Concept for a new minimal SLR system

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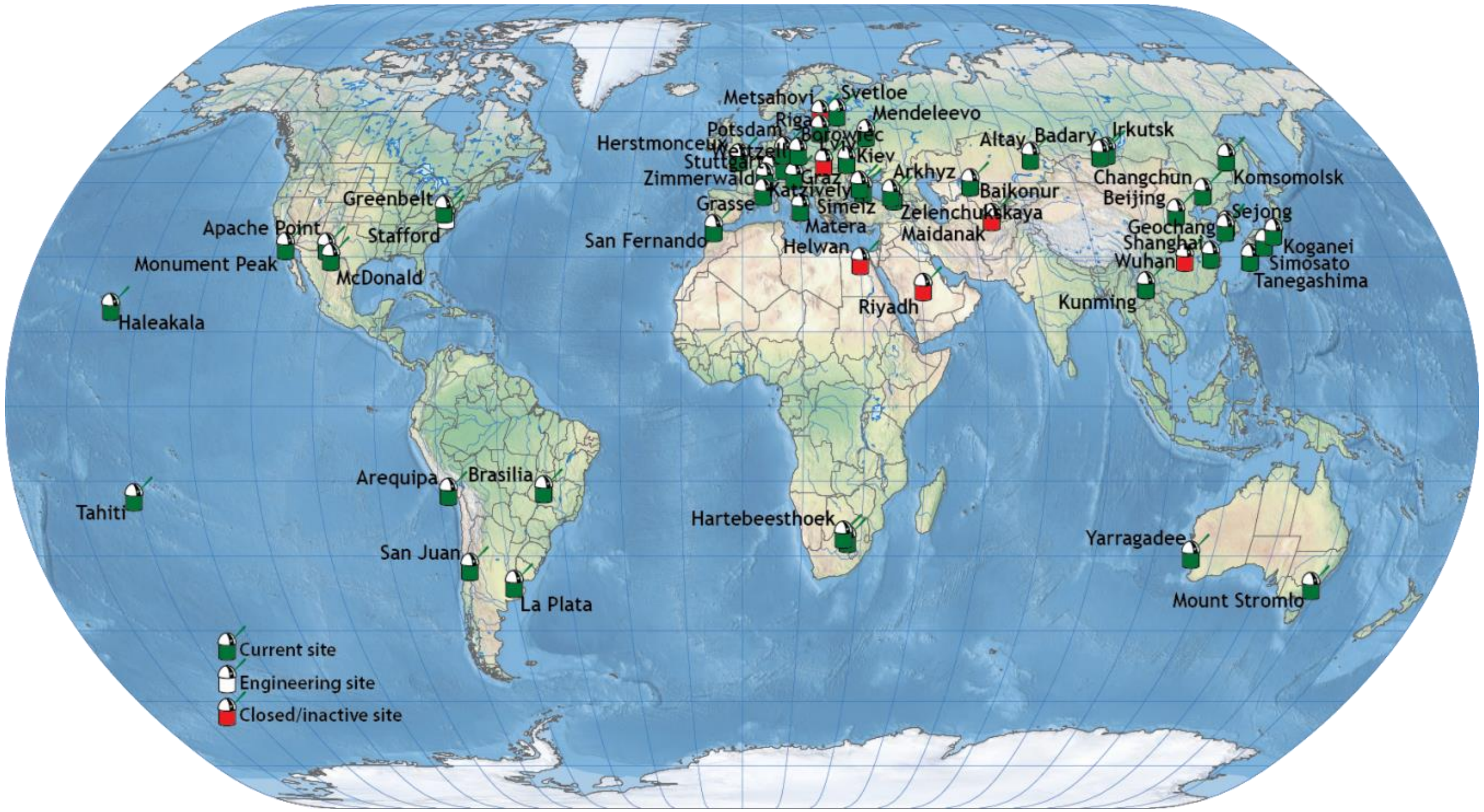
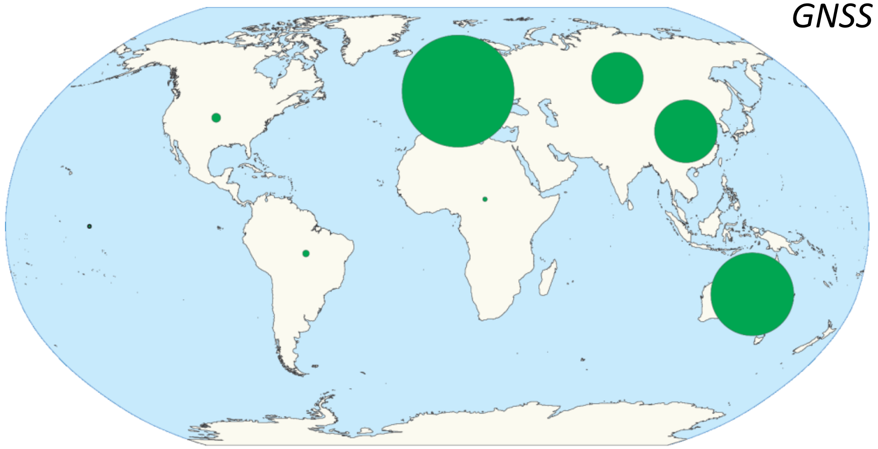
DLR

The need for new SLR stations



ILRS stations (from: ILRS website)

GNSS



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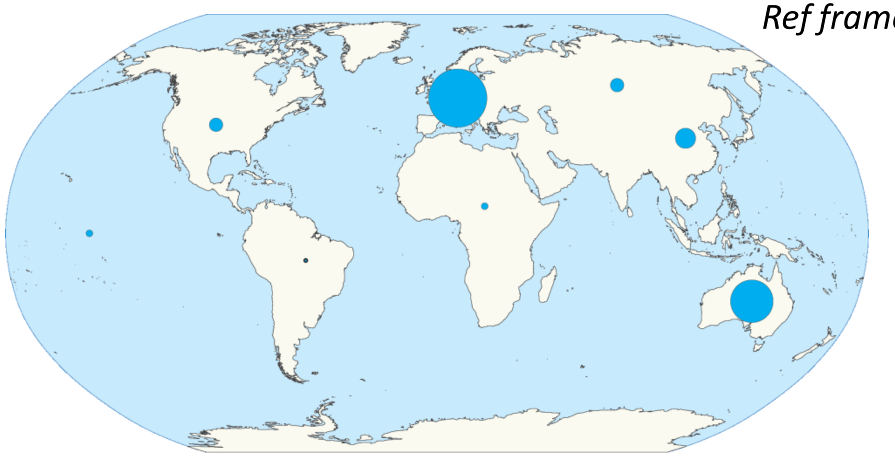


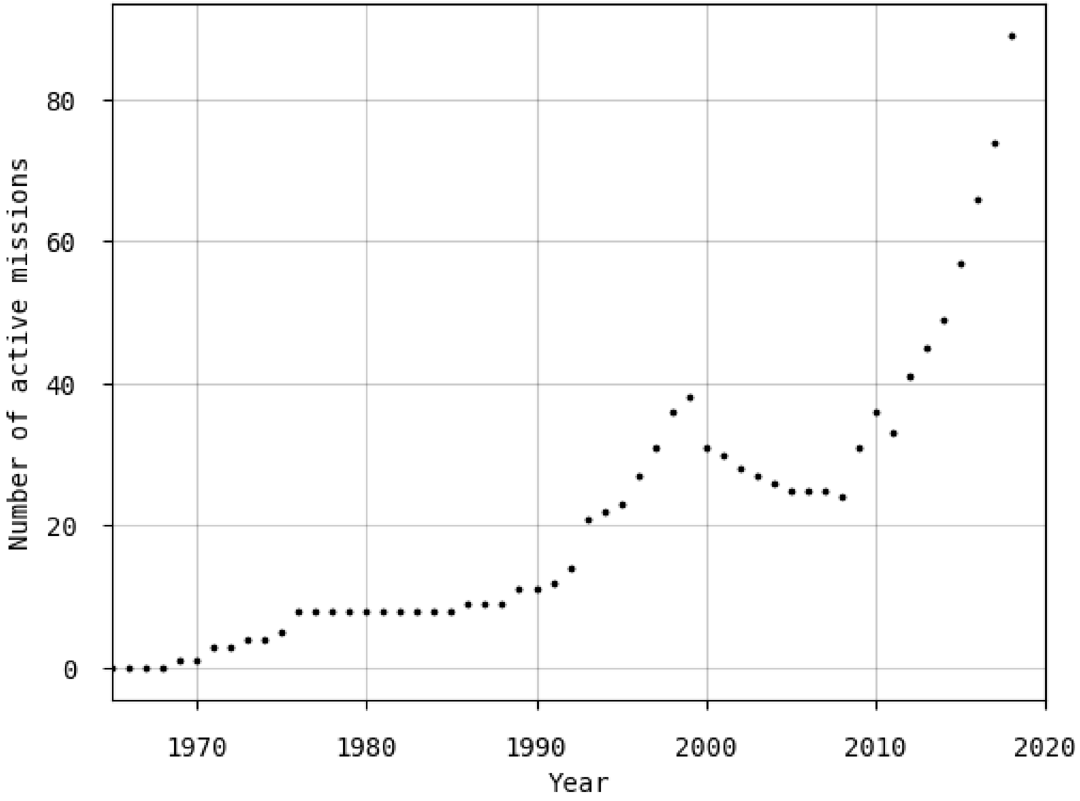
Passes tracked per continent (Pearlman 2017)

More to come…

- More navigation satellites
- More Earth observation satellites
- Space Traffic Monitoring
- …

Satellite Name	Sponsor	Exp.Life Time	Purpose	Launch Date
Approved by ILRS for Future SLR Tracking				
Astrocast	ETH Zurich and Astrocast SA	1-2 yrs	Positioning information, precise orbit determination	November 15 to November 21, 2018
COSMIC-2	UCAR	5 yrs	Atmospheric research, validation of GNSS orbits	NET June 13, 2018
HY-2B	CNES, CNSA		Earth observation	October 25, 2018
ICESat-2	NASA		ice-sheet elevation change, sea-ice freeboard, and vegetation canopy height	September 15, 2018
Lightsail-2	The Planetary Society	30 days	Orbit determination	NET June 13, 2018
NISAR	NASA/JPL, ISRO	3 yrs	Earth observation	2020
PN-1B, -1C, -1D	Beijing Aerospace Control Center	1 yr	Precise orbit determination	Sep-2015
RANGE	Georgia Institute of Technology	1 yr	Positioning information, precise orbit determination	Jul/Aug 2018
Future Satellites with Retroreflectors				
GPS-III (n=??)	DoD, DoT		Positioning, navigation, timing, geodesy	
GRASP	NASA		Positioning, geodesy	TBD
HY-2C	CNES, CNSA		Earth observation	2015
HY-2D	CNES, CNSA		Earth observation	2019
IRS-P5 (CARTOSAT-1)	ISRO	5 yrs	Earth observation	May-2005
Sentinel-6	NASA, NOAA, ESA, EUMETSAT	5.5 yrs	Ocean altimetry	2020
SWOT	NASA, CNES		SAR altimeter	2020

Future SLR missions (Data: ILRS website)



Number of SLR missions (Data: ILRS website)

Minimal SLR - Design goals

- Minimal…
  - Small
  - Inexpensive
  - Few components (COTS where possible)
  - Modular
  - Easy to maintain
  - Eye-safe?

- …yet powerful
  - From LEO up to GNSS orbits
  - 1 cm NP accuracy
  - Day and night ranging
  - Automated operation

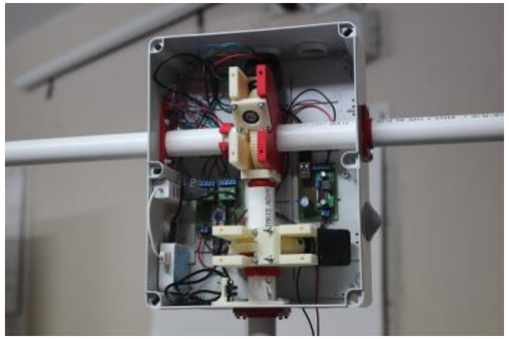
Make it as simple as possible – but not simpler

A unified minimal SLR system – open source

- Together…
  - Share efforts in development
  - Share experiences in operation
  - Share software and hardware designs
- …and alone
  - Funded and built by individual agency
  - Operated locally
  - Enhancements / modifications encouraged

Arduino Uno R3
(From: Wikimedia / user "Clic17")

open source hardware



SatNOGS

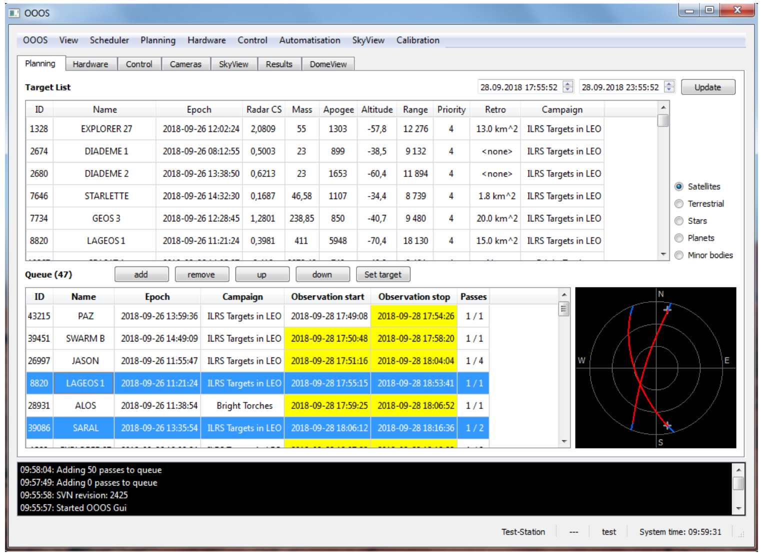
White Rabbit time-synchronisation
(Image from: Sevensolutions)

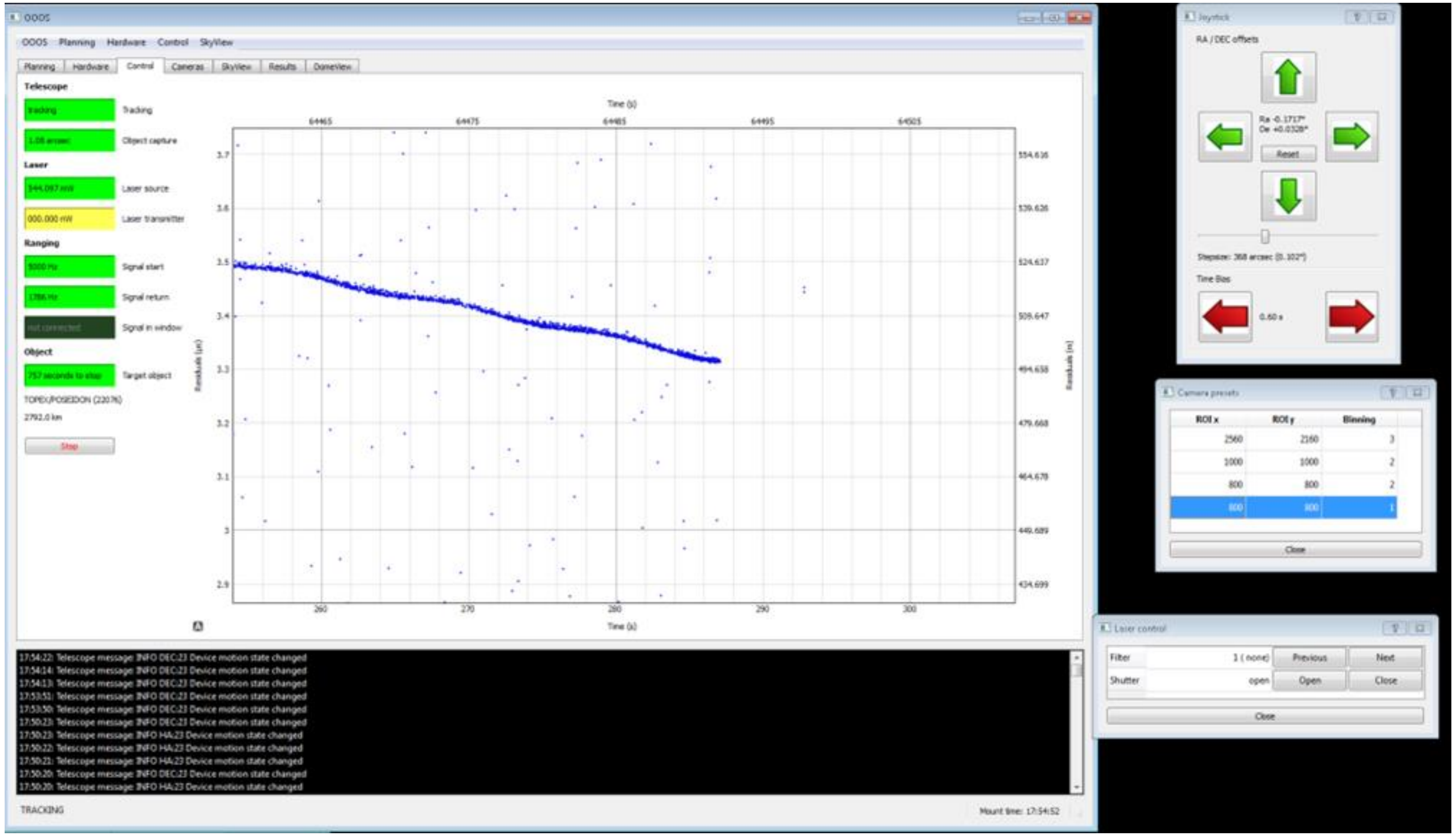
Linux

OOOS: Orbital Objects Observation Software

- Supports full SLR operation
- Modular hardware layer

Released as open source (GPL v3)





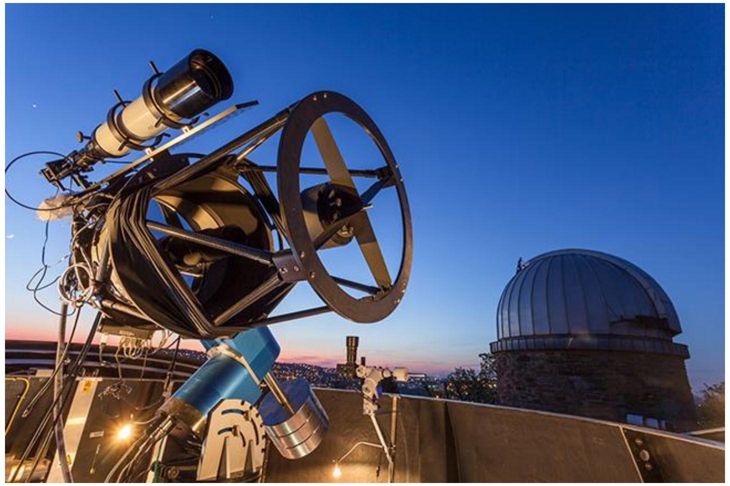
See also: spacedebris.dlr.de/OOOS_software

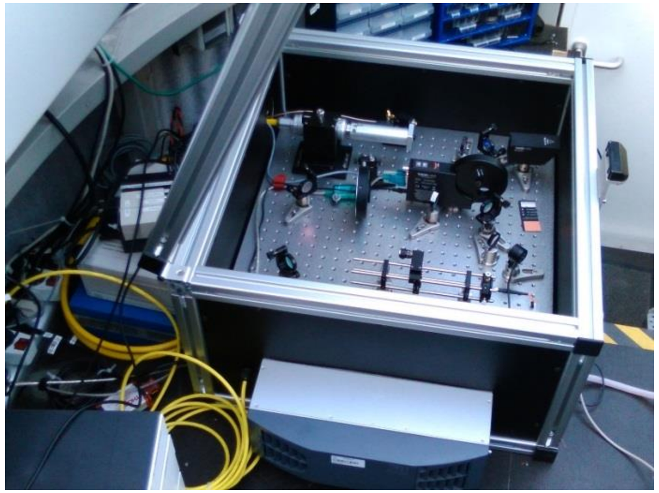
DLR

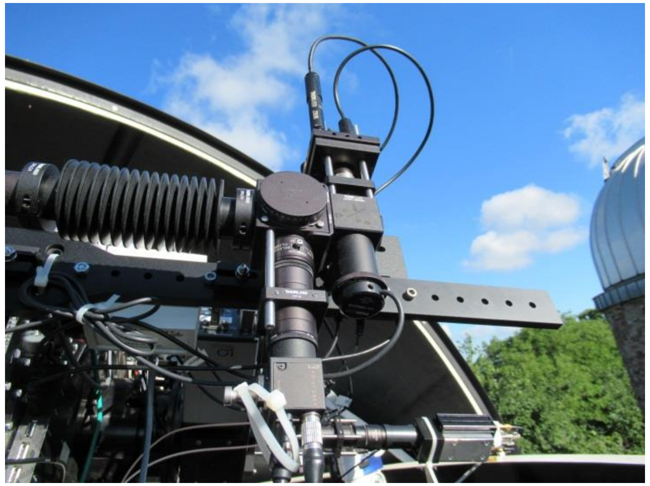
Uhlandshöhe SLR station

- Location: Historic observatory in Stuttgart, Germany
- First returns 2016
- ILRS Engineering station since 2017

- Specs:
  - 100 kHz repetition rate
  - 50 µJ pulse energy
  - 42 cm receiver telescope
  - 10 cm transmitter
  - Fibre coupling
  - Ranging at 1064 nm



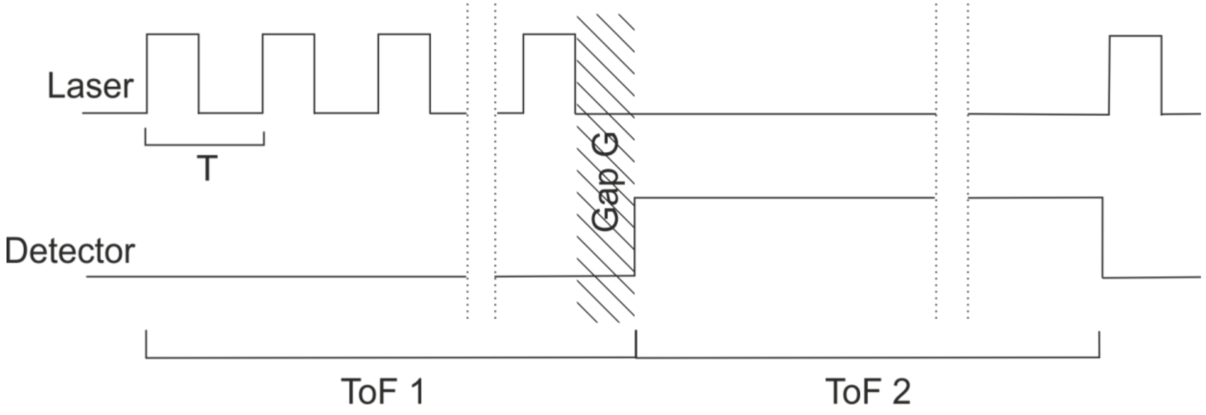




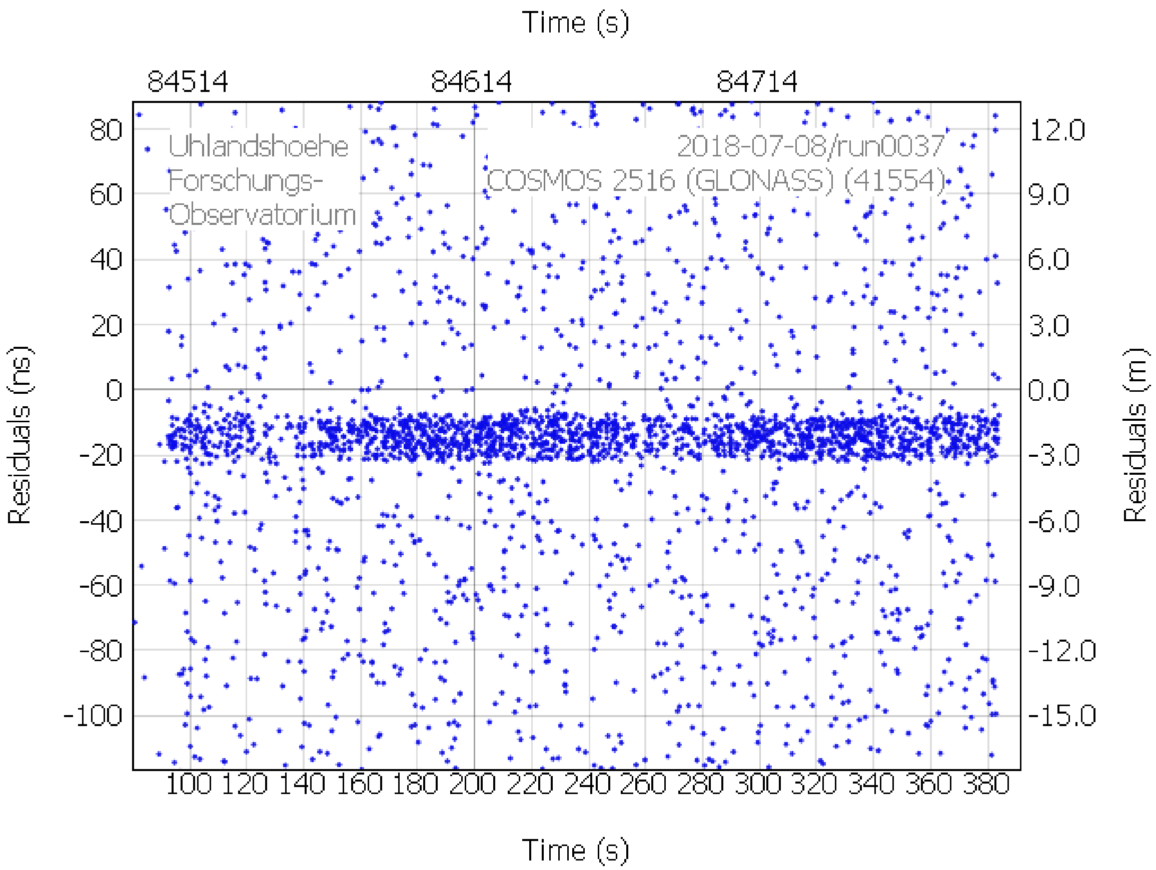
100 kHz laser ranging

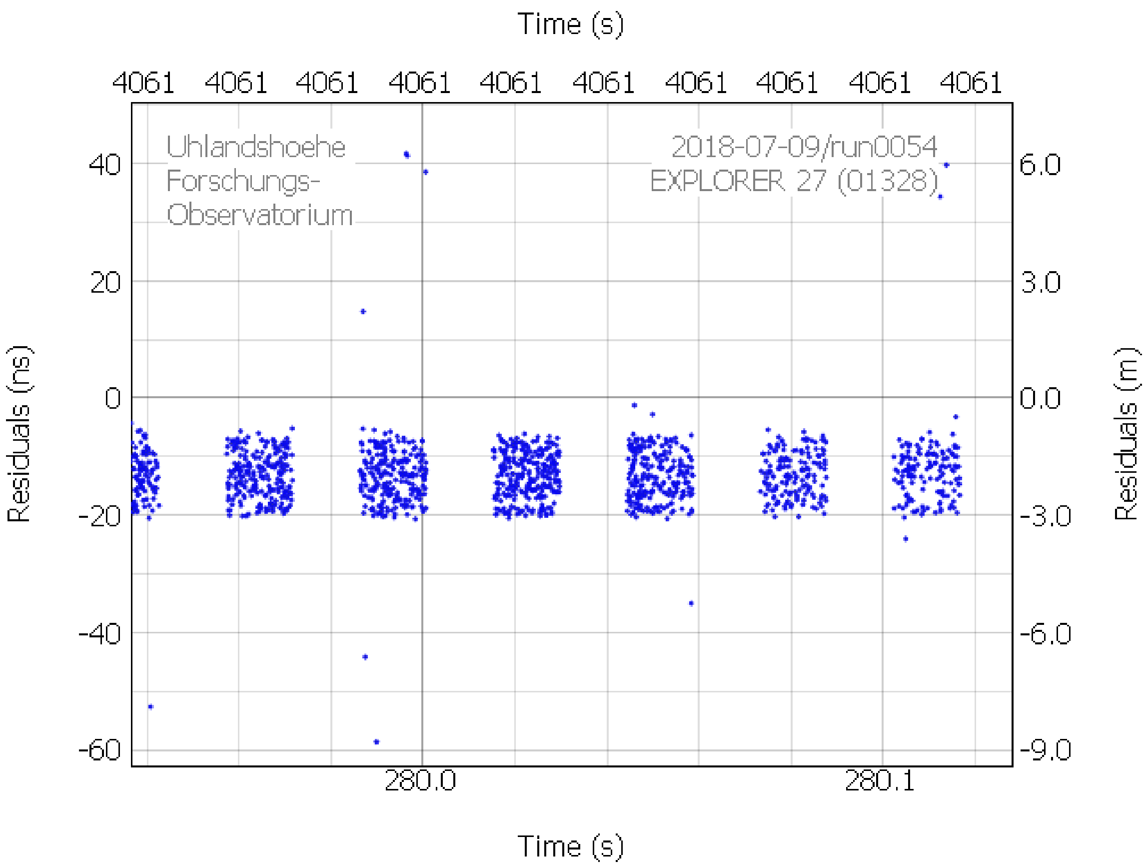
- Why?
  - Low pulse energy (50 µJ)
  - Long pulses (~10 ns)
- How?
  - Burst mode pulse collision avoidance
  - Fast event timer
  - Multithreading
- Results?
  - Ranging up to GNSS targets
  - NP scatter ~ 1 cm

See also: D. Hampf et al: Satellite Laser Ranging at 100 kHz repetition rate (submitted to CEAS space journal)

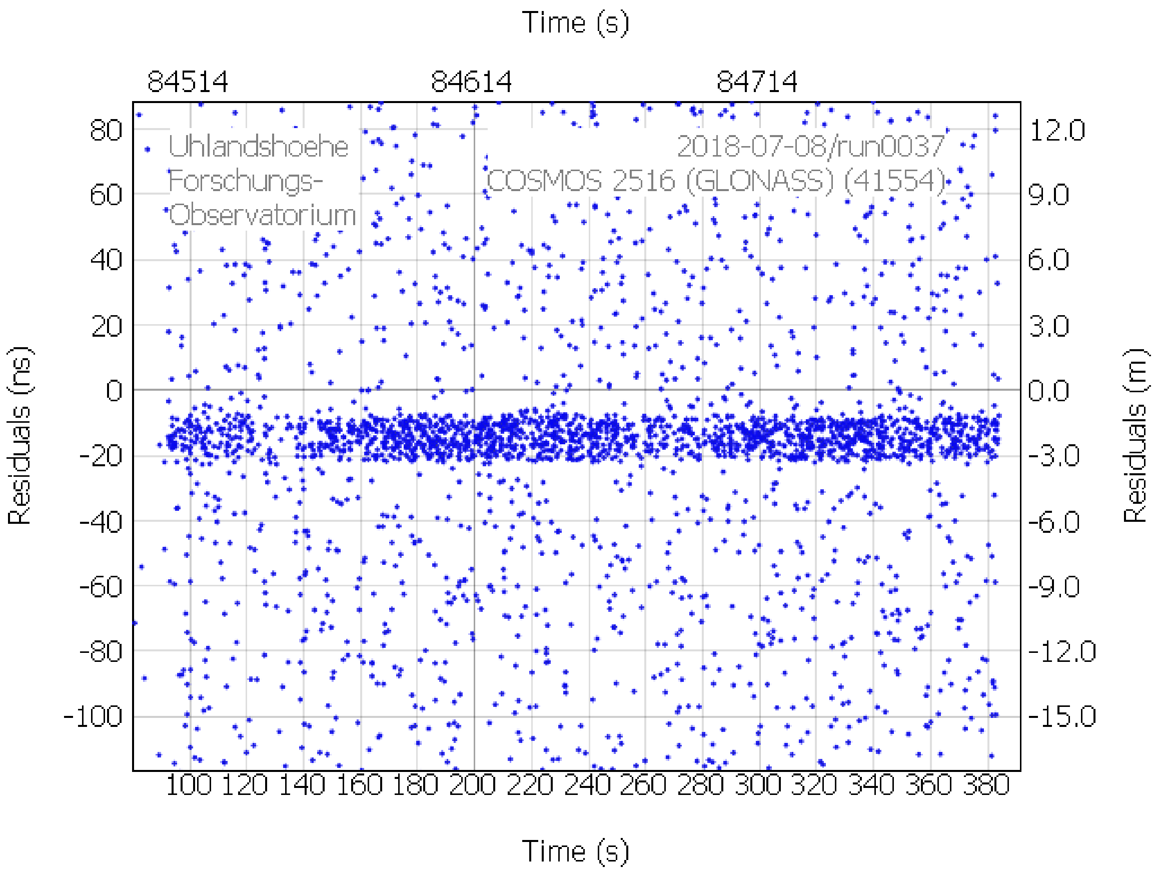


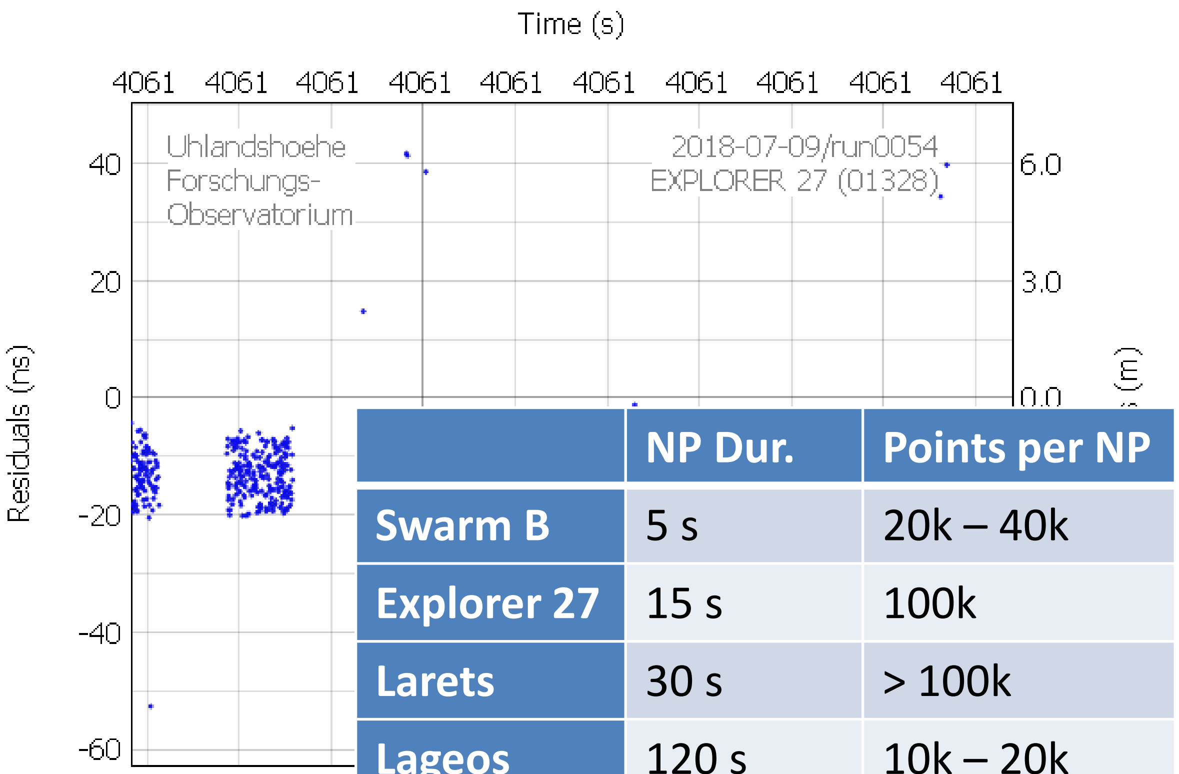
100 kHz laser ranging: Results





100 kHz laser ranging: Results



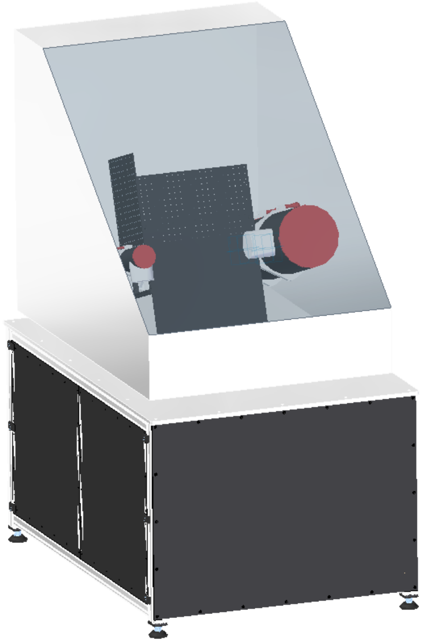


	NP Dur.	Points per NP
Swarm B	5 s	20k – 40k
Explorer 27	15 s	100k
Larets	30 s	> 100k
Lageos	120 s	10k – 20k
GNSS	300 s	1k-2k

miniSLR

- Complete SLR system “in-a-box”

- Transportable
- Fully automated
- Sealed and air-conditioned
- Easy maintenance



	UFO	miniSLR
Energy	50 µJ	200 µJ
Divergence	100 µrad	50 µrad
Aperture	42 cm	20 cm
Photons / Puls	0,02	0,08
Rep-Rate	100 kHz	30 kHz
Return-Rate	2 kHz	2 kHz

Link budget Lageos @ 7000km

Summary

- New technology opens up interesting new possibilities for SLR (fibre coupling, 100 kHz, …)
- Open source software and hardware foster cooperation
- Let’s build a minimal SLR station!

We invite for collaboration!