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

Supplement: Time Department

(1 January 2012 – 31 December 2012)

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Bureau International des Poids et Mesures

BIPM Time Department
Director: E.F. Arias
(1 January 2012 to 31 December 2012)

1. International Atomic Time (TAI) and Coordinated Universal Time (UTC) (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*. The *BIPM Annual Report on Time Activities for 2011*, volume 6, provides the definitive results for 2011 and is available electronically on the BIPM website www.bipm.org/en/publications/time_activities.html.

2. Algorithms for time scales (Z. Jiang, W. Lewandowski, G. Panfilo and G. Petit)

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.

Since September 2011 the clock frequency prediction model in ALGOS takes into account the frequency drift which affects most of the participating atomic clocks. The frequency drift of each clock is estimated with respect to Terrestrial Time (TT) computed at the BIPM and which represents the best reference for frequency. As a consequence, the drift of -1.3×10^{-17} /day observed in EAL with respect to TAI has been completely removed, with an improvement in the long-term stability of EAL.

2.1 EAL stability

Some 87 % of the clocks used in the calculation of time scales are either commercial caesium clocks of the Symmetricom/HP/Agilent 5071A type or active, auto-tuned hydrogen masers. To improve the stability of EAL, a weighting procedure is applied to clocks where the maximum relative weight each month depends on the number of participating clocks. On average during 2011, about 15 % of the participating clocks were at the maximum weight. The change of the frequency prediction model has no impact on the weight of clocks. In order to allow a correct weighting of the hydrogen masers, and for better distribution of the weight among the caesium clocks and hydrogen masers, studies were undertaken to develop a new weighting procedure based on the concept that a good clock is not a stable clock but instead is a predictable clock. At the end of 2012 this procedure had been tested on six previous years of collected data and proved to establish a good distribution of weights; as a consequence, the stability of EAL will be improved. This new prediction model will be implemented in ALGOS during the first few months of 2013. The stability of EAL, expressed in terms of an Allan deviation, is about 3 parts in 10^{16} for averaging times of one month.

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 frequency standards. Since January 2012, individual measurements of the TAI frequency have been provided by ten primary frequency standards, including eight caesium fountains (LNE-SYRTE FO1, LNE-SYRTE FO2, LNE-SYRTE FOM, NIST F1, NPL CSF1, 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*.

Since 2012, measurements of the TAI frequency by secondary frequency standards have been reported in *Circular T*. They have not been used for TAI steering so far, but will be after the implementation of the CIPM 2012 recommendations.

Since January 2012, 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 $+3.5 \times 10^{-15}$ to -0.3×10^{-15}, with a standard uncertainty of maximum 0.5×10^{-15}. Between January and December 2012, ten steering corrections have been applied, giving a total correction to $[f(EAL) - f(TAI)]$ of -0.043×10^{-15}. Since the introduction of the new prediction algorithm in September 2011, monthly steering corrections of -5×10^{-16} and -3×10^{-16} have been applied. Since the drift affecting EAL has completely disappeared no corrections to the frequency of EAL have been applied since November 2012.

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), named TT(BIPM11), valid until December 2011, which had an estimated accuracy of about 3 parts in 10^{16} over recent years. Moreover, the Time Department provides a monthly extension of TT(BIPM11) based on the most recent TAI computation. Such an extension is useful for pulsar analysis pending the yearly updates of TT(BIPM). Studies aimed at improving 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 Frequency Standards (WGPFS), seeking to encourage comparisons, knowledge-sharing between laboratories, the creation of better documentation, and the use of high-accuracy primary frequency standards (Cs fountains) for TAI.

The CCL/CCTF Frequency Standards Working Group 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, containing frequency values and uncertainties for transitions in Rb, Hg^+, Yb^+, Yb, Sr^+, Sr and Al^+ were recommended by the CCTF in September 2012 as secondary representations of the second.

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). Reports with data since November 2009 onwards have been reviewed and approved by the CCTF WGPFS only for comparison via *Circular T* with the frequency of TAI. From May 2012 a new table has been included in *Circular T*; 21 measurement reports of FO2Rb were submitted in 2012.

Advanced time and frequency transfer

The Time Department has not particularly developed activities in this field, but instead has followed the evolution of the techniques for optical clock comparison by contributing to the CCTF WG on Coordination of the Development of Advanced Time and Frequency Transfer Techniques (WGATFT) and by participating in meetings of experts, mainly on the use of optical fibres.

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

At the end of 2012, 72 time laboratories participated in the calculation of TAI at the BIPM. The laboratories are equipped with GNSS receivers and/or operating two-way satellite time and frequency transfer (TWSTFT) stations.

Significant improvements have been made within the Time Department to the time links used for the calculation of TAI; 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, replaced by either multi-channel single- or dual-frequency receivers. The GPS phase and code data provided by time laboratories is processed each month using the Precise Point Positioning (PPP) technique. Fifteen TWSTFT links are officially submitted for use in the computation of TAI, representing 21 % of the time links. Since 2011, 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.

Since January 2011 the Time Department started computing combined GPS/GLONASS links resulting in improved link uncertainty. About four GPS/GLONASS links are regularly computed for *Circular T*.

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.

Geodetic-type receivers also provide raw phase measurements which may be used, along with the code measurements, to compute time links. Since October 2007, the BIPM has computed its own solutions for such time links, using GPSPPP software from Natural Resources Canada (NRCan), and these links have been introduced into the TAI regular computation since September 2009. In 2011 a new version of the NRCan PPP software was installed. It is capable of processing both GPS and GLONASS data. 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.

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

All GNSS links are corrected for satellite positions using IGS and ESA post-processed, precise satellite ephemerides, and those links 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 using 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. A study is being conducted under the framework of the IGS Working Group on Clock Products, which has a physicist from the Time Department as a member.

The method developed to perform absolute calibration of the Ashtech Z12-T hardware delays allows the BIPM to use this receiver for differential calibrations of similar receivers world-wide; calibration campaigns began in January 2001. Calibration results have also been issued for other receivers: the Septentrio PolaRx2 since 2006 and the Dicom GTR50 and Javad JPS E-GGD since 2009. Other types of receivers are being investigated in collaboration with the laboratories equipped with them. Since 2009, the BIPM travelling receiver for differential calibrations is a GTR50. 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.

Data from geodetic-type receivers world-wide 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 work, the software producing 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 2012. The annual meeting of the CCTF WG on TWSTFT was held at the BIPM headquarters in September 2012.

The TWSTFT technique is currently operational in eleven European, two North American and nine Asia-Pacific time laboratories. Fifteen TWSTFT links are routinely used in the computation of TAI; thirteen of them are combined with GPS PPP solutions. Some of them 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 Uncertainties of TAI time links

The values of Type A and Type B uncertainties of TAI time links are published in *Circular T*, together with information on the time links used in each monthly calculation. The values of u_A have been individually updated when deemed necessary, depending on the noise level present in the links. Due to upgrading of time transfer equipment at participating laboratories, the Time Department has refined the methods for clock comparison, and a global re-evaluation of u_A values, using the latest evaluation tools, has been made and published in *Circular T* of December 2011.

4.5 Calibration of delays of time-transfer equipment

The BIPM continues to organize and run campaigns for measuring the relative delays of GPS time equipment in time laboratories that contribute to TAI. The BIPM also supports TWSTFT calibration trips, using a GPS receiver from its time laboratory.

Work on the absolute calibration of GNSS receivers has been carried out by a Ph.D student through a collaboration co-financed with the CNES, and involving the LNE-SYRTE. The doctoral thesis "Contribution to the absolute calibration of a GNSS reception chain" was defended in November 2011, completing the planned programme of work. It focused on the development and optimization of a method of absolute calibration to independently determine the electrical delay of each element in a GNSS reception chain (time receiver, antenna and antenna cable) with an overall uncertainty of less than one nanosecond. The absolute calibration method can be used to characterize performance and environmental sensitivity of each component of the acquisition system.

Cooperation continued with EURAMET to obtain regional support for GNSS equipment calibration in contributing laboratories. This action follows a Recommendation of the CCTF (2009) and opens up the possibility of future interaction with other RMOs.

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*. The CCTF approved updates to the existing guidelines and new guidelines on the evaluation of the uncertainty in frequency and on the evaluation of the uncertainty in the prediction of [*UTC*-*UTC*(*k*)] in September 2012. These guidelines had been prepared by staff of the Time Department to support the CCTF Working Group on the CIPM MRA (WGMRA).

Key comparison of stabilized lasers CCL-K11.UTC

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. During 2012, staff from the Time Department were only involved in the reporting of measurement results and no BIPM presence for measurement campaigns took place.

Key comparison of absolute gravimeters CCM.G-K1

The campaign of comparison of absolute gravimeters ICAG-2009 concluded the contribution of the BIPM to the maintenance of the world global gravity network. Since then the key comparison CCM.G-K1 has been defined as part of the ICAG. This activity has been transferred to the NMIs, and the next ICAG in 2013 will take place in Luxembourg piloted by the METAS. As agreed, the BIPM provided support to the organization of the future ICAG during 2012 and staff from the Time Department contributed to the CCM Working Group on Gravimetry (WGG). A series of relevant publications related to ICAG-2009 have been published, including the reports of the key comparison and a scientific article. Studies based on gravity measurements on the BIPM watt balance site were ongoing at the end of 2012, and a scientific article on the characterization of gravity for the watt balance experiment is expected to be published in the first three months of 2013.

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

At the end of 2011 the Time Department called for expressions of interest to participate in a pilot experiment for producing a "rapid UTC" (UTCr), that is, daily values of [UTCr – UTC(k)] evaluated on a weekly solution. With the full support of the time laboratories and of the CCTF, the pilot experiment started in January 2012 with the participation of about 40 laboratories that contribute approximately 60 % of the clocks in UTC. The first results (ftp://tai.bipm.org/UTCr) were published at the end of February 2012. Since then, the weekly solutions have been published every Wednesday without interruption.

A report was submitted to the CCTF in September 2012 and the pilot experiment is expected to become operational in 2013.

The new product does not change the procedures for the monthly calculation of UTC, which remains the only key comparison on time.

7. **New proposed definition of UTC** (F. Arias, 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. A delegate from the BIPM attended the Radiocommunication Assembly 2012 (RA-12) which was held in Geneva, Switzerland, on 16 to 20 January 2012, where the ITU member states discussed the adoption of modified UTC. It was decided to postpone the decision until the World Radiocommunication Conference 2015 (WRC-15) to be held in Geneva on 2 to 27 November 2015. In the meantime investigations will continue on the feasibility of a continuous timescale to be used as the international time reference. Staff from the Time Department contributed to two Radiocommunication Seminars in St Petersburg, Russian Federation (June 2012) and Manta, Ecuador (September 2012), respectively. Staff from the Time Department attended regular meetings of Study Group 7 and Working Party 7A of the ITU-R.

8. **Pulsars** (G. Petit)

Collaboration continues with radioastronomy groups observing pulsars and analyzing pulsar data to study the potential capability 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)

The BIPM maintains the web and ftp sites for the *IERS Conventions* (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 International Earth Rotation and Reference Systems Service (IERS). After the completion of the new 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 (tai.bipm.org/iers/convupdt).

Activities related to the realization of reference frames for astronomy and geodesy are being developed in cooperation with the 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.

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 sections when needed.

11. Publications

External publications

1. Arias E.F., Jiang Z., Robertsson L., Vitushkin L., Ruess D., Ullrich C., Inglis D., Liard J., Robinson I., Ji W., Shuqing W., Lee C., Palinkas V., Mäkinen J., Pereira Dos Santos F., Bodart Q., Merlet S., Mizushima S., Choi I.-M., Baumann H., Karaböce B., Final report of key comparison CCM.G-K1: International comparison of absolute gravimeters ICAG2009, *Metrologia,* 2012, **49**, *Tech. Suppl.,* 07011.
2. Arias F., Harmegnies A., Jiang Z., Konaté H., Lewandowski W., Panfilo G., Petit G., Tisserand L., UTCr: a rapid realization of UTC, *Proc. EFTF 2012*, 2012, 24-27.
3. Bauch A., Beutler G., Petit G., Time and Frequency Metrology and its use for Navigation: Status and Proposed Future Research Themes, Galileo Science Advisory Committee, 2012.
4. Francis O, Rothleitner Ch., Jiang Z., Accurate determination of the Earth Tidal Parameters at the BIPM to support the Watt balance project, *Proc. IAG Symposium*, **139**, 2012.
5. Jiang Z., Becker M., Jousset P., Coulomb A., Tisserand L., Boulanger P., Lequin D., Lhermitte F., Houillon J.L., Dupont F., High precision levelling supporting the International Comparison of Absolute Gravimeters, *Metrologia,* 2012, **49**(1), 41-48.
6. Jiang Z., Lewandowski W., Use of GLONASS for UTC time transfer, *Metrologia,* 2012, **49**(1), 57-61.
7. Jiang Z., Lewandowski W., Accurate GLONASS time transfer for the generation of Coordinated Universal Time, *Int. Journal of Navigation and Observation*, 2012, **2012**, Article ID 353961, 14pp.

8. Jiang Z., Matsakis D., Mitchell S., Breakiron L., Bauh A., Piester D., Maeno H., Bernier L.G. Long-term Instability of GPS-based Time Transfer and Proposals for Improvements, *Proc. 43rd PTTI Meeting 2011,* 2012, 387-406.

9. Jiang Z., Lewandowski W., Panfilo G., Petit G., Reevaluation of the Measurement Uncertainty of the UTC Time Transfer, *Proc. 43rd PTTI Meeting 2011,* 2012, 133-140.

10. Jiang Z., Lewandowski W. Use of multi-technique combinations in UTC/TAI time and frequency transfer, *Proc. EFTF 2012*, 2012, 335-339.

11. Jiang Z, Lewandowski W., Inter-comparison of the UTC time transfer links, *Proc. EFTF 2012,* 2012, 126-132.

12. Jiang Z., Pálinkáš V., Francis O., Jousset P., Mäkinen J., Merlet S., Becker M., Coulomb A., Kessler-Schulz K.U., Schulz H.R., Rothleitner Ch., Tisserand L., Lequin D., Relative Gravity Measurement Campaign during the 8th International Comparison of Absolute Gravimeters (2009), *Metrologia,* 2012, **49**(1), 95-107.

13. Jiang Z., Pálinkáš V., Arias F.E., Liard J., Merlet S., Wilmes H., Vitushkin L., Robertsson L., Tisserand L., Pereira Dos Santos F., Bodart Q., Falk R., Baumann H., Mizushima S., Mäkinen J., Bilker-Koivula M., Lee C., Choi I.M., Karaboce B., Ji W., Wu Q., Ruess D., Ullrich C., Kostelecký J., Schmerge D., Eckl M., Timmen L., Le Moigne N., Bayer R., Olszak T., Ågren J., Del Negro C., Greco F., Diament M., Deroussi S., Bonvalot S., Krynski J., Sekowski M., Hu H., Wang L.J., Svitlov S., Germak A., Francis O., Becker M., Inglis D., Robinson I, The 8th International Comparison of Absolute Gravimeters 2009: the first Key Comparison (CCM.G-K1) in the field of absolute gravimetry, *Metrologia,* 2012, **49**(6), 666-684.

14. Jiang Z., Pálinkáš V., Francis O., Merlet S., Baumann H., Becker M., Jousset P., Mäkinen J., Schulz H.R., Kessler-Schulz K.U., Svitlov S., Coulomb A., Tisserand L., Hu H., Rothleitner Ch., Accurate gravimetry at the BIPM Watt Balance site, *Proc. IAG Symposium*, **139**, 2012.

15. Matus M., del Mar Pérez M., Zelenika S., Dauletbayev A., Kuanbayev C., Hussein H., Robertsson L., The CCL-K11 ongoing key comparison. Final report for the year 2011, *Metrologia,* 2012, **49**, *Tech. Suppl.,* 04009.

16. Pálinkáš V., Liard J., Jiang Z., On the effective position of the free-fall solution and the self-attraction effect of the FG5 gravimeters, *Metrologia,* 2012, **49**(4), 552-559.

17. Panfilo G., The new prediction algorithm for UTC: application and results, *Proc. EFTF 2012,* 2012, 242-246.

18. Panfilo G., Harmegnies A., Tisserand L., A new prediction algorithm for the generation of International Atomic Time, *Metrologia,* 2012, **49**(1), 49-56.

19. Petit G., Panfilo G., Comparison of frequency standards used for TAI, *IEEE T. Instrum. Meas.,* 2012, **99**, 1-6.

BIPM publications

20. BIPM Annual Report on Time Activities for 2011, **6**, 105 pp., available only at www.bipm.org/en/publications/time_activities.html.

21. *Circular T* (monthly), 7 pp.

22. Liard J., Pálinkáš V., Jiang Z., The self-attraction effect in absolute gravimeters and its influence on CIPM key comparisons, *Rapport BIPM*-2012/01, 12 pp.

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 a member of the CCTF Working Group on Two-Way Satellite Time and Frequency Transfer (TWSTFT), the CCTF Working Group on Primary Frequency Standards (WGPFS) and the CCTF Working Group on TAI (WGTAI).

Z. Jiang is a member of the CCTF Working Group on TWSTFT.

W. Lewandowski is Secretary of the CCTF Working Group on TWSTFT and Secretary of the CCTF Working Group on Global Navigation Satellite Systems Time-Transfer Standards (CGGTTS).

G. Panfilo is a member of the CCTF Working Group on Primary Frequency Standards (WGPFS) and of the Sub-Group on Algorithms of the CCTF Working Group on TAI and collaborates with the CCTF Working Group on the CIPM MRA (WGMRA).

G. Petit is a member of the CCTF Working Group on TAI and its Sub-Group on Algorithms, of the WGPFS, and of the CGGTTS.

L. Robertsson is Executive Secretary of the Consultative Committee for Length (CCL) and 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).

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 System, she 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 of the IERS. She is a member of the International VLBI Service (IVS), and of its Analysis Working Group on the International Celestial Reference Frame. She is the BIPM representative to the Governing Board of the IGS. She is the BIPM representative to the International Committee for GNSS and she is the chairperson of the Task Force on Time References. She is a member of the 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*. She is 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 the Working Party 7A of the Study Group 7 of the ITU-R, and the UN International Committee on GNSS (ICG).

G. Petit is co-director of the Conventions Centre of the IERS. He is president of the IAU Commission 52 'Relativity in Fundamental Astronomy', member of the IAU Working Group on Numerical Standards in Fundamental Astronomy, of the IGS Working Group on Clock Products, of the GNSS Science Advisory Committee of the ESA, and of the Fundamental Physics Group of the CNES.

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:

- Geneva (Switzerland), 16-20 January 2012, for the Radiocommunication Assembly 2012 at the International Telecommunication Union;
- La Plata (Argentina), 19-23 March 2012, for the ADeLa 2012 meeting as invited lecturer and to organize a panel discussion on the future of UTC;
- Gothenburg (Sweden), 24 to 27 April 2012, for the European Frequency and Time Forum (EFTF) and for the meetings of the CCTF WGs on Strategic Planning (as the secretary), on Coordination of the Development of Advanced Time and Frequency Transfer Techniques and on TWSTFT;
- Baltimore (USA), 22 to 24 May 2012, for the IEEE-IFCS 2012 and to give an invited lecture;
- Beijing (China), 22 to 31 August 2012, for the XXVIII General Assembly of the International Astronomical Union, including the Joint Discussion 7 on Reference Systems, and meetings of Commissions 8, 19 and 30, and to visit the NTSC (Lintong) and the NIM;
- Manta (Ecuador), 20 to 29 September 2012, for the ITU Seminar for the Americas, invited to give a lecture and for the meeting of the Working Party 7A as delegate of the BIPM;

Z. Jiang to:

- Vienna (Austria), 13-15 February 2012, for the Joint discussion meeting of IAG JWG2.1 and JWG2.2 at the BEV, with a presentation on the ICAG 2009;
- Gothenburg (Sweden), 24 to 27 April 2012, for the European Frequency and Time Forum (EFTF) with oral and poster presentations, and for the meeting of the CCTF WG on TWSTFT, (acting as secretary);
- Istanbul (Turkey), 29 and 30 May 2012, for the CCM-WGG meeting;
- Reston (USA), 26-29 November 2012, for the 44th PTTI, invited presentations and for a meeting of TW participant laboratories;

W. Lewandowski to:

- Vienna (Austria), 13 February 2012, for the preparatory meeting of the 7th ICG;
- Braunschweig (Germany), 17 April 2012, for the meeting of the Galileo FOC Timing Interface Working Group;
- Warsaw (Poland), 28 June to 3 July 2012, to the Space Research Centre and Space Commission;
- Nashville (Tennessee, USA), 17 to 21 September 2012, for the ION meeting and for the meeting of the Civil GPS Interface Committee (CGSIC) acting as chair of the Timing Sub-committee;
- Beijing (China), 5-9 November 2012, for the 7th Meeting of the ICG and to chair the meeting of the WG D Task Force on Timing References;
- Warsaw (Poland), 19 to 21 November, for meetings on the Galileo system, organized by the European Commission;
- Reston (USA), 26-29 November 2012, for the 44th PTTI, invited presentations and for a meeting of TW participant laboratories;

G. Panfilo to:

- Gothenburg (Sweden), 24 to 27 April 2012, for the European Frequency and Time Forum (EFTF) to give an invited lecture and for the meetings of the CCTF WGs on Coordination of the Development of Advanced Time and Frequency Transfer Techniques and on TWSTFT;
- Turin (Italy), 11-12 October 2012, invited to give a lecture on "Algorithms for the International Atomic Time" at the University of Turin;

G. Petit to:

- Bern (Switzerland), 18-19 January 2012, to attend the IGS workshop on GNSS biases, with oral presentations;
- Paris (France), 1 February 2012, for the meeting of the *Groupe de travail de Physique Fondamentale* of the CNES;
- Paris (France), 8 February 2012, to attend the kick-off meeting of the Labex First-TF network;
- Paris (France), 23 March and 4 October 2012, to attend meetings of the GNSS Science Advisory Committee;
- Vienna (Austria), 20-22 April 2012, to attend a workshop of the IERS Global Geophysical Fluid Center and a meeting of the Directing board of the IERS;
- Gothenburg (Sweden), 24-27 April 2012, to attend the European Frequency and Time Forum, and presentation;
- Alicante (Spain), 11-12 May 2012, to chair a PhD jury;
- Washington DC (USA), 1-5 July 2012, to attend the Conference on Precision Electromagnetic Measurements, to give a presentation, and to visit the USNO and NRL time laboratories;
- Paris (France), 14 November 2012, to attend the *Rencontres de l'Observatoire de Paris*;
- Hoofddorp (The Netherlands), 20-21 November 2012, to attend the workshop 'Optical networks for accurate time and frequency transfer'.

L. Robertsson to:

- Gothenburg (Sweden), 24 to 27 April 2012, for the European Frequency and Time Forum (EFTF) and for the meeting of the CCTF WG on Coordination of the Development of Advanced Time and Frequency Transfer Techniques and on TWSTFT (as the secretary);
- Hoofddorp (The Netherlands), 20-21 November 2012, for the Workshop on Optical Networks for Accurate Time and Frequency Transfer.

15. Visitors

- P. Lejba, Space Research Centre of the Polish Academy of Sciences (Poland), for activities on GNSS time transfer and calibration, under the supervision of W. Lewandowski, 6 to 9 February 2012;
- L.S. Ma, State Key Laboratory of Precision Spectroscopy East China Normal University (China), for discussions on optical frequency activities, 9 to 18 September 2012;
- M. Zucco, INRIM (Italy), for discussions on optical frequency activities, 9 to 18 September 2012;
- Y. Almleaky, Makkah Time Centre (Saudi Arabia), for discussions about the contribution to UTC;
- J. Davis, NPL (UK), for an external audit of the Time Department, 6 December 2012.