BUREAU INTERNATIONAL DES POIDS ET MESURES

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Contents

Practical information about the BIPM Time Department

The BIPM Time Department issues four periodic publications. These are: UTCr (weekly), *Circular T* (monthly), TT(BIPM) (yearly) and the *BIPM Annual Report on Time Activities*.

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Time Department services webpage: https://www.bipm.org/en/bipm/tai/

Staff of the Time Department as of January 2018 :

Dr Elisa Felicitas ARIAS,	Director (retired on Nov. 30, 2017)
Dr Patrizia TAVELLA,	Director (from Dec.1, 2017)
Dr Zhiheng JIANG,	Principal Physicist
Dr Gianna PANFILO,	Principal Physicist
Dr Gérard PETIT,	Principal Physicist
Dr Lennart ROBERTSSON,	Principal Physicist
Ms Johanna GONCALVES,	Assistant
Ms Aurélie HARMEGNIES,	Assistant
Mr Laurent TISSERAND,	Principal Technician

For individual contact details, please refer to the BIPM staff directory

The report on the scientific work of the BIPM on time activities is available in Director's Report Supplement: Time Department. All the documentation mentionned in this report is available under request from the BIPM.

BIPM Annual Report on Time Activities's change log

Changes with respect to 2016 BIPM Annual Report on Time Activities :
(complete information is regularly published and updated on BIPM Time Department FTP server and/or in Database.)

Part	Type of modification	Nature of the change
Director's report Supplement : Time	Removed	Document available at https://www.bipm.org/en/publications/directors-report/
Access to electronic files on the FTP server and the data base of the BIPM Time Department	Modified	Removed annual files : RTAIXY.ar, WTAIXY.ar, DTAIXY.ar, SITAIXY.ar, UTAIXY.ar. Same information is available in PDF files on the BIPM Time Department FTP server
	Added	Link to the BIPM Time Department's database was added
Establishment of International Atomic Time and Coordinated Universal Time	Added	New plots are available : Plot UTC-UTCr Plot y(PFS/SFS – TT)
Table 3	Deprecated	Content of Table 3 is now available in up-to-date version at http://webtai.bipm.org/database/showlab.html .
Table 4	Removed	Columns **SF**,**DF**,**GLONASS** : replaced by **GNSS**
Table 5	Deprecated	Content of Table 5 is now available in up-to-date version at ftp://ftp2.bipm.org/pub/tai/other-products/ealtai/feal-ftai .
	Added	New plot f(EAL)-f(TAI)
Clocks statistics in 2017	Added	Annual clock weights, rate, and drift are no more published but links to the most recent results in the BIPM Time Department FTP are added
Table 8	Removed	
Table 9A	Removed	
Table 9B	Modified	Becomes Table 8
Table 10	Removed	

Access to electronic files on the FTP server and the data base of the BIPM Time Department.

The files and information related to BIPM Time Activities are available from the website: https://www.bipm.org/en/bipm/tai/ .

Four main items are accessible throught this webpage :

1. TimeScales : information on various time scales
2. Database : BIPM Time Department Database
3. FTP server : all publications on the FTP
4. Calibrations : information on calibration status

BIPM Time Department Database content :

The BIPM Time Department Database contains information on the UTC laboratory time scale, GNSS calibration and overall guidelines.

Bureau International des Poids et Mesures

BIPM Time Department Data Base

Participation guidelines | Participants | GNSS equipment | Clocks | Interactive plots | Contact us

In this web site, information can be found on equipment in UTC contributing laboratories
To obtain these information, go to tabs :

Participation guidelines : full documentation and guidelines for UTC and UTCr participation

Participants

Laboratories info : full list of participating labs and their related information
UTC/UTCr Contributors : contributing laboratories to UTC and UTCr

GNSS equipment

Stations : list of all GNSS equipment in UTC participating laboratories
Calibrations : list of all GNSS calibrations in UTC participating laboratories

Clocks

Clock stats & codes : list of all clocks contributing to UTC
Obtain BIPM clock code : Tool to generate the BIPM clock code of a clock (necessary to start reporting the clock for TAI)
by laboratory : list of clocks from a given lab

Interactive plots

UTC(k) and GNSS times : Interactive plot of UTC(k) and GNSS times wrt UTC/UTCr

All products from the BIPM Time Department (such as UTC, Rapid UTC and TT(BIPM), Time link comparisons, ...) can be accessed via BIPM Time department services.

BIPM Time Department FTP server content :

The files can be found in the nine subdirectories: **data**, **Circular-T, Rapid-UTC, ttbipm, other-products, timelinks, scale, and annual-reports.** They are all available by ftp (62.161.69.5 or ftp2.bipm.org, user anonymous, e-mail address as password, cd pub/tai).

data – All data used for the computation of TAI, including reports of evaluation of primary and secondary frequency standards and all clock and time transfer data files used for the computation of TAI, arranged in yearly directories. See readme for details.

Circular-T – All issues of BIPM *Circular T*.

Rapid-UTC – From February 2012 until June 2013 results of the Pilot Experiment on Rapid UTC (UTCr). Starting in July 2013 official results of Rapid UTC (UTCr).

ttbipm – The realizations of terrestrial time TT(BIPMXY).

other-products – Other products, including time differences and monthly values of clock weights and frequency drifts, etc.

timelinks – Results of time links and time link comparisons processed with *Circular T*.

scale – Annual results of time scales data.

annual reports – Archive of the BIPM Annual Reports on Time Activities and extracts from the BIH Annual Reports.

BIPM Time Department main products :

In the following directories XY represents the last two digits of the year number (19XY or 20XY); WW represents the week number in the year, ZT represents the month number in the year (01-12) except until 1997 when Z represents the two-month interval of TAI computation (Z =1 for Jan.-Feb., 2 for Mar.- Apr., etc…); XX, XXX are ordinal numbers.

products	**filename/link**
Acronyms of laboratories	Database
Leap seconds	leaptab.pdf
Circular T	cirt.XXX
Circular T HTML	cirt.XXX.html (starting 2016)
UTCr	UTCr_XYWW
Fractional frequency of EAL from primary and secondary frequency standards	etXY.ZT
Weights of clocks participating in the computation of TAI	wXY.ZT
Rates relative to TAI of clocks participating in the computation of TAI	rXY.ZT
Frequency drifts of clocks participating in the computation of TAI	dXY.ZT
Daily values of the differences between UTCr and its local representation by the given laboratory	UTCr - lab
Values of the differences between TAI and the local atomic scale of the given laboratory, including relevant notes	TAI - lab
Values of the differences between UTC and its local representation by the given laboratory including graphics and relevant notes	UTC - lab (+ plots)

Values of the differences between UTC(k) and UTC(l) obtained from TWSTFT comparisons	lab1 – lab2
Relations of UTC and TAI with GPS and GLONASS system times, and also with the predictions of UTC(*k*) disseminated by GNSS	UTC-GNSS (starting January 2011)
TT(BIPMXY) computation ending in 19XY or 20XY	TTBIPM.XY
Difference between the normalized frequencies of EAL and TAI	f(EAL)-f(TAI)
Measurements of the duration of the TAI scale interval	UTAIXY.pdf (starting 1995)
Mean fractional deviation of the TAI scale interval from that of TT duration of TAI scale interval	SITAIXY.pdf(starting 2000)

Information on time dissemination by laboratories :

Time scales data	**filename/link**
Time Dissemination Services	TIMESERVICES.PDF
Time Signals	TIMESIGNALS.PDF

Older files can be accessed directly from the ftp site (62.161.69.5 or ftp2.bipm.org).

Any comments or queries should be sent to: tai@bipm.org

Leap seconds

Since 1 January 1988, the maintenance of International Atomic Time, TAI, and of Coordinated Universal Time, UTC (with the exception of decisions and announcements concerning leap seconds of UTC) has been the responsibility of the International Bureau of Weights and Measures (BIPM) under the authority of the International Committee for Weights and Measures (CIPM). The dates of leap seconds of UTC are decided and announced by the International Earth Rotation and Reference Systems Service (IERS), which is responsible for the determination of Earth rotation parameters and the maintenance of the related celestial and terrestrial reference systems. The adjustments of UTC and the relationship between TAI and UTC are given in Tables 1 and 2 of this volume.

Further information about leap seconds can be obtained from the IERS:

IERS Earth Orientation Centre
Dr Christian Bizouard
Observatoire de Paris
61, avenue de l'Observatoire
75014 Paris, France

Telephone:	+ 33 1 40 51 23 35
Telefax:	+ 33 1 40 51 22 91
Email:	services.iers@obspm.fr
Website:	http://hpiers.obspm.fr/eop-pc
Anonymous:	ftp://hpiers.obspm.fr or ftp://145.238.203.2/

Establishment of International Atomic Time and Coordinated Universal Time

1. Data and computation

International Atomic Time (TAI) and Coordinated Universal Time (UTC) are obtained from a combination of data from about 500 atomic clocks operated by more than 70 timing centres which maintain a local UTC, UTC(*k*) (see http://webtai.bipm.org/database/showlab.html). The data are in the form of time differences [*UTC*(*k*) - *Clock*] taken at 5-day intervals for Modified Julian Dates (MJD) ending in 4 and 9, at 0 h UTC; these dates are referred to here as "standard dates". The equipment maintained by the timing centres is detailed in Table 4.

An iterative algorithm produces a free atomic time scale, EAL (Échelle Atomique Libre), defined as a weighted average of clock readings. The processing is carried out and, subsequently, treats one month batches of data. The weighting procedure and clock frequency prediction [1, 2] are chosen such that EAL is optimized for long-term stability. No attempt is made to ensure the conformity of the EAL scale interval with the second of the International System of Units (SI).

2. Accuracy

The duration of the scale interval of EAL is evaluated by comparison with the data of primary frequency caesium standards and secondary frequency standards recommended for secondary representations of the second, correcting their proper frequency as needed to account for known effects (e.g. general relativity, blackbody radiation). TAI is then derived from EAL by adding a linear function of time with an appropriate slope to ensure the accuracy of the TAI scale interval. The frequency offset between TAI and EAL is changed when necessary to maintain accuracy, the magnitude of the changes being of the same order as the frequency fluctuations resulting from the instability of EAL. This operation is referred to as the "steering of TAI" and file feal-ftai gives the normalized frequency offsets between EAL and TAI. Measurements of the duration of the TAI scale interval and estimates of its mean duration are reported in Table 6 and Table 7.

3. Availability

TAI and UTC are made available in the form of time differences with respect to the local time scales UTC(*k*), which approximate UTC, and TA(*k*), the independent local atomic time scales. These differences, [*TAI - TA*(*k*)] and [*UTC - UTC*(*k*)], are computed for the standard dates including uncertainties of [*UTC* – *UTC*(*k*)] [3].

The computation of TAI/UTC is carried out every month and the results are published monthly in *Circular T*.

The BIPM pilots the key comparison in time CCTF-K001.UTC. Institutes participating in the key comparison are National Metrology Institutes and Designated Institutes; they constitute a sub-set of the participants in *Circular T*.

A rapid solution, *UTCr* has been published without interruption since July 2013. Regular publication of the values [*UTCr - UTC*(*k*)] allows weekly access to a prediction of UTC [4] for about fifty laboratories which also contribute to the regular monthly publication. However, the final results published in BIPM *Circular T* remain the only official source of traceability to the SI second for participating laboratories.

The difference between UTC and UTCr (calculated as a weighted average over the laboratories participating to UTCr) is reported in Figure (1) from August 2012 until February 2018. In Figure 1 the period from July 2017 to February 2018 is zoomed to highlight the improved results with the implementation of the new algorithm.

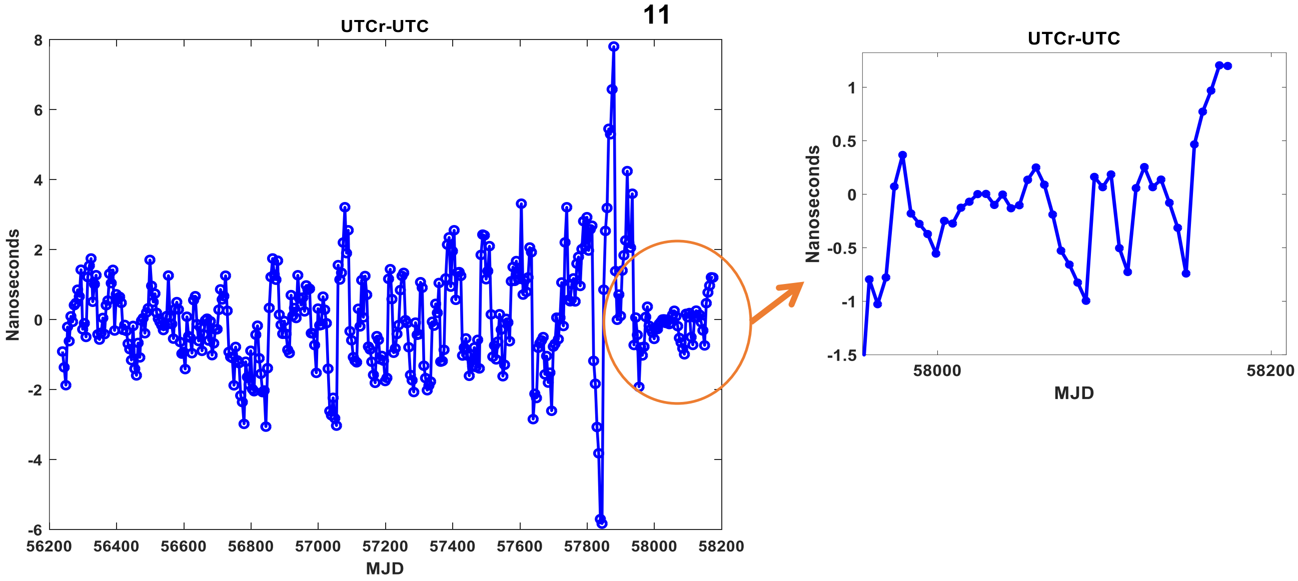

Figure 1. Difference between UTC and UTCr with a zoom from July 2017 when the algorithm has been improved until February 2018.

4. Time links

The BIPM organizes the international network of time links to compare local realizations of UTC in contributing laboratories and uses them in the calculation of TAI. The network of time links used by the BIPM is non-redundant and relies on observation of GNSS satellites and on two-way satellite time and frequency transfer (TWSTFT).

Most time links are based on GPS satellite observations. Data from multi-channel dual-frequency GPS receivers are regularly used in the calculation of time links, in addition to that acquired by a few multi-channel single-frequency GPS time receivers. For those links realized using more than one technique, one of them is considered official for UTC and the others are calculated as back-ups. Single-frequency GPS data are corrected using the ionospheric maps produced by the Centre for Orbit Determination in Europe (CODE); all GPS data are corrected using precise satellite ephemerides and clocks produced by the International GNSS Service (IGS).

GPS links are computed using the method known as “GPS all in view” [5], with a network of time links that uses the PTB as a unique pivot laboratory for all the GPS links. Links between laboratories equipped with dual-frequency receivers providing Rinex format files are computed with the “Precise Point Positioning” method GPS PPP [6].

Clock comparisons using GLONASS C/A (L1C frequency) satellite observations with multi-channel receivers have been in use since October 2009 [7]. These links are computed using the “common-view” [8] method; data are corrected using the IAC ephemerides SP3 files and the CODE ionospheric maps.

A combination of individual TWSTFT and GPS PPP links and of individual GPS and GLONASS links are currently used in the calculation of TAI [9, 10].
The figure showing the time link techniques in the contributing laboratories can be downloaded from the BIPM website and is also reported below as “*Geographical distribution of the laboratories that contribute to TAI and time transfer equipment*”. For more detailed information on the equipment refer to [Table 4], and to BIPM *Circular T* for the techniques and methods of time transfer officially used and for the values of the uncertainty of [$UTC(k_1)$ - $UTC(k_2)$], obtained at the BIPM with these procedures.

The BIPM publishes in *Circular T* daily values of
[*UTC – UTC(USNO)_GPS*] and [*UTC – UTC(SU)_GLONASS*] where *UTC(USNO)_GPS* and *UTC(SU)_GLONASS* are respectively, UTC(USNO) and UTC(SU) as predicted by USNO and SU and broadcast by GPS and GLONASS. Evaluations of [*UTC - GPS time*] and [*UTC - GLONASS time*] are provided only through the ftp server of the Time Department. These tables are based on GPS data provided by the Paris Observatory (LNE-SYRTE), France, and on GLONASS data provided by the Astrogeodynamical Observatory (AOS), Poland.

5. Time scales established in retrospect

For the most demanding applications, such as millisecond pulsar timing, the BIPM retrospectively issues atomic time scales. These are designated TT(BIPMxx) where 19xx or 20xx is the year of computation [11, 12, 13]. The successive versions of TT(BIPMxx) are both updates and revisions; they may differ for common dates.

Starting with TT(BIPM09), until TT(BIPM12) extrapolation for the current year of the latest realization TT(BIPMxx) had been provided in the file TTBIPMxx.ext. It had been updated each month after the TAI computation. Starting with TT(BIPM13), a formula for extrapolation is provided in the file TTBIPM.xx.

In Figure (2) the difference between the frequency of PFS/SFS and TTBIPM is reported. The version of TTBIPM is the one calculated each month for the frequency drift evaluation of the atomic clocks.

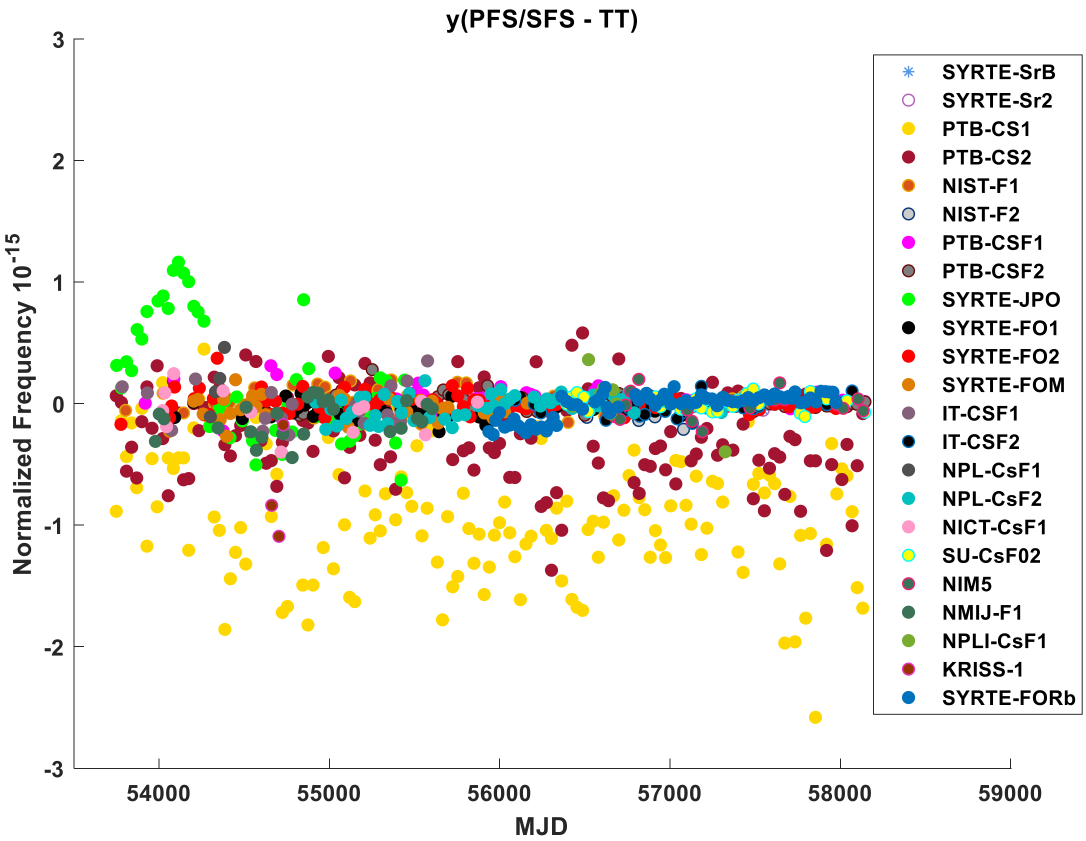

Figure 2. Difference between the frequency of PFS/SFS and TTBIPM.

Notes

Since January 2016 BIPM *Circular T* has been published in a new format with a different distribution of content in the sections. See ftp://ftp2.bipm.org/pub/tai/publication/notes/explanatory_supplement_v0.1.pdf.

Since September 2016, a Time Department Database has been made accessible via the website at http://webtai.bipm.org/database/. It contains all relevant information relating to contributions to UTC and UTCr.

A full list of time signals and time dissemination services is compiled by the BIPM from the information provided by the time laboratories.

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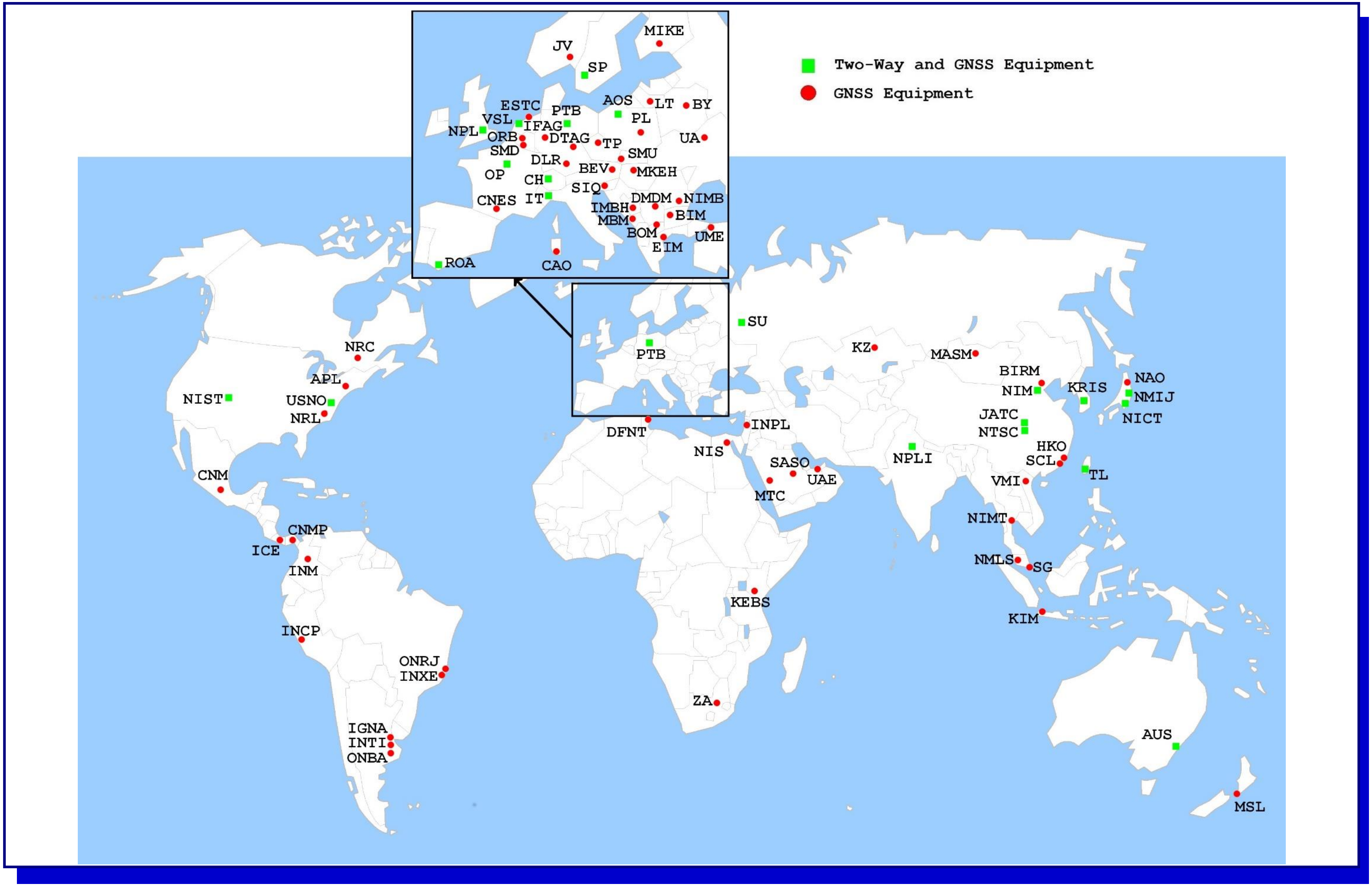

Geographical distribution of the laboratories that contribute to TAI and time transfer equipment (2017)

Table 1. Relative frequency offsets and step adjustments of UTC,
up to 31 December 2018

Date (at 0 h UTC)	Offsets	Steps/s	
1961 Jan. 1		-150×10^{-10}	
1961 Aug. 1	"	+0.050	
1962 Jan. 1		-130×10^{-10}	
1963 Nov. 1	"		−0.100
1964 Jan. 1		-150×10^{-10}	
1964 Apr. 1	"		−0.100
1964 Sep. 1	"		−0.100
1965 Jan. 1	"		−0.100
1965 Mar. 1	"		−0.100
1965 Jul. 1	"		−0.100
1965 Sep. 1	"	−0.100	
1966 Jan. 1		-300×10^{-10}	
1968 Feb. 1	"		+0.100
1972 Jan. 1	0		−0.107
7580			
1972 Jul. 1	"		−1
1973 Jan. 1	"		−1
1974 Jan. 1	"		−1
1975 Jan. 1	"		−1
1976 Jan. 1	"		−1
1977 Jan. 1	"		−1
1978 Jan. 1	"		−1
1979 Jan. 1	"		−1
1980 Jan. 1	"		−1
1981 Jul. 1	"		−1
1982 Jul. 1	"		−1
1983 Jul. 1	"		−1
1985 Jul. 1	"		−1
1988 Jan. 1	"		−1
1990 Jan. 1	"		−1
1991 Jan. 1	"		−1
1992 Jul. 1	"		−1
1993 Jul. 1	"		−1
1994 Jul. 1	"		−1
1996 Jan. 1	"		−1
1997 Jul. 1	"		−1
1999 Jan. 1	"		−1
2006 Jan. 1	"		−1
2009 Jan. 1	"		−1
2012 Jul. 1	"		−1
2015 Jul. 1	"		−1
2017 Jan. 1	"		−1

Table 2. Relationship between TAI and UTC, up to 31 December 2018

Limits of validity (at 0 h UTC)	[*TAI* - *UTC*] / s
1961 Jan. 1 - 1961 Aug. 1	1.422 8180 + (MJD - 37300) × 0.001 296
1961 Aug. 1 - 1962 Jan. 1	1.372 8180 + " "
1962 Jan. 1 - 1963 Nov. 1	1.845 8580 + (MJD - 37665) × 0.001 1232
1963 Nov. 1 - 1964 Jan. 1	1.945 8580 + " "
1964 Jan. 1 - 1964 Apr. 1	3.240 1300 + (MJD - 38761) × 0.001 296
1964 Apr. 1 - 1964 Sep. 1	3.340 1300 + " "
1964 Sep. 1 - 1965 Jan. 1	3.440 1300 + " "
1965 Jan. 1 - 1965 Mar. 1	3.540 1300 + " "
1965 Mar. 1 - 1965 Jul. 1	3.640 1300 + " "
1965 Jul. 1 - 1965 Sep. 1	3.740 1300 + " "
1965 Sep. 1 - 1966 Jan. 1	3.840 1300 + " "
1966 Jan. 1 - 1968 Feb. 1	4.313 1700 + (MJD - 39126) × 0.002 592
1968 Feb. 1 - 1972 Jan. 1	4.213 1700 + " "
1972 Jan. 1 - 1972 Jul. 1	10 (integral number of seconds)
1972 Jul. 1 - 1973 Jan. 1	11
1973 Jan. 1 - 1974 Jan. 1	12
1974 Jan. 1 - 1975 Jan. 1	13
1975 Jan. 1 - 1976 Jan. 1	14
1976 Jan. 1 - 1977 Jan. 1	15
1977 Jan. 1 - 1978 Jan. 1	16
1978 Jan. 1 - 1979 Jan. 1	17
1979 Jan. 1 - 1980 Jan. 1	18
1980 Jan. 1 - 1981 Jul. 1	19
1981 Jul. 1 - 1982 Jul. 1	20
1982 Jul. 1 - 1983 Jul. 1	21
1983 Jul. 1 - 1985 Jul. 1	22
1985 Jul. 1 - 1988 Jan. 1	23
1988 Jan. 1 - 1990 Jan. 1	24
1990 Jan. 1 - 1991 Jan. 1	25
1991 Jan. 1 - 1992 Jul. 1	26
1992 Jul. 1 - 1993 Jul. 1	27
1993 Jul. 1 - 1994 Jul. 1	28
1994 Jul. 1 - 1996 Jan. 1	29
1996 Jan. 1 - 1997 Jul. 1	30
1997 Jul. 1 – 1999 Jan. 1	31
1999 Jan. 1 – 2006 Jan. 1	32
2006 Jan. 1 – 2009 Jan. 1	33
2009 Jan. 1 – 2012 Jul. 1	34
2012 Jul. 1 – 2015 Jul. 1	35
2015 Jul. 1 – 2017 Jan. 1	36
2017 Jan. 1 –	37

Table 3. Acronyms and locations of the timing centres which maintain a local approximation of UTC, UTC(*k*), and/or an independent local time scale, TA(*k*)

The up-to-date list and historical information of laboratories are available at http://webtai.bipm.org/database/showlab.html.

Table 4. Equipment and source of UTC(*k*) of the laboratories contributing to TAI in 2017

Equipment abbreviation used in this table

Atomic clocks

Ind. Cs: industrial caesium standard
Ind. Rb: industrial rubidium standard
Lab. Cs: laboratory caesium standard
Lab. Rb: laboratory rubidium standard
H-maser: hydrogen maser

Time transfer techniques

GNSS: Global Navigation Satellite System receiver (details can be found here)
TWSTFT: Two-Way Satellite Time and Frequency Transfer (details can be found here)

* means 'yes'

Lab *k*	Atomic clock	Source of UTC(*k*) (1)	TA(*k*)	UTCr	Time transfer technique	
					GNSS	TWSTFT
AOS	3 Ind. Cs 2 H-masers	1 H-maser (2) + microphase-stepper	* (15)	*	*	*
APL	3 Ind. Cs 3 H-masers	1 H-maser + frequency synthesizer steered to UTC(APL)			*	
AUS	5 Ind. Cs 2 H-masers	1 Cs		*	*	*
BEV	2 Ind. Cs 1 H-maser	1 Cs		*	*	
BIM	2 Ind. Cs	1 Cs			*	
BIRM	2 Ind. Cs 3 H-masers	1 H-maser + microphase-stepper			*	
BOM	2 Ind. Cs	1 Cs		*	*	
BY	6 H-masers	3-4 H-masers + microphase-stepper			*	
CAO (a)	2 Ind. Cs	1 Cs			*	
CH	3 Ind. Cs (3) 2 H-masers	1 H-maser (3) + frequency synthesizer steered to UTC(CH.P)	*	*	*	*

Table 4. Equipment and source of UTC(*k*) of the laboratories contributing to TAI in 2017 (Cont.)

Lab *k*	Atomic clock	Source of UTC(*k*) (1)	TA(*k*)	UTCr	Time transfer technique	
					GNSS	TWSTFT
CNES	8 Ind. Cs (4) 3 H-masers	1 H-maser (4) + microphase-stepper			*	
CNM	4 Ind. Cs 1 H-maser	1 H-maser + microphase-stepper	*	*	*	
CNMP	5 Ind. Cs	1 Cs + frequency offset generator		*	*	
DFNT	2 Ind. Cs	1 Cs			*	
DLR	3 Ind. Cs 3 H-masers	1 Cs		*	*	
DMDM	2 Ind. Cs	1 Cs + microphase-stepper		*	*	
DTAG	3 Ind. Cs	1 Cs		*	*	
EIM	2 Ind. Cs	1 Cs			*	
ESTC (a)	3 Ind. Cs 3 H-masers	1 H-maser + microphase-stepper		*	*	
HKO	2 Ind. Cs	1 Cs			*	
ICE	3 Ind. Cs	1 Cs + frequency offset generator		*	*	
IFAG (a)	5 Ind. Cs 2 H-masers	1 Cs + microphase-stepper		*	*	
IGNA	1 Ind. Cs	1 Cs			*	

Table 4. Equipment and source of UTC(*k*) of the laboratories contributing to TAI in 2017 (Cont.)

Lab *k*	Atomic clock	Source of UTC(*k*) (1)	TA(*k*)	UTCr	Time transfer technique	
					GNSS	TWSTFT
IMBH (a)	2 Ind. Cs	1 Cs		*	*	
INCP (a)	1 Ind. Cs	1 Cs			*	
INM	2 Ind. Cs	1 Cs + microphase-stepper			*	
INPL	4 Ind. Cs	1 Cs			*	
INTI	3 Ind. Cs	1 Cs		*	*	
INXE	3 Ind. Cs 1 Ind. Rb 1 Lab. Cs	1 Cs + microphase-stepper		*	*	
IT	6 Ind. Cs 4 H-masers 2 Lab. Cs	1 H-maser + microphase-stepper		*	*	*
JATC	(5)	1 H-maser + microphase-stepper	*			
JV (a)	3 Ind. Cs 1 H-maser	1 H-maser + microphase-stepper		*	*	
KEBS	3 Ind. Cs	1 Cs + reference generator			*	
KIM (a)	2 Ind. Cs	1 Cs			*	
KRIS	5 Ind. Cs 4 H-masers	1 H-maser + microphase-stepper	*	*	*	*
KZ (a)	5 Ind. Cs (6)	1 Cs + microphase-stepper			*	

Table 4. Equipment and source of UTC(*k*) of the laboratories contributing to TAI in 2017 (Cont.)

Lab *k*	Atomic clock	Source of UTC(*k*) (1)	TA(*k*)	UTCr	Time transfer technique	
					GNSS	TWSTFT
LT	2 Ind. Cs	1 Cs		*	*	
MASM	1 Ind. Cs	1 Cs + time/frequency steering			*	
MBM	1 Ind. Cs	1 Cs			*	
MIKE	1 Ind. Cs 4 H-masers	1 H-maser + microphase-stepper		*	*	
MKEH	1 Ind. Cs	1 Cs			*	
MSL	2 Ind. Cs	1 Cs + microphase-stepper		*	*	
MTC (a)	11 Ind. Cs	1 Cs		*	*	
NAO	4 Ind. Cs 1 H-maser	1 Cs + microphase-stepper		*	*	
NICT	33 Ind. Cs 8 H-masers (7) 1 Lab. Cs	1 H-maser (8) + microphase-stepper	* (9)	*	*	*
NIM	7 Ind. Cs 6 H-masers 1 Lab. Cs	1 H-maser + microphase-stepper		*	*	*
NIMB (a)	2 Ind. Cs	1 Cs		*	*	
NIMT	5 Ind. Cs	1 Cs + microphase-stepper		*	*	
NIS	2 Ind. Cs	1 Cs		*	*	

Table 4. Equipment and source of UTC(*k*) of the laboratories contributing to TAI in 2017 (Cont.)

Lab *k*	Atomic clock	Source of UTC(*k*) (1)	TA(*k*)	UTCr	Time transfer technique: GNSS	Time transfer technique: TWSTFT
NIST	2 Lab. Cs 14 Ind. Cs 13 H-masers	5 Cs 8 H-masers + microphase-stepper	*	*	*	*
NMIJ	3 Ind. Cs 1 Lab. Cs 4 H-masers	1 H-maser + microphase-stepper		*	*	*
NMLS (a)	2 Ind. Cs	1 Cs		*	*	
NPL	2 Ind. Cs 5 H-masers	1 H-maser		*	*	*
NPLI	5 Ind. Cs 1 H-maser	1 H-maser + microphase-stepper		*	*	*
NRC	6 Ind. Cs (10) 2 H-masers	1 Cs + microphase-stepper	*	*	*	
NRL	9 H-masers	1 H-maser + frequency synthesizer steered to UTC(NRL)		*	*	
NTSC	25 Ind. Cs 6 H-masers	1 H-maser + microphase-stepper	*	*	*	*
ONBA	2 Ind. Cs	1 Cs			*	
ONRJ	7 Ind. Cs 2 H-masers	7 Cs 2 H-masers + frequency offset generator	* (11)	*	*	
OP	5 Ind. Cs 3 Lab. Cs 1 Lab. Rb 4 H-masers	1 H-maser (12) + microphase-stepper	* (13)	*	*	*
ORB	3 Ind. Cs 1 H-maser	1 H-maser or 1 Cs + femtostepper		*	*	
PL	13 Ind. Cs 4 H-masers	1 Cs (14) + femtostepper	* (15)	*	*	

Table 4. Equipment and source of UTC(*k*) of the laboratories contributing to TAI in 2017 (Cont.)

Lab *k*	Atomic clock	Source of UTC(*k*) (1)	TA(*k*)	UTCr	Time transfer technique	
					GNSS	TWSTFT
PTB	3 Ind. Cs 4 Lab. Cs (16) 4 H-masers	1 H-maser (17) + microphase-stepper	* (18)	*	*	*
ROA	6 Ind. Cs (19) 2 H-masers	1 H-maser (20) + frequency synthesizer steered to UTC(ROA)		*	*	*
SASO (a)	5 Ind. Cs	1 Cs		*	*	
SCL	2 Ind. Cs (21)	1 Cs + microphase-stepper		*	*	
SG	5 Ind. Cs 1 H-maser	1 H-maser + microphase-stepper	*	*	*	
SIQ (a)	1 Ind. Cs	1 Cs			*	
SMD	4 Ind. Cs 1 H-maser	1 H-maser + microphase-stepper		*	*	
SMU	1 Ind. Cs	1 Cs + output frequency steering			*	
SP	19 Ind. Cs (22) 8 H-masers	1 H-maser + microphase-stepper		*	*	*
SU	2 Lab. Cs (23) 4 Lab. Rb (24) 12-16 H-masers	8-15 H-masers (25)	* (26)	*	*	* (27)
TL	9 Ind. Cs 4 H-masers	1 H-maser + microphase-stepper	* (28)	*	*	*
TP	5 Ind. Cs	1 Cs + output frequency steering		*	*	
UA (a)	1 Ind. Cs 3 H-masers	3 H-masers + microphase-stepper			*	

Table 4. Equipment and source of UTC(*k*) of the laboratories contributing to TAI in 2017 (Cont.)

Lab *k*	Atomic clock	Source of UTC(*k*) (1)	TA(*k*)	UTCr	Time transfer technique	
					GNSS	TWSTFT
UAE	3 Ind. Cs	3 Cs (29)			*	
UME	5 Ind. Cs	1 Cs		*	*	
USNO	81 Ind. Cs 33 H-masers 6 Lab. Rb	1 H-maser (30) + frequency synthesizer steered to UTC(USNO)	* (30)	*	*	*
VMI	2 Ind. Cs	1 Cs + microphase-stepper			*	
VSL	4 Ind. Cs	1 Cs + microphase-stepper		*	*	*
ZA	6 Ind. Cs 3 H-maser	1 H-maser			*	

Notes

(a)		Information based on the Annual Report for 2016, not confirmed by the laboratory.
(1)		When several clocks are indicated as a source of UTC(*k*), laboratory k computes a software clock, steered to UTC. Often a physical realization of UTC(*k*) is obtained using a Cs clock and a micro-phase-stepper.
(2)	AOS	The UTC(AOS) is formed technically using 1 hydrogen maser and microstepper, it is steered using TA(PL) data as a reference. TA(PL) laboratories are linked via MC GPS-CV and/or two-directional optical fibre connections. Optical Fibre Link *UTC*(*AOS*)-*UTC*(*PL*) is 420 km long.
(3)	CH	All the standards are located in Bern at METAS (Swiss Federal Institute of Metrology). Since November 2007, UTC(CH) is defined in real time by a hydrogen maser steered to the paper time scale UTC(CH.P) which is defined as a weighted average of all the clocks, steered to UTC. TA(CH) is also a weighted average of all the clocks, but free running.
(4)	CNES	All the standards are located in Toulouse at CNES (French Space Agency). UTC(CNES) is defined in real time by a H-Maser steered to an ensemble of industrial high-performance Cs clocks. UTC(CNES) is steered monthly on UTC.
(5)	JATC	The standards are located at National Time Service Centre (NTSC). The link between UTC(JATC) and UTC(NTSC) is obtained by internal connection.
(6)	KZ	The standards are located as follows: *Kazakhstan Institute for Metrology (Astana) — 4 Cs *South-Kazakhstan branch of Kazakhstan Institute for Metrology (Almaty) — 1 Cs
(7)	NICT	The standards are located as follows: * Koganei Headquarters — 20 Cs, 6 H-masers * Ohtakadoya-yama LF station — 4 Cs * Hagane-yama LF station — 5 Cs * Advanced ICT Research Institute in Kobe — 5 Cs, 2 H-masers
(8)	NICT	UTC(NICT) is generated from the output of a hydrogen maser, steered to TA(NICT) regularly, and steered to UTC if necessary.
(9)	NICT	The NICT atomic timescale TA(NICT) is computed from the weighted average of 18 commercial Cs clocks at the Koganei HQ.
(10)	NRC	The standards are located as follows: * Measurement Science and Standards (Ottawa) — 4 Cs, 2 H-masers * CHU Time signal radio station (Ottawa) — 2 Cs
(11)	ONRJ	The Brazilian atomic time scale TA(ONRJ) is computed by the National Observatory Time Service Division in Rio de Janeiro with data from 7 industrial caesium clocks and 2 hydrogen masers.
(12)	OP	Since MJD 56218 UTC(OP) is based on the output signal of a H-maser frequency steered towards UTC using the LNE-SYRTE fountains calibrations.

Notes (Cont.)

(13) OP The French atomic time scale TA(F) is computed by the LNE-SYRTE with data from up to 23 industrial caesium clocks in 2017 located as follows :

* Centre Electronique de l'Armement (CELAR, Rennes)	2 Cs
* Centre National d'Etudes Spatiales (CNES, Toulouse)	4 Cs
* France Telecom Recherche et Developpement (Lannion)	2 Cs
* Observatoire de la Côte d'Azur (OCA, Grasse)	2 Cs
* Observatoire de Paris (LNE-SYRTE, Paris)	5 Cs
* Observatoire de Besançon (OB, Besançon)	3 Cs
* Direction des Constructions Navales (DCN, Brest)	4 Cs
* Spectracom, Orolia (Les Ulis)	1 Cs

All laboratories are linked via GPS receivers. The TA(F) frequency is steered using the LNE-SYRTE PFS data. The difference TA(F) – UTC(OP) is published in the OP Time Service Bulletin.

(14) PL The Polish official timescale UTC(PL) is maintained by the GUM.

(15) PL The Polish atomic timescale TA(PL) is computed by the AOS and GUM with data from 15 caesium clocks and 4 hydrogen masers located as follows:

* Central Office of Measures (GUM, Warsaw)	3 Cs, 1 H-maser
* Astrogeodynamical Observatory, Space Research Center P.A.S. (AOS, Borowiec)	2 Cs, 2 H-masers
* National Institute of Telecommunications (IŁ, Warsaw)	2 Cs
* Polish Telecom (Orange Polska S.A., Warsaw)	3 Cs
* Military Primary Standards Laboratory (CWOM, Warsaw and Poznan)	3 Cs
* Poznan Supercomputing and Networking Center (PSNC, Poznan)	1 H-maser

and additionally

* Time and Frequency Standard Laboratory of the Center for Physical Science and Technology (FTMC), a guest laboratory from Lithuania (LT, Vilnius, Lithuania)	2 Cs

All laboratories are linked via MC GPS-CV and/or two-directional optical fibre connections.

(16) PTB The laboratory Cs, PTB CS1 and PTB CS2 are operated continuously as clocks.
PTB CSF1 and CSF2 are fountain frequency standards using laser cooled caesium atoms. Both are intermittently operated as frequency standards. Contributions to TAI are made through comparisons with one of PTB's hydrogen masers.

(17) PTB UTC(PTB) is based on the output of an active hydrogen maser steered in frequency since MJD 55224 (February 2010).

(18) PTB Since MJD 56079 0:00 UTC TA(PTB) has been generated from an active hydrogen maser, steered in frequency so as to follow PTB caesium fountains as close as possible. The deviation *d* between the fountains and the TAI second is not taken into account.
TAI-TA(PTB) got an initial arbitrary offset from TAI without continuity to the data reported in previous months.

Notes (Cont.)

(19) ROA The standards are located as follows:

* Real Observatorio de la Armada en San Fernando	5 Cs, 1 H-maser
* Centro Español de Metrología	1 Cs
* Added in October 2016, not yet declared to the BIPM	1 H-maser

(20) ROA Since March 2009, UTC(ROA) is defined in real time by a hydrogen maser, steered to the paper time scale UTC(ROA), which is defined as a weighted average of all the clocks, steered to UTC.

(21) SCL There is only one in-service caesium-clock since 23 November 2017.

(22) SP The standards are located as follows (at the end of 2017):

* SP Technical Research Institute of Sweden (SP, Borås)	4 Cs, 2 H-masers
* SP Technical Research Institute of Sweden (SP, Stockholm)	6 Cs, 2 H-masers
* STUPI AB (Stockholm)	8 Cs, 2 H-masers
* Onsala Space Observatory (Onsala)	1 Cs, 2 H-masers

(23) SU CsFO1 and CsFO2 are fountain frequency standards using laser cooled caesium atoms. CsFO2 operated as frequency standard almost regularly and contributed to TAI.

(24) SU Rb01 to Rb04 are fountain frequency standards using laser cooled rubidium atoms. These standards run continuously and produce Rb(i) – H-maser(j) frequency difference at one day basis. These values contributed into time scale maintenance during end of 2017, October-December.

(25) SU Laboratory computes UTC(SU) as a software clock, steered to UTC.

(26) SU TA(SU) is generated from an ensemble of active hydrogen masers, software steered in frequency so as to follow SU caesium fountains as close as possible. The deviation d between the fountains and the TAI second published in Circular T was not taken into account. TAI-TA(SU) has an initial arbitrary offset from TAI.

(27) SU TW time link was stopped at June 2017.

(28) TL TA(TL) is generated from a 9-caesium-clock ensemble.

(29) UAE UTC (UAE) is a software clock, steered to UTC, based on the weighted average of the Cs clocks. A physical realization of UTC(UAE) is obtained using a Cs clock and a frequency synthesizer.

(30) USNO The time scales A.1(MEAN) and UTC(USNO) are computed by USNO. They are determined by a weighted average of Cs clocks, hydrogen masers, and rubidium fountains located at the USNO. A.1(MEAN) is a free atomic time scale, while UTC(USNO) is steered to UTC. Included in the total number of USNO atomic standards are the clocks located at the USNO Alternate Master Clock in Colorado Springs, CO.

Table 5. Differences between the normalized frequencies of EAL and TAI

Values of the difference between the normalized frequencies of EAL and TAI since the beginning of the steering, in 1977, are available at ftp://ftp2.bipm.org/pub/tai/other-products/ealtai/feal-ftai). This file is updated on a monthly basis, with Circular T publication.

As the time scales UTC and TAI differ by an integral number of seconds(see Tables 1 and 2), UTC is necessarily subjected to the same intentional frequency adjustment as TAI.

Table 6. Measurements of the duration of the TAI scale interval

TAI is a realization of coordinate time TT. The following tables give the fractional deviation *d* of the scale interval of TAI from that of TT (in practice the SI second on the geoid), i.e. the fractional frequency deviation of TAI with the opposite sign: $d = -y_{TAI}$.

In Table 6A, *d* is obtained on the given periods of estimation by comparison of the TAI frequency with that of the individual primary frequency standards (PFS) IT-CsF2, NIM5, PTB-CS1, PTB-CS2, PTB-CSF1, PTB-CSF2, SU-CsFO2 and SYRTE-FO2 reported on the year 2017.
In Table 6B, *d* is obtained on the given periods of estimation by comparison of the TAI frequency with that of the individual secondary frequency standards (SFS) SYRTE-FORb, SYRTE-Sr2 and SYRTE-SrB reported on the year 2017.
Previous calibrations are available in the successive annual reports of the BIPM Time Section volumes 1 to 18 and in the BIPM Annual Report on Time Activities volumes 1 to 11 (web only since volume 4 for 2009).

Each comparison is provided with the following information:
u_A is the uncertainty originating in the instability of the PFS,
u_B is the combined uncertainty from systematic effects,
$u_{link/lab}$ is the uncertainty in the link between the PFS and the clock participating to TAI, including the uncertainty due to dead-time,
$u_{link/TAI}$ is the uncertainty in the link to TAI, computed using the standard uncertainty of [UTC-UTC(*k*)],
u is the quadratic sum of all four uncertainty values.

In addition, Table 6B includes the following information:
u_{SRep} is the recommended uncertainty of the secondary representation of the second, as specified in the CIPM Recommendation identified under Ref(u_S).

In these tables, a frequency over a time interval is defined as the ratio of the end-point phase difference to the duration of the interval.

The typical characteristics of the calibrations of the TAI frequency provided by the different primary and secondary standards reported in 2017 are indicated below. Reports of individual evaluations may be found at ftp://ftp2.bipm.org/pub/tai/data/PSFS_reports. Ref(u_B) is a reference giving information on the value of u_B as stated in the 2017 reports, u_B(Ref) is the u_B value stated in this reference. Note that the current u_B values are generally not the same as the peer reviewed values given in Ref(u_B).

Primary Standard	Type /selection	Type B std. uncertainty/ 10^{-15}	u_B(Ref)/10^{-15}	Ref(u_B)	Comparison with	Number/typical duration of comp.
IT-CsF2	Fountain	0.17	0.18	[1]	H maser	3 / 20 d to 30 d
NIM5	Fountain	1.4, then 0.9	1.4	[2]	H maser	3 / 15 d to 20 d
PTB-CS1	Beam /Mag.	8	8.	[3]	TAI	12 / 25 d to 35 d
PTB-CS2	Beam /Mag.	12	12.	[4]	TAI	12 / 25 d to 35 d
PTB-CSF1	Fountain	0.35 to 0.40	1.4	[5]	H maser	7 / 15 d to 30 d
PTB-CSF2	Fountain	0.20 to 0.24	0.41	[6]	H maser	12 / 20 d to 35 d
SU-CsFO2	Fountain	0.24	0.50	[7]	H maser	6 / 15 d to 35 d
SYRTE-FO2	Fountain	0.24 to 0.37	0.23	[8]	H maser	9 / 10 d to 35 d

Secondary Standard	Type	Type B std. uncertainty/ 10^{-15}	u_B(Ref)/10^{-15}	Ref(u_B)	Comparison with	Number/typical duration of comp.
SYRTE-FORb	Fountain	0.28 to 0.30	0.32	[9]	H maser	9 / 10 d to 35 d
SYRTE-Sr2	Lattice	0.04 or 0.20	0.05	[10]	H maser	4 / 10 d to 20 d
SYRTE-SrB	Lattice	0.05	0.05	[10]	H maser	1 / 15 d

More detailed information on the characteristics and operation of individual PFS and SFS may be found in the annexes supplied by the individual laboratories.

Table 6A. Measurements of the duration of the TAI scale interval by Primary Frequency Standards

Standard	Period of estimation		$d/10^{-15}$	$u_A/10^{-15}$	$u_B/10^{-15}$	$u_{link/lab}/10^{-15}$	$u_{link/TAI}/10^{-15}$	$u/10^{-15}$	Note
IT-CsF2	57909	57934	-0.08	0.44	0.17	0.24	0.31	0.61	
IT-CsF2	58004	58024	-0.03	0.62	0.17	0.30	0.38	0.80	
IT-CsF2	58054	58084	0.87	0.56	0.17	0.27	0.30	0.71	
NIM5	57969	57989	-0.16	0.60	1.40	0.20	0.66	1.67	
NIM5	58009	58024	-0.55	0.30	0.90	0.20	0.85	1.29	
NIM5	58094	58114	0.28	0.30	0.90	0.20	0.38	1.04	
PTB-CS1	57749	57784	-12.14	6.00	8.00	0.00	0.11	10.00	(1)
PTB-CS1	57784	57809	-18.71	6.00	8.00	0.00	0.15	10.00	
PTB-CS1	57809	57839	-11.43	6.00	8.00	0.00	0.13	10.00	
PTB-CS1	57839	57869	-26.18	6.00	8.00	0.00	0.13	10.00	
PTB-CS1	57869	57904	0.14	6.00	8.00	0.00	0.11	10.00	
PTB-CS1	57904	57934	-11.57	6.00	8.00	0.00	0.13	10.00	
PTB-CS1	57934	57964	-3.31	6.00	8.00	0.00	0.13	10.00	
PTB-CS1	57964	57994	-7.51	6.00	8.00	0.00	0.17	10.00	
PTB-CS1	57994	58024	-5.51	6.00	8.00	0.00	0.17	10.00	
PTB-CS1	58024	58054	-6.13	6.00	8.00	0.00	0.13	10.00	
PTB-CS1	58054	58084	-9.06	6.00	8.00	0.00	0.13	10.00	
PTB-CS1	58084	58114	-15.27	6.00	8.00	0.00	0.13	10.00	
PTB-CS2	57749	57784	-10.16	3.00	12.00	0.00	0.11	12.37	(1)
PTB-CS2	57784	57809	-0.28	3.00	12.00	0.00	0.15	12.37	
PTB-CS2	57809	57839	-5.45	3.00	12.00	0.00	0.13	12.37	
PTB-CS2	57839	57869	-5.07	3.00	12.00	0.00	0.13	12.37	
PTB-CS2	57869	57904	0.50	3.00	12.00	0.00	0.11	12.37	
PTB-CS2	57904	57934	-12.07	3.00	12.00	0.00	0.13	12.37	
PTB-CS2	57934	57964	-5.05	3.00	12.00	0.00	0.13	12.37	
PTB-CS2	57964	57994	-0.15	3.00	12.00	0.00	0.17	12.37	
PTB-CS2	57994	58024	-6.40	3.00	12.00	0.00	0.17	12.37	
PTB-CS2	58024	58054	-3.54	3.00	12.00	0.00	0.13	12.37	
PTB-CS2	58054	58084	-10.21	3.00	12.00	0.00	0.13	12.37	
PTB-CS2	58084	58114	-5.24	3.00	12.00	0.00	0.13	12.37	
PTB-CSF1	57739	57764	-1.55	0.08	0.35	0.02	0.15	0.39	
PTB-CSF1	57854	57869	0.57	0.11	0.39	0.04	0.24	0.47	
PTB-CSF1	57979	57994	0.12	0.09	0.40	0.05	0.37	0.55	
PTB-CSF1	58004	58024	0.12	0.07	0.38	0.02	0.19	0.43	
PTB-CSF1	58024	58054	-0.34	0.06	0.39	0.02	0.13	0.42	
PTB-CSF1	58054	58084	0.10	0.06	0.39	0.05	0.13	0.42	
PTB-CSF1	58084	58114	-0.16	0.06	0.39	0.05	0.13	0.42	
PTB-CSF2	57749	57774	-1.72	0.12	0.20	0.04	0.15	0.28	
PTB-CSF2	57779	57809	-1.36	0.09	0.20	0.03	0.13	0.26	
PTB-CSF2	57809	57839	-0.83	0.15	0.20	0.03	0.13	0.28	
PTB-CSF2	57839	57869	-0.69	0.10	0.20	0.10	0.13	0.28	
PTB-CSF2	57869	57904	0.27	0.10	0.20	0.10	0.11	0.27	
PTB-CSF2	57904	57934	-0.20	0.20	0.20	0.03	0.13	0.31	
PTB-CSF2	57934	57954	-0.22	0.20	0.24	0.02	0.19	0.37	
PTB-CSF2	57974	57994	-0.18	0.11	0.20	0.05	0.28	0.37	
PTB-CSF2	57994	58024	-0.42	0.10	0.20	0.10	0.17	0.30	
PTB-CSF2	58024	58054	-0.43	0.10	0.20	0.03	0.13	0.26	
PTB-CSF2	58054	58084	-0.16	0.10	0.20	0.03	0.13	0.26	
PTB-CSF2	58084	58114	-0.20	0.09	0.20	0.04	0.13	0.26	
SU-CsFO2	57749	57779	-2.10	0.22	0.24	0.23	0.91	1.00	
SU-CsFO2	57784	57799	-2.12	0.26	0.24	0.11	1.71	1.74	
SU-CsFO2	57809	57839	0.25	0.22	0.24	0.11	0.91	0.98	
SU-CsFO2	57869	57904	0.51	0.21	0.24	0.11	0.77	0.84	
SU-CsFO2	57904	57934	0.40	0.33	0.24	0.11	0.85	0.95	
SU-CsFO2	58024	58054	0.04	0.29	0.24	0.11	0.85	0.93	
SYRTE-FO2	57749	57769	-1.16	0.40	0.37	0.11	0.28	0.62	

SYRTE-FO2	57784	57809	-1.30	0.40	0.32	0.11	0.32	0.61
SYRTE-FO2	57824	57839	-1.04	0.25	0.33	0.12	0.37	0.57
SYRTE-FO2	57844	57869	-0.58	0.30	0.26	0.11	0.38	0.56
SYRTE-FO2	57869	57904	0.77	0.24	0.25	0.10	0.26	0.44
SYRTE-FO2	57904	57924	0.68	0.25	0.24	0.11	0.38	0.52
SYRTE-FO2	57934	57944	0.73	0.60	0.24	0.11	0.70	0.96
SYRTE-FO2	57949	57964	0.02	0.24	0.24	0.10	0.49	0.60
SYRTE-FO2	57964	57984	-0.48	0.25	0.26	0.12	0.38	0.53

Note:
(1) Continuously operating as a clock participating in TAI.

Table 6B. Measurements of the duration of the TAI scale interval by Secondary Frequency Standards

Standard	Period of estimation	$d/10^{-15}$	$u_A/10^{-15}$	$u_B/10^{-15}$	$u_{link/lab}$ $/10^{-15}$	$u_{link/TAI}$ $/10^{-15}$	$u/10^{-15}$	u_{SRep} $/10^{-15}$	Ref(u_S)
SYRTE-FORb	57754 57784	-1.24	0.24	0.28	0.11	0.20	0.43	0.7	[11]
SYRTE-FORb	57784 57809	-0.91	0.20	0.29	0.11	0.32	0.49	0.7	
SYRTE-FORb	57809 57839	-0.28	0.24	0.28	0.10	0.27	0.47	0.7	
SYRTE-FORb	57844 57869	-0.22	0.20	0.29	0.11	0.38	0.53	0.7	
SYRTE-FORb	57869 57904	1.00	0.26	0.30	0.11	0.26	0.49	0.7	
SYRTE-FORb	57904 57924	0.99	0.25	0.28	0.11	0.38	0.54	0.7	
SYRTE-FORb	57934 57944	0.93	0.31	0.28	0.11	0.70	0.82	0.7	
SYRTE-FORb	57949 57964	0.89	0.33	0.28	0.10	0.49	0.66	0.7	
SYRTE-FORb	57964 57984	0.03	0.25	0.30	0.12	0.38	0.56	0.7	
SYRTE-SR2	56954 56964	0.81	0.20	0.04	0.10	0.53	0.57	0.5	[11]
SYRTE-SR2	57179 57199	0.46	0.20	0.04	0.10	0.28	0.36	0.5	
SYRTE-SR2	57469 57479	-1.39	0.25	0.20	0.11	0.53	0.63	0.5	
SYRTE-SR2	57539 57554	-1.24	0.30	0.04	0.11	0.37	0.49	0.5	
SYRTE-SRB	57539 57554	-1.22	0.25	0.05	0.10	0.37	0.46	0.5	[11]

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Annex A: Operation of IT-CsF2 in 2017

F. Levi and G.A. Costanzo

IT-CsF2 is the primary atomic frequency standard operated at INRIM. The frequency standard is based on a laser cooled Cs fountain apparatus operating at cryogenic temperature (88.5K), in order to reduce the blackbody radiation shift. The formal evaluation of the frequency standard is published in [1], while TAI calibration data are reported to BIPM since the end of 2013 and are published in the Circular T. The accuracy evaluation of the PFS involves periodical checks and validations of the whole set of parameters affecting the standard frequency: i.e. Zeeman shift, spectral purity of the microwave synthesis chain, interaction region temperature, atomic density shift, gravitational potential, and laser and microwave leakage.

During 2017 we reported to BIPM three formal TAI evaluations of the standard hereafter summarized. The three measurements have a duration ranging from 20 to 30 days with unwanted dead times of the order of 25% over the various evaluation periods. The total operating time of IT-CsF2 as PFS during 2017 was 75 days.

Circ T	Period	days	d (10^{-15})	uA (10^{-15})	uB (10^{-15})	Ul/Lab (10^{-15})	Ul/Tai (10^{-15})	u (10^{-15})
354	57909 57934	25	-0.08	0.44	0.17	0.24	0.31	0.61
357	58004 58024	20	-0.03	0.62	0.17	0.30	0.38	0.80
359	58054 58084	30	0.87	0.56	0.17	0.27	0.30	0.71

The accuracy of ITCsF2 is nearly the same that was reported in [1] and it is summarized in the following table. It is worth mentioning that the statistical uncertainty associated with the atomic density, is obtained with long measurement time and thus vary from case to case according to the available set of data. Typically the low density uncertainty can reach ~2x10^{-16}.

Typical accuracy evaluation

Physical effect	Bias (10^{-16})	Uncert. (10^{-16})
Zeeman effect	1074.9	0.8
Blackbody radiation	-1.45	0.12
Gravitational redshift	260.4	0.1
Microwave leakage	-1.2	1.4
DCP	-	0.2
2^{nd} order cavity pulling	-	0.3
Background gas	-	0.5
Total Type B	1332.6	1.7
Atomic density (typical LD)	-6.3	1.9
Total	1326.3	2.5

[1] Accuracy evaluation of ITCsF2: a nitrogen cooled caesium fountain, F. Levi, D. Calonico, C.E. Calosso, A. Godone, S. Micalizio and G.A. Costanzo; Metrologia 51 (2014) 270–284

Annex B: Evaluations of NIM5 for BIPM Annual Report 2017

1. Primary clocks

1.1 Fountain clock NIM5

The NIM5 Cs fountain primary frequency standard was reported to BIPM three times in 2017 during MJD 57969-57989, 58009-58024 and 58094-58114. A new microwave synthesizer has been used and a new 100 MHz microwave interferometric switch is used with the same design as before but a different RF switch and a different directional coupler. The instability is improved. A typical fractional frequency instability of 1.4×10^{-13} $(\tau/s)^{-1/2}$ was obtained when running at high atom density. A typical Type B fractional frequency uncertainty was reduced to 0.9×10^{-15}. The results are summarized in the following table.

Table 1 NIM5 evaluation results in 2017

MJD periods	$d/10^{-15}$	$u_A/10^{-15}$	$u_B/10^{-15}$	$U_{l/lab}/10^{-15}$	$U_{l/TAI}/10^{-15}$	$u/10^{-15}$
57969.0-57989.0	-0.16	0.60	1.40	0.20	0.66	1.67
58009.0-58024.0	-0.55	0.30	0.90	0.20	0.85	1.29
58094.0-58114.0	0.28	0.30	0.90	0.20	0.38	1.04

1.2 Research work on the new fountain NIM6

A new fountain clock NIM6 has been built, and the whole system are still under optimizing. Atoms are collected in the lower MOT chamber and then launched to the upper optical molasses chamber with a small angle to reduce the background Cs atoms flying into the detection chamber directly. The total number of atoms at the detection of a few 10^5 can be obtained with MOT loading time 200 ms, and the instability of 1.5×10^{-13} $(\tau/s)^{-1/2}$ is achieved under this density. The second order Zeeman frequency shift, cold collisional frequency shift have been evaluated, and are all in the low 10^{-16}. Microwave power related frequency shift is still under evaluation. A new cryogenic sapphire oscillator (CSO) based frequency synthesizer and ultra-stable microwave generated from ultra-stable laser are also under developing to reduce the microwave phase noise in order to reach the quantum projection noise, thus leading to a lower Type A uncertainty of the new fountain.

Annex C : Operation of the SYRTE fountain PSFS in 2017

In 2017, the Cs and Rb parts of the dual fountain FO2 were operated almost continuously between January and August. Over that period, a total of 18 calibrations reports of the reference maser have been transmitted to BIPM to participate to the steering of TAI: 9 calibrations by the primary frequency standard (PFS) FO2-Cs and 9 calibrations by the secondary frequency standard (SFS) FO2-Rb. FO2-Rb results are included in *Circular T* as SYRTE-FORb SFS.
The FO1 caesium fountain did not contribute to TAI in 2017. Its accuracy budget is still under evaluation after having performed important maintenance operations on the vacuum chamber, on the optical bench and on the electronics.

Concerning the PFS FO2-Cs, the operation was the same as in 2016. The microwave synthesizer of the fountain is referenced to the signal provided by a cryogenic sapphire oscillator (CSO) phase locked to a hydrogen maser taking benefit of the CSO ultra-low phase noise. The relative frequency instability is typically $\sigma_y(\tau)$ ~ $8.5 \times 10^{-14}\ \tau^{-1/2}$. This instability results from the combination of low and high atomic density operations required for the real time extrapolation of the cold collisions frequency shift and corresponds to the quantum projection noise. It is larger than in the past because of a progressive aging of the caesium cold atom source which is based on a 2DMOT. The linear Zeeman shift and the temperature around the interrogation zone are measured every ~1 hour in order to estimate the corresponding frequency shifts of the clock transition. The distributed cavity phase shift is verified from time to time with differential measurements alternating the cavity feeds. Each calibration value is given with typical uncertainties $u_A = 2 - 3 \times 10^{-16}$, u_B ~ 3×10^{-16}, and $1 - 2 \times 10^{-16}$ for the uncertainty due to the link between the reference maser and the standard. Table 1 gives the typical uncertainty budget for FO2-Cs as operating in 2017. The values and the uncertainties of the frequency shifts, which partly depend on the operating parameters, are updated for each TAI monthly contribution.

Fountain	FO2-Cs		FO2-Rb	
Physical origin	Correction	Uncertainty	Correction	Uncertainty
2nd order Zeeman	-1920.3	0.3	-3471.2	0.7
Blackbody Radiation	168.5	0.6	124.5	1.4
Cold Collisions + cavity pulling	74.2	1.4	8.3	1.7
Distributed cavity phase shift	-0.9	1.0	-0.35	1.0
Microwave Leaks, spectral purity	0	<0.5	0	<0.5
Ramsey & Rabi pulling	0	<0.1	0	<0.1
Microwave lensing	-0.7	0.7	-0.7	0.7
Second order Doppler	0	<0.1	0	<0.1
Background gas collisions	0	<1	0	<1.0
Red shift	-65.5	1	-65.5	1
Total (1σ) uncertainty u_B		**2.5**		**3.0**

Table 1: Typical accuracy budgets for the SYRTE fountains FO2-Cs and FO2-Rb adapted from those given in [1] and [2]. (Values given in units of 10^{-16})

Concerning the SFS FO2-Rb, its operation is similar to that of the Cs PFSs. FO2-Rb operates simultaneously to FO2-Cs, but with a slightly different launch velocity allowing for separated time of flights and selective detection of both atom clouds at each fountain cycle. The microwave synthesis of FO2-Rb is also based on the low noise signal provided by the CSO signal slowly phase locked to the reference H-maser. The fountain frequency instability is typically $5 \times 10^{-14}\ \tau^{-1/2}$ when combining low and high atomic density measurements. For each calibration, in addition to the type A uncertainty (typically $1 - 2 \times 10^{-16}$), the type B uncertainty (typically 3×10^{-16}), and the uncertainty due to the link between the reference maser and the standard (typically $1 - 2 \times 10^{-16}$) are included. The recommended uncertainty of the ^{87}Rb secondary representation of the second, corresponding to 0.7×10^{-15} [3], is also taken into account. The typical type B uncertainty budget of FO2-Rb is given in Table 1. In this budget, the uncertainty in the correction for the cold collision (+ cavity pulling) shift is mainly statistical. As for FO2-Cs, sequential and periodical measurements are also performed to determine the uncertainty of the other frequency shifts.

Deep refurbishment was performed on FO2 between August and November 2017. The vacuum chamber was open in order to replace the pumping system and to renew the atom pre-sources based on 2D-MOTs, both for the caesium and the rubidium parts. New control computers together with new control cards and interfaces to the fountain have been implemented for FO2-Cs and for FO2-Rb. Long term measurements in nominal conditions resumed in December 2017. The first reports after re-evaluation of the systematics have been transmitted to BIPM starting January 2018.

Throughout 2017, the frequency calibrations of the reference H-maser by the SYRTE fountains were also used to produce a daily steering of the H-maser output signal for the generation of the French timescale UTC(OP) [4].

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[3] CIPM Recommendation 2 (CI-2015) : Updates to the list of standard frequencies in Procès-Verbaux des Séances du Comité International des Poids et Mesures, 104th meeting (2015), 2016, 47 p.
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Annex D : Report of the SYRTE Sr2 and SrB contributions published in 2017

Two optical lattice clocks with ^{87}Sr atoms have been operated at SYRTE for several years. The frequency of the clock laser probing the clock transition is split into three branches. Two of them are locked to the $^1S_0 \rightarrow {}^3P_0$ transition of Sr2 and SrB respectively, while the third one is measured by a fiber frequency comb connected by a compensated microwave link to other optical oscillator and to the microwave reference (a cryogenic sapphire oscillator (CSO) phase locked to a hydrogen Maser). By combining the frequency offset and beat-notes of these branches, we can deduce the frequency of the H Maser with respect to the ^{87}Sr clock transition. In 2014, an effort to improve the reliability of the clocks has been started, resulting in the ability to operate the clocks over several consecutive TAI intervals. This operation was made more and more autonomous; the clocks can now reliably work overnight, and require only limited maintenance over day [1]. From this operation we could perform calibrations of the Maser frequency over several periods aligned with TAI intervals:

- 10 days in November 2014 with Sr2 (MJD 56954 to 56964)
- 20 days in June 2015 with Sr 2 (MJD 57179 to 57199)
- 10 days in March 2016 with Sr 2 (MJD 57469 to 57479)
- 15 days in June 2016 with Sr2 and SrB (MJD 57539 to 57554)

The stability of the comparison between the two strontium clocks is between 1 and 2×10^{-15} for a 1 s integration time, from which we can infer that at least one of the clock is a factor $1/\sqrt{2}$ better. A statistical uncertainty of 10^{-17} is therefore reached after a few hours of integration. This stability is not a limitation when comparing with microwave oscillators. The systematic uncertainty of the two clocks for this period is typically 4 to 5×10^{-17} with a total uncertainty budget reported in Table 1.

	Correction (10^{-18})	**Uncertainty (10^{-18})**
Black body radiation	*5307*	*28*
Quadratic Zeeman effect	*2569*	*23*
Lattice light-shift	*0*	*10*
Lattice spectrum	*0*	*1*
Density shift	*0*	*8*
Line pulling	*0*	*20*
Probe light shift	*0.4*	*0.4*
AOM phase chirp	*0*	*5*
Servo error	*0*	*3*
Static charges	*0*	*10*
Blackbody radiation oven	*0*	*10*
Background gas collisions	*0*	*8*
Total (1 σ uncertainty u_B)	*7876.4*	*47*
Red shift	*-6114.6*	*10*
Total with red shift	***1761.8***	***48***

Table 1 : typical uncertainty budget of the two Sr clocks for all the calibration reports (here for SYRTE-SrB optical lattice for MJD 57539 to 57554). In 2017, the accuracy budget of Sr2 was evaluated to 2.1×10^{-17}, and latter to the same level for SrB. The systematic effects are evaluated either from self-comparison of by using one of the clocks as a stable reference. This accuracy budget has been confirmed by several local and international, optical-to-optical or optical-to-microwave clock comparisons [1,2,3,4].

The reports were submitted to the BIPM in the second half of 2016, and, after review, were included in the Circular T #350 published in March 2017

In 2017, although both clocks were operated for a period of over a month, a newly introduced and uncontrolled systematic effect altered the accuracy significantly above 10^{-16}. While this effect, due to a technical electrical perturbation of the clock laser frequency, has been characterized and canceled, it prevented the clocks from being reliably operated over long measurement intervals. Because of this issue, no additional reports were submitted in 2017.

References:

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Annex E : Operation of the PTB primary clocks in 2017

PTB's primary clocks with a thermal beam

During 2017 PTB's primary clocks CS1 and CS2 were operated almost continuously. Time differences UTC(PTB) - clock in the standard ALGOS format were reported to BIPM, so that $u_{l/lab}$ is zero. The mean relative frequency offset y(CS1 – CS2) amounted to -5.25×10^{-15}, which is compliant with the stated u_B values [1,2].

The clocks' operational parameters were checked periodically and validated to estimate the clock uncertainty. These parameters are the Zeeman frequency, the temperature of the beam tube (vacuum enclosure), the line width of the clock transition as a measure of the mean atomic velocity, the microwave power level, the spectral purity of the microwave excitation signal, and some characteristic signals of the electronics. Using a high-resolution phase comparator, the 5 MHz output signals of both clocks have been continuously compared to 5 MHz of superior frequency instability to assess the frequency instability of CS1 and CS2, respectively. Data analysis has been made based on several 15 to 20-day batches distributed during 2017.

CS1

The CS1 relative frequency instability $\sigma_y(\tau = 5000\ \mathrm{s})$ was found to vary between 80×10^{-15} and 100×10^{-15} during 2017, in reasonable agreement with the prediction based on the prevailing parameters beam flux, clock transition signal and line width. With reference to TAI, the standard deviation of *d*(CS1) (Circular T Section 3, 12 months) was 7.14×10^{-15}, in slight excess of the value $u_A(\tau = 30\ \mathrm{d}, \mathrm{CS1}) = 6\times10^{-15}$ stated in Circular T. The scatter of data is larger than in previous years, but no root cause can be given. During the year, only one reversal of the beam direction was performed on CS1. No findings call for a modification of the previously stated relative frequency uncertainty u_B, which is 8×10^{-15} for CS1 [2].

CS2

The relative CS2 frequency instability of $\sigma_y(\tau = 5000\ \mathrm{s})$ was measured between 58×10^{-15} and 75×10^{-15} during 2017. The standard deviation of the 12 *d*-values reported in Circular T for 2017 amounted to 4.08×10^{-15}, in slight excess of the stated uncertainty contribution $u_A(\tau = 30\ \mathrm{d}, \mathrm{CS2}) = 3\times10^{-15}$ reported in Circular T. During the year, three reversals of the beam direction were performed on CS2.The uncertainty estimate as detailed in [1, 2] is considered as still valid, and the CS2 u_B is thus estimated as 12×10^{-15}. This value complies well with the mean offset between the CS2 seconds and the scale unit of TAI during 2017 of 5.3×10^{-15}.

PTB's primary caesium fountain clocks

In 2017 both caesium fountain clocks, CSF1 and CSF2, were operated regularly with a high duty cycle. The frequency synthesis for both fountains routinely makes use of an optically stabilized microwave oscillator [3-5] instead of employing quartz based microwave synthesis. For the generation of UTC(PTB) data of both fountains were routinely used for the steering of a hydrogen maser output frequency [6]. The steering data was selected based on the availability of the respective fountain data and the chosen priority.

CSF1

A detailed description of the PTB fountain CSF1 is given in Refs. [7] and [8]. Seven measurements of the TAI scale unit of 15 (2×), 20 (1×), 25 (1×) and 30 (3×) days duration were performed in 2017 and reported to the BIPM. Due to the performance and reliability of the laser systems, dead times are normally kept between 3-6% of the nominal measurement duration, where about 1.5% dead time is caused by the periodic switching between low and high density operation modes and periodical magnetic field measurements. The resulting clock link uncertainty $u_{l/lab}$ was in the range 0.02×10^{-15} to 0.05×10^{-15}. The statistical uncertainty of CSF1 measurements was calculated with the assumption of white frequency noise during the measurement intervals. For the seven TAI contributions in 2017 typically statistical uncertainties $u_A < 0.1\times10^{-15}$ were achieved.

Below we compile typical frequency biases and type B uncertainties of CSF1, valid for TAI scale unit measurements in 2017.

Physical effect	Bias / 10^{-15}	Type B uncertainty / 10^{-15}
Quadratic Zeeman shift	107.95	0.10
Black body radiation shift	- 16.58	0.10
Cold collisions	0.00	0.25
Gravitational red shift	8.556	0.030
Cavity phase		0.10
Majorana transitions		0.10
Rabi and Ramsey pulling		0.10
Microwave leakage		0.10
Electronics		0.10
Light shift		0.10
Background gas collisions		0.10
Total type B uncertainty		0.39

CSF2

A detailed description of the PTB fountain CSF2 is given in Refs. [9] and [10]. Twelve measurements of the TAI scale unit of 20 (2×), 25 (1×), 30 (8×) and 35 (1×) days duration were performed and reported to the BIPM in 2017. The dead times of these measurements were in most cases below 5% and in a few cases 10-15%, where about 1% dead time is caused by the periodic switching between low and high density operation modes and periodical magnetic field measurements. The resulting clock link uncertainty $u_{l/lab}$ was typically below 0.05×10^{-15} and only in a few cases 0.10×10^{-15}. The statistical uncertainty of CSF2 measurements was calculated with the assumption of white frequency noise for the total measurement intervals. For the twelve TAI contributions in 2017 we arrived at statistical uncertainties u_A typically below 0.2×10^{-15}.

Below we compile typical frequency biases and type B uncertainties of CSF2, valid for TAI scale unit measurements in 2017.

Physical effect	Bias / 10^{-15}	Type B uncertainty / 10^{-15}
Quadratic Zeeman shift	100.171	0.010
Black body radiation shift	- 16.526	0.057
Cold collisions	- 8.20	0.04
Gravitational red shift	8.545	0.03
Cavity phase	0.032	0.15
Microwave lensing	0.067	0.034
Majorana transitions		0.0001
Rabi and Ramsey pulling		0.0013
Microwave leakage		0.10
Electronics		0.01
Light shift		0.001
Background gas collisions		0.01
Total type B uncertainty		0.20

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Annex F: Operation of SU-FO2 for BIPM Annual Report 2017

During 2017 we have transmitted to the BIPM 6 calibration of the reference hydrogen masers (CL 40 3853) performed by the VNIIFTRI caesium fountain SU-CsFO2.
The nominal operation of SU-CsFO2 was the same as in 2016. The algorithm of frequency calculations similar to the one given in [1], [2].

A summary of typical frequency shift evaluations for SU-FO2 is listed in the Table 1 below and the combined relative Type B uncertainty is evaluated to be approximately $2.4 \cdot 10^{-16}$.

Physical Effect	**Shifts (10^{-16})**	**Uncertainty (10^{-16})**
Second-order Zeeman effect	1075.8	0.10
Black-body radiation	-164.3	1.0
Gravitational shift	244.3	0.5
Resonator pulling	0.014	0.1
Purity of probe signal spectrum	0	0.1
Light shift	0	0.1
Tilting(DCP)	0.3	0.3
Microwave leakage	0	0.1
Collisions with residual gas	0	1
Microwave power dependence	0.1	1.8
Spin exchange shift (mean density)*	0.19*	0.19*
Total(not including spin exchange)	**1156.1**	**2.4**

Table 1. Typical accuracy budgets for the VNIIFTRI caesium fountain SU-CsFO2 [3]

<u>Reference</u>

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Table 7. Mean fractional deviation of the TAI scale interval from that of TT

The fractional deviation *d* of the scale interval of TAI from that of TT (in practice the SI second on the geoid), and its relative uncertainty, are computed by the BIPM for all the intervals of computation of TAI, according to the method described in 'Azoubib J., Granveaud M., Guinot B., *Metrologia* 1977, **13**, pp. 87-93', using all available measurements from the most accurate primary frequency standards (PFS) IT-CSF2, NIM5, NIST-F1, NIST-F2, NPL-CSF2, NPLI-CSF1, PTB-CS1, PTB-CS2, PTB-CSF1, PTB-CSF2, SU-CSFO2, SYRTE-FO1, SYRTE-FO2 and secondary frequency standard (SFS) SYRTE-FORb consistently corrected for the black-body radiation shift.
In this computation, the uncertainty of the link to TAI has been computed using the standard uncertainty of [UTC-UTC(*k*)], following the recommendation of the CCTF working group on PFS. The model for the instability of EAL has been expressed as the quadratic sum of three components: a white frequency noise $1.7 \times 10^{-15}/\sqrt{(\tau)}$ in 2013 and 2014 and $1.4 \times 10^{-15}/\sqrt{(\tau)}$ in 2015, 2016 and 2017, a flicker frequency noise 0.35×10^{-15} in 2013 and 2014 and 0.3×10^{-15} in 2015, 2016 and 2017 and a random walk frequency noise $0.4 \times 10^{-16} \mathrm{x} \sqrt{(\tau)}$ in 2013 and $0.2 \times 10^{-16} \mathrm{x} \sqrt{(\tau)}$ in 2014, 2015, 2016 and 2017, with τ in days. The relation between EAL and TAI is given at ftp://ftp2.bipm.org/pub/tai/other-products/ealtai/feal-ftai .

Month	Interval	$d/10^{-15}$	uncertainty$/10^{-15}$
Jan. 2015	57019-57049	+0.15	0.26
Feb. 2015	57049-57079	-0.42	0.23
Mar. 2015	57079-57109	-0.13	0.23
Apr. 2015	57109-57139	-0.10	0.23
May 2015	57139-57169	+0.36	0.21
Jun. 2015	57169-57199	+0.81	0.17
Jul. 2015	57199-57234	+0.56	0.24
Aug. 2015	57234-57264	+0.36	0.26
Sep. 2015	57264-57294	+0.09	0.21
Oct. 2015	57294-57324	+0.29	0.24
Nov. 2015	57324-57354	+0.05	0.29
Dec. 2015	57354-57384	-0.11	0.28
Jan. 2016	57384-57414	-0.32	0.25
Feb. 2016	57414-57444	-0.38	0.26
Mar. 2016	57444-57474	-0.76	0.23
Apr. 2016	57474-57504	-1.05	0.17
May 2016	57504-57539	-0.88	0.26
Jun. 2016	57539-57569	-0.55	0.18
Jul. 2016	57569-57599	-0.52	0.20
Aug. 2016	57599-57629	-0.74	0.17
Sep. 2016	57629-57659	-0.85	0.22
Oct. 2016	57659-57689	-1.30	0.21
Nov. 2016	57689-57719	-1.51	0.22
Dec. 2016	57719-57749	-1.32	0.20
Jan. 2017	57749-57784	-1.54	0.23
Feb. 2017	57784-57809	-1.25	0.23
Mar. 2017	57809-57839	-0.76	0.21
Apr. 2017	57839-57869	-0.45	0.20
May 2017	57869-57904	0.37	0.19
Jun. 2017	57904-57934	0.07	0.21
Jul. 2017	57934-57964	0.02	0.25
Aug. 2017	57964-57994	-0.16	0.24
Sep. 2017	57994-58024	-0.25	0.22
Oct. 2017	58024-58054	-0.33	0.20
Nov. 2017	58054-58084	-0.04	0.19
Dec. 2017	58084-58114	-0.17	0.20

Independent local atomic time scales

Local atomic time scales are established by the time laboratories which contribute with the appropriate clock data to the BIPM. Starting on 1 January 1998, the differences between TAI and the atomic scale maintained by each laboratory are available on the Publications page of the Time Department's FTP Server, including the relevant notes. For each time laboratory 'lab' a separate file TAI-lab is provided; it contains the respective values of the differences [*TAI - TA(lab)*] in nanoseconds, for the standard dates.

For dates from January 1982 to December 1992 and from January 1993 to December 1998, the differences between TAI and the atomic scale maintained by each laboratory are available on the Scales page of the Time Department's FTP server including the relevant notes. The values of [*TAI - TA(lab)*] are given in yearly files. Note that the formats of the [TAI – TA(lab)] files are different in the two intervals.

Local representations of UTC

The time laboratories which submit data to the BIPM keep local representations of UTC. Starting on 1 January 1998, the computed differences between UTC and each local representation are available on the Publications page of the Time Department's FTP Server including the relevant notes. For each time laboratory 'lab' a separate file UTC-lab is provided; it contains the values of the differences [*UTC - UTC(lab)*] in nanoseconds, for the standard dates.

For dates from January 1990 to December 1992 and from January 1993 to December 1998, the computed differences between UTC and each local representation maintained by each laboratory are available on the Scales page of the Time Department's FTP server including the relevant notes. The values of [*UTC - UTC(lab)*] are given in yearly files. Note that the formats of the files [*UTC – UTC*(*lab*)] are different in the two intervals.

Starting on MJD 56467 daily values of the differences [*UTCr-UTC(lab)*] in nanoseconds are given in one file per laboratory. The results during the UTCr Pilot Experiment (February 2012-June 2013) are also available.

Relations of UTC and TAI with GPS time, GLONASS time, UTC(USNO)_GPS and UTC(SU)_GLONASS

(File available at ftp://ftp2.bipm.org/pub/tai/other-products/utcgnss/utc-gnss)

[*TAI - GPS time*] and [*UTC - GPS time*]

The GPS satellites disseminate a common time scale designated 'GPS time'. The relation between GPS time and TAI is:

$$[TAI - GPS\ time] = 19\ \text{s} + C_0,$$

where the time difference of 19 seconds is kept constant and C_0 is a quantity of the order of tens of nanoseconds, varying with time.

The relation between GPS time and UTC involves a variable number of seconds as a consequence of the leap seconds of the UTC system and is as follows:

From 1 January 2017, 0 h UTC, until further notice, $[UTC - GPS\ time] = -18\ \text{s} + C_0$,

Here C_0 is given at 0 h UTC every day.

C_0 is computed as follows. The GPS data recorded at the Paris Observatory for highest-elevation satellites are first corrected for precise satellite ephemerides and for ionospheric delays derived from IGS maps, and then smoothed to obtain daily values of [*UTC*(*OP*) - *GPS time*] at 0 h UTC. Daily values of C_0 are then derived by linear interpolation of [*UTC* - *UTC*(*OP*)].

The standard deviation σ_0 characterizes the dispersion of individual measurements for a month. The actual uncertainty of user's access to GPS time may differ from these values. N_0 is the number of measurements.

[*TAI – UTC(USNO)_GPS*] and [*UTC – UTC(USNO)_GPS*]

The GPS satellites broadcast a prediction of UTC(USNO) calculated at the USNO, indicated by UTC(USNO)_GPS. The relation between UTC(USNO)_GPS and TAI involves a variable number of seconds as a consequence of the leap seconds of the UTC system, and is as follows:

From 1 January 2017, 0 h UTC, until further notice, $[TAI – UTC(USNO)\_GPS] = 37\ \text{s} + C_0'$

Here C_0' is given at 0 h UTC every day.

C_0' is computed using the values of [*UTC* - *UTC*(*OP*)] similarly than the computation of C_0.

The relation between UTC(USNO)_GPS and UTC is $[UTC– UTC(USNO)\_GPS] = 0\ \text{s} + C_0'$

The standard deviation σ_0' characterizes the dispersion of individual measurements for a month. The actual uncertainty of user's access to UTC(USNO)_GPS may differ from these values. N_0' is the number of measurements.

Relations of UTC and TAI with GPS time, GLONASS time, UTC(USNO)_GPS and UTC(SU)_GLONASS (Cont.)

(File available at ftp://ftp2.bipm.org/pub/tai/other-products/utcgnss/utc-gnss)

[*UTC - GLONASS time*] and [*TAI - GLONASS time*]

The GLONASS satellites disseminate a common time scale designated 'GLONASS time'. The relationship between GLONASS time and UTC is

$$[UTC - GLONASS\ time] = 0\ \mathrm{s} + C_1,$$

where the time difference 0 s is kept constant by the application of leap seconds so that GLONASS time follows the UTC system, and C_1 is a quantity of the order of several tens of nanoseconds (tens of microseconds until 1 July 1997), which varies with time.

The relation between GLONASS time and TAI involves a variable number of seconds and is as follows:

From 1 January 2017, 0 h UTC, until further notice, $[TAI - GLONASS\ time] = 37\ \mathrm{s} + C_1$.

Here C_1 is given at 0 h UTC every day.

C_1 is computed as follows. The GLONASS data recorded at the Astrogeodynamical Observatory, Borowiec, Poland for the highest-elevation satellites are smoothed to obtain daily values of [*UTC*(*AOS*) - *GLONASS time*] at 0 h UTC. Daily values of C_1 are then derived by linear interpolation of [*UTC* - *UTC*(*AOS*)].

To ensure the continuity of C_1 estimates, the following corrections are applied:

+1285 ns from 1 January 1997 (MJD 50449) to 22 March 1999 (MJD 51259)
+107 ns for 23 March 1999 and 24 March (MJD 51260 and MJD 51261)
0 ns since 25 March 1999, (MJD 51262).

The standard deviation σ_1 characterizes the dispersion of individual measurements for a month. The actual uncertainty of user's access to GLONASS time may differ from these values. N_1 is the number of measurements.

[*TAI – UTC(SU)_GLONASS*] and [*UTC – UTC(SU)_GLONASS*]

The satellites broadcast a prediction of UTC(SU) calculated at the SU, indicated by UTC(SU)_GLONASS. The relation between UTC(SU)_GLONASS and TAI involves a variable number of seconds as a consequence of the leap seconds of the UTC system, and is as follows:

From 1 January 2017, 0 h UTC, until further notice, $[TAI – UTC(SU)\_GLONASS] = 37\ \mathrm{s} + C_1'$

Here C_1' is given at 0 h UTC every day.

C_1' is computed using the values of [*UTC* - *UTC*(*AOS*)] similarly than the computation of C_1.

The relation between UTC(SU)_GLONASS and UTC is $[UTC– UTC(SU)\_GLONASS] = 0\ \mathrm{s} + C_1'$

The standard deviation σ_1' characterizes the dispersion of individual measurements for a month. The actual uncertainty of user's access to UTC(SU)_GPS may differ from these values. N_1' is the number of measurements.

Clocks contributing to TAI in 2017

Clocks characteristics

The annual tables of clock weight, rate, and drift, are no more published, the info can be found in the reported links in monthly files
YY represents the last two digits of the year (20YY) and MM represents the month number of the year (1-12).

Relative clock weights for intervals of one month

Monthly clock weights results are available in file wYY.MM in ftp://ftp2.bipm.org/pub/tai/other-products/weights/.

Monthly rates of TAI- clocks for intervals of one month

Monthly clock rates results are available in file rYY.MM in ftp://ftp2.bipm.org/pub/tai/other-products/rates/.

Frequency drifts of the clocks using a monthly realization of TT(BIPM) as reference

Monthly clock frequency drifts results are available in file dYY.MM in ftp://ftp2.bipm.org/pub/tai/other-products/clkdrifts/.

Table 8 reports the statistical data on the weights attributed to the clocks in 2017

Table 8: Statistical data on the weights attributed to the clocks in 2017

Interval		Number of Clocks			Number of clocks with a given weight									
					Weight = 0*			Weight = 0**			Max weight			Max relative
		HM	5071A	Total	HM	5071A	Total	HM	5071A	Total	HM	5071A	Total	weight
2017	Jan.	132	256	429	20	28	54	5	6	13	56	0	60	1.067
2017	Feb.	135	258	442	16	28	58	7	6	15	55	0	59	1.042
2017	Mar.	136	274	461	14	43	73	7	2	11	58	0	62	1.036
2017	Apr.	137	266	456	17	33	68	6	4	13	58	0	62	1.031
2017	May	136	274	458	14	38	67	6	3	11	58	0	62	1.023
2017	June	146	272	470	24	43	78	3	6	15	60	0	64	1.020
2017	July	143	271	463	22	30	58	6	9	20	65	0	69	0.988
2017	Aug.	144	263	459	19	22	50	7	11	23	68	0	72	0.978
2017	Sep.	145	280	478	18	35	61	8	11	25	65	0	69	0.959
2017	Oct.	146	279	478	13	35	52	13	11	31	65	0	69	0.939
2017	Nov.	146	267	464	12	31	48	11	10	27	67	0	71	0.962
2017	Dec.	140	262	450	8	31	43	13	8	26	66	0	70	0.983

Wmax=A/N, here N is the number of clocks, excluding those with a priori null weight, A=4.00.

* A priori null weight (test interval of new clocks).

** Null weight resulting from the statistics.

HM designates hydrogen masers and 5071A designates Hewlett-Packard 5071A units with high performance tube.

Clocks with missing data during an one-month interval of computation are excluded.

TIME SIGNALS

The time signal emissions reported here follow the UTC system, in accordance with the Recommendation 460-4 of the Radiocommunication Bureau (RB) of the International Telecommunication Union (ITU) unless otherwise stated.

Their maximum departure from the Universal Time UT1 is thus 0.9 seconds.

The following tables are based on information received at the BIPM in March 2018.

AUTHORITIES RESPONSIBLE FOR TIME SIGNAL EMISSIONS

Signal	Authority
BPC, BPL, BPM	National Time Service Center, NTSC Chinese Academy of Sciences 3 East Shuyuan Rd, Lintong District, Xi'an Shaanxi 710600, China
CHU	National Research Council of Canada Measurement Science and Standards Frequency and Time Standards Bldg M-36, 1200 Montreal Road Ottawa, Ontario, K1A 0R6, Canada
DCF77	Physikalisch-Technische Bundesanstalt Time and Frequency Department, WG 4.42 Bundesallee 100 D-38116 Braunschweig Germany
EBC	Real Instituto y Observatorio de la Armada Cecilio Pujazón s/n 11.110 San Fernando Cádiz, Spain
HLA	Center for Time and Frequency Division of Physical Metrology Korea Research Institute of Standards and Science 267 Gajeong-Ro, Yuseong, Daejeon 34113 Republic of Korea
JJY	Space-Time Standards Laboratory National Institute of Information and Communications Technology 4 -2- 1, Nukui-kitamachi Koganei, Tokyo 184-8795 Japan
LOL	Servicio de Hidrografía Naval Observatorio Naval Buenos Aires Av. España 2099 C1107AMA – Buenos Aires, Argentina
MIKES	VTT Technical Research Centre of Finland Ltd Centre for Metrology MIKES P.O. Box 1000, FI-02044 VTT, Finland

Signal	Authority
MSF	National Physical Laboratory Time and Frequency Group Hampton Road Teddington, Middlesex TW11 0LW United Kingdom
RAB-99, RBU, RJH-63, RJH-69, RJH-77, RJH-86, RJH-90,RTZ,RWM	All-Russian Scientific Research Institute for Physical Technical and Radiotechnical Measurements FGUP “VNIIFTRI” Meendeleevo, Moscow Region 141570 Russia
TDF	CFHM Chambre française de l’horlogerie et des microtechniques 22 avenue Franklin Roosevelt 75008 Paris, France and ANFR Agence nationale des fréquences 78, avenue du général de Gaulle 94704 Maisons-Alfort, France and LNE Laboratoire national de métrologie et d’essais 1 rue Gaston Boissier 75724 Paris Cedex 15, France
WWV, WWVB, WWVH	Time and Frequency Division, 688.00 National Institute of Standards and Technology - 325 Broadway Boulder, Colorado 80305, U.S.A.

TIME SIGNALS EMITTED IN THE UTC SYSTEM

Station	Location Latitude Longitude	Frequency (kHz)	Schedule (UTC)	Form of the signal
BPC	Shangqiu China 34° 27'N 115° 50'E	68.5	00 h 00 m to 21 h 00 m	UTC second pulse modulation of the phase shift keying of the carrier. The additional pulse width modulation includes calendar and local time information.
BPL	Pucheng China 34° 56'N 109° 32'E	100	Continuous	The BPL time signals are generated by NTSC and are in accordance with the legal time of China which is UTC(NTSC)+8 . The BPL system is the same as the Loran-C system, utilizing the multi-pulse phase coding scheme. Carrier Frequency of 100KHz. The information that BPL broadcasts contains minutes, seconds, year, month, day, and other information. Using pulse shift modulation.
BPM	Pucheng China 35° 0'N 109° 31'E	2 500 5 000 10 000 15 000	7 h 30 m to 1 h Continuous Continuous 1 h to 9 h	The BPM time signals are generated by NTSC and are in accordance with UTC(NTSC)+8 h. Signals emitted in advance on UTC by 20 ms. Second pulses of 10 ms duration with 1 kHz modulation. Minute pulses of 300 ms duration with 1 kHz modulation. UTC time signals are emitted from minute 0 to 10, 15 to 25, 30 to 40, 45 to 55. UT1 time signals are emitted from minute 25 to 29, 55 to 59.
CHU	Ottawa Canada 45° 18'N 75° 45'W	3 330 7 850 14 670	Continuous	Second pulses of 300 cycles of a 1 kHz modulation, with 29th and 51st to 59th pulses of each minute omitted. Minute pulses are 0.5 s long. Hour pulses are 1.0 s long, with the following 1st to 9th pulses omitted. A bilingual (Fr. Eng.) announcement of time (UTC) is made each minute following the 50th second pulse. FSK code (300 bps, Bell 103) after 10 cycles of 1 kHz on seconds 31 to 39. Year, DUT1, leap second information, TAI-UTC and Canadian daylight saving time format on 31, and time code on 32-39. Broadcast is single sideband; upper sideband with carrier reinsert. DUT1 : ITU-R code by double pulse.
DCF77	Mainflingen Germany 50° 1'N 9° 0'E	77.5	Continuous	The DCF77 time signals are generated by PTB and are in accordance with the legal time of Germany which is UTC(PTB)+1 h or UTC(PTB)+2 h. At the beginning of each second (except in the last second of each minute) the carrier amplitude is reduced to about 15 % for a duration of 0.1 or 0.2 s corresponding to “binary 0” or “binary 1”, respectively, referred to as second marks 0 to 59 in the following. The number of the minute, hour, day of the month, day of the week, month and year are transmitted in BCD code using second marks 20 to the 58, including overhead. Information emitted during minute n is valid for minute n+1. The information transmitted during the second marks 1 to the 14 is provided by third parties. Information on that additional service can be obtained from PTB. To achieve a more accurate time transfer and a better use of the frequency spectrum available an additional pseudo-random phase shift keying of the carrier is superimposed on the AM second markers. No transmission of DUT1.

Station	Location Latitude Longitude	Frequency (kHz)	Schedule (UTC)	Form of the signal
EBC	San Fernando Spain 36° 28'N 6° 12'W	15006 4998	10 h 00 m to 10 h 25 m 10 h 30 m to 10 h 55 m except Saturday, Sunday and national holidays.	Second pulses of 0.1 s duration of a 1 kHz modulation. Minute pulses of 0.5 s duration of 1 250 Hz modulation. DUT1: ITU-R code by double pulse.
HLA	Daejeon Rep. of Korea 36° 23'N 127° 22'E	5 000	Continuous	Second pulses of 9 cycles of 1 800 Hz tones. 29th and 59th second pulses omitted. Hour identified by 0.8 s long 1 500 Hz tones. Beginning of each minute identified by 0.8 s long 1 800 Hz tones. BCD time code given on 100 Hz subcarrier.
JJY	Tamura-shi Fukushima Japan 37° 22'N 140° 51'E	40	Continuous	A1B type 0.2 s, 0.5 s and 0.8 s second pulses, spacings are given by the reduction of the amplitude of the carrier. Coded announcement of hour, minute, day of the year, year, day of the week and leap second. Transmitted time refers to UTC(NICT) + 9 h.
JJY	Saga-shi Saga Japan 33° 28'N 130° 11'E	60	Continuous	A1B type 0.2 s, 0.5 s and 0.8 s second pulses, spacings are given by the reduction of the amplitude of the carrier. Coded announcement of hour, minute, day of the year, year, day of the week and leap second same as JJY(40). Transmitted time refers to UTC(NICT) + 9 h.
LOL	Buenos Aires Argentina 34° 37'S 58° 21'W	10 000	11 h to 12 h except Saturday, Sunday and national holidays.	Second pulses of 5 cycles of 1000 Hz modulation. Second 59 is omitted. Announcement of hours and minutes every 5 minutes, followed by 3 minutes of 1000 Hz or 440 Hz modulation. DUT1: ITU-R code by lengthening.
MIKES	Espoo Finland 60° 11'N 24° 50'E	25 000	Continuous	Modulation as in DCF77, but with 1 kHz amplitude modulation added and without pseudo-random phase shift keying of the carrier. Time code in UTC. As of 2017 the transmission of time-signal is discontinued until further notice.
MSF	Anthorn United Kingdom 54° 54'N 3° 16'W	60	Continuous, except for interruptions for maintenance from 10 h 0 m to 14 h 0 m on the second Thursday of December and March, and from 09 h 0 m to 13 h 0 m on the second Thursday of June and September. A longer period of maintenance during the summer is announced annually.	The carrier is interrupted for 0.1 s at the start of each second, except during the first second of each minute (second 0) when the interruption is 0.5 s. Two data bits are transmitted each second (except second 0): data bit “A” between 0.1 and 0.2 s after the start of the second and data bit “B” between 0.2 and 0.3 s after the start of the second. Presence of the carrier represents “binary 0” and an interruption represents “binary 1”. The values of data bit “A” provide year, month, day of the month, day of the week, hour and minute in BCD code. The time represented is UTC(NPL) in winter and UTC(NPL)+1h when DST is in effect. The values of data bit “B” provide DUT1 and an indication whether DST is in effect. The information transmitted applies to the following minute. DUT1: ITU-R code by double pulse.

Station	Location Latitude Longitude	Frequency (kHz)	Schedule (UTC)	Form of the signal
RAB-99	Khabarovsk Russia 48° 30'N 134° 50'E	25.0 25.1 25.5 23.0 20.5	02 h 06 m to 02 h 36 m 06 h 06 m to 06 h 36 m	A1N type signals are transmitted between minutes 9 and 20 : 0.025 second pulses of 12.5 ms duration are transmitted between minutes 9 and 11; second pulses of 0.1 s duration, 10 second pulses of 1 s duration, 0.1 second pulses of 25 ms and minute pulses of 10 s duration are transmitted between minutes 11 and 20.
RBU	Moscow Russia 56° 44'N 37° 40'E	200/3	Continuous	DXXXW type 0.1 s signals. The numbers of the minute, hour, day of the month, day of the week, month, year of the century, difference between the universal time and the local time, TJD and DUT1+dUT1 are transmitted each minute from the 1st to the 59th second. DUT1+dUT1 : by double pulse.
RJH-63	Krasnodar Russia 44° 46'N 39° 34'E	25.0 25.1 25.5 23.0 20.5	11 h 06 m to 11 h 40 m	A1N type signals are transmitted between minutes 9 and 20 : 0.025 second pulses of 12.5 ms duration are transmitted between minutes 9 and 11 ; 0.1 second pulses of 25 ms duration, 10 second pulses of 1 s duration and minute pulses of 10 s duration are transmitted between minutes 11 and 20.
RJH-69	Molodechno Belarus 54° 28'N 26° 47'E	25.0 25.1 25.5 23.0 20.5	07 h 06 m to 07 h 47 m	A1N type signals are transmitted between minutes 10 and 22 : 0.025 second pulses of 12.5 ms duration are transmitted between minutes 10 and 13; second pulses of 0.1 s duration, 10 second pulses of 1 s duration, 0.1 second pulses of 25 ms and minute pulses of 10 s duration are transmitted between minutes 13 and 22.
RJH-77	Arkhangelsk Russia 64° 22'N 41° 35'E	25.0 25.1 25.5 23.0 20.5	09 h 06 m to 09 h 47 m	A1N type signals are transmitted between minutes 10 and 22 : 0.025 second pulses of 12.5 ms duration are transmitted between minutes 10 and 13; second pulses of 0.1 s duration, 10 second pulses of 1 s duration, 0.1 second pulses of 25 ms and minute pulses of 10 s duration are transmitted between minutes 13 and 22.
RJH-86	Bishkek Kirgizstan 43° 03'N 73° 37'E	25.0 25.1 25.5 23.0 20.5	04 h 06 m to 04 h 47 m 10 h 06 m to 10 h 47 m	A1N type signals are transmitted between minutes 10 and 22 : 0.025 second pulses of 12.5 ms duration are transmitted between minutes 10 and 13; second pulses of 0.1 s duration, 10 second pulses of 1 s duration, 0.1 second pulses of 25 ms and minute pulses of 10 s duration are transmitted between minutes 13 and 22.
RJH-90	Nizhni Novgorod Russia 56° 11'N 43° 57'E	25.0 25.1 25.5 23.0 20.5	08 h 06 m to 08 h 47 m	A1N type signals are transmitted between minutes 10 and 22 : 0.025 second pulses of 12.5 ms duration are transmitted between minutes 10 and 13; second pulses of 0.1 s duration, 10 second pulses of 1 s duration, 0.1 second pulses of 25 ms and minute pulses of 10 s duration are transmitted between minutes 13 and 22.
RTZ	Irkutsk Russia 52° 26'N 103° 41'E	50	00 h 00 m to 19 h 00 m 20 h 00 m to 24 h 00 m	DXXXW type 0.1 s signals. The numbers of the minute, hour, day of the month, day of the week, month, year of the century, difference between the universal time and the local time, TJD and DUT1+dUT1 are transmitted each minute from the 1st to the 59th second. DUT1+dUT1: by double pulse.

Station	Location Latitude Longitude	Frequency (kHz)	Schedule (UTC)	Form of the signal
RWM (2)	Moscow Russia 56° 44'N 37° 38'E	4 996 9 996 14 996	The station operates simultaneously on the three frequencies.	A1X type second pulses of 0.1 s duration are transmitted between minutes 10 and 20, 40 and 50. The pulses at the beginning of the minute are prolonged to 0.5 s. A1N type 0.1 s second pulses of 0.02 s duration are transmitted between minutes 20 and 30. The pulses at the beginning of the second are prolonged to 40 ms and of the minute to 0.5 ms. DUT1+dUT1: by double pulse.
TDF	Allouis France 47° 10'N 2° 12'E	162	Continuous, except every Tuesday from 8 h to12 h (French time)	Phase modulation of the carrier by +1 and -1 rd in 0.1 s every second except the 59th second of each minute. This modulation is doubled to indicate binary 1. The numbers of the minute, hour, day of the month, day of the week, month and year are transmitted each minute from the 21st to the 58th second, in accordance with the French legal time scale. In addition, a binary 1 at the 17th second indicates that the local time is 2 hours ahead of UTC (summer time); a binary 1 at the 18th second indicates that the local time is 1 hour ahead of UTC (winter time); a binary 1 at the 14th second indicates that the current day is a public holiday (Christmas, 14 July, etc...); a binary 1 at the 13th second indicates that the current day is a day before a public holiday.
WWV	Fort-Collins CO, USA 40° 41'N 105° 3'W	2 500 5 000 10 000 15 000 20 000 25 000	Continuous	Second pulses are 1 000 Hz tones, 5 ms in duration. 29th and 59th second pulses omitted. Hour is identified by 0.8 second long 1 500 Hz tone. Beginning of each minute identified by 0.8 second long 1 000 Hz tones. DUT1: ITU-R code by double pulse. BCD time code given on 100 Hz subcarrier, includes DUT1 correction.
WWVB	Fort-Collins CO, USA 40° 41'N 105° 3'W	60	Continuous	Second pulses given by reduction of the amplitude, reversal of phase, and by binary phase shift keying of the carrier, AM, PM and BPSK coded announcement of the date, time, DUT1 correction, daylight saving time in effect, leap year and leap second.
WWVH	Kauai HI, USA 21° 59'N 159° 46'W	2 500 5 000 10 000 15 000	Continuous	Second pulses are 1 200 Hz tones, 5 ms in duration. 29th and 59th second pulses omitted. Hour is identified by 0.8 second long 1 500 Hz tone. Beginning of each minute identified by 0.8 second long 1 200 Hz tones. DUT1: ITU-R code by double pulse. BCD time code given on 100 Hz subcarrier, includes DUT1 correction.

(2) RWM is the radiostation emitting DUT1 information in accordance with the ITU-R code and also giving an additional information, dUT1, which specifies more precisely the difference UT1-UTC down to multiples of 0.02 s, the total value of the correction being DUT1+dUT1.
Positive values of dUT1 are transmitted by the marking of *p* second markers within the range between the 21st and 24th second so that dUT1 = +*p* x 0.02 s.
Negative values of dUT1 are transmitted by the marking of *q* second markers within the range between the 31st and 34th second, so that dUT1 = -*q* x 0.02 s.

ACCURACY OF THE CARRIER FREQUENCY

Station	Relative uncertainty of the carrier frequency in 10^{-10}
BPM	0.01
CHU	0.05
DCF77	0.02
EBC	0.1
HLA	0.02
JJY	0.01
LOL	0.1
MIKES	0.01
MSF	0.02
RAB-99,RJH-63	0.05
RBU,RTZ	0.02
RJH-69, RJH-77	0.05
RJH-86, RJH-90	0.05
RWM	0.05
TDF	0.02
WWV	0.01
WWVB	0.01
WWVH	0.01

TIME DISSEMINATION SERVICES

The following tables are based on information received at the BIPM between February and March 2018.

AUTHORITIES RESPONSIBLE FOR TIME DISSEMINATION SERVICES

AOS	Astrogeodynamical Observatory Borowiec near Poznan Space Research Centre P.A.S. PL 62-035 Kórnik - Poland
AUS	Electricity Section National Measurement Institute PO Box 264 Lindfield NSW 2070 - Australia
BelGIM	Belarussian State Institute of Metrology National Standard for Time, Frequency and Time-scale of the Republic of Belarus Minsk, Minsk Region – 220053 Belarus
BEV	Bundesamt für Eich- und Vermessungswesen Arltgasse 35 A-1160 Wien, Vienna - Austria
BoM	Ministry of economy - Bureau of metrology Jane Sandanski 109a 1000 Skopje, Macedonia
CENAM	Centro Nacional de Metrología km. 4.5 Carretera a Los Cués El Marqués, Querétaro, C.P. 76246 - Mexico
CENAMEP	Centro Nacional de Metrología de Panamá AIP CENAMEP AIP Ciudad del Saber Edif. 206 Panama
DMDM	Directorate of Measures and Precious Metals Group for Time, Frequency and Time Dissemination. Mike Alasa 14 11000 Belgrade Serbia
EIM	Hellenic Institute of Metrology Electrical Measurements Department Block 45, Industrial Area of Thessaloniki PO 57022, Sindos Thessaloniki, Greece
GUM	Time and Frequency Laboratory Główny Urząd Miar – Central Office of Measures ul. Elektoralna 2 PL 00 – 950 Warszawa P–10, Poland
HKO	Hong Kong Observatory 134A, Nathan Road Kowloon, Hong Kong, China

ICE	Instituto Costarricense de Electricidad ICE San Jose Costa Rica
IGNA	Instituto Geográfico Nacional Argentino Servicio Internacional de la Hora General Manuel N. Savio 1898 B1650KLP – Villa Maipú, Provincia de Buenos Aires, Argentina
IMBH	Institute of Metrology of Bosnia and Herzegovina (IMBH) Laboratory for time and frequency Augusta Brauna 2 71000 Sarajevo, Bosnia and Herzegovina
INACAL	Instituto Nacional de Calidad Calle De La Prosa 150 San Borja, Lima 41, Peru
INM	Instituto Nacional de Metrología de Colombia Avenida Carrera 50 No. 26 – 55 Interior 2 Bogotá D.C. – Colombia
INPL	National Physical Laboratory Danciger A bldg Givat - Ram, The Hebrew university 91904 Jerusalem, Israel
INRIM	Istituto Nazionale di Ricerca Metrologica Strada delle Cacce, 91 I – 10135 Turin, Italy
JV	Justervesenet Norwegian Metrology Service PO Box 170 2027 Kjeller, Norway
KIM	Puslit Kalibrasi, Instrumentasi dan Metrologi -- Lembaga Ilmu Pengetahuan Indonesia Research Centre for Calibration, Instrumentation and Metrology -- Indonesian Institute of Sciences (Puslit KIM – LIPI) Kawasan PUSPIPTEK Serpong Tangerang 15314 Banten - Indonesia
KRISS	Center for Time and Frequency Division of Physical Metrology Korea Research Institute of Standards and Science 267 Gajeong-Ro, Yuseong Daejeon 34113 Republic of Korea
KZ	Kazakhstan Institute of Metrology Orynbor str., 11 Astana, Republic of Kazakhstan
LNE-SYRTE	Laboratoire National de Métrologie et d’Essais Systèmes de Référence Temps-Espace Observatoire de Paris 61, avenue de l’Observatoire, 75014 Paris – France

LT	Time and Frequency Standard Laboratory Center for Physical Sciences and Technology Savanoriu av. 231 Vilnius LT-02300, Lithuania
MASM	Time and Frequency Standard Laboratory Mongolian Agency for Standardization and Metrology Peace avenue 46A, Bayanzurkh district, Ulaanbaatar 13343 Mongolia
METAS	Federal Institute of Metrology Sector Length, Optics and Time Lindenweg 50 CH-3003 Bern-Wabern Switzerland
MIKES	VTT Technical Research Centre of Finland Ltd Centre for Metrology MIKES P.O. Box 1000, FI-02044 VTT, Finland
MSL	Measurement Standards Laboratory Callaghan Innovation 69 Gracefield Road PO Box 31-310 Lower Hutt – New Zealand
NAO	Time Keeping Office Mizusawa VLBI Observatory National Astronomical Observatory of Japan 2-12, Hoshigaoka, Mizusawa, Oshu, Iwate 023-0861 Japan
NICT	Space-Time Standards Laboratory National Institute of Information and Communications Technology 4 -2 -1, Nukui-kitamachi Koganei, Tokyo 184-8795 - Japan
NIM	Time & Frequency Laboratory National Institute of Metrology No. 18, Bei San Huan Dong Lu Beijing 100029 - People's Republic of China
NIMB	Time and Frequency Laboratory National Institute of Metrology Sos. Vitan - Barzesti, 11 042122 Bucharest, Romania
NIMT	Time and Frequency Laboratory National Institute of Metrology (Thailand) 3/5 Moo 3, Klong 5, Klong Luang, Pathumthani 12120, Thailand
NIST	National Institute of Standards and Technology Time and Frequency Division, 688.00 325 Broadway Boulder, Colorado 80305, USA

NMIJ	Time Standards Group National Metrology Institute of Japan (NMIJ), AIST Umezono 1-1-1, Tsukuba, Ibaraki 305-8563, Japan
NMISA	Time and Frequency Laboratory National Metrology Institute of South Africa Private Bag X34 Lynnwood Ridge 0040, Pretoria - South Africa
NMLS	Time and Frequency Laboratory National Metrology Institute of Malaysia Lot PT 4803, Bandar Baru Salak Tinggi, 43900 Sepang - Malaysia
NPL	National Physical Laboratory Time and Frequency Group Hampton Road Teddington, Middlesex TW11 0LW United Kingdom
NPLI	Time and Frequency Metrology Section CSIR-National Physical Laboratory Dr.K.S.Krishnan Road New Delhi 110012 - India
NRC	National Research Council of Canada Measurement Science and Standards Frequency and Time Standards Bldg M-36, 1200 Montreal Road Ottawa, Ontario, K1A 0R6, Canada
NSC IM	Time and Frequency Section National Scientific Center "Institute of Metrology" Kharkov - Ukraine Region – 61002 Ukraine
NTSC	National Time Service Center Chinese Academy of Sciences 3 East Shuyuan Rd, Lintong District, Xi’an Shaanxi 710600, China
ONBA	Servicio de Hidrografía Naval Observatorio Naval Buenos Aires Servicio de Hora Av. España 2099 C1107AMA – Buenos Aires, Argentina
ONRJ	Observatorio Nacional (MCTIC) Divisão Serviço da Hora Rua General José Cristino, 77 São Cristovão 20921-400 Rio de Janeiro, Brazil

ORB	Royal Observatory of Belgium Avenue Circulaire, 3 B-1180 Brussels, Belgium
PTB	Physikalisch-Technische Bundesanstalt Time and Frequency Department, WG 4. 42 Bundesallee 100 D-38116 Braunschweig, Germany
ROA	Real Instituto y Observatorio de la Armada Plaza de las Tres Marinas s/n 11.100 San Fernando Cádiz, Spain
SG	National Metrology Centre Agency for Science, Technology and Research (A*STAR) 1 Science Park Drive 118221 Singapore
SIQ	SIQ Ljubljana Metrology department Trzaska ul. 2 1000 Ljubljana Slovenia
SP	SP Technical Research Institute of Sweden Box 857 S-501 15 Borås Sweden
TL	National Standard Time and Frequency Laboratory Telecommunication Laboratories Chunghwa Telecom. Co., Ltd. No. 99, Dianyan Road Yang-Mei, Taoyuan, 32661 Taiwan Chinese Taipei
TP	Institute of Photonics and Electronics Czech Academy of Sciences Chaberská 57, 182 51 Praha 8 Czech Republic
UME	Ulusal Metroloji Enstitüsü Baris Mah. Dr. Zeki Acar Cad. No: 1 41470 Gebze - Kocaeli Turkey
USNO	U.S. Naval Observatory 3450 Massachusetts Ave., N.W. Washington, D.C. 20392-5420 USA
VMI	Laboratory of Time and Frequency (TFL) Vietnam Metrology Institute (VMI) No 8, Hoang Quoc Viet Rd, Cau Giay Dist., Hanoi Vietnam.

VNIIFTRI	All-Russian Scientific Research Institute for Physical Technical and Radiotechnical Measurements, Moscow Region 141570 Russia
VSL	VSL Dutch Metrology Institute Postbus 654 2600 AR Delft Netherlands

TIME DISSEMINATION SERVICES

AOS	AOS Computer Time Service: vega.cbk.poznan.pl (150.254.183.15) Synchronization: NTP V3 primary (Caesium clock), PC Pentium, RedHat Linux Service Area: Poland/Europe Access Policy: open access Contact: Jerzy Nawrocki (nawrocki@cbk.poznan.pl) Robert Diak (kondor@cbk.poznan.pl) Full list of time dissemination services is available on: http://www.eecis.udel.edu/~mills/ntp/
AUS	Network Time Service Computers connected to the Internet can be synchronized to UTC(AUS) using the NTP protocol. The NTP servers are referenced to UTC(AUS) either directly or via a GPS common view link. Please see http://www.measurement.gov.au/Services/Pages/TimeandFrequencyDisseminationService.aspx for information on access or contact time@measurement.gov.au Dial-up Computer Time Service Computers can also obtain time via a modem connection to our dial-up timeserver. For further information, please see our web pages as above.
BelGIM	Internet Time Service: BelGIM operates one time server Stratum 1 using the "Network Time Protocol" (NTP). The server host name is: http://www.belgim.by (Stratum 1)
BEV	Three NTP servers are available; addresses: bevtime1.metrologie.at bevtime2.metrologie.at time.metrologie.at more information on http://www.metrologie.at Provides a time dissemination service via phone and modem to synchronize PC clocks. Uses the Time Distribution System from TUG. It has a baud rate of 1200 and everyone can use it with no cost. Access phone number is +43 1 21110 826381 The system will be updated periodically (DUT1, Leap Second…).
BoM	Internet Time Service BoM operates two Stratum 1 NTP servers referenced to UTC(BoM). BoM also operates one time server Stratum 2 using the "Network Time Protocol" (NTP). Server Host Name: time.bom.gov.mk
CENAM	CENAM operates a voice automatic system that provides the local time for four different time zones for Mexico; Southeast Time, Central Time, Pacific Time and Northwest Time as well the UTC(CNM). The access numbers are: +52 442 211 0505: Southeast Time +52 442 211 0506: Central Time +52 442 211 0507: Pacific Time +52 442 211 0508: Northwest Time +52 442 211 0509: UTC(CNM)

Telephone Code
CENAM provides a telephone code for setting time in computers. For more information about this service please contact Eduardo De Carlos López at edlopez@cenam.mx

Network Time Protocol
Operates two time server using the "Network Time Protocol", it is located at the Centro Nacional de Metrología, Querétaro, Mexico. Further information at http://www.cenam.mx/hora_oficial/

Web-based time-of-day clock that displays local time for Mexico's time zones. Referenced to CENAM Internet Time Service. Available at http://www.cenam.mx/hora_oficial/

CENAMEP

Network Time Server
A Stratum 1 time server is used to synchronize computer networks of the government institutions and companies in the private sector using the NTP protocol. To access the Network time service, send an email to servicios@cenamep.org.pa

Web Clock
A web clock is used to display the time of day in real time. To access the Web Clock, enter the link http://horaexacta.cenamep.org.pa/

Voice Time Server
An assembly of computers provides the local time. To access the service, call the telephone numbers (507) 5173201, (507) 5173202 and (507) 5173203

DMDM

Internet Time Service (ITS)
DMDM operates two Stratum 1 time servers using the "Network Time Protocol" (NTP), synchronized to UTC(DMDM).
Access policy: restricted.
DMDM also operates two Stratum 2 NTP servers:
vreme1.dmdm.rs or vreme1.dmdm.gov.rs
vreme2.dmdm.rs or vreme2.dmdm.gov.rs
Access policy: free.
More information on:
http://www.dmdm.rs/en/GrupaZaVremeFrekfencijuIDistribucijuVremena.php#TacnoVreme

Web-based time-of-day clock that displays local time for Serbia referenced to the DMDM ITS. Available at the web page:
http://www.dmdm.rs/en/index.php

EIM

Internet Time Service
EIM operates a time server using the "Network Time Protocol" (NTP). The address hercules.eim.gr is also accessible through IP address 83.212.233.6. This route is offered under a restricted access policy. The server uses the 10 MHz signal from our primary standard as reference and is synchronized to UTC(EIM).

GUM

Telephone Time Service providing the European time code by telephone modem for setting time in computers. Includes provision for compensation of propagation time delay.
Access phone number : +48 22 654 88 72

Network Time Service
Two NTP servers are available:
tempus1.gum.gov.pl
tempus2.gum.gov.pl
with an open access policy. It provides synchronization to UTC(PL).
Contact: timegum@gum.gov.pl

HKO

Internet Clock Services
HKO operates time-of-day clocks that display Hong Kong Standard Time (=UTC(HKO) + 8 h)
Available as:

1. Web Clock (Flash): http://www.hko.gov.hk/gts/time/HKSTime.htm
2. Web Clock (HTML): http://www.hko.gov.hk/gts/time/clock_e.html
3. Palm Clock (HTML5): http://www.hko.gov.hk/m/clock.htm

Speaking Clock Service
HKO operates an automatic “Dial-a-weather System” that provides a voice announcement of Hong Kong Standard Time.
Access phone number: +852 1878200
(when connected, press “3”, “6”, “1” in sequence)

Network Time Service
HKO operates network time service using Network Time Protocol (NTP). Host names of the NTP servers: stdtime.gov.hk; time.hko.hk (for IPv6 users)
Further information at http://www.hko.gov.hk/nts/ntime.htm

ICE

Network Time Server
A Stratum 1 time server is used to synchronize computer networks of the government institutions and companies in the private sector using the NTP protocol. To access the Network time service, send an email to ofallasc@ice.go.cr

Web Clock
A web clock is used to display the time of day in real time. To access the Web Clock, enter the link:
https://www.grupoice.com/wps/portal/ICE/Electricidad/servicios-especiales/laboratorios

Voice Time Server
An assembly of computers provides the local time. To access the service, call the telephone numbers (506) 1112

IGNA

GPS common-view data
GPS common-view data using CGGTTS format referred to UTC(IGNA) is available through our website at
http://www.ign.gob.ar/NuestrasActividades/Geodesia/ServicioInternacionalHora/TransferenciaDeTiempo

IMBH (1)

Internet Time Service
IMBH operates several Stratum 1 time servers using the NTP protocol. These servers are directly synchronized to UTC(IMBH).
The servers are available at IP address: 185.12.78.85

Common-view data
GPS and GLONASS common-view data using CGGTTS format referred to UTC(IMBH) are available at request.
Further information can be found at: http://met.gov.ba

INACAL (1)

Network Time Server
A time server is used to synchronize computer networks of the government institutions and companies in the private sector using the NTP protocol. To access the Network time enter the link
http://www.inacal.gob.pe/metrologia/categoria/sincronizacion-de-sistemas-de-computo

Web Clock
A web clock is used to display the time of day in real time. To access the Web Clock, enter the link http://www.inacal.gob.pe/

(1) Information based on the Annual Report 2016, not confirmed by the Laboratory.

INM	Network Time Protocol Operates a time server using the “Network Time Protocol”, it is located at the Instituto Nacional de Metrología de Colombia, Bogotá D.C., Colombia. Further information at: http://www.inm.gov.co/index.php/servicios-inm/hora-legal Web Clock Service A web clock is used to display the time of day in real time. The web clock is available at: http://horalegal.inm.gov.co/
INPL	Time dissemination service is performed in Israel by telecommunication companies, whose time and frequency standards are traceable to local UTC(INPL) time and are calibrated regularly once a year against the Israeli Time and Frequency National Standard kept by INPL.
INRIM	CTD Telephone Time Code Time signals dissemination, according to the European Time code format, available via modem on regular dial-up connection. Access phone numbers : 0039 011 3919 263 and 0039 011 3919 264. Provides a synchronization to UTC(IT) for computer clocks without compensation for the propagation time. Internet Time Service INRIM operates two time servers using the "Network Time Protocol" (NTP); host names of the servers are ntp1.inrim.it and ntp2.inrim.it. More information on this service can be found on the web pages: http://rime.inrim.it/labtf/ntp/. SRC (Segnale RAI Codificato) coded time signal broadcast 20 – 30 times per day by “Radio Uno” and “Radio Tre” FM radio stations of the national broadcasting company RAI. The SRC code dissemination to RAI by INRIM, was definitively interrupted since 2017 January 1st. RAI could decide to continue to disseminate the SRC code to the country via Radio1 and Radio3 channels, but the traceability to UTC will not be guaranteed anymore by INRIM. It is worth highlighting that the SRC code is listed among the ITU Time Dissemination Codes (Rec. ITU-R TF.583-4). Web-based time-of-day clock that displays UTC or local time for Italy (Central Europe Time), referenced to INRIM Internet Time Service. Provides a snapshot of time with any web browser. A continuous time display requires a web browser with Java plug-in installed.
JV (1)	Network Time Protocol JV operates an open access stratum 1 server referenced to UTC(JV) ntp.justervesenet.no Other stratum 1 servers over a separate network are available by special agreement. Contact: hha@justervesenet.no
KIM (1)	Network Time Protocol (NTP) Service The NTP time information referenced to UTC(KIM) is generated by Stratum-1 NTP server at URL: ntp.kim.lipi.go.id or IP: 203.160.128.178 The server also provides time services using Daytime Protocol, and Time Protocol.

(1) Information based on the Annual Report 2016, not confirmed by the Laboratory.

KRISS	Telephone Time Service Provides digital time code to synchronize computer clocks to Korea Standard Time (=UTC(KRIS) + 9 h) via modem. Access phone number: + 82 42 868 5116 Network Time Service KRISS operates three time servers using the NTP to synchronize computer clocks to Korea Standard Time via the Internet. Host name of the server: time.kriss.re.kr (210.98.16.100). Software for the synchronization of computer clocks is available at http://www.kriss.re.kr
KZ (1)	Network Time Service Stratum-1 time server using the "Network Time Protocol" (NTP). Restricted access and free access ip 89.218.41.170 Stratum-2 time server using the "Network Time Protocol" (NTP). Free access. Stratum-2 is available: ip 88.204.171.178 Web-based Time Services: A real-time clock aligned to UTC(KZ) and corrected for internet transmission delay. “Six-pip time signals” are broadcast by FM radio stations hourly every day.
LNE-SYRTE	LNE-SYRTE operates several time servers using the “Network Time Protocol” (NTP) : Stratum-1 time server: ntp-p1.obspm.fr (restricted access) Stratum-2 time server: ntp.obspm.fr (free access) Futher information at: http://syrte.obspm.fr/informatique/ntp_infos.php
LT	Network Time Service via NTP protocol NTP v3 DNS: laikas.pfi.lt Port 123 Synchronization from caesium clock (1 pps) System: Datum TymeServe 2100 NTP server Access policy: free Contact: Rimantas Miškinis Mail: Laikas@pfi.lt http://www.pfi.lt/metrology/
MASM	Network Time Service via NTP It provides synchronization to UTC(MASM) Adress: ntp.mn System: LANTIME 600 Ascess policy: free
METAS	Internet Time Service METAS operates stratum-1 public NTP servers in free access. Host names: ntp.metas.ch metasntp11.admin.ch metasntp12.admin.ch metasntp13.admin.ch More information available at http://www.metas.ch/metas/en/home/fabe/zeit-und-frequenz/time-dissemination.html

(1) Information based on the Annual Report 2016, not confirmed by the Laboratory.

MIKES	VTT MIKES provides an official stratum-1 level NTP service to paying organizations and institutions. Stratum-2 level NTP service is freely available to everyone. Both NTP services are provided over public internet. PTP and PTP White Rabbit services are provided to individual customers over dedicated links. Further information can be found at http://www.mikes.fi/ntp-palvelu/
MSL	Network Time Service Computers connected to the Internet can be synchonized to UTC(MSL) using the NTP protocol. Access is available for users within New Zealand. Two servers are available at msltime1.irl.cri.nz and msltime2.irl.cri.nz Speaking Clock A speaking clock gives New Zealand time. Because it is a pay service, access is restricted to callers within New Zealand. Further information about these services can be found at http://measurement.govt.nz/about-us/official-new-zealand-time
NAO	Network Time Service Three stratum 2 NTP servers are available. The NTP servers internally refer stratum 1 NTP server that is linked to UTC(NAO). One of the three stratum 2 NTP servers are selected automatically by a round-robin DNS server to reply for an NTP access. The server host name is s2csntp.miz.nao.ac.jp.
NICT	Telephone Time Service (TTS) NICT provides digital time code accessible by computer at 300/1200/2400 bps, 8 bits, no parity. Access number to the lines: + 81 42 327 7592. Network Time Service (NTS) NICT operates four Stratum 1 NTP time servers linked to UTC(NICT) through a leased line. Internet Time Service (ITS) NICT operates four Stratum 1 NTP time servers linked to UTC(NICT) through the Internet. Host name of the servers: ntp.nict.jp (Round robin). GPS common view data NICT provides the GPS common view data based on UTC(NICT) to the time business service in Japan.
NIM	Telephone Time Service The coded time information generated by NIM time code generator, referenced to UTC(NIM). Telephone Code provides digital time code at 1200 to 9600 bauds, 8 bits, no parity, 1 stop bit. Access phone number: 8610 6422 9086. Network Time Service Provides digital time code across the Internet using NTP server via free IP access: 111.203.6.13 111.203.6.12 Further information at: http://en.nim.ac.cn/page/976

NIMB (1)	1 NTP server is available: Address: ntp.inm.ro (STRATUM 1) with an open access policy Server is referenced to UTC(NIMB).
NIMT	Internet Time Services NIMT operates 3 NTP servers at: time1.nimt.or.th time2.nimt.or.th time3.nimt.or.th The NTP servers are referenced to UTC(NIMT). FM/RDS Radio Transmission The time code is applied to the sub-carrier frequency of 57 kHz using the Radio Data System protocol. The accuracy of time transmission is around 30 ms of UTC(NIMT) depending on the internet traffic. The time code is broadcast via 40 radio stations across the country.
NIST	Automated Computer Time Service (ACTS) Provides digital time code by telephone modem for setting time in computers. Free software and source code available for download from NIST. Includes provision for calibration of telephone time delay. Access phone numbers : +1 303 494 4774 (8 phone lines) and +1 808 335 4721 (2 phone lines). Further information at http://www.nist.gov/pml/div688/grp40/acts.cfm Internet Time Service (ITS) Provides digital time code across the Internet using three different protocols: Network Time Protocol (NTP), Daytime Protocol, and Time Protocol. (Time Protocol is not supported by all servers) Geographically distributed set of multiple time servers at multiple locations within the United States of America. For most current listing of time servers and locations, see: http://tf.nist.gov/tf-cgi/servers.cgi Free software and source code available for download from NIST. Further information at http://www.nist.gov/pml/div688/grp40/its.cfm Telephone voice announcement: Audio portions of radio broadcasts from time and frequency stations WWV and WWVH can be heard by telephone: +1 303 499 7111 for WWV and +1 808 335 4363 for WWVH
NMIJ	GPS common-view data GPS common-view data using CGGTTS format referred to UTC(NMIJ) are available through the NMIJ's web site for the remote frequency calibration service.
NMISA	Network Time Service One open access NTP server is available at address time.nmisa.org. More information is available at http://time.nmisa.org/
NMLS (1)	Web-based time-of-day clock A web clock is used to display the local time for Malaysia. The service is available at http://mst.sirim.my. Network Time Service The NTP time information is referenced to UTC(NMLS) and is currently generated by Stratum-1 NTP servers, made available to the public freely. The NTP server host names are ntp1.sirim.my and ntp2.sirim.my.

(1) Information based on the Annual Report 2016, not confirmed by the Laboratory.

NPL	Telephone Time Service A TUG time code generator provides the European Telephone Time Code, referenced to UTC(NPL), by telephone modem. Software for synchronising computers is available from the NPL web site at www.npl.co.uk/time. The service telephone number is 020 8943 6333. Internet Time Service Two servers referenced to UTC(NPL) provide Network Time Protocol (NTP) time code across the internet. More information is available from the NPL web site at www.npl.co.uk/time. The server host names are: ntp1.npl.co.uk ntp2.npl.co.uk
NPLI	Web Clock Web-based time-of-day clock that displays Indian Standard Time (IST) and UTC(NPLI). It also displays local time in user's time zone, time-of-day of the user's device clock and its difference. Available at the web page: http://www.nplindia.in/clockcode/html/index.php Internet Time Service Two servers referenced to UTC(NPLI) provide Network Time Protocol (NTP) time code across the internet. The server host names are: time1.nplindia.org time2.nplindia.org
NRC	Telephone Code Provides digital time code by telephone modem for setting time in computers. Access phone number: +1 613 745 3900. http://www.nrc-cnrc.gc.ca/eng/services/time/time_date.html Talking Clock Service Voice announcements of Eastern Time are at ten-second intervals followed by a tone to indicate the exact time. The service is available to the public in English at +1 613 745 1576 and in French at +1 613 745 9426. For more information see: http://www.nrc-cnrc.gc.ca/eng/services/time/talking_clock.html Web Clock Service The Web Clock shows dynamic clocks in each Canadian Time zone, for both Standard time and daylight saving time. The web page is at: http://www.nrc-cnrc.gc.ca/eng/services/time/web_clock.html. Short Wave Radio CHU radio station broadcasts the time of day with voice announcements in English and French and time code at three different frequencies: 3.330 MHz, 7.850 MHz and 14.670 MHz. Further information at: http://www.nrc-cnrc.gc.ca/eng/services/time/short_wave.html Network Time Protocol Operates multiple time servers using the " Network Time Protocol " at different locations and on two networks. Host names: time.nrc.ca and time.chu.nrc.ca. Further information at: http://www.nrc-cnrc.gc.ca/eng/services/time/network_time.html The official website for the Frequency and Time group is: http://www.nrc-cnrc.gc.ca/eng/services/time/index.html The contact email is: MSS-SMETime@nrc-cnrc.gc.ca

NSC IM (1)

Network Time Service.
National Science Center Institute of Metrology (Kharkiv, Ukraine) operates one time server Stratum 1 using the "Network Time Protocol" (NTP).

The server host name is: http://www.metrology.kharkov.ua/

NTSC

Network Time Service (NTS)
NTSC operates a time server directly referenced to UTC(NTSC). Software for the synchronization of computer clocks is available on the NTSC Time and Frequency web page: http://www.ntsc.ac.cn/
Access Policy: free
Contact: Shaowu DONG (sdong@ntsc.ac.cn).

ONBA

Speaking clock access phone number 113 (only accessible in Argentina).
Hourly and half hourly radio-broadcast time signal.
Internet time service at web site http://www.hidro.gov.ar/observatorio/lahora.asp

ONRJ

Telephone Voice Announcer (55) 21 25806037.
Telephone Code (55) 21 25800677 provides digital time code at 300 bauds, 8 bits, no parity, 1 stop bit (Leitch CSD5300)

Internet Time Service at the address : 200.20.186.75 and 200.20.186.94
SNTP at port 123
Time/UDP at port 37
Time/TCP at port 37
Daytime/TCP at port 13

WEB-based Time Services:
1) A real-time clock aligned to UTC(ONRJ) and corrected for internet transmission delay.
Further information at: http://200.20.186.71/asp/relogio/horainicial.asp
2) Voice Announcer, in Portuguese, each ten seconds, after download of the Web page at: http://200.20.186.71.

Broadcast Brazilian legal time (UTC – 3 hours) announced by a voice starting with "Observatório Nacional" followed by the current time (hh:mm:ss) each ten seconds with a beep for each second with a 1KHz modulation during 5ms and a long beep with 1KHz modulation during 200ms at the 58 , 59 and 00 seconds. The signal is transmitted every day of the year by the radio station PPE, whose signal is at 10 MHz with kind of modulation A3H and HF transmission power of 1 kW.

ORB

Network Time Service via NTP protocol
Hostname : ntp1.oma.be and ntp2.oma.be
Access policy : free
Synchronization to UTC(ORB)
Contact : ntp-as@oma.be
Information on the web pages
http://www.astro.oma.be/en/scientific-research/reference-systems-and-planetology/time-lab/

ORB provides a time dissemination via phone and modem to synchronize PC clocks on UTC(ORB). The system used is the Time Distribution System from TUG, which produces the telephone time code mostly used in Europe.
The baud rate used is 1200. The access phone number is 32 (0) 2 373 03 20. The system is updated periodically with DUT1 and leap seconds

(1) Information based on the Annual Report 2016, not confirmed by the Laboratory.

PTB	Telephone Time Service The coded time information is referenced to UTC(PTB) and generated by a TUG type time code generator using an ASCII-character code. The time protocols are sent in a common format, the “European Telephone Time Code”. Access phone number: +49 531 51 20 38. Internet Time Service The PTB operates three time servers using the “ Network Time Protocol “ (NTP), see http://www.ptb.de/cms/en/ptb/fachabteilungen/abtq/fb-q4/ag-q42.html for details and explanations. The hostnames of the servers: ptbtime1.ptb.de ptbtime2.ptb.de ptbtime3.ptb.de PTB also provides a secured NTP time service. This service applies NTP’s pre-shared key approach. It arose from PTB’s particular duty to provide a secured NTP service for the smart grid initiative of the German Federal Ministry of Economic Affairs and Energy. The service is restricted to authenticated access only. The hostnames of the servers ntpsmgw1.ptb.de ntpsmgw2.ptb.de
ROA	Telephone Code The coded time information is referenced to UTC(ROA) and generated by a TUG type time code generator using an ASCII-character code. The time protocols are sent in a common format, the "European Telephone Time Code". Access phone number : +34 956 599 429 Network Time Protocol More information is available from the ROA web site at www.roa.es Host names of the servers: hora.roa.es minuto.roa.es
SG	Network Time Service (NeTS) Transmit digital time code via the Internet using three protocols - Time Protocol, Daytime Protocol and Network Time Protocol. Operate one time server at domain name: nets.org.sg Automated Computer Time Service (ACTS) Transmit digital time code (NIST format) via telephone modem for setting time in computers. The coded time information is referenced to UTC(SG). Include provision for correcting telephone time delay. Access phone number: +65 67799978.
SIQ (1)	Internet Time Service (Network Time Protocol) One server referenced to UTC(SIQ) provides Network Time Protocol (NTP) time code across the internet. There is free access to the server for all users. The server host names are:ntp.siq.si or time.siq.si (two URL’s for the same server; IP: 194.249.234.70)
SP	Telephone Time Service The coded time information is referenced to UTC(SP) and generated by two TUG type time code generators using an ASCII-character code. The time protocols are sent in a common format, the "European Telephone Time Code". Access phone number: +46 33 41 57 83

(1) Information based on the Annual Report 2016, not confirmed by the Laboratory.

The coded time information is referenced to UTC(SP) and generated by several NTP servers using the Network Time Protocol (NTP) for both IPv4 and IPv6.
Access host names: ntp1.sptime.se, ntp2.sptime.se, ntp3.sptime.se and ntp4.sptime.se

Speaking Clock
The speaking clock service is operated by Telia AB in Sweden.
The time announcement is referenced to UTC(SP) and disseminated from a computer-based system operated and maintained at SP.
Access phone number : 90510 (only accessible in Sweden).
Access phone number : +4633 90510 (from outside Sweden).

More information about these services are found on the web site www.sp.se

TL

Speaking Clock Service
Traceable to UTC(TL). Broadcast through PSTN (Public Switching Telephone Network) automatically and provides an accurate voice time signal to public users. Local access phone number: 117.

The Computer Time Service
Provides ASCII time code by telephone modem for setting time in computers.
Access phone number: +886 3 4245117.

NTP Service
TL operates the network time service using the "Network Time Protocol" (NTP).
Host name of the server: time.stdtime.gov.tw, further information in
http://www.stdtime.gov.tw/english/e-home.aspx

TP

Internet Time Service
UFE operates time servers directly referenced to UTC(TP).
Time information is accessible through Network Time Protocol (NTP).
Server host name: ntp2.ufe.cz
More information at http://www.ufe.cz/

UME

Network Time Service
UME operates an NTP server referenced to UTC(UME).
Server Host Name: time.ume.tubitak.gov.tr

USNO

Telephone Voice Announcer +1 202 762-1401
Backup voice announcer: +1 719 567-6742

Telephone Code +1 202 762-1594
provides digital time code at 1200 baud, 8 bits, no parity

GPS via subframe 4 page 18 of the GPS broadcast navigation message

Web site for time and for data files: http://tycho.usno.navy.mil/

Network Time Protocol (NTP) see
http://www.usno.navy.mil/USNO/time/ntp
for software and site closest to you.

VMI

Network Time Service
VMI operates one time server Stratum 1 using the Network Time Protocol (NTP). For information on access to the website, please contact phuongtv@vmi.gov.vn. The server host name is:
http://standardtime.vmi.gov.vn/ or IP: 113.160.59.166 port 123

VNIIFTRI

Internet Time Service
VNIIFTRI operates eight time servers Stratum 1 and one time server Stratum 2 using the “Network Time Protocol” (NTP).

The server host names are:
ntp1.vniiftri.ru (Stratum 1)
ntp2.vniiftri.ru (Stratum 1)
ntp3.vniiftri.ru (Stratum 1)
ntp4.vniiftri.ru (Stratum 1)
ntp1. niiftri.irkutsk.ru (Stratum 1)
ntp2. niiftri.irkutsk.ru (Stratum 1)
vniiftri.khv.ru (Stratum 1)
vniiftri2.khv.ru (Stratum 1)
ntp21.vniiftri.ru (Stratum 2).

VSL

Internet Time Service
VSL operates a time server directly referenced to UTC(VSL).
Time information is accessible through Network Time Protocol (NTP).
The URL for the NTP server is: ntp.vsl.nl