GPS calibrations for UTC

BIPM Time Department

CCTF WG on TAI

7 June 2017

21st CCTF Meeting

8-9 June 2017

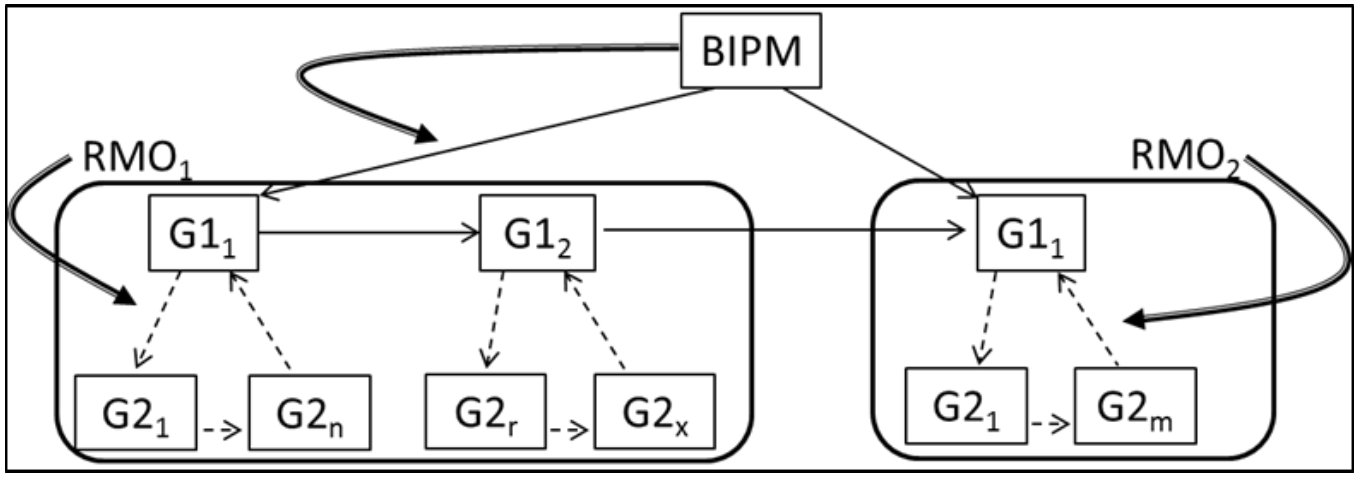
Bureau International des Poids et Mesures

Outline

- 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.



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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
BIPM								
1102-2016	BIPM	BIPM/ G. Petit	08/2016	NMISA (at BIPM)	GPS P1/P2	Completed	Golden (no closure)	
APMP								
1015-2016	NIM	NIM/ K. Liang	06/2016	NIM(G1), BIRM	GPS C1/P3	Completed		
COOMET								
EURAMET								
1011-2016	Euramet	ROA/ H. Esteban	02-08/2016	ROA(G1), BIM, UME, BoM (FYROM), DMDM, IMBiH, INRIM	GPS P1/P2	Completed		
1012-2016	Euramet	PTB/ A. Bauch	04-07/2016	PTB(G1), DLR, BEV, METAS, VSL	GPS P1/P2	Completed		
1013-2016	OP	OP	2016	OP(G1), PTB(G1), INRIM, SP	GPS P1/P2	Completed	Under Galileo TVF	
1019-2016	PTB	PTB/ A. Bauch	11/2016	PTB (G1), ESTEC	GPS P1/P2	Completed		
1101-2015	PTB	PTB/ A. Bauch		ESOC (at PTB)	GPS P1/P2	Completed	Golden (no closure)	
1102-2015	PTB	PTB/ A. Bauch		MIKES (at PTB)	GPS P1/P2	Completed	Golden (no closure)	
1101-2016	OP	OP		CNES (at OP)	GPS P1/P2	Completed	Golden (no closure)	
SIM								
1017-2016	SIM	NIST/ S. Römisch	06-08/2016	NIST(G1), NRC	GPS P1/P2	Completed		

Implementation for Circular T

- January 2016: New form of Circular T with additional information
- $u_{CAL}(t) = (u_{CAL0}^2 + u_{AG}^2 [+ u_{AL}^2])^{1/2}$
  - Typically u_{CAL0} 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.

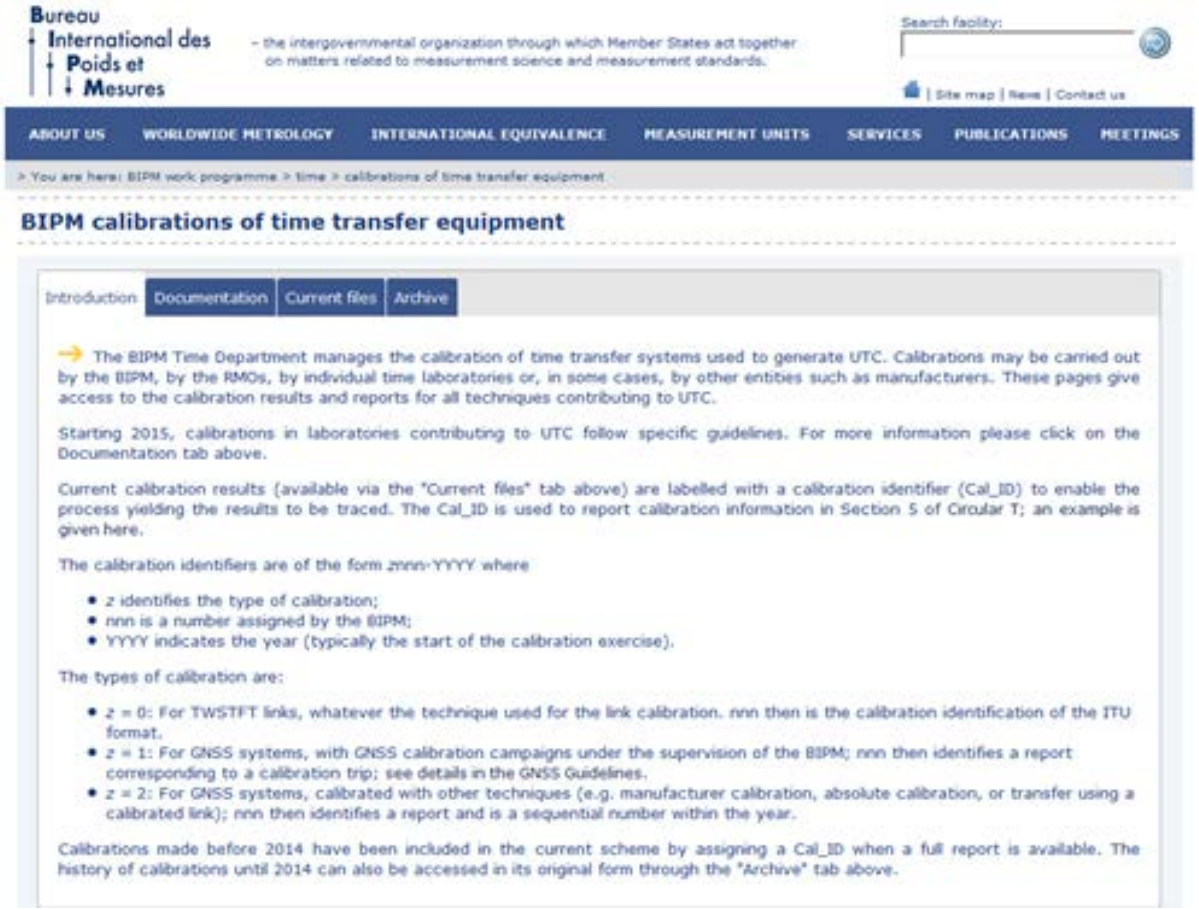
Link	Type	Equipment	Cal_ID1	/ Cal_ID2	u_{Stb}/ns	u_{Cal}/ns	u_{Ag}/ns	Al/ns	YYMM
AOS /PTB	GPSPPP	AO_4 /PT02	1101-2013	/ 1001-2016	0.3	3.2	2		
APL /PTB	GPSPPP	AP__ /PT02	NA_Al	/ 1001-2016	0.3	11.2	10	24.3	1511
AUS /PTB	GPSPPP	AU01 /PT02	1002-2010	/ 1001-2016	0.3	5.8	3		
BEV /PTB	GPSPPP	BE1_ /PT02	1012-2016	/ 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_Al	/ 1001-2016	2.5	11.2	10	-27.3	0804
CNMP/PTB	GPSPPP	MP1_ /PT02	NA_Al	/ 1001-2016	0.5	7.1	1	41.7	1607
DFNT/PTB	GPS P3	DN__ /PT02	NC_Al	/ 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

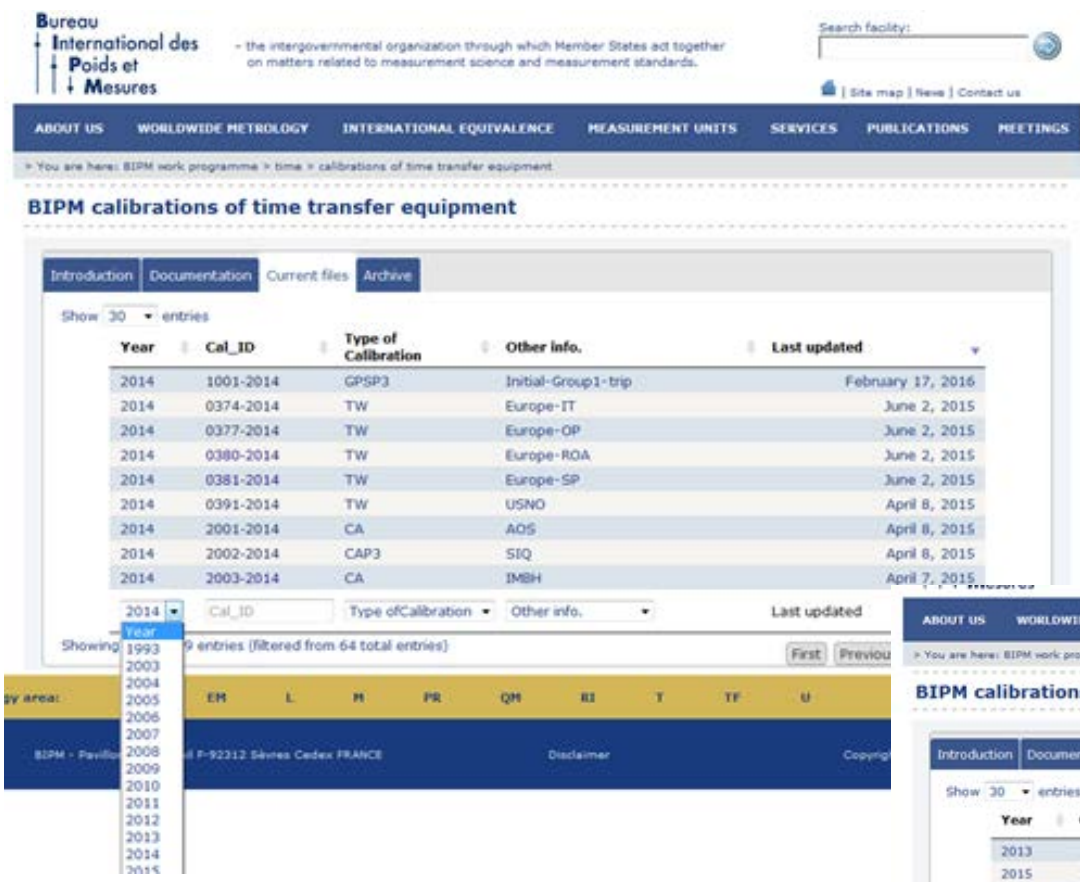
http://www.bipm.org/jsp/en/TimeCalibrations.jsp

On line 09/04/2015

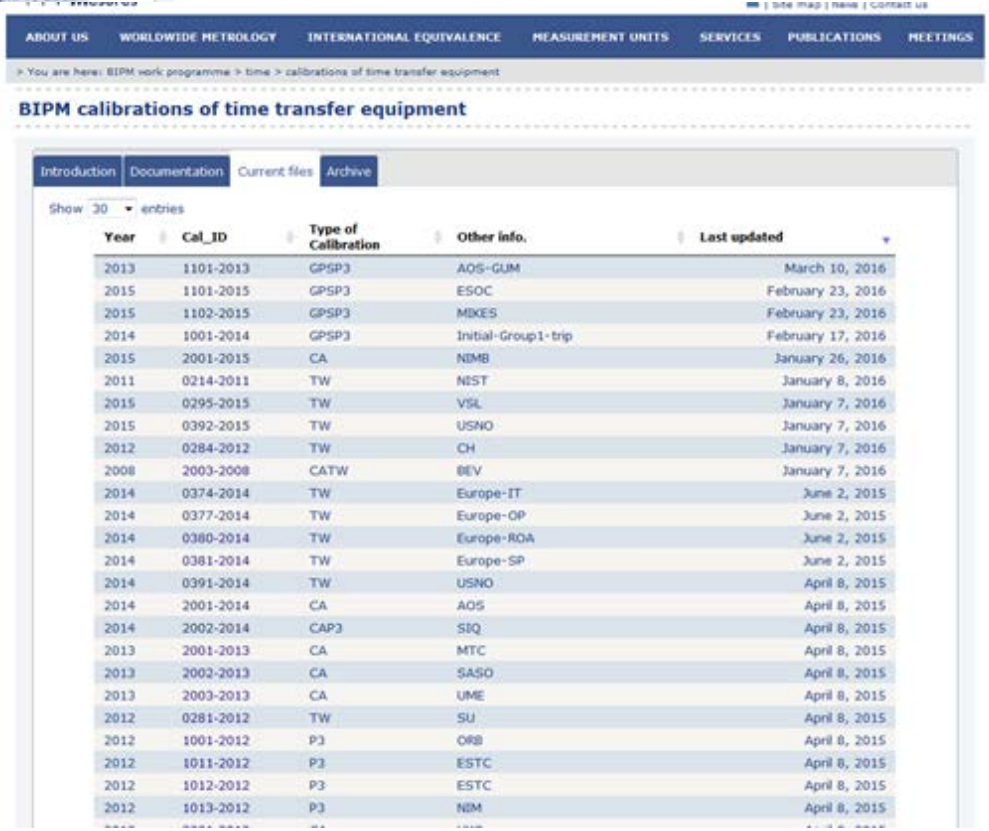
Intended to host all reports of UTC calibrations



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



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



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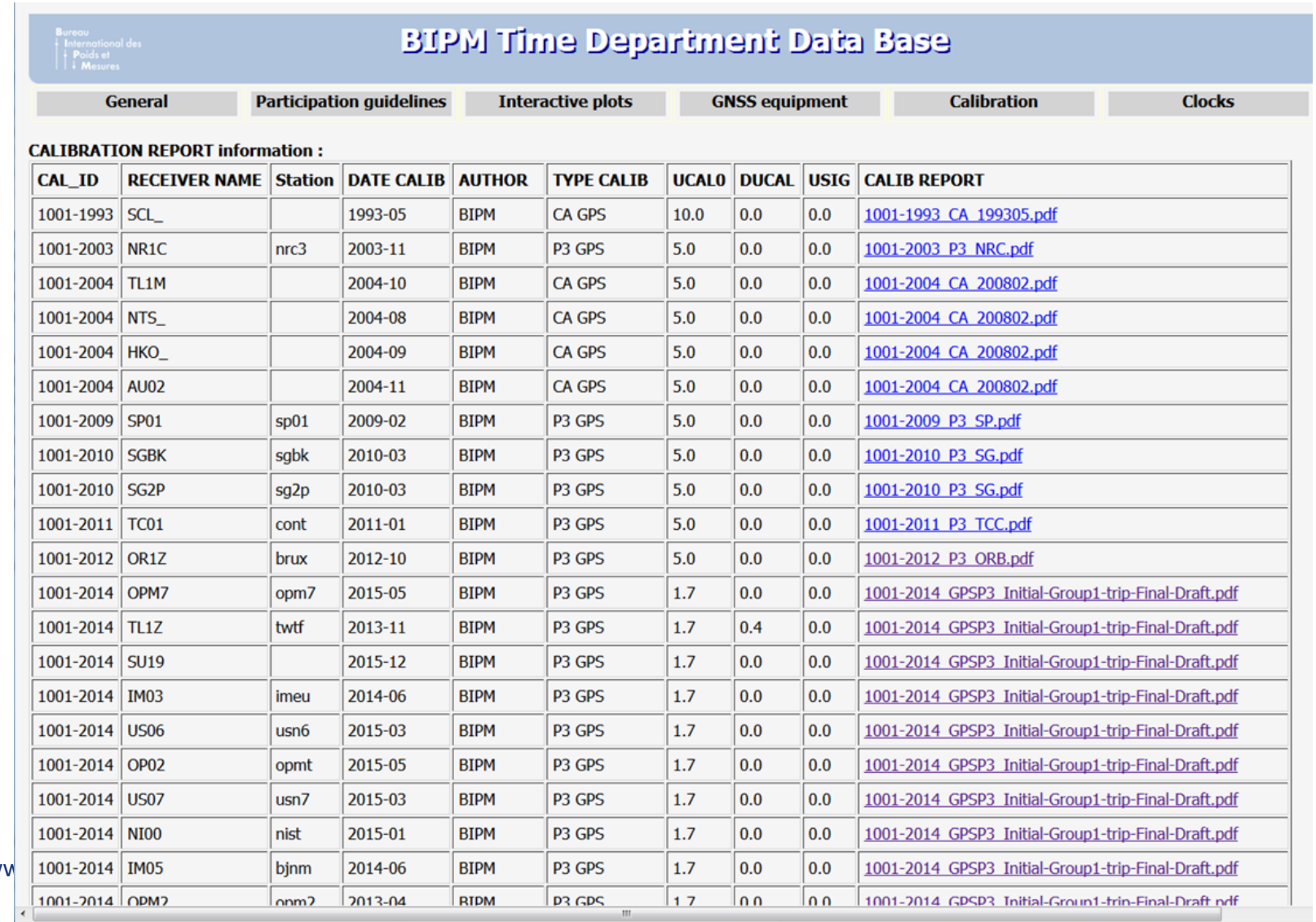
Time Dpt database: http://webtai.bipm.org/database/html/

http://webtai.bipm.org/database/index.html **Example of the Calibrations tab**



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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	1001-1993_CA_199305.pdf
1001-2003	NR1C	nrc3	2003-11	BIPM	P3 GPS	5.0	0.0	0.0	1001-2003_P3_NRC.pdf
1001-2004	TL1M		2004-10	BIPM	CA GPS	5.0	0.0	0.0	1001-2004_CA_200802.pdf
1001-2004	NTS_		2004-08	BIPM	CA GPS	5.0	0.0	0.0	1001-2004_CA_200802.pdf
1001-2004	HKO_		2004-09	BIPM	CA GPS	5.0	0.0	0.0	1001-2004_CA_200802.pdf
1001-2004	AU02		2004-11	BIPM	CA GPS	5.0	0.0	0.0	1001-2004_CA_200802.pdf
1001-2009	SP01	sp01	2009-02	BIPM	P3 GPS	5.0	0.0	0.0	1001-2009_P3_SP.pdf
1001-2010	SGBK	sgbk	2010-03	BIPM	P3 GPS	5.0	0.0	0.0	1001-2010_P3_SG.pdf
1001-2010	SG2P	sg2p	2010-03	BIPM	P3 GPS	5.0	0.0	0.0	1001-2010_P3_SG.pdf
1001-2011	TC01	cont	2011-01	BIPM	P3 GPS	5.0	0.0	0.0	1001-2011_P3_TCC.pdf
1001-2012	OR1Z	brux	2012-10	BIPM	P3 GPS	5.0	0.0	0.0	1001-2012_P3_ORB.pdf
1001-2014	OPM7	opm7	2015-05	BIPM	P3 GPS	1.7	0.0	0.0	1001-2014_GPSP3_Initial-Group1-trip-Final-Draft.pdf
1001-2014	TL1Z	twtf	2013-11	BIPM	P3 GPS	1.7	0.4	0.0	1001-2014_GPSP3_Initial-Group1-trip-Final-Draft.pdf
1001-2014	SU19		2015-12	BIPM	P3 GPS	1.7	0.0	0.0	1001-2014_GPSP3_Initial-Group1-trip-Final-Draft.pdf
1001-2014	IM03	imeu	2014-06	BIPM	P3 GPS	1.7	0.0	0.0	1001-2014_GPSP3_Initial-Group1-trip-Final-Draft.pdf
1001-2014	US06	usn6	2015-03	BIPM	P3 GPS	1.7	0.0	0.0	1001-2014_GPSP3_Initial-Group1-trip-Final-Draft.pdf
1001-2014	OP02	opmt	2015-05	BIPM	P3 GPS	1.7	0.0	0.0	1001-2014_GPSP3_Initial-Group1-trip-Final-Draft.pdf
1001-2014	US07	usn7	2015-03	BIPM	P3 GPS	1.7	0.0	0.0	1001-2014_GPSP3_Initial-Group1-trip-Final-Draft.pdf
1001-2014	NI00	nist	2015-01	BIPM	P3 GPS	1.7	0.0	0.0	1001-2014_GPSP3_Initial-Group1-trip-Final-Draft.pdf
1001-2014	IM05	bjnm	2014-06	BIPM	P3 GPS	1.7	0.0	0.0	1001-2014_GPSP3_Initial-Group1-trip-Final-Draft.pdf
1001-2014	OPM2	opm2	2013-04	BIPM	P3 GPS	1.7	0.0	0.0	1001-2014_GPSP3_Initial-Group1-trip-Final-Draft.pdf

BIPM Guidelines: latest features

- « 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_{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_{CAL} (e.g. by 0.5 ns in quadrature).
- Alignment (AL)
  - Done by the BIPM when no other solution
    - BIPM will slightly expand u_{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
OP              OPMT            OP02                               LABO / RINEX / BIPM
02942                ASHTECH Z-XII3T                               REC # / TYPE
00019                3S-02-TSADM     NONE                          ANT # / TYPE
GPS                      1001-2014                                 GNSS / CAL_ID
 2015    04    01                                                  VALID FROM
 REF = UTC(OP)                                                     LAB REFERENCE
 2 INTDLY P1 =   310.2  P2 =   321.6                               # / DLY / TYPE=VAL
   CABDLY        156.5                                             DLY / VAL / COMMENT
   REFDLY        100.1                                             DLY / VAL / COMMENT
 2015    08    27                                                  VALID FROM
   REFDLY        155.9                                             DLY / VAL / COMMENT
                                                                   END OF STATION CAL
                                                                   START OF STATION CAL
PTB             PTBB            PT02                               LABO / RINEX / BIPM
RT820013901          ASHTECH Z-XII3T                               REC # / TYPE
CR15930              ASH700936E      SNOW                          ANT # / TYPE
GPS                      1001-2014                                 GNSS / CAL_ID
 2015    04    01                                                  VALID FROM
 REF = UTC(PTB)                                                    LAB REFERENCE
 2 INTDLY P1 =   303.9  P2 =   319.3                               # / DLY / TYPE=VAL
   CABDLY        301.7                                             DLY / VAL / COMMENT
```

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Future actions

- 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)]

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THANK YOU

Thanks to all Group 1 and other participating laboratories!