# Omni-SLR First Returns!

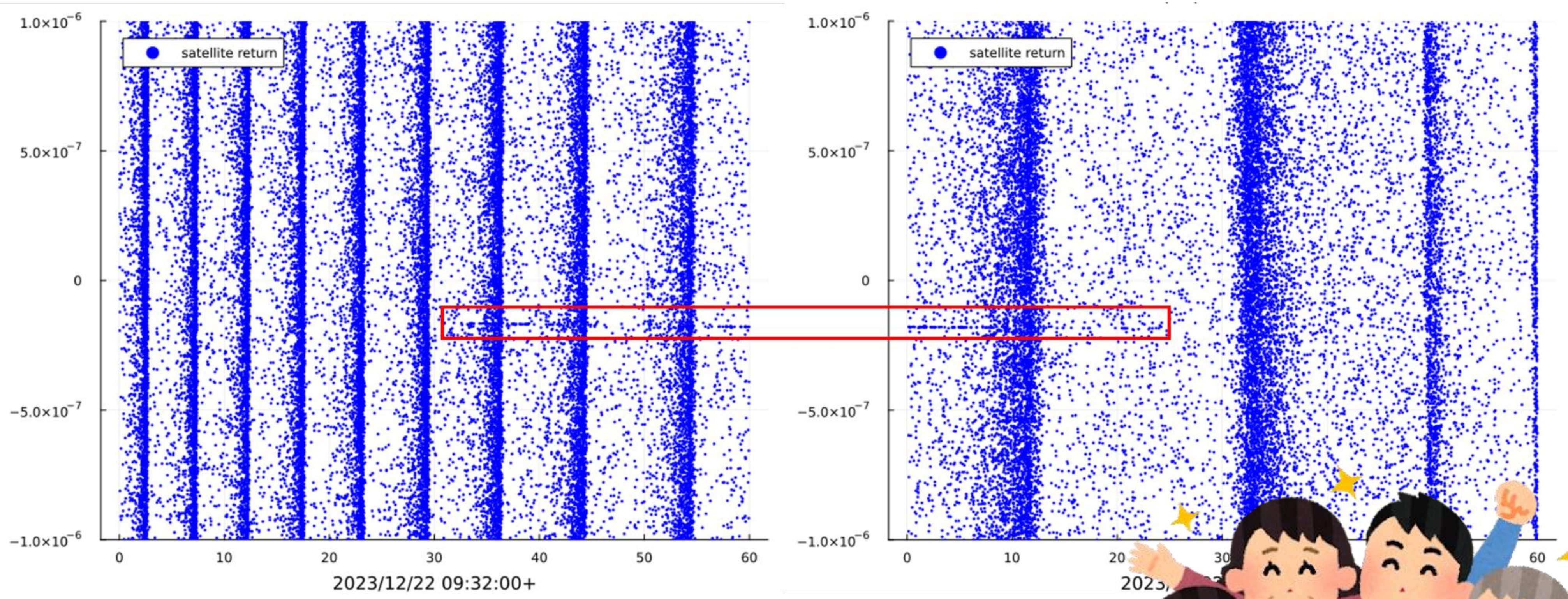
(1) System overview
(2) Projects and prospects

*This work is supported by JSPS KAKENHI Grant Number 20H01993, and the joint research projects of JAXA-HitU-NAOJ-UTokyo, GSI-HitU, NIPR Explanatory Research, Softbank-HitU, MHI-HitU and KHI-HitU.*

Toshimichi Otsubo [1], Hiroshi Araki [2], Yusuke Yokota [3], Kenji Kouno [3],
Takehiro Matsumoto [4], Mihoko Kobayashi [1], Yuichi Aoyama [5],
Junichi Nakajima [6], Kensuke Kokado [7]
and a number of contributors/supporters

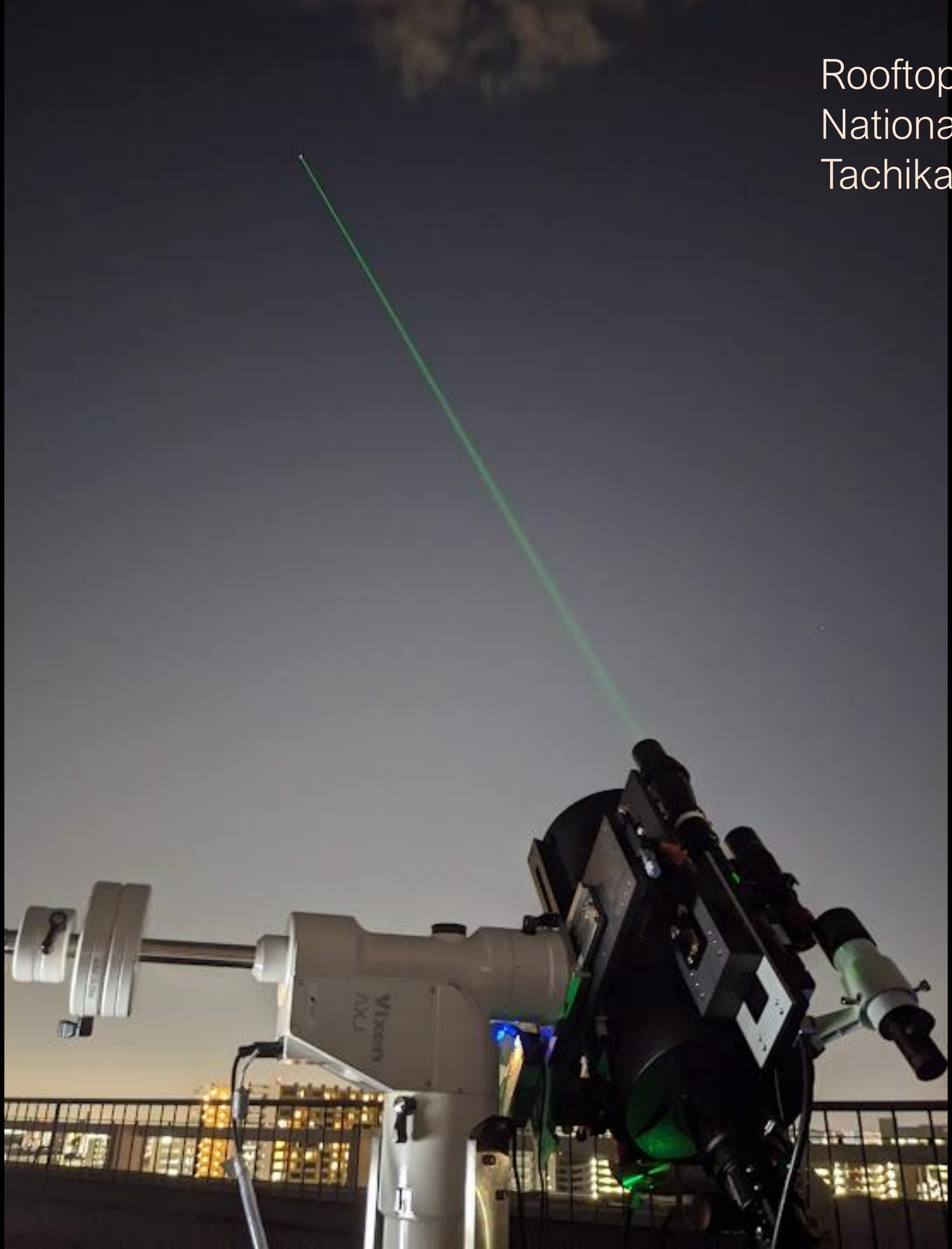
[1] Hitotsubashi Univ, [2] NAOJ, [3] IIS, Univ of Tokyo, [4] JAXA,
[5] NIPR, [6] Softbank Corp, [7] GSI

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

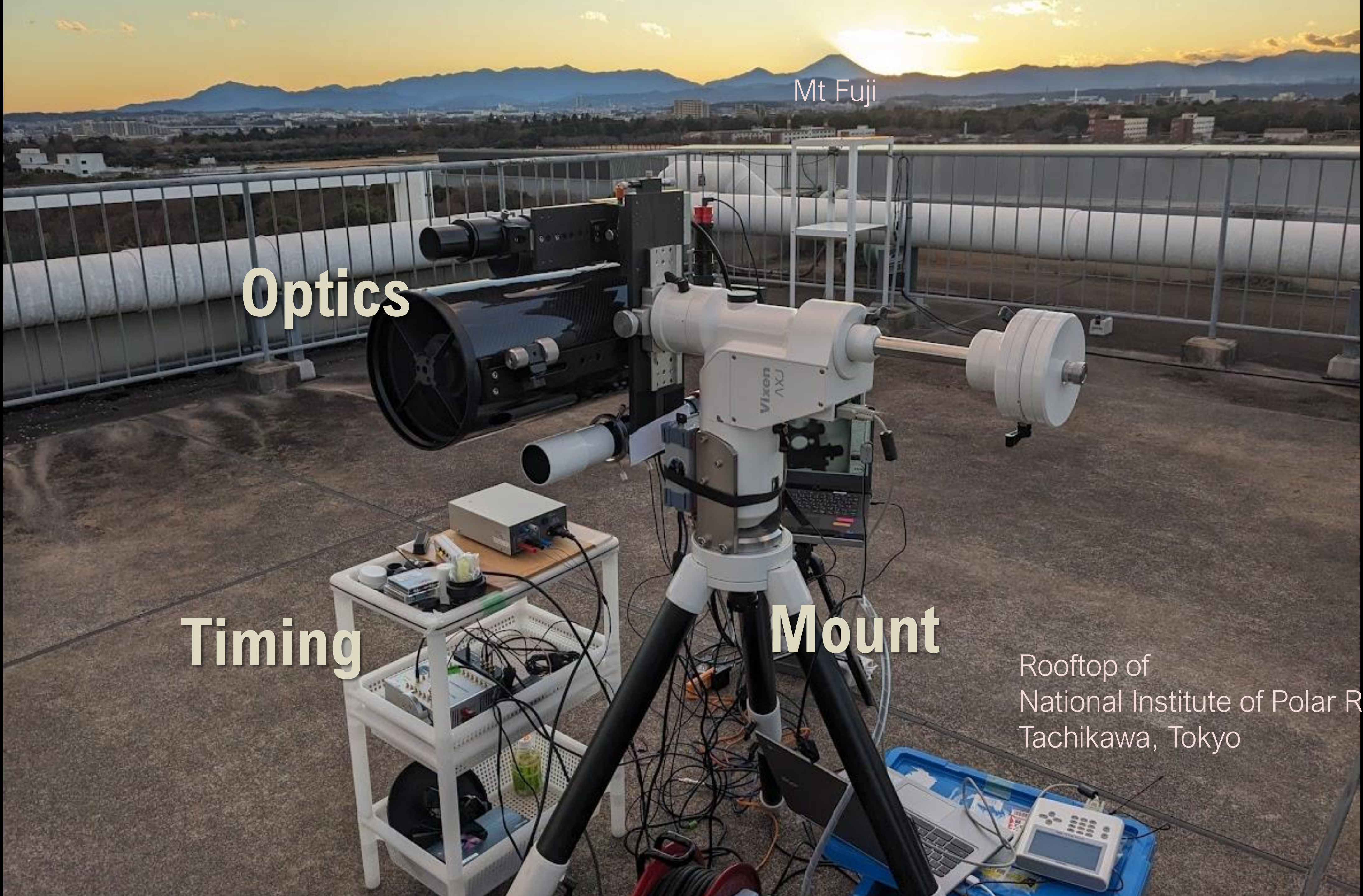



2023-12-22 SARAL & SWARM-C
2023-12-26 BEACON-C & SWARM-C

Rooftop of
National Institute of Polar Research,
Tachikawa, Tokyo



Rooftop of
National Institute of Polar Research,
Tachikawa, Tokyo


Mt Fuji
Optics
Timing
Mount
Vixen
Rooftop of
National Institute of Polar Research,
Tachikawa, Tokyo

# Omni-SLR: Concepts

SLR History Record?
With/without adjusting the value of money?

## Compactness

High mobility. < 100 kg

Conveyable by a car.

Low energy consumption.

## Low-cost

## (net 50-60k EUR/USD)

**COTS products.**

- Swabian Timer
- CryLAS ns pulse laser
- Vixen mount and telescope
- Vaisala Barometer
- Hamamatsu SPAD
- Sony-ZWO Camera

## Multi-purpose

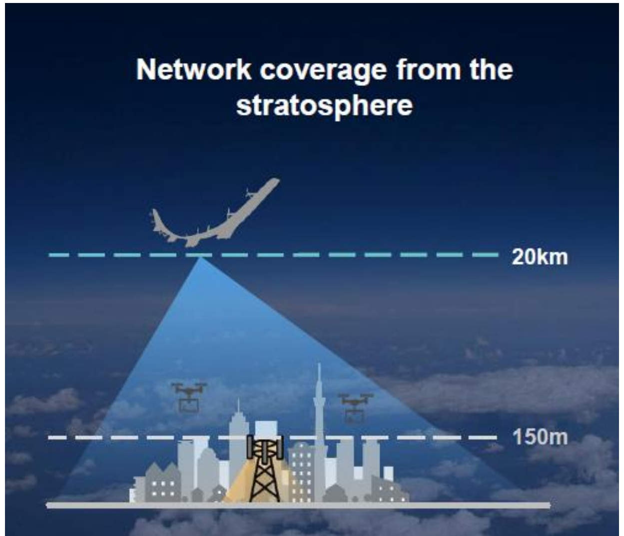
**Primary: SLR.**

**Aircraft tracking (for 6G communications ↓).**

**Space Comm.**

**Possibly applicable to:**

- Photometry
- Space Debris/SSA
- Time Transfer




https://hapsalliance.org/

# Omni-SLR: System Specification (as of Feb 2024)

## Optics

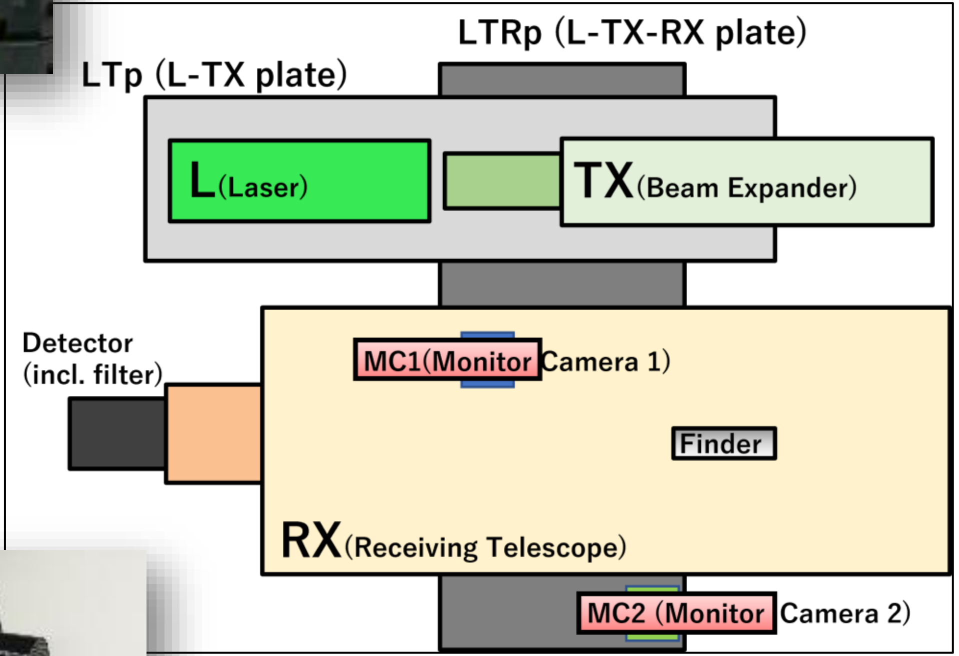
must be < 20 kg.

### CryLAS FDSS532-Q2

λ = 532nm;
pulse width = 1.3ns;
Rep. rate = 10 kHz;
output = 6 μJ/pulse

### (TX) BORG 36ED

Φ = 36 mm; f = 200 mm



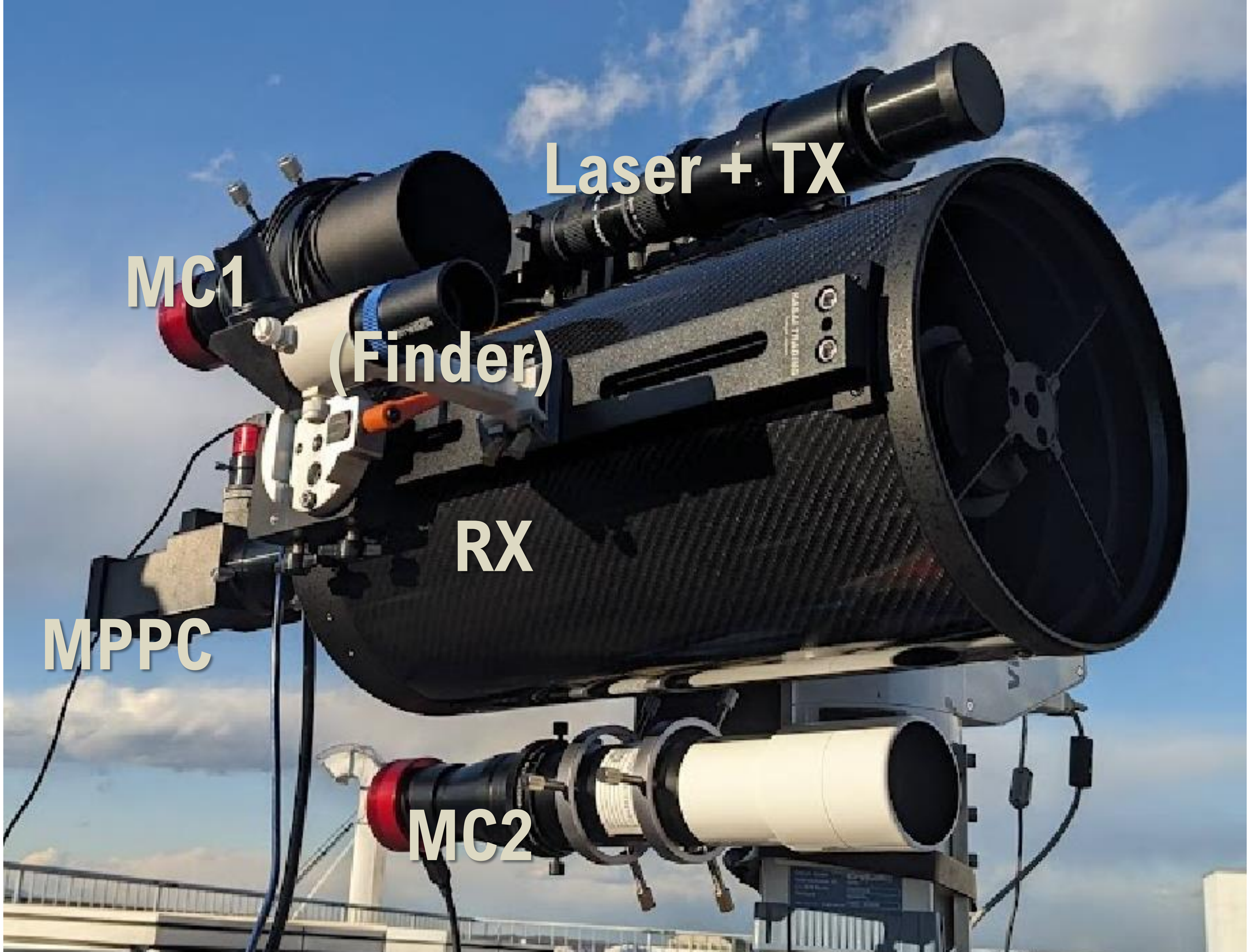

Plates: Futaba's CFRP PLATE
(About 50% of Alminium)

### Hamamatsu C11202-100


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

### (RX) Kasai GS-200RC

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


Laser + TX
MC1
(Finder)
RX
MPPC
MC2

# Omni-SLR: System Specification (as of Feb 2024)

## Timing

### Swabian TimeTagger Ultra (Value Ed)


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

### Furuno TB-1


OCXO

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

### Citizen TSV-500GP


NTP Server
Local delay/stability: < 1 ms

# Omni-SLR: System Specification (as of Feb 2024)

**Mount**

**Equatorial**


**Alt-Az**

UART

LAN Wired

**Raspberry Pi etc (Flask UI)**

cpf-san (192.168.11.21): CPF = ILRS orbit prediction

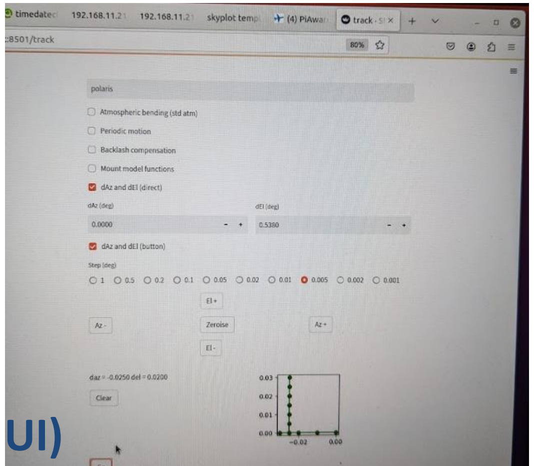
adsb-san (...11.22): ADS-B-based air traffic

laser-san (...11.23): Laser trigger signal

mets-san (...11.25): Barometer and mets sensor

tle-san (...11.26): TLE = Two-Line Element orbit

NTP server (...11.29) = Citizen TSV-500GP




**Linux PC (Streamlit UI)**

# Omni-SLR: Link Budget

## Prediction

**Omni-SLR versus Herstmonceux** (both single p.e.)

Laser: 0.06 W (10 kHz) vs 1 W (1 kHz)

RX: 20 cm vs 50 cm

Others: no major difference

→ 0.0096 vs 1 (About 1%)

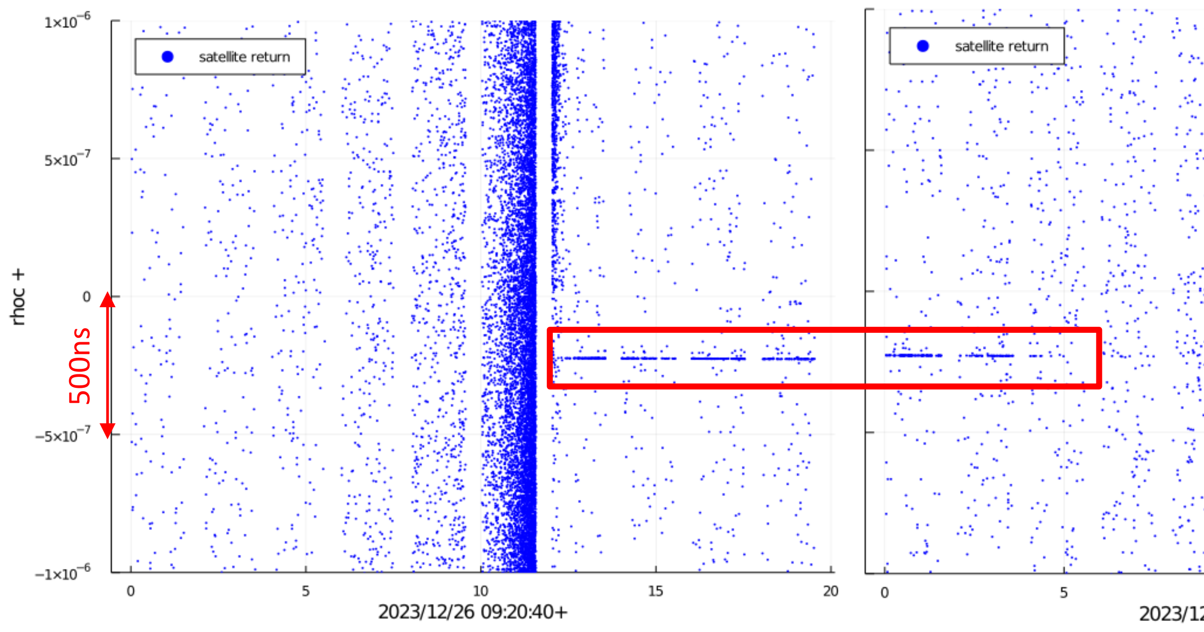
**LEO returns at Herstmonceux**

100 returns/s (ret rate = 10%) with ND 2-3

**Expected LEO returns with Omni-SLR**

100-1000 returns/s (ret rate = 1-10%) without ND

**(LAGEOS should be reachable with Omni-SLR)**




## Omni-SLR Outcome

Best segment ( ↑ ) of Beacon-C 2023-12-26.

50-100 returns/s

Return rate = 0.5 - 1%

# Omni-SLR: Precision

## Omni-SLR Prediction

Laser pulse width: < 1.3 ns FWHM = 550 ps RMS

(FWHM = 2.35 $\sigma$)

= 16.5 cm RMS two-way

= 8.2 cm RMS one-way

Single photo-electron level for all kinds of satellites.

Expected NP precision assuming white noise

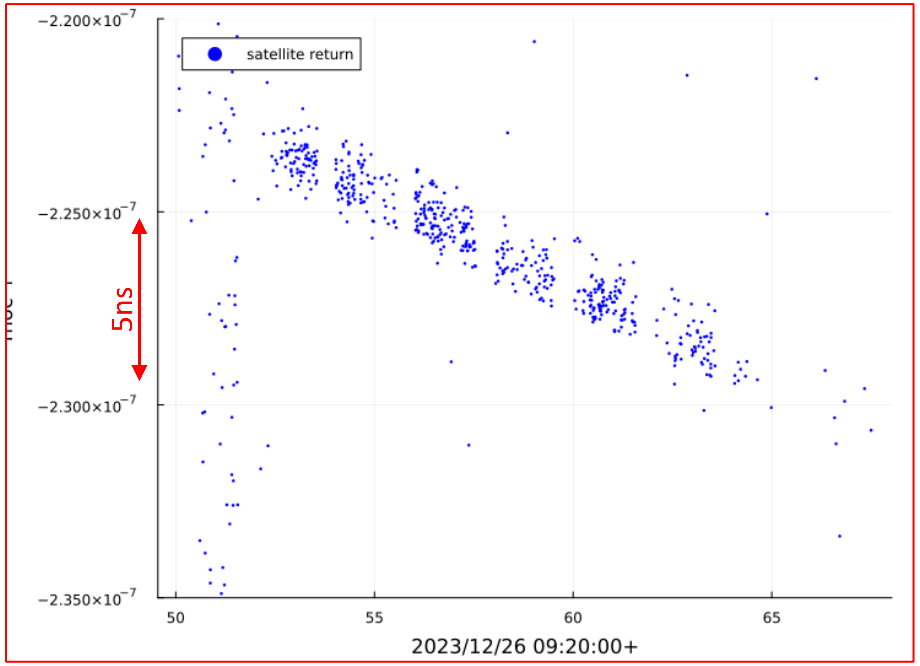
1 return/NP: ~ 8 cm

10 returns/NP: 2-3 cm

100 returns/NP: ~ 8 mm

1000 returns/NP: 2-3 mm

10000 returns/NP: ~ 0.8 mm




## Omni-SLR Outcome

Best segment ( ↑ ) of Beacon-C 2023-12-26.

460 ps RMS and 500 returns/NP

(almost the same as ground target ranging)

~ 7 cm per shot, 3-4 mm per NP

# Omni-SLR: Project Status/prospects (as of Feb 2024)

## Experiments so far

Component tests at our own institutes.

Assembly tests at Simosato (JCG) and Tachikawa (NIPR) – open air.

## ILRS/IERS registration

CDP Number “7317” “95” “01”

DOMES Number 21791S00X (TBD)

## Installation & test at Ishioka (GSI): 2024+

A container (sliding roof) to be built very soon.

More efficient developments.

Collaboration with GSI colleagues.

Collocation with GNSS, VLBI and gravimeters.

Exhibition @ IVS GM 2024 Tsukuba.


**26 Feb 2024**
The container (slide roof; like →) to be installed w/o electricity.
**5 Mar 2024**
IVS GM Excursion.
**End of Mar 2024**
The container to be fully ready.
**Spring-Summer 2024**
Development to be accelerated.
**Autumn-Winter 2024**
Local survey.

https://www1.m1.mediacat.ne.jp/nisshindome

# Omni-SLR: Project Status/prospects (as of Feb 2024)

## Experiments so far

Component tests at our own institutes.

Assembly tests at Simosato (JCG) and Tachikawa (NIPR) – open air.

## ILRS/IERS registration

CDP Number “7317” “95” “01”

DOMES Number 21791S00X (TBD)

## Installation at Ishioka (GSI): 2024+

A container (sliding roof) to be built very soon.

More efficient developments.

Collaboration with GSI colleagues.

Collocation with GNSS, VLBI and gravimeters.

Exhibition @ IVS GM 2024 Tsukuba.

## Time Transfer: 2024+

2nd system being assembled. A -> B, then A <-> B.

Collaboration with NICT, JAXA and Softbank.

## Experiment at Simosato (JCG): 2025?

To collocate within the same-beam distance.

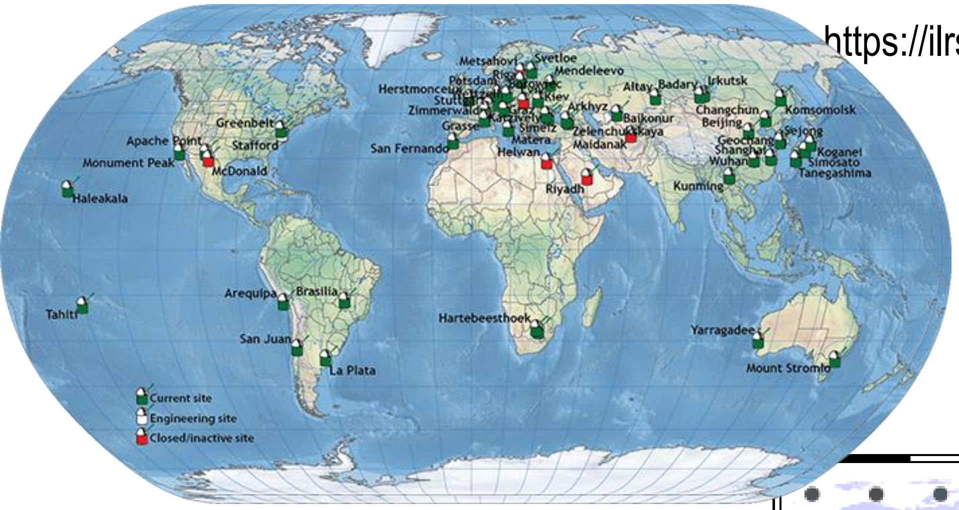
To track the same targets. Simosato -> Omni-SLR.

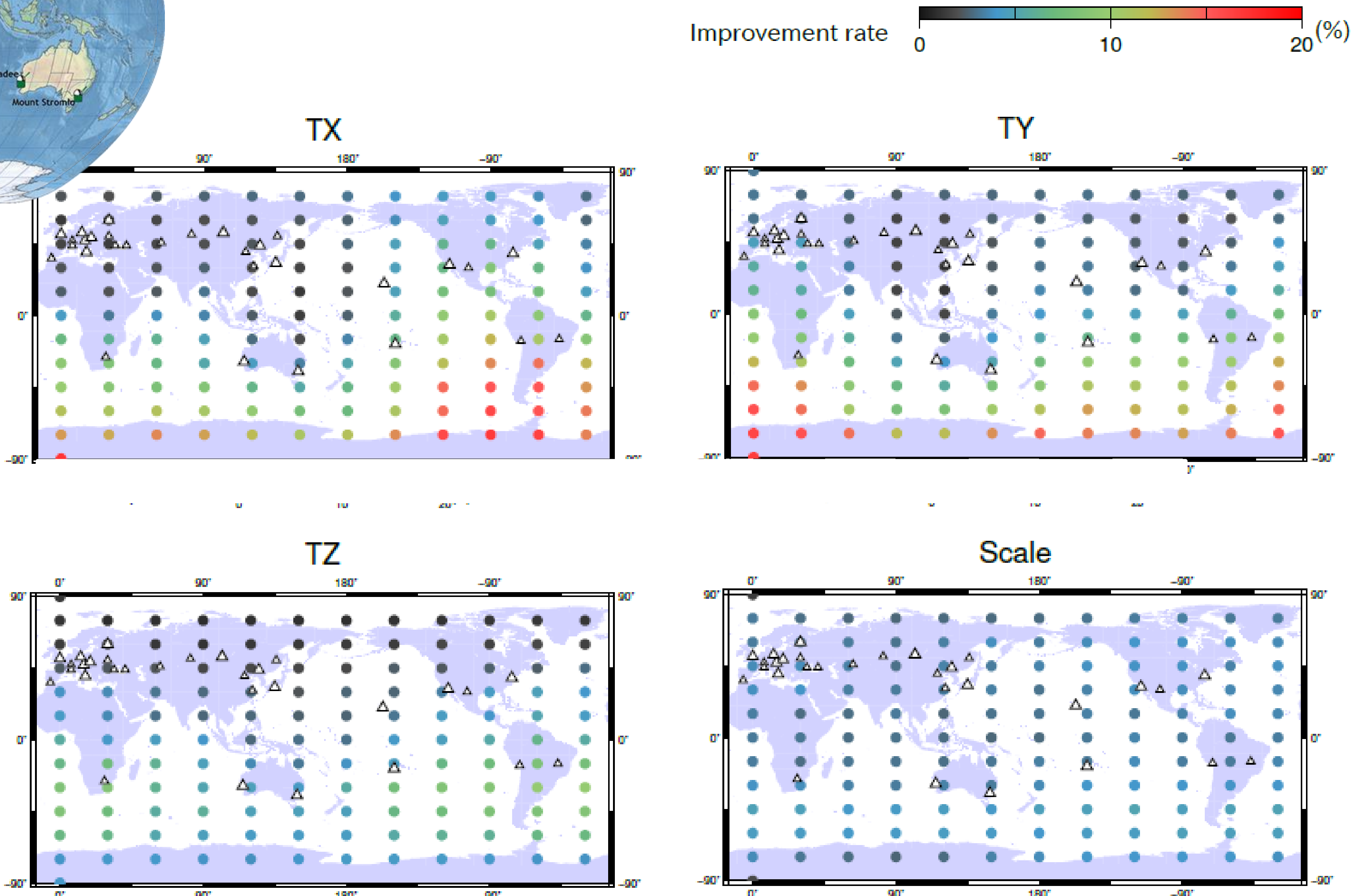
## Tests at Syowa (Antarctica): early 2027

Summer time experiments approved by NIPR.

Challenges: Day-time only operation, Low temperature, Dusts, etc.

https://ilrs.gsfc.nasa.gov/network/stations/index.html




Otsubo et al, EPS, 2016

# 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).

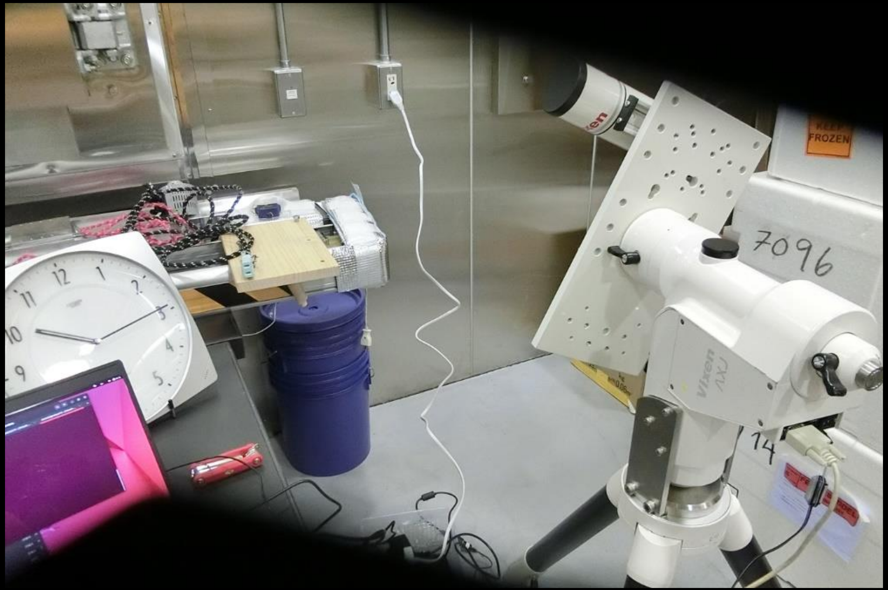

https://www.nipr.ac.jp/english/antarctic/center.html

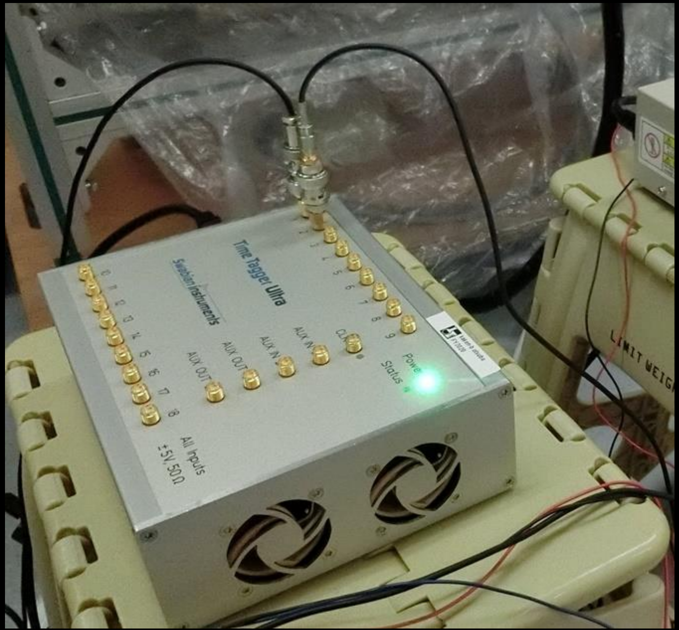

https://www.nipr.ac.jp/antarctic/science-plan10/houga.html

Omni-SLR

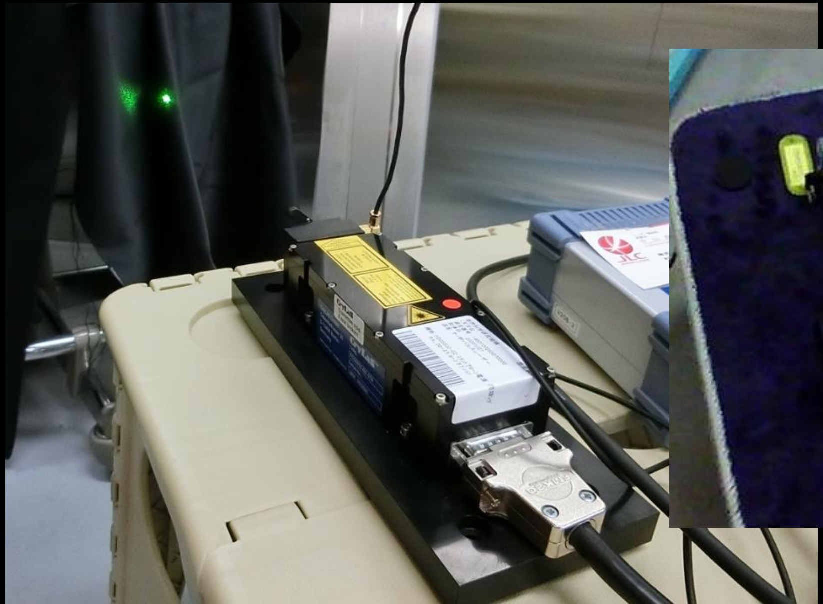


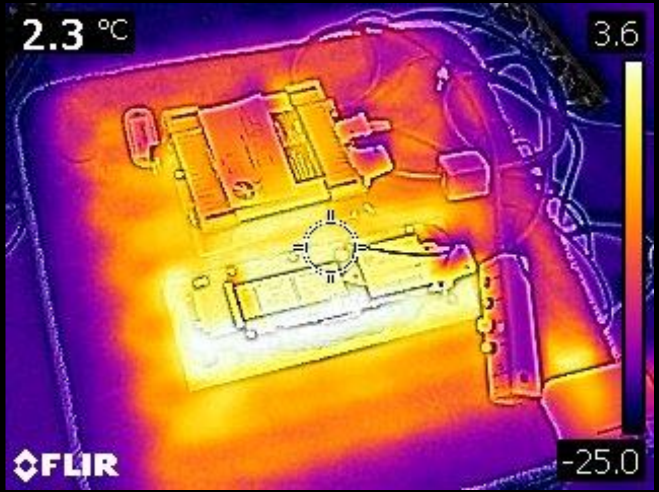
Test 1: Vixen AXJ Mount + PC  Test 3: TimeTagger Ultra + PC Passed at -15 ℃ & -30 ℃



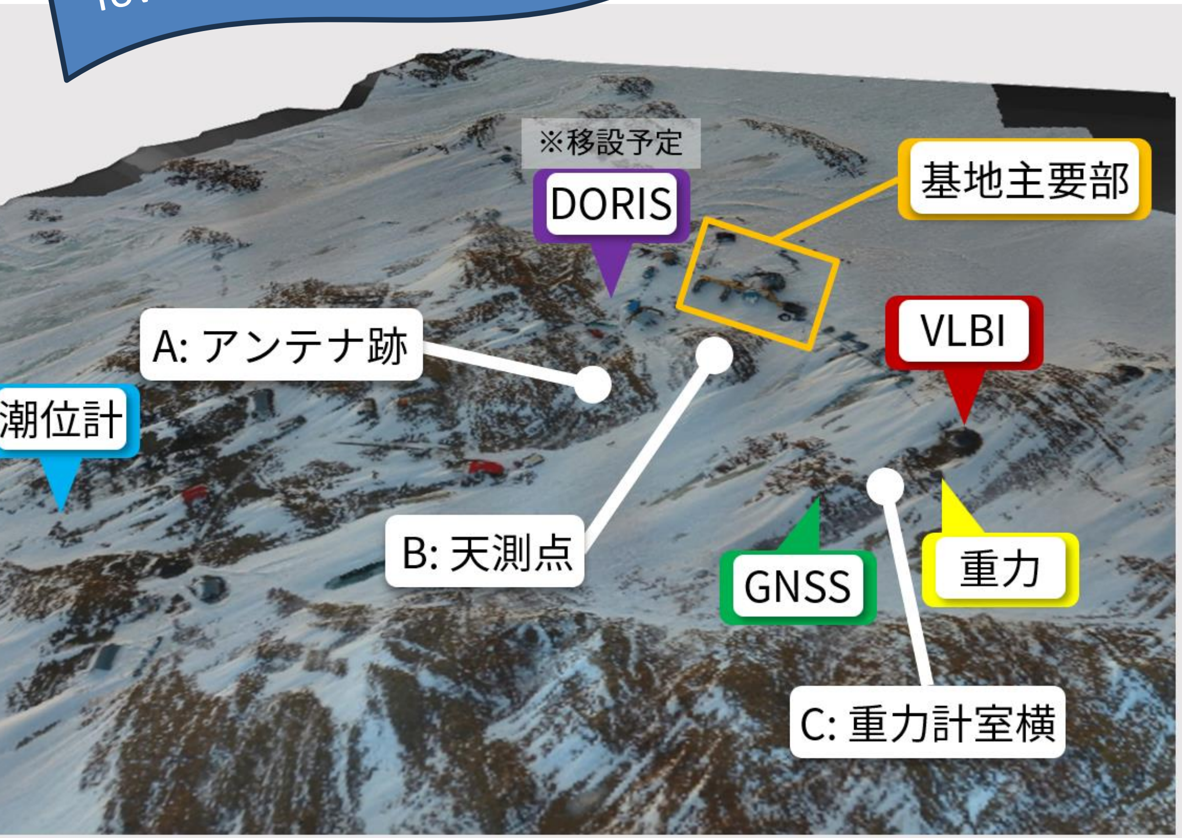

Test 2: CryLAS laser Failed at -15 ℃ first → passed with a heater, Failed at -30 ℃





# Omni-SLR@Syowa? Preliminary site visits in 2018

Toward “GGOS Core Station”




Probable

**A: アンテナ跡**
**平らで，基地主要部からも近く，アクセスが容易**
**設置工事も容易**


**B: 旧天測点**
**基地主要部からは近いが，**
**設置工事がやや困難**


**C: 重力計室横**
**他の測地観測点に近い**
**設置工事は容易**
**アクセスに難あり**

# Omni-SLR: Lots of homework (for us)

## Toward a minimum SLR station.

Calibration. Local survey.

Efficient operation. Day/night operation.

Precision and stability. Better UI.

Eye safety.

RLI's SKYZAN v7 output:
NOHD ~ 1 km (zero with a 6 cm beam)
SZED = 3-4 km (flashblindness)
CZED = 16-17 km (glare; distraction)

## What it can and it cannot.

Low single-shot precision. 7-8 cm rms.

LEO only? LAGEOS reachable? GNSS hopeless.

Upgradable with better lasers?

## Toward globally distributed systems.

Operational cost matters.

Automation. Package. High usability/safety.

## Toward the Antarctica challenge.

Daytime-only operation.

Low-temperature resistance.

Dust, static electricity, remote conditions, etc.

## Multi-purpose (SLR + what?)

Various tracking purposes.

Time transfer.

Airborne/spaceborne communications.

## Budget hunting & collaboration

Publicity.

Academism and industry.

# Omni-SLR: Long-term future homework (for you)

*Having seen the potential of miniSLR (DLR/DiGOS) and Omni-SLR…*

## Station colleagues:

Low-cost SLR not competing against the existing stations. It's *something like SLR*, quite limited.

Think about the 2nd, 3rd, … low-cost testbed operating next to yours.

Better devices? New applications? Fill the network gaps.

## Analysis colleagues:

Can a LEO-tracking-only station contribute to geodesy?

Imagine the number of stations x2, x10, x100… The role of SLR will change in space geodesy and POD.

## CoMers (JC Rodriguez *(now partly with UN-GGCE)*, R Neubert *(congrats on reaching 90 yrs old)* , …):

Think about the system-dependent CoM corrections for this kind of broad-pulse-width systems.

Smallest CoM corrections expected for spherical satellites, by masking the signature effects. 240 mm or even less for LAGEOS? More influenced by the tail of optical response functions?

## Everyone:

*Your ideas, supports, concerns, etc. are all welcome.*

# Galileo for Science (G4S) Tracking Campaign

14-February-2024

# Galileo for Science Campaign Summary Pass Comparison (this week vs last week)

| | Galileo Pass Totals based on Data Received prior to Feb 14, 2024 | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Station | PAD | 101 | 102 | 103 | 201 | 202 | 203 | 205 | 206 | 208 | 209 | 210 | 211 | 212 | 221 | Total | Diffs |
| Riga | 1884 | | 1 | | | | | | | | | | 1 | | | 2 | 0 |
| Yarragadee | 7090 | 9 | 8 | 9 | 11 | 8 | 3 | 11 | 8 | 7 | 6 | 10 | 9 | 10 | 5 | 114 | 33 |
| Greenbelt | 7105 | | 2 | | | | | | | | 1 | | | | 3 | 6 | 0 |
| Monument | 7110 | | 1 | | | | | | | | | | | | | 1 | 0 |
| Changchun | 7237 | 12 | 10 | 8 | 6 | 7 | 10 | 4 | 3 | 7 | 9 | 1 | 3 | 9 | 9 | 98 | 7 |
| Beijing | 7249 | 2 | 4 | | 3 | 1 | 2 | 2 | 2 | 3 | 2 | 1 | 1 | 4 | 4 | 31 | 0 |
| Wuhan | 7396 | | | | | 2 | 1 | | 1 | | | 1 | 1 | | | 6 | 0 |
| Kunming | 7819 | 5 | 7 | 6 | 6 | 6 | 7 | 3 | 4 | 4 | 2 | 3 | 1 | 5 | 4 | 63 | 0 |
| Shanghai | 7821 | 3 | 2 | 3 | | 2 | 2 | | 2 | 1 | 1 | | 1 | 1 | 2 | 20 | 0 |
| Wettzell | 7827 | 5 | 5 | 1 | 6 | 6 | 4 | 3 | 4 | 3 | 3 | 3 | 3 | 3 | 5 | 54 | 5 |
| Graz | 7839 | 5 | 7 | 5 | 5 | 6 | 8 | 4 | 3 | 4 | 4 | 6 | 4 | 3 | 7 | 71 | 3 |
| Herstmonceux | 7840 | 1 | 3 | 2 | 4 | 4 | 2 | 2 | 2 | 2 | 4 | 2 | 2 | 2 | 2 | 34 | 10 |
| Potsdam | 7841 | 4 | 1 | 1 | 1 | | | | 1 | | | 1 | | 1 | 2 | 12 | 1 |
| Grasse | 7845 | 5 | 8 | 4 | 6 | 5 | 2 | 8 | 5 | 4 | 8 | 9 | 4 | 5 | 5 | 78 | 10 |
| Matera | 7941 | 8 | 7 | 8 | 8 | 10 | 8 | 9 | 11 | 11 | 6 | 9 | 8 | 7 | 12 | 122 | 1 |
| Wettzell | 8834 | 1 | 8 | 5 | 1 | 5 | 5 | 4 | 5 | 3 | 6 | 4 | 4 | 4 | 6 | 61 | 3 |
| Totals | | 60 | 74 | 52 | 57 | 62 | 54 | 50 | 51 | 49 | 52 | 50 | 42 | 54 | 66 | 773 | 73 |

| Legend |
|---|
| Elliptical Orbital |
| Differences since last week |

# Galileo for Science Campaign Summary
# NP Comparison (this week vs last week)

| | Galileo NP Totals based on Data Received prior to Feb 14, 2024 | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Station | PAD | 101 | 102 | 103 | 201 | 202 | 203 | 205 | 206 | 208 | 209 | 210 | 211 | 212 | 221 | Total | Diffs |
| Riga | 1884 | | 11 | | | | | | | | | | 6 | | | 17 | 0 |
| Yarragade | 7090 | 42 | 33 | 34 | 34 | 45 | 11 | 24 | 48 | 18 | 20 | 43 | 32 | 28 | 16 | 428 | 132 |
| Greenbelt | 7105 | | 14 | | | | | | | | 3 | | | | 12 | 29 | 0 |
| Monumen | 7110 | | 4 | | | | | | | | | | | | | 4 | 0 |
| Changchu | 7237 | 49 | 47 | 35 | 25 | 18 | 35 | 15 | 10 | 24 | 34 | 3 | 7 | 34 | 36 | 372 | 34 |
| Beijing | 7249 | 6 | 11 | | 9 | 2 | 3 | 4 | 4 | 7 | 5 | 1 | 1 | 10 | 9 | 72 | 0 |
| Wuhan | 7396 | | | | | 6 | 2 | | 1 | | | 2 | 4 | | | 15 | 0 |
| Kunming | 7819 | 12 | 17 | 16 | 15 | 14 | 18 | 6 | 10 | 8 | 4 | 8 | 3 | 15 | 11 | 157 | 0 |
| Shanghai | 7821 | 17 | 8 | 15 | | 8 | 10 | | 11 | 5 | 3 | | 3 | 3 | 12 | 95 | 0 |
| Wettzell | 7827 | 9 | 8 | 1 | 7 | 9 | 4 | 3 | 4 | 4 | 3 | 3 | 3 | 5 | 5 | 68 | 8 |
| Graz | 7839 | 17 | 29 | 11 | 11 | 12 | 25 | 10 | 7 | 10 | 9 | 26 | 11 | 7 | 29 | 214 | 9 |
| Herstmon | 7840 | 6 | 7 | 3 | 19 | 18 | 12 | 9 | 5 | 5 | 14 | 8 | 11 | 5 | 5 | 127 | 39 |
| Potsdam | 7841 | 20 | 8 | 4 | 5 | | | | 3 | | | 4 | | 3 | 6 | 53 | 8 |
| Grasse | 7845 | 18 | 35 | 18 | 17 | 15 | 6 | 33 | 26 | 15 | 31 | 31 | 23 | 20 | 17 | 305 | 31 |
| Matera | 7941 | 60 | 89 | 92 | 59 | 108 | 74 | 67 | 132 | 84 | 77 | 72 | 77 | 61 | 116 | 1168 | 4 |
| Wettzell | 8834 | 3 | 65 | 17 | 1 | 19 | 15 | 14 | 13 | 7 | 26 | 14 | 23 | 15 | 20 | 252 | 11 |
| Totals | | 259 | 386 | 246 | 202 | 274 | 215 | 185 | 274 | 187 | 229 | 215 | 204 | 206 | 294 | 3376 | 276 |

| **Legend** |
|---|
| Elliptical Orbital |
| Differences since last week |

# Galileo for Science Campaign Summary
# NP per Day per Satellite

- **G4S_2.0 Requirement: "At least 10 NPs per day are required to obtain a reliable and sufficiently robust POD"**

| | First Week | | | | | | | Second Week | | | | | | | Third Week | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Satellite | 20-Jan | 21-Jan | 22-Jan | 23-Jan | 24-Jan | 25-Jan | 26-Jan | 27-Jan | 28-Jan | 29-Jan | 30-Jan | 31-Jan | 1-Feb | 2-Feb | 3-Feb | 4-Feb | 5-Feb | 6-Feb | 7-Feb | 8-Feb | 9-Feb |
| GALILEO-101 | 17 | 1 | 31 | 9 | 11 | 23 | 23 | 11 | 6 | 20 | 13 | 3 | 21 | 11 | 11 | 6 | 11 | | 3 | 9 | |
| GALILEO-102 | 12 | 14 | 14 | 18 | | 7 | 39 | 15 | 35 | 27 | 32 | 13 | 14 | 16 | 37 | 5 | 30 | 11 | | 13 | 7 |
| GALILEO-103 | 10 | 7 | 5 | 18 | 5 | 2 | 38 | 11 | 15 | 14 | 16 | 8 | 5 | 8 | 34 | | 16 | 11 | | 5 | 5 |
| GALILEO-201 | 3 | 15 | 10 | 7 | 2 | 15 | 11 | 8 | 14 | 8 | 8 | 12 | 16 | 9 | 11 | 18 | 8 | 9 | 2 | | |
| GALILEO-202 | 5 | 27 | 20 | 4 | 2 | 14 | 11 | 3 | 11 | 23 | 2 | 24 | 21 | 23 | 18 | 14 | 9 | 3 | 7 | 10 | 5 |
| GALILEO-203 | 8 | 21 | 7 | 8 | 2 | 19 | 3 | 12 | 13 | 10 | 18 | 13 | 12 | 5 | 27 | 8 | 2 | 10 | 3 | 4 | 6 |
| GALILEO-205 | 6 | | 16 | 6 | | 26 | 14 | 3 | 6 | 18 | 9 | | 8 | 16 | 9 | 12 | 17 | | 3 | 2 | |
| GALILEO-206 | 2 | 18 | 25 | 5 | 22 | 14 | 13 | 12 | 17 | 28 | 1 | 21 | 18 | | 28 | 9 | 3 | 5 | 12 | | |
| GALILEO-208 | | 8 | 13 | | 12 | 29 | | 24 | 11 | 9 | 2 | 4 | 14 | 4 | 21 | 17 | | 10 | 7 | | |
| GALILEO-209 | 10 | 6 | 11 | 4 | | 14 | 19 | 4 | 9 | 21 | 28 | | 8 | 30 | 15 | 5 | 16 | | 3 | 12 | |
| GALILEO-210 | 3 | 1 | 6 | 19 | 6 | 13 | 3 | 1 | 21 | 15 | 31 | 20 | 4 | 17 | 14 | | 8 | 14 | 4 | | 4 |
| GALILEO-211 | 1 | 7 | 21 | 2 | 7 | 13 | | 2 | 19 | 30 | | 13 | 21 | 20 | 5 | 8 | 13 | 1 | 9 | | |
| GALILEO-212 | | 15 | 17 | | 7 | 34 | 5 | 5 | 12 | 26 | | 9 | 13 | 3 | 17 | 14 | 10 | 5 | 9 | | |
| GALILEO-221 | 2 | 17 | 18 | 2 | 13 | 20 | 9 | 21 | 24 | 22 | 3 | 28 | 32 | 9 | 23 | 13 | 5 | 7 | 8 | 3 | |
| Grand Total | 79 | 157 | 214 | 102 | 89 | 243 | 188 | 132 | 213 | 271 | 163 | 168 | 207 | 171 | 270 | 129 | 148 | 86 | 70 | 58 | 27 |

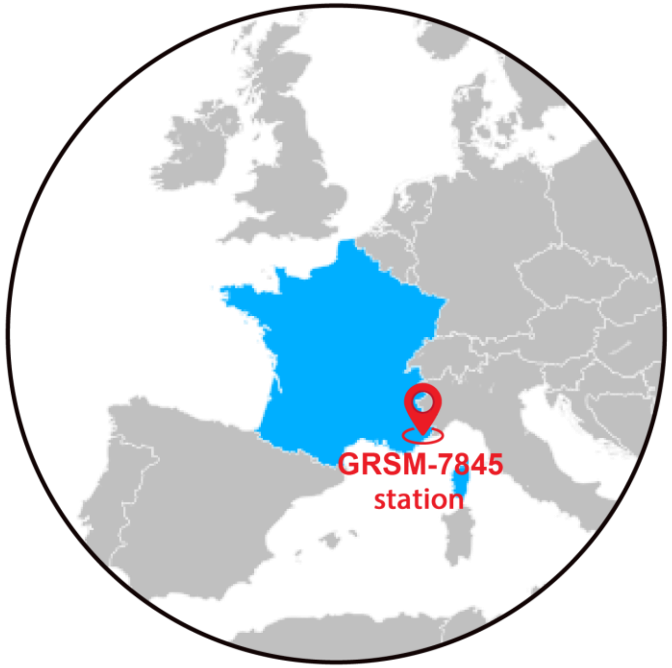
# Automatic determination of the SLR reference point at Côte d'Azur multi-technique geodetic observatory

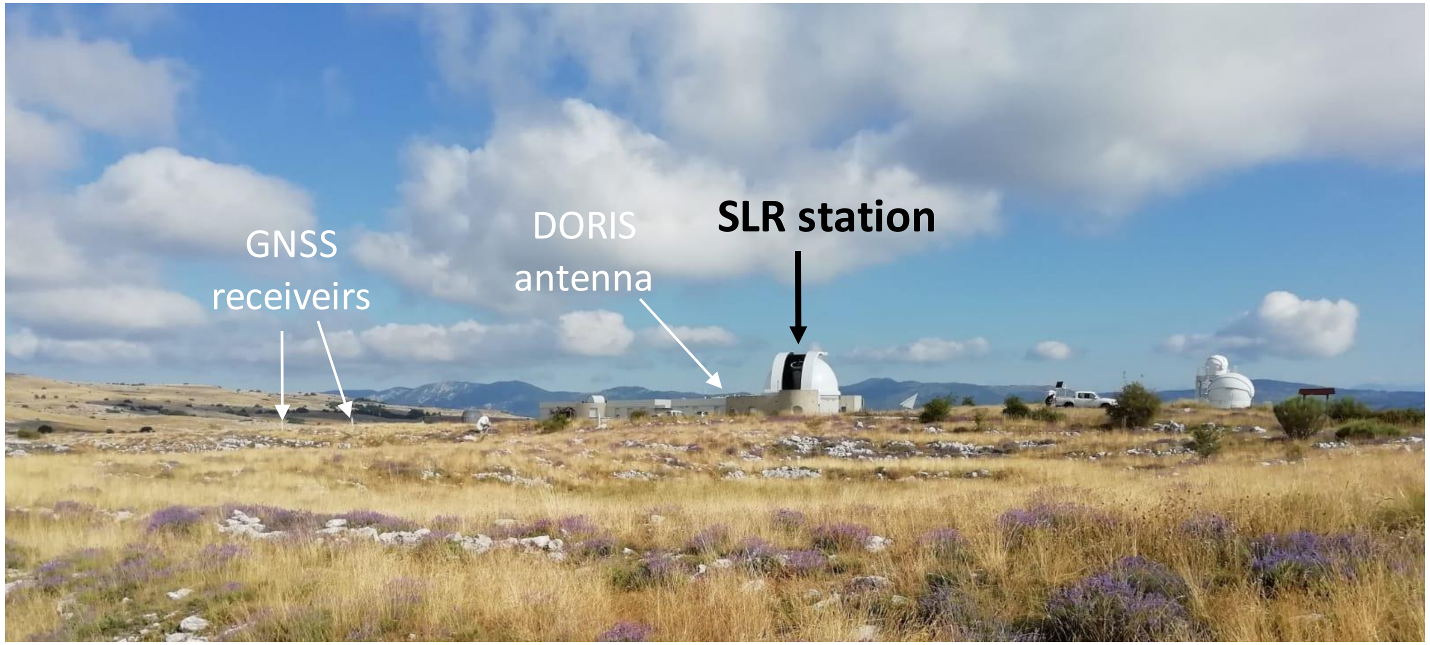
ILRS Networks and Engineering Standing Committee (NESC) online meeting
15th February 2024

Julien Barnéoud[1,2] , Clément Courde[3] , Jacques Beilin[2] , Madec Germerie-Guizouarn[4] , Damien Pesce[4] , Maurin Vidal[3] , Xavier Collilieux[1,2] , Nicolas Maurice[3]

*[1]Université de Paris, Institut de Physique du globe de Paris, CNRS, IGN, F-75005 Paris, France*
*[2]ENSG-Géomatique, IGN, F-77455 Marne-la-Vallée, France*
*[3] Université Côte d'Azur, CNRS, Observatoire de la Côte d'Azur, IRD, Géoazur, 2130 Route de l'Observatoire 06460 Caussols, France*
*[4] Institut National de l'Information Géographique et Forestière (IGN), F-94160 Saint-Mandé, France*

# Context: the Côte d'Azur multi-technique geodetic observatory



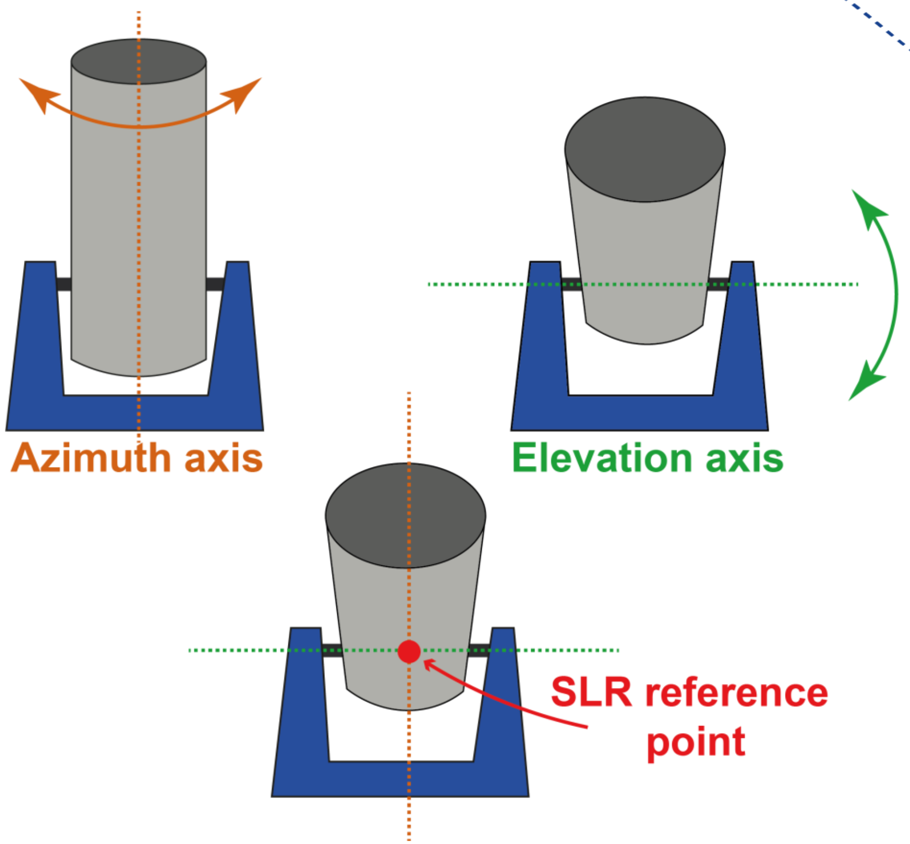




*"Grasse co-location site" (Caussols, France)*

OBSERVATOIRE
DE LA CÔTE D'AZUR

# Context: SLR station GRSM-7845

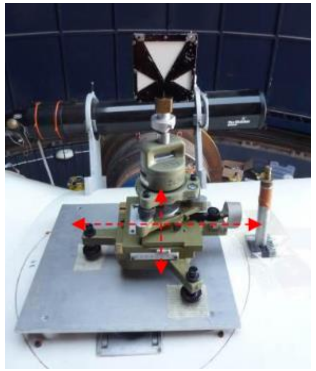
*MeO telescope*




*SLR reference point defined as the intersection of elevation and azimuth axes*

# Context: SLR station GRSM-7845

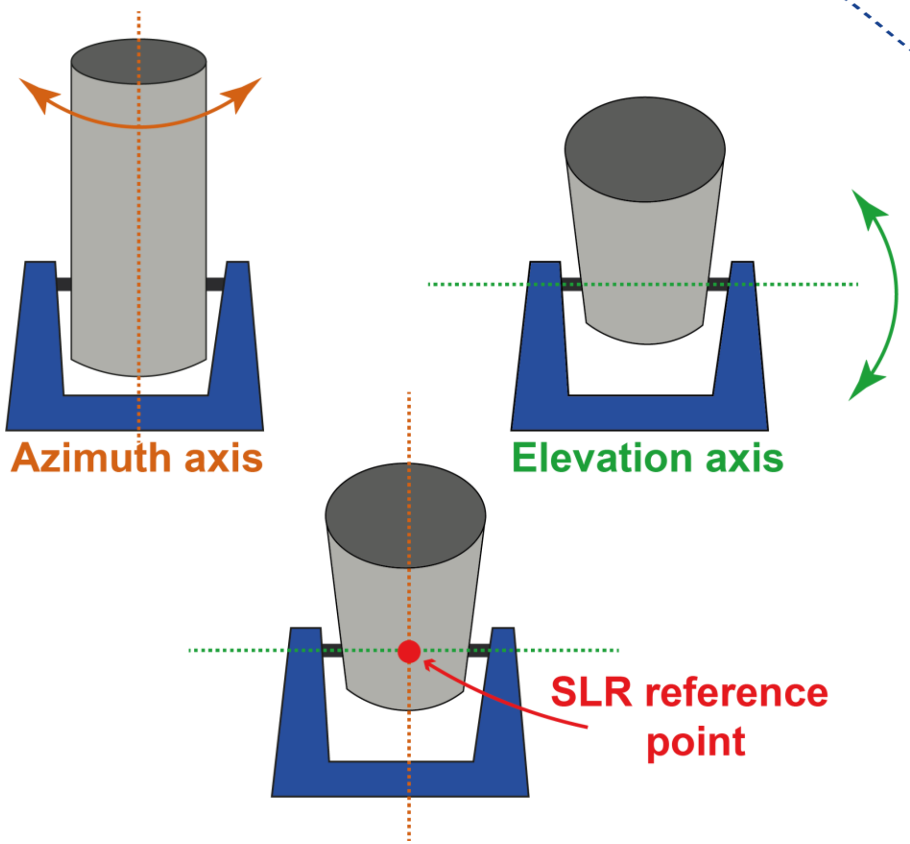
*MeO telescope*



Translation stage *(Pesce et al., 2013)*

Currently: local tie vectors determined once a year

- a time-consuming operation
- specific metrology accessories
- trained surveyors




*SLR reference point defined as the intersection of elevation and azimuth axes*

# Objectives

**Automatically determine the reference point of the SLR station:**

- Set up measuring devices
- Develop data-processing chain

➡ Fast / regular/ continuous determination (seasonal effect, after a maintenance operation…)

# Objectives

**Automatically determine the reference point of the SLR station:**

- Set up measuring devices
- Develop data-processing chain

➡ Fast / regular/ continuous determination (seasonal effect, after a maintenance operation…)

# Project timeline

ENSG Géomatique

OBSERVATOIRE DE LA CÔTE D'AZUR

UNIVERSITÉ CÔTE D'AZUR

**2018**
ENSG student project
1st prototypes, in-house targets

**2019**
3-month internship
Elevation axis (valid) & Azimuth axis (tests)
Start processing line dev.

**2020**
3-month internship
Azimuth axis (motorized corner cube)
Processing line dev.

# Measuring devices

## Steps of field measurements:

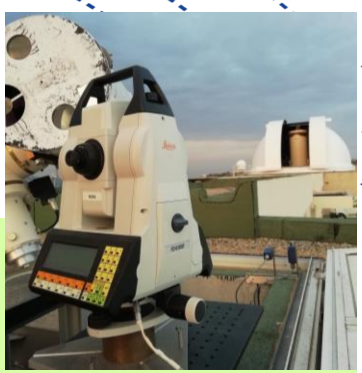
1. Retrieve meteorological data (apply corrections later in post-processing)

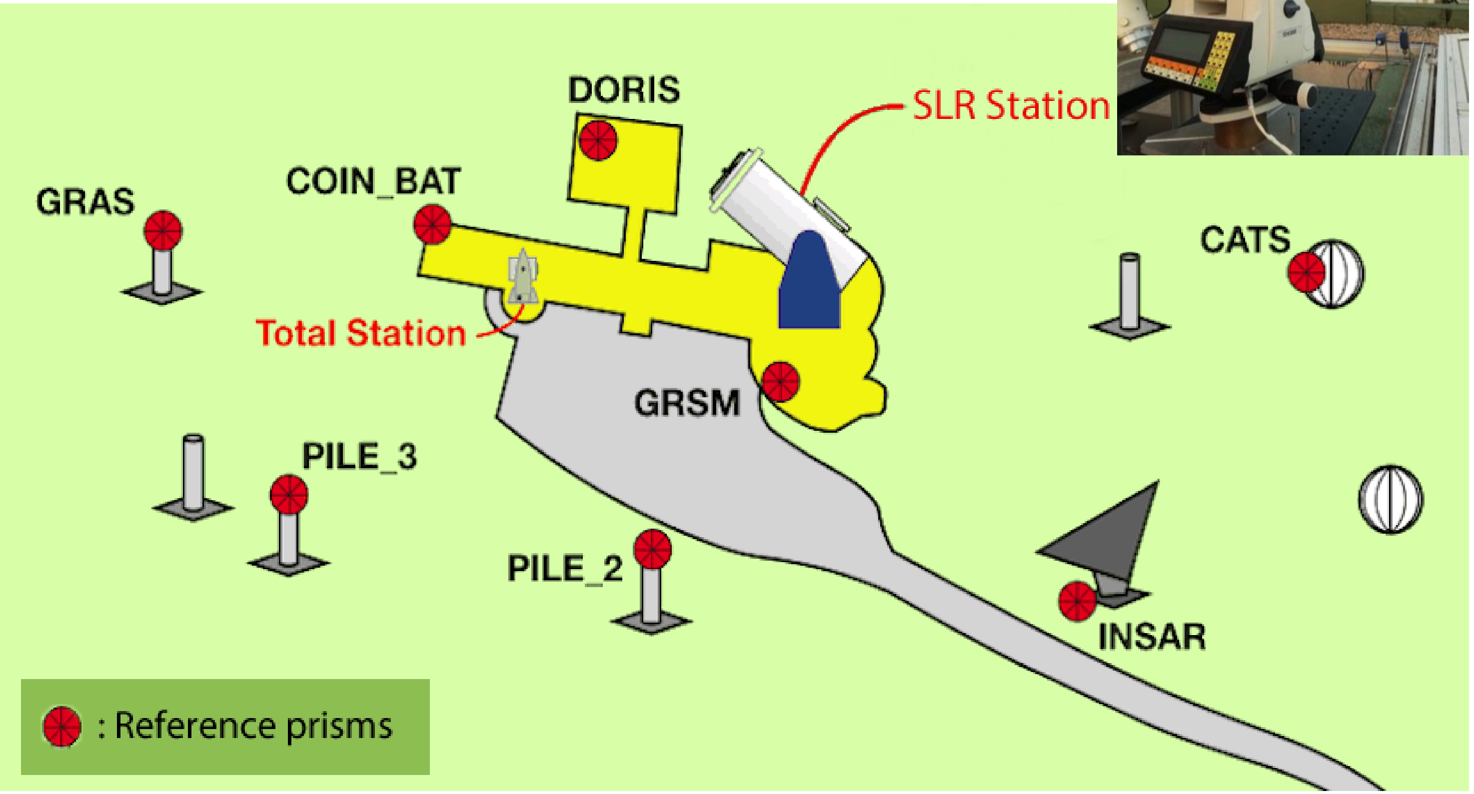
2. Shoot all reference prisms

3. Elevation axis: the telescope is positioned in front of the total station and the pendular prism is targeted, every 5 degrees of elevation

4. Azimuth axis: the telescope is positioned at 90 degrees of elevation and the total station aim at the corner cube.

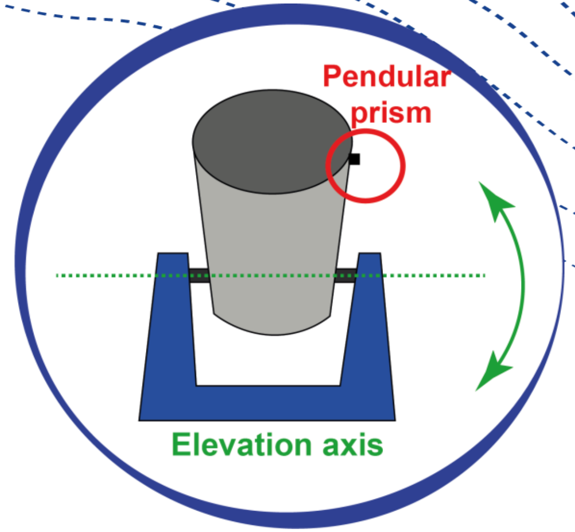
*SLR & total station*

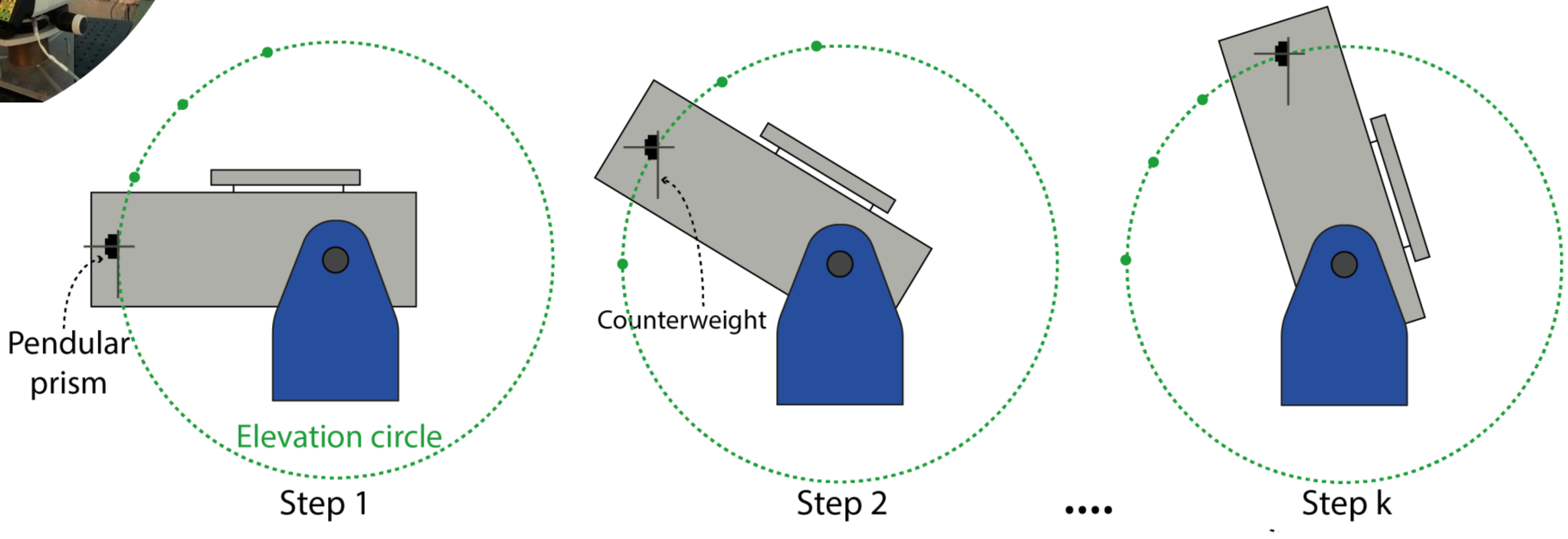




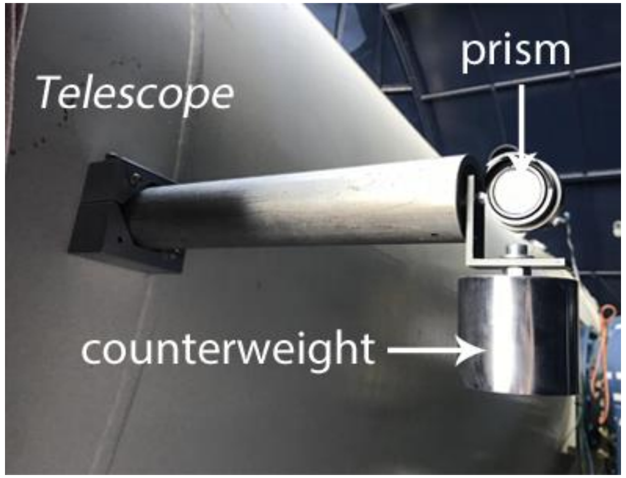

*Overview of the Grasse co-location site configuration during a local tie survey*

# Measuring devices: elevation axis



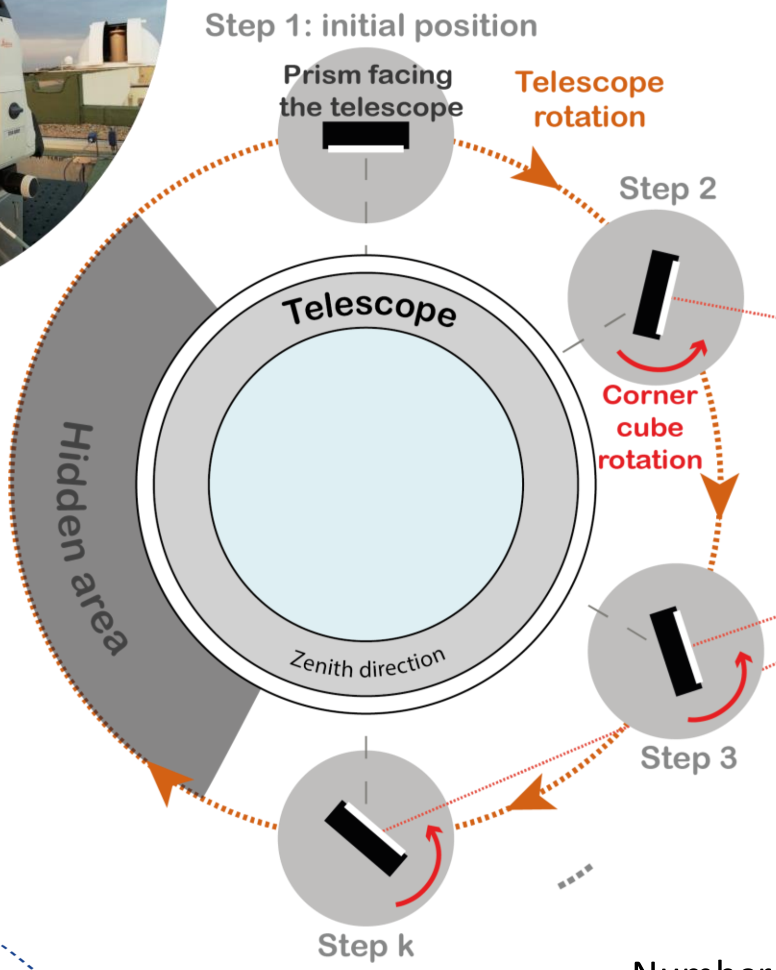




*Steps of elevation circle measurements: thanks to counterweights, the pendular prism always faces the total station*

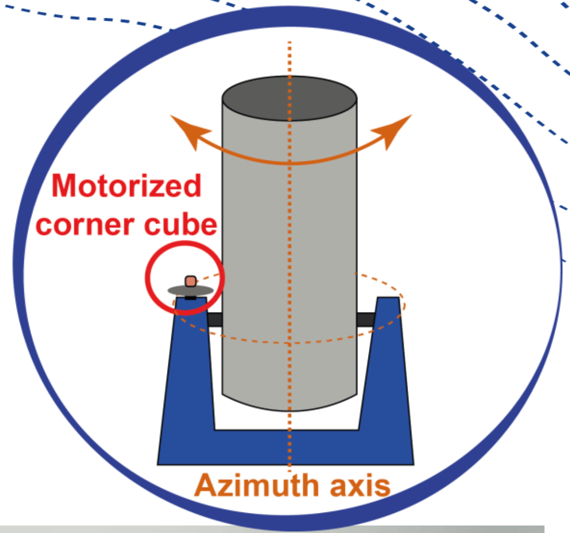


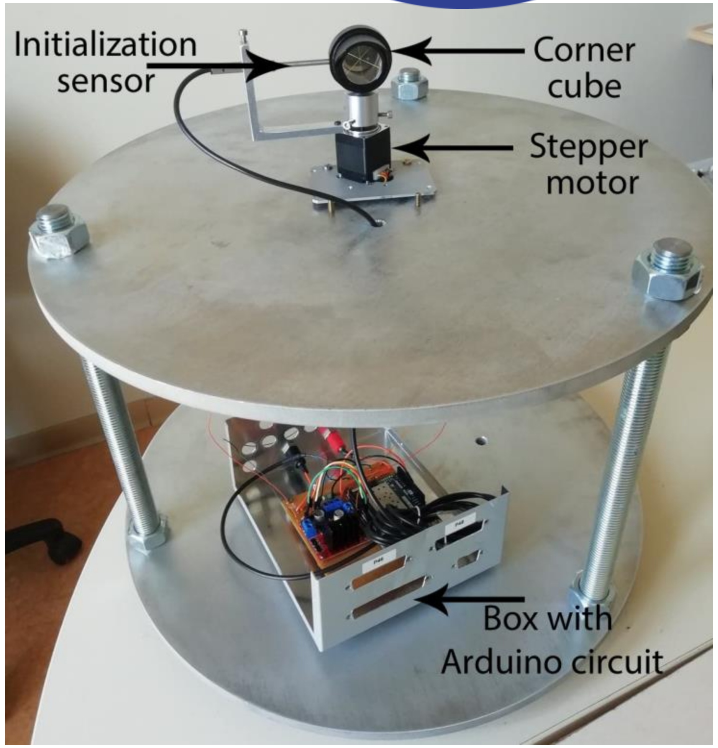

*Setup of a pendular prism on the telescope*

# Measuring devices: azimuth axis




*Azimuth circle: with stepper motor, the corner cube is always visible from the total station (Top view, example of 4 positions)*

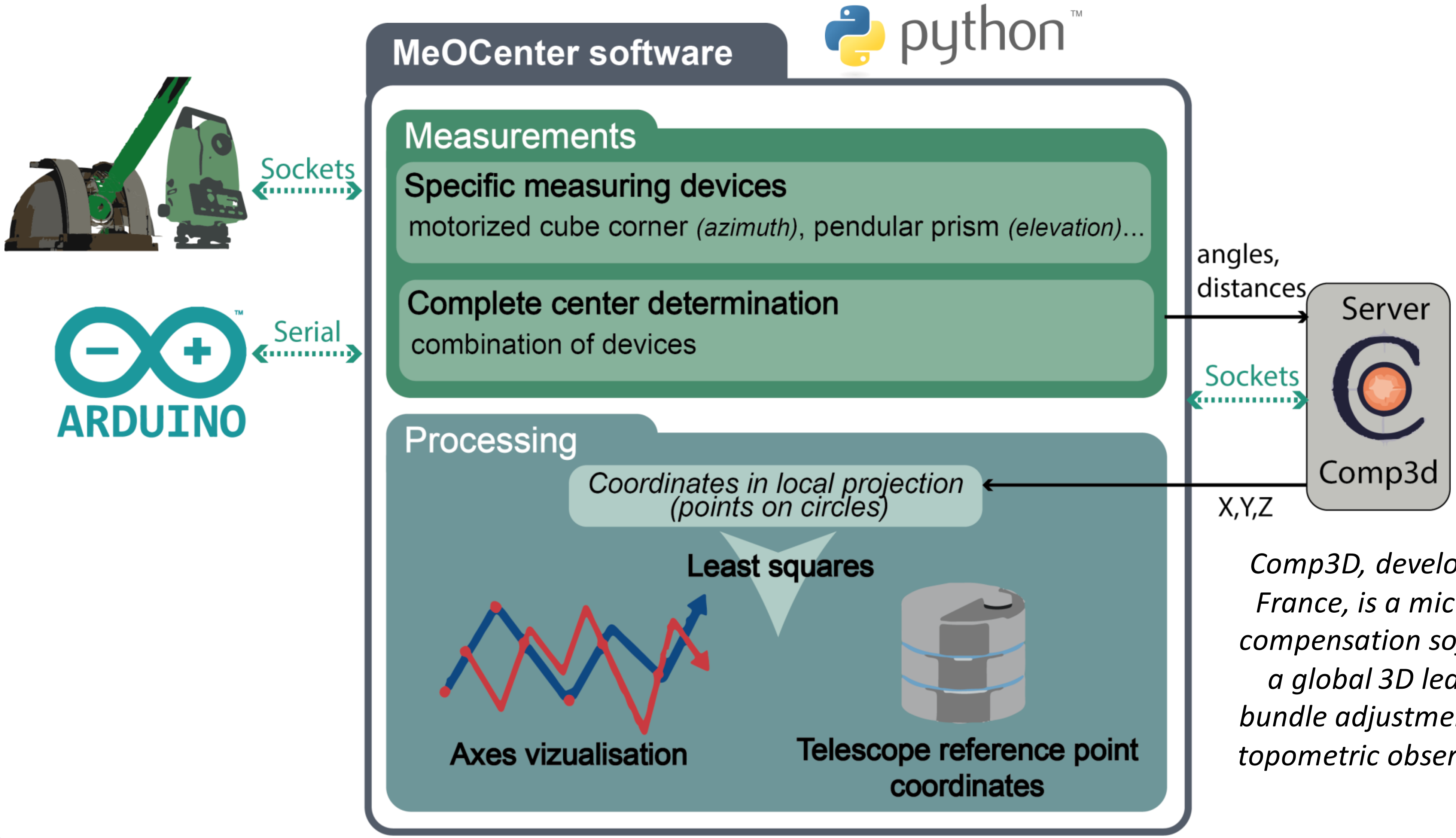



*Arduino circuit & setup*

Number of points (i.e., steps): easily adaptable in software

# Automation: MeO software package



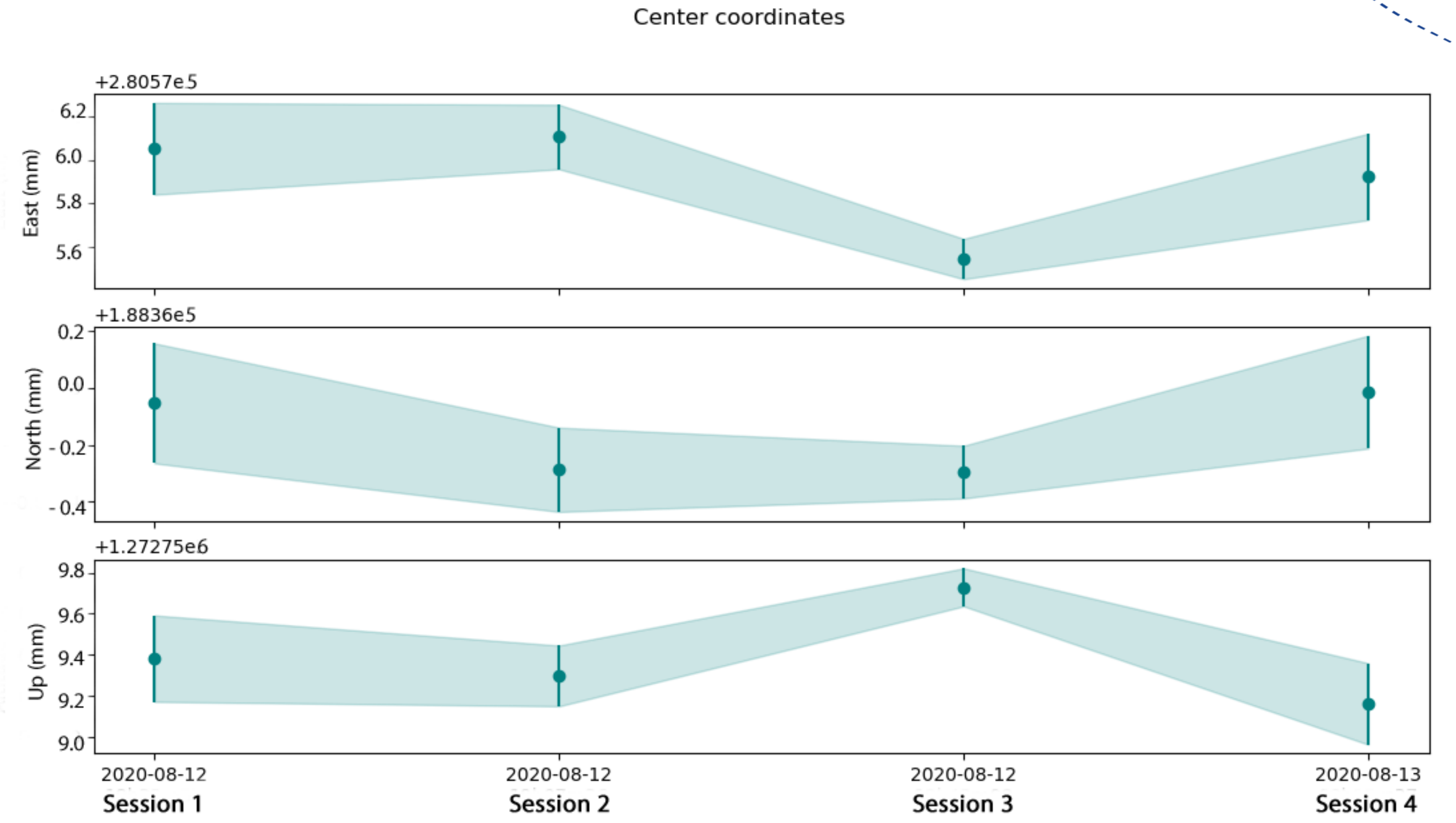

*Comp3D, developed by IGN-France, is a micro- geodesy compensation software using a global 3D least-squares bundle adjustment on several topometric observation types.*

# Measurements tests

Test sessions: determinations agree at the sub-millimeter level

Measurements should be continued to monitor the reference point position:

- with the change of seasons
- after a maintenance operation




*Computed SLR reference point coordinates provided in a local coordinate system.*
*Example of different measurement sessions*

# Conclusion

- This project combines mechanics, electronics and IT developments: **measuring devices + software package**
- A recent installation (2019-2020), compared once with measures of the traditional multi-technique local survey (carried out in April 2021)
- Nevertheless, a total station must remain permanently on the site to continue the measurements (not yet the case).

➡ More regular measurements are necessary to verify the SLR reference point position throughout the year, especially at seasonal time scale.

# Outlook

- Add reflectors to GNSS and DORIS antennas: perform an entire automated re-measurement of the local tie network
- Adapt this system to another telescope (SLR, VLBI...), on another multi-technique geodetic observatory (context of the upcoming ESA-GENESIS mission)

# Thank you for your attention, any questions?

*A special thanks to the OCA team for their advice during the installation of measuring instruments and testings on the telescope. Thanks also to the group of ENSG students who worked on the design of in-house targets to enable the automation of the measurements.*

Presentation based on: Barnéoud, J. *et al.* (2023). Automatic Determination of the SLR Reference Point at Côte d'Azur Multi-Technique Geodetic Observatory. In: International Association of Geodesy Symposia. Springer, Berlin, Heidelberg. https://doi.org/10.1007/1345_2023_223

# References

Altamimi Z, Rebischung P, Métivier L, Collilieux X (2017) TheInternational Terrestrial Reference Frame: lessons from ITRF2014.Rendiconti Lincei - Scienze Fisiche e Nat urali. https://doi.org/10.1007/s12210-017-0660-9

Chabé J, Courde C, Torre JM, Bouquillon S, Bourgoin A, Aimar M.,et al. (2020). Recent progress in lunar laser ranging at Grasse laser ranging station Earth Space Sci 7(3):e2019EA000785

Dawson J, Sarti P, Johnston GM, Vittuari L (2007) Indirect approachto invariant point determination for SLR and VLBI systems: anassessment. J Geodesy 81:433–441

Pesce D (2013) ITRF Co-location Survey Observatoirede la Côte d'Azur Plateau de Calern (Grasse), France, https://itrf.ign.fr/docs/local-ties/reportsCR279_V1_PESCE_ITRFcolocationSurveyCalern.pdf

Poyard JC (2009) GRASSE ITRF co-location survey, IGN Servicede Géodésie et Nivellement, https://itrf.ign.fr/docs/local-ties/reports/RT88_V1_POYARD_GrasseITRFColocationSurvey_ex.pdf

Poyard JC, Collilieux X, Muller JM, Garayt B, Saunier J (2017) IERS technical note 39 - IGN best practice for surveying instrument reference points at ITRF co-location sites, Frankfurt am Main:Verlag des Bundesamts für Kartographie und Geodäsie (ISBN 978-3-6482-129-5)

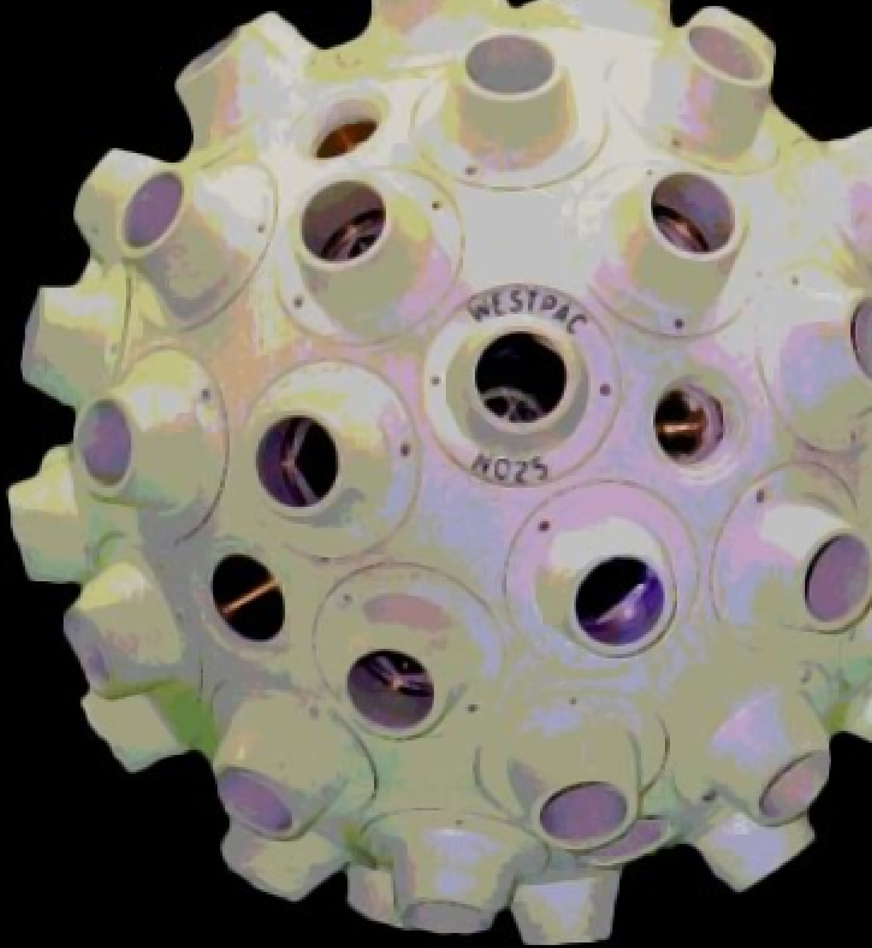
INSTITUT NATIONAL DE L'INFORMATION GÉOGRAPHIQUE ET FORESTIÈRE

ÉCOLE NATIONALE DES SCIENCES GÉOGRAPHIQUES

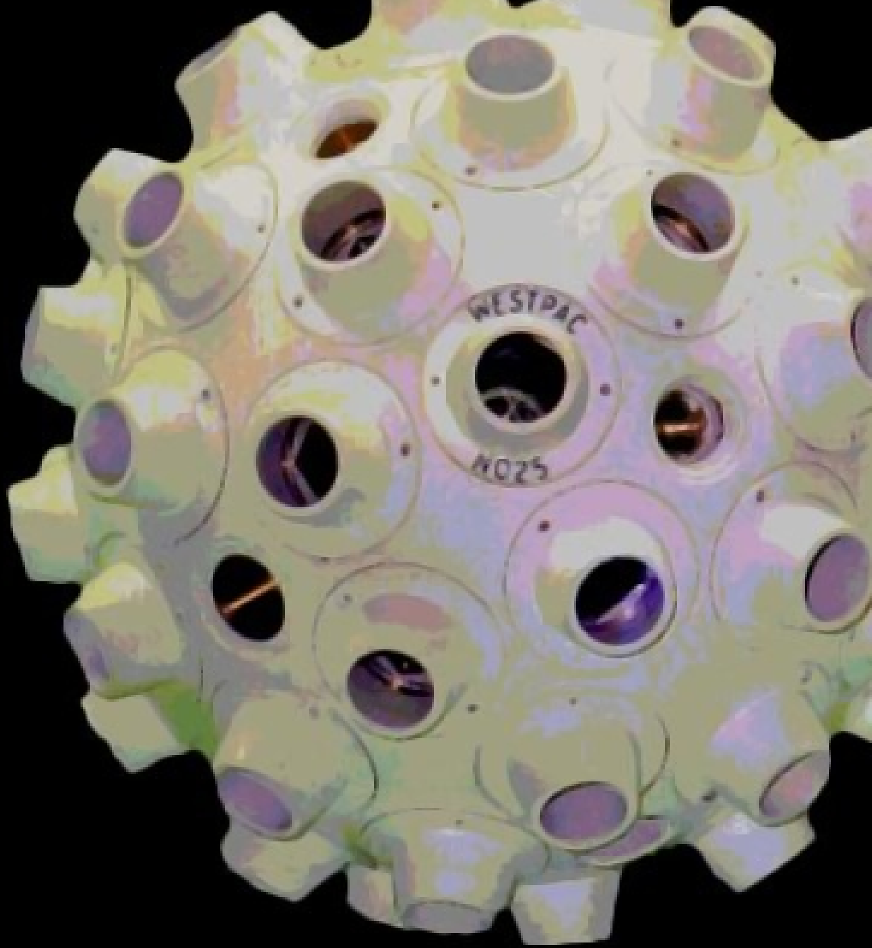
# WESTPAC

| | |
|---|---|
| Launch Date: | **10 July 1998** |
| Orbit: | **sun synchronous** |
| Inclination: | **98 degrees** |
| Eccentricity: | **0.0** |
| Perigee: | **835 km** |

End of ILRS Support: **1 Dec 2002**



# WESTPAC




*Dear Colleague:*

*Our survey of the ILRS analysis community, indicates that the WESTPAC satellite is being used for very little scientific research. The data set is very weak and the satellite does not provide much that is unique. The satellite originators have also agreed that they do not have an immediate need for the data at this time.*

*As of this notice, the WESTPAC Satellite is being deleted from the ILRS Tracking Roster. We leave the option open to revisit WESTPAC tracking at a later time.*

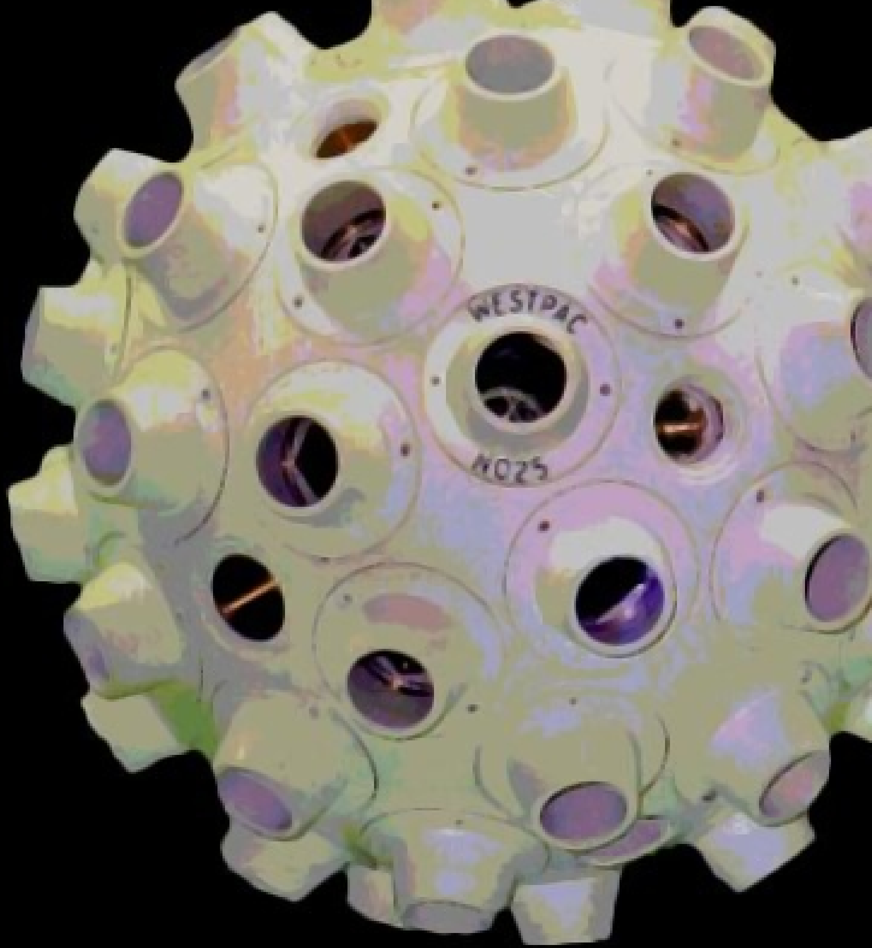
*Best regards,*
*Carey*

SLR Electronic Mail Mon Jan 7 23:08:40 CET 2002 Message No. 0877

# WESTPAC

What has changed?

- Consolidated Prediction Format (CPF) predictions were provided to ILRS stations after June 2008.
- New generation kHz stations began operating after 2003.



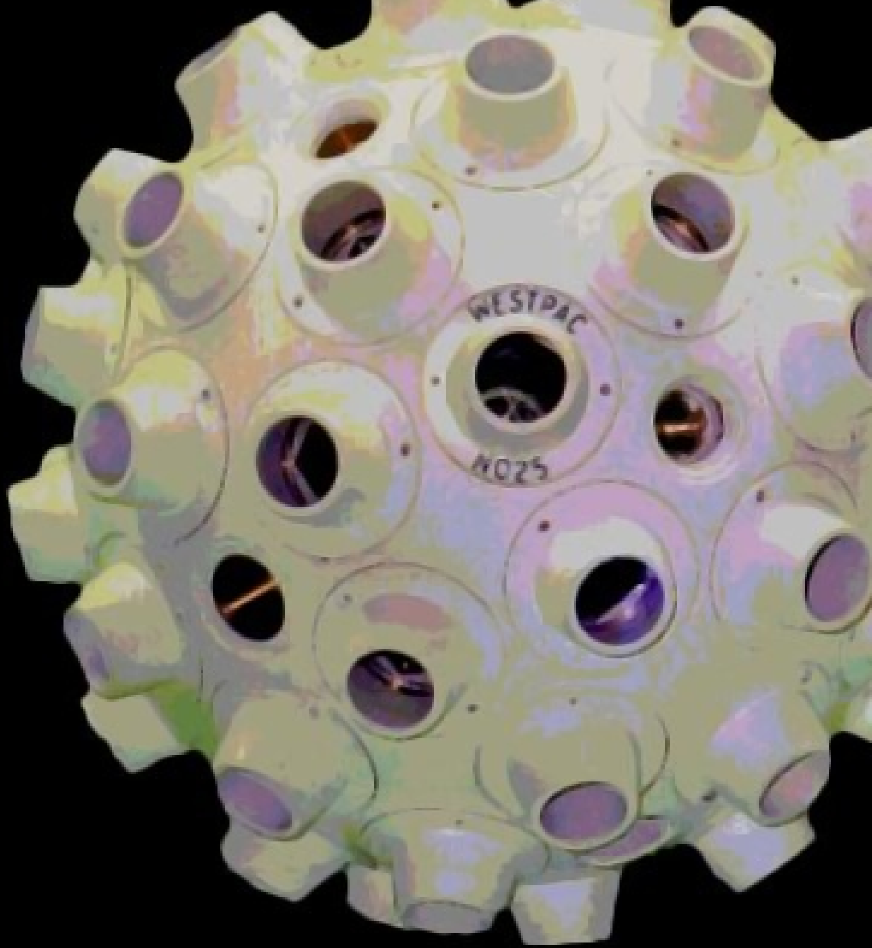
# WESTPAC

Scientific Interest:

*Consistent estimation of geodetic parameters from SLR satellite constellation measurements*

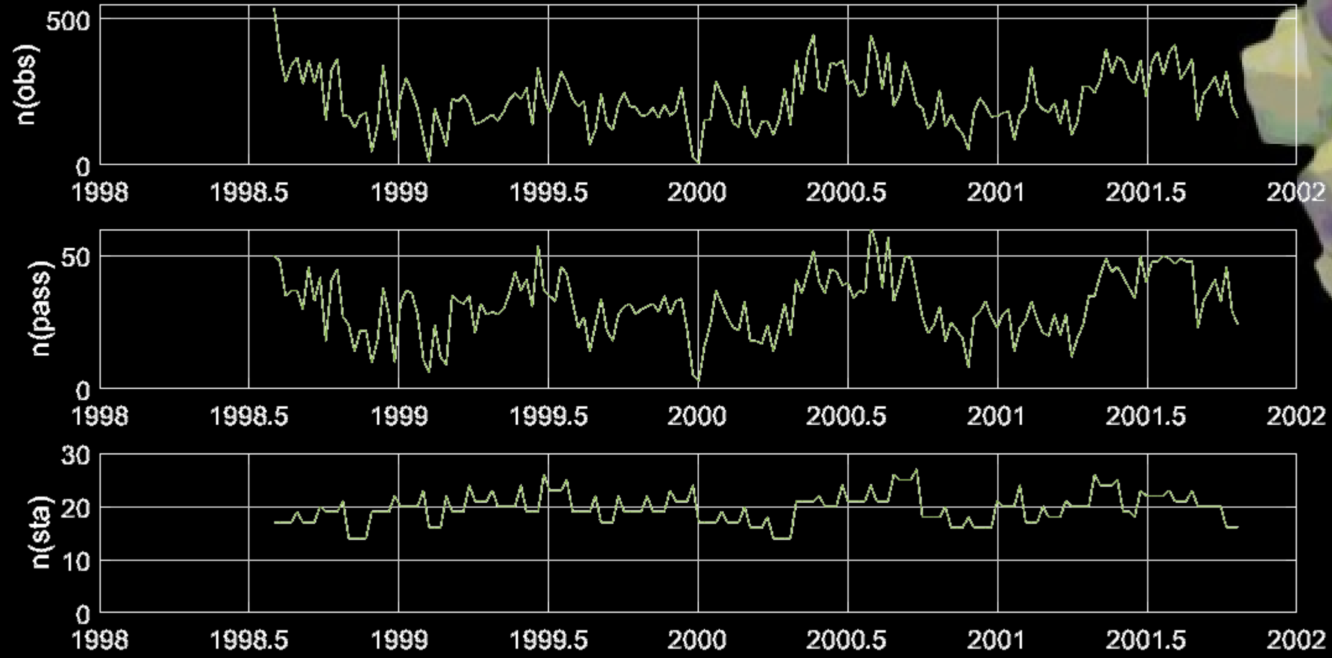
Mathis Bloßfeld et al. Journal of Geodesy 2018

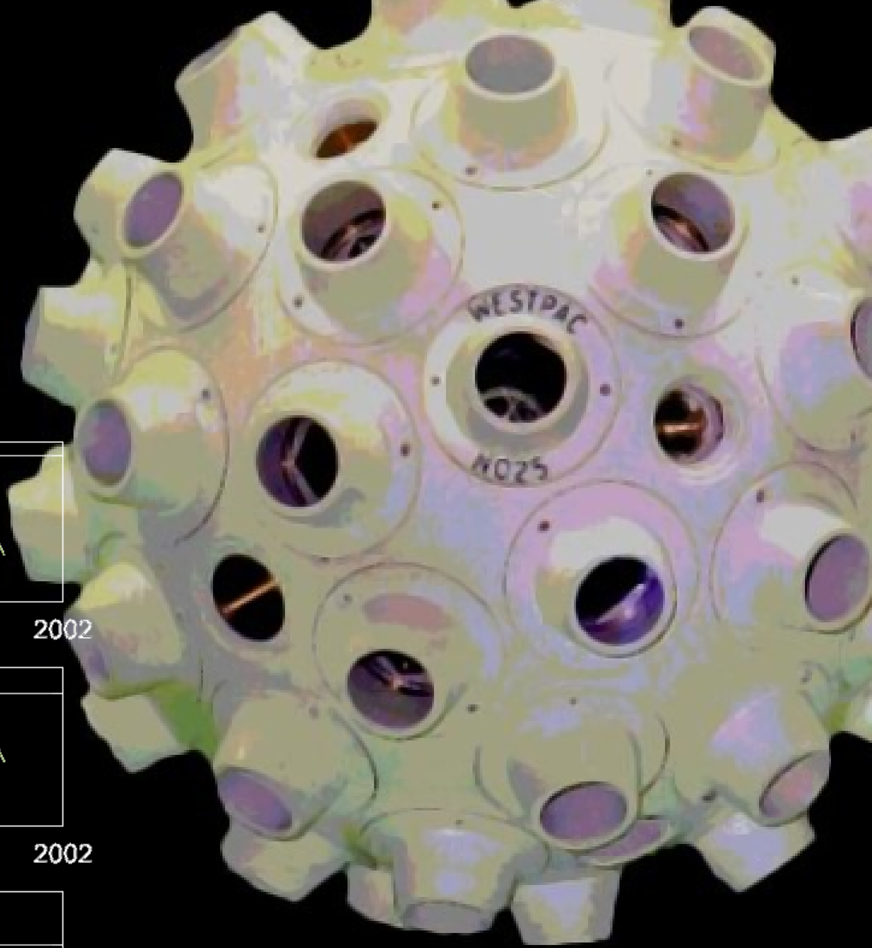
Bloßfeld, M., Rudenko, S., Kehm, A. et al. Consistent estimation of geodetic parameters from SLR satellite constellation measurements. J Geod 92, 1003–1021 (2018). https://doi.org/10.1007/s00190-018-1166-7



# WESTPAC

ILRS Tracking




Bloßfeld, M.