Validation of ESA's IZN-1 station and overview of current station capabilities

Andrea Di Mira[1], Emiliano Cordelli[1], Tim Springer[1], Florian Dilssner[1], Sven Bauer[2], Jens Steinborn[2], Erik Schoenemann[1], Tim Flohrer[1], Clemens Heese[1]

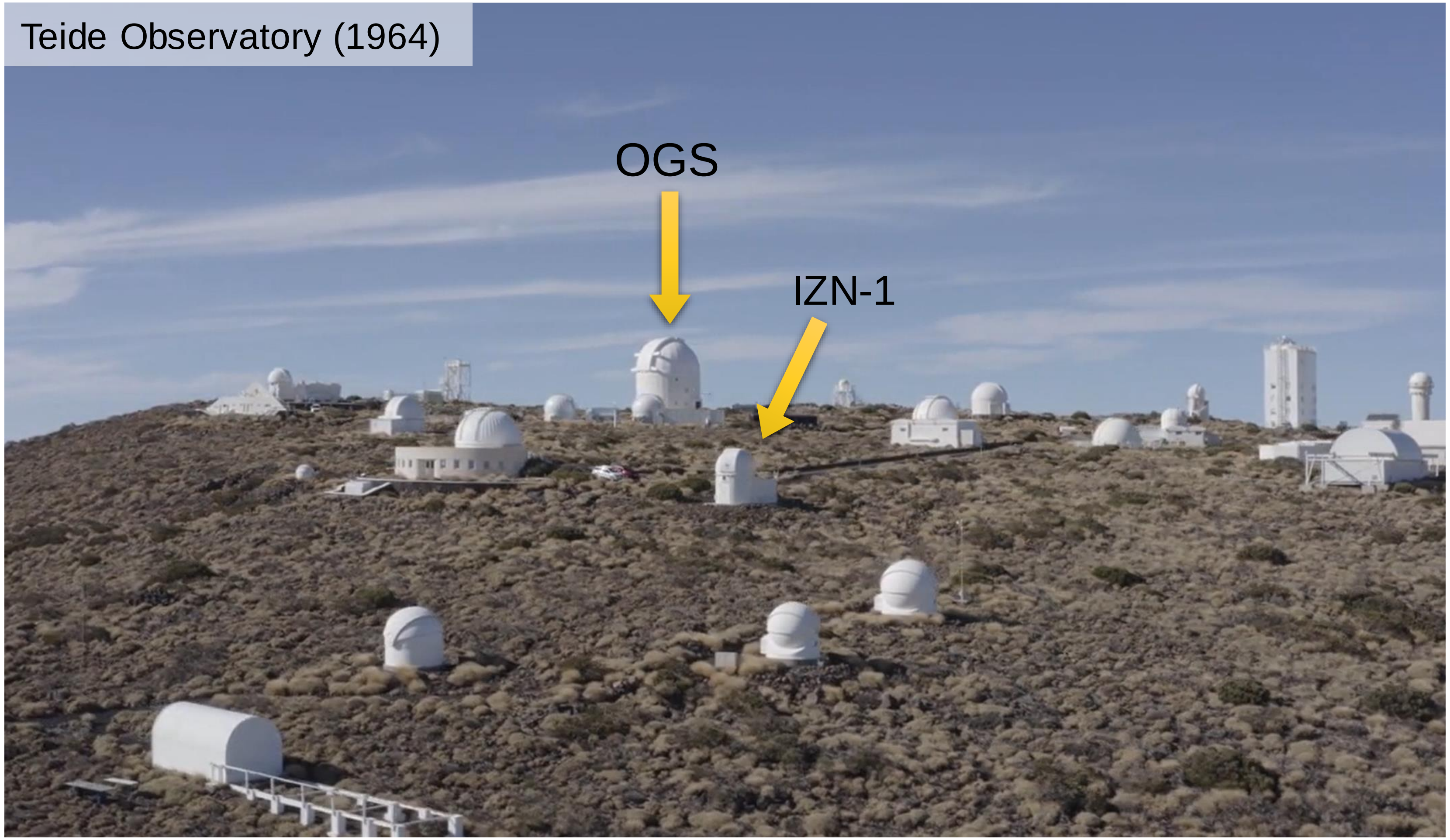
[1] ESA/ESOC, Darmstadt, Germany
[2] DiGOS Potsdam GmbH

22nd International Workshop of Laser Ranging, 7-11 November, Spain

The ESA Laser Ranging Station – IZN-1

- Station site: Teide Observatory (2400 m) in Tenerife
- Turnkey solution based on COTS components
- Remote operations

The Mountain Ridge Izaña



- Instituto de Astrofísica de Canarias (IAC) operates several telescopes
- Laser ranging requires coordination
- Multi-wavelength approach
- LTCS - Laser Traffic Control System for deconflicting

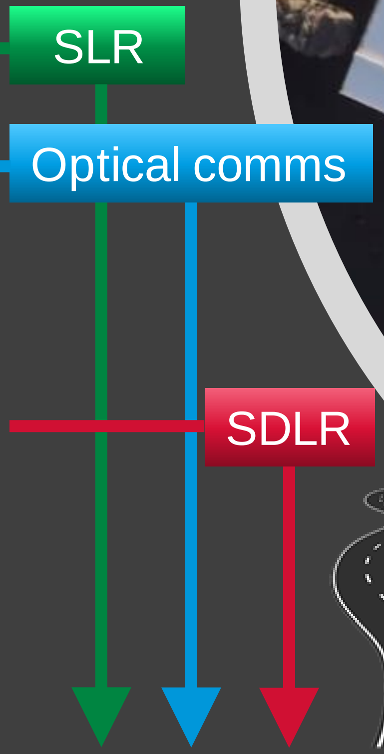
IZN-1 objectives

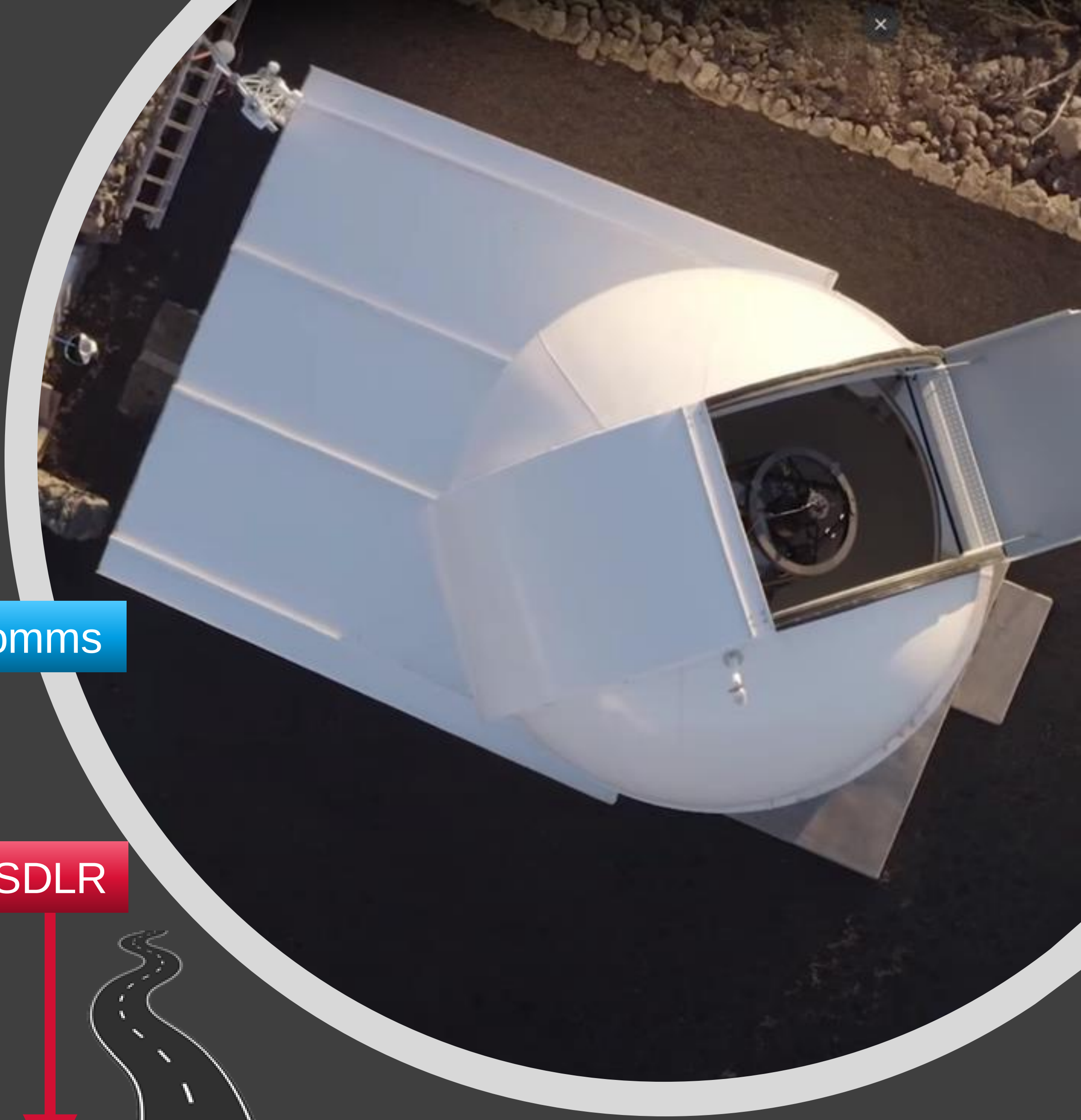
- Satellite Laser Ranging at 532 nm and 1064 nm
- Support ILRS as engineering station
- On-demand SLR support for missions/contingency cases
- Space debris active and passive observations

- LEO-DTE optical communications
- Testbed for European Industry
- Autonomous operations

Development Timeline

- ✓ Kick off 2018
- ✓ Design, procurement and factory pre-integration 2018-2020
- ✓ Deployment in Tenerife June 2021
- ✓ Optical Communication Mode June 2022
- ✓ Main Project Close-out: September 2022
- ➢ Upgrades for Space Debris Laser Ranging 2023

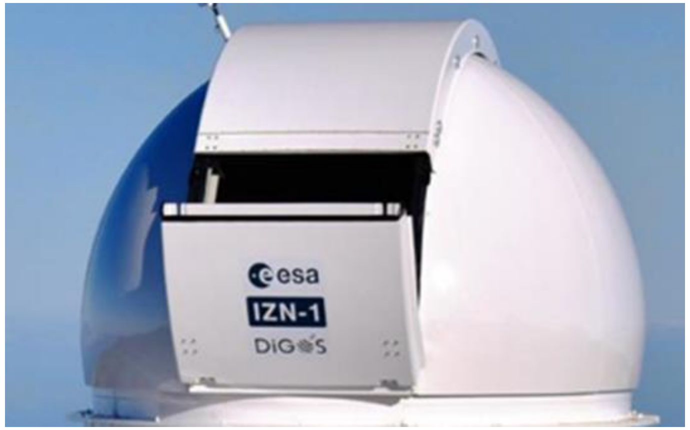




Main station subsystems

Telescope
- ASA AZ800
- Ritchey-Chretien 80 cm f/6.8
- Pointing accuracy <5 arcsec
- 4 Nasmyth foci

Dome
- Baader Planetarium 4.2 m
- Lower flap and rolling shutter



Detector package
- C-SPAD (532 nm)
  PESO Consulting
- IR-SPAD (1064 nm)
  Princeton Lightwave/IWF
- Installed on the telescope fork mount

Laser package
- Passat Compiler 532/1064 nm
- Nd:YAG PRF 400 Hz
- Laser system piggy-back mounted on the telescope

λ	Pulse width	Pulse Energy	Divergence (full-angle)
532 nm	7 ps	380 µJ	28-32 µrad
1064 nm	8.5 ps	550 µJ	56-60 µrad

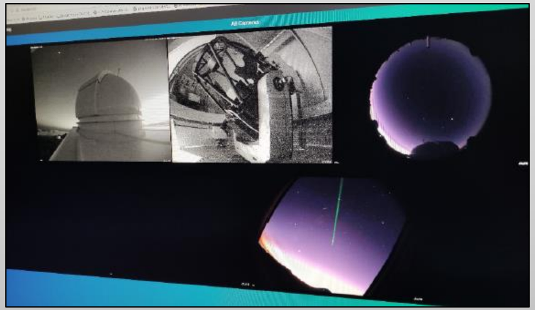
Main station subsystems

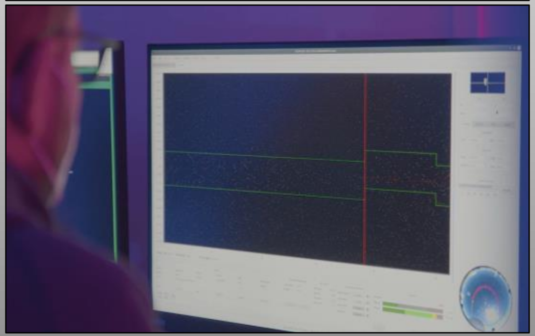
Space Debris Camera

- FLI ML 16070
- Pixel size 7.4 µm
- N of pixels: 4864 x 3232

SLR equipment rack

- Range Gate Generator
- Event timer A033-ET
- NTP
- GNSS receiver / OCXO DHQ
- Stability 2E-12 @1s





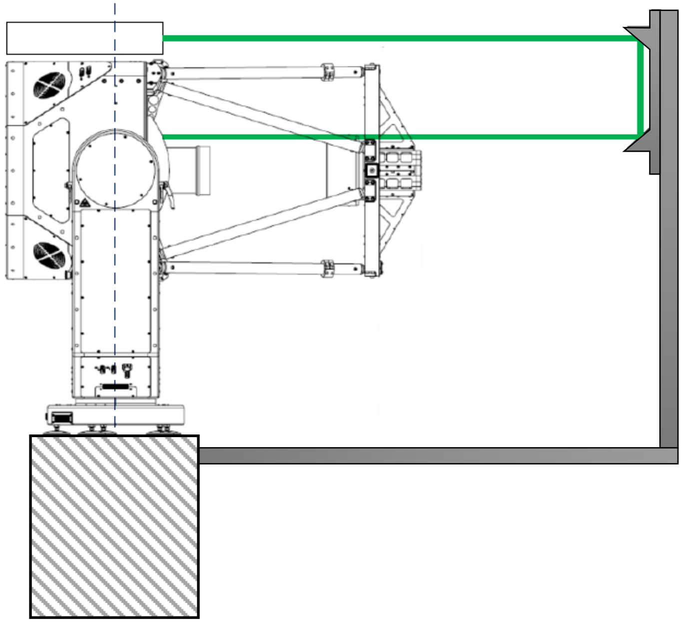
Laser Safety

- Emergency stops
- Interlocks
- ADS-B
- IR cameras

Main station subsystems

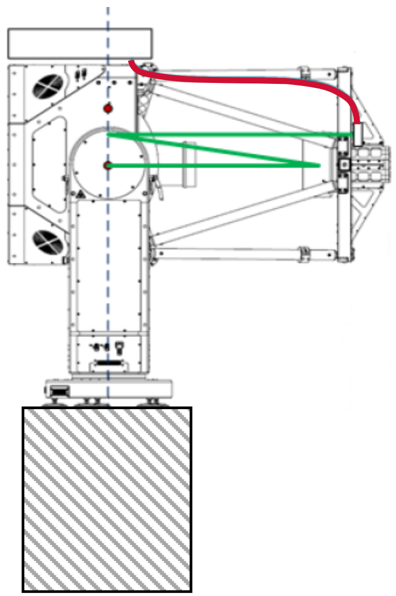
Multi-wavelength Calibration Subsystem

1. Short-distance target



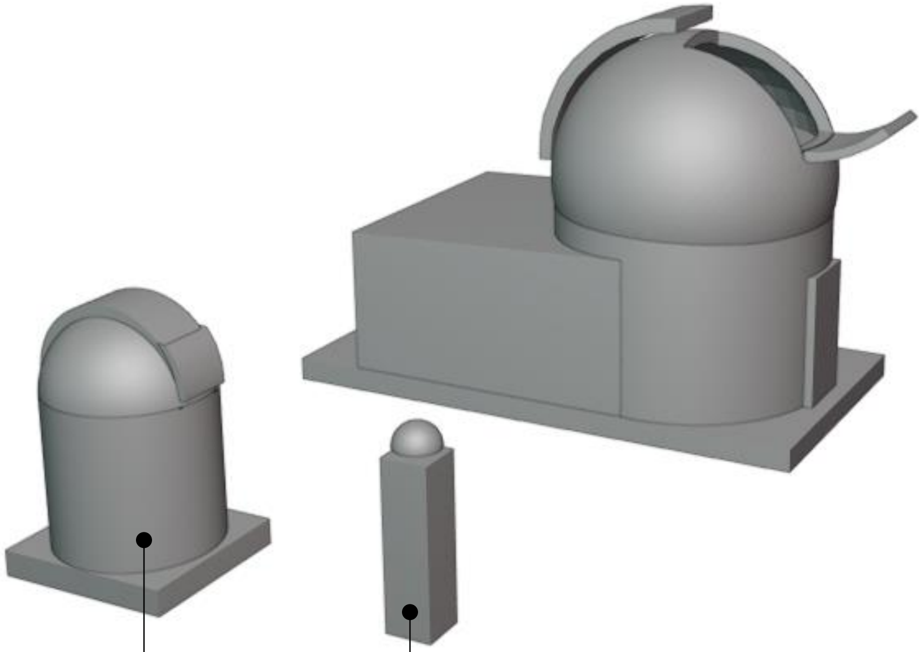
- Mounted inside the dome
- Mechanically connected to telescope pillar

2. Fiber Calibration



- No folding optics
- Baseline calibration mode

Upcoming Developments



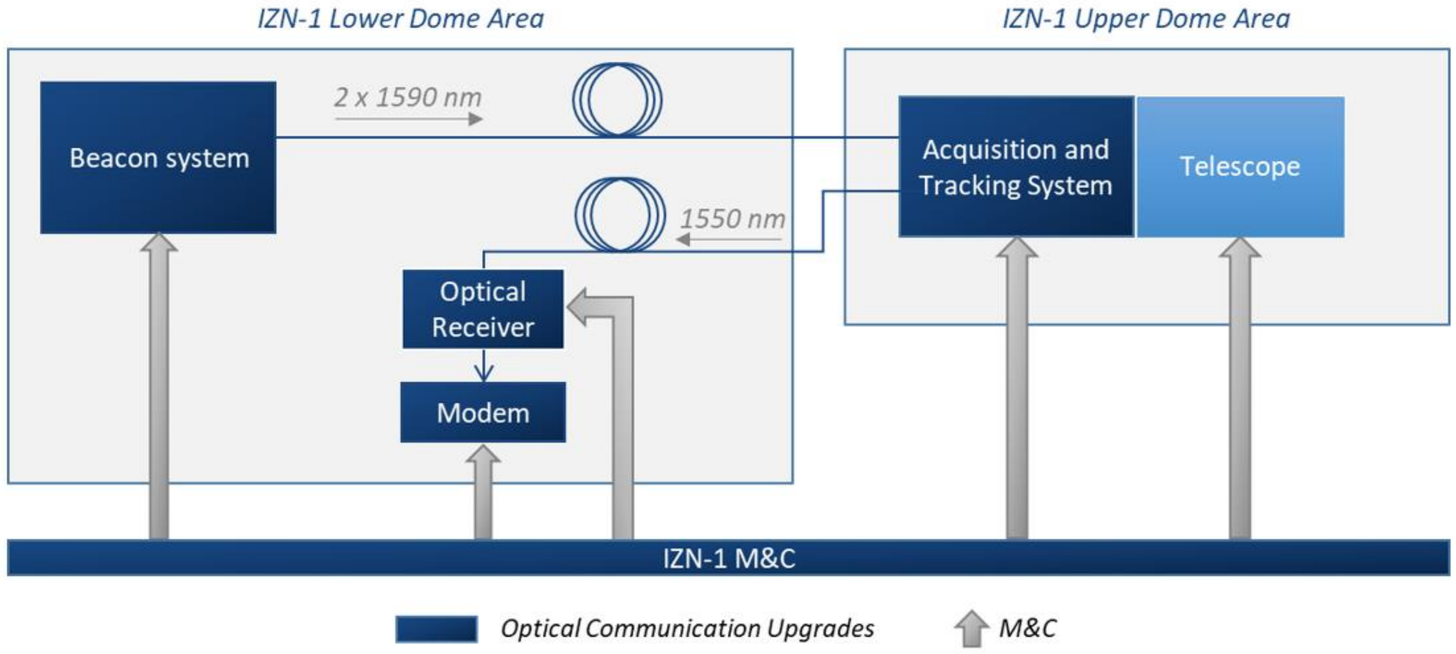
Multi-GNSS receiver for local tie

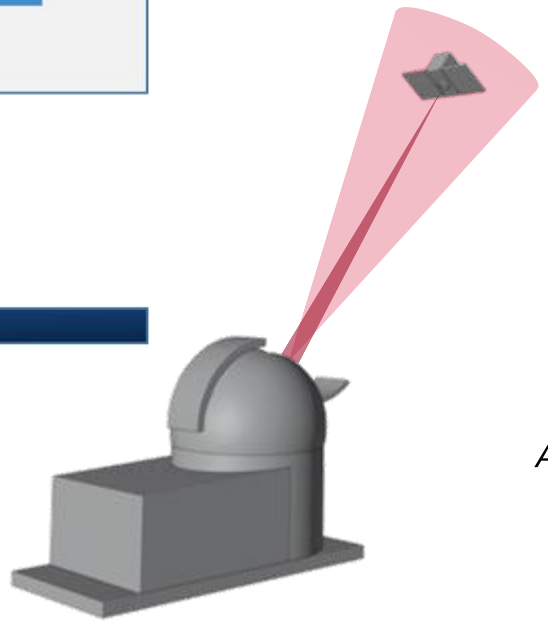
Space Debris laser ranging

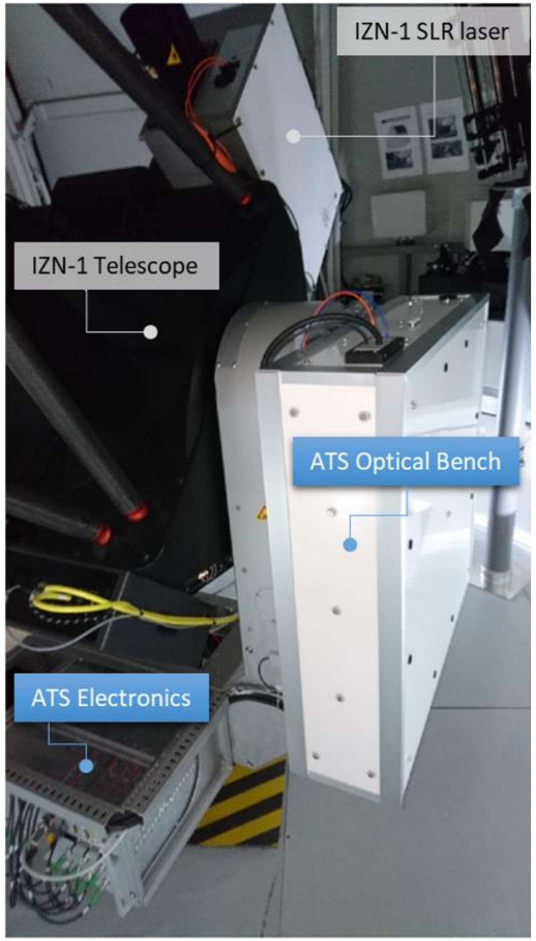
➡ *"Space Debris Laser Ranging – Challenging and Rewarding – Update of the Izaña-1 station"*
Martin Ploner/ Andre Kloth , DiGOS, Session 7, 09:30-09:45

IZN-1 Upgrades for Optical Communications

- Several satellites and constellations of CubeSats are being planned with laser communication terminal on-board
- **CCSDS O3K** (Optical On-Off keying) and **SDA (v3)** standard (Space Development Agency)
- Additional component installed (beacon, optical receiver, modem), infrastructure unchanged







ATS: Acquisition and Tracking System

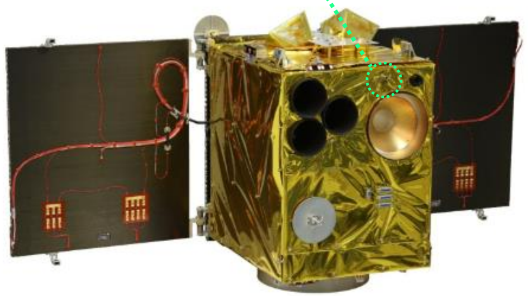
- ✓ O3K uplink beacon implemented 1590 nm (10 and 100 kHz) @6W average power
- ➢ SDA compatibility in preparation (1536 nm)

IZN-1 Upgrades for Optical Communications

GENERAL ATOMICS SYNOPTA DiGOS

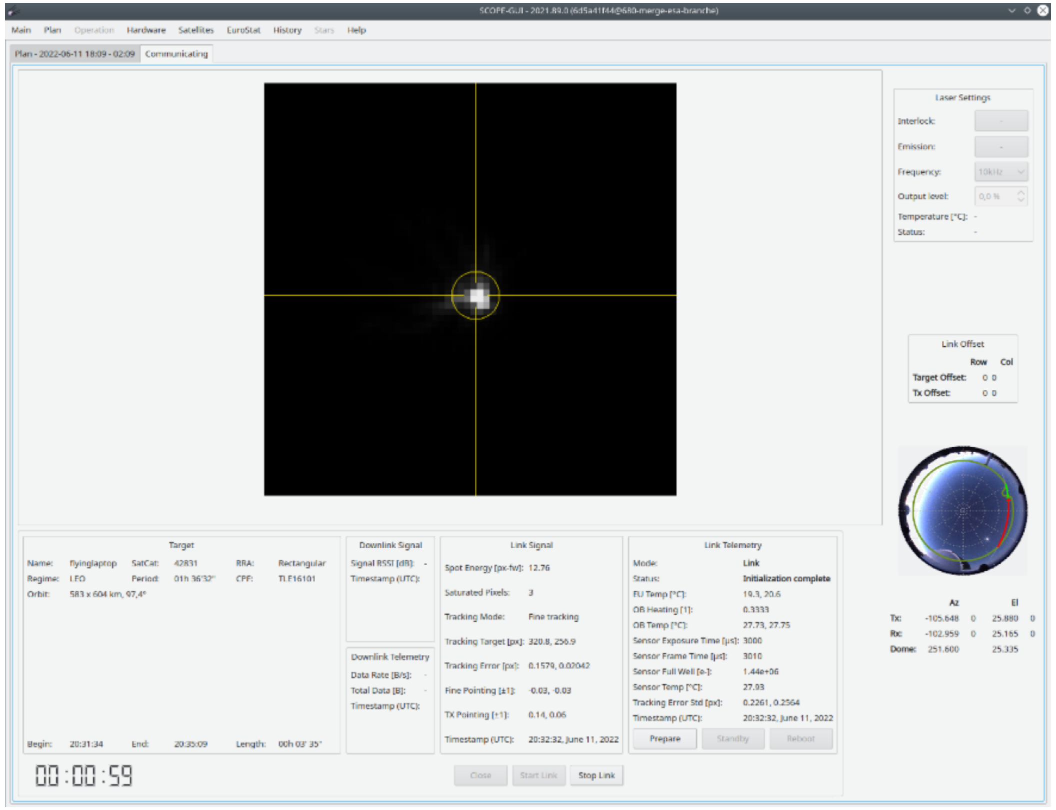
- The **Flying Laptop** has been used for validation. The satellite hosts the DLR **OSIRISv1** terminal
- Coarse and fine pointing could be demonstrated
- Optical downlink signal in C-band successfully coupled in the into the multi-mode fibre in the station receive optical path

DLR OSIRISv1

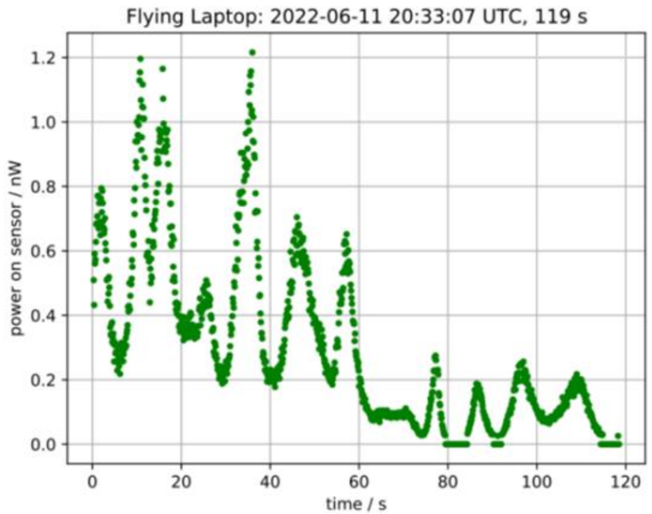


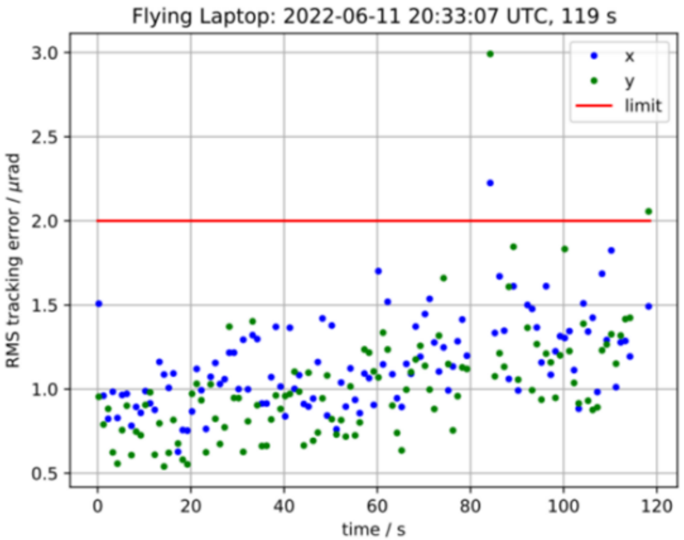
Credit: https://www.irs.uni-stuttgart.de/

University of Stuttgart



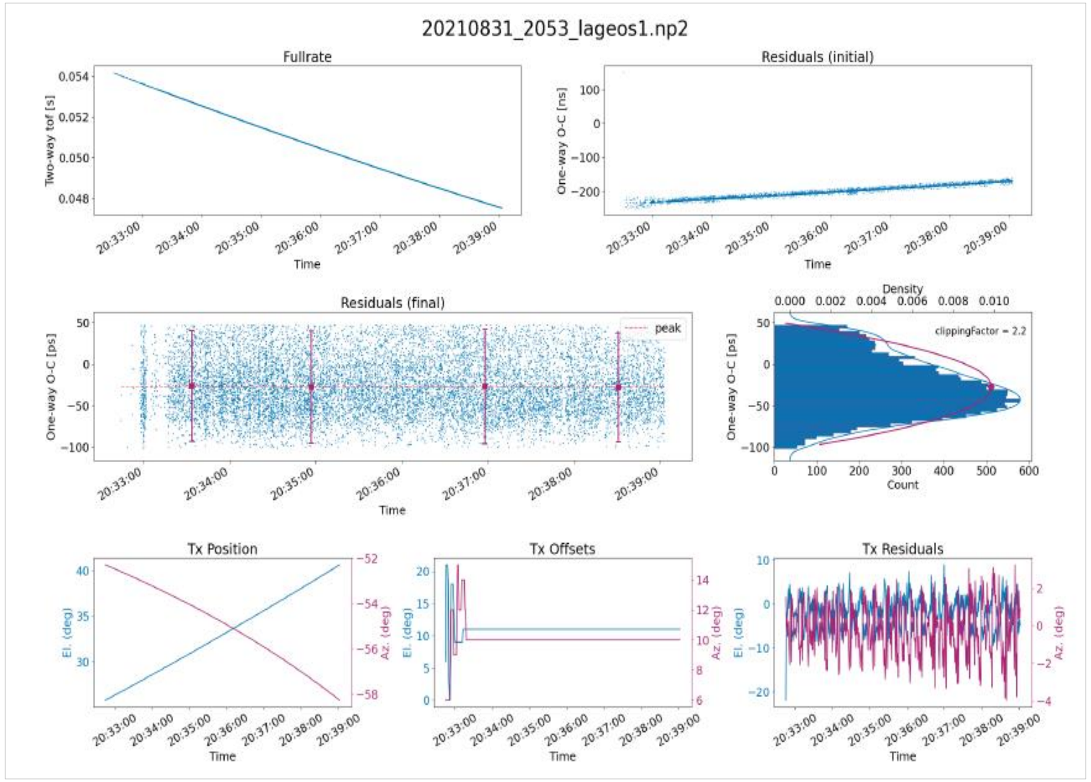
IZN-1 – Optical Communication Mode interface in SCOPE



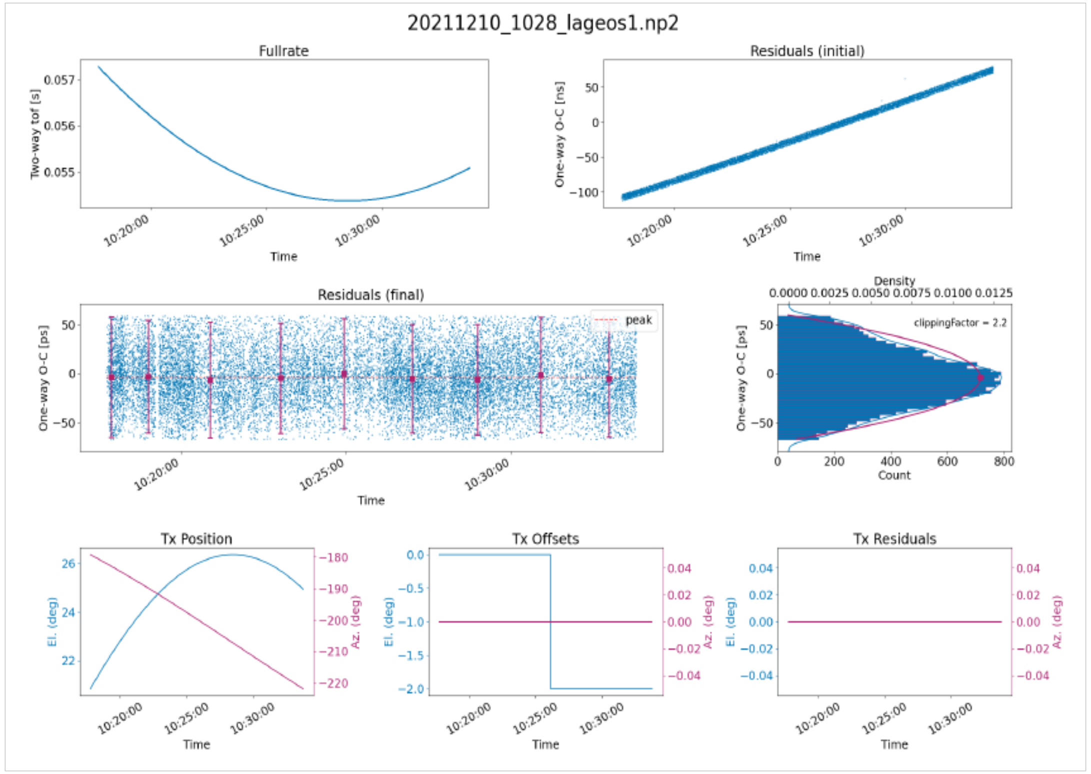


Residual Analysis from SCOPE session summaries

LAGEOS-1 532 nm



LAGEOS-1 1064 nm



LAGEOS-1 532 nm:

Evaluation		Meteo	
Returns	13199	Temp. (°C)	10
RMS (1w, mm)	10.09	Hum. (%)	48.2
RMS (2w, ps)	67.33		
TB (ms)	-1.07	Press. (mbar)	770.6
RB (m)	-3.35		

- Early IZN-1 SLR tests
- Stable NPT distributions at both wavelengths

LAGEOS-1 1064 nm:

Evaluation		Meteo	
Returns	18951	Temp. (°C)	6
RMS (1w, mm)	8.66	Hum. (%)	26.6
RMS (2w, ps)	57.74		
TB (ms)	0.13	Press. (mbar)	771.4
RB (m)	-0.51		

1. Validation by SST Expert Centre

AIUB

Assessment based on analysis of LAGEOS orbits by AIUB as backup for the weekly SLR routine at the ILRS Analysis Center at BKG (Germany)

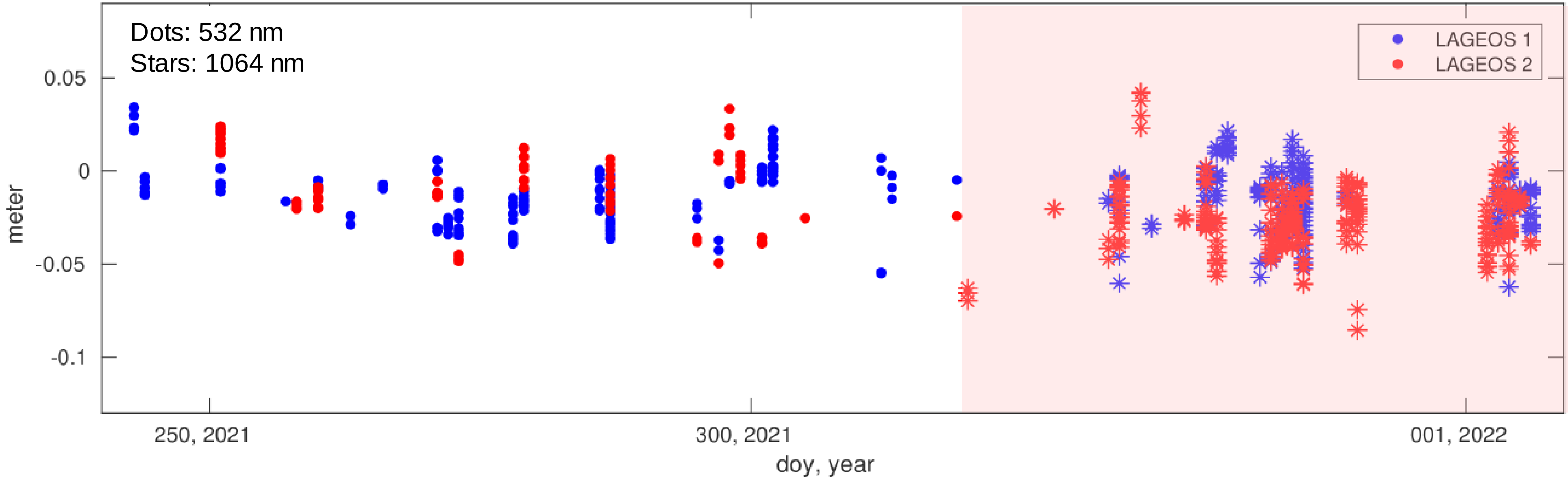
Mean Accuracy of LAGEOS orbits and network solution used as validation reference

Weekly mean RMS within 2021	[m]
LAGEOS orbit and network solutions	0.009
LAGEOS orbit residuals	0.008

IZN-1 validation results

Satellite	# NPT	Mean residuals [m]	Residuals RMS [m]
LAGEOS 1	381	-0.016	0.023
LAGEOS 2	347	-0.022	0.029

Residuals of LAGEOS 1-2 normal point data



Based on 18 weeks of measurements (end 2021/ beginning 2022)

1. Validation by SST Expert Centre

Assessment based on analysis of GNSS orbits in the frame of CODE activities as an analysis centre to the IGS MGEX project

Accuracy (median value) of IGS multi-GNSS satellite orbits used as validation reference

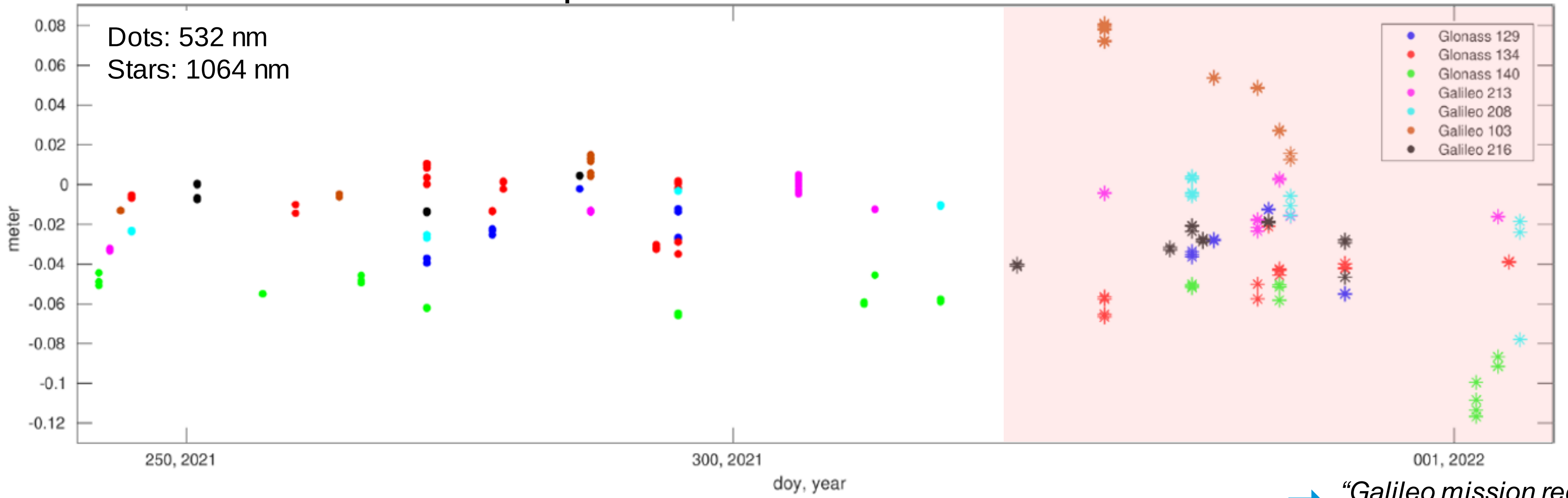
Validation Method	Glonass	Galileo
SLR validation [m]*	0.011	-0.006
Orbits misclosures [m]	0.012	0.011
RMS of 3-day orbit fit [m]	0.015	0.010

*Independent SLR validation

IZN-1 validation results

Satellite	# NPT	Mean residuals [m]
Glonass 129	11	-0.021
Glonass 134	34	-0.023
Glonass 140	17	-0.055
Galileo 213	16	-0.007
Galileo 208	10	-0.015
Galileo 103	12	0.005
Galileo 216	8	-0.004

Residuals of Glonass/Galileo normal point data



Based on 18 weeks of measurements (end 2021/ beginning 2022)

The SST Expert Centre analysis on LAGEOS and GNSS shows that IZN-1 accuracy is comparable with the residuals of the reference orbits

"Galileo mission recent results, ongoing support and future launches"
Francisco González, ESA, Session 5, 12:30-12:45

2. Validation by ESOC Navigation Office

Based on 12 weeks of measurements (end 2021/ beginning 2022)

Residual statistics (2-way ranges [m])

Raw 21-day solution (Fixed Coordinates)

Target	# NPT	Rejections	Median	Mean	RMS	Sigma
ETALON-1	30	0	0.037	0.046	0.053	0.025
LAGEOS-1	586	0	0.024	0.023	0.034	0.024
LAGEOS-2	722	0	0.03	0.029	0.038	0.024
LARES	48	0	0.065	0.052	0.089	0.073

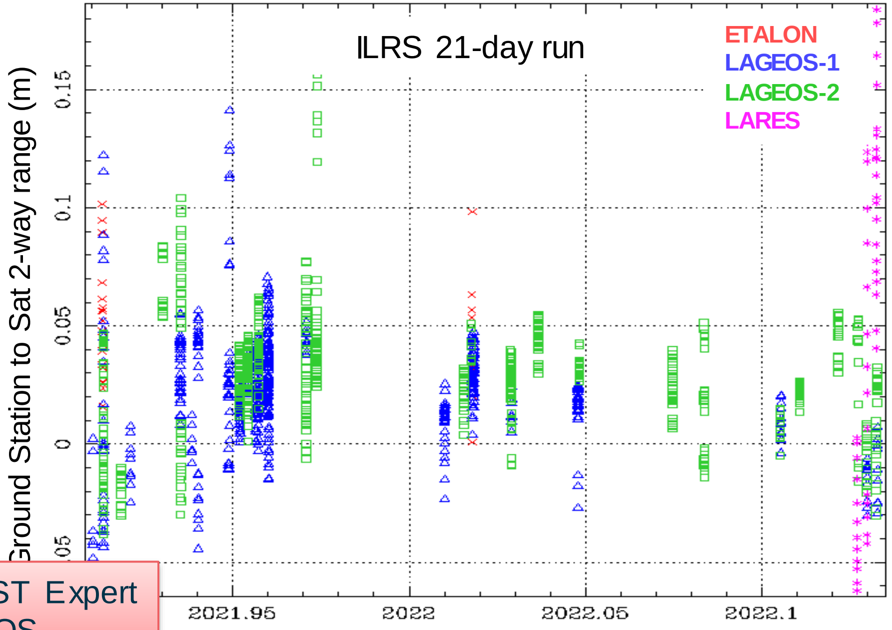
Clean 7-day solution (Free Coordinates)

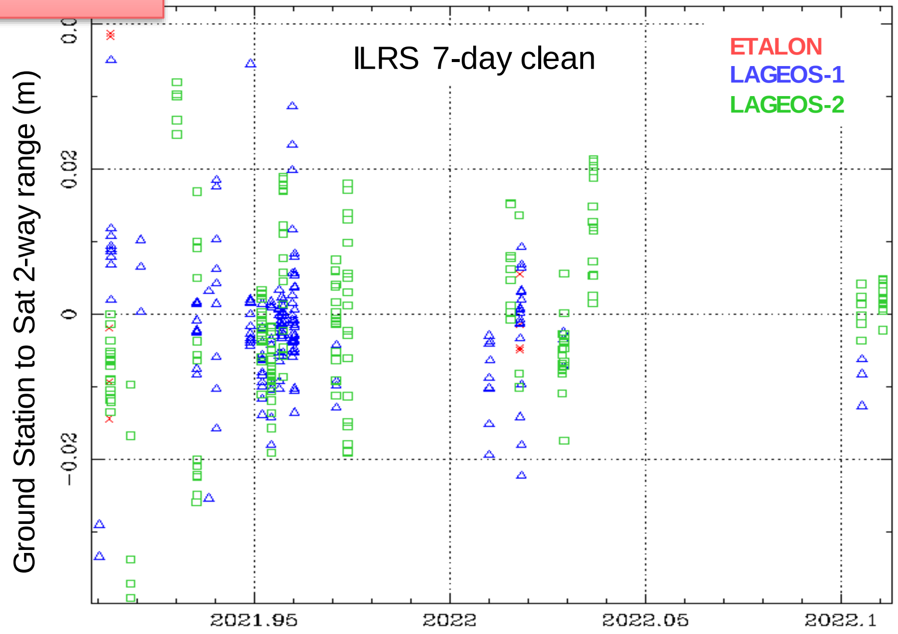
Target	NPT	Rejections	Median	Mean	RMS	Sigma
ETALON-1	10	0	-0.002	0.009	0.023	0.022
LAGEOS-1	182	3	-0.002	-0.002	0.009	0.009
LAGEOS-2	198	2	-0.002	-0.001	0.012	0.012

Good agreement with SST Expert Centre analysis on LAGEOS

Coordinate repeatability (mm) based on ITRF 2020

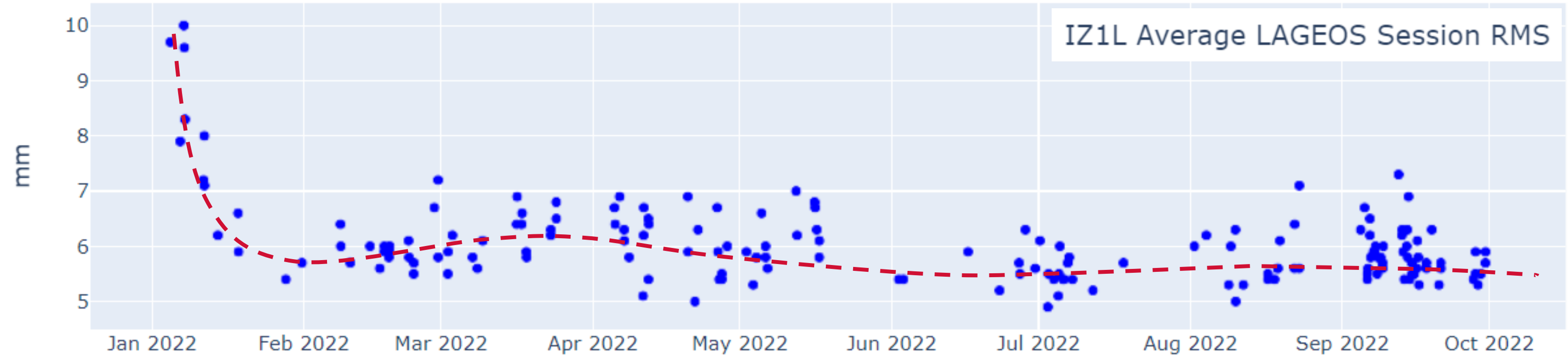
Coordinates	weeks	Rejections	Median	Mean	RMS	Sigma
Up	7	0	-20.584	-18.322	19.704	7.832
North	7	0	-14.422	-13.347	15.186	7.823
East	7	0	7.036	5.56	11.863	11.319

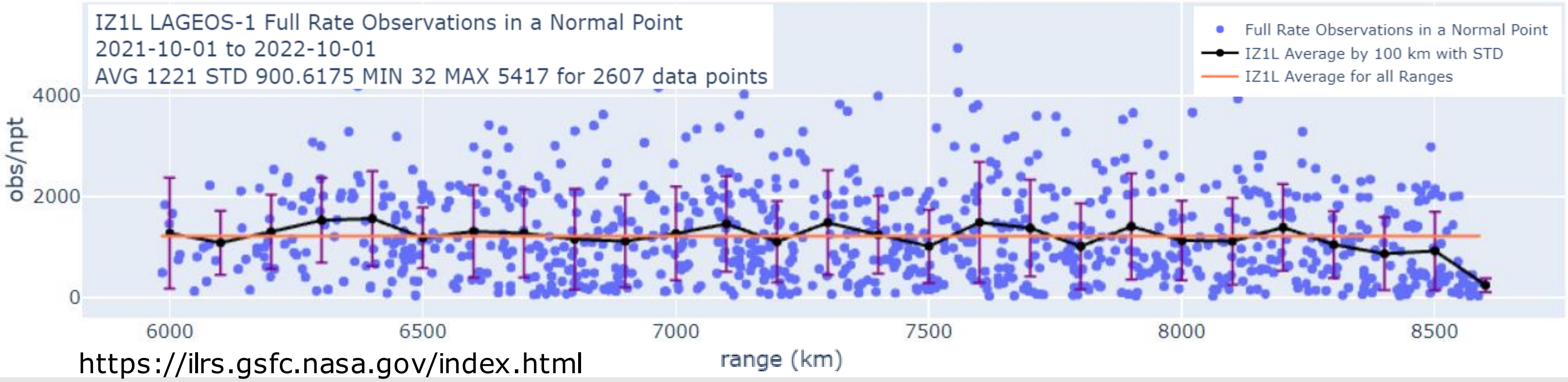




IZN-1 Qualification for ILRS

Monument	Code	Location Name, Country	CDDIS SOD	IERS DOMES Numbers	IGS Site Log	IVS Site Log	IDS Site Log	Date of Latest Site Log	Date of Latest Site History Log
7501	HARL	Hartebeesthoek, South Africa	75010602	30302M003	X	X	X	20210927	20220820
7503	HRTL	Hartebeesthoek, South Africa	75036401	30301S010	X	X	X	20190117	-
7701	IZ1L	Izaña (Tenerife), Spain	77015701	31336S001	-	-	-	20220425	-
7810	ZIML	Zimmerwald, Switzerland	78106801	14001S007	X	-	-	20181001	20220407
7811	BORL	Borowiec, Poland	78113802	12205S001	X	-	-	20211012	20211012
7819	KUN2	Kunming, China	78198201	21609S004	X	X	-	20170119	20220419

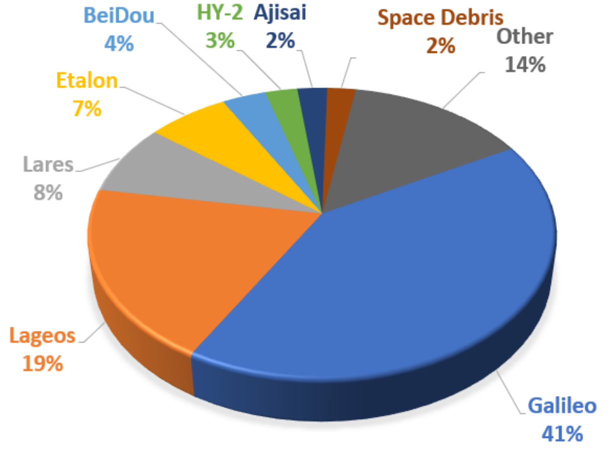




https://ilrs.gsfc.nasa.gov/index.html

- Station Released from ILRS quarantine on April 2022
- Remote operations mainly at 1064 nm

IZN-1 SLR observations (Nov 2021 - Oct 2022)



Source: https://edc.dgfi.tum.de

“Current state of the contribution of ESA’s Izana-1 station to the ILRS”
Sven Bauer, DiGOS, Session 6, 09:30-09:45

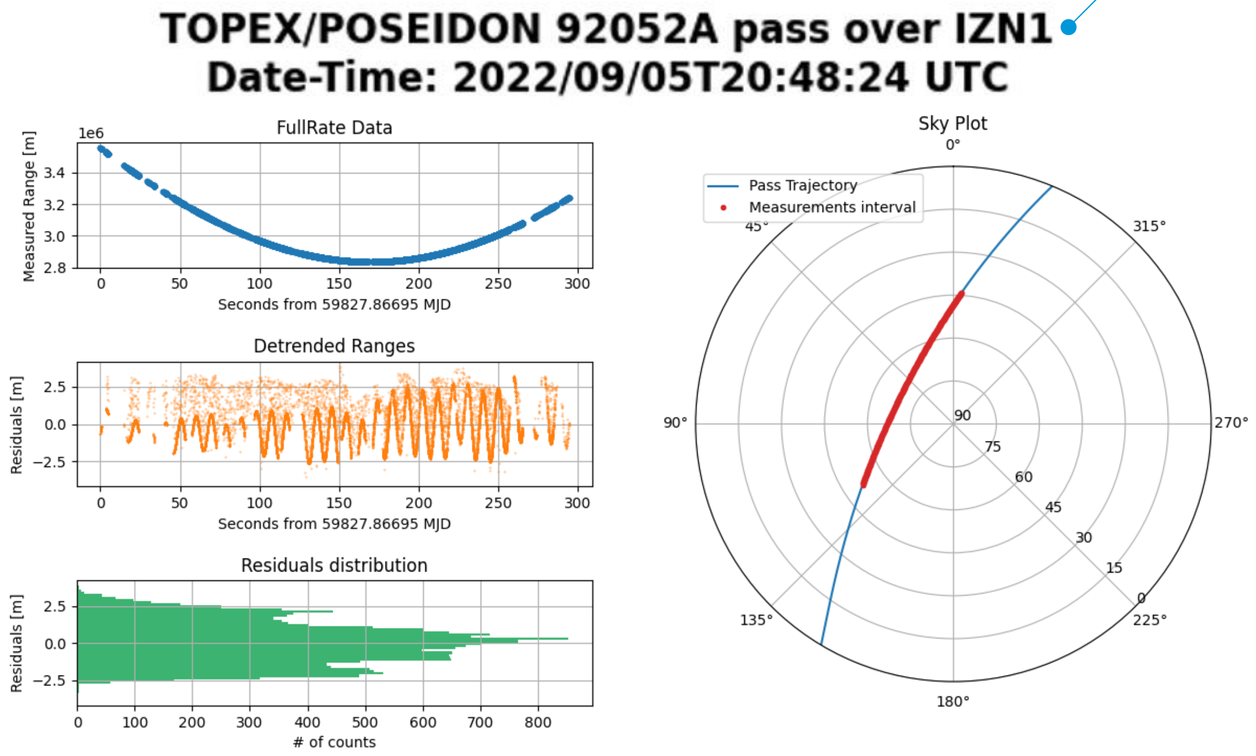
esa

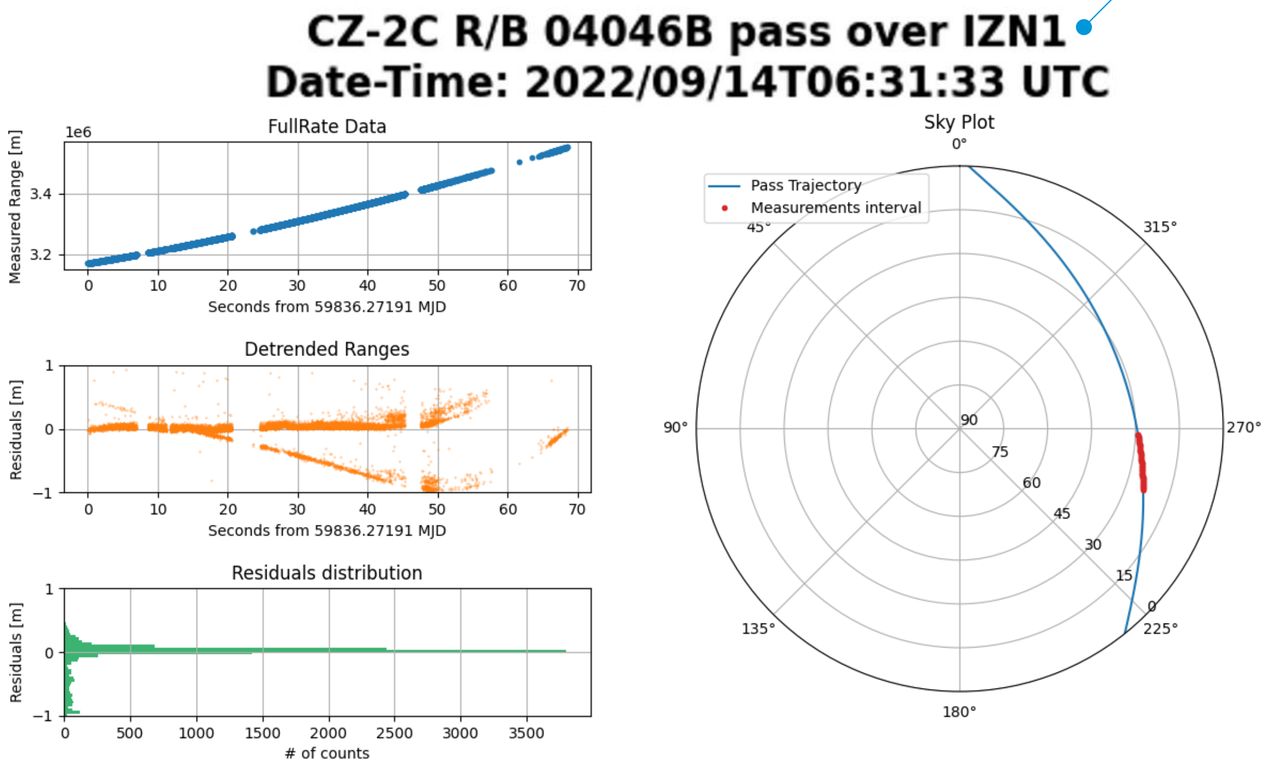
Laser ranging to Cooperative Space debris

- Successful laser tracking of defunct satellites and rocket bodies with retroreflectors
- Laser system with low energy per pulse (550µJ @1064nm)
- Range residuals show behaviour which might be exploited for attitude characterisation

Credit: Wikipedia

Credit: Gunter's Space Page



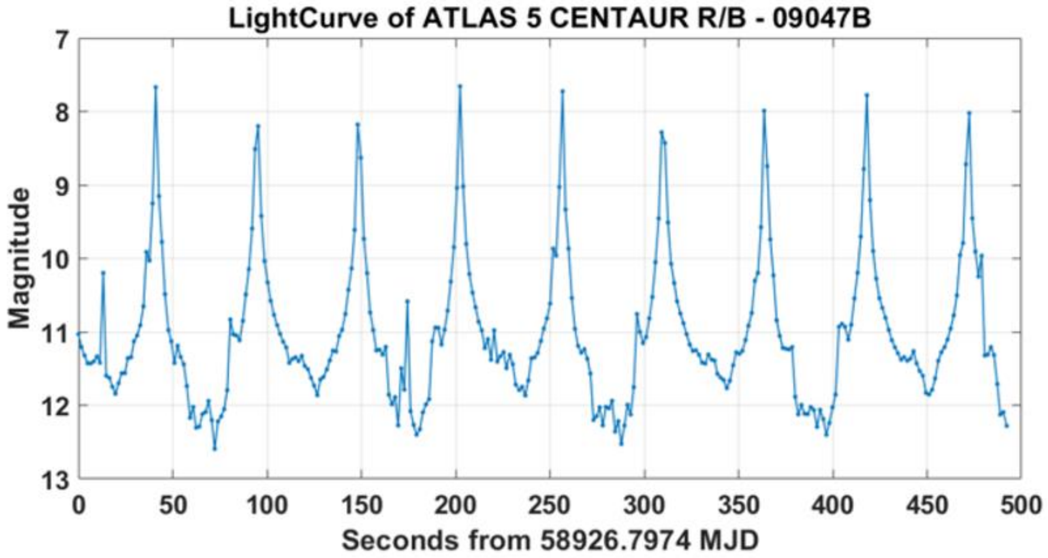


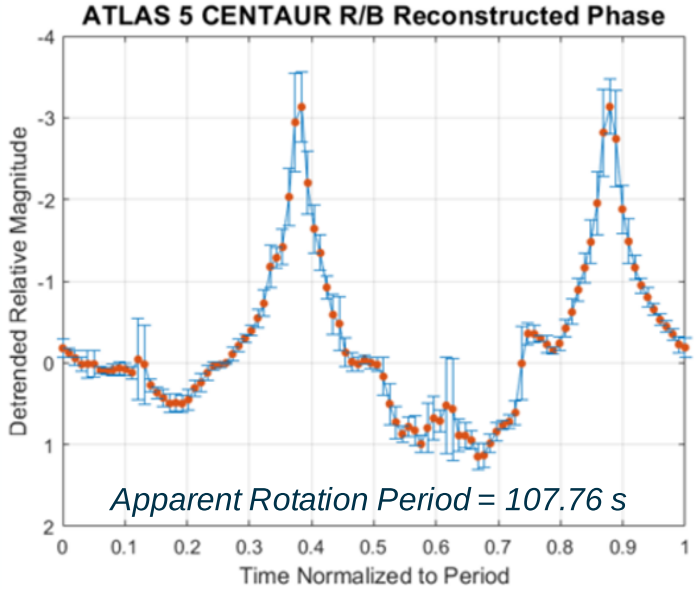
Space Debris Passive observations

- Passive observations of objects from LEO to GEO with space debris camera
- Validation of space debris camera measurements performed by SST Expert Centre (AIUB)
- According to SST Expert Centre rules, a constant time bias < 70 ms and an astrometric accuracy < 3 arcsec, are required for SST applications
- Attitude characterization through acquisition and analysis of light curves (up to 1.5 fps)

Date	# Of Meas.	Time offset [ms]	Mean Astrometric Accuracy [arcsec]
2020/03/18	61 (4*)	-30.42	3.2
2021/07/30	39 (5*)	52.0	0.96

* Number of observed satellites





Summary

- New station in Tenerife operational since 2021 for multiple applications: SLR, optical communications, debris observations.
- IZN-1 is a development platform for prototyping and testing emerging technologies in SLR and LEO-DTE optical communications with emphasis on automation, daylight debris ranging and overall productivity
- IZN-1 joined ILRS as engineering station. Qualification process completed in April 2022.
- Parallel validation from different entities including SST Expert Centre and ESOC Navigation Office

  IZN-1 accuracy comparable with high-performance ILRS stations
- First active and passive observation of space debris performed. IZN-1 is being upgraded to support daytime space debris laser ranging within a network of space debris tracking stations

➡ *"Laser ranging—Evolution towards active sensor networking for debris observation"*
Laura Aivar, GMV, Session 7, 10:15-10:30


Thank you!