ELT Data Filtering in Presence of Multiple Laser Retro-Reflectors

Christoph Bamann, Stefan Marz, Anja Schlicht, Rebekka Abel

Research Facility Satellite Geodesy (FESG), Technical University of Munich

Motivation

- Multiple reflectors mounted on the ISS lead to critical challenges for the ELT experiment
- Signals from the ELT reflector must be identified in the two-way residuals
- Without an identification the ELT Data Center cannot adjust orbit errors based on two-way ranging data
  - ➢ It is neither possible to adjust and filter the one-way residuals, nor can we calculate the data triplets required for the actual ground-to-space time transfer
- Reflector identification is crucial for operational time bias correction
  - ➢ Otherwise it is not possible to strike the ELT detector gate (100 ns) in case of an along-track error larger than about 20 meters (predicted orbits)

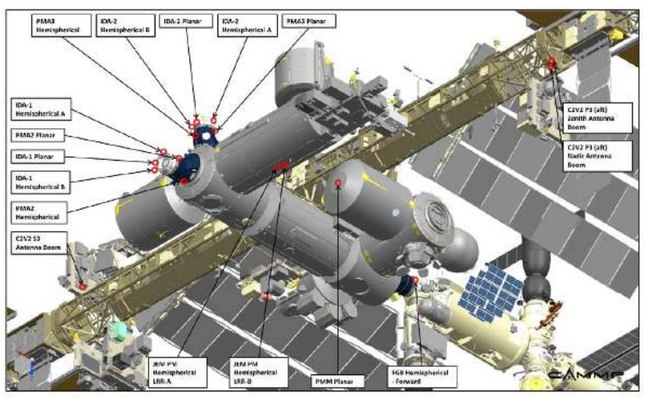

Figure 1: Multiple retro-reflectors on the ISS

Method

1. Apply noise filtering based on binomial event detection statistics on a gridded residual space (see Figure 2)
2. Estimate reflector time bias (TB) using computed (two-way) signal time of flight (tof_c) which is a function of known reflector position (see Figure 3 left):

$$TB = \frac{(tof_o - tof_c)}{\dot{R}} \text{ with } \dot{R} = \frac{d\frac{tof_c}{2}}{dT}$$

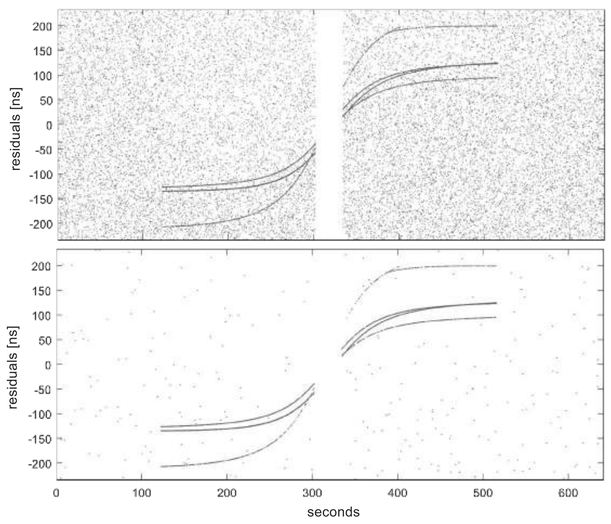

Figure 2: Raw (top) vs. filtered (bottom) two-way range residuals

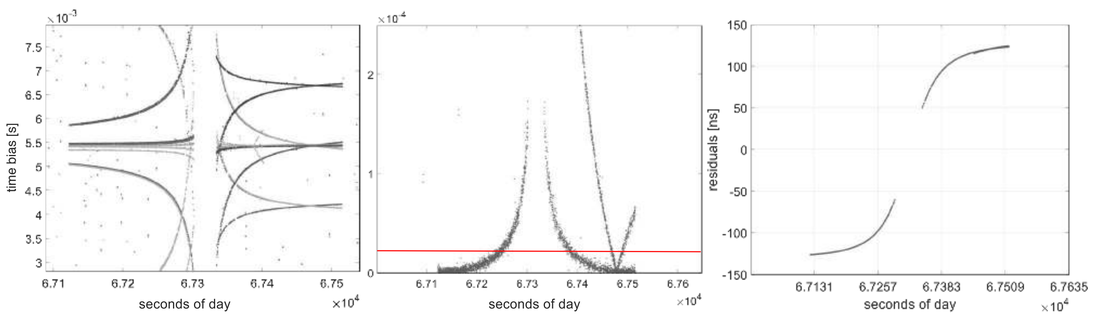

Figure 3: Left: Residuals transformed to TB space
Middle: Absolute values of TB estimates after histogram-based filtering
Right: Remaining range residuals after "cut" highlighted in red

3. Build histogram of TB values and identify the considered reflector based on largest peak (separately for ascending and descending arc)
4. Extract the peak via sigma clipping and retain the absolute values of the corresponding data (see Figure 3 middle)
5. Apply an additional filtering step (red cut in Figure 3 middle) and re-associate the remaining TB values with the original two-way range observations (see Figure 3 right)

Simulations

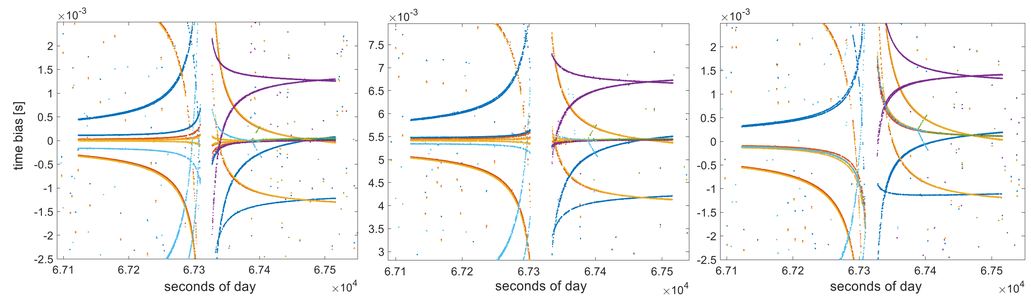

Figure 4: Attitude error (left), along-track orbit error (middle) and radial orbit error (right)

- Orbit and attitude errors affect the offset and slope of the TB curves making data from the individual reflectors harder to identify (see Figure 4 and Figure 5)
- Asymmetric effects on ascending and descending arc require independent processing

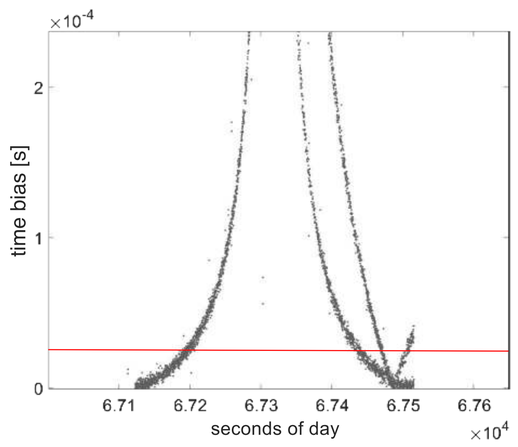

Figure 5: Steeper slopes due to radial orbit error (cf. Figure 3 middle)

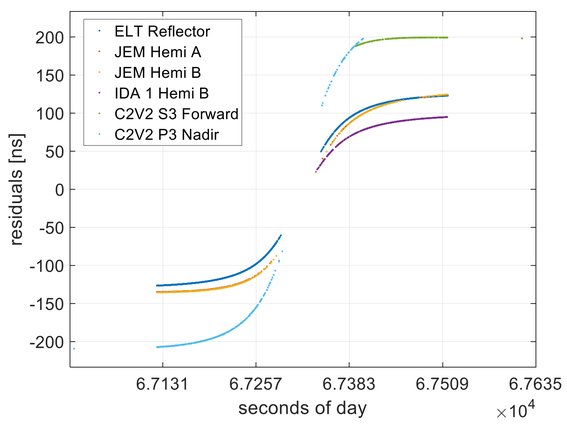

Figure 6: Reflector identification results corresponding to setup of Figure 3

Real-time time bias correction

Aim:

- Compute TB regarding the ELT reflector as soon as possible, without accurate knowledge of the attitude in real-time
- TB correction has to be accurate enough to be able to strike the detector gate (100 ns)

Difficulties:

- No binominal noise filtering is possible due to computation time
- ISS time bias peak has to be identified with few signal data → interval method
- Reflector allocation is not possible if there are only returns from one reflector
- Most returns are assumed to arrive from the ELT reflector

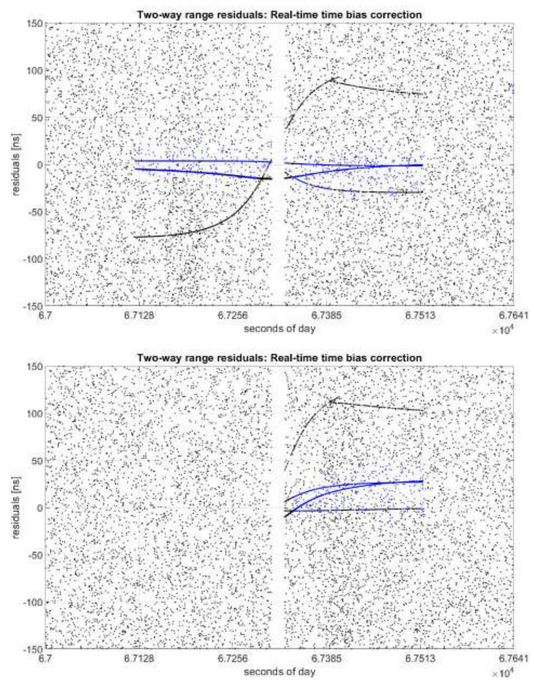

Figure 7: Final result of real-time ELT reflector TB correction for a full and a half pass (cf. Figure 2 top)

Conclusions

- It is possible to identify the reflectors reliably in quick-look data (attitude error < 0.5°)
- Identification problems arise mainly in the zenith area in case of a radial orbit error
- It is sufficient to do real-time TB correction with respect to the ELT detector gate (all reflectors' TBs are close enough to the ELT reflector TB)
- Real-time TB correction is indispensable to get a chance to strike the ELT detector gate in view of the expected orbit prediction accuracy
- We want to make the real-time TB correction available for the SLR stations