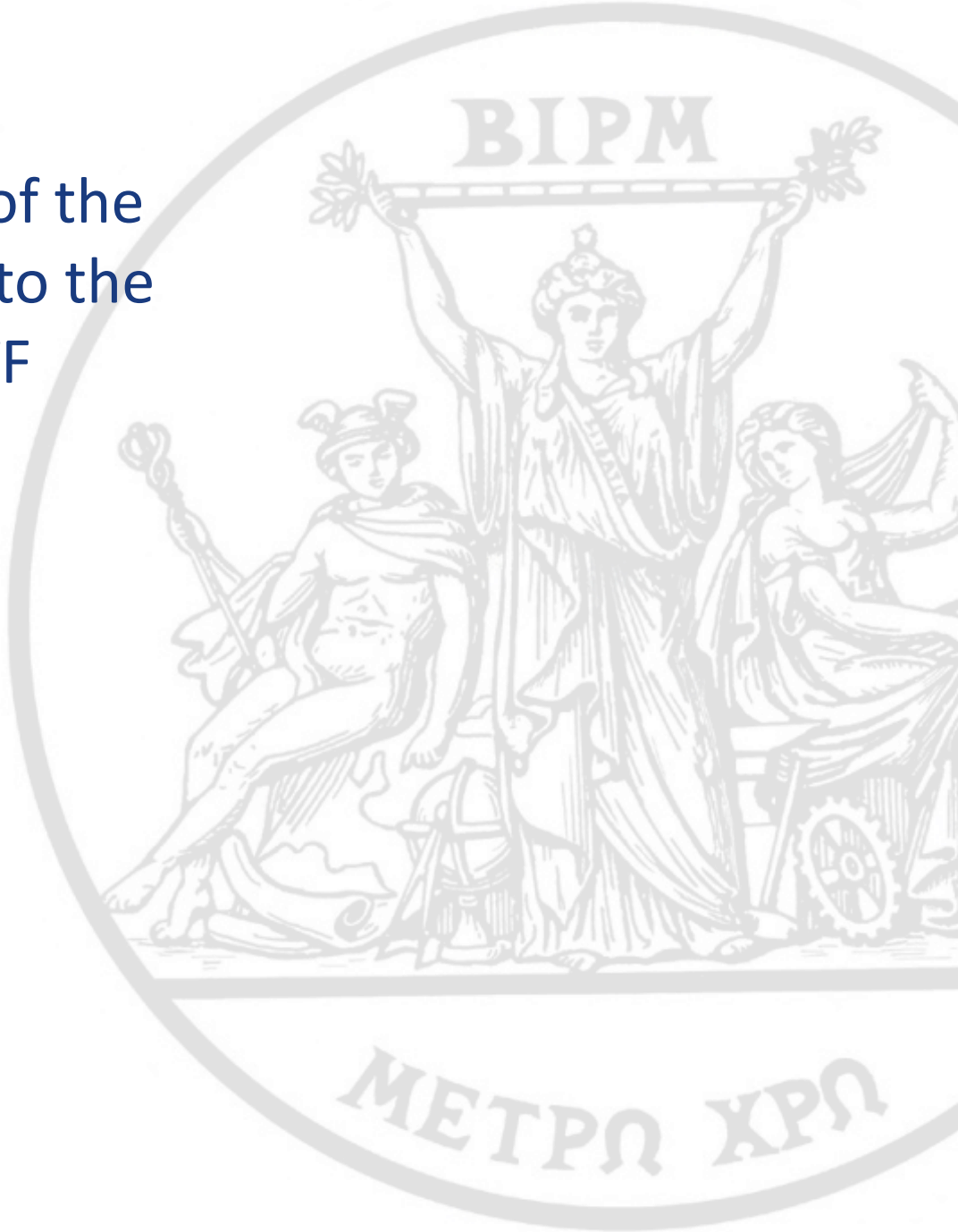
Report on the activities of the BIPM Time Department to the 20th Meeting of the CCTF

Elisa Felicitas Arias

20th Meeting of the CCTF
Sèvres, 17-18 September 2015



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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)

Expenditure 2012-2015

YEAR	ITEMS	COST / k€
2013	GTR-51 PCs, TICs, etc	17 20
2014	Cs clock (high perf) PCs, TICs, etc	76 12
2015	NOVATEL (to do) Other	15 6
Total invest.		146

The Cs standard was purchased to replace the end-of-life CHI-75 H-masers

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, UIGG

ALGORITHM FOR TAI

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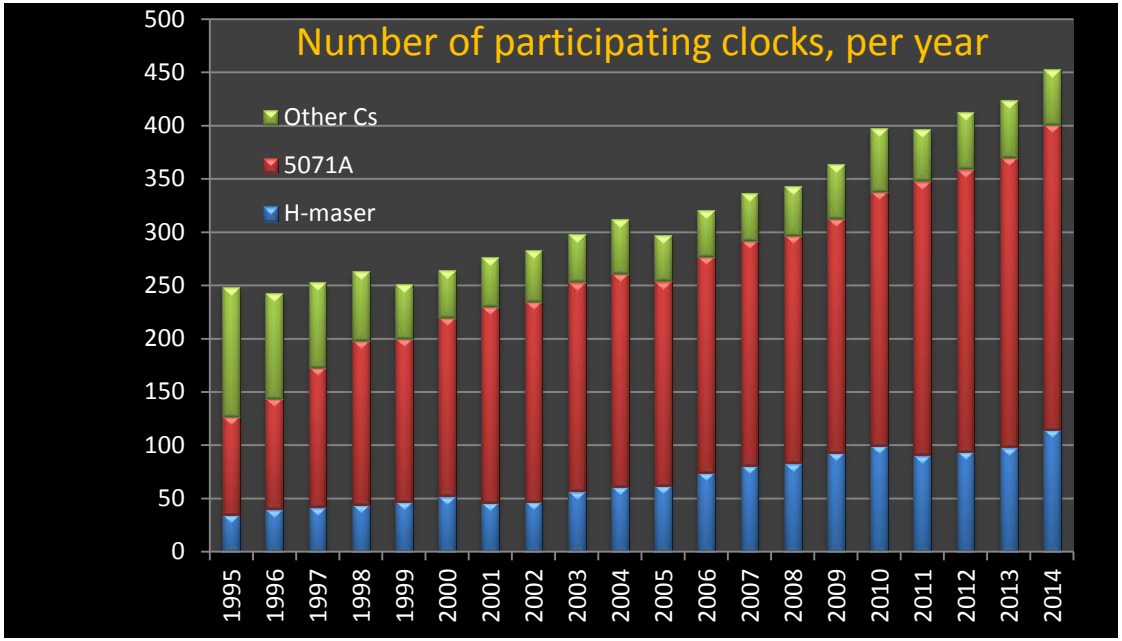


0 (until 2001)

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

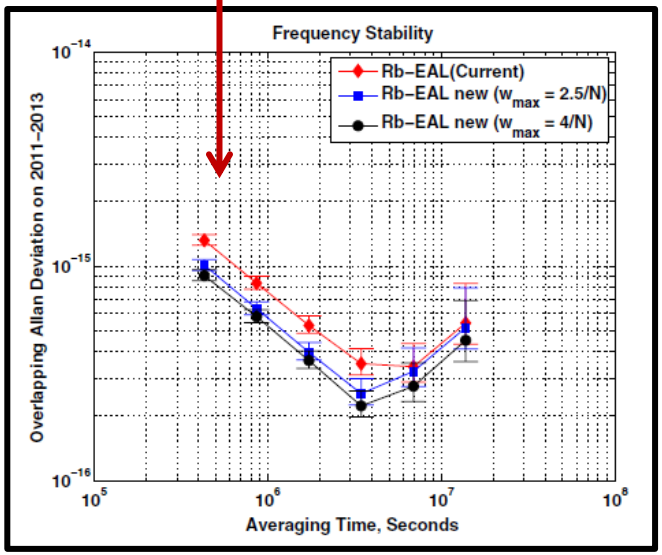
1

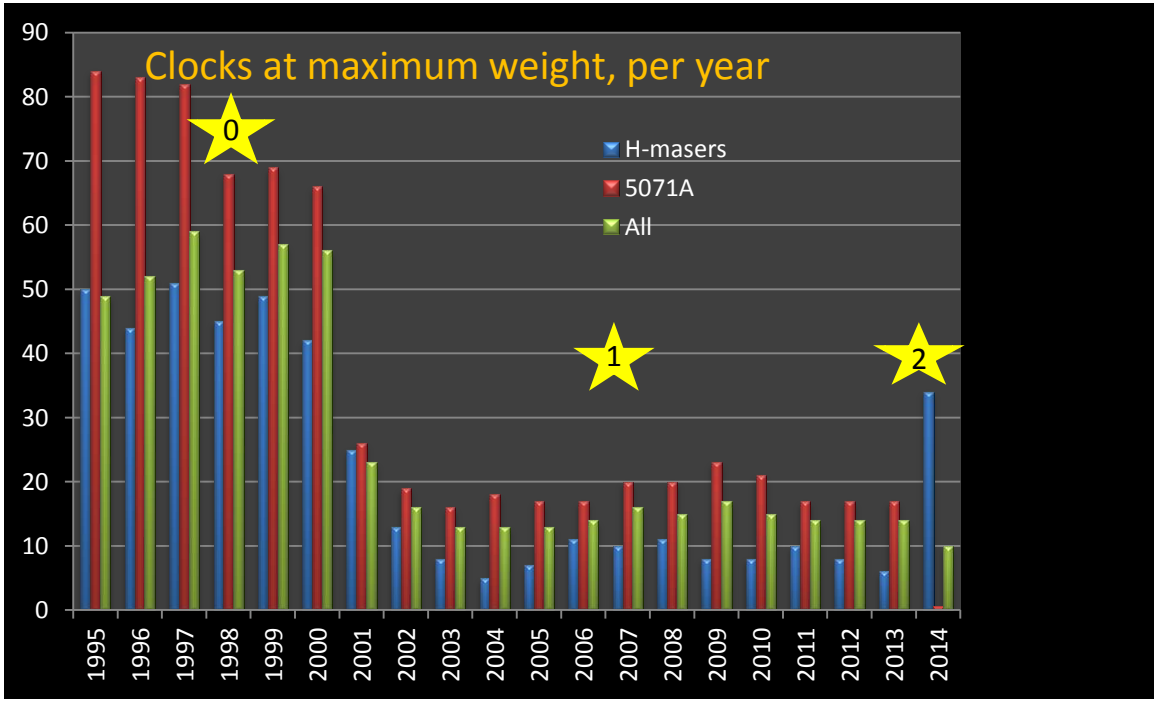
- ✓ Weight reflects the clock stability
- ✓ ω_{max} = 2.5/N

2 (2014 >>)

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

Short- and long-term stability improvement





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RAPID UTC
(UTCr)

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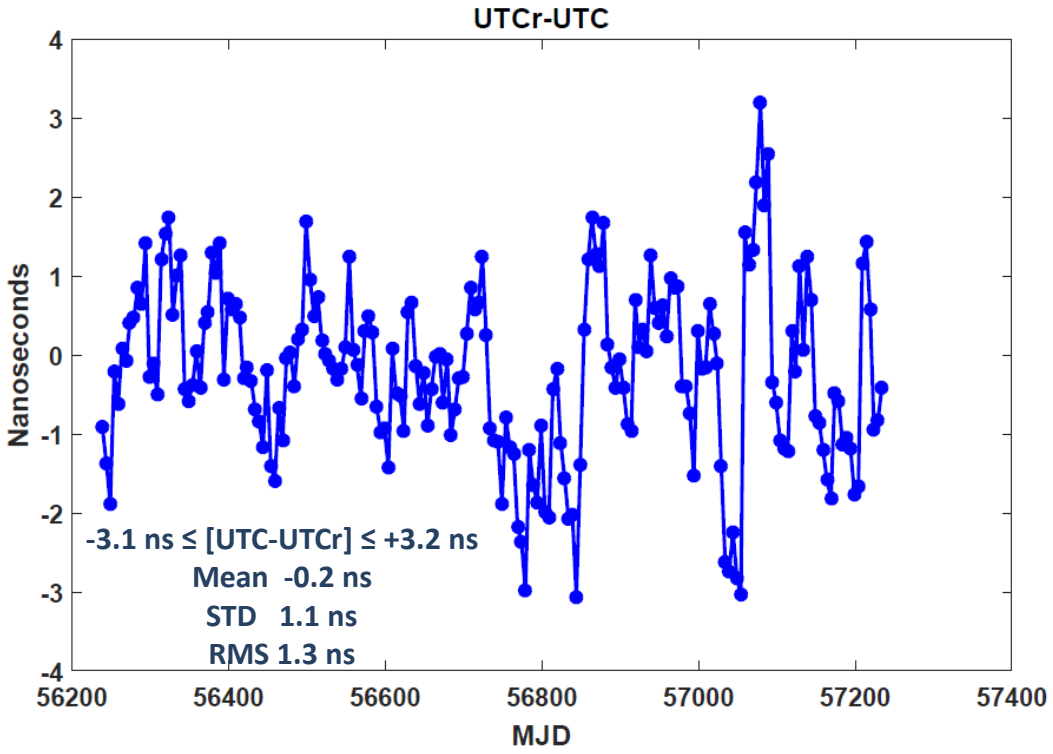
Rapid UTC (UTCr)

- 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
AND
CHARACTERIZATION OF DELAYS IN TIME TRANSFER EQUIPMENT/LINKS

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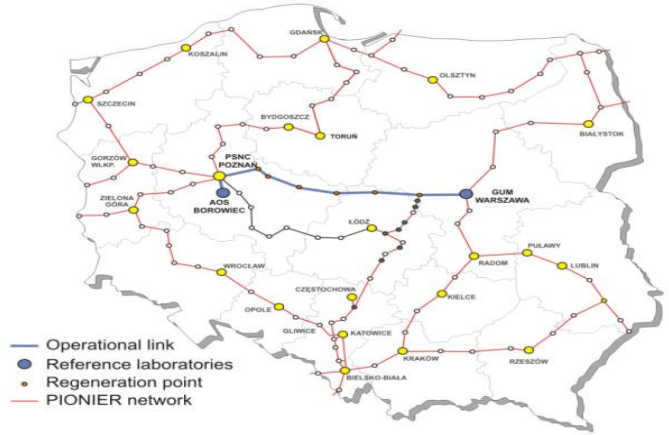
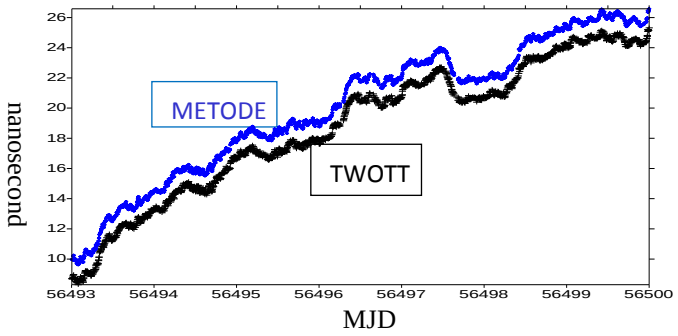
Time transfer

Use of fibre links for link comparison and validation



BIPM calibrator



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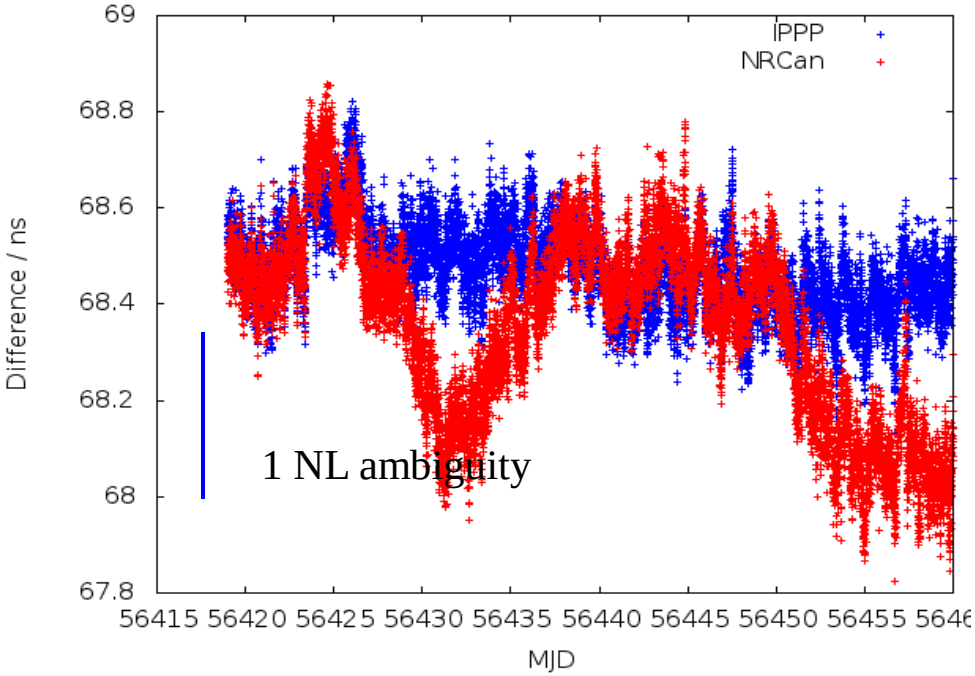
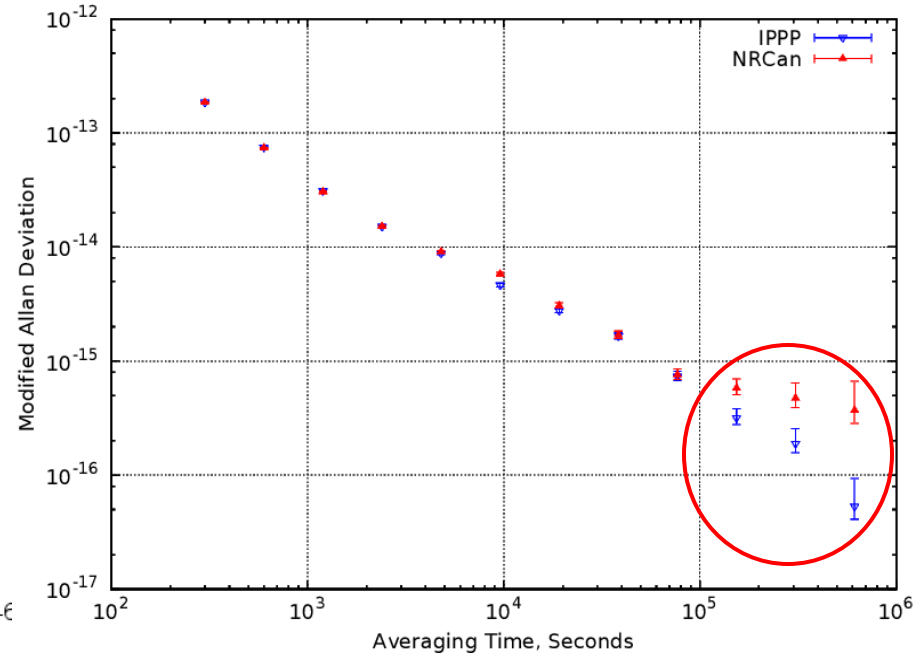
uB≤ 2 ns realistic

IPPP and PPP vs. 420-km fiber 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 – Fiber link
Red = NRCan – Fiber link





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Calibrations for UTC time transfer

GNSS calibrations

- BIPM has been fully responsible until end 2014.
- Cooperation with RMOs has been established during 2014.
- BIPM Guidelines fix the procedures for the calibrations.
- Two approaches are possible, equipment and link calibration.
- BIPM is responsible for maintaining the systems in laboratories G1 calibrated.
- RMOs are responsible for calibrations of laboratories G2 in the regions, and for submitting reports to the BIPM.

TWSTFT calibrations

- Calibrations for UTC are within the activities of the CCTF WG TW.
- The BIPM does not participate to the calibrations, but one responsibility is the validation of a report to be used for UTC.
- The CCTF WG TW and the BIPM worked on the elaboration of guidelines on the procedures for organizing TW calibration campaigns.
- The final text of the guidelines has been agreed at the IFCS-EFTF in April 2015, and approved by the WG TW in September 2015.

Guidelines for GNSS equipment calibration

Coordination of the BIPM with RMOs

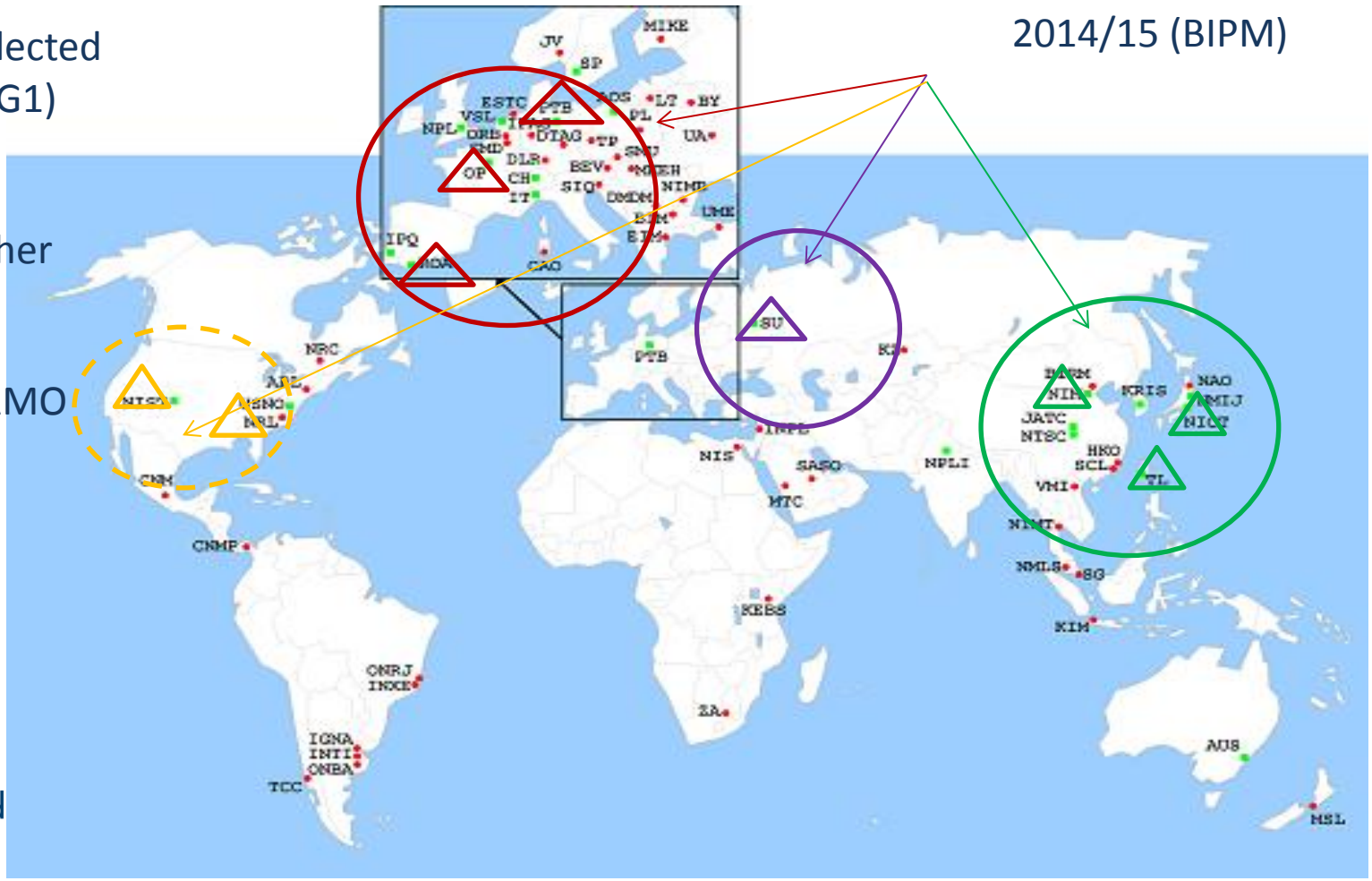
Objective: improving the accuracy of UTC-UTC(k) by implementing continuous calibration campaigns for reducing time link uB from 5 ns to < 2.5 ns

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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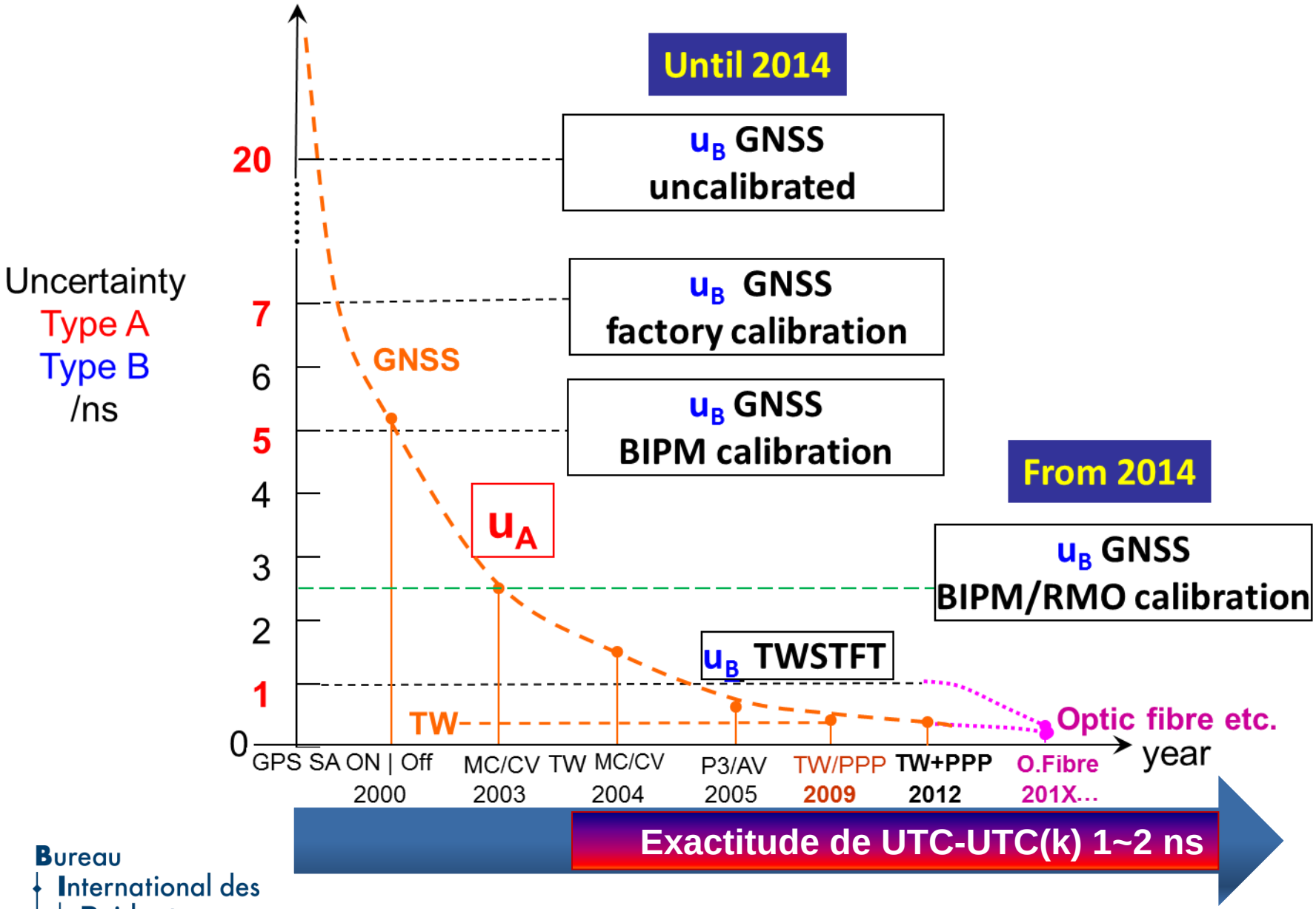

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REDEFINITION OF UTC

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Redefinition of UTC
Contribution to the discussion

- ITU-R/ SG7/WP7A: Regular WP/SG meetings, Regional ITU-R Seminars, Conference Preparatory Meetings (CPM)
- ITU/BIPM Workshop on the future of the international time scale (Geneva, 19-20 September 2013)
  - 16 invited speakers (GPS, Galileo, Glonass, BeiDou, NIST, NPL, ITU-R, ITU-T, BIPM, IERS, IUGG, ISO, TBF)
  - 63 attendees

- Output: Text for WRC-15 Agenda item 1.14 [*to consider the feasibility of achieving a continuous reference time-scale, whether by the modification of coordinated universal time (UTC) or some other method, and take appropriate action, in accordance with Resolution 653 (WRC-12)]*, including
  - a summary of studies undertaken by the ITU to show the motivations and impact of a change in the UTC definition,
  - opinions of different administrations and organizations submitted to the ITU,
  - methods proposed
- Interaction with IAU, URSI

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KEY COMPARISON

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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 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

Bureau International des Poids et Mesures

Publications

- BIPM Publications
  - *BIPM Annual Report on Time Activities* 2012, 2013, 2014
    - Electronic
      http://www.bipm.org/en/bipm/tai/annual-report.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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