Programme of work and budget for 2016-2019
Time Department

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Bureau International des Poids et Mesures

Programme of work 2016-2019

- Prepared along 2012-2013-2014.
- Developed following the consolidated planning process carried out by the BIPM and the CIPM and builds on the interactions with NMI Directors and Member State Representatives, and has been the subject of specific consultation with the Member States.
- Presented to the 25th CGPM (Nov. 2014) supporting the dotation.
- Final approval by the CIPM in March 2015 (104th meeting, Session I).
- The proposal for the time metrology activities at the BIPM is consistent with the Strategy Document adopted by the CCTF (2012).
- It has continuity with the PoW 2013-2015.

The unique role of the BIPM

- The unique role of the BIPM is based on its international and impartial character enabling it:
  - To coordinate the realization and improvement of the world-wide measurement system to ensure it delivers accurate and comparable measurement results.
  - To undertake selected scientific and technical activities that are more efficiently carried out in its own laboratories on behalf of Member States.
  - To promote the importance of metrology to science, industry and society, in particular through collaboration with other intergovernmental organizations and international bodies and in international forums.

The objectives of the BIPM

- To establish and maintain appropriate reference standards for use as the basis of a limited number of key international comparisons at the highest level.
- To coordinate international comparisons of national measurement standards through the CCs of the CIPM; taking the role of coordinating laboratory for selected comparisons of the highest priority and undertaking the scientific work necessary to enable this to be done.
- To provide selected calibrations for Member States.
- To coordinate activities between the NMIs, such as through the CIPM MRA, and to provide technical services to support them.
- To liaise as required with relevant intergovernmental organizations and other international bodies both directly and through joint committees.
- To organize scientific meetings to identify future developments in the world-wide measurement system required to meet existing and future measurement needs in industry, science and society.
- To inform, through publications and meetings, the science community, the wider scientific public and decision makers on matters related to metrology and its benefits.

Key activities

- Creating UTC, improving the accuracy and stability of international time references, increasing dissemination and improving accessibility through:
  - developing the analysis of data provided by new methods for time and frequency transfer.
  - optimizing the algorithms for clock data characterization.
  - reducing the delay in the publication of UTC, maintaining adequate extrapolations.
- *Contributing to the comparison of optical standards with the highest accuracy over all distances, in view of their future use for the improvement of TAI and as a basis for consideration of a redefinition of the SI second. (New)*
- Contributing to the provision of a coherent set of space-time references and models for application in space and earth sciences.

Strategy

- To calculate, disseminate and improve the world reference time scale through integrating data from atomic clocks and frequency standards maintained and operated at the NMIs (and other participating laboratories),
- To contribute to the investigation of the benefits of a future re-definition of the second and of time-keeping based on optical clocks,
- To promote the importance and benefits to the international telecommunications, astronomy and earth science communities of:
  - UTC
  - frequency measurements traceable to the SI and
  - common space-time references.

T-A1 Frequency stability and accuracy of TAI/UTC [1]

Project Code	Name	Deliverables
T-A1.1	Time transfer for TAI/UTC	1) New and refined methods for clock comparison for application on new techniques as implemented in NMIs necessary for the full exploitation of GNSS systems with the calculation of multi-system time links. In parallel, in combination with TWSTFT, this will contribute to the improvement of the uncertainty. Benefits - redundancy of data, impacting on: (a) the reliability of the time links system; (b) the statistical uncertainty of the links; (c) the characterization of clocks; (d) since the time link uncertainty is the major component of the uncertainty of [UTC-UTC(k)], enhanced time transfer will impact on the traceability of local realization UTC(k) to the SI second; (e) the ultimate impact is on the stability of the time scales. 2) Application of novel methods (beyond GNSS and TWSTFT) of time transfer using optical fibres as they are implemented between contributing laboratories. Deliverable is enhanced time links for TAI, Particularly: (a) increasing the reliability of the time link system by the use of an independent technique; (b) improving the statistical uncertainty of time links to the picosecond; (c) improving the Type B uncertainty (calibration, related to T-A2); (d) since the time link uncertainty is the major component of the uncertainty of [UTC-UTC(k)], enhanced time transfer will impact on the traceability of local realization UTC(k) to the SI second; (e) the ultimate impact is on the stability of the time scales. 3) Methods based on optical fibre and space techniques for time and frequency transfer with 10^{-18} targeted relative uncertainty for allowing optical clock comparisons. Benefits: when optical clocks are operated over appropriate time intervals, they could be linked keeping their precision to the UTC system and contribute to the accuracy of the time scales.

T-A1 Frequency stability and accuracy of TAI/UTC [2]

Project Code	Name	Deliverables
T-A1.2	**Algorithms** Development of new algorithms and upgrading of the algorithms already in use for the provision of time scales at the BIPM	1) Improved stability by adequate clock frequency prediction and clock weighting. Target is improving the present 3×10^{-16} frequency stability with a target of improving stability by a factor of two. 2) Improved accuracy by use of primary and secondary frequency standard measurements and procedure for frequency steering. The target is improving the present frequency accuracy (few parts in 10^{-16}) with a target of improving accuracy by a factor of two. 3) Distribution of data, results, comparisons to UTC participants and other relevant users (data distributed – some 200 data/results per day by ftp plus large numbers of web consultations). 4) Generation of TT(BIPM). TT(BIPM) has applications in some fields of astronomy (pulsar timing for the construction of a dynamic time scale), in space research, etc. Its algorithm is similar to that for TAI, but with a major role for the primary frequency standards. The introduction of secondary standards (optical clocks) will demand changes in the algorithm, with impact on the long-term stability and accuracy. TT(BIPM) is published in January every year for (year-1), with monthly extrapolations for the current year.
T-A1.3	**Rapid UTC**	1) Publication of UTCr, rapid UTC providing weekly access to a UTC Rapid solution for better synchronization of local realizations of UTC(k) in contributing laboratories, particularly enabling NMIs to improve the UTC(k) serving as a reference for GNSS time steering (*40 participants in 2013, 100 % increase expected over the programme*).

T-A2 Characterization of delays in GNSS equipment

Project Code	Name	Deliverables
T-A2.1	**Maintenance of BIPM travelling receivers and procedures for calibration**	1) Characterization of equipment compatible with those operated in NMIs. 2) Reliable/redundant travelling and fixed-reference standards. 3) Guidance documents and support for contributing NMIs. 4) Technical protocols for calibration. 5) Methods of calibration aimed at improving the time link uncertainty, which remains the largest component of the uncertainty of *UTC-UTC(k)*. The target is improving the present 5 ns value of the Type B uncertainty by a factor of at least 2.
T-A2.2	**Realization of delay measurement campaigns for pivot laboratories (G1 labs)**	Typically two characterization campaigns (requiring the sending of BIPM travelling system without staff) to each of approximately 15 contributing laboratories (G1 labs) during the programme: 1) Regular assessment of the values of the Type B uncertainty of time links via periodic calibration of GNSS equipment in a selected group of NMIs (potential "pivot" laboratories, laboratories in regions where RMOs are not active or organized). 2) Evolving Protocols for calibration. 3) Improved link accuracy from 5 ns to 2 ns. 4) Input data for time links used in CCTF-K001.UTC, BIPM *Circular T* and rapid UTC.
T-A2.3	**Coordinating with the RMOs for campaigns of G2 laboratories (labs which are not pivot labs) and linking results to the BIPM G1 reference**	1) Provision of Guidelines for the calibrations, including technical instructions for RMOs and protocols for linking their calibrations to the BIPM time link system. 2) Regular assessment of the values of the Type B uncertainty of time links via periodical calibration of GNSS equipment in a set of laboratories as defined by the BIPM for approximately 60 contributing laboratories. 3) Improved link accuracy from 5 ns to 2 ns 4) Generating Input data for time links used in CCTF-K001.UTC, BIPM *Circular T* and rapid UTC.

T-A3 Use of very accurate frequency standards - Secondary representations of the second

Project Code	Name	Deliverables
T-A3.1	**Time and frequency transfer techniques for highly accurate optical standards** Study and implementation of techniques. Cooperation with different sectors is planned (French space agency, NMIs)	1) Comparison of optical standards with $\sim 10^{-18}$ relative uncertainty over short and long baselines. This includes continental links via optical fibres and intercontinental comparisons using enhanced TW links and one-way space techniques. 2) Contributing to the discussion on the redefinition of the second (2018 onwards).
T-A3.2	**Maintenance of equipment** The equipment will serve (a) to study the physics related to the transfer techniques; (b) to develop competency for the statistical treatment of measures for application in time scale construction; (c) to characterize their uncertainties, including calibration. Equipment consists of: Frequency combs and terminals for advanced time transfer using microwave links; H-maser for providing the frequency reference.	1) Evaluation of the use of microwave links as a possible candidate for future high level optical clock comparisons based on a comparison of Space-Earth and Earth-Earth Comparison of atomic clocks, within the ACES. Activities will be in cooperation with the French Space Agency (CNES). 2) Comparison of optical standards with $\sim 10^{-18}$ fractional uncertainty over short and long baselines 3) Improved time link accuracy. 4) Contributing to the discussion on the redefinition of the second (2018 onwards).

common to length and time metrology

Additional activities in the field of Time Metrology

Not covered by the adopted budget

T-A3.3	**Frequency comb validation** Assuring the correct validation of the increasing number of frequency combs in NMIs at accuracy levels aiming to meet both time and length requirements, taking particular note of the emergence of optical clocks	Organising a comparison of NMI frequency combs based on the existing BIPM frequency comb (estimated for maximum of 5 node NMIs for length, and up to 10 NMIs for frequency) Target is parts in 10^{18} (driven by frequency needs), - 10^{16} sufficient for length

International coordination, including executive secretaries [1]

Project Code	Name	Deliverables
CT-A1.1	**Coordination and promotion of SI time activities for the advancement in the development of time scales** Activities within the scope of/linking to/cooperating with: - ITU - IGS - ICG - Space agencies operating GNSS - NMIs	1) TAI/UTC/TT(BIPM)/ maintenance 2) GNSS time transfer 3) GNSS coordination 4) Support to GNSS system times 5) Time and frequency transfer methods.

International coordination, including executive secretaries [2]

CT-A1.2	**Coordination and promotion of SI time activities for scientific applications** Activities within the scope of/linking to/cooperating with: - IERS - IAU - IUGG/IAG - URSI	1) Space-time references, IERS Conventions 2) Timescales for astronomy/TT(BIPM)/Pulsar timescales 3) Time references for geodetic and geophysical applications Geodetic references.
CT-A1.3	**Coordination and Support to the CCTF** (Time and Frequency)	Provision of the CCTF Executive Secretary, general support to the CC and WGs plus specifically support for: 1) Coordination between NMIs for the maintenance of UTC 2) Monitoring and validation of the BIPM Time Department activities and plans 3) Development of strategic plans 4) Key comparisons in time and frequency 5) Recommendation of standard frequencies as secondary representations of the second 6) Secretariat of CCTF and WGs 7) Participation in WGs.

Staff of the Time Department (2016-2019)

Permanent

Felicitas Arias	director [Retires 2017]
Aurélie Harmegnies #	calculation, software development, t. transfer
Zhiheng Jiang #	time transfer, calibration [Retires 2018]
Hawaï Konaté	calculation, data management, publications
Gianna Panfilo	algorithms, pfs, MRA
Gérard Petit	time transfer, PFS/SFS, calibration, international liaison
Lennart Robertsson	freq. transfer, internal services, project support [Retires 2018]
Laurent Tisserand	laboratory management, software development, t transfer

T-Soft maintenance

Year / staff number

2016 / 8 2017 / 8 2018 / 7 2019 / 6

Visiting scientists/secondees/PhD/PostDocs

4 included in PoW