Systematic Bias Elimination by Co-locations as well as by Intra- and Inter- Technique Closure Measurements

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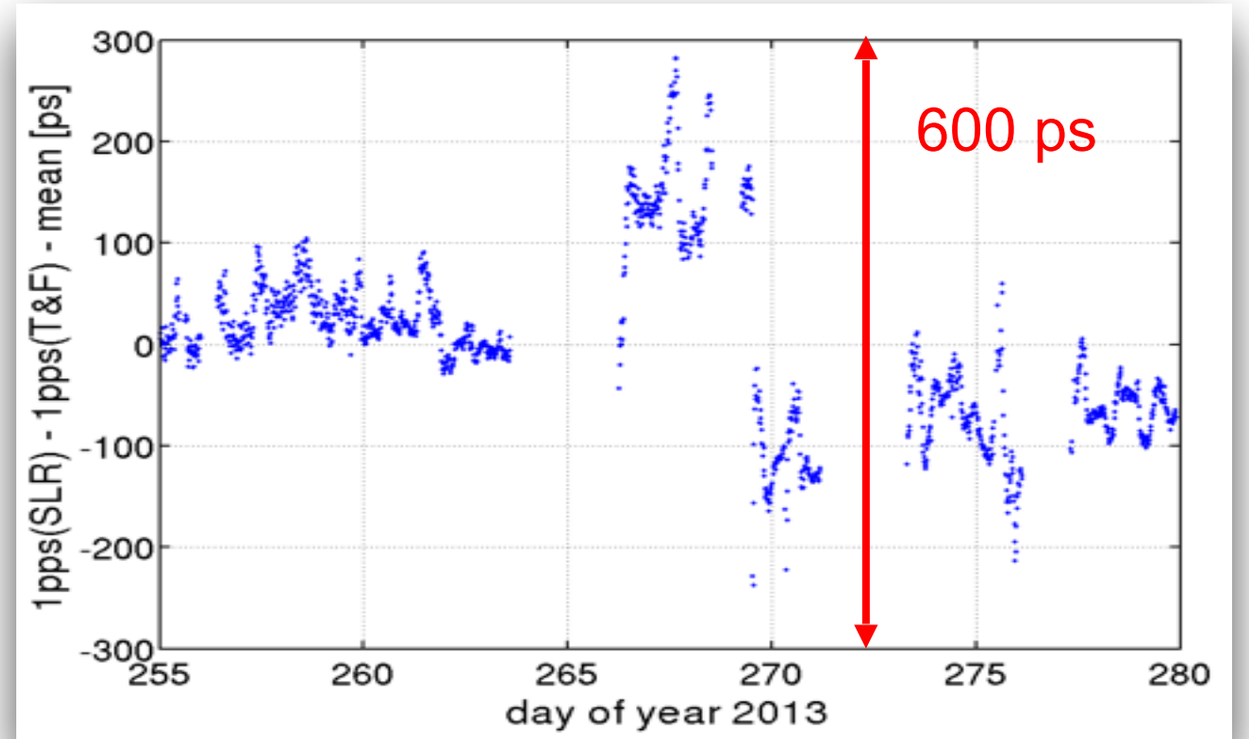
The demands for the accuracy of the GGOS measurements are a high and the system for the distribution of time and frequency on a geodetic fundamental station is in a central position. Variable delays within the main techniques of space geodesy, namely SLR, VLBI, GNSS and DORIS are limiting the stability of the measurements. This leads to the rather paradox situation, that each technique has to adjust the clock offsets independently. Although all main measurements systems on an observatory are usually based on the same clock, each technique provides different offsets. This reflects the fact that the "clock adjustments" are highly contaminated with (variable) system specific delays, which usually have independent causes. None of these delays are stable over time. Closure measurements with an all optical time and frequency system based on the "Einstein Synchronization Procedure" for example allow to reference all measurements to the same time scale at every measurement system and more importantly to control the system delays to a high level of accuracy within each measurement technique and from one technique to the next (e.g. from SLR to VLBI).

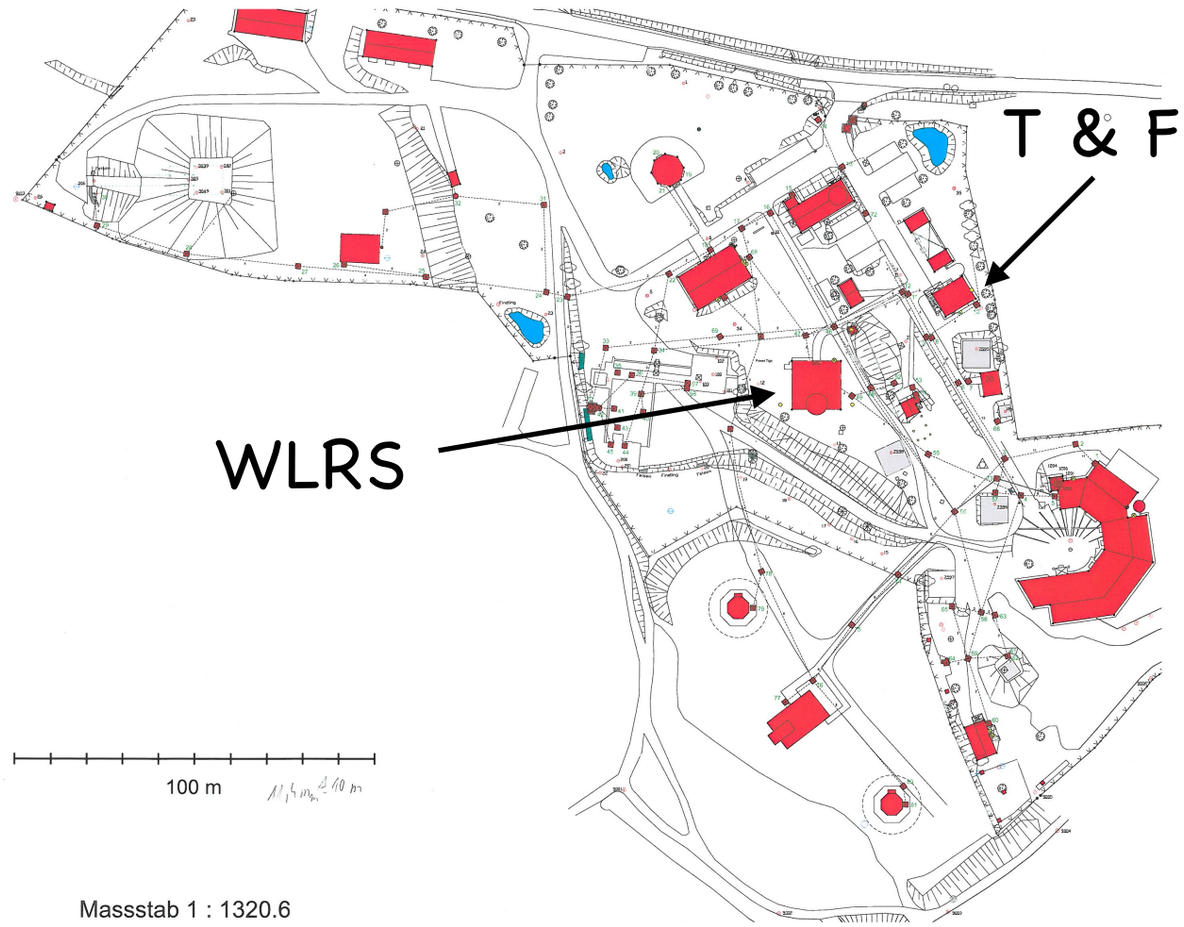
Survey Errors in Wettzell are obtained consistently small

Systematics are hidden in the "TIME"...

…therefore time is not available as an observable!!!

- In order to monitor (variable) delays we need to watch the **phase** of a clock

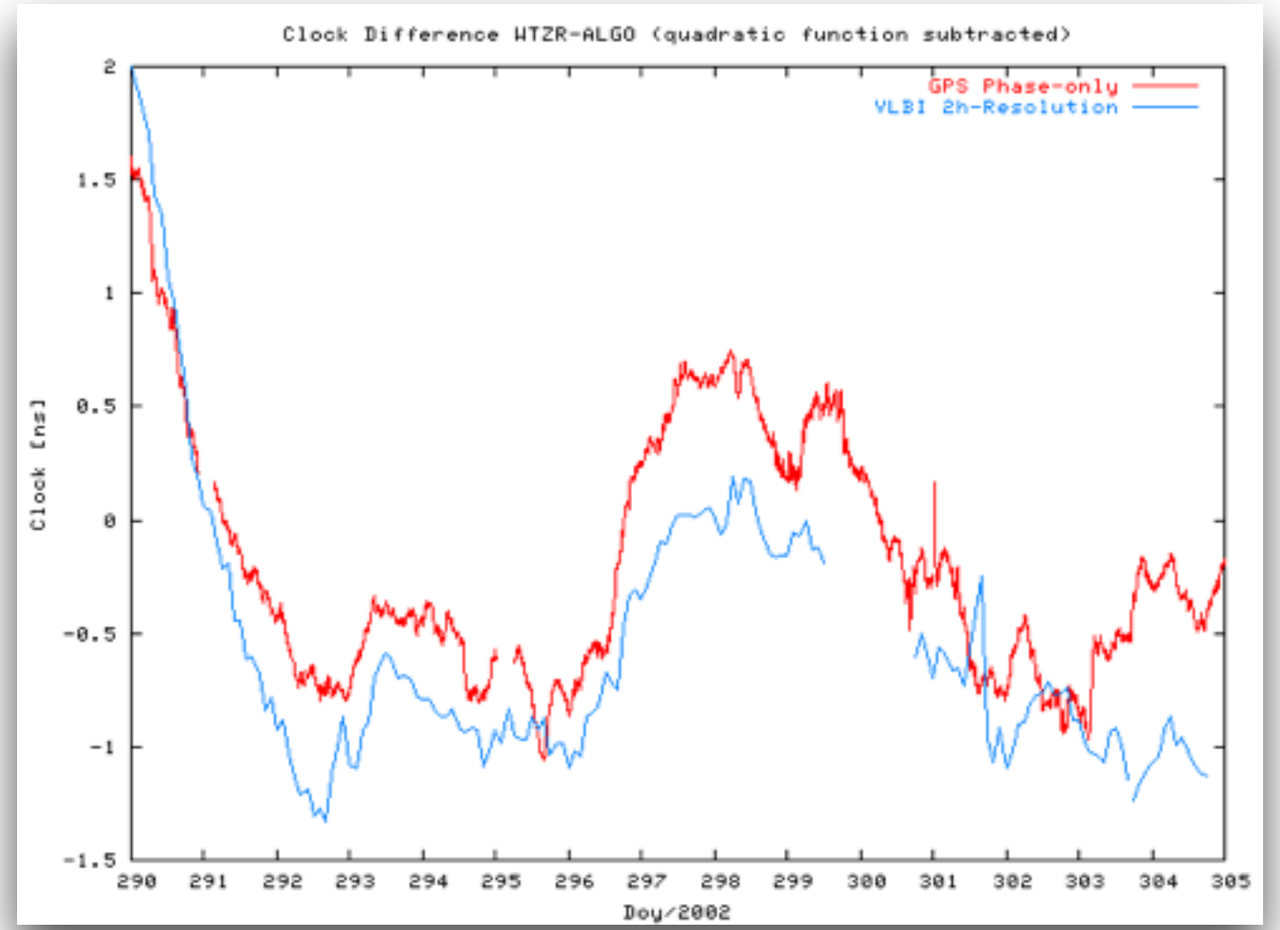




Fact list

- A Campus has varying ground potential
- Electronics are (highly) sensitive to temperature
- Electrical pulses are bandwidth limited

Closure measurements are powerful tools



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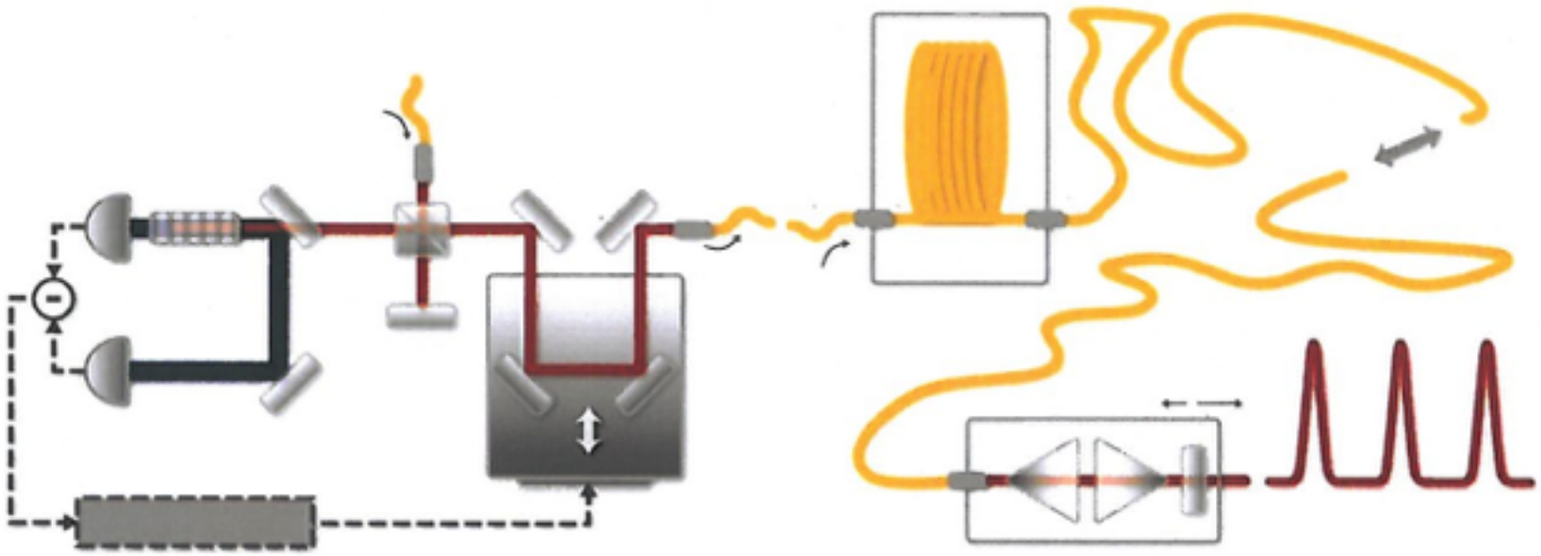
Observation: Clocks accumulate all sorts of systematics (Delays) of the various techniques.

Therefore **clock parameters** are absorbing technique specific delays. On closure inter- and intra- technique comparisons are providing access.

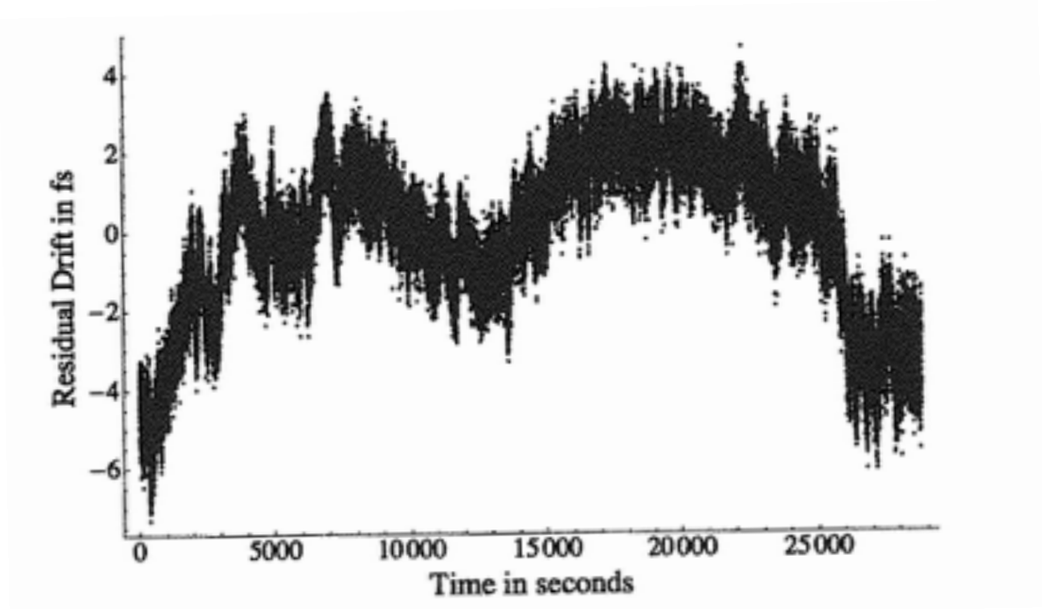
A common clock and "super-conductor for time" can tie all techniques to a single point regardless of their nature

Two- Way Time and Frequency distribution (local)



- 2-Way compensation technique only possible in the optical domain
- required broadband signal available from fs-pulse lasers only
- Expected uncertainty of optical signal < 100 fs:
  ≈ 5 orders of magnitude gain over current situation
- Consequences for Local Survey: 1 mm = 3 ps

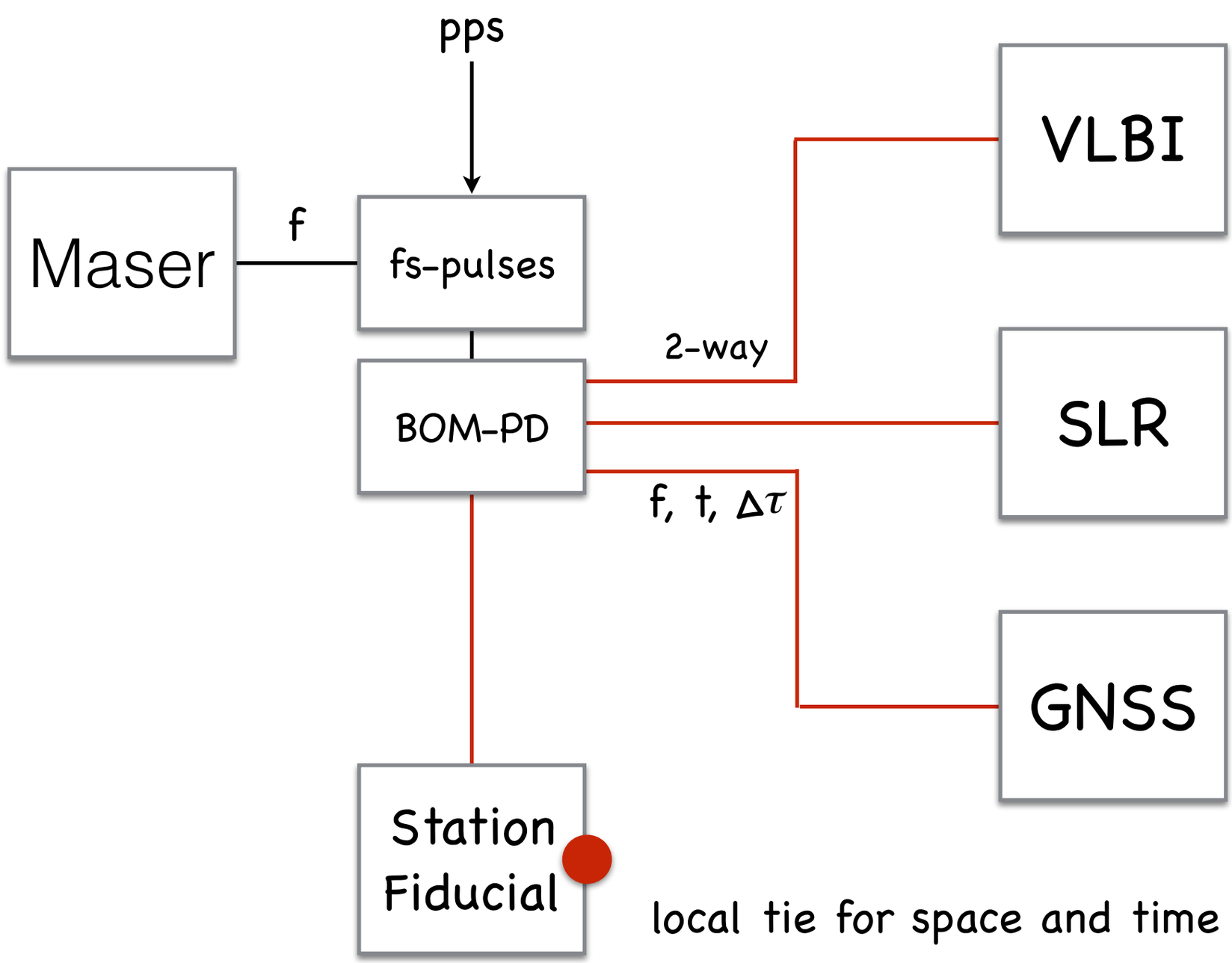
Example of feasibilty: FEL in Trieste



Lossless Distribution

Interpolator

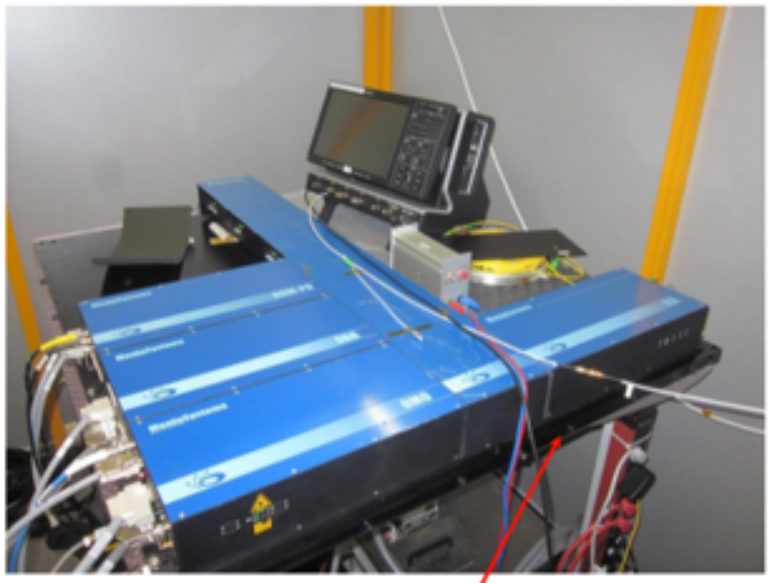
Geodetic Techniques



Consistence check by Closure Measurements

Two- Way Timing Techniques (local)

Timing Distribution System (TDS) (Wettzell)

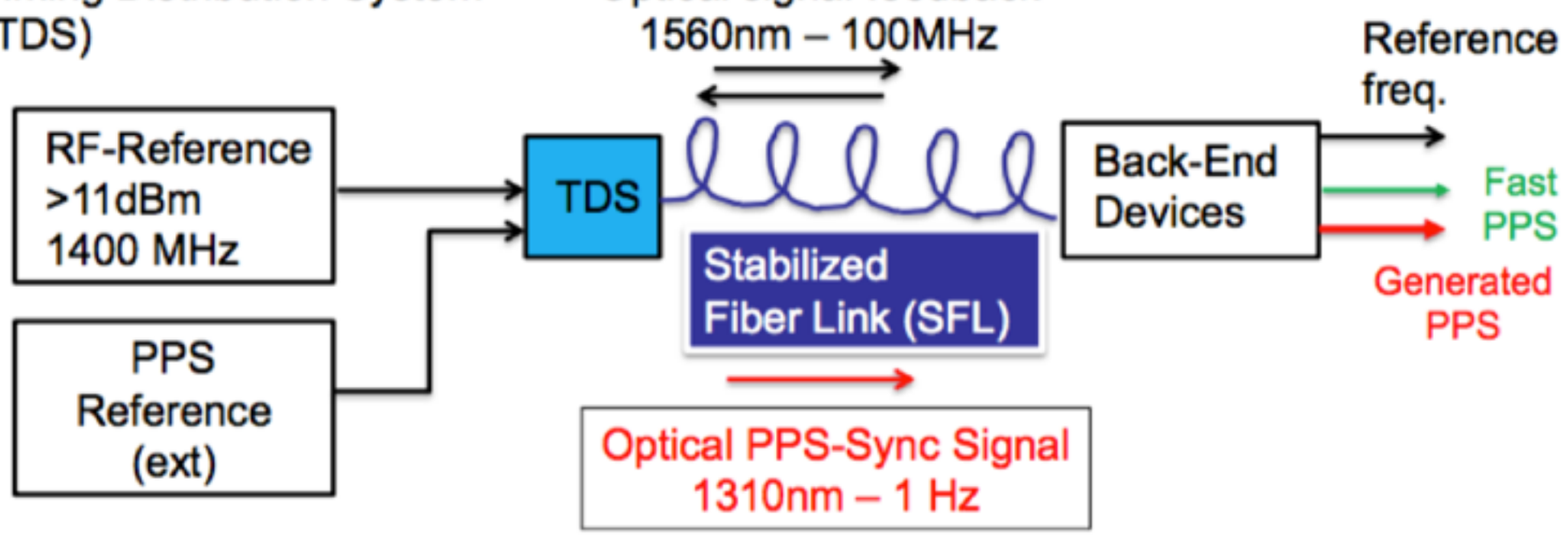


Menlo Systems

Syncronization ASOPS Systems

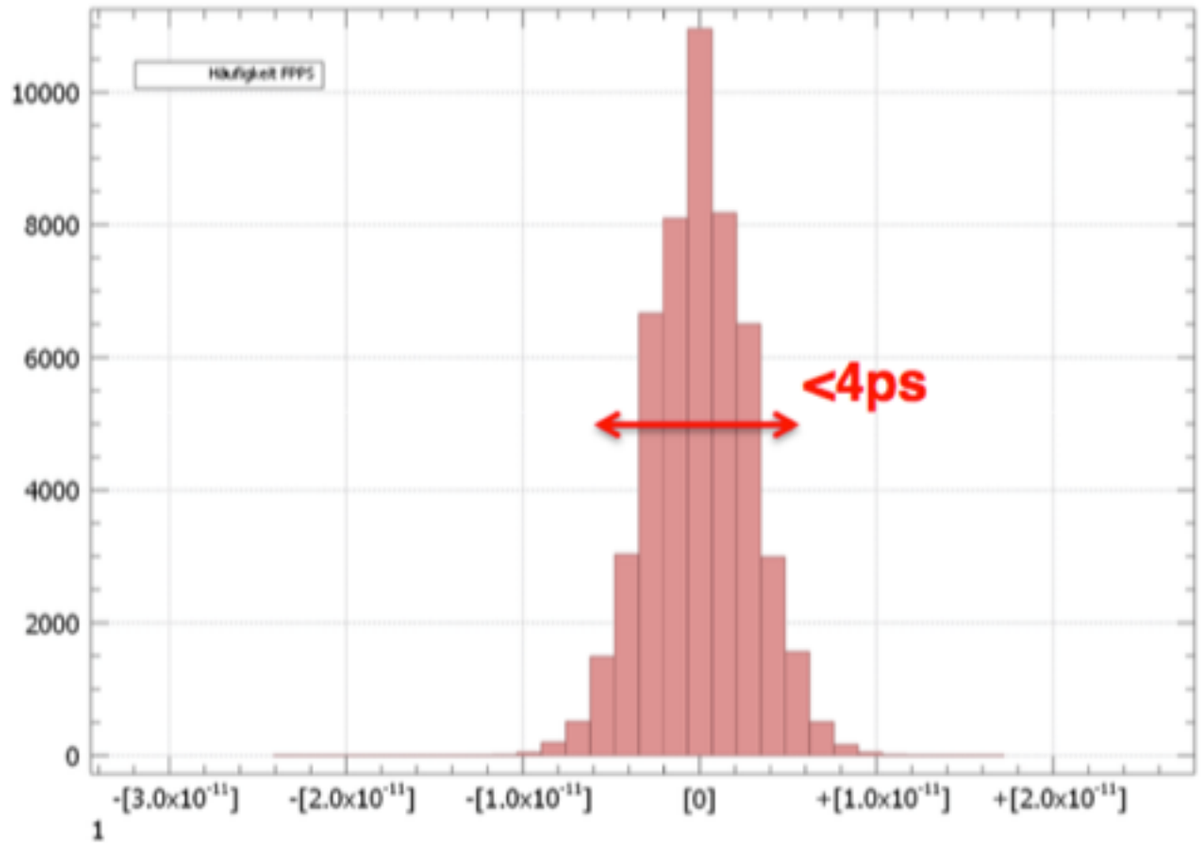
Timing Distribution System (TDS)

Optical signal-feedback 1560nm – 100MHz

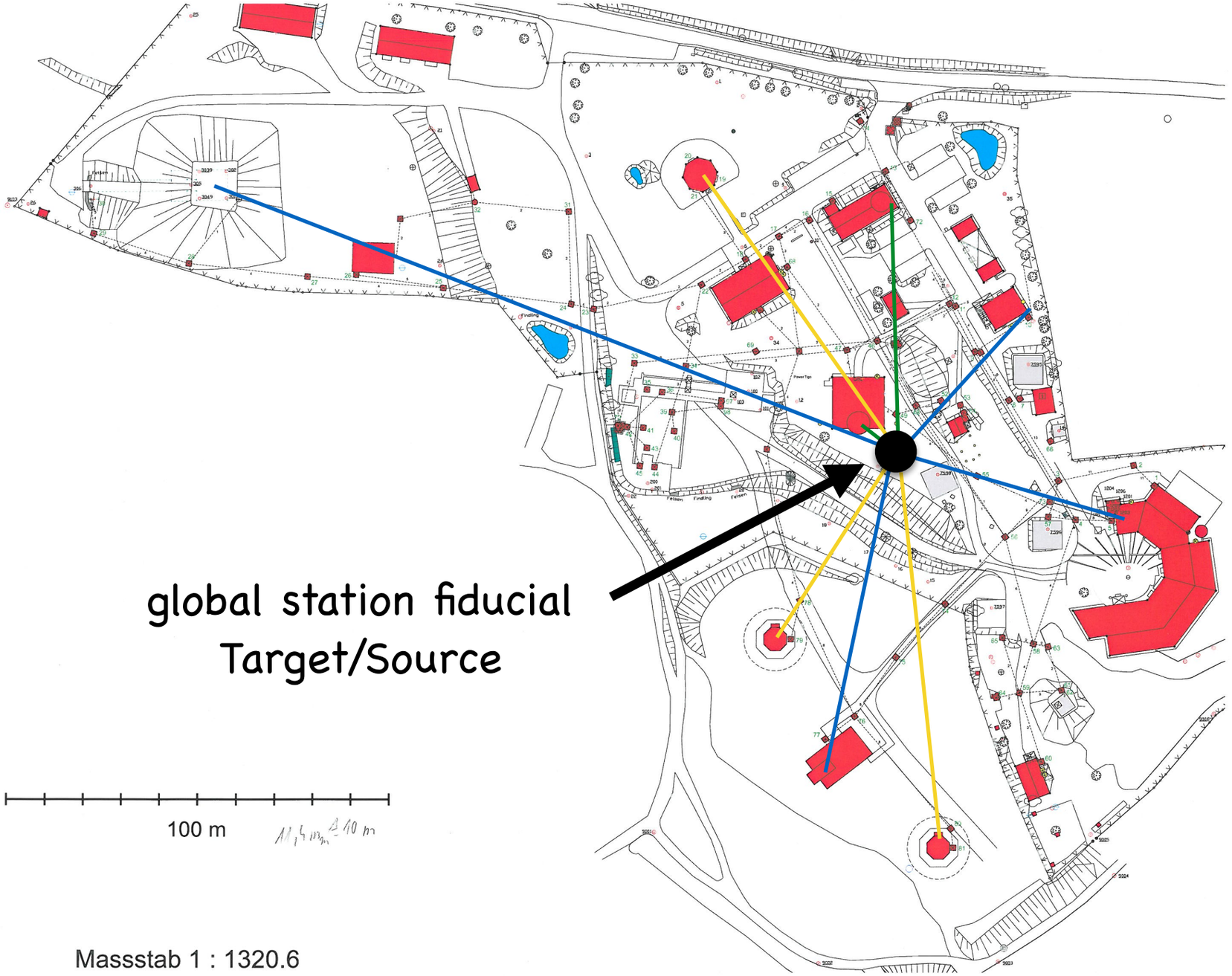


Two- Way Timing Techniques (local)

OFC link stability test (24h) of prototype in laboratory
(Scatter of 1 PPS over ≈350 m of fiber line)



Delay Control and Inter- /Intra- Technique Reference



Delay Control and Inter- /Intra- Technique Reference

GNSS Antenne
(for now)

Goal:
synthetic GNSS Beacon

VLBI Beacon

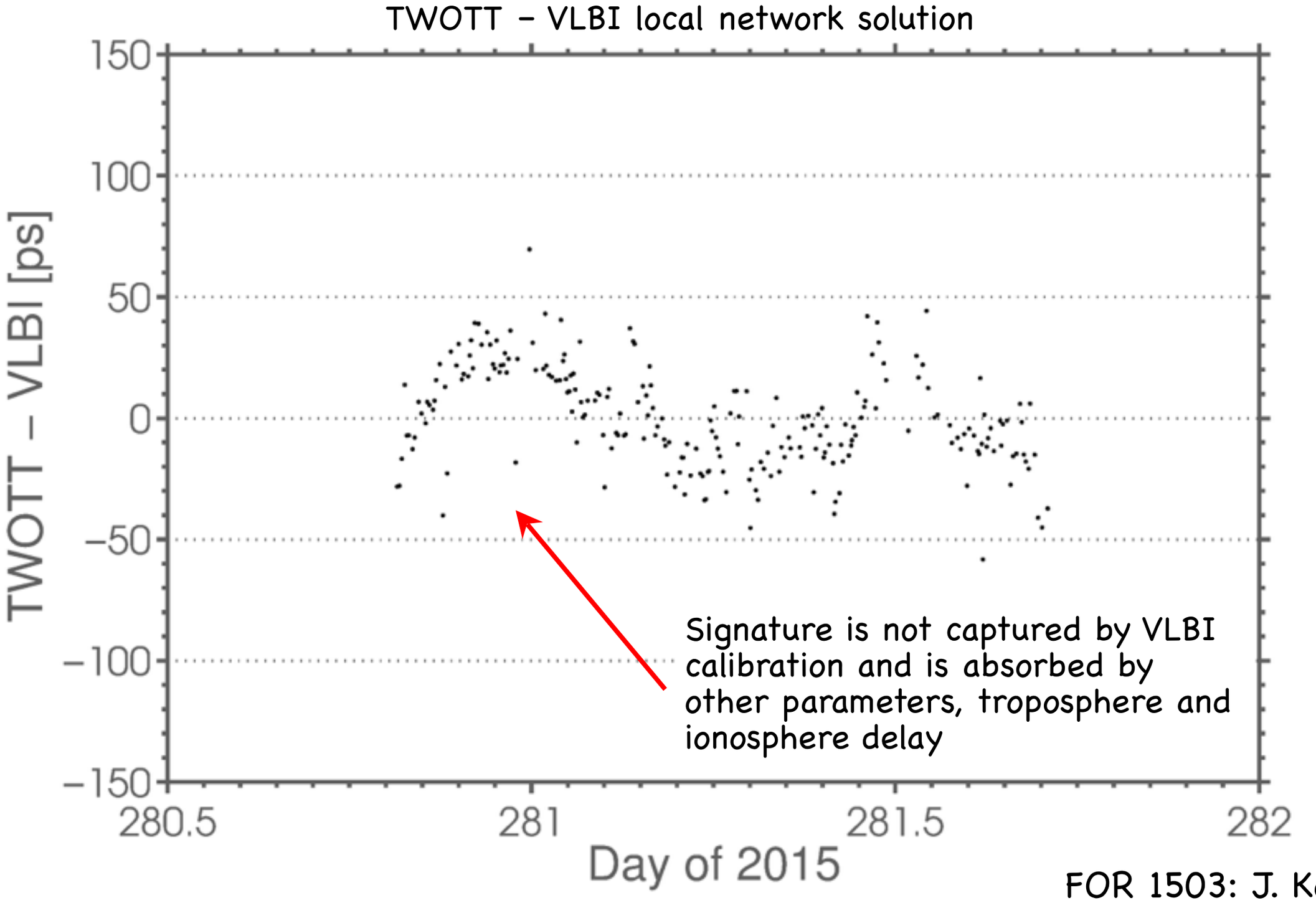
(Access to Timing System)

Laser reflector:

(Luneburg Sphere)

Zero Signature in all directions

Comparing Time Scales Between Two Radio Telescopes



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Summary

- **Local Surveys** have demonstrated stability at the 1 mm level
- **Space Geodesy** does not use accurate time for purposes other than **error assimilation**
- As a consequence **systematic errors** remain, although the data looks smooth.
- **Frequency** has to be stable. It is obtained from quantum mechanics (atomic transition)
- **Time** is a broadband signal: providing reference to the **phase** of a frequency
- It is necessary to track time and add consistent **Closure Measurements** to our repertoire