# GNSS calibrations for UTC
# Evolution of BIPM Circular T
# Rapid UTC, an update
# GLONASS Time and UTC, an update

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Bureau International des Poids et Mesures

# Part I: GNSS calibrations for UTC

## Goals

- Maintain the calibration of the time transfer facilities in laboratories contributing to UTC.
  - Including new calibrations for the many uncalibrated systems or updating outdated values
- Use the calibration trips contributed by RMOs and individual laboratories in a consistent and optimal manner.
- Optimize the set of $u_B$ uncertainties for UTC.
- Maintain Guidelines: a document that covers all aspects of GNSS equipment calibration.
- Maintain a web page with access to all information on calibrations for UTC

# Calibrations web page

http://www.bipm.org/jsp/en/TimeCalibrations.jsp

**On line 09/04/2015**

**Intended to host all reports of UTC calibrations**

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## BIPM calibrations of time transfer equipment

Introduction | Documentation | Current files | Archive

The BIPM Time Department manages the calibration of time transfer systems used to generate UTC. Calibrations may be carried out by the BIPM, by the RMOs, by individual time laboratories or, in some cases, by other entities such as manufacturers. These pages give access to the calibration results and reports for all techniques contributing to UTC.

Starting 2015, calibrations in laboratories contributing to UTC follow specific guidelines. For more information please click on the Documentation tab above.

Current calibration results (available via the "Current files" tab above) are labelled with a calibration identifier (Cal_ID) to enable the process yielding the results to be traced. The Cal_ID will be used to report calibration information in Section 6 of Circular T; an example is given here.

The calibration identifiers are of the form *z*nnn-YYYY where

- *z* identifies the type of calibration;
- nnn is a number assigned by the BIPM;
- YYYY indicates the year (typically the start of the calibration exercise).

The types of calibration are:

- *z* = 0: For TWSTFT links, whatever the technique used for the link calibration. nnn then is the calibration identification of the ITU format.
- *z* = 1: For GNSS systems, with GNSS calibration campaigns under the supervision of the BIPM; nnn then identifies a report corresponding to a calibration trip and is a sequential number within the year.
- *z* = 2: For GNSS systems, calibrated with other techniques (e.g. manufacturer calibration, absolute calibration, or transfer using a calibrated link); nnn then identifies a report and is a sequential number within the year.

Calibrations made before 2014 have been included in the current scheme by assigning a Cal_ID when a full report is available. The history of calibrations until 2014 can also be accessed in its original form through the "Archive" tab above.

**Provision of BIPM technical services per Member State**

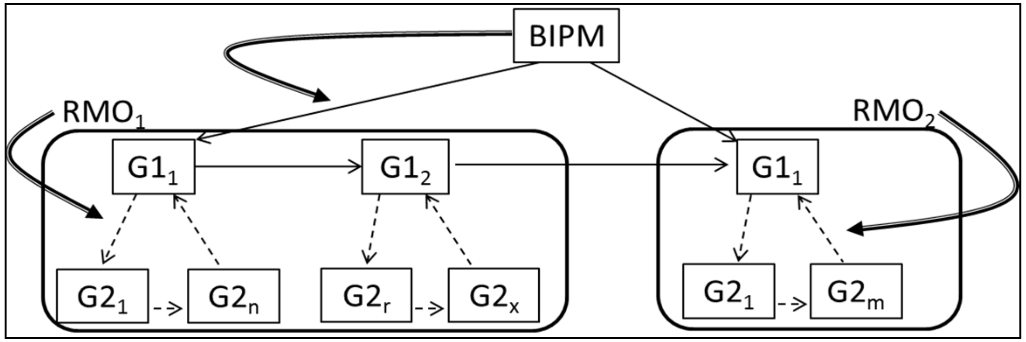
- Chemistry
- Electricity
- Ionizing Radiation
- Mass
- Time

**Related articles**

- Time scales
- BIPM calibration and measurement services
- Comparisons piloted by the BIPM

# Principles

- Two groups of laboratories
  - Group 1: Calibration trips regularly carried out by the BIPM
  - Group 2: Other laboratories. Calibration trips for group 2 are performed under responsibility of the RMOs.
  - Group 1 laboratories are proposed by the RMOs. Typically < 10 such labs. List may evolve with time.




- The BIPM will maintain an open database with all calibration results.
  - Each calibration report will be identified by a unique calibration identifier Cal_Id to be used as a reference for the calibration info (e.g. in CGGTTS header)
- $u_{CAL}$ calibration uncertainties for UTC links are set by the BIPM

# Guidelines

- « BIPM Guidelines for GNSS calibrations » v3.0 distributed in April 2015.
  - Minor update in v3.1 in September 2015

- Practical calibration procedures covering: operations; computation; report of results. (see Guidelines document)
  - Annex 1- Operational procedures for a visit of the traveling equipment
  - Annex 2- Procedure for computing the difference of GPS C/A code measurements (to be finalized)
  - Annex 3- Procedure for computing raw difference of GPS code measurements for geodetic receiver
  - Annex 4- Template for the calibration report to the BIPM

# Status of Group 1 calibrations

| EURAMET | | APMP | | SIM | | COOMET | |
|---|---|---|---|---|---|---|---|
| B3TS/GPS/Equip/Link | | B3TS/GPS/Equip/Link | | B3TS/GPS/Equip/Link | | TTS-4/GPS/Equip | |
| PTB | Concluded | NICT | Concluded | NIST | Concluded | SU | Measurements completed |
| OP | Concluded | NIM | Concluded | USNO | Concluded | | |
| ROA | Concluded | TL | Concluded | | | | |
| Phase 1 - March-April 2013: BIPM-OP-BIPM | | | | | | | |
| Phase 2 - April 2013-Sept. 2014: BIPM-PTB-BIPM-TL-BIPM-NMIJ-NICT-BIPM-NIM-BIPM-PTB-ROA-BIPM | | | | | | | |
| Phase 3 - Nov. 2014-Nov. 2015: BIPM-SU-BIPM (also includes absolute calibration at SU) | | | | | | | |
| Phase 4 - Jan. 2015-June 2015: BIPM-NIST-USNO-BIPM-OP-PTB-BIPM | | | | | | | |

- Results of initial BIPM G1 have been published in July 2015.
- Values implemented in (not all) receivers in September 2015
- New (lower) uncertainties in September 2015 Circular T

# Next actions (1): Implementation for Circular T

- More info will be given in Section 6 of Circular T (see next slides)
- New method for computing calibration uncertainty (1-sigma values)

$$U_{CAL}(A\text{-}B)(t0) = (U_{CAL0}^2\ [+\ \Delta U_{ALIGN}(A/B)^2 + \Delta U_{CAL}(A/B)^2\ ])^{1/2}$$

  - For Group 1: $U_{CAL0}$ as estimated in the analysis report (**typically 1.7 ns**)
  - For Group 2: $U_{CAL0}$ is a default value (**2.5 ns**)
  - Optional values $\Delta U_{CAL}$ for poor behavior during calibration trip and $\Delta U_{ALIGN}$ for alignment of a new receiver to a calibrated one;
- Aging: Calibration uncertainty increases for t > t0

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# Next actions (2): Continuation of trips

- Group 1 SU calibration to be finalized.
- Group 2 trips can start right away.

- BIPM goal to repeat visits to G1 laboratories typically every 2 years
  - Strategy for G1 trips to be designed
  - Corresponding strategy for update of G1 results

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# Part II: Evolution of BIPM Circular T

- Changes to be introduced in January 2016
- Section 2 (TAI - TA(k)) on web only
- Section 5 (UTC-GNSS times) modified (and will become Section 4)
- New calibration information in Section 6 (will become Section 5)
- Explanatory Supplement of BIPM *Circular T* will be available on the ftp server of the Time Department

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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 2015 July 1, 0h UTC, *TAI-UTC* = 36 s.

| Date 2015 0h UTC | AUG 30 | SEP 4 | SEP 9 | SEP 14 | SEP 19 | SEP 24 | SEP 29 | Uncertainty/ns | | | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MJD | 57264 | 57269 | 57274 | 57279 | 57284 | 57289 | 57294 | $u_A$ | $u_B$ | $u$ | |
| Laboratory *k* | | | | [*UTC-UTC(k)*]/ns | | | | | | | |
| AOS (Borowiec) | -0.3 | -1.0 | -1.5 | -1.8 | -1.5 | 0.4 | 1.1 | 0.3 | 5.0 | 5.1 | |
| APL (Laurel) | -4.8 | -2.6 | -1.1 | 2.8 | 4.3 | 4.8 | 4.1 | 0.3 | 4.9 | 4.9 | |
| AUS (Sydney) | -675.5 | -647.2 | -633.5 | -614.1 | -597.8 | -581.3 | -558.3 | 0.3 | 5.0 | 5.1 | |
| BEV (Wien) | 0.8 | -1.8 | -8.4 | -18.0 | -28.6 | -22.2 | -11.3 | 0.3 | 3.1 | 3.1 | |
| BIM (Sofiya) | 2693.2 | 2725.9 | 2765.9 | 2780.0 | 2784.9 | 2821.8 | 2847.7 | 1.5 | 7.0 | 7.2 | |
| BIRM (Beijing) | - | -97.6 | -104.8 | -118.2 | -117.7 | -119.1 | -134.7 | 1.5 | 20.0 | 20.1 | |
| BY (Minsk) | 4.3 | 4.2 | 3.7 | 5.8 | 4.5 | 8.1 | 8.1 | 1.5 | 7.0 | 7.2 | |
| CAO (Cagliari) | -7595.2 | -7696.5 | -7797.3 | -7898.8 | -7988.6 | -8084.2 | -8188.0 | 8.0 | 7.0 | 10.7 | |
| CH (Bern-Wabern) | 12.3 | 14.0 | 12.5 | 11.3 | 10.8 | 12.1 | 6.8 | 0.3 | 1.2 | 1.3 | |
| CNM (Queretaro) | -1.9 | -2.7 | -1.4 | -1.1 | 0.3 | -1.0 | -1.8 | 3.0 | 5.0 | 5.8 | |

# Section 2: [TAI – TA(k)]

- Section 2 will be eliminated from *Circular T*
- Values of [*TAI*-*TA*(*k*)] will continue to be computed and published on the ftp server of the Time Department

(http://www.bipm.org/en/bipm-services/timescales/time-ftp/publication.html).

2 - International Atomic Time TAI and Local atomic time scales TA(k). Computed values of [*TAI*-*TA*(*k*)].

| Date 2015 0h UTC | AUG 30 | SEP 4 | SEP 9 | SEP 14 | SEP 19 | SEP 24 | SEP 29 | |
|---|---|---|---|---|---|---|---|---|
| MJD | 57264 | 57269 | 57274 | 57279 | 57284 | 57289 | 57294 | |
| Laboratory *k* | | | | [*TAI*-*TA*(*k*)]/ns | | | | |
| CH (Bern-Wabern) | 19294.3 | 19235.3 | 19177.7 | 19120.0 | 19063.1 | 19008.0 | 18952.7 | |
| CNM (Queretaro) | -1195.9 | -1224.5 | -1233.2 | -1243.2 | -1204.5 | -1180.0 | -1186.8 | |
| F (Paris) | 167618.3 | 167619.9 | 167617.7 | 167617.7 | 167618.0 | 167618.8 | 167617.4 | |
| JATC (Lintong) | -58181.0 | -58203.0 | -58224.6 | -58246.3 | -58267.8 | -58291.1 | -58313.5 | |
| KRIS (Daejeon) | 46487.5 | 46503.3 | 46519.5 | 46535.5 | 46552.0 | 46569.6 | 46587.0 | |
| NICT (Tokyo) | 1423.4 | 1428.9 | 1434.2 | 1438.4 | 1444.8 | 1447.4 | 1452.3 | |
| NIST (Boulder) | -45421745.1 | -45421929.7 | -45422114.0 | -45422298.0 | -45422481.9 | -45422665.6 | -45422849.4 | |
| NRC (Ottawa) | 20985.8 | 20957.3 | 20936.1 | 20913.3 | 20894.3 | 20882.9 | 20866.3 | |
| NTSC (Lintong) | 21772.8 | 21810.3 | 21848.1 | 21885.0 | 21922.4 | 21959.0 | 21995.8 | |
| ONRJ (Rio de Janeiro) | -23118.3 | -23153.7 | -23188.3 | -23223.9 | -23259.7 | -23295.6 | -23329.8 | |
| PL (Warszawa) | -7194.5 | -7203.9 | -7212.1 | -7222.2 | -7235.3 | -7238.5 | -7243.1 | |
| PTB (Braunschweig) | 2004.5 | 2004.4 | 2004.9 | 2005.0 | 2004.8 | 2005.0 | 2004.8 | |
| SG (Singapore) | 20962.6 | 21034.2 | 21095.4 | 21167.3 | 21230.5 | 21302.8 | 21363.7 | |
| SU (Moskva) | 27291047.1 | 27291046.3 | 27291046.8 | 27291047.6 | 27291046.7 | 27291047.1 | 27291048.2 | (1) |
| TL (Chung-Li) | -12.7 | -6.8 | -4.1 | 0.9 | 6.4 | 11.8 | 14.4 | |
| USNO (Washington DC) | -35176900.9 | -35177187.4 | -35177475.1 | -35177762.8 | -35178051.3 | -35178338.8 | -35178626.5 | |

- Note on section 2:

(1) SU : Listed values are *TAI*-*TA*(*SU*) - 2.80 seconds.

# Section 5 (future section 4) on [UTC-GNSS times]

- New section 4 will provide only the values for the relations of UTC and TAI with predictions of UTC(k) disseminated by GNSS (as decided at the 20th Meeting of the CCTF).
- The relations of UTC and TAI with the GNSS System Times will be calculated and published on the ftp server of the Time Department.

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

[*UTC-GPS time*] = -17 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*] = 36 s + $C_0'$, global uncertainty is of the order of 10 ns.
[*UTC-GLONASS time*] = $C_1$, [*TAI-GLONASS time*] = 36 s + $C_1$, global uncertainty is of the order of hundreds ns.
[*UTC-UTC(SU)_GLONASS*] = $C_1'$, [*TAI-UTC(SU)_GLONASS*] = 36 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 orbits, clocks and ionosphere maps. The $C_1$ and $C_1'$ values provide realizations of GLONASS time and of the prediction of UTC(SU) broadcast by GLONASS, as obtained using the values [*UTC-UTC(AOS)*] and the GLONASS data taken at the Astrogeodynamical Observatory Borowiec (AOS). $N_0$, $N_0'$, $N_1$ and $N_1'$ are the numbers of measurements; when $N_0$, $N_0'$, $N_1$ or $N_1'$ is 0, the corresponding values in the table are interpolated.
The standard deviations $\sigma_0$, $\sigma_0'$, $\sigma_1$ and $\sigma_1'$ characterize the dispersion of individual measurements.
The actual uncertainty of users' access to GPS and GLONASS times may differ from these values.
For this edition of circular, $\sigma_0$= 0.9 ns, $\sigma_0'$= 1.1 ns, $\sigma_1$= 6.7 ns, $\sigma_1'$= 6.7 ns

| 2015 0h UTC | MJD | $C_0$/ns | $N_0$ | $C_0'$/ns | $N_0'$ | $C_1$/ns | $N_1$ | $C_1'$/ns | $N_1'$ |
|---|---|---|---|---|---|---|---|---|---|
| AUG 30 | 57264 | -0.1 | 89 | -2.2 | 79 | 213.7 | 89 | 218.9 | 89 |
| AUG 31 | 57265 | -0.6 | 89 | 1.0 | 89 | 216.9 | 79 | 219.0 | 78 |
| SEP 1 | 57266 | -0.5 | 89 | -1.0 | 89 | 217.6 | 88 | 218.7 | 88 |
| SEP 2 | 57267 | -1.4 | 78 | -0.6 | 78 | 218.7 | 89 | 217.3 | 89 |
| SEP 3 | 57268 | -1.4 | 89 | 0.7 | 89 | 219.5 | 82 | 215.7 | 82 |
| SEP 4 | 57269 | -1.0 | 89 | -1.8 | 89 | 221.1 | 87 | 217.7 | 86 |
| SEP 5 | 57270 | -0.8 | 89 | -0.7 | 88 | 221.9 | 81 | 219.8 | 80 |
| SEP 6 | 57271 | -0.9 | 90 | 0.7 | 90 | 223.0 | 90 | 219.6 | 90 |
| SEP 7 | 57272 | 0.1 | 89 | 0.8 | 89 | 224.0 | 89 | 219.4 | 89 |
| SEP 8 | 57273 | 1.3 | 89 | 1.8 | 89 | 221.0 | 87 | 216.8 | 86 |
| SEP 9 | 57274 | 3.1 | 89 | 1.1 | 89 | 220.8 | 88 | 215.7 | 88 |
| SEP 10 | 57275 | 4.1 | 90 | 1.6 | 90 | 223.0 | 88 | 216.0 | 88 |

# Section 6 (future section 5)

- New section 5 will provide more detailed information on the equipment used.
- The calibration uncertainties will be more reliable. Traceability to the original information will be provided as much as possible.

6 - Time links used for the computation of TAI and their uncertainties.

The time links used in the elaboration of this *Circular T* are listed in this section. The technique for the link is indicated as follows:
GPS SC for GPS all-in-view single-channel C/A data; GPS MC for GPS all-in-view multi-channel C/A data;
GPS P3 for GPS all-in-view multi-channel dual-frequency P code data; GPS PPP for GPS Precise Point Positioning technique;
GPS GT for 'GPS time' observations; GLN MC for GLONASS common-view multi-channel C/A data; GPSGLN for the combination of GPS MC and GLN MC links; TWGPPP/TWGPP3 for the combined smoothing of TWSTFT and GPS PPP/GPS P3; INT LK for internal cable link and TWSTFT for two-way satellite time and frequency transfer data.

For each link, the following uncertainties are provided: $u_A$ is the standard uncertainty accounting for measurement noise and random effects with typical duration between 1 day and 30 days. $u_B$ is the estimated uncertainty of the calibration.

The calibration type of the link is indicated as: GPS EC for GPS equipment calibration; TW EC for two-way equipment calibration; LC (technique) for a link calibrated using 'technique'; BC (technique) for a link calibrated using 'technique' to transfer a past equipment calibration through a discontinuity of link operation. DIC is used for direct internal calibration.

The calibration dates indicate: the most recent calibration results for the two laboratories in the case of EC and the most recent calibration of the link in the case of LC and BC.
NA stands for not available, in this case estimated values are provided.

| Link | Type | $u_A$/ns | $u_B$/ns | Calibration Type | Calibration Dates |
|---|---|---|---|---|---|
| AOS /PTB | GPSPPP | 0.3 | 5.0 | LC(GPS P3) | 2011 Jun |
| APL /PTB | GPSPPP | 0.3 | 5.0 | LC(GPS MC) | 2012 Sep |
| AUS /PTB | GPSPPP | 0.3 | 5.0 | GPS EC/GPS EC | 2010 Oct/2015 Jun |
| BEV /PTB | GPSPPP | 0.3 | 3.0 | BC(GPS MC) | 2012 Mar |
| BIM /PTB | GPS MC | 1.5 | 7.0 | GPS EC/GPS EC | 2007 Nov/2006 Sep |
| BIRM/PTB | GPS MC | 1.5 | 20.0 | NA /GPS EC | NA /2006 Sep |
| BY /PTB | GPS MC | 1.5 | 7.0 | GPS EC/GPS EC | 2008 Jun/2006 Sep |
| CAO /PTB | GPS MC | 8.0 | 7.0 | GPS EC/GPS EC | 2004 Nov/2006 Sep |
| CH /PTB | TWGPPP | 0.3 | 1.0 | LC(TWSTFT)/BC(GPS PPP) | 2008 Sep/2009 Aug |
| CNM /PTB | GPS MC | 3.0 | 5.0 | BC(GPS SC) | 2008 May |

# Section 6 of *BIPM Circular T* (present)

6 - Time links used for the computation of TAI and their uncertainties.

| Link | Type | uA/ns | uB/ns | Calibration Type | Calibration Dates |
|---|---|---|---|---|---|
| AOS /PTB | GPSPPP | 0.3 | 5.0 | LC(GPS P3) | 2011 Jun |
| APL /PTB | GPSPPP | 0.3 | 5.0 | LC(GPS MC) | 2012 Sep |
| AUS /PTB | GPSPPP | 0.3 | 5.0 | GPS EC/GPS EC | 2010 Oct/2004 Aug |
| BEV /PTB | GPSPPP | 0.3 | 3.0 | BC(GPS MC) | 2012 Mar |
| BIM /PTB | GPS MC | 1.5 | 7.0 | GPS EC/GPS EC | 2007 Nov/2006 Sep |
| BIRM/PTB | GPS MC | 1.5 | 20.0 | NA /GPS EC | NA /2006 Sep |
| BY /PTB | GPS MC | 1.5 | 7.0 | GPS EC/GPS EC | 2008 Jun/2006 Sep |
| CAO /PTB | GPS MC | 8.0 | 7.0 | GPS EC/GPS EC | 2004 Nov/2006 Sep |
| CH /PTB | TWGPPP | 0.3 | 1.0 | LC(TWSTFT)/BC(GPS PPP) | 2008 Sep/2009 Aug |
| CNM /PTB | GPS MC | 3.0 | 5.0 | BC(GPS SC) | 2008 May |
| CNMP/PTB | GPS MC | 3.5 | 5.0 | GPS EC/GPS EC | 2004 May/2006 Sep |
| DFNT/PTB | GPS MC | 1.5 | 20.0 | NA /GPS EC | NA /2006 Sep |
| DLR /PTB | NA | | | | |
| DMDM/PTB | GPSPPP | 0.3 | 7.0 | LC(GPS MC) | 2012 Jul |
| DTAG/PTB | GPSPPP | 0.3 | 10.0 | LC(GPS MC) | 2009 Jul |
| EIM /PTB | GPS MC | 7.5 | 5.0 | GPS EC/GPS EC | 2007 May/2003 Aug |
| ESTC/PTB | GPSPPP | 0.3 | 5.0 | GPS EC/GPS EC | 2012 Nov/2004 Aug |
| HKO /PTB | GPSPPP | 0.3 | 5.0 | LC(GPS MC) | 2013 Apr |
| IFAG/PTB | GPSPPP | 0.3 | 5.0 | GPS EC/GPS EC | 2003 Jun/2004 Aug |
| IGNA/PTB | NA | | | | |

$u_A$ , $u_B$ do not have a clear meaning, in particular $u_B$

Time transfer equipment is NOT identified

Calibration Types are unclear, no reference to calibrations

Tracing calibrations and alignements very difficult

# New Section 5 of *BIPM Circular T* (Starting January 2016)

$u_{STB}$ replaces $u_A$ (characterizes the stability of the link)

$u_{CAL}$ replaces $u_B$ (represents the calibration uncertainty)

Time transfer equipment is identified

Cal_IDs allow to access reports of calibration or certificates

Additional info on alignments, transfer of calibration, etc.

Link to web/database from pdf version

| Link | Type | Equipment | Cal_ID1/Cal_ID2 | uStb/ns | uCal/ns | uAg/ns | Al/ns | YYMM |
|---|---|---|---|---|---|---|---|---|
| AOS /PTB | GPSPPP | AO_4 /PT02 | 1005-2008/1001-2014 | 0.3 | 5.8 | 3 | | |
| APL /PTB | GPSPPP | AP__ /PT02 | NA_A1 /1005-2014 | 0.3 | 11.2 | 10 | 109.4 | 1402 |
| AUS /PTB | GPSPPP | AU01 /PT02 | 1002-2010/1001-2014 | 0.3 | 5.4 | 2 | | |
| BEV /PTB | GPSPPP | BE1_ /PT02 | NA_A1 /1005-2014 | 0.3 | 4.2 | 3 | -3.2 | 1203 |
| BIM /PTB | GPS MC | BM37 /PT05 | 2004-2008/1005-2008 | 1.5 | 8.6 | 5 | | |
| BIRM/PTB | GPS MC | BI01 /PT05 | NC_A1 /1005-2008 | 1.5 | 20.0 | | -30.0 | 0709 |
| BY /PTB | GPS MC | BY__ /PT05 | NA_A1 /1005-2008 | 1.5 | 8.6 | 5 | 53.0 | 0804 |
| CAO /PTB | GPS MC | CA__ /PT05 | NC /1005-2008 | 8.0 | 20.0 | | | |
| CNM /PTB | GPS MC | CN00 /PT05 | NA_A1 /1005-2008 | 3.0 | 7.9 | 6 | -27.3 | 0804 |
| CNMP/PTB | GPS MC | MP__ /PT05 | 1002-2004/1005-2008 | 3.5 | 14.1 | 10 | | |
| DFNT/PTB | GPSPPP | DN__ /PT02 | NC_A1 /1005-2014 | 0.3 | 20.0 | | 10.3 | 1507 |
| DMDM/PTB | GPSPPP | ZM68 /PT02 | NA_A1 /1005-2014 | 0.3 | 6.5 | 4 | -15.0 | 1303 |
| DTAG/PTB | GPSPPP | DT01 /PT02 | NA /1001-2014 | 0.3 | 7.6 | 3 | | |
| EIM /PTB | GPS MC | EI__ /PT05 | 1011-2007/1005-2008 | 7.5 | 7.8 | 6 | | |
| ESTC/PTB | GPSPPP | ES03 /PT02 | 1012-2012/1001-2014 | 0.3 | 5.2 | 1 | | |
| HKO /PTB | GPSPPP | HK01 /PT02 | NA_A1 /1001-2014 | 0.3 | 7.1 | 1 | +15.9 | 1304 |
| IFAG/PTB | GPSPPP | IF13 /PT02 | 1011-2011/1001-2014 | 0.3 | 5.4 | 2 | | |
| IGNA/PTB | NL | | | | | | | |
| IMBH/PTB | GPSPPP | BH01 /PT02 | NA_A1 /1005-2014 | 0.3 | 7.0 | 0 | 31.6 | 1505 |

| Link | Type | Equipment | Cal_ID | uStb/ns | uCal/ns | uAg/ns | Al/ns | YYMM |
|---|---|---|---|---|---|---|---|---|
| CH /PTB | TWGPPP | CH01 /PTB01 | 0211-2011 | 0.3 | 1.4 | 1 | | |
| IT /PTB | TWGPPP | IT02 /PTB01 | 0374-2014 | 0.3 | 1.0 | 0 | | |
| NIST/PTB | TWGPPP | NIST01/PTB01 | 0214-2011 | 0.3 | 5.1 | 1 | | |
| OP /PTB | TWGPPP | OP01 /PTB01 | 0377-2014 | 0.3 | 1.0 | 0 | | |
| ROA /PTB | TWGPPP | ROA01 /PTB01 | 0380-2014 | 0.3 | 1.0 | 0 | | |
| SP /PTB | TWGPPP | SP01 /PTB01 | 0381-2014 | 0.3 | 1.0 | 0 | | |
| USNO/PTB | TWGPPP | USNO01/PTB01 | 0391-2014 | 0.3 | 1.0 | 0 | | |
| VSL /PTB | TWGPPP | VSL01 /PTB01 | 0220-2011 | 0.3 | 1.4 | 1 | | |

# Part III: Rapid UTC, an update

- UTCr official BIPM product in July 2013
- Made available every week since that time
- Paper published ***Metrologia* 51 33, 2014**
- UTCr remains within 1.1 ns RMS from UTC

# Rapid UTC project and UTCr

- UTC is not adapted for real and quasi-real time applications.
  - UTC is calculated with one-month data batches, and available monthly in *BIPM Circular T* under the form of [*UTC*-*UTC*(*k*)] at five-day intervals;
  - Extrapolation of values over 10 to 45 days based on prediction models is necessary to many applications.
- The Rapid UTC project (UTCr) was presented at the CCTF(2012)
- UTCr declared an official product in July 2013 (week 1336)
- Impact of UTCr
  - on UTC contributing laboratories: More frequent assessing of the UTC(K) steering, and consequently better stability and accuracy of [UTC(k)]; Enhanced traceability to UTC.
  - on users of UTC(K): Access to a better “local” reference, and indirectly, better traceability to the UTC “global” reference;
  - on GNSS: Better synchronization of GNSS times to UTC, through improved UTC and UTC(k) predictions.

# Publication of UTCr

Every Wednesday before 18:00 UTC on ftp://tai.bipm.org/UTCr/Results/ and on the regular Time Dpt ftp server.

Also ASCII files with UTCr-UTC(k)

Results of the official UTCr product since July 2013;

Back results of the pilot experiment stage in subdirectory Results/pilot_experiment;

UTCr_1344
2013 NOVEMBER 06, 12h UTC

BUREAU INTERNATIONAL DES POIDS ET MESURES
ORGANISATION INTERGOUVERNEMENTALE DE LA CONVENTION DU METRE
PAVILLON DE BRETEUIL F-92312 SEVRES CEDEX TEL. +33 1 45 07 70 70 tai@bipm.org

Computed values of [UTCr-UTC(k)]

| Date 2013 0h UTC | OCT 28 | OCT 29 | OCT 30 | OCT 31 | NOV 1 | NOV 2 | NOV 3 |
|---|---|---|---|---|---|---|---|
| MJD | 56593 | 56594 | 56595 | 56596 | 56597 | 56598 | 56599 |
| Laboratory k | [UTCr-UTC(k)]/ns | | | | | | |
| AOS (Borowiec) | 0.3 | 0.6 | 0.1 | -0.3 | -0.4 | -1.2 | -1.0 |
| BEV (Wien) | -36.1 | -37.0 | -31.8 | -25.5 | -26.1 | -20.5 | -20.9 |
| CH (Bern-Wabern) | -3.7 | -6.4 | -7.6 | -8.3 | -8.2 | -9.1 | -9.5 |
| CNM (Queretaro) | -5.4 | -6.4 | -5.0 | -5.8 | -5.3 | -5.9 | -6.6 |
| CNMP (Panama) | 0.0 | -1.6 | -8.5 | -13.2 | -23.9 | -17.1 | -25.4 |
| DMDM (Belgrade) | -13.1 | -16.6 | -17.5 | -22.3 | -30.5 | -31.0 | -29.4 |
| DTAG (Frankfurt/M) | 240.8 | 240.5 | 239.0 | 239.9 | 238.4 | 235.1 | 233.7 |
| IFAG (Wettzell) | -863.1 | -863.1 | -865.7 | -871.3 | -875.1 | -876.9 | -875.4 |
| IGNA (Buenos Aires) | 4621.9 | 4637.8 | 4654.7 | 4669.3 | 4686.0 | 4705.1 | 4724.0 |
| INTI (Buenos Aires) | 62.2 | 61.0 | 61.3 | 60.7 | 67.8 | 75.9 | 73.1 |
| IT (Torino) | -8.8 | -9.2 | -8.9 | -9.0 | -9.2 | -10.3 | -10.0 |
| KRIS (Daejeon) | -16.0 | -16.3 | -15.8 | -15.7 | -15.3 | -15.7 | -15.0 |
| LT (Vilnius) | 410.7 | 402.9 | 393.9 | 396.9 | 391.9 | 389.0 | 382.2 |
| MSL (Lower Hutt) | 782.4 | 781.8 | 791.7 | 802.6 | 813.9 | 828.0 | 842.6 |
| NAO (Mizusawa) | -20.3 | -23.1 | -23.2 | -20.5 | -23.4 | -23.8 | -25.4 |
| NICT (Tokyo) | 10.9 | 10.6 | 10.4 | 10.2 | 10.0 | 8.9 | 8.3 |
| NIM (Beijing) | -7.8 | -7.7 | -7.8 | -9.1 | -8.5 | -9.7 | -9.9 |
| NIMT (Pathumthani) | 0.1 | 1.8 | 2.5 | -2.1 | -2.3 | -1.0 | 0.0 |
| NIST (Boulder) | -1.4 | -1.9 | -2.7 | -3.5 | -3.5 | -4.3 | -3.9 |
| NMIJ (Tsukuba) | 0.6 | 0.3 | 0.0 | -0.4 | -0.3 | -1.1 | -1.2 |
| NMLS (Sepang) | 1119.1 | 1104.1 | 1084.3 | 1072.6 | 1053.4 | 1037.7 | 1018.2 |
| NPLI (New-Delhi) | -3.7 | -3.4 | -3.7 | -4.2 | -4.0 | -3.6 | -3.3 |
| NRC (Ottawa) | -22.6 | -19.6 | -22.1 | -20.6 | -26.5 | -26.6 | -22.8 |
| NRL (Washington DC) | -4.6 | -4.4 | -4.2 | -4.1 | -3.4 | -2.1 | -1.1 |
| NTSC (Lintong) | -0.1 | -0.2 | -1.3 | 0.7 | -2.6 | -1.9 | -3.6 |
| ONRJ (Rio de Janeiro) | -11.8 | -12.1 | -13.0 | -13.5 | -14.8 | -14.3 | -15.0 |
| OP (Paris) | -3.1 | -2.8 | -3.1 | -3.3 | -3.2 | -3.6 | -3.4 |
| ORB (Bruxelles) | -11.4 | -10.6 | -10.7 | -12.9 | -12.4 | -15.2 | -17.3 |
| PL (Warszawa) | 38.2 | 38.8 | 35.7 | 32.6 | 29.9 | 32.5 | 29.1 |
| PTB (Braunschweig) | -6.9 | -6.6 | -7.1 | -7.7 | -8.1 | -8.7 | -8.5 |
| ROA (San Fernando) | 0.4 | 0.6 | 0.2 | -1.1 | -1.8 | -3.2 | -4.0 |
| SCL (Hong Kong) | 33.7 | 35.6 | 27.5 | 34.7 | 29.3 | 32.4 | 28.1 |
| SG (Singapore) | -17.2 | -17.9 | -19.2 | -20.6 | -19.2 | -20.2 | -19.4 |
| SP (Boras) | -6.4 | -5.7 | -6.3 | -6.9 | -7.2 | -7.6 | -7.5 |
| SU (Moskva) | -2.0 | -1.7 | -2.1 | -2.4 | -2.2 | -2.6 | -1.9 |
| TL (Chung-Li) | -5.6 | -6.2 | -6.9 | -7.4 | -7.8 | -8.9 | -8.1 |
| UME (Gebze-Kocaeli) | 1363.3 | 1367.5 | 1369.9 | 1370.5 | 1376.8 | 1380.7 | 1379.1 |
| USNO (Washington DC) | -3.4 | -3.8 | -4.2 | -5.0 | -5.1 | -5.3 | -5.5 |
| VSL (Delft) | -23.0 | -22.2 | -22.0 | -20.5 | -18.3 | -18.8 | -12.9 |

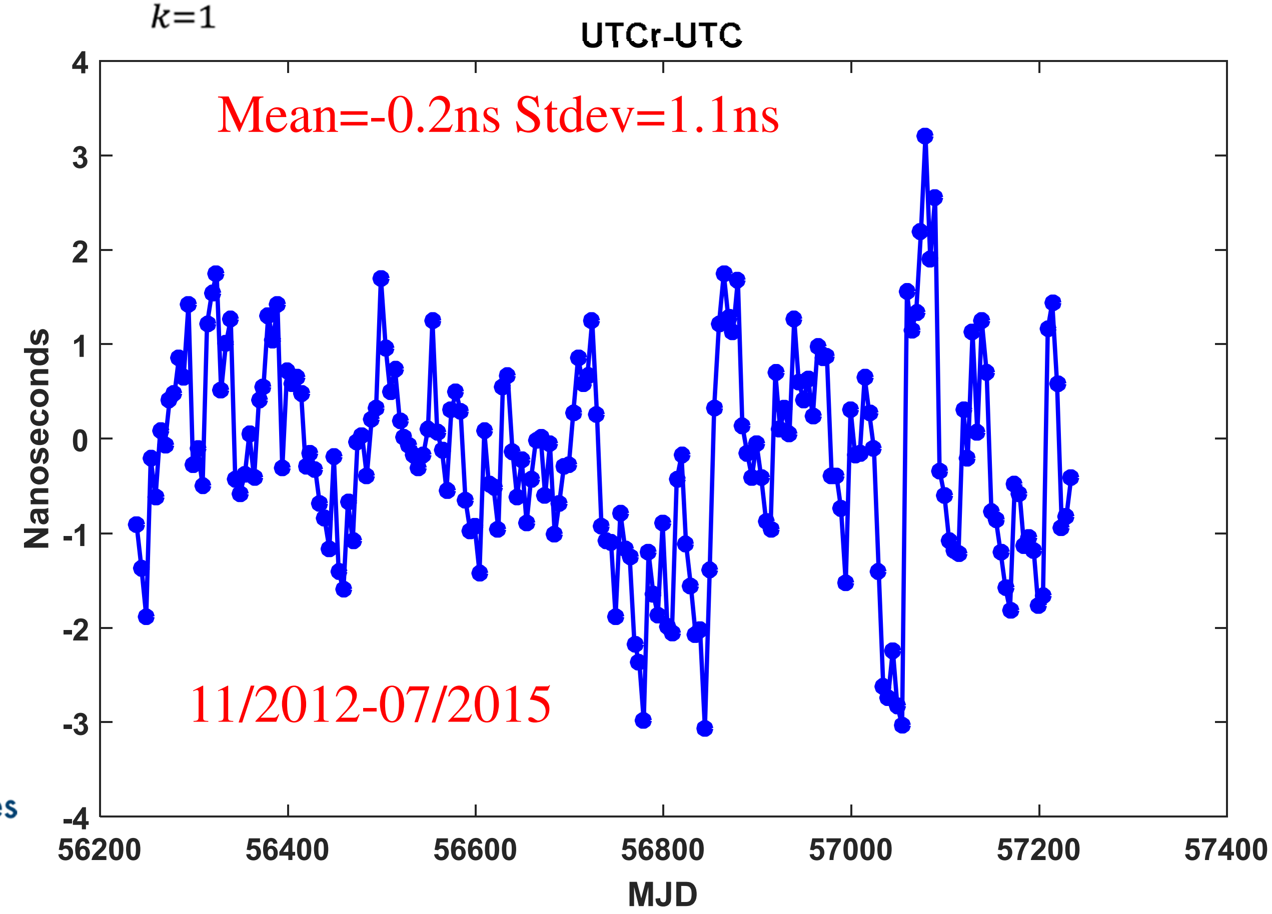
UTC remains available from the monthly Circular T at
(http://www.bipm.org/jsp/en/TimeFtp.jsp?TypePub=publication).

# Comparisons between UTCr and UTC

Not a single way to estimate UTCr-UTC.

We use a weighted average over the laboratories participating to UTCr:

$$D(t_j) = \sum_{k=1}^{N_k} W_k\left([UTCr - UTC(k)](t_j) - [UTC - UTC(k)](t_j)\right)$$

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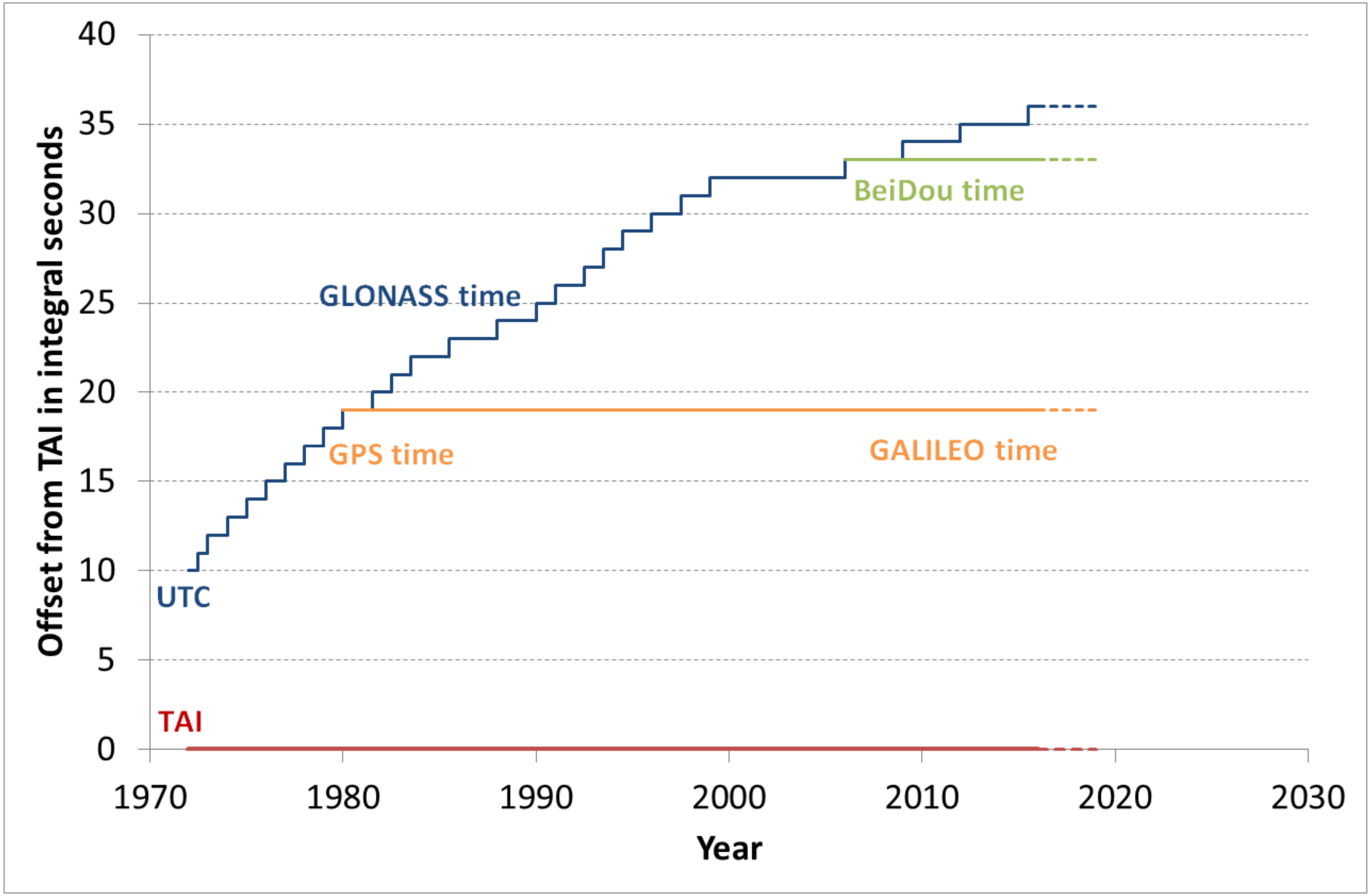
# Part IV: GLONASS Time and UTC, an update

- As seen from BIPM Circular T, GLONASS time and UTC(SU)$_{\_GLONASS}$ are now in line. Calibration still to be performed.
- Reminder: some changes to be introduced in January 2016 in Circular T section 5 (as mentioned before)

# GNSS Timescales



# [UTC – GLN time] and [UTC - UTC(SU)_GLN] from Circular T