CCTF

GNSS calibration status: update

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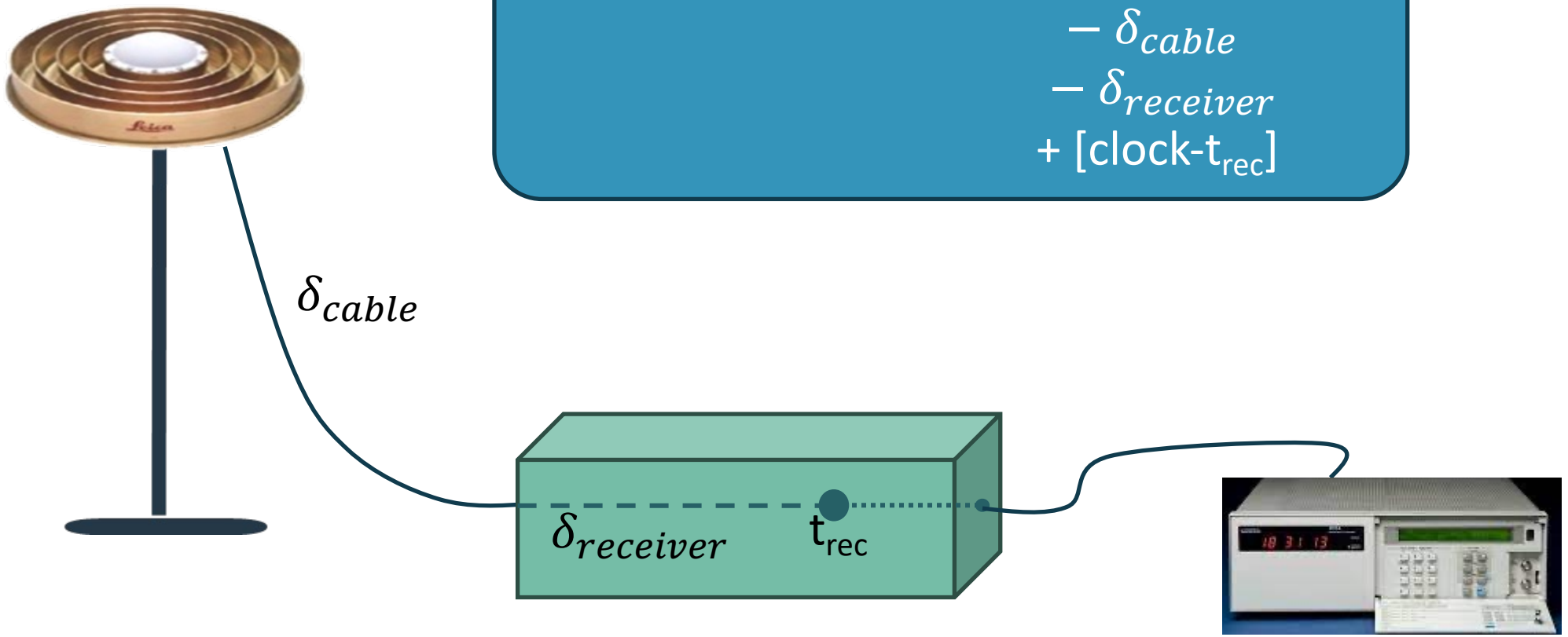
CONSULTATIVE COMMITTEE
FOR TIME AND FREQUENCY

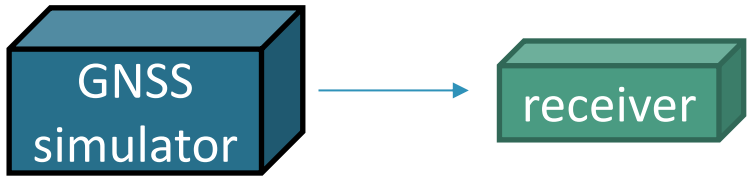
GNSS calibration

$$\Delta t_{clock} = \Delta t_{rec}(GNSS) - \delta_{antenna} - \delta_{cable} - \delta_{receiver} + [\text{clock-}t_{rec}]$$



Absolute / Relative

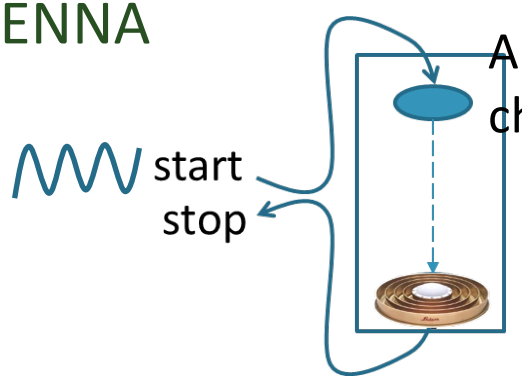
RECEIVER



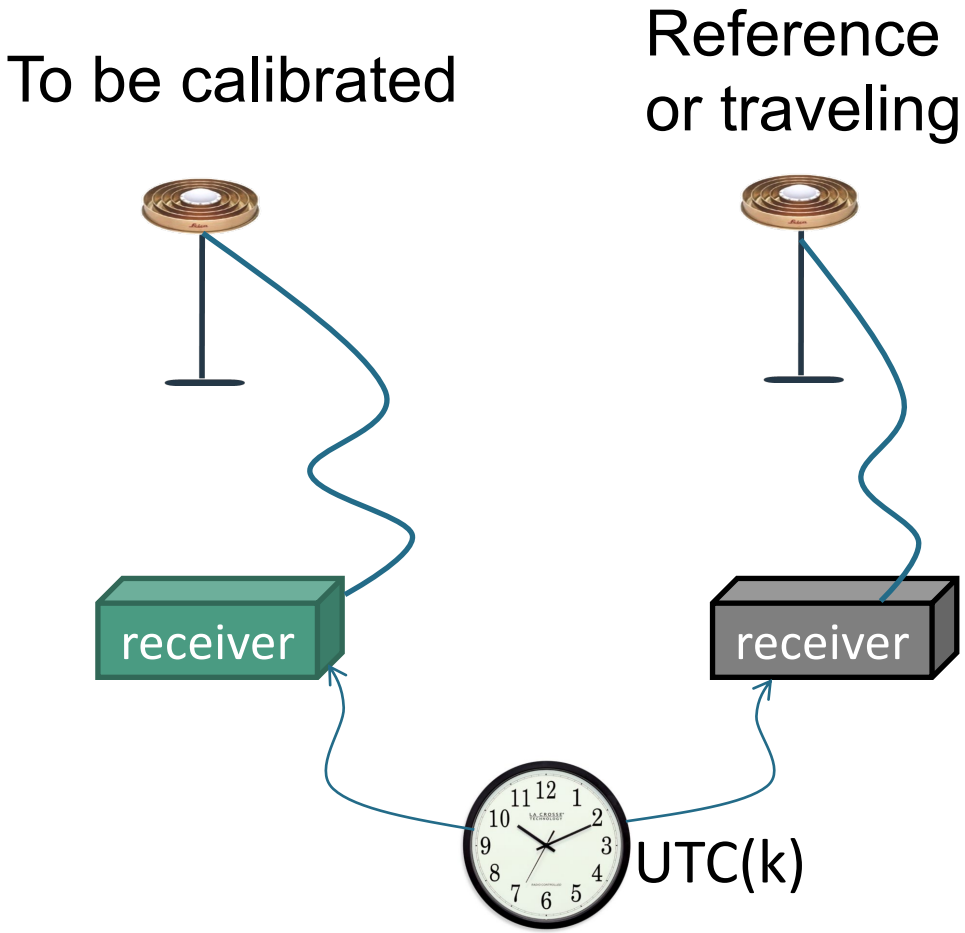
Simulated signals, free from any perturbation

Measurements → **receiver delays** $\delta_{receiver}$

ANTENNA



→ **antenna delay** $\delta_{antenna}$

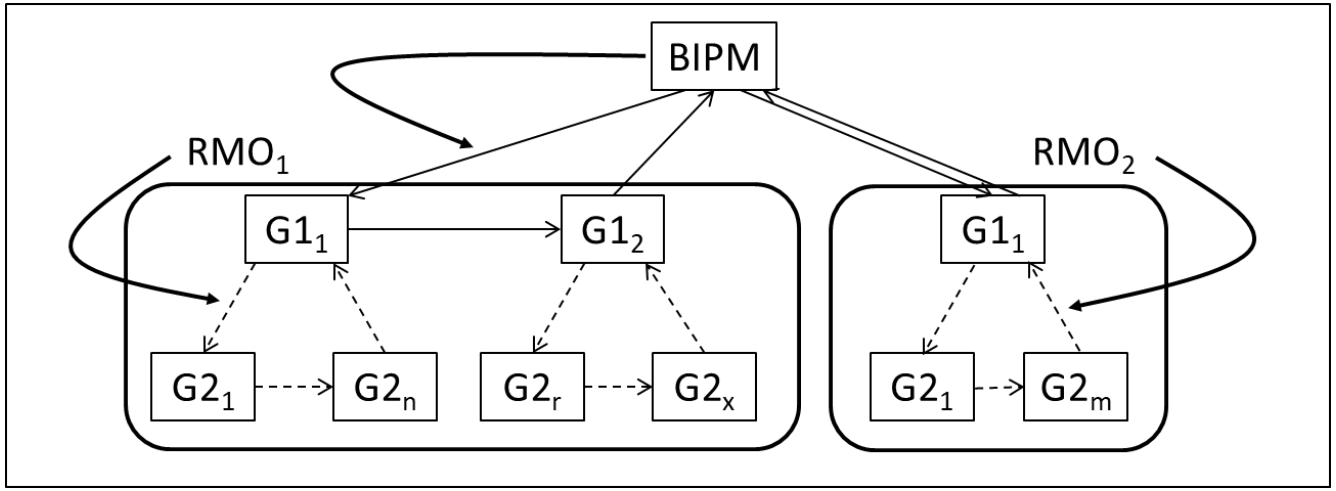


Measurement differences → **station delays**

Status on Absolute calibration

- Important for :
  - Having some reference for the differential calibrations
  - Mandatory for the validation of $bUTC_{GNSS}$ through (UTC-UTC(k)) – (UTC(k)-$bUTC_{GNSS}$)
- Consistency of the different results at the level of 1-2 ns (a bit larger than the combined uncertainties)
- Realized only in a few labs: CNES, ESA(ESTEC), JPL, VNIIFTRI.
- To date: results available for GPS, Galileo, GLONASS, BDS-2 and BDS-3.

Relative calibration scheme for UTC



BIPM organises the calibration of some labs (named Group 1, G1) in each RMO using a Traveling System

The other labs (named Group 2, G2) ask G1 labs to get calibration

Contacts for G1 laboratories

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AFRIMETS			
GULFMET			

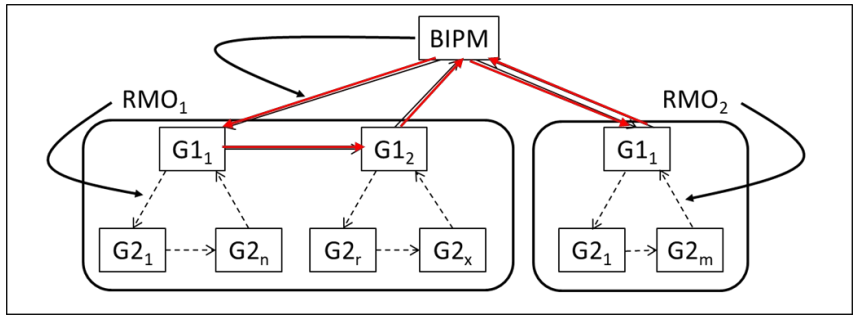
Uncertainties

For the link UTC(k)-UTC(s) (noted A-B) :

BIPM Convention:

- 1.5 ns if the receiver in B has been calibrated in a Group 1 trip;
- 2.5 ns if the receiver in B has been calibrated in a Group 2 trip;
- 4.0 ns if the receiver in B has been calibrated in a “Direct calibration” vs. a Group 1;
- 5.0 to 7.0 ns if the receiver in B has been calibrated by an “authorized third party”;

Status on Relative calibration / G1



Group 1:

- One complete calibration (all G1 in all RMOs) every 2 years

-The 1001-2022 G1 calibration started last year, APMP, EURAMET and SIM covered.

- This G1 campaign also calibrates Beidou-3 delays for B1C and B2a signals.

- All G1 laboratories have at least one permanent receiver tracking such signals.

- This will allow the calibration of Beidou 3 in future G2 trip.

Stability of G1 results

Average difference of HW delays between 2018 and 2020 G1 campaigns

Ensemble	# rec				
2020 – 2018 GPS		**ΔP1**	**ΔP2**	**ΔC1**	**ΔP3**
APMP	9	0.19	0.22	0.17	0.14
EURAMET	10	-0.10	0.11	-0.21	-0.42
SIM	6	-0.07	0.03	0.00	-0.22
APMP+EURAMET+SIM	23	0.01 (0.6)	0.14 (0.5)	-0.03 (0.6)	-0.19 (0.7)
2020 – 2018 GAL		**ΔE1**	**ΔE5a**		**ΔE3**
EURAMET	6	-0.03	0.10	N/A	-0.20
SIM	3	0.07	-0.23	N/A	0.44
EURAMET+SIM	8	0.00 (0.6)	-0.01 (0.7)	N/A	0.02 (0.6)

Max difference: 140 ps / Dispersion (Stdev) < 0.8 ns

→ G1 reference very stable

Stability of G1 results

Average difference of HW delays between 2020 and 2022 G1 campaigns

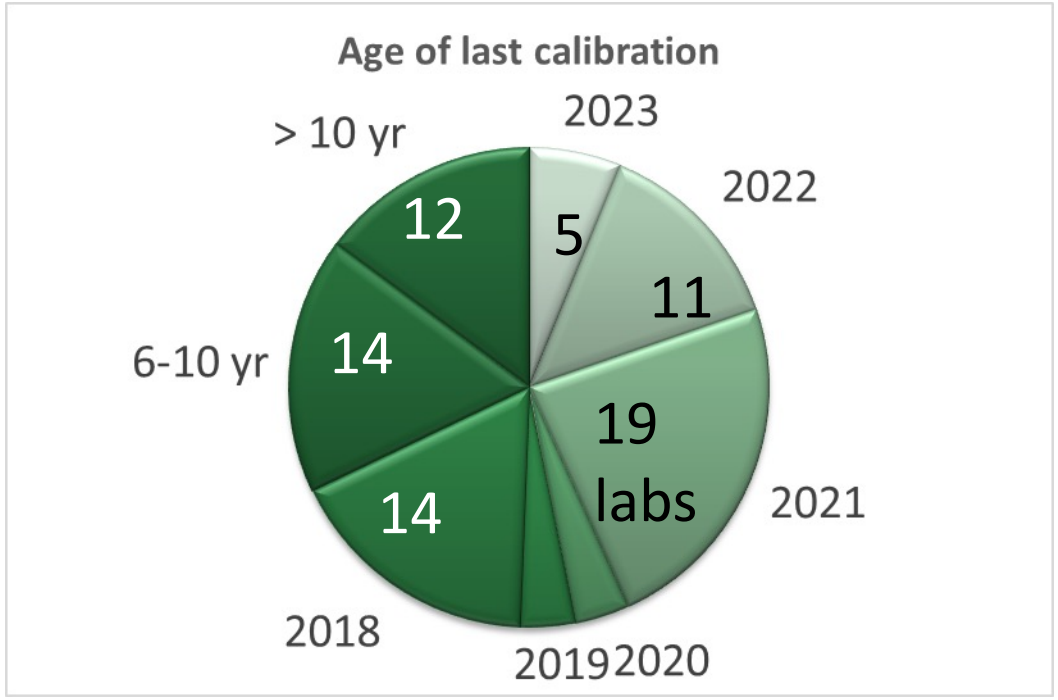
Ensemble	**#rec**				
2020-2022 GPS		**ΔP1**	**ΔP2**	**ΔC1**	**ΔP3**
APMP	9	0.19 (0.44)	0.06 (0.54)	0.12 (0.44)	0.40 (0.82)
EURAMET	8	0.07 (0.40)	0.29 (0.31)	-0.01 (0.37)	-0.28 (0.64)
APMP+EURAMET	17	0.13 (0.42)	0.17 (0.45)	0.06 (0.40)	0.06 (0.80)
2020-2022 GAL		**ΔE1**	**ΔE5a**		**ΔE3**
APMP	4	0.09 (0.58)	0.36 (1.38)		-0.24 (1.04)
EURAMET	7	0.03 (0.43)	0.21 (0.26)		-0.20 (0.66)
APMP+EURAMET	11	0.05 (0.46)	0.26 (0.79)		-0.22 (0.76)

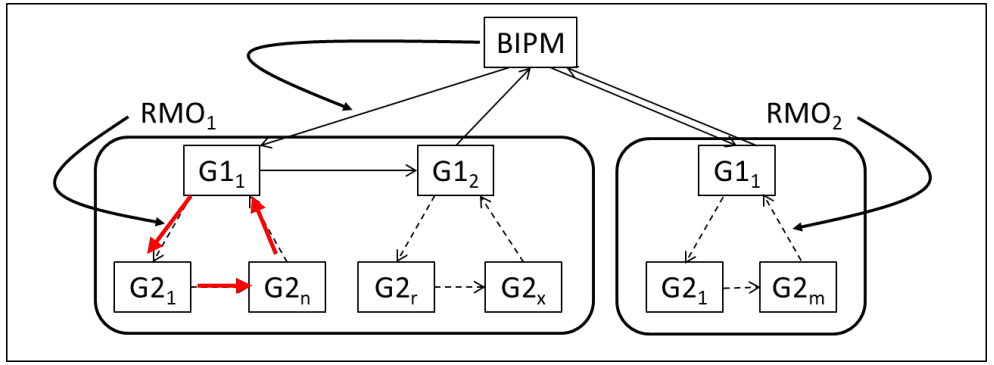
Max difference: 260 ps / Dispersion (Stdev) < 0.8 ns

→ G1 reference very stable

Status on G2 calibration

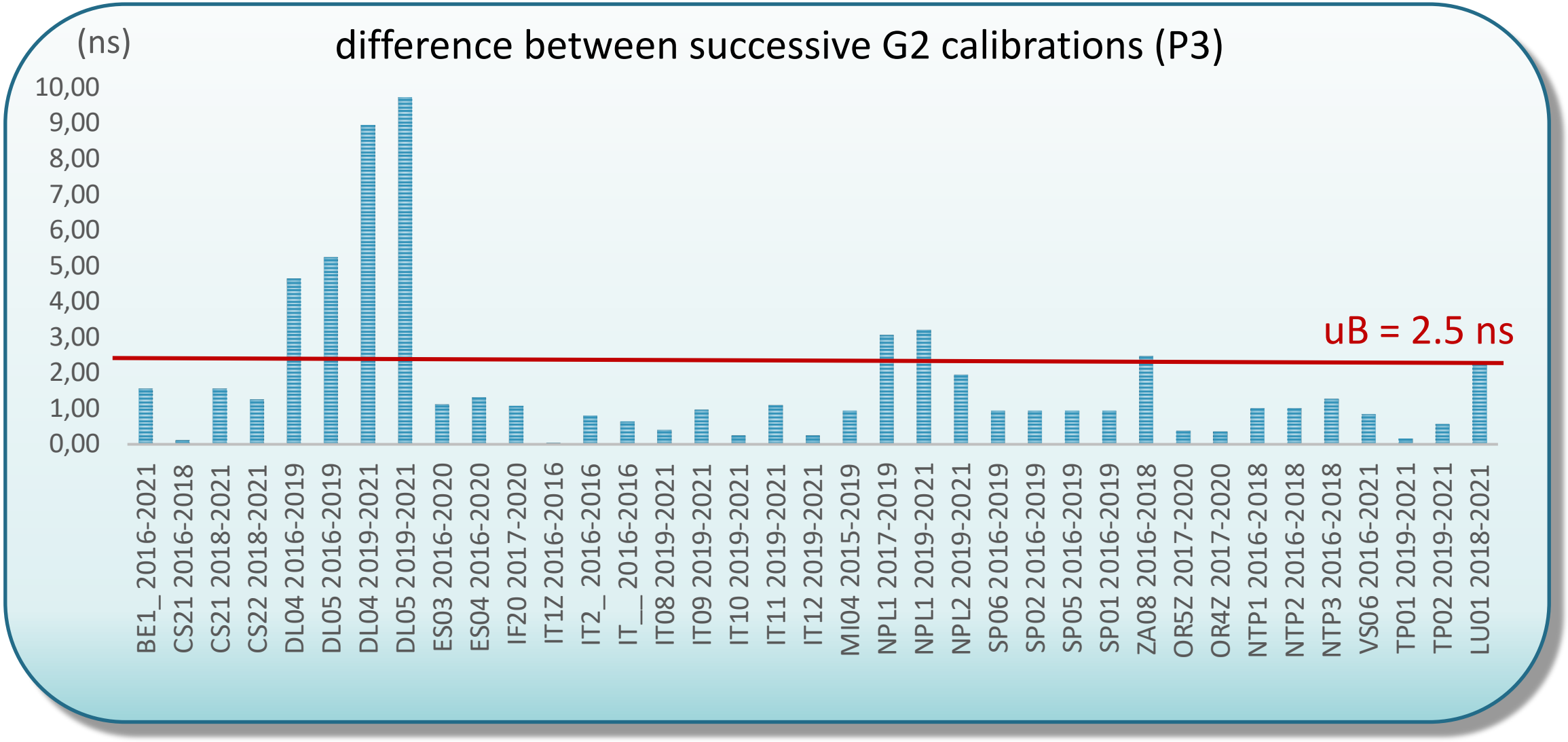
G2: Date of last calibration





- 35 G2 labs in 2021-2023
- 25 G2 calibrated for Galileo

Stability of G2 calibration results



Thank You

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