Time Transfer, LRO, LLR and SLR2.0 at Wettzell

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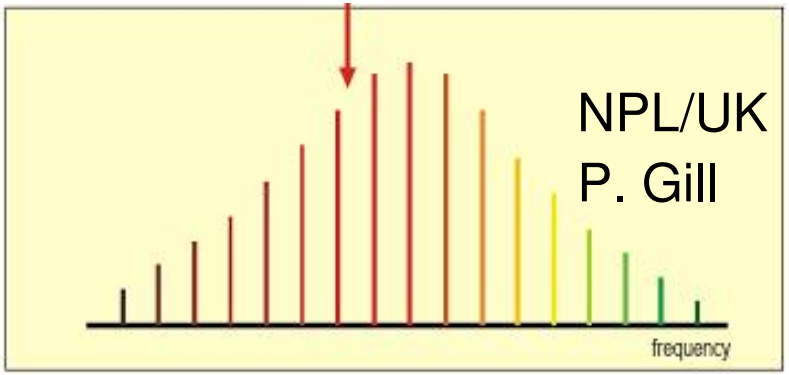
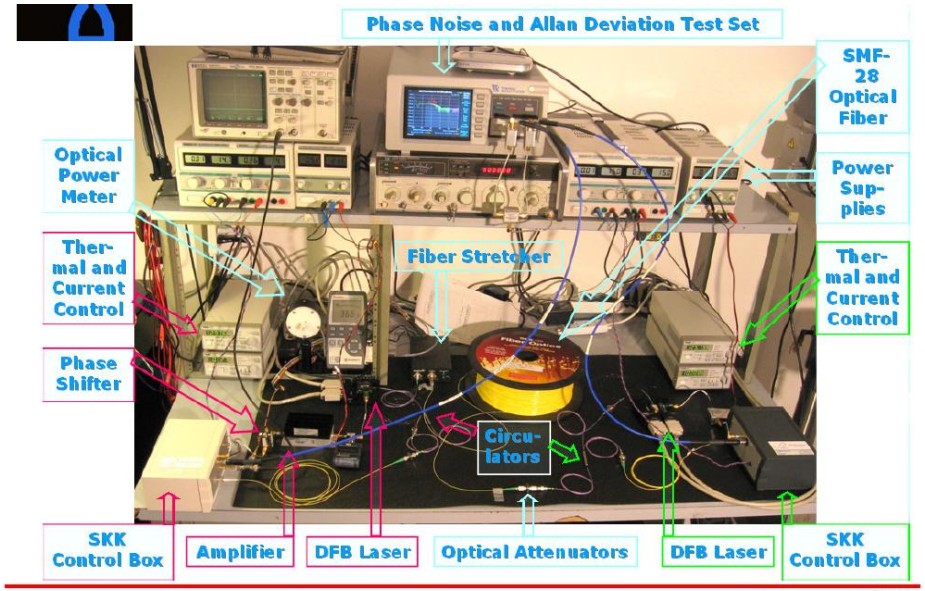
Time Transfer – Availabilities

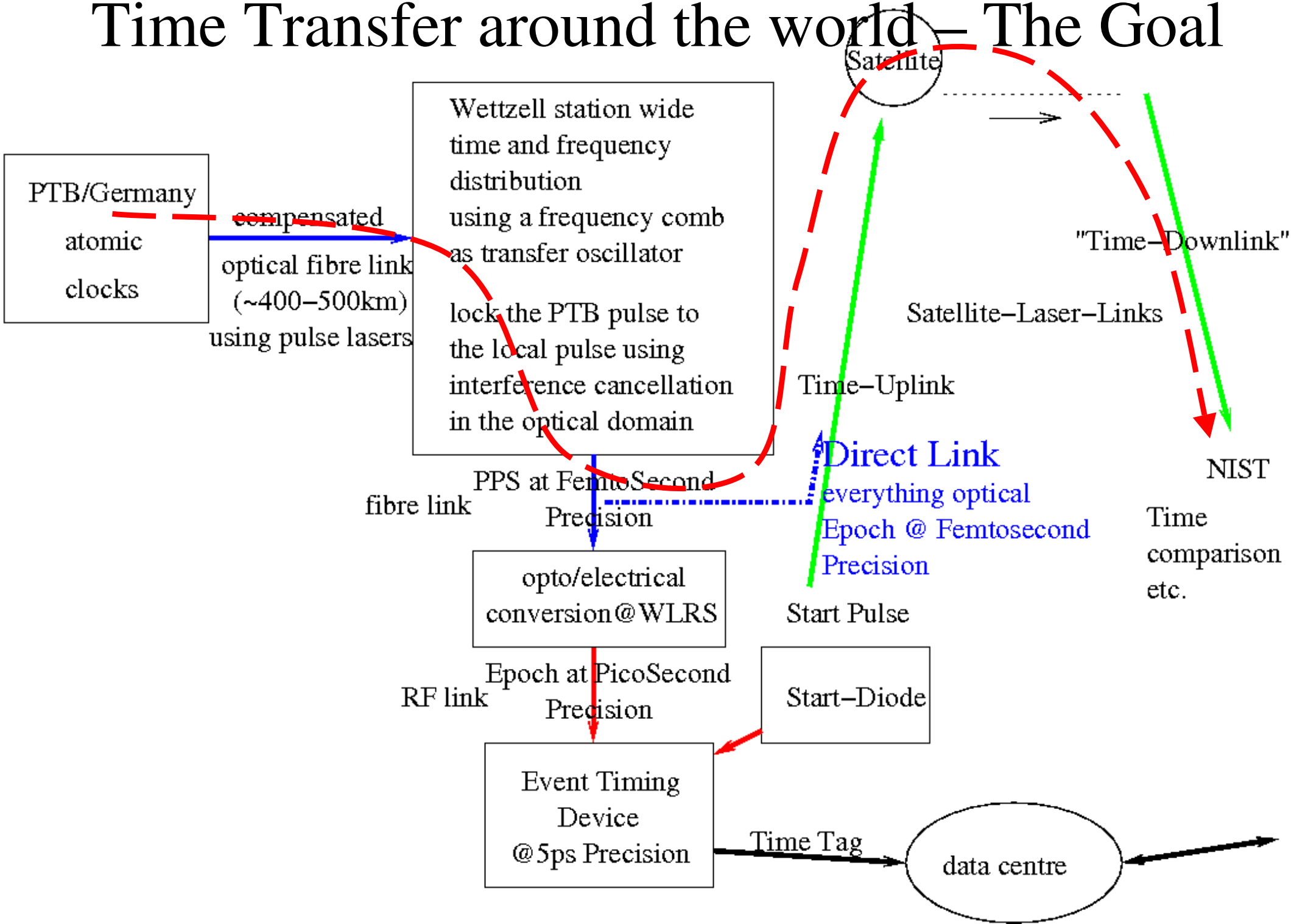
- femtosecond pulse laser
- optical frequency comb
  - pulses in the time domain and
  - spectral lines in the frequency domain
  - connection to rf-signals: rf-periods are integer multiples of optical periods!
  - some different techniques
- compensated optical fibre link
  - a lot of links/publications already exist @SYRTE, PTB, NIST,...
  - compensated: phase delay adjustment and phase jitter minimisation by using interference cancellation with return signals and e.g. fibre stretcher
  - some different techniques too



femtosecond optical frequency comb (counter)

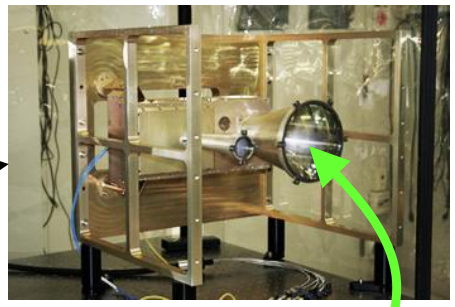


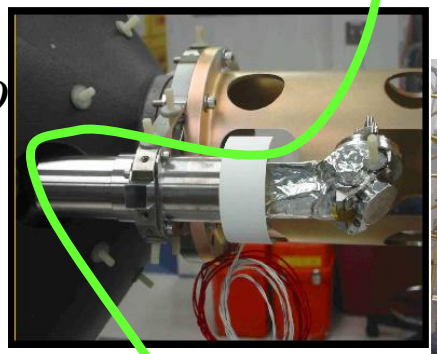
Time Transfer around the world – The Goal

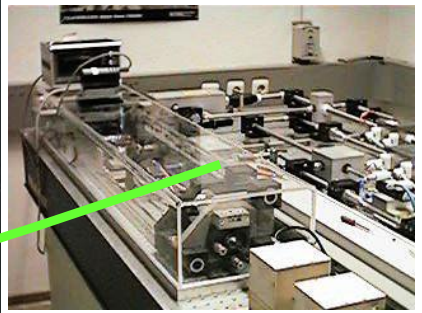


Lunar Reconnaissance Orbiter/ LRO-LR, NASA (1)

Detector @Spacecraft: @ 28Hz gated,
8ms Gate window, very sensitive (fJ/cm^2)



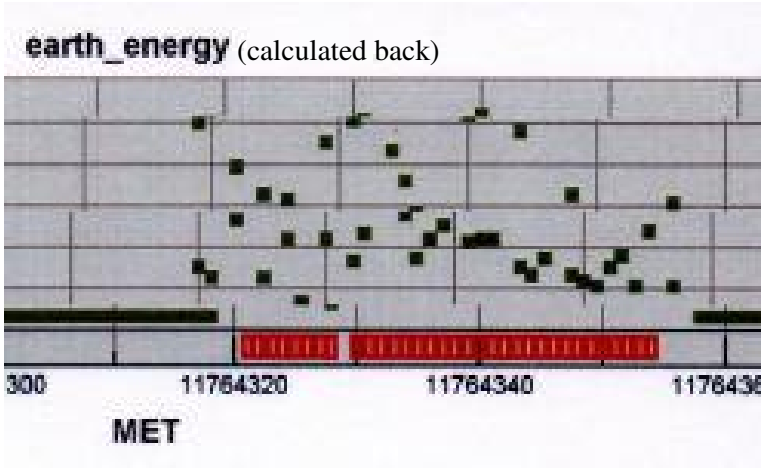




- ***Adaptation of the Hardware***
  - *Asynchronous Laser pulse-fire@WLRS, that is 9.3Hz not synchronous @ 28Hz GateOpen@LRO*
  - *Fire frequency/-periodic duration made easily changeable, in order to hit (0.5ms/Fire)*
  - *Telescope-Pointing error - Minimisation*
    Mount-Model, Re-evaluation of the Software, analysis of the results of the high earth orbit Satellites
  - *Laser-Power boost (30mJ..90mJ)*
  - *Divergence-Adaptation (1”..330” half angle)*
- ***Adaptation of the Software***
  - *Security: Implementation of the Go-NoGo-Flag*
  - *One-Way-Mode and Data evaluation of the involved Softwares enabled*

LRO (2) - Tracking

- *Variation of the fire frequency AND Pointing*
- NASA gets via the LRO RF-Downlink the Detector-Hit-Event-Data
- *Feedback on Real-time Hit-Window of the NASA via Internet*
- Handicaps: Weather, Technics, Moon constellation/-elevation, Schedules, Error estimations, …



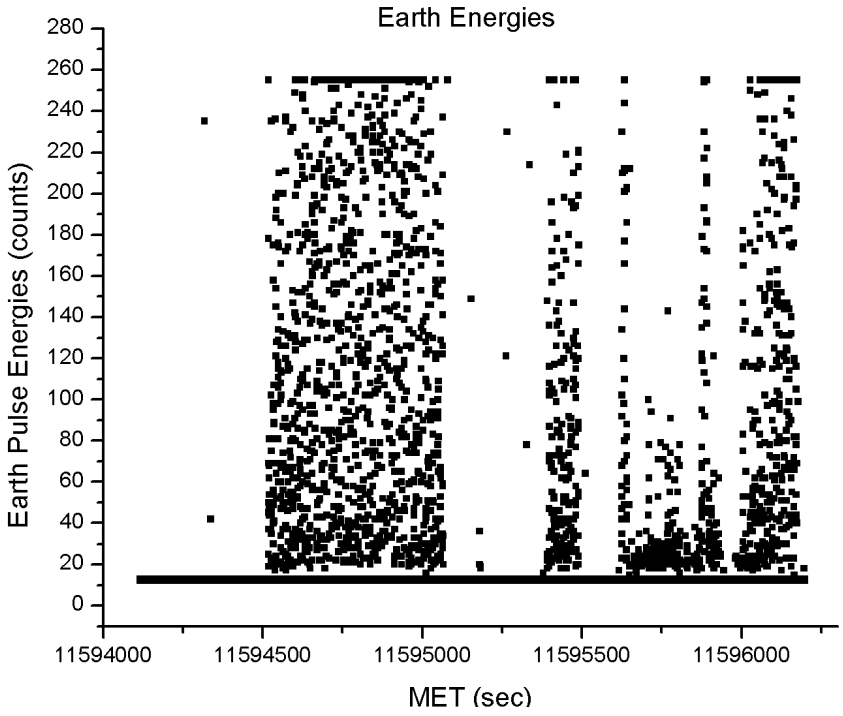
while(1)

- *WLRS-Start-Events send to the NASA*

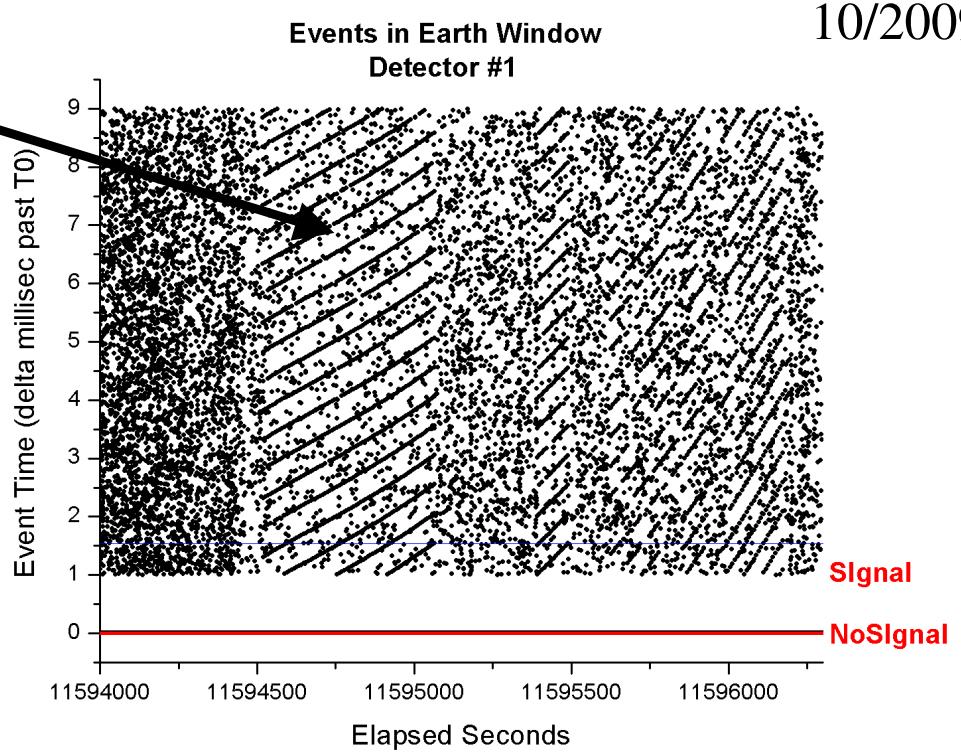
LRO (3) – Evaluation

- NASA processes Data
- WLRS and LRO not frequency-synchronous -> Hits drift within Gate: Lines having gradients
- ***First two Hit-Passages: 16+20Minutes in 10/2009***

  Therewith Wettzell has realised Time Transfer to a moon spacecraft



10/2009



LRO (4) - Outlook

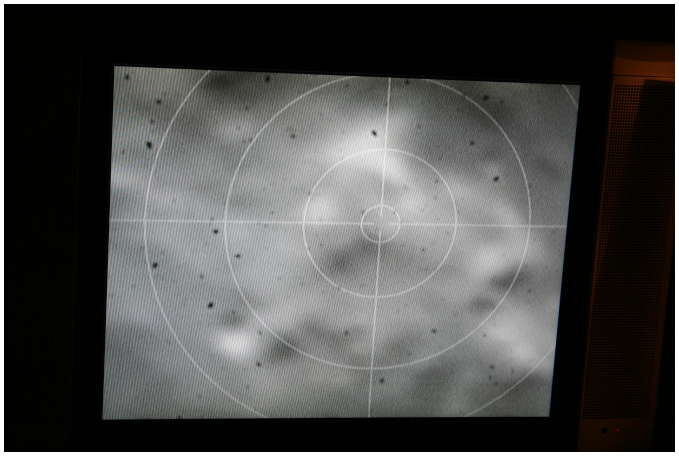
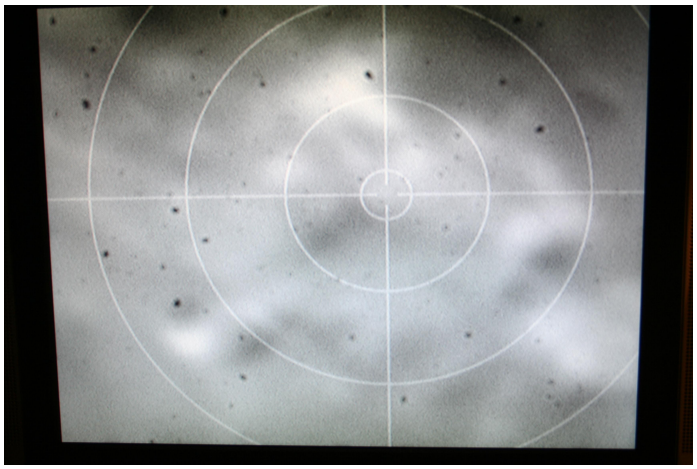
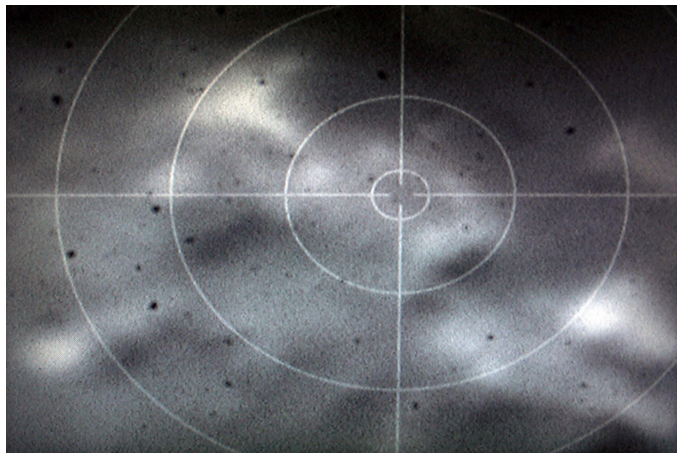
- observation now routinely
- use LRO for Time Transfer in the real sense: with another station
- @Wettzell responsible: lauber@fs.wettzell.de

LLR – Preparations

- Predictions (by A. Neidhardt and L. Schreiber)
  - for new data base: verifications, fixes:
  - checking in-bounce/out-bounce time,
  - checking of different source code distributions
- Mount model (by M. Ettl)
  - verifications/improvements,
  - WLRS telescope mount tilt modelling
- Event Timer
  - capable to group these long start-stop delays by design,
  - hit detection: made passage re-processable (apply other hit detection/statistics parameters on original saved values)

LLR – Pointing Test Session



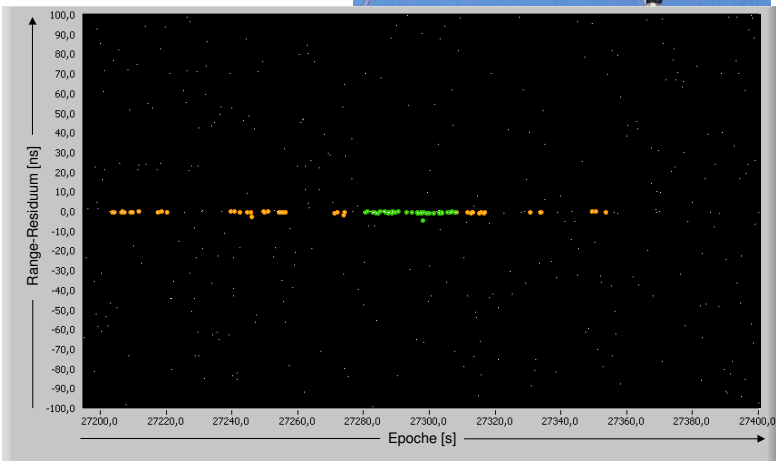
successful visual track 02/2011 ☺

LR-Station Refurbishments

- Telescope Hardware
  - WLRS: mechanics, engines, engine drivers, control unit, ... (finished since mid 2010)
  - SOS-W telescope returned to manufacturer (before first standardised operation): secondary mirror mount not stiff enough (pointing error)
- Software SLR1.0 (the old one): historically overloaded:
  - too much added over a lot of years,
  - too much programming languages involved (LabView, Python...),
  - too much unstructured cross links between the softwares and the PCs,
  - too much developers wrote on different code parts and are no longer available for up-dating/maintenance,
  - maximum RepRate only ~20Hz

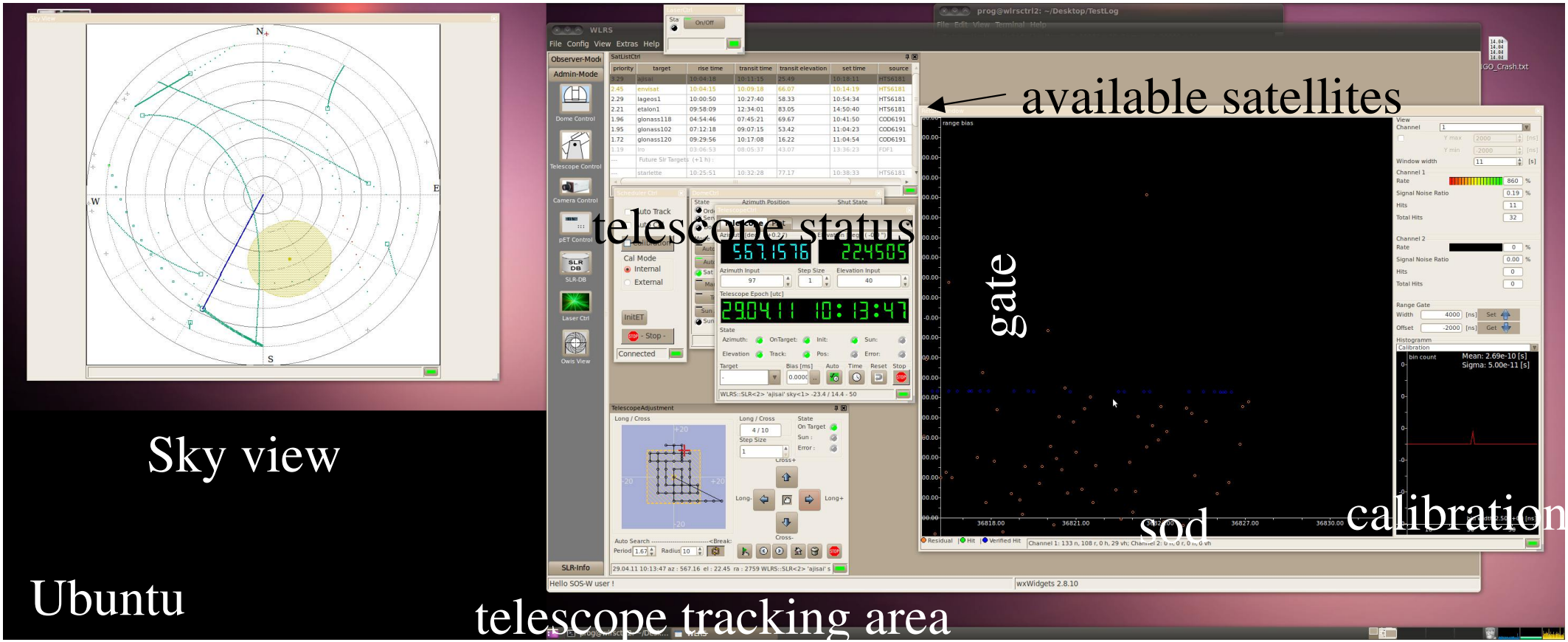
WLRS

SOS-W



LabView Gate vs. Sod

New Control System Software SLR2.0 (1)



Satellites can be tracked and the observation evaluated!

Software SLR2.0 (2)

- basis
  - Linux OS, C++
  - cross platform GUI library (wxWidgets, open source),
  - unique hierarchy (sockets/RPC client/server)
- complete new by design
  - configurable: porting from one SLR-system to another easy: “almost” a change of some configuration parameters
  - fully automated for unattended operation,

    only currently for tracking, observer needed and due to security reasons
  - independent device driver stubs, GUI
  - ***RepRate 1kHz***
  - ***meets all the requirements needed for the time transfer applications e.g. start epochs at maximum precision***

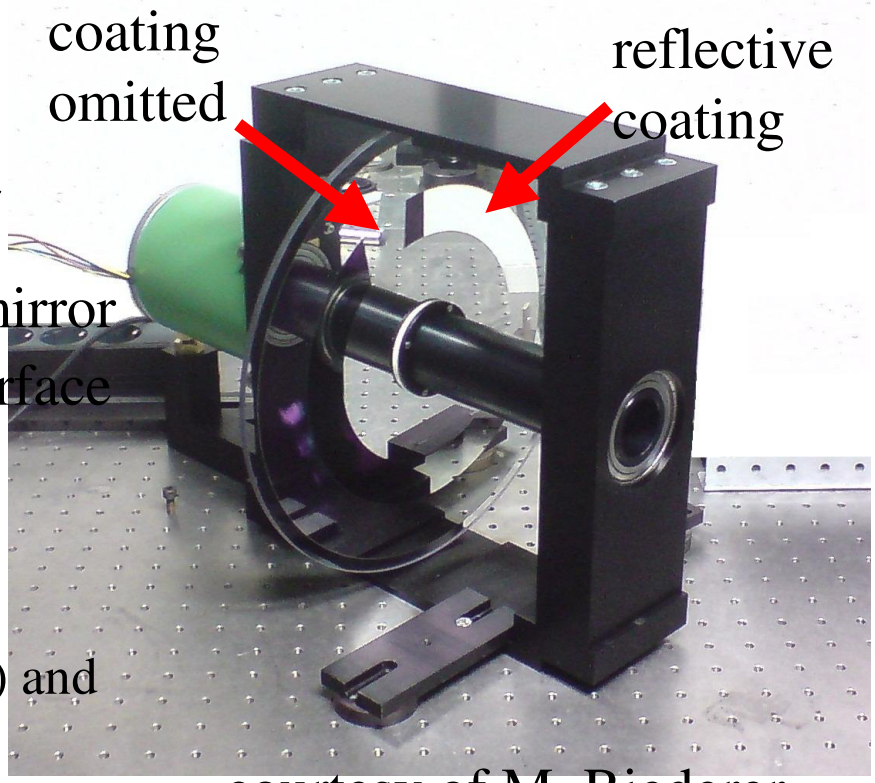
Software SLR2.0 (3)

independent device driver stubs:

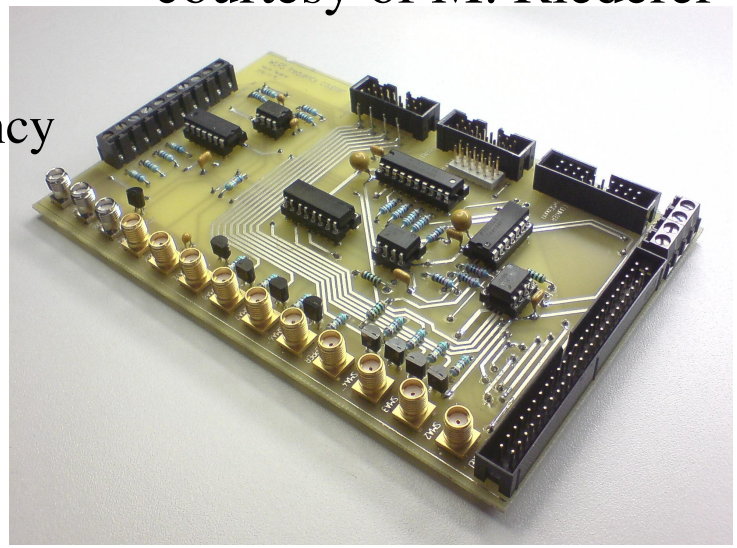
- data base: new CPF, much faster,
- control instances of
  - telescope, dome, laser, event timer device, radar/transponder/lidar, optical path,
  - observer-mode: telescope tracking area,
    tracking parameter IO (range gate, hit benchmark, calibrations...)
- system monitoring
  - security interlocks,
  - data and debug logging,
  - weather station and it's data transfers, etc.
- signal data processing path
  - real-time data acquisition,
  - compression/decompression for LAN transfers and for data archives,
  - hit detection (partial orbit fit), observation evaluation (complete orbit fit),
  - generation of the standardised output data files (CRD: NP, FR and the old ones)

@WLRS: New T/R unit

- stepping motor rotates glass instead of mirror
- glass segments coated with reflecting surface
- Advantages:
  - no unbalanced mass
  - ***RepRate 20Hz (30Hz)***
  - adjustable frequency (division of 5MHz) and different delays (multiples of 200ns)
  - laser fire frequency and delay is generated similar and synchronous
  - everything synchronous to H-maser frequency and adaptable to local time (1PPS)
- Disadvantages:
  - RepRate 10Hz < 20Hz << 1kHz
  - Absorptions through the glass in the return path



courtesy of M. Riederer



Frequency coupler

Outlook

- Implement optical time and frequency system
- LRO Time Transfer to another station
- Start Lunar Ranging
- finish SLR2.0 software for both SLR systems, and start to port to TIGO
- Upgrade to new hardware over again, especially at WLRS:
  - add-on a high stable laser,
  - change to yet another new T/R unit

Thank you for your attention!