Director's Report on the Activity and Management of the International Bureau of Weights and Measures

Supplement: Time Department

(1 January 2017 – 31 December 2017)

May 2018

Bureau International des Poids et Mesures

BIPM Time Department

Director: E.F. Arias (retired end of November 2017), P. Tavella (since 1 December 2017)

(1 January 2017 to 31 December 2017)

1. International Atomic Time (TAI), Coordinated Universal Time (UTC) and Rapid UTC (UTCr)

(E.F. Arias, A. Harmegnies, J. Gonçalves, Z. Jiang, , G. Panfilo, G. Petit, L. Tisserand, and P.Tavella)

The reference time scales, International Atomic Time (TAI) and Coordinated Universal Time (UTC), are computed from data reported regularly to the BIPM by various timing centres that maintain a local UTC time scale; monthly results are published in *Circular T*. The UTC rapid solution (UTCr) is published every Wednesday by 18 h UTC at the latest. All information related to the publication of UTC and UTCr can be accessed at https://www.bipm.org/en/bipm-services/timescales/time-ftp.html.

The structure and content of BIPM *Circular T* were updated in 2016 with the introduction of an interactive version, which gives complete access to the information hosted on the BIPM website and ftp server. The dissemination of information has significantly improved following the development and launch of the 'BIPM Time Department Data Base'. Time Department services can be accessed at https://www.bipm.org/en/bipm/tai/.

The *BIPM Annual Report on Time Activities for 2017*, volume 12, provides comprehensive data for 2017 and is available on the BIPM website at https://www.bipm.org/en/bipm/tai/annual-report.html, as well as previous annual reports,

2. Algorithms for time scales (G. Panfilo, G. Petit, A. Harmegnies, J Gonçalves, and L. Tisserand)

The algorithm used by the Time Department to calculate time scales is an iterative process that starts by producing a free atomic scale (*Échelle atomique libre,* EAL) from which TAI and UTC are derived. Research into time-scale algorithms is ongoing in the department, with the aim of improving the long-term stability of EAL and the accuracy of TAI. After the implementation of the new algorithms (prediction and weights) for UTC calculation, the behaviour of UTC is routinely and carefully monitored to detect and fix unexpected anomalies. In late 2016 and early 2017 a frequency drift was observed that affected EAL behaviour. A revision of the algorithm has been undertaken to fix the problem, which could have affected the performance of UTC. The studies showed that the algorithm's weakness was due to the length of the window over which past data was used for estimating the frequency drift of the atomic clocks participating in UTC. After appropriate tests and evaluations, the window length was optimized and the problem was resolved. The time scale is now free from the frequency drift and is stable and accurate, as is required for an international reference.

The algorithm for the evaluation of the uncertainties of [*UTC-UTC(k)*], reported in Section 1 of *Circular T*, has been revised and the work is being concluded. With the proposed formalism, the correlations among different measures can be taken into account, and the uncertainty of the PTB (pivot laboratory) is more realistic. The uncertainty of uncalibrated laboratories now equals to a more realistic value (arbitrarily fixed to 20 ns) without affecting the uncertainties of the ensemble and the calibrated laboratories. The proposed algorithm represents a first step towards the use of redundant time links in UTC calculation.

Until now only two independent techniques (GNSS and TWSTFT) were used for UTC calculation. A complete set of redundant measurements is available but is not yet used. The core concept is to introduce a redundant time link system to take full advantage of all the available measurements.

This is a significant evolution in time link calculation introducing important changes in terms of algorithms and checks of the results. For this reason, it was decided to proceed step-by-step to control each detail to achieve a robust solution. The first step of the planned work consists in the development of the algorithm for redundant time links and in its application to the uncertainty evaluation of the offset [UTC-UTC(k)].

2.1 EAL stability

A subset of 89 % clocks used in the calculation of UTC are either commercial atomic clocks with high-performance caesium tubes or active hydrogen masers. The number of hydrogen masers operated by contributing laboratories is increasing and represented 32 % of participating clocks in 2017. The weighting procedure involved in time scale computation guarantees the long-term stability of EAL. To prevent domination of the scale by a small number of very stable clocks, a maximum relative weight is used each month, which depends on the number of participating clocks. On average, about 13 % of participating clocks were at the maximum weight during 2017; almost all of which were hydrogen masers. The weighting algorithm, which has been in use since 2014, is based on the predictability of the clock's frequency. It enhances the influence of hydrogen masers on the resulting time scale; 45 % of the contributing hydrogen masers were, on average, at the maximum weight in 2017, whilst no caesium clocks reached the maximum weight.

UTC implicitly relies on hydrogen masers in the short term and on caesium clocks in the long term, which was an aim of the new weighting procedure. The stability of EAL at the end of 2017, expressed in terms of an Allan deviation, is about three parts in 10^{16} for averaging times of one month.

2.2 TAI accuracy

To characterize the accuracy of TAI, the relative deviation of the duration of the TAI scale interval from the SI second, as produced on the rotating geoid, by primary and secondary frequency standards is estimated together with its uncertainty. Since January 2017, individual measurements of the TAI frequency have been provided by eight primary frequency standards, including six caesium fountains (SYRTE FO2, IT CSF2, SU CSFO2, PTB CSF1, PTB CSF2 and NIM 5), and by a rubidium secondary frequency standard (SYRTE FORb). A few measurements by strontium lattice secondary frequency standards (SYRTE Sr2 and SrB) have also been reported for the first time in 2017, but were not used in estimating the duration of the TAI scale unit following advice by the working group on PSFS. Reports of the operation of the primary and secondary frequency standards are regularly published on the BIPM website and collated in the *BIPM Annual Report on Time Activities*.

Since January 2017, the global treatment of individual measurements has led to a relative departure of the duration of the TAI scale unit from the SI second on the geoid ranging from -1.46×10^{-15} to $+0.39 \times 10^{-15}$, with a maximum standard uncertainty of 0.28×10^{-15}. A steering correction of $+0.3 \times 10^{-15}$ has been applied each month from January to May 2017. A procedure has been developed to estimate the duration of the TAI scale unit on any interval. This is provided upon request to laboratories developing secondary standards in order for them to get optimal traceability to the SI second.

2.3 Independent atomic time scales: TT(BIPM)

TAI is computed almost in 'real-time' and is subject to operational constraints; as a result, it does not provide an optimal realization of TT, the Terrestrial Time, i.e. the time coordinate of the geocentric reference system. The BIPM therefore computes an additional realization, TT(BIPM), in post-processing, which is based on a weighted average of the evaluation of the TAI frequency by the primary frequency standards. The Time Department provided an updated computation of TT(BIPM) in January 2017, known as TT(BIPM16), valid until December 2016, which had an estimated accuracy of about 2-3 parts in 10^{16} over recent years. Moreover, the Time Department provides a formula to extend TT(BIPM16) based on the most recent TAI computation. Such an extension is useful for pulsar analysis pending the yearly updates of TT(BIPM). Studies to improve the computation of TT(BIPM) are ongoing in order to keep it in line with improvements in primary and secondary frequency standards.

2.4 Local representations of UTC in national laboratories as broadcast by the GNSS

The Time Department continues to calculate and publish the differences between the predictions of UTC(USNO) and UTC(SU) (as broadcast by GPS and GLONASS) and UTC in BIPM *Circular T*. Following the calibration of receivers at the Astrogeodynamical Observatory of the Space Research Centre (AOS, Borowiec, Poland) which provides data for GLONASS, the large offset that used to exist between UTC and GLONASS time was corrected on 1 March 2017.

3. **Primary frequency standards and secondary representations of the second** (E.F. Arias, G Panfilo, G. Petit and L. Robertsson)

Members of the BIPM Time Department actively participate in the work of the CCL-CCTF Frequency Standards Working Group (WGFS), and the CCTF Working Group on Primary and Secondary Frequency Standards (WGPSFS). These Working Groups seek to encourage comparisons, knowledge-sharing among laboratories, the creation of better documentation, the use of high-accuracy primary frequency standards (Cs fountains) and secondary frequency standards in TAI.

Following an invitation by the CCTF to systematically study frequency ratios of ultra-high precision frequency standards, a somewhat different approach is needed to generate the update of the frequency list. Redundant measurements in this scheme allow for consistency studies but also require a non-linear least squares approach for complete evaluation. Such resources have been developed at the BIPM, based on graph theory concepts. This method is a simplified approach, which is an alternative but complementary method to that developed at the NPL. Numerical validation of the two approaches has been successfully carried out and they have been used for the elaboration of the new recommended frequency list examined by the WGFS at meetings on 3-4 May and 6 June 2017. The new frequency list was adopted by the CCTF at its 21st meeting in 2017.

Secondary representations of the second reported in BIPM Circular T

Since January 2012 the LNE-SYRTE has regularly reported frequency measurements of the Rb microwave transition obtained with a double Cs-Rb fountain (FORb). In addition, measurements of two Sr optical lattice clocks were reported for the first time by the LNE-SYRTE in October 2016. After approval by the CCTF Working Group on Primary and Secondary Frequency Standards, they were published in *Circular T* in February 2017.

4. **Time links used for UTC** (E.F. Arias, A. Harmegnies, Z. Jiang, J. Gonçalves, G. Panfilo, G. Petit and L. Tisserand)

At the end of 2017, 80 time laboratories supplied data to the BIPM for the calculation of UTC. The laboratories are equipped with GNSS receivers and some of them also operate a two-way satellite time and frequency transfer (TWSTFT) station.

Data from three independent techniques are included in the process of comparison of laboratories' clocks based on the tracking of GPS and GLONASS satellites, and TWSTFT.

The GPS all-in-view method is widely used and takes advantage of the quality of the International GNSS Service (IGS) products (clocks and IGS time). Clock comparisons are obtained by using C/A code measurements from GPS single-frequency receivers, or dual-frequency, multi-channel GPS geodetic-type receivers (P3). The GPS phase and code data provided by time laboratories which operate geodetic-type receivers are processed monthly using the Precise Point Positioning (PPP) technique. The Time Department also regularly computes combined GPS/GLONASS links, some of which are used for *Circular T*.

Thirteen laboratories operating TWSTFT stations officially submitted data in 2017 for use in the computation of UTC, representing 16 % of the time links. The number of TW links decreased during the year with the lack of satellite service for laboratories in the Asia Pacific region. The combination of TWSTFT and PPP (so called

TWPPP) has been used whenever possible. This combination takes advantage of the small noise of the GPSPPP and of the accuracy of the TWSTFT links.

GPS PPP alone or in combination with TWSTFT are in use for UTC clock comparisons in almost 60 % of the links, where the statistical uncertainty of time transfer is well below the nanosecond, the best value being 0.3 ns.

4.1 Global Positioning System (GPS) and Global Navigation Satellite System (GLONASS)

All GNSS time and frequency transfer data are corrected for satellite positions using IGS and the Information and Analysis Centre of Navigation (IAC) of the Mission Control Centre in Russia. The measurement data obtained by using single-frequency receivers are corrected for ionospheric delays using maps of the total electron content of the ionosphere provided by the Centre for Orbit Determination in Europe (CODE).

Techniques that use dual-frequency GNSS carrier-phase measurements in addition to the codes, are widely used by the geodetic community and have been adapted to the needs of time and frequency transfer. This topic is studied within the framework of the IGS Working Group on Clock Products, which includes a physicist from the BIPM Time Department as a member.

Data from world-wide geodetic-type receivers are collected for UTC computation, using procedures and software that were developed in collaboration with the Observatoire Royal de Belgique (ORB). These P3 time links are routinely computed and compared to other available techniques, notably two-way time transfer. The software that produces ‘iono-free’ solutions has been updated to cover all GNSS and implemented in some receivers and these now automatically produce formatted code results for GPS or for all available GNSS. These newly available data will be used in multi-GNSS system time links after validation of such processing.

The NRCan’s PPP software is used for the time link calculation using phase and code measurements. The current version of the software is capable of processing both GPS and GLONASS data, but only GPS results are used operationally. Comparisons with other PPP software have been carried out. Studies are ongoing to improve long-term stability, using new processing techniques, in collaboration with software developers at NRCan, the ORB, the *Centre National d’Études Spatiales* (CNES), and also with other institutes. A novel PPP technique using integer phase ambiguities (IPPP) has been successfully developed and is being further improved within the framework of a post-doctoral project. It significantly improves the stability in the medium term (several hours), but mostly in the long term (days). Since 2015 the IPPP technique has been used regularly to compare IPPP results to the few available optical fibre links.

Comparisons of the different links available between pairs of contributing laboratories, are computed and published monthly on the Time Department’s ftp server.

4.2. Two-way satellite time and frequency transfer

The 25th annual meeting of the CCTF Working Group on Two-Way Satellite Time and Frequency Transfer (WGTWSTFT) was held on 18-19 May 2017 at the National Time Service Center (NTSC) of the Chinese Academy of Sciences in Xi’an (China).

Two major issues were discussed at the meetings concerning the time link calibrations carried out by the laboratories and the realization of a pilot project involving the BIPM and the WGTWSTFT.

The first topic was presented by each participating station in its annual report. From 2017, all the TW laboratories have been asked to report the TWSTFT and GNSS calibrations performed in their laboratories to the WGTWSTFT to better facilitate tracking and monitoring of the UTC calibrations and their long-term variations. This request was one of the outputs of the Task Group, established by the 2016 TW WG meeting at NIST, to study the long-term comparison of GPS and TWSTFT links. The Task Group was discontinued following a conclusion report given by the Chair of the WG, Victor Zhang.

The second issue is to summarize the status of the BIPM-WGTWSTFT pilot project on the use of the Software-Defined Radio (SDR) receiver technique in UTC generation. Dr Jiang of the BIPM gave the status report. The results are encouraging and the WGTWSTFT decided to make a Recommendation to the CCFT meeting in June 2017 to use SDR in UTC computation. An *ad hoc* group composed of TL, NIST, OP, PTB and BIPM experts was set up to handle the practical issues for the implementation of SDR in UTC computation.

The *ad hoc* group met at the 31st European Frequency and Time Forum (EFTF) in Besancon (France) in July 2017 and a roadmap was established. The first step is to use the SDR link as the backup UTC link: this has been carried out since October 2017.

The TWSTFT technique is currently operational in ten European, two North American and several Asia-Pacific time laboratories. Most of the TWSTFT links had been used in the computation of UTC in 2017 in Europe, USA and Asia; they are often combined with GPS PPP solutions. Some of the TWSTFT links involved in the computation of UTC are used in the experiment 'Time Transfer by Laser Link' (T2L2). In the long-term, the BIPM plans to develop studies on this technique, which could be used to validate less accurate time links and their calibrations.

Results of the time links and link comparison using GNSS single-frequency, dual-frequency and TW observations are published monthly on the Time Department's ftp server (ftp://ftp2.bipm.org/pub/tai/timelinks/lkc/).

4.3 Calibration of delays of time-transfer equipment and time links

The characterization of the delays (so-called "calibration") of time transfer equipment in the contributing laboratories is necessary to improve the uncertainty of [*UTC-UTC*(*k*)] and for the accuracy of UTC dissemination.

The *BIPM Guidelines for GNSS calibration* are intended for Regional Metrology Organizations (RMOs) with whom a permanent cooperation is established for sharing the organization of campaigns to determine the relative delays of time transfer equipment and links in UTC contributing laboratories. The '*Guidelines*' are under continuous improvement; the latest revision was issued in March 2016.

The BIPM continued the second calibration campaign of the "Group 1" laboratories in SIM and COOMET in 2017, following the planned periodicity of two years. Regional calibration trips concerning "Group 2" laboratories continued in the RMOs in 2017 in accordance with the *BIPM Guidelines* and the results have been implemented in *Circular T*. By repeatedly applying this new procedure, time transfer accuracy is expected to improve by a factor of at least two with respect to the pre-2015 situation.

The BIPM Time Department is not directly involved in specific TWSTFT calibration trips, but is responsible for the validation of the calibration reports and implementation of the results in the calculation of UTC. It also provides support whenever necessary to maintain a TW calibration by alignment with a calibrated GPS link (see section 4.2).

Results of the differential calibration exercises are made available on a dedicated web page (www.bipm.org/jsp/en/TimeCalibrations.jsp), where past calibration results are also provided.

4.4 Advanced time and frequency transfer

Data from two fibre links between UTC contributing laboratories in Europe are regularly submitted to the Time Department and compared with the corresponding links by GNSS time transfer techniques. The Time Department aims to include fibre links in the computation of UTC in the future, and for this purpose the CCTF WG on Coordination of the Development of Advanced Time and Frequency Transfer Techniques (WGATFT) has established a Study Group to develop the strategy for the use of these very accurate links in UTC. This Study Group has made progress on this subject and has been merged into the CCTF WGATFT.

5. **Key comparisons** (E.F. Arias, , G. Panfilo, A. Harmegnies, j. Gonçalves, and L. Robertsson)

Key comparison in Time CCTF-K001.UTC

Results of the key comparison in time, CCTF-K001.UTC, involving the time laboratories that participate in the CIPM MRA, are published monthly in the BIPM key comparison database (KCDB). The number of participants at the end of 2017 was 63, and they constitute a subset of the participants to BIPM *Circular T*.

Key comparison of stabilized lasers CCL-K11

Following a decision at the 98th meeting of the CIPM (2009) the BIPM continues to support the CCL-K11 key comparison by participating in measurement campaigns and by providing general advice whenever solicited. This comparison is the internationally recognized traceability chain to the SI metre and is supervised by the CCL-CCTF Working Group on Frequency Standards, which submits results to the CCL for formal approval. In 2017, BIPM staff members supported the key comparison on issues relating to the development of the measurement campaigns and reporting.

6. **Rapid UTC** (A. Harmegnies, G. Panfilo, G. Petit and L. Tisserand)

Since January 2013 the Time Department has published a UTC rapid solution 'UTCr', that is, daily values of [$UTCr – UTC(k)$] evaluated on a weekly solution on one-month batches of data. More than 50 laboratories that are traceable to UTC contribute to UTCr, which together represent some 70 % of the clocks that participate in UTC.

To improve the stability of rapid UTC, a new weighting algorithm was introduced. As a result, since July 2017, the weekly UTCr solution is consistent within 2 ns peak to peak with the UTC values published monthly in BIPM *Circular T*. The results (ftp://ftp2.bipm.org/pub/tai/Rapid-UTC) have been published every Wednesday, without interruption since the end of February 2012.

UTCr does not change the procedures for the monthly calculation of UTC, which remains the only key comparison on time. However, UTCr has a favorable impact on the quality of the local representations UTC(k) in national laboratories, and on the steering of GNSS times to UTC via some UTC(k).

7. **Revision of the definition of UTC** (F. Arias, P.Tavella)

The BIPM has actively participated in discussions about a possible revision of the definition of UTC without leap seconds since 2000. This proposal favours systems that require precise time synchronization and does not allow a discontinuity in the time scale that they use as a reference.

The BIPM contributed to this process at the International Telecommunication Union (ITU), and participated in the meeting of Study Group 7 (Science services) and Working Party 7A (Time signals and frequency standard emissions) in October 2017.

The CCTF established a task group for proposing definitions of TAI and UTC to be submitted to the CGPM in 2018. This was in response to an invitation by the World Radiocommunication Conference 2015 (WRC15) to strengthen the cooperation between the ITU and the BIPM on this matter, and in preparation for the discussions scheduled for the WRC23. This task group, which includes two Time Department staff members, drafted a text of the recommendation discussed and endorsed by the CCTF in June 2017 and successively by the CIPM in November 2017. This recommendation will be submitted to the CGPM in November 2018.

8. **Space-time references** (E.F. Arias and G. Petit)

Activities related to the realization of reference frames for astronomy and geodesy are ongoing, in cooperation with the International Earth Rotation and Reference Systems Service (IERS). In these domains, improvements in accuracy will increase the need for a full relativistic treatment, and continued participation to the international working groups in this field is essential.

Cooperation continues on the maintenance of the international celestial reference system within the framework of the activities of a working group created by the International Astronomical Union (IAU) in August 2012. This working group met within the period and submitted a report on the features of the next realization of the International Celestial Reference Frame (ICRF3) to the IAU General Assembly held in Honolulu (USA) in August 2015, with a view to the submission of the catalogue with the set of coordinates in the ICRF3 in 2018.

With the development of optical clocks accurate at the 10^{-18} level, "relativistic geodesy" is the subject of numerous developments, which suggest the full potential of these clocks for the measurement of terrestrial gravity potential and the definition of systems of altimetry references. A physicist from the Time Department is co-chairing a new IAG working group on this subject. A first meeting of this working group was held in May 2017 and international collaborations led to publications on the implications of such "chronometric geodesy" for geodesy and the definition of time scales and on the calculation of the relativistic frequency shift with the required accuracy for optical clocks.

9. **Comb activities** (L. Robertsson)

The BIPM comb activities are limited to maintenance of the BIPM frequency comb for internal use related to laser applications only and in other departments when needed.

10. **Publications**

External publications

1. Denker H., Timmen L., Voigt C., Weyers S., Peik E., Delva P., Wolf P., Petit G., Geodetic methods to determine the relativistic redshift at the level of 10^{-18} in the context of international timescales – A review and practical results; *J. Geodesy*, 2017, doi:10.1007/s00190-017-1075-1.
2. Hachisu H., Petit G., Nakagawa F., Hanado Y., Ido T, SI-traceable measurement of an optical frequency at the low 10^{-16} level without a local primary standard, *Opt. Express* **25**, 8511-8523, 2017.
3. Jiang Z., Zhang V., Parker T.E., Yao J., Huang Y.-J., Lin S.-Y., (2017) Accurate TWSTFT time transfer with indirect links, *Proc. PTTI 2017*, 30 January – 2 February 2017, Monterey, California, USA.
4. Jiang Z., Arias F.E., (2017) Pilot study on the validation of the Software-Defined Radio Receiver for TWSTFT -- BIPM contribution to the validation of the SDR for TWSTFT, *Proc. PTTI 2017*, 30 January - 2 February 2017, Monterey, California, USA.
5. Jiang Z., Matsakis D., Zhang V., (2017) Long-term instability in UTC time links, *Proc. PTTI 2017*, 30 January - 2 February 2017, Monterey, California, USA.
6. Jiang Z., Lin S.-Y., Tseng W.-H., (2017) Fully and optimally use the redundancy in a TWSTFT network for accurate time transfer, *Proc. ETFT-IFCS2017*, 9-13 July Beçsançon, France, 367-380.
7. Lin S. Y., Jiang Z., (2017) GPS All in View Time Comparison using Multireceiver Ensemble, *Proc. ETFT-IFCS2017*, 9-13 July Beçsançon, France, 362-365.
8. Liang K., Zhang A., Yang Z., Tisserand L., Jiang Z., Petit G., Arias E.F., (2017) Experimental research on BeiDou time transfer using the NIM made GNSS time and frequency receivers at the BIPM in Euro-Asia link, *Proc. ETFT-IFCS2017*, 9-13 July Besançon, France, 788-797.

9. Liang K., Zhang A., Yang Z., Wang J.-L., Lin H.T., Wang Y., Yang F., Yang J., Gotoh T., Cai Z., Jiang Z., Mou W., (2017) UTC time link calibration in the frame of APMP - Campaigns in 2014-2016, Proc. ETFT-IFCS2017, 9-13 July Beçsançon, France, 826-834.

10. Matus M., Gavalyugov V., Tamakyarska D., Ranusawud M., Tonmueanwai A., Hong F.-L., Ishikawa J., Moona G., Sharma R., Hapiddin A., Boynawan A.M., Alqahtani N., Alfohaid M., Robertsson L., Report on on-going CCL Key Comparison for the year 2014 Comparison of optical frequency and wavelength standards CCL-K11, *Metrologia*, 2017, **54**, *Tech. Suppl.*, 04001.

11. Müller J., Dirkx D., Kopeikin S.M., Lion G., Panet I., Petit G., Visser P.N.A.M., High performance clocks and gravity field determination, *Space Sci. Rev.*, 2018, **214**:5.

12. Petit G., Leute J., Loyer S., Perosanz F., Sub 10^{-16} frequency transfer with IPPP: Recent results, Proc. 2017 Joint EFTF/IFCS, 2017, 784-787.

13. Wielgosz R., Arias F., Los Arcos J.-M., Stock M., Milton M., News from the BIPM laboratories – 2016, *Metrologia*, 2017, **54**, 148-151.

BIPM publications

14. *BIPM Annual Report on Time Activities for 2017*, 12. available only at http://www.bipm.org/en/bipm-services/timescales/time-ftp/annual-reports.html

15. *Circular T* (monthly)

16. *Rapid UTC* (*UTCr*) (weekly)

11. Activities related to the work of Consultative Committees

E.F. Arias is Executive Secretary of the Consultative Committee for Time and Frequency (CCTF). She is the Secretary of the CCTF Working Group on TAI (WGTAI) and the CCTF Working Group on Strategic Planning (WGSP).

Z. Jiang is Secretary of the CCTF Working Group on Two-Way Satellite Time and Frequency Transfer (WGTWSTFT).

G. Panfilo is Secretary of the CCTF Working Group on the CIPM MRA (WGMRA) and the CCTF Working Group on Time Scale Algorithms (WG-ALGO). She is the Executive Secretary of the Consultative Committee for Acoustics, Ultrasound and Vibration (CCAUV). She is Secretary of the CCAUV Working Groups for Key Comparisons (CCAUV-KCWG), for RMO coordination (CCAUV-RMO) and on Strategic Planning (CCAUV-SPWG).

G. Petit is Secretary of the CCTF Working Group on Primary and Secondary Frequency Standards (WGPSFS) and the Working Group on Global Navigation Satellite Systems (WGGNSS).

L. Robertsson is Executive Secretary of the Consultative Committee for Length (CCL), a member of the CCL Working Group on Strategic Planning (WG-S) and of the Discussion Group DG-11 (Lasers). He is the BIPM representative on the CCM Working Group on Gravimetry (WGG). He is also Secretary for the CCTF WG on Coordination of the Development of Advanced Time and Frequency Transfer Techniques (WGATFT) and shares the secretariat of the CCL-CCTF Frequency Standards WG (WGFS) with E.F. Arias.

12. Activities related to external organizations

E.F. Arias is a member of the IAU and participates in its working group on the International Celestial Reference Frame (ICRF); she is a member of the Steering Committee of IAU Division A on Fundamental Astronomy and a member of the Division A Working Group on the Third Realisation of the International Celestial

Reference Frame. She is an associate member of the IERS, a member of its International Celestial Reference System Centre, and until end 2016 of the Conventions Centre. E.F. Arias is a member of the International VLBI[1] Service (IVS). She is the BIPM representative to the Governing Board of the International GNSS Service (IGS). She is the BIPM representative to the UN sponsored International Committee on GNSS (ICG) and the chairperson of its Task Force on Time References. She is a member of the Technical Advisory Committee of International Union of Radio Science (URSI) Commission A. E.F. Arias is a member of the IAG Global Geodetic Observing System (GGOS) Steering Committee representing the BIPM. She is a member of the Argentine Council of Research (CONICET) and an associate astronomer at the LNE-SYRTE, Paris Observatory. She is a corresponding member of the *Bureau des longitudes* and the BIPM representative to the Working Party 7A of Study Group 7 of the International Telecommunication Union – Radiocommunication Sector (ITU-R).

G. Petit is an associate member of the IGS and member of the IGS Working Groups on Clock Products and on Bias Calibration. He represents the BIPM at the United Nations International Committee on Global Navigation Satellite Systems (ICG), where he chairs the Task Force on Time References. He is co-chair of the IAG Joint Working Group on Relativistic Geodesy and a member of the IAU Working Groups on Numerical Standards in Fundamental Astronomy and on Pulsar Time Scale.

P. Tavella is Vice Chair of the EFTF Executive Committee, she is a member of the AdCom of the IEEE UFFC Society, a member of the Technical Advisory Committee of International Union of Radio Science (URSI) Commission A, and a member of the ION PTTI (Precise Time and Time Interval) Advisory Committee.

13. Travel in 2017 (conferences, lectures and presentations, visits)

E.F. Arias to:

- Monterey (USA), for PTTI Tutorials on 30 January to give a lecture and for the PTTI 2017 from 31 January to 2 February to chair a session and participate to CCTF Working Group meetings;
- Madrid (Spain); 19-29 March, for lecturing at PhD courses in Engineering, Mathematics, Statistics and Research, Universidad Complutense y Politécnico de Madrid;
- San Fernando (Spain), in 8-9 March, the Technical Committee on Time and Frequency of EURAMET to give reports on BIPM activities and to coordinate calibrations;
- Teddington (UK), in 23-24 February, for the meeting of the Programme Expert Group on Digital;
- London (UK) for the UTC Traceability Workshop, 28 February;
- Beijing (China) for a visit to NIM and validation of facilities for the key comparison of absolute gravimeters 2017, 14-19 May;
- Shanghai (China) for the 8th China Satellite Navigation Conference, invited to give a lecture, 22 – 25 May;
- Besancon (France), 9-13 July, for the EFTF-IFCS 2017 congress and related CCTF WG meetings;
- Montreal (Canada), 19-26 August, for attending the General Assembly and Scientific Symposium of the International Union of Radio Science, chairing a session and presenting a paper;
- Xian (China), 7-8 September, to the 25th Annual meeting of the CCTF WG on TWSTFT and to give oral reports on the WG activities;
- San Fernando (Spain), 15 September, for participating to the inauguration of the new building of ROA devoted to Time and Frequency metrology
- Teddington (UK), 11-12 October, for the meeting of the Programme Expert Group on Digital;

[1] Very Long Baseline Interferometry (VLBI)

- La Plata (Argentina), 25 October for the workshop on time and frequency at the Argentinian-German Geodetic Observatory (AAGO), to give a lecture;
- Buenos Aires (Argentina) 26-27 October for the technical peer review of the time and frequency activities at the Instituto Nacional de Tecnologia e Industria (INTI);
- Geneva (Switzerland), 25 October - 1 November, for the meeting of Study Group 7 and Working Party 7A at the ITU;
- Valencia (Spain), 27 October, for the 22nd meeting of the Galileo Scientific Advisory Committee (GSAC).

P. Tavella to:

- Bruxelles (Belgium), 23 November, for a meeting of the Executive Committee of the European Time and Frequency Forum (Vice Chair).

Z. Jiang to:

- Besancon (France), 9-13 July, for the ETFT-IFCS 2017 meeting and the meeting of the *ad hoc* for the SDR;
- Xian (China), 7-8 September, to the 25th Annual meeting of the CCTF WG on TWSTFT and to give oral reports on the WG activities and the status of the pilot project on SDR;
- NIM, Beijing (China), 17-25 October, for the International Comparison of Absolute Gravimeters 2017 (ICAG 2017), co-chair the workshop on ICAG and Watt Balance held during the comparison.

G. Petit to:

- San Fernando (Spain), 8-9 March, to attend the Euramet TC-TF meeting, with one presentation;
- Hannover (Germany), 15-16 May, to attend the meeting of the IAG Working Group 2.1 on relativistic geodesy, as co-chair of the WG;
- Paris (France), 30 May, to attend the Journées CNES “GNSS and science”, with one presentation;
- Besançon (France), 27-28 June, to give two lectures at the European Frequency and Time Seminar;
- Paris (France), 5-7 July, to attend the IGS Workshop, to chair one session and give one presentation;
- Besançon (France), 10-13 July, to attend the EFTF 2017 meeting, to chair one session and give two oral presentations;
- Paris (France), 13 October, to attend the *Journée thématique* “50th anniversary of the definition of the second” to give one oral presentation.

14. Visitors, secondees in 2017

- H. Hachisu, NICT (Japan), for a discussion on the use of Sr lattices for UTC, 13 January.
- K. Liang, NIM (China) to work on calibration and time transfer with the Beidou system, 9 January to 20 December.
- H. Yuan, NTSC (China), for discussions on the BeiDou system, 4 July.
- J. Leute, CNRS (France), to develop methods and tools for the IPPP technique, 1 Aug 2017- 31 July 2019
- D. Matsakis, USNO (USA), for a discussion on uncertainty of *[UTC-UTC(k)]*, 11 September.