European Laser Timing (ELT)
System delays calibration

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OUTLINE

- European Laser Timing principle and challenges
- Time delays involved
- Calibration Device concept and the first experiments
- SLR hardware prerequisites for ELT participation
- Conclusion
Laser Time Transfer principle

T ... ground clock
E ... space clock
D ... distance / propagation delay by Satellite Laser Ranging

OPERATIONAL on Compass LTT, T2L2 & Glonass-M

NEW CHALLENGE to determine the **systematic** contributors on ~ 10 ps level

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ELT Laser Time Transfer delays

- **GOAL** $T_s$ versus $T_g$

- **GROUND SEGMENT**
  - $DT_{1,2}$ optical
  - $DT_3$ photodiode + discr.
  - $DT_4$ cabling
  - $ET_1$ internal delays

- **GROUND – SPACE**
  - $DTr$ via SLR

- **SPACE SEGMENT**
  - $DT_5$ ELT detector
  - $DT_6$ cabling
  - $ET_2$ internal delays

- All other components difficult to determine on < 10 ps level
ELT Calibration Device

- PHILOSOPHY
  - Tool for ELT system delays calibration for ground - ground and ground – space LTT

- CONCEPT
  - “Twin” of ELT space segment detector, timing and cabling
    Calibrated versus FM before launch
  - Kept identical within pre- and flight phase of the mission for calibration purposes
  - photon - > electrical - > “1pps” absolute delays calibrated
  - Used to determine the SLR systems internal delays
  - Used to determine the flight HW internal delays

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ELT delays on SLR site

Ground – Ground referencing

Every participating ground station will be characterised by a single delay calibration value $DE$

$DE$ is a difference between emitting epoch reading $E1$ and a time of crossing of the optical pulse the reference point

Calibration value computed from:
- epoch dif. $(E2-E1)$
- geometry distance $L$

Both systems use common time & frequency

For G-G time transfer the Calibration Tool delay stability is the only critical parameter
ELT Calibration Device  G-G demo

- Range 50 .... 250 mm in 6 steps
- Angles +/- 5 to +/-60 degrees
- 7 consecutive days, averages

Mean value 1484.4 ps

ACCURACY < 10 ps (!!!)

“SLR” Calib.Device

NPET #1 timing  NPET #2 timing
Common 10MHz, 1pps

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ELT Calibration Device HW

- Optical receiver head, twin of FM
- Photon -> electrical delay measured (~10ps)
  

- Signal cabling
- Delay determined within 10 ps

- NPET timing system with input board
  - “1pps” to detector channel delay measured(<10ps)
  - Sub-ps stability and linearity

- The listed delay resulting accuracy of 25 ps is influencing only the Ground – Space LTT accuracy
ELT EM timing stability Laser+Start+NPET+EM

- 3 days, normal lab. Conditions, +/- 1 K
- $T_{dev} \sim 150 \text{ fs} @ 1000 \text{ s up to days}$

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### SLR hardware prerequisites for ELT full participation

- **SLR tracking capability**: ISS orbit
- **local time base ties to UTC**: GNSS, (opt. fiber)
- **frequency reference**: $\text{H}_2$ maser
- **laser fire epoch precision**: 20 ps or better
- **laser wavelength**: 532+/- 2 nm
- **laser nominal rep.rate**: 10 Hz min., >= 100 Hz opt.
- **laser fire epoch**: prgm <= 100 ns steps
- **laser power density adjustable**: beam divergence control in real time
Conclusion

- European Laser Timing should provide laser time transfer ground-ground and ground to space with accuracy of a few 10 of ps

- The critical system delays should be mapped down to 10 ps level using a Calibration Device

- The participating SLR stations should be calibrated before and during the mission

- The Calibration Device is simulating ELT operation - the calibration campaign will serve as an “exercise” before the real mission operation

- The SLR hardware prerequisites for ELT participation have been defined

Thanks for your attention