



The BIPM

The BIPM is an intergovernmental organization established by the Metre Convention, through which Member States act together on matters related to measurement science and measurement standards.

THE VISION AND MISSION OF THE BIPM

Its **vision** is to be universally recognized as the world focus for the international system of measurement.

Its **mission** is to work with the NMIs of its Member States, the RMOs and strategic partners world-wide and to use its international and impartial status to promote and advance the global comparability of measurements for:

- Scientific discovery and innovation,
- Industrial manufacturing and international trade,
- Sustaining the quality of life and the global environment.

THE OBJECTIVES OF THE BIPM

- To represent the world-wide measurement community aiming to maximize its uptake and impact.
- To be a centre for scientific and technical collaboration between Member States providing capabilities for international measurement comparisons on a shared-cost basis.
- To be the coordinator of the world-wide measurement system ensuring it gives comparable and internationally-accepted measurement results.

Contents

The BIPM	2	CIPM MRA	12
Director's introduction	3	Promotion of the SI and metrology	13
Physical Metrology	4	Financial summary	14
Time	6	Comparisons and calibrations	16
Ionizing Radiation	7	Organizational structure	17
Chemistry	8	Publications	18
Liaison and Communication	10	Useful links	19

Director's introduction

I am pleased to bring you this report which shows how the work of the BIPM has developed during the first year of our programme of work (2016-2019).

The major highlight has been the completion of our first activities in the new area of capacity building during 2016. These include a workshop for 18 participants from ten Member States and five Associates entitled "Leaders of Tomorrow" which was sponsored by the NIST. (It is described in this report on page 11). Also the first technical activities under the "Metrology for Safe Food and Feed" project are being coordinated by the BIPM Chemistry Department to support NMI in strengthening their national mycotoxin analysis and standards infrastructure.

We continue to be active in promoting the role of metrology internationally. In September 2016 we hosted a workshop together with the World Anti-Doping Agency (WADA). This aimed to identify opportunities for WADA laboratories to collaborate with NMIs.

The review of the CIPM MRA has been completed and the results have been published. Work is now under way by all parties involved in the MRA to implement the recommendations. These will include the development of a new Key Comparison Database (KCDB 2.0) by the BIPM which is planned for first implementation in 2018.

The CIPM has started to plan the 26th meeting of the General Conference on Weights and Measures (CGPM) which will be held in Versailles on 13 to 16 November 2018. As part of the CIPM's role of overseeing the work of the BIPM, it has agreed a revised statement of the Vision, Mission and Objectives for the BIPM, which will be the basis for the proposals for the BIPM work programme for discussion at the Conference. (This is presented on the inside front page of this report).

This report also includes summaries of the BIPM financial performance, and complements the *Rapport Financier* and the annual proceedings of the CIPM (both of which are available in French and English). All of these documents can be downloaded from our website together with extended reports of the achievements of each of the BIPM Departments.



The BIPM Director, Dr Martin Milton (centre) with the Directors of the BIPM Departments. Left to right: Mr Andy Henson (ILC), Dr Robert Wielgosz (Chemistry), Dr José María Los Arcos (Ionizing Radiation), Dr Michael Stock (Physical Metrology) and Dr E. Felicitas Arias (Time).

Highlights of 2016

- The review of the effectiveness and efficiency of the CIPM MRA has been completed and published.
- The first Capacity Building workshop was held at the BIPM for "Leaders of Tomorrow" for 18 participants from 15 Member States and Associates.
- A workshop was held at the BIPM in collaboration with the World Anti-Doping Agency (WADA) to highlight the role of metrology in the fight against illegal drug use in sport.
- The pilot comparison of future primary realizations of the kilogram was coordinated and results prepared for publication.
- The CIPM has implemented reforms to address the long-term financial sustainability of the BIPM Pension Fund.
- Capacity Building projects supporting metrology for "Safe Food and Feed" and "Clean Air" have been launched by the Chemistry Department.
- A new facility for brachytherapy and x-ray imaging has opened in the Ionizing Radiation Department.

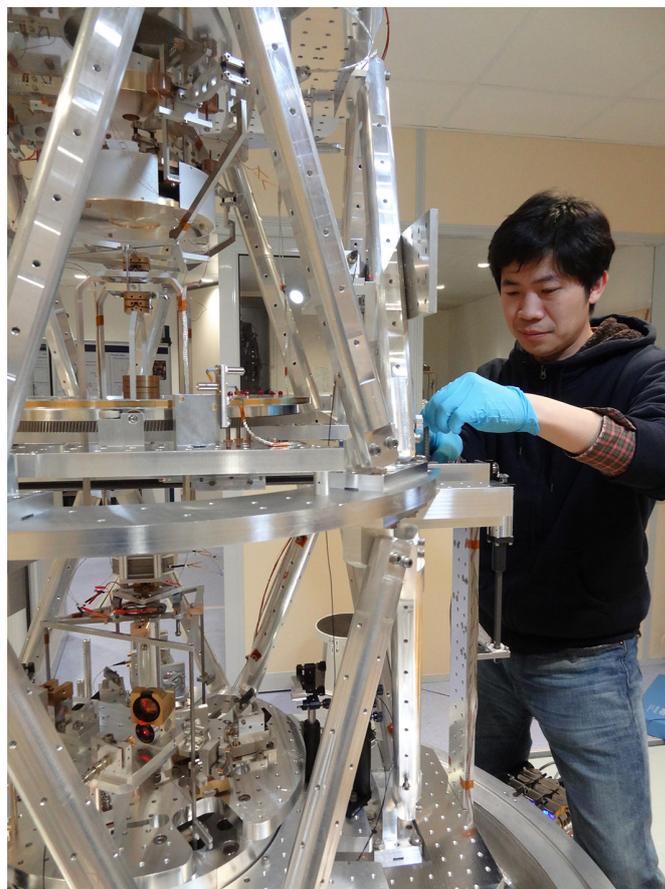
Physical Metrology

The Consultative Committee for Mass and Related Quantities (CCM) Pilot Study of future primary realizations of the kilogram has the objective of testing the consistency of future kilogram realizations based on different primary realization experiments, and continuity with the realization based on the present definition of the kilogram. The BIPM is the pilot laboratory for this study, with participation from the LNE (France), the NIST (USA), the NMIJ (Japan), the NRC (Canada) and the PTB (Germany). Three of the institutes participated with Kibble/watt balances and two with ^{28}Si -Avogadro spheres. All measurements have been completed and the Draft A report is being reviewed. During the Pilot Study, the mass artefacts of the BIPM Ensemble of Reference Mass Standards (ERMS) were calibrated in their specific gaseous environments against the primary mass standards of the five National Metrology Institute (NMI) participants. The storage networks under nitrogen and argon flow are now fully operational. The storage system under vacuum is undergoing further development.

Papers describing the results of the extraordinary calibration campaign using the IPK in 2014 have been published^[1,2] along with a paper explaining the foundation for the redefinition of the kilogram^[3].

The BIPM Kibble balance has been fully reassembled following several modifications and is now operational in air. Alignment of the system has been optimized and a number of complete measurements in air were carried out in June 2016. The signal-to-noise ratio of the voltage-to-velocity ratio was improved by a factor of five as a consequence of improvements to the interferometer. The Planck constant h was determined with an uncertainty of a few parts in 10^6 . The uncertainty is now dominated by noise on the force signal and the remaining misalignment of the coil with respect to the magnet, both of which will be the focus of future work. The entire apparatus worked correctly, with the positional stability of the magnet ensured through a more rigid and adjustable mechanical support that was fabricated and installed. The target uncertainty for mid-2017 is about 1 part in 10^7 . Operation of the Kibble balance under vacuum has been studied.

The second on-site comparison using the transportable ac Josephson Voltage Standard (JVS), which had been supplied to the BIPM by the NIST, was carried out at CENAM (Mexico) during 2016. As a result, the BIPM gained



Dr Shisong Li (BIPM) working on the BIPM Kibble balance

valuable experience in comparing stepwise approximated ac voltages at a frequency of 50 Hz, in preparation for a future on-site comparison programme. This will extend the present JVS comparisons (BIPM.EM-K10) at 1.018 V and 10 V to alternating signals. Both Josephson standards were compared indirectly by using a calibrator as a transfer standard. Both systems agreed satisfactorily within 3 parts in 10^7 at 1 V_{rms} and within 7 parts in 10^7 at 7 V_{rms} . This comparison was considered to be a trial and was not registered as a key comparison. The comparison technique will be further developed in 2017 by a secondeé from the KRISS (Republic of Korea). Five bilateral comparisons were successfully arranged in 2016 in the fields of voltage (DEFNAT, Tunisia), resistance (SMD, Belgium) and capacitance (NMIA, South Africa; NIS, Egypt; and NSAI, Ireland) using BIPM transfer standards.

The technical protocol for the Consultative Committee for Electricity and Magnetism (CCEM) key comparison of capacitance calibrations, CCEM-K4.2017, has been discussed and approved with the eight NMI participants. The measurements will be carried out between March and September 2017 with the BIPM as the coordinator. This comparison follows EURAMET.EM-S31, which was a supplementary comparison of capacitance and capacitance ratio, in which the BIPM participated. The first circulation of capacitance standards led to an unexpectedly large spread of results, requiring a second circulation of the capacitors and ac standard resistors. Investigations into systematic errors in the measuring bridges of several participants allowed the origin of these inconsistencies to be identified.

The calculable capacitor has been relocated to a dedicated laboratory where it is now installed on a concrete block for improved vibration isolation. A removable clean room

enclosure has been built around the capacitor so that precision alignment of the electrode bars can be carried out in a clean environment. The electrode bars have been aligned using a set of capacitive probes, so that the contributions of the residual misalignments are now 3 parts in 10^9 , compared to 3 parts in 10^7 previously. Completion of the reassembly and the start of a new series of measurements are planned for early 2017.

Measurements of the quantized Hall resistance (QHR) have been made on a commercial graphene sample, as part of the project to develop a readily transportable quantum Hall system. Three Hall bars on the same chip have been investigated. Quantization of the resistance could be achieved, but required the application of a high magnetic field, probably due to non-uniformity in the samples. The development of transportable QHR standards will require operation at lower magnetic field values.

Support for regional key comparison of Zener voltage standards

The Physical Metrology Department has set up a project to provide support for the organization of one of GULFMET's first key comparisons - GULFMET.EM.BIPM-K11 - a comparison of Zener voltage standards. The project was established in response to a discussion at the March 2016 meeting of the Joint Committee of the Regional Metrology Organizations and the BIPM (JCRB) on cross-membership of Regional Metrology Organizations (RMOs) in the context of providing assistance to GULFMET, the newest RMO. JCRB members affirmed at their meeting that various RMO activities are open to GULFMET within the resources available to accommodate them, including RMO comparisons, training initiatives, and attendance at RMO plenaries.

The comparison is being coordinated by the Standards and Calibration Laboratory (SCL), Hong Kong (China). The BIPM is a member of the comparison support group and will participate in the measurements to link the results of the GULFMET comparison to those of the comparisons. BIPM.EM-K11.a and BIPM.EM-K11.b.

The comparison coordinator, Dr Steven Yang from SCL, was seconded to the BIPM voltage laboratory from 9 January to 13 March 2017 to work and share experience on the calibration of Zener voltage standards using Josephson voltage standards.

The technical protocol is under discussion and the measurements are planned for the period June 2017 to February 2018.



Dr Steven Yang (SCL, centre) with Dr Stéphane Solve (BIPM, left) and Mr Régis Chayramy (BIPM, right) in the BIPM voltage laboratory



Time

The Time Department continued to work on improvements to the estimation of time transfer uncertainty for Coordinated Universal Time (UTC) in 2016. The department's proposal to optimize the calibration of Global Navigation Satellite Systems (GNSS) equipment received an excellent response from the RMOs. Results of Global Positioning System (GPS) calibrations organized by EURAMET laboratories have been implemented in the computation of UTC. The BIPM has started the second calibration campaign in selected institutes; measurements have been completed by the APMP and are in progress within EURAMET. With this continuous process in place, the number of laboratories with calibration uncertainty at or below 2.5 ns is increasing. The BIPM is coordinating a pilot study that aims to reduce the additional noise, with diurnal signature, observed in most Two-Way Satellite Time and Frequency Transfer (TWSTFT) links. The first results obtained with the operation of a "software designed radio" (SDR) in TWSTFT stations has shown a substantial reduction of the diurnal noise, which may help to understand the origin of the perturbation.

Research into a new approach to UTC calculation proved that the frequency stability of UTC can be significantly improved by using a Kalman filter^[4]. Revision of the algorithm for the uncertainty of $[UTC-UTC(k)]$ has started with the aim of correcting undesired effects that come from the present procedure. A new approach is under development that takes into account the correlations, which are not fully considered in the current algorithm.

A paper was published in *Metrologia* giving a detailed comparison of two continuous GPS carrier-phase time transfer techniques^[5]. In this paper, the performance of continuous GPS carrier-phase time transfer techniques is discussed and it is clarified that one recently published such method, known as RRS, does not provide significantly better frequency stability than other similar techniques.

Advances in optical frequency standards at the NMIs indicate that the definition of the second will probably be revised during the next decade. In preparation, the Consultative Committee for Time and Frequency (CCTF) is identifying candidate transitions for recommendation by the CIPM as secondary representations of the second (SRS). However, before any individual atom/ion species can be chosen among these candidates, a thorough

investigation of its properties and suitability to become the base of a redefined second must be undertaken. To this end "direct frequency ratio measurements between standards" is a major tool and such measurements are already in progress at several NMIs. The BIPM has developed a novel method to allow the study of consistency within the set of frequency ratio measurements to be compared to the estimated individual uncertainties of the standards^[6]. A technique based on "graph theory concepts" readily isolates inconsistencies and allows evaluation of the full set of ratio measurements, providing an interesting and simplified alternative to the non-linear least squares approach.

BIPM *Circular T* is published monthly and gives traceability to the SI second via UTC to its local realizations in national laboratories. It is the most frequent key comparison, with one evaluation of the key comparison reference value UTC and the degrees of equivalence $[UTC - UTC(k)]$ every five days for the 77 participants that together contribute data from about 500 atomic clocks.

The Time Department improved the archiving and dissemination of its services in 2016. A new HTML version of monthly *Circular T* with improved access to the data, results and plots supporting the values published in its sections was launched. User access to the FTP server has been redesigned to allow easier consultation and historical information on timescales has been added to allow the tracking of laboratories' contributions over the long term. A database has been developed that gives an inventory of the complete set of information relevant to the time scales calculated at the BIPM; it is linked to the processes involved in the computation of time scales within the department. Since September 2016 the database has been available at: webtai.bipm.org/database/html/.

The World Radiocommunication Conference (2015) called for stronger links between the International Telecommunication Union (ITU) and the BIPM in coming to a decision on the adoption of a continuous reference time scale by 2023. As a consequence, the Time Department actively contributed to the work of a Task Group created by the CCTF in 2016 to provide formal definitions of the current time scales International Atomic Time (TAI) and UTC and to recommend actions to be proposed to the CGPM in 2018.

Ionizing Radiation

The project within the BIPM dosimetry programme to develop an absorbed-dose standard for medium-energy x-rays, which will form the basis for a ninth comparison series (BIPM.RI(I)-K9), was completed in 2016 with further measurements of photon attenuation in air and the characterization of three more transfer instruments. Measurements for the first full comparison, with the PTB, were made during November and December 2016. The new standard will be presented to the CCRI(I) at its 2017 meeting, with the aim of gaining approval to launch the new comparison series and publish the results of the PTB comparison.

New software for data acquisition and analysis was developed for the BIPM.RI(I)-K6 comparison series of absorbed dose to water in high-energy photon beams. The new system was used for the tenth comparison in the series, which was carried out on-site at the NIM (China), in November 2016, using their 6 MV and 10 MV linear accelerator beams.

The new laboratory to support measurements for the BIPM.RI(I)-K8 comparison series for high dose rate (HDR) ^{192}Ir brachytherapy sources was completed. A system for digital radiography has been installed in the new laboratory (see below).

Within the radionuclide measurements programme, the *Système International de Référence* (SIR) received four ampoules of three different radionuclides, ^{88}Y , ^{133}Ba and

^{134}Cs from three laboratories (LNE-LNHB (France), NRC and PTB), all of which were sent to establish equivalence values in the ongoing BIPM.RI(II)-K1 comparison.

The second calibration measurements of the SIR Transfer Instrument (SIRTI) against the SIR were carried out for ^{64}Cu by measuring a solution from the NPL in both systems. The analysis is in progress. The SIRTI comparisons (BIPM.RI(II)-K4) took place on-site at the NIST for ^{18}F and ^{64}Cu and at POLATOM (Poland) for ^{18}F , ^{64}Cu and $^{99\text{m}}\text{Tc}$. These laboratories were the first participants in the BIPM.RI(II)-K4.Cu-64 comparison. A paper was published on the comparison of ^{18}F activity measurements at the VNIIM (Russia), NPL and the ENEA-INMRI (Italy) using the SIRTI^[7].

The pilot study for the extension of the SIR to beta emitters by liquid scintillation counting will resume with the collaboration of a secondee from the NIST. The newly purchased balance is now fully in service and has been used to prepare 10 ml sources of ^3H with three scintillators from the six ampoules previously received from the IFIN (Romania), IRMM, NIM, NMIJ, POLATOM and PTB. Measurements have been completed in the Beckman LSC 6000 TA counter and are in progress in the Quantulus 1220. Measurements with the Perkin Elmer TriCarb 2910 TR and with the BIPM-designed Triple-to-Double Coincidence Ratio (TDCR) counters will soon follow.

New BIPM facility for brachytherapy and x-ray imaging

The Ionizing Radiation Department opened a new facility for brachytherapy and x-ray imaging in 2016. It will support a series of international comparisons (BIPM.RI(I)-K8) being run by the BIPM to meet the needs of NMIs in the field of brachytherapy, a radiotherapy treatment in which calibrated radioactive sources are positioned inside the patient. The comparison concerns primary determinations of reference air-kerma rate using ^{192}Ir brachytherapy sources. Comparison measurements take place on-site at the NMIs, using two ionization chambers similar to those used in hospitals for the calibration of therapeutic radiation beams: a thimble-type and a well-type chamber.

The stability and characterization of the thimble chamber is determined at the BIPM using the existing ^{60}Co facility for dosimetry of external radiotherapy beams whereas the stability of the well chamber is determined using the same kind of radioactive source designed for brachytherapy, which is manipulated by remote 'afterloading' machines. For this reason, the stability of the well chamber is determined using a ^{137}Cs check source at the BIPM, mounted on a rigid stem and placed inside the chamber.



The robotic arm for manipulation of radioactive sources

The new facility is equipped with a robotic arm to allow the remote manipulation of the source. In addition, the facility was designed to house a digital imaging system that comprises a portable x-ray tube and a flat panel detector. The robot, located in the middle of the measurement table, can rotate towards the imaging system and manipulate the instrument to be imaged in the x-ray beam.



Chemistry

New values of the ozone absorption cross-section, based on gas phase titration have been published in *Analytical Chemistry*^[9]. The BIPM contributed to the review and recommendations on absorption cross-sections of ozone in the ultraviolet and visible spectral regions published in the *Journal of Molecular Spectroscopy*^[10] as part of an initiative of the International Ozone Commission (IO3C), the World Meteorological Organization (WMO) and the IGACO–O₃/UV (Integrated Global Atmospheric Chemistry Observations) subgroup. This initiative will study, evaluate, and recommend the most suitable ozone absorption cross-section laboratory data to be used in atmospheric ozone measurements. The BIPM is contributing to the Consultative Committee for Amount of Substance: Metrology in Chemistry and Biology (CCQM) GAWG Ozone Cross Section Task Group. This Task Group was created within the CCQM Gas Analysis Working Group (GAWG) to review and recommend the best value and uncertainty for the ozone cross-section to be used in the key comparison BIPM.QM-K1. Measurements for the CCQM-K90 comparison on formaldehyde standards were completed. The final report will be published in early 2017.

Validation work was completed for the CCQM-K120 comparison (carbon dioxide in air), with Fourier Transform Infrared (FTIR), isotope ratio infrared spectrometer (IRIS) and gas chromatography – flame ionization detector (GC-FID) methods being fully characterized. A method for measuring isotopic abundances in CO₂, which was required for corrections to be applied to the comparison method, was developed. A paper on *Calibration strategies for FTIR and other IRIS instruments for accurate δ¹³C and δ¹⁸O measurements of CO₂ in air*, in collaboration with the University of Wollongong (Australia) has been submitted to *Analytical Chemistry*. Forty-four standards will be compared as part of the comparison, with measurements expected to be completed by the end of May 2017. Development and validation of a manometric system for CO₂ measurements has progressed with secondments from the NIST and the SP (Sweden). This work demonstrated that the first all-glass prototype can produce results within 1 % of certified gravimetric values. Encouraging results on treated steel surfaces have permitted the design of a more robust second prototype, with testing and validation of the system planned for the first half of 2017. Preparation for a comparison on CO₂ isotope ratio standards, coordinated jointly by the BIPM and the International Atomic Energy Agency (IAEA), has started with the development of a stable isotope reference mixture generation facility at the BIPM, supported by a secondee from the NIM. The department's work in the area of supporting measurements for key climatological observables advanced with the publication of a paper in *Metrologia*^[11].

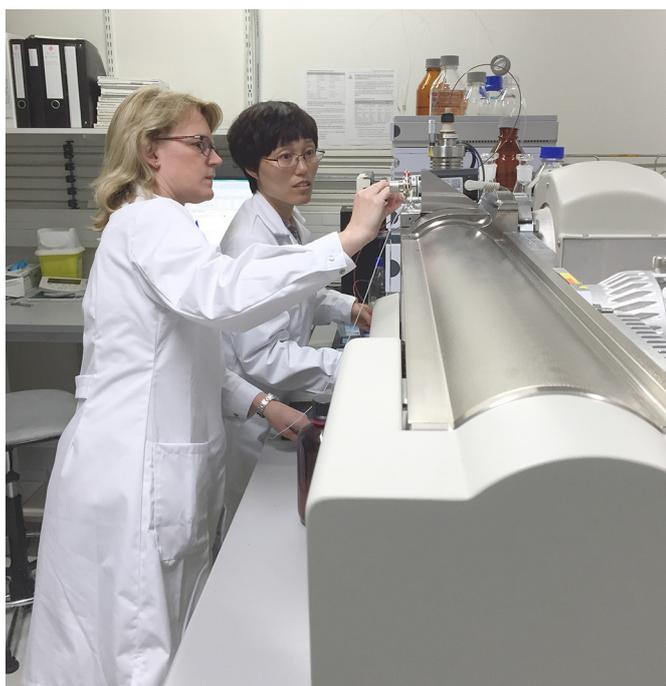
Within the BIPM's organic primary calibrator programme, the CCQM-K55.d comparison on folic acid purity was completed. The final report will be published in 2017. The comparison demonstrated the increasing use of quantitative NMR (qNMR) at NMIs for the value assignment of this category of standard. The universal calibrator programme for qNMR at the BIPM, an activity initiated together with the NMIJ, was supported by secondees from the NIM and INMETRO (Brazil), with characterization of the performance of standards soluble in deuterated chloroform and methanol. Preparations for the CCQM-K78.a comparison on multi-component amino acid calibration solutions were completed. Ampouled samples were distributed to participants in November-December 2016, with results expected in the first quarter of 2017. The final report of the key comparison on C-peptide purity (CCQM-K115/P55.2), coordinated by the BIPM in collaboration with the NIM, was completed. A paper on the evolving calibration hierarchies for C-peptide measurements in collaboration with the University of Missouri (USA), NIM, NMIJ and NIBSC (UK) has been submitted to *Clinical Chemistry*. The general approach to pure peptide calibrator value assignment was presented at the Protein and Peptide Therapeutics and Diagnostics: Research and Quality Assurance (PPTD-2016) workshop, held in Chengdu (China) in June 2016. This workshop was organized jointly by the BIPM and the NIM.

The work undertaken on *Impurity Determination for Hepcidin by Liquid Chromatography – High Resolution and Ion Mobility Mass Spectrometry for the Value Assignment of Candidate Primary Calibrators*, which was supported by a secondment from the LNE (France) was submitted to *Analytical and Bioanalytical Chemistry*. Development of methods to characterize calcitonin calibrators was undertaken by a secondee from the HSA (Singapore), with the material intended as a future candidate key comparison material for small peptides with disulfide bonds.

The BIPM hosted a joint symposium with the World Anti-Doping Agency (WADA) on 28-29 September 2016. One hundred invited experts from National Measurement Institutes, the clinical chemistry and laboratory medicine community and from WADA and the WADA-accredited anti-doping laboratories discussed the latest initiatives in areas of metrology for organic and biological analysis relevant to this high-profile measurement sector^[12].

Capacity Building projects on metrology for “Safe Food and Feed” and “Clean Air” launched at the BIPM

The Capacity Building projects on Mycotoxin Metrology started in the BIPM Chemistry Department in April 2016. As part of the initiative, Dr Xiuqin Li, from NIM (China) joined the BIPM as a visiting scientist for one year to develop methods for the characterization of aflatoxin B1 and zearalenone pure materials. These will form the basis of calibration solutions that will support training and skills-broadening secondments to be organized at the BIPM from 2017 to 2019.



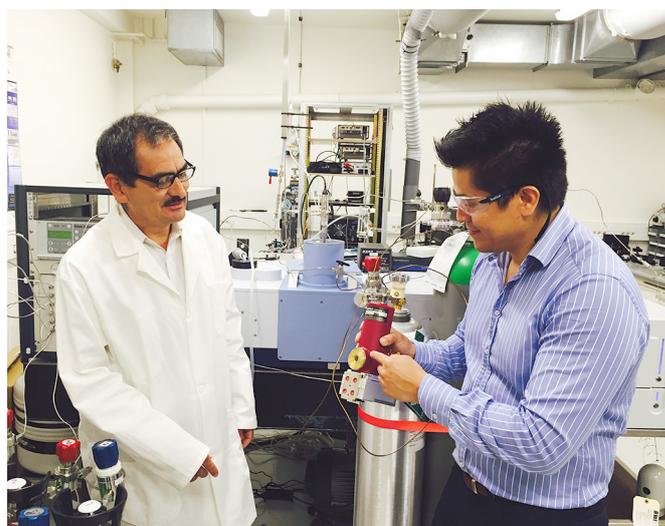
Ms A. Daireaux (BIPM) and Dr Xiuqin Li (NIM) starting the characterization of mycotoxin calibrants by LC-MS analytical methods

Food safety and trade is a major concern for countries with developing metrology and quality assurance systems. Both microbiological and chemical hazards are of concern, including the contamination of food and feed by mycotoxins (toxic metabolites of fungi), which are significant sources of food-borne disease. The knowledge that mycotoxins can have serious effects on humans and animals has led many countries to establish regulations on mycotoxins in food and feed over the last few decades to safeguard the health of humans, as well as the economic interests of producers and traders. Over 100 countries have implemented specific regulatory limits for mycotoxins in foodstuffs and feedstuffs, and these need to be supported by a robust measurement infrastructure for mycotoxin analysis in order to enforce and verify products, protect populations and avoid technical barriers to trade in food stuffs. This project will allow the BIPM and NMIs to work together to: strengthen mycotoxin metrology infrastructure; provide knowledge transfer to scientists who are developing capabilities in this area;

and enable NMIs to provide mycotoxin calibrants and matrix reference material and proficiency testing materials to support mycotoxin testing laboratories within their countries.

The capacity building project will be extended with visiting scientist training programmes foreseen at the NIM on mycotoxin matrix certified reference materials as well as training on analytical methods for mycotoxins at the NMISA (South Africa). In addition to providing staff resources to support the programme, the NIM has donated the pure materials required to deliver the programme. Training secondments for three visiting scientists from NMIs to the BIPM in 2017 are being supported by the PTB.

Air pollution can cause both short-term and long-term effects on health and many people are concerned about pollution and air quality. This in turn has resulted in regulations on air quality and requirements to monitor gaseous pollutant concentrations, for which traceable gas concentration standards are required. The BIPM comparison programme on air quality and greenhouse gas standards has relied on FTIR methods for the analysis of NO₂, NO, HCHO, CO₂ and CH₄ gas standard concentrations. This has led to the development of a CBKT project in metrology for clean air at the BIPM, focused on knowledge transfer on the use of FTIR for gas standard analysis. The programme started in June 2016, with Mr Manuel de J. Avila from the CENAM (Mexico) joining the BIPM on a skills broadening secondment on FTIR operation and analysis of FTIR spectra for gas analysis.



Mr M. de J. Avila (CENAM) with Dr E. Flores (BIPM) in the BIPM gas metrology laboratory, setting up the FTIR system for the comparison of CO₂ gas standards

International Liaison and Communication

The BIPM has an ongoing relationship and interacts with around thirty international organizations and provides or shares information with these bodies relating to the SI and the international comparability of measurements. Collaborations are both institutional and technical. In 2016, a typical year, BIPM staff undertook more than 100 missions to countries and economies to provide their expertise to such organizations and to NMIs.

Key liaison activities are with intergovernmental organizations such as the World Trade Organization (WTO), the World Health Organization (WHO), the International Atomic Energy Agency (IAEA), the World Meteorological Organization (WMO), the International Organization of Legal Metrology (OIML) and international bodies such as the International Organization for Standardization (ISO) and the International Laboratory Accreditation Cooperation (ILAC). Interaction varies from high-level discussions to participation in dedicated working groups but the objective remains the same: to promote the importance of measurement, the SI and the comparability of measurement, and to ensure the

appropriate use of metrology and the international infrastructure. Notably in 2016 the Department Director participated in ISO/CASCO Working Group 44, and the WG core drafting team, on the revision of the international standard ISO/IEC 17025:2005 "General requirements for the competence of testing and calibration laboratories". This is an essential international standard for NMIs world-wide. Work is in full flow, with the revised standard expected to be published in late 2017 or early 2018. The BIPM contributed in accordance with a position paper agreed with the CIPM.

The BIPM contributes to activities that support developing countries' technical infrastructure by participating in the DCMAS Network and, increasingly, through the new BIPM Capacity Building and Knowledge Transfer Programme (CBKT). The BIPM has been successful in attracting sponsors for the programme. In addition to launching laboratory-based CBKT activities, 2016 saw the first CBKT courses delivered, including two courses that involved 62 participants from 22 Member States and Associates with sponsorship from NIST and GULFMET.

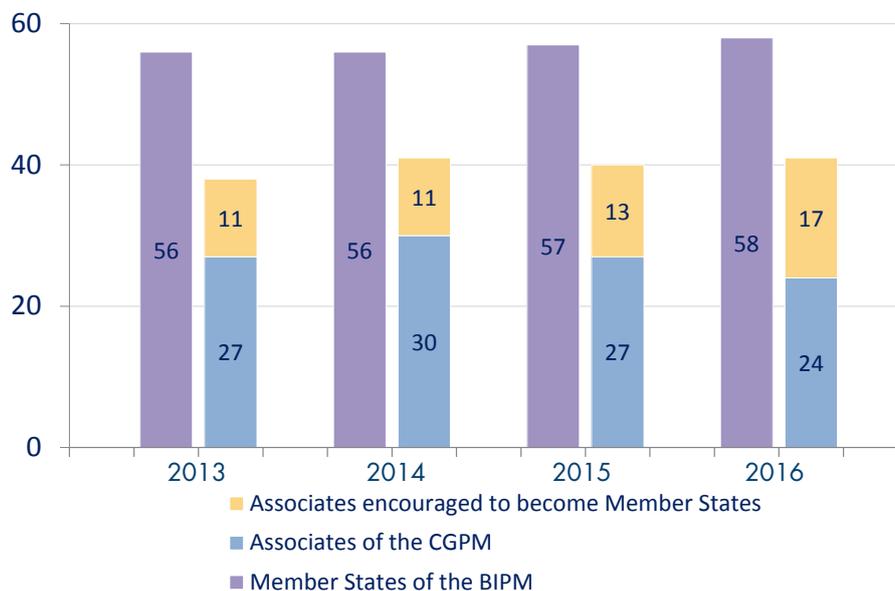
The BIPM welcomed the following new Member State in 2016:
→ **The Republic of Slovenia** on 23 March

And the following new Associates of the CGPM:

→ **The State of Qatar** on 10 March

→ **The Democratic Socialist Republic of Sri Lanka** on 17 August

Member States and Associates of the CGPM



An up-to-date list of the BIPM's Member States and Associates of the CGPM can be found at:
www.bipm.org/en/about-us/member-states/

The BIPM Capacity Building and Knowledge Transfer programme 2016 “Leaders of Tomorrow” course

Eighteen participants, designated by their RMOs as future leaders in the global metrology system, completed a two-week “Leaders of Tomorrow” training course from 7-18 November 2016 as part of the BIPM Capacity Building and Knowledge Transfer (CBKT) programme. The course was fully sponsored by the NIST (USA).



Participants receiving instruction on the CMC review process

This new course, which was held at the BIPM, brought together highly respected professional experts in measurements and quality systems from leading NMIs, representatives of international organizations (OIML, ISO, ILAC), and BIPM staff members, to teach the participants their personal perspectives on conducting measurement comparisons, reviewing calibration and measurement capabilities and supporting the national quality infrastructure.

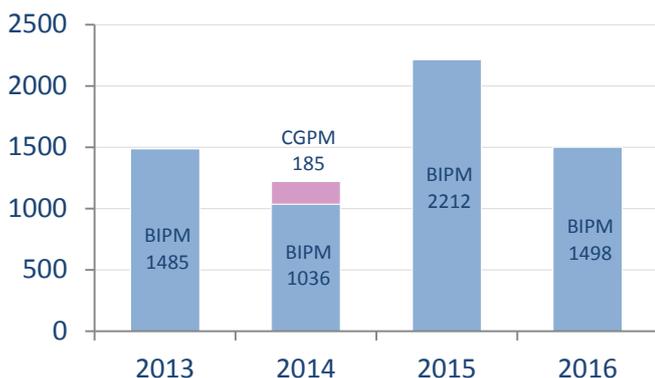
The course was aimed at new and potential RMO Technical Committee (TC) Chairs and RMO Working Group Convenors. The training provided participants with an understanding of the Global Quality Infrastructure and international best practice in metrology. By combining theoretical and practical perspectives, participants benefited from a comprehensive overview of the internationally accepted Consultative Committees’ guidelines on metrology. They also gained practical experience, through group working sessions, on Calibration and Measurement Capabilities (CMC) review and lectures that illustrated common challenges and the mistakes made in practice. The course included a popular multi-day module on laboratory priority setting and project management.

Lecturers gave comprehensive talks that explained procedures and processes, as well as their personal perspective on the context and drivers related to their specific areas. Topics included: the CIPM MRA mechanisms and outcomes; specific guideline documents from the Consultative Committees on comparisons and CMCs; Consultative Committee strategies and structure; specific requirements of different RMOs on quality assurance; use of the BIPM key comparison database (KCDB); the CMC review process; and the role of international organizations - BIPM, ISO, OIML, ILAC - in the Global Quality Infrastructure.

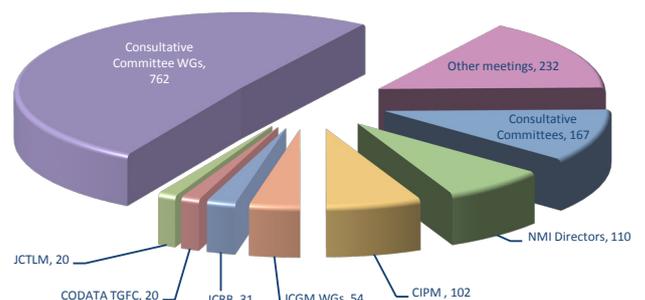
Full details of the BIPM Capacity Building and Knowledge Transfer Programme can be found at:
www.bipm.org/en/cbkt/

Meetings

Attendance at meetings hosted at the BIPM



Meeting attendance at the BIPM 2016



The CIPM MRA

The CIPM Mutual Recognition Arrangement (CIPM MRA) is the framework through which NMIs demonstrate the international equivalence of their measurement standards and the calibration and measurement certificates they issue. The outcomes of the Arrangement are the internationally recognized (peer-reviewed and approved) Calibration and Measurement Capabilities (CMCs) of the participating institutes. Approved CMCs and supporting technical data are publicly available from the BIPM key comparison database (the KCDB). After a decade and a half of successful operation, the CIPM MRA is being reviewed to ensure its sustainability for the future. Based on the outcomes from the Working Group on the Implementation and Operation of the CIPM MRA, which met in August 2016, it was recommended that the KCDB be revised. Discussions have taken place with the Joint Committee of the Regional Metrology Organizations and the BIPM (JCRB) and the Consultative Committees and the specifications for a revision of the KCDB have been drafted.

New signatories of the CIPM MRA in 2016:

The **Qatar General Organization for Standards and Metrology (QGOSM)**, Qatar, on 16 March.
 The **Emirates Authority for Standardization & Metrology (ESMA)**, United Arab Emirates, on 2 February.

An up-to-date list of CIPM MRA participants can be found at:
www.bipm.org/en/cipm-mra/participation/signatories.html

Key and supplementary comparisons

On 31 December 2016, the KCDB included 967 key comparisons and 491 supplementary comparisons. Both the number of key and supplementary comparisons increased by around 45 during the year, but the relative increase in supplementary comparisons was twice that of the key comparisons. Around 90 comparisons were completed and published during 2016. Today, almost 90 % of the 89 ongoing BIPM key comparisons and around 70 % of all comparisons registered by the Consultative Committees and RMOs have published results in the KCDB. Almost all Associates participating in the CIPM MRA had at least one of their metrology institutes listed as a participant in a key or supplementary comparison.

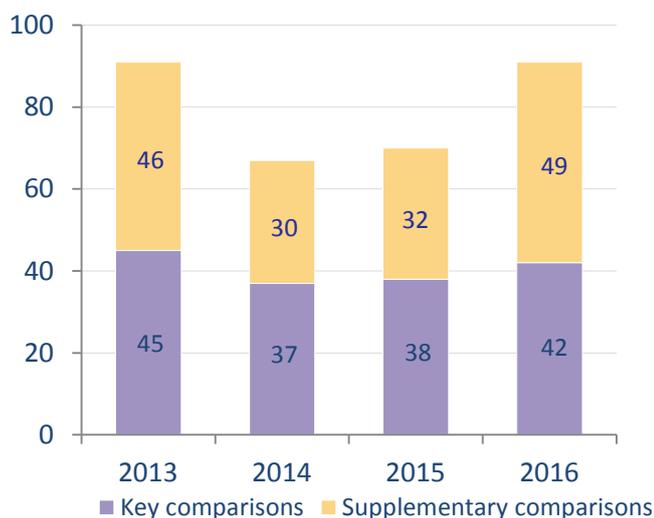
The KCDB currently includes a dozen examples where more than seven key comparisons are linked together.

Calibration and Measurement Capabilities

On 31 December 2016, 24 900 CMCs were registered in the KCDB. Of these, 14 570 were in the field of general physics, 4 100 in ionizing radiation, and 6 230 in chemistry. The total number of CMCs increased by 600 during 2016. The first sets of CMCs were declared by Bolivia (in chemistry) and published in July 2016. Only 22 of the 41 Associates that participate in the CIPM MRA had CMCs published in the KCDB at the end of 2016.

At the end of 2016, 200 CMCs were temporarily removed from the KCDB ("greyed out"), a slight decrease from 2015. Another 62 were definitively deleted from the KCDB in 2016, either by request from the corresponding NMI, or due to the lack of a QMS. Both these numbers are negligible when compared to the total number of registered CMCs.

Number of new comparisons registered in the KCDB



Total number of CMCs registered at 31st December



Promotion of the SI and metrology

CIPM Task Group for Promotion of the SI

It is expected that the CGPM will adopt a substantial redefinition of the International System of Units (SI) in 2018. This will be an important event for the world-wide metrology community, which will require thorough and understandable communication of the technical consequences of the proposed changes to the way that traceability will be disseminated to users. It will also provide a special opportunity to raise awareness of the SI, promote metrology in general, and educate the general public about the importance of accurate measurement in daily life.

To support the redefinition of the SI, the CIPM has set up a Task Group to identify and develop key tools to support all Member States to promote the new SI among a wide range of different audiences. The Group will share communication tools and messages through a page on the BIPM website: www.bipm.org/en/committees/cc/wg/cipm-tgsi.html. The messages and tools developed by the Group will be available for use by Member States.

The webpage includes a dedicated section on the latest updates: www.bipm.org/en/news/new-si.html.



World Metrology Day

World Metrology Day is held annually on 20 May to celebrate the anniversary of the signing of the Metre Convention in 1875. The original aim of the Metre Convention - the world-wide uniformity of measurement - remains as important today as it was in 1875. Each year World Metrology Day is organized and celebrated jointly by the BIPM and the OIML with the participation of the national organizations responsible for metrology.

World Metrology Day 2016, which was on the theme of 'Measurements in a dynamic world', was a great success, with the number of hits on the website and downloads setting a new record. Events were held in more than 30 countries and 25 bespoke versions of the poster were produced by various countries and RMOs. The topic was chosen to align with the increasingly rapid pace of change in measurement science, and indeed changes within the world around us.

World Metrology Day: www.worldmetrologyday.org

Metrology

Measurements in a dynamic world

World Metrology Day

20 May

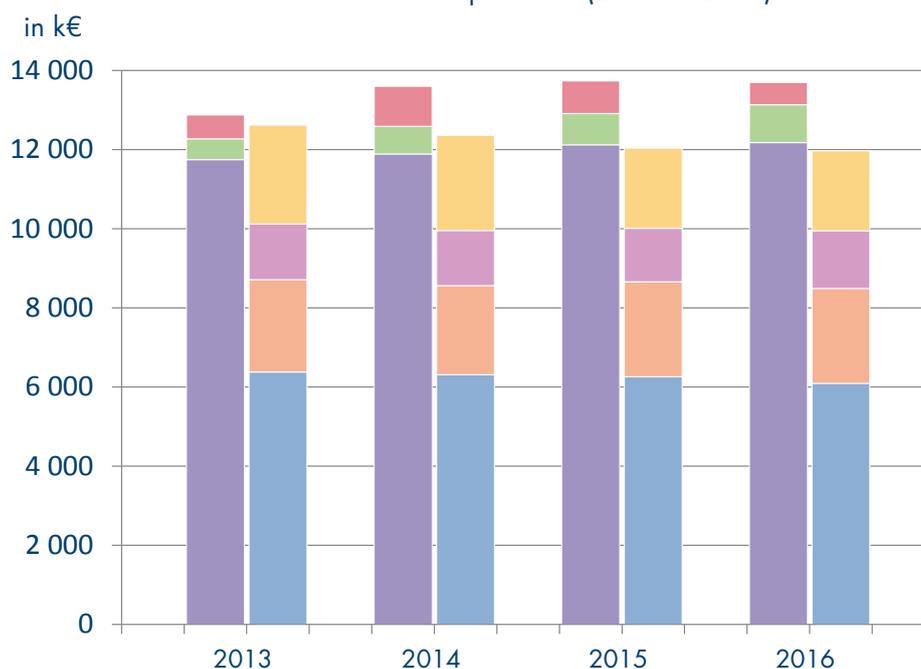
www.worldmetrologyday.org

Financial Summary

Key financial points

- Income follows forecast, with a number of Associate States increasing their subscriptions following their first registration of CMCs in the KCDB confirming their active participation in the CIPM MRA.
- Direct staff costs are being controlled by a limit on pay awards in 2016, and from further selected “contracting out” of site reception and security services. These actions complement the measures in place since the beginning of 2017 to limit the long-term pension liability.
- Other operating costs have been controlled carefully in advance of planned fees for access to an outsourced radiation facility starting in 2017.
- Capital spend was within budget following the projected increase from the 2015 level, reflecting the start of new laboratory and building renovation projects in the first year of the latest 4-year Work Programme.

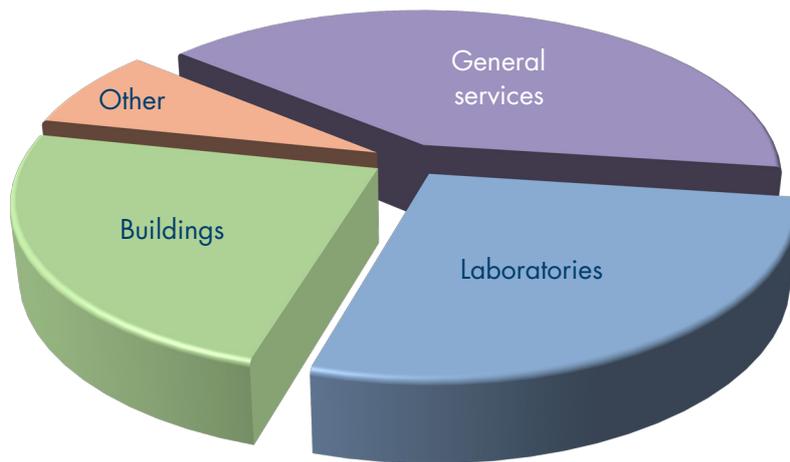
Revenue and expenditure (2013 to 2016)



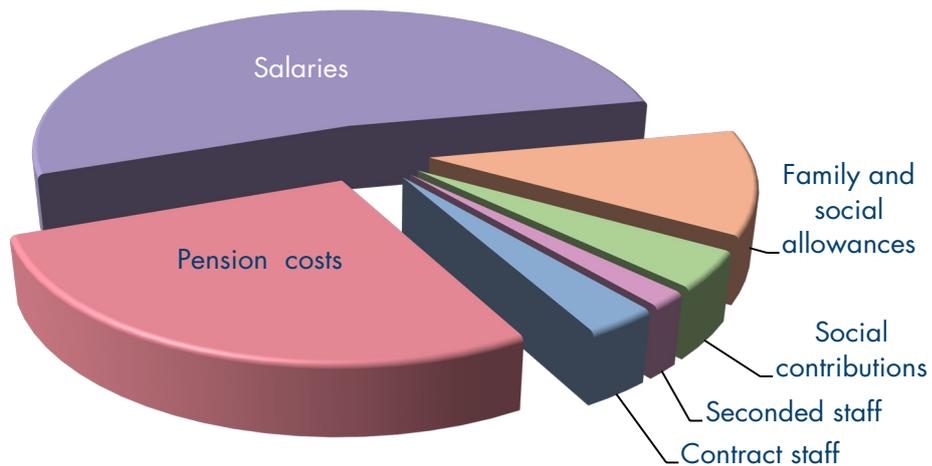
in k€	2013	2014	2015	2016
Operating, laboratory and building expenditure	2496	2405	2027	2020
Capital spend	1411	1394	1353	1458
Contribution to the pension fund	2329	2251	2400	2400
Current staff cost	6382	6309	6256	6091
Other income	598	1009	823	561
Subscriptions	530	702	790	955
Contributions	11744	11885	12121	12178

Financial Summary

Operating expenses



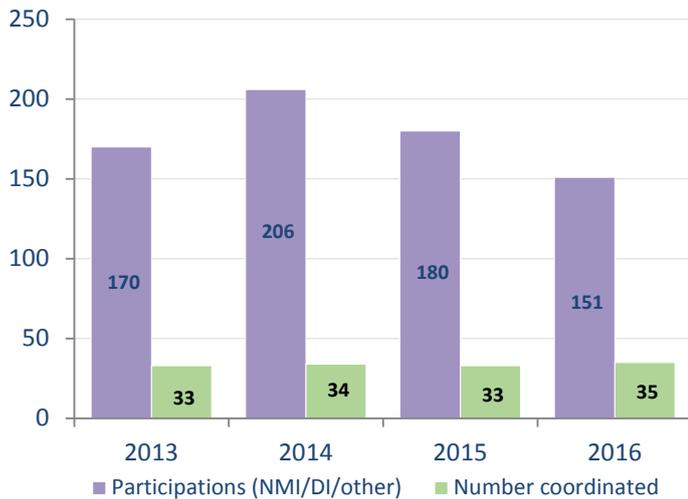
Staff costs



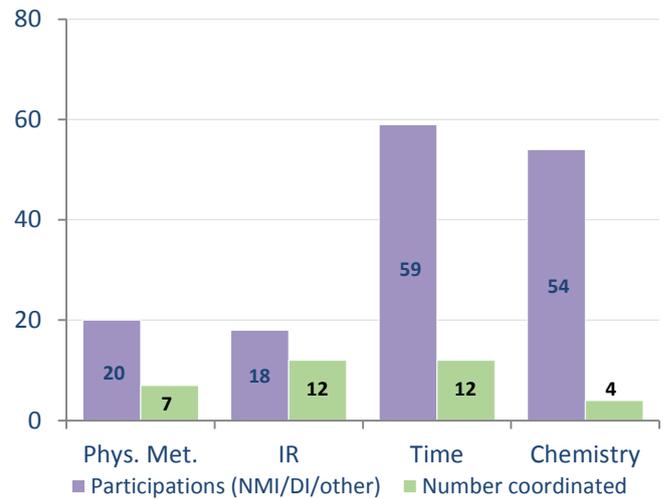
Comparisons and Calibrations

Comparisons coordinated by the BIPM

2013-2016



2016 - Breakdown by Department



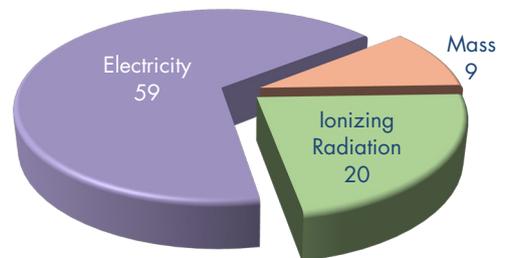
Full details of the BIPM's comparison programme can be found at:
www.bipm.org/en/bipm-services/comparisons/

BIPM Calibrations and Study Notes

2013-2016



2016 - Calibrations by metrology area



Full details of the BIPM's calibration and measurement services can be found at:
www.bipm.org/en/bipm-services/calibrations/

Organizational structure of the BIPM

The CIPM

President

Dr B. Inglis (Australia)

Secretary

Dr J. McLaren (Canada)

Vice-Presidents

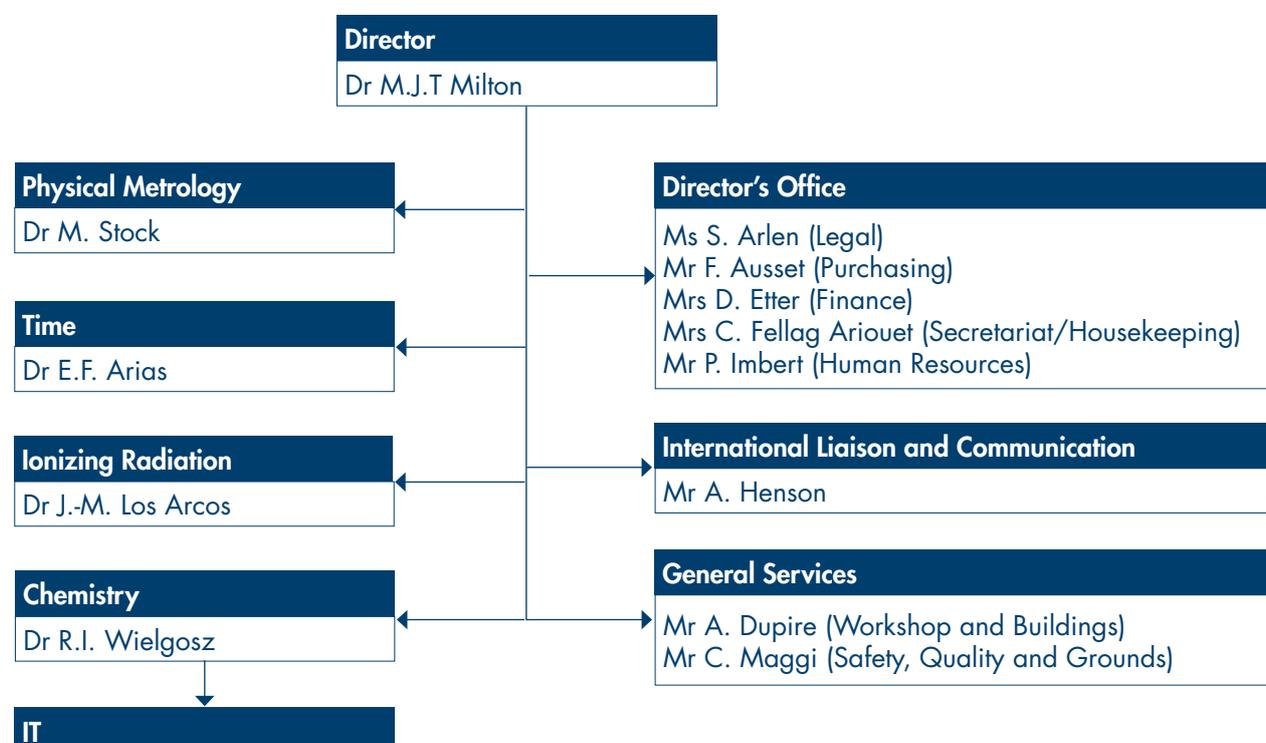
Dr W.E. May (United States of America)
Prof. J. Ullrich (Germany)

Other CIPM members

Dr F. Bulygin (Russian Federation)
Dr M. Buzoianu (Romania)
Dr I. Castelazo (Mexico)
Dr Y. Duan (People's Republic of China)
Mr L. Énard (France)
Dr D.-I. Kang (Republic of Korea)
Dr H. Laiz (Argentina)*
Dr T. Liew (Singapore)
Dr W. Louw (South Africa)
Dr M.L. Rastello (Italy)*
Dr P. Richard (Switzerland)
Dr G. Rietveld (Netherlands)
Dr M. Sené (United Kingdom)*
Dr T. Usuda (Japan)

*Provisionally elected to the CIPM on 7 December 2016

The BIPM



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Metrologia, 2016, **53**(1), R1-R11
Feistel R. and Wielgosz R.I. *et al.*
12. **Report on the BIPM-WADA Workshop: Standards and metrology in support of anti-doping analysis**
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Westwood S. and Wielgosz R.I.



Useful links

BIPM Work Programme

The BIPM has the mandate to provide the basis for a single, coherent system of measurements throughout the world, traceable to the International System of Units (SI). This task takes many forms, from direct dissemination of units (as in the case of mass and time) to coordination through international comparisons of national measurement standards (as in electricity and ionizing radiation).

View full details of the BIPM Work Programme at: www.bipm.org/en/bipm/

Committee structure

CGPM: www.bipm.org/en/worldwide-metrology/cgpm/

CIPM: www.bipm.org/en/committees/cipm/

The CIPM has established a number of Consultative Committees, which bring together the world's experts in their specified fields as advisers on scientific and technical matters.

Consultative Committees: www.bipm.org/en/committees/cc/

In addition the BIPM participates in the work of a number of Joint Committees which have been created in collaboration with other international entities to undertake particular tasks of common interest.

Joint Committees: www.bipm.org/en/committees/jc/

Measurement units: the SI

The recommended practical system of units of measurement is the International System of Units (Système International d'Unités, with the international abbreviation SI). The SI is not static but evolves to match the increasingly demanding requirements for measurements globally. Currently much work is under way related to the intended future revision of the SI.

The SI: www.bipm.org/en/measurement-units/

Revision of the SI: www.bipm.org/en/measurement-units/new-si/



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