Time Transfer: sideline or geodetic objective?

Anja Schlicht, Ulrich Schreiber
(Technische Universität München),
Ivan Prochaska (Czech Technical University of Prague)
Pierre Exertier (Observatoire de la Cote d’Azur)
Why time transfer?
How precise are clocks?

Why do we put clocks in orbit?

- **Navigation**: GPS, GLONASS, QZSS, BeiDou, Galileo, DORIS
  
  1-way: „pseudoranges“ -> „biased ranges“

- **Fundamental physics**: ACES, STE-QUEST
  
  gravity red-shift

- **Transponder**: LRO, Messenger

- **Global time scale**: clock in GEO/Lagrange/GNSS
How can we compare space and ground clocks?

- Microwave links: 100MChips/s Ku Band (ACES)
- T2L2: optical pulsed 10Hz
- LRO

Future:
- ELT: optical pulsed single photon (1kHz)
- LCT: optical modulated 5Gbit/s

SLR contribution:
- Experience with range biases, accuracy
- Distance: Single photon, 1-way transponder
T2L2 – ELT: What’s the difference?

- Space segment: clock, detector (T2L2: multiphoton, ELT: single photon)
- Efforts from the individual stations:
  - both: ps resolution of start event crd format definition and calibration to clock reference point (integrated GPS)
  - ELT specific: single photon mode at ISS (and on ground) fit into short timing window on ISS (200ns)
    - laser response to trigger < 30ns uncertainty
    - synchronisation to UTC < 30ns accuracy
    - laser safety
Which „clock“ do we need?

The clock should be better or comparable to the one on board:

- in our case: MASER with relation to UTC
Preparing the future

Tokyo area

Courtesy NICT
Preparing the future (II)

Courtesy PTB
Preparing the future (III)

Australia

Courtesy Michael Tobar
<table>
<thead>
<tr>
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<th>SLR</th>
<th>Data transfer</th>
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<tbody>
<tr>
<td>Limitation of precision</td>
<td>10 kHz but low dispersion</td>
<td>100MChip/s (5Gbit/s) higher dispersion</td>
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<td>Influence of atmospheric fluctuations</td>
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<td>accuracy</td>
<td>T2L2: 50ps (repeatability) ELT: 50ps ground-space ELT: 25ps ground-ground LRO: combination of MWL and optical</td>
<td>MWL ACES : 100ps</td>
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<tr>
<td>distance</td>
<td>LRO, Messenger</td>
<td>Optical TT limited</td>
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<td>infrastructure</td>
<td>ILRS</td>
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What can a station gain?

Let’s find our place in this synergy diagram!

ranging

coding/calibration

data transfer

clock

clock

time transfer

Please contribute to T2L2 and ELT!
Thank you very much!