

The European Laser Timing Experiment and Data Centre



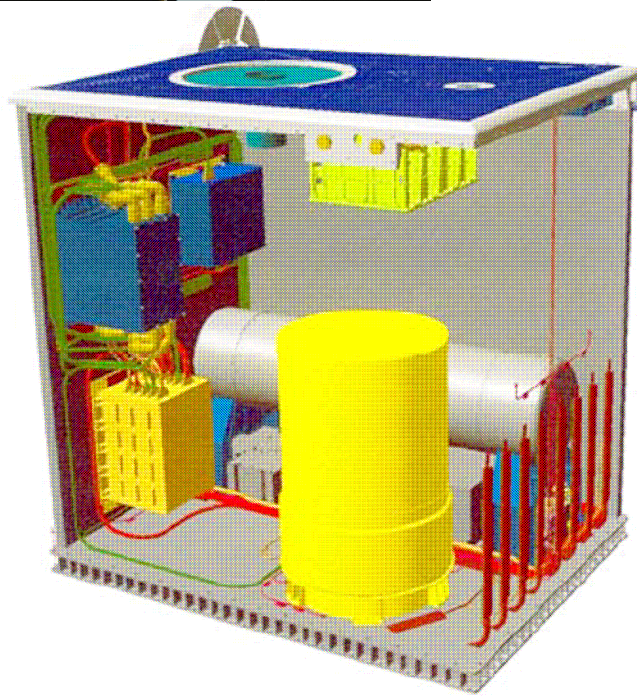
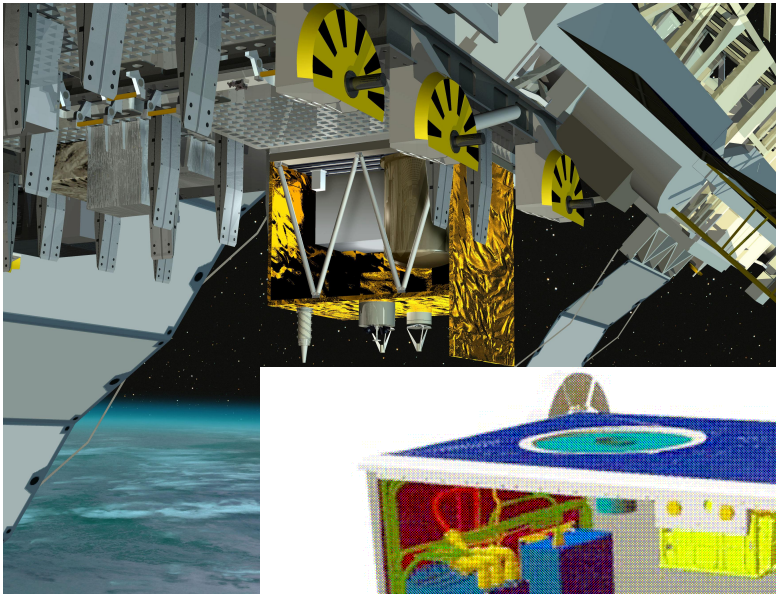
Anja Schlicht

Ulrich Schreiber

Ivan Prochazka

ACES

Atomic Clock Ensemble in Space



Time generation:

Caesium fountain clock PHARAO
Active hydrogen maser SHM
Frequency comparison unit

Time transfer:

Microwave link MWL
Laser link ELT

GPS

ACES objectives

Test of new generation space clocks

cold atoms in microgravity

test of PHARAO frequency stability $10^{-13}\chi\tau^{-1/2}$ and accuracy 3×10^{-16}

test of SHM frequency stability 2.1×10^{-15} @ 1000 s

Frequency transfer via MWL

test of the microwave performance 0.4 ps @ pass, 8 ps @ 1d

common view comparison of ground clocks 1 ps @ pass

non-common view comparison of ground clocks 3 ps @ 1000 s,
10 ps @ 10^4 s

absolut synchronisation of ground clocks better 100 ps

contribution to TAI

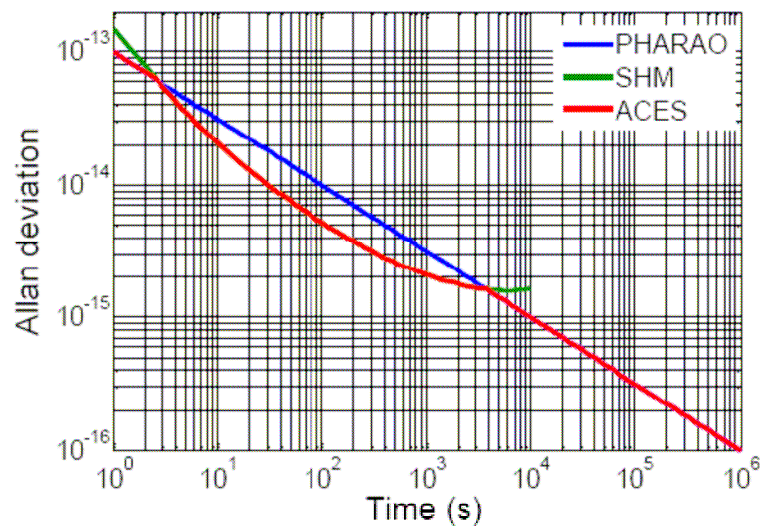
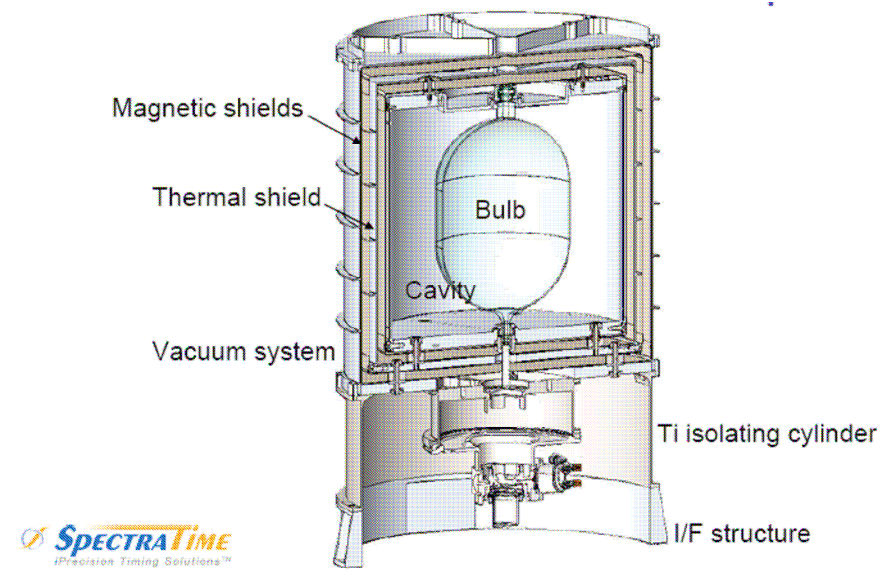
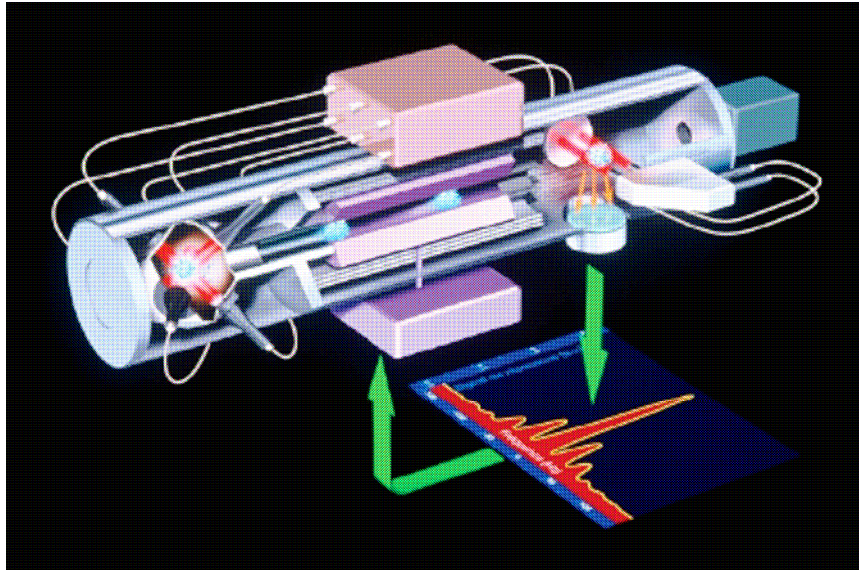
Fundamental Physics

gravitational red-shift

drift in fine structure constant

anisotropy of light

ACES clocks

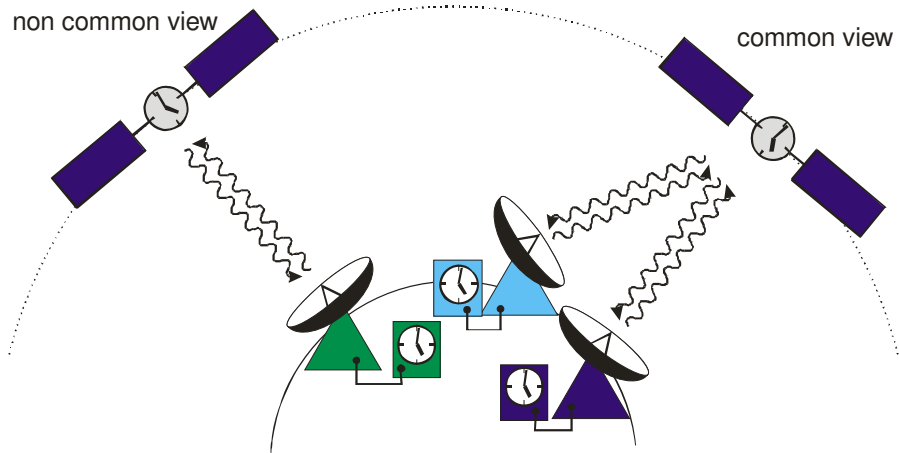


Two servo-loops:

Short-term servo-loop stabilizes PHARAO on SHM

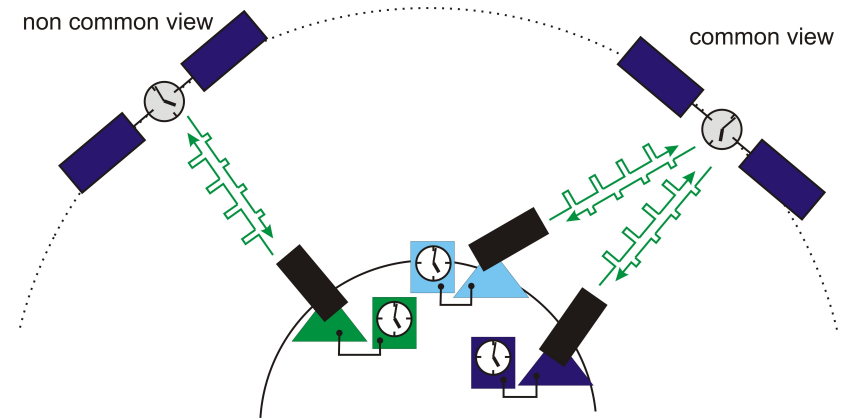
Long-term servo-loop stabilizes SHM on PHARAO

Time transfer

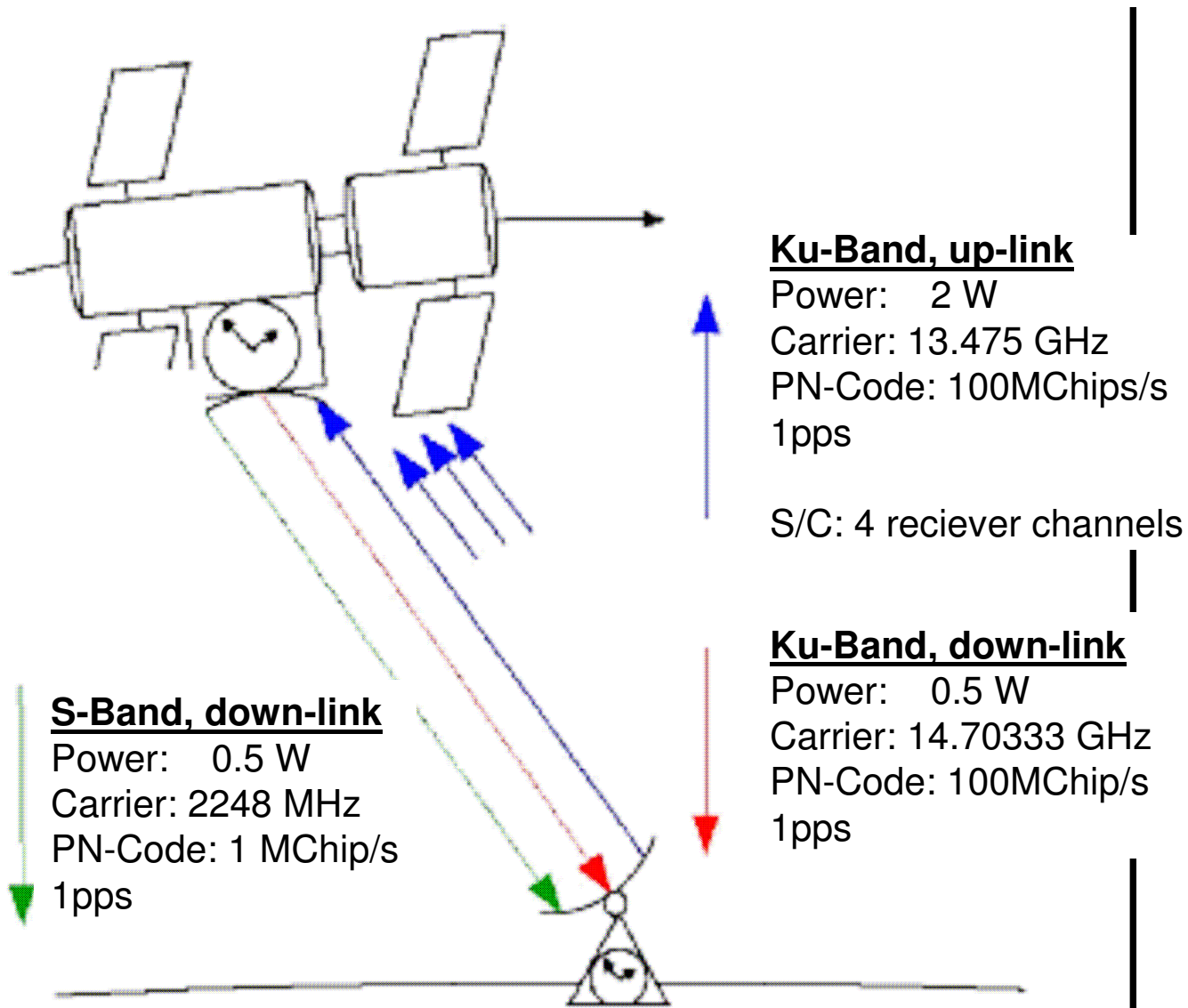


**MWL –
MicroWave Link**

**ELT –
European Laser Timing
Experiment**



Microwave Link (MWL)

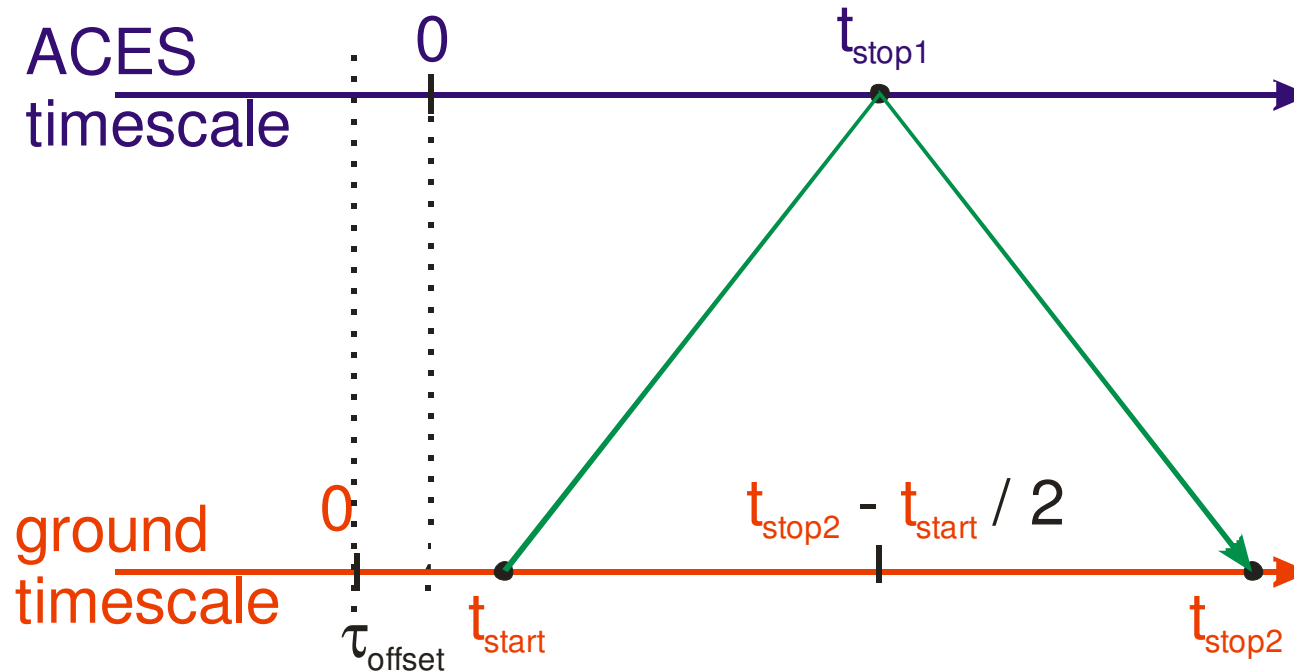


Requirements:

230 fs @ 300 s
1.2 ps @ 5000 s
8 ps @ 1 d
10 ps @ 10 d

ELT

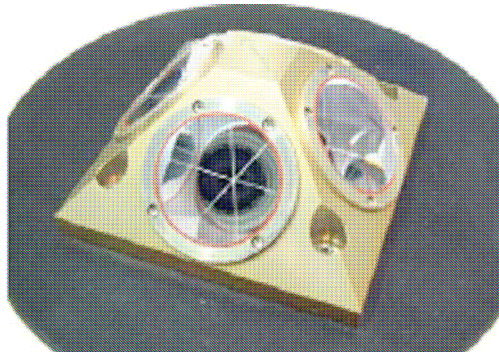
European Laser Timing Experiment



$$\tau_{\text{offset}} = t_{\text{stop2}} - t_{\text{start}} / 2 - t_{\text{stop1}} + \tau_{\text{Relativity}} + \tau_{\text{Atmosphere}} + \tau_{\text{Geometry}}$$

We need fullrate data with ps resolution of t_{start} !!!

ELT - Payload



Requirements:

$$\sigma_x(10 \text{ s} < \tau < 300 \text{ s}) = 60 \times 10^{-12} \tau^{-1/2}$$

$$\sigma_x(300 \text{ s} < \tau < 10^4 \text{ s}) = 4 \times 10^{-12}$$

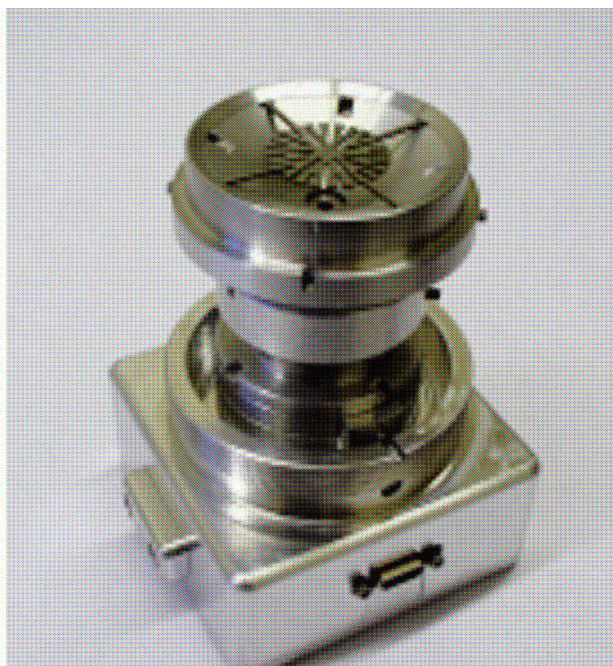
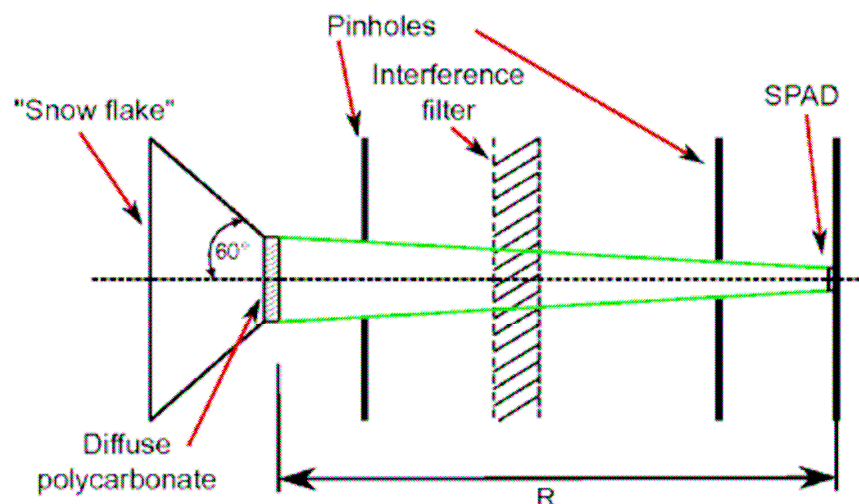
$$\sigma_x(10^4 \text{ s} < \tau < 10^6 \text{ s}) = 7 \times 10^{-12}$$

Absolut calibration delay < 50 ps



courtesy of W. Schäfer

ELT - detector



- K14 SPAD 100 μ m
- Filter 532 \pm 3 nm
- Pinholes blocking non axial photons
- Narrow bandwidth filter blocks background photons
- Ground glass for attenuation
- Snowflake shield for angular independent attenuation
- Attenuation 10^{13}
- Gating locked to 10pps (100pps) on ACES timescale
- Single photon mode

ELT objectives

- Space to ground comparison of clocks 4 ps @ pass, 7 ps @ 10^6 s, accuracy 50 ps
- Common view comparison of clocks 6 ps
- Non-common view 6 ps @ 1000 s, 7 ps @ 10^4 s
- Clock synchronisation 50 ps
- Comparison of ranging techniques
- Analysis of atmospheric propagation delays

MWL contra ELT

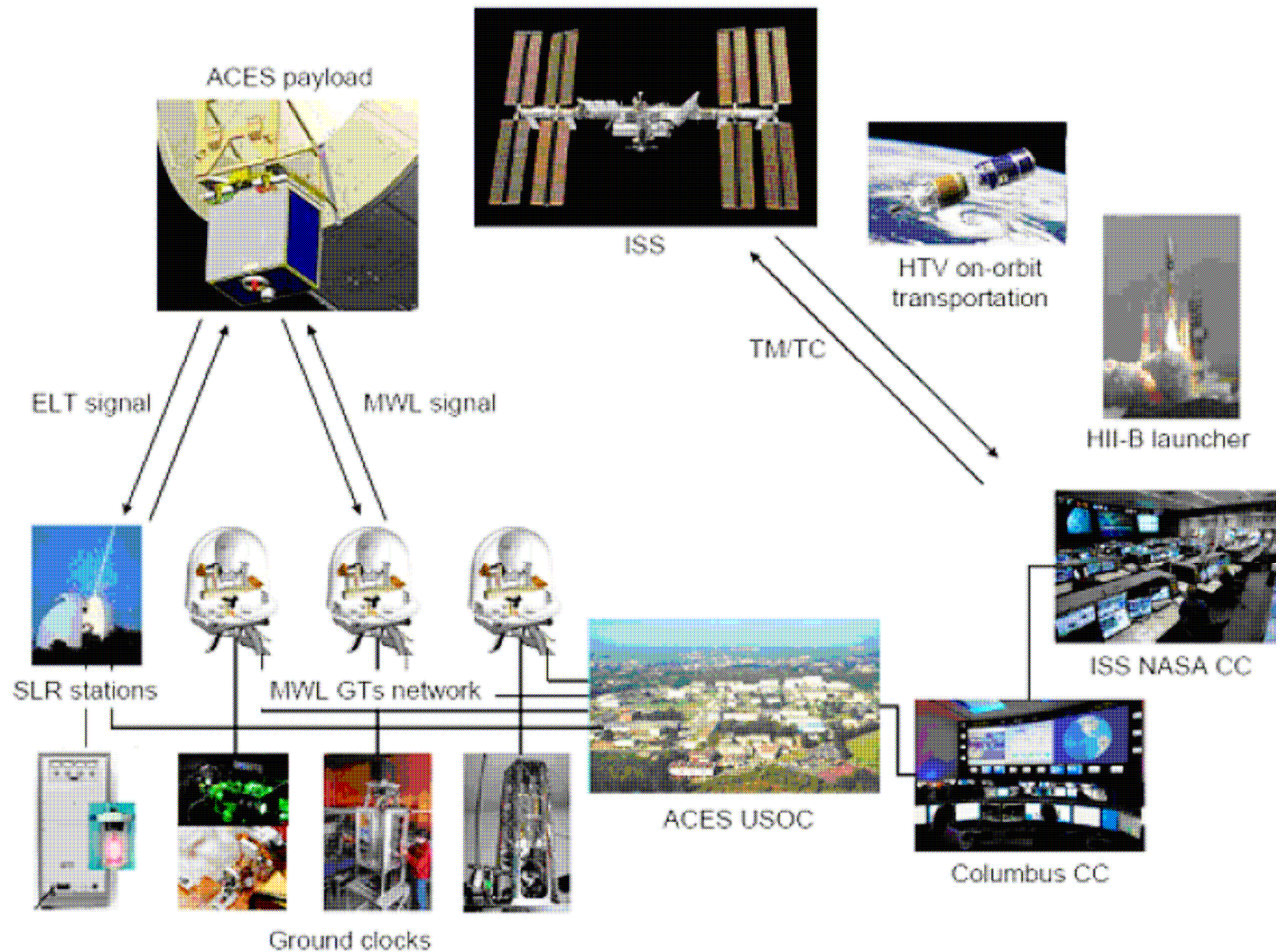
MWL

- All weather
- High availability
- Time proven
- Easy to operate

ELT

- Low dispersion
- Single shot
- Accurate time tagging
- Used to calibrate
MWL

ACES Ground Segment



ELT – Data Center

communication center

network interface

data center (ACES, SLR)
ILRS and SLR stations ("real time" feedback)
ESA and cooperating partners
data users
fundamental physics community

communication platforms

internet
bulletin
call for participation
data server

common-view campaigns

emphasis on VLBI/SLR stations

scientific mission center

predictions

definition of products,
data processing

support for SLR stations

comparison of TT methodes
MW, GNSS, optical, and VLBI

monitoring of space instruments
calibration campagne

clock modelling, time scale

Products

Shadowing

For each station (including MWL-Terminals) entrance and exit of the shadowing of the ACES module by solar panels or orientation.

Quick look

For each ELT station sending high accuracy fullrate data an analysis of time triples and a detection rate. **Warning for not being in single photon mode!!**

Detector performance

Space-ground-TTF

Common-View TTF

Per-revolution Non-Common-View TTF

Once per revolution of the ISS a clock offset between all the stations successfully tracked ACES is calculated.

Longtime Non-Common-View TTF

For monitoring ground clocks the time evolution of the time-offset to ACES timescale is calculated.

Laser ranging Performance

MWL calibration

Signal delays MWL-ELT for atmospheric analysis

Performance of SLR stations

- Fullrate data with ps resolution of start puls and should be send within one hour after the pass
- clock with frequency stability comparable to ACES
- Station has to time the laser firing better 100 ns (active/active laser)
- Tracking of low satellites
- Predictions every 90 min
- Single photon mode
- Handling of a go/nogo-flag

ACES ready for Take off beginning
of 2014!!

schlicht@bv.tum.de