Realization and maintenance of UTC

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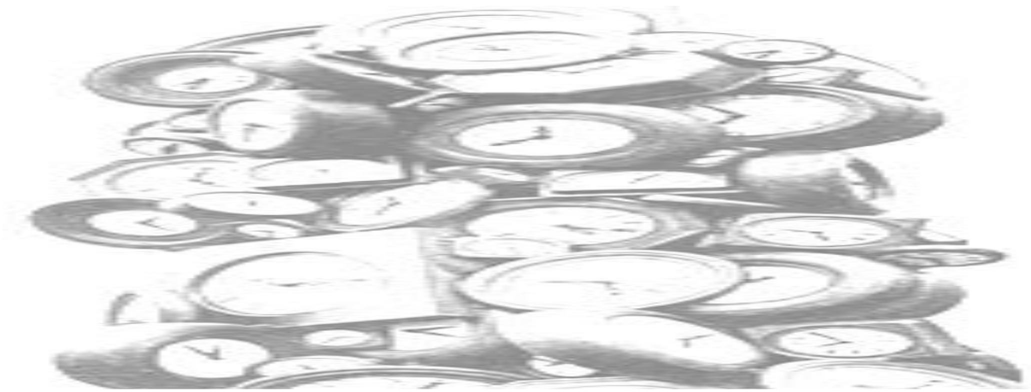
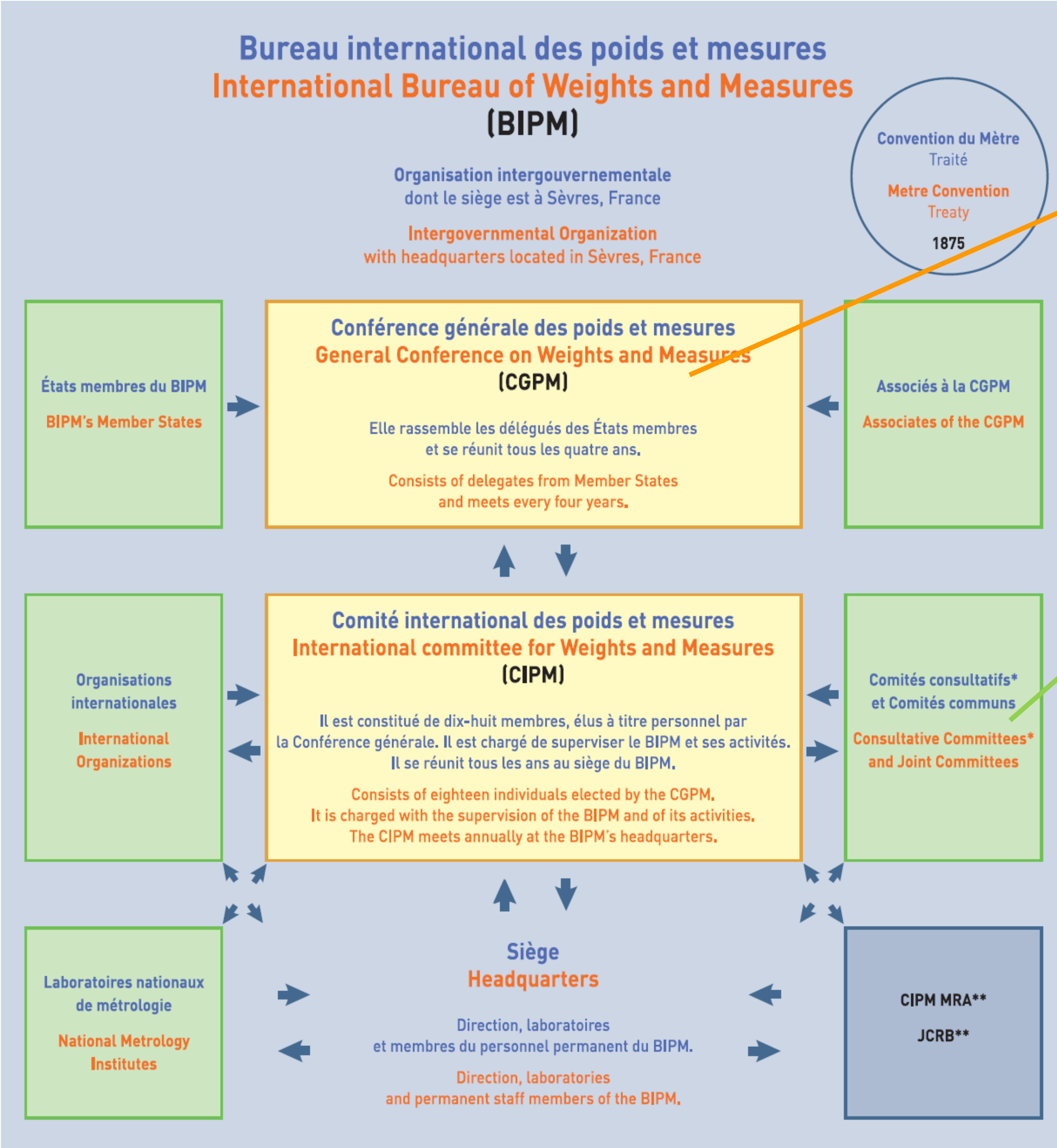


ITU/BIPM Workshop on the future of the international time scale

Geneva, 19-20 September 2013

Outline

- ✓ Responsibilities in the establishment and realization of the international reference time scale UTC
- ✓ The concept of traceability in metrology
- ✓ The various time scales; characteristics
- ✓ Maintenance and dissemination of UTC
- ✓ Opinion of the CCTF y CIPM on the future of the international time scale
- ✓ Considerations for the future



CGPM
Diplomatic Treaty of the Metre Convention

55 Member States of BIPM
38 Associates

Consultative Committee for Time and Frequency (CCTF)

Members:

- National Metrology Institutes and others
- ITU-R
- IAU
- IUGG
- IGS
- URSI

Responsibilities on time scales

General Conference on Weights and Measures (CGPM)

- ✓ Defined the second – 1967
- ✓ Adopted International Atomic Time (TAI) - 1971
- ✓ Endorsed Coordinated Universal Time (UTC) – 1975

International Telecommunication Union (ITU)

- ✓ Fixes de rules for t&f dissemination by signals
- ✓ Rec ITU-R TF.460-6 (describes the process for synchronizing UTC to UT1 better than 0.9 s)

Responsibilities on time scales (cont.)

International Bureau of Weights and Measures (BIPM)

- ✓ Calculates UTC based on data provided by ~ 70 institutes world-wide spread
- ✓ Coordinates activities for accomplishing this mandate

International Earth Rotation and Reference Systems Service (IERS)

- ✓ Monitors the rotation of the Earth and provides EOP
- ✓ Announces the dates of application of leap seconds

National institutes (72)

- ✓ Maintain local approximations to UTC (UTC(*k*))
- ✓ Broadcast UTC(*k*)

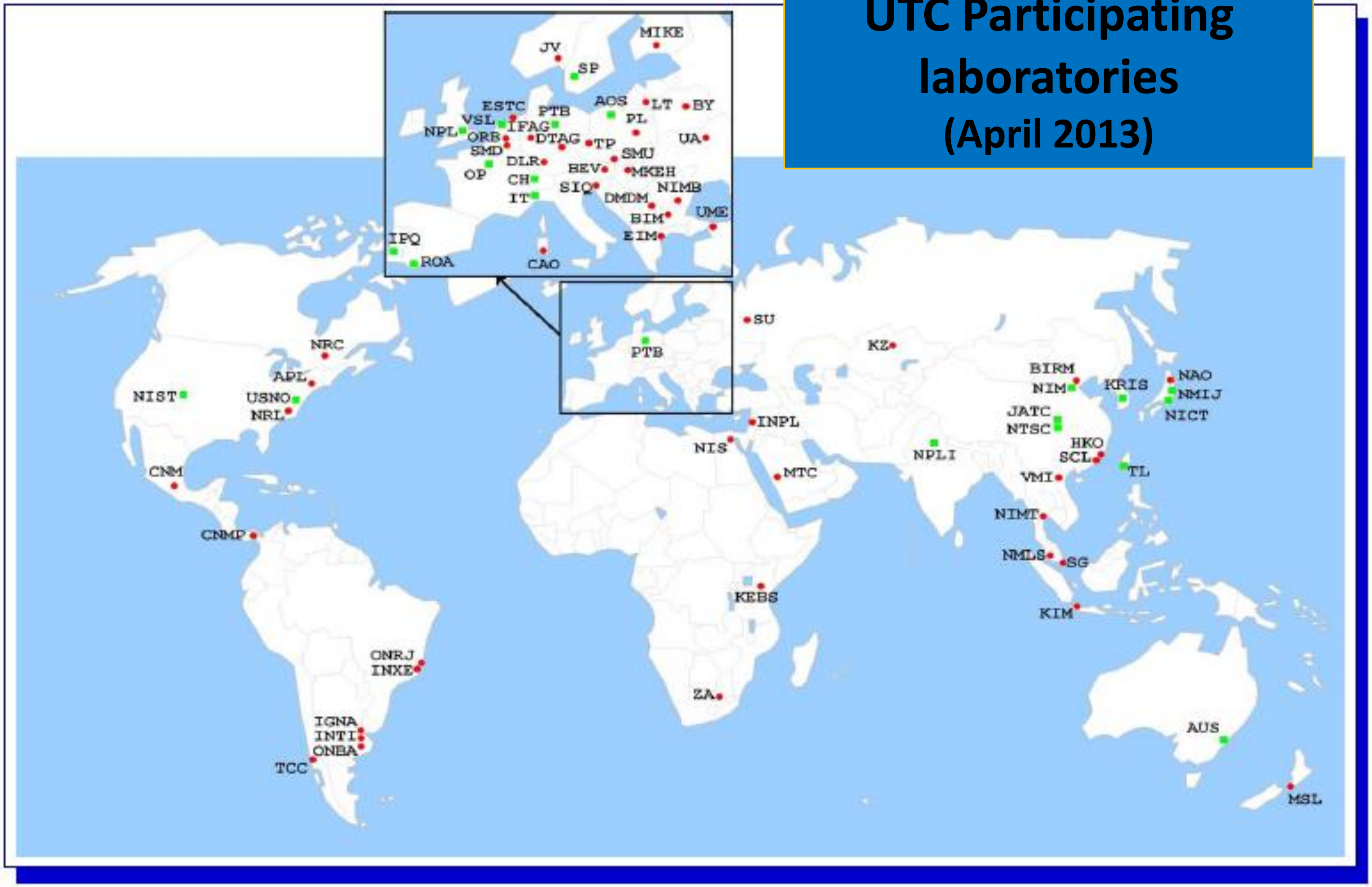
The concept of metrological traceability

A National Metrology Institute (…) can establish traceability to the SI via a primary realization or representation of the unit of measurement concerned …

In the case of the SI second and the reference time scale UTC, the key comparison CCTF K-001.UTC gives traceability to the SI to the atomic time scales maintained in the participant laboratories.

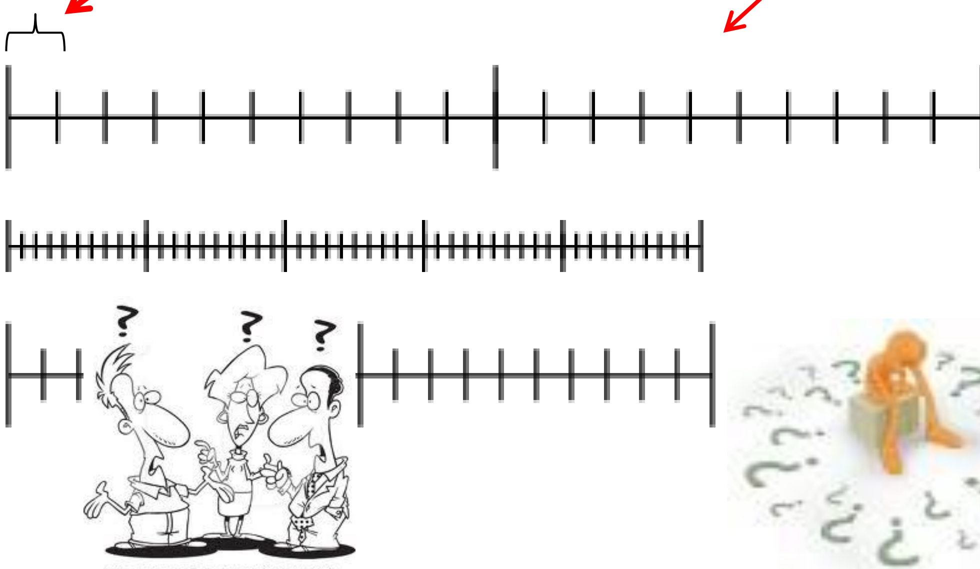
The time scales maintained by this laboratories are considered the unique representations of UTC, and are designed as UTC(*k*).

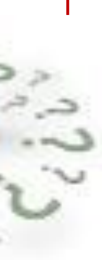
UTC Participating laboratories
(April 2013)



Unit, time scale

- ✓ unit of time: SI second
- ✓ Measuring time intervals:
  - ✓ Time scale
- ✓ Unitary interval of a time scale traceable to the SI
  - ✓ SI second





- ✓ Unique definition of a unit (i.e. the SI second)
- ✓ Unique reference time scale
  - CIPM (2012)

The various time scales

International Atomic Time (TAI)

- ✓ Continuous
- ✓ Interval unit is the SI second
- ✓ Calculated monthly at BIPM
- ✓ No clock representation, no broadcast

Coordinated Universal Time (UTC)

- ✓ 1-second discontinuities
- ✓ Interval unit is the SI second
- ✓ Calculated monthly at BIPM, derived from TAI

Local representations UTC(*k*)

- ✓ Traceable to UTC via monthly BIPM *Circular T*
- ✓ Clock representation
- ✓ Broadcast
- ✓ Basis of legal times

Other time scales (scientific, space navigation, etc)

- ✓ *Coordinate times*
- ✓ Related to TAI
- ✓ No clock representation
- ✓ No broadcast

UTC

Coordinated | Universal | Time

Coordinated broadcast of time signals at laboratories

(ITU-R)

Time for the entire Earth, universality of the time scale

TAI differs from UTC in an integral number of seconds (35 until July 2014 at least)

Leap second announcement is the responsibility of the IERS

- GMT (Greenwich Mean Time) was replaced by UT in 1948 (IAU)
- UT was replaced by UTC in 1972

Each month: → ~70 participants

ftp server

~400 clocks,

one measurement / 5 days, t&f corr.

monthly

13 primary freq. standard data

monthly

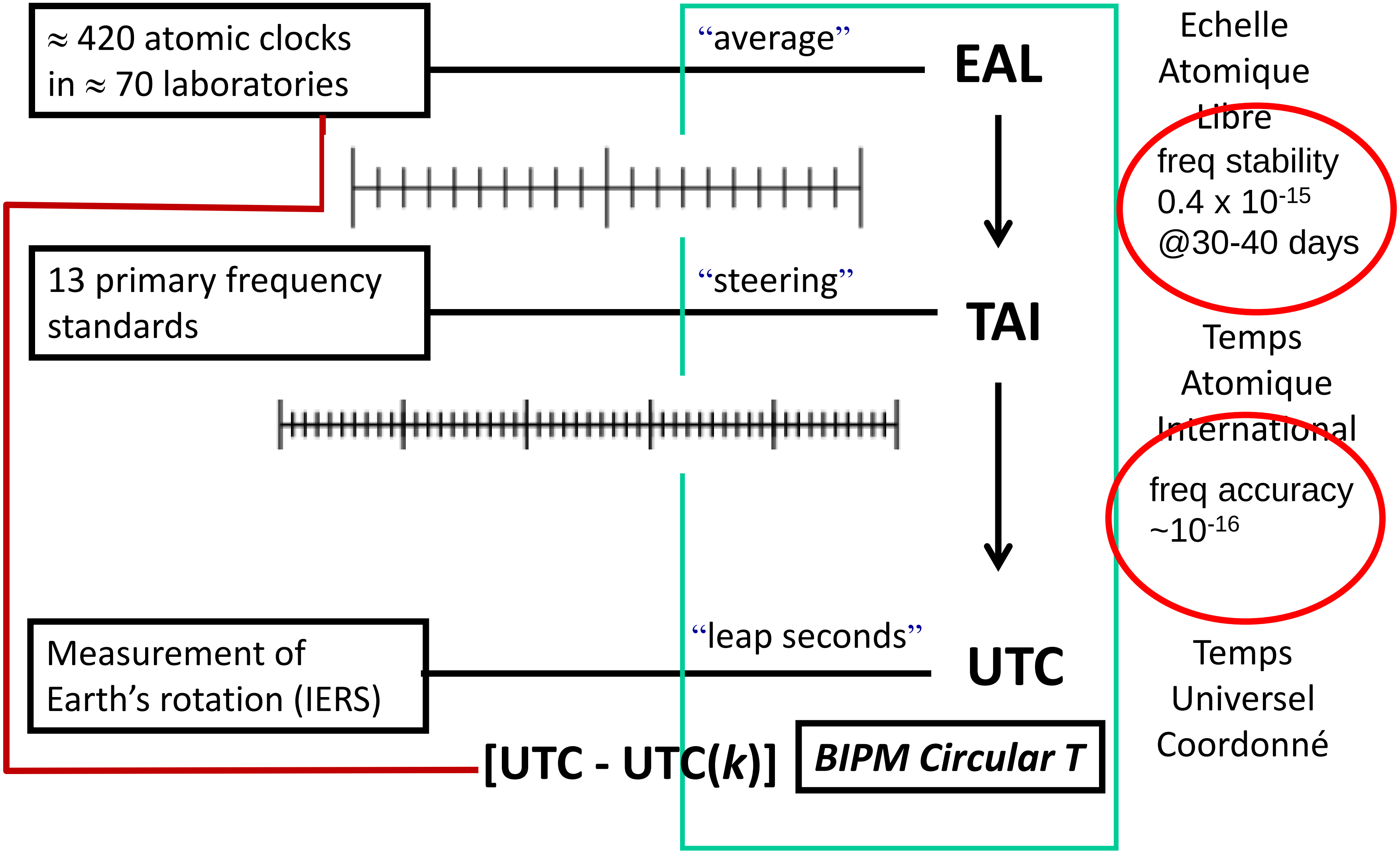
~180 time transfer files

daily, weekly, (monthly)

Data submission deadline 4/mm/yy/

Datation is in « Modified Julian Date », a contiuous count of days since an arbitrary origin

Elaboration of TAI and UTC - ALGOS



Traceability of UTC(*k*) to UTC
BIPM Circular T

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1 - Coordinated Universal Time UTC and its local realizations UTC(k). Computed values of [*UTC-UTC(k)*] and uncertainties valid for the period of this Circular. From 2012 July 1, 0h UTC, *TAI-UTC* = 35 s.

Date 2013 0h UTC	JUL 31	AUG 5	AUG 10	AUG 15	AUG 20	AUG 25	AUG 30	Uncertainty/ns			Notes
MJD	56504	56509	56514	56519	56524	56529	56534	u_A	u_B	u	
Laboratory *k*				[*UTC-UTC*(*k*)]/ns							
AOS (Borowiec)	-1.2	-3.1	-3.4	-4.1	-4.0	-3.9	-2.2	0.3	5.2	5.2	
APL (Laurel)	2.2	2.3	3.4	1.8	1.6	1.7	2.6	0.3	5.2	5.2	
AUS (Sydney)	282.7	267.8	260.6	257.6	256.9	251.4	249.7	0.3	5.2	5.2	
BEV (Wien)	49.8	51.2	58.4	60.6	65.0	47.0	39.0	0.3	3.4	3.4	
BIM (Sofiya)	367.3	386.8	378.6	395.2	401.6	405.1	405.8	1.5	7.1	7.3	
BIRM (Beijing)	227.8	226.6	226.8	223.7	226.9	231.5	234.0	1.5	20.1	20.1	
BY (Minsk)	-	-	-	-	-	-	-				
CAO (Cagliari)	-	-	-	-	-	-	-				
CH (Bern-Wabern)	10.1	11.5	12.5	10.4	13.8	16.5	18.7	0.3	1.8	1.9	
CNM (Queretaro)	-6.4	-8.8	-10.1	-12.4	-12.1	-16.1	-18.3	2.0	5.2	5.6	
CNMP (Panama)	16.3	17.7	31.9	20.7	9.9	17.5	30.1	3.5	5.2	6.3	
DLR (Oberpfaffenhofen)	-18.1	-20.8	-27.4	-32.2	-26.8	-14.2	-7.2	0.7	5.2	5.3	
DMDM (Belgrade)	20.8	15.3	16.3	23.1	30.6	18.4	8.1	0.3	7.1	7.1	(1)
DTAG (Frankfurt/M)	337.1	337.6	336.9	333.7	330.8	325.8	329.2	0.3	10.1	10.1	
EIM (Thessaloniki)	7.3	16.3	10.9	6.1	6.5	-3.9	0.0	4.5	5.2	6.9	
ESTC (Noordwijk)	-5.2	-5.5	-4.8	-1.3	0.0	0.9	2.3	0.3	5.2	5.2	
HKO (Hong Kong)	1649.3	445.6	443.8	436.3	432.6	426.7	430.8	1.0	5.2	5.3	(2)
IFAG (Wettzell)	-695.6	-704.0	-713.6	-714.8	-720.8	-737.5	-747.9	0.3	5.2	5.2	
IGNA (Buenos Aires)	2868.5	2962.6	3064.0	3162.3	3259.1	3365.1	3464.0	2.0	5.2	5.6	
INPL (Jerusalem)	43.4	37.2	35.1	34.0	40.7	42.6	34.2	0.7	19.9	19.9	
INTI (Buenos Aires)	28.4	63.6	82.8	47.7	38.2	17.0	11.7	2.5	20.1	20.2	
INXE (Rio de Janeiro)	4.4	-0.1	-0.9	-0.5	0.3	-4.7	3.4	0.3	20.0	20.0	
IPQ (Caparica)	-	-	-	-	-	-	-				
IT (Torino)	-6.8	-7.3	-7.6	-9.7	-11.0	-12.5	-12.8	0.3	1.9	2.0	
JATC (Lintong)	11.5	15.9	15.7	12.2	5.1	3.4	2.5	0.5	5.1	5.1	
JV (Kjeller)	488.6	477.0	471.1	497.3	488.4	465.2	489.8	5.0	20.0	20.6	
KEBS (Nairobi)	-	-	-	-	-	-	-				
KIM (Serpong-Tangerang)	634.7	643.2	679.8	710.5	741.6	754.6	754.6	2.0	20.1	20.2	
KRIS (Daejeon)	-1.4	-4.5	-7.5	-10.0	-10.7	-11.0	-8.8	0.3	5.2	5.2	
KZ (Astana)	2347.8	2301.1	2249.8	2188.4	2141.3	2078.2	2025.9	2.5	20.1	20.2	

Relations between UTC and time scales and system times broadcast by GNSS

Predictions of: UTC(USNO) ; UTC(SU) – differ from UTC by a few ns and hundreds of ns, respectively

GPStime – offset from UTC by 16 s + few ns, offset changing (leap second insertion)

GLONASStime – 0 ns offset from UTC + hundreds of ns

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5 - Relations of UTC and TAI with predictions of UTC(k) disseminated by GNSS and their System Times.

[*UTC-GPS time*] = -16 s + C_0 , [*TAI-GPS time*] = 19 s + C_0 , global uncertainty is of the order of 10 ns.
[*UTC-UTC(USNO)_GPS*] = C_0', [*TAI-UTC(USNO)_GPS*] = 35 s + C_0', global uncertainty is of the order of 10 ns.
[*UTC-GLONASS time*] = C_1 , [*TAI-GLONASS time*] = 35 s + C_1 , global uncertainty is of the order of hundreds ns.
[*UTC-UTC(SU)_GLONASS*]= C_1', [*TAI-UTC(SU)_GLONASS*]= 35 s + C_1', global uncertainty is of the order of hundreds ns.

[*UTC(USNO)_GPS*] and [*UTC(SU)_GLONASS*] are, respectively, UTC(USNO) and UTC(SU) as predicted by USNO and SU and disseminated by GPS and GLONASS. The C_0 and C_0' values provide realizations of GPS time and of the prediction of UTC(USNO) broadcast by GPS, as obtained using the values [*UTC-UTC(OP)*] and the GPS data taken at the Paris Observatory, corrected for IGS precise [illegible] C_1' values provide realizations of GLONASS time and of the prediction of [illegible] GLO[illegible] the values [*UTC-UTC(AOS)*] and the GLONASS data take[illegible] (AOS). N_0, N_0', N_1 and N_1' are the numbers of measurements; when N_0, N_0' [illegible] table are interpolated. The standard deviations σ [illegible] individual measurements. The actual uncertainty of users' access to GPS and GLONASS times may differ from these values. For this edition of circular, σ_0= 1.1 ns, σ_0'= 1.2 ns, σ_1= 6.3 ns, σ_1'= 6.3 ns

GPStime
UTC(USNO)

GLONASStime
UTC(SU)

2013	0h UTC	MJD	C_0/ns	N_0	C_0'/ns	N_0'	C_1/ns	N_1	C_1'/ns	N_1'
	JUL 31	56504	0.3	88	1.4	88	-172.9	89	-361.8	89
	AUG 1	56505	-0.3	89	-0.2	88	-173.4	90	-362.5	90
	AUG 2	56506	-0.1	86	-2.3	86	-171.8	89	-361.0	89
	AUG 3	56507	-0.2	89	-2.2	89	-173.1	88	-363.0	88
	AUG 4	56508	-0.2	89	-0.2	89	-172.1	89	-362.9	89
	AUG 5	56509	0.0	90	-2.0	90	-169.3	90	-361.2	90
	AUG 6	56510	-0.4	89	-1.4	89	-170.2	84	-362.7	84
	AUG 7	56511	-1.1	89	-0.6	89	-169.7	87	-362.2	87
	AUG 8	56512	-1.2	89	-2.2	89	-168.1	89	-360.7	89
	AUG 9	56513	-2.4	89	-2.5	89	-168.4	90	-360.2	90

Opinion of the CCTF and CIPM on the future of the international time scale

The CCTF has discussed at its meeting on 13-14 September 2012 the feasibility of achieving a continuous reference time scale and made a recommendation to the International Committee on Weights and Measures (CIPM) which met on 18-19 October 2012. The CIPM considered the matter and concluded that

1. a continuous time scale is indeed achievable, and it has been realized and maintained by the BIPM (TAI);
2. a continuous reference time scale corresponds to UTC without leap second discontinuities;
3. the concepts of continuity and uniformity should be applied strictly in a reference time scale;
4. the unit for any quantity in metrology is unique, and as such, a single time scale shall also be unique;

Opinion of the CCTF and CIPM on the future of the international time scale

5. in the event of a redefinition of any quantity in metrology, the unit should be invariant, and particularly for the second of the International System of Units (SI) the respective scale shall be continuous and uniform;
6. the name “Coordinated Universal Time (UTC)” should be retained for a new continuous time scale based on a redefinition of UTC without leap second adjustments;
7. the International Earth Rotation and Reference Systems Service (IERS) provides a means of accessing UT1 in real-time by means of routinely available predictions of UT1 - UTC with high precision
8. a wider dissemination of UT1 - UTC should be encouraged;

Consequences of stopping the insertion of leap seconds in UTC

- ✓ **UTC will have no more discontinuities;**
- ✓ **UTC and TAI will differ in a constant offset,**
  - ✓ **CCTF, then CIPM and finally CGPM could decide on suppressing TAI;**
- ✓ **Continuous system times and time scales created for avoiding the discontinuities of the present UTC will have constant offsets wrt UTC;**
- ✓ **Broader dissemination of the values of UT1-UTC, enhancing the role of the IERS.**

Thanks for your attention!