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

Supplement: Time Department

(1 January 2013 – 31 December 2013)

March 2014

Bureau International des Poids et Mesures

BIPM Time Department
Director: E.F. Arias
(1 January 2013 to 31 December 2013)

1. International Atomic Time (TAI), Coordinated Universal Time (UTC) and Rapid UTC (UTCr) (E.F. Arias, A. Harmegnies, Z. Jiang, H. Konaté, W. Lewandowski, G. Panfilo, G. Petit and L. Tisserand)

The reference time scales, International Atomic Time (TAI) and Coordinated Universal Time (UTC), are computed from data reported regularly to the BIPM by the various timing centres that maintain a local UTC; monthly results are published in *Circular T*. Starting on 1 July 2013 the official UTC rapid solution *UTCr* has been published every Wednesday at 18 h UTC at the latest. All information related to the publication of UTC and UTCr can be accessed at www.bipm.org/en/scientific/tai/ftp_server/introduction.html.

The *BIPM Annual Report on Time Activities for 2012*, volume 7, provides the definitive results for 2012 and is available electronically on the BIPM website at www.bipm.org/en/publications/time_activities.html.

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

The algorithm ALGOS used for the calculation of the 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 continues in the department with the aim of improving the long-term stability of EAL and the accuracy of TAI.

As a consequence of the introduction of the quadratic clock frequency prediction since September 2011, no drift of EAL has been observed during 2013. A new clock weighting procedure has been developed based on the concept of clock frequency predictability. It results in a more balanced distribution of clock weights and enhances the influence of the H-masers in the ensemble. An improvement on the short- and long-term stability of EAL is observed by applying the new weighting algorithm.

2.1 EAL stability

Some 88 % of the clocks used in the calculation of time scales are either commercial atomic clocks with high performance caesium tubes or active hydrogen masers. In the current weighting procedure the weight attributed to a clock reflects its long-term stability in order to guarantee 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 and depends on the number of participating clocks. On average during 2013, about 14 % of the participating clocks were at the maximum weight. Since 2001, when the present weighting procedure was adopted, the number of hydrogen masers doubled, whilst the number of caesium clocks increased by 50 %. In order to optimize the impact of the hydrogen masers on the time scale, and for better distribution of the weight among the caesium clocks and hydrogen masers, a new weighting procedure based on the concept that a good clock is not a stable clock but instead is a predictable clock has been developed and validated. This new prediction model will be implemented in UTC calculation starting on 1 January 2014. Tests over the past eight years demonstrated that a better distribution among the clock weights is achieved, with a 40 % increase in hydrogen masers at the maximum weight. Both short- and long-term stability of EAL will improve by 20 %. The stability of EAL, as at the end of 2013, expressed in terms of an Allan deviation, is about 3 parts in 10^{16} for averaging times of one month. A long-interval estimation of the frequency stability of EAL after the introduction of the new weighting procedure indicates that it will decrease up to 1.8 parts in 10^{16} in the next few years.

2.2 TAI accuracy

To characterize the accuracy of TAI, estimates are made of the relative departure, and its uncertainty, of the duration of the TAI scale interval from the SI second, as produced on the rotating geoid, by primary and secondary frequency standards. Since January 2013, individual measurements of the TAI frequency have been provided by eight primary frequency standards, including six caesium fountains (LNE-SYRTE FO1, LNE-SYRTE FO2, NIST F1, NPL CSF2, PTB CSF1 and PTB CSF2). Reports on the operation of the primary frequency standards are regularly published on the BIPM website and collated in the *BIPM Annual Report on Time Activities*.

During 2013, measurements of the TAI frequency by a rubidium secondary frequency standard (LNE-SYRTE FO2Rb) have been reported in *Circular T*. They have been used for TAI steering since July 2013, after the publication of the CIPM 2012 recommendations.

Since January 2013, 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 $+0.7 \times 10^{-15}$ to -0.6×10^{-15}, with a standard uncertainty of maximum 0.3×10^{-15}. No steering corrections have been applied in 2013, showing the positive impact of the new algorithm on the accuracy of TAI.

2.3 Independent atomic time scales: TT(BIPM)

Because TAI is computed in 'real-time' and has operational constraints, it does not provide an optimal realization of TT, 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), known as TT(BIPM12), valid until December 2012, which had an estimated accuracy of about 2-3 parts in 10^{16} over recent years. Moreover, the Time Department provides a monthly extension of TT(BIPM12) 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 the 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*.

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), seeking to encourage comparisons, knowledge-sharing between laboratories, the creation of better documentation, the use of high-accuracy primary frequency standards (Cs fountains) and secondary frequency standards for TAI.

The WGFS maintains a list of recommended values of standard frequencies for applications including secondary representations of the second. At its meeting in September 2012 it proposed additions and updates to microwave and optical atomic transitions in the list. The latest changes to the list, as recommended by the CCTF in September 2012 as secondary representations of the second have been endorsed by the CIPM in Recommendation 1(CI-2013).

Secondary representations of the second reported in BIPM Circular T

Since January 2012 the LNE-SYRTE has reported frequency measurements of the Rb microwave transition obtained with a double Cs-Rb fountain (FO2Rb). Fifteen measurement reports of FO2Rb were submitted in 2013. With the agreement of the CCTF Working Group on Primary and Secondary Frequency Standards (WGPSFS), the Time Department updated its procedures and programs in order to include secondary frequency standards in the estimation of TAI accuracy (see §2.2) and in the computation of TT (see §2.3). These measurements have been officially used for the accuracy of TAI since July 2013 and will be used in January 2014 for the computation of TT(BIPM13).

Advanced time and frequency transfer

One of the Time Department's innovative activities in this field is related to the establishment of optical fibre links between some laboratories which maintain local representations of UTC. A successful experiment was conducted using BIPM GPS equipment in parallel to the fibre link regularly operated between two representations of UTC in Poland. This experiment demonstrated excellent agreement (at the level of the GPS PPP uncertainty) between the GPS PPP link calculated with the BIPM equipment and the optical fibre link. The optical fibre link can be used to assess the calibration of a UTC link calculated with the current time transfer techniques as a result of the small (hundred picoseconds) and stable calibration uncertainty. This experiment allowed the validation of the new BIPM calibration system with u_B within 1 ns. Several other fibre links between contributing laboratories are calculated on a regular basis, with a potential measurement uncertainty of about 100 ps in the future. In order to benefit from the quality of these links, the Time Department initiated a discussion with the laboratories already implementing time transfer via optical fibres with the aim of establishing standards for data transmission and validating the compatibility of the different techniques.

In parallel, the Time Department continued with activities in the frame of the CCTF WG on Coordination of the Development of Advanced Time and Frequency Transfer Techniques (WGATFT), and followed the progress in the NMIs and other institutes in this field of activity.

4. **Time links used for TAI** (E.F. Arias, A. Harmegnies, Z. Jiang, H. Konaté, W. Lewandowski, G. Panfilo, G. Petit and L. Tisserand)

At the end of 2013, 73 time laboratories supplied data for the calculation of TAI at the BIPM. The laboratories are equipped with GNSS receivers and some of them also operate two-way satellite time and frequency transfer (TWSTFT) stations.

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

The GPS all-in-view method is widely used and takes advantage of the increasing quality of the International GNSS Service (IGS) products (clocks and IGS time). Clock comparisons are possible using C/A code measurements from GPS single-frequency receivers, or dual-frequency, multi-channel GPS geodetic-type receivers (P3). The older GPS single-channel single-frequency receivers have almost disappeared from use, replaced by either multi-channel single- or dual-frequency receivers.

The Time Department also regularly computes combined GPS/GLONASS links resulting in improved link uncertainty. About five GPS/GLONASS links are regularly computed for *Circular T*.

Fifteen TWSTFT links are officially submitted for use in the computation of TAI, representing 19 % of the time links. The combination of TWSTFT and PPP (so called TWPPP) is used whenever possible. This generally concerns about a dozen links for which the two techniques are available.

The GPS phase and code data provided by time laboratories which operate geodetic-type receivers is processed each month using the Precise Point Positioning (PPP) technique. The NRCan PPP software is used for the time link calculation. 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 continuing to improve long-term stability, using new processing techniques, in collaboration with software developers at NRCan, the *Observatoire Royal de Belgique* (ORB), the *Centre National d'Études Spatiales* (CNES) and also with other institutes.

GPS PPP alone or in combination with TWSTFT are in use for TAI clock comparison in 55 % of the links, where the statistical uncertainty of time transfer is well below the nanosecond, the best value is 0.3 ns for 46 % of the time links.

Testing continues on other time and frequency comparison methods and techniques.

Comparisons of the different possible links on a baseline linking two contributing laboratories are computed and published monthly on the Time Department's ftp server.

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

All GNSS time and frequency transfer data are corrected for satellite positions using IGS and ESA precise satellite ephemerides. The measurement data obtained by using single-frequency receivers are corrected for ionospheric delays using IGS maps of the total electron content of the ionosphere.

4.2 Phase and code measurements from geodetic-type receivers

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 in the framework of the IGS Working Group on Clock Products, which has a physicist from the Time Department as a member.

Data from world-wide geodetic-type receivers are collected for TAI computation, using procedures and software developed in collaboration with the ORB. These P3 time links are now routinely computed and compared to other available techniques, notably two-way time transfer. After one year of operation, the software that produces GPS P3 (iono-free) data has been upgraded and is now able to produce GLONASS P3. It will be implemented in some receivers to automatically produce both formatted GPS and GLONASS P3 code results. In the future, these newly available data are likely to be used in multi-GNSS system time links, but further studies on inter-frequency biases have to be carried out.

4.3. Two-way time transfer

Two meetings of the TWSTFT participating stations were held during 2013. The 21st annual meeting of the CCTF WG on TWSTFT was held at the TL premises in Chinese Taipei in September 2013.

The TWSTFT technique is currently operational in twelve European, two North American and nine Asia-Pacific time laboratories. Fifteen TWSTFT links are routinely used in the computation of TAI; fourteen are combined with GPS PPP solutions. Some of the TWSTFT links are used for particular studies such as the Time Transfer by Laser Link (T2L2) experiment. The TWSTFT technique applied to clock comparisons in TAI is at present reaching its maximum potential with sessions scheduled every two hours.

The BIPM is also involved in the calibration of two-way time-transfer links by comparison with GPS.

Results of 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://tai.bipm.org/TimeLink/LkC).

4.4 Calibration of delays of time-transfer equipment

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 continues to organize and run campaigns to measure the relative delays of GPS time equipment in time laboratories that contribute to TAI.

The method developed to perform absolute calibration of the Ashtech Z12-T hardware delays has allowed the BIPM to use this receiver for differential calibrations of similar receivers world-wide; calibration campaigns began in January 2001 and have been continued and expanded to include other types of receivers (Septentrio PolaRx2-3-4, Dicom GTR50 and Javad JPS E-GGD). New types of receivers are being investigated in collaboration with the laboratories that are equipped with them. In all cases, at least two receivers remain at the BIPM to serve as a local reference to which the travelling receiver is compared between calibration trips. 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.

Starting in 2012, the BIPM initiated work to adopt a new organization for calibrations:

- In the frame of the Pilot Project of the UTC time link calibration, a time transfer system, consisting of two GNSS receivers, antennas, additional equipment and a calibration scheme has been developed with the aim of performing time link calibrations that could be transferred to any other technique on a same baseline. In 2013 this equipment had visited five laboratories in Europe and Asia under the pilot experiment to validate METODE (MEasurement of TOtal DElay).
- Following a recommendation by the CCTF, the Time Department has issued BIPM Guidelines for GNSS equipment calibration in UTC contributing laboratories, which are in the process of being revised by the CCTF Working Groups on GNSS and on the CIPM MRA. This process will be concluded in early 2014. This document is addressed to Regional Metrology Organizations with the aim of establishing a permanent cooperation for sharing the organization of campaigns to determine the relative delays of time transfer equipment in UTC contributing laboratories.

Work continues on absolute calibration of GNSS receivers in collaboration with the CNES.

The BIPM is not directly involved in TWSTFT calibration trips, but provides support whenever requested using a GPS receiver from its time laboratory.

5. **Key comparisons** (E.F. Arias, H. Konaté, Z. Jiang, W. Lewandowski, G. Panfilo, G. Petit, L. Tisserand, A. Harmegnies and L. Robertsson)

Key comparison in Time CCTF-K001.UTC

Results of the key comparison in time, CCTF-K001.UTC, involving the time laboratories participating in the CIPM MRA, are published regularly in the form of the monthly BIPM *Circular T*.

Key comparison of stabilized lasers CCL-K11

The BIPM continues to support the CCL-K11 key comparison in terms of participation in measurement campaigns as well as by providing general advice. This follows a decision at the 98th meeting of the CIPM in 2009. This comparison is the internationally recognized and CCL supervised traceability chain to the SI metre. Even though this adds to the work load of the pilot and the four node laboratories that run the comparison, it effectively provides traceability to the metre for some eight NMIs per year. During 2013, staff from the Time Department were only involved in the reporting of measurement results and no BIPM presence for measurement campaigns took place.

Activities in gravimetry

The contribution of the Time Department to gravimetry covers two aspects:

a) The follow-up of the International Comparison of Absolute Gravimeters (ICAG), which has been under the responsibility of the NMIs since 2010. The key comparison CCM.G-K1 has been defined as part of the ICAG. The ICAG 2013 took place in Luxembourg piloted by the METAS. The BIPM provided support to the organization of this comparison and a member of the Time Department was present during the measurement campaign. The Time Department has also contributed to the CCM Working Group on Gravimetry (WGG).

b) A series of relevant publications related to gravity measurements at the BIPM, including a contribution to the watt balance experiment have been published.

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

From January 2012 until the end of June 2013 the Time Department conducted a pilot experiment to produce a "rapid UTC" (UTCr), that is, daily values of [*UTCr* – *UTC*(*k*)] evaluated on a weekly solution. About 40 laboratories that contribute approximately 60 % to 70 % of the clocks in UTC contributed to the pilot experiment.

UTCr became an official publication of the BIPM on 1 July 2013. This followed CCTF approval of a report which demonstrated that UTCr has reached the expected quality, providing a weekly solution which is consistently better than ± 2 ns peak to peak with the values published in the monthly BIPM *Circular T*. The results (ftp://tai.bipm.org/UTCr) have been published every Wednesday, without interruption since the end of February 2012.

The new product does not change the procedures for the monthly calculation of UTC, which remains the only key comparison on time. However, UTCr favourably impacts 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. New proposed definition of UTC (F. Arias and W. Lewandowski)

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

The actions of BIPM delegates during this process have been critical at the International Telecommunication Union (ITU), and also in disseminating information and promoting decision making at the level of national representatives. Particularly important in 2013 was the organization of a joint workshop by the BIPM and the ITU on the future of the international time scale. This event was held in Geneva, Switzerland, on 19-20 September 2013. The workshop was in preparation for the next World Radiocommunication Conference in 2015 (WRC15), where a decision is to be taken on the redefinition of UTC without leap second adjustments. This meeting provided a unique opportunity to solicit input from most of the relevant communities, among then the two fully operational GNSS providers: GPS and GLONASS, the forthcoming GNSS Galileo and BeiDou, the telecommunications sector, time stamping authorities, and scientific organizations that represent astronomers, geodesists and geophysicists.

8. Pulsars (G. Petit)

Collaboration continues with radioastronomy groups that observe pulsars and which analyse pulsar data to study the possibility of using millisecond pulsars as a means of sensing the very long-term stability of atomic time. The Time Department provides these groups with its post-processed realization of Terrestrial Time, TT(BIPM) and participates in a Working Group on pulsars and time scales established by the International Astronomical Union (IAU).

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

Activities related to the realization of reference frames for astronomy and geodesy are being developed 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 it is essential to continue to participate in international working groups on these matters.

Cooperation continues for the maintenance of the international celestial reference system within the framework of the activities of a working group created by the IAU in August 2012; the target is to report on the features of the next realization of the International Celestial Reference Frame (ICRF3) to the IAU General Assembly in 2015 and to provide the ICRF3 in 2018.

As part of its participation in the Conventions Centre of the IERS, the BIPM maintains the web and ftp sites for the *IERS Conventions* (http://tai.bipm.org/iers/). The Conventions describe the latest realizations of the celestial and terrestrial reference frames, and of the model for the transformation between them. They also describe conventional models for the gravitational field, the displacement of markers on the Earth's crust and for the propagation of electromagnetic signals. In addition, the *Conventions* now provide a complete set of associated conventional software. These tasks are carried out with the help of the Advisory Board for the *IERS Conventions* updates, including representatives from all groups involved in the IERS. Since the completion of the latest reference edition, *IERS Conventions* (2010) in December 2010, work is continuing to provide updates to the *Conventions* (2010) which are regularly posted on the website (http://tai.bipm.org/iers/convupdt).

10. Comb activities (L. Robertsson)

As a result of the reorganization of activities in the Time Department, BIPM comb activities are limited to the maintenance of the BIPM frequency comb for internal use related to laser applications only and in other departments when needed.

11. Publications

External publications

1. Defraigne P., Aerts W., Harmegnies A., Petit G. *et al.*, Advances in multi-GNSS time transfer, *Proc. IFCS-EFTF 2013*, 2013, 508-512.
2. Fang H., Kiss A., de Mirandés E., Lan J., Robertsson L., Solve S., Picard A., Stock M., Status of the BIPM watt balance, *IEEE Trans. Instrum. Meas.*, 2013, **62**, 1491-1498.
3. Harmegnies A., Defraigne P., Petit G., Combining GPS and GLONASS in all-in-view for time transfer, *Metrologia*, 2013, **50** (3)**,** 277-287.
4. Jiang Z., *et al*., On the gravimetric contribution to watt balance experiments, *Metrologia*, 2013, **50**, 452–471.
5. Jiang Z., Arias E.F., Use of the Global Navigation Satellite Systems for the construction of the international time reference UTC, *Proc. China Satellite Navigation Conference*, 457-468.
6. Jiang Z., Improving the time link calibration for the generation of UTC, *Proc. Asia-Pacific Time and Frequency Workshop*, on the internet only, Session A3 – Time and Frequency Transfer, http://www.apmpweb.org/fms/workshop3.php?tc_id=TF.
7. Jiang Z., Petit G., Tisserand L., Uhrich P., Rovera G.D. and Lin S.Y., Progress in the link calibration for UTC time transfer, *Proc. IFCS-EFTF 2013*, 2013, 861-864.
8. Jiang Z., Konaté H. and Lewandowski W., Review and Preview of Two-way Time Transfer for UTC generation – from TWSTFT to TWOTFT, *Proc. IFCS-EFTF 2013*, 2013, 501-504.
9. Panfilo G. and Harmegnies A., A new weighting procedure for UTC, *Proc. IFCS-EFTF 2013*, 2013, 652-653.
10. Panfilo G., Harmegnies A., Tisserand L., Arias E.F., The algorithm for the generation of UTC: latest improvements, *Proc. 45th PTTI Meeting*, 2013.
11. Petit G., Arias E.F., Harmegnies A., Panfilo G., Tisserand L., UTCr: a rapid realization of UTC, *Metrologia*, **51,** 2014, 33-39.
12. Solve S., Chayramy R., Picard A., Kiss A., Fang H., Robertsson L, de Mirandés E., Stock M., A bias source for the voltage reference of the BIPM watt balance. *IEEE Trans. Instrum. Meas.*, 2013, 1594-1599.
13. Zucco M., Robertsson L. and Wallerand J.-P., Laser-induced fluorescence as a tool to verify the reproducibility of iodine-based laser standards: a study of 96 iodine cells. *Metrologia* **50**, 2013, 402–408.

BIPM publications

14. *BIPM Annual Report on Time Activities for 2012*, 7, 121 pp., available only at http://www.bipm.org/en/publications/time_activities.html.
15. *Circular T* (monthly), 8 pp.
16. *Rapid UTC* (*UTCr*) (weekly), 1 pp.
17. Panfilo G., Harmegnies A., Tisserand L., A new weighting procedure for UTC. Report to the CCTF Working Group on TAI and to the CCTF working group on Time Scale Algorithms, December 2013.

12. 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).

W. Lewandowski is Secretary of the CCTF Working Group on TWSTFT (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).

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) since June 2013.

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.

13. 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 vice-president of the Commission 31 (Time) and co-chairs the working group on the redefinition of UTC. She is an associate member of the IERS, a member of its International Celestial Reference System Centre, and of the Conventions Centre. E.F. Arias is a member of the International VLBI 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. 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 associated 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 the Study Group 7 of the International Telecommunication Union – Radiocommunication Sector (ITU-R).

W. Lewandowski is the BIPM representative to the Civil GPS Service Interface Committee and chairman of its Timing Sub-Committee. He is a member of the Scientific Council of the Space Research Centre of the Polish Academy of Sciences. He is also a member of a consultative Group on the Reform of Metrology at the Polish Ministry of Economy, an adviser to a Parliamentary Group on Space, and a member of the Committee on Research on Space Techniques of the Polish Academy of Sciences. He is member of European Commission Advisory Group on Galileo Time Infrastructure. Together with E.F. Arias, he is the BIPM representative to Working Party 7A of the Study Group 7 of the ITU-R, and to the ICG.

G. Petit is co-director of the Conventions Centre of the IERS. He is an associate member of the IGS and member of the IGS Working Groups on Clock Products and on Bias calibration. He is a member of the IAU Working Groups on Numerical Standards in Fundamental Astronomy and on Pulsar Time Scale.

G. Panfilo collaborates with the Working Group 1 (WG1) on the Expression of uncertainty in Measurement (GUM) of the Joint Committee for Guides in Metrology (JCGM) to provide an example for the new version of the GUM.

14. Travel (conferences, lectures and presentations, visits)

E.F. Arias to:

- Tokyo (Japan), 5-8 February 2013, for the NICT workshop on optical frequency standards (invited as a lecturer) and for a visit to the NMIJ;
- Geneva (Switzerland), 10-18 September 2013, for meetings of Study Group 7 and Working Party 7A of the International Telecommunication Union (ITU-R);
- Geneva (Switzerland), 19-20 September 2013, for the ITU/BIPM Workshop on the future of the international time scale at the International Telecommunication Union; charged with its organization and for giving presentations;
- Dubai (United Arab Emirates), 10-15 October 2013, for the 8th meeting of the International Committee on GNSS (ICG), with presentations and chairmanship of task group meetings;
- Bellevue (Washington, USA), 2-6 December 2013, for the PTTI2013 meeting with oral presentations, a panel discussion and two CCTF WG meetings;
- San Francisco (California, USA), 8 December 2013, for the IGS Governing Board meeting.

A. Harmegnies to:

- Prague (Czech Republic), 22-25 July 2013, to attend the IFCS-EFTF 2013 meeting and to give an oral presentation;
- Besançon (France), 26-30 August 2013, for training at the European Frequency and Time Seminar.

Z. Jiang to:

- Wuhan (China), 4-7 May 2013, for the China Satellite Navigation Conference 2013;
- Prague (Czech Republic), 22-25 July 2013, to attend the IFCS-EFTF 2013 meeting;
- Zdiby (Czech Republic), 26 July 2013, for a visit to the Research Institute of Geodesy, Topography and Cartography (VÚGTK/RIGTC);
- Taipei (Chinese Taipei), 4-9 September 2013, for the 21st meeting of the CCTF Working Group on TWSTFT, the AP-RASC'13 and the ATF Workshop;
- Bellevue (Washington, USA), 2-6 December 2013, for the PTTI 2013 meeting with oral presentations, a panel discussion and two CCTF WG meetings.

W. Lewandowski to:

- Vienna (Austria), 17-18 February 2013, for the preparatory meeting of the 8th ICG;
- Warsaw (Poland), 5-12 February and 18-23 April 2013, to the Space Research Centre and Space Commission;
- Brussels (Belgium), 4-5 June 2013, for GNSS Program Board;
- Warsaw-Poznan (Poland), 11-16 July 2013, for a GNSS calibration trip and experiment with fibre links;
- Taipei (Chinese Taipei), 4-9 September 2013, for the 21st meeting of the CCTF Working Group on TWSTFT, the AP-RASC'13 and the ATF Workshop;
- Geneva (Switzerland), 18-21 September 2013, for the ITU/BIPM Workshop on the future of the international time scale at the International Telecommunication Union;
- Dubai (United Arab Emirates), 10-15 October 2013, for the 8th meeting of the International Committee on GNSS (ICG), with presentations and task group meetings;

- Warsaw (Poland), 25-28 November 2013, for the Metrology Working Group and the Conference "Metrology - the engine of innovation";
- Bellevue (Washington, USA), 2-6 December 2013, for the PTTI2013 meeting with oral presentations.

G. Petit to:

- New Delhi (India), 20-23 February 2013, to attend the 8th International Conference of Advances in Metrology, with an invited talk, and to visit the NPLI time laboratory;
- Toulouse (France), 26 March 2013, to visit the CNES time laboratory for collaboration in GNSS analysis and calibration;
- Paris (France), 10-11 April 2013, to attend the GRAMAP workshop and to give an oral presentation;
- Paris (France), 23-24 May 2013, to participate in the IERS Retreat;
- Toulouse (France), 3-7 June 2013, for training on GNSS processing and to visit the CNES time laboratory with a travelling GNSS receiver;
- Ottawa (Canada), 12-14 June 2013, to attend the GNSS Precise Point Positioning Workshop, to give an oral presentation and to visit the NRC time laboratory;
- Brussels (Belgium), 26 June 2013, to visit the ORB time laboratory for collaboration in GNSS analysis;
- Prague (Czech Republic), 22-25 July 2013, to attend the IFCS-EFTF 2013 meeting, to give oral presentations, a CCTF WG meeting and a CCL-CCTF WG meeting;
- Besançon (France), 27-29 August 2013, to give two lectures at the European Frequency and Time Seminar;
- Paris (France), 16-17 September 2013, to attend the Journées 2013 SRST and to give an oral presentation;
- Bellevue (Washington, USA), 2-6 December 2013, for the PTTI2013 Meeting with oral presentations and two CCTF WG meetings.

L. Robertsson to:

- Walferdange (Luxembourg), 10-14 November 2013 for the ICAG 2013, being a member of the steering committee.

15. Visitors

- P. Nogaś from the Polish Space Research Centre (SRC) for a cooperation on the improvement of GNSS time transfer, 23 April – 1 May 2013;
- T. Bartholomew (NIST, ITU) for a cooperation on ITU-R activities, 15-19 July 2013;
- Ł. Śliwczyński and P. Krehlik from the AGH University of Science and Technology, Krakow, Poland for discussions on the use of optical fibres for time transfer, 20 November 2013;
- M. Khalid Al-Dawood, Supervisor of Time and Frequency Laboratory (SASO) and R. Hamid, Head of the Time, Frequency and Wavelength Laboratory (TÜBİTAK - UME), and Chair of the EURAMET Technical Committee for Time and Frequency, for discussions on the participation of SASO in the key comparison CCTF-K001.UTC, 3 October 2013.