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Report of the TC Time and Frequency

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UME

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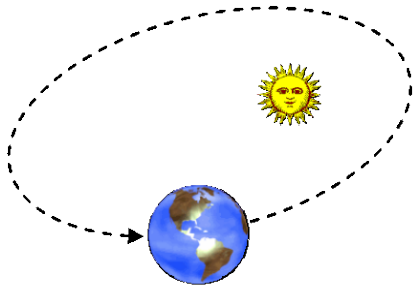
Highlight-1, Future optical redefinition of the second

Definition of second until 1960 based on Earth rotation around itself

Uncertainty ~3x10^{-8} (2-3 ms/day)

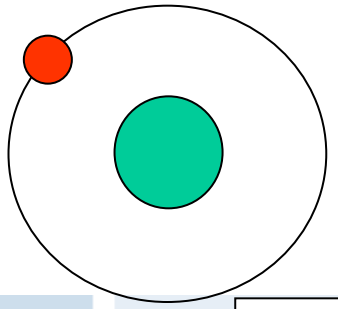
Definition of second between 1960 and 1967 based on Rotation of Earth around the Sun

Uncertainty ~3x10^{-9} (0.2-0.3 ms/day)

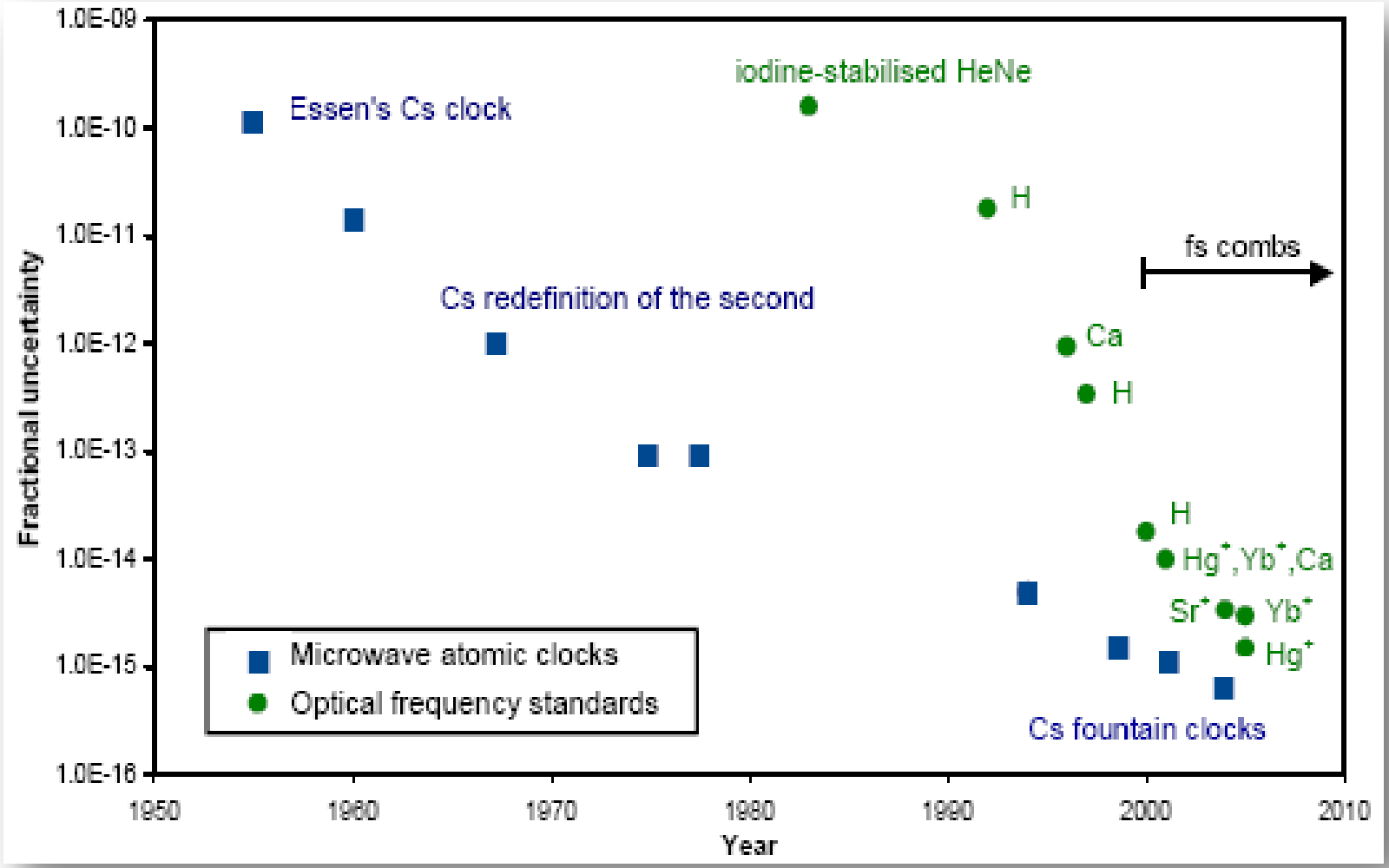


Definition of second after 1967 based on Cs atoms

Uncertainty ~1x10^{-14} (1ns/day)



Highlight-1, Future optical redefinition of the second



CCTF-2006

Highlight-1, Future optical redefinition of the second

Species	Transition	Frequency/Hz	Estimated relative standard uncertainty
^{199}Hg	$6s^2\ ^1S_0 - 6s\ 6p\ ^3P_0$	1 128 575 290 808 162.	1.7×10^{-14}
$^{40}Ca^+$	$4s\ ^2S_{1/2} - 3d\ ^2D_{5/2}$	411 042 129 776 395.	1.5×10^{-14}
^1H	1S – 2S	1 233 030 706 593 518.	1.2×10^{-14}
$^{171}Yb^+$	$6s\ ^2S_{1/2} - 4f\ ^{13}6s^2\ ^2F_{7/2}$	642 121 496 772 645.6	1.3×10^{-15}
^{171}Yb	$6s^2\ ^1S_0 - 6s\ 6p\ ^3P_0$	518 295 836 590 865.0	2.7×10^{-15}
$^{27}Al^+$	$3s^2\ ^1S_0 - 3s\ 3p\ ^3P_0$	1 121 015 393 207 857.3	1.9×10^{-15}
$^{199}Hg^+$	$5d^{10}6s\ ^2S_{1/2} - 5d^9 6s^2\ ^2D_{5/2}$	1 064 721 609 899 145.3	1.9×10^{-15}
$^{171}Yb^+$	$6s\ ^2S_{1/2}$ ($F = 0, m_F = 0$) – $5d\ ^2D_{3/2}$ ($F = 2, m_F = 0$)	688 358 979 309 307.1	3×10^{-15}
$^{88}Sr^+$	$5s\ ^2S_{1/2} - 4d\ ^2D_{5/2}$	444 779 044 095 485.3	4.0×10^{-15}
^{87}Sr	$5s^2\ ^1S_0 - 5s5p\ ^3P_0$	429 228 004 229 873.4	1×10^{-15}
^{87}Rb		6 834 682 610.904 312	1.3×10^{-15}

Microwave and Optical Frequency Standards,

BIPM, 2013

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EMRP Projects

2010 call:

IND14, New generation of frequency standards for industry

2011 call:

SIB02, Accurate time / frequency comparison and dissemination through optical telecommunication networks

SIB04, High-accuracy optical clocks with trapped ions

2012 call:

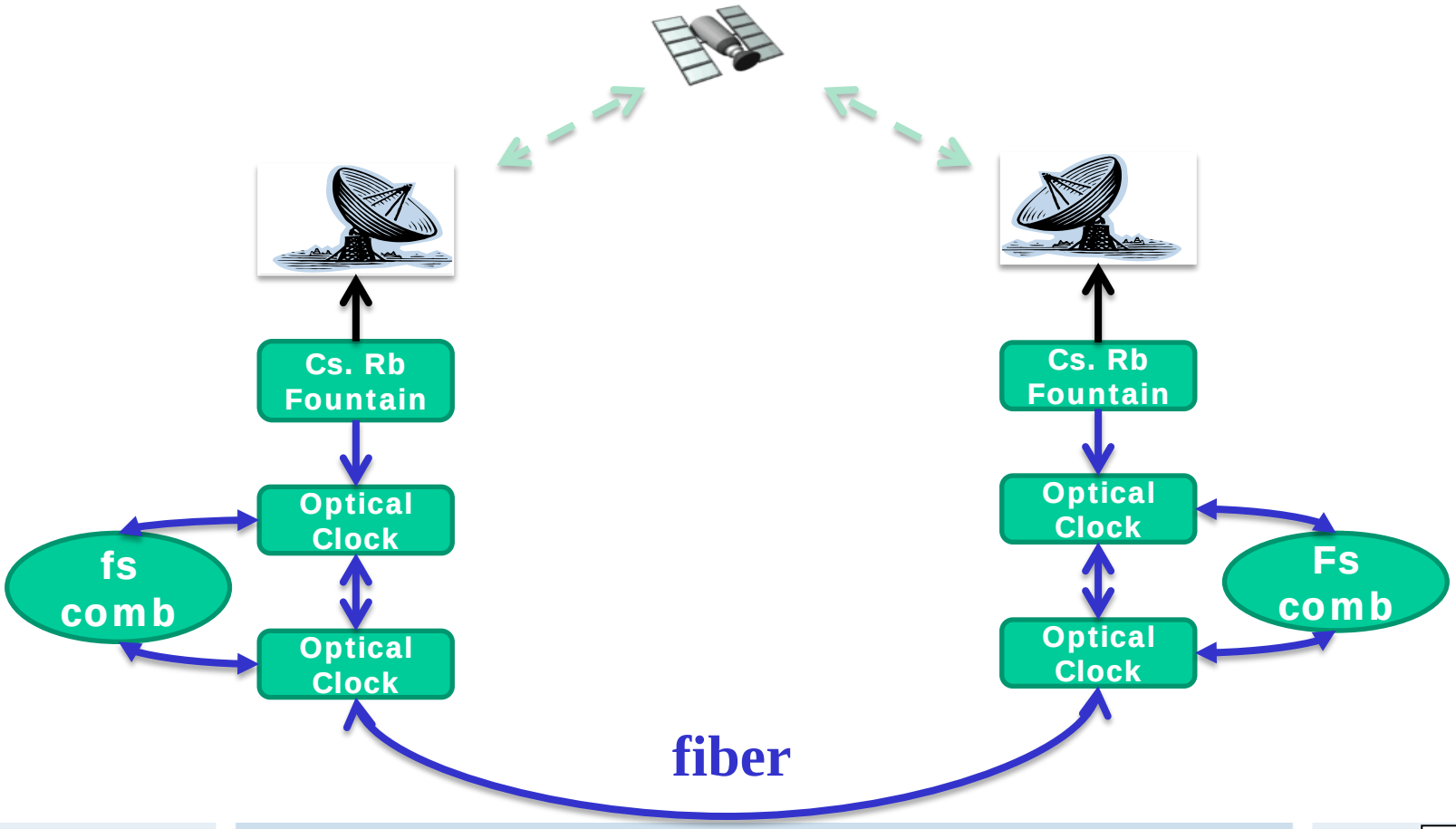
IND55, Compact microwave clocks for industrial applications

SIB55, International timescales with optical clocks

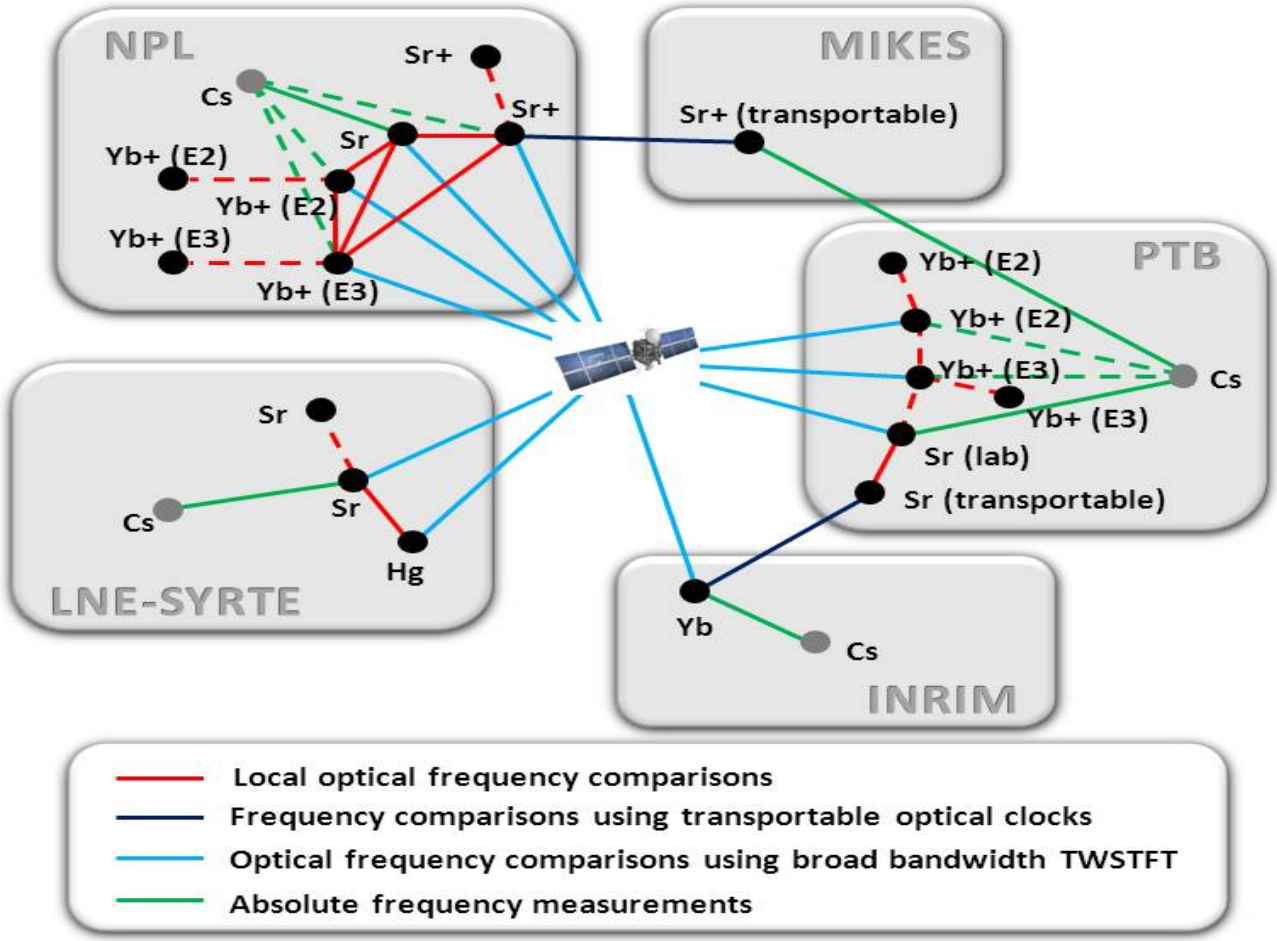
SIB60, Metrology for long distance surveying

EXL01, Quantum engineered states for optical clocks and atomic sensors

SIB55, International timescales with optical clocks



SIB55, International timescales with optical clocks

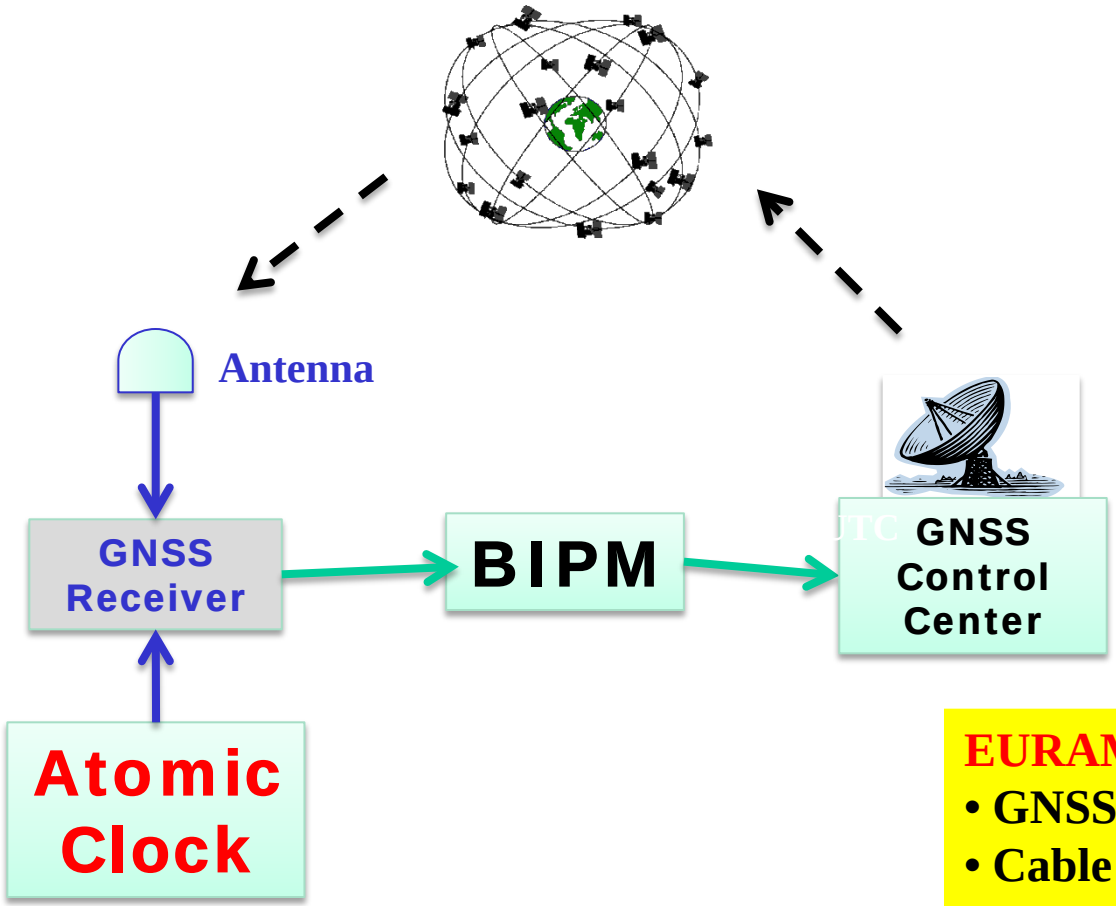


Key Deliverable:

Comparison at 10^{-17} - 10^{-16} level,

Future optical redefinition of the second

Highlight-2 , Time scale generation with low uncertainty



Atomic Clocks Accuracy
10^{-14} - 10^{-16}

Time deviation
$\Delta t / t = \Delta f / f =$ 1 – 0.01 ns/day

Time scale generation depends

- Delay on antenna
- Delay on Cables
- Delay on GNSS receivers

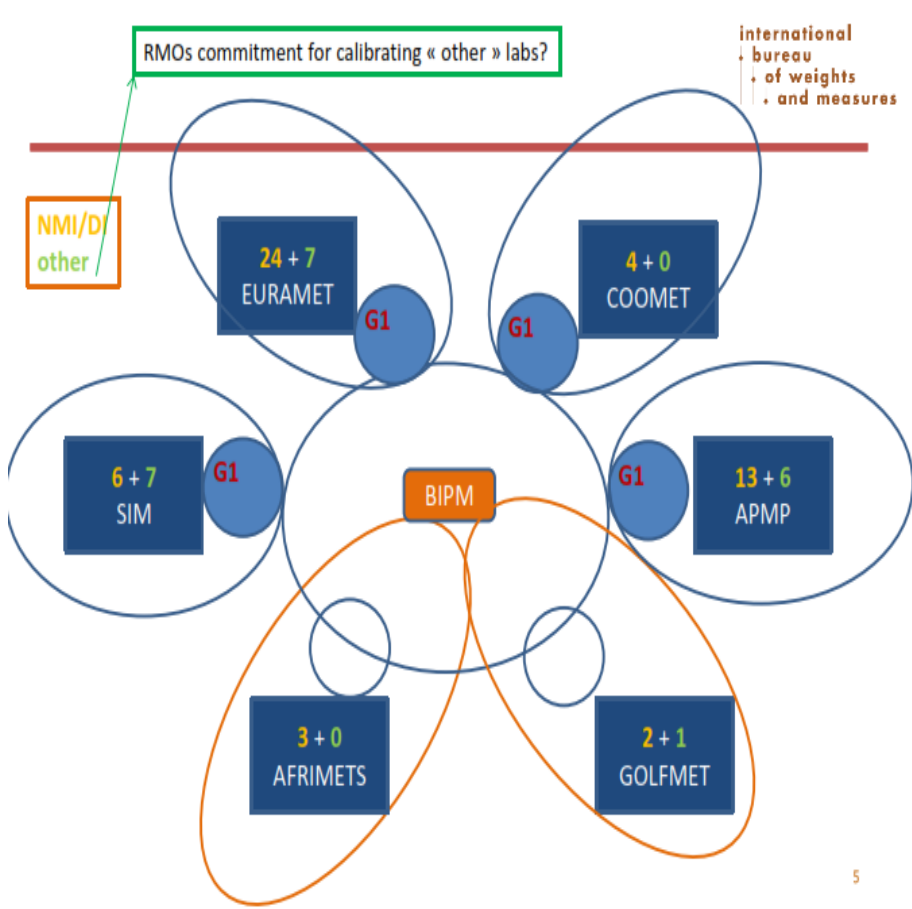
Time Scale Shift
UTC- UTC(k) : 5 -100 ns

EURAMET Projects:
- **GNSS Receiver Comparisons**
- **Cable Delay Measurents**

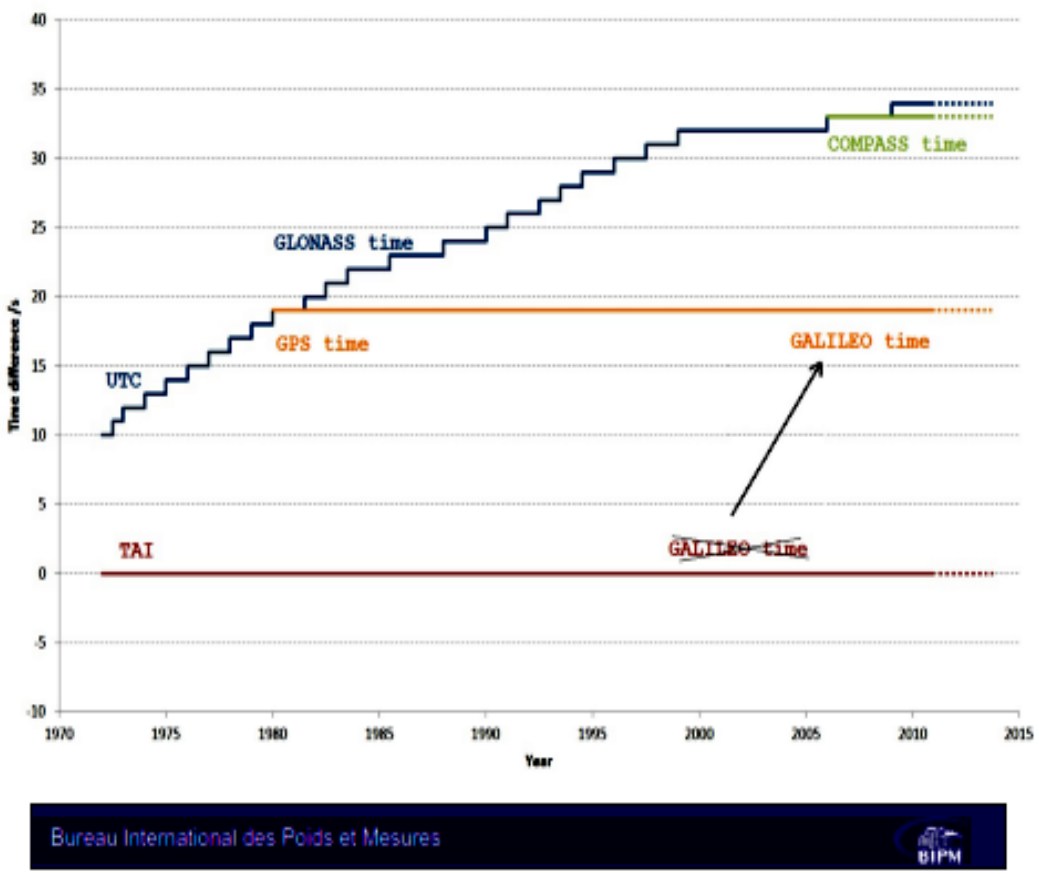
BIPM guidelines for GNSS equipment calibration

GNSS Receiver Comparison

- **BIPM** prepared **Guidelines**
- Sharing with RMOs the task of GNSS equipment calibration for UTC time comparisons,
- Most TF lab contributing to UTC with **uB uncertainty ≈7 ns** (5-10 ns)
- Contributing to the evaluation of the **uB, targeting at 2-3 ns,**



ITU-BIPM Workshop "Future of International Time Scale"



GPS time: steered to UTC(USNO) modulo 1s

- ✓ [TAI – GPS time] = 19 s + C_0
- ✓ [UTC – GPS time] = -16 s + C_0
- ✓ Tolerance is 1 μs

GLONASS time: steered to UTC(SU) with leap second

- ✓ [TAI – GLONASS time] = 35 s + C_1
- ✓ [UTC – GLONASS time] = C_1
- ✓ Tolerance is 1 ms

Galileo time: steered to a set of EU UTC(k); using GPS time seconds, GGTO

- ✓ [TAI – Galileo time] = 19 s + C_2
- ✓ [UTC – Galileo time] = -16 s + C_2
- ✓ Tolerance is 50 ns

BeiDou time: will be steered to set of Chinese UTC(k)

- ✓ [TAI – BeiDou time] = 33 s + C_3
- ✓ [UTC – BeiDou time] = -2 s + C_3
- ✓ Tolerance is 100 ns

BIPM : No leap second. UTC will have no more discontinuities, UTC-TAI = constant,

GPS – US : *GPS Directorate is positioned to support continuation or discontinuation of leap seconds.* If leap seconds are discontinued, minor GPS software changes will likely be necessary in the Control Segment. One change will be to relax the constraint on UT1 – UTC. GPS time was implemented without leap seconds to avoid operational problems associated with leap seconds.

NIST: No change to existing UTC time scale, no additional leap seconds, increase on order of 1 minute per century, Leap seconds have significant impact on digital time services, the price of continuing leap seconds is not worth the benefit of keeping dut1 small, NIST does not have an official position on this question.

GALILEO: Introduction of the leap second is undesirable from the point of view of System Operat. No leap second

GLONASS: Taking into account existing number of users decision is "No changing", generation of time scale with leap second

BEIDOU: The elimination of leap seconds maybe have no negative impacts on the operation of Beidou system, it is convenient not only to the operator, but also to the users.

IERS: Whatever decision the ITU makes, the IERS will continue to serve the community by providing the necessary data and expertise

ITU: Recommendation to modify UTC to a continuous atomic time scale, no leap second

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Thank you for your attention