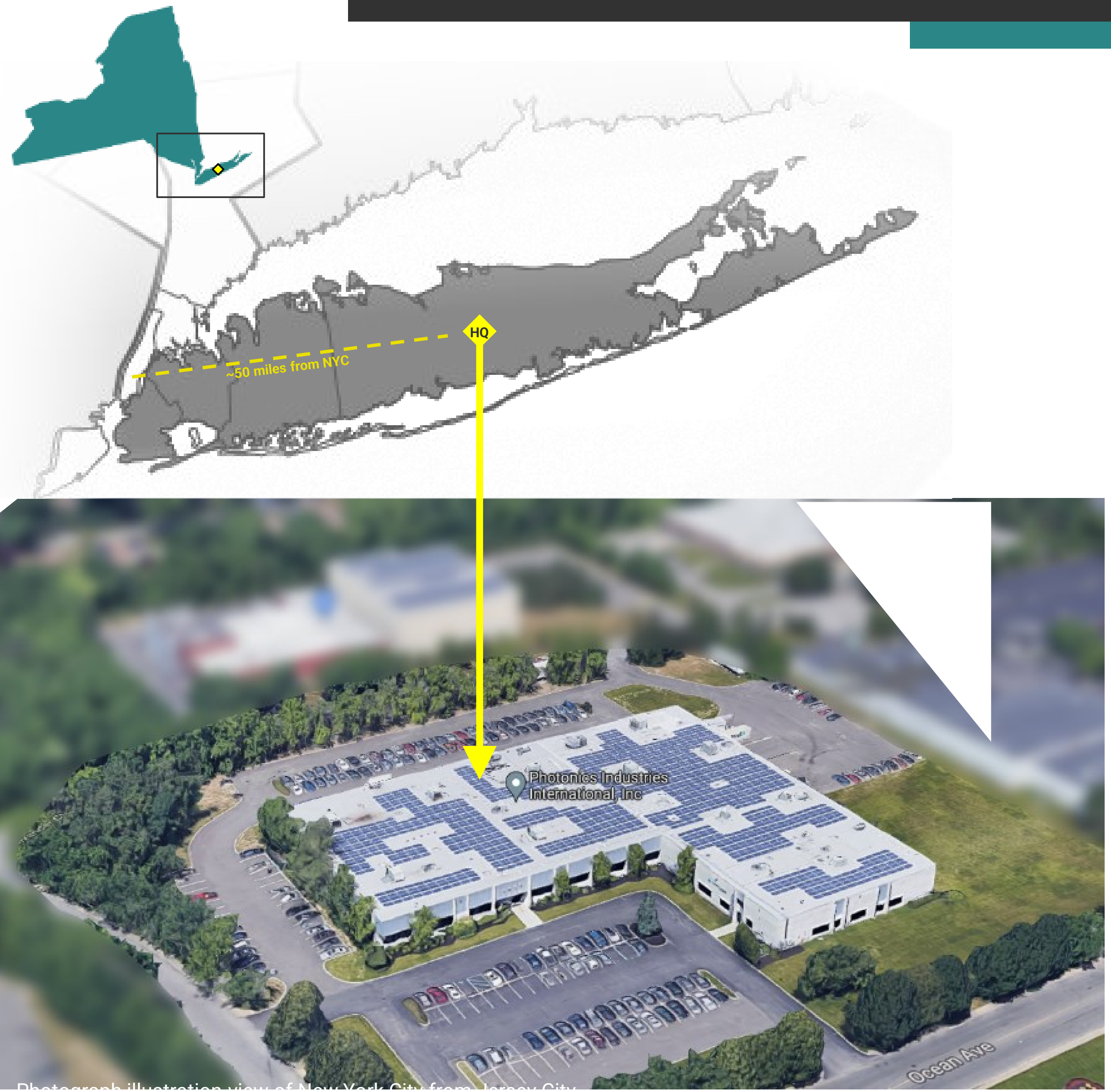
Lasers for Ranging and Satellite Tracking

A brief technology overview.

Hans Taylor – MD – Photonics Industries BV – Netherlands.

Contents



PI AT A GLANCE

"The pioneer of intracavity harmonic lasers"
Manufacturer of ns, ps, sub-ns, and fs lasers

Founded in 1993
Celebrating 31 years a company

International, worldwide company
>250 employees worldwide

Headquarters and manufacturing
Ronkonkoma, New York, USA

Privately owned and operated

Vertically Integrated Factory
6750 sqm, 6.5 acre lot
4000 sqm of clean room

Technology Leader
30+ Patents Granted or Pending

NANO/PICO/FEMTOSECOND LASERS

Photonics Industries International, Inc. (www.photonix.com) is *the pioneer of intracavity harmonic lasers*, and manufactures a wide range of lasers in the **nanosecond**, **sub-nanosecond**, **picosecond**, and **femtosecond regimes**

Intracavity Ultraviolet and Green Q-switched nanosecond lasers
Short pulse ~ 4 to 50ns Intermediate ~ 80ns and long pulse >300ns
From **500mW** to **50W UV** and Green to **>400W**
High pulse energies from µJ-level to **>200mJ**

Pulsed Pumped Q-switched nanosecond lasers
Short pulse 8 ns and up to 1000Hz
TEMoo: **20 to 50mJ** & Multimode: **>200mJ**
Harmonics Wavelengths: Green | UV | Deep UV

Picosecond and Sub-Nanosecond lasers
Picosecond - **10 to 7ps** - Sun-Nanosecond – 100ps to 5ns
From **10W to >150W IR**
Harmonics Wavelengths: Green | UV | Deep UV

Femtosecond lasers
Ultrashort pulses down to ~450fs
From **5W to 100W IR**
Harmonics Wavelengths: Green | UV | Deep UV

Dedicated to OEM Laser Manufacture

- Only Make Laser Sources
- Only make solid-state DPSS Lasers
- Six product ranges – 100+ individual models
- 95% of our output goes directly to industrial systems
- Our installed based measures >40,000 units.

You will today, use, wear, watch or interact with a piece of technology that was directly or in some part made or enabled by using a PI laser.

LOW PRF – HIGH PULSE ENERGY LASERS

RGLX Series – was designed specifically to meet the specifications provided by NASA.

Wavelength:	**1064nm or 532nm**
Pulse Duration:	**<30 ps**
Pulse Frequency:	**1000Hz – Master 1 to 5 kHz capable.**
Pulse Energy:	**2 mJ or 4 mJ @ 1064nm**
	1.5 mJ or 2.5 mJ @ 532nm
Beam Mode:	**True TEMoo M2 < 1.3 (ISO)**
Pointing Stability:	**< 50 µrad – full angle (ISO)**

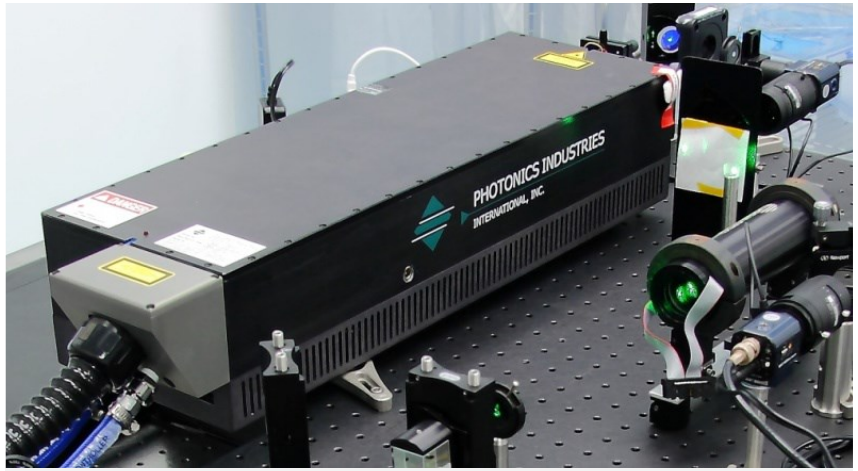
Exceptionally Compact Form Factor.
Optionally: air-cooled.

Technology Overview:

Mode-Locked Master Oscillator
Free Space Regenerative Amplifier – Diode (Fiber pumped)
Pockels Cell Based Pulse Picker

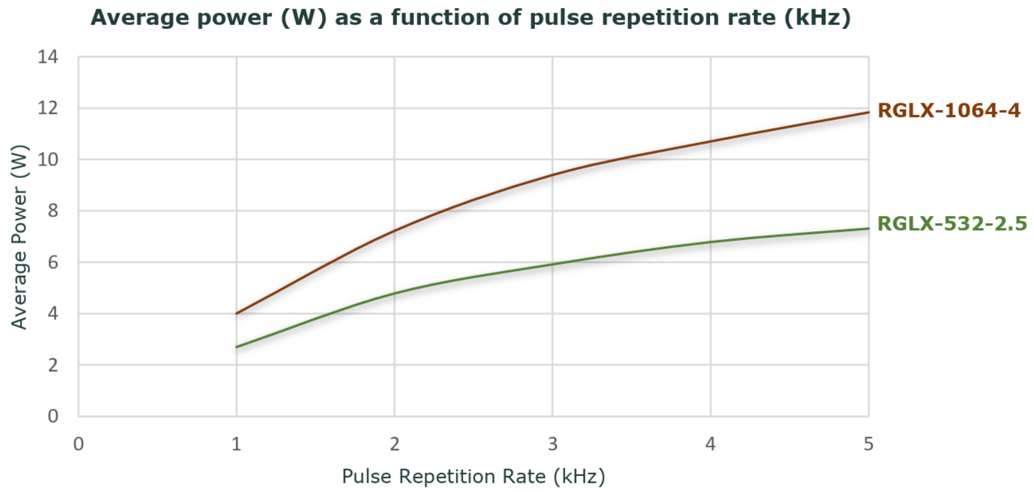
532nm – “Extra cavity” – Using a RX based Optical Sub Assembly.

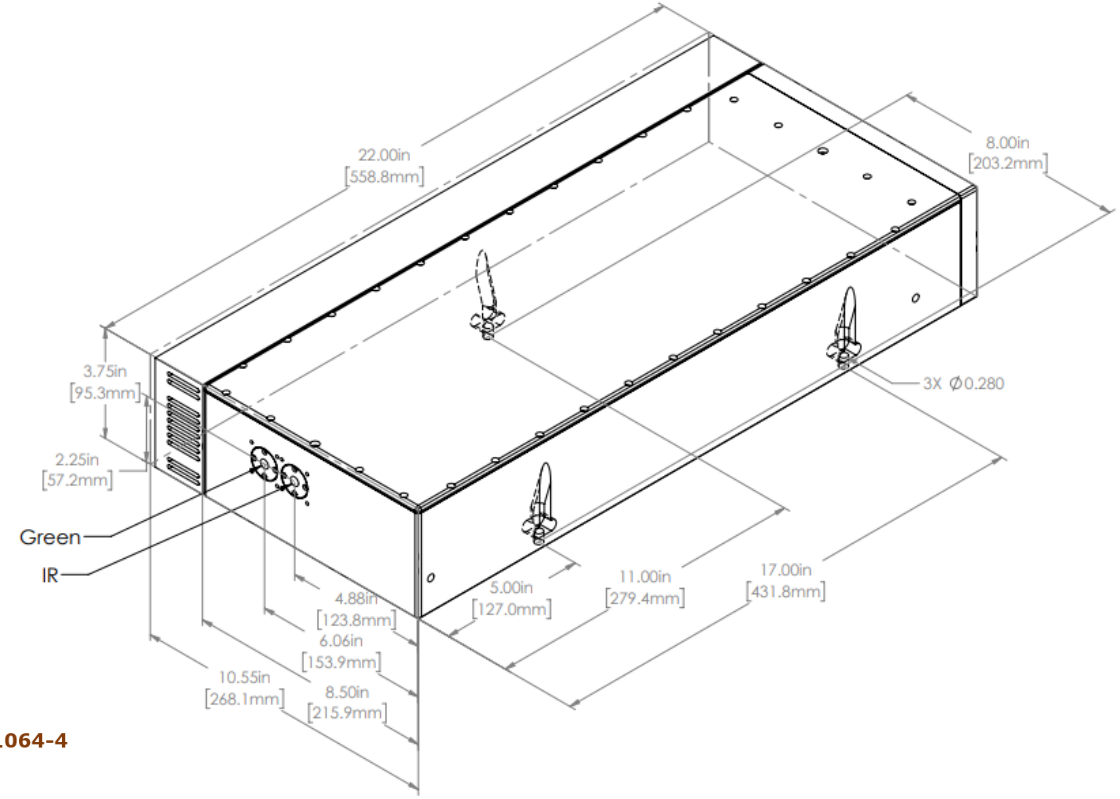
LOW PRF – HIGH PULSE ENERGY LASERS



The first RGLX Image: Courtesy NGSLR – Greenbelt

~ 50ps - 2.7 mJ @ 532.19nm





Current RGLX – Air Cooled – All In One Laser
No External Water or 19” Rack PSU.

HIGH PRF – HIGH PULSE ENERGY LASERS

RX-HE Series – Developed for industrial hard materials processing.

Wavelength: 1064nm
Pulse Duration: 10 ps
Pulse Frequency: 100,000Hz – Master
PRF Range: 1kHz to > 1MHZ
Pulse Energy: 650 μJ @ 100KHz
900 μJ @ 100KHz
Beam Mode: True TEMoo M2 < 1.3 (ISO)
Pointing Stability: < 25 μrad – full angle (ISO)

Exceptionally Compact Form Factor.

Technology Overview:
Mode-Locked 100% Fiber Seeder and Pre-amplification
Free Space – Multi-stage Amplifier – Diode (Fiber pumped)
Acousto-Optic Modulator Based Pulse Picker
AOM – Pulse Energy Control – Attenuator. 100% to >1%

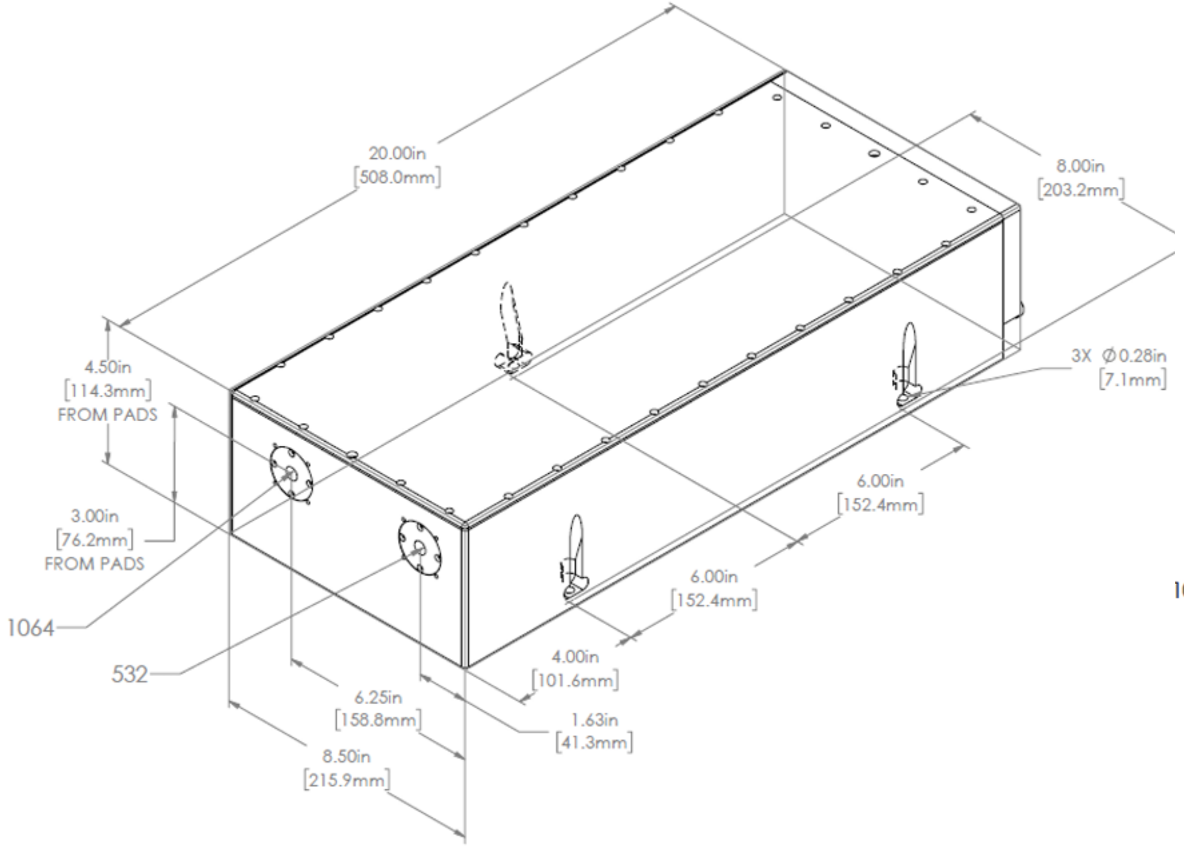
532nm – "Extra cavity" – Using a RX based Optical Sub Assembly.

Exceptionally Compact Form Factor.

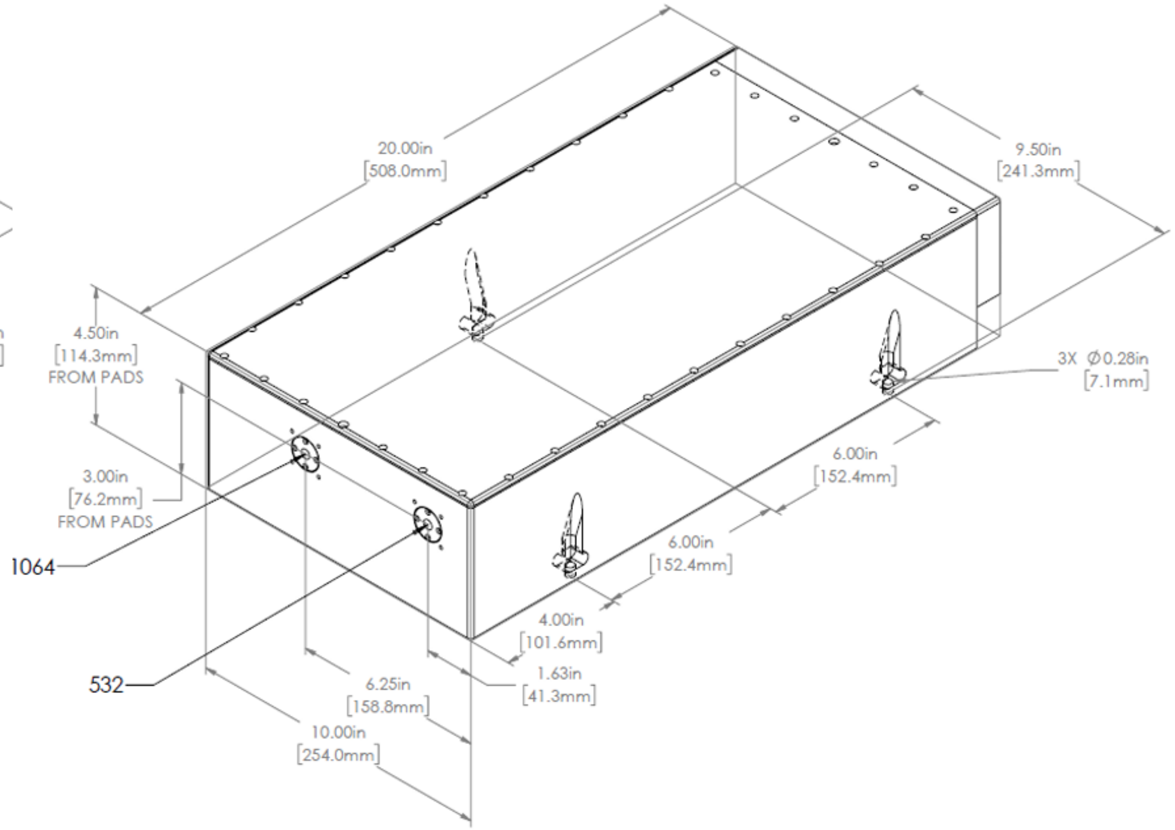
HIGH PRF – HIGH PULSE ENERGY LASERS

RX-HE Series – Form Factors

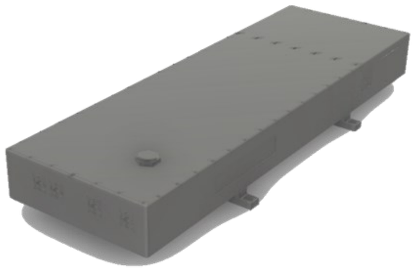
RX-100-HE - 508 x 115 x 203mm – 21.5 Kg
65W - 650 µJ @ 100 kHz



RX-150-HE - 508 x 115 x 241mm – 26 Kg
95W – 950 µJ @ 100 kHz

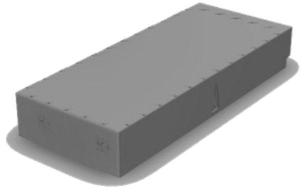


RX Series Journey - Continuous Innovation



2015
No separate controller, All-in-one (AIO) ps Laser

2018/19



2020
35% Smaller form factor from predecessor ps laser

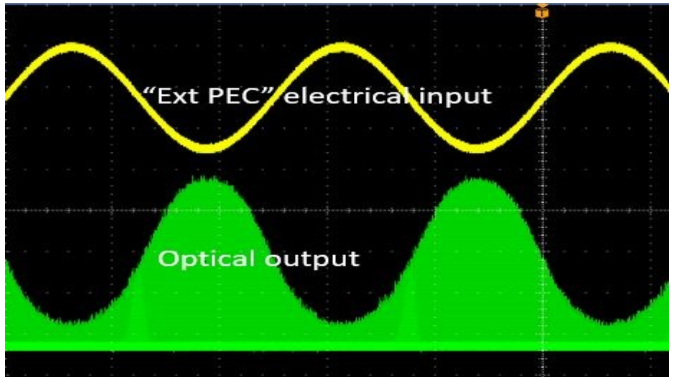
2022
25% Smaller form factor from predecessor ps laser

2025
~10% Smaller form factor from predecessor ps laser

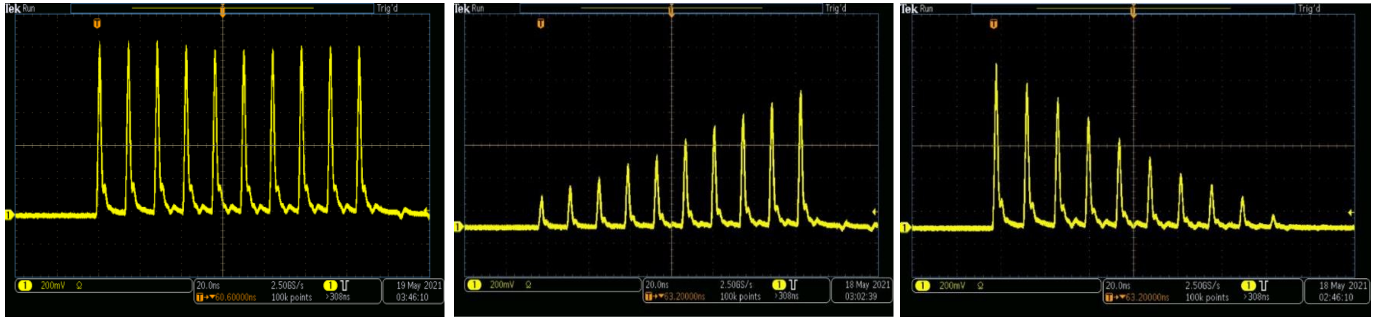
- **Flex-Pulse™** offered by the RX Series Lasers provide complete control over the pulsed output:
    - **PEC** (Power or Pulse Energy Control) controlling the overall optical energy from the laser
    - **PSO** (Position Synchronized Output) support for external triggering to any arbitrary PRF while maintaining a constant, stable pulse energy with low jitter
    - **Digi-Burst™** for individually controllable bursts of up to 10 pulses with a separation of about 31 ns
    - **POD** (Pulse-On-Demand) pulse bursts can be triggered internally, externally, or continuously, while maintaining constant pulse energy

RX Series – FLEX-Pulse™

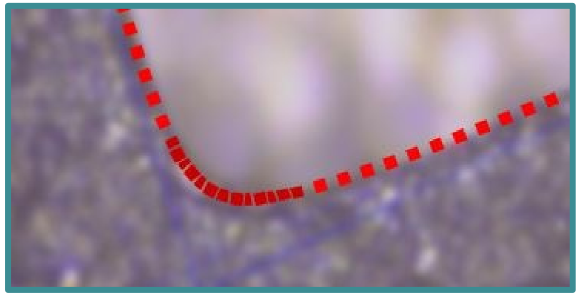
- **PEC** (Power or Pulse Energy Control) controlling the overall optical energy from the laser

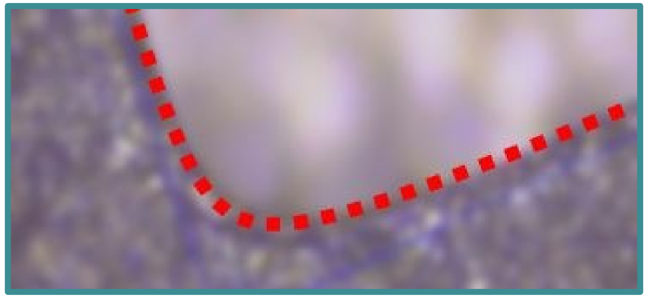


- **Digi-Burst™** for individually controllable bursts of up to 10 pulses with a separation of 31 ns



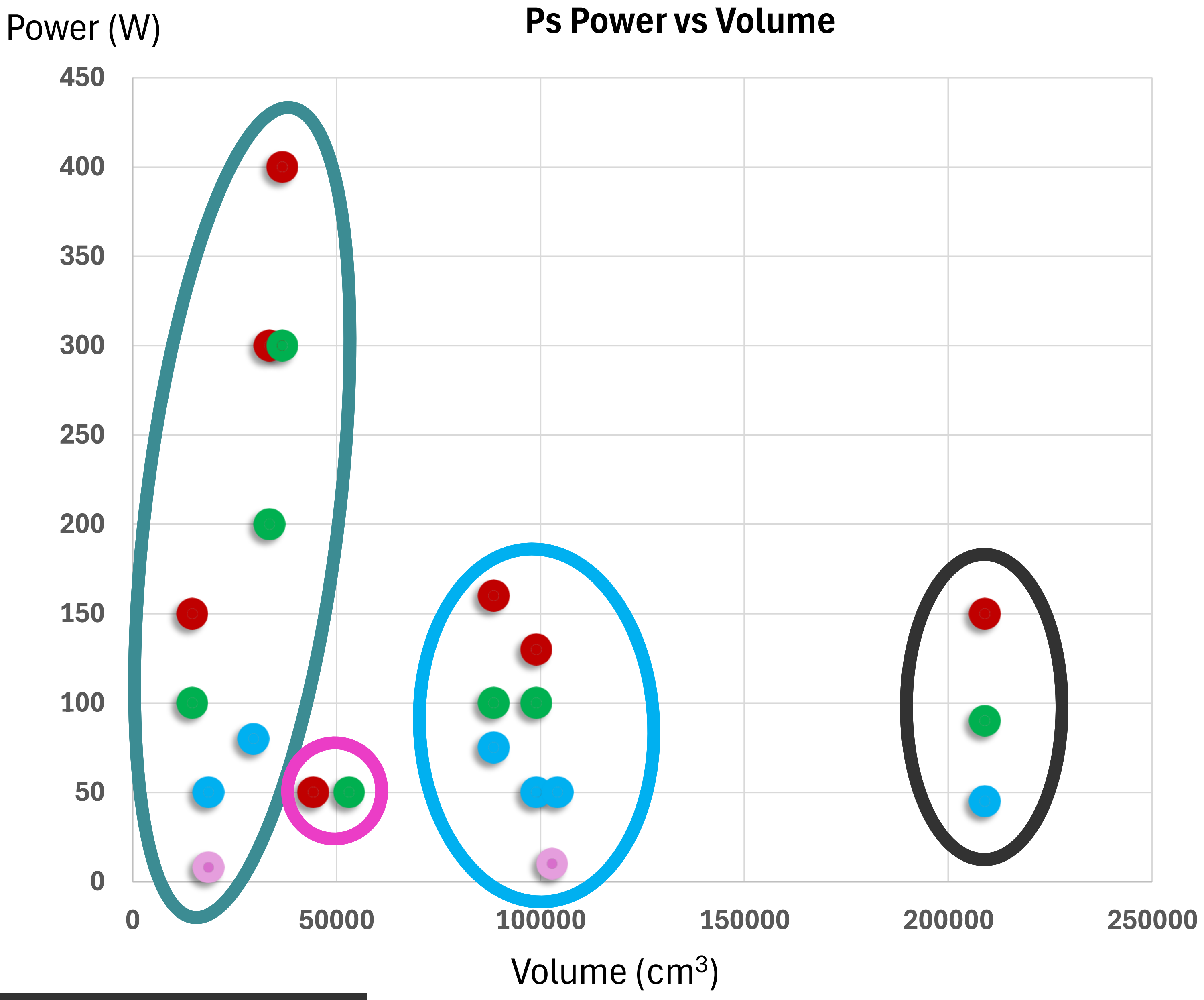
- **PSO** (Position Synchronized Output) support for external triggering to any arbitrary PRF while maintaining a constant, stable pulse energy with low jitter.





RX-GEN 4

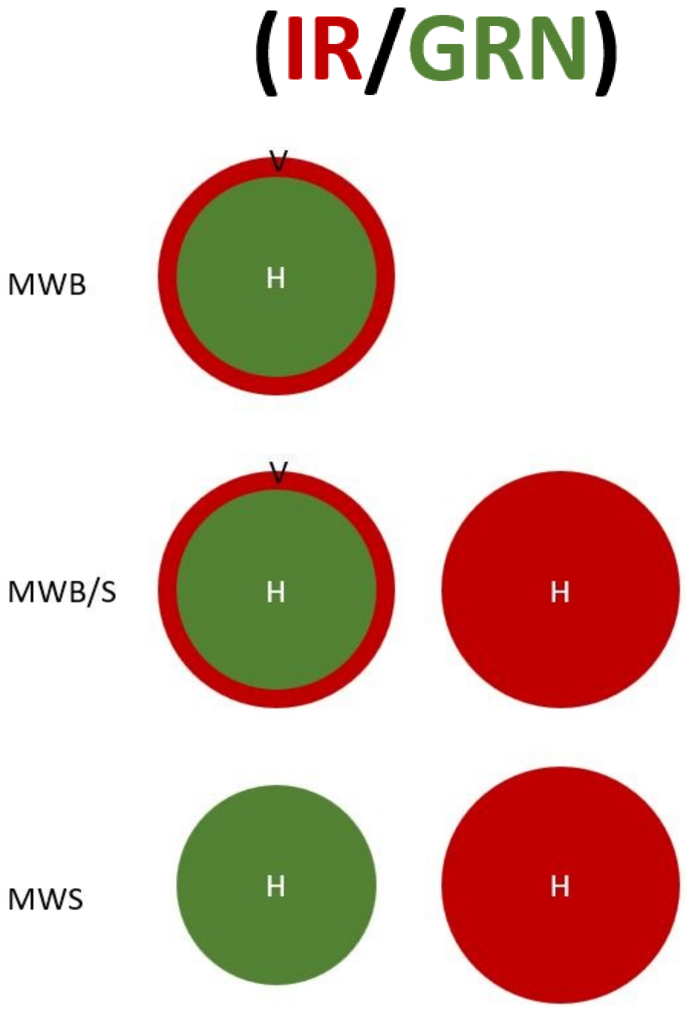
- Hybrid Laser Configuration
  - Seeder – 100% fiber
  - OSA's already very small
  - Onboard Electronics (water/cooled)
  - Integrated 2HG if specified.
  - All DC and highly efficient
  - Fully temperature stabilised optical base
- Free Space Amplification:
  - All w/c solid state amplifiers
  - Multi-stage using proven DPSS Technology
  - Flexible power scaling - Simple/reliable
  - Pulse Energy biased
- Size to power comparison:
  - Green – PI
  - Pink – MKS
  - Blue – Lumentum / Coherent
  - Black - Trumpf



RX Series – Wavelength Switching Features

MWB – Multiwavelength Blended
Both wavelengths come out of a single exit port all blended together.

MWS – Multiwavelength Switchable
IR or green emitted from the same single exit port.
The user selects which individual single wavelength is emitted at any given time via the GUI. The advantage is having access to all the available wavelengths collinearly from a single exit port with fast (<3 sec) wavelength switching on the fly.



LOW PRF – VERY HIGH PULSE ENERGY LASERS

- Traditionally Lamp-Pumped Q-Switched Lasers
  - > 1 to 5J @ 532nm required
  - Very large | Very Heavy Optical Heads
  - Very Large 19” Rack Mounted PSU
  - <1 % Wall plug to optical efficiency
  - Very Larger ~ 4kH water cooling
  - Large Format – very expensive 2HG Crystal
  - HV Lamp PSU and frequent lamp changes.

- 2025 – DPSS
  - New DPSS Pumping Chambers
  - Over Design Concept Unchanged
  - Large Frame Optical heads.
  - Optical Tables and Heavy Mechanical optical mounts.

Lamp PSS - 2100 mm x 210 x 330mm – 150 Kg

DPSS - 1300 mm x 210 x 330mm – 100 Kg

LOW PRF – VERY HIGH PULSE ENERGY LASERS

DPM Series – Developed for industrial semiconductor processing

Wavelength:	**1064nm or 532nm**
Pulse Duration:	**~ 10ns**
Pulse Frequency:	**10Hz**
Pulse Energy:	**4 J @ 1064 nm** **2 J @ 532 nm**
Beam Mode:	**Multi-mode : M2 < 8 (ISO)**
Pointing Stability:	**< 50 µrad – full angle (ISO)**

Exceptionally Compact Form Factor.
Water Cooled
Onboard: Mode Monitoring / 100% Energy Monitoring / 532 nm Auto-Tuning.

Technology Overview:
Compact Low M2 Master Oscillator
Free Space Amplifiers – Direct Diode Pumped – Patented Designs
Pockels Cell Q-Switch

532nm – “Extra-cavity” full auto-tune – 100% beam dump shutter.

QI – Quite Interesting

MID PRF – HIGH PULSE ENERGY LASERS

SN Series – Developed for industrial hard materials processing.

Wavelength: 1064nm & 532nm
Pulse Duration: 100 ps to 5 ns - Selectable
Pulse Frequency: 10kHz
100,000Hz
Pulse Energy: 4+ mJ @ 10KHz (2.5mJ @ 532nm)
2.5 mJ @ 100KHz (1.5mJ @ 532nm)
Beam Mode: True TEMoo M2 < 1.3 (ISO)
Pointing Stability: < 25 µrad – full angle (ISO)

Exceptionally Compact Form Factor.

Same form factor as RX Series

Technology Overview:
Seeder: Proprietary DPSS USP Seeder – 100ps to 5ns
Free Space – Multi-stage Amplifier – Diode (Fiber pumped – RX Series)
Acousto-Optic Modulator-Based Pulse Picker
AOM – Pulse Energy Control – Attenuator. 100% to >1%

532nm – “Extra cavity” – Using a RX based Optical Sub Assembly.

Thank you for your time.

Any Questions?

ILRS Network & Engineering Standing Committee Meeting, 11 Dec 2025

Omni-SLR in 2025: What's new and what's next

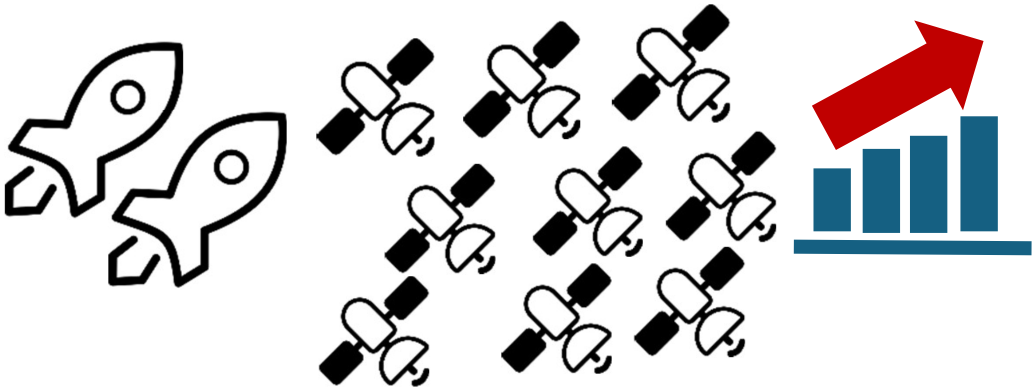
This work has been supported by JSPS KAKENHI Grant Number 20H01993 and 25K01089 , and the joint research projects of JAXA-HitU-NAOJ-UTokyo, GSI-HitU, NICT-HitU, NIPR Exploratory Research, Softbank-HitU, MHI-HitU and KHI-HitU.

Toshimichi Otsubo [1], Hiroshi Araki [2], Yusuke Yokota [3], Kenji Kouno [3],
Mihoko Kobayashi [1], Akihisa Hattori [4], Yuichi Aoyama [4],
Haruna Furui [5], Shino Araki [5]
and a number of contributors/supporters

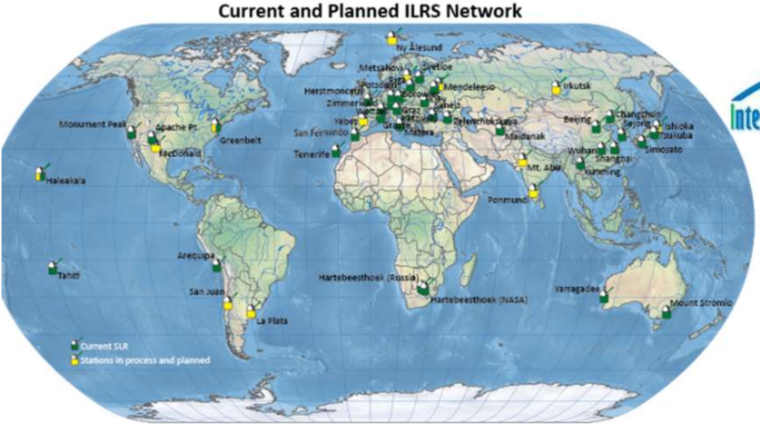
[1] Hitotsubashi Univ, [2] NAOJ, [3] IIS, Univ of Tokyo, [4] NIPR, [5] GSI

Omni-SLR: new attempts for SLR

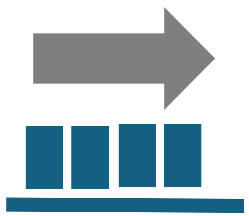
SLR Targets: monotonically increasing



SLR Stations: almost the same



International Laser Ranging Service



Very Compact

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

Very Low-cost

A bit more expensive in 2025

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 and operate SLR stations.*
- *the SLR global network and the products are drastically enhanced.*
- *the SLR optical tracking/ranging technologies are more versatile.*

Omni-SLR: conveyable by a car

Omni-SLR: project status

being developed by the team of

Hitotsubashi University
(PI: T Otsubo)

The University of Tokyo

NAOJ National Astronomical Observatory of Japan

being supported by:

- GGOS Japan.
- 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 Number 7317 95 01 assigned
2024 DOMES Number 21791M008 assigned
2024 Field test at GSI Ishioka
2025 First data release to ILRS, First coordinates
2026-2027 First Antarctica SLR test at Syowa

Omni-SLR ISHIOKA 7317

国土地理院

Omni-SLR: 2025 Updates

Omni-SLR: key components (Omni-SLR A25.02 & A25.09)

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 Instruments TimeTagger Ultra (Value Ed)

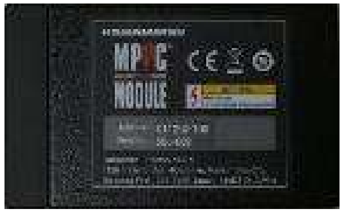
4 ch
(ch1 = start; ch2=stop; ch3=1PPS)
42 ps RMS
70 M events/sec

Furuno TB-1

GNSS OCXO

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

Hamamatsu Photonics 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

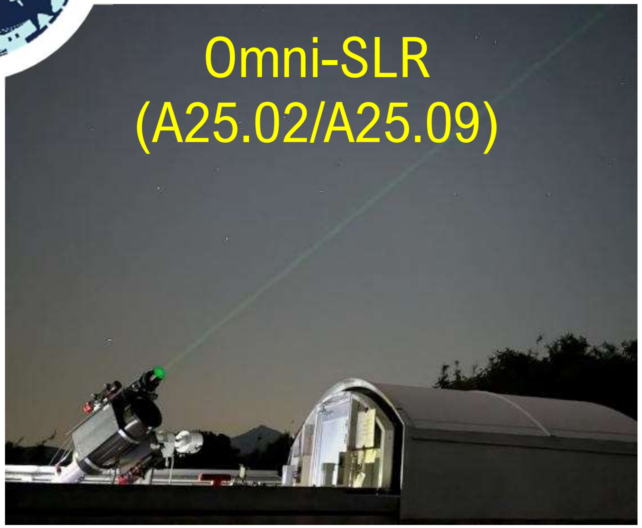
Vixen AXJ Mount (Eq.)

Converted to Alt-Az
Load: 22 kg max

Vaisala PTB-330

3 sensor barometer
0.2 hPa per sensor

Link budget calculation (simplified)



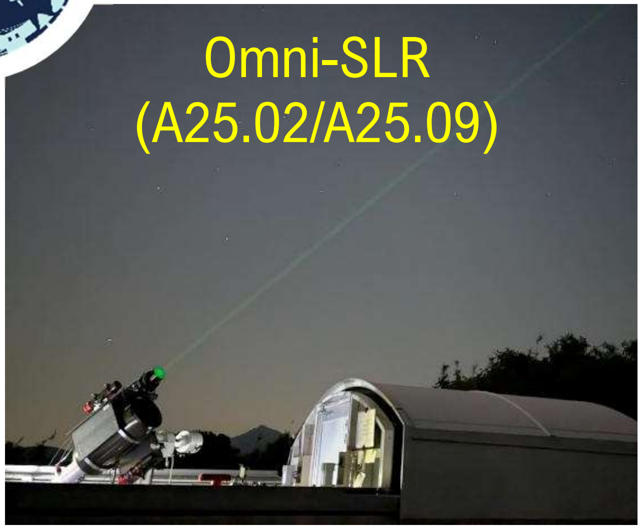
Telescope diameter m Φ

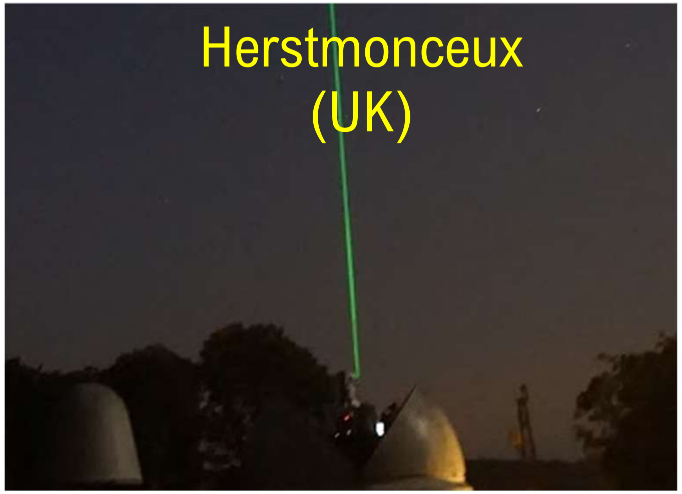
Laser output W

0.006 mJ, 5 kHz

$$= \left[\frac{0.2}{0.76}\right]^2 \frac{0.03}{1.0} \fallingdotseq \frac{\mathbf{0.002}}{1}$$

Link budget calculation (simplified)





Telescope diameter m Φ

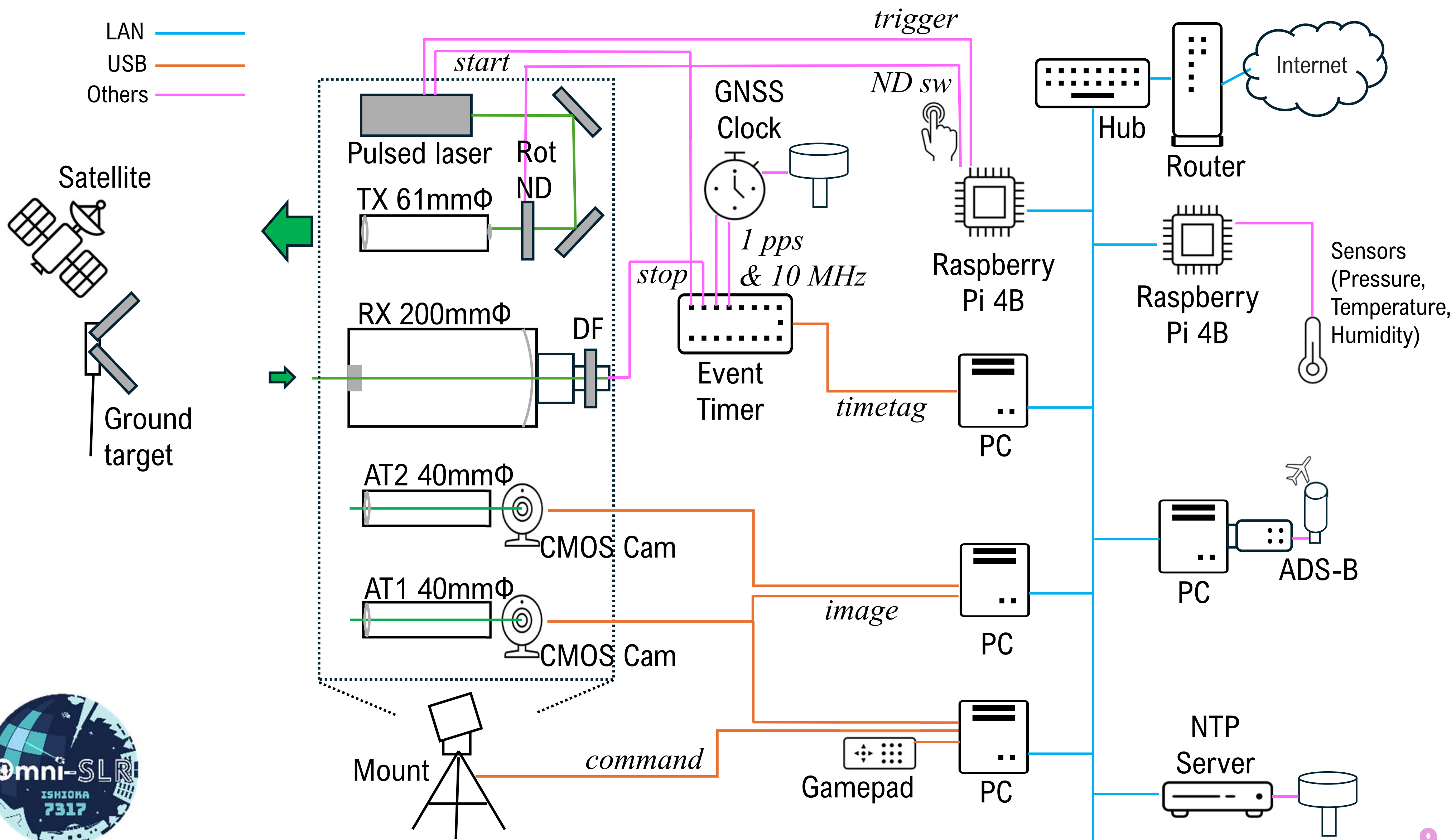
Laser output W

0.006 mJ, 5 kHz

$$= \left[\frac{0.2}{0.5}\right]^2 \frac{0.03}{1.0} \fallingdotseq \frac{\mathbf{0.005}}{1}$$

1 mJ, 1 kHz

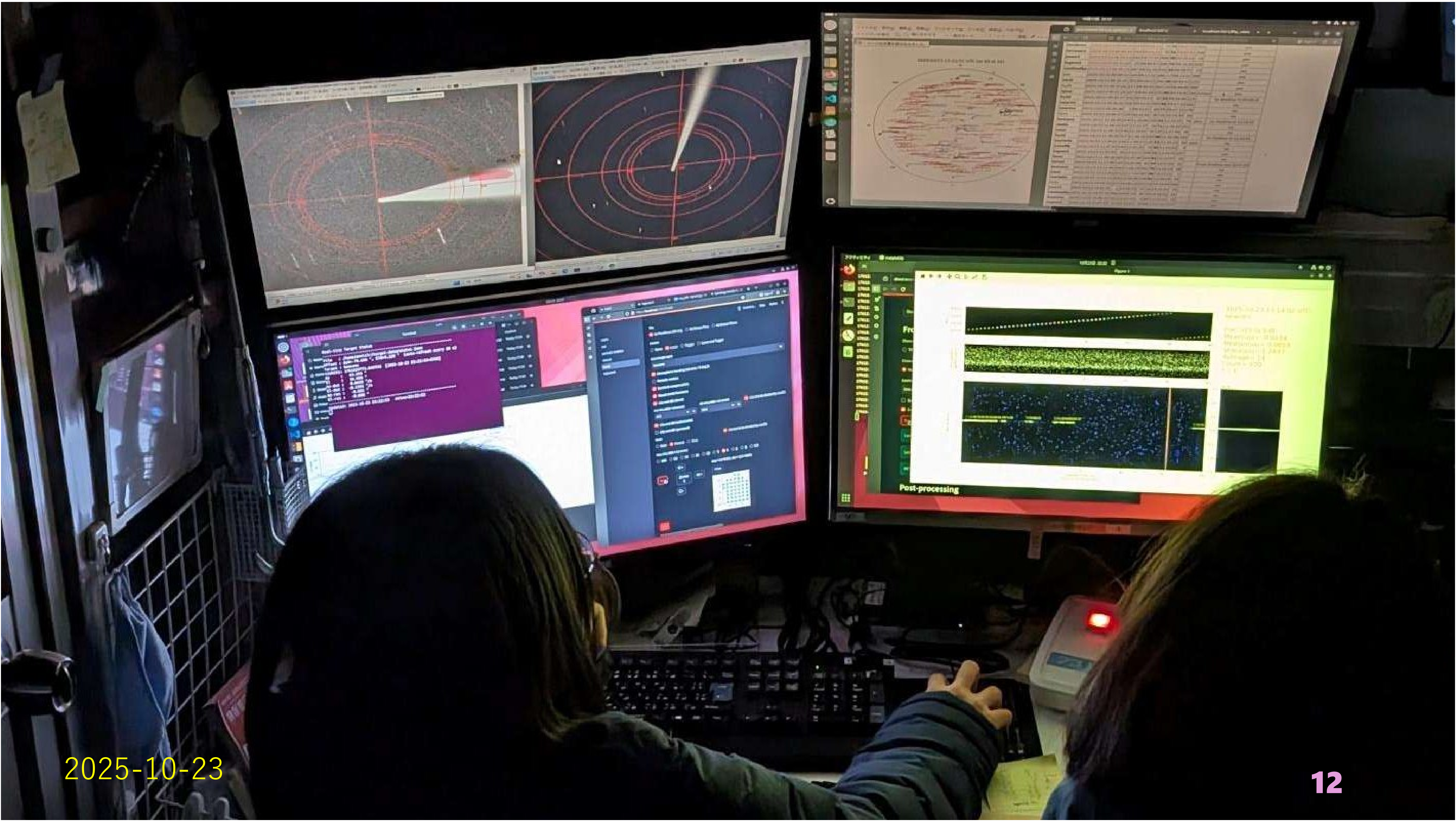
Hx applies ND 2 or 3 (1/100 or 1/1000) for LEO, and still gets 1000 returns/NP.

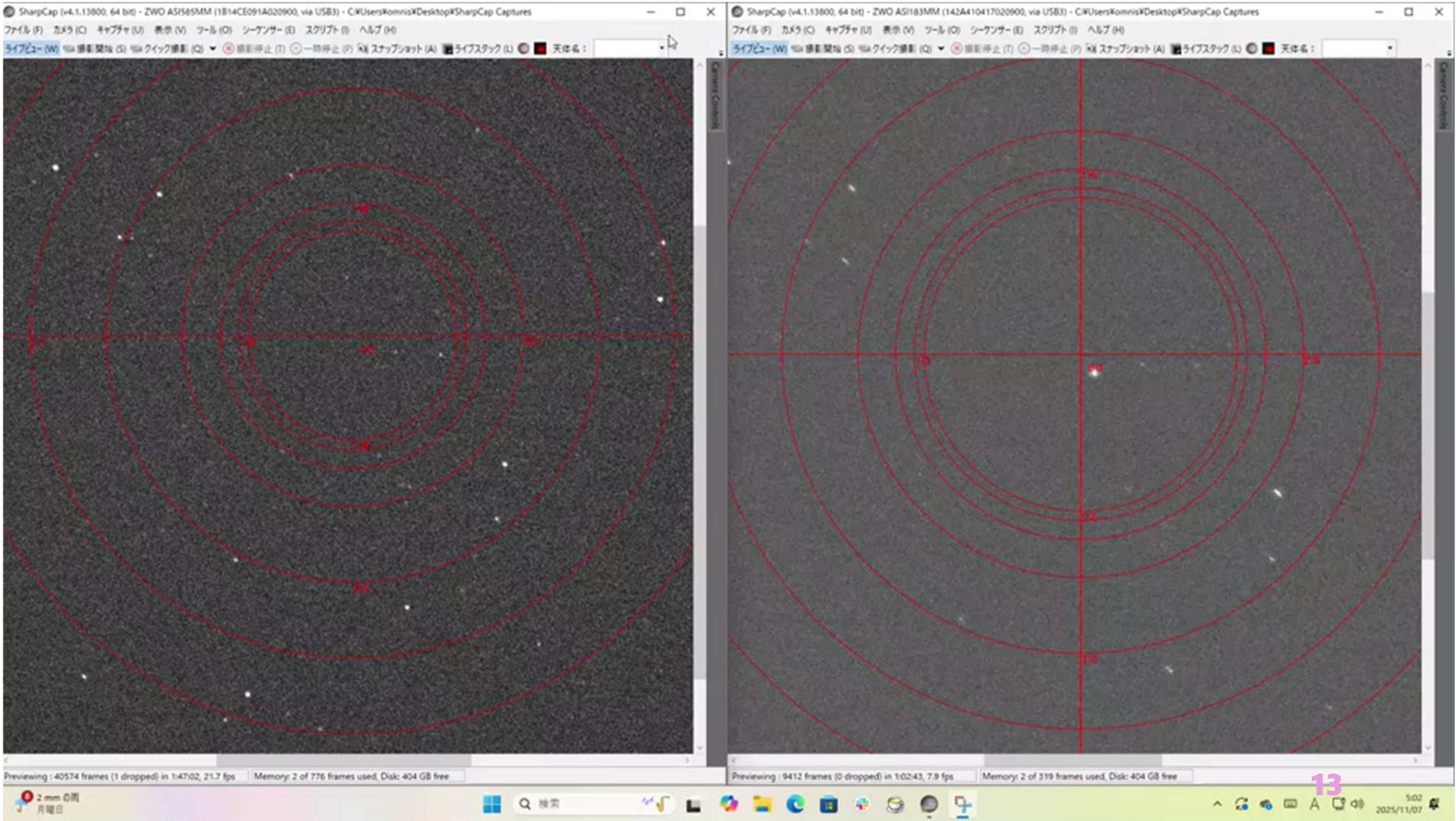

LAN
USB
Others
trigger
start
ND sw
GNSS Clock
Pulsed laser
Rot ND
TX 61mmΦ
Satellite
Ground target
RX 200mmΦ
DF
stop
1 pps & 10 MHz
Event Timer
timetag
Raspberry Pi 4B
Hub
Router
Internet
Raspberry Pi 4B
Sensors (Pressure, Temperature, Humidity)
PC
AT2 40mmΦ
CMOS Cam
AT1 40mmΦ
CMOS Cam
image
PC
PC
ADS-B
Mount
command
Gamepad
PC
NTP Server

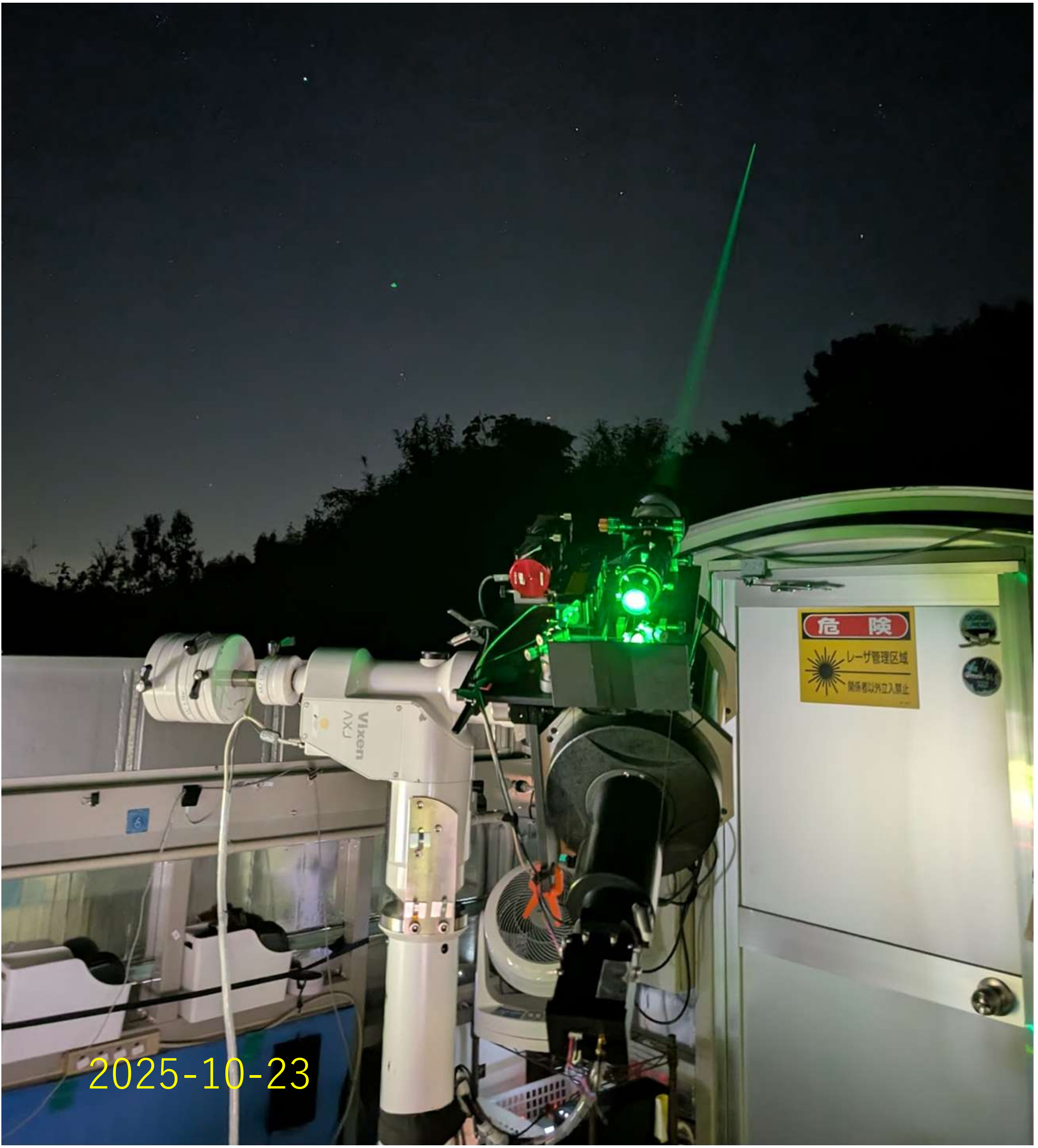
2025.9

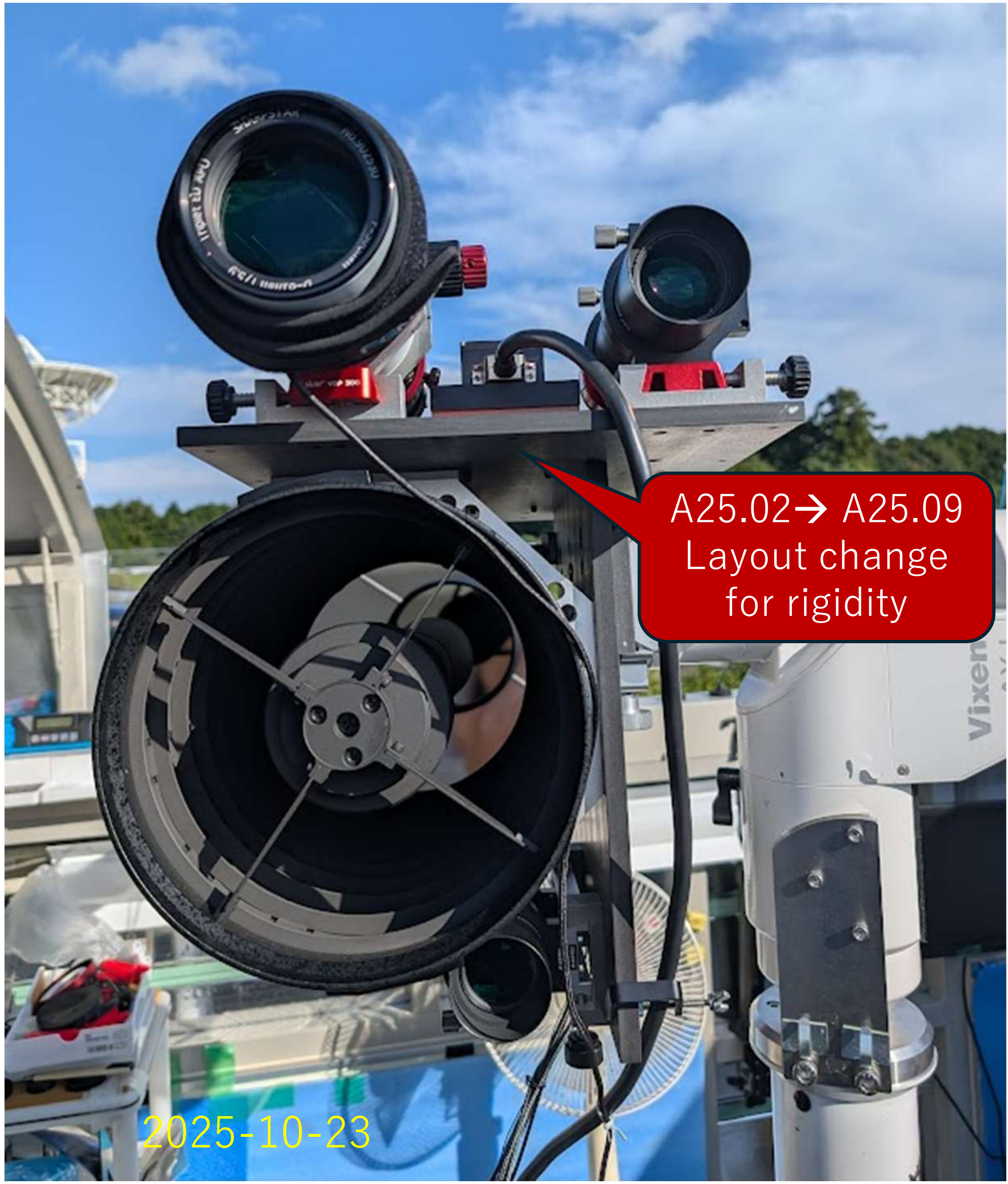
Ishioka Geodetic Observing Station of GSI


2025-10-23
11


Post-processing
2025-10-23


SharpCap (v4.1.13800, 64 bit) - ZWO ASI585MM (1B14CE091A020900, via USB3) - C:¥Users¥omnis¥Desktop¥SharpCap Captures
ファイル (F)
カメラ (C)
キャプチャ (U)
表示 (V)
ツール (O)
シーケンサー (E)
スクリプト (I)
ヘルプ (H)
ライブビュー (W)
撮影開始 (S)
クイック撮影 (Q)
撮影停止 (T)
一時停止 (P)
スナップショット (A)
ライブスタック (L)
天体名：
Previewing : 40574 frames (1 dropped) in 1:47:02, 21.7 fps
Memory: 2 of 776 frames used, Disk: 404 GB free
SharpCap (v4.1.13800, 64 bit) - ZWO ASI183MM (142A410417020900, via USB3) - C:¥Users¥omnis¥Desktop¥SharpCap Captures
Previewing : 9412 frames (0 dropped) in 1:02:43, 7.9 fps
Memory: 2 of 319 frames used, Disk: 404 GB free
検索
5:02
2025/11/07


2025-10-23
危　険
レーザ管理区域
関係者以外立入禁止
Vixen


A25.02→ A25.09
Layout change
for rigidity
2025-10-23
Vixen

Component	Manufacturer	Model	Main specifications
Pulsed laser	CryLAS	FDSS532-Q2	10 kHz, 6μJ, 1.06 ns
RX Telescope	Kasai Trading	GS-200RC	203 mm diameter
Detector	Hamamatsu Photonics	C11202-100	0.1 mm aperture, SPAD
Mount	Vixen	AXJ equatorial mount	Converted to Alt-Az
Event Timer	Swabian Instruments	Time Tagger Ultra Value Edition	42 ps random jitter
GNSS Time Generator	Furuno	TB-1	
NTP Time Server	Citizen	TSV-500GP	
Barometer	Vaisala	PTB-330	3 sensors
Temperature and humidity sensor	T&D	TR-72nw	

Omni-SLR@Ishioka
13 Feb to 4 Dec, 2025

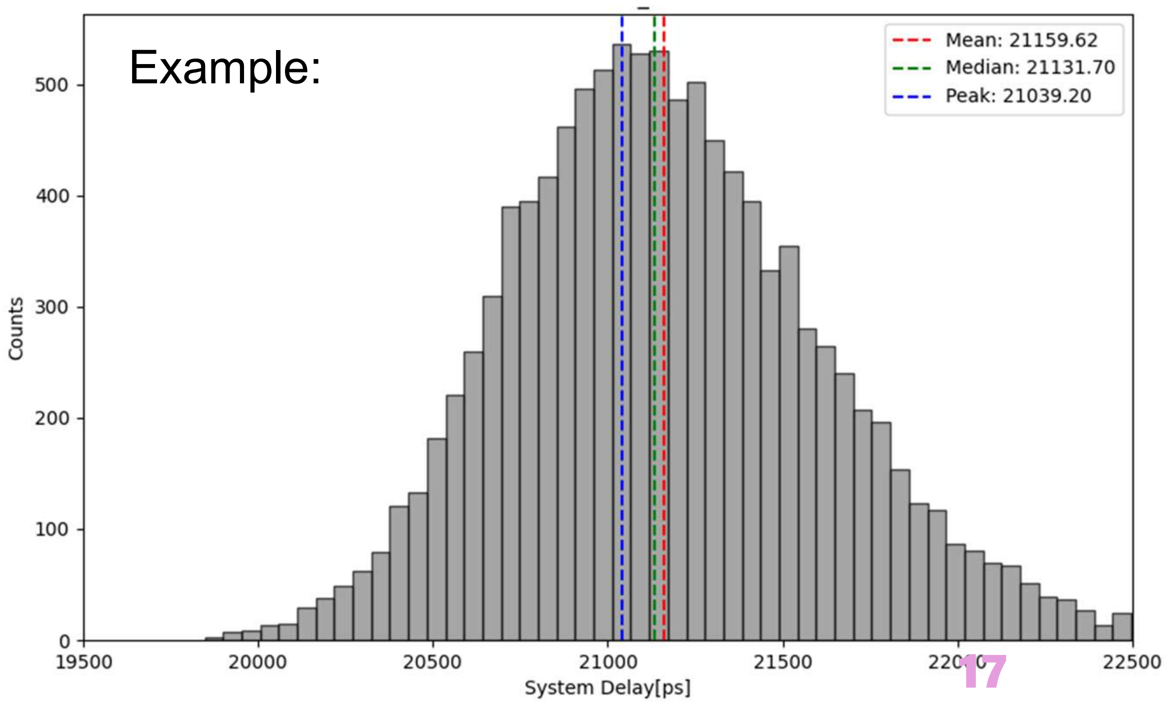
178 passes, mostly released to EDC

Satellite	PASS	NP	FR
ajisai	41	401	177400
beaconc	27	300	78332
starlette	17	64	13200
stella	15	60	15512
swot	9	71	13740
hy2c	8	32	3692
jason3	8	24	1243
lares	8	22	1342
lageos1	6	23	2047
sentinel6a	6	27	1161
cryosat2	5	23	1423
hy2d	5	21	5236
lares2	5	7	292
saral	5	37	5541
hy2b	3	17	1415
swarmb	3	33	8401
lageos2	2	3	617

and several satellites with only one pass taken.

External calibration

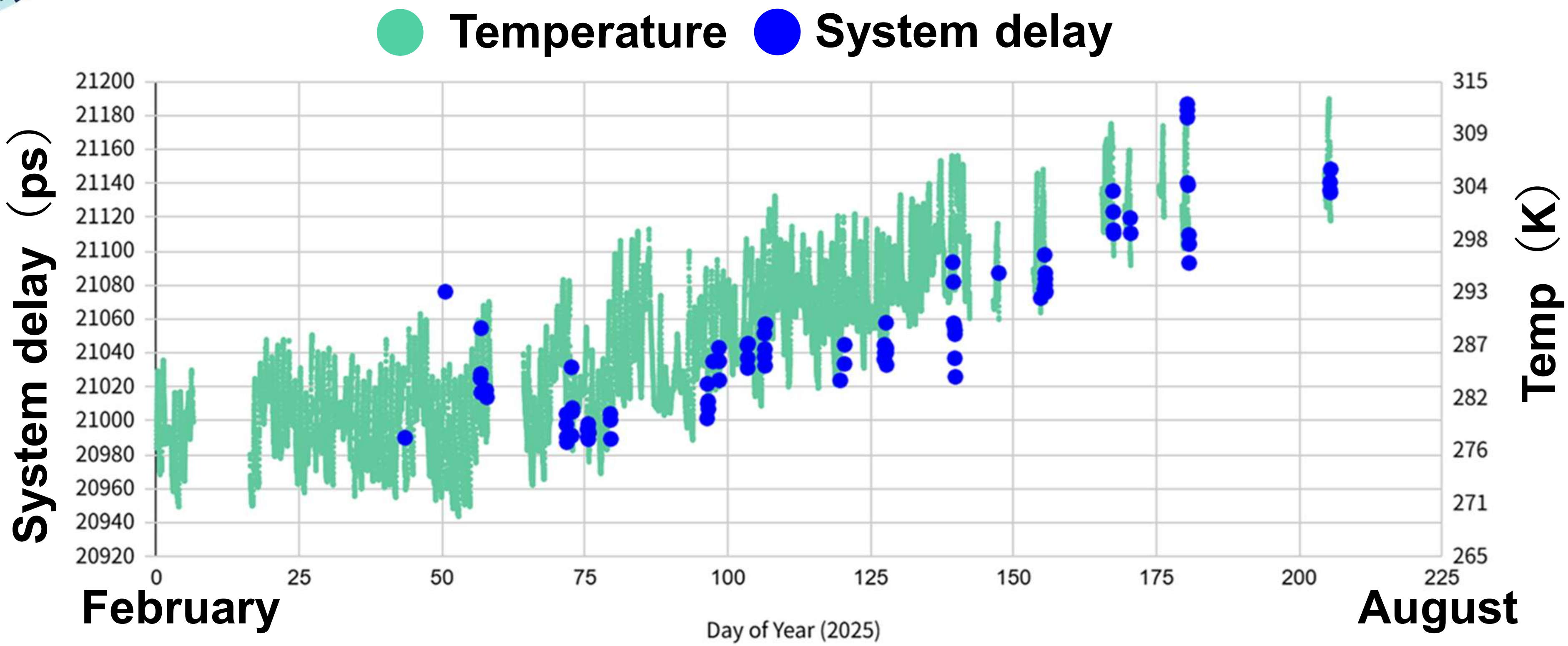
Typically 10000 returns per session



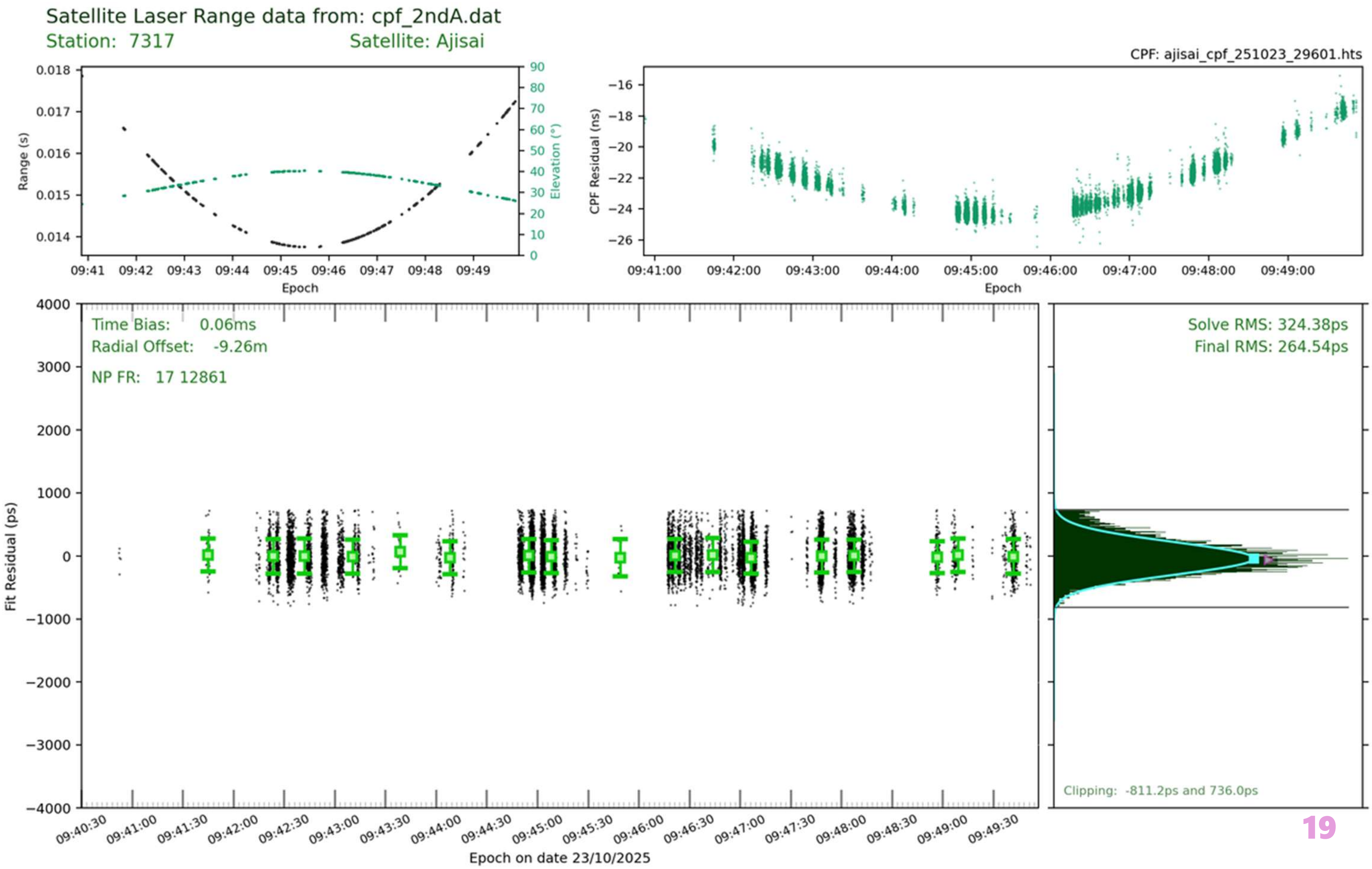
System delay : <u>~21ns</u>
RMS : <u>~435ps</u>

→ almost the same as the 1.06 ns FWHM laser pulse

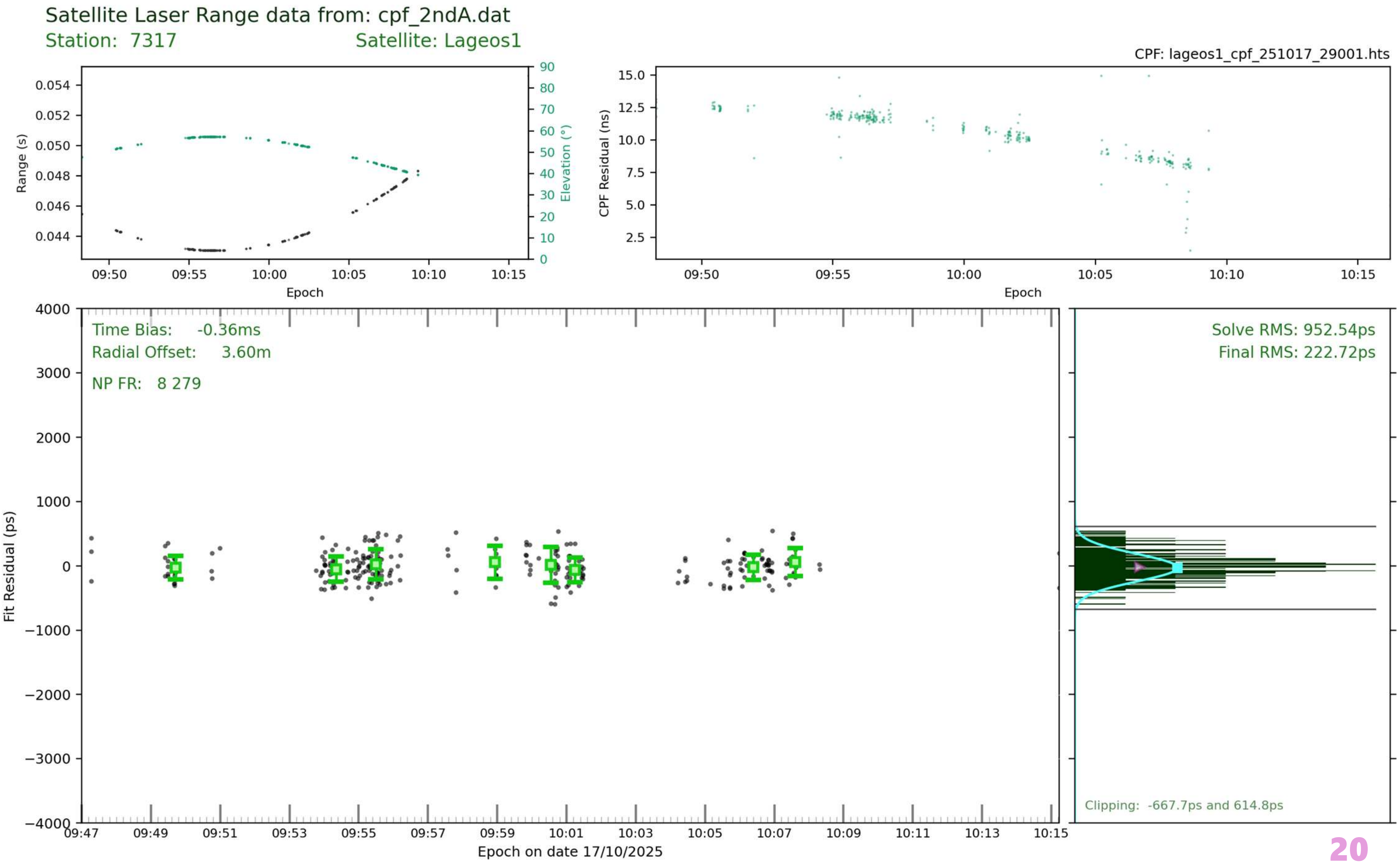
Omni-SLR A25.02 System Delay



- *Within 200 ps for 6 months, ~ 5.5 ps/K: reasonably good for an open air system*
- *Pre- vs Post-cal difference: typ. < 10 ps, largest = 50 ps*
- *Short cables → Small system delay and small variation (to be stabilized more in the future)*



Satellite Laser Range data from: cpf_2ndA.dat
Station: 7317
Satellite: Ajisai
CPF: ajisai_cpf_251023_29601.hts
Range (s)
Elevation (°)
Epoch
CPF Residual (ns)
Time Bias: 0.06ms
Radial Offset: -9.26m
NP FR: 17 12861
Solve RMS: 324.38ps
Final RMS: 264.54ps
Clipping: -811.2ps and 736.0ps
Fit Residual (ps)
Epoch on date 23/10/2025

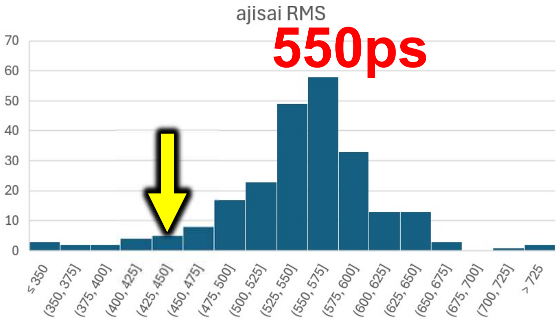

Satellite Laser Range data from: cpf_2ndA.dat
Station: 7317
Satellite: Lageos1
CPF: lageos1_cpf_251017_29001.hts
Range (s)
Elevation (°)
Epoch
CPF Residual (ns)
Epoch
Time Bias: -0.36ms
Radial Offset: 3.60m
NP FR: 8 279
Fit Residual (ps)
Epoch on date 17/10/2025
Solve RMS: 952.54ps
Final RMS: 222.72ps
Clipping: -667.7ps and 614.8ps

Single-shot RMS and skew

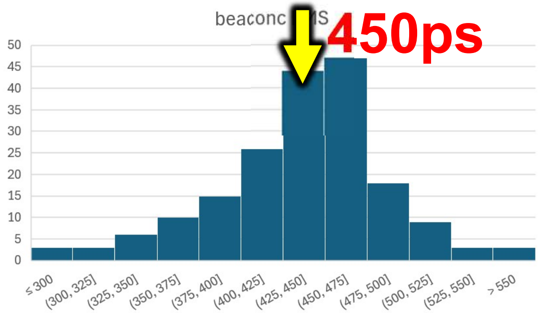
Single-shot RMS (NP basis) for LEOs

Terrestrial Ranging : 435 ps

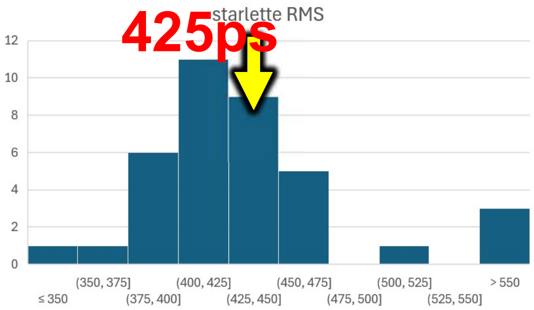
ajisai



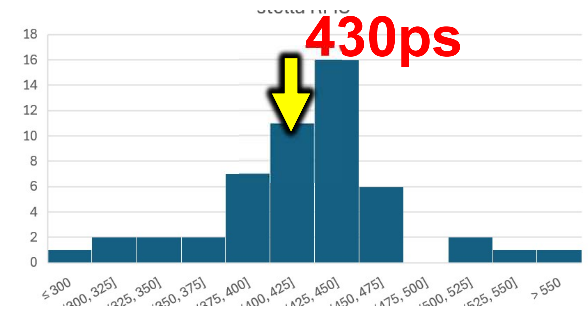
beacon-c



starlette



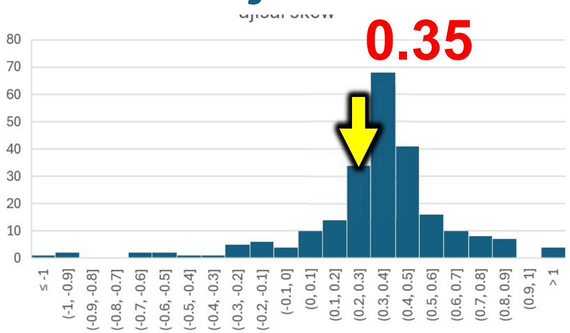
stella



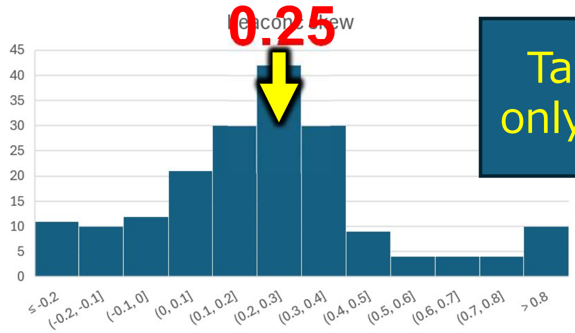
Single-shot Skew (NP basis) for LEOs

Terrestrial Ranging: 0.25

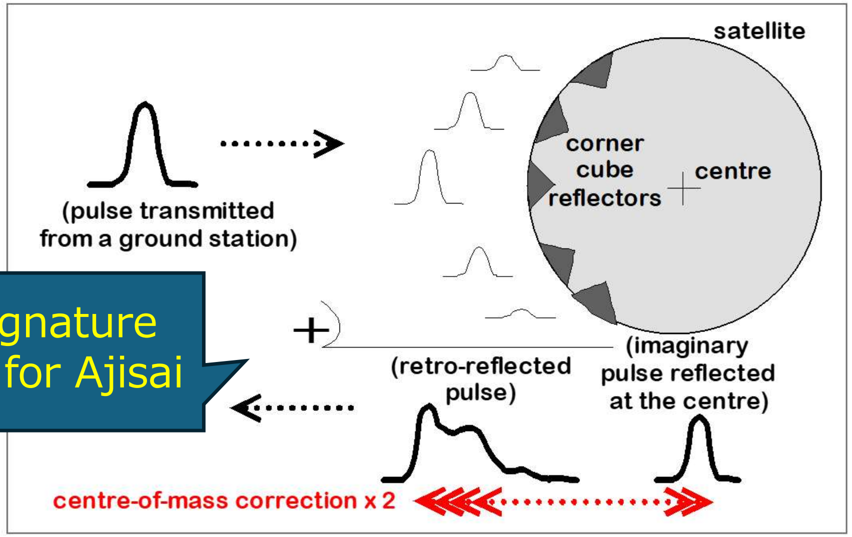
ajisai



beacon-c



Target signature only seen for Ajisai



Otsubo & Appleby 2003 JGR

SLR Data → First solution

First estimate of station coordinates

Using our own c5++ software

3 satellites (Ajisai, Starlette, Stella) combined

Applying Ishioka's velocity and PSD of ITRF2020-u2024:

7317 ISHL
X = 3959591.0713 ± 0.0133 m
Y = 3296886.2143 ± 0.0098 m
Z = 3747021.1178 ± 0.0130 m
Range bias = 0.0005 ± 0.0128 m

→ To Do: Include LAGEOS-1, -2, LARES, LARES-2

→ To Do: Compare them with GSI's local tie (2025.10)

QC'ed by ourselves

Multi-Satellite Bias Analysis Report v2

for Worldwide Satellite Laser Ranging Stations

being updated every 6 hours!

Geoscience Hitotsubashi

Latest Analysis Report: >> from **12h UTC, 26 Oct 2025** to **12h UTC, 09 Nov 2025** (updated 14:15 UTC, 9 Nov 2025)

Stations with high productivity

sat	orbit fit WRMS in mm	# pass/# NP	1st site(ID) # pass/# NP	2nd site(ID) # pass/# NP	3rd site(ID) # pass/# NP
Lageos-1	9	309 / 2599	Yarragadee (7090) 35/332	Potsdam (7841) 32/171	Graz (7839) 24/301
Lageos-2	10	204 / 1824	Yarragadee (7090) 41/478	Zimmerwald (7810) 19/250	Potsdam (7841) 18/104
Etalon-1	12	44 / 257	Wettzell (8834) 10/87	Yarragadee (7090) 10/58	Graz (7839) 6/18
Etalon-2	9	46 / 259	Wettzell (8834) 8/72	Graz (7839) 7/47	Wettzell (7827) 6/40
Ajisai	30	337 / 4526	Yarragadee (7090) 62/693	Wettzell (8834) 26/597	Zimmerwald (7810) 25/404
Lares	14	279 / 2986	Yarragadee (7090) 38/398	Potsdam (7841) 38/234	Graz (7839) 28/374
Lares-2	8	226 / 2077	Yarragadee (7090) 27/268	Potsdam (7841) 23/138	Zimmerwald (7810) 21/381
Starlette	25	334 / 2890	Yarragadee (7090) 59/563	Graz (7839) 29/367	Changchun (7237) 27/160
Stella	25	219 / 1735	Yarragadee (7090) 35/330	Graz (7839) 20/190	Potsdam (7841) 17/90

and more satellites (GNSS and LEO) are included in the reports!!

Archive: (each covers 14 days from the date) 2024 2023 2022 2021 2020 2019 2018 2017 2016 2015 2014 2013 2012 v1: Year 2011 20

Oct 2025	Sep 2025	Aug 2025	Jul 2025	Jun 2025	May 2025	Apr 2025	Mar 2025	Feb 2025	Jan 2025
26 (00 06 12)	30 (00 06 12 18)	31 (00 06 12 18)	31 (00 06 12 18)	30 (00 06 12 18)	31 (00 06 12 18)	30 (00 06 12 18)	31 (00 06 12 18)	28 (00 06 12 18)	31 (00 06 12 18)
25 (00 06 12 18)	29 (00 06 12 18)	30 (00 06 12 18)	30 (00 06 12 18)	29 (00 06 12 18)	30 (00 06 12 18)	29 (00 06 12 18)	30 (00 06 12 18)	27 (00 06 12 18)	30 (00 06 12 18)
24 (00 06 12 18)	28 (00 06 12 18)	29 (00 06 12 18)	29 (00 06 12 18)	28 (00 06 12 18)	29 (00 06 12 18)	28 (00 06 12 18)	29 (00 06 12 18)	26 (00 06 12 18)	29 (00 06 12 18)
23 (00 06 12 18)	27 (00 06 12 18)	28 (00 06 12 18)	28 (00 06 12 18)	27 (00 06 12 18)	28 (00 06 12 18)	27 (00 06 12 18)	28 (00 06 12 18)	25 (00 06 12 18)	28 (00 06 12 18)
22 (00 06 12 18)	26 (00 06 12 18)	27 (00 06 12 18)	27 (00 06 12 18)	26 (00 06 12 18)	27 (00 06 12 18)	26 (00 06 12 18)	27 (00 06 12 18)	24 (00 06 12 18)	27 (00 06 12 18)

QC'ed by ourselves

(only spherical satellites)

```
#
#  7317 = ISHIOKA
# sat site       date   time dur   rb mm   error        tb us    error    prec bad total  rms   pres  temp hum  sdelay
 LAG1 7317 2025/10/17 09:50  17     -58 (    25 )       8.3 (   22.7 )    12   0 /   8   65 1012.1 289.5  84    3088
 AJI1 7317 2025/10/17 11:03   6       5 (     9 )       8.5 (    3.9 )     3   0 /  13   80 1012.1 289.2  84    3088
 LARS 7317 2025/10/17 12:36   0     116 (    68 )  --------.- ( ----.- )    23   0 /   3   55 1012.1 289.2  81    3089
 STRL 7317 2025/10/17 17:03   0    -186 (    13 )  --------.- ( ----.- )     2   0 /   3   58 1009.5 287.8  91    3086
 LAR2 7317 2025/10/17 17:59   0 ------- ( ----- )  --------.- ( ----.- ) -----   0 /   1   60 1009.0 287.2  91    3087
 AJI1 7317 2025/10/23 09:41   7      22 (     7 )      10.3 (    3.1 )     7   0 /  17   80 1013.6 285.5  74    3093
 STEL 7317 2025/10/23 11:34   0      25 (    17 )  --------.- ( ----.- )     2   0 /   2   64 1014.0 285.1  74    3092
 STRL 7317 2025/10/23 13:31   0 ------- ( ----- )  --------.- ( ----.- ) -----   0 /   1   41 1013.8 283.9  78    3091
 LAG1 7317 2025/10/23 15:37   2     -72 (    41 )  --------.- ( ----.- )    10   0 /   2   59 1013.0 283.5  76    3092
 LAR2 7317 2025/11/13 16:17   1     -30 (    22 )  --------.- ( ----.- )     3   0 /   2   75  998.1 282.7  70    3088
 LAG2 7317 2025/11/13 16:53   1      -5 (    27 )  --------.- ( ----.- )     4   0 /   2   65  998.4 282.5  73    3088
 LARS 7317 2025/11/13 17:33   0 ------- ( ----- )  --------.- ( ----.- ) -----   0 /   1   62  998.1 281.9  74    3087
 AJI1 7317 2025/11/13 17:49   7      93 (    26 )     -14.1 (   11.1 )    12   0 /  11   83  998.4 281.7  74    3086
 LAG1 7317 2025/11/13 18:24  27     -16 (    11 )      -9.9 (    7.7 )    10   0 /   8   60  998.3 282.1  69    3086
 LARS 7317 2025/11/13 19:26   1      13 (    32 )  --------.- ( ----.- )    25   0 /   3   73  998.5 281.9  70    3087
 AJI1 7317 2025/11/13 19:51   9      -1 (    28 )     -19.3 (    7.8 )    15   0 /  14   87  998.4 281.8  70    3087
```

- ***Single-shot RMS: ~ 80 mm for Ajisai and ~ 65 mm for others***
- ***NP RMS (fitted per pass): < 10 mm for densely-tracked satellites***
- ***Range bias for LEO spherical satellites: comparable to the existing stations.***

QC'ed by ourselves

```
#
#  7317 = ISHIOKA
# sat site        date    time  dur     rb mm    error          tb us      error       prec  bad total  rms    pres   temp  hum    sdelay
 SARL 7317 2025/10/17 09:31    2      -50 (     16 )  --------.- ( ----.- )     5    0 /  10    58 1011.8 290.4  80      3090
 LAG1 7317 2025/10/17 09:50   17      -58 (     25 )       8.3 (   22.7 )    12    0 /   8    65 1012.1 289.5  84      3088
 AJI1 7317 2025/10/17 11:03    6        5 (      9 )       8.5 (    3.9 )     3    0 /  13    80 1012.1 289.2  84      3088
 LARS 7317 2025/10/17 12:36    0      116 (     68 )  --------.- ( ----.- )    23    0 /   3    55 1012.1 289.2  81      3089
 CRY2 7317 2025/10/17 15:31    0     1405 (     66 )  --------.- ( ----.- )     9    0 /   2    53 1010.4 289.2  83      3088
 BECC 7317 2025/10/17 15:55    0  ------- ( ----- )  --------.- ( ----.- ) -----    0 /   1    56 1010.3 287.4  92      3086
 STRL 7317 2025/10/17 17:03    0     -186 (     13 )  --------.- ( ----.- )     2    0 /   3    58 1009.5 287.8  91      3086
 BECC 7317 2025/10/17 17:50    1      352 (     54 )  --------.- ( ----.- )    13    0 /   6    68 1009.1 287.6  88      3087
 LAR2 7317 2025/10/17 17:59    0  ------- ( ----- )  --------.- ( ----.- ) -----    0 /   1    60 1009.0 287.2  91      3087
 AJI1 7317 2025/10/23 09:41    7       22 (      7 )      10.3 (    3.1 )     7    0 /  17    80 1013.6 285.5  74      3093
 BECC 7317 2025/10/23 11:23    3       52 (     29 )      -8.0 (   17.3 )     8    0 /   9    65 1013.8 285.4  73      3092
 STEL 7317 2025/10/23 11:34    0       25 (     17 )  --------.- ( ----.- )     2    0 /   2    64 1014.0 285.1  74      3092
 BECC 7317 2025/10/23 13:22    0       73 (     74 )  --------.- ( ----.- )    10    0 /   2    61 1013.9 284.1  77      3091
 STRL 7317 2025/10/23 13:31    0  ------- ( ----- )  --------.- ( ----.- ) -----    0 /   1    41 1013.8 283.9  78      3091
 BECC 7317 2025/10/23 15:09    6       48 (     35 )      24.9 (   10.2 )    10    0 /   9    61 1013.0 284.6  74      3092
 CRY2 7317 2025/10/23 15:26    3      -50 (    705 )  --------.- ( ----.- )   113    0 /   2    43 1012.9 283.9  75      3092
 LAG1 7317 2025/10/23 15:37    2      -72 (     41 )  --------.- ( ----.- )    10    0 /   2    59 1013.0 283.5  76      3092
```

- ***Single-shot RMS: ~ 80 mm for Ajisai and ~ 65 mm for others***
- ***NP RMS (fitted per pass): < 10 mm for densely-tracked satellites***
- ***Range bias for LEO spherical satellites: comparable to the existing stations.***

Omni-SLR: Ongoing/Future plans

Omni-SLR: possible upgrades (Omni-SLR A-Next)

Teem BNG-15E-000

1-a: Controller

1-b: Laser head

λ = 532nm; pulse width = 0.75 ns;
Rep. rate = 22 kHz; output = 17 μJ
Sync output; int/ext trigger mode

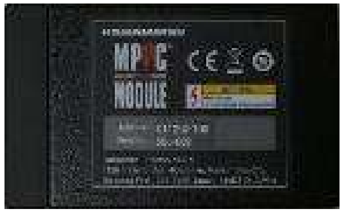
Swabian Instruments TimeTagger Ultra (Value Ed)

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

FreqTime FT-RB or?

GNSS Rb
2 × 10-11@1s
2 × 10-12 @100 s

Hamamatsu Photonics 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

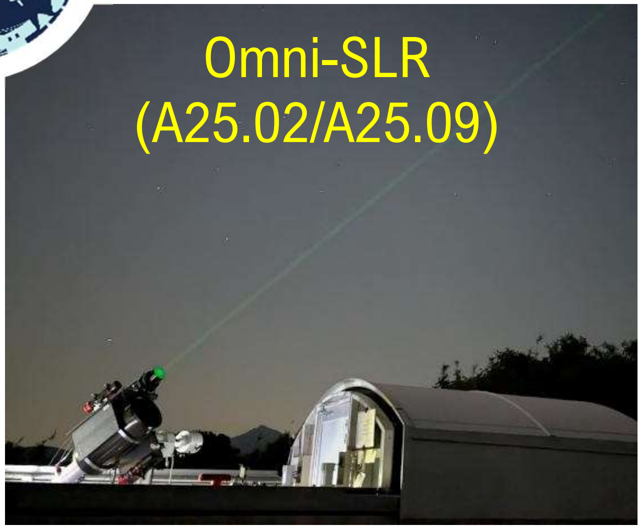
Hobym Crux200MF

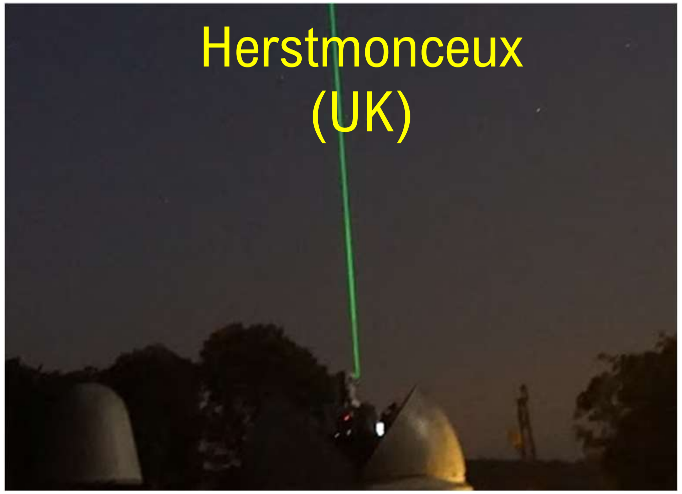
Alt-Az mode
Load: 30 kg max

Vaisala PTB-330

3 sensor barometer
0.2 hPa per sensor

Link budget calculation (simplified)





Telescope diameter m Φ

Laser output W

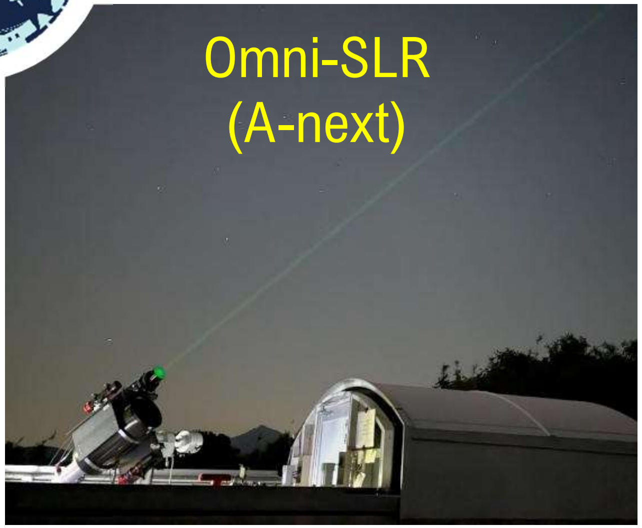
0.006 mJ, 5 kHz

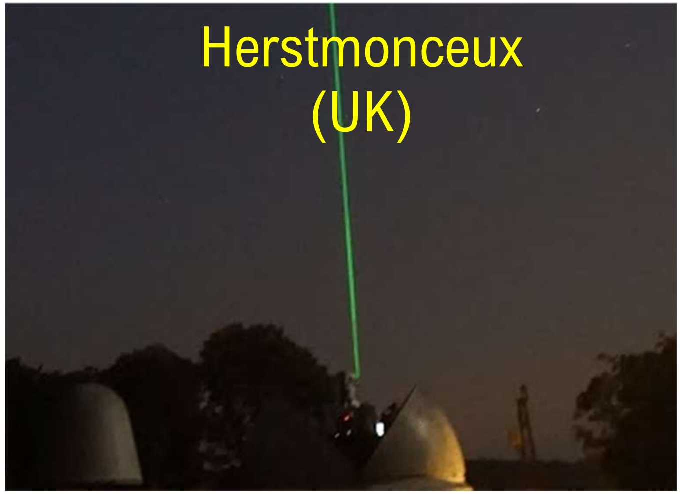
$$= \left[\frac{0.2}{0.5}\right]^2 \frac{0.03}{1.0} \fallingdotseq \frac{0.005}{1}$$

1 mJ, 1 kHz

Hx applies ND 2 or 3 (1/100 or 1/1000) for LEO, and still gets 1000 returns/NP.

Link budget calculation (simplified)





Telescope diameter
m Φ

Laser
output W

0.15 mJ, 20 kHz

(just arrived)

Additional
budget
options

$$= \left[\frac{0.2}{0.5}\right]^2 \frac{\overset{0.15}{\cancel{0.03}}}{1.0} \fallingdotseq \frac{\mathbf{0.025}}{1}$$

1 mJ, 1 kHz

Antarctic test approved

NIPR Exploratory Research Project

"Development of a compact SLR system for the first antarctica experiment"

3 years: FY2024 to FY2026. Syowa: 69S 35E.

FY2024-FY2025

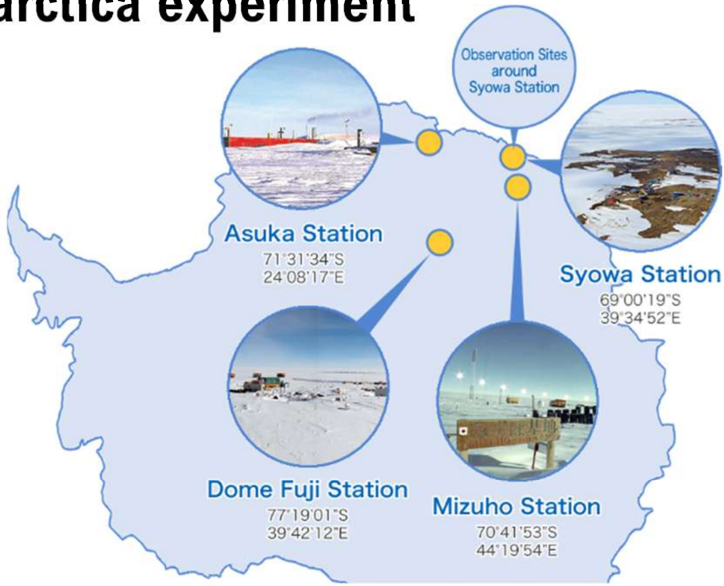
Preliminary tests in Japan.

FY2025

A roll-off roof container to be installed at Syowa (if possible).

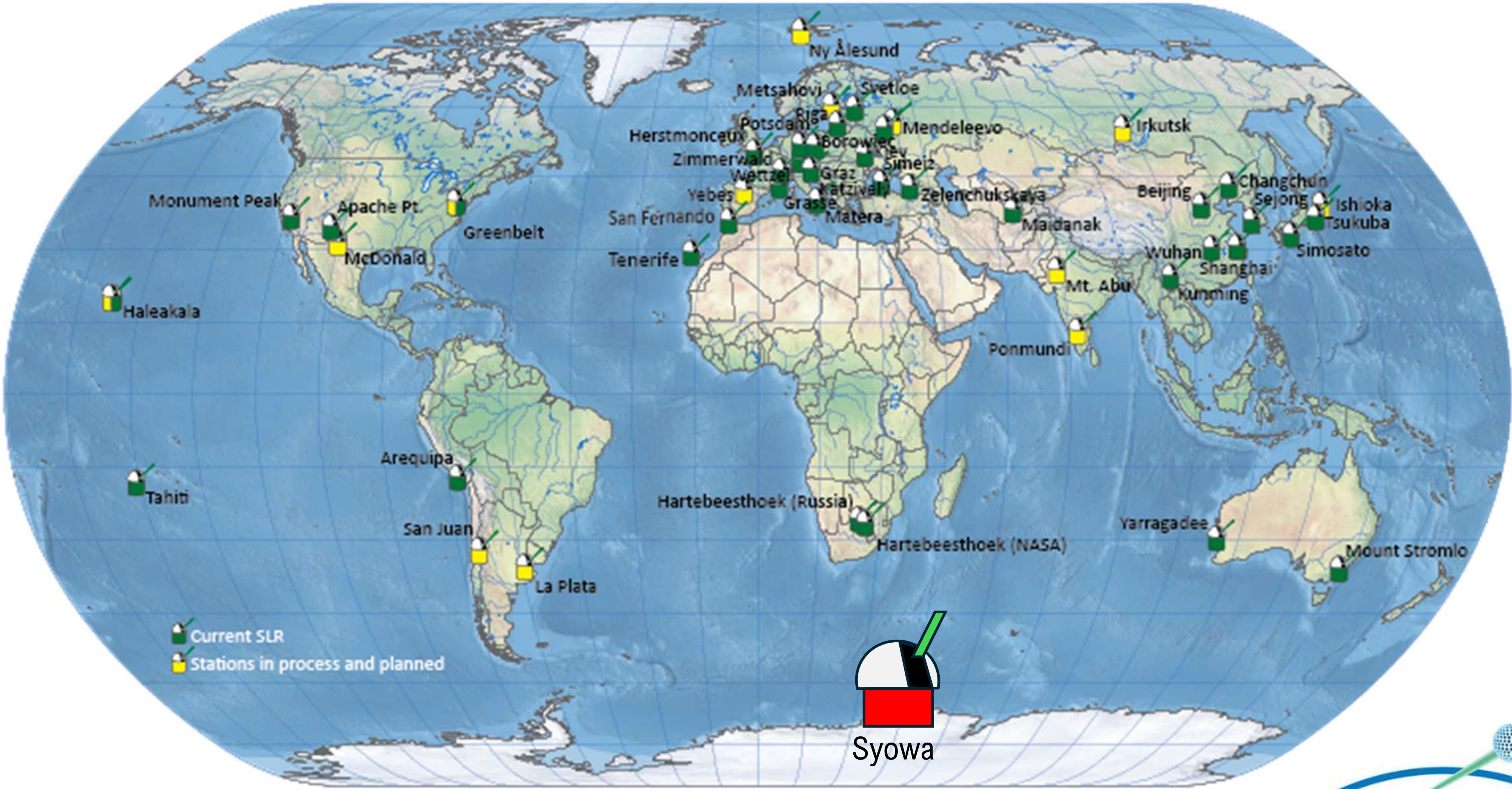
FY2026 (JARE68)

Shipped to Syowa (Nov 2026). **SLR test at Syowa (Jan-Feb 2027).**



→
Syowa's container
= 3.0 m x 2.4 m

Current and Planned ILRS Network



31

International Laser Ranging Service

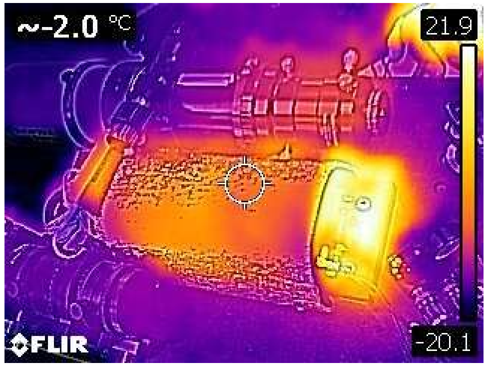
SLR@Syowa

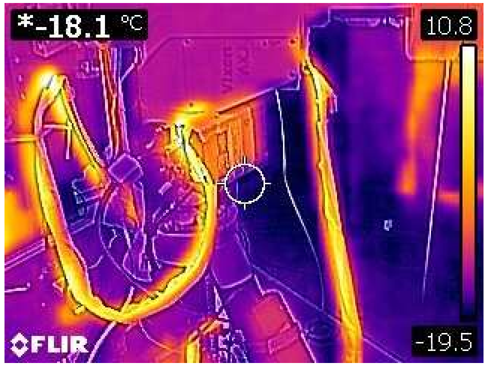
Exploratory Research Projects, AH1004 (FY2024-2026)

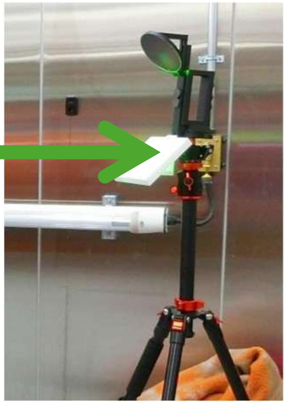
✔ Roll-off roof

Being shipped to Syowa JARE67.

✔ Low-temperature test







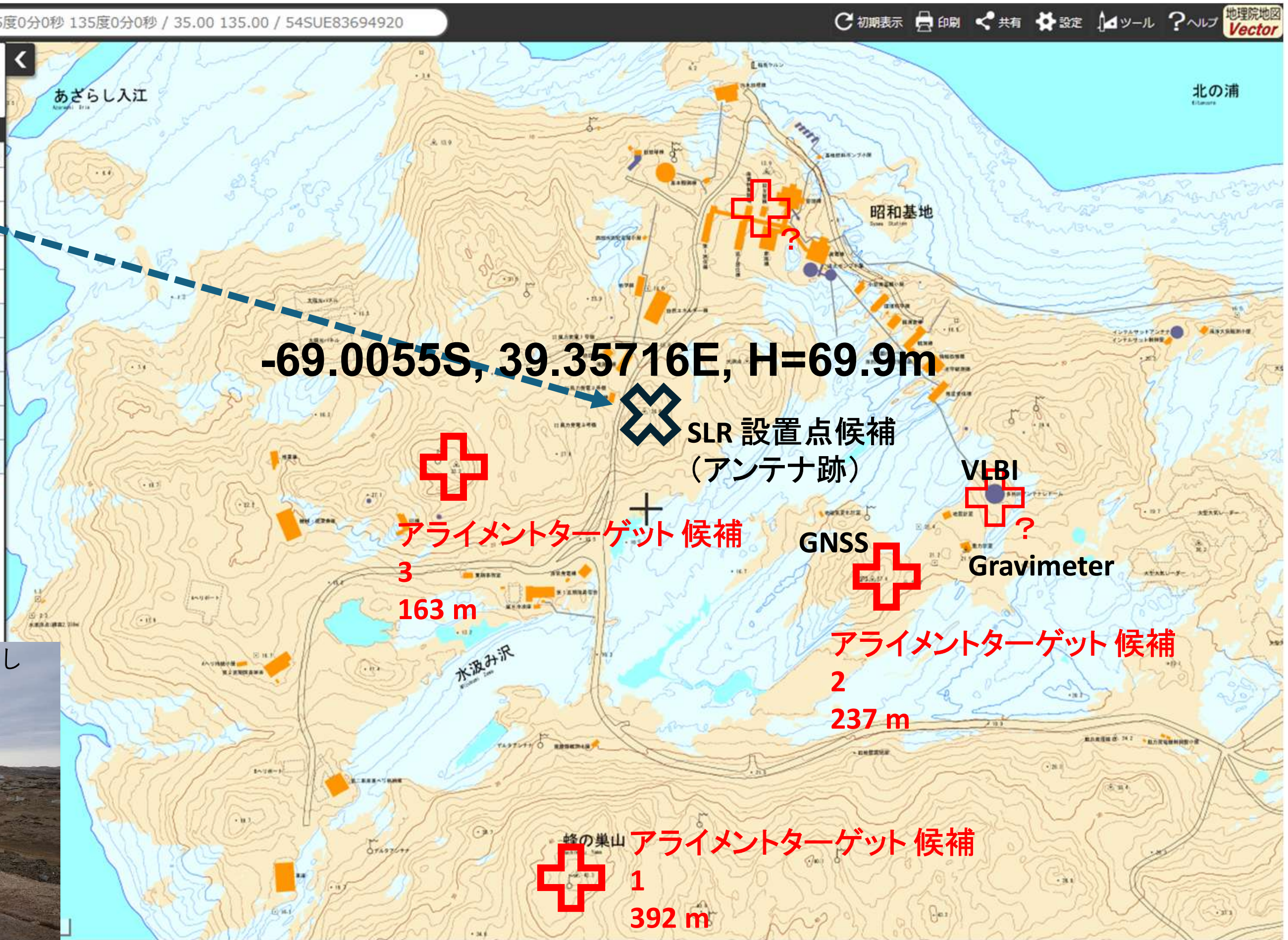
□ Daytime-only operation (being tested@Ishioka)

SLR@Syowa

Antarctica's First SLR attempts, Jan to Feb 2027 (JARE68)

(After JARE68, the Omni-SLR equipment will be removed and stored, awaiting the next project.)

Site survey done by JARE59 and 66



Conclusions & Ongoing+Future projects

- A very low-cost SLR works! 150+ LEO passes and several LAG passes.
- Initial coordinates of Ishioka estimated.
- Random errors tolerated; systematic errors suppressed.
- Limits: optical link, tracking stability,…

✔ 2025.10 Local tie incl Omni-SLR (by GSI)

✔ 2025.11 1st paper submitted to J Geodesy

☐ 2025 4Q Installation of a new laser (Teem)

☐ 2026 1Q cm coordinates solution to be compared with GSI's local tile

☐ 2026 1Q Daytime observation (SLR and StarCal)

☐ 2026 1Q-2Q Solid LAGEOS tracking → Sub-cm coordinates.

☐ 2026 3Q-4Q First SLR in Antarctica ("S set") ← ILRS site registration soon.

☐ 2027+ Remote operation, Automation,…

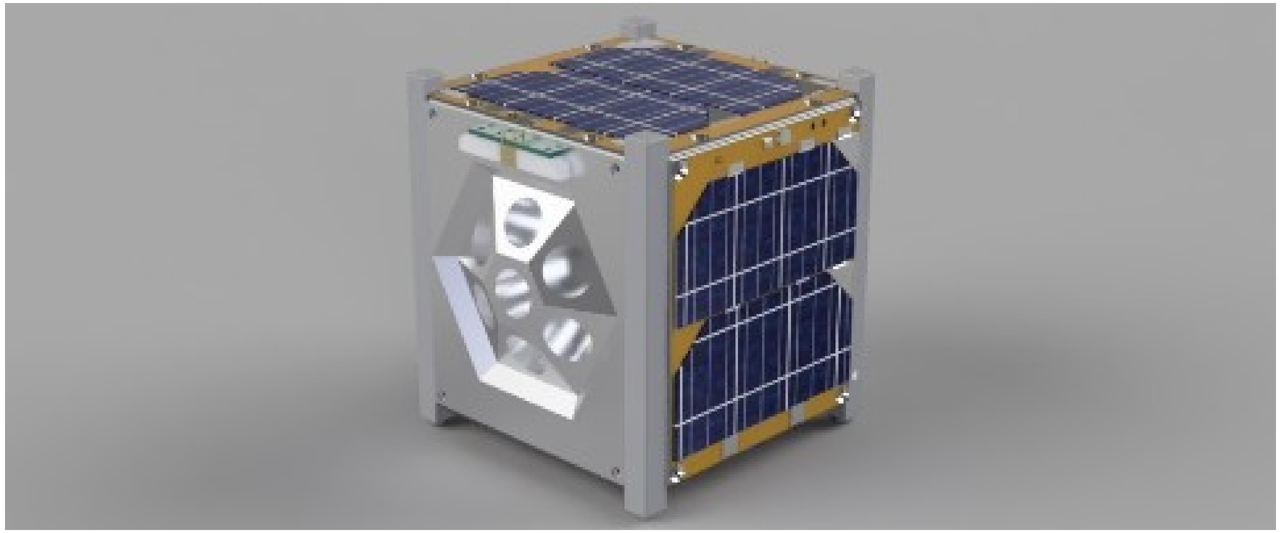
Omni-SLR

Happy Holidays and Happy New Year!

2025/12/11

Difficulties in observing the e-kagaku satellite using SLR

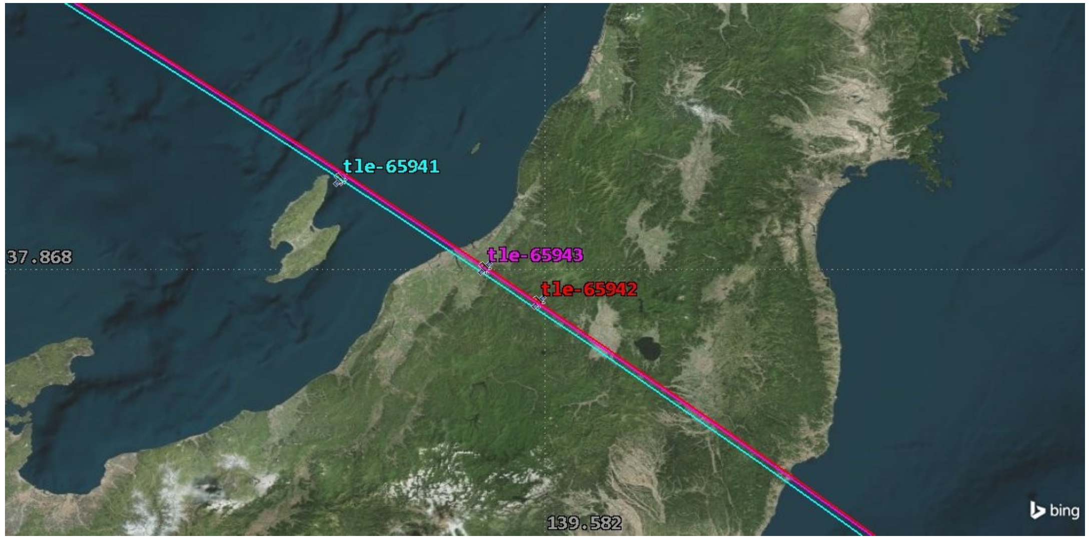
JAXA Shinichi Nakamura



First and foremost, we would like to express our gratitude for your cooperation with the SLR observations of the ekagaku1 satellite.We also apologize for the lack of response from the ekagaku1 satellite. Today, we will explain the cause of this issue and share some points to keep in mind during SLR observations.

Cause 1: TLE Misassignment

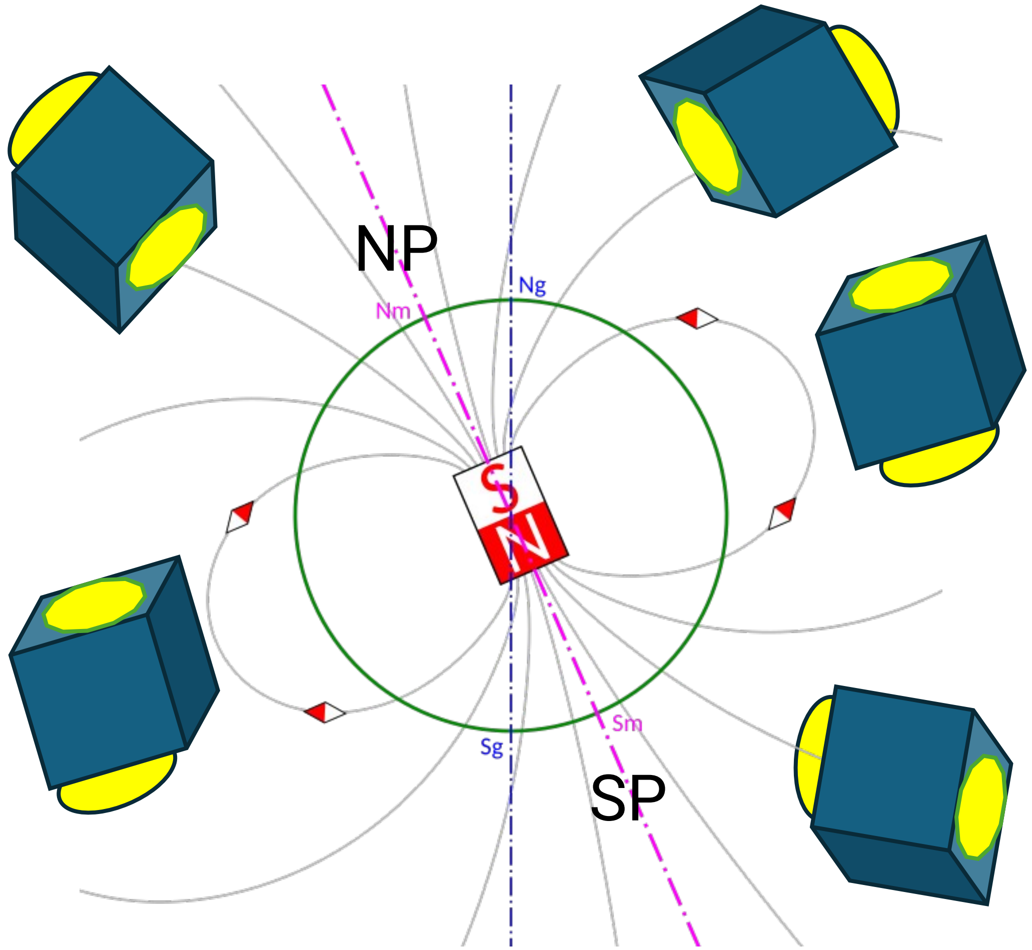
On October 10th, three small satellites were deployed from the ISS.
Unfortunately, radio communication was not established, so we made a CPF for the ekagaku1 satellite using TLE from <u>November 4th to 8th</u>.
According TLE, 65941 Clover, <u>65942 ekagaku1</u>, and 65943 BOTAN.
However, on November 11th, with the cooperation of the amateur radio community, it was determined that <u>TLE-65942 was the BOTAN</u> satellite.



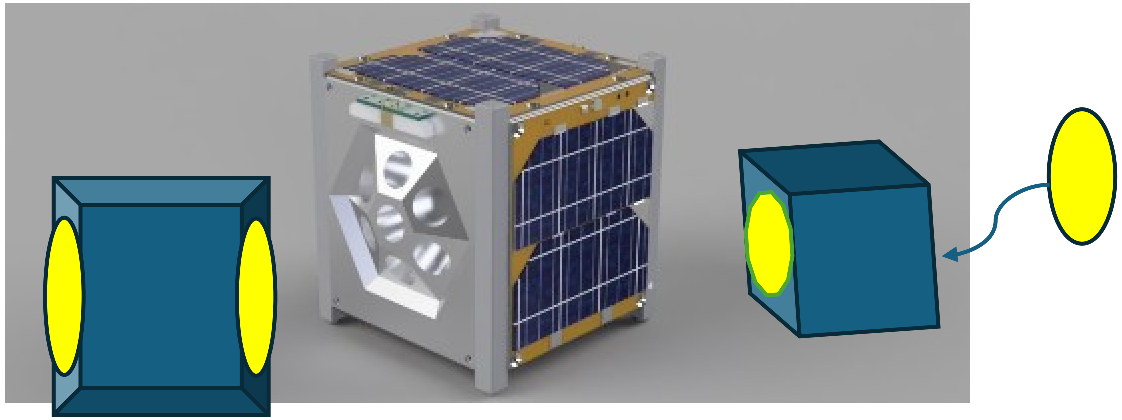
On Oct 15th
The direction of travel is from top left to bottom right. The flight order, from the front, is 65942, 65943, 95941.

Also, since the Clover satellite is a 2U satellite and the ekagaku1 satellite is a 1U satellite, we determined that TLE-65943 was the ekagaku1 satellite based on a radar cross section evaluation using the JAXA SSA radar. So, we made the CPF by considering TLE-65943 as the ekagaku1 satellite. (The CPF was based on the orbit determined by the JAXA SSA radar, not the TLE.)
However, we have not yet obtained return signal to the SLR laser.

Cause 2: Satellite Design

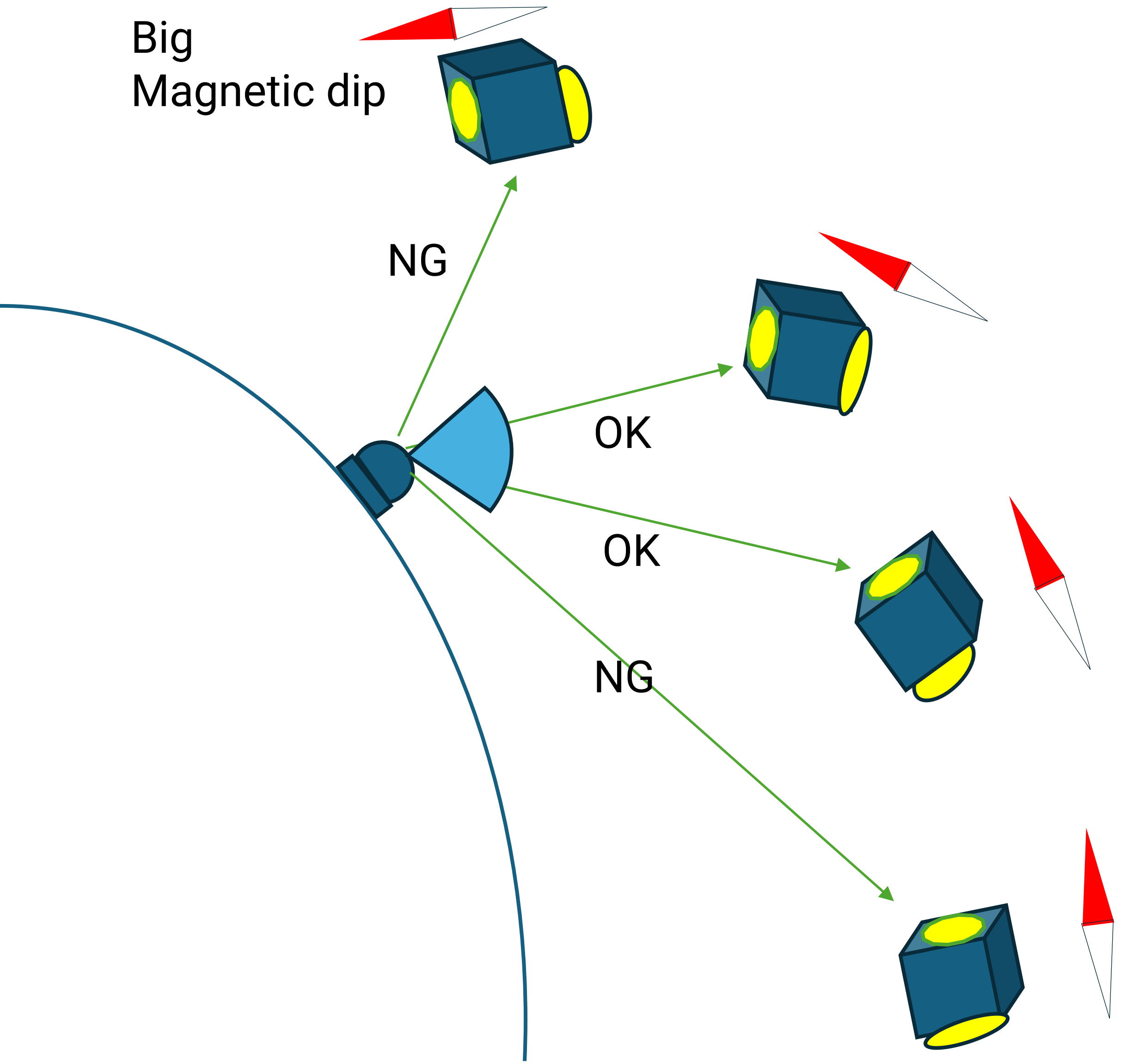


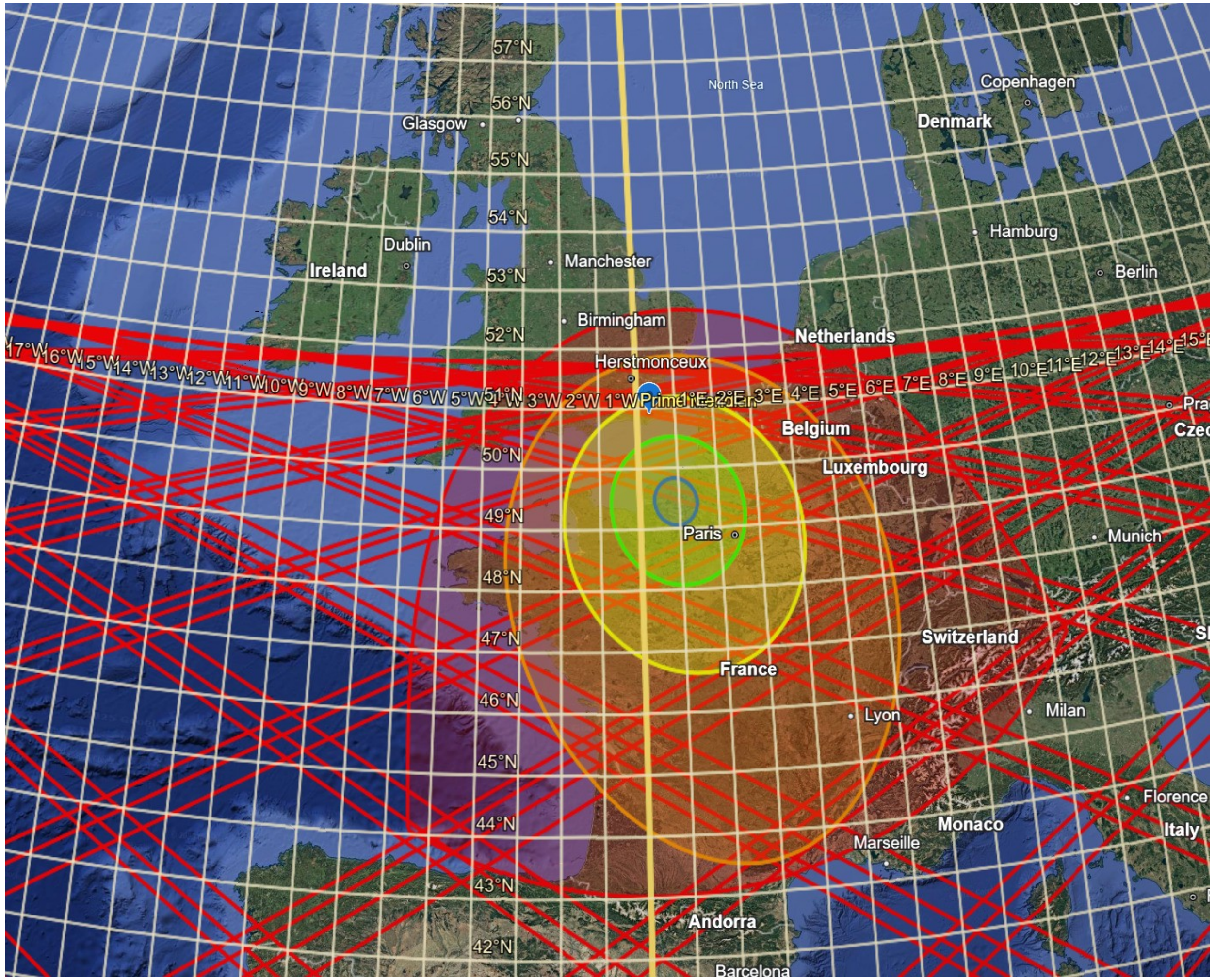
Last week, I discussed the ekagaku project and the cause of the SLR failure.
There was insufficient communication between JAXA and the junior and senior high school students who developed the ekagaku1 satellite.
The reflector attached to the ekagaku1 satellite was not facing toward the Earth.
The reflector faces north, along the Earth's magnetic field lines.



High-latitude stations (Latitude < 51)

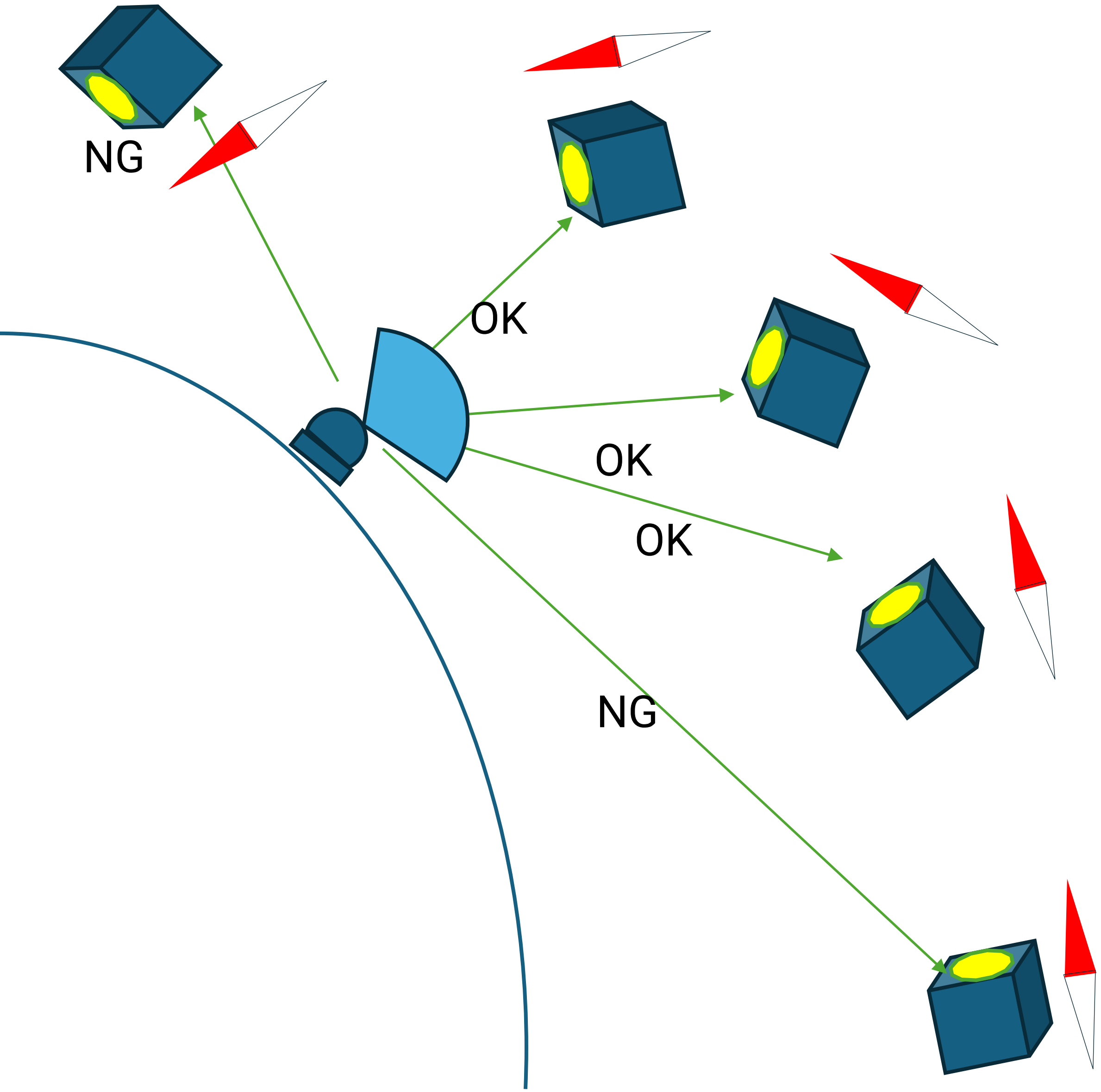
northern hemisphere SLR station

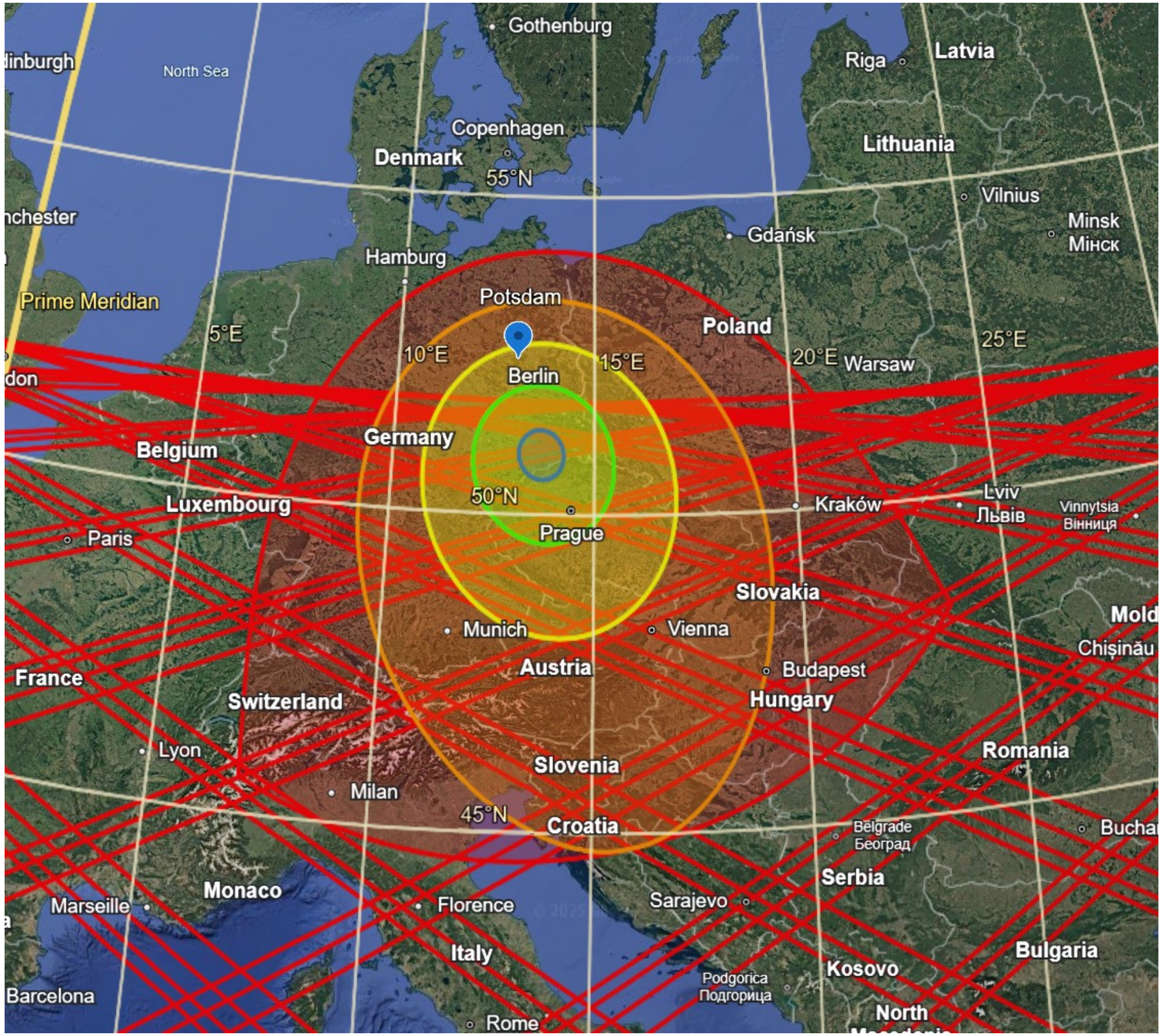




High-latitude stations (Latitude >51)

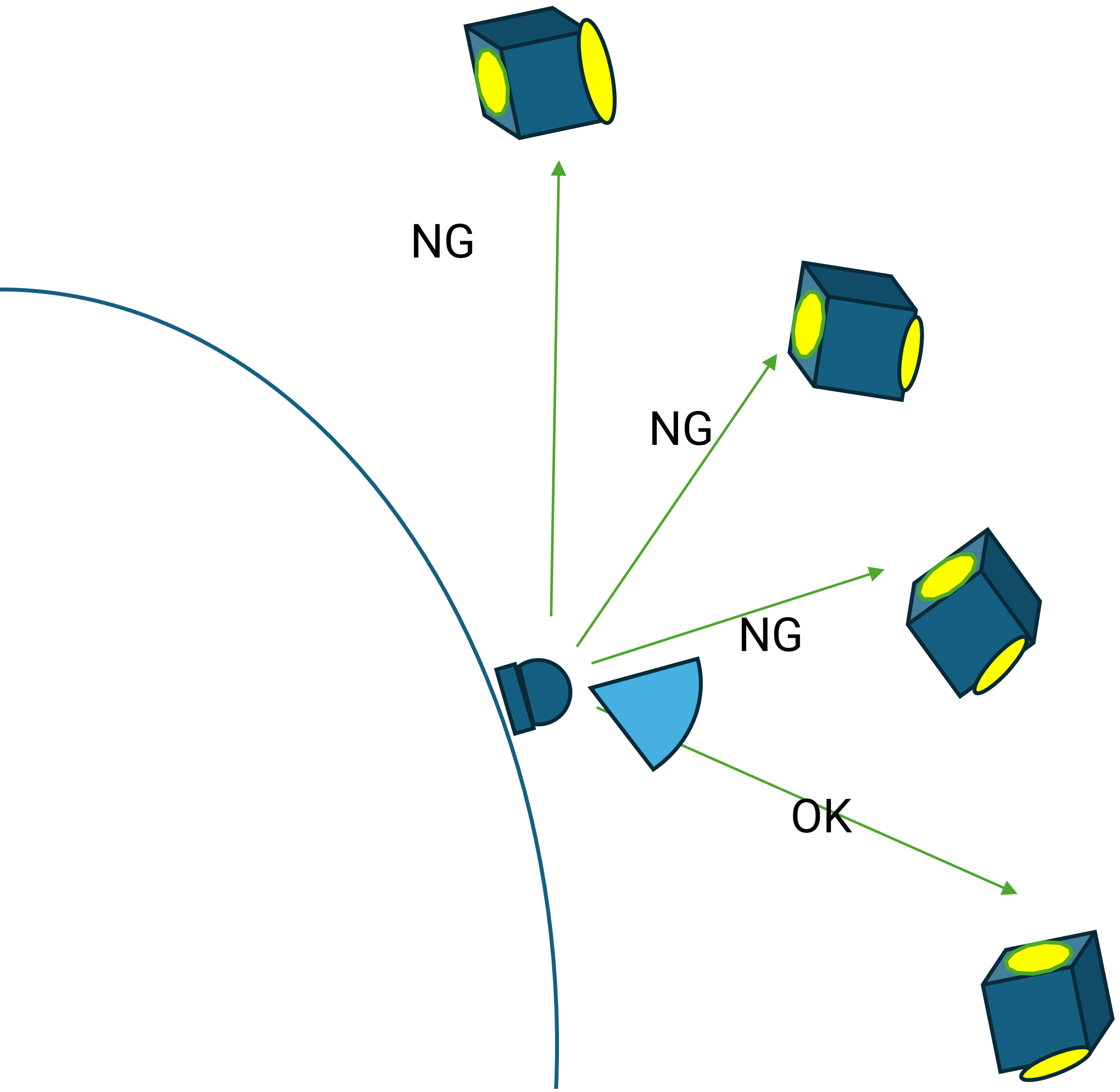
Northern hemisphere SLR station

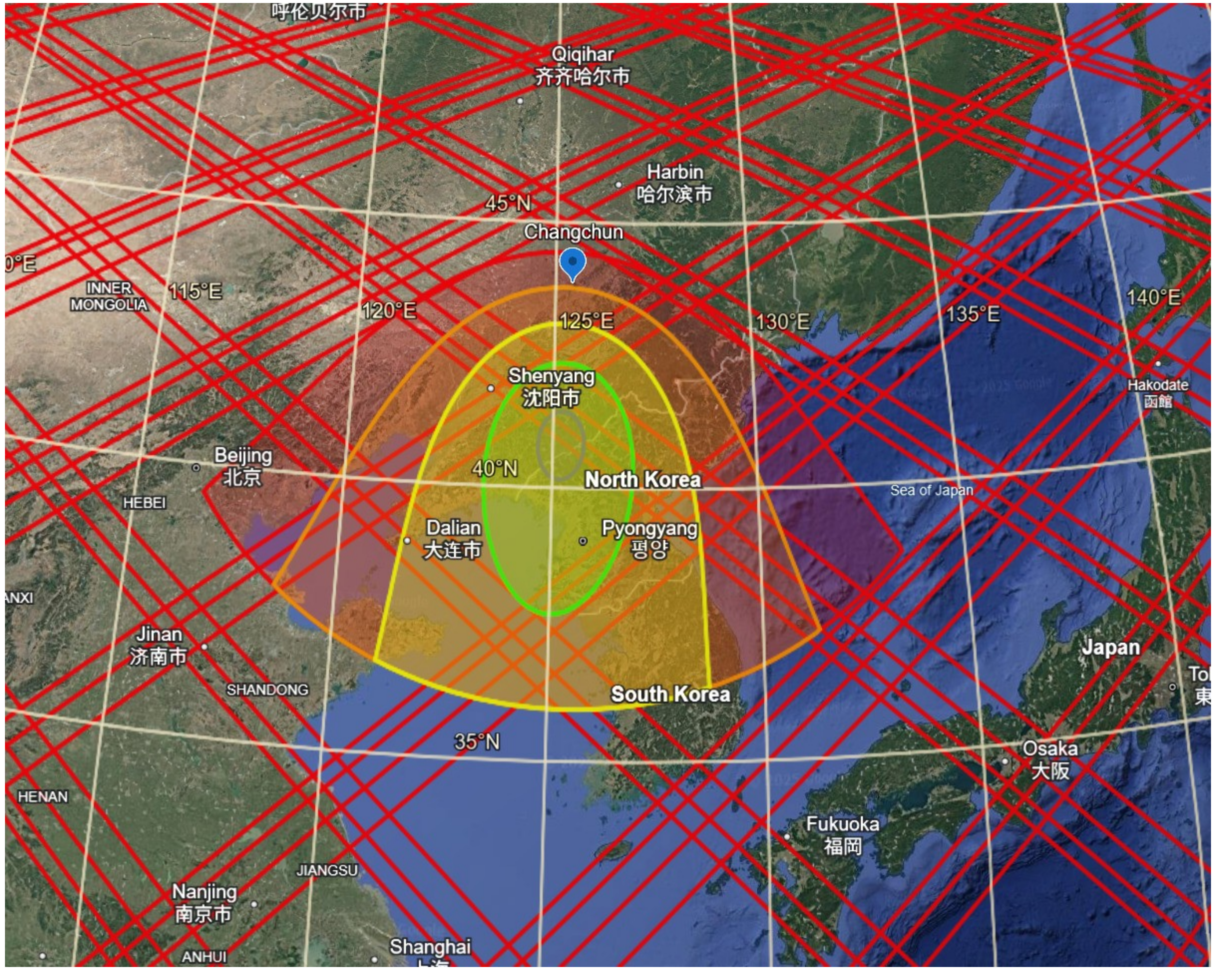




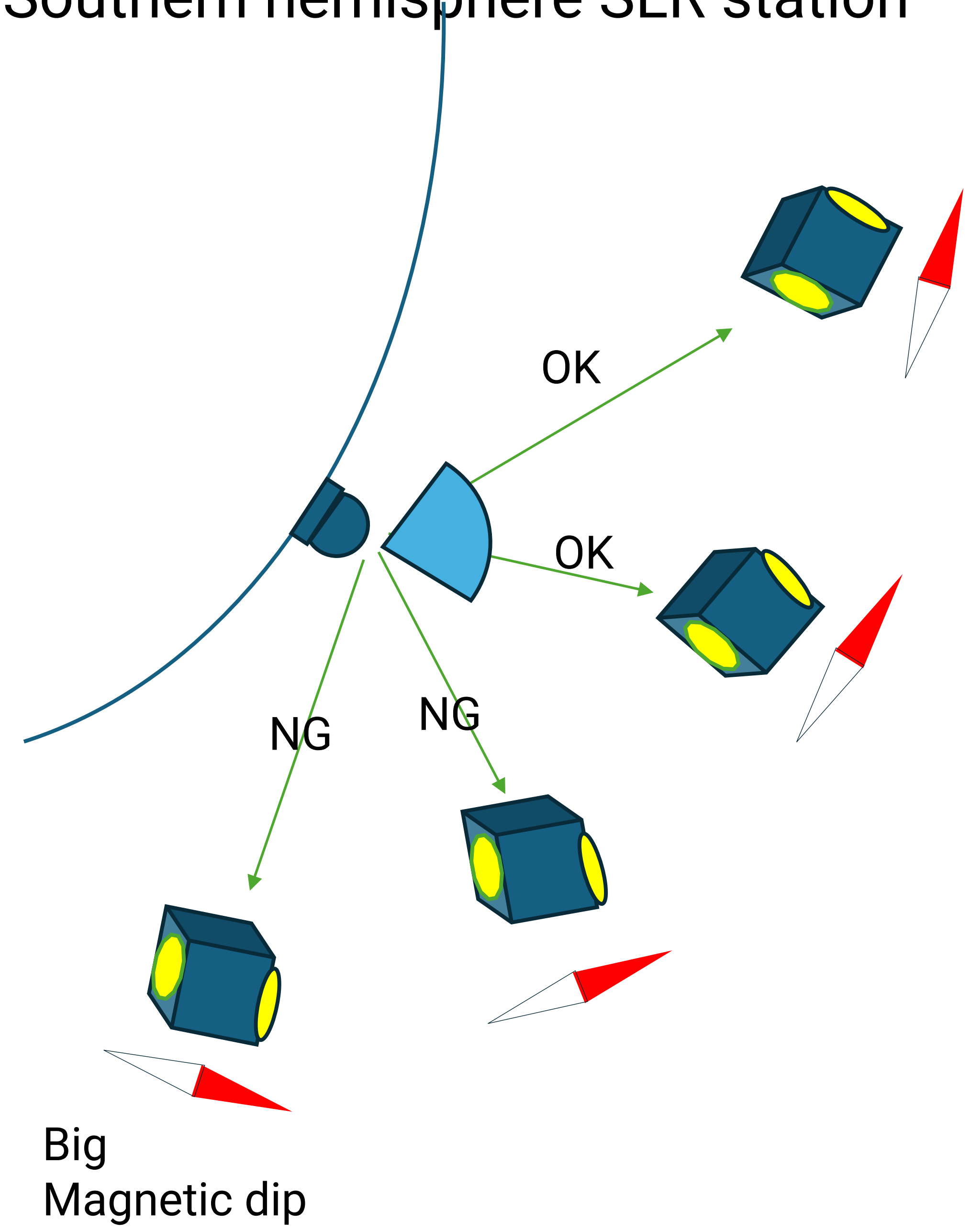
Middle latitude stations

northern hemisphere SLR station

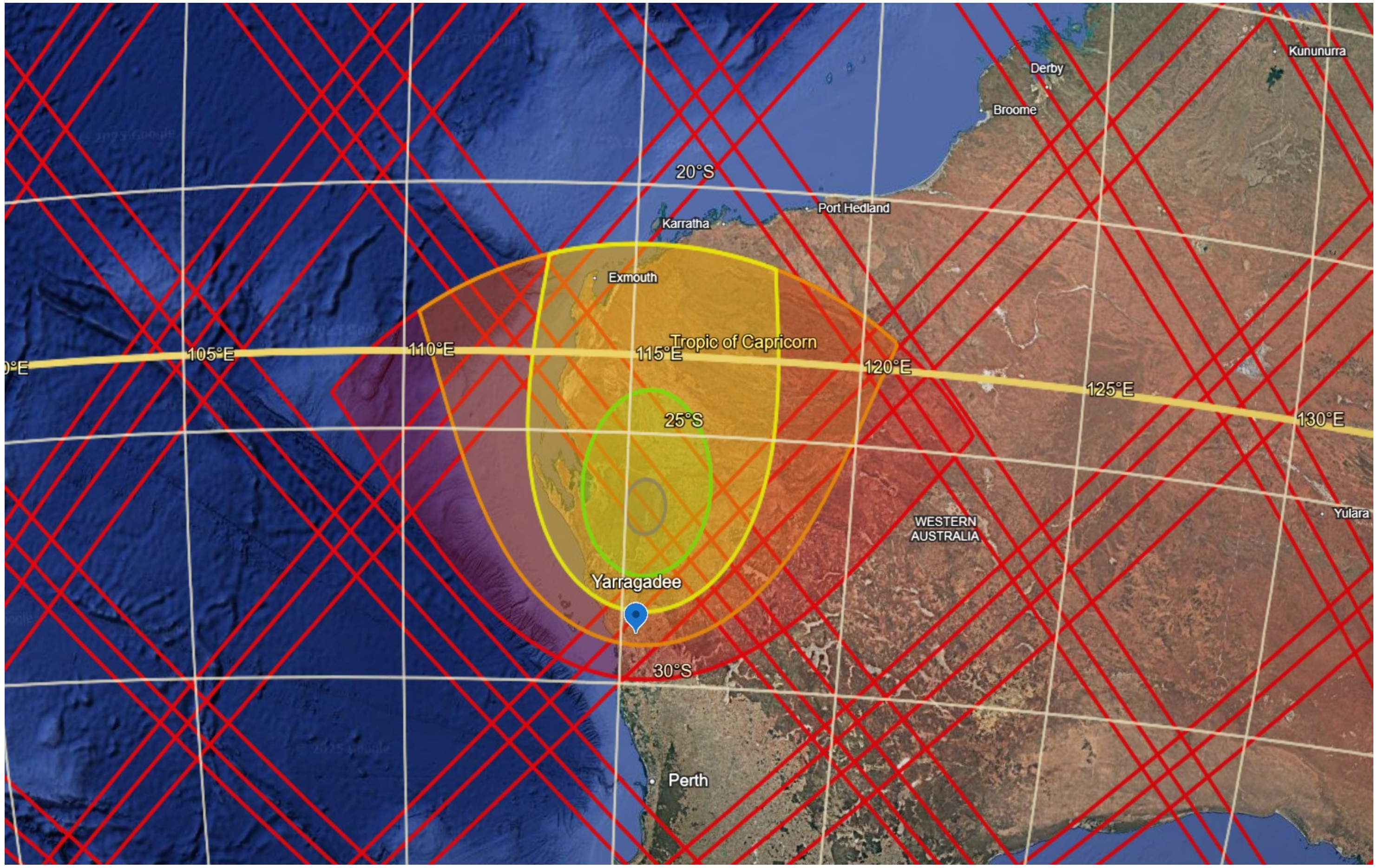




Southern hemisphere SLR station



Middle latitude stations



Restriction by NASA ISS team

NASA prohibits SLR observations for 10 days after a new spacecraft is launched toward the ISS or after it departs from the ISS.

The next SLR observation of the ekagaku1 satellite is on December 16.

Future Plam (Plan B)

Today – 2026/Jan End : JAXA will make CPF of TLE-65942 BOTAN

If No return
2026/Feb – Future : JAXA will make CPF of TLE-65941 YOTSUBA

Conclusion:

Even if the ekagaku1 satellite is visible, you will not be able to receive a return signal due to the relative positions of the SLR station and the ekagau1 satellite.

Northern Hemisphere SLR stations: You can observe the ekagaku1 satellite when it is located between your station's south to the zenith.
Southern Hemisphere SLR stations: You can observe the ekagaku1 satellite when it is located between your station's north to the zenith.

Currently, our guess is:
TLE-65941 Clover <-- TLE is correct
TLE-65942 BOTAN <-- TLE is misassigned. TLE gives name "ekagaku1" now.
TLE-65943 ekagaku1 <-- TLE is misassigned. TLE gives name "BOTAN" now.

If we receive an SLR response from TLE-65943, we plan to report the TLE misassignment to the SpaceTrack.org based on that evidence.

We apologize for putting you through this tedious observation, and we sincerely appreciate your cooperation.

Thank you Shinichi Nakamura

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Recent discussion topics of the ASC connected to NESC

ILRS core sites, pass performance criteria, satellite priorities, and FR/NP data submissions

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ILRS NESC, 11.12.2025, online

ILRS core sites

The current list of ILRS core sites should be updated to account for major updates of some stations, etc. The existing list was slightly modified in 2023 last (cf. right plot).

- The ASC initiated a task force to revisit the criteria (e.g., observation time span and coverage, discontinuities, stability and consistency of range biases). This task force should also
  - assess the current ILRS tracking network quality (performance/quantity, quality, etc.)
  - screen the combined weekly v280/v320 data to identify core stations
  - compile guidelines and a recommendation to GB (core site list + description how they had been identified)
  - Include information in new section in ILRS DHF

- Does anybody from NESC wants to join this task force?

  (current members: L. Geisser, V. Husson, D. Sarrocco, M. Bloßfeld)

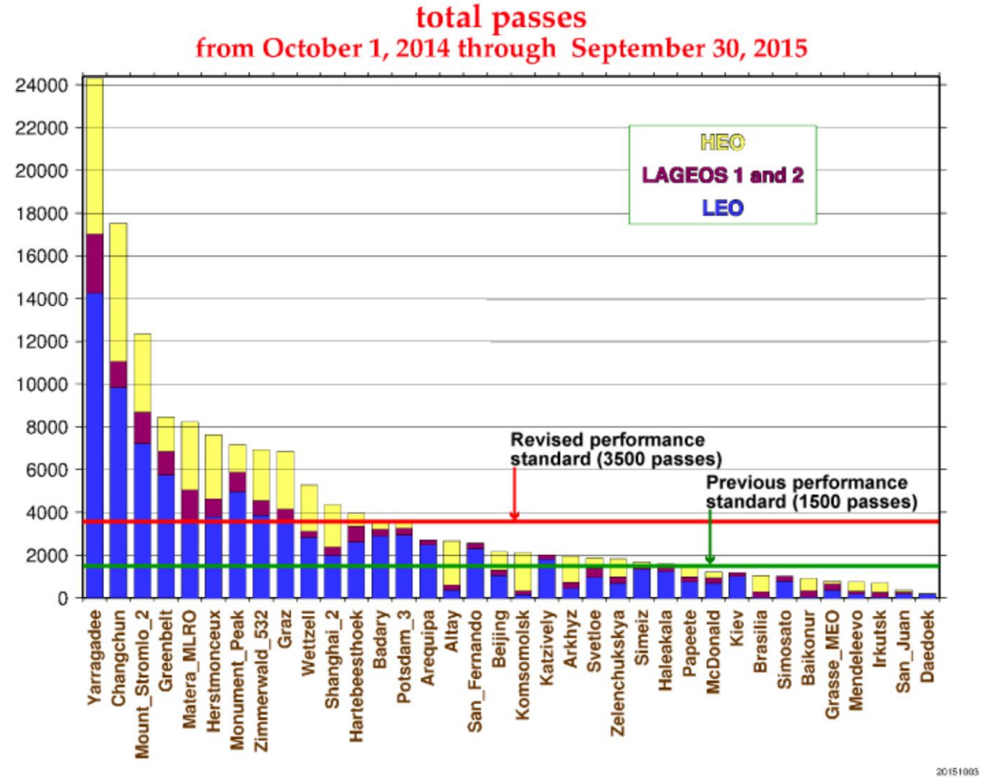
40442M006	7080	-7305.50000	17897.50000
50107M001	7090	-7670.50000	17897.50000
40451M105	7105	-6939.50000	17897.50000
40433M002	7109	-6939.50000	-731.50000
40497M001	7110	-6939.50000	3286.50000
40445M004	7119	4168.50000	17897.50000
40445M001	7210	-2160.50000	1825.50000
21611S001	7237	4382.50000	17897.50000
42202M003	7403	-3652.50000	365.50000
30302M003	7501	-0.50000	17897.50000
14001S007	7810	-730.50000	2960.50000
14001S001	7810	3022.50000	17897.50000
50119S003	7825	1460.50000	17897.50000
20101S001	7832	365.50000	17897.50000
14201S002	7834	-8766.50000	-2923.50000
10002S001	7835	-4109.50000	2190.50000
14106S009	7836	-2556.50000	1825.50000
21605S001	7837	-1095.50000	2190.50000
11001S002	7839	-6209.50000	17897.50000
13212S001	7840	-6209.50000	17897.50000
14106S011	7841	1491.50000	17897.50000
50119S001	7849	-730.50000	1459.50000
42202S001	7907	-8766.50000	-2558.50000
12734S001	7939	-6209.50000	364.50000
12734S008	7941	365.50000	17897.50000
14201S018	8834	-1340.50000	3336.50000

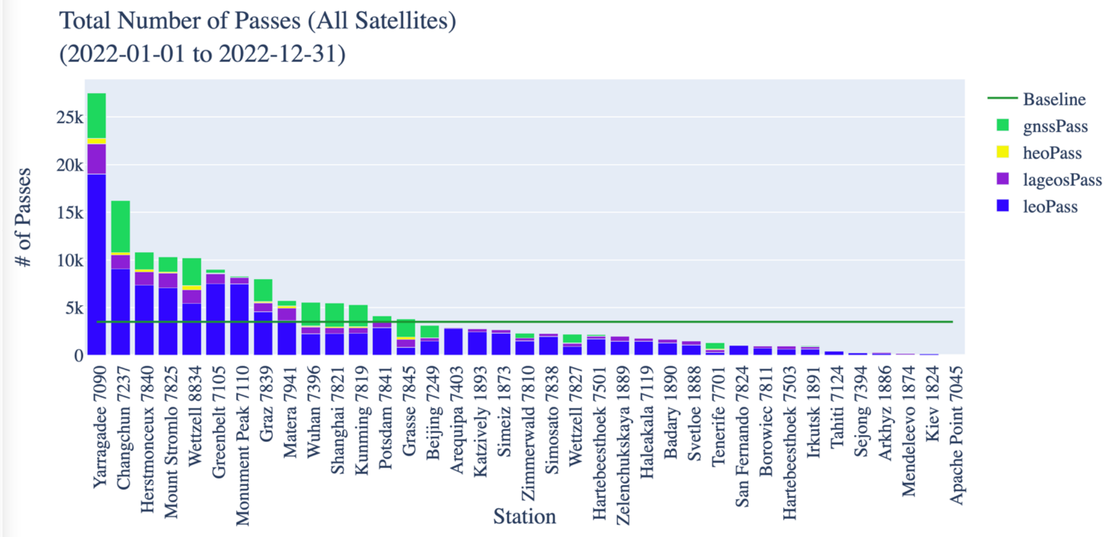
ILRS station pass performance criteria

- More and more satellites are in orbit which require SLR tracking!
- ILRS GB raised pass performance standards from 1500 passes (1996) to 3500 passes (2015)
- BUT: only 25% of stations reach these standards, i.e. contribute significantly to the TRF!

- Now, a raise to 4900 passes will be proposed to the GB
  - kHz laser systems, new generation of event timers, new stations, …

- What is the opinion of the NESC here?
- The ASC is thinking to assess the need how many passes are needed to obtain reliable/stable station coordinates (via simulations).





ILRS satellite priorities

The ILRS has ordered its tracking priority list according to satellite orbital parameters and special project needs.

- Priorities decrease with:
  - increasing orbital altitude, and
  - increasing orbital inclination (at a given altitude)
- Priority of some satellites may then be increased to intensify support for:
  - active missions (such as altimetry), special campaigns, or
  - post-launch intensive tracking phases, and
  - some slight reordering may be done to give higher priority to missions with increased importance to the analysis community.
- Stations may adjust priorities to accommodate local conditions such as system capabilities, weather, and special program interests.
- Unfortunately, very important satellites like LA-1/-2 are at place 24/25 → creates confusion, maybe also leads to less LA-1/-2 passes per station!
- The ASC discussed at its last meeting if one should define the priority list not based on height but category (e.g., high priority of ITRF satellites). What’s the NESC opinion on this?

Priority	Mission	ILRS Name	COSPAR ID	SIC	Sponsor	Altitude (km)	Inclination (degrees)	Comments
1	GRACE-FO-1/2	gracefo1 gracefo2	1804701 1804702	0123 0124	NASA JPL and the German Research Centre for Geosciences (GFZ)	500	89	1-month campaign
2	ICESat-2	icesat2	1807001	6873	NASA	496	92	Restricted tracking; authorization required
3	CryoSat-2	cryosat2	1001301	8006	ESA	450-720	92	
4	PAZ	paz	1802001	2501	HISDESAT	514	97.44	
5	TanDEM-X	tandemx	1003001	6202	Infoterra/ DLR/ GFZ/CSR	514	98	Tandem with TerraSAR-X
6	TerraSAR-X	terrasarx	0702601	6201	Infoterra/ DLR/ GFZ/CSR	514	97.44	Tandem with TanDEM-X
7	Sentinel-3B	sentinel3b	1803901	8011	ESA/ EUMETSAT	814.5	98.65	Restricted tracking; authorization required
8	Sentinel-3A	sentinel3a	1601101	8010	ESA/ EUMETSAT	814.5	98.65	Restricted tracking; authorization required
9	SWOT	swot	2217301	4381	NASA/CNES	857 then 890	77.6	
10	Swarm-A/C	swarma swarmc	1306702 1306703	8007 8009	ESA	460 530	88.35 88.95	
11	Swarm-B	swarmb	1306701	8008	ESA	460	88.35	
12	SARAL	saral	1300901	3201	CNES and ISRO	814	98.55	
13	HY-2D	hy2d	2104301	2211	China	971	66	
14	HY-2C	hy2c	2006601	2209	China	957	66	
15	HY-2B	hy2b	1808101	2208	China	971	98.55	
16	Sentinel-6A/ Jason-CSA	sentinel6a	2008601	4380	NASA, ESA, EUMETSAT, NOAA, CNES	1339.4-1355.9	66.042	
17	Jason-3	jason3	1600201	4379	NASA, CNES, Eumetsat, NOAA	1,336	66.0	
18	LARES-2	lares2	2208001	5988	ASI	5,899	70.16	
19	Larets	larets	0304206	5557	IPIE	691	98.204	
20	Starlette	starlette	7501001	1134	CNES	815-1,100	49.8	
21	Stella	stella	9306102	0643	CNES	815	98.6	
22	WESTPAC	westpac	9804305	8801	Western Pacific Laser Tracking Network	835	98	Resumed tracking on 2025-03-17
23	LARES	lares	1200601	5987	ASI	1,450	69.5	
24	LAGEOS-2	lageos2	9207002	5986	ASI/NASA	5,625	52.6	
25	LAGEOS-1	lageos1	7603901	1155	NASA	5,850	109.8	
26	Etalon-1	etalon1	8900103	0525	Russia	19,100	65.3	
27	Etalon-2	etalon2	8903903	4146	Russia	19,100	65.2	
28	Ajisai	ajisai	8606101	1500	JAXA	1,485	50	
29	IRNSS-1J	irnss1j	2307601	3310	ISRO	35,790	5	
30	GLONASS-141	glonass141	1908801	9141	Russia	19,140	65	
31	Galileo-102	galileo102	1106002	7102	ESA	23,220	56	

ILRS FR/NP data submission

Within the analysis of SLR observations, the range bias is highly correlated with the satellite target signature, which itself depends partly on the applied algorithm to compute a NP at each station

- Based on a former request (NESC/ASC?), the ILRS network stations should upload the computed NPs as well as the respective FR data to the ILRS data portals (format: CRDv2)
- Up to now, stations upload “only” the clipped FR data used to generate the NP to EDC/CDDIS

- With this data set, we cannot recompute the NP using other algorithms which means we cannot assess the impact of the NP algorithm on the target signature model (red arrow)
- The ASC wants to approach the stations (via CB) to stress the need for publishing the unclipped FR data again (with the help of NESC?)
- Afterwards, an ASC task force might investigate the impact of a commonly applied NP algorithm for analysis products (and models)

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Topics of Interest (include but are not limited to)

- Recent Progress in ILRS
- SLR for Geodesy and Geophysics
- Station Operations and Upgrades
- Lunar Laser Ranging and Future Missions
- Space Debris Laser Ranging
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