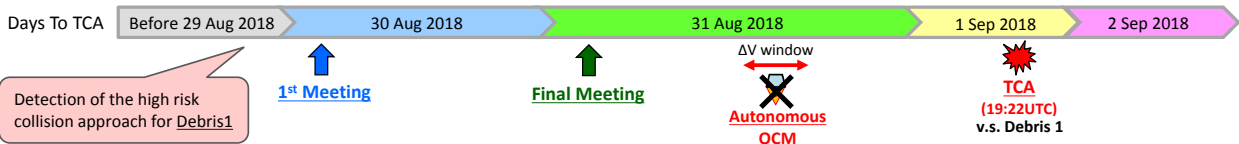
The left figure(JAXA PCT Output) shows ...

 - Collision risk might be high in case of autonomous OCM.

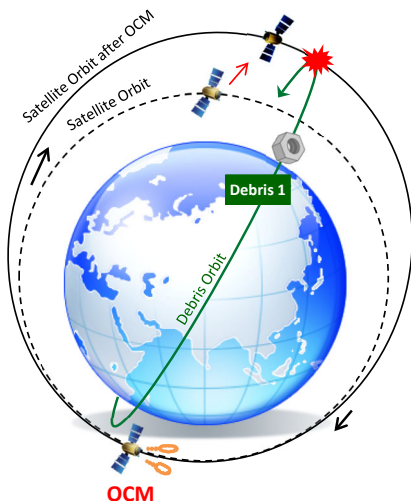
5. Practical examples of DAM operation



■ (Ex.2) DAM of satellite with OCM(Autonomous Orbit Control Maneuver)



Detection of the high risk collision approach for Debris1



□ Final Meeting (DAM GO/NOGO)



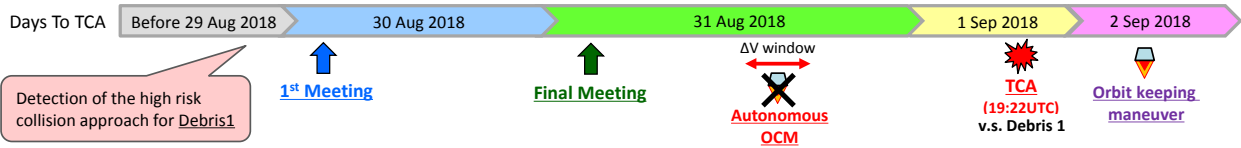
- ✓ **OCM GO/NOGO**
 - Collision risk against Debris 1 might increase in case of autonomous OCM.

➔ **Autonomous OCM was canceled (NOGO)**

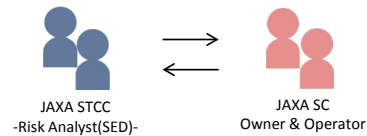
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■ (Ex.2) DAM of satellite with OCM(Autonomous Orbit Control Maneuver)



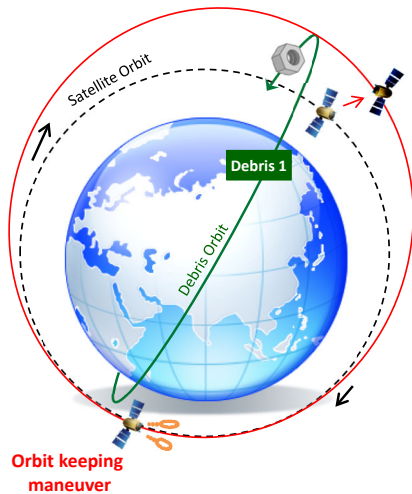
□ Planning of orbit keeping maneuver



✓ Orbit keeping maneuver execution after TCA

- The satellite condition after TCA was normal.
- Additional maneuver was needed for orbit keeping.

➡ [The satellite returned to normal operation](#)



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6. Summary



- We prepare Space Debris Avoidance Maneuver(DAM) process manuals considering the feature of each satellite and perform DAM operations.
- SED continue collision risk analysis and DAM operations to protect the JAXA satellites.
- SED will utilize our operation knowledge and support reliable satellite operation in consideration of the mission in the future.

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Thank you for your kind attention.

