A02

JAXA 追跡ネットワーク技術センターにおける 宇宙状況認識に関する活動の現状

Current Activities on Space Situational Awareness at STCC, JAXA

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宇宙開発の開始以来、我々は衛星からもたらされる恩恵への依存が高まり、昨今では、市民生活まで浸透し、今や人工衛星は欠くことできない国際的なインフラとなっている。この恩恵を享受する一方で、宇宙開発は軌道上にスペースデブリという脅威を発生させている。欠くことのできないインフラである人工衛星を保護、維持していくために、宇宙環境の理解、物体の追跡、及び、接近解析を行う宇宙状況認識（Space Situational Awareness: SSA）は重要な意味を有する。 これまで JAXA 追跡ネットワーク技術センターでは、SSA として上齋原スペースガードセンターのレーダと美星スペースガードセンターの光学望遠鏡によるデブリ観測運用、観測物体の軌道決定、JAXA 運用衛星に接近するスペースデブリのリスク評価、スペースデブリ回避制御運用を実施してきた。 本発表では、過渡期を迎える JAXA の SSA に関する取組と開発・試験中の新 SSA システムについて紹介する。

Since the inception of space exploration, we have become increasingly dependent on the benefits that come from satellites, and nowadays, they have penetrated into our civilian lives, making satellites now an indispensable international infrastructure. While we enjoy this benefit, space exploration has generated the threat of space debris in orbit. Space Situational Awareness (SSA), which is the understanding of the space environment, object tracking, and conjunction analysis, is important for the protection and maintenance of satellites as an essential infrastructure. So far, JAXA's SSA has carried out debris observations using the radar at the Kamisaibara Space Guard Center and the optical telescope at the Bisei Space Guard Center, orbital determination of objects, risk assessment of space debris approaching JAXA's operational satellites, and space debris avoidance control operations. This presentation will introduce JAXA's efforts on SSA and the new SSA system under development and testing as it enters a transitional phase.

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Current Activities on Space Situational Awareness at STCC, JAXA

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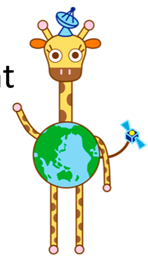
Abstract

The objectives of this presentation

To introduce current SSA activities at STCC, JAXA.
Space ***T***racking and ***C***ommunications ***C***enter

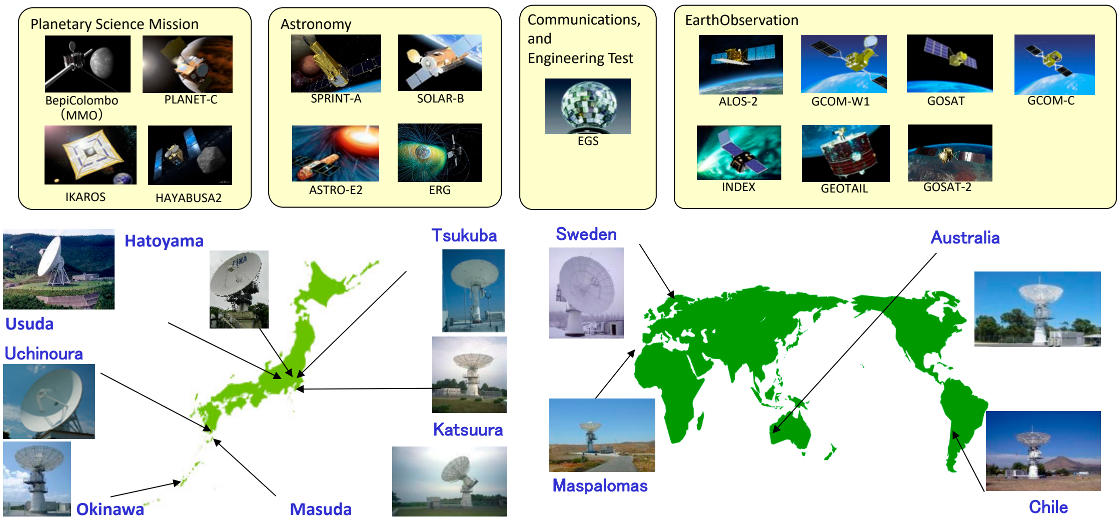
- Conjunction assessment
- Introduction of RABBIT
- Space Debris Observations
- Report the status of future SSA system development



TSUISEKIRIN

Introduction: Activities on STCC

We are operating spacecraft using ground stations not only in Japan but also around the world.



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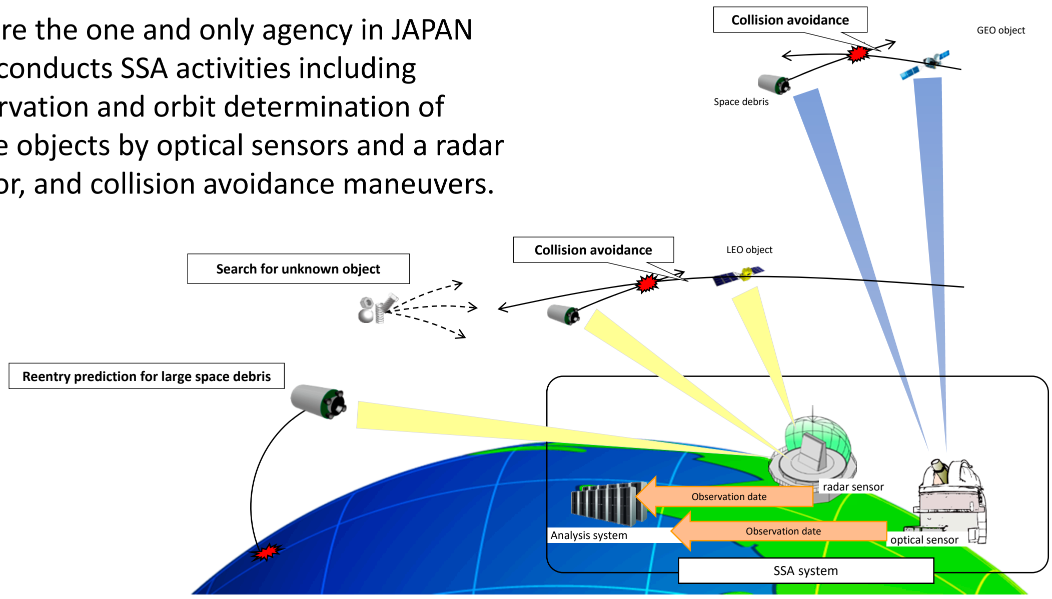
Introduction: SSA Activities

We are the one and only agency in JAPAN that conducts SSA activities including observation and orbit determination of space objects by optical sensors and a radar sensor, and collision avoidance maneuvers.



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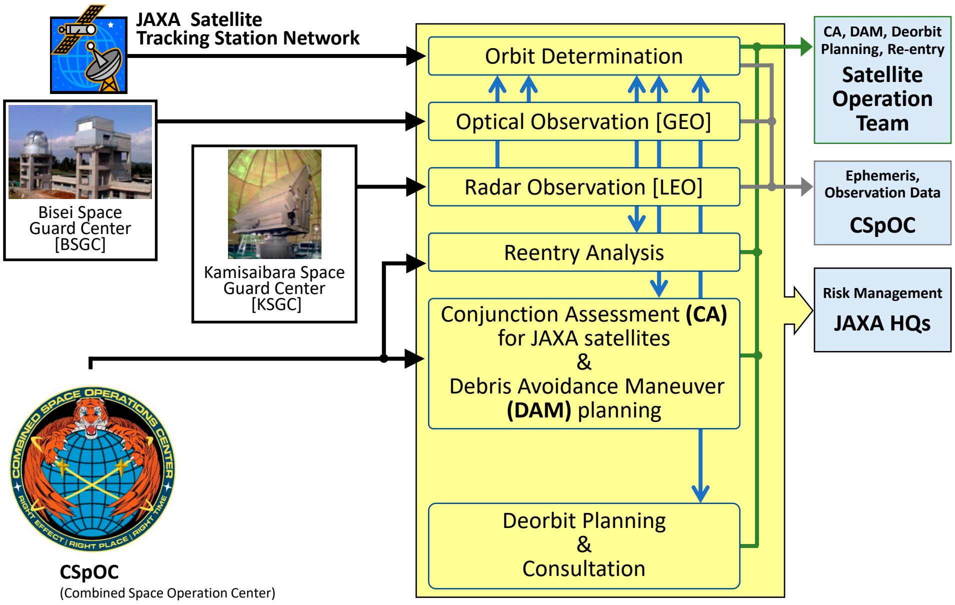
Introduction: SSA Activities



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Conjunction Assessment

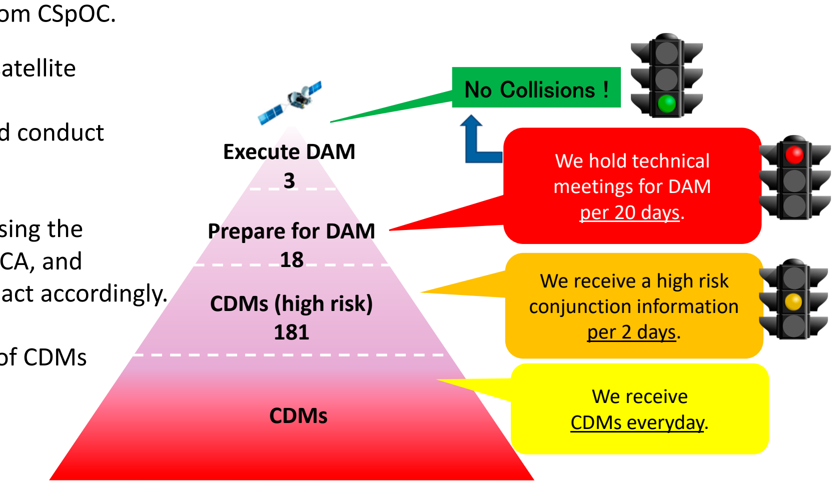
・We have received high risk alerts as CDM(Conjunction Data Message) from CSpOC.

・We analyze them and discuss with satellite operation team.
If the risk is high, we prepare for and conduct DAM(Debris Avoidance Maneuver).

・We assess the criticality of events using the probability of collision and days to TCA, and categorize them into three levels to act accordingly.

・The right figure shows the number of CDMs and the measures we took last year.

・We executed 3 DAMs to mitigate threat of conjunctions per year.



Statistics for conjunction assessment towards JAXA satellites
1 Apr 2019 ～ 31 Mar 2020 / the number of satellites: 14

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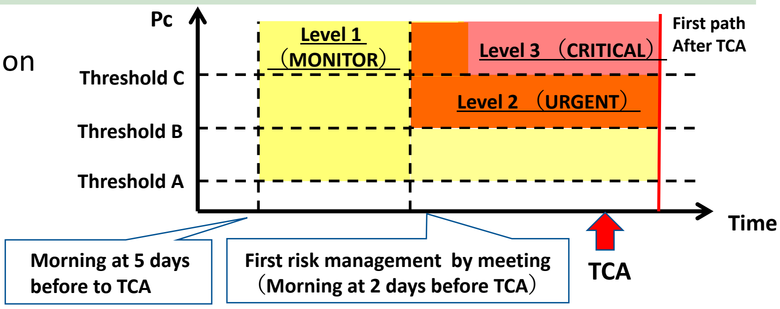
Conjunction Assessment (continued)

Category	Classification	Condition
Level 1	MONITOR	• We have enough time to perform DAM by TCA. • We pay close attention to the situations.
Level 2	URGENT	• Related parties take necessary measures for crisis-management. The first priority is to decrease the risk of collisions. • If necessary, we plan and conduct a maneuver to decrease the risk.
Level 3	CRITICAL	• We cannot perform DAM at this level because there is not enough time left or the satellite has some restrictions. At this point we can not control the risk. • We take all possible measures for crisis-management in order to maintain the operation of the satellite.

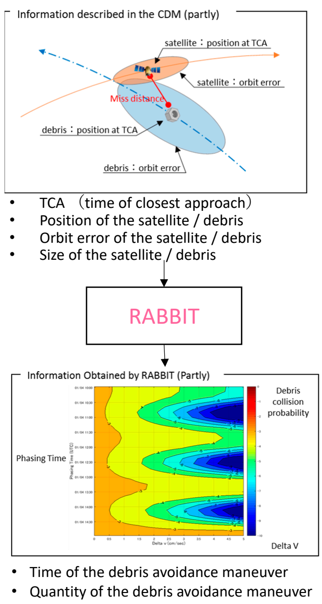
We evaluate the risk of conjunction in terms of both

1. Probability of Collision and
2. Days to TCA.



Introduction of RABBIT

- RABBIT (Risk Avoidance assist tool based on debris collision proBaBliTy)
  An assistant tool developed by JAXA for decision-making on debris avoidance maneuver using CDMs provided by CSpOC.
- RABBIT is a GUI tool based on PCT (Probability of Collision Contour Tool) that calculates and visualizes collision probability and closest approach distance by taking the control values in the cross-track direction as input.
- RABBIT has two modes:
  - Calculator mode
    To calculate collision probabilities and miss distance at TCA corresponding to the CDM(s) and maneuver planning information
  - Visualizer mode
    To visualize the results obtained by Calculator mode



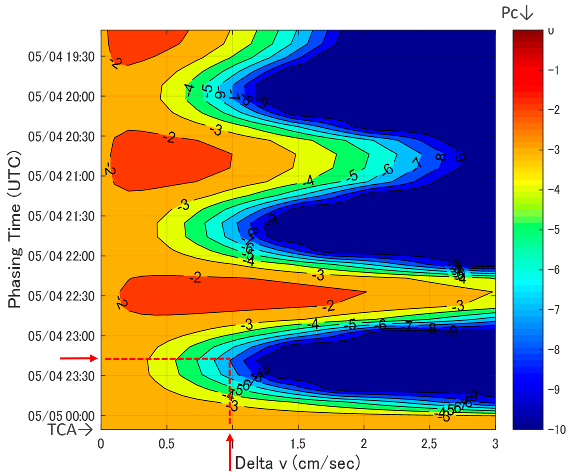
Introduction of RABBIT

When the altitude of debris is lower than that of a satellite

- Consider the debris avoidance operation based on the right figure obtained by RABBIT :

  In order to lower the collision probability to 1.0E-06 order or less, recommend the following measures as a maneuver plan

  - ✓ Maneuver time : Half a revolution before TCA
  - ✓ Maneuver quantity : **<u>1.0 cm/s</u>**



Introduction of RABBIT

Soon to be published on the JAXA website

- RABBIT Environmental Conditions
  - Prepare the CDM
  - Computer specifications is equal to or greater than the following
    - OS ： Windows10
    - Processor ： Intel® Core™ i5-6300U CPU@2.40GHz 2.50GHz
    - Installed memory (RAM) ： 3.89GB
    - System type ： 64-bit Operating System
  - Need more than 7GB of free space
    - MATLAB Runtime : 6.5GB
    - RABBIT : 200MB

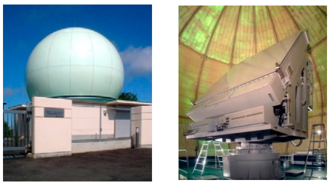
- Setting of satellite data
  - Individual designation of hard body radius is possible

Space Debris Observations

Since 2002

Bisei Space Guard Center (BSGC)
[Telescopes]

From 2004 to 2020

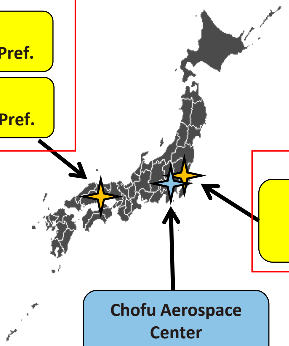


Kamisaibara Space Guard Center (KSGC)
[Radar]

Observations

BSGC
Okayama Pref.

KSGC
Okayama Pref.



Analysis

Tsukuba Space
Center
Ibaraki Pref.

Chofu Aerospace
Center
Tokyo (we are here)

To migrate to the new system, the radar was taken out of operation in 2020.

Current Issues and Future SSA System

Current Issue

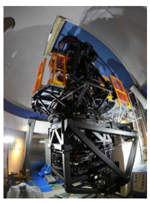
・Aging System: Both the radar and telescope systems were constructed more than 10 years ago.
・Low Capability: Current radar can observe only 6% of LEOs in CSpOC catalog.

→ **SSA analysis JAXA can perform with our own data is limited.**

NEW SSA System

・**Radar**: *Newly developing*
Enhances capability for LEO debris observation.
・**Telescope**: *Refurbishing*
Maintains the current capability.
・**Analysis System**: *Restructuring*
Enhances the capability for conjunction assessment and re-entry analysis with the data that will be provided by the new radar and the telescopes.

→ **Constructing now!**



1m telescope

New radar

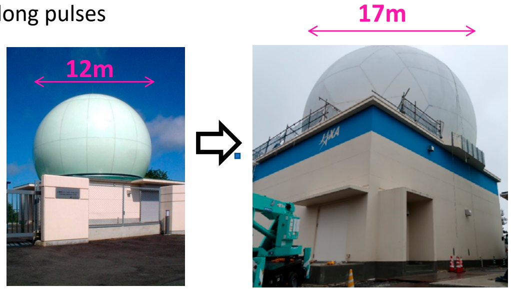
New Radar Concept

Scope

- Improving the ability to understand the trajectory of space debris in the low orbit zone (altitude 500-800 km) where many JAXA satellites are active
- Space debris detection of 10 cm or more in diameter at altitudes below 650 km
- More than 200-fold improvement in detection capability against current radar at 650 km altitude in comparison

To achieve the above

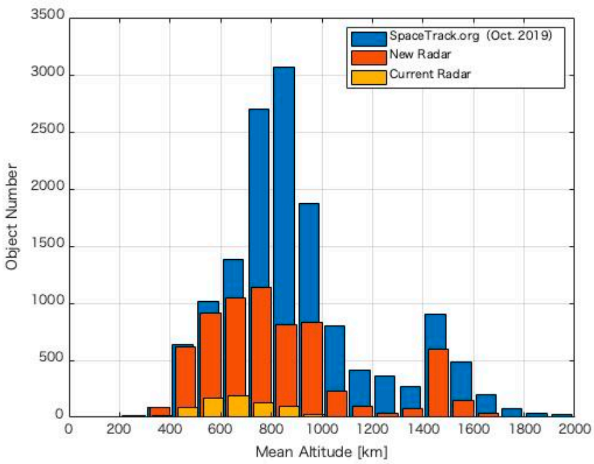
- Adopt a semiconductor capable of transmitting high power and long pulses
- Increasing the number of elements in the antenna
- (i.e. increasing the size of the antenna aperture)
- Increase the sensitivity of the receiver
- Adoption of digital beamforming
- Hardware configurations
- that can be enhanced by later software modifications



Current Radar New Radar

New Radar

Comparison of Current Radar and New Radar



This graph shows the mean altitude distribution of objects that can be observed by JAXA's current radar (yellow) and that of the future SSA radar (orange), in comparison to the number of space debris published by CSpOC as of October 2019 (blue). CSpOC publication includes the number of objects that cannot be observed by JAXA's radar located at Okayama Prefecture.

New Radar

Aiming to acquire the ability to observe unknown objects

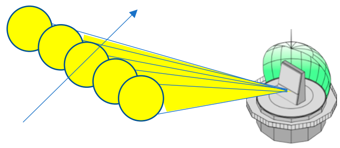
The key technology elements required for unknown object observation

- Scanning Methods for Initial Acquisition in Radar
- Tracking filter
- Integral Processing and Integrated Phase Correction

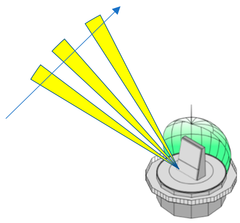
e.t.c.

The above is expected to be improved through accumulation, analysis and further study of operational data.

It also has the ability to reflect research results in the system by improving software.



Scanning



Tracking

AZ Mechanical Axis Rotation Combined with Electron Beam Scanning

Major Specifications and Schedule

		New System	Present System
Radar	Observation capability	10 cm Φ (650 km high)	1.6 m Φ（650 km high）
	# of simultaneously observable objects	Max 30	Max 10
Telescope	Limiting magnitude	18th (1mΦ telescope) 16.5th (50cmΦ telescope)	18th (1mΦ telescope) 16.5th (50cmΦ telescope)
Analysis system	# of managed objects	Max 100,000	Max 30,000
	# of observation paths（radar）	10,000 paths/day	200 paths/day
	Observation planning	Automatically	Manually

	2016	2017	2018	2019	2020	2021	2022	2023
Basic Plan on Space Policy	Construct SSA facilities and an operational framework integrated with MOD, JAXA and other Japanese governmental institutions.							
	Preliminary Design	Detail Design				Integration Test	Trial Operation	Operation
			Development		Now			

New radar will be completed soon

Transmitter hanging operation

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New radar will be completed soon

Fixed-point camera video

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New 1m telescope will be completed soon

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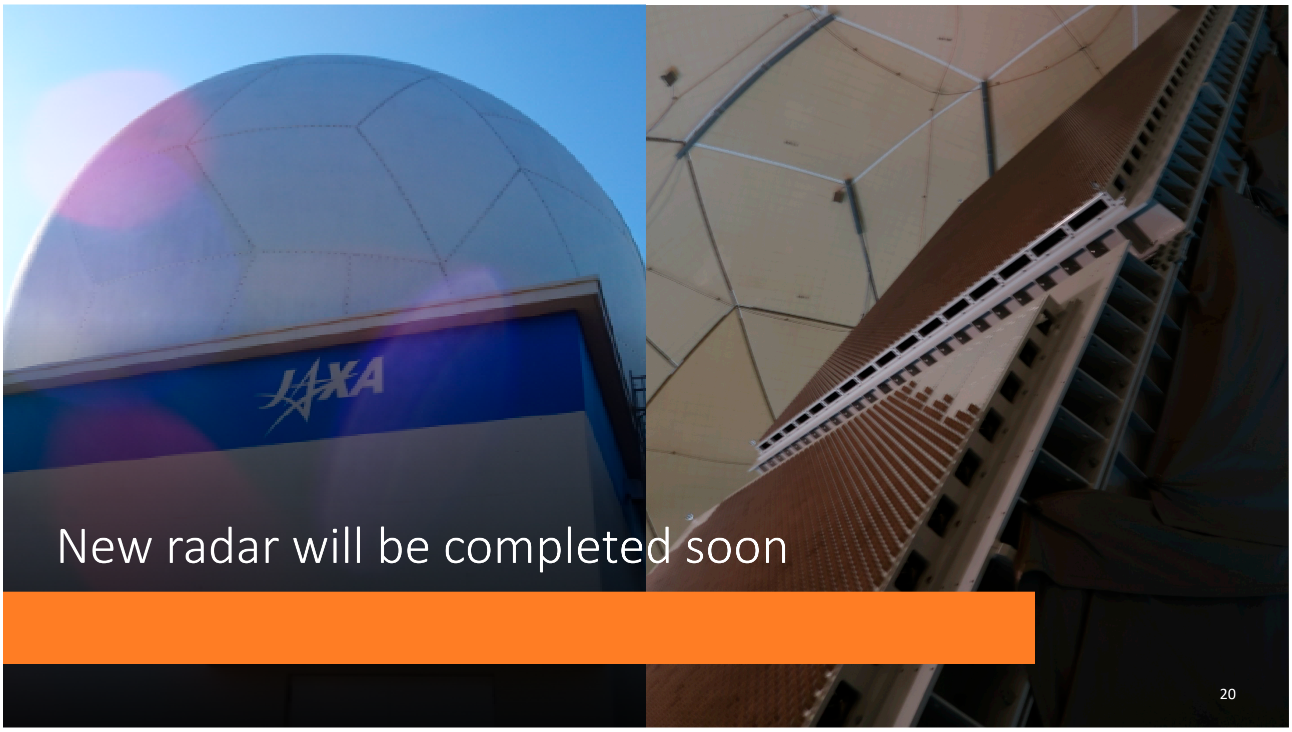

New radar will be completed soon

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Summary

<u>JAXA works on SSA activities using both our own sensors and analysis system, and data from CSpOC.</u>

・We observe space debris using optical sensors(1mφ and 50cmφ) and a phased array radar for GEO and LEO respectively.

・At the same time, we are developing the new SSA system and will start its operation from 2023.

・We do conjunction assessment and collision avoidance maneuvers to defend our satellites against threats of space debris.

・We do re-entry analysis of large space objects using own system.

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Thank you for your kind attention.

There is a movie that summarize our SSA activities.
↓↓↓ Click Here! ↓↓↓
https://www.youtube.com/watch?v=zcYE9JH5_UY