# SUB-CM RANGING WITH THE miniSLR®

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DLR

# Project miniSLR ®

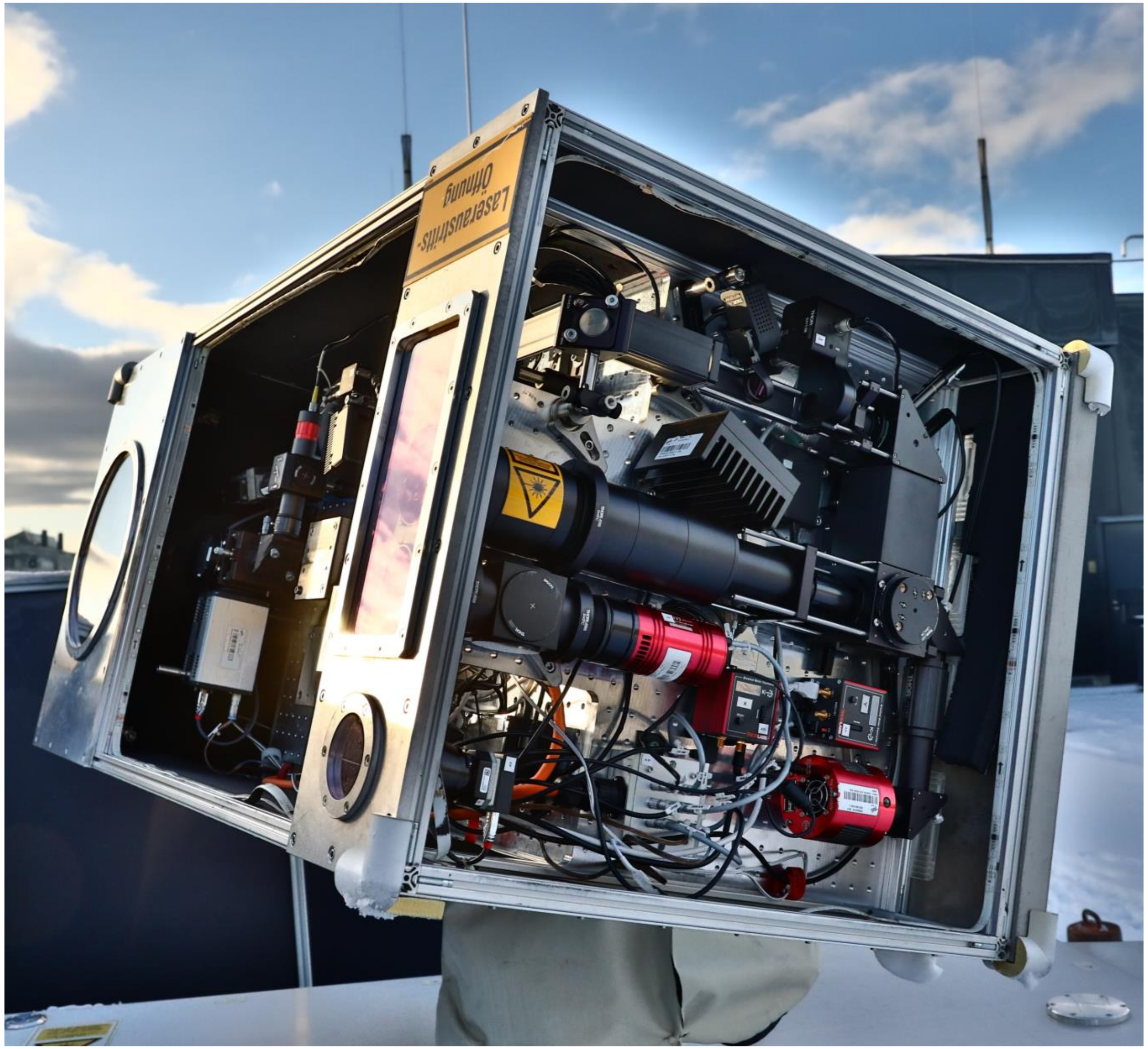
- Location: Stuttgart, Germany
- Ranging measurements to almost all cooperative targets in LEO possible (closed loop)
- Some GNSS successful (Cosmos 2024)
- Range and stability still need improvement
- Engineering station at ILRS with uploads to EDC server
- Technology Transfer to DiGOS complete


2021
Mistral 260
Wissen für Morgen


2023
Laseraustritts-
Öffnung
UC1

# Technical Specifications

- Small footprint: 2 m x 1.6 m x 2 m
- Mass: 600 kg
- Fully sealed, waterproof and air conditioned
- Telescope: 20 cm
- Emitter: 7.5 cm
- Laser Standa MOPA-4
- Single Photon Detektor: Aurea OEM
- Multiple cameras for adjusting, aircraft detection and closed loop tracking



# New laser: Standa MoPa 4

- Very compact laser source, especially laser head
- Wavelength: 1064 nm
- Pulse duration: 500 ps
- Pulse energy: 100 µJ
- Repetition rate: 50 kHz

# Validation Precision

## Single Shot Precision

| Component | Symbol | Value |
|---|---|---|
| Laser | $\sigma_L$ | 210 ps |
| Start detektor | $\sigma_{D_1}$ | 40 ps |
| Stop detektor | $\sigma_{D_2}$ | 150 ps |
| Eventtimer | $\sigma_{ET}$ | 9 ps |

$$\sigma_{single} = \sqrt{\sigma_L^2 + \sigma_{D_1}^2 + \sigma_{D_2}^2 + \sigma_{ET}^2} = 261\,ps \triangleq 39\,mm$$

## Normal Point Precision

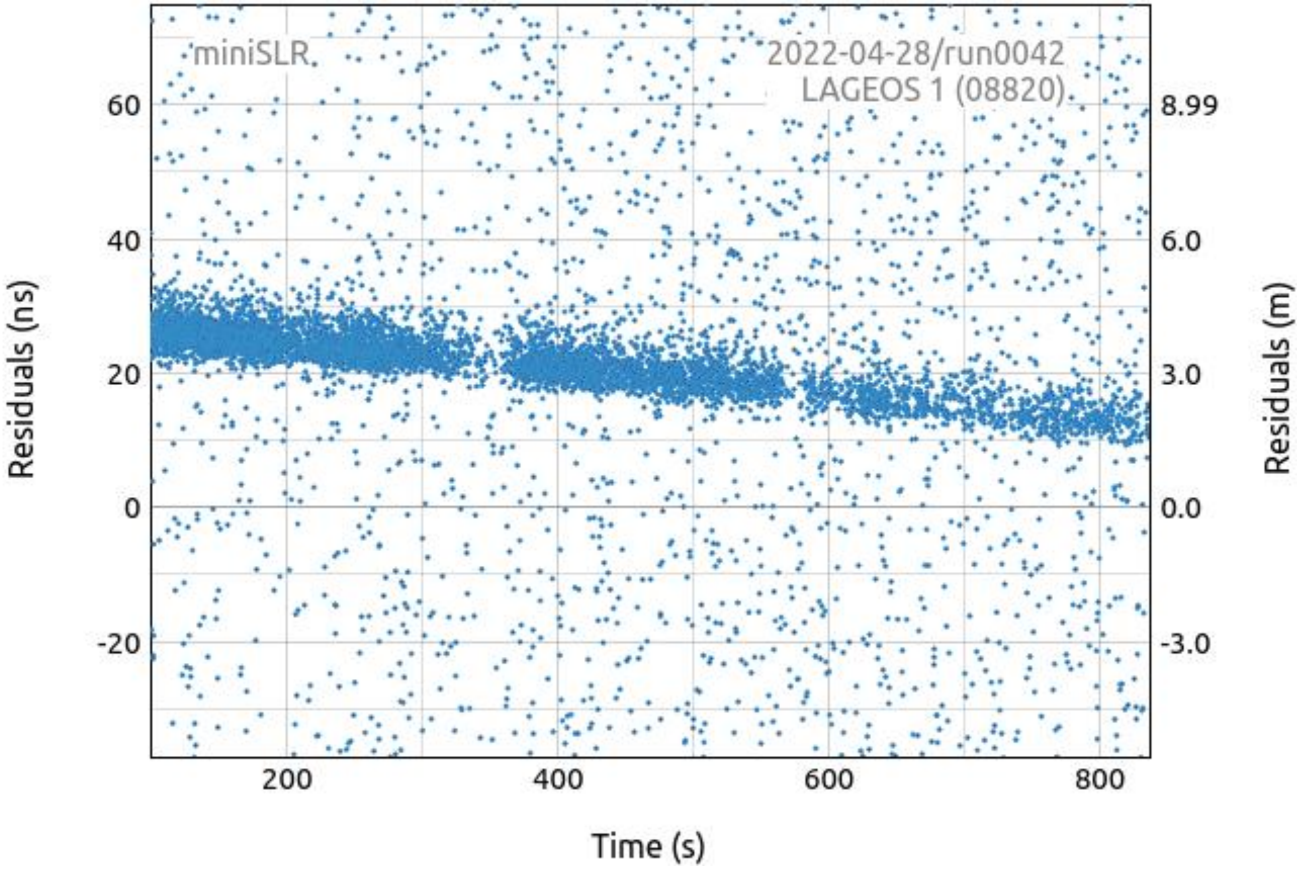
$$\sigma_{NPT} = \frac{\sigma_{single}}{\sqrt{N}}$$

| Satellite Type | Goal | Returns needed / NPT |
|---|---|---|
| GNSS | 35 ps / 5 mm | 55 |
| other | 7 ps / 1 mm | ~1500 |

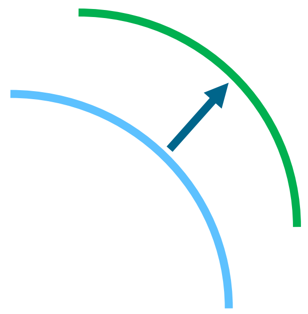
# Data accuracy, first estimation

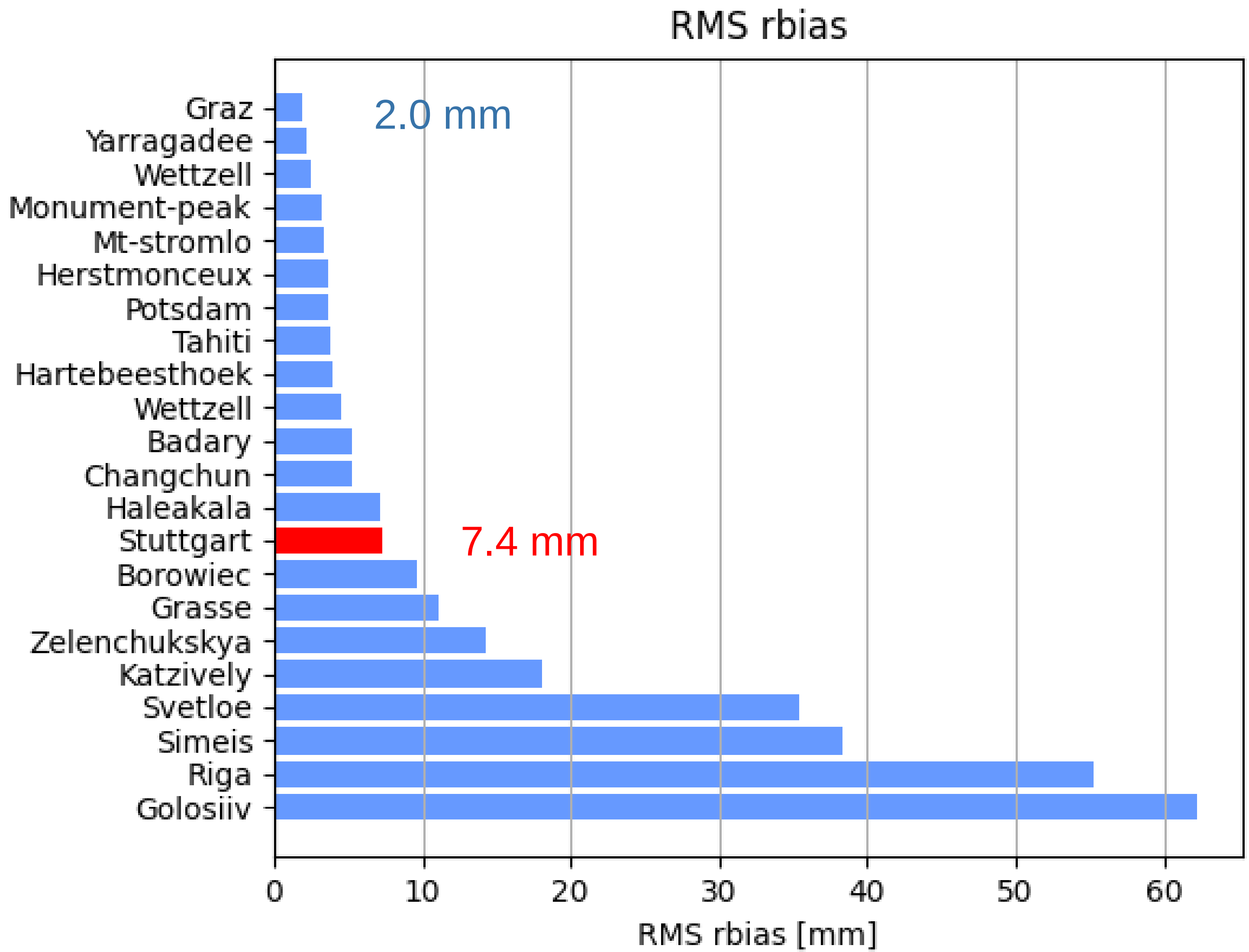
Analysis by Toshimichi Otsubo (rapid quality control software) thanks!

- Data from February 7-13
- Lageos 1 & 2, Stella, Ajisai, Lares
- 15 passes, 163 normal points

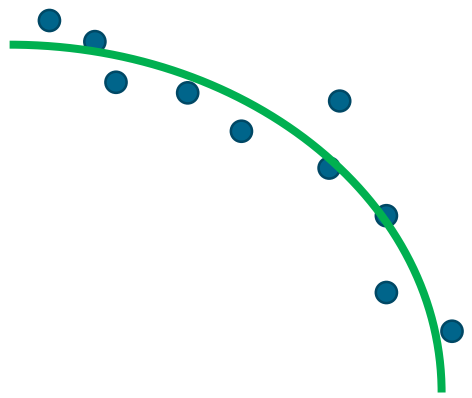


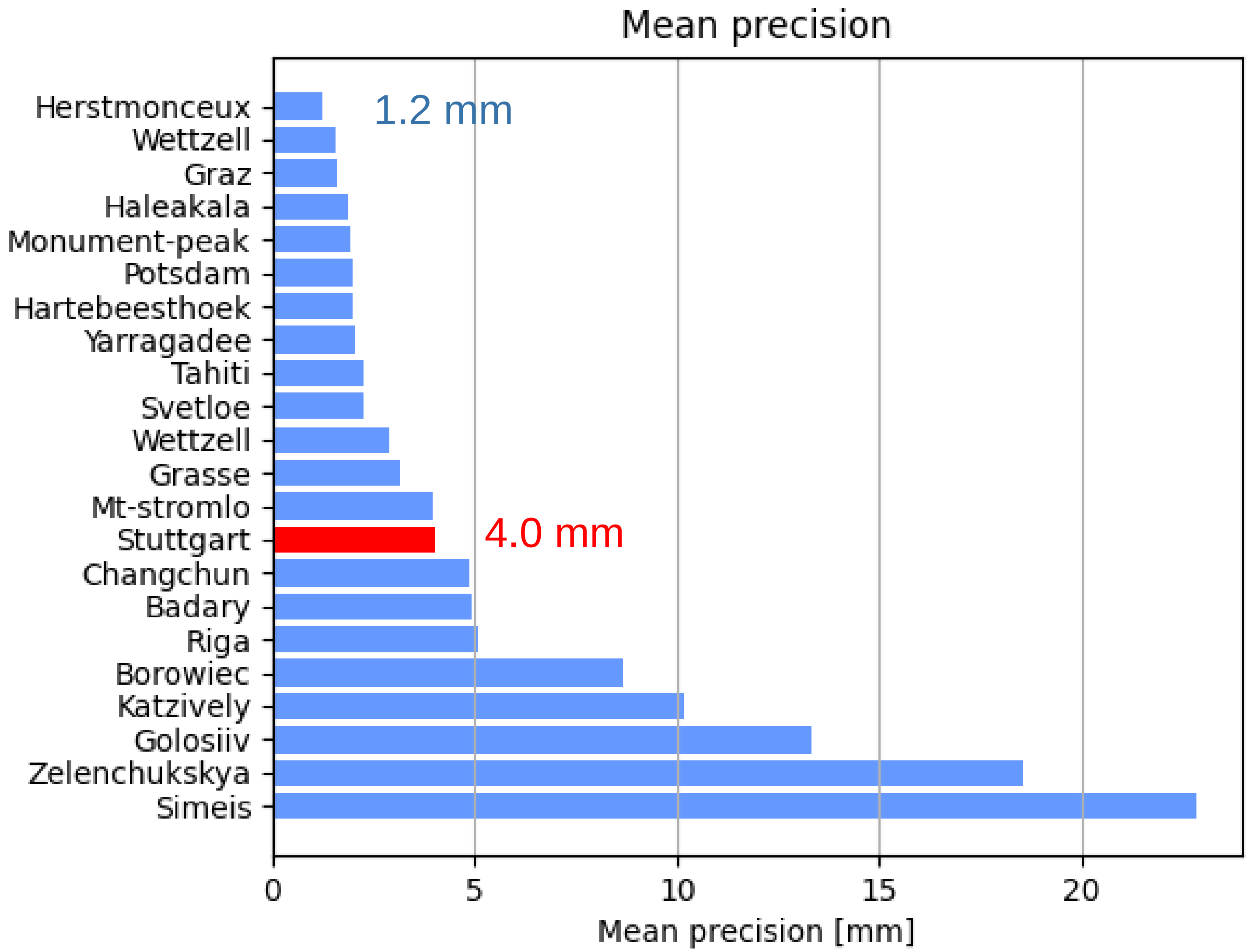
# RMS Pass Range Bias





# Normal Point Precision





# Where to go?

- Daylight Ranging
- Satellite identification with polarimetric ranging
- Lightcurves (investigation of rotational properties)

# Current Publications


1. Riede, W.; Hampf, D.; Bartels, N. (2023) *Satellite retroreflectors and laser ranging for space traffic management.* UN COPUOS 2023 - Session of the Scientific and Technical Subcommittee, 9. Feb. 2023, Wien, Österreich.
2. Bartels, N.; Hampf, D.; Heidenreich, B.; Niebler, F.; Vogel, M.; Riede, W. (2022) *Polarimetric satellite laser ranging.* 22nd International Workshop on Laser Ranging, 7.-11. Nov. 2022, Yebes, Spanien
3. Hampf, D.; Niebler, F.; Meyer, T.; Riede, W. (2023), The miniSLR: A low-budget, high-performance satellite laser ranging ground station, submitted to Journal of Geodesy, [2306.13741] The miniSLR: A low-budget, high-performance satellite laser ranging ground station (arxiv.org)
4. Hampf, D.; Niebler, F.; Bartels, N., Riede, W. (2023) *The miniSLR: A low-cost, high-performance laser ranging system for the ILRS.* International Workshop on Laser Ranging (IWLR), 7.-11. November 2022, Yebes, Spanien.
5. Niebler, F.; Wagner, P.; Hampf, D.; Bartels, N.; Meyer, T.; Schafer, E.; Riede, W. (2022) *Compact Ground Station for Satellite Laser Ranging and Identification.* 73rd International Astronautical Congress (IAC), 18.-22. Sept. 2022, Paris, Frankreich.
6. Meyer, T. (2022) *Analysis of the performance parameters of Satellite Laser Ranging (SLR) systems based on the link budget under exemplary inclusion of the miniSLR system.* Masterarbeit, University of Stuttgart.