Verfication of ELT performance by Monte Carlo Simulations

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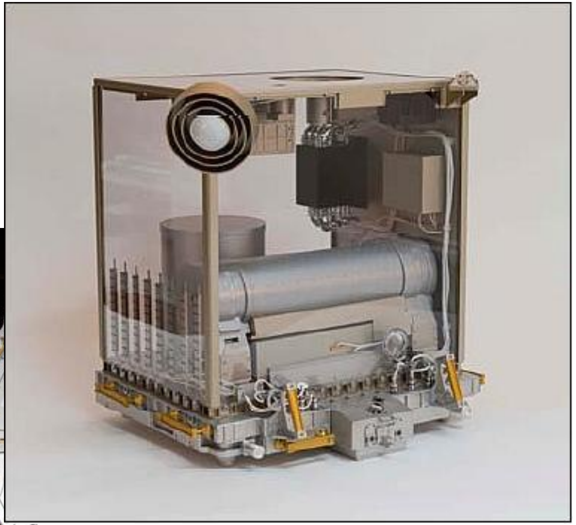
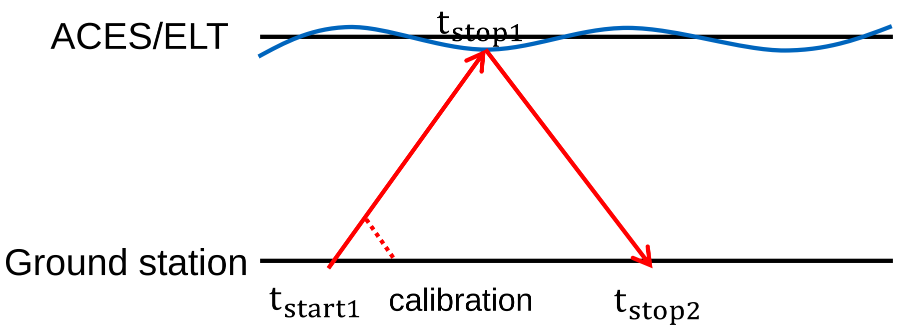
The ELT experiment



Optical time transfer



- One way: $tof_{1W} = R_{CoM} + \tau_{troposphere} + \tau_{Sagnac} + \tau_{Shapiro} + \tau_{attitudeDetector}$

- Two way: $tof_{2W} = 2 * \left(R_{CoM} + \tau_{troposphere} + \tau_{Shapiro} + \tau_{attitudeReflector}\right) + \tau_{Reflector}$

- Time transfer: $\tau = \frac{t_{return} + t_{start}}{2} - t_{detector} + \tau_{corr} = \frac{tof_{2W}}{2} + t_{start} - t_{detector} + \tau_{corr}$

Simulation tool

Geometric components

- Earth orientation (IERS 2010 Conventions)
- ISS attitude simulation
  (3 axes, constant offsets and oscillations)
- Detector and reflector position
- Intra-reflector delay (function of incidence angle)
- Visibility constraints (minimum elevation)

Signal delays

- Troposphere (including cloud cover)
- Sagnac effect (processing in ITRF)
- Shapiro delay

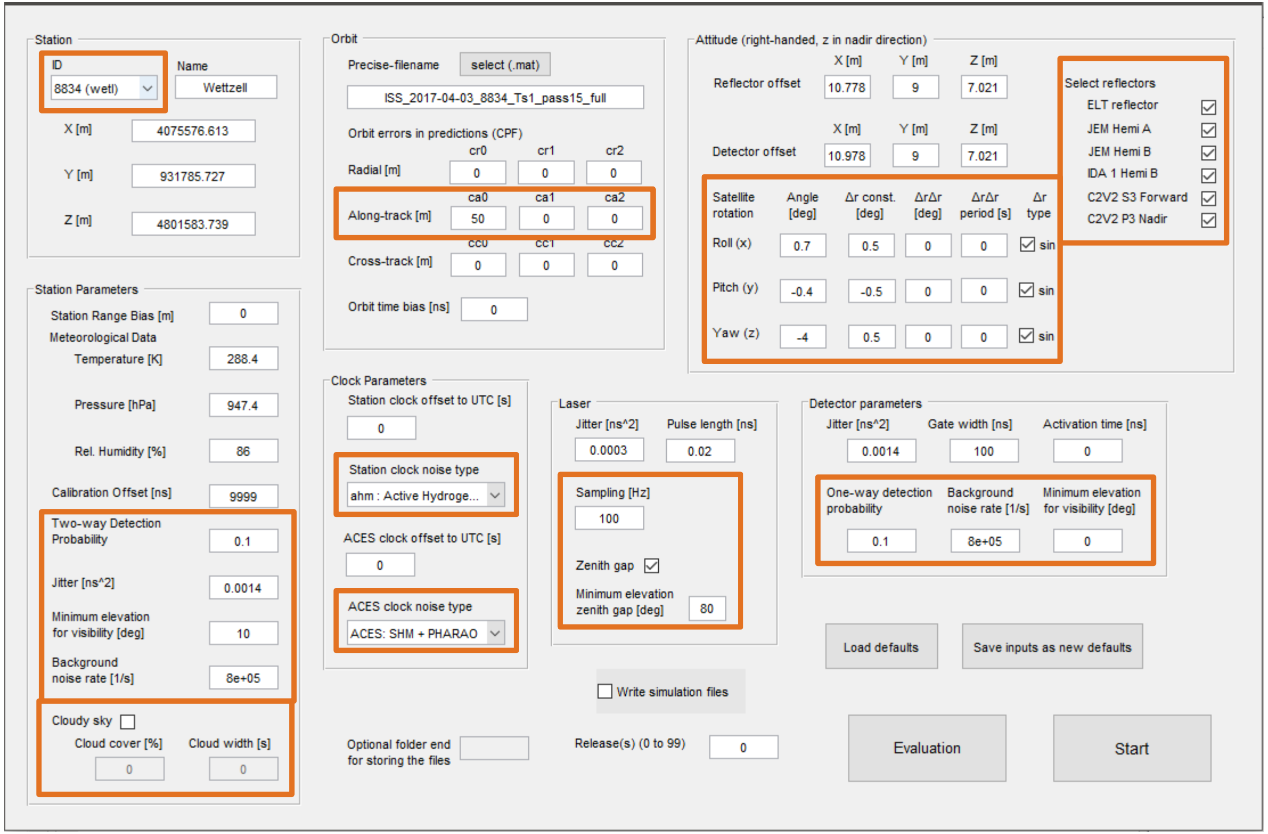
Relativistic effects on clocks

- Drift of clocks w.r.t. to UTC
  - … due to special relativity (relative velocity)
  - … due to different gravitational potential

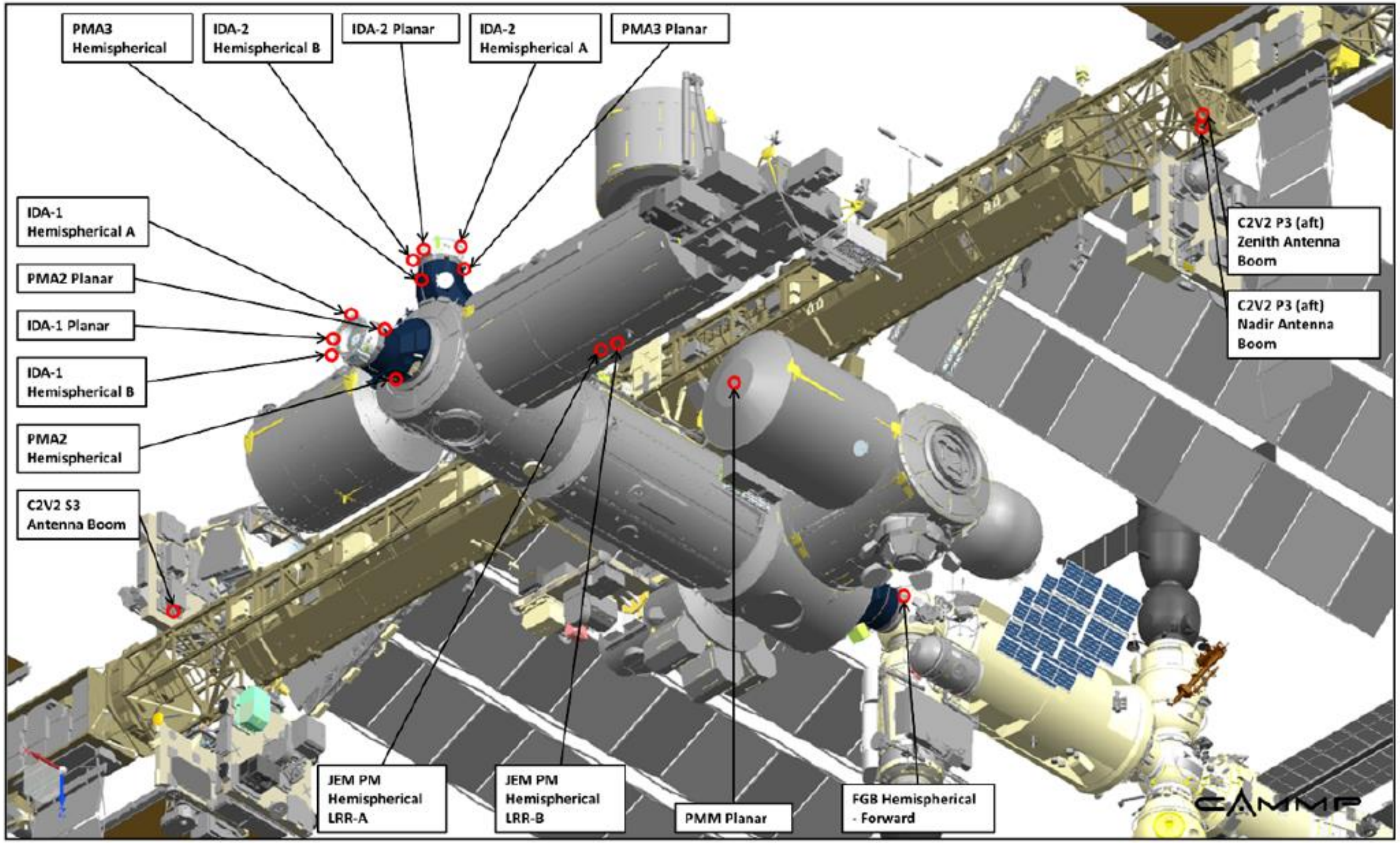
Stochastic components

- Background noise
- Laser Jitter
- Pulse width
- Noise of ground- and space-based clocks
- Cloud coverage (frequency and duration)

Simulation tool



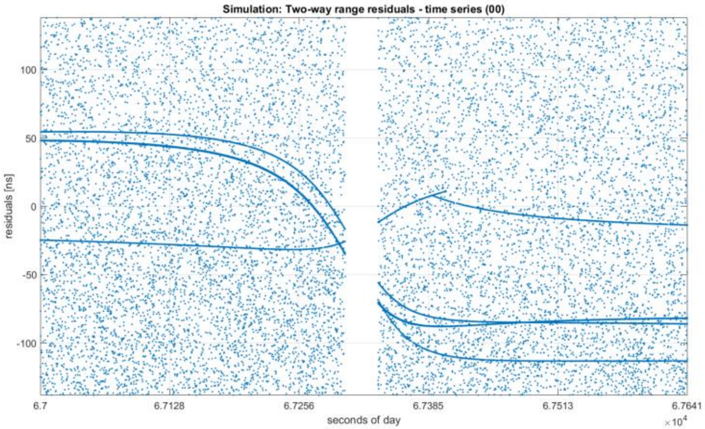
Multi-reflector problem



Reflector identification

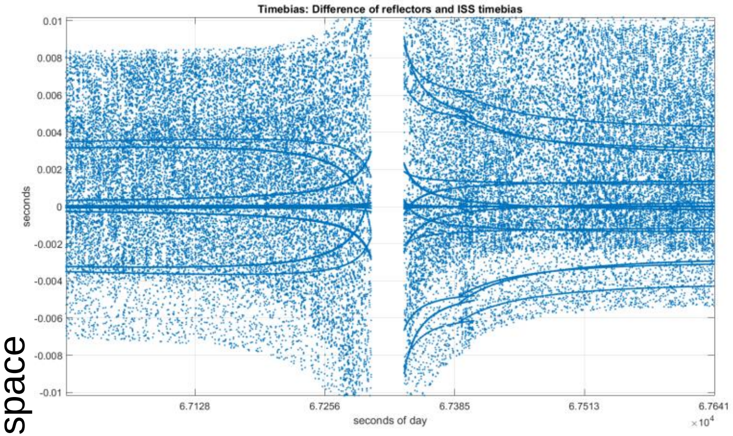
1

Simulation



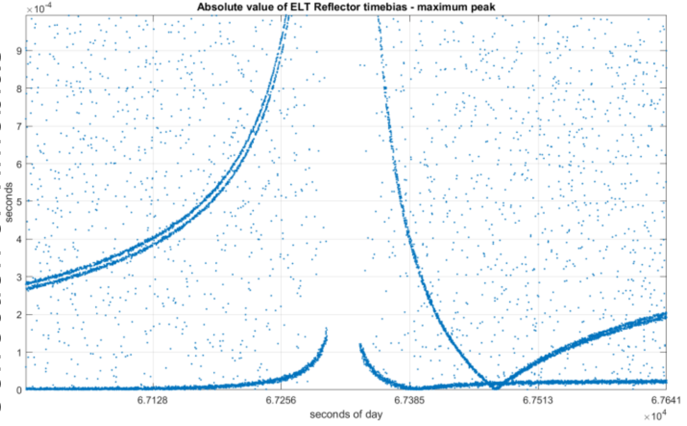
2

Transformation in Timebias space



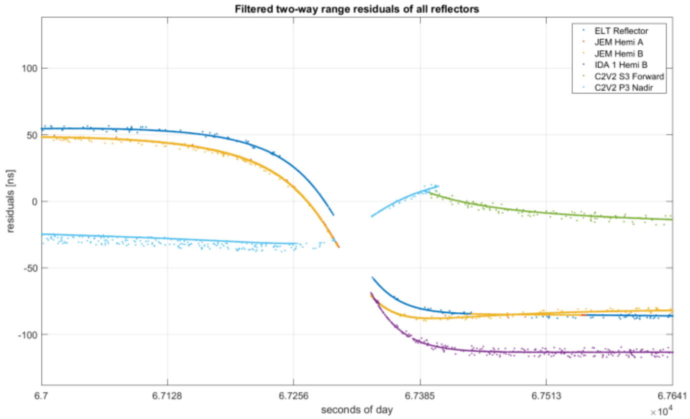
3

Correction of Timebias

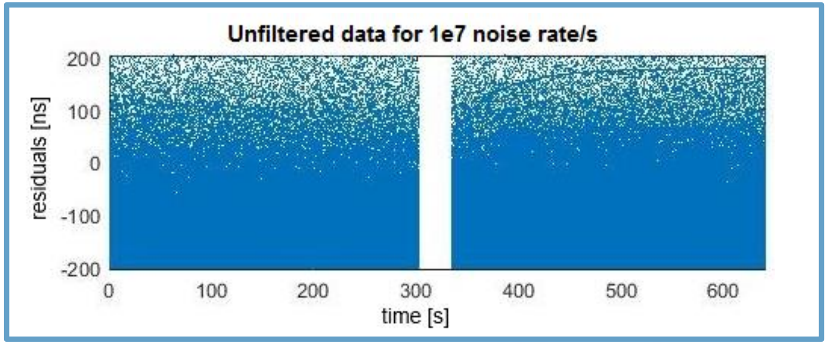


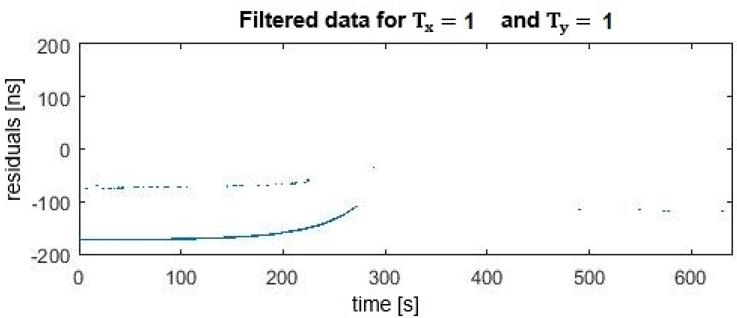
4

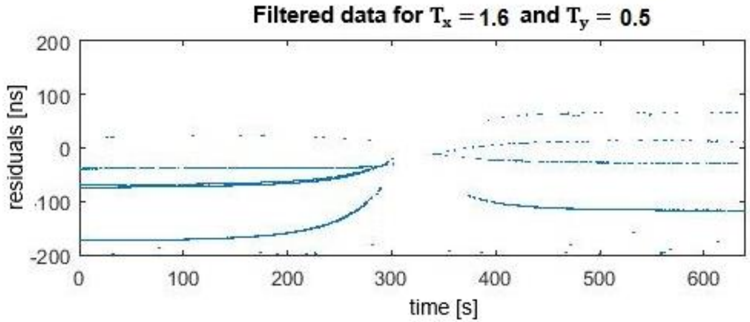
Identification of Reflectors

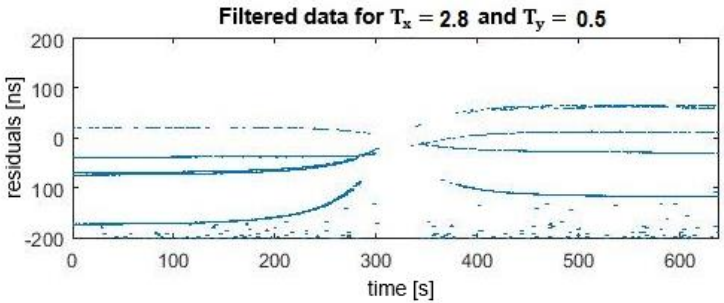


Binominal filtering









Monte-Carlo simulations

- **Data simulation and processing for identical parameters**
  - Passes
  - Laser system characteristics
  - Signal propagation characteristics
  - … (neglecting multiple reflectors on the ISS)

- **Randomness introduced by the following sources**
  - Background noise
  - Laser jitter
  - Pulse width
  - Clock noise

- **Studies without systematic errors**
  - Expected to converge to “true” clock offset
  - … if filtering does not fail
  - … and yields unbiased time transfer triplets
  - How does filtering perform statistically?

- **Studies with systematic errors**
  - Unknown attitude and orbit errors will be present (particularly in quick-look processing)

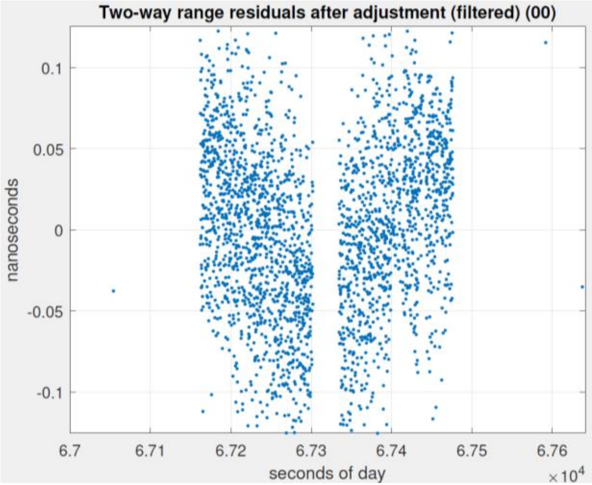
- Effects of cloud coverage and other constraints on performance

Results

Background noise rate [1/s]	**Noise reduction**	**Time transfer $\boldsymbol{\sigma}$ [ps]**
5.00E+05	no	1.6979
5.00E+05	yes	0.4541
5.00E+06	no	4.7743
5.00E+06	yes	1.8626

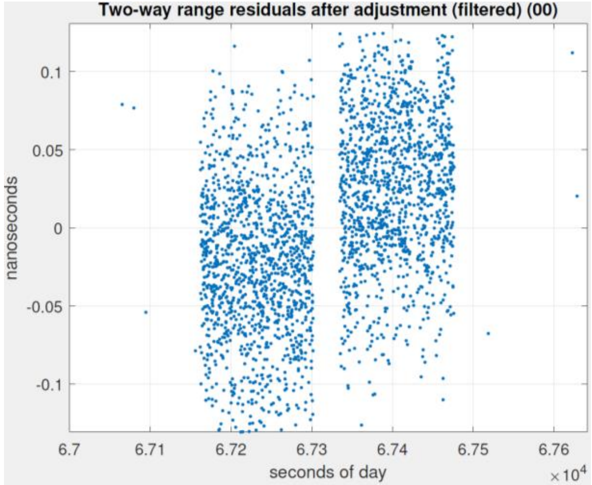
Monte-Carlo simulations

<u>Attitude error (only roll)</u>



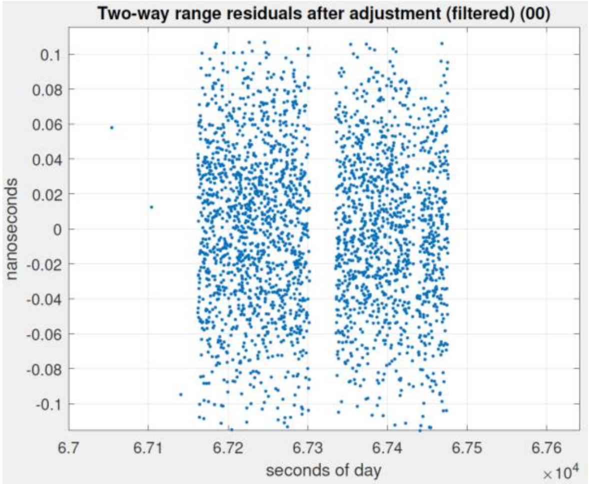
4rev/orbit

σ = 4.4ps



2rev/orbit

σ = 2.75ps



1rev/orbit

σ = 0.35ps

Real-time TB correction

100 m along-track orbit error, 1 m radial orbit error, constant 0.5° attitude error