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# Activities on Space Situational Awareness at STCC, JAXA

**Arimi Uemoto, Takuya Hatakeyama, Shinichi Nakamura, Saeko Kuchiki, Saori Ikeda and Hideaki Hinagawa(JAXA)**

Since the beginning of space engineering development, many objects have been emitted to space, and the number of debris has increased rapidly. It is now estimated that about 20,000 debris of various shapes and sizes exist in space.
As the space environment deteriorates, various efforts to grasp and avoid the possible threat of space debris, such as colliding into spacecraft and re-entering to the Earth, have been conducted worldwide. The efforts consist of observing the space debris, calculating their orbits, and cataloging them, and these are called “Space Situational Awareness" or SSA activities.
At JAXA, our SSA activities include observations of space debris using radar at Kamisaibara Space Guard Center and optical telescopes at Bisei Space Guard Center, orbit determination, risk evaluation of space debris approaching our satellites, and avoidance maneuver operations.
In this presentation, we introduce our SSA activities at Space Tracking and Communications Center and the outline of our new SSA system.

***Biography***

**Arimi Uemoto**
Researcher
Flight Dynamics Team, Space Tracking and Communications Center

Majored in astrophysics at university. Joined Japan Aerospace Exploration Agency (JAXA) in 2016 and have been engaged in SSA activities and satellite operation for flight dynamics at the Space Tracking and Communications Center.

**Takuya Hatakeyama**
Engineer
Flight Dynamics Team, Space Tracking and Communications Center

Majored in astronomy at university. Joined SED Co., Ltd. in 2016 and was in charge of satellite operation until June 2017. In July, seconded to JAXA and have been engaged in satellite operation for flight dynamics and SSA activities since then.

# Activities on Space Situational Awareness at STCC, JAXA

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Japan Aerospace Exploration Agency

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## Abstract

### The objectives of this presentation

To introduce current SSA activities at STCC, JAXA.

***S**pace **T**racking and **C**ommunications **C**enter*

- Observations with optical sensor and radar sensor
- Conjunction assessment
- Collision avoidance and Maneuver planning
- Re-entry analysis
- Report the status of future SSA system development

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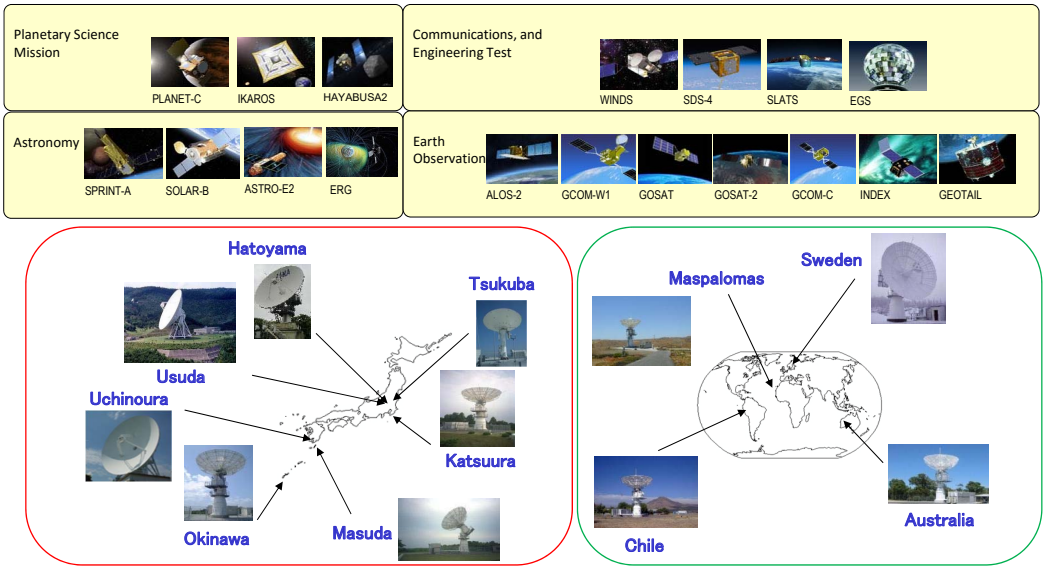
# Introduction: Activities on STCC

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

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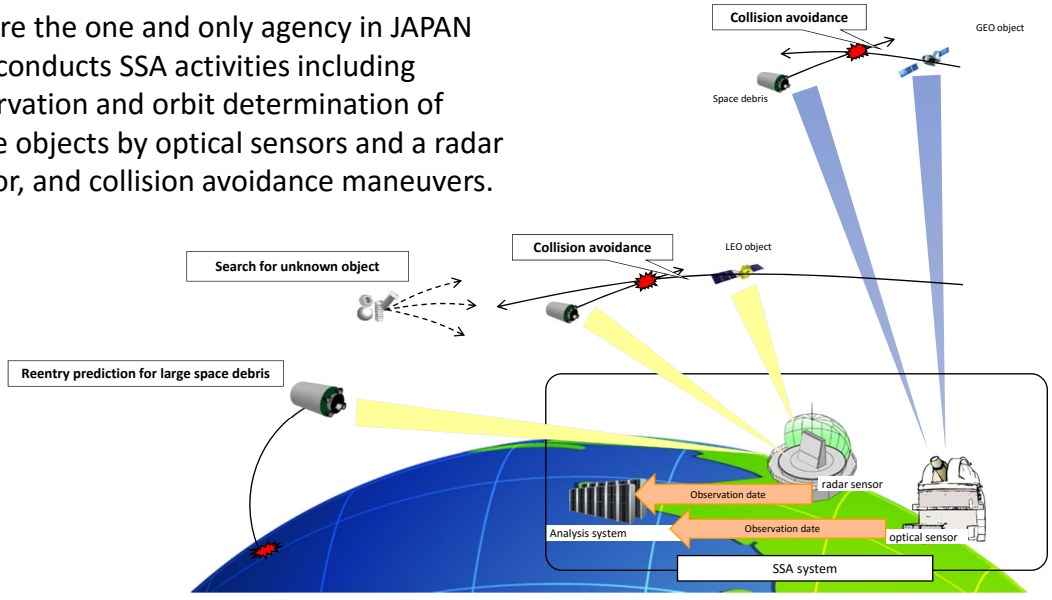
# Introduction: SSA Activities

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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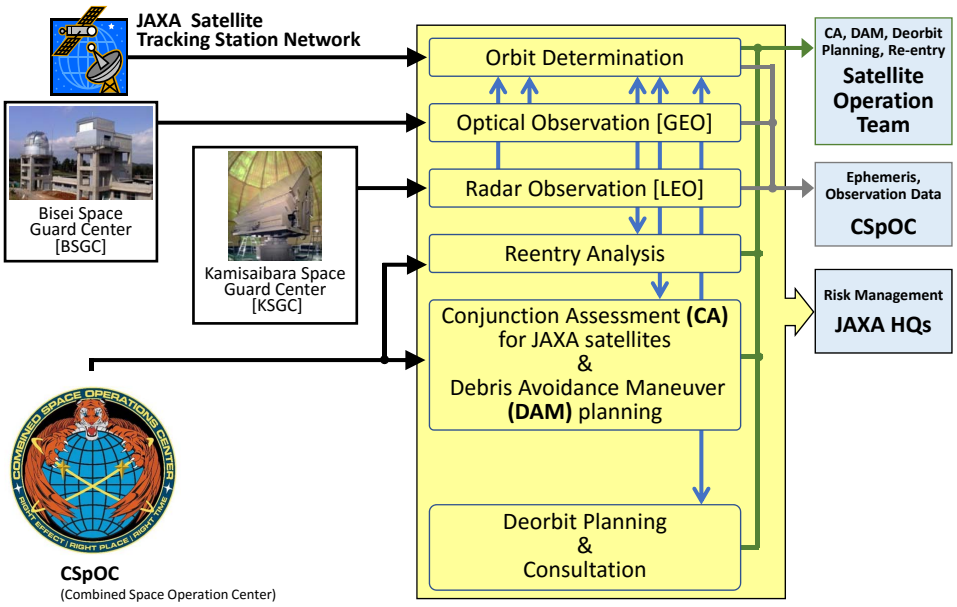
# Introduction: SSA Activities

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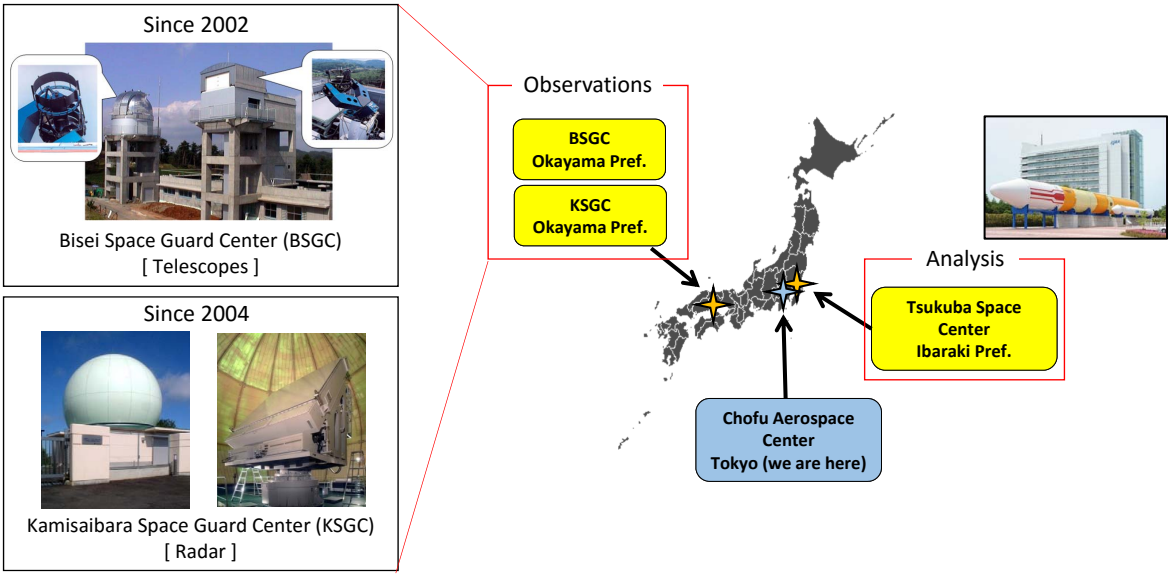
# Space Debris Observations

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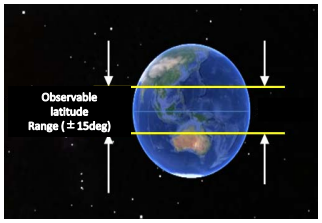
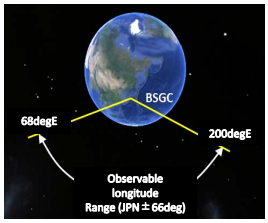
# Space Debris Observations: Optical Sensor


GEO-region Observation




Seen from the direction of equator.
(latitude range: 0±15 degrees)




Seen from the direction of the Arctic.
(longitude range:
East: 68 degrees to 200 degrees)

| Aperture | 1 m |
|---|---|
| limit. mag. | 18.5 (19:under fine sky condition) |
| max tracking speed | RA/Dec 2.5 deg/s |
| Type | fork type equatorial indicator |
| CCD camera | FOV 2.4deg × 1.2deg 2K × 4K pixel CCD |
| **Aperture** | **50 cm** |
| limit. mag. | 16.5 (17:under fine sky condition) |
| max tracking speed | RA/Dec 5 deg/s |
| Type | fork type euatorial indicator |
| CCD camera | FOV 1.7deg × 1.7deg 2K × 2K pixel CCD 1set |

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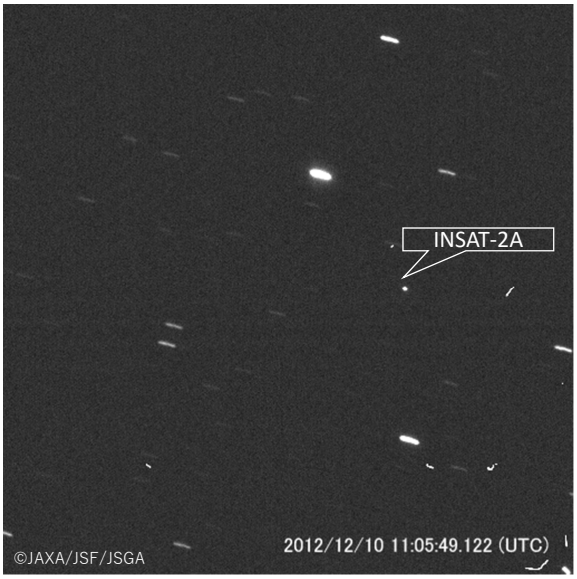
# Space Debris Observations: Optical Sensor

This movie is a combination of images taken when INSAT 2 A approached ETS - 8.

- TCA (Time of Closest Approach)
  December 10, 2012 at 23:06 (UTC)
- Observations were carried out while tracking INSAT using 1 m telescope.
  The exposure time was 2 seconds.
- These observations were conducted around 11:06 (UTC)(12 hours before TCA).
- The minimum distance was about 12 km.

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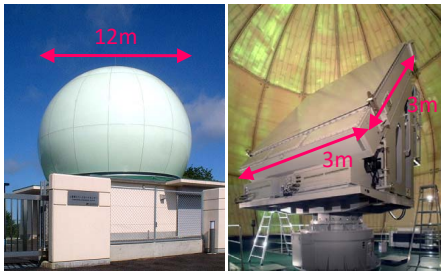
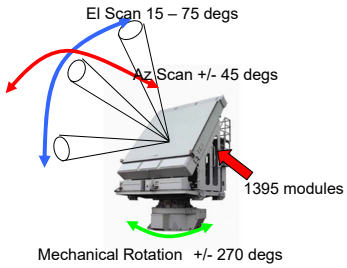
# Space Debris Observations: Radar Sensor




| Specification & Capability | |
|---|---|
| Radar Type | Phased Array |
| Frequency | S-band |
| Beam Size | Horizontal : 2 deg<br>Vertical : 2 deg |
| Transmission & Receiving Modules | 1395 modules<br>75kW (Max Power) |
| Beam Scan | Mechanical Scan：<br>AZ：±270 deg<br>(Rotation Velocity : 10.8 deg/s)<br>EL: 54 deg fixed<br>Electrical Scan<br>AZ: ±45 deg<br>EL: 15～75 deg |
| Tracking Capability of Simultaneous Observations | 10 objects |
| Detection Capability | 1.6mφ @ altitude : 650 km<br>Max slant-range : 1350 km |

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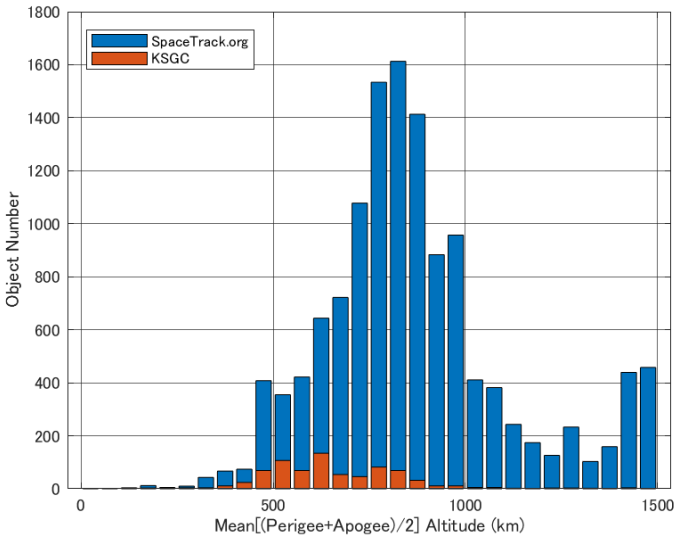
# Space Debris Observations: Radar Sensor

- We observe 750 LEOs.
- This is a histogram showing the mean altitude vs the number of objects.
- We observe 6% of LEOs that cataloged in Space-Track.org.
- We use this radar to observe re-entry objects.

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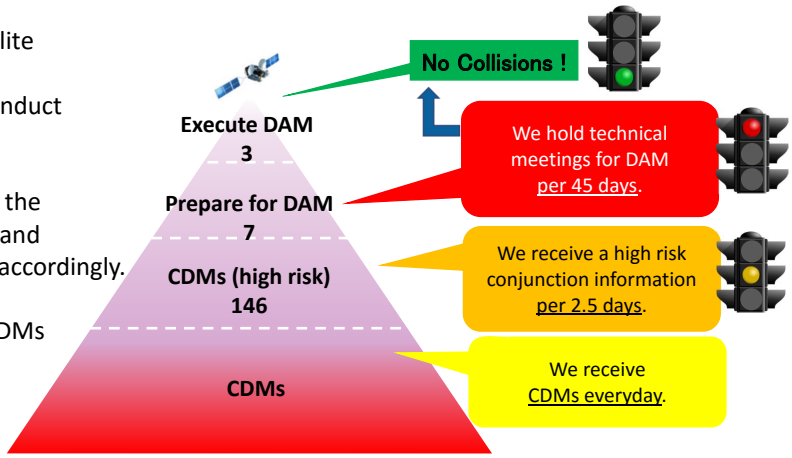
# Conjunction Assessment

- 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 2017 ～ 31 Mar 2018 / the number of satellites: 14

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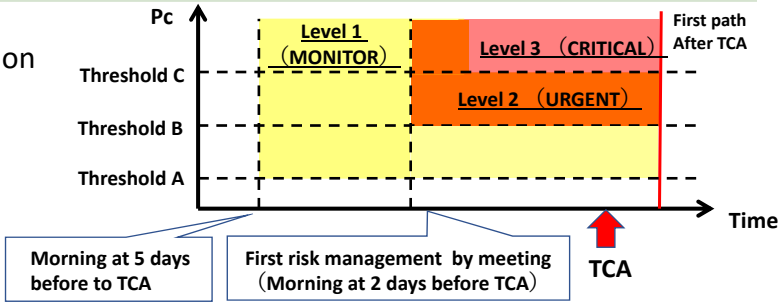
# Conjunction Assessment (continued)

| Category | Classification | Condition |
|---|---|---|
| Level 1 | MONITOR | • We have enough time to perform DAM by TCA.<br>• 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.<br>• 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.<br>• 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.

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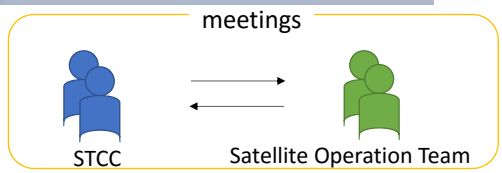
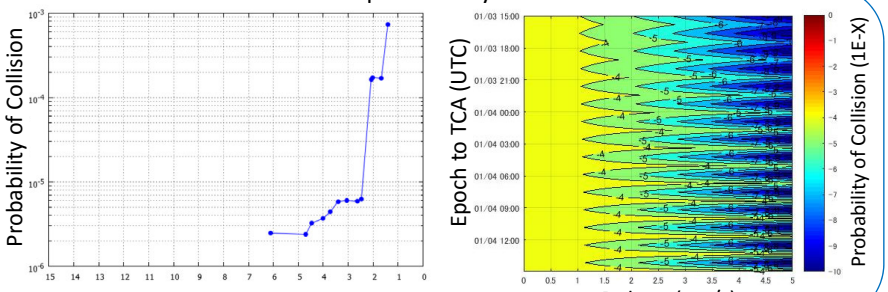
# Collision Avoidance and Maneuver Planning

・First risk management meeting
- Share details of the conjunction
- Discuss a maneuver plan
- Coordinate a timeline etc.

・Final decision-making meeting
- Share results of screenings between the primary object (JAXA satellite) and other space debris including another spacecraft
- Make a Go/No-Go decision to execute debris avoidance maneuver




sample of analysis

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# Re-entry Analysis

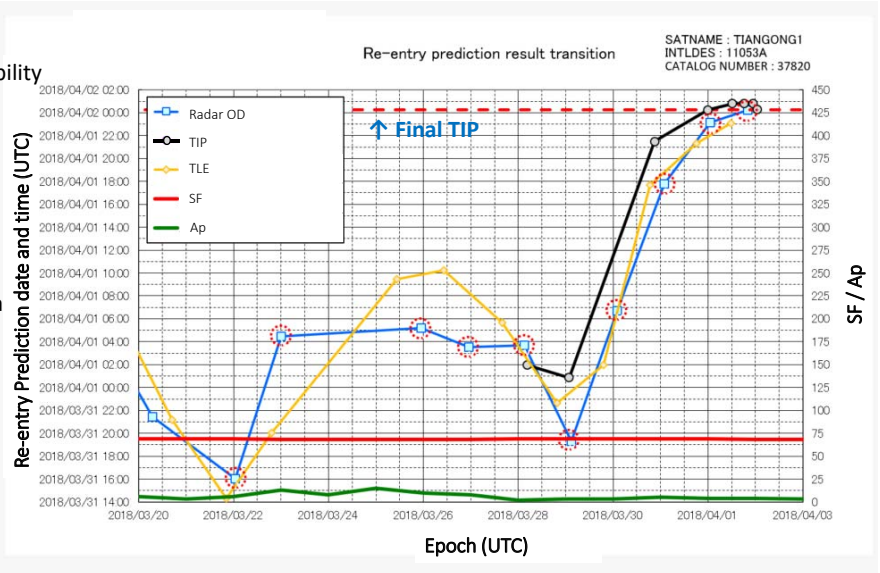
・conduct re-entry analysis for large objects that will have the possibility of impact ground by our own system, DOARS※1

・calculate when & where (latitude / longitude) an object re-enters

・using TLEs published on SpaceTrack.org and/or our radar data

・We have participated IADC※2 campaigns.

・The right figure shows the results of re-entry of Tiangong-1. The result may be correct because of the difference with final TIP※3




※1：Debris Orbit Analysis Research System ※2：Inter Agency Space Debris Coordination Committee
※3：Tracking and Impact Prediction (from SpaceTrack.org)

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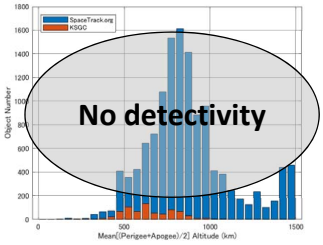
# Current Issues and Future SSA System

## Current Issue

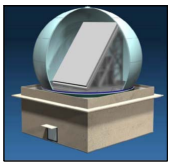

・Aging System: Both the radar and telescope systems were constructed more than 10 years ago.
・Low Capability: Current radar can observe only 6% of LEOs in CSpOC catalog.

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




## NEW SSA System


1m telescope


New radar

・**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!**

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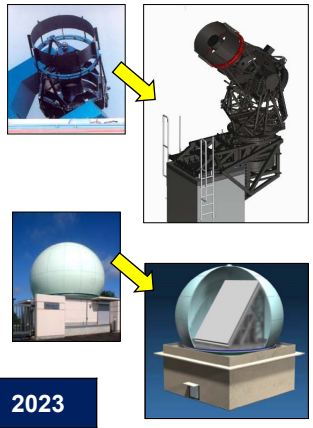
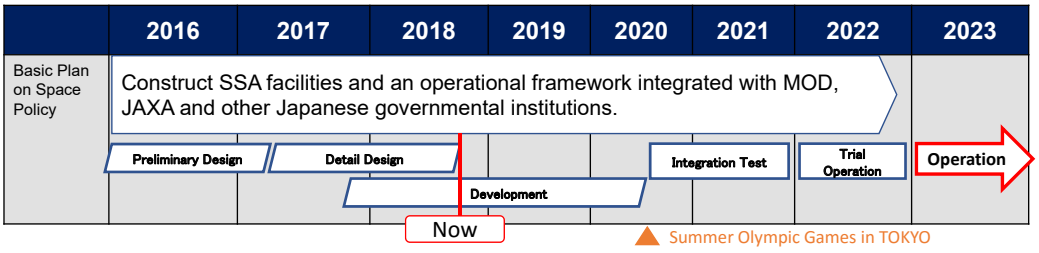
# Major Specifications and Schedule

| | | 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)<br>16.5th (50cmΦ telescope) | 18th (1mΦ telescope)<br>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 |



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# Summary

**JAXA works on SSA activities using both our own sensors and analysis system, and data from CSpOC.**

・We observe space debris using optical sensors(1mϕ and 50cmϕ) and a phased array radar sensor 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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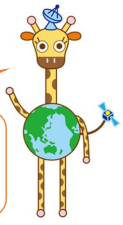
Thank you for your kind attention.



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