Installation and first results of the Yebes Laser Ranging Station (YLARA)

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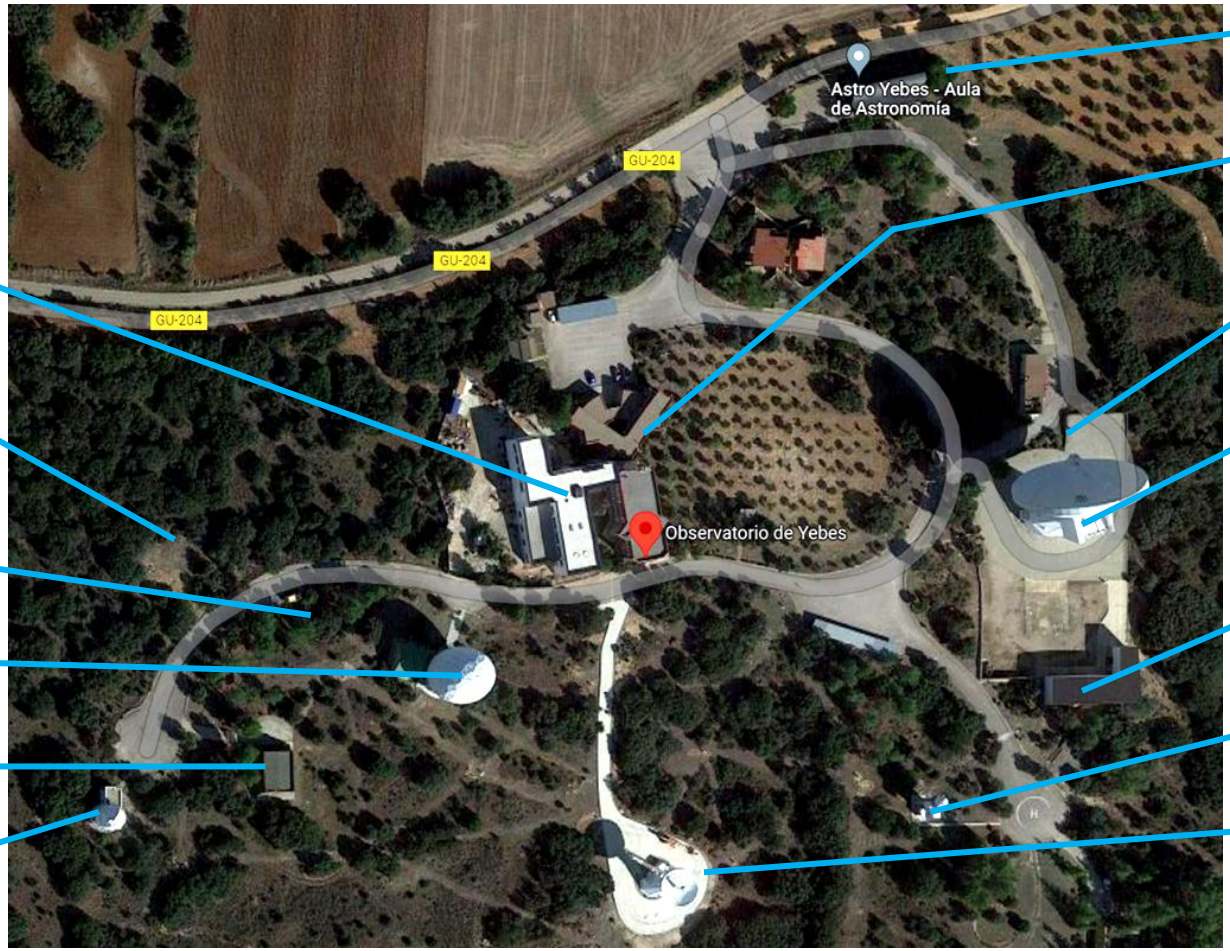
(1) Yebes Observatory (IGN/CNIG), Yebes, Spain; (2) DiGOS Potsdam GmbH, Potsdam, Germany

2023 Virtual International Workshop on Laser Ranging

17-10-2023

Yebes towards the GGOS Core Site



Office buildings, laboratories and workshops

Yebes Laser Ranging (YLARA) (finalizing commissioning)

Meteo sensors

14 m RT

Gravimetry

Astrograph (2x40 cm)

Outreach pavilion

GNSS Receivers (x3)

Local tie (20 pillars) +2/3 more for SLR

40 m Radio Telescope + Hydrogen masers room

Anechoic Chamber

Solar Tower

13.2 m VGOS Radio Telescope (2013) RAEGE Project

YLARA Station Objetives

Turning Yebes into a Geodetic Fundamental Station

- Fulfilling the requirements of the GGOS project

Observations to satellites equipped with retro-reflectors (mainly geodetic satellites and GNSS)

- Contributing to the ILRS network
- Observations at 532 nm and 1064 nm

active in progress

https://ggos.org/item/ggos-core-sites/

Future upgrades or new applications implementation

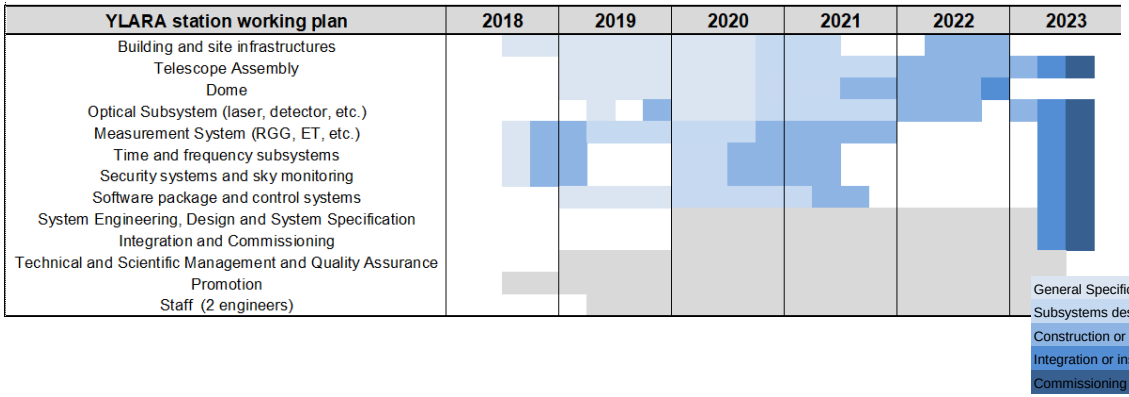
- Space debris observations (in progress)
- Light curve detection (future)
- Optical communications (under study)

Project Development

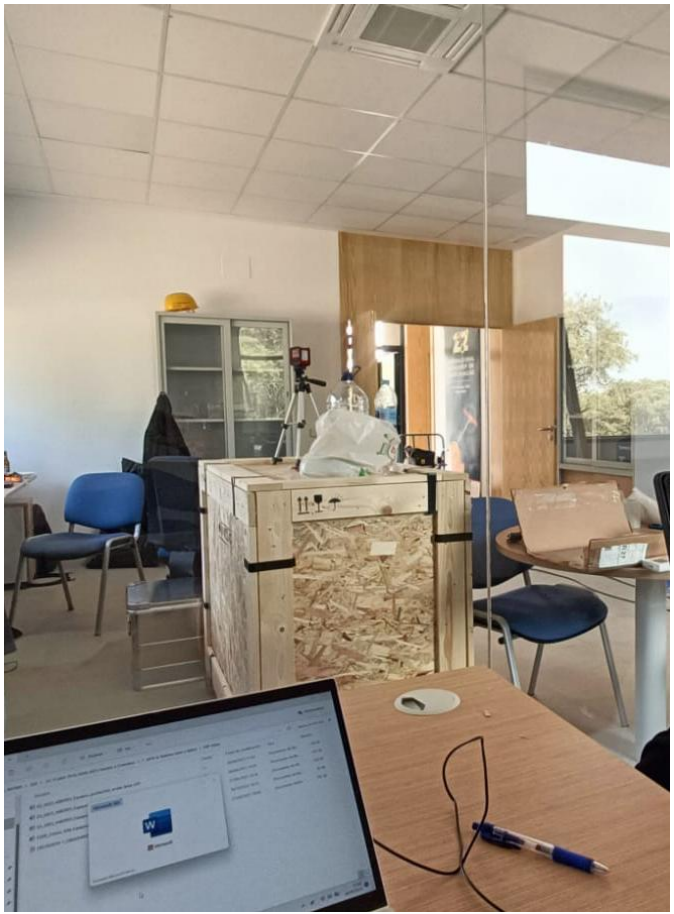
YLARA building, constructed from May to November 2022

Main Milestones

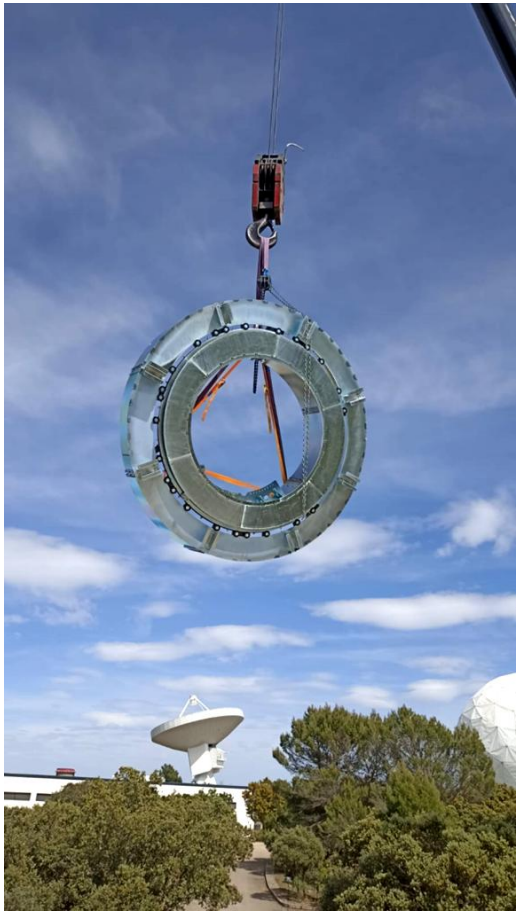
- ERDF for YDALGO Operation approval → January 2018
- General specifications definition → 2018-2019
- Turnkey contract TTI/Digos, Kick off → October 2020
- Subsystems design and construction → 2021-2022
- Building construction and dome installation → Autumn 2022
- Subsystems installation and integration on site → Spring 2023
- Commissioning → July - October 2023

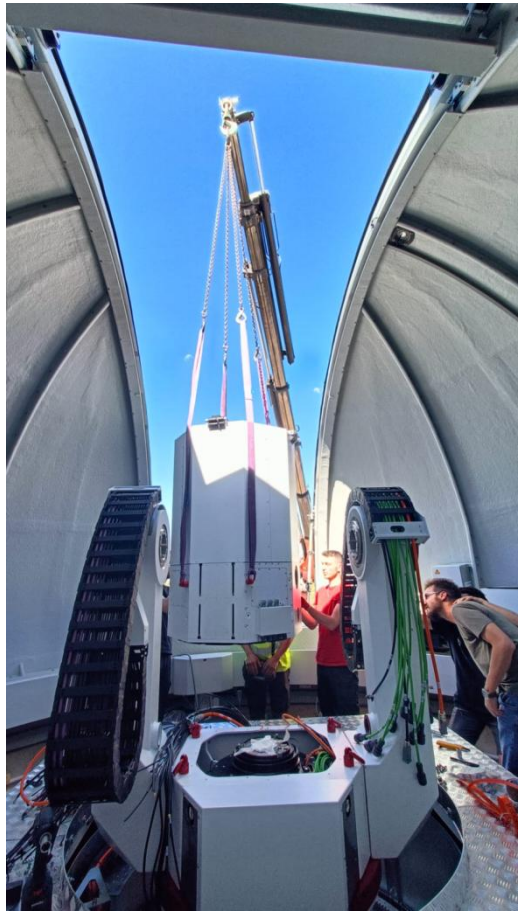


Subsystems installation and integration on site



Subsystems installation and integration on site



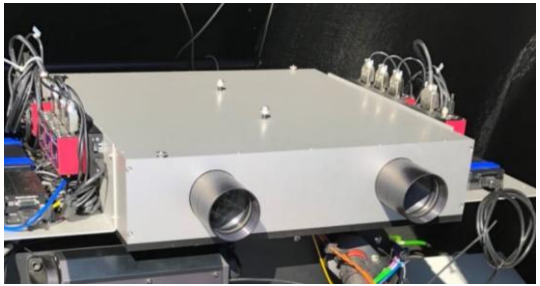


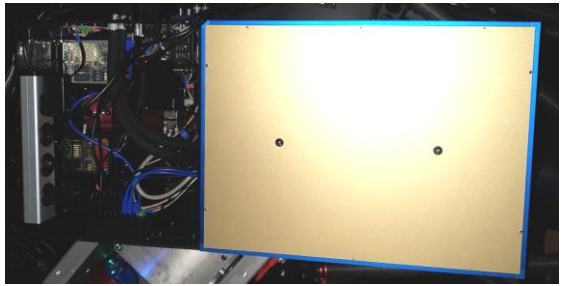
Telescope assembly installation: cable wrap, mount and telescope receiver (from left to right)

System features

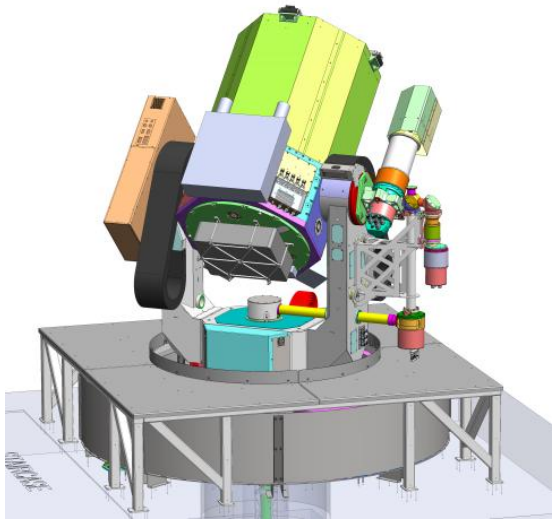
Customized RC700 model by Officina Stellare

- M1 diameter: 700 mm
- 3 Nasmyth foci
- Operation rotation range on azimuth: -270º/+270º
- Atl-Azimuth Mount. Slew rate: 12°/s for Az and El
- Transmission path: coudé path + beam expander





Laser and Detector packages. Subsystem designed and integrated by IWF-Graz



Telescope Assembly Overview (Officina Stellare)

Piggy-back configuration

- Laser package mounted directly on top of the main mirror cell
- Detector package mounted directly on the first Nasmyth focus

Coudé Focus

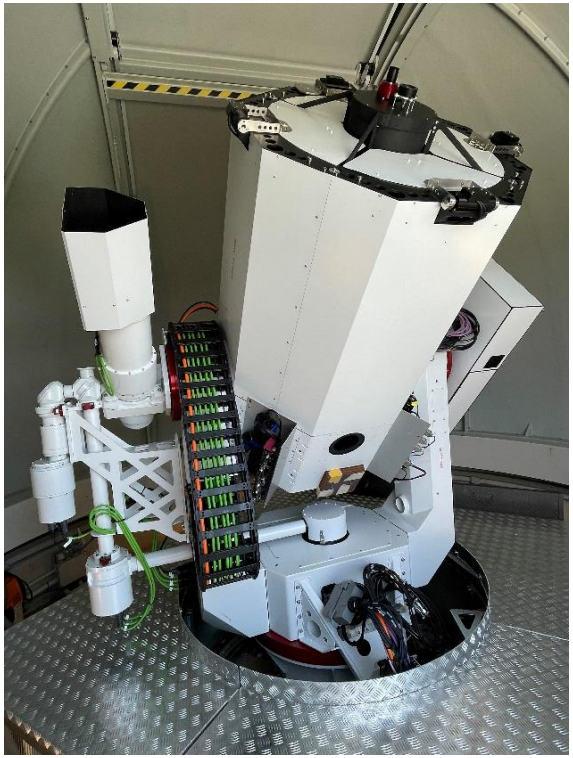
- Laser installation in a conditioned room, transmitting the pulses through the Coudé path

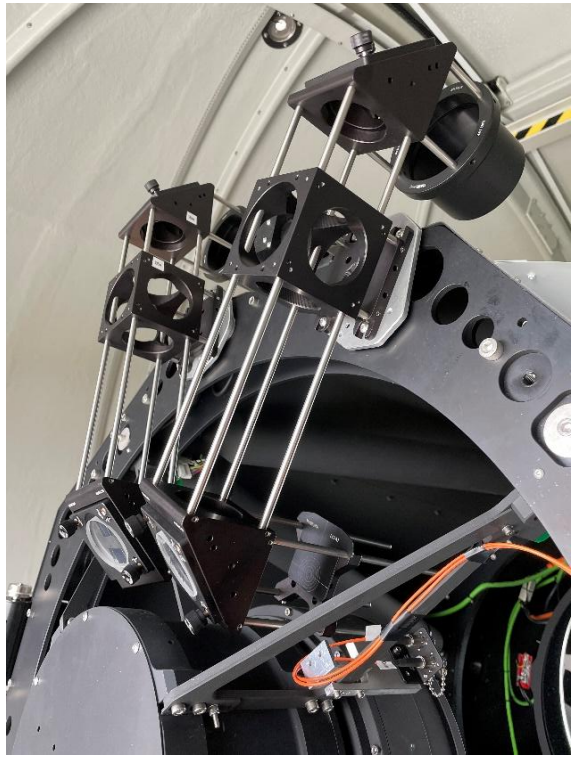
Model	Compiler Compact Passat
Pulse Repetition rate	1000 Hz (adjustable)
Energy per pulse	355 µJ avg @ 532 nm 543 µJ avg @ 1064 nm
Pulse width	7 ps @ 532 nm 8,5 ps @ 1064 nm

Detector	λ	Diameter	QE @ λ
C-SPAD	532 nm	200 µm	> 40 %
IR-SPAD	1064 nm	80 µm	max 30 %

System features

Coudé path transmitter telescope, receiver telescope, detector package and laser package



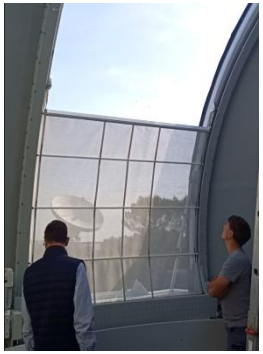


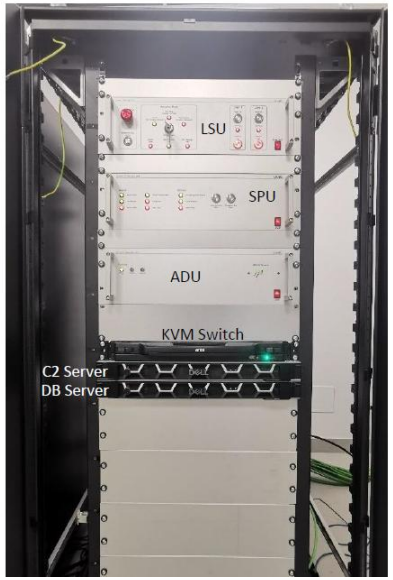
Fiber calibration
with mountable external target

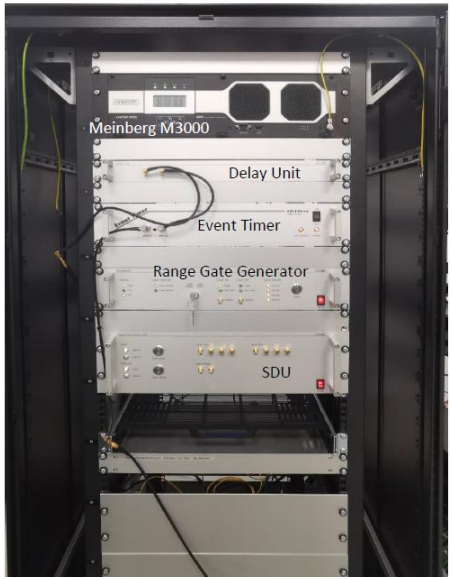
System features

Baader dome

- 5,3 m diameter
- Slit-type: horizontal lower flap and shutter + solar shield protection
- Installed October 27th, 2022







Racks installed in the Coudé room

Rack 1

- Laser Safety Unit, SLU
- Station Protection Unit, SPU
- Aircraft Detection Unit (ADU)
- Command & Control (C2) & Database (DB) Servers

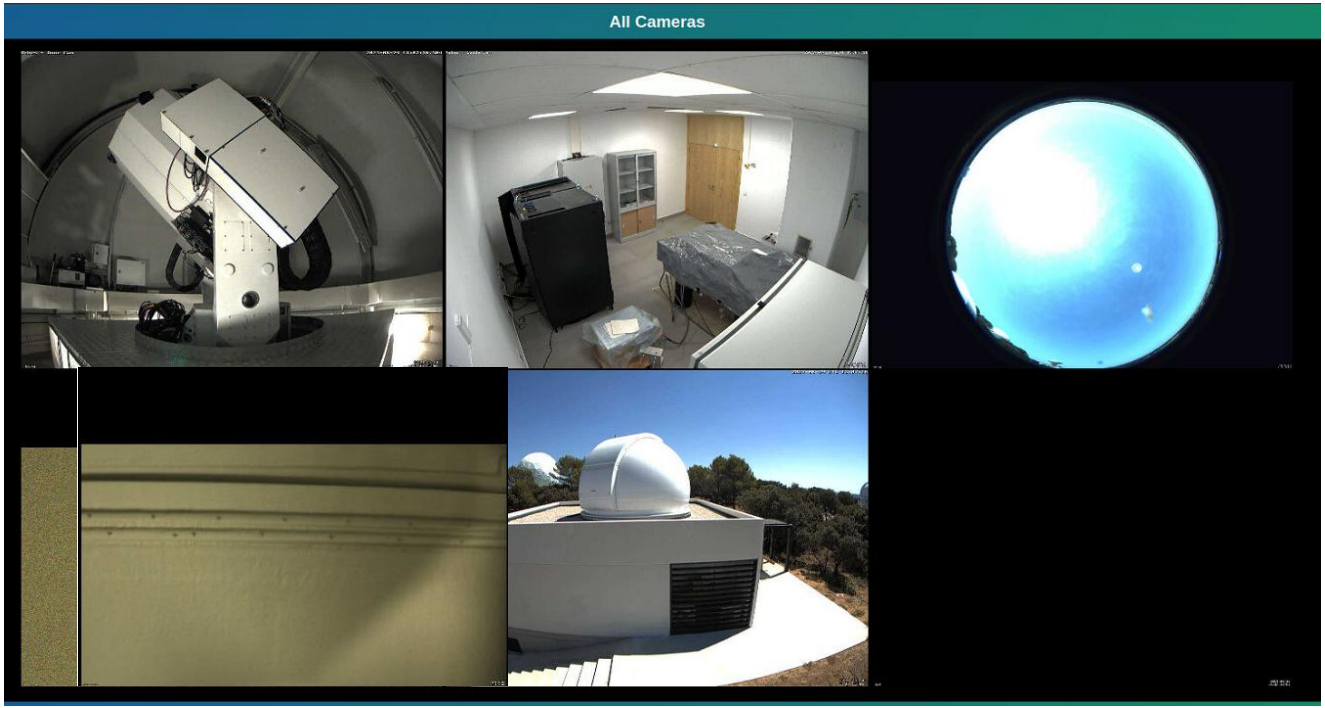
Rack 2

- Lantime M3000 + Timing Antenna
- Riga Event timer A033-ET/USB
- Range Gate Generator, RGG
- Signal Distribution Unit, SDU

System features

Meteorological mast + Laser Safety Subsystems (aircraft safety)

- Temperature, humidity and pressure sensors, rain sensor ON/OFF, cloud and wind speed sensor
- ADS-B and FLARM receivers, OMEA 8C all sky camera

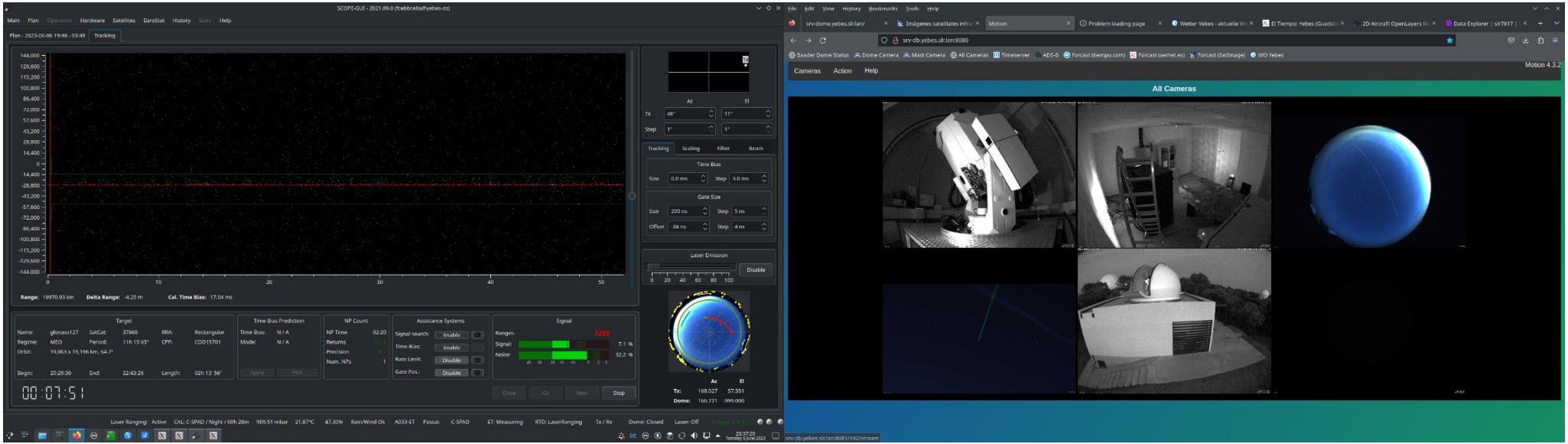


Complete monitoring of all relevant parts (TA, Coudé room, Allsky, Inbeam, Station, Satellite Camera)

System features

SCOPE - Centralized complete station operation, control, monitoring, data analysis and processing

- All items integrated via a modular platform with intuitive and modern IFs (SCOPE GUI, Motion, Grafana, …)
- The full station can be controlled completely via one PC and even just one screen, both locally or remotely
- Is running in Potsdam, Tenerife, Tsukuba and now also Yebes



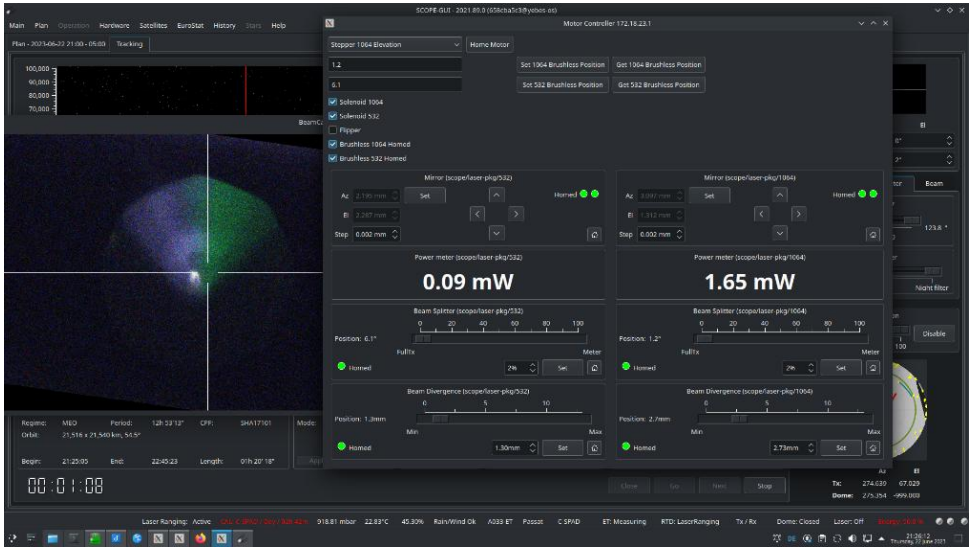
Satellite tracking in SCOPE GUI with surveillance camera IF in browser (Developed by DIGOS)

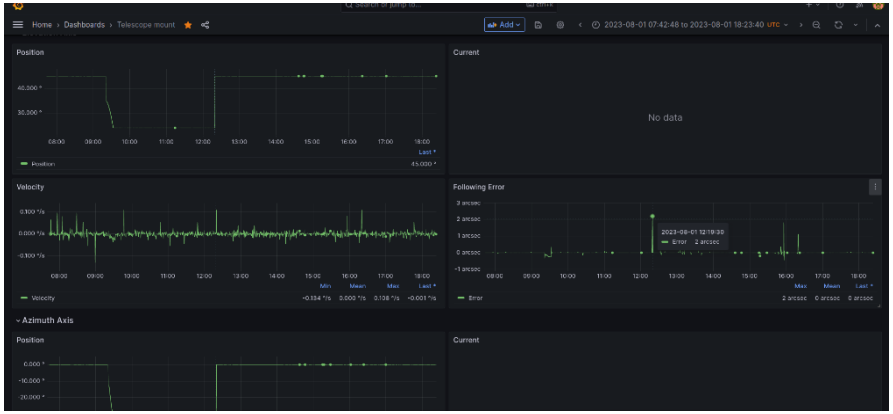
System features

End to end fully integrated SW and HW solutions

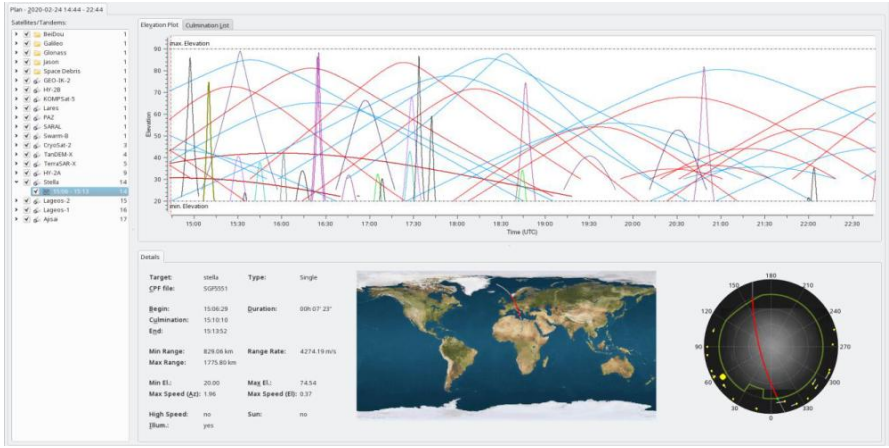
- Complete configuration, adjustment, alignment, surveillance as well as monitoring possible

Laser and alignment control IFs and camera showing the 532 nm and 1064 nm laser beam as well as the satellite



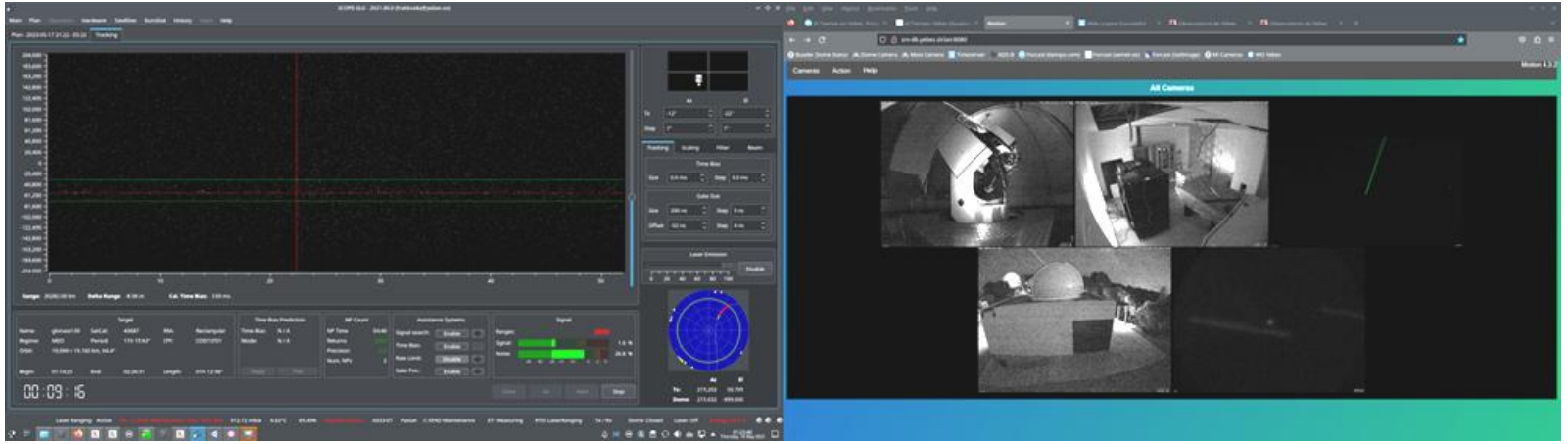


Monitoring database and visualization IF

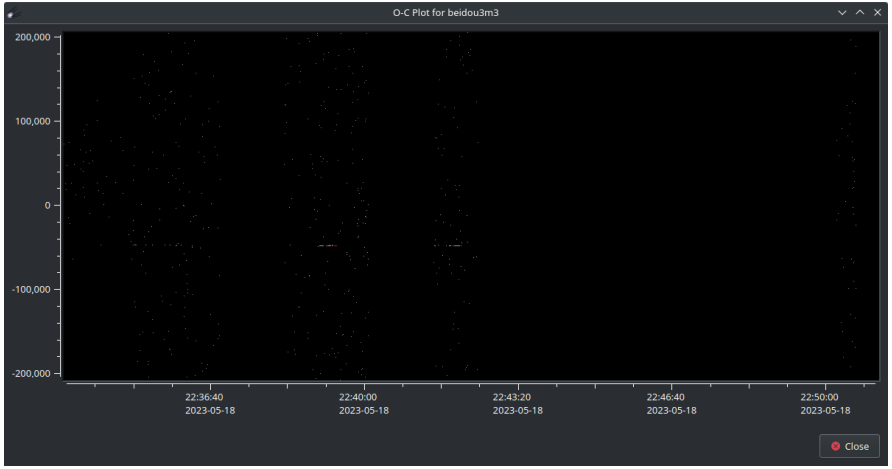


SCOPE screenshot, visible passes for 8 hours

May18th, 2023 → First SLR Observation



532 nm: GLO139 2023-05-18, 00:24 UTC



1064 nm: Beidou 3M3
18-05-2023, 22:30 UTC
(short pass due to weather)

Data collected for station commissioning

94 passes in total from 18-05-2023 until 31-07-2023

Calibration statistics

- Calibration history was stable
- One offset in 1064 nm corrected, now monitoring
- 532 nm calibration RMS = ~ 25 ps
- 1064 nm calibration RMS = ~ 21 ps

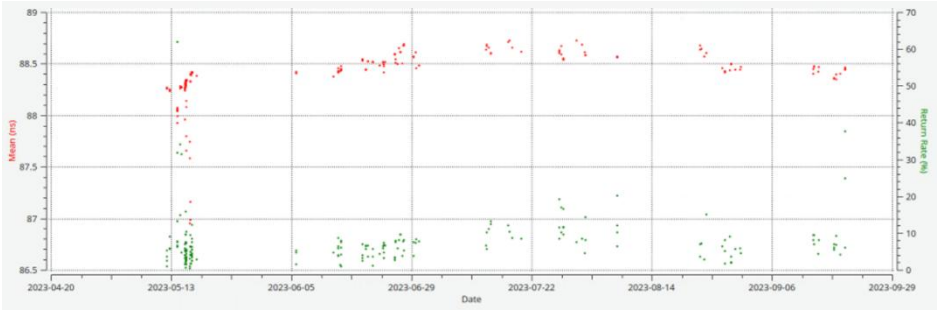
λ	LEO	Lageos	Etalon	GNSS	IRNSS	Total
0532	9	12	4	23	0	48
1064	11	21	3	9	2	46
Both	20	33	7	32	2	**94**

Number of passes collected in the different satellite classes

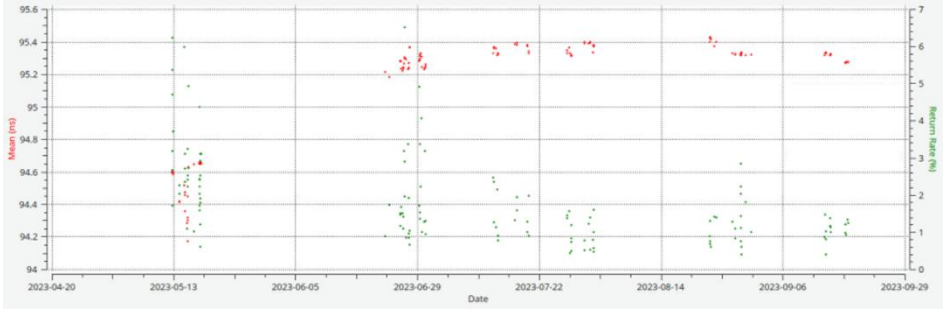
Lageos-1/2 , Lares-1/2 data statistics for 23 of the 33 collected passes, on average

- FR data RMS = 5.79 mm
- NP data RMS = 0.26 mm

532 nm calibration history during Commissioning



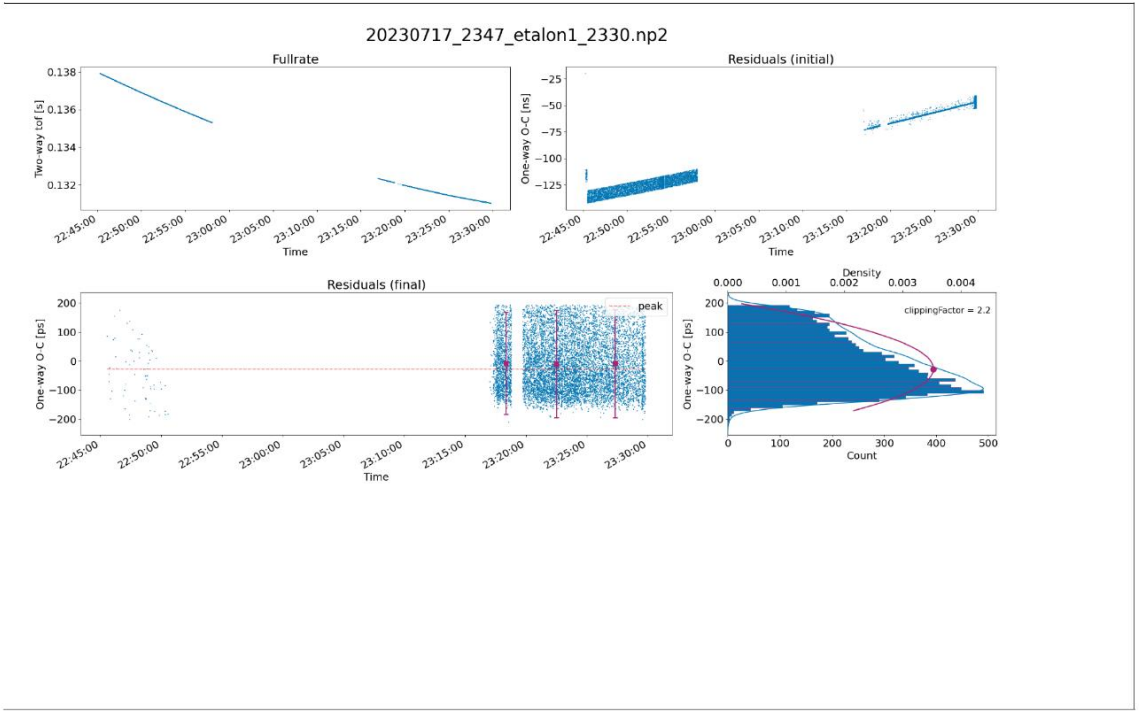
1064 nm calibration history during Commissioning



Some examples

Etalon 1 in 532 nm from 17-07-2023 23:47 UTC

- 9758 FR returns with a 27 mm RMS formed into 3 NPs with 0.51 mm RMS



TARGET	
etalon1	
WAVELENGTH (nm)	
532.0	

EVALUATION	
Total Returns	18714
FR Obs.	9758
Num. NPTs	3
Obs. per NP	3252.67
Stderr (mm)	0.51
RMS (mm)	27.28
RMS w/o cal	23.53
Baseline RMS	30.93
Baseline STD	2.67
TB (ms)	2.02
RB (m)	-3.37

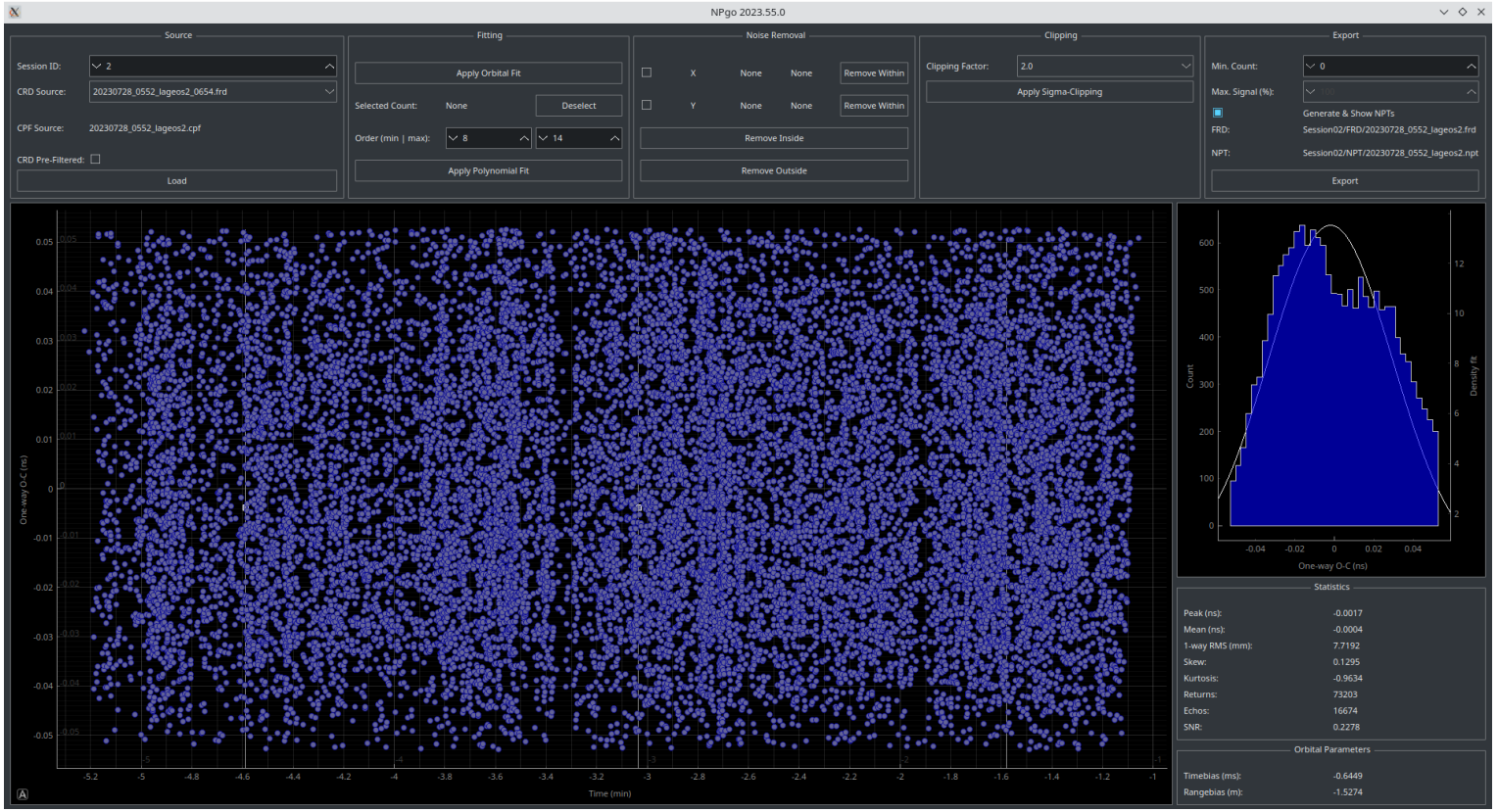
METEO	
Temp. (℃)	29.0
Hum. (%)	22.8
Press. (mbar)	914.2

NPs formed with automatic DiGOS NPgo module

Some examples

Lageos 2 in 1064 nm from 28-07-2023 05:52 UTC

- 16674 FR returns with 7.72 mm RMS formed into 3 NPs at an average return rate of ~ 7%

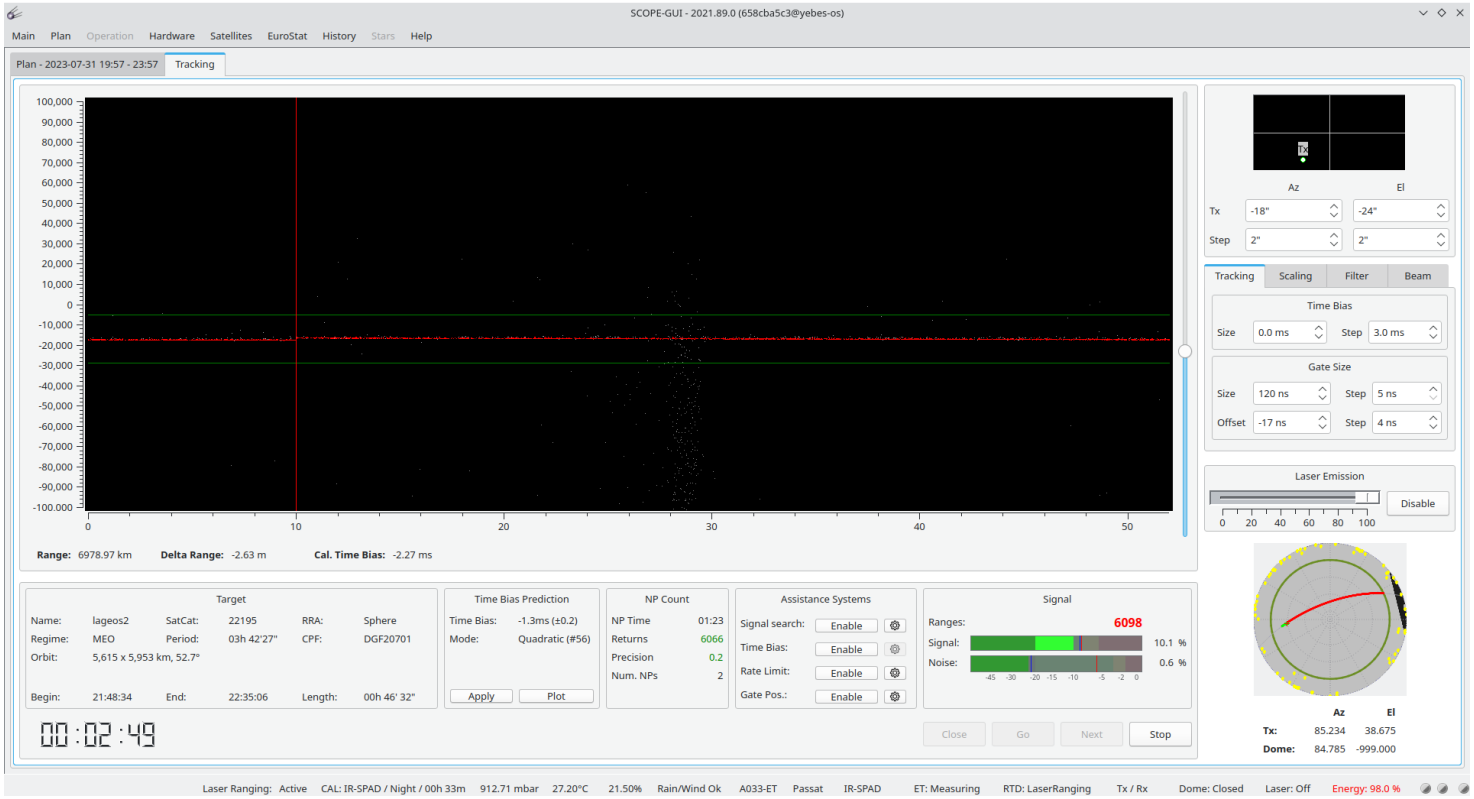


NPs formed with manual DiGOS NPgo module

Some examples

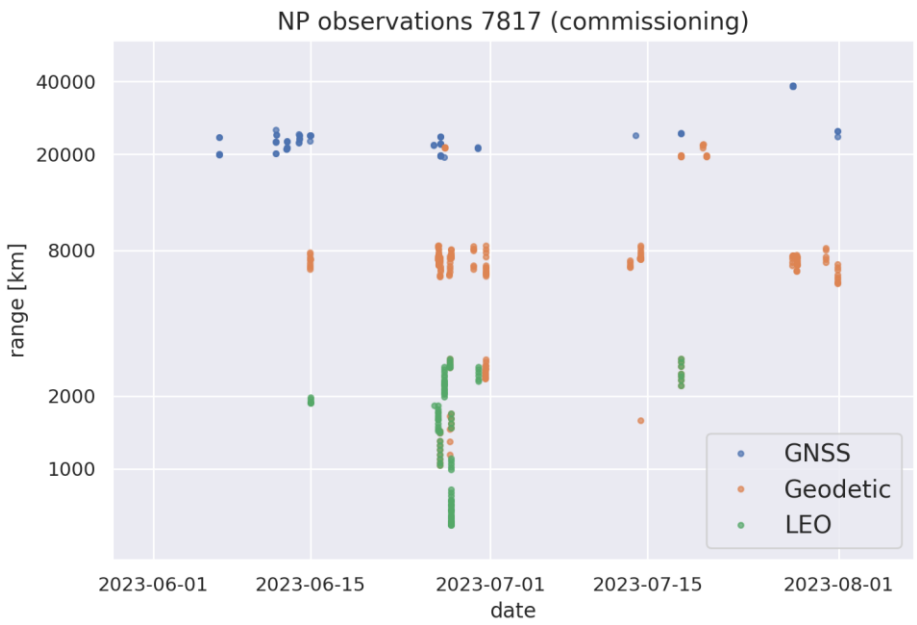
Lageos 2 in 1064 nm from 31-07-2023 21:50 UTC

- 6066 FR returns in 83s formed into 1 NP at return rate of 10% instantaneous and 7% average at 38° elevation

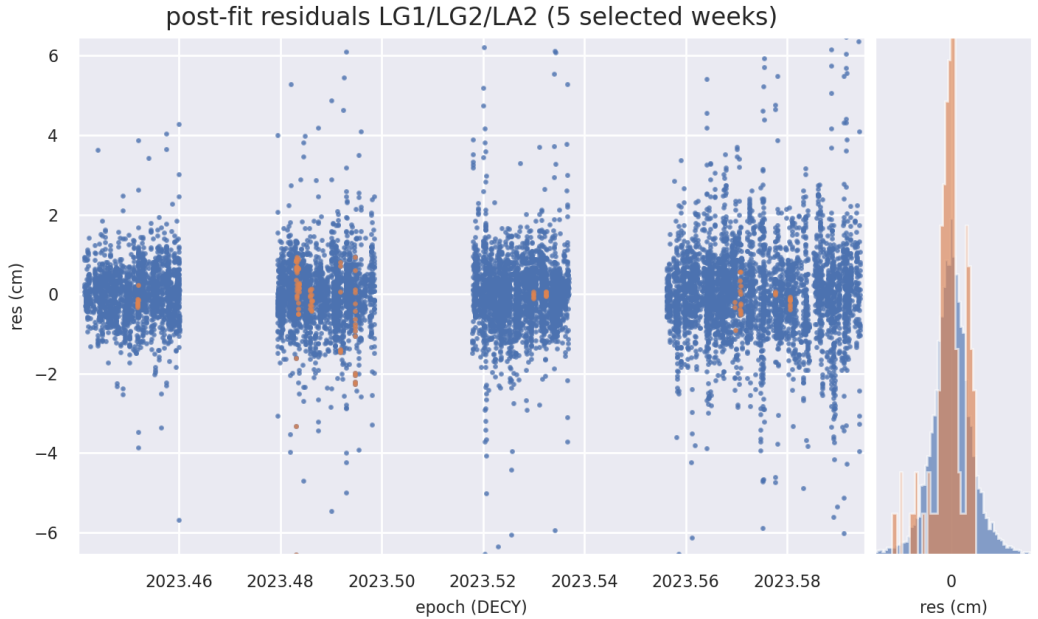


Satellite tracking IF in DiGOS SCOPE SW

Analysis by the AAC IGN-Yebes



Data from all satellite altitudes collected during commissioning

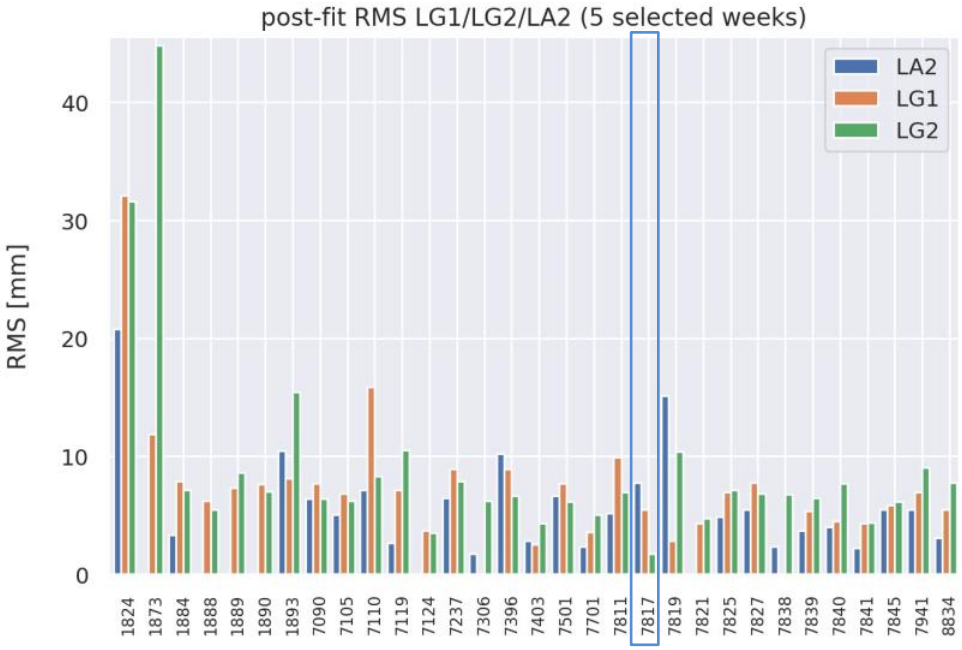


Quality of observations assessed with geodetic solutions

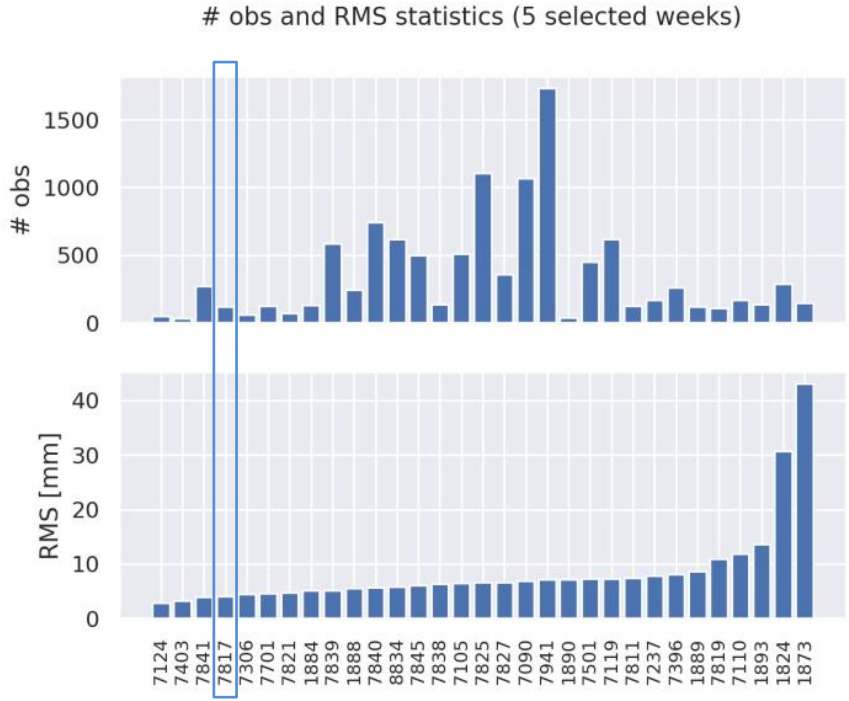
- **Yebes NPs to LAGEOS-1/2, Etalon-1/2, and LARES-2 included in global solutions**
- **5 weeks available**
- **Setup similar to ILRS ASC**

- Satisfactory bias magnitude (~1 cm level, exc. outliers)
- Station coordinates estimated for the first time from SLR data

Analysis by the AAC IGN-Yebes



Post-fit RMS LAGEOS-1/2 and LARES-2

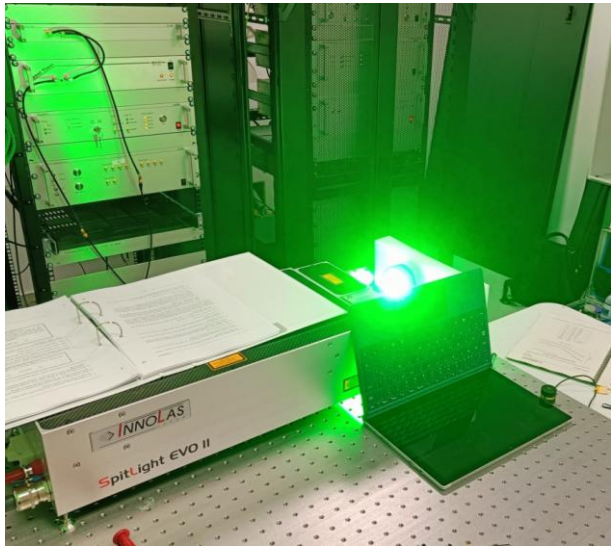


Number of Observations and RMS statistics

- Very good precision obtained for all satellites
- Among the top stations in terms of post-fit RMS, in the available weeks
- Promising results that indicate the readiness of the station to pass quarantine with no issues

Laser system for space debris observation

Model	Innolas SpliLight EVO II
Repetition rate	200 Hz
Pulse Energy	> 350 mJ @ 1064 nm > 200 mJ @ 532 nm
Beam diameter	7 mm
Divergence	< 0,5 mrad full angle
Pulse duration	5 - 8 nm



- Delivery and pre-installation carried out on May 18th and 30th
- Pending to integrate in the laser ranging station at HW and SW level

Acknowledgements

- Sven Bauer (Digos)
- Beatriz Sarmiento (TTI)

- Bea Vaquero
- José Rodríguez
- Adolfo García
- José Antonio López-Pérez


THANK YOU!