

# GPS calibrations for UTC

BIPM Time Department

CCTF WG on TAI

7 June 2017

21st CCTF Meeting

8-9 June 2017



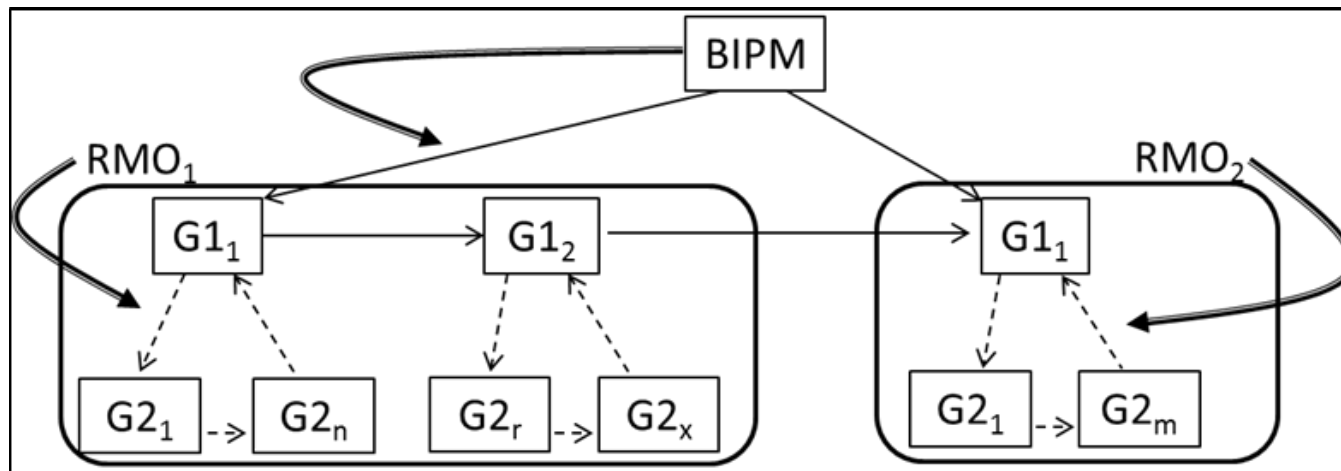
# Outline

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- ◆ The BIPM scheme for GNSS calibrations
- ◆ Status of GPS G1 and G2 calibrations
- ◆ Improving the dissemination of results:
  - Changes in the BIPM Circular T
  - Calibrations web page
  - Time department database
- ◆ Recent and future actions

# The GNSS calibration scheme of the BIPM

- ◆ Cooperation with RMOs has been established, and Calibration guidelines written during 2014.
- ◆ New scheme in place in 2015 for GPS P1/P2 (P3)
  - BIPM calibrates the systems in laboratories G1
  - RMOs are responsible for calibrations of laboratories G2 in the regions, and for submitting reports to the BIPM.



# Status of G1 and G2 calibrations


- ◆ Group 1 (2016) under way (9 visits total, 8 completed)
  - APMP-EURAMET results published 01/2017; SIM results soon
- ◆ Group 2: 21 Cal\_Id (trips) attributed.
  - 11 Cal\_Id (trips), with 20 G2 labs, completed.

The third table is a reminder of past completed calibrations

Cal_Id	Umbrella	Responsible	Planned period	Involved labs/visits	Type	Links to documents	Comments	Note
<b>BIPM</b>								
1102-2016	BIPM	BIPM/ G. Petit	08/2016	NMISA (at BIPM)	GPS P1/P2	<a href="#">Completed</a>	Golden (no closure)	
<b>APMP</b>								
1015-2016	NIM	NIM/ K. Liang	06/2016	NIM(G1), BIRM	GPS C1/P3	<a href="#">Completed</a>		
<b>COOMET</b>								
<b>EURAMET</b>								
1011-2016	Euramet	ROA/ H. Esteban	02-08/2016	ROA(G1), BIM, UME, BoM (FYROM), DMDM, IMBII, INRIM	GPS P1/P2	<a href="#">Completed</a>		
1012-2016	Euramet	PTB/ A. Bauch	04-07/2016	PTB(G1), DLR, BEV, METAS, VSL	GPS P1/P2	<a href="#">Completed</a>		
1013-2016	OP	OP	2016	OP(G1), PTB(G1), INRIM, SP	GPS P1/P2	<a href="#">Completed</a>	Under Galileo TVF	
1019-2016	PTB	PTB/ A. Bauch	11/2016	PTB (G1), ESTEC	GPS P1/P2	<a href="#">Completed</a>		
1101-2015	PTB	PTB/ A. Bauch		ESOC (at PTB)	GPS P1/P2	<a href="#">Completed</a>	Golden (no closure)	
1102-2015	PTB	PTB/ A. Bauch		MIKES (at PTB)	GPS P1/P2	<a href="#">Completed</a>	Golden (no closure)	
1101-2016	OP	OP		CNES (at OP)	GPS P1/P2	<a href="#">Completed</a>	Golden (no closure)	
<b>SIM</b>								
1017-2016	SIM	NIST/ S. Römisch	06-08/2016	NIST(G1), NRC	GPS P1/P2	<a href="#">Completed</a>		

# Implementation for Circular T

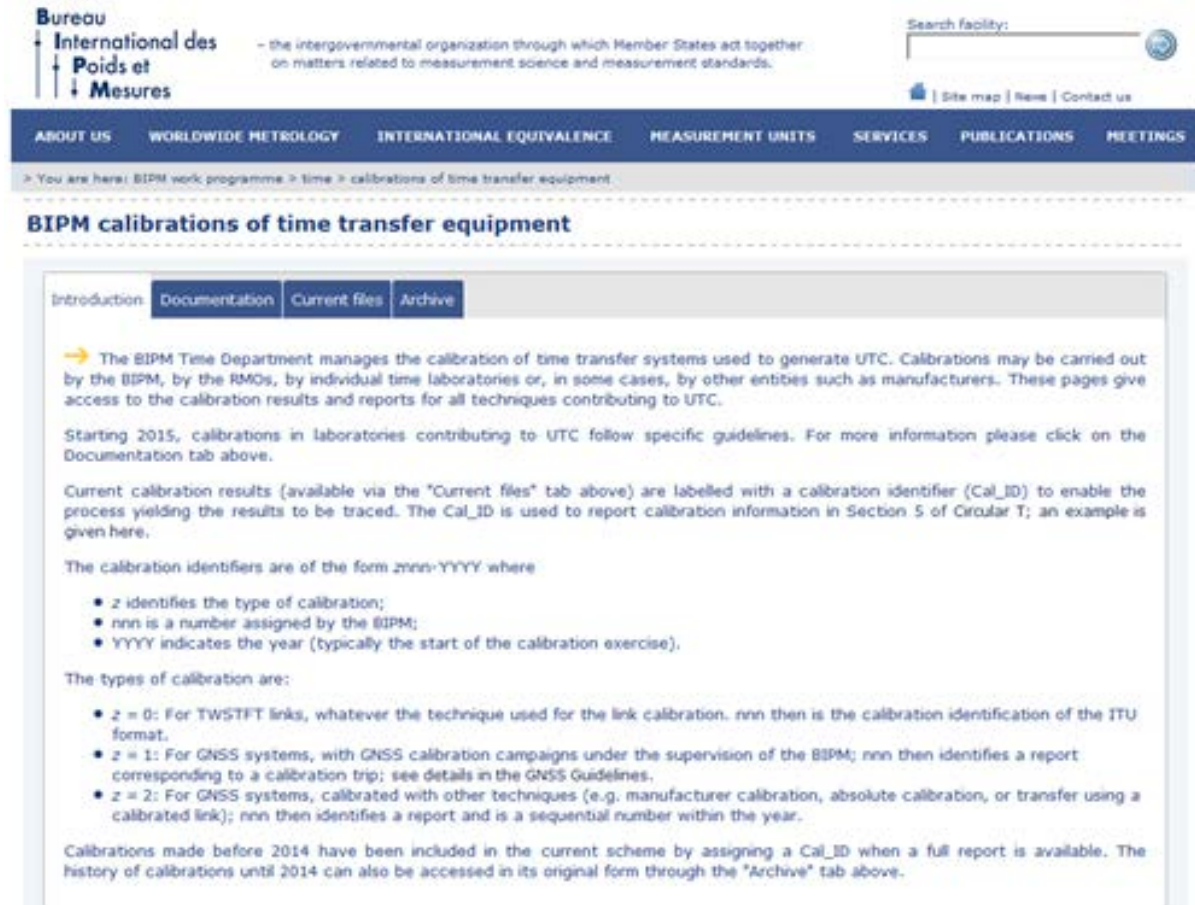
- ◆ January 2016: New form of Circular T with additional information
- ◆  $u_{\text{CAL}}(t) = (u_{\text{CALO}}^2 + u_{\text{AG}}^2 [+ u_{\text{AL}}^2])^{1/2}$ 
  - Typically  $u_{\text{CALO}}$  is 1.5 ns for G1, 2.5 ns (default) for G2 trips (closure), 4 ns (default) for “golden system” (no closure).

 5 - Time links used for the computation of TAI, calibrations information and corresponding uncertainties.

Link	Type	Equipment	Cal_ID1 / Cal_ID2	$u_{\text{Stb}}/\text{ns}$	$u_{\text{Cal}}/\text{ns}$	$u_{\text{Ag}}/\text{ns}$	Al/ns	YYMM
AOS /PTB	GPSPPP	AO_4 /PT02	1101-2013 / 1001-2016	0.3	3.2	2		
APL /PTB	GPSPPP	AP__ /PT02	NA_AI / 1001-2016	0.3	11.2	10	24.3	1511
AUS /PTB	GPSPPP	AU01 /PT02	1002-2010 / 1001-2016	0.3	5.8	3		
BEV /PTB	GPSPPP	BE1_ /PT02	1012-2016 / 1001-2016	0.3	2.5	0		
BIM /PTB	GPS P3	BM37 /PT10	1011-2016 / 1001-2016	0.7	2.5	0		
BIRM/PTB	GPSPPP	BIRM /PT02	NC / 1001-2016	0.4	20.0			
BOM /PTB	GPSPPP	MABM /PT10	1011-2016 / 1001-2016	0.3	2.5	0		
BY /PTB	GPS MC	BY46 /PT10	NA / 1001-2016	1.5	9.2	6		
CAO /PTB	GPS MC	CA__ /PT10	NC / 1001-2016	8.0	20.0			
CNES/PTB	GPSPPP	CS22 /PT02	1101-2016 / 1001-2016	0.3	4.0	0		
CNM /PTB	GPS MC	CN00 /PT10	NA_AI / 1001-2016	2.5	11.2	10	-27.3	0804
CNMP/PTB	GPSPPP	MP1_ /PT02	NA_AI / 1001-2016	0.5	7.1	1	41.7	1607
DFNT/PTB	GPS P3	DN__ /PT02	NC_AI / 1001-2016	0.7	20.0		10.3	1507
DLR /PTB	GPS P3	DL05 /PT02	1012-2016 / 1001-2016	0.7	2.5	0		

# Calibrations web page

<http://www.bipm.org/jsp/en/TimeCalibrations.jsp>



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> You are here: BIPM work programme > time > calibrations of time transfer equipment

## BIPM calibrations of time transfer equipment

Introduction Documentation Current files Archive

→ The BIPM Time Department manages the calibration of time transfer systems used to generate UTC. Calibrations may be carried out by the BIPM, by the RMOs, by individual time laboratories or, in some cases, by other entities such as manufacturers. These pages give access to the calibration results and reports for all techniques contributing to UTC.

Starting 2015, calibrations in laboratories contributing to UTC follow specific guidelines. For more information please click on the Documentation tab above.

Current calibration results (available via the "Current files" tab above) are labelled with a calibration identifier (Cal\_ID) to enable the process yielding the results to be traced. The Cal\_ID is used to report calibration information in Section 5 of Circular T; an example is given here.

The calibration identifiers are of the form znn-YYYY where

- z identifies the type of calibration;
- nnn is a number assigned by the BIPM;
- YYYY indicates the year (typically the start of the calibration exercise).

The types of calibration are:

- z = 0: For TWSTFT links, whatever the technique used for the link calibration. nnn then is the calibration identification of the ITU format.
- z = 1: For GNSS systems, with GNSS calibration campaigns under the supervision of the BIPM; nnn then identifies a report corresponding to a calibration trip; see details in the GNSS Guidelines.
- z = 2: For GNSS systems, calibrated with other techniques (e.g. manufacturer calibration, absolute calibration, or transfer using a calibrated link); nnn then identifies a report and is a sequential number within the year.

Calibrations made before 2014 have been included in the current scheme by assigning a Cal\_ID when a full report is available. The history of calibrations until 2014 can also be accessed in its original form through the "Archive" tab above.

On line 09/04/2015

Intended to host all reports of UTC calibrations

**WARNING: ftp contents have been moved from <ftp://tai.bipm.org/TFG/> to <ftp://ftp2.bipm.org/pub/tai/> on 24/03/2016.**



## BIPM calibrations of time transfer equipment

Introduction Documentation **Current files** Archive

Show 30 entries

Year	Cal_ID	Type of Calibration	Other info.	Last updated
2014	1001-2014	GPSP3	Initial-Group1-trip	February 17, 2016
2014	0374-2014	TW	Europe-IT	June 2, 2015
2014	0377-2014	TW	Europe-OP	June 2, 2015
2014	0380-2014	TW	Europe-ROA	June 2, 2015
2014	0381-2014	TW	Europe-SP	June 2, 2015
2014	0391-2014	TW	USNO	April 8, 2015
2014	2001-2014	CA	AOS	April 8, 2015
2014	2002-2014	CAP3	SIQ	April 8, 2015
2014	2003-2014	CA	IMBH	April 7, 2015

2014 Cal\_ID Type of Calibration Other info. Last updated

Showing 9 entries (filtered from 64 total entries) [First](#) [Previous](#)

Year

- 1993
- 2003
- 2004
- 2005
- 2006
- 2007
- 2008
- 2009
- 2010
- 2011
- 2012
- 2013
- 2014
- 2015

EM L M PR QM III T TF U

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- Contents can also be accessed through the Time Dpt database.

## BIPM calibrations of time transfer equipment

Introduction Documentation **Current files** Archive

Show 30 entries

Year	Cal_ID	Type of Calibration	Other info.	Last updated
2013	1101-2013	GPSP3	AOS-GUM	March 10, 2016
2015	1101-2015	GPSP3	ESOC	February 23, 2016
2015	1102-2015	GPSP3	MKES	February 23, 2016
2014	1001-2014	GPSP3	Initial-Group1-trip	February 17, 2016
2015	2001-2015	CA	NMB	January 26, 2016
2011	0214-2011	TW	NEST	January 8, 2016
2015	0295-2015	TW	VSL	January 7, 2016
2015	0392-2015	TW	USNO	January 7, 2016
2012	0284-2012	TW	CH	January 7, 2016
2008	2003-2008	CATW	BEV	January 7, 2016
2014	0374-2014	TW	Europe-IT	June 2, 2015
2014	0377-2014	TW	Europe-OP	June 2, 2015
2014	0380-2014	TW	Europe-ROA	June 2, 2015
2014	0381-2014	TW	Europe-SP	June 2, 2015
2014	0391-2014	TW	USNO	April 8, 2015
2014	2001-2014	CA	AOS	April 8, 2015
2014	2002-2014	CAP3	SIQ	April 8, 2015
2013	2001-2013	CA	MTC	April 8, 2015
2013	2002-2013	CA	SASO	April 8, 2015
2013	2003-2013	CA	UME	April 8, 2015
2012	0281-2012	TW	SU	April 8, 2015
2012	1001-2012	P3	ORB	April 8, 2015
2012	1011-2012	P3	ESTC	April 8, 2015
2012	1012-2012	P3	ESTC	April 8, 2015
2012	1013-2012	P3	NIM	April 8, 2015

Time Dpt database: <http://webtai.bipm.org/database/html/>

<http://webtai.bipm.org/database/index.html>

Example of the Calibrations tab

Bureau International des Poids et Mesures

### BIPM Time Department Data Base

General Participation guidelines **Interactive plots** GNSS equipment Calibration Clocks

**CALIBRATION REPORT information :**

CAL_ID	RECEIVER NAME	Station	DATE CALIB	AUTHOR	TYPE CALIB	UCAL0	DUCAL	USIG	CALIB REPORT
1001-1993	SCL_		1993-05	BIPM	CA GPS	10.0	0.0	0.0	<a href="#">1001-1993_CA_199305.pdf</a>
1001-2003	NR1C	nrc3	2003-11	BIPM	P3 GPS	5.0	0.0	0.0	<a href="#">1001-2003_P3_NRC.pdf</a>
1001-2004	TL1M		2004-10	BIPM	CA GPS	5.0	0.0	0.0	<a href="#">1001-2004_CA_200802.pdf</a>
1001-2004	NTS_		2004-08	BIPM	CA GPS	5.0	0.0	0.0	<a href="#">1001-2004_CA_200802.pdf</a>
1001-2004	HKO_		2004-09	BIPM	CA GPS	5.0	0.0	0.0	<a href="#">1001-2004_CA_200802.pdf</a>
1001-2004	AU02		2004-11	BIPM	CA GPS	5.0	0.0	0.0	<a href="#">1001-2004_CA_200802.pdf</a>
1001-2009	SP01	sp01	2009-02	BIPM	P3 GPS	5.0	0.0	0.0	<a href="#">1001-2009_P3_SP.pdf</a>
1001-2010	SGBK	sgbk	2010-03	BIPM	P3 GPS	5.0	0.0	0.0	<a href="#">1001-2010_P3_SG.pdf</a>
1001-2010	SG2P	sg2p	2010-03	BIPM	P3 GPS	5.0	0.0	0.0	<a href="#">1001-2010_P3_SG.pdf</a>
1001-2011	TC01	cont	2011-01	BIPM	P3 GPS	5.0	0.0	0.0	<a href="#">1001-2011_P3_TCC.pdf</a>
1001-2012	OR1Z	brux	2012-10	BIPM	P3 GPS	5.0	0.0	0.0	<a href="#">1001-2012_P3_ORB.pdf</a>
1001-2014	OPM7	opm7	2015-05	BIPM	P3 GPS	1.7	0.0	0.0	<a href="#">1001-2014_GPSP3_Initial-Group1-trip-Final-Draft.pdf</a>
1001-2014	TL1Z	twf	2013-11	BIPM	P3 GPS	1.7	0.4	0.0	<a href="#">1001-2014_GPSP3_Initial-Group1-trip-Final-Draft.pdf</a>
1001-2014	SU19		2015-12	BIPM	P3 GPS	1.7	0.0	0.0	<a href="#">1001-2014_GPSP3_Initial-Group1-trip-Final-Draft.pdf</a>
1001-2014	IM03	imeu	2014-06	BIPM	P3 GPS	1.7	0.0	0.0	<a href="#">1001-2014_GPSP3_Initial-Group1-trip-Final-Draft.pdf</a>
1001-2014	US06	usn6	2015-03	BIPM	P3 GPS	1.7	0.0	0.0	<a href="#">1001-2014_GPSP3_Initial-Group1-trip-Final-Draft.pdf</a>
1001-2014	OP02	opmt	2015-05	BIPM	P3 GPS	1.7	0.0	0.0	<a href="#">1001-2014_GPSP3_Initial-Group1-trip-Final-Draft.pdf</a>
1001-2014	US07	usn7	2015-03	BIPM	P3 GPS	1.7	0.0	0.0	<a href="#">1001-2014_GPSP3_Initial-Group1-trip-Final-Draft.pdf</a>
1001-2014	NI00	nist	2015-01	BIPM	P3 GPS	1.7	0.0	0.0	<a href="#">1001-2014_GPSP3_Initial-Group1-trip-Final-Draft.pdf</a>
1001-2014	IM05	bjnm	2014-06	BIPM	P3 GPS	1.7	0.0	0.0	<a href="#">1001-2014_GPSP3_Initial-Group1-trip-Final-Draft.pdf</a>
1001-2014	OPM2	opm2	2013-04	BIPM	P3 GPS	1.7	0.0	0.0	<a href="#">1001-2014_GPSP3_Initial-Group1-trip-Final-Draft.pdf</a>



# BIPM Guidelines: latest features

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- ◆ « BIPM Guidelines for GNSS calibrations » Update v3.2 in February 2016
- ◆ Covers evolution of a calibrated system between two calibration exercises
  - Change in set-up (affecting only REFDLY)
  - or change in some elements (antenna cable?)
  - or replacement of a full system
  - or ...
- ◆ What should be done?
  - If change affects only REFDLY AND if calibration results are expressed as INTDLY or SYSDLY, just measure and report the new REFDLY value. No change in Calibration Identifier (Cal\_Id) nor in  $u_{\text{CAL}}$ .
  - In all other cases, the laboratory should perform and report a “transfer of calibration”

# Transfer of calibration / Alignement

- ◆ Transfer of calibration (TC)
  - Typically done by simultaneous operation of two systems in common-clock;
    - ◆ Either the new receiver in parallel to the old one
    - ◆ Or using a backup receiver to bridge between the new system/set-up and the old one
  - Short report to be transmitted to the BIPM;
  - Cal\_Id (znnn-YYYY) will be expanded to reflect the TC
    - ◆ Same system as was initially calibrated: New Cal\_Id = znnn-YYYY-TC1
    - ◆ New system: New Cal\_Id = znnn-YYYY-SSSS-TC1 where SSSS is the originally calibrated system
    - ◆ TC counter can be incremented (TC2, TC3 ...), each time with a report
    - ◆ BIPM will slightly expand  $u_{\text{CAL}}$  (e.g. by 0.5 ns in quadrature).
- ◆ Alignment (AL)
  - Done by the BIPM when no other solution
    - ◆ BIPM will slightly expand  $u_{\text{CAL}}$  (e.g. by 0.5 / 1 ns in quadrature).
- ◆ We are trying to implement such report of info in Circular T ...

# Calex file

- ◆ One single file to gather all calibration history, similar to IGS Antex
- ◆ To be maintained by the BIPM
- ◆ Should be linked to the BIPM database, under development...

Sample Calex file: BIPM\_2016712.clx

```
2.0 CALEX VERSION
CGGTTS header CALEX TYPE
##### COMMENT
CGGTTS header = provides all information needed for the COMMENT
header of the CGGTTS format (INT DLY, CAB DLY, REF DLY) COMMENT
SYSDLY = INTDLY + CABDLY may be used in CGGTTS V2E COMMENT
TOTDLY = SYSDLY + REFDLY may be used in CGGTTS V2E COMMENT
TOTDLY can be directly removed from the PPP solutions COMMENT
Other CALEX TYPES to be defined COMMENT
##### COMMENT
END OF HEADER
START OF STATION CAL
LABO / RINEX / BIPM
REC # / TYPE
ANT # / TYPE
GNSS / CAL_ID
VALID FROM
LAB REFERENCE
# / DLY / TYPE=VAL
DLY / VAL / COMMENT
DLY / VAL / COMMENT
VALID FROM
DLY / VAL / COMMENT
END OF STATION CAL
START OF STATION CAL
LABO / RINEX / BIPM
REC # / TYPE
ANT # / TYPE
GNSS / CAL_ID
VALID FROM
LAB REFERENCE
# / DLY / TYPE=VAL
DLY / VAL / COMMENT

OP OPMT OP02
02942 ASHTECH Z-XII3T
00019 3S-02-TSADM NONE
GPS 1001-2014
2015 04 01
REF = UTC(OP)
2 INTDLY P1 = 310.2 P2 = 321.6
CABDLY 156.5
REFDLY 100.1
2015 08 27
REFDLY 155.9

PTB PTBB PT02
RT820013901 ASHTECH Z-XII3T
CR15930 ASH700936E SNOW
GPS 1001-2014
2015 04 01
REF = UTC(PTB)
2 INTDLY P1 = 303.9 P2 = 319.3
CABDLY 301.7
```

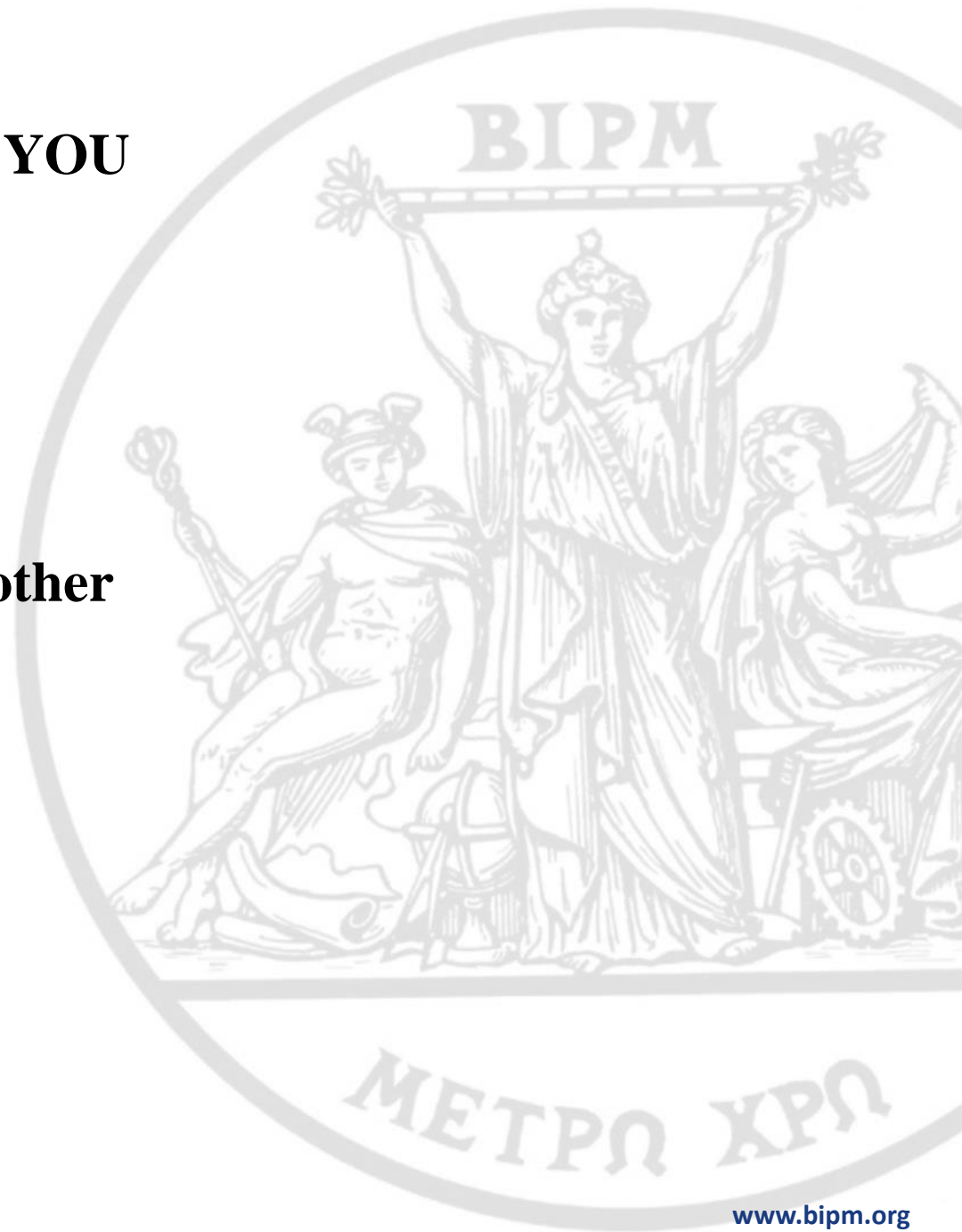
# Future actions

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- ◆ G1 2016 trip to be finished and findings to be published
- ◆ More G2 trips.
  - More/different G1 labs needed?
- ◆ GPS L1C and other codes
- ◆ Complete the information on calibrations in BIPM publications
  - Transfer of calibration / Alignments
- ◆ Link to the new method for computation of uncertainties in [UTC-UTC(k)]

**THANK YOU**

**Thanks to all Group 1 and other participating laboratories!**



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