

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

(File available on <ftp://ftp2.bipm.org/pub/tai/other-products/utai/utai2019.pdf>)

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: $d = -y_{\text{TAI}}$.

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) METAS-FOC2, NIM5, PTB-CS1, PTB-CS2, PTB-CSF1, PTB-CSF2, SU-CsFO2, SYRTE-FO1, SYRTE-FO2 and SYRTE-FOM reported on the year 2019.

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) IT-Yb1, NICT-Sr1, NIST-Yb1 and SYRTE-FORb reported on the year 2019.

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 13 (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 (including the relativistic frequency shift),

$u_{\text{link/lab}}$ is the uncertainty in the link between the PFS and the clock participating to TAI, including the uncertainty due to dead-time,

$u_{\text{link/TAI}}$ 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 2019 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 2019 reports, $u_B(\text{Ref})$ 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}	$u_B(\text{Ref})/10^{-15}$	Ref(u_B)	Comparison with	Number/typical duration of comp.
METAS-FOC2	Fountain	1.38	1.99	[1]	H maser	1 / 30 d
NIM5	Fountain	0.9	1.4	[2]	H maser	6 / 15 d to 25 d
PTB-CS1	Beam /Mag.	8	8.	[3]	TAI	12 / 25 d to 35 d
PTB-CS2	Beam /Mag.	12	12.	[4]	TAI	11 / 25 d to 35 d
PTB-CSF1	Fountain	0.26 to 0.32	0.28	[5]	H maser	9 / 10 d to 35 d
PTB-CSF2	Fountain	0.17 to 0.18	0.17	[5]	H maser	14 / 10 d to 30 d
SU-CsFO2	Fountain	0.22 to 0.24	0.50	[6]	H maser	10 / 30 d to 35 d
SYRTE-FO1	Fountain	0.31 to 0.32	0.37	[7]	H maser	12 / 25 d to 35 d
SYRTE-FO2	Fountain	0.21 to 0.24	0.23	[7]	H maser	12 / 15 d to 35 d
SYRTE-FOM	Fountain	0.61 to 0.66	0.7	[7]	H maser	12 / 15 d to 30 d

Secondary Standard	Type	Type B std. uncertainty/ 10^{-15}	$u_B(\text{Ref})/10^{-15}$	Ref(u_B)	Comparison with	Number/typical duration of comp.
IT-Yb1	Lattice	0.03	0.028	[8]	H maser	5 / 10 d to 30 d
NICT-Sr1	Lattice	0.07 to 0.08	0.06	[9]	H maser	3 / 20 d to 35 d
NIST-Yb1	Lattice	0.03	0.006	[10]	H maser	8 / 25 d to 35 d
SYRTE-FORb	Fountain	0.24 to 0.26	0.34	[11]	H maser	12 / 25 d to 35 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		$d/10^{-15}$	$u_A/10^{-15}$	$u_B/10^{-15}$	$u_{\text{link/lab}}/10^{-15}$	$u_{\text{link/TAI}}/10^{-15}$	$u/10^{-15}$	Note
METAS-FOC2	58599	58629	-1.07	1.00	1.38	0.04	0.27	1.73	
NIM5	58544	58569	-0.14	0.20	0.90	0.20	0.31	0.99	
NIM5	58634	58659	0.55	0.20	0.90	0.20	0.23	0.97	
NIM5	58679	58694	-0.25	0.30	0.90	0.20	0.37	1.04	
NIM5	58694	58719	-0.21	0.20	0.90	0.20	0.23	0.97	
NIM5	58729	58749	-0.41	0.20	0.90	0.20	0.28	0.98	
NIM5	58764	58784	-0.14	0.20	0.90	0.20	0.28	0.98	
PTB-CS1	58479	58514	-14.78	8.00	8.00	0.00	0.11	11.31	(1)
PTB-CS1	58514	58539	-10.35	8.00	8.00	0.00	0.15	11.31	
PTB-CS1	58539	58569	-22.91	8.00	8.00	0.00	0.13	11.31	
PTB-CS1	58569	58599	-9.30	8.00	8.00	0.00	0.13	11.31	
PTB-CS1	58599	58634	-10.52	8.00	8.00	0.00	0.09	11.31	
PTB-CS1	58634	58664	-4.67	8.00	8.00	0.00	0.07	11.31	
PTB-CS1	58664	58694	-4.80	8.00	8.00	0.00	0.07	11.31	
PTB-CS1	58694	58724	3.61	8.00	8.00	0.00	0.07	11.31	
PTB-CS1	58724	58754	-3.26	8.00	8.00	0.00	0.07	11.31	
PTB-CS1	58754	58784	2.33	8.00	8.00	0.00	0.07	11.31	
PTB-CS1	58784	58814	4.07	8.00	8.00	0.00	0.07	11.31	
PTB-CS1	58814	58844	-7.50	8.00	8.00	0.00	0.07	11.31	
PTB-CS2	58479	58514	-2.97	5.00	12.00	0.00	0.11	13.00	(1)
PTB-CS2	58514	58539	5.90	5.00	12.00	0.00	0.15	13.00	
PTB-CS2	58539	58569	-10.68	5.00	12.00	0.00	0.13	13.00	
PTB-CS2	58569	58599	-0.23	5.00	12.00	0.00	0.13	13.00	
PTB-CS2	58634	58664	0.42	5.00	12.00	0.00	0.07	13.00	
PTB-CS2	58664	58694	-7.38	5.00	12.00	0.00	0.07	13.00	
PTB-CS2	58694	58724	-2.79	5.00	12.00	0.00	0.07	13.00	
PTB-CS2	58724	58754	4.92	5.00	12.00	0.00	0.07	13.00	
PTB-CS2	58754	58784	8.04	5.00	12.00	0.00	0.07	13.00	
PTB-CS2	58784	58814	-3.45	5.00	12.00	0.00	0.07	13.00	
PTB-CS2	58814	58844	-12.52	5.00	12.00	0.00	0.07	13.00	
PTB-CSF1	58469	58479	0.57	0.11	0.27	0.03	0.35	0.46	
PTB-CSF1	58479	58514	0.52	0.06	0.27	0.02	0.11	0.30	
PTB-CSF1	58514	58539	0.66	0.08	0.30	0.05	0.15	0.35	
PTB-CSF1	58554	58569	1.23	0.08	0.28	0.02	0.24	0.38	
PTB-CSF1	58624	58634	0.45	0.11	0.32	0.03	0.18	0.38	
PTB-CSF1	58694	58724	0.43	0.06	0.31	0.02	0.07	0.32	
PTB-CSF1	58724	58754	-0.05	0.06	0.31	0.04	0.07	0.32	
PTB-CSF1	58754	58784	-0.20	0.06	0.28	0.03	0.07	0.30	
PTB-CSF1	58784	58814	-0.13	0.07	0.26	0.02	0.07	0.28	
PTB-CSF2	58469	58479	0.57	0.16	0.17	0.03	0.35	0.42	
PTB-CSF2	58479	58514	0.42	0.09	0.17	0.06	0.11	0.23	
PTB-CSF2	58514	58539	0.49	0.17	0.18	0.06	0.15	0.30	
PTB-CSF2	58539	58569	0.44	0.09	0.17	0.05	0.13	0.24	
PTB-CSF2	58569	58599	0.44	0.09	0.17	0.05	0.13	0.24	
PTB-CSF2	58599	58624	0.62	0.10	0.17	0.06	0.12	0.24	
PTB-CSF2	58624	58634	0.51	0.22	0.17	0.06	0.18	0.33	
PTB-CSF2	58634	58664	0.59	0.11	0.17	0.06	0.07	0.22	
PTB-CSF2	58664	58684	0.45	0.12	0.17	0.03	0.09	0.23	
PTB-CSF2	58694	58724	0.31	0.10	0.17	0.03	0.07	0.21	
PTB-CSF2	58724	58754	-0.22	0.09	0.17	0.04	0.07	0.21	
PTB-CSF2	58754	58784	-0.37	0.10	0.17	0.03	0.07	0.21	
PTB-CSF2	58784	58814	-0.42	0.11	0.17	0.02	0.07	0.21	
PTB-CSF2	58814	58834	-0.61	0.13	0.17	0.02	0.09	0.23	
SU-CsFO2	58479	58514	2.20	0.24	0.24	0.13	0.74	0.82	
SU-CsFO2	58539	58569	0.69	0.25	0.24	0.12	0.85	0.92	
SU-CsFO2	58569	58599	1.07	0.22	0.24	0.11	0.85	0.92	
SU-CsFO2	58634	58664	1.17	0.37	0.22	0.13	0.46	0.64	

SU-CsFO2	58664	58694	0.86	0.21	0.22	0.12	0.46	0.56
SU-CsFO2	58694	58724	1.12	0.31	0.22	0.12	0.46	0.61
SU-CsFO2	58724	58754	0.51	0.22	0.22	0.11	0.46	0.56
SU-CsFO2	58754	58784	-0.02	0.16	0.22	0.11	0.46	0.54
SU-CsFO2	58784	58814	-0.11	0.20	0.22	0.10	0.46	0.55
SU-CsFO2	58814	58844	-0.69	0.21	0.22	0.11	0.46	0.56

Standard	Period of estimation		$d/10^{-15}$	$u_A/10^{-15}$	$u_B/10^{-15}$	$u_{\text{link/lab}}/10^{-15}$	$u_{\text{link/TAI}}/10^{-15}$	$u/10^{-15}$	Note
SYRTE-FO1	58479	58514	0.39	0.25	0.32	0.05	0.23	0.47	
SYRTE-FO1	58514	58539	0.16	0.25	0.32	0.06	0.31	0.51	
SYRTE-FO1	58539	58569	0.31	0.20	0.31	0.06	0.26	0.46	
SYRTE-FO1	58569	58599	0.08	0.20	0.31	0.05	0.26	0.45	
SYRTE-FO1	58599	58634	0.66	0.20	0.32	0.06	0.20	0.43	
SYRTE-FO1	58634	58664	0.18	0.15	0.32	0.05	0.20	0.41	
SYRTE-FO1	58664	58694	0.62	0.30	0.32	0.10	0.20	0.49	
SYRTE-FO1	58694	58724	0.08	0.20	0.32	0.05	0.20	0.43	
SYRTE-FO1	58724	58754	-0.25	0.20	0.32	0.06	0.20	0.43	
SYRTE-FO1	58754	58784	-0.78	0.30	0.32	0.05	0.20	0.48	
SYRTE-FO1	58789	58814	-0.62	0.30	0.32	0.06	0.23	0.50	
SYRTE-FO1	58814	58844	-0.59	0.50	0.32	0.07	0.20	0.63	
SYRTE-FO2	58479	58514	0.66	0.35	0.23	0.07	0.23	0.48	
SYRTE-FO2	58514	58539	0.38	0.30	0.22	0.06	0.31	0.49	
SYRTE-FO2	58549	58569	0.94	0.30	0.22	0.06	0.38	0.53	
SYRTE-FO2	58569	58599	0.44	0.25	0.21	0.05	0.26	0.42	
SYRTE-FO2	58599	58634	0.57	0.20	0.21	0.06	0.20	0.36	
SYRTE-FO2	58634	58664	0.75	0.20	0.21	0.08	0.20	0.36	
SYRTE-FO2	58664	58694	0.95	0.20	0.24	0.16	0.20	0.40	
SYRTE-FO2	58694	58724	0.14	0.20	0.21	0.06	0.20	0.36	
SYRTE-FO2	58724	58754	0.05	0.25	0.21	0.05	0.20	0.38	
SYRTE-FO2	58754	58784	-0.67	0.30	0.21	0.08	0.20	0.42	
SYRTE-FO2	58789	58814	-0.51	0.30	0.22	0.09	0.23	0.45	
SYRTE-FO2	58829	58844	-0.42	0.30	0.23	0.09	0.37	0.53	
SYRTE-FOM	58484	58514	0.48	0.20	0.64	0.07	0.26	0.72	
SYRTE-FOM	58514	58539	0.36	0.25	0.65	0.05	0.31	0.76	
SYRTE-FOM	58539	58569	0.21	0.25	0.66	0.05	0.26	0.75	
SYRTE-FOM	58569	58599	0.23	0.20	0.65	0.06	0.26	0.73	
SYRTE-FOM	58599	58629	0.73	0.20	0.65	0.06	0.23	0.72	
SYRTE-FOM	58649	58664	0.44	0.20	0.61	0.05	0.37	0.74	
SYRTE-FOM	58664	58694	0.56	0.25	0.61	0.06	0.20	0.69	
SYRTE-FOM	58694	58724	0.26	0.20	0.64	0.05	0.20	0.70	
SYRTE-FOM	58724	58754	0.27	0.25	0.64	0.12	0.20	0.72	
SYRTE-FOM	58754	58784	-0.11	0.30	0.60	0.13	0.20	0.71	
SYRTE-FOM	58789	58814	-0.44	0.30	0.61	0.06	0.23	0.72	
SYRTE-FOM	58814	58844	-0.93	0.40	0.66	0.06	0.20	0.80	

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		$d/10^{-15}$	$u_A/10^{-15}$	$u_B/10^{-15}$	$u_{\text{link/lab}}/10^{-15}$	$u_{\text{link/TAI}}/10^{-15}$	$u/10^{-15}$	u_{SRep}	Ref(u_s)
IT-Yb1	58389	58419	0.17	0.01	0.03	0.32	0.26	0.41	0.5	[12]
IT-Yb1	58419	58434	0.14	0.01	0.03	0.57	0.49	0.75	0.5	[12]
IT-Yb1	58459	58469	-0.10	0.01	0.03	0.59	0.70	0.92	0.5	[12]
IT-Yb1	58489	58514	0.65	0.01	0.03	0.39	0.31	0.50	0.5	[12]
IT-Yb1	58514	58539	0.75	0.01	0.03	0.26	0.31	0.40	0.5	[12]
NICT-Sr1	58479	58509	0.90	0.04	0.08	0.32	0.23	0.40	0.4	[12]
NICT-Sr1	58514	58534	1.21	0.02	0.07	0.22	0.28	0.37	0.4	[12]
NICT-Sr1	58644	58679	0.68	0.01	0.07	0.21	0.17	0.28	0.4	[12]
NIST-Yb1	58054	58084	-0.21	0.01	0.03	0.29	0.26	0.39	0.5	[12]
NIST-Yb1	58084	58114	0.20	0.01	0.03	0.35	0.26	0.44	0.5	[12]
NIST-Yb1	58114	58149	-0.43	0.01	0.03	0.26	0.23	0.35	0.5	[12]
NIST-Yb1	58149	58174	0.67	0.01	0.03	0.32	0.31	0.45	0.5	[12]
NIST-Yb1	58174	58204	0.27	0.01	0.03	0.26	0.26	0.37	0.5	[12]
NIST-Yb1	58204	58234	0.48	0.01	0.03	0.48	0.26	0.55	0.5	[12]
NIST-Yb1	58234	58269	0.01	0.01	0.03	0.48	0.23	0.53	0.5	[12]
NIST-Yb1	58269	58299	0.77	0.01	0.03	0.22	0.26	0.34	0.5	[12]
SYRTE-FORb	58479	58514	0.76	0.32	0.24	0.05	0.23	0.46	0.6	[12]
SYRTE-FORb	58514	58539	0.53	0.25	0.26	0.06	0.31	0.48	0.6	[12]
SYRTE-FORb	58539	58569	0.63	0.20	0.25	0.05	0.26	0.42	0.6	[12]
SYRTE-FORb	58569	58599	0.38	0.20	0.25	0.06	0.26	0.42	0.6	[12]
SYRTE-FORb	58599	58634	0.95	0.20	0.25	0.06	0.20	0.38	0.6	[12]
SYRTE-FORb	58634	58664	0.77	0.18	0.25	0.07	0.20	0.37	0.6	[12]
SYRTE-FORb	58664	58694	0.87	0.15	0.25	0.07	0.20	0.36	0.6	[12]
SYRTE-FORb	58694	58724	0.38	0.17	0.25	0.06	0.20	0.37	0.6	[12]
SYRTE-FORb	58724	58754	0.02	0.20	0.25	0.08	0.20	0.38	0.6	[12]
SYRTE-FORb	58754	58784	-0.42	0.30	0.25	0.05	0.20	0.44	0.6	[12]
SYRTE-FORb	58789	58814	-0.34	0.30	0.25	0.06	0.23	0.46	0.6	[12]
SYRTE-FORb	58814	58844	-0.47	0.40	0.25	0.07	0.20	0.52	0.6	[12]

References:

- [1] Jallageas A. *et al.*, [Metrologia 55, 366, 2018.](#)
- [2] Fang F. *et al.*, *Metrologia* **52**, 454, 2015.
- [3] Bauch A. *et al.*, [Metrologia 35, 829, 1998](#); Bauch A., [Metrologia 42, S43, 2005.](#)
- [4] Bauch A. *et al.*, *IEEE Trans. IM* **36**, 613, 1987; Bauch A., [Metrologia 42, S43, 2005.](#)
- [5] Weyers S. *et al.*, [Metrologia 55, 789, 2018.](#)
- [6] Domnin Y.S. *et al.*, *Measurement Techniques*, Vol. 55, No. 10, January, 2013.
- [7] Guéna J. *et al.*, *IEEE Trans. Ultr. Ferr. Freq. Contr.* **59** (3), 391-410, 2012.
- [8] Pizzocaro M., Bregolin F., Barbieri P. *et al.*, *Metrologia* 57 035007, 2020.
- [9] Hachisu H. *et al.*, *Opt. Express* **25**, 8511, 2017.
- [10] McGrew W.F., Zhang X., Fasano R.J. *et al.*, *Nature* 564, 87-93, 2018.
- [11] Guéna J. *et al.*, *Metrologia*. **51**, 108, 2014.
- [12] CCTF Recommendation 2 (2017) : Updates to the CIPM list of standard frequencies in Consultative Committee for Time and Frequency Report of the 21st meeting (2017), 2017, 56 p.