

# Tsukuba SLR station, current status 2023

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DiG<sup>S</sup>

TOYO Corporation  
Quest for Precision

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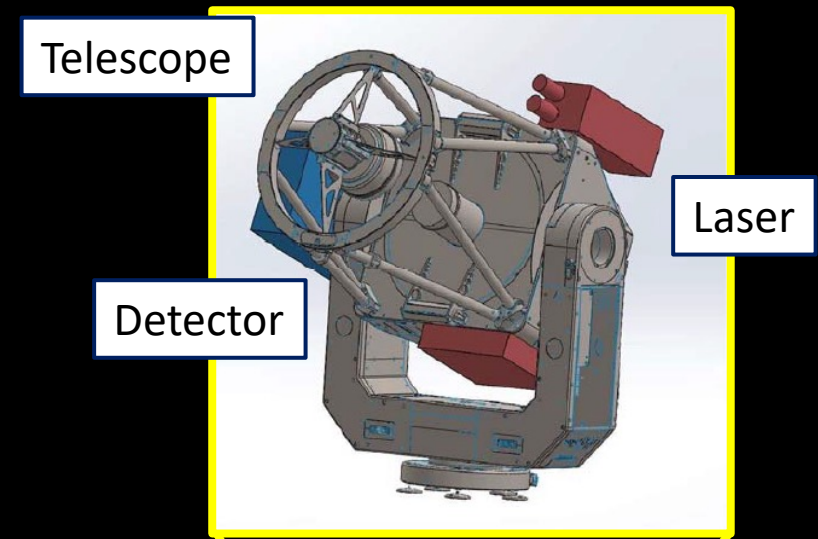
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# 1. Introduction

- JAXA's SLR station, named **TsuKuBa satellite Laser ranging station (TKBL)**, started operation in June 2023.
  - ✓ Mainly developed by KDK (Japan), TOYO (Japan), and DiGOS (Germany),
  - ✓ Ranging capability from LEO to GEO,
  - ✓ Single-photon mode with 1 kHz repetition rate,
  - ✓ Wavelength : 532nm (primary), 1064nm,
  - ✓ Piggyback (lasers and detectors),
  - ✓ New Technique : Fiber-based calibration system, and
  - ✓ Eye Safe : Radar and ADS-B for aircraft detection.

# 2. Specification

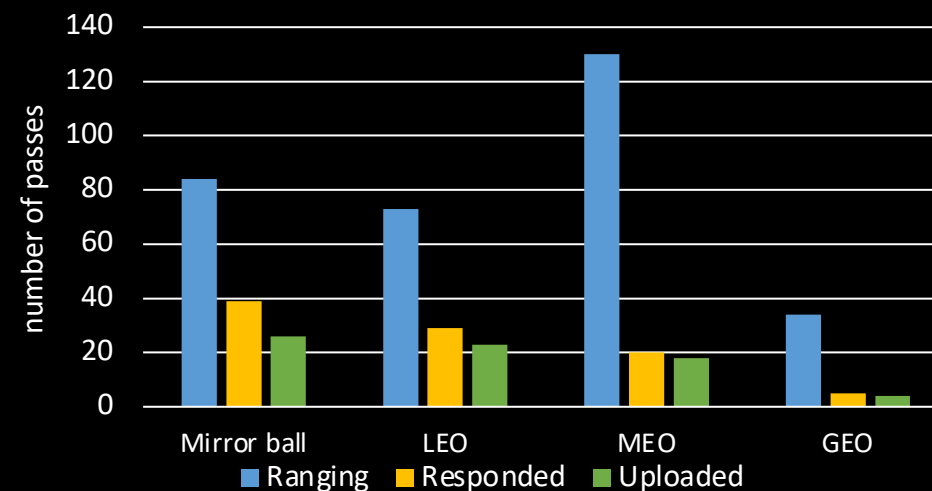
Telescope		
Model	AZ800 (ASA)	
Optical diameter	800 mm	
Laser		
Model	Compiler Compact (Passat)	
Wavelength	532 nm	1064 nm
Repetition Rate	1 kHz	1 kHz
Pulse Energy	260 $\mu$ J	350 $\mu$ J
Pulse Width	7 ps	8 ps
Detector		
Model	C-SPAD (Peso Consulting)	PGA-200 (RMY)
Wavelength	532 nm	1064 nm
Quantum Efficiency	> 40%	Max 30%
Single Photon Jitter	< 40 ps	< 100 ps



# 3. Operation Status

- TKBL was in operation from June to August 2023.  
 ( Unfortunately, TKBL has now stopped ranging due to a laser equipment failure. )
- TKBL has completed the qualification for operational status in the ILRS and operated as the official SLR station of ILRS on June 14, 2023.
- A total of 321 passes have been taken and 71 passes have been uploaded to Eurolas Data Center (EDC) from June 16 to August 4.

Satellite classification	Ranging	Responded	Uploaded
Mirror ball	84	39	26
LEO	73	29	23
MEO	130	20	18
GEO	34	5	4
Total	321	93	71



✂Mirror ball satellites: Ajisai, Etalon1, Etalon2, Lares, Lares2, Starlette, Stella

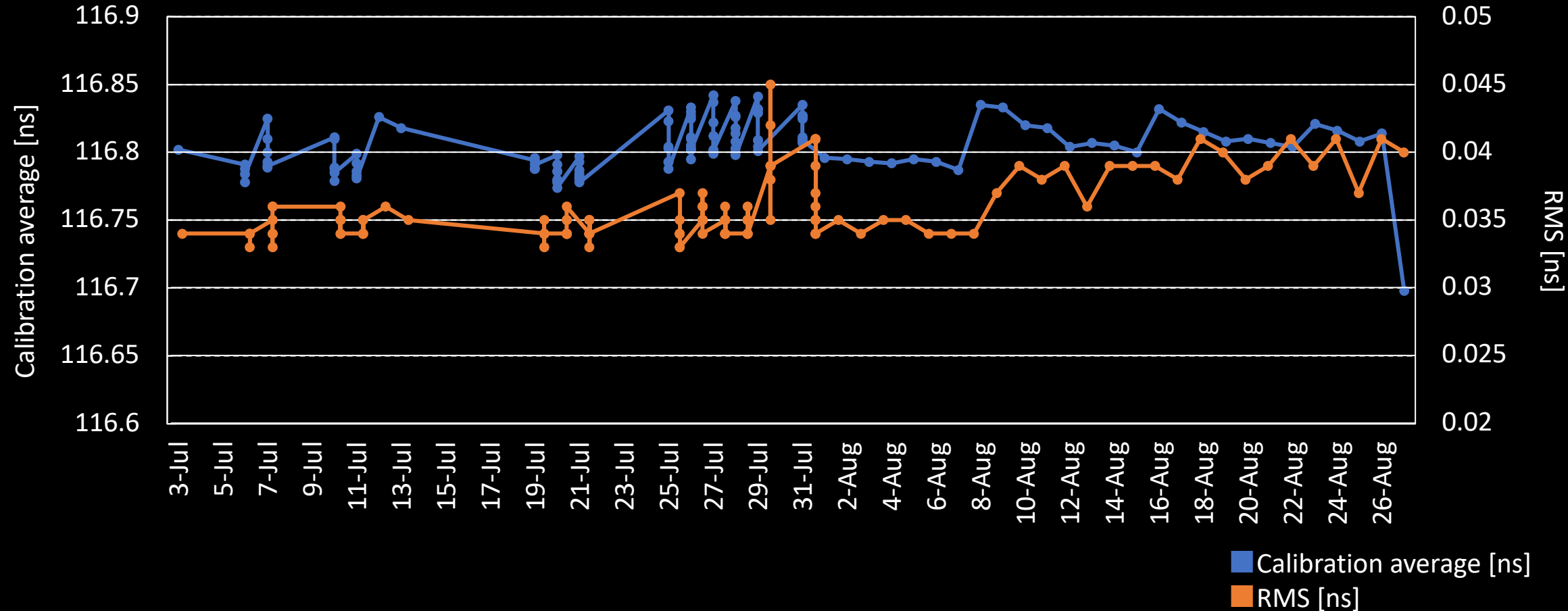
# RMS value of TKBL

- The average RMS of TKBL for each satellite in July 2023 is shown in the table.
- Almost RMS value is within 10 mm.  
→ TKBL has sufficient accuracy of ranging.

Satellite name	RMS[mm]
stella	9.79
lageos2	5.85
ajisai	26.65
lares	7.82
lares2	9.14
starlette	9.62

# Calibration status

- Fiber calibration (532 nm) value is stable at  $\sim 116.8$  ns and average RMS is  $\sim 0.0358$  ns.
- The variation of calibration value and RMS depends on the temperature inside the dome.



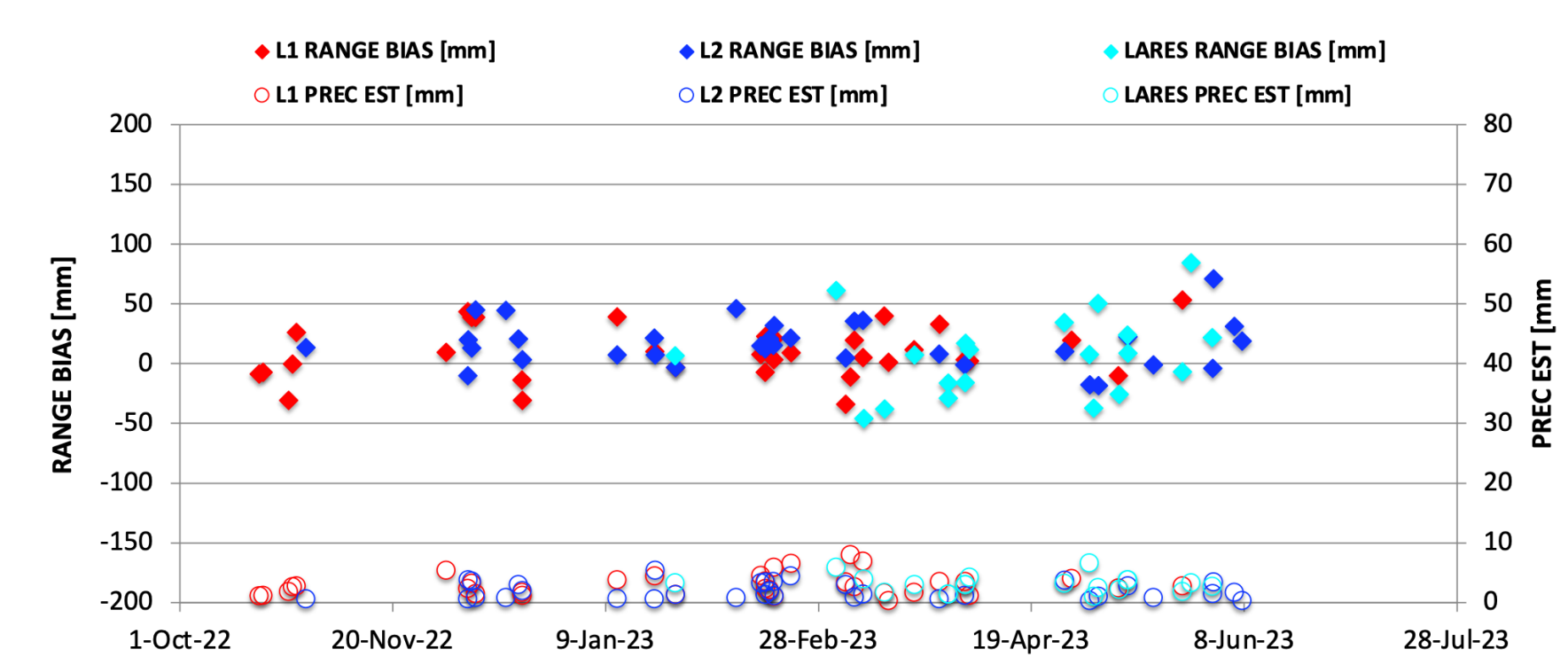
# Results of Quarantine

LAGEOS 1

LARES

LAGEOS 2

SLRF 2014 QC L1 73069301	PREC EST [mm]	RANGE BIAS [mm]	SLRF 2014 QC LR 73069301	PREC EST [mm]	RANGE BIAS [mm]	SLRF 2014 QC L2 73069301	PREC EST [mm]	RANGE BIAS [mm]
Mean	3.0	9.3	Mean	3.1	5.9	Mean	1.9	16.3
STD	1.8	22.0	STD	1.4	34.5	STD	1.4	18.7
RMS	3.5	23.6	RMS	3.4	34.2	RMS	2.3	24.7
Passes	34	34	Passes	20	20	Passes	35	35

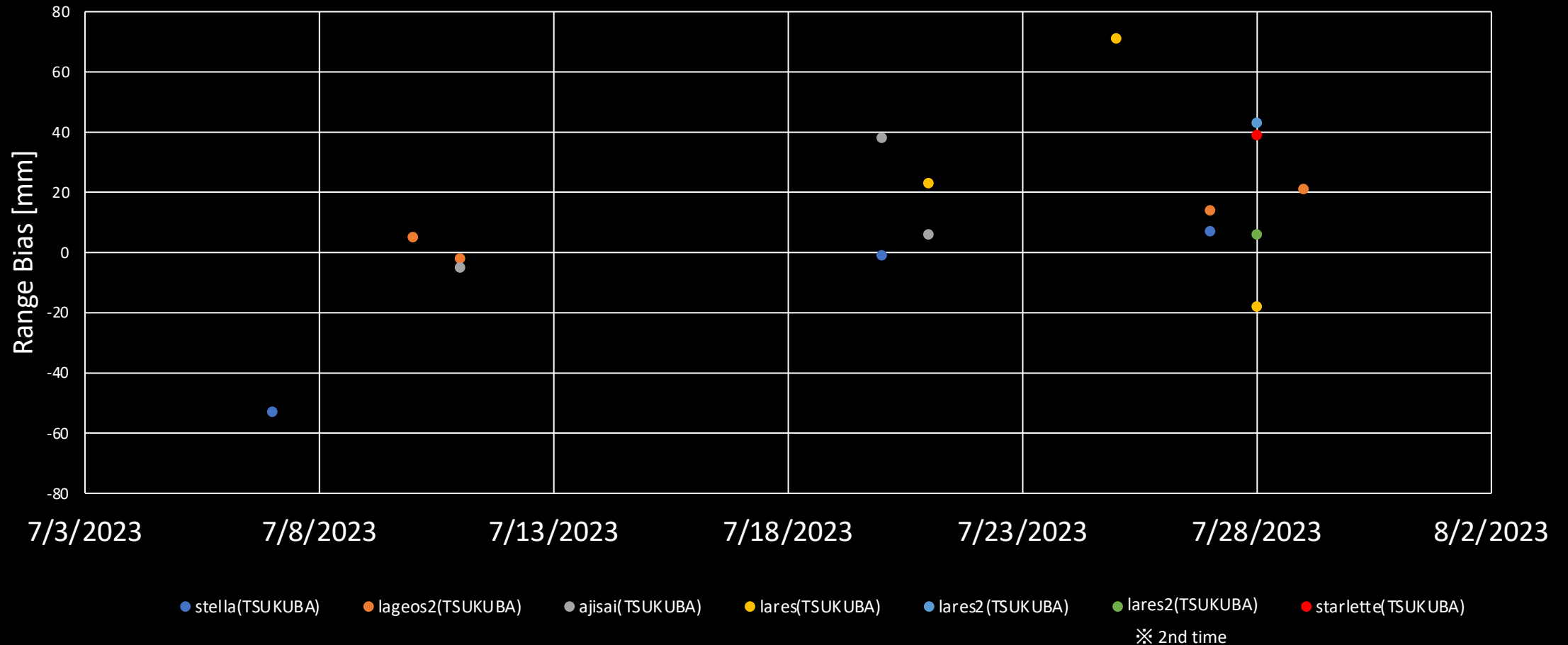


These data are provided from Acs.



# Result of range bias evaluation

- Range bias evaluation is carried out by Hitotsubashi Univ.
- The range bias of TKBL is stable under 100 mm.



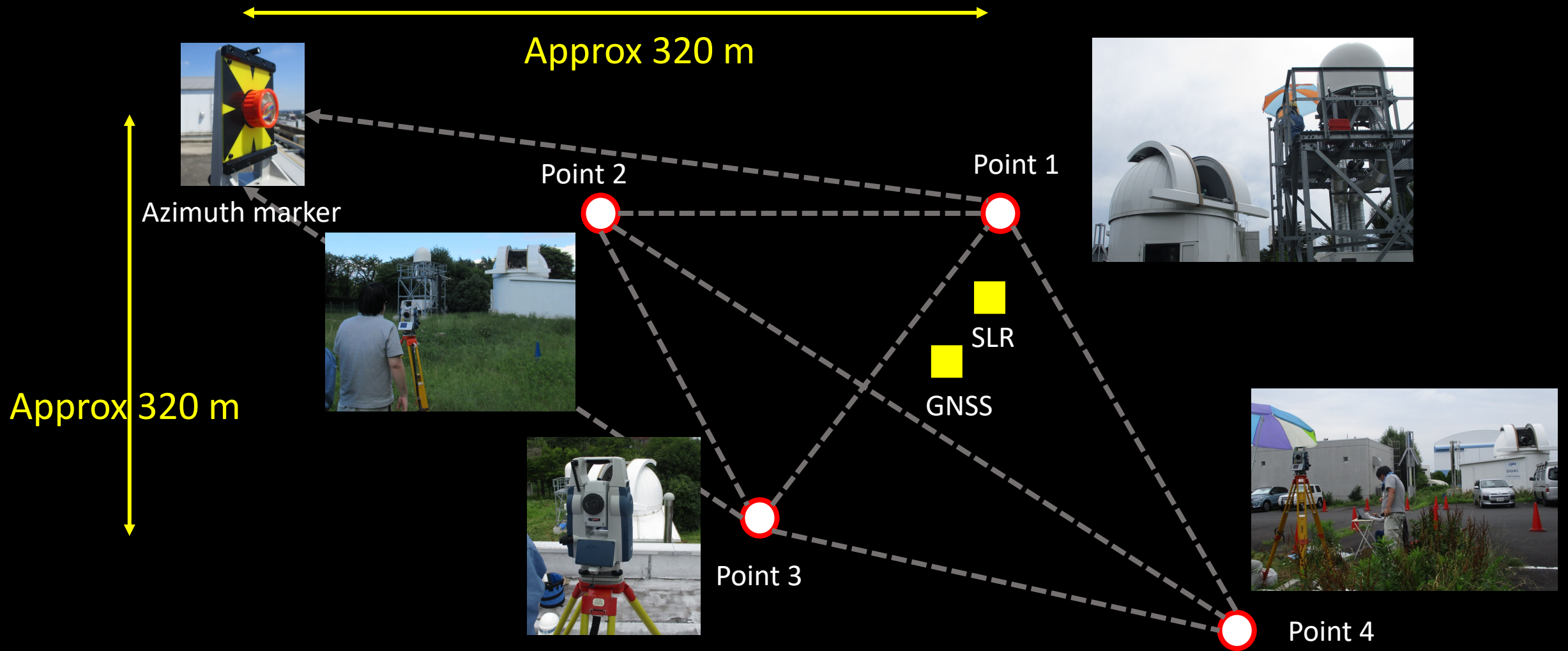
# 4. Local tie survey

- SLR ranging makes it possible to evaluate the accuracy of the orbit determination of the satellites using GNSS.
- JAXA carried out local tie survey to obtain the relative position between TKBL and the GNSS station with the cooperation of GSI on July 2023.
- It leads to the construction of International Terrestrial Reference Frame (ITRF) coordinate system.



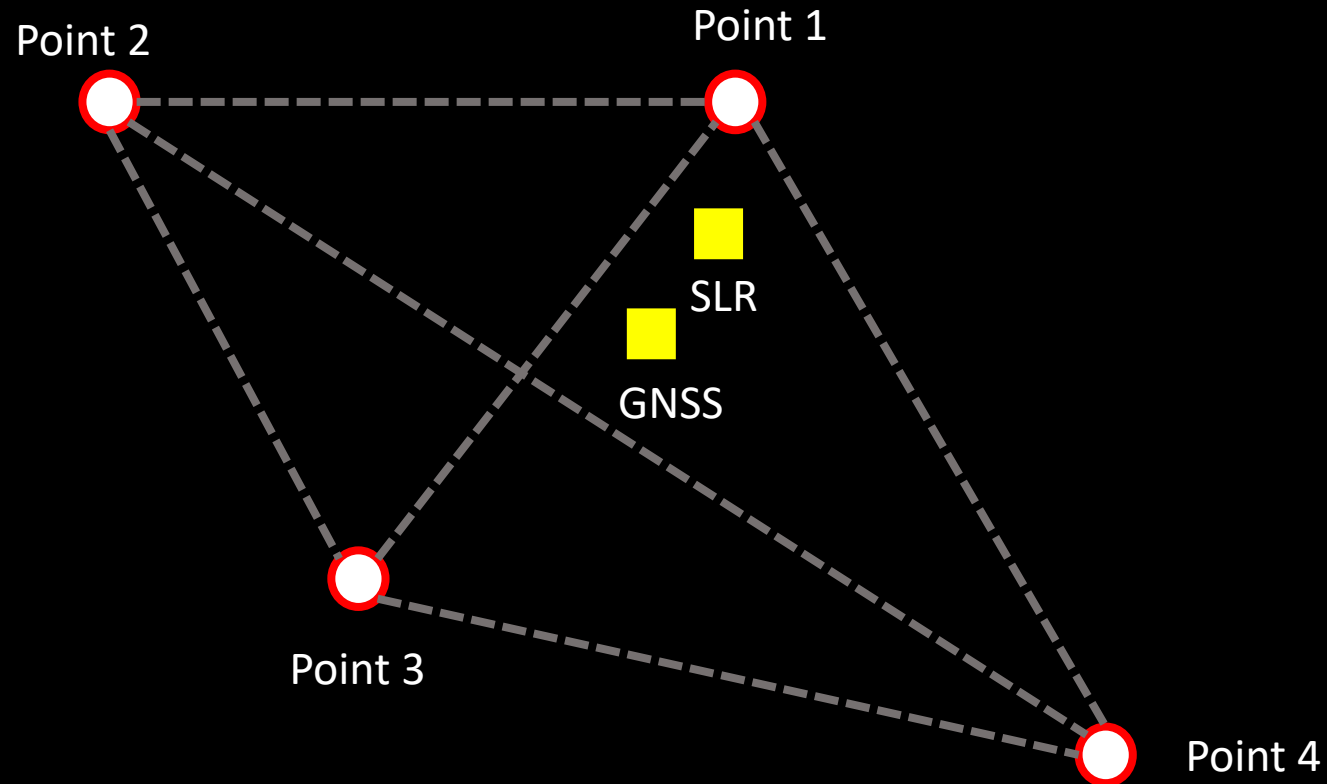
# 4. Local tie survey

- The configuration of the Local tie survey.



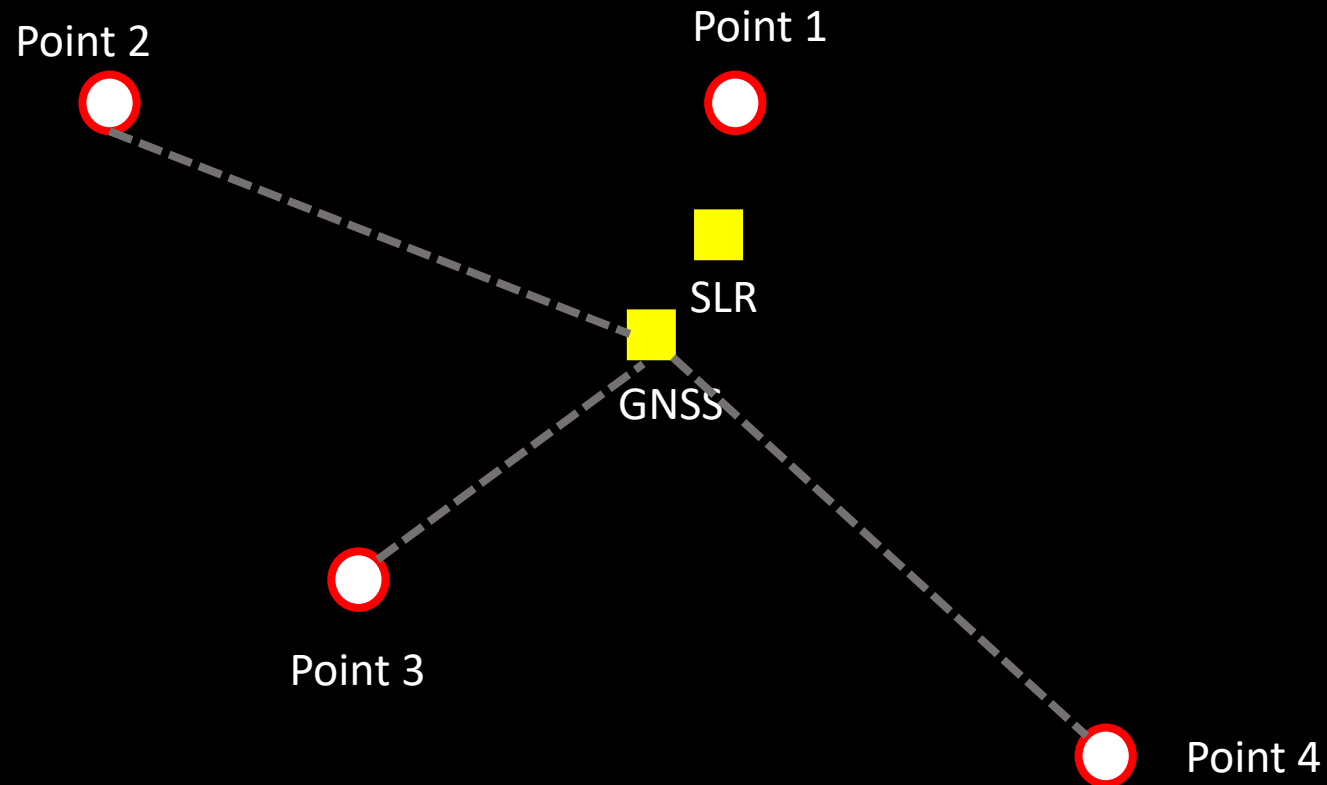
# 4. Local tie survey

- We measured the relative position (horizontal angle, vertical angle and distance) and height difference between each observation point.



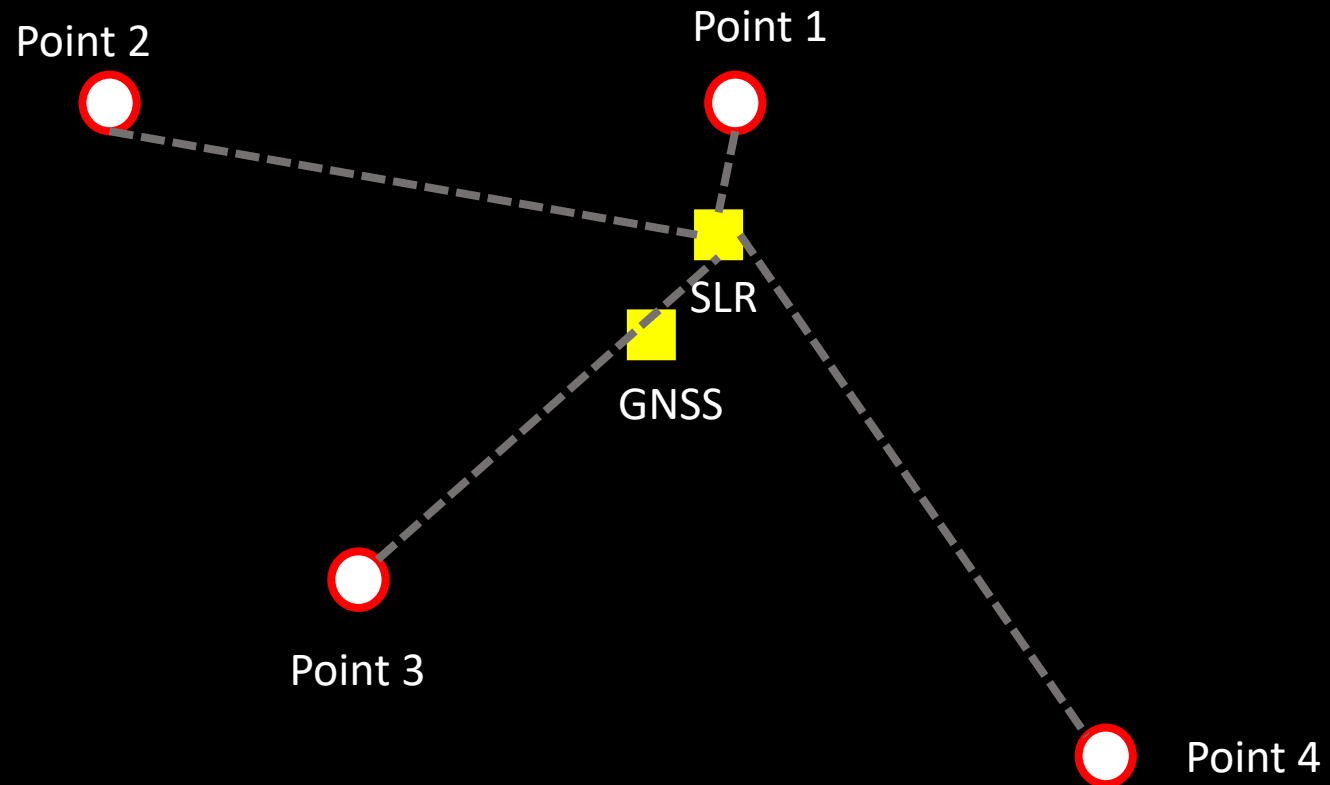
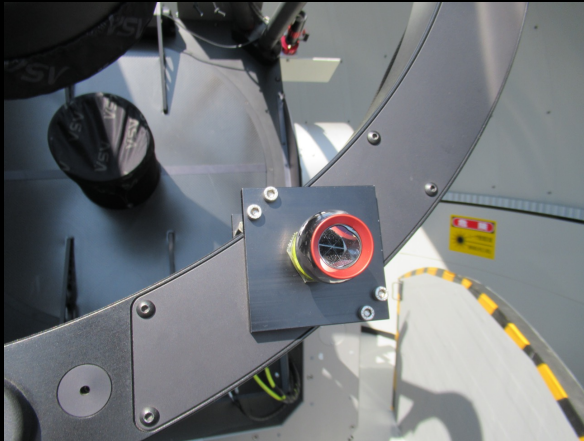
# 4. Local tie survey

- We measured the relative position from each point to Tsukuba GNSS.



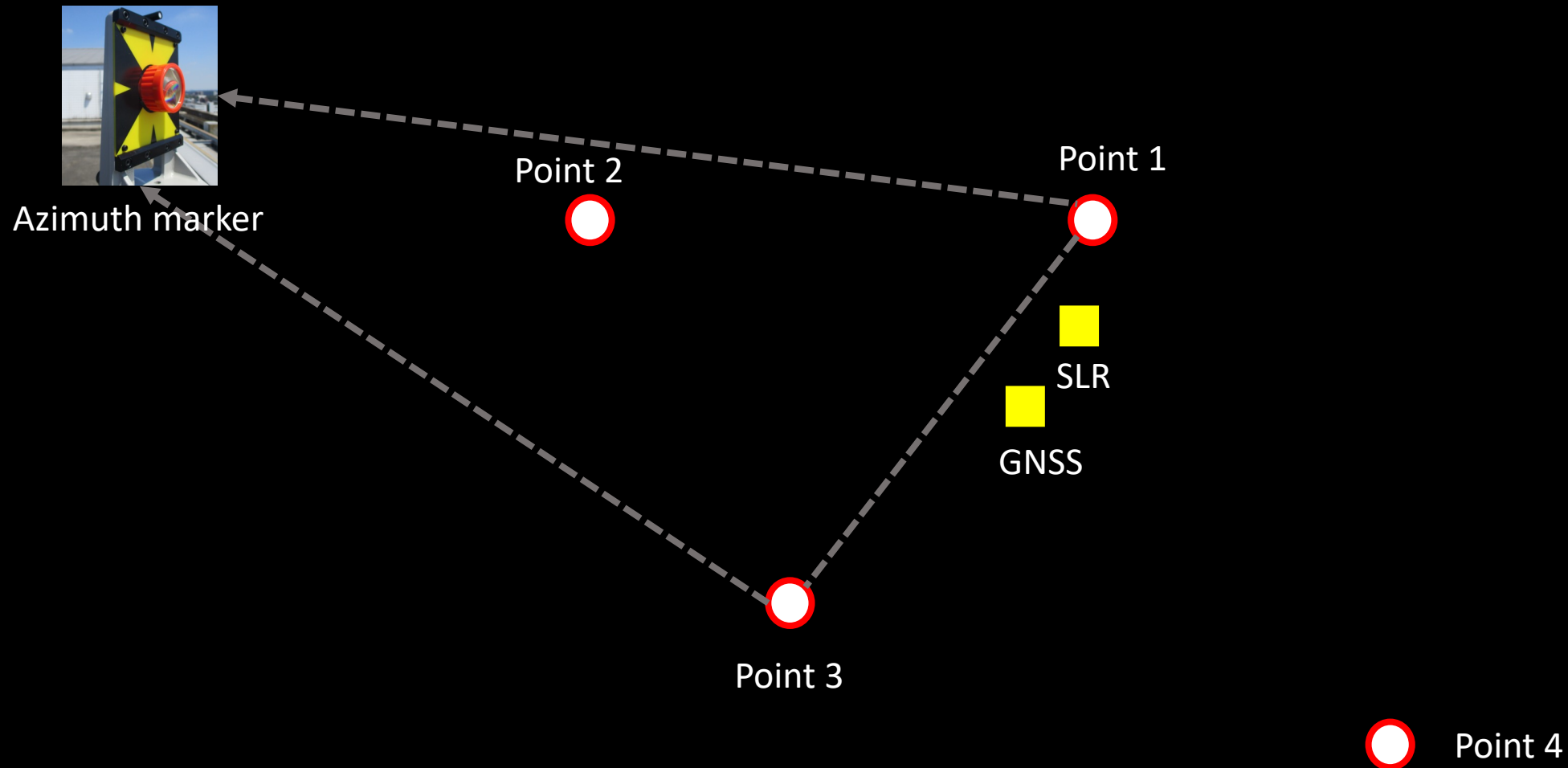
# 4. Local tie survey

- We measured the relative position from each point to the mirror attached to the telescope of Tsukuba SLR.



# 4. Local tie survey

- We measured the azimuth angle between azimuth marker and two observation points in order to convert the local coordinate into IFTRF



# 4. Local tie survey

- We used these observational data and calculated the Tsukuba GNSS-SLR local tie vector using pyaxis produced by Dr. Chris Crook of LINZ.
- Each component of the local tie vector (x, y, z) resulted within 1.0-1.1 mm standard deviation.  
↔ IERS's target precision: 1.0 mm



# 5. Summary

- **TsuKuBa satellite Laser ranging station (TKBL)**, started operation in June 2023.
- TKBL was in operation from June to August 2023.
- JAXA will do our best to acquire as much passes as possible.
- JAXA carried out local tie survey to obtain the relative position between TKBL and the GNSS station with the cooperation of GSI on July 2023.
- According to these surveys and analyses, we will reduce systematic errors caused by each geodetic technique and lead to the construction of a more accurate ITRF coordinate system.