Steering or not steering ?

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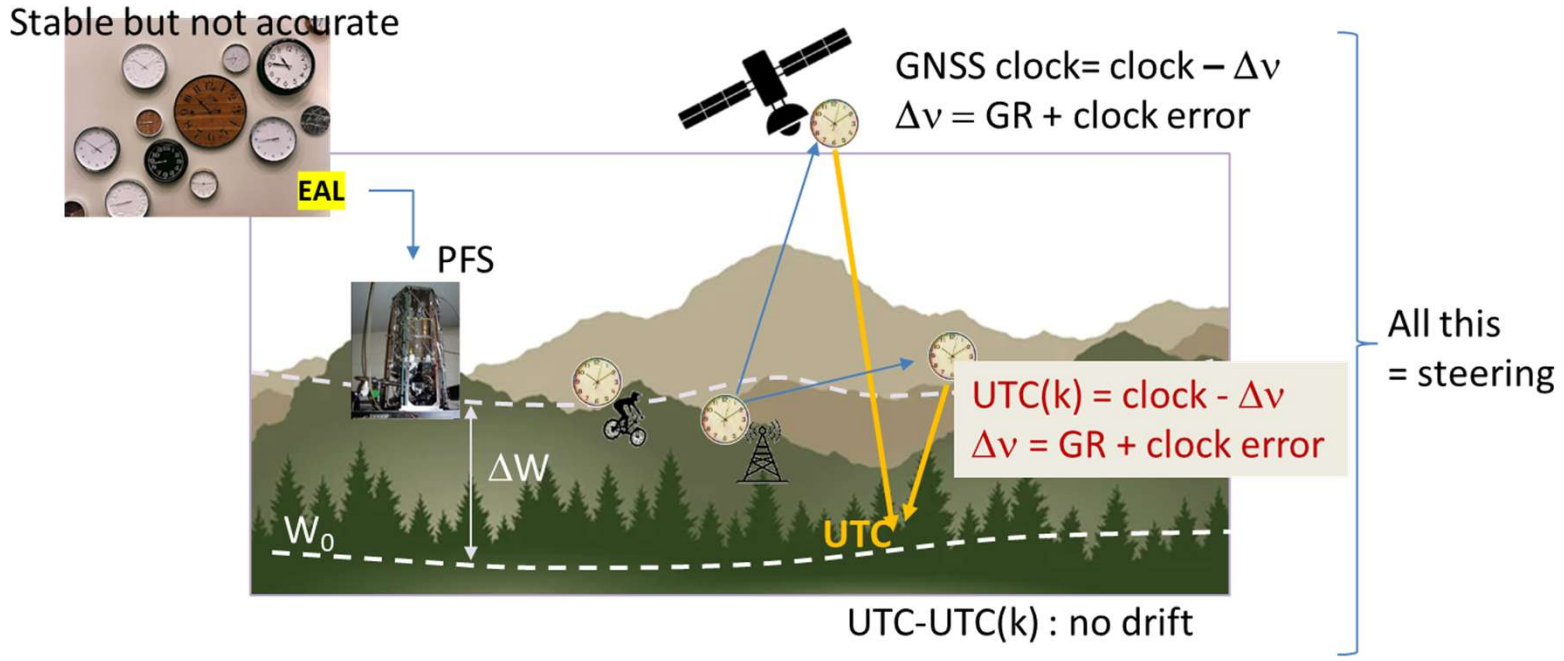
context

→ Some space agencies prefer option 2 because

- Prefer avoiding the need to steer the clocks when possible

- Prefer having system similar as with Earth GNSS

How do we manage the relativity on Earth ?



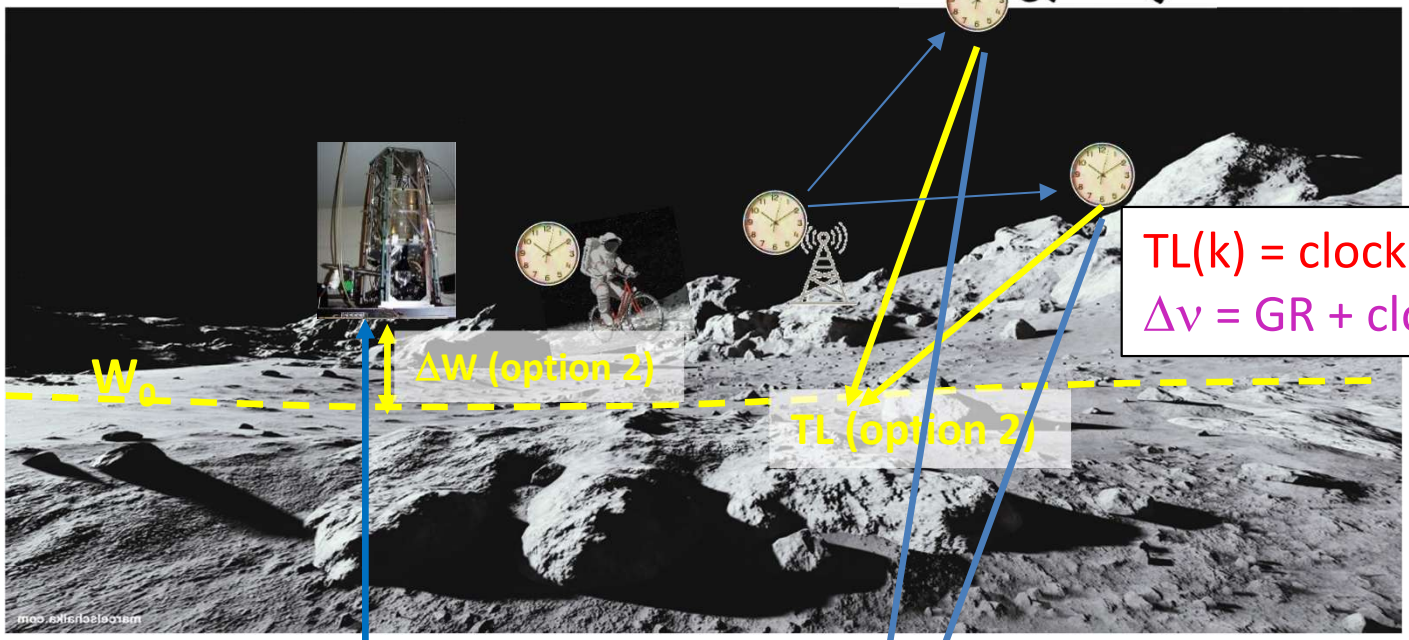
PFS: no steering but frequency offset correction: $\Delta W/c^2$

Example NIST : 1600 m

$\Delta W /c^2 \sim 10^{-13}$ in relative frequency

PFS (Primary Frequency Standard) =
the most accurate clocks with full uncertainty budget
→ provide the accuracy of the scale unit of UTC

Same principle will be applied on the Moon



LCNS clock:
$\Delta\nu$ = GR + clock error

TL(k) = clock - $\Delta\nu$
$\Delta\nu$ = GR + clock error

All this
= steering

ΔW (option 1,3)

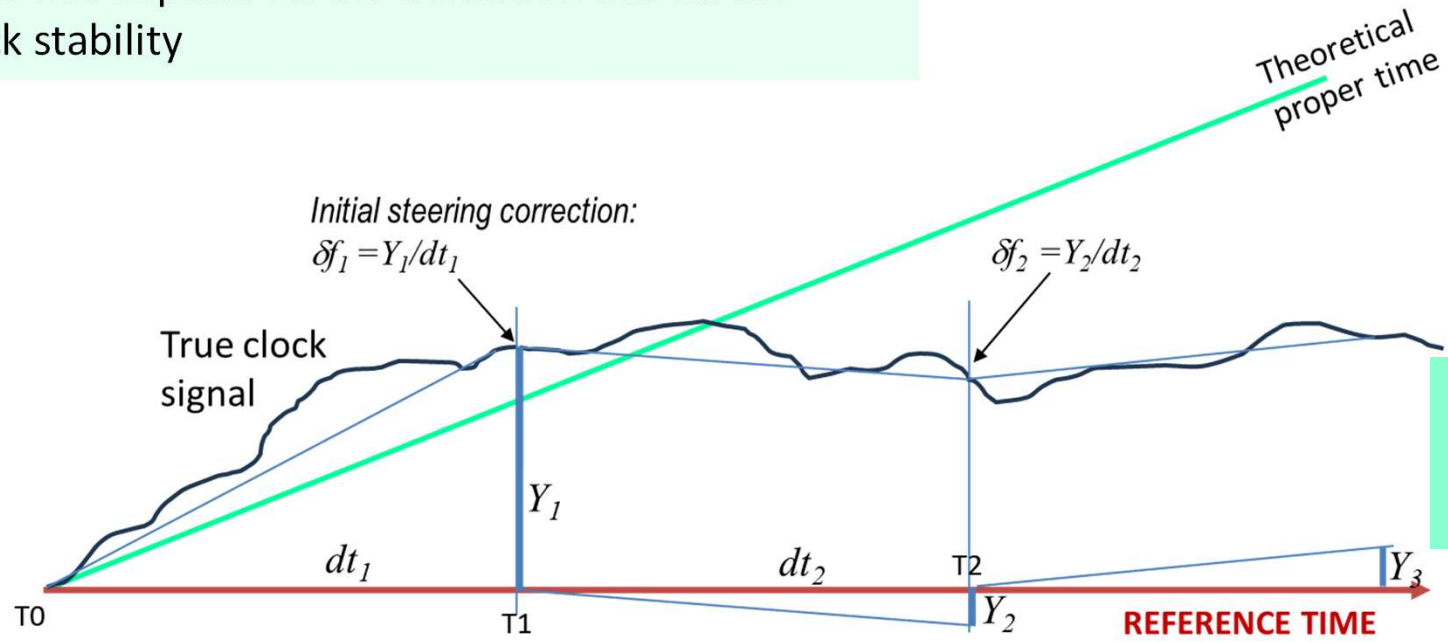
TL (option 1,3)

Exactly the same principle
for options 1 2 3,
only the ΔW is different

Process of steering

(clock – reference) is measured at T0, T1, T2

Holdover / Independence from the Earth :
Does not depend on the definition but on the clock stability



δf_2, δf_3 ... depend on the clock stability only, not on the TL definition

1. Same principle, same clock behaviour, whichever the TL definition
2. δf_{theor} can also be already corrected before launch, as done in GPS

Steering correction for clock on the Surface

10^{-9} ~steering O3
10^{-11} ~steering O2

	Clock accuracy (10^{-Y})	User need (10^{-X})								
		< 9			9 – 11			> 11		
Option →		O1	O2	O3	O1	O2	O3	O1	O2	O3
Quartz	< 9	--	--	--	< 9	< 9	< 9	< 9	< 9	< 9
Quartz-Rb	9 – 11	--	--	--	--	--	**9**	9 – 11	9 – 11	**9**
Cs/H-maser/ optical	> 11	--	--	--	--	--	**9**	**11**	> 11	**9**

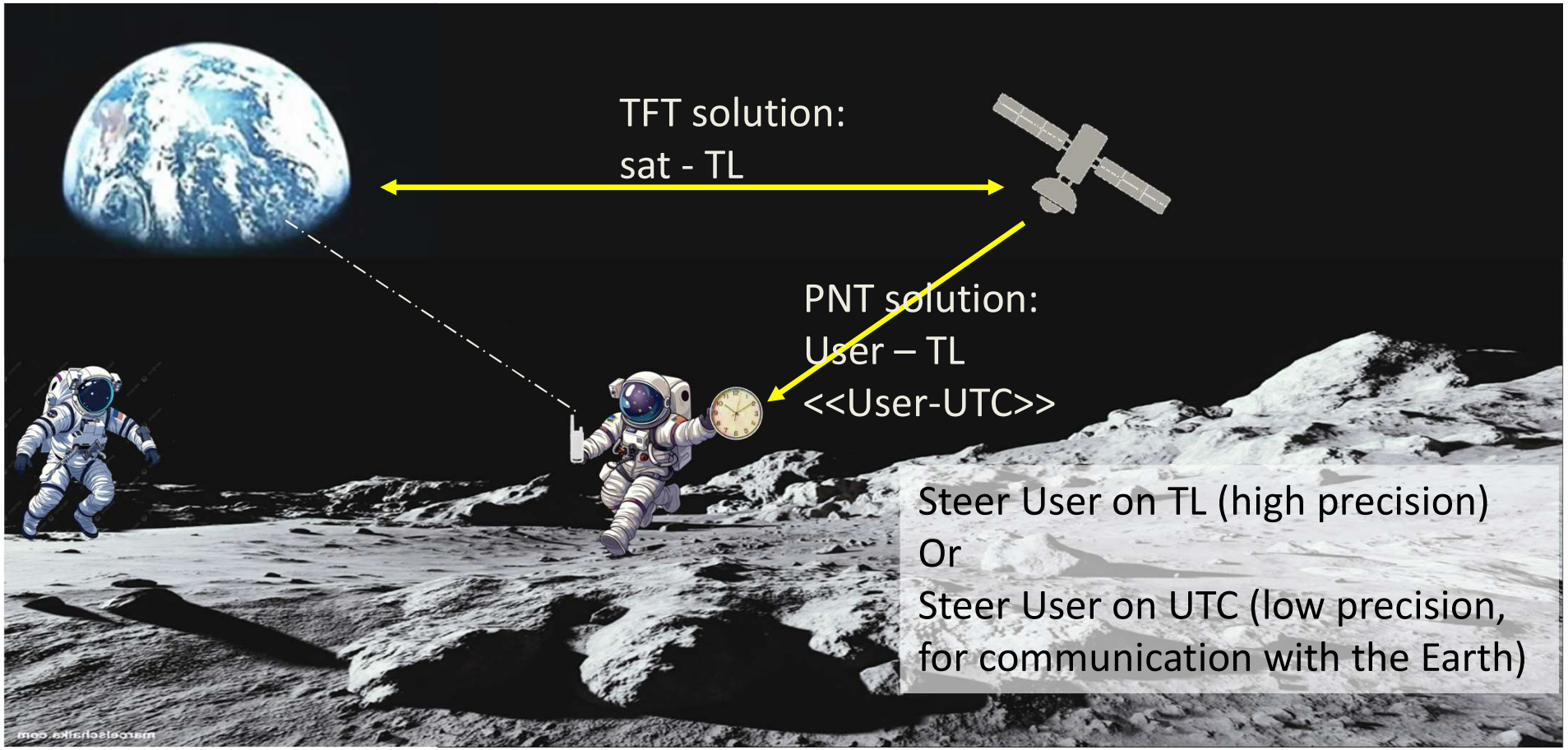
Current space clocks

Black = Steering needed due to user need & clock accuracy
Bold red = steering needed due to the definition option

Needs for PNT ($<10^{-13}$)

CONCLUSION : Option 2 reduces the magnitude of the initial steering correction only for accurate clocks like Cs/H-maser/optical, and user needs higher than those clock accuracies.

Time from the LCNS



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Task Group on Moon Timing

THANK YOU