Status Report of Tanegashima SLR Station (GMSL) and Developing Status of JAXA's Next SLR Station

Takehiro Matsumoto, Katsuhide Yonekura, Moeko Ryoki, Shin Miyatani, Kazuhiro Yoshikawa, Takushi Sakamoto, Yuki Akiyama, Hiroyuki Ito and Shinichi Nakamura

Japan Aerospace Exploration Agency (JAXA)

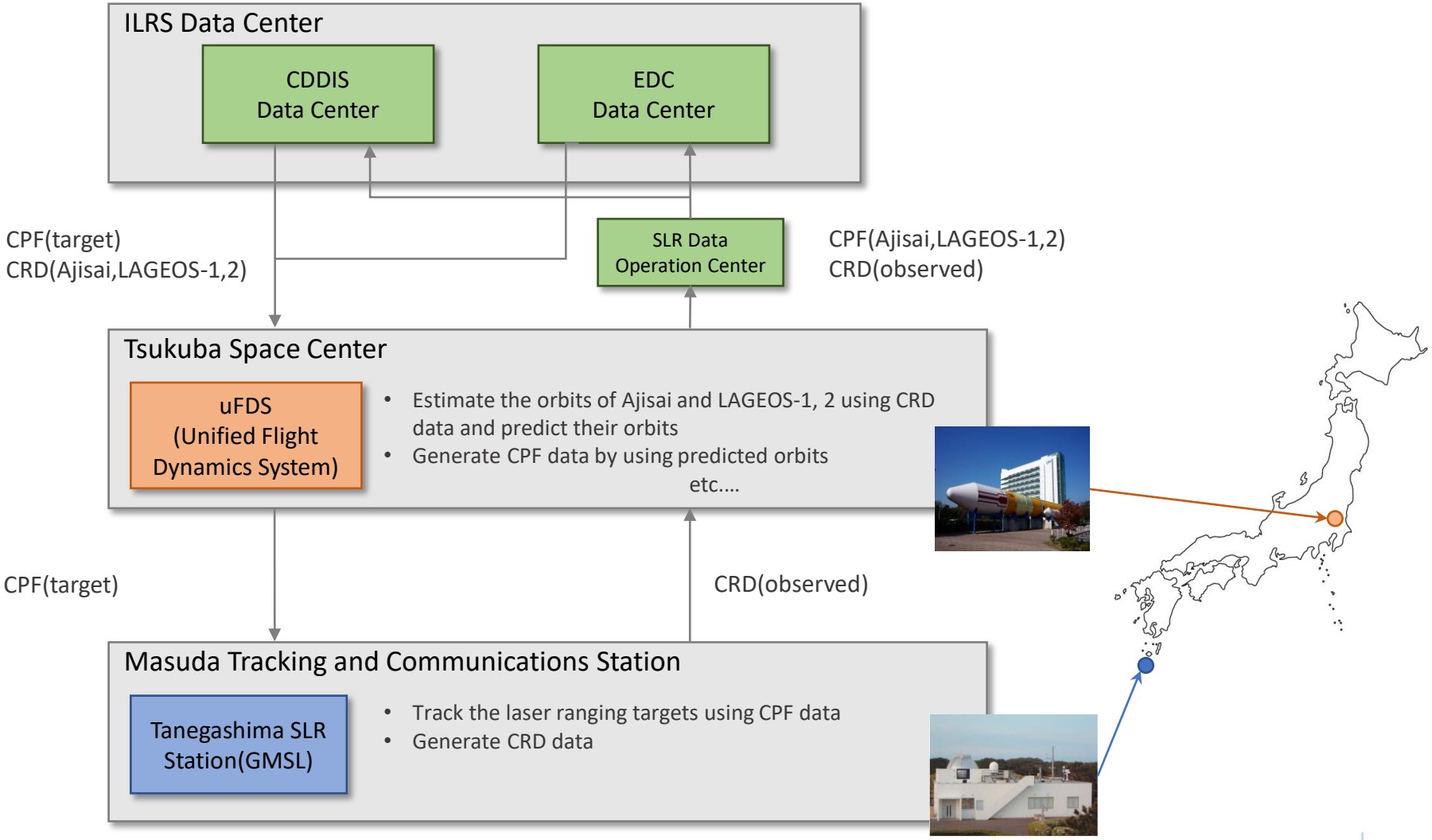
Overview

The objectives of this presentations are:

- To report JAXA's current operation status (Tanegashima SLR station and flight dynamics system).
- To report the progress status of JAXA's next SLR station.

JAXA Current Operation

Systems and data flow



Tanegashima SLR station

System Overview

- Tanegashima station was built in 2004.
- It has the capability of ranging satellites with a laser retroreflector array (LRA) from low Earth orbit to geostationary orbit.
- Unfortunately, it has been in Quarantine since 2012 due to the temporary facility troubles.

Telescope	
Aperture	1 m
Type	Cassegrain
Pointing Accuracy	< 2 arcsec
Laser	
Wavelength	532 nm
Pulse Width	Low Mode: 50 ps High Mode: 250 ps
Repetition Rate	10 Hz
Maximum Energy	Low Mode: 50 mJ/pulse High Mode: 250 mJ/pulse
Detector	
Type	MCP-PMT

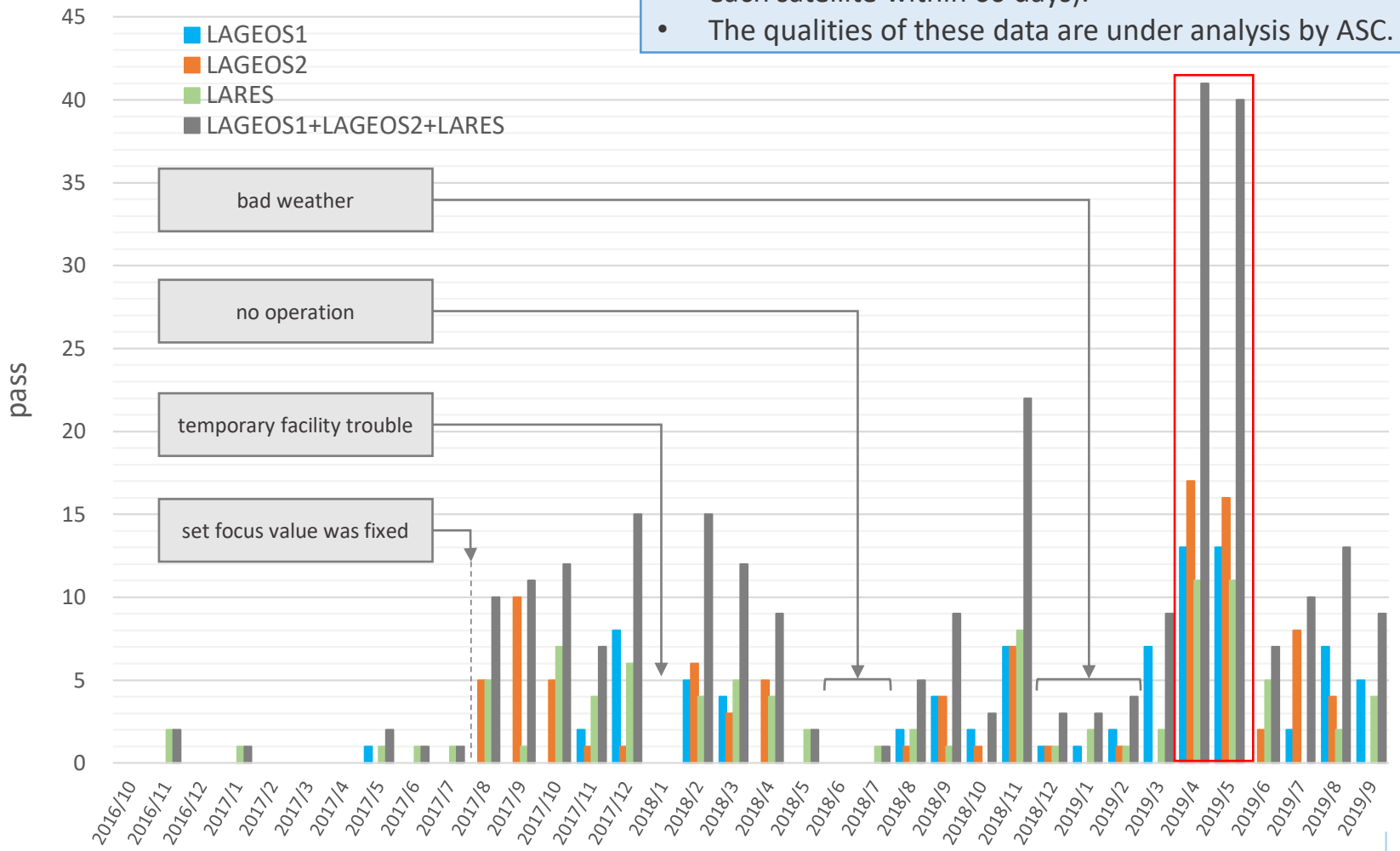
Telescope

Laser and Coude Path

Tanegashima SLR station

Pass Performance

- Number of data during this period was over the minimum pass criteria to return to Normal operation (20 passes on each satellite within 60 days).
- The qualities of these data are under analysis by ASC.



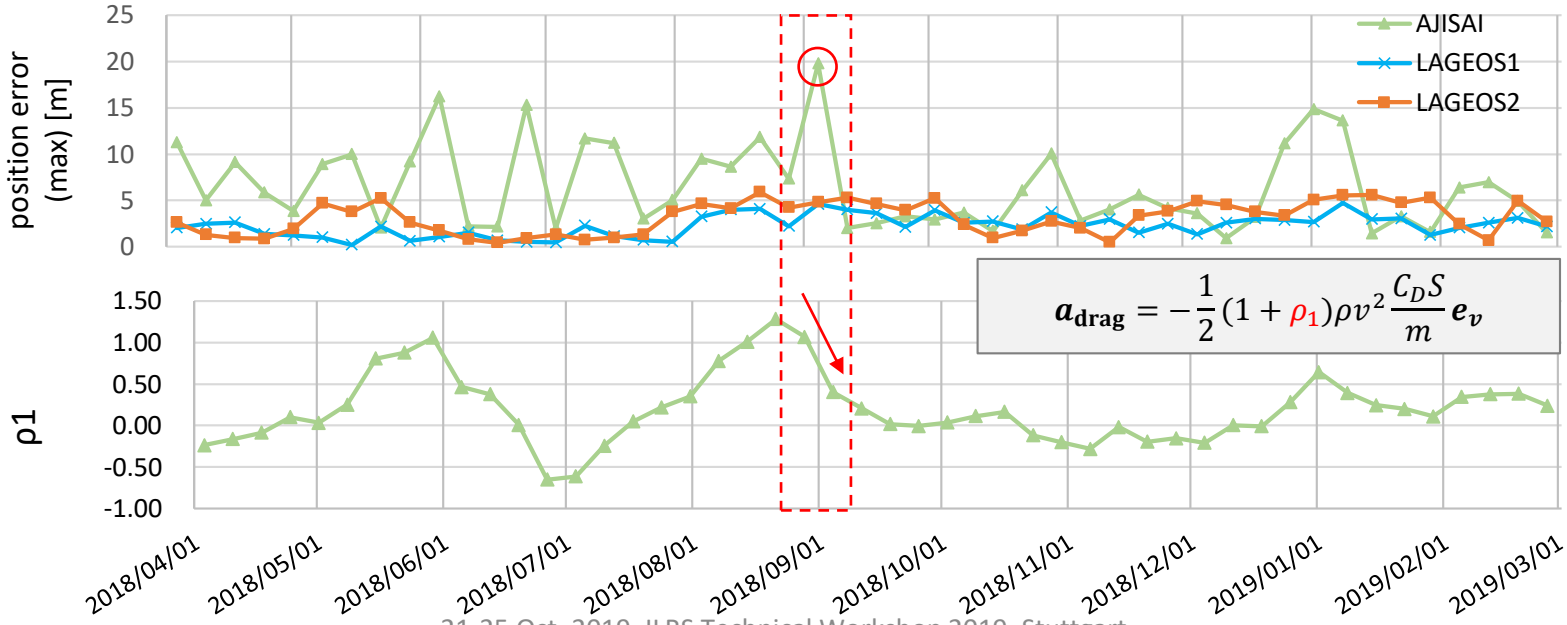
Flight Dynamics System

Orbit Estimation and Prediction

- JAXA estimates the orbits of Ajisai and LAGEOS1, 2 using our flight dynamics system, and distribute the predicted ephemerides (CPF) every day.

Accuracy Evaluation of CPF

- Predicted vs. Observed ephemeris (upper figure)
  - The maximum position errors of Ajisai, LAGEOS1, 2 are no more than 20m, 5m, 5m respectively.
- The scale factor of atmospheric density ρ1 (lower figure)
  - Estimated as a part of the orbit estimation process (for only Ajisai).
  - The rapid change of atmospheric density caused bad accuracy of Ajisai CPF.



Next SLR station

Motivation

- Tanegashima station is too old to acquire sufficient amount of data and continue to work for long.
- SLR technology has evolved over the last few decades(kHz ranging, SPAD, infrared wavelength, etc.).

Location

- JAXA's next SLR station will be located in Tsukuba Space Center, Ibaraki Pref.
- Quicker access than Tanegashima station saves time:
  - to change the system configuration
  - to find causes of troubles
- Tsukuba is more suitable for laser ranging because the weather is better than that of Tanegashima.

Concept

- The concepts of the next SLR are simple, compact and cost-effective.
- It is planned to be equipped with new SLR technologies.

Next SLR station

Comparison with Tanegashima

	Tanegashima	Tsukuba
Wavelength	532 nm	532 nm and 1064 nm
Repetition Rate	10 Hz	1 kHz
Detector Type	MCP-PMT	SPAD
Safety System	Radar	Radar and ADS-B

Accuracy (design value)

Target	Single-Shot (RMS) (σ_{SS})	Normal Point Precision (σ_{NP})	Pass-by-Pass Bias Stability* (σ_{RB})	$\sqrt{\sigma_{NP}^2 + \sigma_{RB}^2}$
LAGEOS (532nm)	< 7.1 mm	< 0.6 mm	< 8.0 mm	< 8.0 mm
LAGEOS (1064nm)	< 15.5 mm	< 1.4 mm		< 8.1 mm
GNSS/GEO (532nm)	< 30.7 mm	< 1.7 mm		< 8.2 mm
GNSS/GEO (1064nm)	< 33.6 mm	< 1.9 mm		< 8.2 mm

* Pass-by-Pass Bias Stability means the standard deviation of range bias of each pass during 3 months.

assume we can acquire more than 1 return/sec

NP Bin Size
LAGEOS : 120 sec
GEO : 300 sec

→ Num. of data compressed
LAGEOS : ≥ 120
GEO : ≥ 300

→ $\sigma_{NP} \leq \frac{\sigma_{SS}}{\sqrt{120}}$ (LAGEOS)
$\sigma_{NP} \leq \frac{\sigma_{SS}}{\sqrt{300}}$ (GEO)

Next SLR station

Return Rate

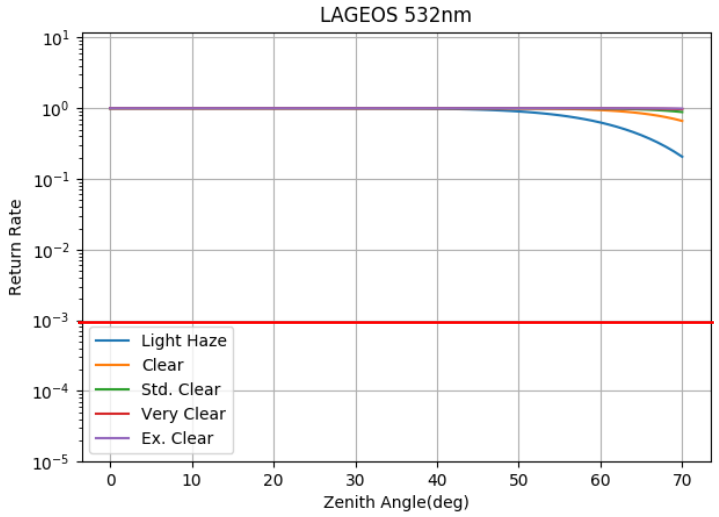
Below figures show the results of Return Rate analysis for LAGEOS and GEO when using 532nm laser. As can be seen, the return rate always exceeds 0.1% (correlates 1 return/sec @1kHz).

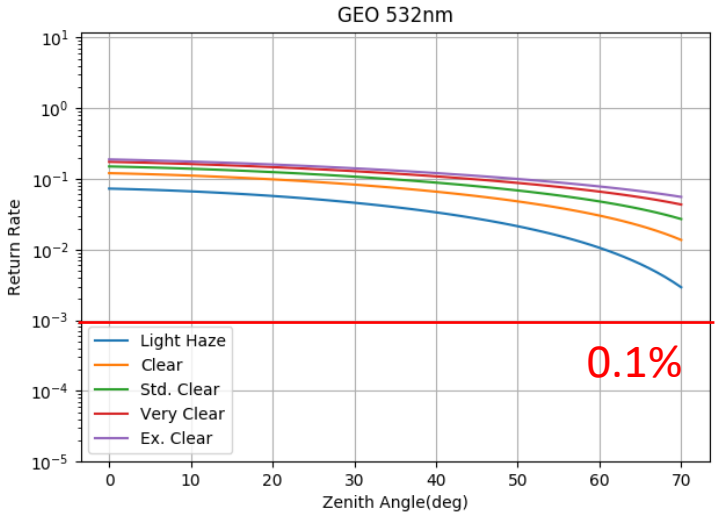
The mean number of photoelectrons

$$N_{PE} = \eta_{QE}\left(E_T \frac{\lambda}{hc}\right)\eta_T G_T \sigma_S \left(\frac{1}{4\pi R^2}\right)^2 A_R \eta_R T_A^2 T_C^2$$

Return Rate

$$P = 1 - e^{-N_{PE}}$$

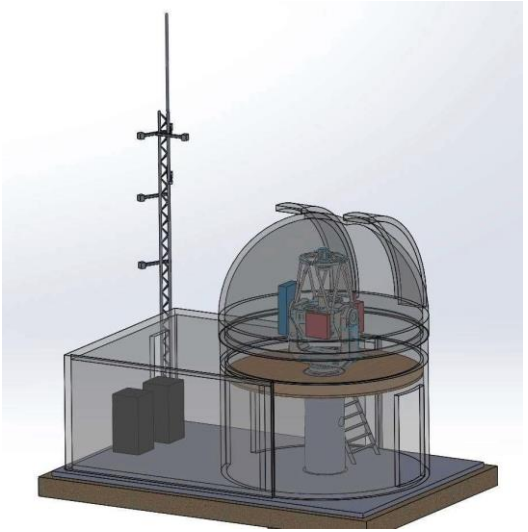




Next SLR station

Overall Station Design

- The overall dimension of the station is 7300(W) × 4760(D) × 5575(H) mm.
- The dome is an off the shelf slit type with 4 m inner diameter and 4.2 m outer diameter.
- The utility mast will be equipped with GPS antenna, Camera, and ADS-B antenna.



Telescope

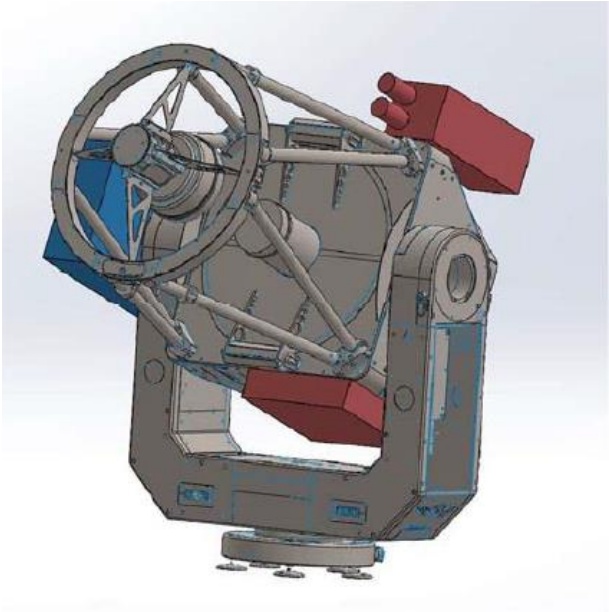
Parameter	Value
telescope	AZ800 (ASA)
Focus	Nasmyth
Focal length	5476 mm
f-number	6.8
Optical diameter	800 mm
Pointing accuracy	< 8”(RMS)
Tracking accuracy	< 0.25”(RMS)
Slewing speed	6 deg/sec

Next SLR station

Laser Package

- Laser optics package includes the Laser head unit and the transmit optics.
- Laser electronics package includes pumping unit and thermostat.
- Both packages will be mounted directly on the telescope.

Parameter	Value	
Wavelength	532 nm	1064 nm
Repetition rate	1 kHz	1 kHz
Pulse energy	260 µJ	350 µJ
Pulse width	7 ps	8.5 ps
Beam diameter	< 65 mm	< 65 mm

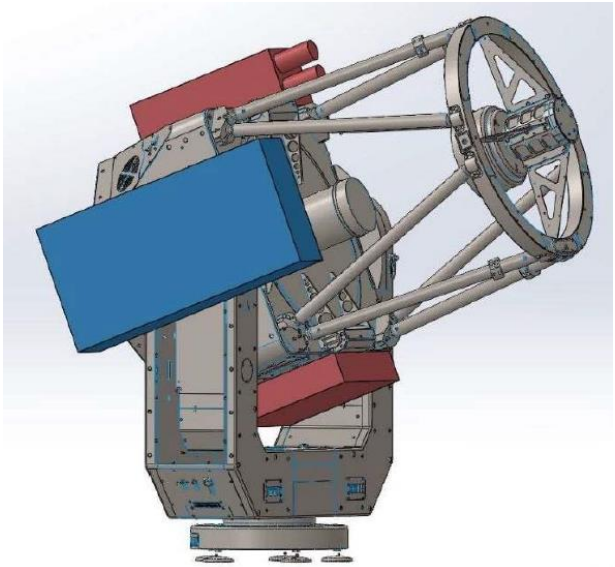


Next SLR station

Detector Package

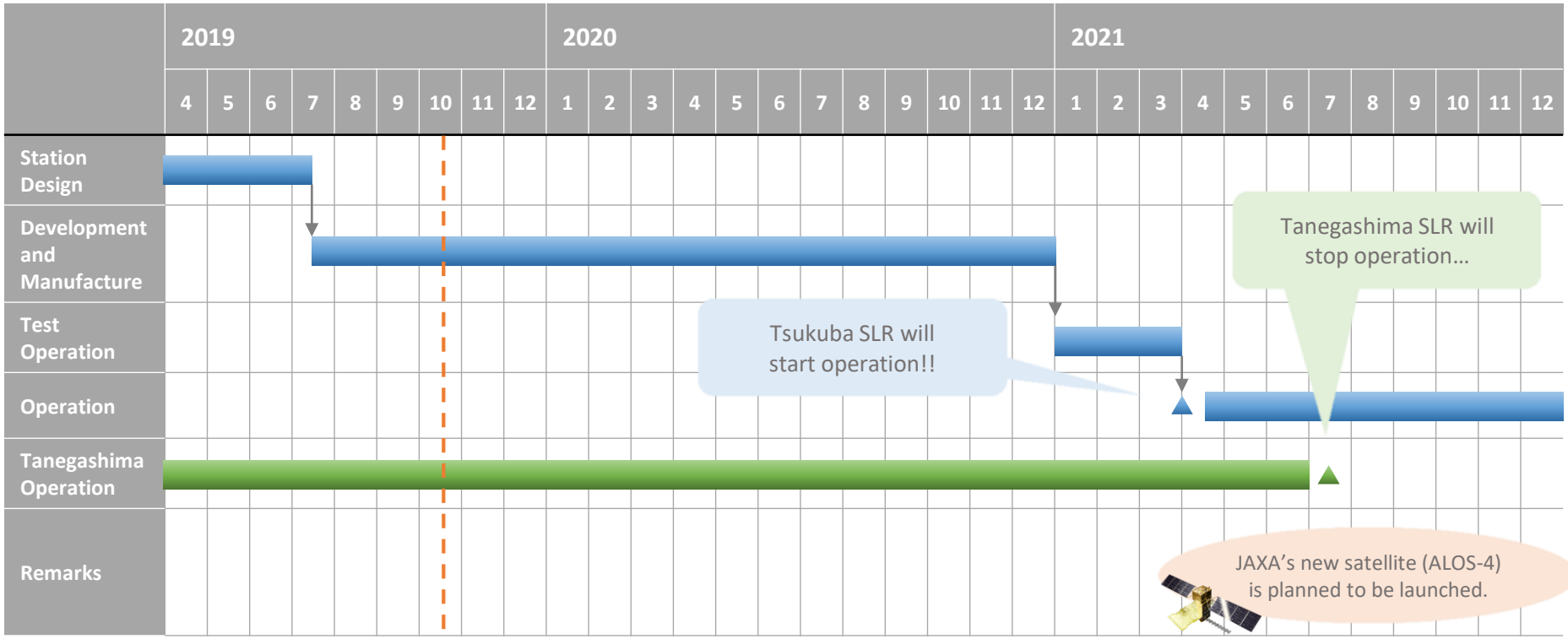
- Detector package will be also mounted directly on the telescope.
- It includes SPAD for both wavelength, optical components, CCD camera, shutters and so on.

Parameter	Value	
Wavelength	532 nm	1064 nm
Detector	C-SPAD	IR-SPAD
Active area diameter	200 µm	80 µm
Quantum efficiency	> 40 %	Max 30%
Single photon jitter	< 40 ps	< 100 ps
Dark count	200-600 kHz	300-700 kHz



Next SLR station

Schedule



Development of JAXA's LRAs – Mt.FUJI Series

JAXA's LRAs for LEO Objects, Mt.FUJI Series

- Mt.FUJI : MulTiple reFlector Unit from Jaxa Investigation
  - Standard size
  - Passed EM test; vibration test, shock test, and thermal cycle test
  - FM test starts in this November
- Mini-Mt.FUJI
  - Small size
  - EM test starts in this November

Mt. Fuji

Both are planned to be sold at an affordable price in the future ...

Parameter	Mt.FUJI	Mini-Mt.FUJI
Target Altitude (assuming circular orbits)	< 800 km	< 500 km
Diameter	112 mm	< 70 mm
Height	32 mm	< 20 mm
Weight (including CCRs)	< 280 g	< 120 g
CCR size	1 inch	0.5 inch
Number of CCR	7	7

Mt.FUJI (EM model)

Thank you!