

# European Laser Timing (ELT) System delays calibration

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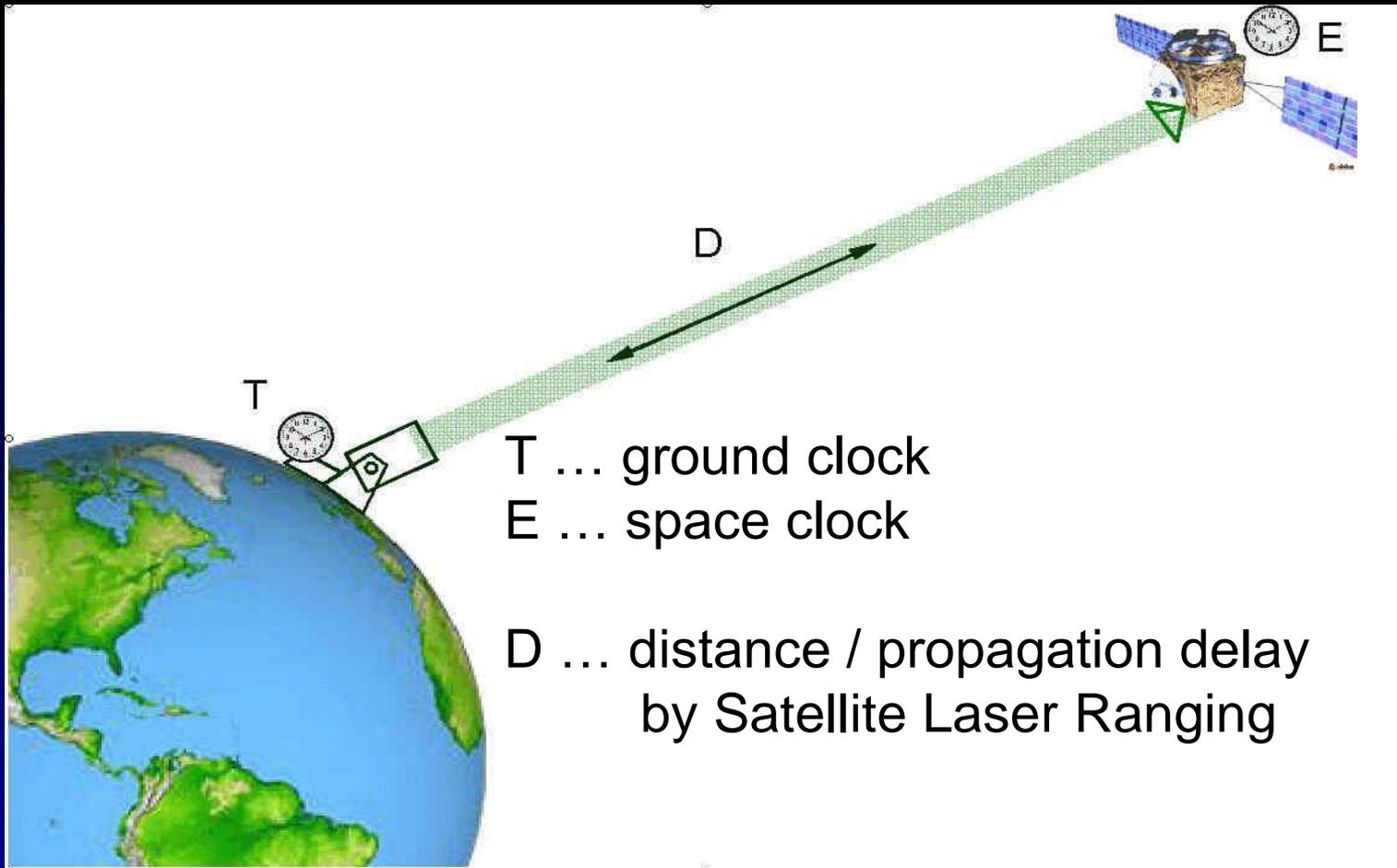
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# OUTLINE

- 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



OPERATIONAL

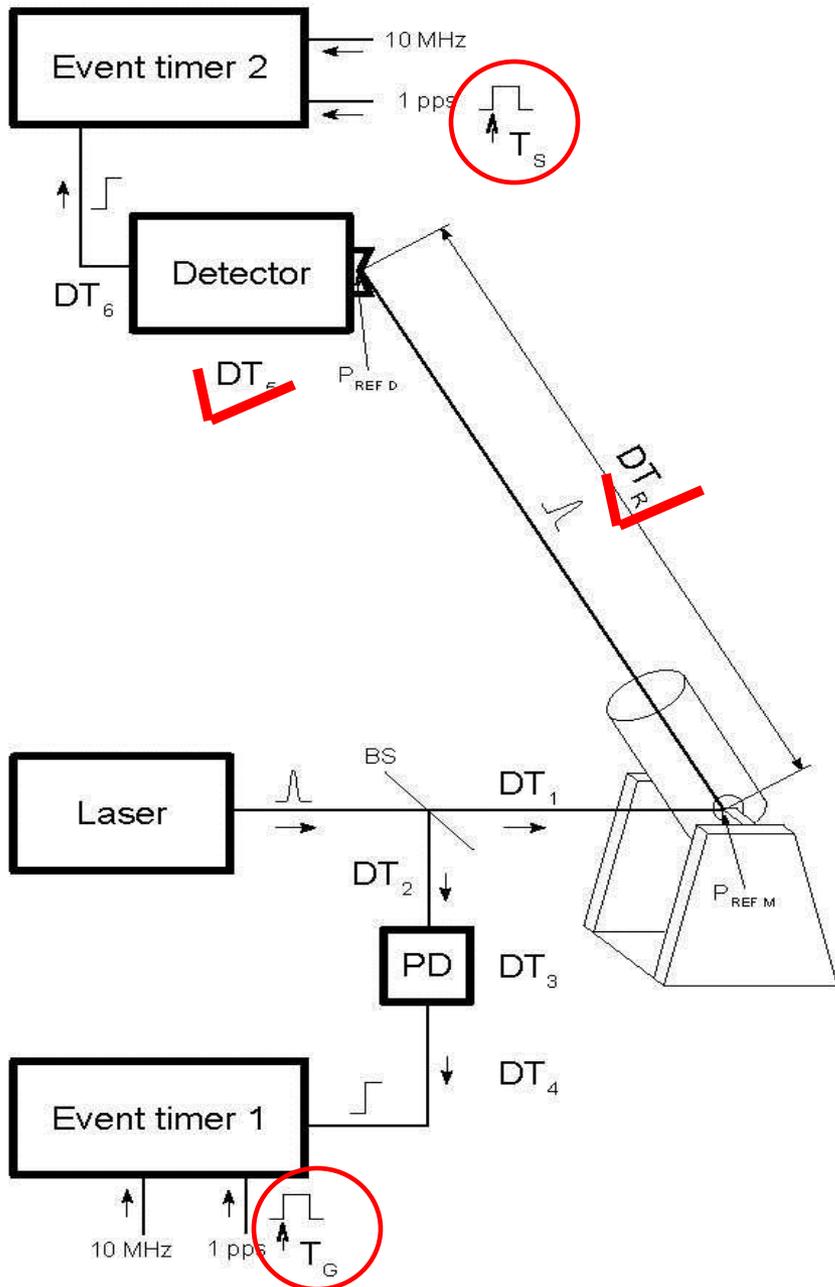
on Compass LTT, T2L2 & Glonass-M

NEW CHALLENGE

to determine the systematic contributors  
on ~ 10 ps level

I.Prochazka et al, 18th WLRI, Fujioshida, Japan, Nov. 2013

# ELT Laser Time Transfer delays



- GOAL Ts versus Tg
- GROUND SEGMENT
  - DT1,2 optical
  - DT3 photodiode + discr.
  - DT4 cabling
  - ET 1 internal delays
- GROUND – SPACE
  - DT<sub>r</sub> via SLR
- SPACE SEGMENT
  - DT5 ELT detector
  - DT6 cabling
  - ET 2 internal delays
- All other components difficult to determine on < 10 ps level

# ELT Calibration Device

- PHILOSOPHY

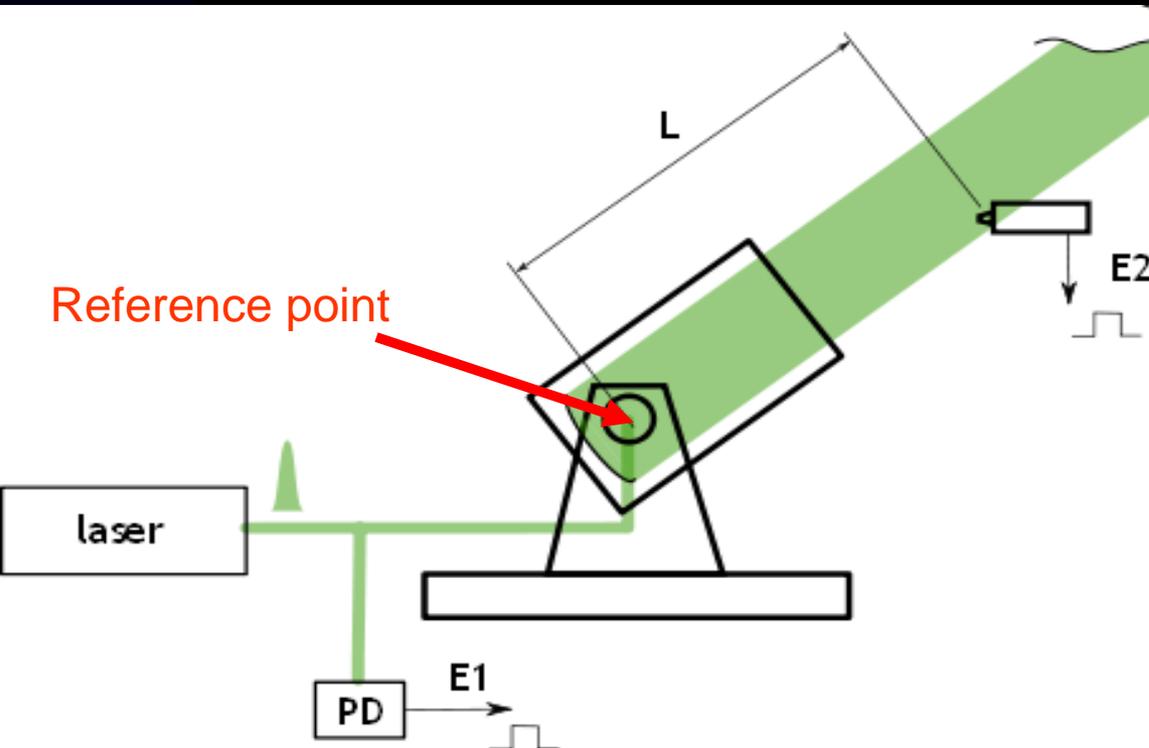
- Tool for ELT system delays calibration for ground - ground and ground – space LTT

- 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

# 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

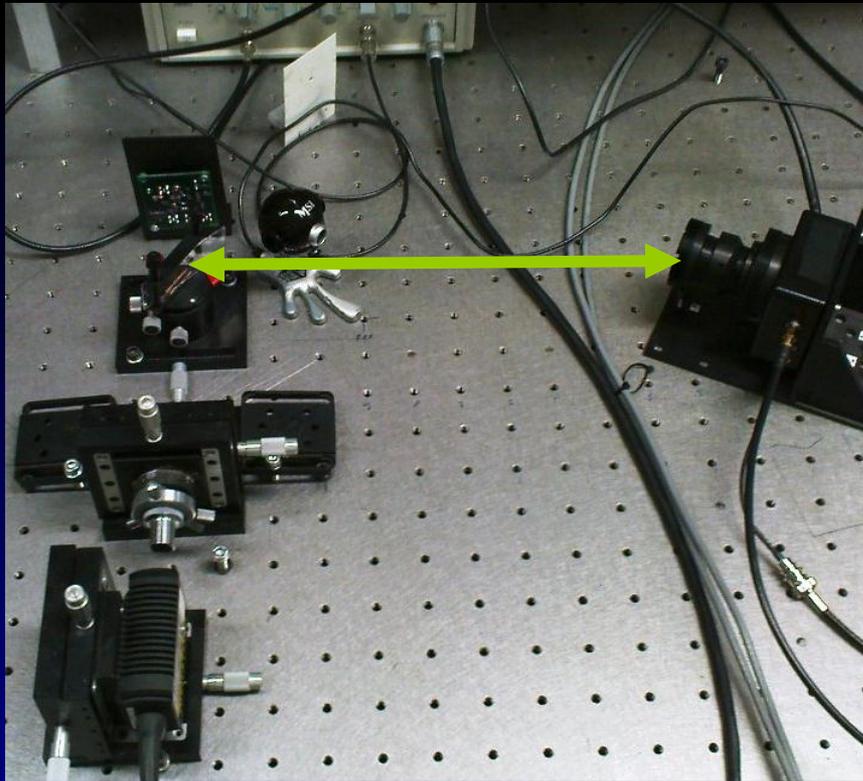
Calibration value computed from

- epoch dif. **(E2-E1)**
- geometry distance **L**

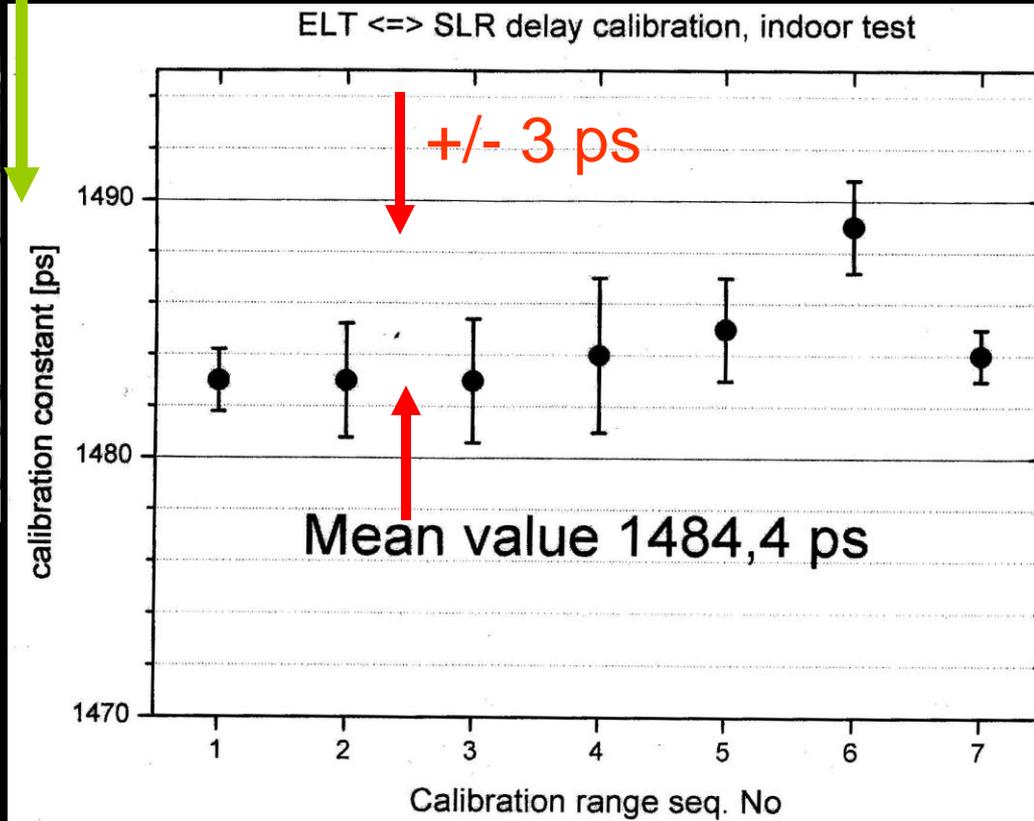
Both systems use common time & frequency

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



“SLR”

Calib.Device

NPET #1 timing

NPET # 2 timing

Common 10MHz, 1pps

**= > ACCURACY < 10 ps (!!)**

# ELT Calibration Device HW



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

*Prochazka I, et al, Metrologia 48 (2011) L13-L16*



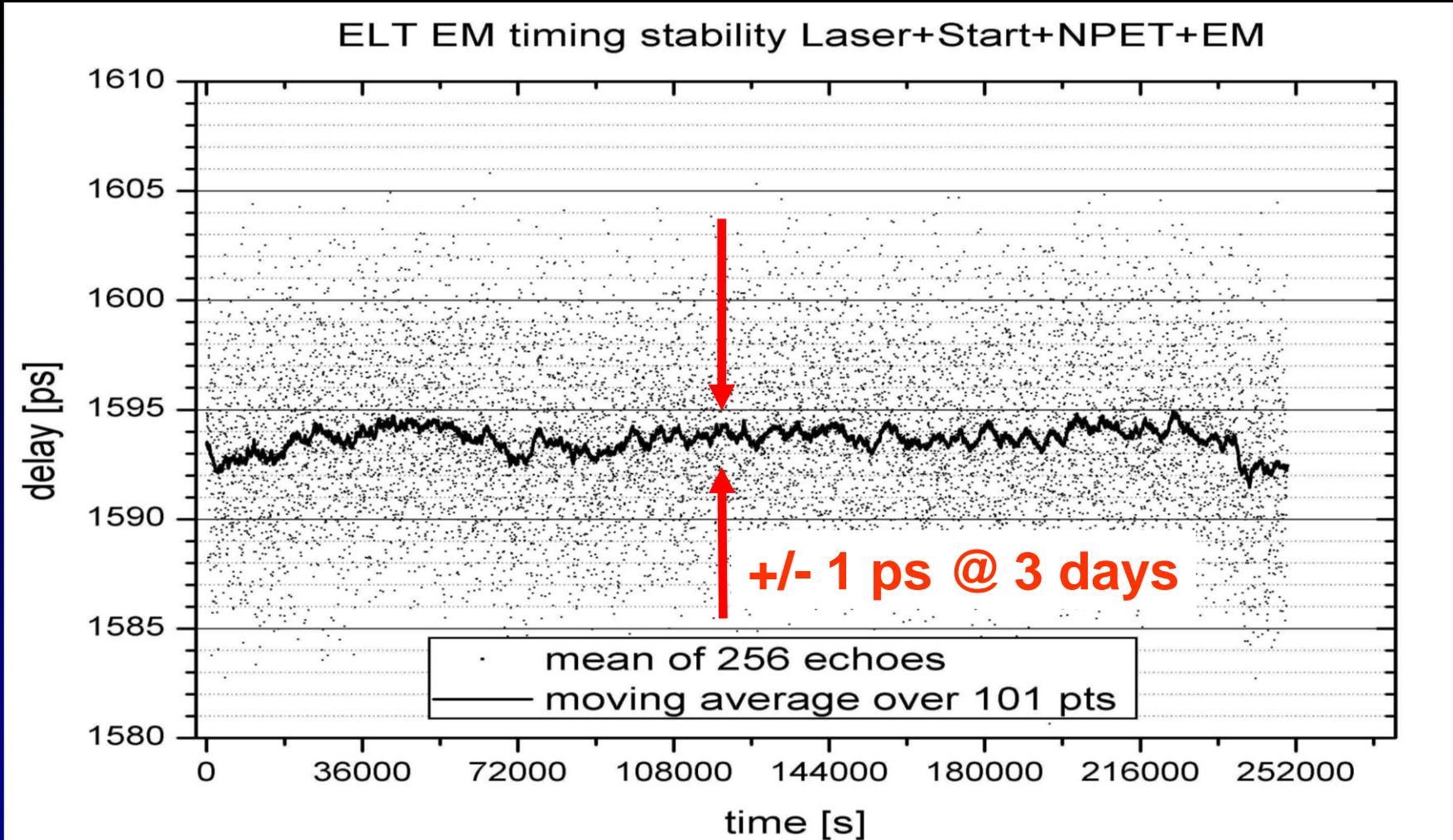
- Signal cabling
- Delay determined within 10 ps



- 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 Calibration Device Stability test



- 3 days , normal lab. Conditions, +/- 1 K
- Tdev ~ 150 fs @ 1000 s up to days

# SLR hardware prerequisites

for ELT full participation

- SLR tracking capability ISS orbit
- local time base ties to UTC GNSS, (opt. fiber)
- frequency reference H<sub>2</sub> 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 a 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

