23rd International Workshop on Laser Ranging, Kunming, 23 Oct 2024

Development of the Omni-SLR system: concepts and project status

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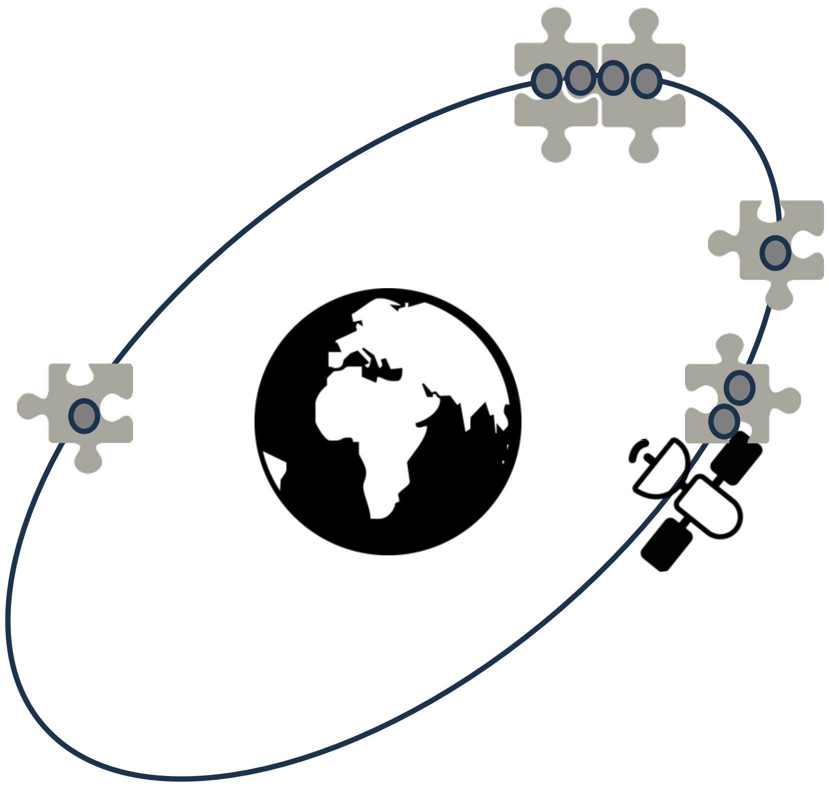
Current SLR tracking coverage

How much of satellite orbits is laser-ranged by International Laser Ranging Service *?*



ILRS typical data production rate 2024

LAGEOS (per sat)	~150 NP/day x 2 min/NP = 5 hr (24 hr x 20%)
LARES	~150 NP/day x 30 sec/NP = 1.2 hr (24 hr x 5%)
ETALON (per sat)	~15 NP/day x 5 min/NP = 1.2 hr (24 hr x 5%)
STARLETTE	~220 NP/day x 30 sec/NP = 2 hr (24 hr x 8%)
AJISAI	~300 NP/day x 30 sec/NP = 2.5 hr (24 hr x 10%)
JASON-3	~360 NP/day x 15 sec/NP = 1.5 hr (24 hr x 6%)
SENTINEL-6A	~280 NP/day x 15 sec/NP = 1.1 hr (24 hr x 5%)

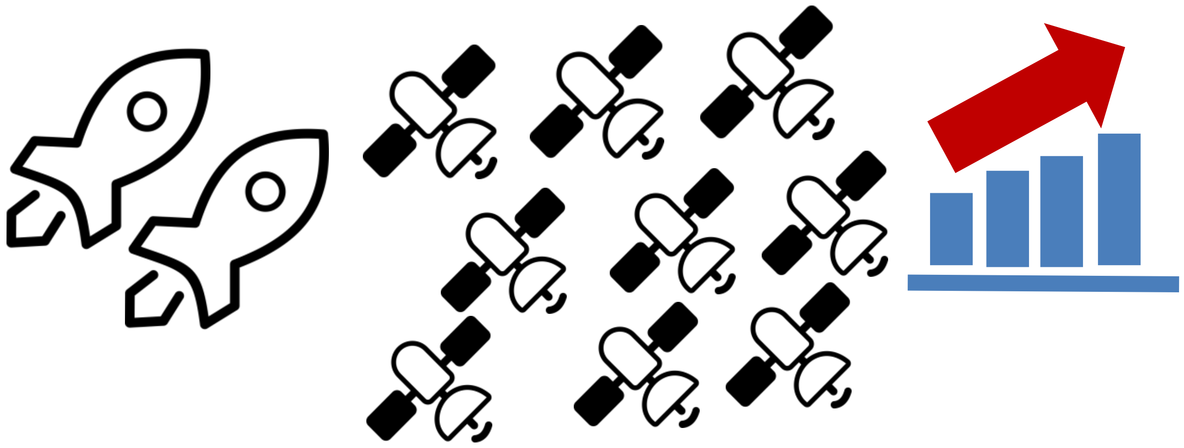
(overlaps not considered)

- *Far from continuous tracking (contrast to GNSS and DORIS)*
- *Unreachable zones for LEOs: South pole, Oceans, etc.*
- *Heavily relying on orbit dynamics.*

Omni-SLR: SLR for everyone

International Laser Ranging Service

SLR Targets: monotonically increasing



SLR Stations: almost the same

Very Compact

High mobility. < 100 kg. Low energy consumption < 100 W.

Very Low-cost

Hardware: net 50-60k EUR/USD. Key components = COTS.

Multi-purpose

Primary: SLR.

Linked with various applications

(time transfer, space comm, 6G airborne comm, etc).

Envisaging that…

- *new countries/institutes can own & operate SLR stations.*
- *the SLR global network and the products are drastically enhanced.*
- *the optical tracking/ranging technologies are more versatile.*

Omni-SLR: key components (as of 2024)

CryLAS FDSS532-Q2

λ = 532nm; pulse width = 1.06 ns;
Rep. rate = 10 kHz; output = 5.7 μJ
Sync output; int/ext trigger mode

Swabian TimeTagger Ultra (Value Ed)

4 ch
(ch1 = start; ch2=stop; ch3=1PPS)
42 ps RMS
70 M events/sec

Furuno TB-1

GNSS OCXO

10 MHz: ~ 5 x 10^-11 @ 1s
1 PPS: ~ 40 ns

Hamamatsu C11202-100

Aperture = 100 μm; Efficiency = 70%;
Dark noise = 30 cps; No gate control

(RX) Kasai GS-200CC

Ritchey–Chrétien
Φ = 203 mm; f = 1624 mm

Vixen AXJ Mount (Eq.)

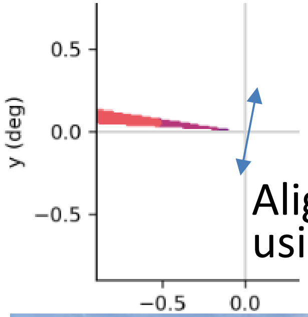
Converted to Alt-Az
Load: 22 kg max

Vaisala PTB-330

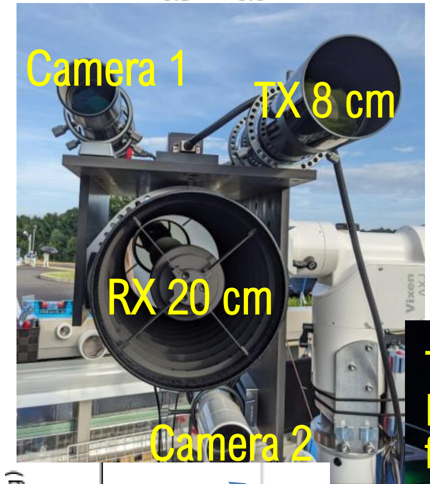
3 sensor barometer
0.2 hPa per sensor

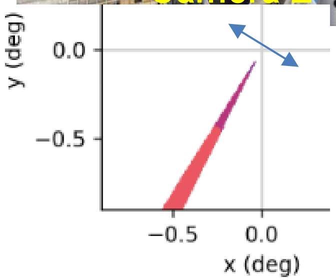
Omni-SLR: peripheral components (as of 2024)

2-camera TX-RX alignment



Align TX to RX
using the laser images



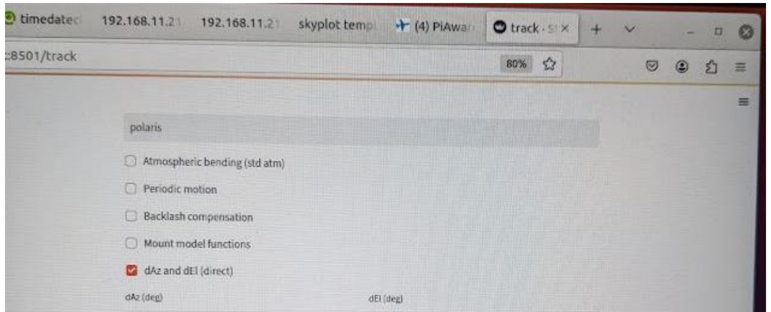


Raspberry Pis, Mini PCs & NTP Server

Distributed system.
Device control or specified task for:

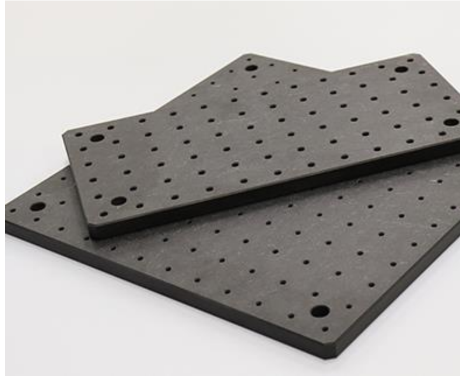
- Orbit prediction (CPF and TLE)
- ADS-B
- Mets
- Laser trigger
- Mount control
- Event timer
- NTP
- CMOS Camera

Web UI with Flask and Streamlit



Mount & Plates

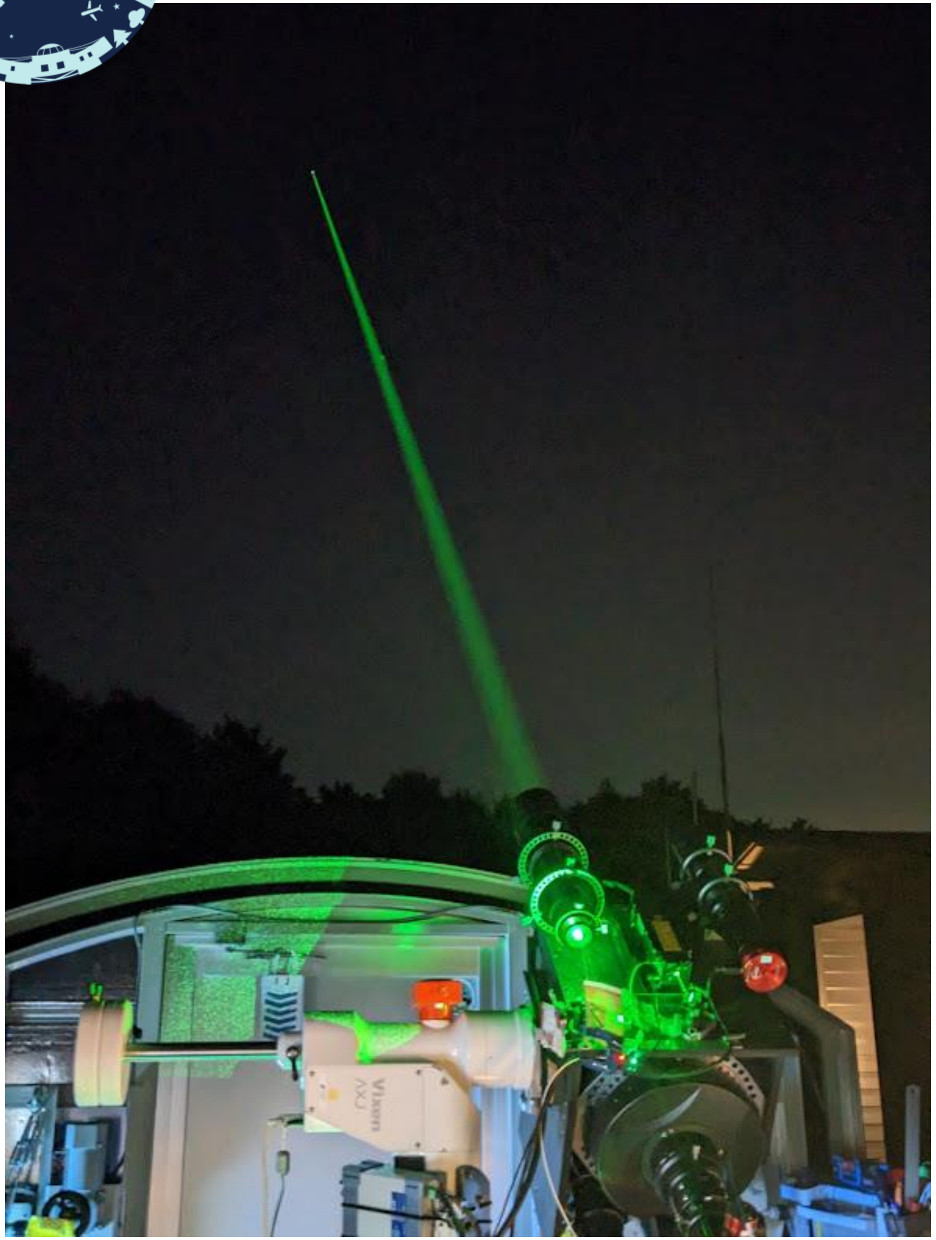
Vixen's Alt-Az fork for eq mount (AXJ)
Futaba's lightweight CFRP



DOMES "M"

Ground marker
to represent the station position
CDP Number 7317
= DOMES 21791M00X
Eccentricity vector

Omni-SLR system: features



Broad (~1 ns) laser pulse width

High repetition laser (10 kHz)

Low laser power (6 microJ; 60 mW)

8 cm trasmitter -> Zero NOHD (nominal ocular hazard distance)

No coude path

No (hardware) range gates

Conventional Eq mount converted to Alt-Az

Plate-solving-based mount model

Station point = A ground marker (DOMES “M”)

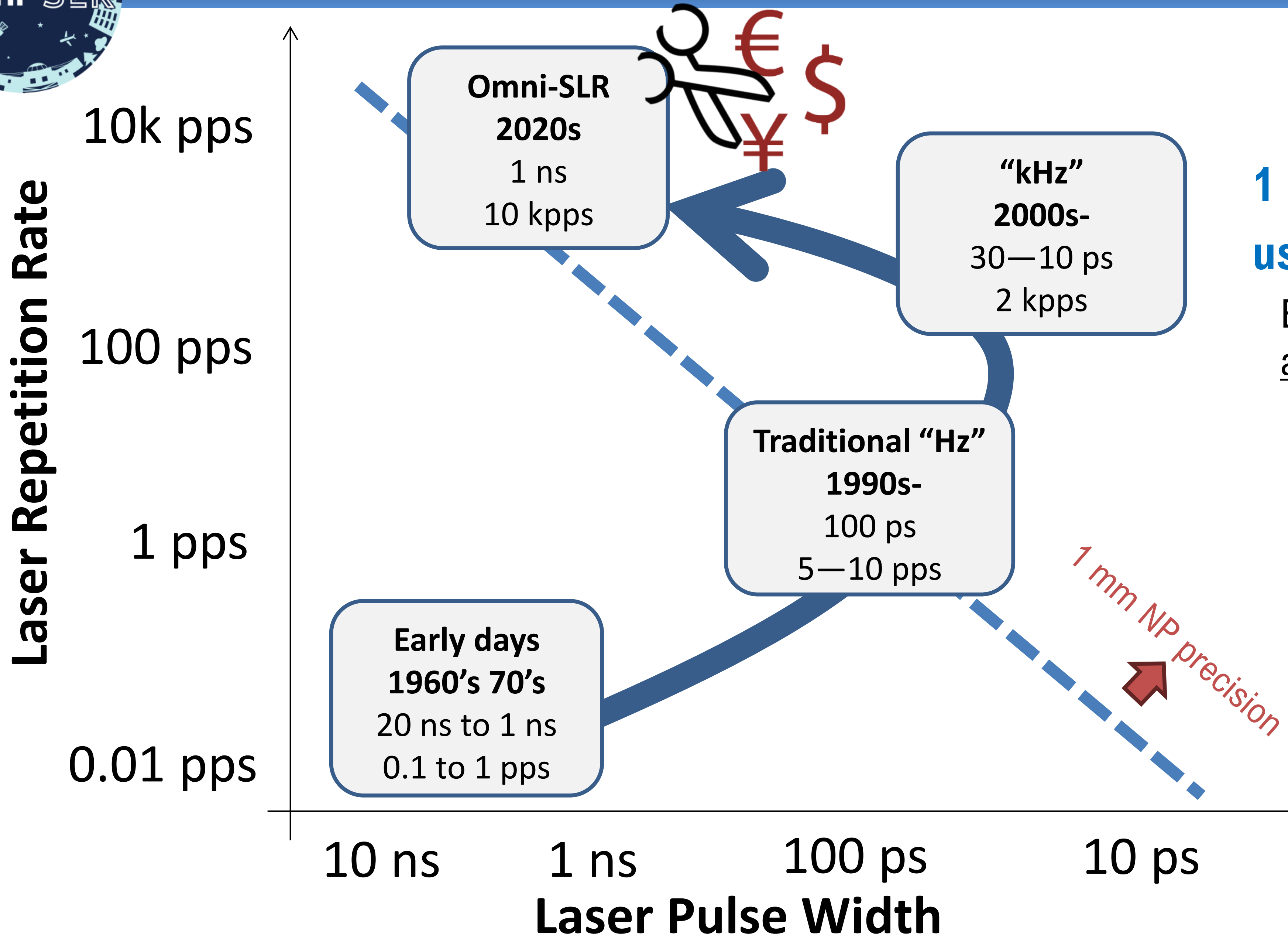
ADS-B aircraft safety

Web-based UI with Streamlit & Flask

Distributed system with Raspberry Pi & Mini PC

Our own software in Python, C++ and Julia + OrbitNP.py

Omni-SLR: reversing the trend?

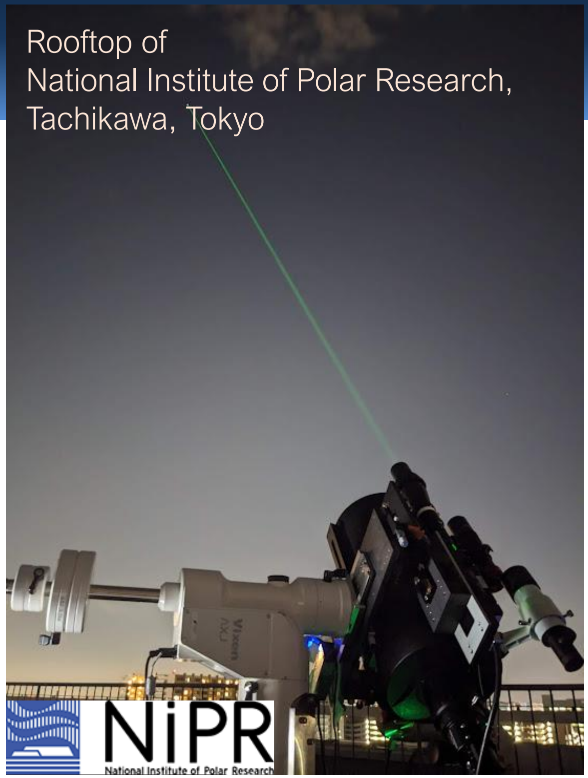


1 ns pulse width laser useless for mm geodesy?

Expected NP precision
assuming white noise

- 1 return/NP: ~ 7 cm
- 10 returns/NP: 2-3 cm
- 100 returns/NP: ~ 7 mm
- 1000 returns/NP: 2-3 mm
- 10000 returns/NP: ~ 0.7 mm

Omni-SLR: project status



being developed by the team of

HITOTSUBASHI UNIVERSITY
(PI: T Otsubo)

NAOJ National Astronomical Observatory of Japan

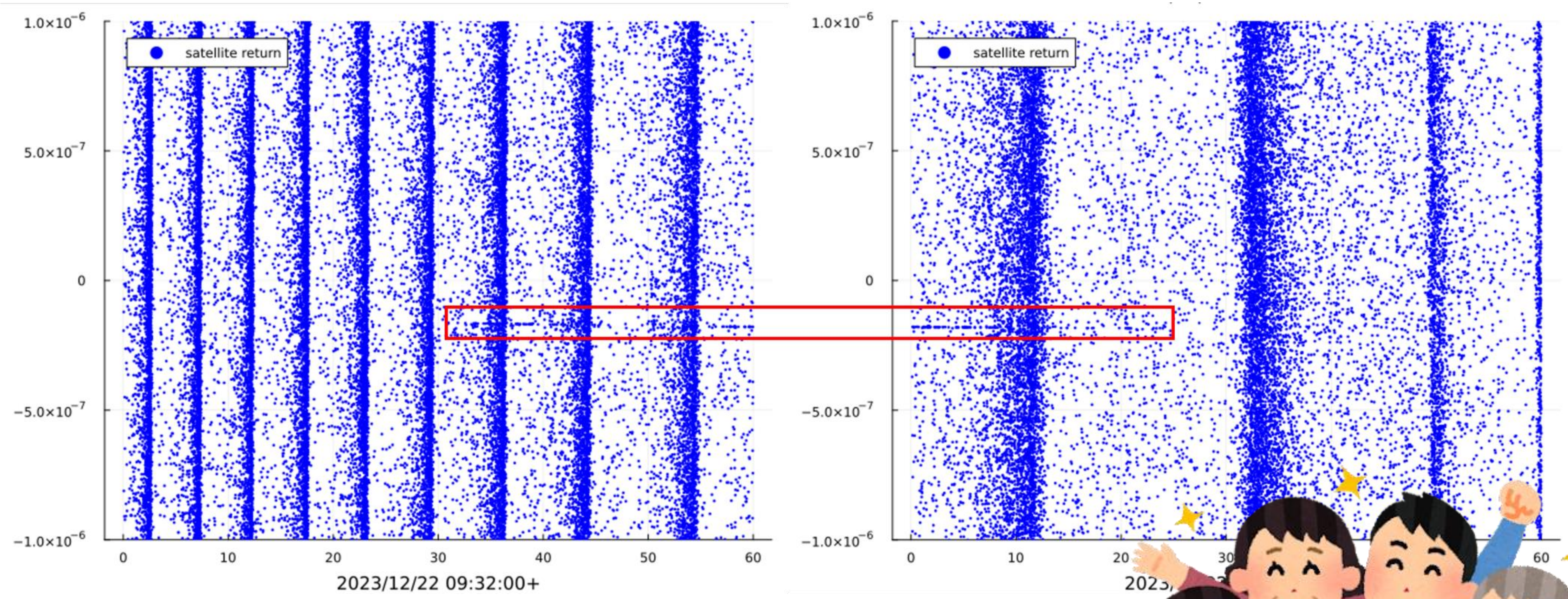
THE UNIVERSITY OF TOKYO

being supported by:

- the national institutes such as GSI, NIPR, NICT, Japan Coast Guard and JAXA.
- private companies in the fields of telecommunications and heavy industries.

2020-2023 First successful budget hunting (Kakenhi)
followed by various joint research projects
2020 Concept design
2021 Component tests
2022 Assembly tests
2023 Field test at NIPR Tachikawa
2024 CDP No 7317 95 01
DOMES No 21791M008 (S002) assigned
2024 Field test at GSI Ishioka
(more development & improvements)
2026-2027 First Antarctica SLR test at Syowa

Omni-SLR First Returns@NIPR: SARAL 9:32 UT, 22 Dec 2023

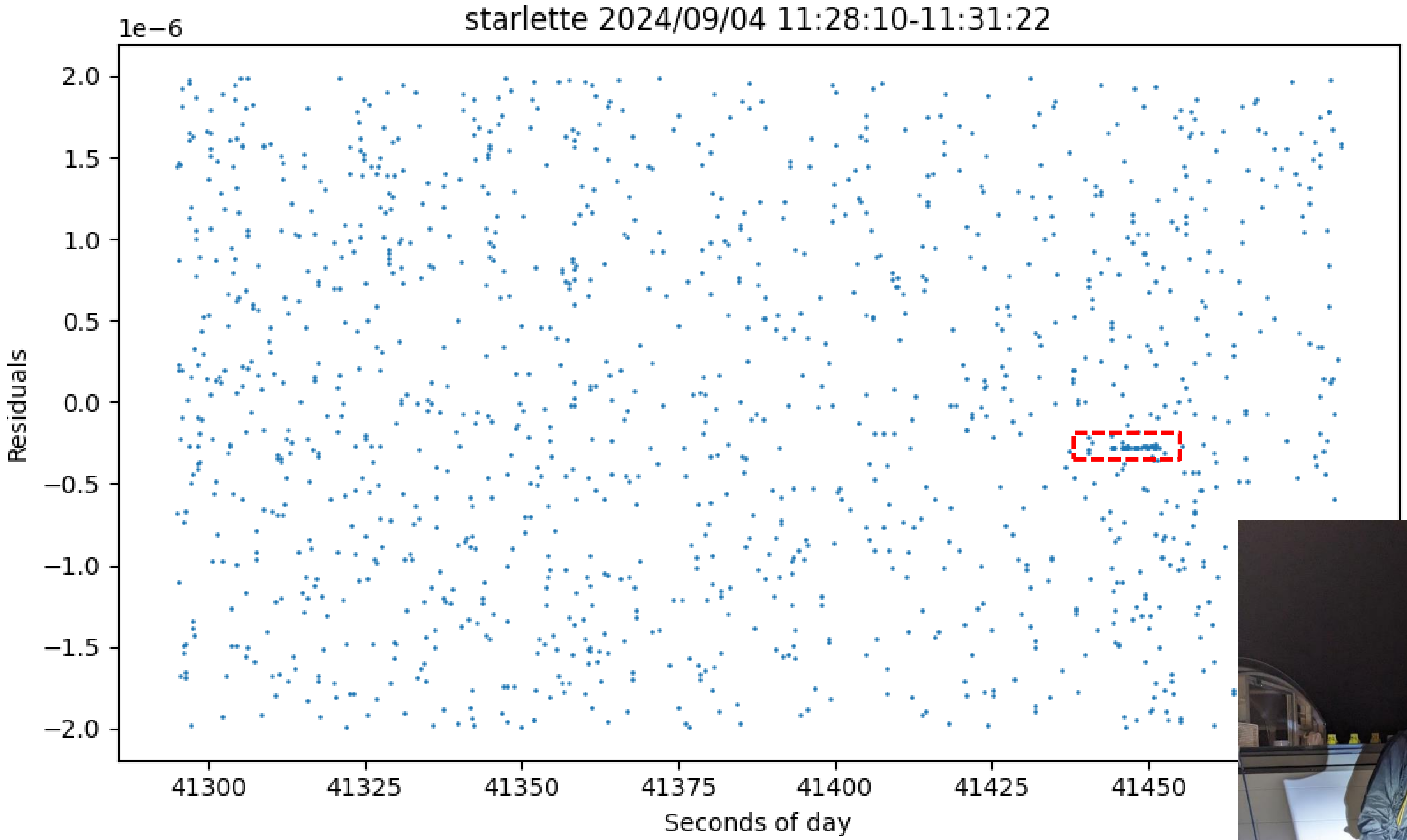


2023-12-22 SARAL & SWARM-C
2023-12-26 BEACON-C & SWARM-C

Rooftop of
National Institute of Polar Research,
Tachikawa, Tokyo

NiPR
National Institute of Polar Research

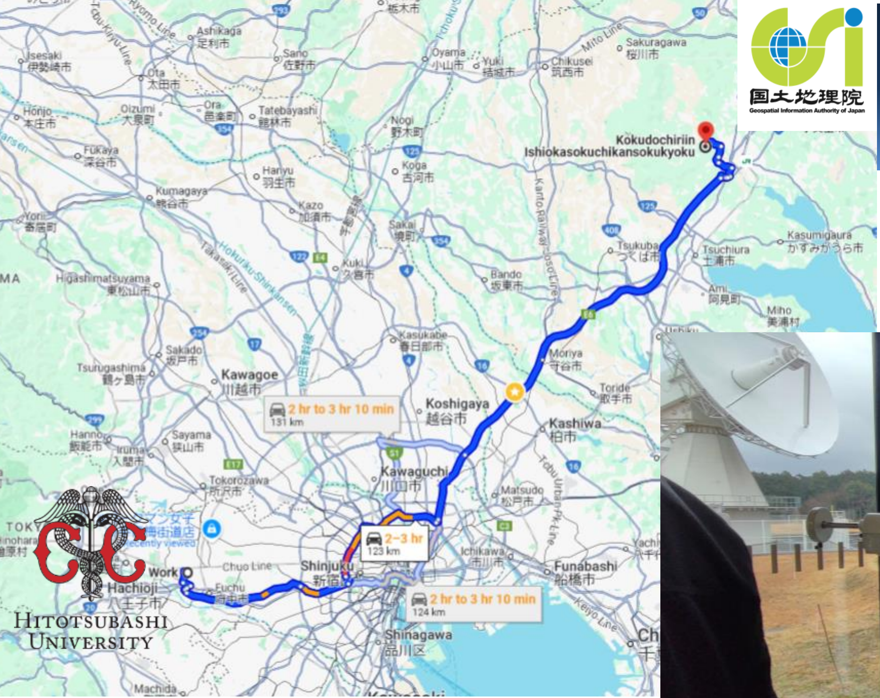
Omni-SLR First Returns@GSI: Starlette 11:30 UT, 4 Sep 2024



Burst mode (interleaving)
→ No vertical lines

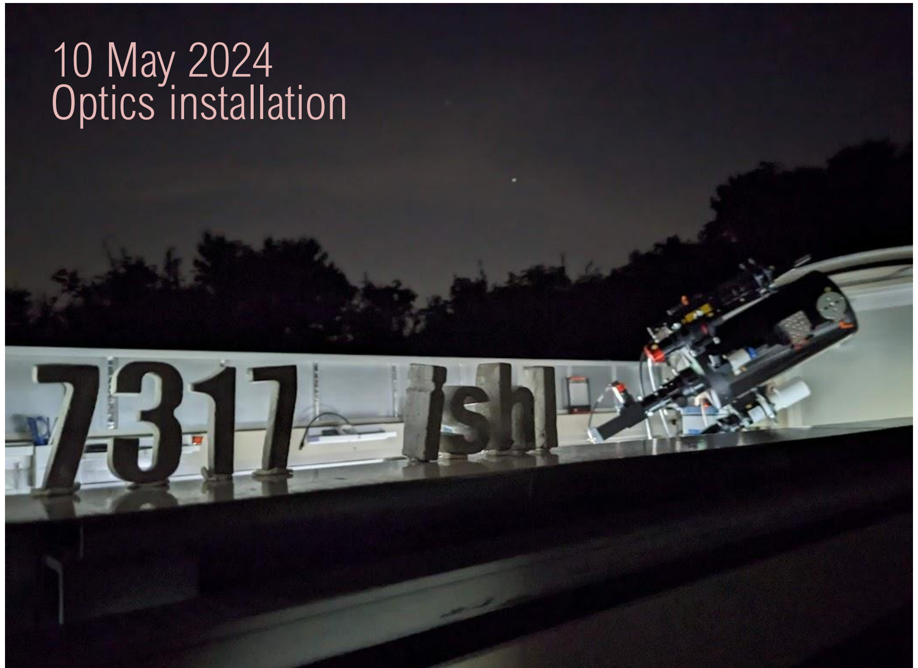
followed by Beacon-C, AJISAI, Stella, Swarm, etc. (more returns)

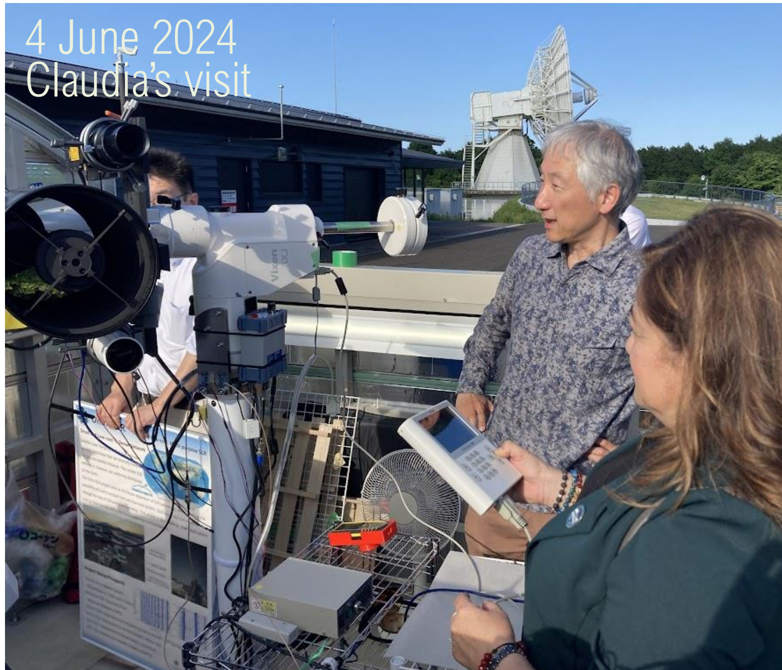
Omni-SLR Installation@Ishioka 2024



Issues (expected and unexpected):

- High temperature in summer.
- Insects flying to monitors and LEDs.
- High humidity. Dew.
- Insufficient accuracy of weather forecast.
- Limited chances of sun-illuminated passes.
- Inconsistent TX-RX alignment.





Omni-SLR x 2 = time transfer!

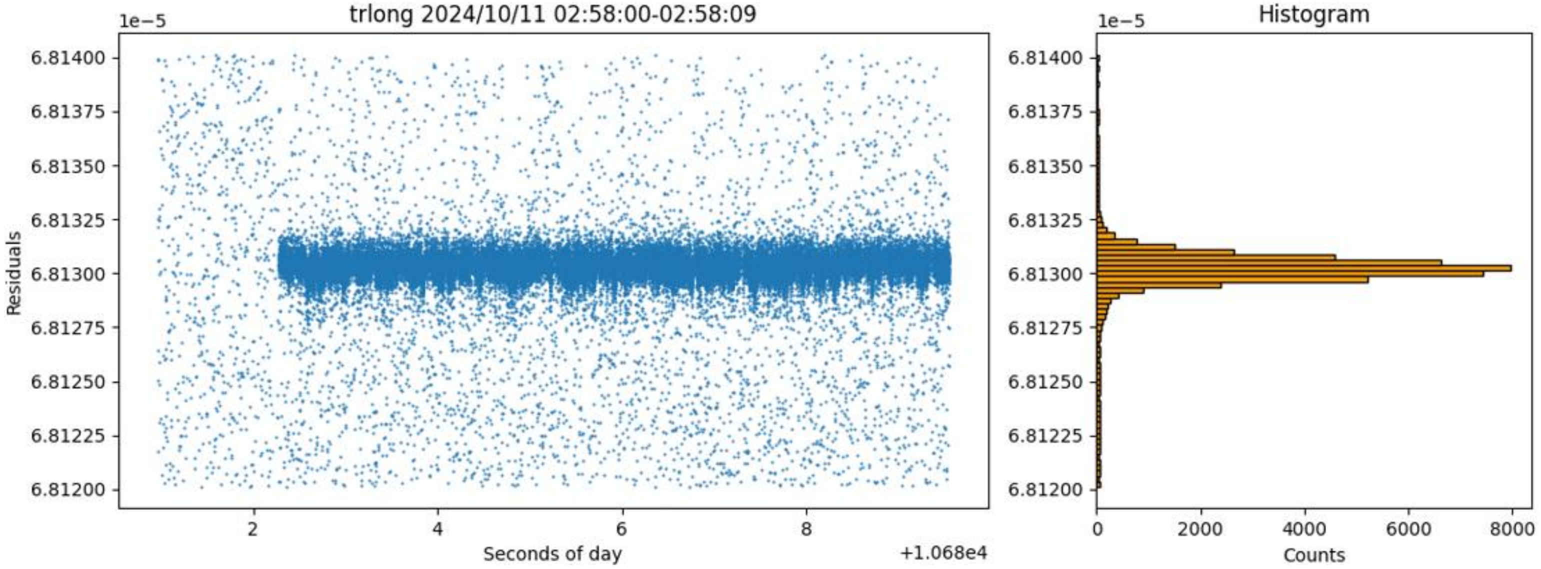
Time for time!

New definition of “one second” coming soon.
Precise time: new infrastructure for future communications.
No sufficient tool for comparison (time transfer).

SLR technique

Applicable from very short to very long range.
Feasible option for no-optical-fibre cases.

Omni-SLR for volcano monitoring?



n 33074, Ave 68130208 ps, Std 341 ps, RRate 38.39 %

Very long terrestrial ranging

Ishioka to Mt Tsukuba: Over 10 km, about 4-deg El.

Eye safety: NOHD = 0, SZED ~ 3.5 km, CZED ~ 15 km with Omni-SLR laser/optics.

New application of SLR technique?

111 active volcanoes in Japan. Useful for disaster prevention? Hard to model delays?

Time transfer?

Our Proposal Approved by NIPR!

“Development of a compact SLR system for the first antarctica experiment” 3 years: FY2024 to FY2026. Syowa: 69S 35E.

FY2024-FY2025
  Preliminary tests in Japan. Ex. Low temperature, Daytime only.

FY2025
  A container to be installed at Syowa.

FY2026 (JARE68)
  Shipped to Syowa (Nov 2026). SLR at Syowa (Jan-Feb 2027).

https://www.nipr.ac.jp/english/antarctic/center.html

小型衛星レーザ測距システムの開発と南極初試験

課題番号：AH1004
代表者：大坪 俊通（一橋大学）

観測概要

パルス型のレーザ光により人工衛星の軌道を正確に測る技術を衛星レーザ測距と呼びます。地上からレーザを発射し、それが衛星に搭載された反射鏡で戻され、また地上に戻ってくるまでの時間を非常に正確に測ります。世界には30局程度のレーザ測距観測局があります。本来、できるだけ地球上の広い範囲にレーザ測距観測局を設置できるとよいのですが、導入コスト・運用コストが高いため、現状は北半球中緯度域に偏って、南緯36度以南は空白域になっています。本研究では、低価格でコンパクトなレーザ測距装置を開発し、各種試験を経て、世界で初となる南極でのレーザ測距に挑戦するものです。さらに、将来の定常運用化をめざして、現地にて発生する問題点を収集することも重要な課題です。

長年にわたる多くの方によるご尽力により、昭和基地にはVLBI・DORIS・GNSS・重力計といった測地関連施設がすでに備わっており、南極で最も測地観測が進んでいる場所です。これに衛星レーザ測距装置が加わると、フルセット（国際的に「GGOS コアサイト」と呼ばれる）を装備することになります。人工衛星が南半球高緯度域を通過するときにもレーザ測距観測ができるようになると、衛星の軌道決定精度が高まり、汎地球規模での位置や重力がより正確に求められるようになります。海面の上昇や氷の減少など地球環境変動監視に欠かせないものです。

https://www.nipr.ac.jp/antarctic/science-plan10/houga.html

Omni-SLR: lots of to-do's

Groundwork as an SLR station
- Improvement in TX/RX alignment.
- Eccentricity vector: Marker to Ref point.
- Site log. Webpage@ILRS.
- CRD FR & NP generation.
- Daytime ranging.
- Improvement in UI.
- Quality assessment.

For global geodesy
- Clarification of what it can do and cannot do.
- Local tie with VLBI and GNSS at Ishioka.
- Attractive scenario for new users.
- Expansion of global SLR network.
- Mixture of "big" and "small" SLR.
- Better geodetic products.
- Refresh people's mindset.

For our Antarctica Project 2026-2027
- Daytime star calibration.
- Low-temperature tests.
- Container. Packaging. Dome.
- Dust, Low-band comm., Static, etc.

Beyond SLR
- Satellite/aircraft tracking for optical comm.
- Time comparison.
- Disaster monitoring.
- More?

Omni-SLR
ISHIOKA
7317

More updates soon!

Thank you
谢谢
ありがとう