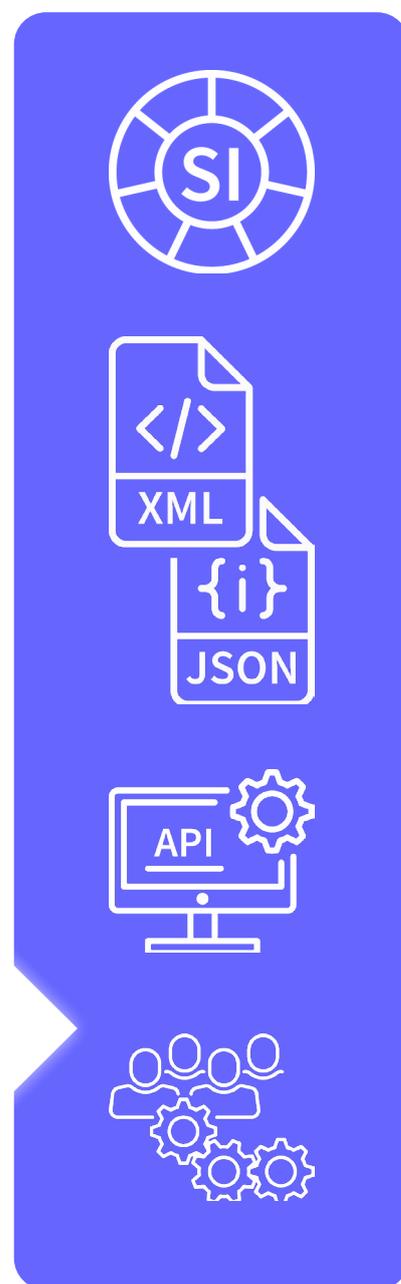


# Annual Review **2022/2023**





# 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,
- Improving the quality of life and sustaining 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.

## Fulfilling the BIPM mission and objectives is complemented by its work in:

- Capacity building, which aims to achieve a global balance between the metrology capabilities in Member States,
- Knowledge transfer, which ensures that the work of the BIPM has the greatest impact.

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# Introduction

*“In 2022, the metrology community experienced significant advances. We are now tasked with envisioning a modern, forward-looking BIPM that meets the metrological challenges of a rapidly changing world with utmost competence and the necessary resources to carry out its work. Additionally, I eagerly anticipate the strengthening of the BIPM’s role through our drive towards universal adherence to the Metre Convention.*

*Lastly, my heartfelt congratulations to the BIPM staff for their dedication, hard work and outstanding professionalism that enabled the successful completion of numerous projects”.*

**Dr Wynand Louw**  
CIPM President

The major event of 2022 was the 27th meeting of the General Conference on Weights and Measures which took place in November. It was the first CGPM meeting that allowed attendance by Member State representatives using online technology as well as participating in the meeting itself in Versailles.

The resolutions adopted by the CGPM set a new direction for the BIPM, which the CIPM President addresses in his Welcome Message. The CGPM also gave its support to an increase of 1.5 % per annum in our dotation for the next four-year period. I want to thank Member States for placing their trust in the BIPM and its staff.

The timescale for the work ahead of us is now focused on one date - 20 May 2025, which will be the day of the 150th anniversary of the signing of the Metre Convention. We will host a large celebration in Paris to bring together as many people as possible to celebrate what has been achieved by us over 150 years and also to announce new initiatives for the coming decades.

In last year’s report, I introduced our plans for the digital transformations of our services so that they will continue to play a central role in the digital world of measurement science. This year we report that we have now started to launch these services: a new way for computers to access the data in the KCDB and a trial system that enables NMIs to access more data from the Time Department databases. These and other initiatives have been welcomed by the CIPM and many NMIs. We are looking forward to continuing our work on digital transformation and all its associated benefits to the global metrology and wider communities.

**Dr Martin Milton**  
BIPM Director



**Wynand Louw**



**Martin Milton**

# Physical Metrology

## Second key comparison of kilogram realizations

The second key comparison of realizations of the kilogram according to its new definition, CCM.M-K8.2021, was launched by the BIPM in the second half of 2021 and was completed at the end of 2022 [1]. Seven institutes participated with Kibble balances and two with the XRCD method. Each participant calibrated one or two 1 kg mass standards with its realization experiment and sent them to the BIPM Headquarters for a comparison. The comparison showed again a statistically significant difference between the realizations with the smallest uncertainty. The weighted mean of the realizations of the participants deviates by  $-0.015$  mg from the mass value based on the International Prototype of the Kilogram (IPK).

## Second CCM consensus value

In 2017 the Consultative Committee for Mass and Related Quantities (CCM) recommended that the dissemination of the mass unit should initially be based on an international mean kilogram, also called the “consensus value”, until satisfactory agreement between independent realizations could be achieved. The consensus value is determined and regularly updated as the arithmetic mean of the key comparison reference values of the last three key comparisons, which should be organized by the BIPM on a biennial basis. Based on the results of the key comparisons CCM.M-K8.2021, CCM.M-K8.2019 and the pilot study from 2016, the most recent consensus value is  $1 \text{ kg} - 7 \mu\text{g}$  with an uncertainty of  $20 \mu\text{g}$ . To achieve consistency with the consensus value, all NMIs would need to reduce the mass value of their national as-maintained mass unit by  $7 \mu\text{g}$  with respect to the mass value based on the IPK or by  $5 \mu\text{g}$  with respect to the consensus value of 2021.

## Kibble balance improvements

The BIPM continued its efforts to improve the operation of its Kibble balance. Three issues related to the electrical measurements were identified and resolved, which led to a reduction of the voltage measurement uncertainty by a factor of two. The BIPM successfully participated in the second key comparison of realizations of the kilogram, CCM.M-K8.2021, described above. The relative standard uncertainty was reduced from  $5.0 \times 10^{-8}$  in the first key comparison to  $4.1 \times 10^{-8}$  [2]. In parallel, a new balance beam mechanism is being developed with the objective of reducing the largest uncertainty component, due to misalignment of the Kibble balance apparatus [3].

## Improved $1 \Omega$ resistance standards

The study of new  $1 \Omega$  resistance standards for possible use in the BIPM.EM-K12 on-site comparisons of quantum Hall resistance standards has progressed. Performed in collaboration with the AIST-NMIJ (Japan) and the PTB (Germany), its main objective is to evaluate the frequency dependence of a set of commercial resistor prototypes developed by AIST-NMIJ. The frequency dependence of  $1 \Omega$  resistors has previously been a limiting factor for

the uncertainties which could be achieved during the comparisons. A first measurement campaign ended with encouraging results. Some unexplained discrepancies at very low frequency for certain measurement configurations require further investigation.

## Calculable capacitor

The assembly of the calculable capacitor was focused on the precision alignment of the four electrode bars [4]. The use of specific capacitive probes has allowed the BIPM to achieve an angular positioning of adjacent bars at  $\pi/2$  within  $\pm 0.3$  mrad and limits the skew angle to less than  $\pm 1.4$  mrad. These dimensional uncertainties correspond to an uncertainty of  $1 \text{ nF/F}$  on the realized capacitance. The main electrode bars have been further aligned to obtain distances between opposite and adjacent bars within  $\pm 1 \mu\text{m}$  on average. Finer adjustments are required to reach the target uncertainty of  $0.2 \mu\text{m}$ .



BIPM capacitors bank

## Programmable Josephson Voltage Standard

The voltage team has completed its work on establishing a protocol for an extension of the bilateral on-site comparison of programmable Josephson Voltage Standards (PJVSs) from dc to ac voltages. It received the support of a dedicated Consultative Committee for Electricity and Magnetism (CCEM) Task Group established in April 2021. The protocol includes two options for the comparison of differential sampling setups of the BIPM and the participating NMI [5].

## Calibrations of masses and electrical standards

The BIPM continues to provide calibrations of  $1 \text{ kg}$  Pt-Ir prototypes and stainless-steel mass standards for the NMIs of its Member States. During 2022, nine Pt-Ir prototypes and thirteen stainless steel standards were calibrated. In the field of electricity, more than 90 electrical standards were calibrated, and five bilateral comparisons were carried out. [6-8]

**Comparisons completed: 7**

**Calibration certificates delivered: 123**

**Study notes delivered: 9**

# Ionizing Radiation

Throughout 2022 the department continued its commitment to help ensure safe and effective use of ionizing radiation in healthcare and industry by providing comparison services for radiation dosimetry and radioactivity, as well as associated calibration services for dosimetry. [9-14]

## Radionuclide metrology

Comparisons of national activity standards of gamma-ray emitting radionuclides rely on the International Reference System (SIR). Eleven SIR comparison reports were produced and six were published, thanks to new software enabling automatic generation of comparison reports, calculation of the comparison results, key comparison reference values and degrees of equivalence based on the SIR database implemented to this end.

The SIR transfer instrument (SIRTI) enables comparisons of many short-lived radionuclides used in nuclear medicine to be carried out on site, operated by NMI staff while remotely overseen by BIPM scientists. In 2022 the SIRTI was linked to the SIR using measurements for  $^{153}\text{Sm}$  carried out at the BIPM and the PTB. The first  $^{123}\text{I}$  SIRTI comparison took place at the KRISS.

In response to the need expressed by the APMP and SIM, work was initiated under the responsibility and budget of each RMO to develop regional SIRTI to be linked to the SIR or the BIPM SIRTI. This approach enables the provision of more comparisons at the regional level for radioelements that are critical to nuclear medicine. It also expands these comparisons to institutes that are not yet signatories to the CIPM MRA.

The SIR and SIRTI can only be used if a radionuclide emits photons with enough energy to significantly pass through the wall of the detectors. For pure (or almost pure)  $\beta$ -emitting radionuclides, a new instrument (the ESIR) has been developed, based on a liquid-scintillation counting technique (the Triple-to-Double Coincidence Ratio method). The pilot study to validate the ESIR against the reference SIR with the use of  $^{60}\text{Co}$  solutions standardized by thirteen participating NMIs/DIs was completed successfully. The system is now ready for comparison services for high-energy pure  $\beta$ -emitters.

## Dosimetry metrology

Several comparisons and calibrations were carried out as follows:

- Ten comparisons for Australia, Japan, Korea, USA and UK.
- Twenty-nine calibrations for Finland, IAEA, India, Slovakia and Sweden.

Sixteen comparison reports were delivered with 13 of them published as Technical Supplements in *Metrologia*.

Preparations for the re-establishment of  $^{137}\text{Cs}$  services by the BIPM at the IAEA facility have progressed as planned.

The BIPM developed a complete dedicated measurement system, comprising the hardware to be installed at the IAEA and the operation software. After validation in the BIPM  $^{60}\text{Co}$  facility, preliminary tests were successfully carried out in the  $^{137}\text{Cs}$  beam at the IAEA. The BIPM additionally advised

the IAEA on the analysis and dissemination of calibration coefficients for the linear accelerator installed at the IAEA dosimetry laboratory.

At the BIPM headquarters, a new medium-energy x-ray tube was installed and critically aligned to produce a horizontal radiation beam perpendicular to the measurement bench. Despite being essentially the same as the existing tube, measurement of the radial profiles at 1 m distance were significantly less homogeneous than expected. This potential difficulty was solved by selecting a smaller focal-spot setting for the new tube. Work will continue during 2023 to characterize the new beams and the conversion from air kerma to absorbed dose to water. In 2022, the design of the new primary standard for these beams was finalized and the instrument, a free-air ionization chamber, has been manufactured and assembled with the first test measurements scheduled for January 2023.



New BIPM measurement system (left) developed for the dosimetry K5 key comparisons using the  $^{137}\text{Cs}$  irradiator facility at the IAEA (right)

## Additional activities

- membership of the consultants group revising the IAEA Code of Practice TRS-398 for external beam radiotherapy.
- membership of the International Commission on Radiation Units and Measurements (ICRU) and chair of the ICRU Fundamental Quantities and Units Committee.
- participation in the IEC/ISO joint group 5 working on a new standard for radionuclide calibrators.
- vice presidency of the International Committee for Radionuclide Metrology.
- participation in eleven CCRI Working Group meetings; support and organization of eight CCRI webinars; knowledge transfer through attendance at all RMO technical committee meetings.

**Comparisons completed: 24**

**Calibration certificates delivered: 14 (corresponding to 29 calibrations)**

# Chemistry

The Chemistry Department progressed sixteen interlaboratory comparisons in 2022, including comparisons of standards for greenhouse gases, food contaminants and diagnostic markers, with 91 laboratory participations. New knowledge transfer activities were initiated, the onsite visiting scientist programme restarted, with seventeen publications including nine comparison reports and three papers in peer reviewed journals.

## Work related to Metrology for the Environment undertaken by the Department included

- The comparison of CO<sub>2</sub> isotope ratio measurements (CCQM-P204) on pure CO<sub>2</sub> samples and preparation for a comparison of CO<sub>2</sub> isotope ratios supported by visiting scientists from CSIRO and NPL.



Isotope ratio Mass Spectrometer facility for comparison of pure CO<sub>2</sub> and CO<sub>2</sub> in air isotope ratio standards

- A paper on 'Minimum requirements for publishing HCNOS stable isotope delta results' was published *Pure and Applied Chemistry* [15].
- Development of scale facilities for CO<sub>2</sub> in air, in preparation for BIPM.QM-K5, supported by a joint technical project with VSL.
- Completion of the nitrous oxide (N<sub>2</sub>O) in air standard comparison (CCQM-K68.2019), protocol development for the CCQM-K82.2023 methane in air comparison, and initiation of the CCQM-P225.a and b comparison for CO<sub>2</sub> standards in air and nitrogen matrices.
- Four bilateral comparisons and three comparison reports for ozone standards comparison, BIPM.QM-K1 [17,18,19].
- Publication of a paper on 'Units and values for the ozone absorption cross section at 253.65 nm (air) with appropriate significant digits and rounding for use in documentary standards' [20].

- Publication of the final report of the HNO<sub>3</sub> in NO<sub>2</sub>/N<sub>2</sub> standards study (CCQM-P172) and initiation of joint technical projects with the NPL and METAS for development of future activities for NO<sub>2</sub> in nitrogen/air standards.
- Provision of the on-line course on 'FTIR Measurements on Gas Standards' (NO<sub>2</sub>, NO, HNO<sub>3</sub>, CO<sub>2</sub>) to scientists from NIMT (Thailand) and NMISA (South Africa) resulting in operational FTIR facilities at both NMIs.

## Work related to Metrology for Health and diagnostic markers included

- Publication of a paper on compositional analysis of C3-triskelion in *iScience* [21], as well as the final reports of CCQM-K115.c [22] and P55.2.c [23] (HbA1c hexapeptide (GE) purity) CCQM-K115.2018 [24] and P55.2.2018 [25] (HbA0 hexapeptide (VE) purity).
- Drafting of the final report of part II of the CCQM SARS-CoV-2 antibody quantification pilot study, CCQM-P216, coordinated by NIM, with BIPM and NRC and continued collaboration with NRC, NIBSC, NIM, CDC and IFCC to plan for the parathyroid hormone (PTH 1-84) comparison (CCQM-K115.d).
- Provision of a new version of the JCTLM database for *in vitro* diagnostics and publication of a paper on overcoming challenges to global standardization of clinical laboratory testing; reference materials and regulations was published in *Clinical Chemistry and Laboratory Medicine (CCLM)* [26].

## Work related to Metrology for Safe Food and Feed, included

- Publication of the final reports of the comparisons of Aflatoxin B1 calibration solutions (CCQM-K154.b) [27] and Deoxynivalenol calibration solutions (CCQM-K154.c) and purity evaluation guidelines for Deoxynivalenol [28] and Patulin [29] as well as a Calibrant Assessment Guideline for Patulin [30].
- Publication of the the Patulin Calibration Solutions comparison protocol (CCQM-K154.d), with measurements completed of samples submitted by ten NMIs measured at the BIPM.
- Drafting of the first report of the comparison of pesticide multicomponent calibration solutions, CCQM-K78.b, with twenty-one results submitted by participating NMIs to the BIPM.
- Completion of the knowledge transfer study measurements on the purity evaluation of Tetracycline by fourteen participating laboratories.
- Completion of the Oxytetracycline sample characterization and the comparison protocol for CCQM-K148.b.

**Comparisons completed: 9**

# Time

## Towards the redefinition of the second

The Time Department supported the Consultative Committee for Time and Frequency (CCTF) in the discussion of four important hot topics, which lead to Resolution 4 “On the use and future development of UTC”, and Resolution 5 “On the future redefinition of the second” approved by the CGPM in November 2022. [32]

The “Task Force on the Roadmap for the redefinition of the second” developed a roadmap by fixing the mandatory criteria that are to be fulfilled to be ready for a new definition. An important criterion is the availability of optical frequency standards and their regular contribution to UTC. The quality of this contribution can be monitored by new plots available on the BIPM web page and automatically updated at each UTC computation.

## Towards a continuous UTC

The Time Department is reinforcing the liaison with the International Telecommunication Union (ITU) to highlight the importance of the need for a continuous UTC [48]. A session on UTC was organized at the 2nd ITU Inter-regional Workshop on WRC-23 Preparation [54], the department has contributed to the ITU report on “Content and structure of time signals to be disseminated by radiocommunication systems and various aspects of current and potential future reference time scales, including their impacts and applications in radiocommunication”, REPORT ITU-R TF.2511-0 [55]. A special issue of the ITU News magazine devoted to “The future of the Coordinated Universal Time” [56] was prepared in collaboration with the ITU.

## Production of UTC

The regular collection of data, computation of Coordinated Universal Time (UTC), rapid UTC and the key comparison CCTF-K001.UTC continued without interruption. Research activities in the department progressed along two lines: (i) the evaluation of possible new algorithms for jump detection [31] and (ii) clock weighting [34,45,46] leading to the modification of the current upper limit of weights for the UTC clocks.

## Characterization of time transfer equipment

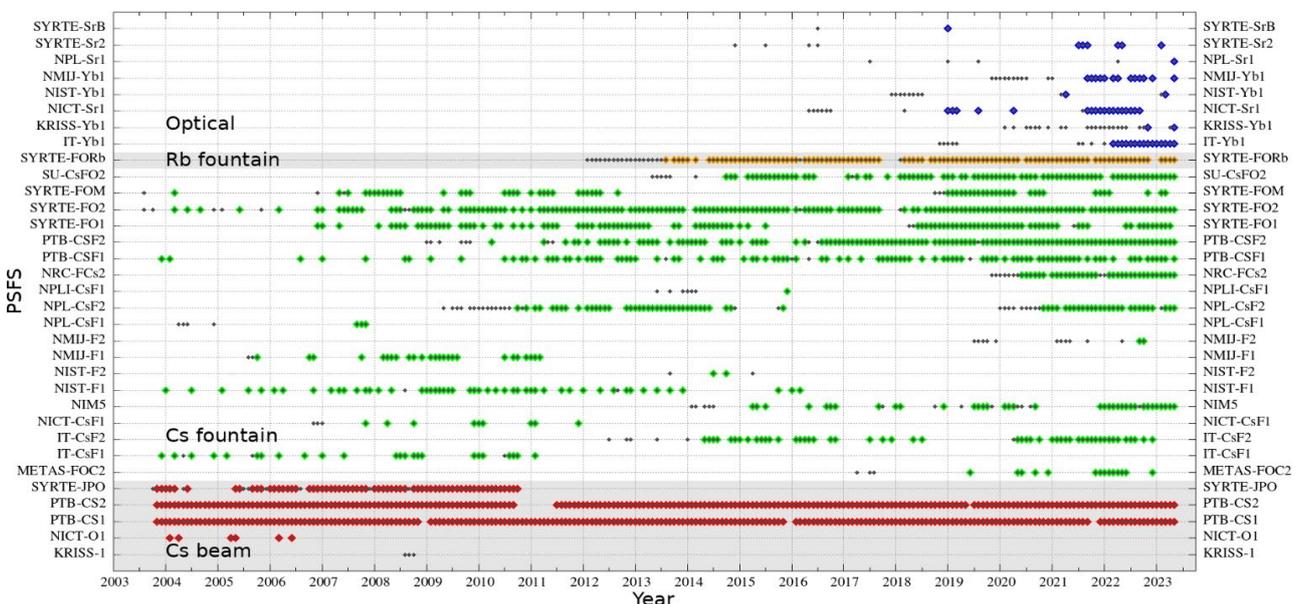
The biannual calibration campaign of the Group 1 laboratories continued by finishing the visit in COOMET (SU laboratory) and restarting with APMP G1 laboratories (NIM, NICT, TL). An analysis of repeated Global Navigation Satellite Systems (GNSS) calibration and their stability was carried out [50] showing that most of the receiver internal delays are stable at the level of 1 ns.

## Circular T future update

Notable improvements of UTC *Circular T* are in progress. Section 5, which reports the used time links and their calibration information will soon evolve with the addition of more information and the handling of non-calibrated laboratories [51]. Section 4, which reports information on the prediction of UTC broadcast by GPS and GLONASS will be updated with the addition of the same information for the European Galileo and the Chinese BeiDou systems.

## Comparing clocks with IPPP

Significant work was carried out in the application of Integer Precise Point Positioning (IPPP) to UTC links to improve current GNSS time links. This work was undertaken in collaboration with the CNRS (France), allowing the development of a preliminary tool for possible future routine use in UTC computation [33,38,49]. Some aspects of other clock comparison techniques were also explored [37,41,47].



Graphical representation of all evaluations of Primary and Secondary Frequency Standards reported since Circular T 190  
Enhanced colour dots indicate evaluations carried out within the month of TAI computation

# International Liaison and Communication

## World Metrology Day

Each year on 20 May, the global metrology community commemorates the signing of the Metre Convention in 1875. The 2022 theme was “Metrology in the Digital Era”, chosen because digital technology is revolutionizing our community and is one of the most exciting trends in society today. The 2022 poster was designed under the auspices of the COOMET Regional Metrology Organization. The poster was translated into more than 20 languages and information on more than 30 national celebratory events were promoted on the World Metrology Day website.



## Key step towards the recognition of World Metrology Day by UNESCO

The UNESCO Executive Board took a key step towards recognizing 20 May - World Metrology Day at their session on 13 October 2022, following the proposal presented by Kazakhstan and supported by 42 UNESCO Member States. The decision will need to be ratified by the 42nd session of the UNESCO General Conference in November 2023. It is expected that 20 May will be proclaimed as a UNESCO world day to be celebrated from 2024 onwards.

## The BIPM admitted by COP27 as an observer to the UNFCCC

The BIPM was admitted by the 27th session of the Conference of the Parties (COP27) held in Sharm-El-Sheikh, Egypt, as an observer organization to the United Nations Framework Convention on Climate Change, (UNFCCC). Admission as an observer is a one-off process and the BIPM will henceforth be able to attend and submit statements to future COPs as well as proposing side events and/or exhibitions to represent the world-wide metrology community. A statement by the BIPM Director was published under Statements by Observer Organizations delivered at the resumed High-Level Segment – 16 November 2022 at COP27.



## International rulemaking for the future

The Organisation for Economic Co-operation and Development (OECD) established the Partnership of rulemaking (IO Partnership) as a voluntary platform of international organizations (IOs), academics and OECD Regulatory Policy Committee delegates. Its aim is to exchange good practices and promote greater quality, effectiveness and impact in international rulemaking. The BIPM has been a cofocal point of WG5: IO Coordination since 2019 and a focal point of WG2: Inclusiveness (stakeholder engagement and IO coordination) since 2021.

## Cooperation with the World Trade Organization

The BIPM and the World Trade Organization (WTO) cooperate to ensure effective dissemination of information on the importance of the quality infrastructure. A particular focus of this cooperation is metrology as one of the key components among trade regulators and international / intergovernmental organizations that hold *ad hoc* observer status at the WTO Committee on Technical Barriers to Trade (WTO TBT Committee). The BIPM submitted the liaison report and attended the meetings of the WTO TBT Committee in March and July 2022.



# CBKT and e-learning

The BIPM Capacity Building and Knowledge Transfer (CBKT) Programme aims to increase the effectiveness with which Member States and Associates engage in the world-wide coordinated metrological system. It is delivered through theoretical (workshops), practical (laboratory placement), remote (online) activities.

## Capacity Building

Covers areas of vital importance to Member States and the BIPM. It also addresses topics of specific interest for Member States and Associates.

## Knowledge Transfer

Takes many forms, involving the BIPM staff, visiting scientists from NMIs/DIs and groups of experts from around the world.

## NMI/DI Participation

- 527 in-person
- 2 950 online
- 885 registered users on the e-learning platform

BIPM-ILAC webinars:

- 604 members.

## Statistics

- 27 projects in-person at the BIPM HQ and RMOs
- 26 projects online (13 repeated)
- over 60 lecturers from NMIs/DIs and international organizations.

## CIPM MRA Brochures

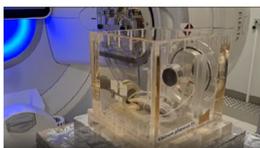
New suite of brochures providing information on key roles and mechanisms within the CIPM MRA.

<https://www.bipm.org/en/committees/cb/cbkt/cipm-mra-brochures>



## e-learning platform: new courses available

The BIPM e-learning platform was launched in 2021. It is now shared with five RMOs and continues to support new learning materials.



How to enter a CMC claim for ionizing radiation metrology



Small Volume Comparisons



Non Structure-Related Impurity Content in Organic Pure Materials



The realization of the kilogram following its redefinition on 20 May 2019

Realization of the kilogram following its redefinition



Good practice in evaluating measurement uncertainty: EMPIR Project EMUE 17NRM05



SSDL and ISO/IEC 17025:2017



Estimation of Measurement Uncertainty in Chemical Analysis University of Tartu



Information about COOMET activities



Raman spectroscopy of graphene masterclass



LC-MS Method Validation University of Tartu



ISO 4037:2019 - Radiological protection reference field



CIPM MRA



Dissemination of the kilogram following its redefinition on 20 May 2019

Dissemination of the kilogram following its redefinition



FTIR Analysis for Gas Standards



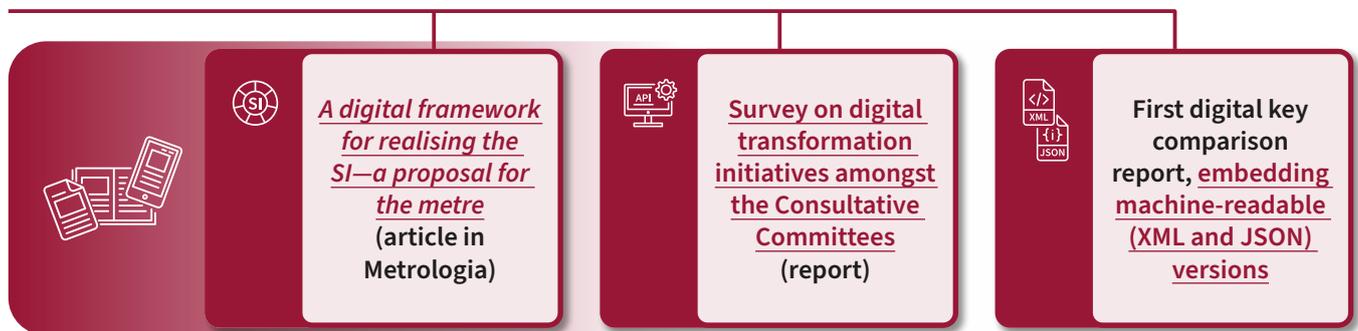
Annual Reporting within EURAMET TC-Q

# Promoting the Digital Transformation of Metrology

## Events

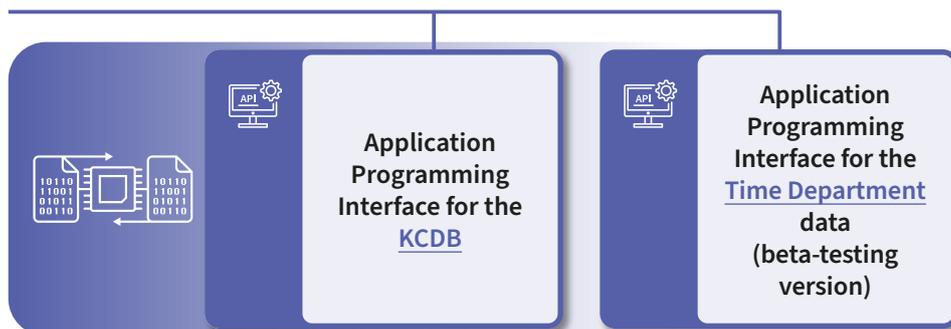


## Publications

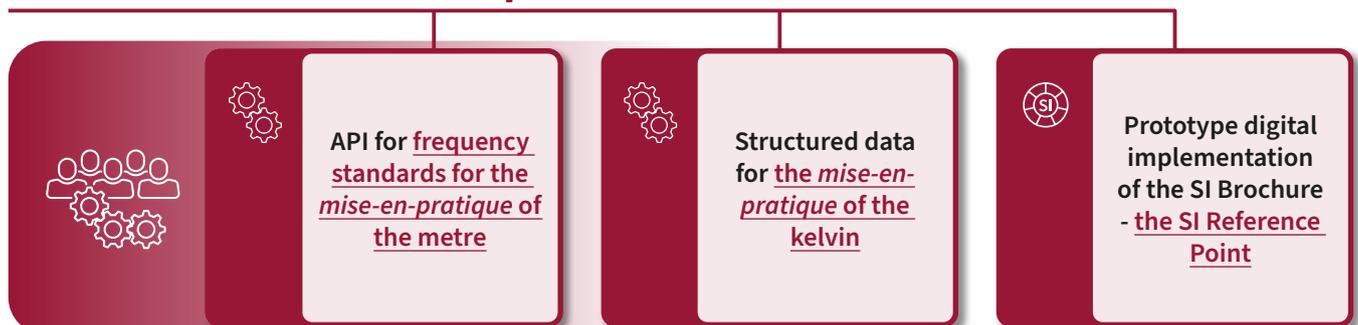


# Digital Transformation of the BIPM metrological services

## New services launched



## New services under development



# The CIPM MRA

- The CIPM MRA is a framework through which national metrology institutes demonstrate the international equivalence of their national measurement standards and calibration and measurement certificates.
- The KCDB supports the CIPM MRA activities and publishes internationally recognized Calibration and Measurement Capabilities (CMCs) for services provided by participating institutes and key and supplementary comparisons supporting these CMCs.
- The Joint Committee of the Regional Metrology Organizations and the BIPM (JCRB) is charged with coordinating the activities among the RMOs in establishing confidence for the recognition of CMCs according to the terms of the CIPM MRA.

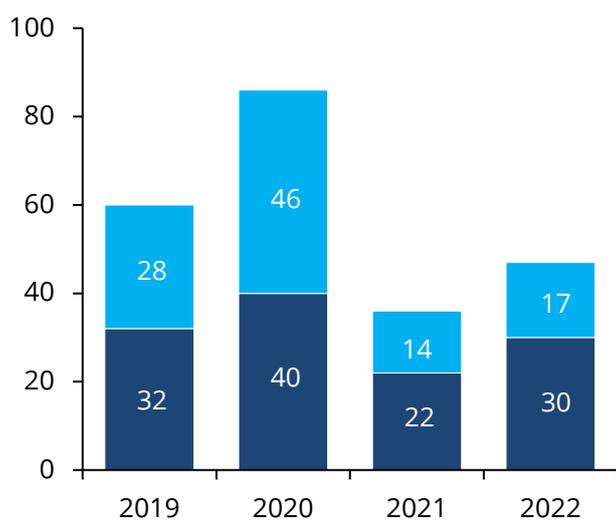
## Statistics (on 31 December 2022)

- 25 907 CMCs published in the KCDB: 15 963 in general physics, 3 723 in ionizing radiation, 6 221 in chemistry.
- 586 CMCs were greyed out, representing a 26 % increase compared to 2021.
- 1 139 key comparisons and 665 supplementary comparisons listed in the KCDB.
- 80 comparisons were completed and published.
- The KCDB 2.0 plus other efforts made by the RMOs, the BIPM and the NMIs/DIs has halved the CMC processing time (on average 70 days) as compared to the KCDB 1.0 (on average 140 days).

## Publications

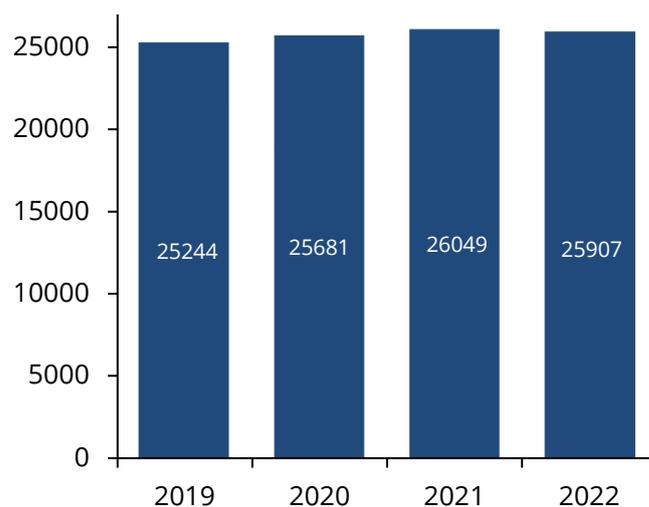
- In 2022, two KCDB Reports were made available via <https://www.bipm.org/en/cipm-mra/kcdb-reports>
- A set of brochures summarizing all aspects of the CIPM MRA mechanisms, were developed to explain the benefits of the CIPM MRA and the implementation of data quality principles:  
<https://www.bipm.org/en/committees/cb/cbkt/cipm-mra-brochures>.

**Number of new comparisons registered in the KCDB**



- Key comparisons
- Supplementary comparisons

**Total number of CMCs registered at 31st December**



# Consultative Committee meetings held in 2022



**30th meeting - February 2022**

25 members, 3 observers

## **Progressing the state-of-the-art**

- CCT internal Recommendation T1 (2021) regarding new determinations of thermodynamic temperature above 400 K
- Metrology focused guides for ear and forehead thermometry
- Identification, extraction and validation of data from ten top-priority CCT documents, to be built into APIs
- Restructuring of the *MeP* for the definition of the kelvin in the SI to improve its machine readability.

## **Facilitating stakeholder dialogue**

- 2021 revision of the CCT Strategic plan; top-level stakeholder needs identified in seven key areas
- WMO decision INFCOM-2 d07-4(2) on Uncertainty assessment and harmonization of uncertainty terminology, envisaged to align relevant INFCOM publications to the terminology definitions of the VIM.

## **Global comparability of measurements**

- 2 915 approved CMCs
- 51 comparisons completed from 2019 to 2022 including CCT-K9 (repeat of CCT-K3) and CCT-K10 (between 960°C and 3000 °C)
- Protocol for the KC of IR clinical thermometer calibrators.



**27th meeting - April 2022**

24 members, 13 observers, 6 liaisons organizations

## **Progressing the state of the art**

- CCQM Workshop on Microplastics Measurements and Standards
- CCQM Workshop on Particle Metrology
- CCQM OAWG Workshop on Metrology for Food Safety
- CCQM Roadmap to Metrology Readiness for Infectious Disease Pandemic Response published
- CCQM-GAWG Task Group on Greenhouse Gas Scale Comparisons
- CCQM-GAWG Task Group on Advanced Spectroscopy.

## **Facilitating stakeholder dialogue**

- CCQM Task Group on Infectious Disease Diagnostics and Metrology for Pandemic Preparedness established
- CCQM Task Group on Nano- and Microplastics Measurements and Standards established
- Report from the CCQM Task Group on Stakeholder Engagement
- CCQM-GAWG Task Group for Ozone Cross-Section.

## **Global comparability of measurements**

- 6 081 approved CMCs in 15 service categories
- Ten new key comparisons and five pilot study comparisons approved in 2022 for initiation
- CCQM Task Group on Guidance for the estimation of a consensus KCRV
- CCQM SPWG Task Group on Comparisons.



**25th meeting - May 2022**

25 members, 1 observer, 2 liaison organizations

### **Progressing the state-of-the-art**

- New Task Group on cone-fundamentals
- New Task Group on digitalization
- New CCPR Strategy for 2022-2032 addressing key scientific, economic and social challenges: lighting, optical properties of materials, energy/ photovoltaics, environment and climate observation, quantum photonics, general challenges such as the extension of the comparisons into different spectral regions and the need for alternative reference instruments and methods.

### **Facilitating stakeholder dialogue between the NMIs and IOs to cover three main fields:**

- Human vision and colour technologies
- Health, safety and sustainable environment
- Photonics, lighting and optical industries.

### **Global comparability of measurements**

- 1 345 approved CMCs in 85 service categories are registered in the KCDB
- Strengthening core competencies at the CC level (2nd round of key comparisons ongoing)
- Extending comparability world-wide with the RMOs (ten RMO comparisons in progress)
- Testing future standards in pilot studies (for example detection efficiency of single-photon detectors).



**23rd meeting - July 2022**

26 members, 4 observers, 5 liaison organizations

### **Work focused on four fundamental topics**

- Updating the Roadmap towards the redefinition of the SI second
- Leap seconds in UTC – building a consensus for a continuous timescale
- Promoting the mutual benefits of UTC and GNSS
- Sharing resources to improve international timekeeping.

### **Outcomes**

- Update of twelve recommended frequencies for the secondary representation of the second
- Adoption of ten internal CCTF recommendations
- Organization of a workshop on “redefinition options”
- Publication of a *Metrologia* Focus Issue on Challenges in Time and Frequency Metrology
- Preparation of four open access white papers
- Adoption of two Resolutions by the CGPM.

### **Global comparability of measurements**

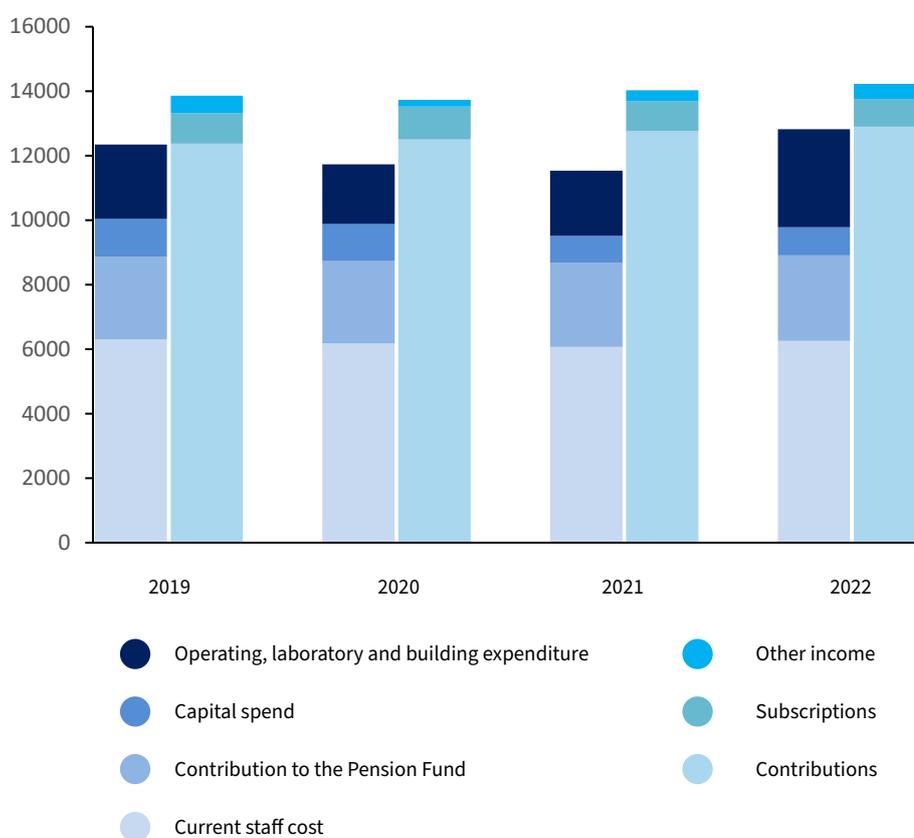
- 776 approved CMCs in 19 service categories
- One CCTF comparison repeated monthly
- Establishment of a CBKT project in collaboration with the IEEE UFFC aiming to widen the community involvement in UTC generation and dissemination.

# Financial Summary

## Key financial points

- Revenue increased because of the 1 % increase agreed in the contributions and the subscriptions.
- Staff costs increased by 3.3 % since 2021. Operating costs were higher due to the cost of hosting the CGPM and the increasing price of electricity.
- For the second consecutive year, the CIPM decided to transfer 3 million € from the BIPM reserves to the reserves of the BIPM Pension Fund.

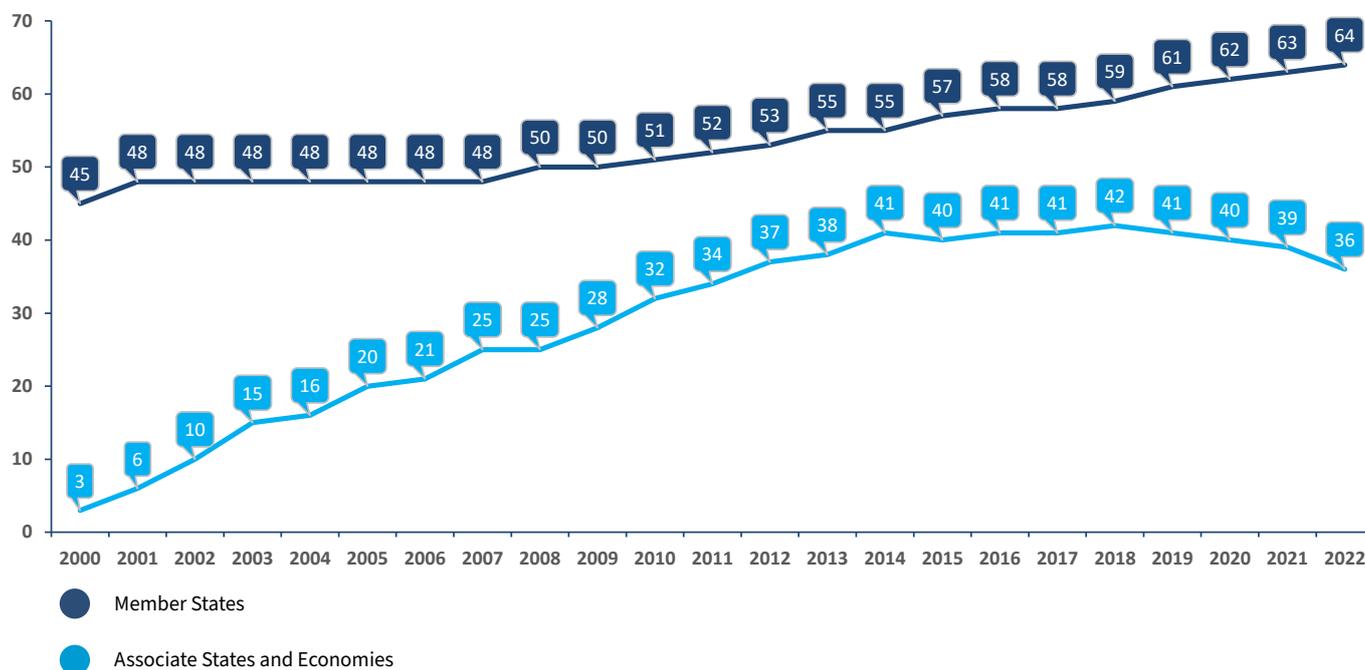
Revenue and expenditure (2019 to 2022)



in k€	2019	2020	2021	2022
Operating, laboratory and building expenditure	2 302	1 848	2 020	3 045
Capital spend	1 184	1 153	844	869
Contribution to the Pension Fund	2 550	2 550	2 600	2 650
Current staff cost	6 310	6 180	6 072	6 261
Other income	547	209	390	466
Subscriptions	935	1 022	928	867
Contributions	12 379	12 503	12 767	12 897

# Financial Summary

## Evolution in Member States and Associate States and Economies from 2000 to 2022



Full details of the financial and administrative situation of the BIPM are available in the “Financial Report 2022”

# Metrologia

The leading international journal in pure and applied metrology, *Metrologia*, covers the fundamentals of measurements, particularly those dealing with the seven base units of the International System of Units (metre, kilogram, second, ampere, kelvin, candela, mole) or proposals to replace them.

The journal also publishes papers that contribute to the solution of difficult measurement problems and improve the accuracy of derived units and constants that are of fundamental importance to physics.

A total of 4 250 articles have been published in *Metrologia* since it went online in 2003 and the end of 2022.

Further details about *Metrologia* are available here: <https://iopscience.iop.org/journal/0026-1394>



## Key figures 2022

- Number of received/published manuscripts	333/83
- Number of technical supplement abstracts	85
- Number of published articles in open access	41
- Average time between submission and acceptance, for all revision types (days)	35
- Total number of downloads in 2022 to articles published in 2022	198 790
- Total number of downloads in 2022 to all articles	231 160

## Most-read articles (2022 downloads)

The uncertainty of the half-life, S. Pommé, 2015, <i>Metrologia</i> , <b>52</b> , S51	6 621
Dimensionless units in the SI, P.J. Mohr and W.D. Phillips, 2015, <i>Metrologia</i> , <b>52</b> , 40	3 421
The CODATA 2017 values of $h$ , $e$ , $k$ and $N_A$ for the revision of the SI, D.B. Newell et al, 2018, <i>Metrologia</i> , <b>55</b> , L13	3 073
Amount of substance and the mole in the SI, B. Güttler et al, 2019, <i>Metrologia</i> , <b>56</b> , 044002	2 417



# 27th meeting of the CGPM

## 15-18 November 2022

<https://www.bipm.org/en/cgpm-2022>

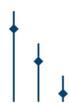
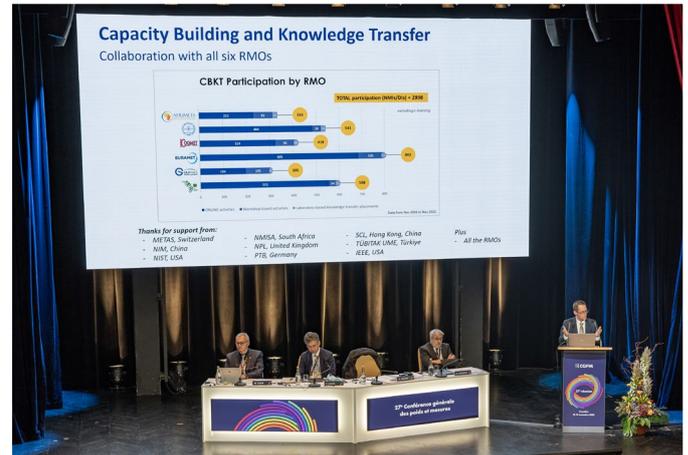


The 27th meeting of the General Conference on Weights and Measures (CGPM) was held at the Palais de Congrès in Versailles. The CGPM was Chaired by Prof. Patrick Flandrin of the *Académie des sciences de Paris* and was opened by M. Thomas Grenon, Director General of the LNE, on behalf of the French Government. Reports were given by the Presidents of the ten Consultative Committees of the CIPM and there was a full programme of presentations by eleven invited speakers. The presentations are available at: <https://www.bipm.org/en/cgpm-2022/documents-talks>

The CGPM adopted seven resolutions at the meeting:

- **Resolution 1:** *On the report prepared by the International Committee for Weights and Measures on the “Evolving Needs in Metrology”*
- **Resolution 2:** *On the global digital transformation and the International System of Units*
- **Resolution 3:** *On the extension of the range of SI prefixes*
- **Resolution 4:** *On the use and future development of UTC*
- **Resolution 5:** *On the future redefinition of the second*
- **Resolution 6:** *On universal adherence to the Metre Convention*
- **Resolution 7:** *On the dotation of the International Bureau of Weights and Measures for the years 2024 to 2027*

Please see the BIPM website for the full text of the resolutions.



# Metrology for Climate Action Workshop

## 26-30 September 2022

<https://www.bipmwmo22.org/>



### Key figures

- 1 078 registered participants
- 200 presentations
- Two themes, nine topics
- 81 identified issues on key technical challenge areas for metrology and related areas
- 126 workshop recommendations ([Metrology for Climate Action report](#)).

### Context and objectives

Metrology can support effective climate change mitigation through measurement-based monitoring to locate, quantify and thereby manage greenhouse gas emissions and removals. It also helps track the efficacy of emission reduction initiatives. The workshop therefore aimed to:

- present progress and identify requirements for further development of advanced measurements, standards, reference data, comparisons and calibrations supporting the physical science basis for and adaptation to climate change
- identify stakeholders' metrology needs, assess current metrological techniques, analyses, and modeling capabilities
- identify gaps in quantifying greenhouse gas emissions and uptake for effective actions on mitigating climate change and its impacts.

### Workshop Themes

1. *Metrology in support of the physical science basis of climate change and climate observations*
2. *Metrology towards operational systems to estimate greenhouse gas emissions based on accurate measurements.*

### Participation and organization

- Hosted by the BIPM and the World Meteorological Organization (WMO), in partnership with EURAMET
- Twelve stakeholder organizations
- Two plenary webinars
- Nine online parallel meetings
- Interactive sessions through the Gather Town platform.

# Organizational structure

## The CIPM (since March 2023)

### President

Dr W. Louw (South Africa)

### Secretary

Dr T. Usuda (Japan)

### Vice-Presidents

Dr J. Olthoff (United States of America)

Dr P. Richard (Switzerland)

### Other CIPM Members

Prof. Dr V.G. Achanta (India)

Dr V. Coleman (Australia)

Dr D. del Campo Maldonado (Spain)

Dr N. Dimarcq (France)

Dr Y. Duan (People's Republic of China)

Dr J.T. Janssen (United Kingdom)

Dr H. Laiz (Argentina)

Dr G. Macdonald (Canada)

Prof. P. Neyezhnikov (Ukraine)

Dr S.-R. Park (Republic of Korea)

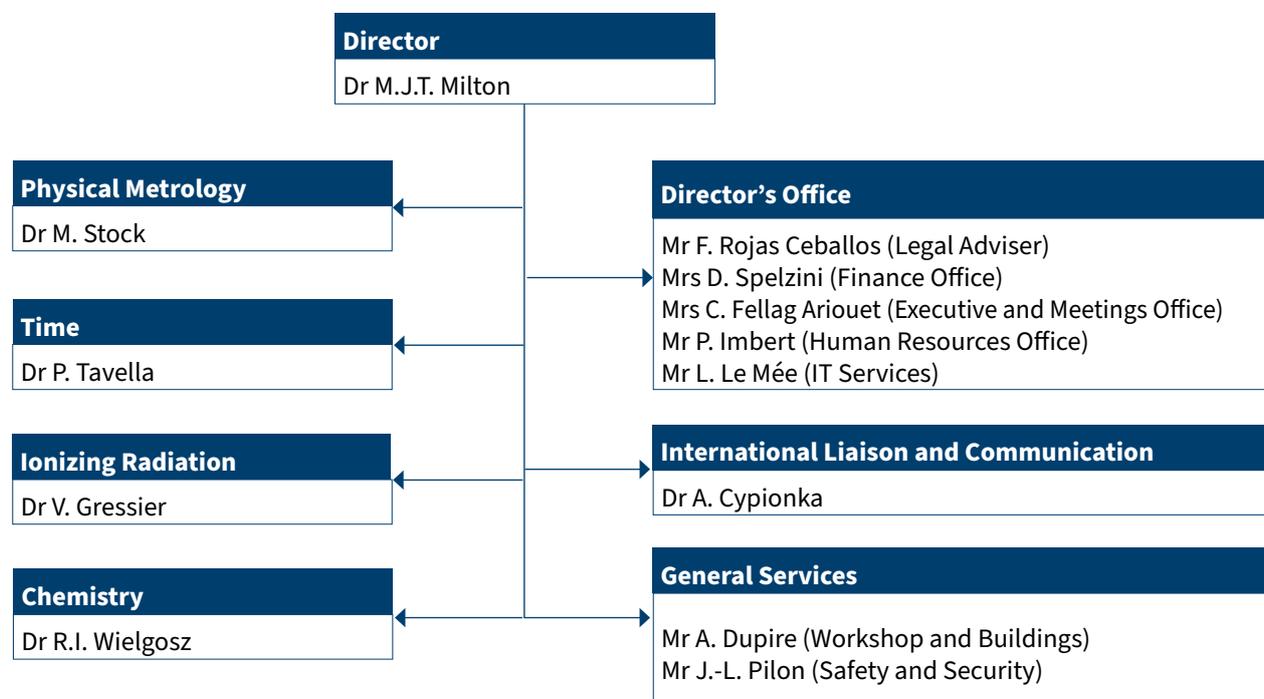
Dr M.L. Rastello (Italy)

Prof. G. Rietveld (Netherlands)

Dr G.P. Ripper (Brazil)

Prof. J. Ullrich (Germany)

## Organigram of Headquarters' Departments and Services (since March 2023)



# Publications

## Physical Metrology

- Final report on the CCM key comparison of kilogram realizations, CCM.M-K8.2021**  
*Metrologia*, 2023, **60**, 07003 <https://doi.org/10.1088/0026-1394/60/1A/07003>  
M. Stock et al
- Report on the BIPM Kibble balance**  
*CPEM 2022 Final Digest*, December 2022  
F. Bielsa, H. Fang, A. Kiss, M. Stock
- A new beam mechanism for the BIPM Kibble balance**  
*CPEM 2022 Final Digest*, December 2022  
F. Bielsa, H. Fang, A. Kiss, M. Stock
- Status of the BIPM Calculable Capacitor Project**  
*CPEM 2022 Final Digest*, December 2022  
P. Gournay, J.A. Moreno
- BIPM on-site Josephson comparison programme: from DC to AC voltages**  
*CPEM 2022 Final Digest*, December 2022  
S. Solve
- Bilateral comparison of 1  $\Omega$  and 10 k $\Omega$  standards between the NPLI (India) and the BIPM**  
*Metrologia*, 2022, **59**, Tech. Suppl., 01010 <https://doi.org/10.1088/0026-1394/59/1A/01010>  
B. Rolland, et al
- Bilateral comparison of 1  $\Omega$  and 10 k $\Omega$  standards between the INMETRO (Brazil) and the BIPM**  
*Metrologia*, 2022, **59**, Tech. Suppl., 01004 <https://doi.org/10.1088/0026-1394/59/1A/01004>  
B. Rolland, M. Stock, P. Gournay, V. Coutinho de Oliveira, H.R. Carvalho, R. Landim
- Bilateral comparison of 1.018 V and 10 V standards between the SMD (Belgium) and the BIPM**  
*Metrologia*, 2022, **59**, Tech. Suppl., 01005 <https://doi.org/10.1088/0026-1394/59/1A/01005>  
S. Solve, R. Chayramy, M. Stock, D. Vlad

## Ionizing Radiation

- Machine-readable data and metadata of international key comparisons in radionuclide metrology**  
*Meas. Sci. Technol.*, 2023, <https://doi.org/10.1088/1361-6501/accd0b>  
R. Coulon, F. Grasso Toro, C. Michotte
- Test of a digitizer to process the pulse signal from the 3 photomultiplier tubes of a TDCR liquid scintillation counter**  
*Appl. Radiat. Isotopes*, 2023, <https://doi.org/10.1016/j.apradiso.2022.110598>  
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- Traceability for nuclear medicine: the status of primary radioactivity standards**  
*Metrologia*, 2023, <https://doi.org/10.1088/1681-7575/aca67a>  
S.M. Judge, R.M. Coulon, M.G. Cox, L. Karam, P. Knoll, C. Michotte, Z. Msimang, B.E. Zimmerman
- The new international reference system for pure  $\alpha$ - and pure  $\beta$ -emitting radionuclides and some electron capture decaying radionuclides by liquid scintillation counting**  
*J. Radioanal. Nucl. Ch.*, 2022, <https://doi.org/10.1007/s10967-022-08337-7>  
R. Coulon, R. Broda, P. Cassette, S. Courte, A. Dupire, S. Jerome, S. Judge, K. Kossert, H. Liu, C. Michotte et al
- Stop squandering data: make units of measurement machine-readable**  
*Nature*, 2022, <https://doi.org/10.1038/d41586-022-01233-w>  
R. Hanisch, S. Chalk, R. Coulon, S. Cox, S. Emmerson, F. J. Flamenco Sandoval, A. Forbes, J. Frey, B. Hall, R. Hartshorn, P. Heus, S. Hodson, K. Hosaka, D. Hutzschenreuter, C.-S. Kang, S. Picard, R. White
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- Minimum requirements for publishing hydrogen, carbon, nitrogen, oxygen and sulfur stable-isotope delta results (IUPAC Technical Report)**  
*Pure Appl. Chem.*, 2022, <https://doi.org/10.1515/pac-2021-1108>  
G. Skrzypek, et al
- Upgrade of the electronics modules of the BIPM Standard Reference Photometers for ozone and the effect on the on-going key comparison BIPM.QM-K1**  
*Rapport BIPM-2022/01*  
J. Viallon, M. Nonis, P. Moussay, F. Idrees, R.I. Wielgosz
- Final report, ongoing key comparison BIPM. QM-K1, ozone at ambient level, comparison with DMDM, September 2022**  
*Metrologia*, **60**, Tech. Suppl., 08003 <https://doi.org/10.1088/0026-1394/60/1A/08003>  
J. Viallon, F. Idrees, P. Moussay, R. Wielgosz, J. Bebic
- Final report, ongoing key comparison BIPM. QM-K1, ozone at ambient level, comparison with INRIM, February 2022**  
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J. Viallon, F. Idrees, P. Moussay, R. Wielgosz, L. Revel, M. Zucco
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J. Viallon, F. Idrees, P. Moussay, R. Wielgosz, M. Vokoun
- Units and values for the ozone absorption cross section at 253.65 nm (air) with appropriate significant digits and rounding for use in documentary standards**  
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R.S. Davis, B. Niederhauser, J. Hodges, J. Viallon, R.I. Wielgosz
- An SI-traceable reference material for virus-like particles**  
*iScience* **25** (5), 104294 <https://doi.org/10.1016/j.isci.2022.104294>  
A. Briones, G. Martos, M. Bedu, T. Choteau, R.D. Josephs, R.I. Wielgosz
- Key comparison study on peptide purity-glycated hexapeptide of HbA1c**  
*Metrologia*, **59**, Tech. Suppl., 08006 <https://doi.org/10.1088/0026-1394/59/1A/08006>  
R.D. Josephs, Q. Liu, G. Martos, M. Bedu, A. Daireaoux, T. Choteau
- Pilot study on peptide purity-glycated hexapeptide of HbA1c**  
*Metrologia*, **59**, Tech. Suppl., 08007 <https://doi.org/10.1088/0026-1394/59/1A/08007>  
R.D. Josephs, Q. Liu, G. Martos, M. Bedu, A. Daireaoux, T. Choteau
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*Metrologia*, **59**, Tech. Suppl., 08013 <https://doi.org/10.1088/0026-1394/59/1A/08013>  
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- Pilot study on peptide purity-hexapeptide of HbA0**  
*Metrologia*, **59**, Tech. Suppl., 08014 <https://doi.org/10.1088/0026-1394/59/1A/08014>  
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*Clin. Chem. Lab. Med. (CCLM)*, **61**, (1), 48-54 <https://doi.org/10.1515/cclm-2022-0943>  
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- [BIPM PEG-03] - Purity Evaluation Guideline: Deoxynivalenol (DON)**  
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S. Westwood, R. Josephs, G. Martos, T. Choteau, X. Li, I. Ün, L. Santos
- [BIPM PEG-04] - Purity Evaluation Guideline: Patulin (PAT)**  
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S. Westwood, R. Josephs, G. Martos, T. Choteau, Y. Gao, I. Ün, T. Gökçen, L. Santos
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## Time

31. **Automatic jump detection in time transfer link for the calculation of UTC**  
Presentation at the URSI AT-AP-RASC 2022, Gran Canaria  
Baudiquez A., Panfilo G.
32. **Comparison of primary and secondary frequency standards used for TAI**  
Presentation at the URSI AT-AP-RASC 2022, Gran Canaria  
Petit G., Panfilo G.
33. **Continuous IPPP links for UTC**  
Presentation at the URSI AT-AP-RASC 2022, Gran Canaria  
Petit G., Meynadier F., Harmegnies A., Parra C.
34. **Machine-readable data within the context of disseminating the Coordinated Universal Time (UTC)**  
Presentation at the SCIDatacon 2022  
Meynadier F.
35. **A new way to set the maximum weight in the weighting algorithm of UTC**  
Presentation at the EFTF/IFCS 2022, Paris  
Milton J., Panfilo G.
36. **Current activity of the CCTF to address the needs of time and frequency metrology and its applications**  
Presentation at the EFTF/IFCS 2022, Paris  
Dimarcq N., Tavella P.
37. **Understanding TWSTFT Diurnals**  
Presentation at the EFTF/IFCS 2022, Paris  
Meynadier F.
38. **Continuous IPPP links for UTC**  
Presentation at the EFTF/IFCS 2022, Paris  
Petit G., Meynadier F., Harmegnies A., Parra C.
39. **Temps universel ou temps international ?**  
Presentation at the meeting “Phénoménotechique du temps”, Besançon, 2022  
Panfilo G.
40. **Time metrology and the redefinition of the second: Some present and future challenges**  
Platinum Jubilee CSIR-NPL 4 January 2022  
Petit G.
41. **Ambiguity fixing on geometry free like model using modernized GNSS signals**  
EGU General Assembly 2022, Vienna, Austria, 23–27, <https://meetingorganizer.copernicus.org/EGU22/EGU22-4881.html>  
Tagliaferro G.
42. **Task force on the Redefinition of the Second / Subgroup A: Impact on users and stimulus for the redefinition**  
Presented at the EFTF/IFCS 2022, Paris  
Gertsvoif M., Mileti G., Meynadier F., et al
43. **Current activities of CCTF to update the roadmap for a redefinition of the second: Options for the redefinition**  
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Bize S., Peik E., Oates C., Petit G.
44. **Time and Frequency Dissemination and Time Scales, Task Force on the Roadmap for the Redefinition of Second**  
Presented at the EFTF/IFCS 2022, Paris  
Calonico D., Ido T., Panfilo G.
45. **A new way to set the maximum weight in the weighting algorithm of UTC**  
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Milton J., Panfilo G.
46. **The maximum weight in UTC: proposal for a new approach**  
Submitted to IEEE UFFC Trans, 2023  
Milton J., Panfilo G.
47. **A three-cornered hat analysis of instabilities in two-way and GPS carrier phase time transfer systems**  
*Metrologia*, 2022, **59**, 035007  
Parker T.E., Zhang V., Petit G., Yao J., Brown R.C., Hanssen J.L.
48. **Towards a consensus on a continuous coordinated universal time**  
*Metrologia*, 2023, **60**, 014001 <https://doi.org/10.1088/1681-7575/ac9da5>  
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*Metrologia*, 2022, **59**, 045007 <https://doi.org/10.1088/1681-7575/ac7687>  
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54. <https://www.itu.int/en/ITU-R/conferences/wrc/2023/irwsp/Pages/2022.aspx>
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56. [https://www.itu.int/en/ituNews/Documents/2023/2023-02/2023\\_ITUNews02-en.pdf](https://www.itu.int/en/ituNews/Documents/2023/2023-02/2023_ITUNews02-en.pdf)

## Miscellaneous

57. **News from the BIPM laboratories**  
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Gressier V., Wielgosz R.I., Stock M., Tavella P., Milton M.J.T.
58. **A digital framework for realising the SI—a proposal for the metre**  
*Metrologia*, 2022, **59**, 044004 <https://doi.org/10.1088/1681-7575/ac7fce>  
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59. **Henri Fayol, Charles-Édouard Guillaume et Pierre Chevenard : un Industriel, un Physicien et un Ingénieur à l'origine d'une nouvelle métallurgie**  
*Le Marteau Pilon*, Tome XXXIV, juillet 2022 (2022)  
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Wielgosz R., Forgan B., del Campo Maldonado D., Rea A., Woolliams E., Fulford J., Madonna F., Whetstone J.R., DeCola P., Vermeulen A., Flores E., Ruedi I.

# World Metrology Day



Measurements supporting  
the global food system



**20 May 2023**  
[www.worldmetrologyday.org](http://www.worldmetrologyday.org)

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