

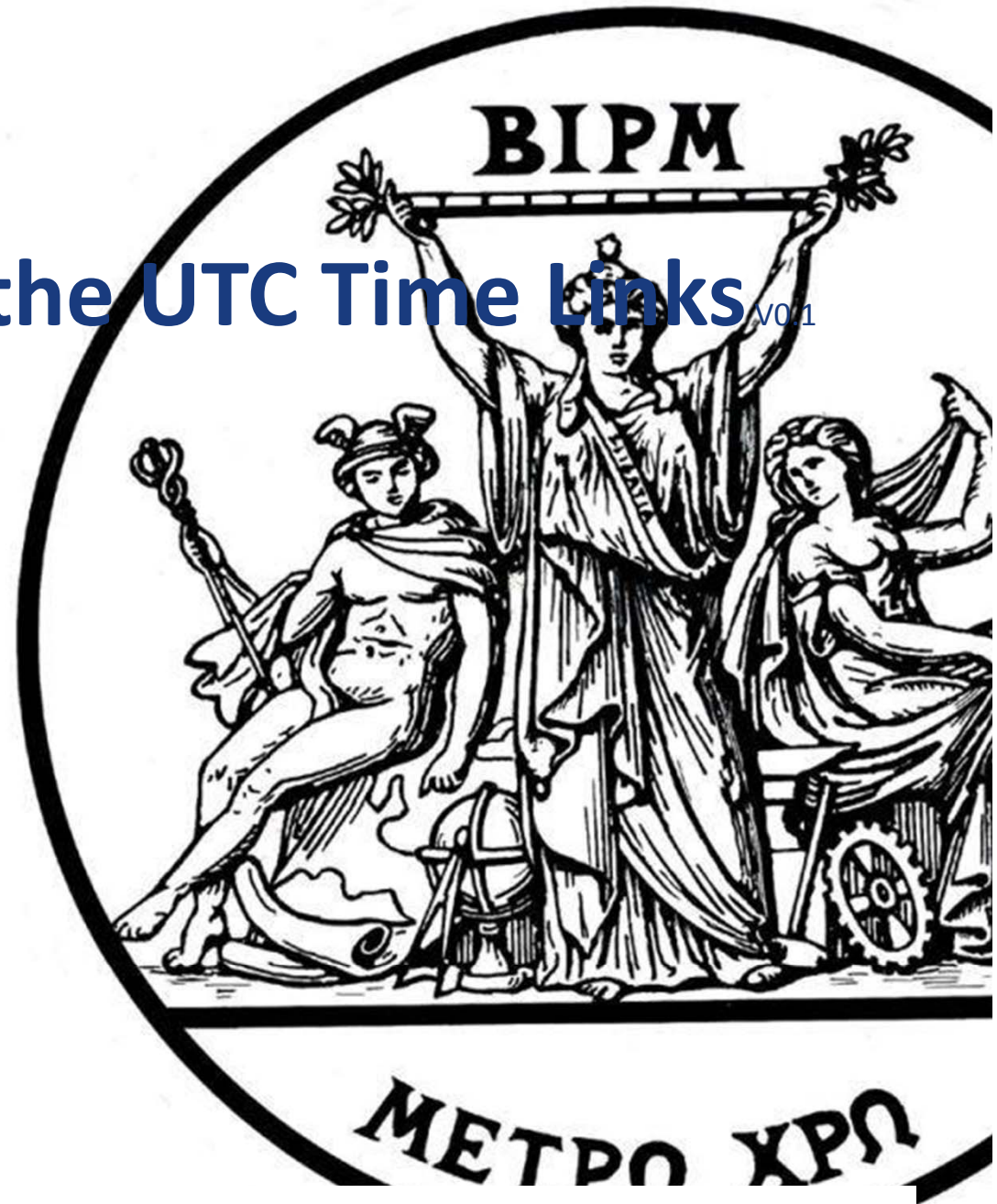
Performance of the UTC Time Links v0.1

Z Jiang, G Petit and F Arias

20th CCTF

16 September 2015

BIPM



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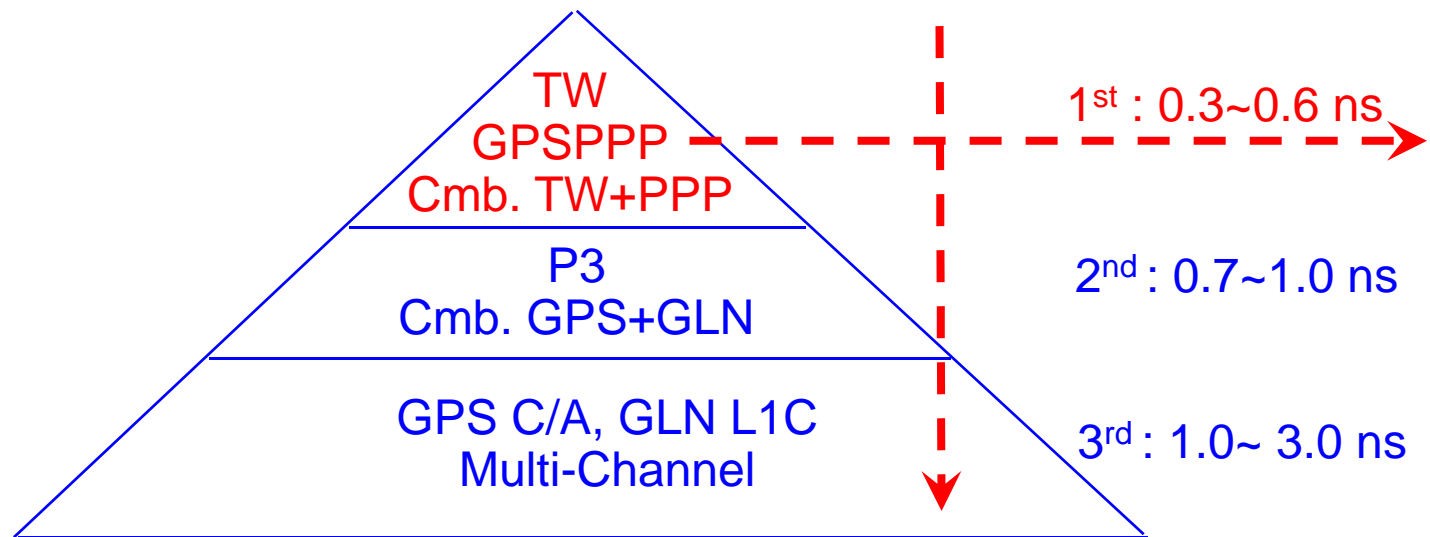
CCTF LAB contributing to TAI, 16 Sept. 2015, BIPM

Outline

- ◆ What has not changed since CCTF 2012
- ◆ What is new since CCTF 2012
- ◆ Calibrations and uncertainties ←

Type A uncertainty u_A , no change since 2011

Class	Type of link (72 in total)	u_A / ns
I	TW, GPSPPP, TW+PPP /50%	0.3 ~ 0.6
II	P3 /11%	0.7 ~ 1.0
III	GPS+GLN etc. /11%	1.0 ~ 1.5
IV	GPSMC /28%	≥ 1.5



Type B uncertainty u_B

Changed but only TW calibration has been implemented

- ◆ GPSPPP/P3: $u_B = 5$ ns
- ◆ GPS/GLONASS L1C: $u_B = 5\sim 7$ ns
- ◆ Europe-USA-Asia TW links: $u_B = 1\sim 1.5$ ns

→ according to the study Jiang et Lewandowski PTTI2014, the real u_B are 1~3 ns for the TW and GPS links maintained by the active UTC labs.

Multi-technique time links

One (primary) technique before 2009 (either TW or GNSS)

Multi-technique after 2009 (combination of different techniques):

- ◆ 13 links combining TW+GPSPPP
- ◆ 4 links combining GPS+Glonass

➔ 24% of the total UTC time links are combined today (vs. 29% in 2012)
because some of the GPS+GLN have been replaced by GPSPPP

Calibration Uncertainty u_B of the UTC time links

u_B /ns	Percentage N/72	Calibration method
<u>20</u>	<u>26%</u>	<u>Never calibrated</u>
10	3%	Very old calibration
7	16%	Timing-receiver manufacturers
<u>5</u>	<u>44%</u>	<u>BIPM or individual labs</u>
3	1%	GPS link by TW mobile station
<u>1~1.2</u>	<u>7%</u>	<u>TW links by TW mobile station</u>
1.0	1%	Internal cable

→ We expect u_B values significantly reduced in the coming two years !

News on UTC time links since CCTF2012 ^{1/3}

- ◆ Experiments on the TWOTFT (Two-Way Optical-fibre Time and Frequency Transfer) with < 200 ps accuracy
 - AOS-PL 420 km data submit to BIPM since 2013
 - BEV-TP 550 km data submit to BIPM since 2015
 - Study on its application in UTC time transfer
 - Validation of new calibration method and of and T/F transfer techniques:
 - * GPS link comparison/calibration, *Metrologia* 52 2015 (Jiang et al.)
 - * IPPP, *Metrologia* 52 2015 (Petit et al.)
 - * Revised Rinex-Shift technique, *Metrologia* 52 2015 (Yao et al.)
 - Future application → UTC generation

News on UTC time links since CCTF2012 ^{2/3}

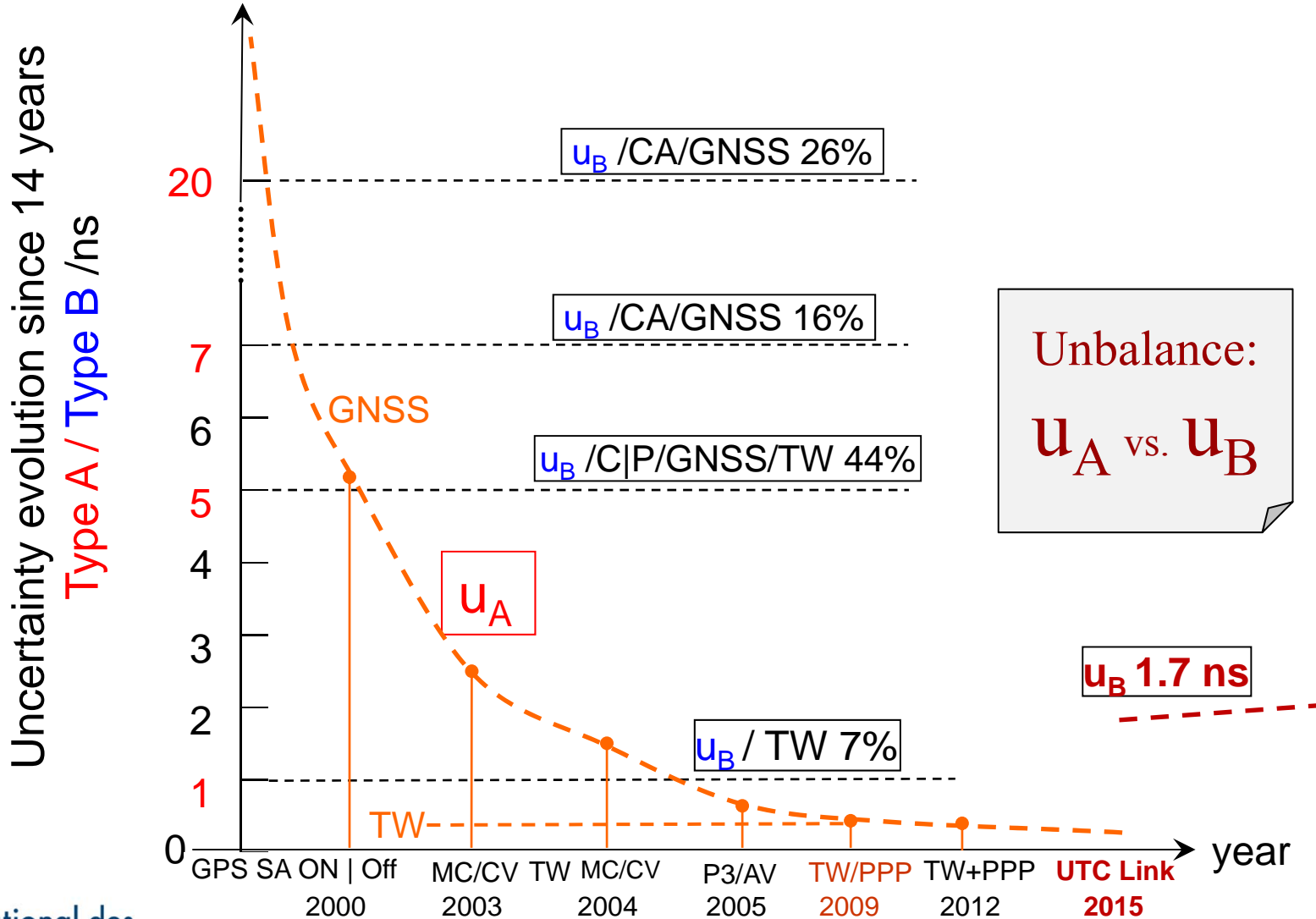
◆ Calibrations

- Several TWSTFT Europe-America-Asia campaigns
- BIPM-RMO coordination
- BIPM Pilot Project on TW-GNSS link calibrations
- BIPM GNSS equipment calibration
- Calibration guidelines for TW and GNSS
- Calibrations performed at 16 labs/links: OP, PTB, AOS, PL, TL, NIM, NICT, NMIJ, ROA, NIST, USNO, IT, CH, SP, VSL

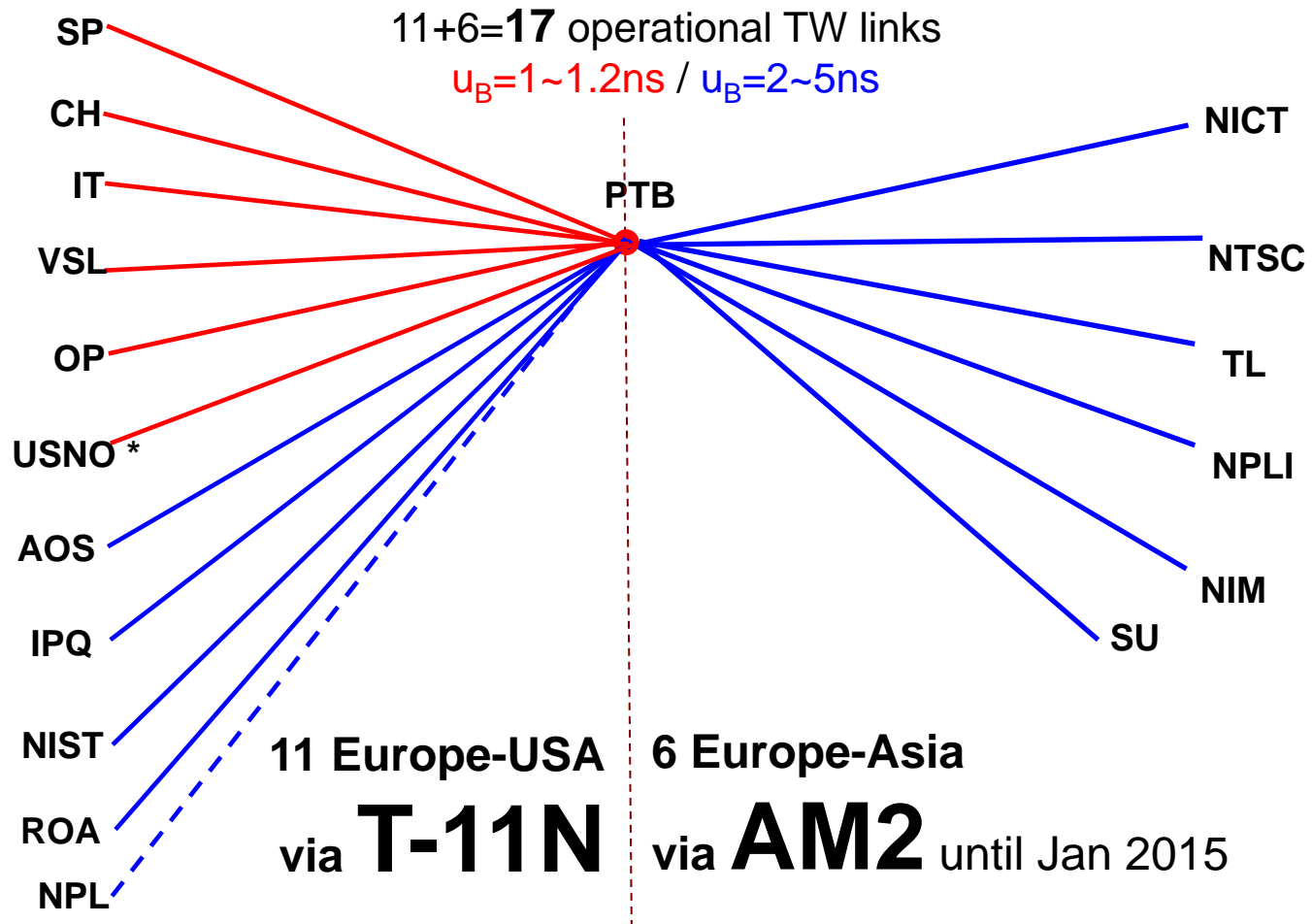
News on UTC time links since CCTF2012 ^{3/3}

- ◆ Calibration uncertainties:
 - TW: $u_B \sim 0.6-0.8$ ns, conventional value is 1 ns
 - Inter-continental TWSTFT: 5 ns \searrow 1.5 ns
 - GNSS : u_B 5 ns \searrow 2 ns
- ◆ Implementation:
 - TW: done
 - GNSS: since the next Circular T 333, Sept. 2015
- ◆ 98% of uncertainty in $[UTC-UTC(k)]$ comes from the time link $[\text{Lab}(k)-\text{PTB}] \rightarrow$ Direct gains in $[UTC-UTC(k)]$

Evolution u_A/u_B since 2000

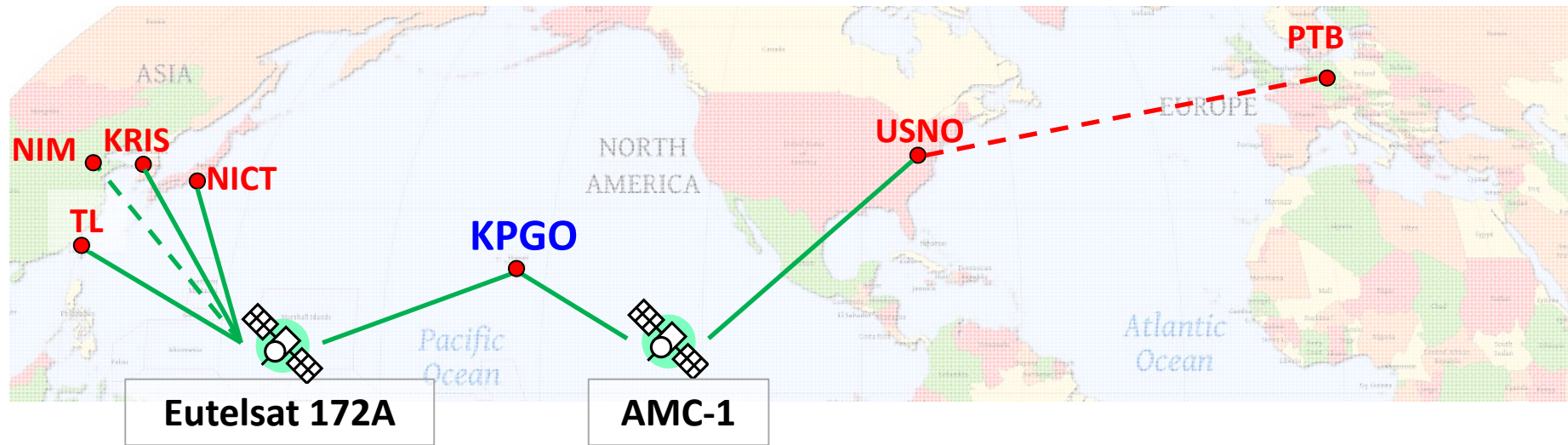


Operational Europe-US-Asia TW links until Jan 2015



(*) calibrated using X-band

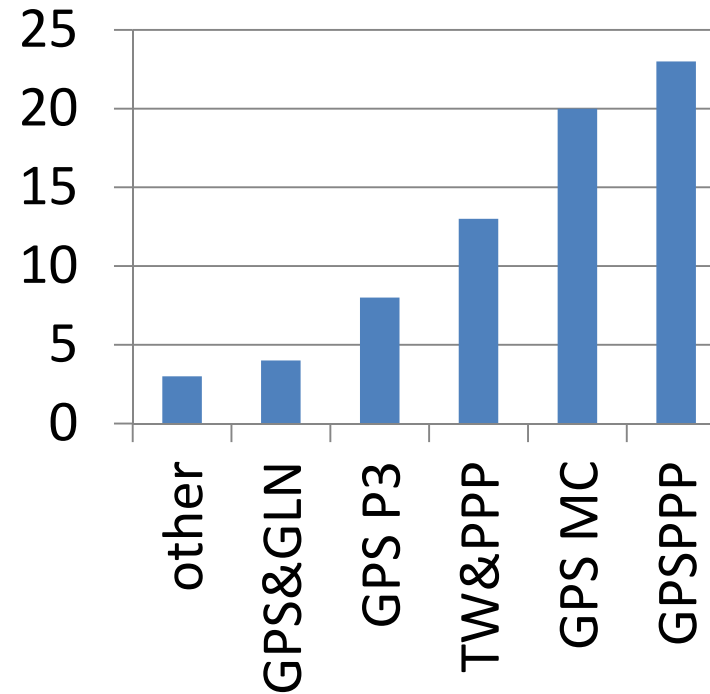
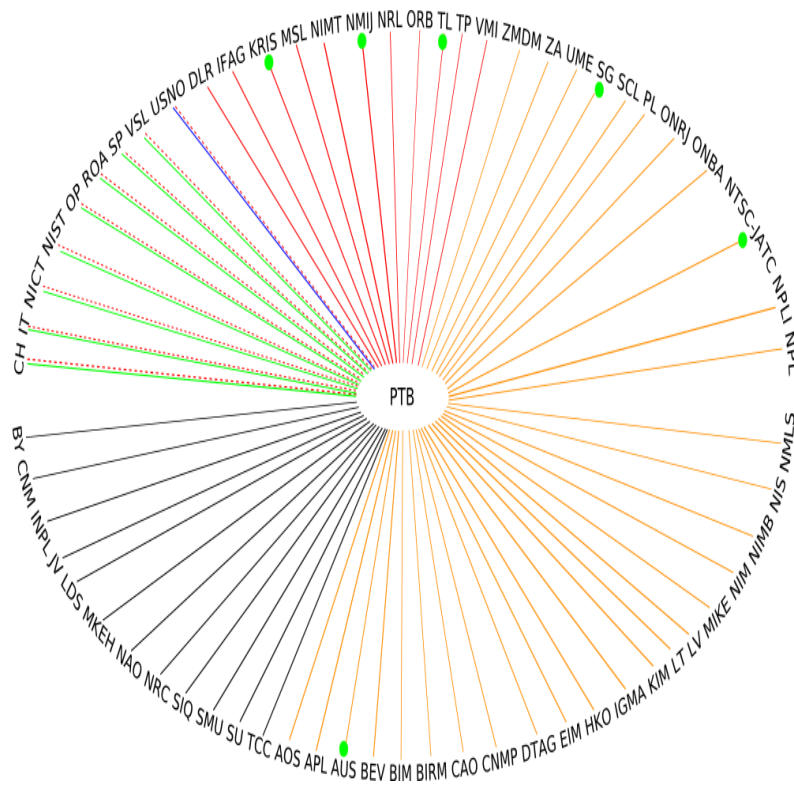
Re-establishment of Asia-Europe TW link



- (1) Replace AM2 by AM22
- (2) Asia ↔ KPGO ↔ USNO ↔ PTB

The UTC network: 72 Links

Time Transfer Techniques used in UTC (2014)



- GNSS code links (48%)
- 17 Combined links of TW+PPP and GPS+GLN (24%)

Analysis of UTC time links

Monthly and long-term products on BIPM ftp server

The screenshot shows the BIPM website interface. At the top left is the BIPM logo and the text 'Bureau International des Poids et Mesures'. A search bar is present with the text 'New search facility: BIPM metrology portal'. A navigation menu includes links for 'METRE CONVENTION', 'CIPM MRA', 'COMMITTEES', 'BIPM', 'SCIENTIFIC WORK', 'SI', 'PUBLICATIONS', and 'DATABASES'. Below the menu, a breadcrumb trail reads '> You are here: scientific work > time, frequency and gravimetry > FTP server'. The main content area is titled 'Time Department' and features a sidebar with a 'Summary' section containing various links. The main content area has a tabbed interface with tabs for 'Introduction', 'Data', 'Publications', 'Scales', and 'Links'. The 'Links' tab is highlighted with a red circle. The text under the 'Links' tab states: 'The complete set of publications and time-data files can be accessed via anonymous ftp (ftp:82.161.69.5 or ftp2.bipm.org). The files are organized in the following four subdirectories: data, publication, scale, and links. At the bottom of the page, there is a 'Related articles' section with a yellow arrow icon. The browser's address bar shows 'http://www.bipm.org/en/publications/'.

Summary ^{1/2}

- ◆ Major achievement since CCTF 2012: the calibration
 - BIPM-RMO coordination
 - TWSTFT and GNSS calibration guidelines
 - Performance of about 17 UTC links
 - Attainable uncertainty 1.0~ 2.0 ns
- ◆ Repeated calibration every 2 years for the G1 labs by BIPM
- ◆ Performance of the G2 labs' calibrations by RMOs
- ◆ Considerable improvement in UTC-UTC(k) is expected

Summary 2/2

- ◆ Application of Optical fibre technic in UTC T/F transfer
 - theoretical study
 - validations of new high accurate technics
 - Maintain the two links: AOS-PL and BEV-TP
 - Study group un CCTF WG ATFT has been created

Thank for your attention