UTC, its computation and traceability and Circular T requirements

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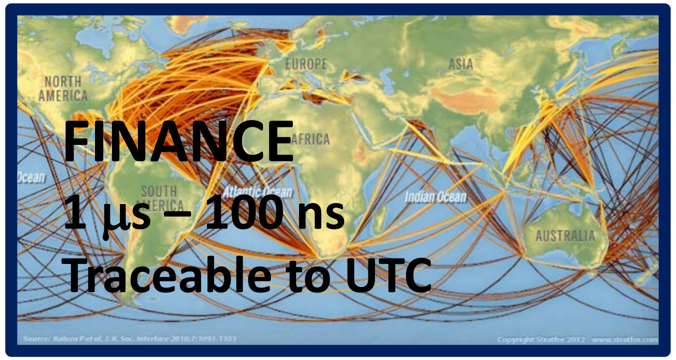
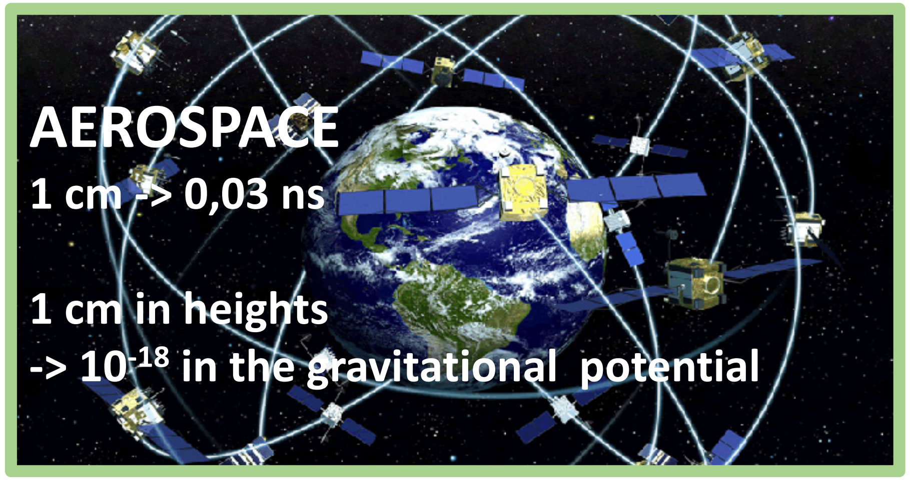
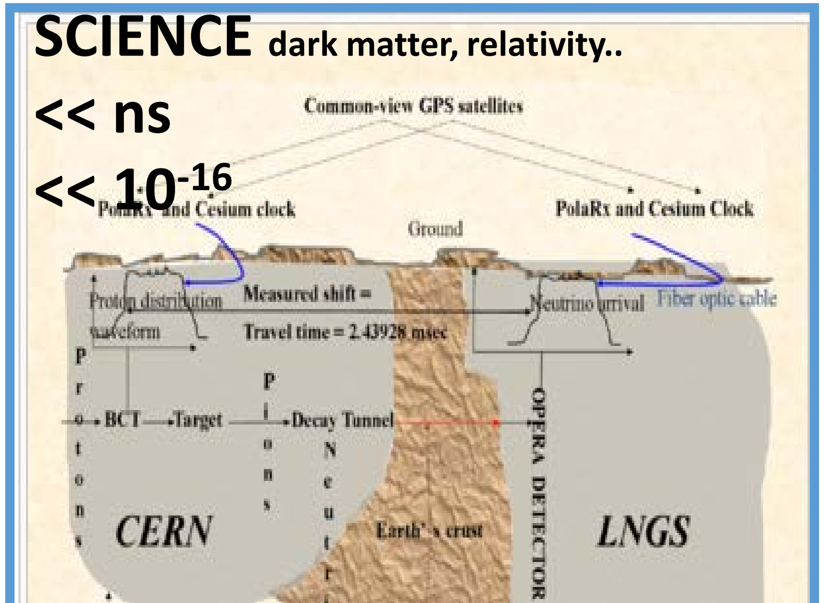
Time Department, BIPM

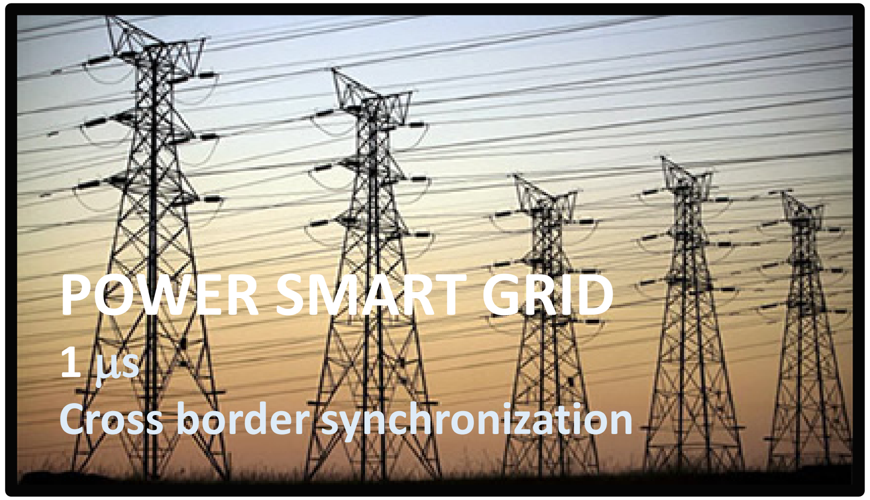
BIPM-SIM UTC Summer School

What time is it?









What time is it?

The international reference time scale for all the applications is the

Coordinated Universal Time UTC

computed and distributed by the Bureau International des Poids et Mesures (BIPM) in Sevres, France

Resolution 2 of the 26th CGPM (2018)
On the definition of time scales

The General Conference on Weights and Measures (CGPM), at its 26th meeting,

recognizing that

•**the mission of the BIPM is to ensure and promote the global comparability of measurements**, including the provision of a coherent international system of units,

•**states** that

•**TAI is a continuous time scale produced by the BIPM based on the best realizations of the SI second, and is a realization of TT** as defined by IAU Resolution B1.9 (2000),

•**UTC produced by the BIPM, based on TAI, is the only recommended time scale for international reference and the basis of civil time in most countries,**

•**UTC differs from TAI only by an integral number of seconds** as published by the BIPM,

•**traceability to UTC is obtained through local real-time realizations "UTC(*k*)" maintained by laboratories contributing data to the calculation of UTC, identified by "*k*",**

Full text on
https://www.bipm.org/en/committees/cg/cgpm/26-2018/resolution-2

What time is it? How do we get UTC?

In almost each country a national time scale is use as the reference for legal time and synchronization. This can be:

- UTC(k) = a real time approximation of UTC realized by a time laboratory "k", inside the National Metrology Institute or in a Designated Institute which is part of the metrological infrastructure of a country. This national time laboratory contributes to UTC by providing its clock data to the BIPM and it is listed in the BIPM Circular T

Uncertainty = a few ns

Traceability to UTC
CCTF WGMRA Guideline 9
https://www.bipm.org/en/committees/cc/cctf/wg/cctf-wgmra

- a UTC approximation obtained by other countries realizing a UTC(k) time scale by a direct connection (GNSS, fibre…) or by the Network Time Protocol on the Internet

Uncertainty = 10 - 100 ns

Traceability to UTC
CCTF WGMRA Guideline 9
https://www.bipm.org/en/committees/cc/cctf/wg/cctf-wgmra

- a UTC approximation obtained through the GNSS and other time dissemination services

Uncertainty = 1 – 100 microseconds

What is UTC(k) ?

The reference time scale in each country is (usually) UTC(k)

see Mauricio, Andrew talks

It is a real-time local approximation of the Coordinated Universal Time realized by the laboratory "k"

see BSJ, CENAMEP, IBMETRO, CENAM experience

This is realized and disseminated in real-time

see Nelida, Eduardo talk

This is the basis for the legal time and the synchronization in the country

see Oscar, Claudia, Andrew talks

The "k" laboratory is contributing to the fabrication of UTC with its clocks

Only laboratories contributing to UTC can realize a UTC(k) time scale

The BIPM computes UTC:
a unique, accessible, universal, international reference time scale

- We compute the Coordinated Universal Time based on your free running atomic clocks (not UTC(k)) every months

- The definitive reference results are the deviation

  UTC – UTC(k)

- We compute a provisional weekly rapid solution called rapid UTC

- We compute also the Terrestrial Time TT(BIPM) based on the optimal use of Primary Frequency Standards for advanced scientific use

How can we do that?

see Bharath, talks

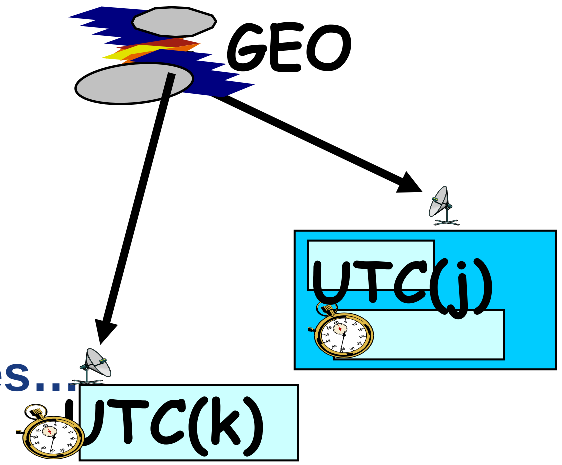
- We need the measures of your free running clocks
- We need the measures of your Primary and Secondary Frequency Standards to ensure the accuracy of UTC
- We need also the comparison between your local UTC(k) and an external UTC(j)

Comparison obtained by:

- **GNSS Common or All in view**
- **GNSS (Integer) Precise Point Positioning**
- **Two Way Satellite Time Frequency Transfer**
- **In future Optical fibers, other space techniques…**

See Bharath, Giulio, Andrew, Ben, Carlos, Francisco, Alexander, Diego talks

See Tara talks



How can we do that?

See Bharath, Giulio, Andrew, Ben, Carlos, Francisco, Alexander, Diego talks

- We need to ensure that all the time transfer measures used to generate UTC are calibrated.
- Calibrations may be carried out by the BIPM, by the RMOs, by G1, G2 or other time laboratories or, in some cases, by other entities such as manufacturers.
- All the calibration results are to be documented. We provide a data base containing all the calibration info and reports.

How to enter in UTC?

http://webtai.bipm.org/database/

Bureau International des Poids et Mesures

BIPM Time Department Data Base

Participation | Equipments | Calibrations | Resources | Web services | Home

Website content description

Participation

Laboratories : full list of participating labs and their related information

Current status : current laboratories participation to UTC and UTCr

Geographical map : Geographical distribution of partcipating laboratories

Rules & guidelines : Full documentation and guidelines for UTC and UTCr participation

Dissemination services : Time dissemination services list and Time signals emissions

Equipments

Clocks : list of clocks by laboratory

GNSS : list of all GNSS equipments in UTC participating laboratories and their calibration status

TWSTFT : list of all TWSTFT equipments in UTC participating laboratories and their calibration status

source of UTC(k) : Equipment and source of UTC(k) of the laboratories contributing to TAI

PSFS : Access to PSFS evaluation reports

Calibrations : Documentation

GNSS status : list of GNSS calibration exercices (past and future)

GNSS results : results of GNSS calibration exercices

TWSTFT status : list of TWSTFT calibration exercices

Resources

Graphs

[UTC-UTC(k)] : Interactive plot of UTC(k) wrt UTC/UTCr

[UTC-GNSS] : Interactive plot GNSS times wrt UTC

PSFS contributions : Plot with Primary and Secondary Frequency Standards participating to TAI

Check the technical and administrative requirements.
When you feel ready at the technical level and your institute is compliant with BIPM rules, propose your contribution to the UTC

How a laboratory can contribute to UTC

CBKT

BIPM guidelines for the time laboratories to participate in the UTC are [CCTF WGMRA Guideline 8/2017.]
A UTC(k) lab should fulfill the following technical requirements to contribute its clock data to UTC

Criterion 1. Realization of local time scale, UTC(k), which represents a real time approximation of UTC:
The time scale UTC(k) shall be based on state-of-the-art commercial atomic clocks and should be maintained in close agreement versus UTC. The laboratory contributes its clock data to the realization of UTC

Criterion 2. Time Transfer Link:
There should be a calibrated equipment for time transfer. Commonly a GNSS time transfer receiver operated as per the BIPM guidelines (measurement data, format, sampling time, …)

Criterion 3. Measurement of clock performance with respect to UTC(k):
There should be the capability to measure the instantaneous value of the offset " UTC(k) - free running clock" at 00:00 hrs UTC on BIPM standard dates. In case UTC(k) lab has one or few clocks that have to be corrected by a time or frequency step, the corresponding corrections shall be recorded as well.

Criterion 4. Sharing the data with BIPM as per the BIPM format:
Upload these measured values with required information in the standard BIPM format with the requested periodicity and schedule.

Let's see each requirement in detail further….

Criterion 1. Realization of local time scale UTC(k), which represents a real time approximation of UTC

- A UTC(k) time scale is to be realized in real time from the output of one or more state of the art atomic clocks, maintained in appropriate environmental conditions to ensure their stability.

- A UTC(k) time scale can be realized as a minimum by an atomic clock and a GNSS receiver.

- The CCTF recommends that the designation “k” in UTC(k) refers only to those institutes that participate in the formation of TAI and appear in Section 1, UTC-UTC(k), of the monthly BIPM Circular T, https://www.bipm.org/en/committees/cc/cctf/15-2001/resolution-3

- The CCTF recommends that a UTC(k) time scale should be **with in 100 ns** of standard deviation with respect to UTC (Recommendation 1993)

- When the time laboratory realizes a UTC(k) time scale and contributes to the UTC, it will have access to the results of the BIPM computations as UTC-UTC(k) in the Circular T, and all other results available on https://webtai.bipm.org/database/, https://webtai.bipm.org/ftp/pub/tai/

Criterion 2. Time Transfer Link

i. The most common method to have a time transfer link is the **GNSS time transfer link** via GPS/GLONASS/GALILEO/BDS.

ii. Advanced time transfer can be achieved by a **TWSTFT** technique or optical fiber link.

iii. All links need to be calibrated. For example, GNSS equipment can be calibrated with the help of G1 or G2 laboratories through a travelling GNSS equipment, or by the GNSS receiver manufacturer. For complete information on calibration please see [TWSTFT & GNSS] .

iii. Time transfer data are to be submitted in the **agreed format as CGGTTS, RINEX, ITU**

If the time transfer equipment is not calibrated, can the lab participate to UTC?

- Calibration is a fundamental step to participate to UTC. Traceability and accuracy of UTC(k) time scale can only be ensured by calibrated, and periodically recalibrated, time transfer equipment.

- If the UTC(k) time transfer equipment calibration is outdated or temporary unavailable, the time transfer link is **no more a reliable and accurate measure** of synchronization of UTC(k) with UTC and **traceability** to UTC cannot be achieved.

- Since the stability of the UTC(k) time transfer equipment, and hence the capacity to measure clocks, is not affected by calibration, the clocks can still contribute to UTC, but this shall be a temporary situation

Criterion 3. Measurement of clock performance with respect to UTC(k)

- Only state of the art **free running atomic clocks can contribute to UTC**. They mostly are commercial Cs clocks and H masers.
- Any **new clock** that start contributing to UTC needs a unique clock code. You can generate your clock code here (Generate BIPM clock code).
- **Record of the measurements** of each clock compared against UTC(k) using a time interval counter or a phase comparator should be submitted to BIPM, according to the BIPM schedule and format. (Clock Data File guidelines). The needed measurements are UTC(k) - clock
- Only the instantaneous **measurements at 00:00 hrs UTC** shall be submitted. Usually some lab submit the average of the 30 - 300 seconds data around 00:00 hrs UTC in order to avoid any spurious values instead of a single measured value. This is acceptable as this small averaging does not affect significantly the performance of the clock.
- A new clock to start contributing to UTC is **assessed for at least 3 to 6 months** by BIPM to evaluate its frequency stability and to assign a weight in UTC.
- For any reason, if a single clock measurement is not submitted to BIPM in the monthly data submission, the **clock will be assigned zero weight** in the UTC. The performance of the clock will be re-assessed considering it as a new clock.
- Some clocks may be located outside the main laboratory and need to be connected by a calibrated national time link (see Data submission from remotely located clocks in Clock Data File guidelines)

One step more: the Mutual Recognition Arrangement

- **If you want to sell calibration services and issue certificates, you need a step more** demonstrating that your national measurements and certificates are equivalent to those of any other country
- You need to prove that your national standards are equivalent to others participating to the key comparison, i.e. CCTF- K001.UTC
- You need to demonstrate that you work in a Quality system
- You can then publish Calibration and Measurement Capability - CMC in the Key Comparison data Base - KCDB and offer services to the customers

See CCTF WGMRA Guideline 7 (201509) Participation in the ongoing key comparison in time CCTF-K001.UTC, https://www.bipm.org/en/committees/cc/cctf/wg/cctf-wgmra

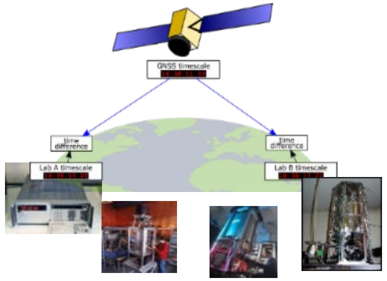
The International Atomic Time and the Universal Time Coordinated are the ultimate time reference but available

in deferred time

Local time scale UTC(k) are realised by national laboratories

in real-time

Construction of the Coordinated Universal Time



National time laboratories realize real-time approximations **UTC(k)**

≈ 450 atomic clocks
≈ 15 primary frequency standards

in ~ 85 laboratories

TAI

International Atomic Time

Measurement of Earth's rotation UT1 (by IERS International Earth Rotation and Reference Systems Service)

leap seconds

UTC

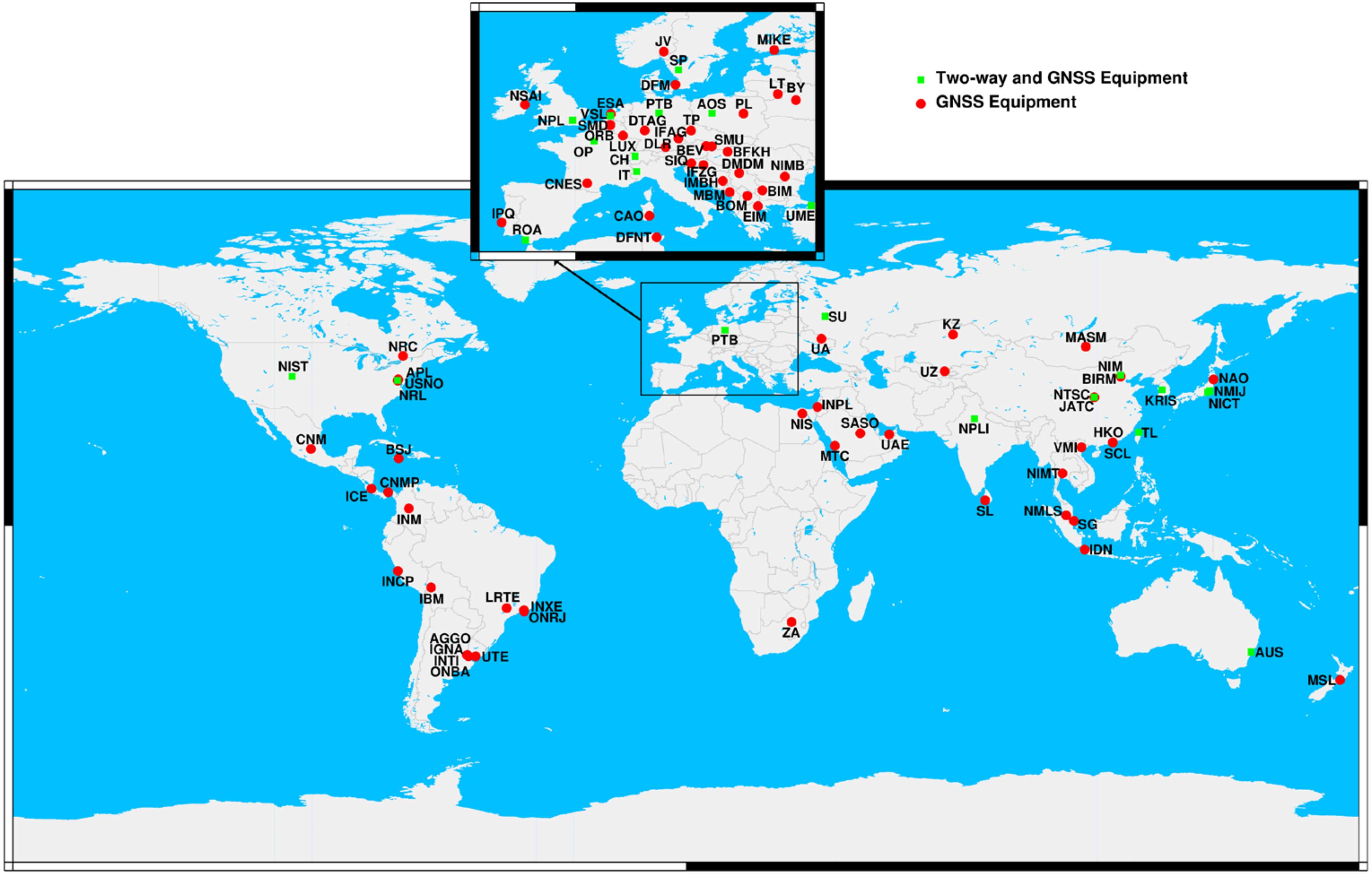
Coordinated Universal Time

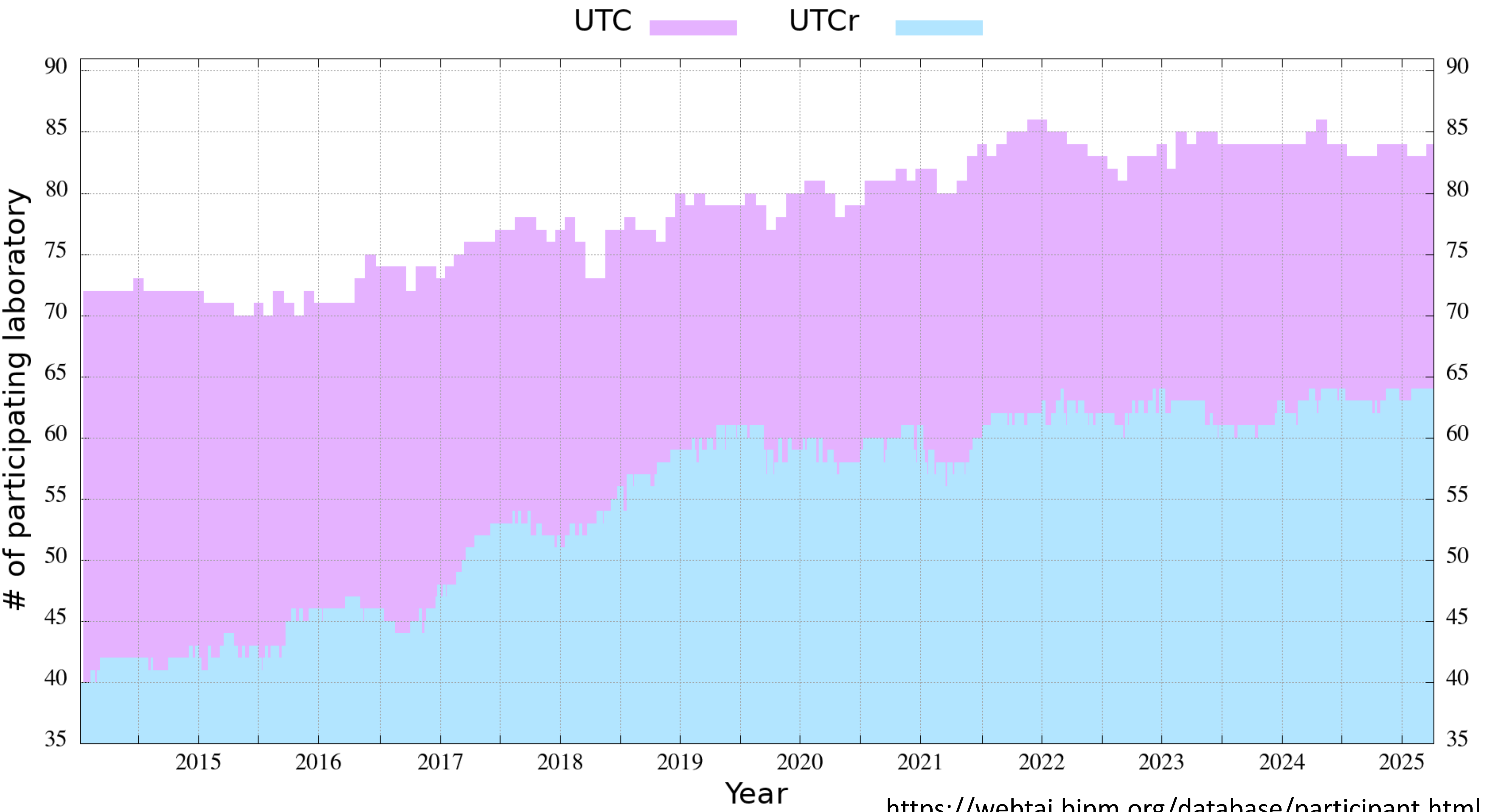
|UT1 – UTC| < 1 s

The offset **[*UTC* - *UTC*(*k*)]** is published in **BIPM *Circular T***

UTC definitive results each month
UTC Rapid solution each week
UTC(k) are national realizations in real time

UTC is based on ≈ 450 atomic clocks kept in ≈ 85 laboratories in the world



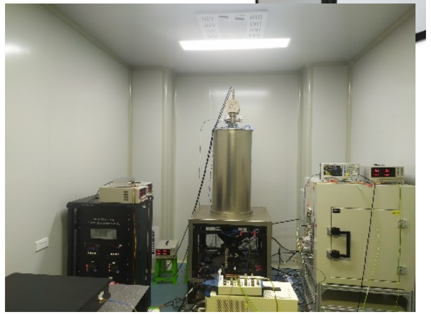


https://webtai.bipm.org/database/participant.html

About 450 Clocks participating in UTC

- Cesium clocks 55%
- Hydrogen masers 35%
- Others 10%

PTB-CS1
PTB-CS2



NTSC and USNO

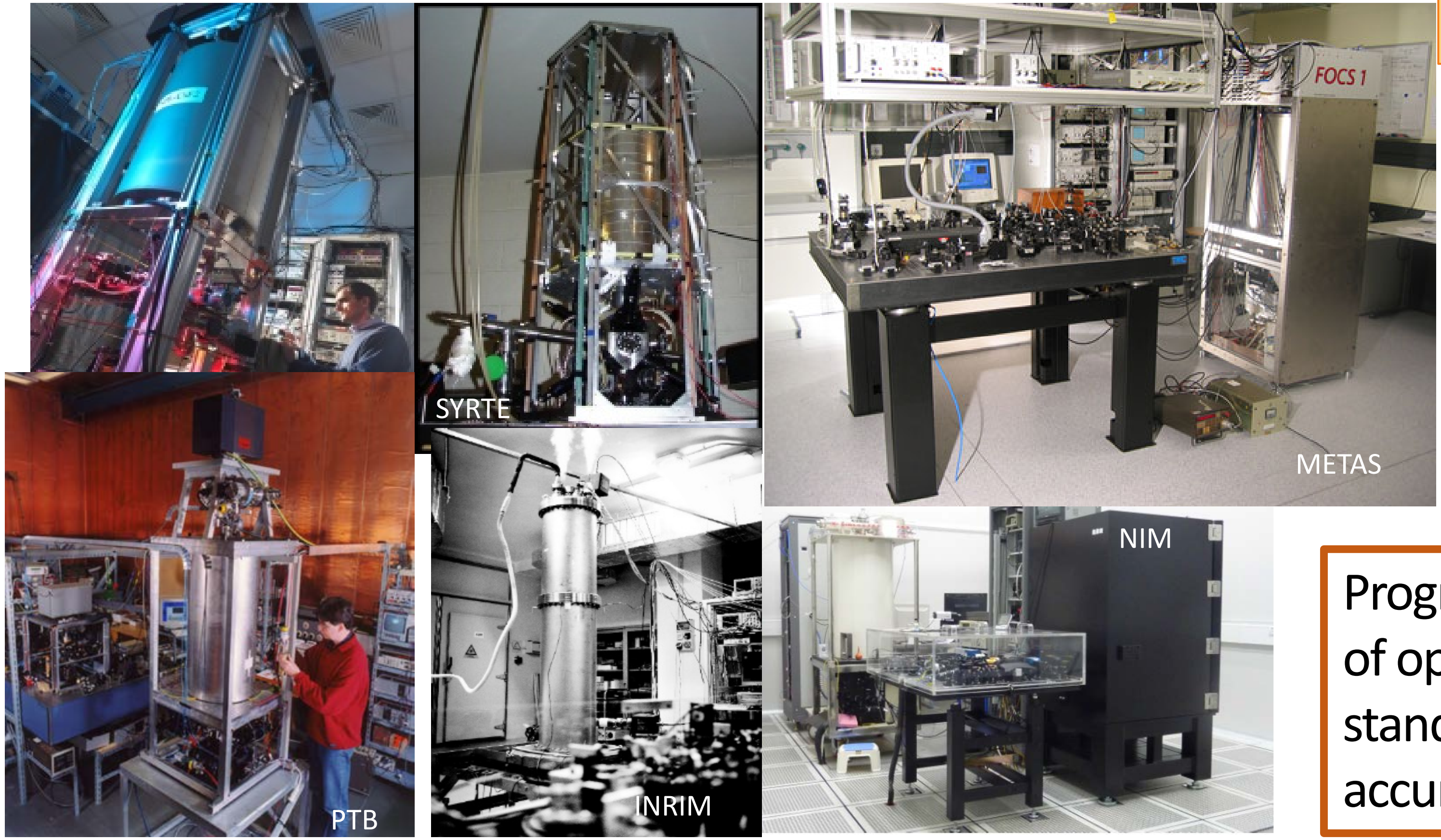
Rubidium Fountain

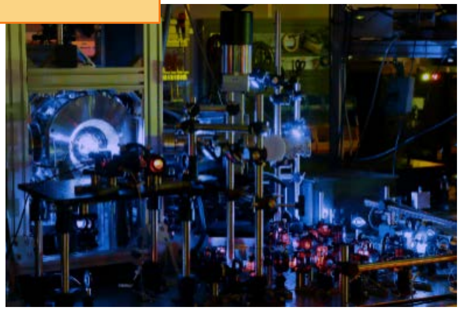
Primary frequency standards

About 12 laboratories operate primary frequency standards. Their uncertainty can be evaluated a priori by examining the different effects perturbing the Cesium atom

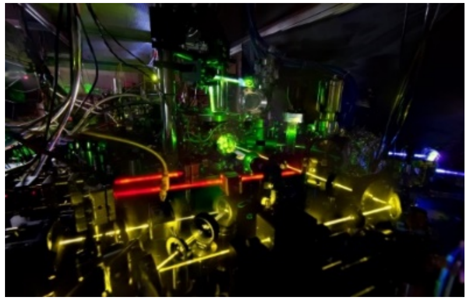
The uncertainty of Caesium primary fountains can reach 10^{-16}

3 nanoseconds accumulated in ~~1~~ 100 year

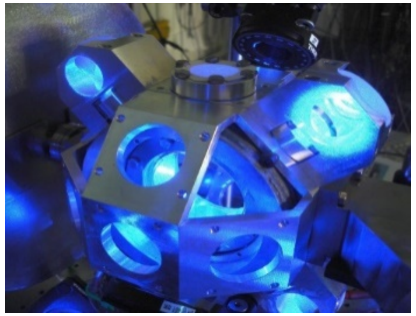




Sr lattice Clock (Photo: NICT)



Yb Lattice Clock (Photo: NIST)

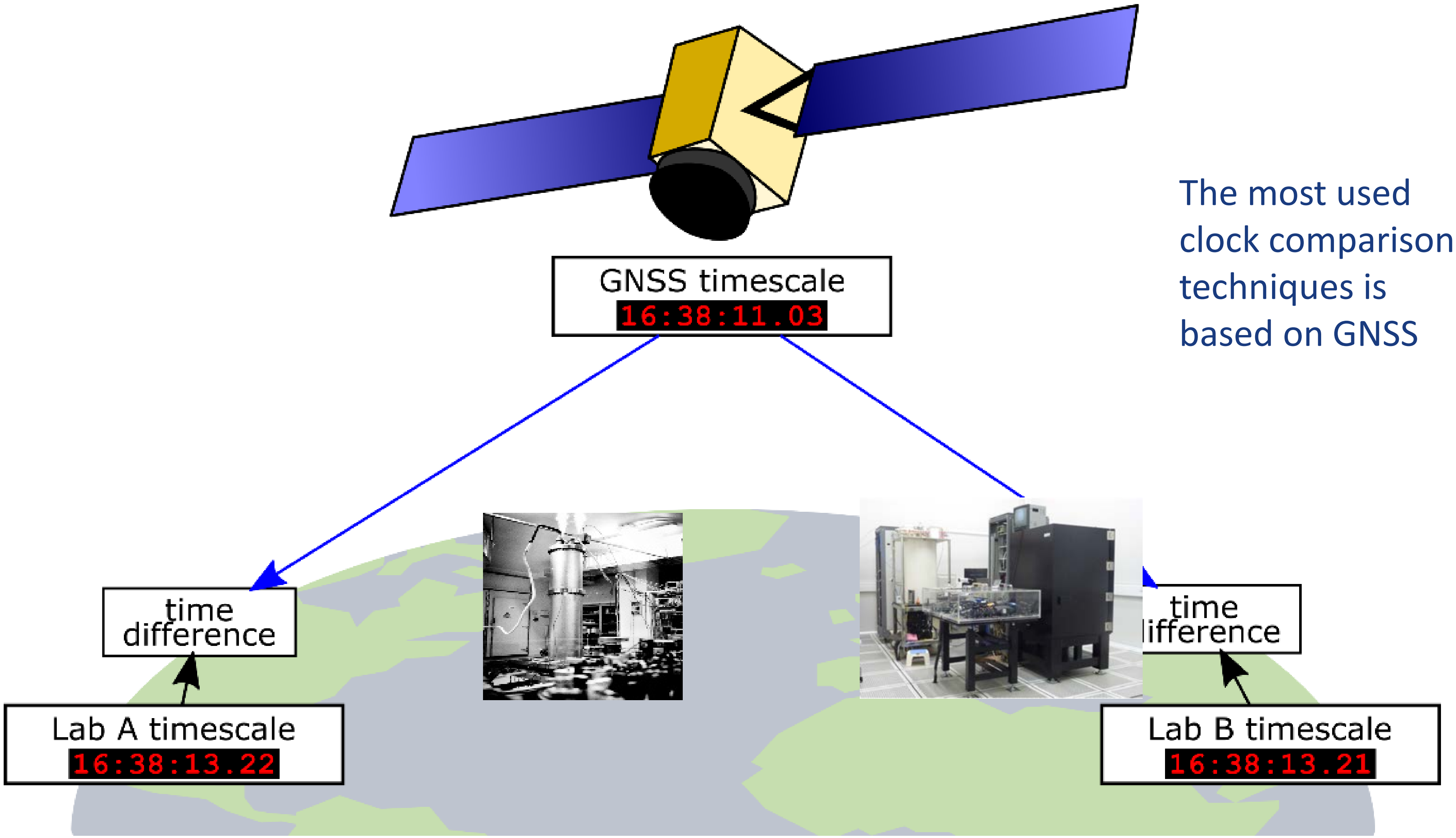


Sr Clock (Photo: LNE–SYRTE)

Progress in the construction of optical frequency standards allows now 10^{-18} accuracy

This is why we are working on the redefinition of the second

Clocks need to be compared

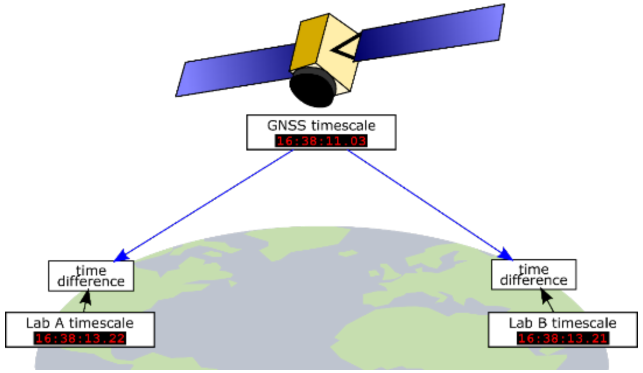


The most used clock comparison techniques is based on GNSS

Clocks in different laboratories are compared by suitable **time and frequency transfer techniques**

Global Navigation Satellite Systems (GNSS)

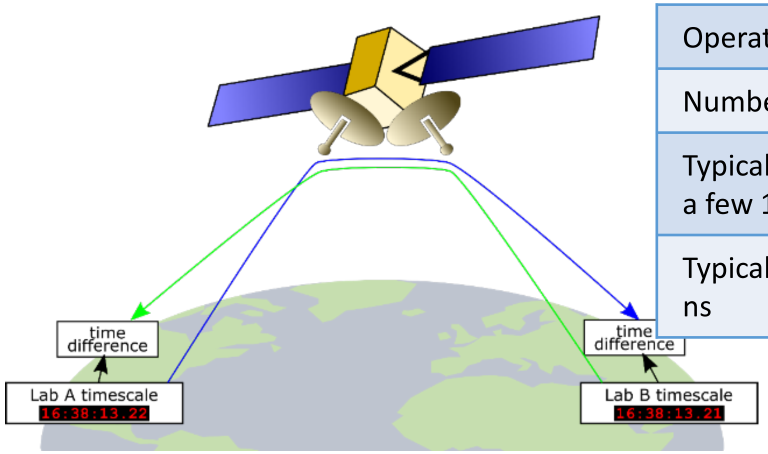
GNSS are based on time broadcasting from satellites to ground receivers (one-way time transfer). Distant labs equipped with GNSS receivers periodically compare their clocks to the broadcasted time and send the result to the BIPM.
Typical algorithms are All in View, Common View, and Precise Point Positioning



Operational since ~ 1980
Number of links : all contributing laboratories
Typical freq. transfer accuracy @1d : a few 10^{-15}
Typical time transfer accuracy : a few ns

Two-Way Satellite Time & Freq. Transfer (TWSTFT)

dedicated ground terminals simultaneously receive and transmit time transfer signals (two-way time transfer) on geostationary telecom satellites.
Two-way method cancels out (at first order) the propagation time of the signal.



Operational since ~2000
Number of links : 18
Typical freq. transfer accuracy @1d : a few 10-15
Typical time transfer accuracy : $\gtrsim$ 1 ns

Progress in GNSS measures

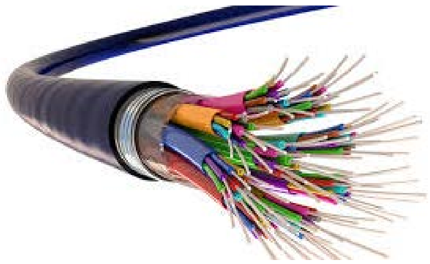
GPS+ GLONASS + Beidou + Galileo
IPPP : Precise Point Positioning with integer ambiguity resolution

Progress in TWSTFT

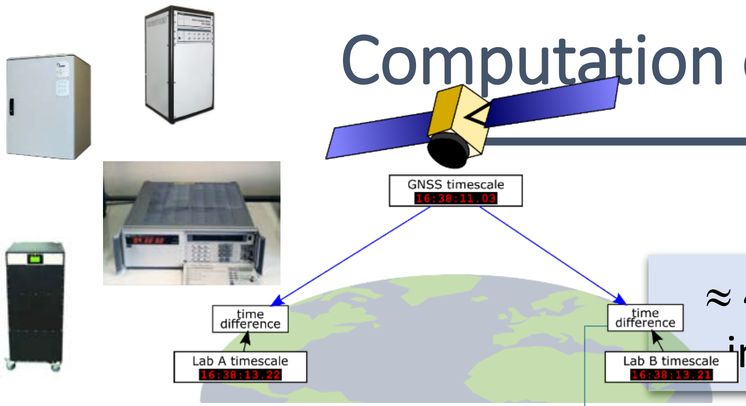
Software Designed Radio and TWSTFT Carrier Phase

In development : Optical Fiber links

A growing number of UTC laboratories are gaining access to fiber links dedicated to time and frequency. Although few of them are currently interconnected by operational, high-duty cycle links, this number is expected to grow quickly during the next decade.



Computation of UTC (monthly) at the BIPM

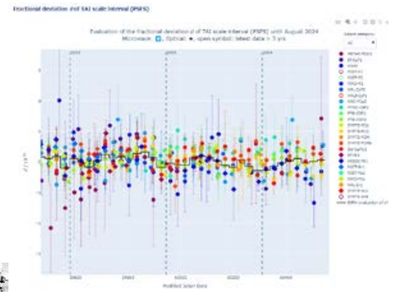


≈ 450 atomic clocks in 85 laboratories

weighted average

EAL

Echelle Atomique Libre
freq stability
3×10^{-16}
@ 30-40 days



≈ 10-15 primary and secondary frequency standards

frequency steering

TAI

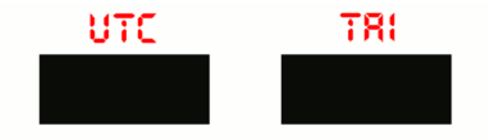
International Atomic Time
freq accuracy $\sim 10^{-16}$

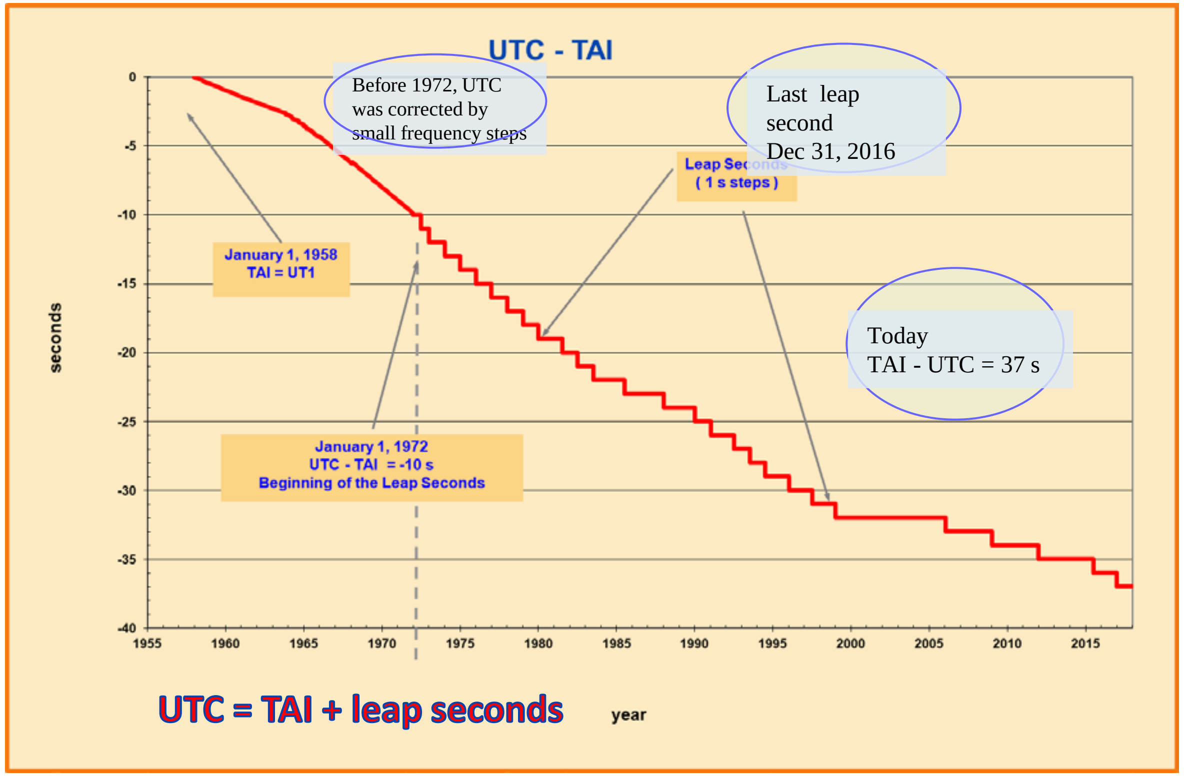
Coordinated Universal Time UTC is in agreement with the rotational angle of the Earth UT1

Timekeeping is related to the rotation of the Earth.

The real time timekeeping is based on atomic clocks and, since 1972, UTC is obtained from the International Atomic Time (TAI) plus leap seconds.

When the difference between the Earth rotational angle UT1 time scale and UTC reaches 0.9 second, an integer second is inserted to UTC to keep it within 1 s of UT1.



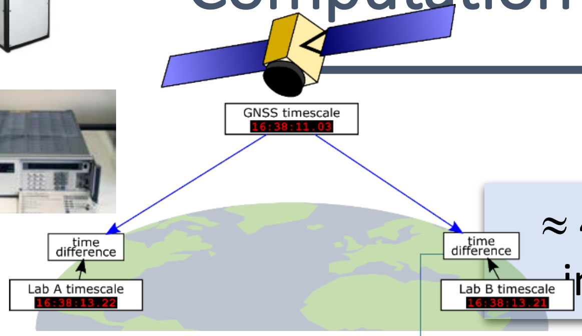


|UTC - UT1| < 1 second

UTC = TAI + n seconds

The process to insert the leap second and the code to transmit DUT1= UT1-UTC are described in Rec ITU-R TF 460-6

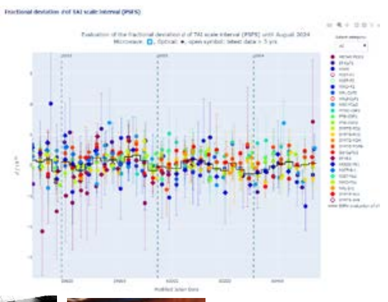
Computation of UTC (monthly) at the BIPM



≈ 450 atomic clocks in 80 laboratories

weighted average **EAL**

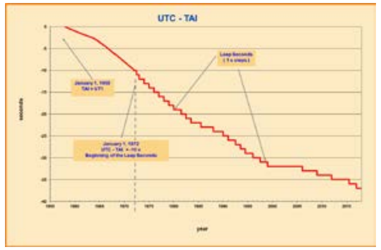
Echelle Atomique Libre
freq stability
3×10^{-16}
@ 30-40 days



≈ 10 primary and secondary frequency standards

frequency steering **TAI**

International Atomic Time
freq accuracy ~10^{-16}



Measurement of Earth's rotation (IERS)

leap seconds **UTC**

Coordinated Universal Time

[UTC - UTC(k)] **BIPM *Circular T***

The results are the differences **UTC- UTC(k)** of the previous month (or week with the rapid UTC solution)

Bureau International des Poids et Mesures

CIRCULAR T 447

UTC

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BUREAU INTERNATIONAL DES POIDS ET MESURES
THE INTERGOVERNMENTAL ORGANIZATION ESTABLISHED BY THE METRE CONVENTION
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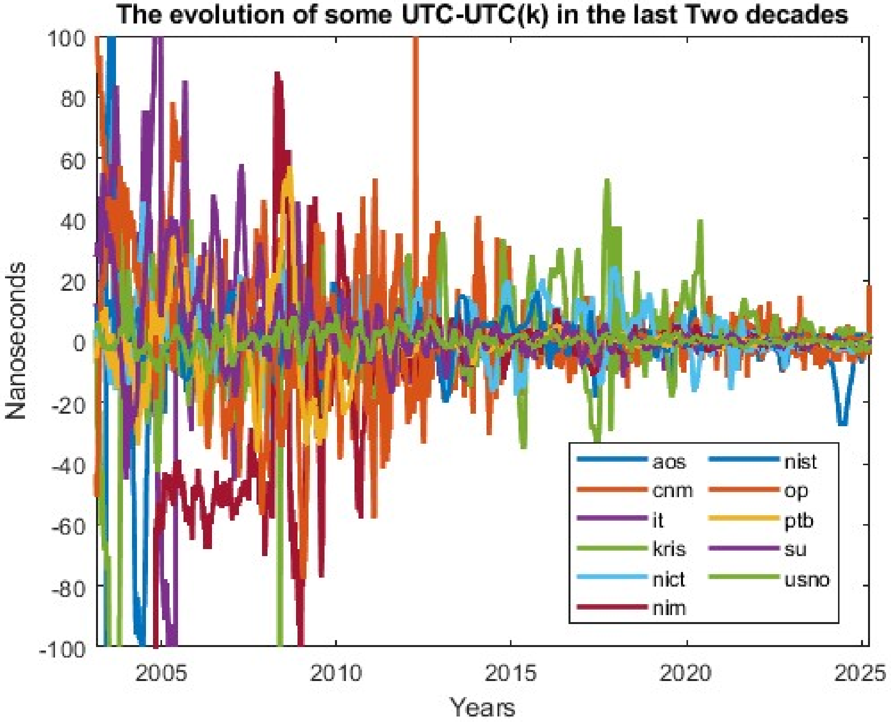
The contents of the sections of BIPM *Circular T* are fully described in the document " Explanatory supplement to BIPM Circular T " available at https://webtai.bipm.org/ftp/pub/tai/other-products/notes/explanatory_supplement_v0.8.pdf

1 - Difference between UTC and its local realizations UTC(k) and corresponding uncertainties. From 2017 January 1, 0h UTC, *TAI-UTC* = 37 s.

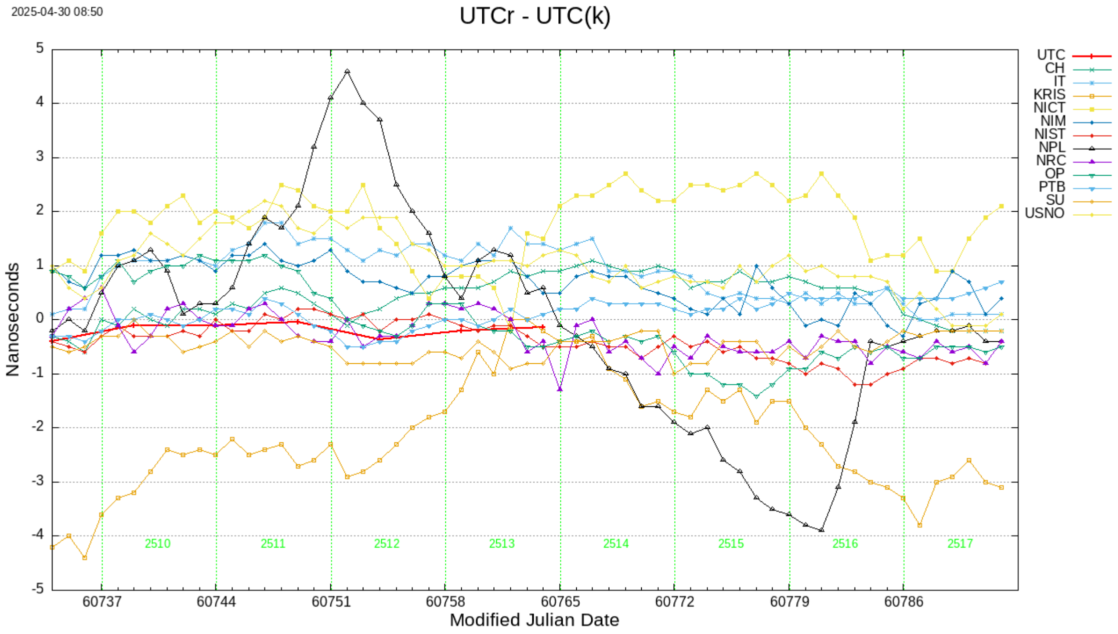
Date 2025 0h UTC		FEB 28	MAR 5	MAR 10	MAR 15	MAR 20	MAR 25	MAR 30	Uncertainty/ns			Notes
	MJD	60734	60739	60744	60749	60754	60759	60764	u_A	u_B	u	
Laboratory *k*					[*UTC-UTC*(*k*)]/ns							
AGGO	(La Plata)	427.9	416.1	407.1	410.8	426.7	412.6	405.9	0.7	3.0	3.1	
AOS	(Borowiec)	-0.8	-0.9	-1.5	-1.1	-1.5	-1.7	-1.7	0.2	2.7	2.7	
APL	(Laurel)	1.3	1.6	1.0	-0.1	0.4	0.5	1.3	0.2	NC	-	
AUS	(Sydney)	17.5	-2.3	3.3	0.6	-0.9	-9.8	8.8	0.2	3.0	3.0	
BE							2.8	31.2	0.2	3.0	3.0	
BF							9.5	1886.4	0.7	7.1	7.1	
BIM							3.3	3659.2	0.2	2.7	2.7	
BIR							1.4	0.8	0.2	3.5	3.5	
BS							7.7	28.0	7.0	7.1	10.0	
BY							-0.6	-0.3	1.5	3.1	3.4	
CA							5.6	-20563.8	0.7	NC	-	
CH							0.7	1.0	0.2	1.0	1.0	
CN							1.0	1.0	0.2	3.1	3.1	
CN							-4.2	6.1	3.0	4.4	5.3	
CN							1.0	2.8	0.2	5.5	5.5	
DF							-3.4	-4.1	0.2	2.8	2.8	
DF							7.4	-8573.6	0.7	2.7	2.8	
DM							1.6	-	0.2	7.4	7.4	
DT							9.7	18.8	0.2	3.4	3.4	
ES							-0.6	-0.9	0.2	2.8	2.8	
HK							4.1	81.4	0.4	3.7	3.7	
IBM							1.4	354.4	4.0	7.6	8.6	
ICE							4.1	-33.7	0.2	7.1	7.1	
IDN							4.1	-736.8	0.2	NC	-	
IFA							0.2	-692.1	0.2	3.2	3.2	
IFZ							1.8	120.4	0.2	2.7	2.7	
IGN							-	-				
IMI							4.8	3.1	0.2	2.8	2.8	
INO							0.4	1.3	5.0	NC	-	



Today we get:

Time uncertainty at best at 1-2 ns (many labs are at 5-10 ns, a few > 20 ns)

Relative frequency uncertainty at best 10^{-16}
(commercial clocks at 10^{-12})



FTP products – what's available ?

List of products :
https://webtai.bipm.org/ftp/pub/tai/readme.pdf

Available products on ftp2.bipm.org (machine/non-machine readable):

TXT

Bulletins

- Circular T
- Rapid UTC

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(BIPMYY)-TAI

PSFS

- f(TAI)-f(PSFS$_i$)
- f(TAI)-f(PSFS)
- PSFS reports

PDF

Equipment diagnostics

- Clock weight
- Clock rate
- Clock drifts
- Time links
- Link comparisons

FTP products – data files examples

(List of products : https://webtai.bipm.org/ftp/pub/tai/readme.pdf)

UTC-UTC(NIST)

UTC-GNSS related time scales

This file contains: # # col 1 : MJD /day # # col 2 : UTC-bUTC_GNSS /ns # # col 3 : UTC-GNSST /ns # # col 4 : sigma /ns # # col 5 : used receivers

```
60756    2.4    2.6    5.0  IM02,NC5S,NISG,OP73
60757    2.3    2.2    5.0  IM02,NC5S,NISG,OP73
60758    2.9    1.8    5.0  IM02,NC5S,NISG,OP73
60759    0.5    1.4    5.0  IM02,NC5S,NISG,OP73
60760   -0.2    1.0    5.0  IM02,NC5S,NISG,OP73
                                S,NISG,OP73
                                S,NISG,OP73
                                S,NISG,OP73
                                S,NISG,OP73
```

You can develop your **own scripts** in any language
to implement **diagnostic** and **monitoring tools**
based on these available results in an automated way !

Clock weights

Fractionnal deviation (d)

UTCr-UTC(NIST)

Consultation portal – https://webtai.bipm.org

HTML TXT CSV

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
- Dissemination services

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

Calibrations
- GNSS status
- GNSS results
- TWSTFT status

Resources
- Graphs
  - [UTC-UTC(k)]
  - [UTC-GNSS]
  - ...ation d
- ...ck stats and codes
- Get clock code
- Time scales

Web services
- API Time scales
- API CCL-CCTF
- FTP results

Home
- Sitemap
- Newsletter
- Contact us

➔ Always up-to-date !

➔ Guidelines for participation (file f... ...ules…)

...atus of participating laboratories
- *Time transfer equipments*
- *Calibrations*
- *Clocks distribution*

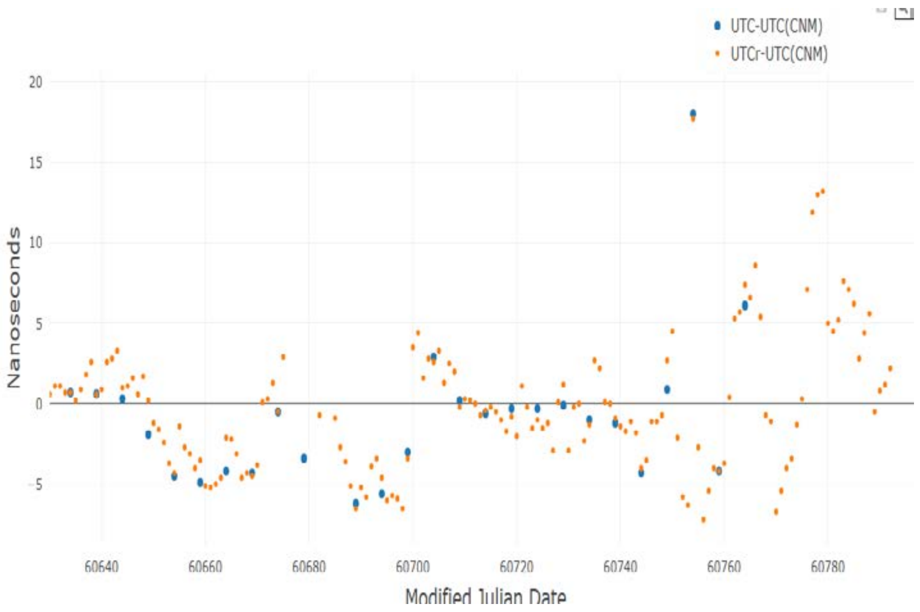
➔ Plots of the products
- *UTC-UTC(k)*
- *UTCr-UTC(k)*
- *UTC-GNSSTimes*
- *f(PSFS) vs f(TAI)*

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

Consultation portal

https://webtai.bipm.org

Available on-demand dynamic plots:



Bureau International des Poids et Mesures

BIPM Time Department Data Base

Participation guidelines | Participants | Lab. equipment | Clocks | Calibrations | Interactive pl

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

Calibrations on-going

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

Calibrations listing

Past GNSS calibration exercises

CAL_ID	Author	Comment/report	Validation date
1101-2021	ROA	1101-2021_GPSP3C1-GALE3_ROA-TC_V1-0.pdf	2021-03
1011-2021	PTB	1011-2021_GPSP3-GALE3_INRIM_V1-1.pdf	2021-03
1106-2020	internal TC	1106-2020_GPSP3_SP-TC_V1-0.pdf	2020-09

Calibrations results

GPS calibration results : GPS

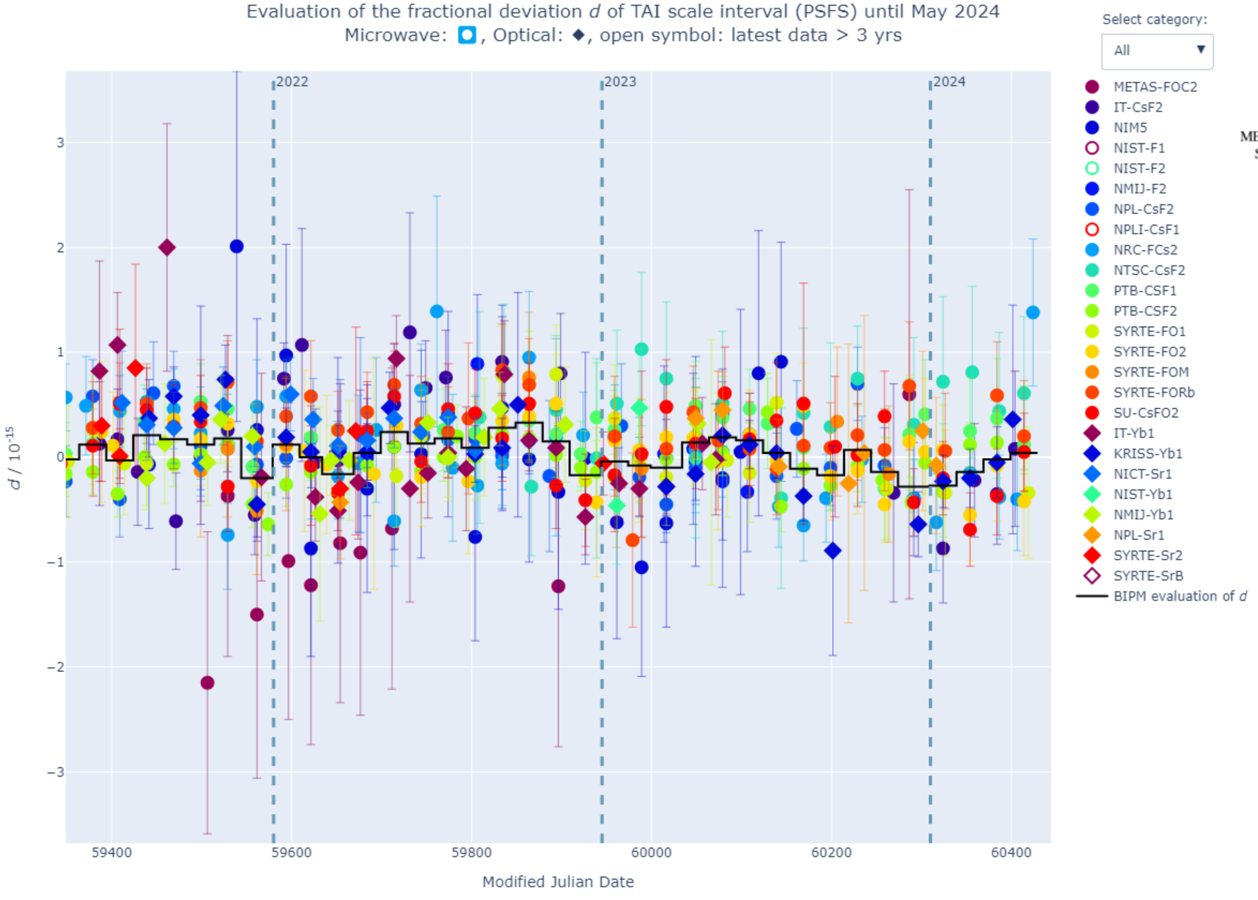
Calibration trip (Cal_ID) information						GPS calibration results (ns)															
Report	Laboratory	Receiver BIPM ID	Date Calib	Author	Calib. trip type	Delays from calibration trip													Calibration uncertainties		
all	ORB	all	up|down			CAB	REF	INT C1	INT P1	INT P2	SYS C1	SYS P1	SYS P2	SYS P3	TOT C1	TOT P1	TOT P2	TOT P3	uCal0 (C/A)	uCal0 (P3)	ΔuCAL
1011-2020	ORB	OR5Z	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

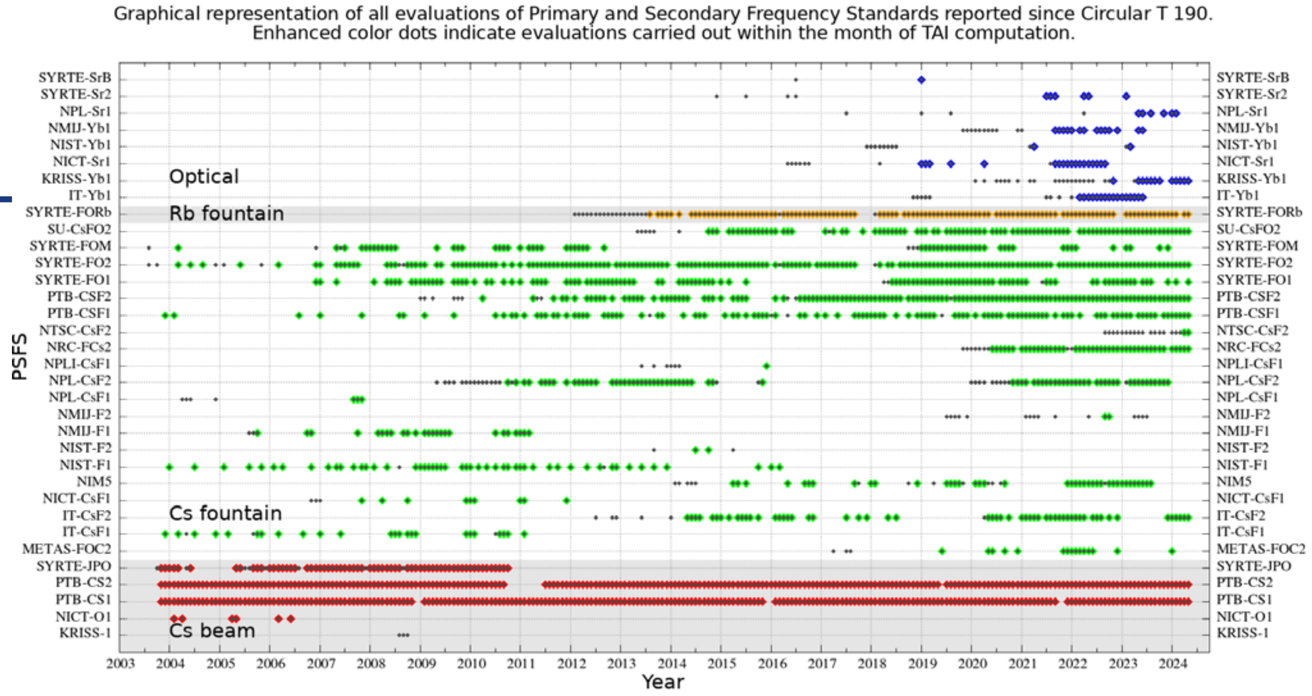
GALILEO calibration results : Galileo

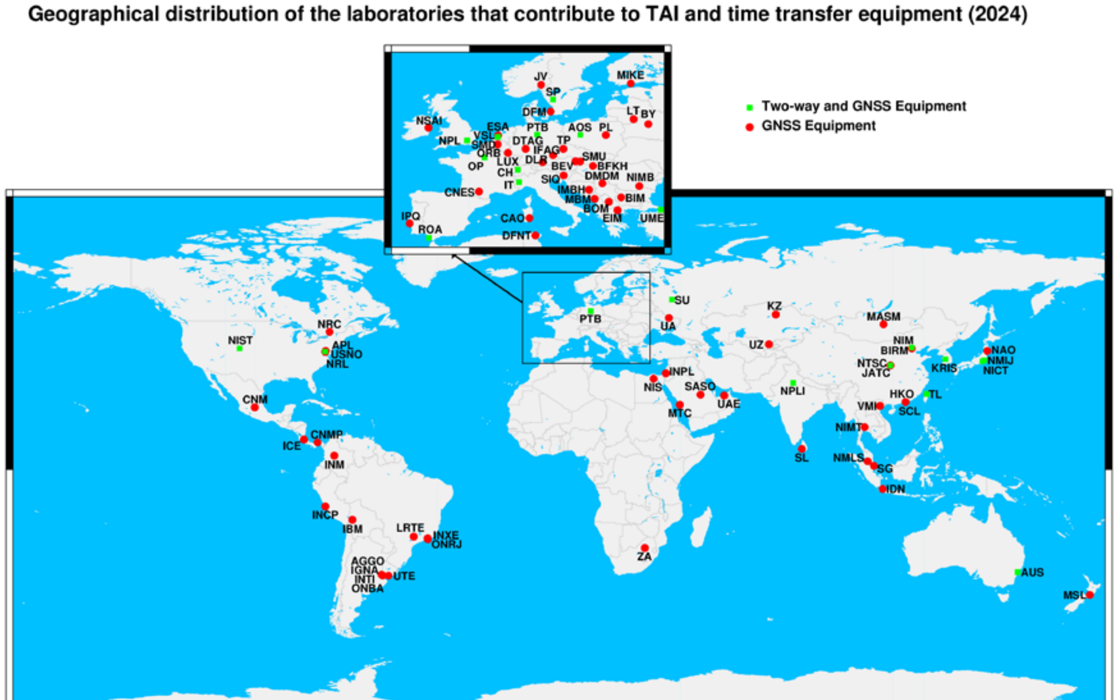
Calibration trip (Cal_ID) information						GALILEO calibration results (ns)										
Report	Laboratory	Receiver BIPM ID	Date Calib	Author	Calib. trip type	Delays from calibration trip								Calibration uncertainties		
			up|down			CAB	REF	INT E1	INT E5a	SYS E1	SYS E5a	TOT E1	TOT E5a	uCal0 (E1)	uCal0 (E5a)	ΔuCAL
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

Consultation portal

PSFS contributions







Consultation portal

HTML CSV TXT

https://webtai.bipm.org

Equipment inventory of participating laboratories :

- GNSS receivers

Laboratory	Receiver BIPM ID	Station	Model	Serial Number	REC #	ANT #	ANT TYPE	Cal_ID	Introd. date	Last CGGTTS
all	all		all		* information based on RINEX files header			all		
AGGO	TC_2	tc_2	PolaRx5TR	3228290						59366
AOS	AO_1		TTS-2	023				1005-2008		59366
AOS	AO_2		TTS-3	002				1005-2008		59366
AOS	AO_3		TTS-3	035						59367
AOS	AO_4	ao_4	TTS-4	112		00271	AOAD/M_T NONE	1014-2018	58941	59367

- TWSTFT

Station (Lab 1)	Station (Lab 2)	Cal_ID	Calib. Date
show lab all		all	
AOS01	PTB05	0449-2017	2017-07-01
AOS01	PTB05	0520-2021	2019-09-18
CH01			2019-09-18

- Clocks

Laboratory	BIPM clock code	
KRIS	1350321	
KRIS	1350739	
KRIS	1351135	MICROSEMI 5071A HIGH PERFORMANCE TUBE.
KRIS	1351693	MICROSEMI 5071A HIGH PERFORMANCE TUBE.
KRIS	1351783	MICROSEMI 5071A HIGH PERFORMANCE TUBE.

➔ Please check your information and inform us in case of update need !

API UTC (2020)

JSON CSV TXT https://webtai.bipm.org/api

We developed an Application Programming Interface web service to allow machines and applications to collect data according to custom requests.

The documentation describing the use of the API is accessible at https://webtai.bipm.org/api

It allows retrieving data under TXT, CSV or JSON format.

Currently, only [UTC-UTC(k)], [UTCr-UTC(k)]

and [UTC-GNSS times] are proposed.

The service is planned to provide a larger variety

of data in the future…

BIPM Time Department API Web Service

Overview

To answer the need of providing machine readable data, the BIPM Time Department started providing access to machine readable data through automatized process.

Results are still available using FTP protocol, this remains unchanged. In addition to the historical FTP access, it is proposed an application programming interface (API) using GET method which gives access to machine readable data regarding various time scales. The method to access these data is using HTTP/HTTPS protocol: This can be done using utilities to transfer data from a server (such as cURL, wget or any programming languages supporting HTTP protocol). Data are provided in standard exchange format, such as JSON, CSV and text.

Execution documentation

Custom requests syntax and arguments

The API using GET method uses URL general syntax below :
`https://webtai.bipm.org/api/v0.2-beta/get-data.html?arg1=xxxx&arg2=yyyy` …
Using as many arguments as needed by your query.

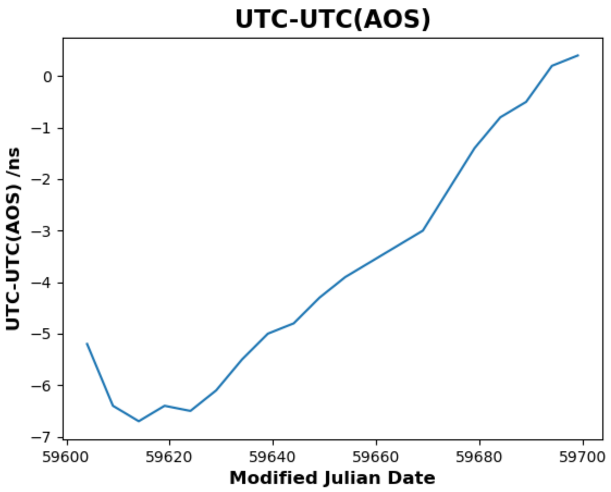
- customized period
  To get only a subset of available data between given two MJDs, following URLs should be completed with:
  `&mjd1=59000&mjd2=59200` (example for request between MJD 59000 and 59200)

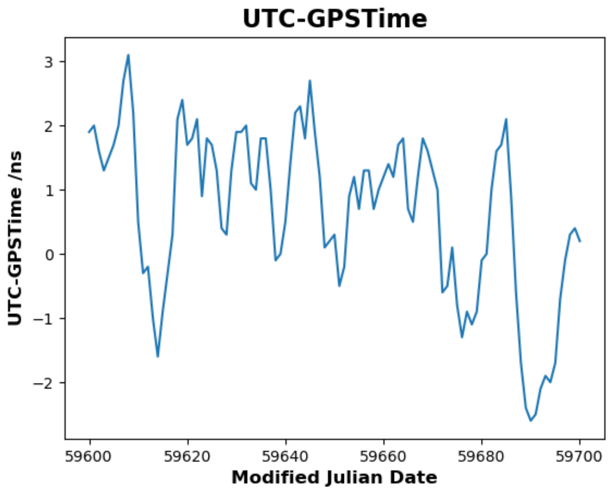
API UTC (2020)

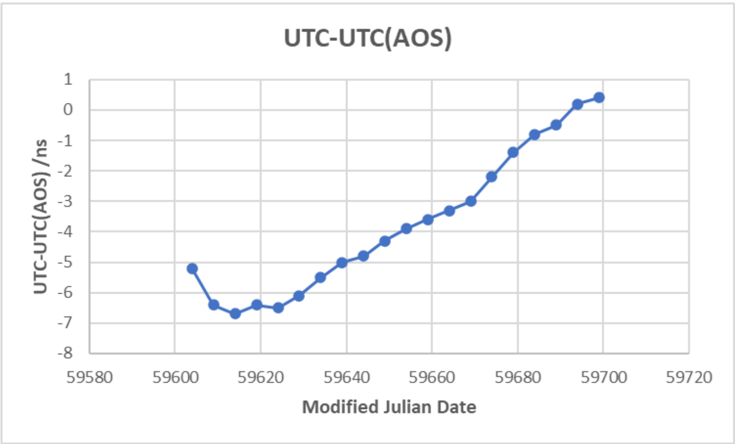
```
$ wget https://webtai.bipm.org/api/v0.2-beta/get-data.html?scale=utc&lab=AOS
$ curl -k --url "https://webtai.bipm.org/api/v0.2-beta/get-data.html?scale=utc&lab=AOS"
```

standard exchange file formats:
allow use of coding libraries already existing to handle data !

What is ns?



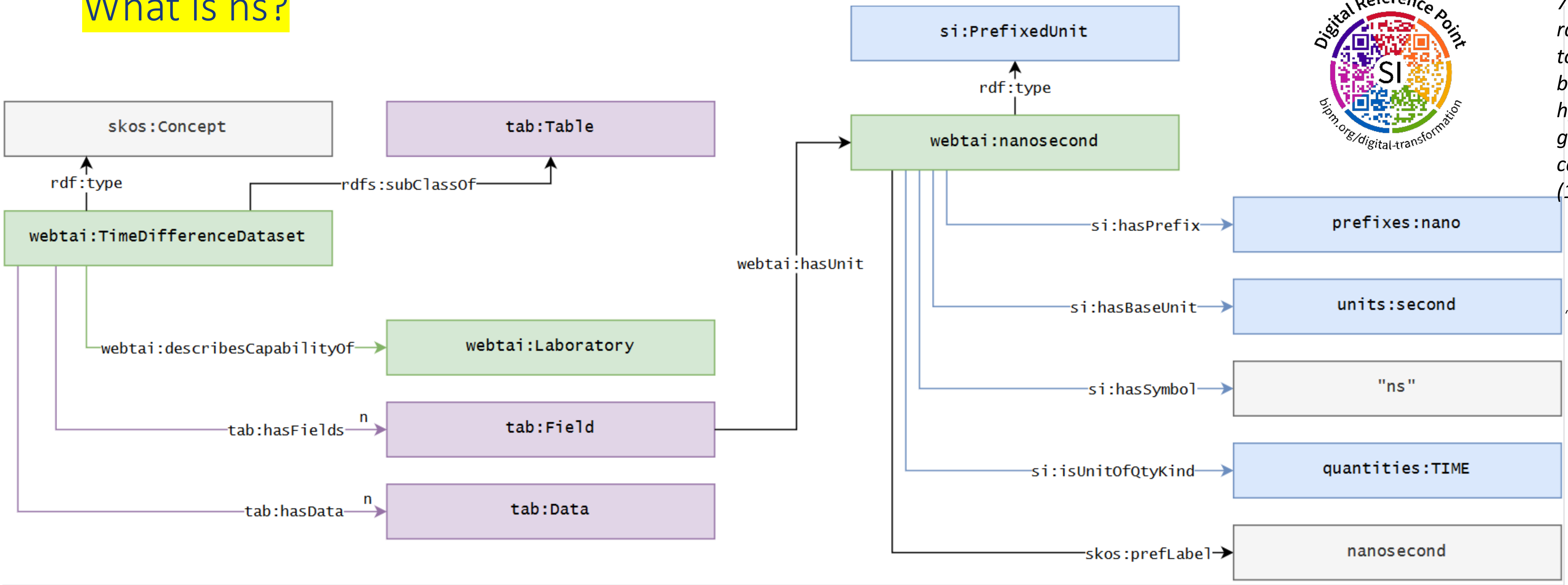




How to improve the description of the retrieved data?

We work towards enhancing the semantic content of UTC – UTC(k) products by connecting to the SI Reference Point

What is ns?



The second is the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium 133 atom (1967)

Example of a representation of a knowledge graph node, using subject/predicate/object triples to model the relationships

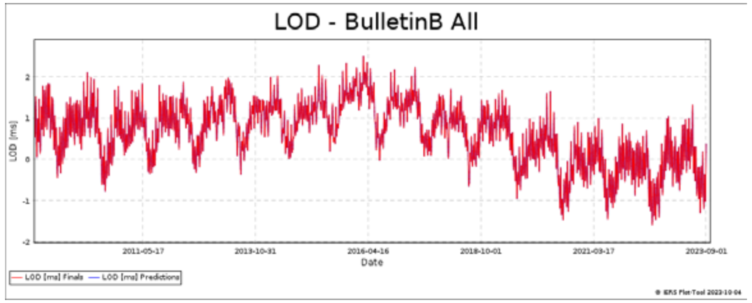
Coordinated Universal Time

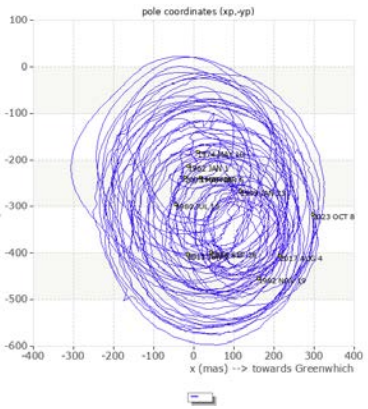
something is changing…

the CCTF at work…

the Earth rotation rate is not constant, and not enough well known to be predictable

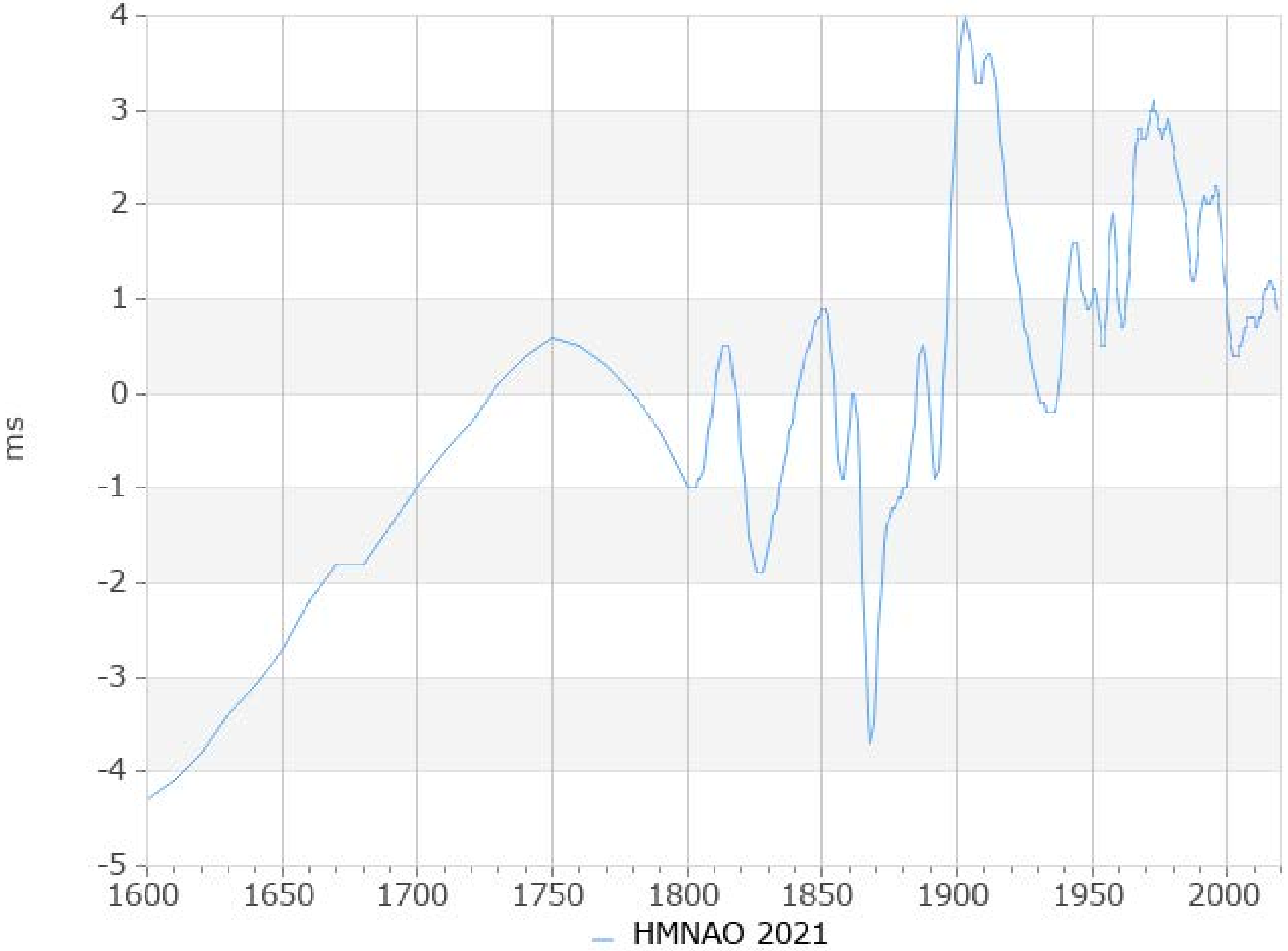
the leap second is decided with 6 month notice, when necessary





Secular slowing down

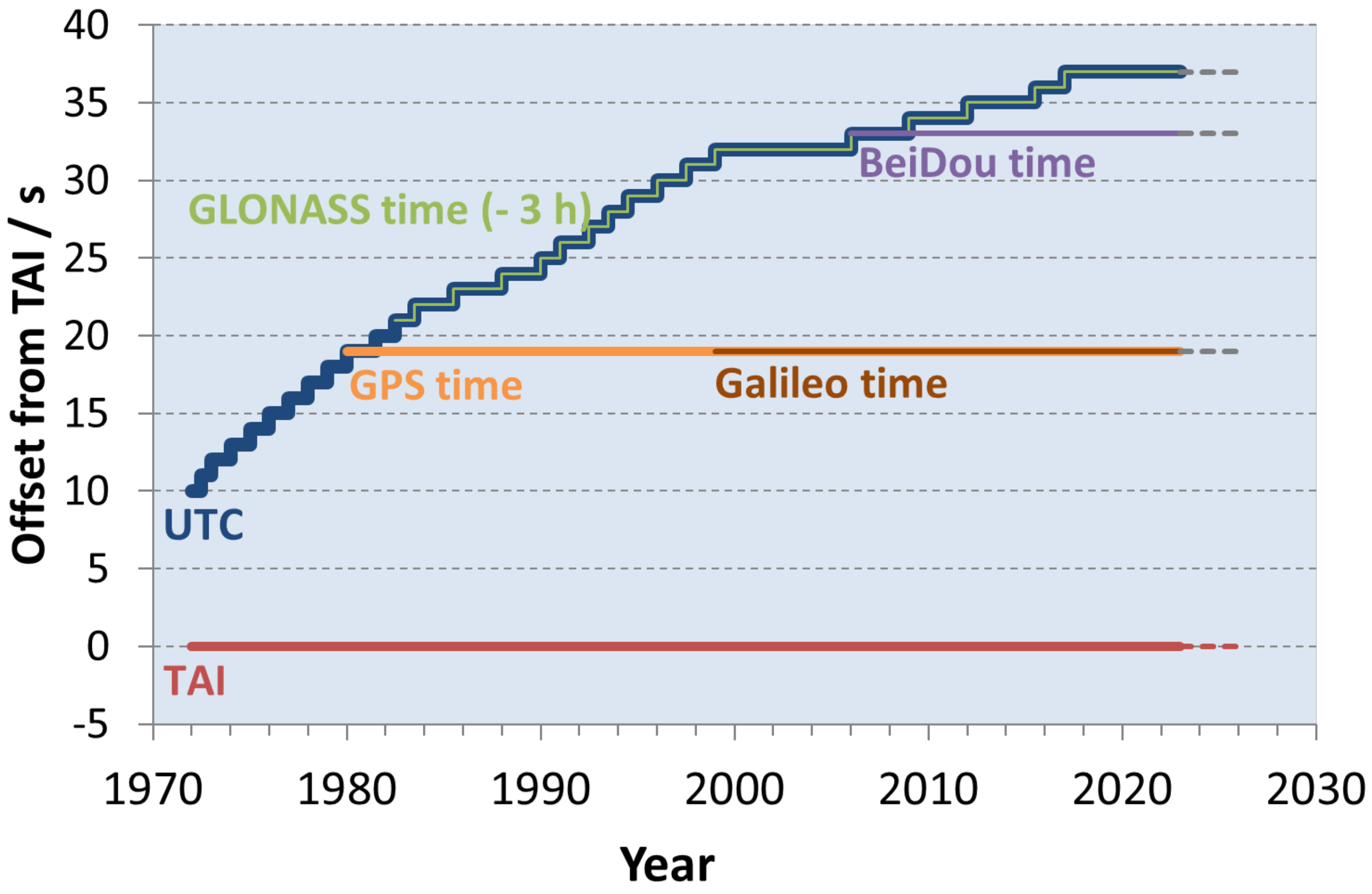
LENGTH OF DAY exceeding 86400 s



http://www.iers.org *International Earth Rotation and Reference Systems Service*

Global Navigation Satellite System (GNSS) need a continuous time scale

GNSSs prefer a continuous time scale and do not add leap seconds on their GNSS time scale (except GLONASS which applies leap seconds). These time scales are easily available all over the world, are commonly used as time and frequency references, and differ from each other and from UTC by several seconds



The digital networks cannot cope with unpredictable leap seconds

Consultative Committee on Time and Frequency User Survey (2021)

- > 200 answers
- The large majority asks to get rid of discontinuities in UTC
- GPS time and TAI are used, instead of UTC, as continuous time scales

WIRED — The Inside Story of the Extra Second That Crashed the W

BUSINESS | CULTURE | GEAR | IDEAS | SCIENCE

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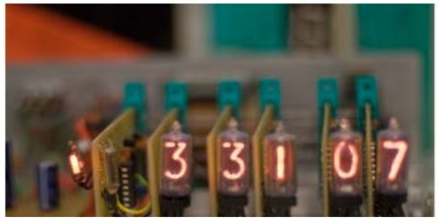
ROBERT MCMILLAN AND CADE METZ — BUSINESS 07.02.12 07:54 PM

The Inside Story of the Extra Second That Crashed the Web



自由時報 Liberty Times Net

https://3c.ltn.com.tw/news/18985/2

61 seconds in a minute? Understand the computer and the stock market enemy "leap second"

2015/07/01 06:27

Text/Reporter Liu Jiqing

Leap second hits Qantas air bookings, while Reddit and Mozilla stutter

The addition of an extra second between Saturday and Sunday to account for the slowing rotation of the Earth affected flight check-ins in Australia, and hit popular websites including Yelp and Foursquare

More than 400 Qantas flights were delayed when the 'leap second' confused web servers on Sunday. Photograph: Mark Baker/AP

The Telegraph

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Politics | Investigations | Obits | Education | Science | Earth | Weather | Health | Royal | C

Science News | Dinosaurs | Space | Night Sky | Evolution | Picture Galleries | Science Video

HOME » NEWS » SCIENCE » SCIENCE NEWS

Leap Second confuses Twitter and Android

Users reported problems with Android and Twitter as the leap second was added to atomic time

IDG TECH(Talk) · IoT · 2-minute Linux tips · Newsletters · Resources/White Papers

NETWORKWORLD FROM IDG

'Leap second' snafu affects Oracle clusterware

By Chris Kanaracus

U.S. Correspondent, IDG News Service | JANUARY 06, 2009 12:00 AM PT

DIGITAL MAGAZINE | EVENTS & AWARDS PROGRAMS | VIDEO

Time Waits for No One: 'leap Seconds' May Be Cut | Security Implications of the Humble Computer Clock | The Big Promise of Big Data | Hadoop Enhance

NEWS

Leap Second Bedevils Web Systems Over Weekend

Reddit, LinkedIn and other sites were knocked offline by an extra second added to the official time

By Joab Jackson

U.S. Correspondent, IDG News Service | JULY 02, 2012 08:00 AM PT

Time travels on the network

Computer operating systems are not easily able to handle a minute with 61 seconds https://engineering.fb.com/2022/07/25/production-engineering/its-time-to-leave-the-leap-second-in-the-past/

POSTED ON JULY 25, 2022 TO PRODUCTION ENGINEERING

It's time to leave the leap second in the past

By Oleg Obleukhov, Ahmad Byagowi

The leap second concept was first introduced in 1972 by the International Earth Rotation

INTERNATIONAL UNION OF RADIO SCIENCE
UNION RADIO-SCIENTIFIQUE INTERNATIONALE
info@ursi.org www.ursi.org

XXXIVth General Assembly and Scientific Symposium
Rome 2021

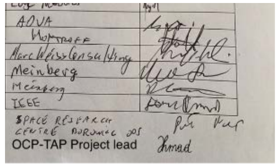
Council IV
Vote on URSI Resolutions

GASS 2021 : Vote on URSI Resolutions and Recommendation

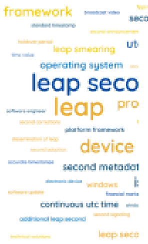
R1. Resolution on the need for a continuous reference time scale

The URSI Council,

Industry Perspectives & Insights on Impacts of Leap Seconds Practice in UTC Time Scale



Companies and trade association members from IT, Timing and Electric Power industries articulate their insights into impacts of leap seconds practice in UTC time scale on their products and services, as well as their customers. From this collective experience, a shared preference emerges for a continuous UTC time scale without additional leap seconds.



Contact information at
available from Dr. Patr

May 1, 2022

IGS INTERNATIONAL GNSS SERVICE

Statement on Leap Second

The International GNSS Service (IGS) publishes many GNSS analysis products based on satellite data collected from a network of over 400 ground stations. In keeping with the IGS's legacy conventions, data and product records have timestamps aligned to TAI – 19 seconds making its timescale consistent with GPS System Time, Galileo System Time and QZSS System Time. These timestamps vary, however, with respect to UTC depending on the present number of leap seconds.

Systems underpinning critical infrastructures, need a continuous timescale
Several "ah hoc" methods have been developed to avoid leap seconds

- Ignore leap seconds after an initial synchronization
  - GPS, Galileo, BeiDou system times.
  - Most current versions of Windows (till next synchronization)
- Stop clock for 2 seconds at 23:59:59 or 00:00:00
  - Network Time Protocol, Posix time on many computers
  - Two seconds have same name
  - Problems with causality, time ordering, time intervals
  - Leap second has no indicator
- Reduce frequency of clock over some interval
  - Google (24 h before), Microsoft, Facebook (18 h after), Alibaba (12 h before – 12 h after) …

All of these methods are not in agreement with UTC on the leap second day, and many disagree with each other

Users cannot tell which method is used by a time source, especially a posteriori

Leap second and the alternative methods threatens the resilience of the synchronization

The leap second process in UTC needs to be revised
The CCTF is working

Solution to progress towards a continuous UTC

Increase the tolerance between the Earth rotation and UTC: |UT1 - UTC| to a new limit (e.g. 100 seconds reached after ≈1 century or 1 hour reached after ≈ 3 - 5000 years) or to an unlimited value (= the difference UT1 – UTC will be let growing with no limit).

→ **UTC remains linked to UT1**, the Earth's rotation angle, whose origin is the reference meridian of Greenwich.

In the daily life, there is no change for the general public since the evolution of |UT1 - UTC| will remain negligible compared to the +/- 15 min seasonal day variations, for centuries. The general perception of conformity to astronomical phenomena is not challenged.

Users needing the knowledge of UT1-UTC find accurate and real time estimations by the services of IERS, NASA, GNSS, ITU-R broadcast signals

In the '70s UTC was used as approximation to UT1 mostly for navigation with traditional optical instruments.

Approximation UTC ≈ UT1 corresponds to an uncertainty in the position up to 400 m (at the equator). It is used only in low accuracy applications (as amateurs telescope pointing).

But it is not adapted for high precision applications (as high accuracy astronomy and space applications) that are already using the IERS and NASA estimates with 10 microsecond uncertainty, corresponding to about 0.3 cm uncertainty in the position

CGPM 2022 Resolution 4 - On the use and future development of Universal Coordinated Time (UTC)

decides that the maximum value for the difference (UT1-UTC) will be increased in, or before, 2035,

When?

requests that the CIPM consult with the ITU, and other organizations that may be impacted by this decision in order to

- propose a new maximum value for the difference (UT1-UTC) that will ensure the continuity of UTC for at least a century,

What?

- prepare a plan to implement by, or before, 2035 the proposed new maximum value for the difference (UT1-UTC),
- propose a time period for the review by the CGPM of the new maximum value following its implementation, so that it can maintain control on the applicability and acceptability of the value implemented,

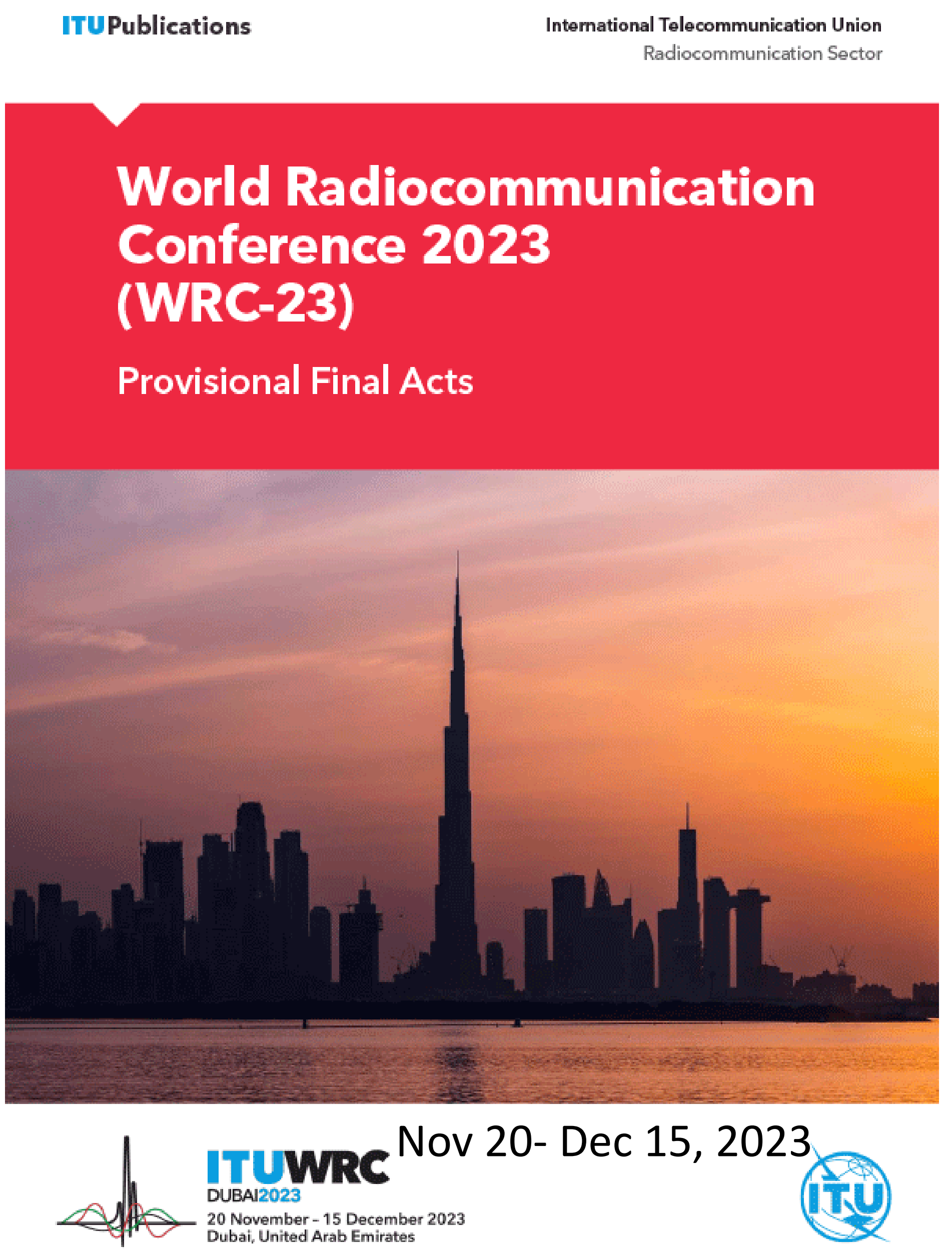
Review

- draft a resolution including these proposals for agreement at the 28th meeting of the CGPM (2026)

Next step

encourages the BIPM to work with relevant organizations to identify the need for updates in the different services that disseminate the value of the difference (UT1-UTC) and to ensure the correct understanding and use of the new maximum value.

ENDORSED by

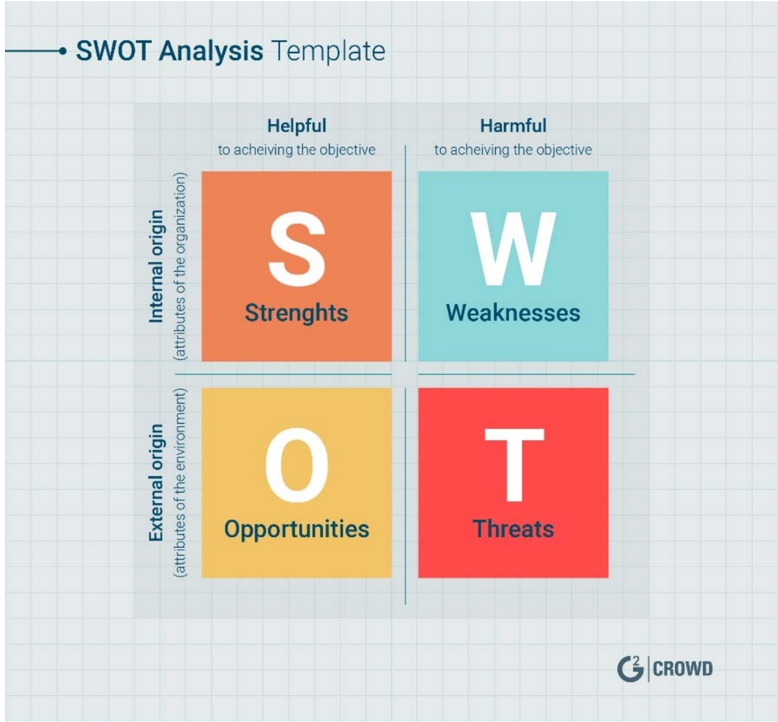


Nov 20- Dec 15, 2023

https://www.itu.int/en/itunews/Documents/2023/2023-02/2023_ITUNews02-en.pdf

The International Telecom Union – R is responsible for setting standards concerning time signals and frequency standard emission by radio systems

The CCTF Task Group has *to* ***prepare the draft resolution for the CGPM 2026*** *with the extended tolerance value of UT1-UTC, …*



1) Provide the value of the new limit for UTC-UT1 to ensure a continuous UTC over one century / 2 options:

- 100 seconds (or 5 min) => continuity about one century

- **1 hour** (daylight saving time/ time zone) similar as No limit => continuity about one millennium

2) Provide the date of implementation (in or before 2035) :

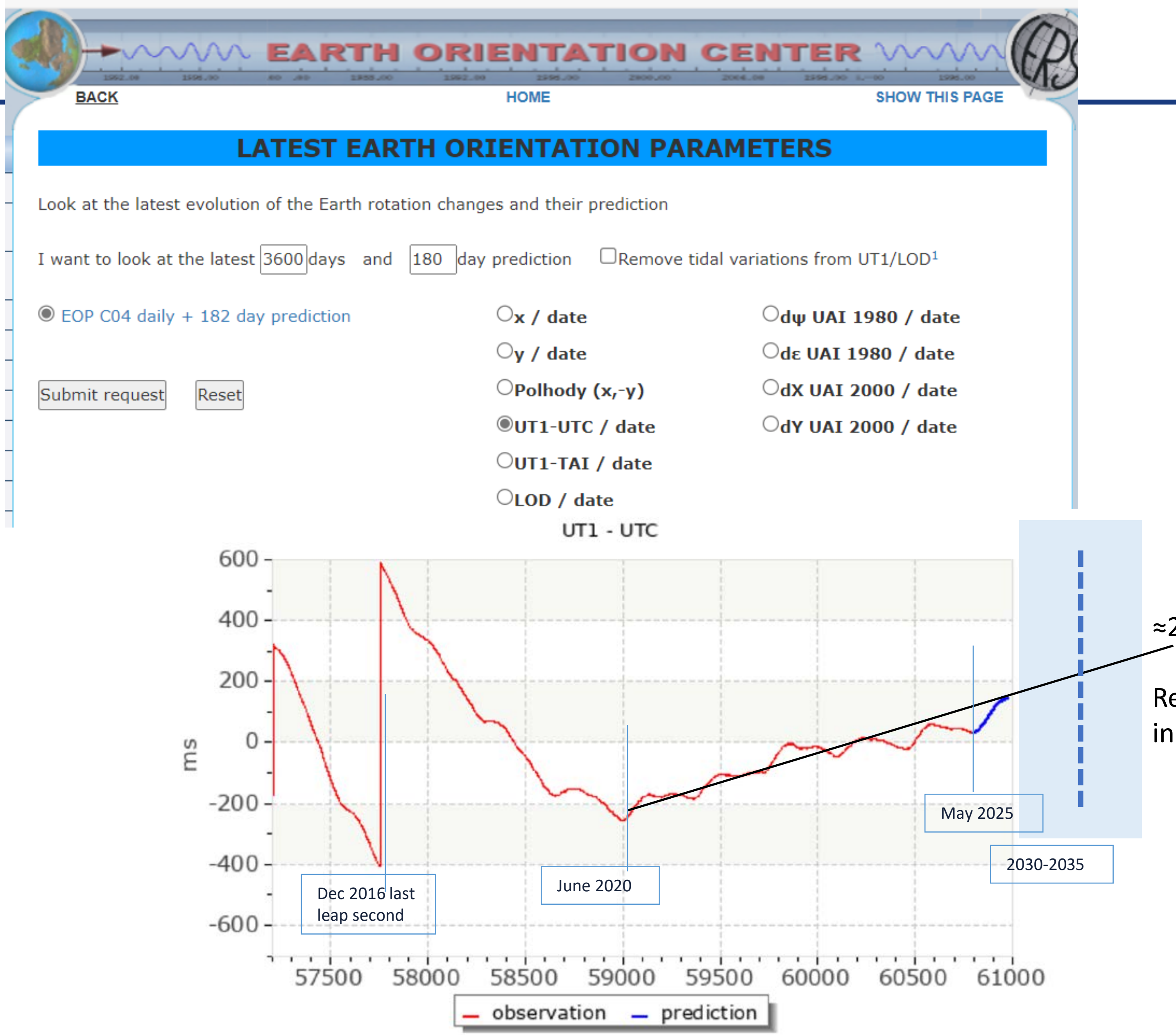
Some countries recommend 2035 to update technological systems, other countries and user communities are urging the change

Ready for a negative leap second?

Work in progress

Is the Earth deciding for us?

https://eoc.obspm.fr/index.php?index=realtime&lang=en



We receive requests from BIPM member states and stakeholders NOT to allow a negative leap second

Possibility for the first negative leap second ?

A negative leap second coming soon?

almost as likely as not to experience a negative leap second in the next 12 years

March 27 on Nature: UTC as now defined will require a negative discontinuity by 2029 (could have been in 2026)

https://www.nature.com/articles/d41586-024-00850-x

A global timekeeping problem postponed by global warming

https://doi.org/10.1038/s41586-024-07170-0

Received: 4 August 2023

Accepted: 6 February 2024

Check for updates

Duncan Carr Agnew[1]

The historical association of time with the rotation of Earth has meant that Coordinated Universal Time (UTC) closely follows this rotation[1]. Because the rotation rate is not constant, UTC contains discontinuities (leap seconds), which complicates its use in computer networks[2]. Since 1972, all UTC discontinuities have required that a leap second be added[3]. Here we show that increased melting of ice in Greenland and Antarctica, measured by satellite gravity[4,5], has decreased the angular velocity of Earth more rapidly than before. Removing this effect from the observed angular velocity shows that since 1972, the angular velocity of the liquid core of Earth has been decreasing at a constant rate that has steadily increased the angular velocity of the rest of the Earth. Extrapolating the trends for the core and other relevant phenomena to predict future Earth orientation shows that UTC as now defined will require a negative discontinuity by 2029. This will pose an unprecedented problem for computer network timing and may require changes in UTC to be made earlier than is planned. If polar ice melting had not recently accelerated, this problem would occur 3 years earlier: global warming is already affecting global timekeeping.

Why the timekeeping and GNSS communities should start preparing.

DEMETRIOS MATSAKIS, MASTERCLOCK

DENNIS MCCARTHY, U.S. NAVAL OBSERVATORY, CONTRACTOR

https://insidegnss.com/will-we-have-a-negative-leap-second/

No reliable prediction is possible in the long term, let's observe the Earth rotation and let's the future generations decide

L. Zotov, C. Bizouard, C.K. Shum, C. Zhang, N. Sidorenkov, V. Yushkin, "Analysis of Earth's polar motion and length of day trends in comparison with estimates using second degree stokes coefficients from satellite gravimetry", *Advances in Space Research* **69**, 308–318 (2022). https://doi.org/10.1016/j.asr.2021.09.010

An important risk of a negative leap second could definitely push towards a quicker change in UTC

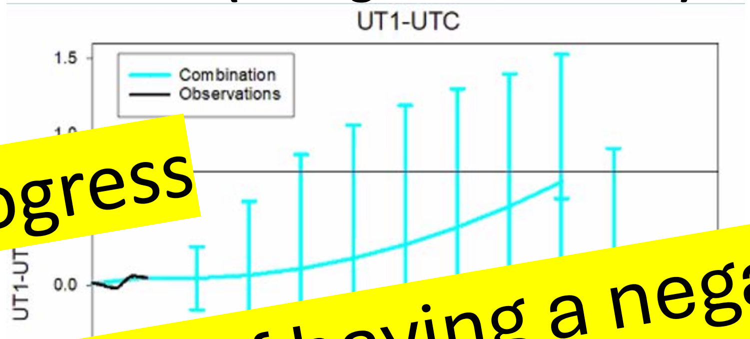
Joint BIPM-IERS workshop on Earth rotation modelling (March 13 and 27, 2025)

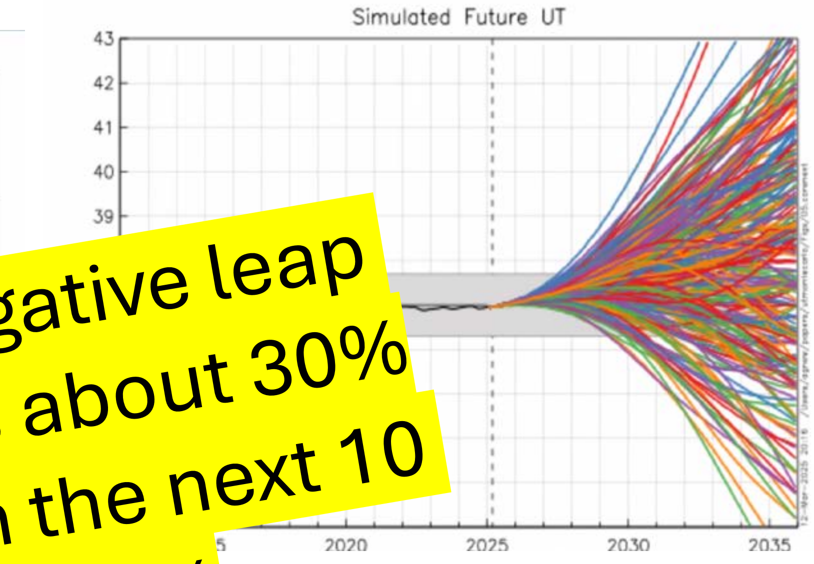
→ Gathering experts of Earth rotation modelling to evaluate a probability range for a negative leap second

Each model takes into account one or a few effects (no « global » model) :

- Global mean sea level
- Core-mantle interaction
- Glacial isostatic adjustment
- Tidal friction
- Moment of inertia
- Atmospheric and oceanic effects
- Climate processes

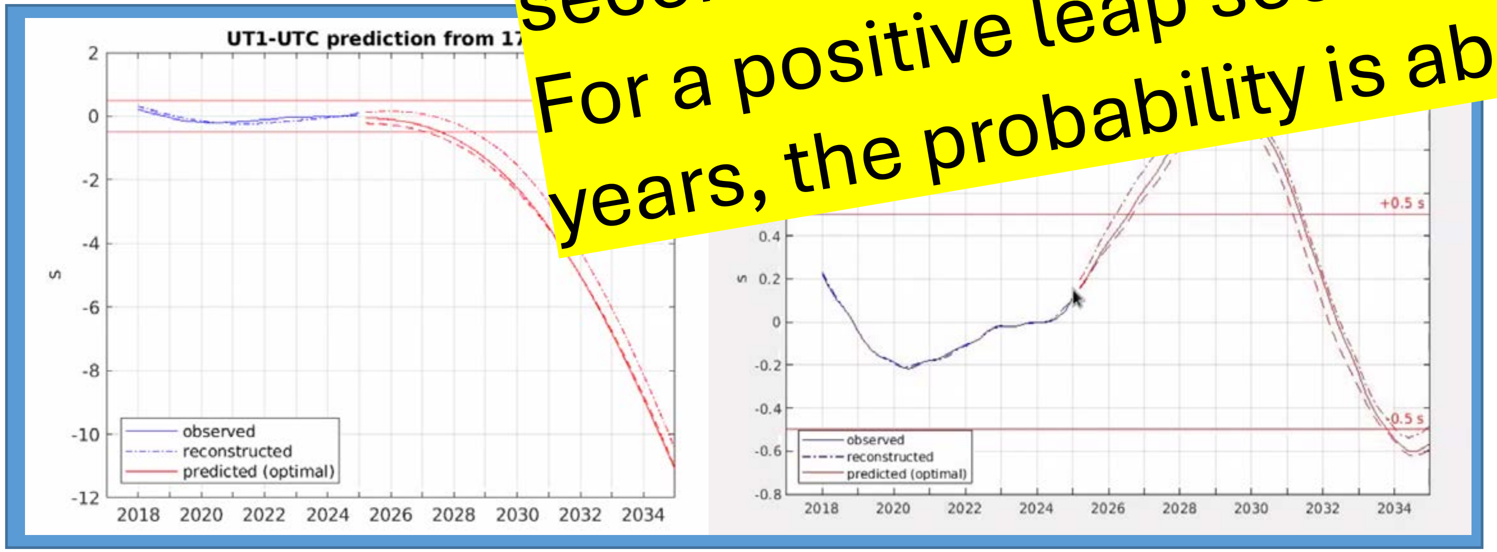
+ Purely statistical prediction

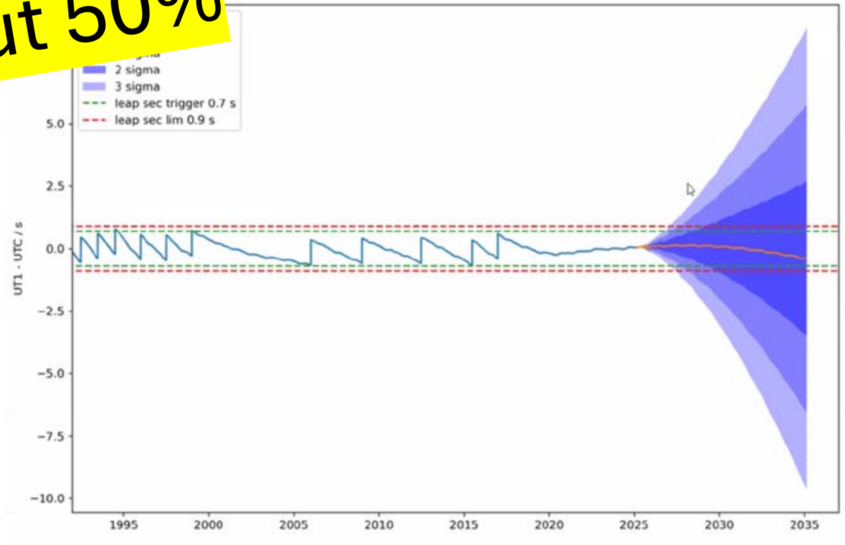




Work in progress

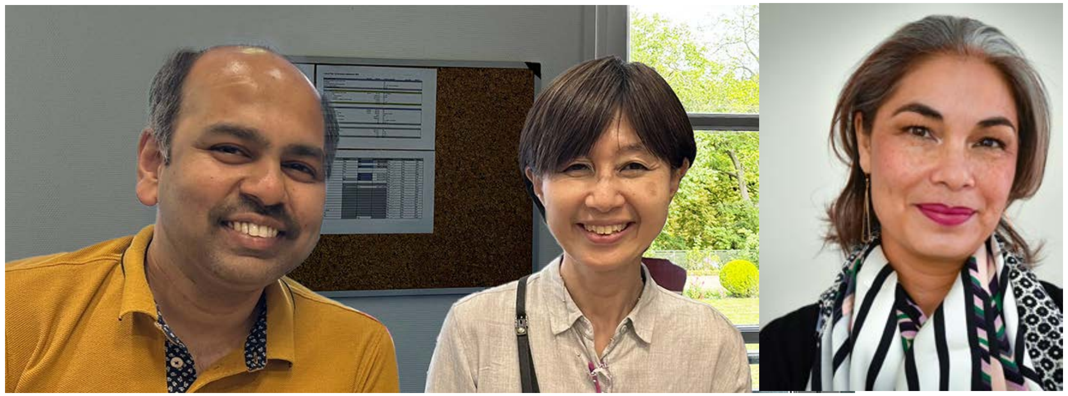
The probability of having a negative leap second in the next 10 years is about 30%
For a positive leap second, in the next 10 years, the probability is about 50%





This school is part of the CCTF program

Sharing Resources for Capacity Building to Improve the (Inter) National Timekeeping



The CCTF programs is based on secondees:

- Dr Bharat Vattikonda, from NPL India (October 23 - September 24)
- Dr Yuko Hanado, formerly NICT Japan (in 2019 and April - July 24)
- Dr Tara Fortier, from NIST USA (September 24 - August 25)

→Development of training tools: videos, guidelines, software modules..

- Already available:
  - GNSS Time transfer interactive software
  - Clock Data Checking
- Coming soon:
  - BIPM-CBKT courses on Algorithms and Applications of Ensemble Timescales,
  - Ensuring BIPM Compliance of Clock Data Files,
  - G2 Calibration Good Practices

Recommendation CCTF 3 (2022):

On the establishment of a UTC capacity building programme based on shared resources

- All realizations of UTC(*k*), the atomic clock ensembles, and links affect the quality of TAI, UTC and UTC(*k*)
- The BIPM has a CBKT program that can be extended to support UTC labs, and the CCTF considers capacity building to be of strategic importance.

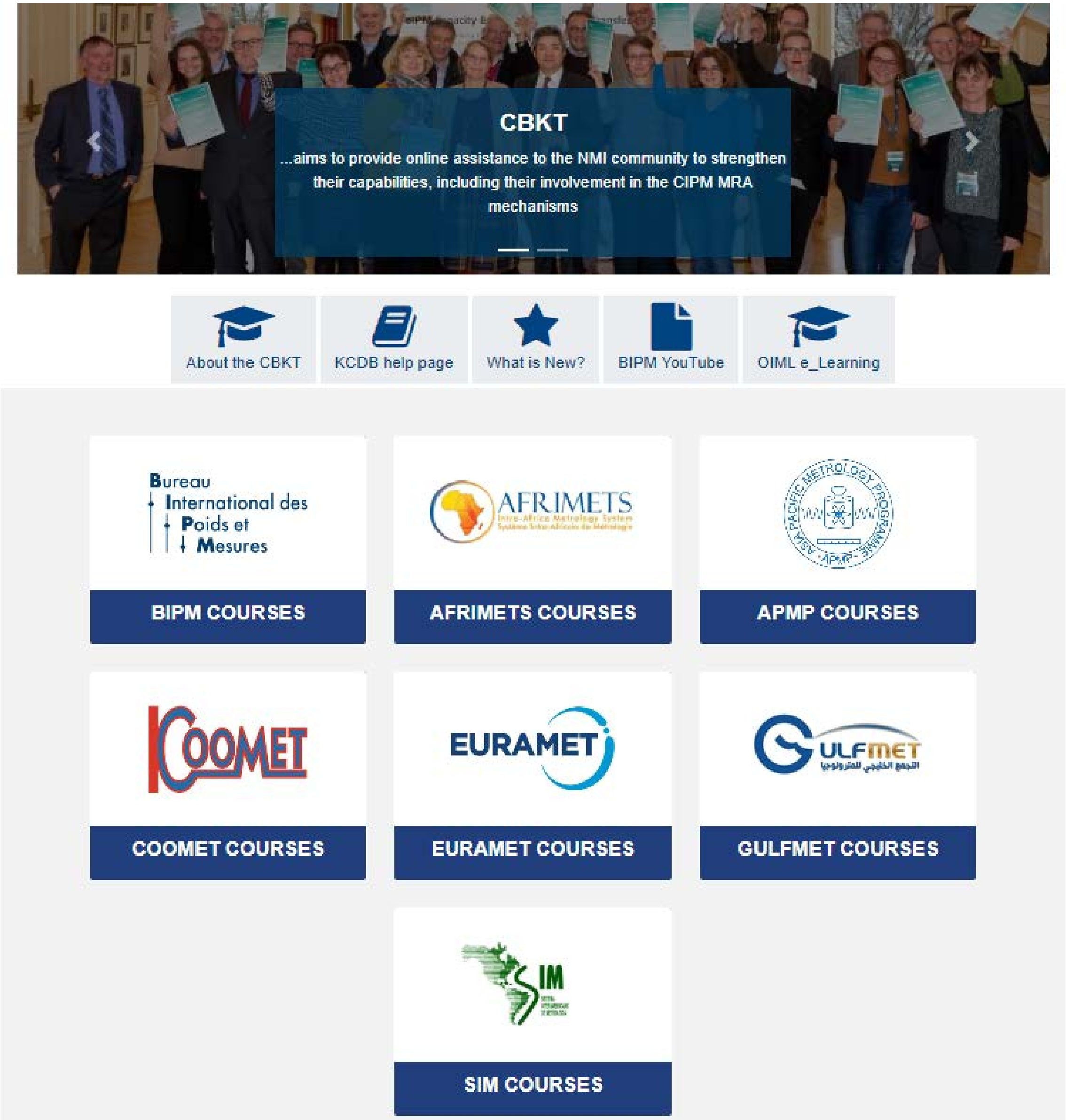
The CCTF proposes to build a “secondee-based” programme at the BIPM to extend capacity building and resource sharing for the improvement of UTC(*k*) and UTC

The BIPM: creates and maintains a website for resource sharing; establishes a secondment programme for support and development

The CCTF WGs, NMIs, and RMOs: contribute to the collection, development and dissemination of training tools; organize conferences, workshops, and training opportunities

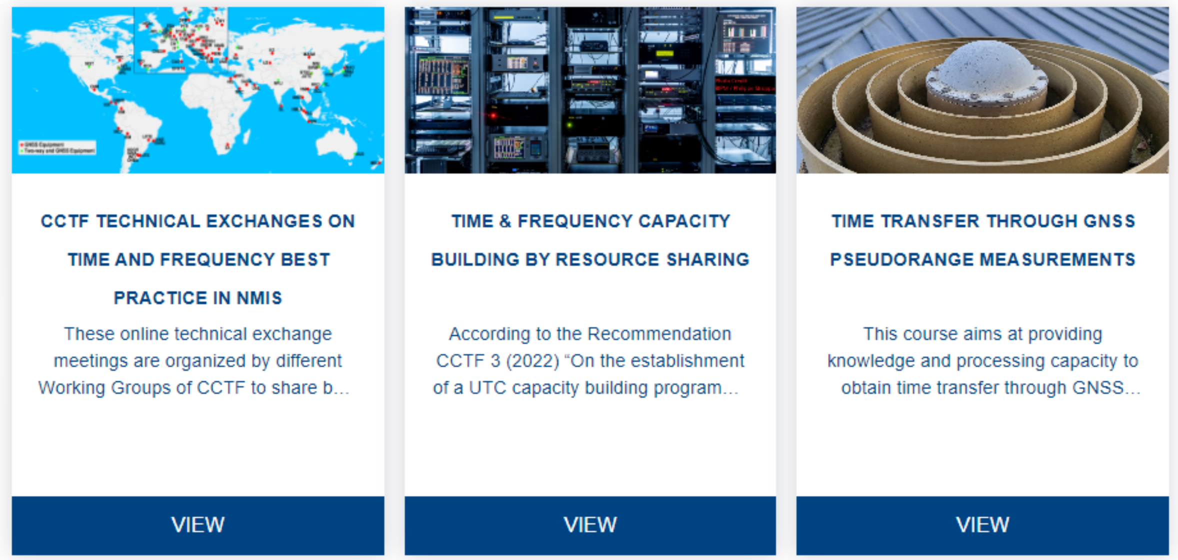
The NMIs: support and possibly fund an expert as a secondee to the BIPM

Capacity building in the BIPM eLearning platform



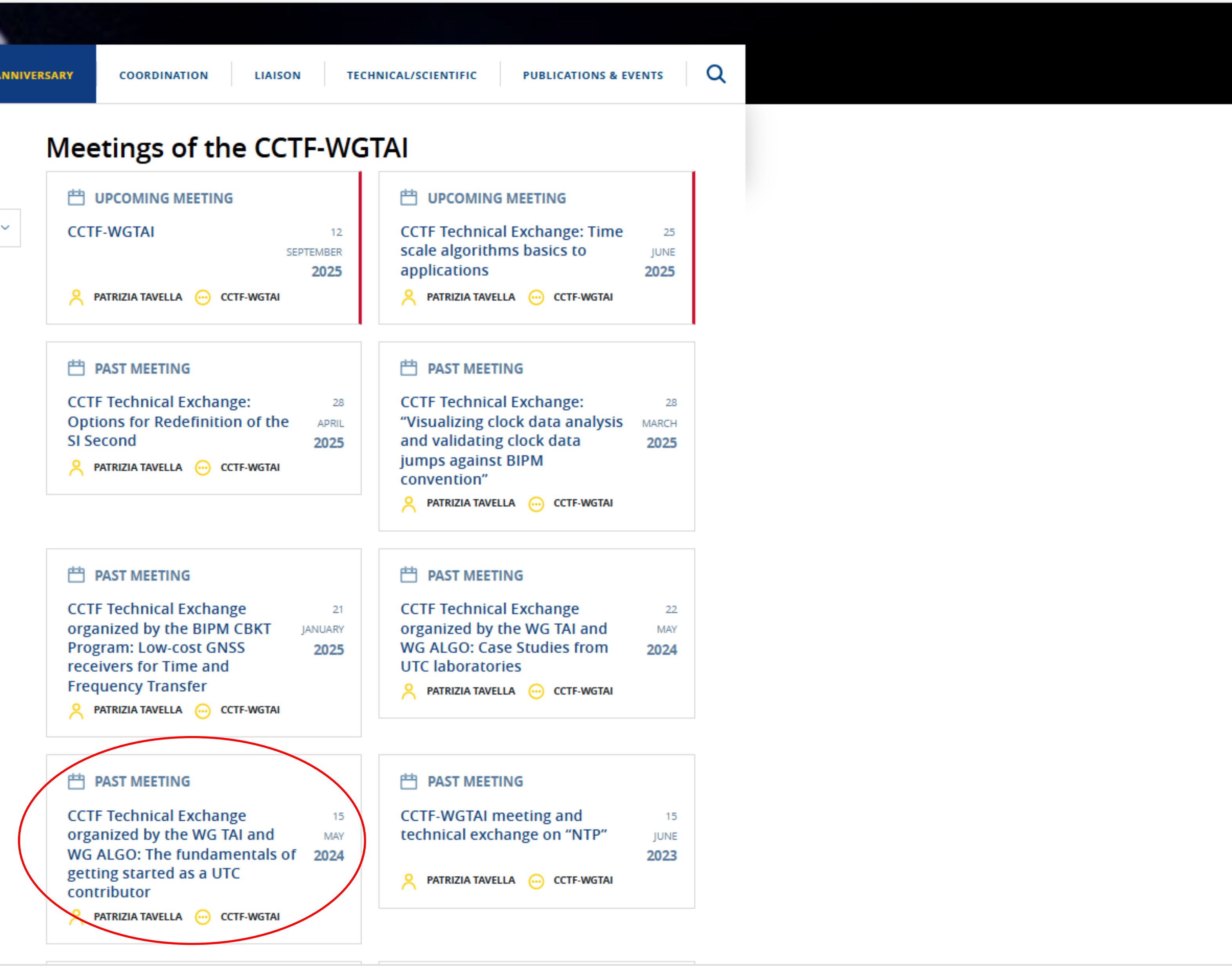
https://e-learning.bipm.org/

- BIPM courses
- Filter by topic area: “Time and Frequency”



The CCTF Working Group on TAI organizes Technical Exchanges. Slides and videos are available online

https://www.bipm.org/en/committees/cc/cctf/wg/cctf-wgtai/meetings



On the BIPM database you can find also tutorial information

https://webtai.bipm.org/database/presentations.html

CBKT master document list 2025 | SIM Summer School Program - | ifcs 2025 - Recherche | 2025 IEEE International Frequen | CCTF Working Group on TAI (CC | Présentation PowerPoint | BIPM Time Dept database

https://webtai.bipm.org/database/presentations.html

Time metrology - BI... | SI REFERENCE POINT | taigit.bipm.org:8888... | CCTF - BIPM | eoc.obspm.fr/index.... | webtai.bipm.org/da... | Posta in arrivo (25) -... | CBKT master docum... | CCTF-2020 - YouTube | 27th meeting of the... | Monitoring of the o... | pdf | Autres favoris

Bureau International des Poids et Mesures

BIPM Time Department Data Base

Participation | Equipments | Calibrations | Resources | Web services | Home

Tutorials and CBKT (capacity building and knowledge transfer):

- Participation to UTC

- Guidelines for the participation in UTC (CCTF WG TAI-TE 15/05/2024, slides 1-8)

- Data submission

- Technical guidelines for data submission (CCTF WG TAI-TE 15/05/2024, slides 9-22)

- Time scales computation / Algorithms

- Time scales computation (UTC, TAI, UTCr, TT)
- PSFS contributions to TAI performance

- CCTF activities and impact on UTC

- The Redefinition of the Second and upcoming changes in timekeeping (Colloquium of the Brussels University, April 2024)

- GNSS and time/frequency transfer links

- GNSS Receiver Operations at an UTC Lab: A Guide to Delays Measurements (Technical Memorandum, May 2023)

- Web services

- BIPM Time Department database and FTP server (CCTF WG TAI-TE 15/05/2024, slides 23-35)

Useful links :

- CCTF WG MRA guidelines
- CBKT e-learning platform, T&F resources
- Shared T&F resources
- BIPM GitHub repositories

If you have not found an answer to your question in this documentation, please contact us ✉

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This page was created after the BIPM Quality survey in 2024 and your received suggestions

Any time you have suggestions, doubts, information to give us, please write to

tai@bipm.org

Thanks for your attention

Thanks to CENAM, SIM, UFFC

Thanks to the BIPM time dept and to our Secondees

CELEBRATING 150 BIPM 1875 – 2025

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