CCTF Workshop on Lunar Time
2nd part
December 2, 2025

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Previous workshop (Nov 18, 2025)

- Presentation of 3 options for a Lunar Reference Time:
  (O1) TCL
  (O2) scaled TCL : TL equivalent of TT on Earth → TL rate ~proper time of a clock on the surface
  (O3) scaled TCL : TL – TT = only periodic terms (no increasing difference TL-UTC)

- needs and constraints for a Lunar time scale from Space agencies
  JAXA, NASA, ESA, DSEL, ROSCOSMOS

- Steering (P. Defraigne) → whatever the definition, steering will be needed,
  the magnitude could be different only for high accuracy frequency standards.

- Scaling (S. Klioner) → O2 and O3 requires scaling of masses and distances

- IAG (K. Sośnica) → LCRS will be compatible with the definition of Lunar Reference Time.

What we propose for today:

General definition of a Lunar Reference Time

$$TL = TCL - \Delta f \times (t - t_0) + \Delta T_0$$

To Be Discussed

2 options only retained now:

- O1: TL = TCL ($\Delta f = 0$)
- O2: TL equivalent of TT on Earth ($\Delta f \sim 3.14e\text{-}11$)

$\Delta T_0 = 0$ (TL-UTC ~70s)

$\Delta T_0 \neq 0$

AGENDA :

1. Δf , O1/O2 : specific questions
2. Difference TL-UTC
3. ΔT_0

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Δf : Option 1 / Option 2

O1: $\Delta f = 0$ → use TCL as reference time
→ for accurate clocks (Cs or better): steering larger than O2 (3×10^{-11}) if need to be aligned on the reference

Why preferred *? no possible confusions associated with multiplicity of time scales and with associated scaling.*

Constraint *: no constrained identified yet*

O2: $\Delta f = \sim 3 \times 10^{-11}$ → steering can be $<10^{-11}$ for accurate clocks (Cs or better)
→ needs a reference W_0 definition
→ implies a scaling of Mass and distances, + confusion

Why preferred ? *to have a reference time with a scale unit closer to the SI second on the Moon surface*

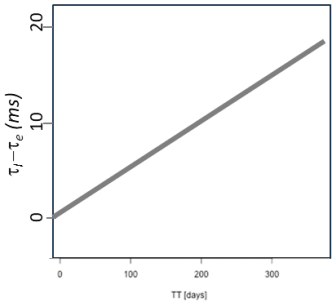
Constraint *: need for a conventional W0 definition*

Associated questions:

- To Space agencies in favor of O2: could you clarify what the technical constraints of O1 are?
- How is the meter defined ? Is it tied to particular time scale ?
- Could you provide a concrete example where the scaling can bring confusion and complications?

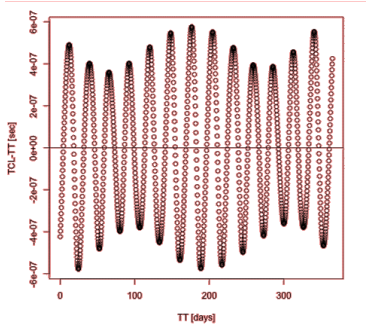
Question over the difference TL-UTC

~ 56 µs/day
(1s after 50 yr)



TCL - TT

+



Depend on the
- Coordinate system
- Clock positions

2 events simultaneous if they have the same coordinate time.

2 events simultaneous in TCB → not simultaneous in the TCG
2 events simultaneous in TCG → not simultaneous in the TCL

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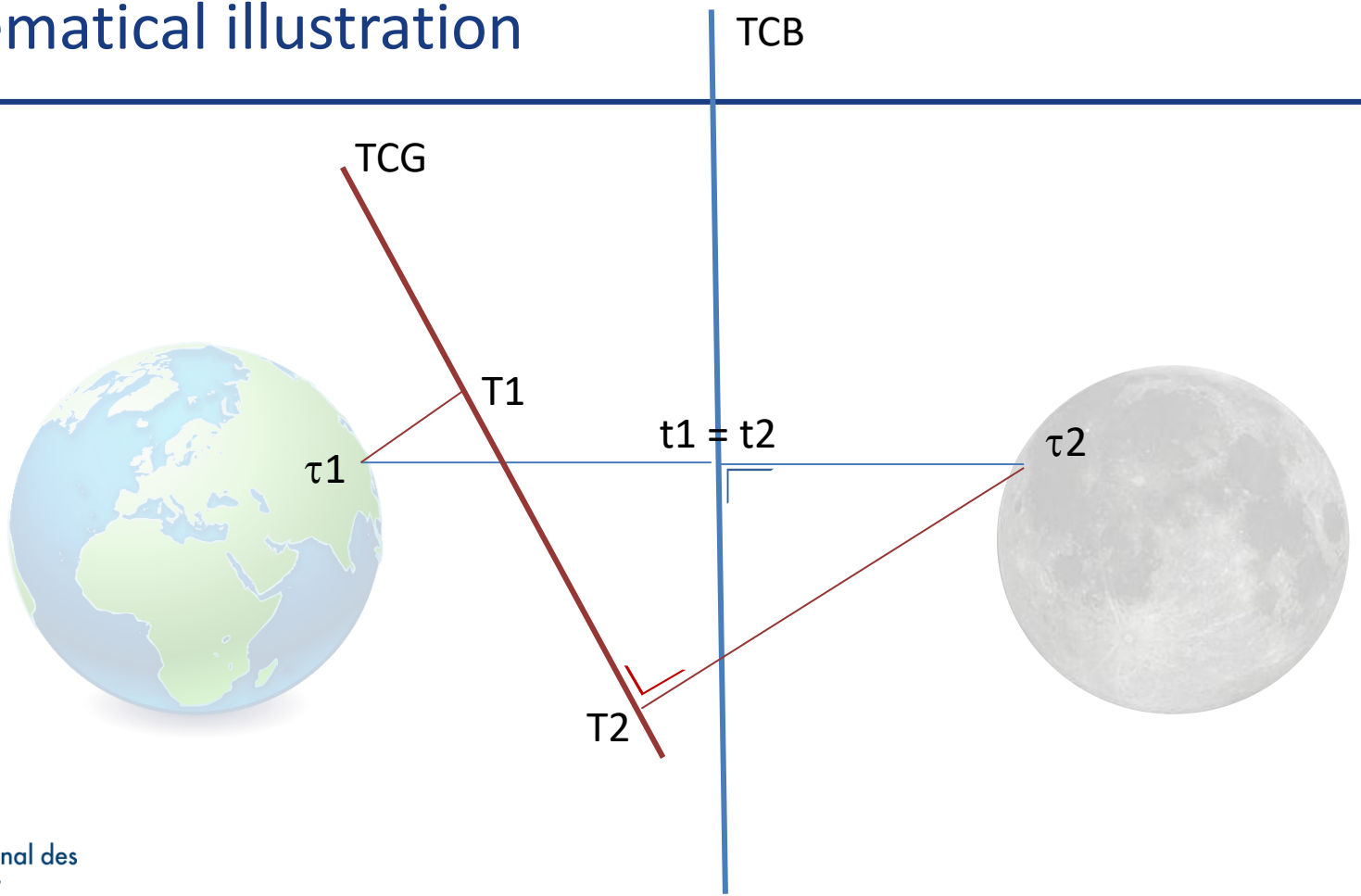
TL-UTC depends on the coordinate time used to express the difference

Schematical illustration



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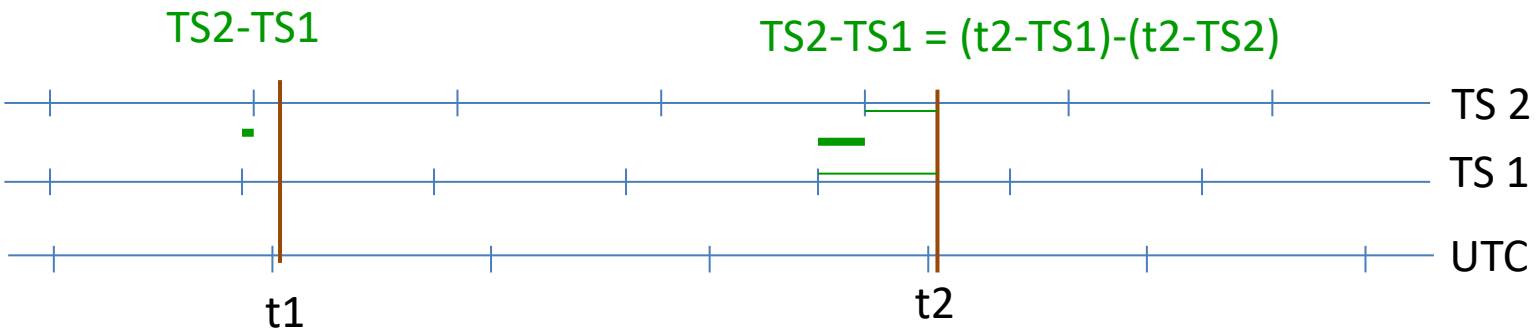
Simultaneity on the Earth



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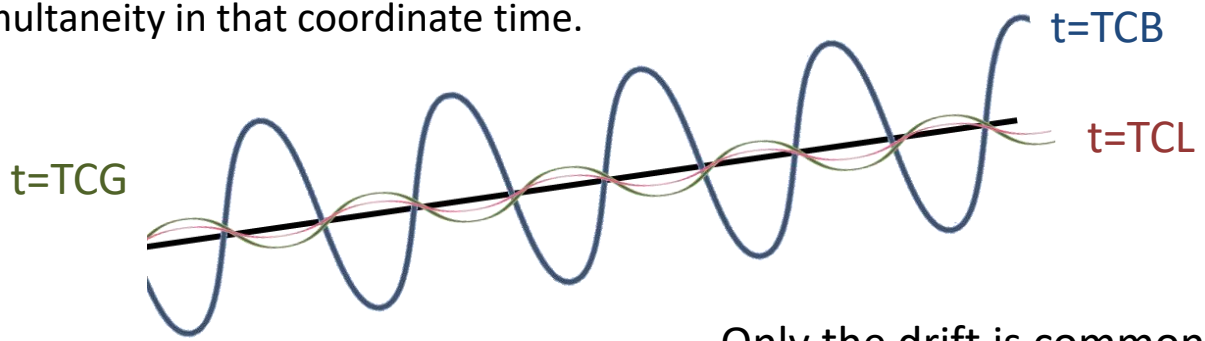
Difference TL-UTC depends on choice on simultaneity (and clock positions)

δ= Difference between TL computed at a given position (in the Moon region) and TT is computed at a given position (in the Earth region)

1. To compare clocks you need a common coordinate time t and define simultaneity in that coordinate time.



Only the drift is common.

2. The transformation is 4D → additional periodical position-dependent variations

$TL = TCL - \Delta f \times (t-t_0) + \Delta T_0$

If $\Delta T_0 = 0$ (and t_0 =1977.0 as defined by the IAU) → ? How much is TL-UTC ?

→ As TL-UTC is 4D, and syst-dependent, we can only get an approximation which is a valid approximation in all positions and all systems

TL – TT = (O1) : 58.7 µs/day since 1997.0 → ~ 1.051 second at 2026.0
(O2) : 56 µs/day since 1997.0 → ~ 1.002 second at 2026.0

For something more accurate, we must specify the position and the coordinate system.

ΔT_0?

TL – TT = + 1 s
TAI – TT = – 32.184s
TAI – UTC = + 37 s (leap seconds)

→ At 2026.0 we have TL – UTC ~ 70.2 s

CASE 1:
Keep ΔT_0 = 0
So it is easy to distinguish which is the UTC and which is the TL.
Then the difference will increase by ~1s/50yr

CASE 2:
Fix ΔT_0 = 70 s (more digits ?)
So UTC –TL~0 now,

and the difference will increase by ~1s/50yr

Further steps before a consolidated CGPM draft resolution

- Draft already discussed at the CCTF in Sept 2025
- Session devoted to “Lunar ref frame and timing” at the ICG in October 2025
- **Workshop on Nov 18-Dec 2** organized by the CCTF task group:
  - Space agencies
  - Future scientific users of Time on the Moon

  → **Define the list of open questions**

- CCTF task group participation to bilateral and ICG WG L meetings in Dec 2025

- 2nd workshop IOAG/ICG in Vienna in Feb 2026 *(time session under organization)*
  https://www.unoosa.org/oosa/en/ourwork/icg/working-groups/l/CislunarPNT2026.html

- Draft CGPM draft resolution published on the BIPM web in Jan 2026
- Some TBC may remain till February 2026

- Oct 2026 meeting of the General Conference on Weights ad Measures for adoption by BIPM member states

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All presentations (if agreed) available on
https://www.bipm.org/en/committees/cc/cctf/wg/cctf-tgmt/2025-11-18

Thank you for your participation

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