Status of UTC
Presented to the 10th meeting of contributing laboratories

Elisa Felicitas Arias

10h Meeting of laboratories contributing to UTC
Sèvres, 16 September 2015

Bureau International des Poids et Mesures

Programme of Work and Budget 2012-2015

- Establishment of TAI/UTC/UTCr
- Time and frequency transfer studies
  - For TAI/UTC
  - For application in optical standards comparisons
- Time transfer equipment calibration
  - GPS/TWSTFT guidelines
  - Progress in calibrations
- Improvement of TAI frequency accuracy and stability
  - Evolution of the algorithm
- Publications
  - BIPM publications
  - Scientific publications and reports
- Coordination and international liason
  - CCs, WGs, CIPM MRA - KCs
  - Regional and international organizations
- Internal services
  - Frequency reference

Staff of the Time Department (2012-2015)

Permanent

Felicitas Arias	director
Aurélie Harmegnies #	calculation, software development, t. transfer
Zhiheng Jiang #	time transfer, calibration
Hawaï Konaté	calculation, data management, publications
Włodek Lewandowski *	time transfer, international liaison, calibration
Gianna Panfilo	algorithms, pfs, MRA
Gérard Petit	time transfer, PFS/SFS, calibration, international liaison
Lennart Robertsson	freq. transfer, internal services, project support
Laurent Tisserand	laboratory management, software development, t transfer

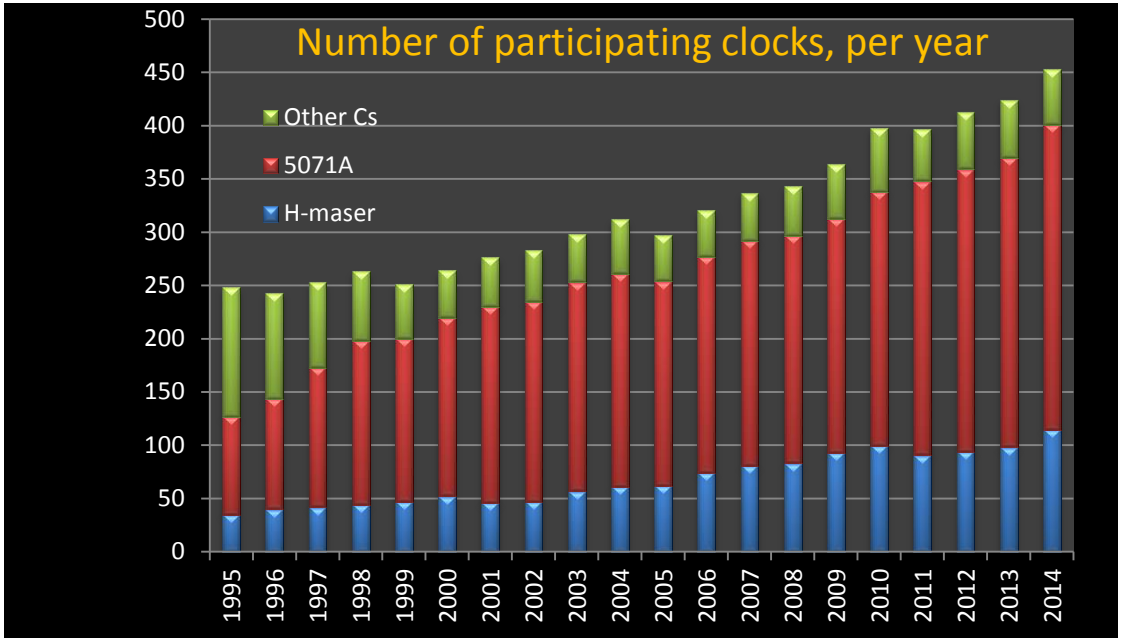
* Retired since June 2014 # T-Soft maintenance

Visitors/secondees

Amale Kanj (post-Doc, BIPM/CNES)	time transfer and GPS absolute calibration (2013/14)
Wenjun Wu (visiting scientist, NTSC)	time transfer and calibration (06/2014-06/2015)
Federica Parisi (student, Torino Univ.)	algorithms, time scales (6 months in 2014/15)
Julia Leute (student, PTB)	time/frequency transfer (3 months in 2015)

Achievements

- **Algorithm for TAI**
  - New model of clock weighting implemented January 2014
- **Rapid UTC**
  - Continuous publication on Wednesdays before 18 h UTC
- **Time transfer**
  - Validation of GPS PPP and GPS calibration on 420 km optical fibre link
  - Comparison of optical fibre link with « classic techniques »
  - Improved GPS frequency transfer with integer ambigüities (with CNES)
- **Characterization of delays in time transfer equipment/links**
  - New calibration scheme in coordination with RMOs has been implemented (Guidelines for GNSS calibrations)
  - BIPM calibrations trips in EURAMET, APMP, SIM, COOMET concluded
- **Redefinition of UTC**
  - BIPM interacted with ITU-R, URSI, IAU, IUGG



0 (until 2001)

- ✓ Weight reflects the clock stability
- ✓ ω_{max} = 0,7% (fix)

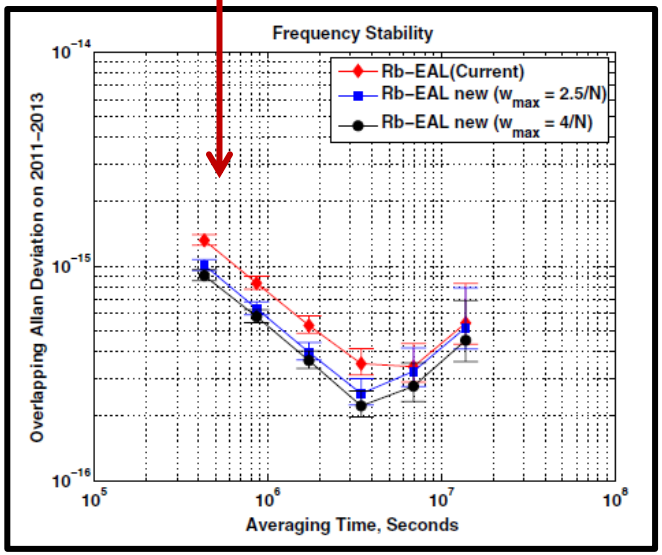
1

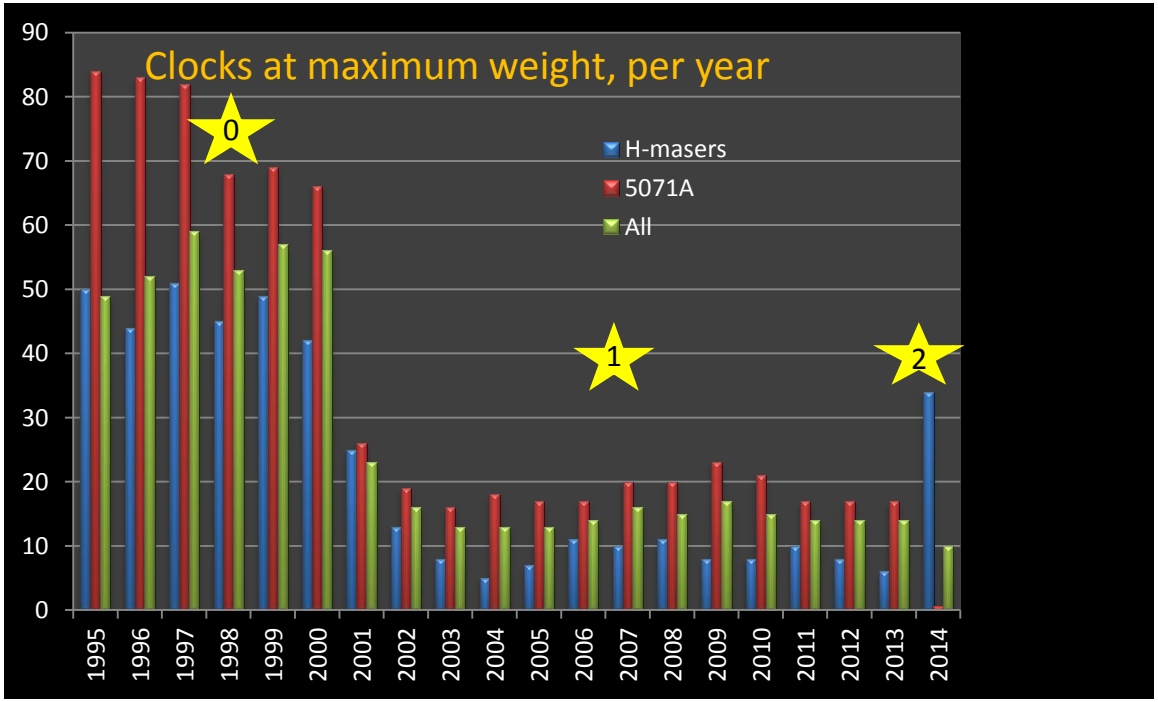
- ✓ Weight reflects the clock stability
- ✓ ω_{max} = 2.5/N

2 (2014 >>)

- ✓ Weight reflects the clock predictibility
- ✓ ω_{max} = 4/N

Short- and long-term stability improvement





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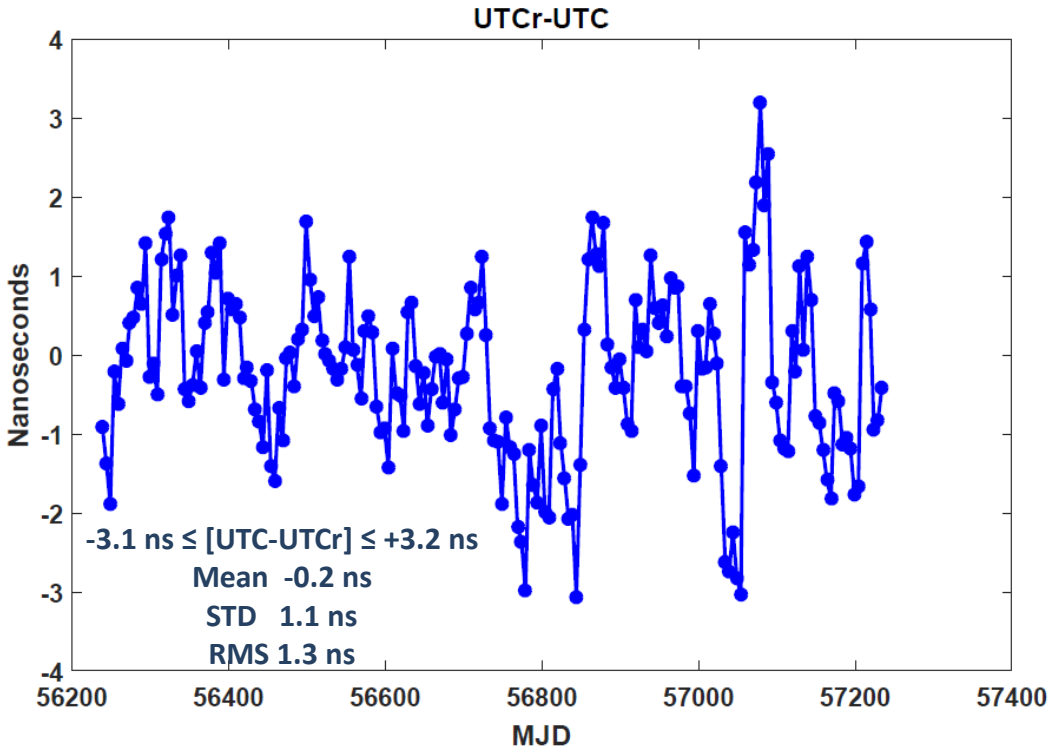
Rapid UTC (UTCr)

- Uninterrupted publication since July 2013 (weekly)
- 42 participants
- ~ 70% of the clocks in UTC
- Difference [*UTC-UTC*r] is minimized (steering to UTC after publication of *BIPM Circular T*)



Stability @ 1 month

- UTC = 3×10^{-16}
- UTCr= 4×10^{-16}

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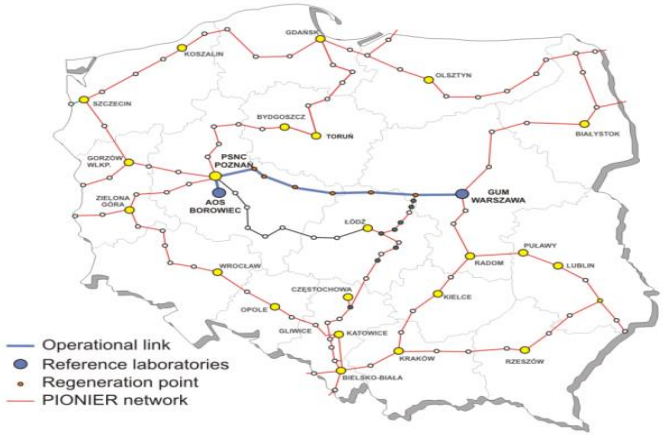
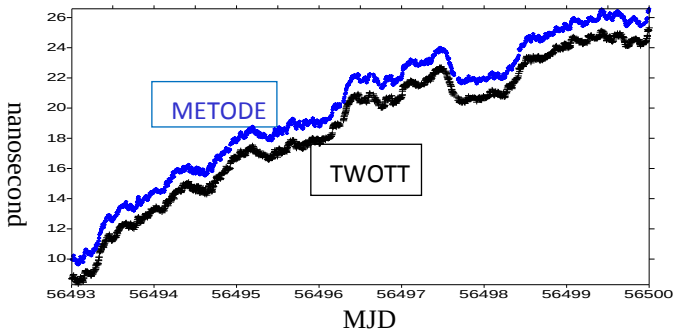
Time transfer

Use of fibre links for link comparison and validation



BIPM calibrator



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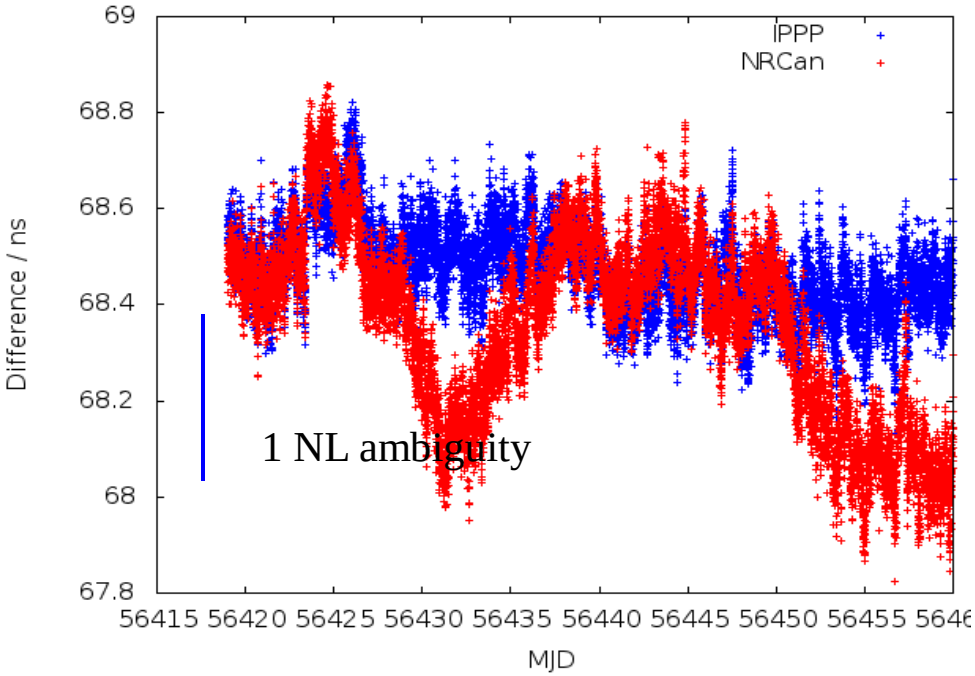
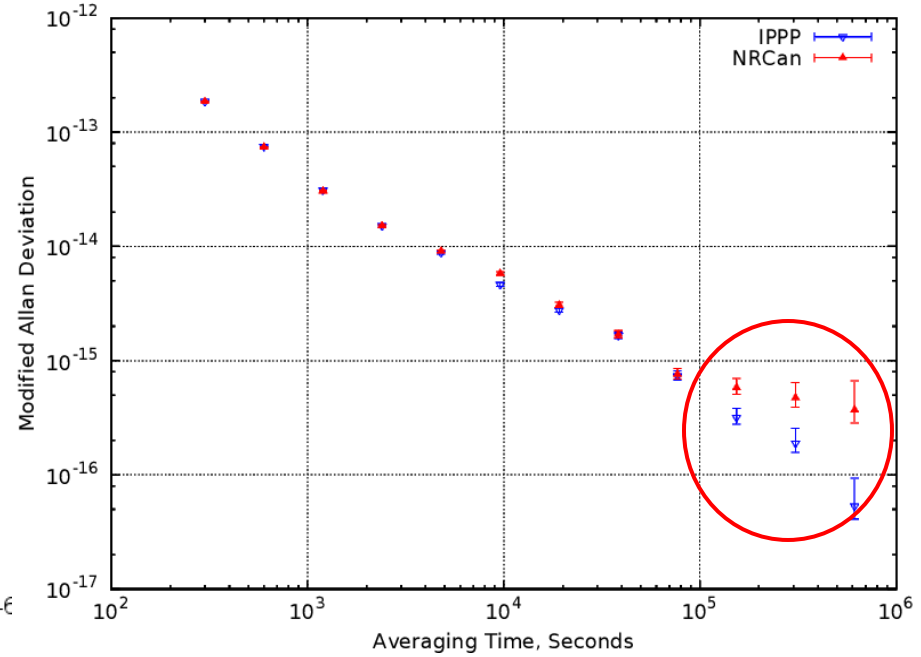
uB≤ 2 ns realistic

IPPP and PPP vs. 420-km fibre link

- IPPP technique: 100% success at solving integer λ_c boundaries over ~6 months
- A 41-day period (longest continuous operation for all systems):
  - Stability of IPPP better at few hours and at long term : 5.3×10^{-17} @ 7.1 days
  - PPP apparent slope of order 1×10^{-16} , IPPP has no significant slope

Blue = IPPP – Fibre link
Red = NRCan – Fibre link





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Guidelines for GNSS equipment calibration

Coordination of the BIPM with RMOs

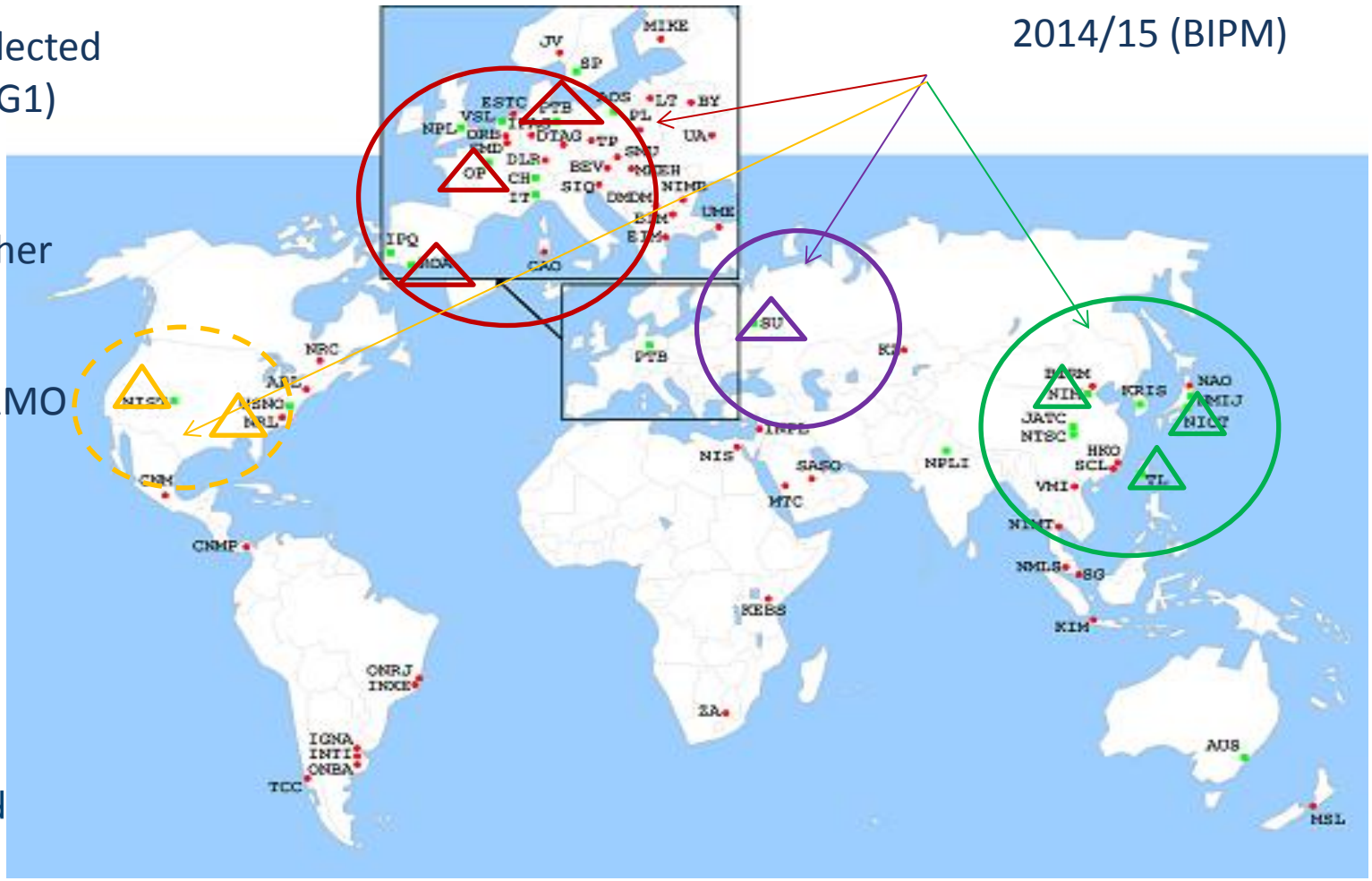
Objective: improving the accuracy of UTC-UTC(k) by implementing continuous calibration campaigns for reducing time link uB from 5 ns to < 2.5 ns

BIPM calibrates equipment in selected labs per region (G1)

RMOs calibrate equipment in other labs (G2)

BIPM validates RMO calibrations and computes final results

Calibrated 2014/15 (BIPM)



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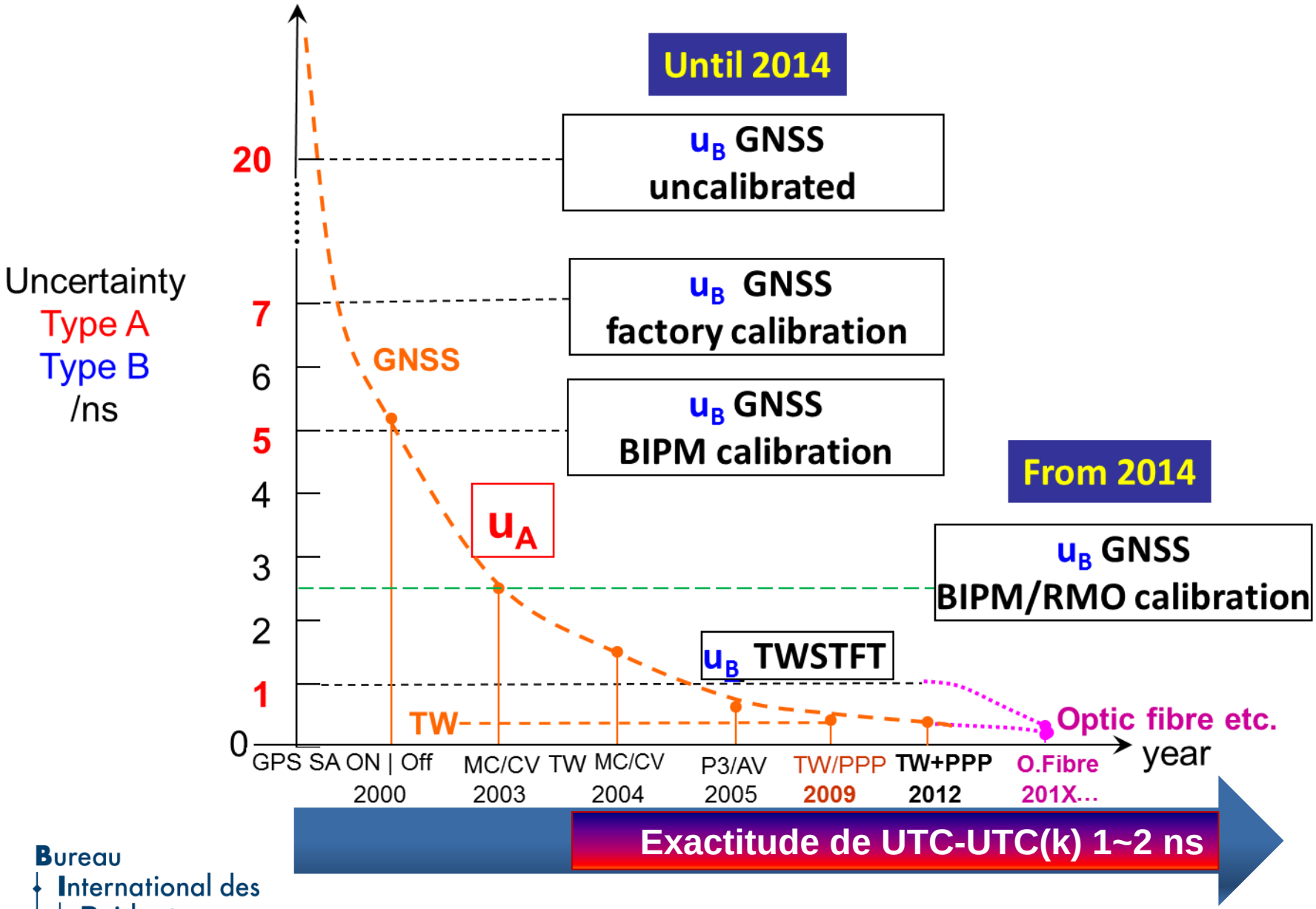

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Key comparison CCTF-K001.UTC

Following the discussions at the 19th Meeting of the CCTF (2012) , in agreement with the CCTF WG MRA and in concertation with the staff of the BIPM KCDB, the monthly publication of results of the key comparison CCTF-K001.UTC in the BIPM KCDB has been re-iniciated in 2015. Degrees of equivalence are provided for laboratories contributing to UTC operating in NMIs and DIs signatories of the CIPM MRA.

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Key and supplementary comparisons - Results KCDB

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- BIPM.KCDB@bipm.org

CCTF-K001.UTC

Results

Laboratory individual measurements | **Equivalence statements** | Degrees of equivalence | Graph(s) of equivalence

The key comparison reference value of the key comparison CCTF-K001.UTC is **UTC**, as decided by the CCTF at its 15th meeting held in 2001.

The degree of equivalence of each laboratory k with respect to the key comparison reference value is given by a pair of terms both expressed in ns:
$D_k = [UTC - UTC(k)]$, where **UTC(k)** is the local representation of **UTC** maintained by laboratory k, and
U_k, the expanded uncertainty (coverage factor equal to 2), of D_k.

The KCDB gives access to the degrees of equivalence for the last month.

$U_k = 2\ u_k$ where u_k is the combined standard uncertainty of $[UTC - UTC(k)]$.
U_k does not include the *prediction component* due to the delay of publication of $[UTC - UTC(k)]$.
The u_k values are valid for the whole month of calculation.

No pair-wise degrees of equivalence are computed for this key comparison.

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Key comparison CCTF-K001.UTC - Results
Degrees of equivalence $D_k = [UTC - UTC(k)]$ for July 2015
Computed 2015 AUGUST 10, 10h UTC

Coordinated Universal Time UTC and its local realizations UTC(k) in National Metrology Institutes and Designated Institutes.

Computed values of $[UTC - UTC(k)]$ and uncertainties valid for the period of this publication

Date 2015 0h UTC	JUL 1	JUL 6	JUL 11	JUL 16	JUL 21	JUL 26	JUL 31	Uncertainty/ns
MJD	57204	57209	57214	57219	57224	57229	57234	
Laboratory k				$[UTC - UTC(k)]$/ns				U_k
BelGIM	6.3	5.3	4.9	6.1	7.1	6.5	7.0	14.4
BEV	-28.3	-23.8	-23.0	-17.3	-3.0	12.2	27.3	6.2
BIM	2481.7	2494.3	2506.8	2503.8	2516.5	2525.3	2537.7	14.4
CENAM	1.8	4.5	6.1	8.2	11.2	-1.1	-3.6	11.6
CENAMEP AIP	-	-	-	-57.2	-104.3	-150.6	-90.5	12.4
DEF-NAT	10630.8	10818.7	11016.0	11191.6	11358.9	11547.1	11741.1	40.0
DMDM	-12.1	2.8	7.6	-6.0	-7.4	-6.8	-5.0	14.0
EIM	7.5	18.2	9.3	17.5	5.3	5.7	14.7	18.0
ESA	1.3	3.4	1.1	-1.6	1.0	0.6	-0.5	10.0
FMTC	919.2	913.5	933.7	939.0	918.3	925.3	952.1	10.8
GUM	-29.9	-40.3	-32.6	-24.9	-12.0	-3.8	-3.3	10.0
IMBIH	-185.0	-102.1	-17.8	-20.0	-13.2	-10.2	-1.3	14.2
INM	1054.6	1064.5	1077.3	1082.0	1089.1	1079.1	1069.8	41.0
INMETRO	-24.6	-24.8	-38.1	-34.0	-34.2	-34.1	-32.4	40.0
INPL	36.7	42.2	44.3	37.3	31.4	33.5	42.2	40.0
INRIM	-3.8	-2.9	-2.1	-1.3	-1.7	-1.8	-1.4	2.6
INTI	16.8	36.9	45.5	46.1	58.9	56.4	65.6	40.4
IPE/ASCR	-29.4	-31.7	-30.0	-32.7	-34.7	-	-38.4	10.2
JV	-43.2	-44.3	-47.0	-47.0	-39.2	-22.8	-39.5	41.2
KazInMetr	-811.7	-799.8	-784.2	-778.9	-763.5	-753.6	-750.9	14.4
KEBS	-45.1	-334.5	-612.2	-894.1	-1173.7	-1460.5	-1753.5	40.2
KIM-LIPI	494.8	504.4	526.6	546.6	573.6	584.2	620.6	40.2
KRISS	18.5	20.6	22.0	23.1	23.2	24.2	26.0	10.0
LNE/SYRTE	-1.9	-1.7	-1.8	-1.6	-1.5	-1.7	-1.7	2.6
MASM	-	-	-	-	-	-	-	
METAS	21.7	20.6	17.2	13.7	10.9	8.8	7.0	2.6

Publications

- BIPM Publications
  - *BIPM Annual Report on Time Activities* 2012, 2013, 2014
    - Electronic
      http://www.bipm.org/metrology/time-frequency/publications.html
  - *BIPM Circular T*, monthly
    http://www.bipm.org/en/bipm-services/timescales/time-ftp/publication.html
  - *UTCr*, weekly
    http://www.bipm.org/en/bipm-services/timescales/time-ftp/publication.html
  - ftp://62.161.69.5/pub/tai/publication/utcr/
  - TT(BIPMXY) for 2012, 2013, 2014
    ftp://tai.bipm.org/TFG/TT(BIPM)/
  - Scientific publications (staff)
  - About 50 in the period
- Web/ftp server of the Time Department

THANKS FOR YOUR ATTENTION

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