

Contributing to UTC

Inputs (from laboratories) & Outputs (from the BIPM)

Aurélie HARMEGNIES

aharmeq@bipm.org

Outline

➤ Part 1: Technical requirements

- Technical requirements
- Timeline for first participation



➤ Part 2: Input data to be provided by the laboratories

- Input data list
- FTP submission rules & recommendations
- Input files and their format



➤ Part 3: Output data & products provided by the BIPM

- Products list & locations
- API UTC , API CCL-CCTF
- FTP data files
- webtai portal





Guideline 8 of the CCTF WG-MRA:

What is needed ?

- ✓ one or more **atomic clocks** (not disciplined !)
- ✓ Local time scale UTC(k) based on **commercial atomic clocks**
- ✓ be in capacity to measure “**UTC(k)-clock**” at 00:00 UTC
- ✓ keep UTC(k) in agreement with UTC, with time and **frequency steering**
($|UTC - UTC(k)| < 100\text{ns}$) *CCDS recommendation S 5 (1993)*
- ✓ be in capacity to **generate clock files automatically**, according to the required format



Laboratories willing to participate in the calculation of UTC should :

- ✓ have instruments to allow **remote clock comparisons**, such as:
 - ♦ **Timing GNSS receivers** : recommended multi-channel, dual-frequency, code and phase measurements, compatible with multi-constellation (min. 2 Rx)
Calibration of delays of these equipments must be considered to produce Calibration and Measurement Capabilities (CMCs) and get uncertainty in *CircularT*. These calibrations may be carried out by the *RMOs*, the *BIPM*, *individual time laboratories or manufacturers*.
 - ♦ **Two-way satellite** time and frequency transfer (TWSTFT) station
(needs arrangements with TWSTFT working group)

Technical requirements

Laboratories willing to participate in the calculation of UTC should have the capacity to :

- ✓ run **an uninterrupted time scale**, needs regular data submission
- ✓ fill a strong need for **automatization**
 - **measurements** (locally)
 - **data transfer** (remotely)
- ✓ Put in place **monitoring tools** and **recovery plans** to improve the time scale quality
- ✓ **Maintain UTC(k) close to UTC** by applying steerings
(offset recommended below 100ns)



Timeline before starting participation

Once all previous technical requirements are met :

- ✓ **fill** dedicated **form** and send to tai@bipm.org for evaluation of your setup before use in Circular T
- ✓ BIPM will provide all internal codes necessary to implement the automatic data submission process.
- ✓ **start uploading** the data, then BIPM will perform some preliminary checks
- ✓ data sent will be **monitored for few months**, to ensure some continuity of the data before introduction
- ✓ the **laboratory** will then be **included in Circular T**.

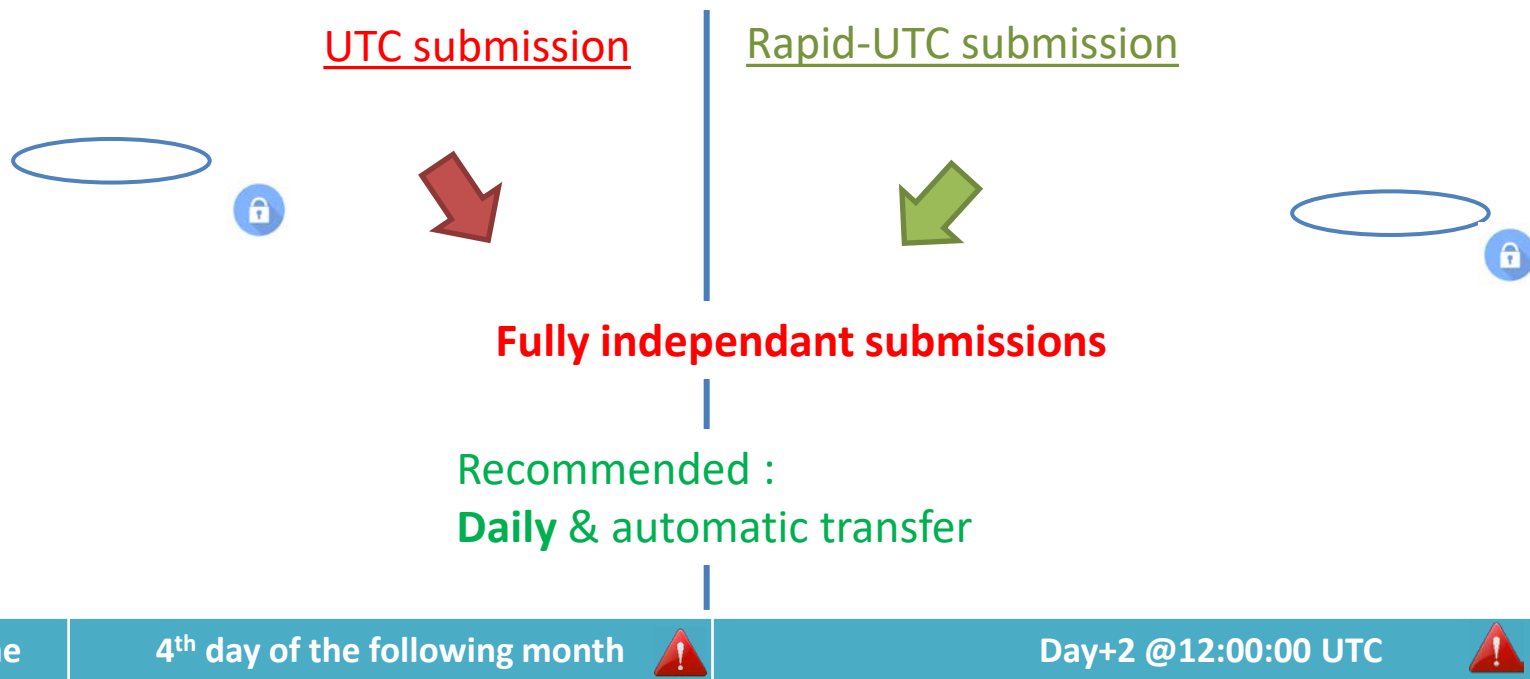


This initial phase requires around three months...

Input data to be provided by laboratories

FTP submission rules (@URL: <ftp://tai.bipm.org>)

- ◆ Use **FTP/FTPS protocol** to transfer data files



FTP submission - Files naming

Type of data	UTC path	UTC filename	UTCr path	UTCr filename
Clock	/data/UTC/xxxx/clocks/	CDLL__YY.MM_	/data/UTCr/xxxx/CLOCK/	CDLL__dd.ddd
CGGTTS	/data/UTC/xxxx/links/cggtts/	ZZLLmodd.ddd	/data/UTCr/xxxx/CGGTTS/	ZZLLmodd.ddd
RINEX	/data/UTC/xxxx/links/rinex/	LLmodoy0.YYo.Z	/data/UTCr/xxxx/RINEX/	LLmodoy0.YYo.Z
HD	/data/UTC/xxxx/links/hd/	LLmodd.ddd	/data/UTCr/xxxx/HD/	LLmodd.ddd
LZ	/data/UTC/xxxx/links/lz/	LLmodd.ddd	/data/UTCr/xxxx/LZ/	LZLLmodd.ddd
TWSTFT	/data/UTC/xxxx/links/twstft/ modem/region/	TWxxxxdd.ddd	/data/UTCr/xxxx/TWSTFT/ modem/region/	TWxxxxdd.ddd
PFS SFS	/data/UTC/xxxx/ clocks/PFS_eval/	xxxxYYMM.PFS xxxxYYMM.SFS psfs(i)-mjd_mjd.pdf		

File naming is quite complex :
Automatization is THE key ... to avoid typos !

dddd = MJD, xxxx = Lab acronym, LL = 2-characters lab ID, LLmo = GNSS equipment (Rx+Antenna), YYMM = year last 2 digits(YY)+month(MM), ZZ is the constellation and the frequency+channels code



Input data to be provided

◆ Expected files

-  Clock data
-  CGGTTS
-  RINEX
-  TWSTFT
-  HD
-  LZ
-  Primary and Secondary Frequency Standard evaluations

Full documentation is online at
<https://webtai.bipm.org/database/guidelines.html>



Content : [UTC(k)-clock] at 00:00:00 UTC (values in ns)

MJD	LabCode	ClockCode	UTC(k)-clock
60859	10011	1350219	-000600.4
60859	10011	1401104	0022176.6
60864	10011	1350219	-000606.0
60864	10011	1401104	0021943.9
60869	10011	1350219	-000600.4
60869	10011	1401104	0022176.6

- 5 max measurements over one line
- Value format : « f9.1 »
- Effective contribution to UTC requires clock data files
→ 7 laboratories still not providing them ...

→ UTC : for each standard MJD ending by 4 or 9

→ UTCr : data for each MJD

Clock corrections

When clocks are voluntarily corrected, the BIPM needs to correct clock data, so that « EAL-clock » remains continuous and the clock keeps its weight.

It is important to report such corrections as :

$$[UTC(k)\text{-clock}]_{\text{before}} - [UTC(k)\text{-clock}]_{\text{after}}$$

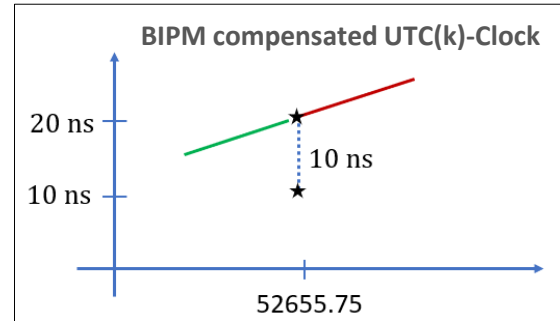
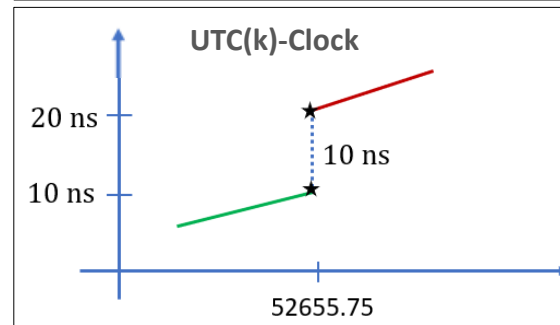
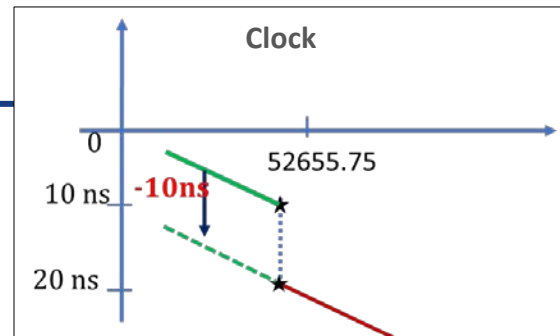


(or *NEW*[clock value] - *OLD*[clock value])

using an extra line, formatted as:

MJD	ClockCode	$\Delta\text{phase}(\text{ns})$	$\Delta\text{frequency}(\text{ns/d})$	Labo	LabCode
52655.75	1411036	-10.0	0.000	OP	10008

If not declared, not compensated : clock is deweighted ...



Common Generic GNSS Time Transfer Standards (CGGTTS) files

- ◆ Daily observation file : produced by the receiver or using R2CGGTTS software (ROB)



```
CGGTTS GPS/GLONASS DATA FORMAT VERSION = 02
REV DATE = 2017-02-03
RCVR = ASHTECH Z-XII3T RT820013901 R2CGGTTS v4.3
CH = 12 (GPS)
IMS = ASHTECH Z-XII3T RT820013901
LAB = PTB
X = +3844059.89 m (GPS)
Y = +709661.48 m (GPS)
Z = +5023129.73 m (GPS)
FRAME = ITRF
COMMENTS = PT02 Cal_Id=1001-2016
INT DLY = 304.5 ns (GPS P1), 319.8 ns (GPS P2)
CAB DLY = 301.7 ns (GPS)
REF DLY = 73.9 ns
REF = UTC(PTB)
CKSUM = 90
```

Calibration values

PRN	CL	MJD	STTIME	TRKL	ELV	AZTH	REFSV	SRSV	REFGPS	SRGPS	DSG	IOE	MDTR	SMDT	MDIO	SMDI	MSIO	SMSI	ISG	FR	HC	FRC	CK
			hhmmss	s	.1dg	.1dg	.1ns	.1ps/s	.1ns	.1ps/s	.1ns		.1ns	.1ps/s	.1ns	.1ps/s	.1ns	.1ps/s	.1ns				
27	FF	58126	000200	780	187	2706	-3612641	+34	22	+57	60	105	251	-81	62	-32	62	-32	46	0	0	L3P	3
16	FF	58126	000200	780	454	3015	-343929	+0	32	-6	30	78	113	-14	32	-3	32	-3	24	0	0	L3P	86
29	FF	58126	000200	780	337	814	-5142813	+68	88	+14	53	47	145	+25	34	-2	34	-2	38	0	0	L3P	CB
26	FF	58126	000200	780	721	2603	+2956914	-175	45	-35	17	1	85	-1	36	+28	36	28	13	0	0	L3P	CF



[Receiver Reference-GNSS Time]



- ◆ Versions supported v2.xx, v3.xx.  Short filename « ssssdoy0.yy0.Z »
-  Single daily observation file per receiver, **no navigation files** !
-  Unix compressed (.Z) and possible Hatanaka compression
-  **RINEX** measurement **must not be calibrated**. (check your config!)
-  **HD files** are **required** for PPP so that BIPM can apply calibrated delays
-  Antenna type and radome in the RINEX header must be valid and referenced in https://files.igs.org/pub/station/general/rcvr_ant.tab or <https://files.igs.org/pub/station/general/igs20.atx>, else PPP cannot be used in Circular T.

HD file (to apply calibrations to PPP)



Example :

```
CGGTTS GPS/GLONASS DATA FORMAT VERSION = 02
REV DATE = 2017-02-03
RCVR = ASHTECH Z-XII3T RT820013901    R2CGGTTS v4.3
CH = 12 (GPS)
IMS = ASHTECH Z-XII3T RT820013901
LAB = PTB
X = +3844059.89 m (GPS)
Y = +709661.48 m (GPS)
Z = +5023129.73 m (GPS)
FRAME = ITRF
COMMENTS = PT02 Cal_Id=1001-2016
INT DLY = 304.5 ns (GPS P1), 319.8 ns (GPS P2)
CAB DLY = 301.7 ns (GPS)
REF DLY = 73.9 ns
REF = UTC(PTB)
CKSUM = 90
```



Do not forget to upload the new file
each time a parameter is modified !

➔ Total delay: **508.662 ns** ($= 2.54 \times 304.5 - 1.54 \times 319.8 + 301.7 - 73.9$)
applied to the PPP solution obtained with NRCan processing on RINEX files

TWSTFT file

Files formatted according to [ITU-Rec1153](#).

2 time differences files received by the BIPM :

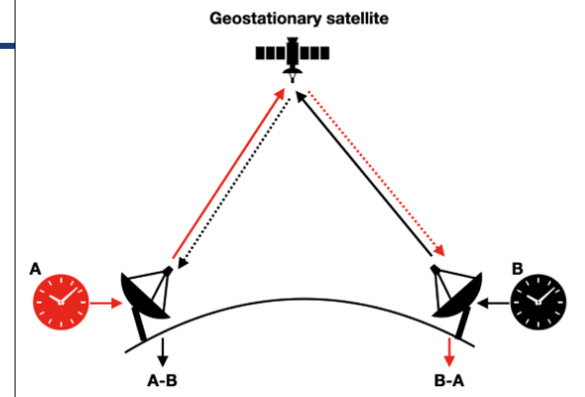
- [A-B] by A laboratory
- [B-A] by B laboratory

Example :

**	EARTH-STAT	LI	MJD	STTIME	NTL	TW	DRMS	SMP	ATL	REFDELAY	RSIG	CI	S	CALR	ESDVAR	ESIG	TMP	HUM	PRES
* LOC	REM			hhmmss	s	s	ns		s	s	ns			ns	ns	ns	degC	%	mbar
PTB05	IT02	14	58126	001300	119	0.264718944304	1.453	120	119	0.000000736134	0.020	434	1	274.900	-5.920	0.600	-2	98	1021
PTB05	ROA01	14	58126	001600	119	0.260351698126	0.765	120	119	0.000000736134	0.020	440	1	-31.600	-5.920	0.600	-2	98	1021
PTB05	OP01	14	58126	001900	119	0.264560413657	1.028	120	119	0.000000736134	0.020	437	1	7113.800	-5.920	0.600	-2	98	1021
PTB05	NPL02	14	58126	002200	119	0.264751791632	0.898	120	119	0.000000736134	0.020	450	1	-728.100	0.000	0.000	-2	98	1021

...

Two-way satellite time/frequency transfer



Source NIST



Necessary only if receiver's reference is not directly UTC(k) but another reference

Example :

58082.00301

20225.031

58082.04468

20224.977

58082.08634

20224.073



MJD



UTC(k) – Ref (ns)



Evaluations of PFS or SFS should be reported in monthly ASCII file :

Labo	PFS	PfsCode	FreqRef	MJD1	MJD2	[Ref-PFS] 10E-15	uA 10E-15	uB 10E-15	uA/Lab 10E-15	uB/Lab 10E-15	Uptime %	Ref(uB) T389	uB(Ref) 10E-15
XXXX	XXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXX	XXXXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
NRC	NRC-FCs2	1920301	NRC	60399	60414	-1.37	0.18	0.25	0.11	0.00	93.7	T389	0.23
NRC	NRC-FCs2	1920301	NRC	60419	60429	-2.07	0.28	0.21	0.30	0.00	57.2	T389	0.23

ADDITIONAL INFORMATION :

Reported by : NRC

Date of report : 07 05 2024

Name of the reporter : Scott Beattie and Bin Jian

END

Comments from the reporter:

Other information:



+ PDF reports to be uploaded on the FTP

Used as documentation, available online after publication of Circular T.



Evaluations period might require to be changed by the lab, when there are issues on the usual time link ! Try to prevent as much as possible

1ns on link|clock → 4×10^{-16} on f(PSFS)-f(TAI)

Output data & products provided by BIPM

Products list & locations

BIPM Time Department is providing a large quantity of products that are accessible through :
[API](#) / [website](#) / [FTP](#) (open-access) .

- ✓ [API “UTC”](#) provides a subset of products (in standard file exchange formats (TXT, CSV, JSON))
 - *[UTC-UTC(k)]*
 - *[UTCr-UTC(k)]*
 - *[UTC-GNSS times]*
- ✓ [API “CCL-CCTF”](#) provides the list of recommended values of standard frequencies and their validity (XML)
- ✓ website webtai.bipm.org providing additional database information (views+download)
- ✓ FTP Online ASCII formatted results files, can be read by any home-made script.

Products list & locations

(API, FTP, webtai)

Bulletins

Circular T

Rapid UTC

Participants

Lab. info

Lab. Equipment

Data processed

Clocks

Time transfer
(raw&corrected)

Time scales

UTC-UTC(k)

TAI-TA(k)

UTCr-UTC(k)

UTC-GNSS Times

UTC-
Broadcast_UTC_{GNSS}

TT(BIPMY)-TAI

PSFS

$f(\text{TAI})-f(\text{PSFS}_i)$

$f(\text{TAI})-f(\text{PSFS})$

PSFS reports



CCL-CCTF Ref. freq.

Calibrations

reports

status

Equipment diagnostics

Clock weight

Clock rate

Clock drifts

Time links

Link comparisons

API UTC (2020)

<https://webtai.bipm.org/api/v1.0/get-data.html?scale=utc&lab=AOS&mjd1=60834&mjd2=60854>
<https://webtai.bipm.org/api/v1.0/get-data.html?scale=gnss>

UTC-UTC(AOS)

```
{
  "errorCode":0,
  "message":"ok",
  "data":{
    {
      "y_tot":5,
      "xmin":60824,
      "ymax":-7.4,
      "y":[-10,-9.5,-8.7,-8,-7.4],
      "unc":["2.7","2.7","2.7","2.7","2.7"],
      "x_tot":5,
      "ymin":-10,
      "xmax":60844,
      "x":[60824,60829,60834,60839,60844],
      "name":"UTC-UTC(AOS)"
    }
  ],
  "api_...",
  "succ..."
}
```

JSON

UTC-GPSTime

```
{
  "api_version":"1.0",
  "message":"ok",
  "success":true,
  "data":{
    {
      "name":"UTC-GPS_Time",
      "unc":["5.0","5.0"],
      "x_tot":2,
      "y_tot":2,
      "ymin":-0.1,
      "xmin":60824,
      "xmax":60825,
      "ymax":0.6,
      "x":[60824,60825],
      "y":[0.6,

```

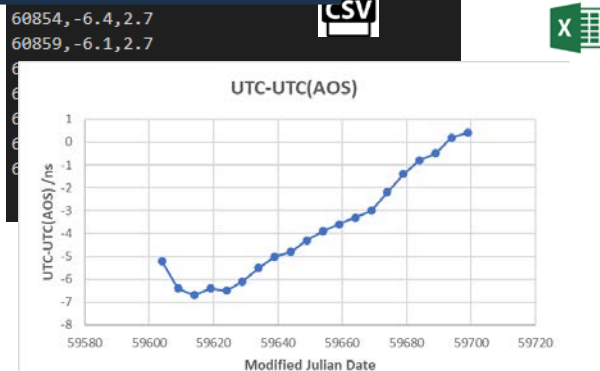
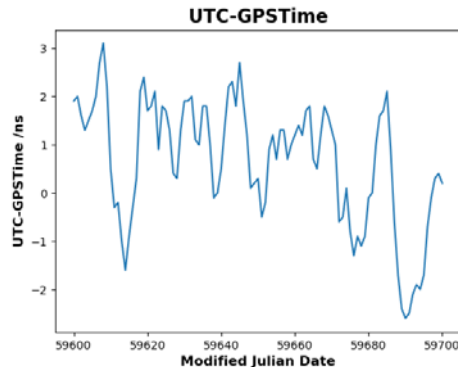
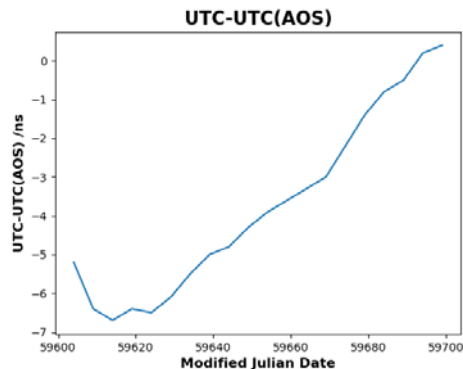
JSON

UTC-UTC(AOS)

#MJD	UTC-UTC(AOS)(ns)	uncertainty(ns)
60839	-8.0	2.7
60844	-7.4	2.7
60849	-7.0	2.7
60854	-6.4	2.7
60859	-6.1	2.7
60864	-5.8	2.7
60869	-5.5	2.7
60874	-4.9	2.7
60879	-4.3	2.7
60884	-4.0	2.7

TXT

To be informed about future versions, subscribe to the **API Newsletter** ✉



API CCL-CCTF (2023)



- database developped with MeP content.
 - new CCL-CCTF API developped to support Automatization of Digital Calibration Certificates generation.
- Example of call of the API:*

« Request of recommended values for standard frequencies »

Strontium (88Sr isotope)
 $\nu = 429 \text{ THz}$
on 15/05/2024

Machine request

Machine
answer

```
$ wget -O 88Sr-429THz.xml 'https://webtai.bipm.org/api/ccl-cctf/v1.0/xml_auto.html?target=88Sr|429+THz&date=2024-05-15'
```

```
<?xml version="1.0" encoding="UTF-8"?>
<freq:stdfreq
  xmlns:freq="NPL_MeP_Schema"
  xmlns:xs="http://www.w3.org/2001/XMLSchema"
  xmlns:si="https://ptb.de/si"
  >
  <freq:label>429 THz - 88Sr</freq:label>
  <freq:freqlabel>429 THz</freq:freqlabel>
  <freq:target>88Sr</freq:target>
  <freq:validfrom>2022-04-13</freq:validfrom>
  <freq:srs>true</freq:srs>
  <freq:transitionname>5s^2 ^1S_0 - 5s5p ^3P_0</freq:transitionname>
  <freq:compname></freq:compname>
  <freq:value>
    <si:real>
      <si:value>429228066418007.01</si:value>
      <si:unit>\hertz</si:unit>
      <si:expandedUnc>
        <si:uncertainty>0.09</si:uncertainty>
        <si:coverageFactor>1</si:coverageFactor>
        <si:coverageProbability>0.68</si:coverageProbability>
        <si:distribution>normal</si:distribution>
      </si:expandedUnc>
    </si:real>
  </freq:value>
  <freq:numberofrules>0</freq:numberofrules>
  <freq:numberoffuncs>0</freq:numberoffuncs>
  <freq:numberoftransitions>0</freq:numberoftransitions>
</freq:stdfreq>
```

FTP data files examples (ASCII files)

UTC-UTC(NIST)

UTC-GNSStimes (+ broadcasted)

Clock weights

Fractionnal deviation (d)

Bureau
International des
Poids et
Mesures

BIPM Time Department Data Base

Participation

Equipments

Calibrations

Resources

Web services

Home

Sitemap

Participation

- Laboratories
- Current status
- Geographical map
- Rules & guidelines
- >>Tutorials & CBKT<<
- Dissemination services

Equipments

- Clocks
- GNSS
- TWSTFT
- source of UTC(k)
- PSFS

Calibrations

- GNSS status
- GNSS results
- TWSTFT status
- Documents & Guidelines

Resources

- Graphs
 - [UTC-UTC(k)]
 - UTC and GNSS
 - PSFS contributions
 - Fractional deviation d
- Clock stats and codes
- Get clock code
- Time scales

Web services

- API UTC
- API CCL-CCTF
- FTP results

Home

- Sitemap
- Newsletter
- Contact us

→ Guidelines for participation
(file format, rules...)

→ Status of participating laboratories

- Equipments
- Calibrations

→ Plots of the products

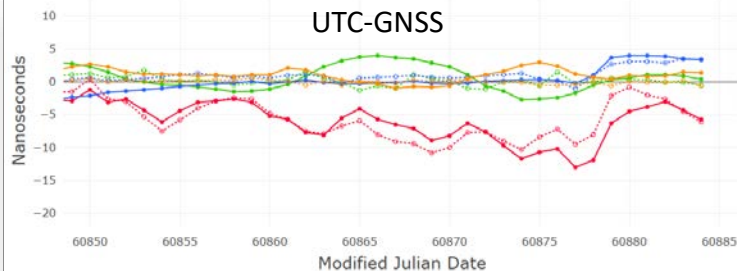
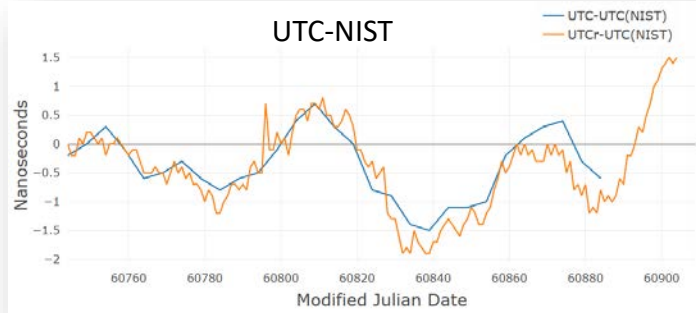
- UTC-UTC(k)
- UTCr-UTC(k)
- UTC-GNSSTimes
- $f(PSFS)$ vs $f(TAI)$

+ Access to **FTP data** and **API**

25

webtai portal

Available on-demand
dynamic plots:



Bureau International des Poids et Mesures

BIPM Time Department Data Base

Participation guidelines Participants Lab. equipment Clocks Calibrations Interactive plots

Status of ongoing, planned, requested and past GNSS calibration exercises

Ongoing, planned and requested GNSS calibration exercises

CAL_ID	Author	Comment/report	Type of trip	Creation date
1201-2021	PTB	JV	G2 Golden	2021-03-02 12:53:43
1014-2021	NIST	AGGO-IGNA-INTI-ONBA	G2	2021-05-06 15:31:28
1013-2021	PTB	TP	G2	2021-04-30 12:37:53
1012-2021	LNE-SYRTE	CNES-ILNAS	G2	2021-01-22 10:51:24
1201-2020	ROA	SMD	G2 Golden	2020-09-14 14:27:10

Past GNSS calibration exercises

CAL_ID	Author	Comment/report	Validation date
1101-2021	ROA	1101-2021_GSP3C1-GALE3_ROA-TC_V1-0.pdf	2021-03
1011-2021	PTB	1011-2021_GSP3-GALE3_INRIM_V1-1.pdf	2021-03
1106-2020	Internal TC	1106-2020_GSP3_SP-TC_V1-0.pdf	2020-09



Calibrations
on-going

Calibrations
listing

GPS calibration results :

GPS

Calibrations results



Calibration trip (Cal_ID) information						GPS calibration results (ns)																	HTM
Report	Laboratory	Receiver BIPM ID	Date Calib	Author	Calib. trip type	Delays from calibration trip														Calibration uncertainties			
all	ORB	all	up/down			CAB	REF	INT C1	INT P1	INT P2	SYS C1	SYS P1	SYS P2	SYS P3	TOT C1	TOT P1	TOT P2	TOT P3	uCal0 (C/A)	uCal0 (P3)	AuCAL		
1011-2020	ORB	ORSZ	2020-04-02	PTB	G2	237.5	68.5		28.0	23.8										2.5	0.0		
1011-2020	ORB	OR4Z	2020-04-02	PTB	G2	149.2	158.4		55.1	55.1										2.5	0.0		

GALILEO calibration results :

Galileo

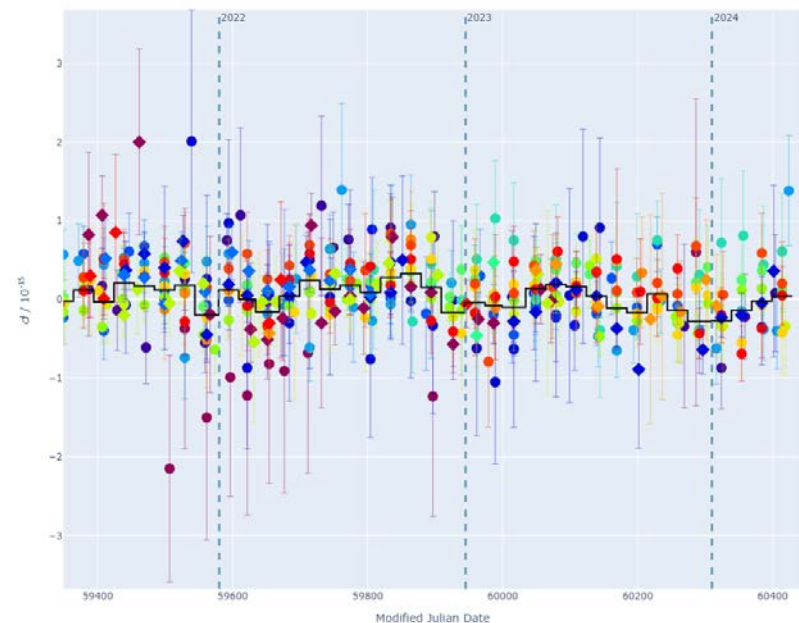
Calibration trip (Cal_ID) information						GALILEO calibration results (ns)											
Report	Laboratory	Receiver BIPM ID	Date Calib	Author	Calib. trip type	Delays from calibration trip								Calibration uncertainties			
			up/down			CAB	REF	INT E1	INT E5a	SYS E1	SYS E5a	TOT E1	TOT E5a	uCal0 (E1)	uCal0 (E5a)	AuCAL	
1011-2020	ORB	OR21	2020-04-02	PTB	G2		69.9			248.0	247.6				2.5	0.0	
1011-2020	ORB	OR20	2020-04-02	PTB	G2	96.3	70.2	35.8	33.7						2.5	0.0	

webtai portal

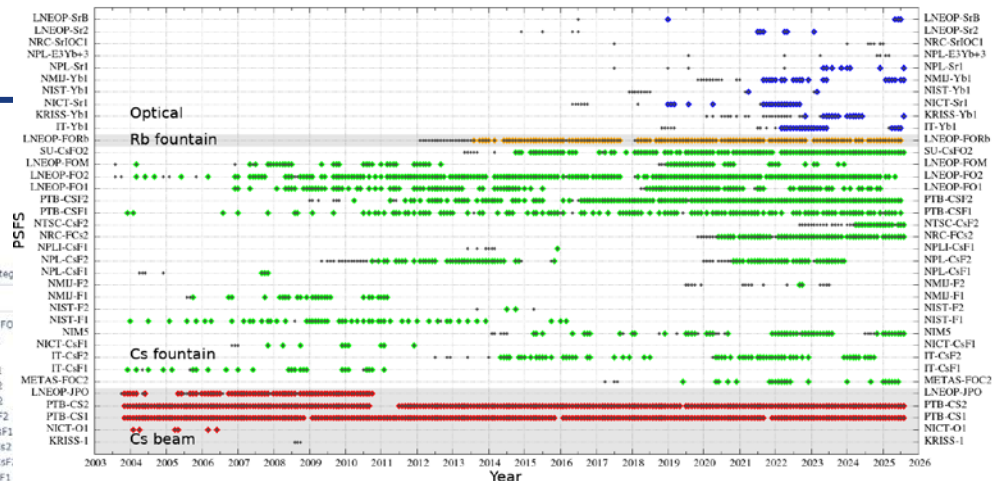
PSFS contributions

$$f(\text{PSFS}) - f(\text{TAI})$$

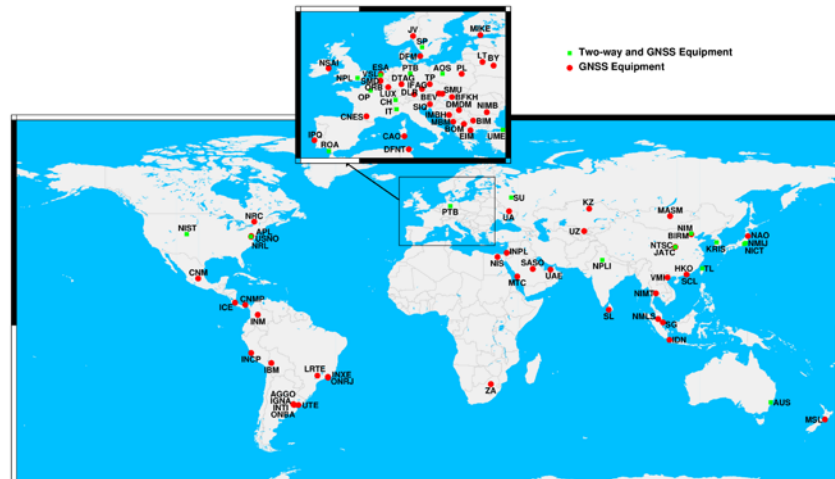
Evaluation of the fractional deviation d of TAI scale interval (PSFS) until May 2024
Microwave: ■, Optical: ◆, open symbol: latest data > 3 yrs



Graphical representation of all evaluations of Primary and Secondary Frequency Standards reported since Circular T 190.
Enhanced color dots indicate evaluations carried out within the month of TAI computation.



Geographical distribution of the laboratories that contribute to TAI and time transfer equipment (2024)



Thank you for your attention

Contact : tai@bipm.org

Useful links:

BIPM Time Department database website : <https://webtai.bipm.org/database/>

BIPM Time Department API web service : <https://webtai.bipm.org/api>

Full technical guidelines available at : <https://webtai.bipm.org/database/guidelines.html>



Bureau
♦ **I**nternational des
♦ **P**oids et
♦ **M**esures



www.bipm.org