Annual Review: Supplement

Activities of the BIPM Departments

1 January 2024 – 31 December 2024

Bureau International des Poids et Mesures

Work Programme (2024 - 2027)

Contents

This report is published annually and covers the calendar year.

Key achievements *(1 January 2024 – 31 December 2024)*

The Work Programme for 2024-2027 is described in terms of 9 major activities, including 82 projects and 145 tasks (deliverables) for the BIPM Headquarters. Some of the key activities during the reporting period are highlighted below:

LABORATORY WORK CARRIED OUT BY THE BIPM

- **Physical Metrology**
  - Successful pilot study with NIST and KRISS confirming the suitability of the differential sampling technique for a new comparison of Josephson voltage standards at ac (up to 1 kHz) at uncertainty levels of 10^8 to 10^7.
  - Provision of a magnetic circuit for a table-top Kibble balance through a joint technical cooperation with Tsinghua University.
- **Time Metrology**
  - Update in the BIPM Circular T with new treatment of the time transfer uncertainty and inclusion of Galileo and Beidou in the evaluation of the prediction of UTC broadcast by GNSS.
  - Starting the CCTF CBKT program with the development of e-Learning module and interactive software for the processing of time and frequency data.
- **Chemical Metrology**
  - 1st qNMR Summer School held at the BIPM and accompanying eLearning course developed
  - Methods developed for the purity assignment of the SARS-CoV-2 monoclonal antibody CCQM-P216 published in peer reviewed journal
  - New on-going comparison of CO_2 in air standards (BIPM.QM-K2) launched
- **Ionizing Radiation Metrology**
  - Finalization of the characterization of the medium-energy x-ray facility
  - Setting-up of ionization chambers for the new SIR (SIR 2.0)
  - Start of the ESIR service (BIPM.RI(II)-K5 comparisons)
  - Production of long term BIPM IR department strategy report for the CIPM

INTERNATIONAL LIAISON

- A joint BIPM-OECD workshop *"Building Stronger Connections Between Quality Infrastructure and Regulation"* was successfully organized at the BIPM (in person and online).
- The World Metrology Day 2024 launch event *"We Measure Today for a Sustainable Tomorrow"* was successfully organized at the UNESCO headquarters, in partnership with the BIPM and the OIML, to mark the official recognition by UNESCO of 20 May each year as a UNESCO International Day.

COORDINATION

- A report summarizing the visionary ideas of young metrologists has been published. It is based on an online questionnaire (over 170 questionnaire responses), online workshops in six RMOs with the participation of 380 young metrologists and a consolidation meeting with the 11 RMO coordinators.

CAPACITY BUILDING AND KNOWLEDGE TRANSFER

- A joint BIPM and OIML e-learning course consisting of 5 Modules was launched on the BIPM e-learning platform in July 2024. The course is based on the BIPM and OIML joint publication – *"National Metrology Systems - Developing the Institutional and Legislative Framework"*.

COMMUNICATION AND PROMOTION

- The poster for 2024 was designed by Tübitak UME (Türkiye) in collaboration with EURAMET. The 54 national and RMO posters, and details of 37 national events were published on the website.

DIGITAL TRANSFORMATION AND NEW DIGITAL SERVICES

- Three new services have been released for beta-testing: the SI Reference Point, a reference for Service Categories in Physics and Ionizing Radiation, and a reference point for Nuclides. The knowledge bases underlying these references can be interrogated directly by machines, and an application programming interface is provided for the use of programmers and to generate the web interface.

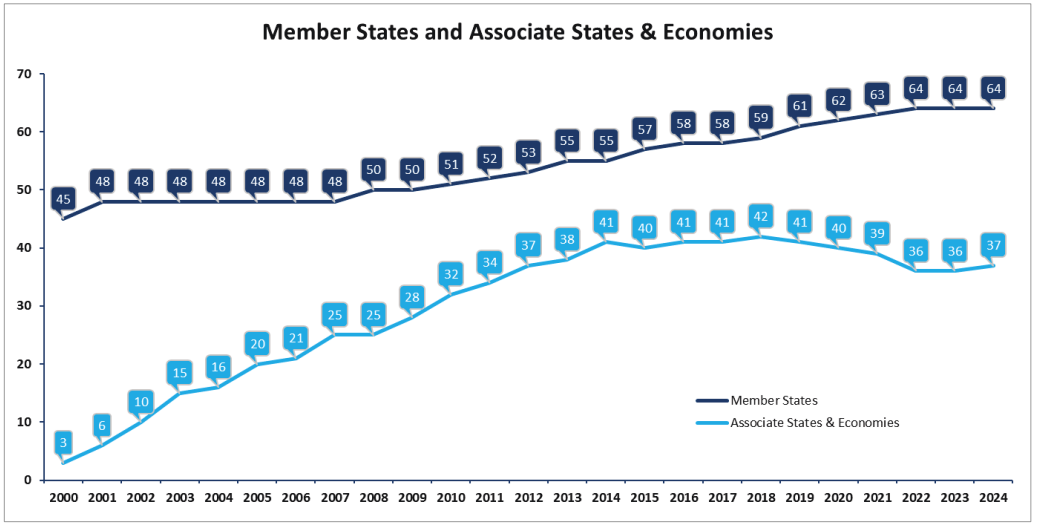
Key figures *(as of 31 December 2024)*

- Member States and Associates

– 64 Member States* and

– 37 Associates of the CGPM
(States and Economies)

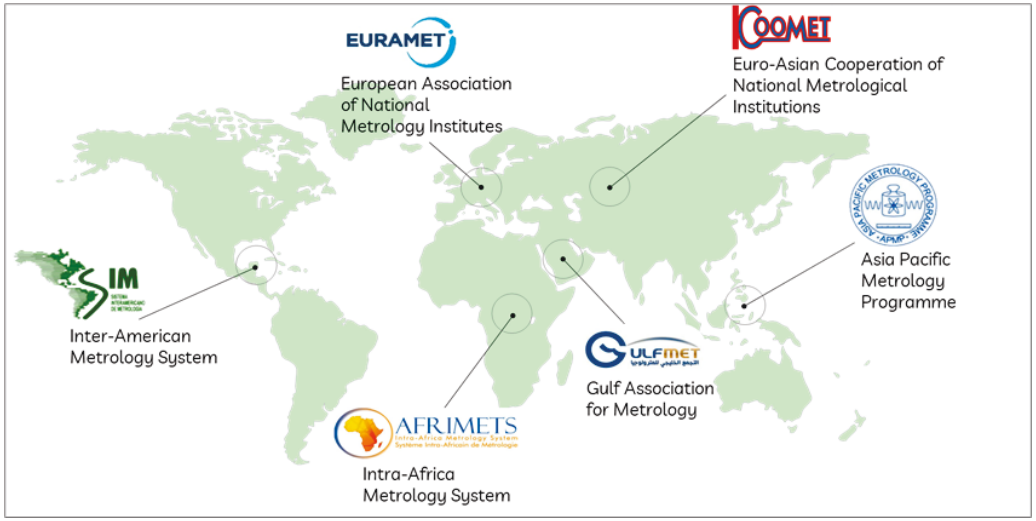
**The official term is "States Parties to the Metre Convention"; the term "Member States" is its synonym and used for easy reference.*



- KCDB data

<u>251 institutes in the CIPM MRA</u>
The CIPM MRA has been signed by representatives of institutes from:
- 64 Member States
- 37 Associates States of the CGPM, and
- 4 international organizations

and covers a further 150 institutes designated by the signatory bodies.



1 932 comparisons 1215 KCs, 717 SCs	26 124 CMCs Peer-reviewed declarations

I	**Physical Metrology**	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
1. PMD-E1: INTERNATIONAL REFERENCE STANDARD FOR VOLTAGE		
E1.1: Bilateral on-site comparisons of Josephson voltage standards (JVSs) *NMI Participations: 7 (comparisons)*	Direct comparison of JVSs at dc and/or ac using the BIPM transportable JVSs to obtain the lowest possible uncertainty 1. Bilateral on-site comparisons at dc and/or ac as part of BIPM.EM-K10.a/b with relative uncertainty of 1×10^{-10} at dc and less than 1×10^{-7} at ac. 2. Maintenance of the transportable Josephson voltage standards, supporting also bilateral comparisons of Zener voltage standards (E1.2) and calibrations of Zener voltage standards for NMIs (E1.3).	• Two pilot studies were carried out in preparation of on-site Josephson voltage comparisons at ac, one with the PTB (Germany) at the BIPM and one with NIST (USA) and KRISS (Rep. of Korea) at the NIST. • During the latter, the BIPM programmable JVS was successfully compared with a NIST Josephson arbitrary waveform generator, confirming the suitability of the differential sampling technique for the new comparison (up to 1 kHz) at uncertainty levels of 10^8 to 10^7. • For the pilot study at NIST, a new probe was designed to mount a 2 V Josephson standard provided by NIST. The ensemble was successfully tested in dc and ac voltages. • The first two key comparisons with ac measurements are being planned for 2025 with PTB (Germany) and CENAM (Mexico). • A new bias source was implemented for the BIPM Josephson transportable system giving more flexibility to the standard. • The primary voltage standard of the BIPM Kibble balance was validated by a direct comparison with the BIPM transportable Josephson standard within 5×10^{-9} at 1 V.
E1.2: Bilateral voltage comparisons using Zener diode transfer standards *NMI Participations: 8 (comparisons)*	For NMIs not possessing JVSs, and as a first step before an on-site comparison of JVSs (E1.1) 1. Bilateral comparisons of Zener voltage standards as part of BIPM.EM-K11.a/b with relative uncertainty of 5×10^{-8}. 2. Participation in related RMO comparisons to link them to BIPM.EM-K11. 3. Maintenance of the BIPM secondary voltage standards (Zeners), also supporting the calibration of Zener voltage standards for NMIs (E1.3).	• Finalization of BIPM.EM-K11 comparisons with SASO (Saudi Arabia) and INRIM (Italy). • Organization of a BIPM.EM-K11 comparison with NSAI (Ireland). • Launch of BIPM.EM-K11 comparisons with EMI (UAE) and SMD (Belgium). • The BIPM Zener secondary voltage standards operated for BIPM.EM-K11 were maintained traceable to the BIPM primary voltage standard.
E1.3: Calibrations of Zener diode secondary standards *NMI Participations: 12 (calibrations)*	For NMIs not possessing a primary voltage standard, as for most of the new Member States, using measurement systems already in place for comparison activities 1. Calibration of Zener diode secondary standards for NMIs without a primary realization and for	• Four Zener voltage standards calibrated for SMU (Slovakia), KEBS (Kenya) and GUM (Poland).

I	**Physical Metrology**	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
	internal customers (Ionizing Radiation Dept. and Kibble balance).	
2. PMD-E2: INTERNATIONAL REFERENCE STANDARD FOR RESISTANCE		
E2.1: Bilateral on-site comparisons of quantum Hall resistance (QHR) standards *NMI Participations: 6 (comparisons)*	Direct comparison of QHR standards using the BIPM transportable standard, to obtain the lowest possible uncertainty 1. Bilateral on-site comparisons of quantum Hall standards (including new graphene samples) as part of BIPM.EM-K12 with relative uncertainty of 1×10^{-9}. 2. Providing the basis for the realization of the capacitance unit farad (E3). 3. Maintenance of the transportable standard and related measurement chain, also supporting bilateral resistance comparisons using resistance transfer standards (E2.2) and calibrations of secondary standards for NMIs (E2.3).	• Two BIPM.EM-K12 comparisons planned this year with LNE (France) and INRIM (Italy) have been postponed upon their request. • BIPM.EM-K12 comparisons for 2025 are currently being planned. A comparison with PTB (Germany) is planned for end of March 2025. Discussions with CEM (Spain) and NPL (UK) are ongoing. • Design of the mechanical and electronic components for the fabrication of a new 1 Hz bridge for the comparison of resistance standards. Fabrication of these parts is in progress and the assembly is expected to start soon. • First tests of a new cryogenic current comparator (CCC) designed and assembled in 2023 gave encouraging results, showing that the new CCC performs at least as good as the old one. Spare CCC windings are planned to be wound soon in collaboration with LNE. • A new QHR probe for dc-QHR, intended to replace an old one has been designed. The mechanical parts have been fabricated and the assembly is about to begin. • Installation of a helium liquefier for impedance and voltage service activities.
E2.2: Bilateral resistance comparisons using resistance transfer standards *NMI Participations: 8 (comparisons)*	As a first step before an on-site comparison and for NMIs not possessing a QHR standard 1. Bilateral comparisons of resistance transfer standards as part of BIPM.EM-K13.a/b with relative uncertainty of 5×10^{-8}. 2. Participation in related RMO comparisons to link them to BIPM.EM-K13. 3. Maintenance of BIPM secondary resistance standards and related measurement chain, also for the calibration of resistance secondary standards for NMIs (E2.3).	• The calibration of the BIPM resistance reference base from a QHR standard was carried out twice, in January and July. This reference is the basis for the calibration of resistance working standards and for the realization of the farad from the ohm (E3.1). • Regular maintenance of the measurement bridges. • A BIPM.EM-K13.a/b comparison with TÜBITAK UME (Türkiye) started in late 2024.
E2.3: Calibrations of resistance secondary standards	For NMIs that do not possess a primary resistance standard, as for most of the new Member States, using measurement systems already in place for comparisons	• 19 resistance standards calibrated for 3 NMIs: BFKH (Hungary), NIMT (Thailand) and SMU (Slovakia). • 5 internal certificates (for Masse, Voltage and Ionizing Radiation services). • Maintenance of the quality system associated with resistance services.

I	**Physical Metrology**	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
NMI Participations: 40 (calibrations)	1. Calibration of resistance secondary standards for NMIs without primary realizations and for internal customers (Mass, Ionizing Radiation, Kibble balance).	
E2.4: Development of a graphene-based QHR standard	For a more compact and economic QHR standard, operating at higher temperature (5 K) and lower magnetic field (< 5 T) 1. Development of a QHR standard based on a graphene sample, replacing the GaAs QHR standard to simplify QHR implementation during on-site comparison and to reduce costs.	• One of the two epitaxial graphene based QHR standards (with F4-TCNQ molecular doping) provided by PTB has been regularly tested to evaluate its long-term stability. Unlike PTB, which stores this type of standard in nitrogen between uses, the BIPM keeps it in air under controlled ambient conditions: constant temperature of 23 °C and relative humidity ≤15 %. So far, a decrease of the carrier density is observed but the comparison with a GaAs reference device remains within less than 2 nΩ/Ω. This graphene-based QHR standard will continue to be monitored over the coming year.
3. PMD-E3: INTERNATIONAL REFERENCE STANDARD FOR CAPACITANCE		
E3.1: Bilateral capacitance comparisons using capacitance transfer standards *NMI Participations: 4 (comparisons)*	For NMIs wishing to demonstrate their capabilities in capacitance calibrations 1. Bilateral comparisons of capacitance transfer standards as part of BIPM.EM-K14.a/b with relative uncertainty of 5×10^{-8}. 2. Maintenance of the measurement systems to derive the capacitance unit from the quantum Hall effect and/or the calculable capacitor, also supporting the calibrations of capacitance secondary standards (E3.2).	• Two realizations of the farad from the ohm in February and July 2024 to ensure the traceability of the capacitance reference base used for services. • Characterization of the frequency coefficient of two resistors used in the quadrature bridge. • Monthly measurements for the surveillance of the capacitance bank of 10 pF capacitors. • Maintenance of measuring bridges and standards used for capacitance services and repair of a temperature controlled oil bath for capacitance standards. • Participation in the pilot group of the next EURAMET-K4 comparison intended to start in the first part of 2025. • Related to the coming EURAMET-K4 comparison, characterization of the capacitance change of AH-type standard capacitors submitted to thermal and electromagnetic disturbances in their near vicinity. • A BIPM.EM-K14.a/b comparison with CENAM started in late 2024.
E3.2: Calibrations of capacitance secondary standards *NMI Participations: 40 (calibrations)*	For NMIs that do not possess a primary capacitance standard, as for most of the new Member States 1. Calibrations of capacitance secondary standards for NMIs without primary realizations.	• 29 capacitance standards calibrated for 8 NMIs: BFKH (Hungary), INMETRO (Brazil), NIMT (Thailand), NMIM (Malaysia), CMI (Czech Republic), CEM (Spain), VSL (Netherlands) and SMU (Slovakia).
E3.3: Development of the ac quantum Hall	To develop a primary method to realize ac impedances according to the revised SI	• No work during this period.

I	**Physical Metrology**	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
effect into an impedance standard	1. Development of the ac quantum Hall effect into an operational primary standard of impedance, to reduce the uncertainty of the realization of the capacitance unit. 2. Direct comparison of the ac quantum Hall effect and the calculable capacitor, for verification of the validity of the equation for the von Klitzing constant at the 10^{-9} level, supporting the *mise en pratique* for the electrical units.	
4. **PMD-M1: MASS DISSEMINATION**		
M1.1: Calibration of 1 kg national Pt-Ir prototypes and stainless steel mass standards *NMI Participations: 32 (calibrations)*	1. Calibration of existing 1 kg national Pt-Ir prototypes in air or under vacuum. 2. Calibration of 1 kg stainless steel national mass standards, including volume and centre-of-gravity determination, if requested. 3. Monitoring of the mass evolution of the BIPM working standards. Providing stable linkage between successive key comparisons (M1.3) to allow the calculation of the consensus value. 4. Calibration of pressure gauges, as an internal service necessary to support mass calibrations at the required uncertainty, and for other BIPM departments (Chemistry, Ionizing Radiation).	• Completed two mass calibration campaigns with the calibration of five prototypes and 12 stainless steel mass standards for 11 NMIs. • One volume and three centre-of-mass determinations of mass standards from NMIs. • A bilateral comparison of measurements of centre-of-mass was carried out with NPL (UK). • Monitoring the evolution of the mass of the BIPM working standards for limited use using those for exceptional use (done every 5 years). Cleaning and washing of the standards for exceptional use. • Establishment of the link of working standards for current use with those for limited use in March 2024. • Executed three internal pressure campaigns for the mass, electricity and chemistry laboratories (15 certificates).
M1.2: Provision of 1 kg Pt-Ir prototypes *Fabrication for: 2 NMIs*	1. Fabrication in the BIPM workshop of 1 kg Pt-Ir prototypes for Member States. 2. Calibration of new 1 kg Pt-Ir prototypes including volume determination.	• Quotation provided to an NMI for the fabrication of a Pt-Ir prototype and a stack consisting of eight disks.
M1.3: Organization of two CCM key comparisons of kilogram realizations	1. Organization of two key comparisons of kilogram realizations with Kibble balances, joule balances and the XRCD method, CCM.M-K8. 2. Calculation of a new consensus value after each comparison.	• Launch of the third key comparison of kilogram realizations (CCM.M-K8.2024), technical protocol approved, list of participants established, comparison measurements at BIPM planned for early 2025.

I	**Physical Metrology**	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
NMI Participations: 18 (comparisons); plus stainless steel mass comparison participation 16 NMIs		
5. PMD-M2: KIBBLE BALANCE Developing and maintaining the Kibble balance. International reference facility for realization of the new definition of the kilogram on a long-term cost-shared basis		
M2.1:	1. Evaluate the performance improvement to the Kibble balance by use of an equal-arm balance mechanism in order to reach a target uncertainty of 2×10^{-8} at the 1 kg level (see also new application for this technology in M2.5).	• A refined mechanism, based on an equal-arm single-pan beam, was installed, aligned and characterized on a test bench in air. • Static measurements confirmed the results obtained with the first prototype of a double-pan beam. As expected, an improved behaviour was achieved in the velocity phase. Parasitic coil translation was effectively corrected. No unwanted oscillation of the counterweight was observed. There was room for optimizing the beam behaviour by adjustment which was not possible with the previous double-pan device.
M2.2:	1. Maintain and refine operation of the BIPM Kibble balance on the established design to sustain "turn-key" performance as an international reference facility for realization of the new definition of the kilogram at 5×10^{-8} and as the platform for the improved equal-arm balance design (see M2.1).	• A member of the Kibble balance team, Dr Franck Bielsa, was on secondment for five months at the NIST Kibble balance team. He had extended technical exchanges with the members of the NIST Kibble balance group about the operation of the NIST4 Kibble balance and contributed to the development of the NIST new quantum electro-mechanical metrology suite (QEMMS).
M2.3:	1. Contribute the results of an independent Kibble balance determination to the biennial comparison of realizations of the kilogram (CCM.M-K8) and host the meeting of the international Kibble balance collaboration of NMIs on one occasion during the period of the work programme.	• Preparations for participating in the next key comparison of kilogram realizations (CCM.M-K8.2024) were started in September.

I	**Physical Metrology**	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
M2.4:	1. Determine the gravitational acceleration in the Kibble balance laboratory in collaboration with NMIs. This will require absolute gravimeter(s) to be brought to the BIPM from NMIs that have successfully participated in the most recent comparison of absolute gravimeters, CCM.G-K2.XXXX. To verify the stability of the spatial gravity gradient in the laboratory; the replacement of the relative gravimeter is planned.	• The study investigating the possibility of linking the absolute gravitational acceleration values between BIPM and LNE using a relative gravimeter was continued. A second run using a CG5 relative gravimeter was carried out in March 2024. These measurements were limited by the repeatability and tilt sensitivity of the CG5 device. Another run was carried out in autumn using a CG6 relative gravimeter which is much more repeatable and less sensitive to tilt.
M2.5:	1. Design and construct a prototype apparatus that implements the equal-arm balance (see M2.1) design as the basis for a compact Kibble balance for use at masses of 500 g and below. (For planned CBKT activities see PMD-CBKT2).	• The first design of some main elements of a compact Kibble balance was carried out. • The gravimetry concrete block located in the Kibble balance laboratory was chosen to accommodate the future compact BIPM Kibble balance. Measurements were carried out to evaluate the vibration isolation of the block. • A simple, low-cost and high-precision home-made voltmeter was designed and fabricated. First characterization showed a noise level comparable to that of the commercial DVM presently used in the Kibble balance apparatus. • A compact closed magnetic circuit was provided by Tsinghua University (China) in the framework of a joint technical cooperation between the BIPM and Tsinghua University. The uniformity of the magnetic field produced by the circuit was successfully measured using a home-made gradient coil.

II	Time Metrology	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
1. TIME-U1: GENERATION OF TAI/UTC, STABLE AND ACCURATE INTERNATIONAL REFERENCES		
U1.1: Computation of UTC, UTC_r, TT, and KC for Time and Frequency transfer *Participating laboratories in UTC: 83 (2022), 86 (2024)* *Participating laboratories in UTC_r: 58 (2022), 63 (2024)*	*Monthly* provision of the international reference time scale UTC, through the computation of International Atomic Time, and the distribution and publication of all the related reference data, continuously improving the metrological quality. The results giving the differences between UTC and the local real time realizations UTC(*k*) of the contributing laboratories are published in the monthly BIPM *Circular T*. Data are also provided to the KCDB for the key comparison CCTF-K001.UTC. The process to obtain UTC and its validation is part of the BIPM Quality System. *Weekly* provision of a rapid solution called UTC_r computed and published on Wednesdays on a subset of UTC laboratories sending data daily. *Annual* provision of the Terrestrial Time, TTBIPM, with optimized long-term accuracy, *a posteriori*, for the studies requiring the best performance over the long term.	• The monthly UTC and the weekly rapid UTC computation have been processed and published regularly. Some new laboratories have joined UTC and UTCr. A new automatic plot allows to visualize the number of participating laboratories, https://webtai.bipm.org/database/participant.html • The KCDB has been updated monthly, accordingly. • The Terrestrial Time 2023 has been computed and published. • The *Circular T* was renewed with two important improvements: 1. The uncertainty of the time transfer links is able to correctly treat the Not calibrated equipment which appear as NC in the sec 5 of the Circular T 2. The sec 4 reporting the offset of the UTC predictions broadcast by GNSS has been complemented by the evaluation for the European system Galileo and the Chinese one Beidou, together with the previously published values for GPS and GLONASS. • Following the QMS survey on customer satisfaction, a new web page with tutorials and explanation on the circular T have been added. • The need of CBKT for the UTC labs, large or small, is more and more evident and the dept is engaged, with the support of a secondee, to develop training tools and interactive software for the time and frequency data processing. • The Department is deeply involved in the CCTF project to transform UTC into a continuous time scale by enlarging the tolerance UT1-UTC. Several presentations and CCTF internal documents have been prepared. *Publications and presentations:* – G Petit and G Panfilo, "Discussion on the calculation of the uncertainties of [UTC-UTC(k)]", 2024 Metrologia, Volume 61, Number 4 – P. Tavella, A. Harmegnies, F. Meynadier, G. Panfilo, G.Tagliaferro, L. Tisserand, A. Baudiquez, F. Collini, B. Vattikonda, M. Gruber, "News from the BIPM time department on the realization of the Coordinated Universal Time and support to the CCTF", presented at the ION PTTI meeting, Jan 2024, Long Beach USA – P Defraigne et al., Monitoring of the offset between UTC and its prediction broadcast by the GNSS"", 2023 Metrologia 60 065010 DOI 10.1088/1681-7575/ad0562 – P. Tavella, J. Levine, "Towards a continuous UTC", presented at the European Frequency and Time Forum (EFTF), 2024

II	Time Metrology	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
		Guest collaborating to the different dept activities. The Department has guest for collaboration on different scientific and CBKT activity, as well as journalists and writers interested in UTC and timekeeping: – Tara Fortier September 2024 – August 2025 – Yuko Hanado 17 April – 10 July 2024 – Bharat Vattikonda Oct. 23 - Sept. 24, with a contribution from the IEEE UFFC Society – Francesca Collini, consultant, October 2023 - September 2024 – Arianna Abis, student, November 2023 – March 2024 – Enrico Bibbona 19-20 February 2024 – Freya Berry, English writer 28-29 February 2024 – Nate Hopper, US journalist 12-13 March 2024
U1.2: Development and optimization of the algorithms and tools for UTC and other time product computation	The algorithms developed, maintained, and continuously improved by the Time Department are devoted to: – the ensemble time scale formation, – the accurate processing of the time and frequency transfer measures, – the steering by the use of primary and secondary frequency standards. The main goals for the development are related to the jump detection, link comparison and switching, redundant and multi-constellation GNSS time transfer, with optimal processing of GNSS phase measurements, as well as optimization of the individual clock statistical model. The use of a GIT(*) laboratory capability will be consolidated within the CCTF-WGTWSTFT for collaborative work on the SDR software development and validation. A similar tool will be used for the CBKT programme. The experience on time transfer based on optical fibres, their calibration, and comparison with other time transfer techniques will be consolidated.	• The dept. research activity is mostly in developing and using algorithms for data processing for the benefit of UTC and related products. • A new algorithm for detecting jump in the time transfer link, based on the Kalman filter has been developed. • Concerning the GNSS time transfer links, several tests and developments are in progress to adapt the Integer Precise Point Positioning (IPPP) to time transfer based on the different GNSS network solution software currently available from the geodesy community. • The IPPP solutions are compared to the existing optical fibre network for validation. • The Time Department has been solicited to work on the definition of a Lunar time and its possible comparison with UTC. The initial phase is mostly devoted to the study the relativistic framework and the possible collaboration with other int organizations. The Department has contributed to the organization of an international workshop on Lunar PNT (Positioning, Navigation, and Timing) together with the main world space agencies, contributing on the Moon reference time discussion on behalf of the CCTF task group recently created on this topic. • The department's IT system has been improved with the creation of a network of virtual machines with automatic back up *Publications and presentations:* – A.Baudiquez and G. Panfilo, "Automatic Detection of Anomalies in Post-Processed Data Applied to UTC Time Transfer Links", IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, vol. 71, no. 9, pp. 1162-1169, Sept. 2024

II	Time Metrology	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
	The contribution of a secondee would be fundamental to ensure the necessary progress of all these activities. The continuous improvement of UTC, UTCr, and related products is also based on the development of appropriate software tools, ensuring reliability of the available computational resources. To this aim the main goals are: – further automation of the computation system to augment the automatic checks on input and output data to improve the reliability of the results, – Use of a redundant and secure ensemble of servers based on virtualization technology, – Use of a database structure for the time transfer and calibration data to provide machine readable access to the results to the contributing NMIs. **GIT is a free and open-source distributed version control system*	– Antoine Baudiquez, Pascale Defraigne, Marina Gertsvolf, Jiang Guo, Bin Jian, Frédéric Meynadier, Giulio Tagliaferro," A Comparison of IPPP GNSS Solutions for Time and Frequency Transfer", presented at the European Frequency and Time Forum (EFTF), 2024. – Giulio Tagliaferro, Pascale Defraigne, "The Use of GNSS and IGS Products for UTC Computation: Past, Present and Future" IGS 2024 Workshop – G. Tagliaferro, "Towards Operational Ready Multi-Constellation PPP/IPPP Links for UTC Computation," presented at the ION PTTI meeting, Jan 2024, Long Beach USA – Antoine Baudiquez, Pascale Defraigne, Erik Dierikx ;Marina Gertsvolf, Jiang Guo, Bin Jian, Frederic Meynadier, Cedric Plantard, Bernardino Quaranta ,Giulio Tagliaferro, Pierre Waller, "A Comparison of White Rabbit and IPPP for Time Transfer for UTC(k) comparison", Scientific and Fundamental Aspects of GNSS, 9th International Colloquium, Sept 2024, Poland – Antoine Baudiquez, Baptiste Chupin, Giulio Tagliaferro, Pierre Uhrich, Frédéric Meynadier, "Operational Enhancements and Application of IPPP Toolbox for GNSS Time and Frequency Transfer at the BIPM", European Frequency and Time Forum 2024 (Neuchâtel, Switzerland) – Frédéric Meynadier, Pascale Defraigne, "Looking for a lunar reference timescale", European Frequency and Time Forum 2024 (Neuchâtel, Switzerland). – Pascale Defraigne, Frédéric Meynadier, Patrizia Tavella, Noël Dimarcq, "Looking for a Lunar Reference Timescale", 9th edition of the International Colloquium on Scientific and Fundamental Aspects of GNSS, 2022 (Wrocław, Poland)
2. TIME-D1: CHARACTERIZATION OF DELAYS IN TIME TRANSFER EQUIPMENT OPERATED IN UTC CONTRIBUTING LABORATORIES		
D1.1: Maintenance of BIPM travelling receivers, measurement reference, and procedures for calibration. Realization of delay measurement campaigns for specific laboratories (GNSS G1, TWSTFT, others)	A set of (absolutely) calibrated reference GNSS receivers is maintained to ensure the overall coherency of the time transfer delay calibration in the UTC time links (GNSS, TW, others, ...) of all the contributing laboratories. Some of these reference receivers are continuously travelling to selected laboratories for on-site delay comparison. This activity requires: 1. Characterization, study, and experimental tests of equipment compatible with those operated in NMIs.	• In 2024 the G1 calibration campaign, that started in 2022, has closed with the publication of the final report and application of the updated measured equipment delays. • A guideline for the measurement of the GNSS equipment REFDELAY has been prepared and published. • In collaboration with the CCTF WG GNSS, a study on the stability of the GNSS delays has been carried out. • The calibration of the TWSTFT stations in Europe has been accomplished at the end of 2023. The Time Department has supported the data analysis.

II	**Time Metrology**	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
	2. Guidance documents for the travelling box installation and measurement for the delay measurement of UTC laboratory equipment (G1 GNSS, TW, others). 3. Organization of the travelling campaigns (requiring the shipping of the BIPM travelling system without staff) to about 10-15 selected laboratories, usually every other year. 4. data analysis, uncertainty evaluation, publication of the report and application to UTC computation. Access to a "dark fibre" will be rented to connect the BIPM to the nearest point in the NMI network to facilitate improved calibration of receiver delays, high-stability measurement of PSFS, and comparison with other high-stability time transfer techniques. The establishment of this link involves operational costs that will depend on telecom suppliers in the Sèvres area. It will only be realized if a good balance between costs and benefits can be reached. The time laboratory also ensures the provision of a frequency reference to the other BIPM laboratories. The dissemination of this frequency signal and the related internal calibrations are part of the BIPM Quality System.	• Two different absolute calibrations for the BIPM GNSS receivers have been accomplished in collaboration with the Joint Research Center in Ispra, Italy, and the European Space Agency, NL. • The provision of the reference frequency to the BIPM labs has continuously been provided with the issue of calibration certificates when requested. • The possible fibre connection to the French Time laboratories has not yet started for economic reasons. *Publications and presentations:* – Pascale Defraigne, Giulio Tagliaferro, Michel Abgrall, Jérôme Delporte, Zhengsen Jia, Shinn-Yan Lin, Ju-Ik Oh, Elisa Pinat, "Variations of GNSS Hardware Delays and UTC", presented at the European Frequency and Time Forum (EFTF), 2024.
D1.2: Coordinating measurement campaigns with the RMOs for GNSS G2, linking results to the BIPM G1 reference, and other BIPM coordinated campaigns	For the UTC laboratories subsequently visited by the previous group of G1 laboratories, the BIPM has the role to: – Provide guidelines, – Validate the calibration reports and their application in UTC computation.	• The calibration of the G2 labs is supported. • In 2024, eight G2 calibration started and other 4 were completed.

II	Time Metrology	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
3. TIME-O1: USE OF VERY ACCURATE OPTICAL FREQUENCY STANDARDS - SUPPORT TO THE REDEFINITION OF THE SI SECOND		
O1.1: Optimal use of optical standard measurements in TAI/UTC, support to NMIs and CCTF in the development of optical frequency standards and advanced time and frequency transfer techniques in TAI/UTC	New optical standards as well as a new time and frequency comparison in the optical domain call for an update of the TAI/UTC data processing to optimize the contribution of these new measures. In particular: (a) Development of the statistical treatment of measures that may have peculiarities (dead time, long period of missing data, only frequency comparison…) and the uncertainty evaluation. (b) Adaptation of the TAI algorithm for the optimal introduction of the optical frequency standard measurements. (c) Collaborate with NMIs and the CCTF for standardization of measurement process, data format, and to set up calibration techniques and guidelines. These additional activities would require additional effort that the BIPM staff could ensure only at a very basic level. To face the new challenges with appropriate resources and optimizing the use in TAI/UTC, the support of a full time secondee is necessary. In case this support should not be available, only a limited activity can be ensured. The department will also contribute to the activities illustrated in the CCTF roadmap for the redefinition of the second.	• A major effort has been devoted to the development, comparison, and validation of an algorithm and the related software for the evaluation of the values of the secondary representations of the second from the comparison measurements. The BIPM algorithm has been compared with a different one developed by NPL and NIST. • The Department is strongly involved in the CCTF Task Force for the redefinition of the second offering support particularly in the understanding of the option 2 for an ensemble redefinition and for the evaluation of the fulfillment indices of the redefinition criteria. Several presentations and CCTF internal documents have been produced. *Publications and presentations:* – N Dimarcq et al, “Roadmap towards the redefinition of the second”, 2024 Metrologia 61 012001, DOI 10.1088/1681-7575/ad17d2 – H S Margolis, G Panfilo, G Petit, C Oates, T Ido and S Bize, “The CIPM list 'Recommended values of standard frequencies': 2021 update”, 2024 Metrologia, Volume 61, Number 3 – N. Dimarcq, S. Bize, F. Fang, E. Peik, D. Calonico, T. Ido, S. Weyers, M. Gertsvolf, G. Mileti, P. Tavella, F. Meynadier, G. Panfilo, G. Tagliaferro, “Redefinition of the second: why, how, when?”, presented at the European Frequency and Time Forum (EFTF), 2024 – P. Tavella, “UTC Time scale and SI second redefinition” tutorial presented at the UFFC IFCS sept 2024, Taipei – P.Tavella, “News from the Consultative Committee for Time and Frequency: Redefinition of the Second and a Continuous Coordinated Universal Time (UTC), invited presentation at the UFFC IFCS sept 2024, Taipei

III	Chemical Metrology	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
1. Chem-G1: SURFACE OZONE AND AIR QUALITY GAS STANDARD COMPARISONS Coordination of comparisons to determine and improve the international equivalence of gas standards for air quality monitoring		
G1.1: *NMI participations: 20*	20 ozone standards bilateral comparisons as part of BIPM.QM-K1 coordination (2020-2023), based on the unique triad of standards at the BIPM, which will maintain consistency of calibration services for surface ozone measurements for local, regional, national and global air quality monitoring networks.	• 3 bilateral comparisons performed in BIPM laboratories for VSL (April 2024), JRC (July 2024), and KRISS (September 2024). • 7 key comparison reports published for FMI (March 2023), NIM (Oct. 2023), EMPA (June 2023), NPL (June 2022), NMC/A*STAR (July 2022), VSL (April 2024) and CMS/ITRI (March 2024).
G1.2:	Installation and validation of new SRP electronics systems for National Ozone Standards, on request from NMIs participating in BIPM.QM-K1.	• Electronics upgrade completed for the JRC owned SRP at the BIPM Laboratories (July 2024).
G1.3: *NMI participations: 30*	Coordination of reactive gas/air quality comparisons (development and implementation of on-going comparison on NO_2 standards, BIPM.QM-K6), based on state-of-the-art dynamic standard reference facilities at the BIPM, enabling NMIs to demonstrate equivalence of their standards for air quality and vehicle emission verification measurements.	• The stability study at the BIPM of six NO_2 in nitrogen standards at 10 µmol/mol, using three different cylinder types, is ongoing. 3 bimonthly measurements versus BIPM MSB reference facility completed. • Three standards returned and measured at NPL for testing the key comparison protocol. Returned to BIPM in October 2024 andfinal measurements completed. • Preparation of 2 standards at 10 µmol/mol completed at the LNE, for short interval testing of the comparison protocol. LNE standards are expected to arrive at the BIPM in 2025 for measurement.
2. Chem-G2: INTERNATIONAL REFERENCE FACILITIES AND COMPARISONS OF GHGs		
G2.1: *NMI participations: 20*	Coordination of BIPM.QM-K2.a and b on Carbon dioxide in air and nitrogen, based on a unique manometric reference comparison facility maintained at the BIPM, providing on-demand comparisons of gravimetrically prepared NMI standards for greenhouse gas and emissions measurement calibrations, and core comparisons for NMIs developing binary gas mixtures.	• Second series of CO_2 in air amount fraction measurements completed on the 18 standards constituting the BIPM scales with the BIPM PVT-CO_2 facility. • Regular measurements of critical parameters of the PVT-CO_2 central facility as part of the quality controls undertaken, demonstrating the readiness of the facility for the on-demand comparison BIPM.QM-K2.a and b which started in October 2024. • Control software of the central facility updated to communicate with the newly installed database for greenhouse gases and to use it to record and retrieve data from measurements and from external calibrations. • Documentation written: Software manuals and validation reports, quality system procedures, comparison protocol and forms. Protocol circulated to CCQM/GAWG in September 2024, published online in November 2024.

III	Chemical Metrology	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
		• Measurements for the first participant, E+E ELEKTRONIK (DI of Austria) completed in December 2024.
G2.2: *NMI participations: 12*	Establishment and coordination of BIPM.QM-K5 on CO_2 in air GHG Scale comparisons, providing on-demand comparisons for NMIs developing and maintaining GHG scale standards for background, emission and flux determinations, based on scales and facilities maintained at the BIPM, with SI value assignment provided through the BIPM manometric facility and a database consultable for scale and standard relationships.	• Database for GHG Scale measurements and reference data developed, as part of collaborative effort and secondment with University of Colorado/NOAA, including for measurement data that will be recorded as part of BIPM.QM-K5 and BIPM.QM-K2 comparisons. • Validation of the measurement method to be employed for the comparison BIPM.QM-K5 with two different analyzers of CO_2 in air completed. • Concept for data treatment for the comparison BIPM.QM-K5, including correction for differences in isotopic composition of standards, presented and agreed with CCQM-GAWG-GHG-TG. • Comparison protocol for BIPM.QM-K5 development completed with Team 2 of the CCQM/GAWG/Task Group on GHG scale comparisons, to be presented to GAWG in October 2024.
G2.3: *NMI participations: 20*	Coordination of CH_4, N_2O GHG comparisons, and completion of CCQM-K82.2023 on methane at ambient levels, based on comparative measurements undertaken at the BIPM, and supporting NMI standards for greenhouse gas and emissions measurement calibrations.	CCQM-K82.2023 on methane standards: • Measurements on 25 standards using both CRDS and GC-FID completed (January to April). • Comparison cylinders returned to participants in May. • Stability measurements of mixtures by participants completed, Draft A report in preparation.
3. Chem-G3: INTERNATIONAL REFERENCE FACILITIES AND COMPARISONS FOR ISOTOPE RATIOS Coordination of comparisons to support the international infrastructure for isotope ratio standards including for measurements on radiative forcing gases.		
G3.1: *NMI participations: 40*	Establishment and coordination of BIPM.QM-K3 on CO_2 isotope ratios in pure CO_2 gas, based on dedicated CO_2 gas sample generation facilities and an IRMS-based comparison facility with traceability to carbonate reference methods and international standards, supporting NMIs providing carbon isotope ratio scale standards, highest accuracy CO_2 amount fraction standards with on demand comparison and calibration services.	• 16 CO_2 pure gas isotopic research samples prepared, value assigned and shipped to NPL (9 samples) and KRISS (7 samples). • 6 CO_2 pure gas isotopic research samples in preparation for NIST.

III	Chemical Metrology	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
G3.2: *NMI participations: 12*	Establishment and coordination of BIPM.QM-K4 on CO_2 isotope ratios in CO_2 in air mixtures, based on cryogenic separation and IRMS reference facilities maintained at the BIPM with traceability to carbonate reference methods and international standards, supporting NMIs providing CO_2 in air isotope ratio standards and amount fraction standards, with an on-demand comparison service.	• CCQM-P239 launched as pre-comparison to the future BIPM.QM-K4 on-demand comparison: protocol circulated in January 2024, 15 participants registered in April 2024, with 41 standards consisting of CO_2 in air mixtures expected at the BIPM in September 2024. 27 standards received at BIPM by 31 December 2024 and measurements on 12 standards were completed at the BIPM.
G3.3:	Develop methods for reduced uncertainties for isotope ratio measurements and comparisons of CO_2, based on preparation of CO_2 mixtures with well-established equilibration properties, and characterization by IRMS and IRIS methods as pure gases and in air matrix, and development of models to deal with non-stoichiometric distributions of isotopes in standards samples. Methods to be applied to on-going comparisons for CO_2 isotope and amount fraction, and support of NMI activities in development of reduced uncertainties in SI traceable values.	• 3-month secondment (University of Groningen) completed with nitrous oxide correction method revised and implemented into IRMS measurement protocol; data treatment for clumped isotope data from IRMS developed; impact of non-equilibration of CO_2 isotope mixtures model completed. • Participation and contribution to IAEA experts meeting (January) with development of new format and definitions for $\delta^{13}C$ and $\delta^{18}O$ scales for isotope ratio measurement. Publication in preparation. • 4 months of 6-month secondment from NIM completed for the development of calibration methods of optically-based instrument for CO_2 isotope ratio measurement, with setup designed and implemented for 2 different analyzers and 6 samples, measurements performed under different conditions and data treatment under validation.
International equivalence of organic primary calibrators for clinical chemistry and laboratory medicine, food analysis, environmental analysis, forensics and pharma		
4. Chem-O1: SMALL MOLECULE ORGANIC PRIMARY REFERENCE COMPARISONS (PURE MATERIALS) Coordination of comparisons to determine and improve the international equivalence of organic primary calibrators for clinical chemistry and laboratory medicine, food analysis, environmental analysis, forensics and pharma.		
O1.1: *NMI participations: 20*	Completion of purity comparison CCQM-K148.c (MW 500-1000 Da) with, Draft A, B and Final Reports completed and providing a core comparison enabling NMIs to demonstrate capabilities and continued improvement in providing SI traceability for small molecule organic analytes.	CCQM/-K148.b/K179 (oxytetracycline hydrochloride and salt purity comparison) • Draft A agreed by participants and circulated to CCQM OAWG for approval in their October 2024 meeting. • Draft B approved by OAWG and submitted to CCQM WG chairs in November for approval. CCQM-K148.c Digitoxin purity comparison • Characterization measurements completed for water content and variability with relative humidity using by KFT and DVS. • Unit size of 50 mg approved for comparison protocol by CCQM OAWG.

III	Chemical Metrology	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
		• Comparison batch of 150 units filled by UME, labeled and shipped to the BIPM. • Units for homogeneity and stability studies selected and set aside. • Measurements of homogeneity and stability study samples performed by LC-UV-MS/MS and finalised within a 3-month secondment of GLHK. • Study approved as Track A by OAWG in autumn and study number assigned.
O1.2: *NMI participations: 20*	Coordination of CCQM-K148.a.1 (Non-polar organic (MW 75-500 Da) with mass-balance and qNMR value assignment at the BIPM, and homogeneity and stability analysis, providing a core comparison enabling NMIs to demonstrate capabilities and continued improvement in providing SI traceability for small molecule non-polar organic analytes.	• Discussion on potential candidate materials (e.g. quinidine) launched at the autumn 2024 OAWG meeting.
O1.3:	Development of purity evaluation guidelines for pesticide, drug and mycotoxin samples, supporting knowledge transfer and BIPM on-line e-learning, modules and comparisons for NMIs with developing programmes in metrology on organic analysis in support of food safety.	• Internal standard reference document (ISRD) for ^{19}F qNMR using BTFMBA published as BIPM Rapport 2024-02. • BIPM Rapport on Purity Evaluation Guideline for Tetracycline 80 % completed with publication foreseen in beginning of 2025.
5. Chem-O2: SMALL MOLECULE ORGANIC PRIMARY REFERENCE COMPARISONS (CALIBRATION SOLUTIONS) Coordination of comparisons standards and methods for organic calibrants.		
O2.1: *NMI participations: 20*	Coordination of calibration solution comparison CCQM-K78.a.1 (Multi-component aqueous solution), based on BIPM gravimetrically prepared samples with multi-component polar analytes, with the mass fractions of primary reference materials quantified within the BIPM purity measurement facilities, providing a core comparison for polar organic calibration solutions for NMIs.	CCQM-K78.a.202x planning • A selection of potential polar pesticides (phosphonic acids (glyphosate), quaternary ammonium compounds and cyclitol glycosides reviewed together with NIM, the study co-coordinator NIM. • Glyphosate and a metabolite material have been obtained for feasibility studies. • The glyphosate comparison was presented, discussed and approved as Track A comparison at the autumn OAWG meeting.
O2.2: *NMI participations: 20*	Coordination of calibration solution comparison CCQM-K78.b.1 (Multi-component, non-polar), based on BIPM gravimetrically prepared calibration solutions with multi-component non-polar analytes, with the mass fractions of primary reference materials quantified within the BIPM purity	CCQM-K78.b (Methoxychlor and Trifluralin: Pesticide Calibration Solution Comparison) • Draft B report distributed and discussed and KCRV agreed by OAWG in April 2024. • Final Report was distributed to CCQM OAWG for final review in October 2024. • Fiinal Report was corrected and has been provided to CCQM chairs awaiting approval.

III	Chemical Metrology	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
	measurement facilities, providing a core comparison for non-polar organic calibration solutions for NMIs.	CCQM-K78.b 2026 (Calibration solution comparison) • Proposal based on a multicomponent solution of Atrazine, Carbofuran, Dimethoate and Endosulfan presented at CCQM OAWG meeting with agreement to continue as a Track C comparison. • Pure materials received at the BIPM from NIM. • Nine of twelve-month secondment of NIM scientist completed for the development and validation of LC-DAD-CAD methods for multicomponent solution analyte quantification. • GC-MS for VOCs and KFT measurements for water content in pure pesticide materials completed. QNMR measurements completed and evaluation and report at 75 %.
O2.3: *NMI participations: 20*	Coordination of CCQM-K154.e (Ochratoxin A), and development of calibrant assessment guidelines, and qNMR internal standard reference documents, providing support to NMIs developing and providing measurements standards in support of food safety and extending the scope of applicability of qNMR for SI traceable measurements on organic analytes, and support for NMI measurement services and their comparisons.	CCQM-K154.b.1 (AfB1 mycotoxin calibrant) • Bilateral subsequent CCQM-K154.b.1 (AfB1 mycotoxin calibrant) Draft A, Draft B and final report completed and published in the KCDB and Metrologia. CCQM-K154.e (Ochratoxin A Calibrants) • Ochratoxin A pure material characterization completed and discussed. • Gravimetric preparation of stock and calibration solutions completed. • Filling and labeling of stock and calibration solution ampoules completed (200 ampoules of each). • Homogeneity and stability studies protocol completed and units set aside. • Measurements of homogeneity study samples performed by LC-UV-MS/MS at 80 %. • Study approved as Track C Model 2 by OAWG in autumn and study number assigned.
6. Chem-O3: LARGE MOLECULE ORGANIC PRIMARY REFERENCE METHOD DEVELOPMENT AND COMPARISONS Coordination of comparisons to determine and improve the international equivalence of organic primary calibrators for clinical chemistry and laboratory medicine, forensics and pharma		
O3.1: *NMI participations: 15*	Completion of CCQM-K155.d Primary peptide calibrator (5 kDa to 10 kDa), based on mass-balance and protein impurity corrected amino acid analysis characterization performed at the BIPM, providing a core comparison of capabilities for value assignment of primary reference material straight chain peptides with molecular weights between 5 kDa to 10 kDa at NMIs, and underpinning reference	• Shipment of CCQM-K155.d / P55.2.d comparison samples to 10 of 12 participants completed. Shipments to CSIRO (Australia) and VNIIMS / Rostest (Russia) delayed due to issues with customs and reorganization, respectively. • Nine of twelve-month secondment of NIM scientist completed with development of LC-hrMS method for the quantification of structurally related impurities in PTH material completed and LC-MS method based on quanification of proteotypic peptides on-going. • Characterization of comparison material by BIPM ongoing (50 %).

III	Chemical Metrology	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
	measurement systems for parathyroid hormone (PTH) measurements and their development for diagnosis and patient monitoring.	
O3.2: *NMI participations: 15*	Coordination of peptide/protein purity key comparison CCQM-K115.e, intact proteins MW > 10 kDa, based on methodologies developed in running CCQM-P216, on SARS-CoV-2 monoclonal antibody quantification, and providing a core comparison of capabilities for value assignment of primary reference methods for proteins with molar masses of greater than 10 kDa at NMIs, and underpinning reference measurement systems diagnosis and therapeutics.	• Paper published on the methods developed for the purity assignment of the SARS-CoV-2 monoclonal antibody in the CCQM-P216 material_: Anal Bioanal Chem. 2024 Apr;416(10):2423-2437. doi: 10.1007/s00216-024-05205-z. Epub 2024 Mar 1. PMID: 38427100.
O3.3: *NMI participations: 15*	Coordination of peptide/protein purity key comparison CCQM-K115.a.2, 1 kDa < peptide < 5 kDa, based on mass-balance and protein impurity corrected amino acid analysis characterization performed at the BIPM, providing a core comparison of capabilities for value assignment of primary reference material peptides with molecular weights between 1 kDa and 5 kDa, and underpinning reference measurement systems for protein diagnostics.	• Sourcing of cyclosporin A candidate comparison material for CCQM-K115.c.2026 identified in collaboration with the NML at LGC. • Comparison proposal discussed at PAWG meeting in October and OAWG in November.

IV	Ionizing Radiation Metrology	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
1. IR-D1: RADIATION DOSIMETRY International reference system for x-ray dosimetry Underpinning the international equivalence of national standards for radiotherapy, diagnostic x-rays, mammography and radiation protection, through the provision of comparison and calibration services. *NMI Participations: 24 (comparisons); 16 (calibrations)*		
D1.1:	Validation of national primary standards through bilateral comparisons and traceability of national secondary standards through calibrations: air kerma for low energy (BIPM.RI(I)-K2), medium energy (-K3) and mammography (-K7); absorbed dose to water for medium energy (-K9).	• 4 comparisons performed, all for PTB (Germany): K2, K3, K7M and K7W. • 3 comparison reports published in 2024: K7 (BFKH-2021), K2 and K3 (PTB-2024) • All requested calibrations and corresponding certificates have been completed for the IRCL (Greece), STUK (Finland) and IRD (Brazil): 9 calibrations corresponding to 8 NMI participations.
D1.2:	Quality assurance to demonstrate the high accuracy and long-term stability of the BIPM primary standards and reference x-ray beams for air kerma and absorbed dose to water. Continual improvement of the BIPM standards and x-ray facilities to assure long-term reliability and compliance with evolving regulations and norms.	• Quality assurance checks continued all through the year. • Improvement of the medium energy x-rays facility: final characterization of the new primary standard and radiation fields. • Transfer knowledge from retiring physicist (David Burns) to the new physicist (Anna Villevalde).
D1.3:	Development of a new reference low energy x-ray facility to improve the efficiency and assure the long-term provision of the existing service.	• This work is scheduled to start in 2025.
2. IR-D2: INTERNATIONAL REFERENCE SYSTEM FOR GAMMA-RAY DOSIMETRY Underpinning the international equivalence of national standards for radiotherapy, brachytherapy, radiation protection and radio-sterilization through the provision of comparison and calibration services. *NMI Participations: 30 (comparisons); 30 (calibrations)*		
D2.1:	Validation of national primary standards through bilateral comparisons and traceability of national secondary standards through calibrations: – BIPM ^{60}Co beam: air kerma (BIPM.RI(I)-K1), absorbed dose to water (-K4), – Off-site ^{137}Cs beam (IAEA): air kerma (-K5),	• 5 comparisons performed: K1 for PTB (Germany), K5 for GUM (Poland), K5 and K8 for LNHB (France) and NIM (China). • 5 comparison reports published in 2024: K5 (BEV and CIEMAT, 2023), K8 (VSL-2019, PTB-2023 et LNE-LNHB-2024). • 17 calibrations and corresponding certificates completed for the IRCL (Greece), METAS (Switzerland), DTU (Denmark), IRD (Brazil) and IAEA, corresponding to 10 NMI participations.

IV	Ionizing Radiation Metrology	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
	– Off-site ^{192}Ir HDR source: travelling instrument for comparisons of reference air kerma rate standards (-K8).	
D2.2:	Quality assurance to demonstrate the high accuracy and long-term stability of the BIPM primary standards and reference gamma-ray beams for air kerma and absorbed dose to water. Continual improvement of the BIPM standards and gamma-ray facilities to assure long-term reliability and compliance with evolving regulations and norms.	• Quality assurance checks continued all through the year.
3. IR-D3: INTERNATIONAL REFERENCE SYSTEM FOR HIGH-ENERGY RADIATION DOSIMETRY Underpinning the international equivalence of national standards for high-energy radiation beams to meet the expanding and emerging needs in dosimetry for radiotherapy, through the provision of comparison and calibration services. *NMI Participations: 5 (comparisons); 10 (calibrations)*		
D3.1:	Validation of national primary standards through bilateral comparisons and traceability of national secondary standards through calibrations at the off-site DOSEO facility: absorbed dose to water for high-energy photon beams (BIPM.RI(I)-K6).	• 1 comparison performed for GUM (Poland). • 4 calibrations and corresponding certificates completed for the DTU (Denmark) and IAEA, corresponding to 2 NMI participations.
D3.2:	Quality assurance to demonstrate the high accuracy and long-term stability of the BIPM primary standard (graphite calorimeter) and transfer instruments for absorbed dose to water. Continual improvement of the BIPM standards and equipment to assure long-term reliability.	• Quality control checks continued throughout 2024 to ensure that the BIPM standards and radiation beams are stable. • Supporting calibrations for DOSEO in the BIPM Co-60 facility.
D3.3:	Development of a new calorimeter standard for high-energy photons, with a smaller core aimed to reduce uncertainties.	• A preliminary study has been carried out on the uncertainty budget. It appears that what would be gained on one side would be lost on the other. As a result, the value of the project is very limited, and because of the high human and financial investment required, it has been abandoned, with efforts being redirected towards upgrading low-energy x-rays.
D3.4:	Extension of the comparison and calibration services to high-energy electrons at the off-site DOSEO facility, using the new calorimeter.	• This project is expected to be carried out mainly through secondments. However, this development would make no sense if the BIPM changed its off-site facility for high-energy photons in the next few years (this development would then have to be largely redone). The project plan has options depending on the choice made for the future off-site facility for high-energy photons and electrons being either DOSEO or IAEA.

IV	Ionizing Radiation Metrology	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
Radionuclide Metrology		
4. IR-R1: INTERNATIONAL REFERENCE SYSTEM FOR ACTIVITY MEASUREMENTS OF GAMMA-RAY EMITTING RADIONUCLIDES (SIR) Underpinning the international equivalence of national standards of gamma-ray emitting radionuclides for applications in nuclear medicine, the nuclear industry, nuclear physics, environmental protection, radiation protection and nuclear forensics, through the provision of BIPM key comparisons. *NMI Participations: 32 (comparisons)*		
R1.1:	Provision of BIPM key comparisons (BIPM.RI(II)-K1) of national activity standards of gamma-ray emitting radionuclides using the high precision, high stability, SIR ionization chambers.	• 11 comparison measurements performed corresponding to 11 NMI participations in 2024: Sc-47 (POLATOM), Mn-54 (NPL, POLATOM), Ru-106 (LNMRI/IRD), Sn-113 (KRISS), I-123 (LNHB), Ba-133 (CMI and LNMRI/IRD), Lu-177 (LNHB), Pb-212 (LNHB), Ac-225 (NPL). • 10 reports of K1 comparisons were published in 2024 for the following radionuclides: Cr-51 (KRISS-2012 and POLATOM-2022), Co-57 (BEV-2023), Zn-65 (LNMRI/IRD-2015, LNHB-2018), Ga-67 (CMI-2023), Ge-68 (NIM-2021), Cs-137 (NRC-2014 and TENMAK-NÜKEN-2018), Tb-161 (NPL-2022) and Lu-177 (CMI-2023).
R1.2:	Quality assurance and continual improvement to demonstrate the high precision and long-term stability of the SIR services and assure compliance with evolving regulations and norms.	• Quality control checks continued throughout the period. • Mathematical modelling to transfer KCRVs from one ionization chamber to another to avoid the need to measure samples of every radionuclide covered by the SIR: modelling being finalized, publication in preparation. • Transition to Ho-166m as reference sources delayed due to manufacturing delays at LNHB. • Preliminary study on how to run in the SIR comparisons of Th-227 which is not at equilibrium.
R1.3:	Transfer of the SIR services to the updated SIR device and measurement method, based on state-of-the-art instrumentation for measuring low currents, assuring the long-term continuity of the international equivalence of national standards.	• Setting-up of the ionization chambers for the new SIR (SIR2.0). • Tests of the new ionizing chambers in the lead shielding of the system. • Tests of the acquisition system with ULCA (Ultra Low Current Amplifier). • Tests of the new version of the source holder.
5. IR-R2: INTERNATIONAL REFERENCE SYSTEM FOR ACTIVITY MEASUREMENTS OF SHORT-LIVED GAMMA-RAY EMITTING RADIONUCLIDES (SIRTI) Underpinning the international equivalence of national standards of short-lived gamma-ray emitting radionuclides for particular applications in nuclear medicine and other domains, through the provision of BIPM key comparisons. *NMI Participations: 25 (comparisons)*		
R2.1:	Provision of BIPM key comparisons (BIPM.RI(II)-K4) of national activity standards of short-lived gamma-ray emitting radionuclides using the high precision, high stability SIRTI scintillation counter, in remote or on-site modes.	• 3 comparisons carried out in hybrid mode (LNMRI – Brazil: F-18, I-123 and Sm-153) and 1 carried out at IRA, Switzerland (F-18; Tc-99m: abandoned).

IV	Ionizing Radiation Metrology	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
R2.2:	Quality assurance and continual improvement to demonstrate the high precision and long-term stability of the SIRTI services and assure compliance with evolving regulations and norms.	• Quality control checks continued throughout the period. • Investigation of reproducibility of ^{123}I SIRTI measurements in collaboration with LNE-LNHB.
R2.3:	Duplication of the SIRTI to a second device equipped with dedicated digital electronics, assuring the long-term continuity of the SIRTI services, and transfer of the SIRTI method to several RMOs.	• Development of a digital electronic acquisition system for SIRTI with CAEN module and first tests using a F-18 solution showing capabilities up to 20 000 s^{-1} counting rates. • As a general service, beyond the SIRTI, development of method (to be approved by CCRI) to validate software used to analyze digital electronic data, by comparing the results obtained with reference measurement data.
R2.4:	Extension of SIRTI services to new (3) radionuclides requiring metrological studies and cross-calibration with the SIR.	• Finalization of the link to the SIR for Sm-153 and I-123 postponed to 2025. • First measurements of the link to the SIR for Sc-47 and Pb-212.
6. IR-R3: INTERNATIONAL REFERENCE SYSTEM FOR ACTIVITY MEASUREMENTS OF ALPHA- AND BETA-PARTICLE EMITTING RADIONUCLIDES (ESIR) Underpinning the international equivalence of national standards of alpha- and beta-particle emitting radionuclides for applications in nuclear medicine, environmental protection, radiation protection and nuclear forensics, through the provision of BIPM key comparisons. *NMI Participations: 20 NMIs (comparisons)*		
R3.1:	Provision of BIPM key comparisons (BIPM.RI(II)-K5) of national activity standards of medium- and high-energy beta-particle emitting radionuclides using the high precision, high stability ESIR liquid scintillation counter based on the TDCR method.	• Preparation of the comparison protocol. • Start the BIPM.RI(II)-K5 service for a few of the 11 selected isotopes: Measurement of the first source of ^{99}Tc sent by the LNE-LNHB.
R3.2:	Quality assurance and continual improvement to demonstrate the high precision and long-term stability of the ESIR services and assure compliance with evolving regulations and norms.	• Update of the quality system with a full review and completion of the ESIR related procedures. • Periodic quality controls ensured during the period.
R3.3:	Extension of the services to cover additional radionuclides, low energy beta and alpha emitters, thanks to digital pulse processing systems.	• Setting-up of a PhD (co-direction by BIPM and LNE-LNHB) to study the corrections for impurities of ESIR measurements allowing the use of additional radionuclides at the next Working Plan. Start of the PhD has been delayed to 2025 due to administrative issues at the LNE-LNHB. • Publication of a stochastic Python code dedicated to TDCR measurements.

V	Coordination and institutional liaison	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
SUPPORT for CCs (including provision of Executive Secretaries)		
PMD-C1:	Provision of CCEM (Electricity and Magnetism) Executive Secretary to support: 1. Two CCEM meetings 2. Annual working group meetings 3. Pro-active interaction on strategy and communication 4. Coordination of CCEM processes.	• Treatment of a backlog of reviews of comparison reports in the low-frequency field. • Organization of two CCEM webinars. • Lauch of the organization of the CCEM meeting in March 2025.
PMD-C2:	Provision of CCM (Mass and Related Quantities) Executive Secretary to support: 1. Two CCM meetings 2. Annual working group meetings 3. Pro-active interaction on strategy and communication 4. Coordination of CCM processes.	• Meeting of TGPfD-kg in preparation of the third key comparison of kilogram realizations (CCM.M-K8.2024). • Organization (preparing agenda and working documents) and co-chairing of the WGS meeting. • CCM webinars: collation of proposals and organization of first two webinars. • Update of the CCM Strategy document. • Organization of online WG and TG meetings. • Member of the Steering and Programme Committees of the International Conference of Weighing (meetings for the conference in 2026). • CMCs: update of CCM Service Categories for digitalization and request for change on molar flow etc. • Coordination of the registration, approval and publication of the final reports of KCs.
PMD-C3:	Provision of CCT (Thermometry) Executive Secretary to support: 1. Two CCT meetings 2. Annual working group meetings 3. Pro-active interaction on strategy and communication 4. Coordination of CCT processes.	• Organization of the CCT meeting and all WG and TG meetings at the BIPM headquarters in May 2024 gathering 52 attendees on site and 36 attendees online. • The TG on Digitalization was turned into a WG in regards with the growing needs on activities on machine-readable access to ITS-90 and *mise en pratique* related data.
PMD-C4:	Provision of CCU (Units) Executive Secretary to support: 1. Two CCU meetings 2. Annual working group meetings	• Organization of the CCU meeting at the BIPM headquarters in April 2024, with 35 attendees on site and 23 attendees online; publication of CCU report • Organization of four online meetings of WG-CMT (now TG-FCM) • Organization of the first meeting of TG-KTSIB

V	**Coordination and institutional liaison**	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
	3. Pro-active interaction on strategy and communication 4. Coordination of CCU processes.	• Publication of version 3.01 of the 9th edition of the SI Brochure. • Submission of a paper to Metrologia – together with R. Brown - on the new version of the SI Brochure.
Time-C1:	Provision of CCTF (Time and Frequency) Executive Secretary to support: 1. Organizing the CCTF bi/triennial meetings and more frequent meetings of the CCTF WG on Strategic Planning 2. Providing secretariat for CCTF and WGs 3. Pro-active interaction on strategy and communication 4. Key comparisons in time and frequency and other MRA activities 5. Contribution to the estimation of the recommended frequencies for the secondary representations of the second.	The Time Department is deeply involved in supporting the CCTF, its 9 WGs, and the special task force, task groups created to deal with the 4 hot topics*:* *1. Updating the Roadmap for the redefinition of the second* *2. Leap seconds in UTC - building a consensus for a continuous timescale* *3. Promoting the mutual benefit of UTC and GNSS* *4. Sharing resources to improve international timekeeping* The CCTF WG on Strategic Planning meets every two months (online and in 2024 also in person). A CCTF task group has been formed on Lunar Time aiming to recommend a possible reference time for the Moon and its traceability to UTC. The CCTF met for its first session in Nov 2024. A survey on the status of the NMI plans towards the redefinition of the second has been launched. *Publications and presentations:* – P.Tavella, J.Mitrovica, "Melting ice solves leap-second problem — for now", https://www.nature.com/articles/d41586-024-00850-x, Nature 628, 273-274 (2024), doi: https://doi.org/10.1038/d41586-024-00850-x – A. Sen Gupta, P. Tavella, "Overview of the Recent Activities of BIPM – CCTF", 4th URSI AT-RASC, Gran Canaria, 19-24 May 2024
Time-C2:	Provision of CCL (Length) Executive Secretary to support: 1. CCL meetings 2. Participation in WGs 3. Pro-active interaction on strategy and communication	• The CCL meeting was held in October 2024. • The related preparation meetings, as well as the WG meetings have been supported and the BIPM web page has been updated accordingly.

V	**Coordination and institutional liaison**	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
	4. Coordination between NMIs for length related activities. Key comparisons in length, support to comparisons of stabilized lasers piloted by NMIs 5. Recommendation of standard frequencies and wavelength for the practical realization of the metre.	
Chem-C1:	Provision of CCQM (Chemistry and Biology) Executive Secretary to support: 1. Annual CCQM meetings (four plenary meetings) and meetings of eleven WGs (in presence and on-line) 2. Pro-active interaction on strategy and communication 3. Coordination of review of CC and RMO comparison reports before publication 4. Development and review of CCQM documents and guidelines 5. Organization and coordination of CCQM workshops.	• Organization of CCQM meetings (7 days) at BIPM in April 2024, with 10 WG meetings and plenary session. • Organization of CCQM Online Workshop on Digital and FAIR Chemical and Biological Reference Data and Certificates: Challenges and Opportunities, (450 registered participants) with development of workshop website and pre-recorded presentations and meetings with steering committee and panelists. • Support for CCQM Task Groups on: Microplastics Measurement Standardization- hosting of monthly progress meetings. • CCQM Task Group of Food Measurements established. Several virtual meetings hosted. Planning of stakeholder workshop initiated.
Chem-C2:	Provision of CCPR (Photometry and Radiometry) Executive Secretary to support: 1. Two CCPR plenary meetings and associated WG meetings 2. Pro-active interaction on strategy and communication 3. Coordination of review of CC and RMO comparison reports before publication 4. Development and review of CCPR documents and guidelines.	• Organization of CCPR meetings (4 days) at BIPM in June 2024 and publication of the meeting report • Support provided for the organization of a CCPR-CIE Workshop on 100 years of V(λ) (3 June 2024, 142 online participants and 84 on site). • Support provided for the publication of 1 RMO comparison report in the KCDB. • Support provided to launch a new Task Group (TG17) of the CCPR-WG-SP on Metrology for Satellite Observations. • Support provided to secure the venue of CCPR Working Groups meetings in July 2025, to be held in BEV, Vienna, in conjunction with CIE midterm meeting 2025.
IR-C1:	Provision of the Scientific Secretary for JCGM WG1 and support including: 1. Rapporteur; 2. Two annual meetings.	• JCGM-WG1 plenary meetings in May at the BIPM and December 2024 on-line • Production of the minutes • Recollection of the membership history since the first meeting in 2000.

V	Coordination and institutional liaison	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
IR-C3 (Time-C3):	Provision of CCAUV (acoustics, ultrasound and vibration) Executive Secretary to support: 1. Biennial CCAUV meetings and three WG meetings 2. Pro-active interaction on strategy and communication 3. Development of strategic plans 4. Coordinate review of CC and RMO comparison reports before publication 5. Related liaisons with RMOs and CTBTO.	• The CCAUV met in 2023. This year the activity continued in supporting the WGs. • In September 2024 the support to the CCAUV was transferred to another department.
CIPM MRA COORDINATION AND PROVISION OF THE KCDB		
ILC-C1:	1. Coordination of the CIPM MRA mechanisms through the JCRB 2. Provision of the KCDB database and API (including Exec. Sec. of the JCRB) 3. Maintenance and minor updates for KCDB 4. Publication of comparison data and interventions on CMCs 5. Advising the CIPM MRA participants and mining the data for stakeholders.	As of December 2024, the CIPM MRA has been signed by representatives of 64 Member States, 37 Associates, and four international organizations – and covers a further 153 institutes designated by the signatory bodies. One NMIs changed its name. • A new KCDB Assistant Executive Secretary was appointed on 1 February 2024 • During the reporting period around 940 CMCs were processed (including greyed-out CMCs) and 526 published in the KCDB. • 16 key and 21 supplementary comparisons were published in the KCDB. • The 48th meeting of the JCRB in September 2024 was organized as a hybrid meeting. Participants representing all six RMOs and the CIPM took part. • KCDB reports to the JCRB in March and September 2024 were published and presented; KCDB reports have been made publicly available through the BIPM and JCRB website. • An evaluation of the KCDB web platform performance has been conducted and included in the two KCDB reports to the JCRB. • Continuous support was provided to RMOs in operation of the CIPM MRA processes, including support for RMOs TC Chairs, CMC Reviewers, comparison pilots and CMC writers. • A three-point Checklist for CMC submitters was developed to improve the preparedness and effectiveness for CMC reviews and published on the KCDB website. • The comments section in KCDB web platform was improved to provide guidance for CMC writers and reviewers.
ILC-C2:	Provision of JCRB Executive Secretary (Secondee position) to support:	• Agreed actions arising from the 47th meeting of the JCRB were all implemented.

V	**Coordination and institutional liaison**	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
	1. Organization and participation in biannual JCRB meetings 2. Pro-active monitoring the JCRB CMC review process 3. Analysis and reporting on the efficiency and effectiveness of the JCRB CMC review process 4. Maintenance of the CIPM MRA documents suite, JCRB database, DI registry etc. 5. Interface with the KCDB office 6. Provision of assistance to CIPM MRA participants and RMOs.	• The March 2024 meeting was skipped after a unanimous decision by JCRB members in the 47th meeting. The 48th meeting of the JCRB was successfully organized in September 2024 at the BIPM. The draft minutes and actions arising from it were circulated thereafter to the delegates. • The JCRB CMC review process was monitored daily, and various stakeholders were alerted including the KCDB Office for appropriate mitigations whenever there was departure from the CIPM MRA expectations. • The JCRB review process was analyzed especially on CMCs review durations, loss of CMCs review rights, CMCs that have overstayed the status "revision requested" and CMCs that slipped through the regular JCRB review process. This was continually done, and the statistics were reported to the JCRB, CCs, CBKT Technical Exchanges and other relevant stakeholders. • A study was conducted on the contribution of devices under tests uncertainties on CMCs uncertainties. The findings were shared with the Executive Secretaries to the CCs. • A 3-point checklist was developed with the KCDB Office and deployed on the KCDB webpage to guide CMC Writers for smooth approval of CMCs upon submission. • The KCDB reports to the JCRB in March and September 2024 were published; KCDB reports have been made publicly available through the BIPM and JCRB website. • The 6 policy and guidance documents on CIPM MRA and associated documents were well maintained in a central repository. • The DI nomination form was modified to capture the digital identity of nominated DIs. It was endorsed by the JCRB and the changes are now implemented. • The JCRB database and the NMI/DIs database were maintained to reflect the current status. As of December 2024, the CIPM MRA has been signed by representatives of 101 institutes – from 64 Member States, 37 Associates, and 4 international organizations – and covers a further 153 institutes designated by the signatory bodies. One DI changed its name. • The following DIs were designated as participants of the CIPM MRA: NIOT – National Institute of Ocean Technology, on 30 January 2024, VFCL – VF Calibration Laboratory, on 25 March 2024, CICANUM-Centro de Investigación en Ciencias Atómicas, Nucleares y Moleculares on 20 August 2024. Three DIs from Cuba were reinstated as participants of the CIPM MRA on 16 October 2024: CENTIS – Centro de Isotopos, CPHR – Centro de Proteccion e Higiene de la Radiaciones and INIMET– Instituto Nacional de Investigaciones en Metrología.

V	Coordination and institutional liaison	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
		• Three DIs left the CIPM MRA: PTKMR-BATAN– Center for Technology of Radiation Safety and Metrology / National Nuclear Energy Agency, from Indonesia, NMRO – National Measurement and Regulation Office, formerly National Measurement Office from United Kingdom and MIRS/ZAG/SM480 - MIRS/Slovenian National Building and Civil Engineering Institute/Laboratory for Cements, Mortars and Ceramics from Slovenia. • Continuous support was provided to RMOs in the operation of the CIPM MRA processes, including support for RMOs TC/WG Chairs and CMC writers. It was ensured with the Head of Digital Transformation that all listed NMIs/DIs participating in the CIPM MRA are digitally identified except for three from Cuba that are in the process.
JCGM		
ILC-C3:	Provision of JCGM and JCGM WG2 Executive Secretary and rapporteur (JCGM - one annual meeting, JCGM WG2 - two annual meetings), general support to JCGM, representation in JCGM WG2.	• The BIPM provides the Executive Secretary, who acts as rapporteur, for both the JCGM and JCGM-WG2: VIM. • The 26th meeting of the JCGM (24 January 2024) and the meeting of JCGM-WG2: VIM (27-31 May 2024) were successfully organized with 10 and 15 participants respectively. • The reports of both meetings were drafted and published during the period.
IR-C2:	Provision of the Scientific Secretary for JCGM WG1 and support including: 1) *Rapporteur;* 2) Two annual meetings.	• JCGM-WG1 plenary meetings in May at the BIPM and December 2024 on-line. • Production of the minutes • Recollection of the membership history since the first meeting in 2000.
JCTLM		
Chem-C3:	Support for: 1. JCTLM Executive and WG meetings (in presence and on-line) 2. JCTLM Database entry/nomination review process 3. Maintenance and continued development of the JCTLM Database 4. JCTLM Stakeholder meetings 5. Development of on-line programmes on JCTLM nomination and review processes.	• Organization and hosting of 26th Executive Committee and associated JCTLM DB and TE{P WG meetings • Report of the 25th Executive Committee meeting drafted and published. • Report of the December 2023 DBWG meeting drafted and distributed. • Videoconference of JCTLM Executive held in July 2024. • Update of JCTLM procedures. • Call for experts participation among the JCTLM Members and CCQM WGs for JCTLM Review Team Membership. • Preliminary review of 110 nominations before distribution to the DBWG review teams completed. • 64 new entries published in the JCTLM database.

V	Coordination and institutional liaison	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
		• Review the JCTLM submission and review workflow in consultation with the JCTLM Task Group for JCTLM Database expansion, including organization of 4 meetings. • Support for JCTLM Working Group on Traceability: Education and promotion including organization of a meeting, and development of terms of reference for task team on promotion activities.
INSTITUTIONAL LIAISON		
LIAISON WITH MEMBER STATES, ASSOCIATES, THE CIPM AND RMOs		
ILC-L1:	1. Support to Member States and Associates, CIPM and the BIPM Director 2. Promotion of the Metre Convention and support to potential Member States and Associates 3. Supporting the CIPM in its activities towards universal adherence to the Metre Convention 4. Support for and representation to RMOs (AFRIMETS, APMP, COOMET, EURAMET, GULFMET and SIM).	• As of December 2024, the BIPM has 64 Member States and 37 Associates: – The BIPM provided necessary support/advice to the governments of Member States and Associates with outstanding contributions and subscriptions to avoid suspension and exclusion. – Support was provided to the Finance Office Head on arrears of Member States and Associates as well as supplementary sums of Member States for reporting purposes in the next BIPM Financial Report. – Many countries with emerging metrology systems *(Dominican Republic, Venezuela, Cuba, Sudan, Jordan, Bahrain, Guatemala, Uganda, Kyrgyzstan, Armenia, Fiji, Cote d'Ivoire;* also current Associate States – *Azerbaijan, Latvia, Luxembourg, Panama, Peru, Philippines, Uzbekistan, Viet Nam)* were advised on the process to become an associate or member of the BIPM and a signatory to the CIPM, during visits to the respective countries, visits of delegations to the BIPM and at online meetings. Cuba was reinstated as an Associate State on 16 October 2024. – To implement Resolution 6 *On universal adherence to the Metre Convention* adopted at the 27th meeting of the CGPM in November 2022, the updated proposal on the new membership category - "Observer" status was presented to the CIPM in June and October 2024 as well as to the 23rd meeting of the Partners/NMI Directors and State Party representatives in October 2024. Appropriate actions will be proposed for consideration by the CGPM at its 28th meeting scheduled for October 2026. – BIPM participated in all RMO annual meetings online or in person. – BIPM participated in the annual meetings of NCSLI. • BIPM supported the preparation and participated in the 2nd GULFMET Metrology Forum.

V	**Coordination and institutional liaison**	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
PMD-L1:	1. Representation of the BIPM in the CODATA Task Group on Fundamental Constants (4 meetings) 2. Representation of the BIPM in the Executive Committee of the CPEM (Conference on Precision Electromagnetic Measurements) (4 meetings) 3. Representation of the BIPM in RMO Technical Committee meetings in Mass, Electricity and Thermometry (8 meetings).	• Participation in the meeting of the CPEM Executive Committee at CPEM 2024 in Denver, planning of future CPEM conferences. • Organization of the CODATA-TGFC meeting, 10-11 September.
Time-L1:	Coordination and promotion of time activities for the advancement in the understanding, development, and applications of time scales. Importance of a unique world-wide reference time scale and the correct implementation in all applications, including scientific projects, and industrial systems, for example digital networks and satellite systems. 1. Work with scientific organizations such as the IGS, and ICG in the GNSS field, and the IAU, IUGG, IERS, URSI 2. Work with industrial application organizations as the ITU.	• The BIPM participates to the IGS Governing Board, in the limit of available time, and, regularly, to the activity of the IGS WG on clock and ambiguity resolution. • A more intense collaboration started with IAU as F. Meynadier is Chair of a IAU WG on timing standards. Also a collaboration is in progress for the definition of a Lunar Time. • The liaison with ITU and the related discussion on the continuous UTC is very important and it is proactively followed by participating in the meetings and submitting input documents. • The dept. collaborates with the ICG, international committee on GNSS, concerning timing aspects by supporting the organization of the scientific session and workshops. • A first approach versus the IERS is in progress to collaborate on the continuous UTC and the need of IERS services on the computation of UT1-UTC.
Chem-L1:	1. Maintain working relationships with IFCC, ICSH, ISO TC 212, WHO, IUPAC, IAEA, WMO, ISO TC 207, ISO TC 146, WADA, Codex in support of CCQM and JCTLM activities 2. Support liaison activities required for the CCQM Task Group for Ozone Cross Section to facilitate global implementation of CCQM recommended cross section values for surface ozone monitoring world-wide 3. Support liaison activities required for the CCQM-GAWG Task Group on GHG Scale Comparisons to facilitate expansion of the global measurement infrastructure for atmospheric	• Active liaison with ISO TC 212 maintained. Lead role in the revision of ISO Standards 15193 and 15194 which have progressed to FDIS voting stage and are the basis of the JCTLM review process for reference methods and materials. • Active liaison with ISO TC 146 maintained to ensure the publication of the amended ISO Standards 13964 and 10313 in July 2024. Both documents are references for ozone monitoring networks and now refer to the CCQM recommended value of the ozone absorption cross-section CCQM.O3.2019. • Supported activities of the CCQM-GAWG-TG on Ozone Cross-Section implementation, including online meetings, creation and update of a specific BIPM webpage for ozone, and coordination of drafting of guidelines on how to implement the value CCQM.O3.2019, made publicly available in April 2024.

V	Coordination and institutional liaison	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
	GHG measurements in support of emission inventory verification 4. Support liaison activities required in support of CIPM Sector Task Group initiatives in the field of: health, food safety, and environment and climate.	• Active liaison with IFCC and IFCC Executive board maintained to progress discussions on future funding models for JCTLM; and liaison with IFCC SD to strengthen interaction between IFCC, CCQM and JCTLM. • Continued participation in the JCTLM review team for drugs. • Active liaison with the Inter-Agency Meeting of the CODEX. • Organization and hosting of meetings of CCQM-GAWG Task Group on GHG Scale Comparisons. • Organization of 1st CIPM-STG-CENV stakeholder hybrid meeting (over 400 registered participants), with website and open call for poster and presentations, and pre-meetings and SharePoint site Core Group and Session Co-chairs. Contact initiated with organizations identified for leading recommendations from the BIPM-WMO 2022 workshop. • CCQM-TG-FOOD established. Webpage created and ToR developed. Three online meetings with selected members of WGs and RMOs organized. Initiation and organization of virtual wider stakeholder meeting for early 2025.
IR-L1:	1. International Commission on Radiation Units (ICRU) (Commissioner and sponsor of Report Committees) 2. International Atomic Energy Agency (IAEA) (SSDL Scientific Committee) 3. International Committee for Radionuclide Metrology (ICRM) 4. ISO (TC 85/SC 2 and working group meetings).	• BIPM representative on the IAEA SSDL Scientific Committee and participation in the biennial meeting in March. • Organization of a liaison meeting between IAEA, BIPM and CCRI on radionuclide metrology. • Membership of the consultants group revising the IAEA Code of Practice TRS-398 for external beam radiotherapy; revision in final stages of publication. • Commissioner of the ICRU. • Chair of the Fundamental Quantities and Units Committee of the ICRU. • Participation in the work of the ICRU, notably the publication of an ICRU glossary and representation of the ICRU on the CCRI-DT-WG (Digital Transformation). • Participation in the advisory board of the European provider of medical radionuclides (PRISMAP). • Vice presidency of the ICRM, preparation of the ICRM2025 conference and participation in ICRM WG. • Production of a BIPM IR Department long-term strategy report for the CIPM.
SUPPORTING NMI DIRECTORS MEETING AND RMO CHAIRS/SECRETARIAT		
ILC-L2:	1. To work with the panel of NMI Directors to organize an annual meeting at the BIPM	• The Directors' meeting was organized focusing on Digitalization, Quantum Technology and the CIPM Strategy.

V	Coordination and institutional liaison	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
	2. Development of a global perspective on key issues 3. Provide focused support for states with emerging metrology systems 4. Facilitate annual meetings of the BIPM and RMO Chairs.	• The CIPM Strategy Process was supported as requested and complemented by ideas from a consultation of young metrologists from around the world. • BIPM and RMO Chairs met during the JCRB meeting. No separate meeting was held.
LIAISON WITH STRATEGIC PARTNERS		
ILC-L3:	Institutional liaison with International/intergovernmental organizations/Quality Infrastructure players: – INetQI, OIML, UNIDO, UNESCO, ILAC, ISO, OECD, WTO, World Bank, – institutional liaison with other international organizations as required.	• BIPM-UNESCO cooperation: – The World Metrology Day 2024 launch event "We Measure Today for a Sustainable Tomorrow" was successfully organized at t the UNESCO headquarters on 14 May 2024, in partnership with the BIPM and the OIML, to mark the official recognition by UNESCO of 20 May each year as a UNESCO International Day. Around 200 participants in person and online (Permanent Delegations to UNESCO, Embassies of BIPM Member States and Associates to France, International Organizations and members of the metrology community) and speakers from the UNESCO Secretariat, Permanent Delegation of Kazakhstan to UNESCO, BIPM, OIML, representatives of EURAMET, NMIs from France, Kenya and Republic of Korea attended the event; the event was followed by reception. – The BIPM continued the discussion with the UNESCO Secretariat regarding signing a Memorandum of Understanding with UNESCO on cooperation (to revise the 1949/1952 CIPM-UNESCO Agreement). – Preparation of the World Metrology Day 2025 celebration is well advanced; venue is confirmed, and the draft agenda being prepared. • BIPM-UNFCCC cooperation: – The BIPM attended the UNFCCC Conference of the Parties (COP29) in November 2024 in Baku, Azerbaijan. • BIPM-UNIDO cooperation: – The BIPM drafted and proposed a concept note on coordinated outreach activities by the BIPM and United Nations Industrial Development Organization (UNIDO) to make the worldwide measurement system more widely accessible (including a proposal to organize of a side event and/or thematic session at the 21st session of

V	Coordination and institutional liaison	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
		the UNIDO General Conference in November 2025 or any other occasion to mark the 150th anniversary). – The BIPM contributed to the UNIDO document: Tackling climate change with quality and standards – fostering trust in climate action through quality and standards published in June 2024. • BIPM-WTO cooperation: – The BIPM statement was submitted to the WTO TBT Committee; the BIPM was represented remotely at the WTO TBT Committee meetings in March, June and in person in November 2024. – The BIPM supported the delegation of Australia to draft a proposal to organize a side event and/or thematic session at the WTO TBT Committee in 2025 to mark the 150th anniversary. • BIPM-OECD cooperation: – The one-day joint BIPM-OECD workshop (in person and online) "Building Stronger Connections Between Quality Infrastructure and Regulation" was successfully organized at the BIPM headquarters on 6 December 2024 to explore key findings and share the outcomes of the OECD project "Interlinkages between regulation and quality infrastructure" funded by the National Metrology Institute of Germany (PTB) in order to illustrate the diverse regulatory and quality system landscape. – A BIPM staff member was seconded to the OECD, from 4 September 2023 to 29 March 2024, under a part-time loan programme to support the OECD Regulatory Policy Division in the project "Interlinkages between regulation and quality infrastructure". The BIPM staff contributed to various activities, including drafting analytical content, participating in stakeholder interviews, and preparing a mapping of international bodies involved in quality infrastructure. – The BIPM submitted feedback received from the BIPM Chemistry Department regarding BIPM instruments to address emerging critical existential risks within the OECD coordinated Partnership on effective international rulemaking (IO Partnership) Workshop on Emerging Critical Risks held in Geneva on 17-18 June 2024.

V	Coordination and institutional liaison	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
		• BIPM-IPCC cooperation: – The Sixty-first Session of the Intergovernmental Panel on Climate Change (IPCC-61) adopted a decision granting observer status to the BIPM in August 2024 (application to IPCC for observer status was submitted in March 2024). The BIPM nominated its focal point to the IPCC. • Formalization of institutional liaison – Some agreements (for example, Memorandum of Understanding with CIE - International Commission on Illumination to replace CIPM-CIE Agreement of 2007) were drafted to formalize existing links with strategic partners.
YOUNG METROLOGISTS' FORESIGHTING EXERCISE		
ILC-L4:	Facilitating visionary ideas for future opportunities and challenges via workshops, debates and interviews with young metrologists to encourage strategic thinking on long-term issues and challenges. – This exercise will be conducted bottom-up in collaboration with RMOs before being brought into a common perspective for presentation at the 150th anniversary of the signing of the Metre Convention (20th May 2025).	• Eleven RMO coordinators from all RMOs have been nominated. An online questionnaire was developed and launched in 2023. Online workshops in six RMOs were organized with the participation of 380 young metrologists. A consolidation meeting was organized in July 2024. The consolidation meeting concluded with a summary of inputs from young metrologists, gathered through over 170 questionnaire responses. This summary was then made available on the e-learning platform for a second round of comments. The final report on the Young Metrologists Vision 2050+ Project was published and presented to the CIPM in October 2024.

VI	Communication and promotion	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
PROMOTION, REPORTING, PUBLICATIONS AND THE BIPM WEBSITE		
ILC-CP1:	Provision of BIPM internet: 1. Continue to adapt effectively to the rapidly changing world of electronic media to ensure that the website continues to deliver services effectively and portrays an up-to-date image of the BIPM. 2. Develop web services as required to meet the needs of the BIPM, CIPM and CCs. 3. Adapt the site to display landing pages for documents published by the BIPM and identified with DOIs (see ILC-DT1.2).	• The BIPM website continues to be the BIPM's primary means of communication and is supplemented by specialized sites (KCDB, JCTLM database, SI Digital Reference, BIPM e-learning platform, BIPM Time Department database, BIPM SharePoint, BIPM YouTube channel and LinkedIn profile). • The dedicated search engine covers both open and restricted-access content on the website (with the results tailored to the access rights of the individual user), as well as the contents of the KCDB, the JCTLM database and *Metrologia*. • During a typical working week, the BIPM website receives visits from approximately 2000 different users per day. The website contains around 1100 official documents, 30000 working documents, and 14 000 individual user accounts (providing access to restricted content where appropriate). • Forty-two news stories were published on the front page of the BIPM website in 2024. • A new section of the website was created to promote the celebrations of the 150th anniversary of the signing of the Metre Convention and to highlight the events and projects (articles published in journals, videos, exhibitions, etc.) in preparation for the anniversary week in May 2025. • A new section of the website was created to act as a repository for BIPM News and Updates. • Specifications were developed to implement and maintain digital object identifiers (DOIs) for key publications (official and CC reports, Rapports BIPM) to ensure long-lasting references and reliable document access by humans and machines.
ILC-CP2:	Promotion and Enhancement: 1. Creation of newsletters, posters, and videos in support of the BIPM's programmes. 2. Creation of a repository of BIPM images. 3. Work with the Communications teams of the RMOs to pool resources and maximize the impact of both regional and world-wide campaigns. 4. Develop the BIPM's presence on social media such as YouTube and LinkedIn.	• The BIPM worked with an external designer to produce the poster for World Metrology Day 2025 along with a new 'macaron'. • The BIPM worked with OIML to update and prepare the poster resource website for 2025 World Metrology Day. • The BIPM sent six issues of the newsletter BIPM eNews to subscribers using the external platform MailChimp. As of 31 December 2024, there were almost 4 000 subscribers. • The BIPM posted 44 articles to LinkedIn during the period, and its LinkedIn site had around 7 000 followers as of 31 December 2024. • The BIPM upgraded to LinkedIn Pro, to gain analytics and publishing tools to better serve the needs of their community.

VI	Communication and promotion	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
		• The BIPM developed a comprehensive, integrated communications strategy for the l5Oth Anniversary campaign, ensuring alignment across platforms and global visibility. • BIPM improved operational efficiency and campaign readiness by procuring essential tools and services, including Sprout Social, Canva, Restream and filming equipment, to ensure robust support for 2025 initiatives. • The BIPM successfully expanded its YouTube channel, which includes 226 videos and has 3 460 subscribers. Fifty-four videos have been uploaded since the start of 2024. • The BIPM created new YouTube thumbnail templates and enhanced descriptions, subtitles and playlists, to better align with YouTube and SEO best practices.
ILC-CP3:	Publications: 1. Publish meeting reports - including drafting/minuting, editing, translation into French, typesetting, and printing as required – for the BIPM, CIPM, and CGPM as well as the Joint Committees. 2. Editing, translation into French if required, typesetting and publication of other key reports and documents. 3. Editing of papers by the BIPM staff for publication in the scientific literature. 4. Register the BIPM's publications in an external repository, to improve their Findability and Accessibility (see ILC-DT7).	Official Publications • The proceedings of the 27th meeting of the CGPM (2022), 424 pp / bilingual version, were typeset and published during the first quarter. • The report of the 112th meeting of the CIPM (2023) was typeset and published in English and French. • The reports of Sessions I and II of the 113th meeting of the CIPM (March and June 2024) were drafted, edited, typeset, translated and published in English and French. The report of Session III was drafted in English and published. • The BIPM Annual Review 2023/2024 was drafted, edited, typeset and published. • The Financial Report 2023 and the Notification 2025 were published in French and English. • The By-Laws and Commentary, drafted by an external expert, were translated into French. • Version 3.01 of the SI Brochure was prepared and published. Reports of Consultative Committees • The report of the 14th CCAUV meeting (2023) was edited and published. • The report of the 29th CCQM meeting (2024) was edited and published. • The report of the 26th CCU meeting (2024) was edited and published. • The report of the 31st CCT meeting (2024) was edited and published. • The report of the 19th CCL meeting (2024) was edited and published.

VI	Communication and promotion	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
		Other publications • The *News from the BIPM laboratories 2023 was* drafted, edited and published in *Metrologia*. • Four Rapports BIPM were edited and published. • Specifications have been developed to register digital object identifiers (DOIs) for key publications in the external repository CrossRef. The first stage of the project will cover official and CC reports, and Rapports BIPM. This project is ongoing.
ILC-CP4:	1. Editing and publication of *Metrologia* 2. Ensure the success of *Metrologia* as the key scientific publication for high-level metrology, with a robust editorial team and appropriate publishing partner. 3. Liaise with the CIPM and CCs to identify topics of interest, as well as publications that should be included in the *Guides, Standards and Conventions* section. 4. Produce Focus Issues on key topics of interest. 5. Maintain the journal's viability taking account of evolving trends such as towards open-access publishing. 6. Encourage the publication in *Metrologia* of open-access review papers by senior scientists, through funding the Article Processing Charge for selected papers. 7. Celebrate the journal's 60th anniversary in 2025, alongside celebrations of the anniversary of the *Metre Convention*. 8. Provision of external Deputy editor support.	• *Metrologia* is published by IOP Publishing on behalf of the BIPM. The editorial team comprises an Editor-in-Chief and 2 Deputy Editors. Part of the Editor-in-Chief's time (RISE) and 1 of the Deputy Editors' time (INRIM) are financially supported by the named NMIs. • Six regular issues were published in 2024, comprising: 62 Papers, 2 Reviews, 1 Short Communication, 5 Letters and 1 Guides Standards and Conventions. • 81 abstracts were published in the Technical Supplement. • Papers were added to the following Focus Issues: Challenges in Time and Frequency Metrology (1), NEWRAD 2023 (5). • The 2 Review papers were both published Open Access. In total, 41 out of 71 (58 %) items in 2024 were published Open Access. • A strategy paper was drafted for the CIPM's consideration and the CIPM endorsed *Metrologia* as its journal of choice for reporting advances in pure and applied metrology at the highest level. • Following Decision CIPM/113-29 (2024), the BIPM has initiated with IOP Publishing the transfer of *Metrologia* from a hybrid journal to a fully Open Access journal (from 2026). • A first joint Focus Issue has been opened in partnership with Measurement Science and Technology: *Focus on Digitalization in Metrology*.
ILC-CP5:	Journal subscriptions (on-line or hard copy); pay-per-view access (or rental) of individual scientific articles; reference books for BIPM staff.	• Five journal subscriptions were renewed and a few books, articles and ISO standards were purchased.

VI	Communication and promotion	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
WORLD METROLOGY DAY		
ILC-CP6:	Build on the success of World Metrology Day (WMD), doubling participation through all media (Project run jointly with OIML): 1. Provision of WMD Website content: – Poster (in consultation RMOs and with a selected NMI) – Directors' messages and press release – Poster and events listings for all participating countries 2. Participation in at least four national events and hosting events at the BIPM for Embassy Representatives. 3. Promoting World Metrology Day with International, Regional and National Stakeholders via social media.	• The poster for 2024 was designed by Tübitak UME (Türkiye) in collaboration with EURAMET. • The 2024 OIML and BIPM Director's messages and press release were published on the WMD website. • The 54 national and RMO posters, along with the French and English versions, were published on the website. • Details of 37 national events were listed. • The World Metrology Day 2024 Launch Event, organized by UNESCO in partnership with the BIPM and the OIML, was held at the UNESCO headquarters on 14 May 2024 to mark the official recognition by UNESCO of 20 May each year as a UNESCO International Day. • Approximately 200 guests from the Permanent Delegations to UNESCO, Embassies of BIPM Member States and Associates to France, International Organizations and members of the metrology community attended the Launch Event in person and online. • The ILC Department is working with an external designer to produce a poster for World Metrology Day 2025, to tie in with the 150th anniversary celebrations. • Online participation in WMD events of several NMIs of Member States and Associates (including video messages from the BIPM Director).
WORKSHOPS ON KEY TOPICS		
ILC-CP7:	1) To identify (with the CIPM and NMIs) topics of importance to the metrology community to be addressed at BIPM Workshops.	• This year, the BIPM organized workshops in Quantum Technology, Digital Transformation and Climate Change as well as a consolidation workshop for young metrologists vision 2050+. • A joint workshop with OECD on quality infrastructure and regulation was organized at the BIPM headquarters on 6 December 2024.

VII	Digital Transformation and New Digital Services	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
1. DEVELOPMENT OF SI DIGITAL REFERENCES The basis for the SI Digital Framework proposed by the CIPM will be the provision of the reference data in digital format that provide the essential definition of the SI. These data will be a digital representation of the data that are currently included in the SI Brochure which includes all of the decisions made by the CGPM and the CIPM that underpin the SI. Additionally, databases and associated APIs will be developed in collaboration with Working Groups of each of the CCs to facilitate machine access to the *mises en pratique* for the base SI units.		
ILC-DT1.1:	Development of the Unique SI Digital Reference Point. This will be the digital (machine-readable) resource from which all of the information about base units, derived units, prefixes and units accepted for use with the SI can be accessed digitally.	• The SI Reference Point was released for beta-testing at https://si-digital-framework.org/SI • A unit expression parser allows the dynamic interpretation of prefixed units and compound unit expressions. • An open GitHub repository is available at https://github.com/TheBIPM/SI_Digital_Framework for the collation of feedback and is maintained and further developed by staff member of Time Department and a group of external experts. • The knowledge base underlying the SI Reference Point can be interrogated directly by machines, and an application programming interface is provided for the use of programmers and to generate the web interface. The same principle has been applied to the other machine-interpretable services listed under XXX-DT2.
ILC-DT1.2:	Development and maintenance of digital identifiers for key reference texts underpinning the Unique SI Reference Point (e.g., definitions, resolutions, CMCs, etc.)	• The Resolutions of the CGPM and Recommendations of the CIPM were registered with DOIs in 2023, and these references have been integrated into the "decisions" part of the SI Reference Point. • Reference points for the CC Service Categories in Physics and in Ionizing Radiation were released for beta-testing at https://si-digital-framework.org/kcdb-sc • A reference point for Nuclides was released for beta-testing at https://si-digital-framework.org/nuclides • External references related to the Service Categories in L, PR and RI have been collated and integrated into the knowledge base. • The quantities covered by the Service Categories in Physics and Ionizing Radiation have been identified and integrated into the knowledge base.
Time-DT2:	Work with representatives of the CCL and the CCTF to provide machine-readable access to the standard frequencies that underpin the *mise en pratique* of the metre and the secondary representations of the second. The work will require	• The CCL CCTF database and API for the secondary representations of the metre and the second is available and under undertest by NMIs.

VII	Digital Transformation and New Digital Services	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
	the development of a special database and a custom API for each community.	
PMD-DT2:	Work with representatives of the CCT to provide machine-readable access to the agreed data for the fixed points of the ITS-90 that are specified in the *mise en pratique* of the kelvin. The work will require the development of a special database and a custom API.	• The CCT-TG-DIG has collated structured data from its CCT Guides and specified the first set of calls that an application programming interface should provide. The first calls have been programmed and are being tested on a restricted-access site. APIs for: – ITS-90 temperature scale – PLTS-2000 temperature scale are almost ready for beta-testing by the wider CCT.
XXX-DT2:	Machine-readable access to the *mise en pratique* for the other base units will be put in place during the Work Programme. All of this activity will be undertaken in collaboration with working groups of each of the CCs involved to ensure that the facilities developed meet the needs of each user community.	• APIs for: – Primary radiometric temperature measurements – Acoustic gas thermometry – High-temperature fixed point thermodynamic temperatures have been programmed and are undergoing initial testing.
2. DEVELOPMENT OF NEW DIGITAL SERVICES The digital references developed by the activities above will provide the basis for new metrology services at the BIPM, in the NMIs and amongst sectors of society that use the SI. Such services will enable data to be available for analysis; they will improve data quality and increase reliability in its use. The projects below describe the actions planned to develop some of these new digital services at the BIPM.		
ILC-DT3:	Undertake actions necessary to ensure that the KCDB data environment can provide machine readable data. 1) Upgrade of the KCDB database and creation of a back office to provide "Digital CMCs" (DCMCs) and support for DCCs. 2) Development and maintenance of an API for DCMCs.	• The KCDB API on CMCs was updated to extend the search to 'no-longer valid CMCs', and to include PIDs for NMI/DIs and KCDB Service Category Code. • Permanent access to CMC data, using the KCDB's persistent identifiers for the CMCs, has been enabled through a dedicated service on the SI Digital Framework. The KCDB identifiers have been made visible on the KCDB website (through the quick search) and the KCDB API. • The structure of the CCAUV classification of services in the field of vibration was revised to align with other domains in physics to further facilitate the implementation of PIDs for quantities and units.
Time-DT4:	Undertake actions necessary to ensure that the UTC and UTC-rapid data, and other services currently available from the BIPM Time Department database are available in a machine-readable format.	• A database and a test API were developed and published in 2023 for the UTC data retrieval by the users. Comments are received and the service has been updated with the recent updates of Circular T.

VII	Digital Transformation and New Digital Services	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
Chem-DT5:	Maintain machine readability of the JCTLM Database. Continue to deliver machine readability of the database with future operational updates.	• Completion of technical specification for the extension of the JCTLM Database and contract with service provider for the development of a submission and review web platform Development and project to start in October 2024.
ILC-DT6:	Develop new digital services, as required by the CIPM and CCs, including an extension of the machine-readability for the KCDB to access the results of key and supplementary comparisons (Appendix B).	• A proposal for provision of machine-readable comparison data via a KCDB API for comparisons was discussed at the JCRB 48th Meeting and specifications will be developed.
3. DEVELOPMENT OF NEW DATA PORTAL AND SUPPORT FOR COMPONENTS OF THE "INTEROPERABILITY AND REUSABILITY" RESOURCE LAYER In order to provide efficient user access to the new digital services described in the projects above, they will be accessible directly and through the International Metrology Resource Registry (IMRR). This is already hosted on the BIPM website as a result of a collaboration with NIST. The project work proposed here will greatly extend the functionality of the IMRR to enable direct access (via APIs) to data held within the resources in its registry. Additionality, this project will support the development of the interoperability and reusability resource layer of the SI Digital Framework. This layer includes the mapping, translation and ontology services needed to develop the "I" and the "R" of FAIR.		
ILC-DT7:	Strengthen the International Metrology Resource Registry (IMRR) through liaison with the CCs to identify key data that could usefully be shared across the metrology community; encourage the inclusion of supporting data for digital calibration certificates (DCCs); further develop the IMRR in accordance with the FAIR principles to provide direct mining of resources through APIs.	• The previous version of the IMRR was withdrawn from service in 2022. Further development of IMRR or reincarnation were not prioritized by the FORUM-MD. The project is currently discontinued.
XXX-DT8:	Enable the interoperability of representations of units of measurement in the community through development of a unit mapping service between broadly adopted unit of measurement representation systems (UMRSs) aligned with SI units; enable semantic representation of core concepts in metrology through development of ontologies as appropriate; develop metadata and a metadata schema ('m-layer') in support of digital translation between units and quantity kinds; support the JCGM-WG2 in their revision of the annotated VIM to meet the demands of machine	• The Unit mapping service has not been prioritized by the FORUM-MD, therefore the project has not been taken up. • The next edition of the VIM (VIM4, currently in its 3rd Committee Draft) will – like the Annotated VIM3 – be published in a machine-friendly form whereby reference can be made to the individual terms.

VII	Digital Transformation and New Digital Services	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
	readability, and machine-actionability where possible/appropriate.	
4. OTHER DIGITAL TRANSFORMATION ACTIVITIES INCLUDING SUPPORT FOR THE CIPM		
ILC-DT9:	Coordination of the "Digital Discussion group" amongst BIPM staff working on Digital Transformation projects to ensure effective collaboration on these topics.	• The BIPM Work Programme regarding the Digital Transformation projects of the BIPM headquarters is now coordinated by the TG-SI Digital Framework of the FORUM-MD which also receives input from other relevant groups in the FORUM-MD. • The FORUM-MD-TG-SIDF met twice during the period.
ILC-DT10:	Support for the work and meetings of the CIPM Digital EG and TG. External consultancy to support the digital transformation activities described above.	• The Digital EG and TG were closed at the end of 2023 and are now replaced by the FORUM-MD and its nine task and working groups. • The Time Department offer also the scientific secretariat to the Forum of Digitalization in Metrology.

VIII	IT services	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
IT INFRASTRUCTURE; NETWORK, STORAGE AND SECURITY INFRASTRUCTURE		
1. INF-NNA: NETWORK INFRASTRUCTURE Due to product lifetime and warranty expirations, parts of the BIPM IT datacentre infrastructure will have to be renewed during the period 2024-2027. The network core and edge devices, installed in 2013, are running out of maintenance contracts and need to be replaced in 2024.		
NNA.1:	Network core infrastructure	• The data and routing and distribution layers have been split in a multi-tiered architecture to increase performance, security and reliability. The network storage now performs with a 2x10Gb/s bandwidth from its network interfaces to the network backbone. • The two IT rooms (main and backup) are now connected with 2x25Gb/s bandwidth. • The data synchronization performance between the two data network nodes have been largely improved. • All appliances such as firewalls, Internet routers, load balancers and other security devices have been completed without outage thanks to the redundancy of devices (active/active or active/passive modes). • Network core infrastructure supports any device (servers, appliances) with a 10 Gb/s Ethernet connection.
NNA.2:	Network Edge infrastructure	• The distribution layer (backbone to the buildings) performs now with a 2x10Gb/s bandwidth. • Each building has a set of new network switches which offers PoE+ Ethernet ports.
NNA.3:	Licenses and services	• The network configuration has been completely reviewed to fit with current network protocol versions and network security recommendations. • The smooth switchover between the previous network architecture and the new one have been completed in early July.
2. INF-NSA: STORAGE INFRASTRUCTURE Taking into account the increased use of Cloud-based storage as a major solution to host external data, the internal network storage, which hosts the IT services and the internal network data, will have to be updated in 2027		
NSA.1/NSA.2:	Storage infrastructure	• Planned Q1/Q2 2027.
NSA.3:	Backup infrastructure	• Planned 2025 (Archive) – Study on needs for long term archiving ongoing.
NSA.4:	Licenses and services	• Yearly maintenance for 2024-2027.

VIII	IT services	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
3. INF-SEC: SECURITY INFRASTRUCTURE		
SEC.1:	Firewall Cluster and Intrusion Prevention System devices	• Large consultation of current firewalls solutions to determine whether we need to change the firewall platform provider in 2025.
SEC.2:	Anti-virus Cloud Service	• Yearly subscription for 2024-2027.
SEC.3:	Multi-factor authentication services and devices	• Multi-factor authentication has been implemented for O365 administrator accounts and for managing the anti-virus cloud service.
SEC.4:	Licenses and services	• Yearly subscription and maintenance for 2024-2027.
SEC5:	IT External Security review	• Planned in 2026.
IT SERVICES; WEB, DATABASES, SCIENTIFIC AND CLOUD SERVICES		
4. SRV-SER: SERVERS AND VIRTUALIZATION PLATFORM FOR HOSTING SERVICES BIPM Web and all Intranet services rely on a virtualized platform that operates on dedicated hardware servers in a disaster recovery scheme. This allows redundancy of services as well as load balancer dispatch Web traffic among several virtual servers. As the five-year lifetime of hardware servers is the standard, they should be renewed in 2026.		
SER.1/2:	Virtualization platform and hardware hosts	• Many virtual servers have been setup in order to serve the new Web and API services. • A complete Web design architecture have been implemented for the SI-digital-framework API services portal which relies on multiple virtualized servers.
SER.3:	Load balancer Servers	• Planned for 2026.
SER.3:	Licenses and services	• Yearly subscription & maintenance for 2024-2027.
5. SRV-PH: PHONE SYSTEM SERVICES In the framework of revamping its phone service in 2024, IT services will prioritize a strong interaction between the classic phone service and O365 services in order to get a full cloud-based telephony solution that will offer new business services.		
PH.1:	Core infrastructure	• Phone/O365 integration Study in 2026.
PH.2:	Dedicated Data Link	• The ISDN link over copper has been replaced by a Trunk SIP over optical fibre. We are now completely compliant with Voice Over IP technology.
PH.3:	Phone set	• Planned in 2026.
PH.4:	Licenses and services	• Yearly subscription & maintenance for 2026-2027.

VIII	IT services	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
DATABASE, SCIENTIFIC AND CLOUD SERVICES Among other Web services, databases have a major role in serving the world-wide metrology community. The goal is to consolidate all these databases into a single repository which can be searchable and findable by the community. O365 cloud services have a key role in sharing information among BIPM stakeholders, such as working groups. It has improved communications and provides new services that offer productivity gains. Other Cloud services will be implemented such as long-term data archiving and on-line web firewalling.		
DB.1:	Database core infrastructure	• A major upgrade of our Intranet database system has been carried out.
DB.2:	Database infrastructure integration	• Many databases have been setup in order to serve the new API services and other database projects.
DB.3:	Licenses and support	• Yearly maintenance for 2024-2027.
SRV-NI:	National instruments site license and other sitewide scientific software licenses	• The yearly National instruments sitewide license has been installed successfully.
O365.1:	O365 Development	• IT services support all O365 BIPM departments and services developments. • IT services has launched the new IT services SharePoint portal which reflects the push of IT Services to be compliant with ITIL standards.
O365.2:	Licenses and support	• Yearly maintenance for 2024-2027.
WEB.1:	Cloud Infinite archiving system	• See NSA3.
WEB.2:	Web service firewall and security	• Study is ongoing.
OTHER ACTIVITIES: USER HELPDESK AND APPLICATION SUPPORT - INFRASTRUCTURE ADMINISTRATION AND SUPPORT		
IT-HELP:	User helpdesk and application support	• In the framework of ITIL implementation at the BIPM, IT Services have completed the IT services catalogue, which lists technology resources and offerings available from the IT services. This catalogue is intended to help the IT services efficiently and effectively manage and meet staff members expectations. • In the framework of ITIL implementation at the BIPM, a helpdesk platform integrated through 0365 has been successfully installed and configured by IT Services. It is plainly operational since October 2024. • IT Services offer support for all BIPM applications such as Web applications (KCDB, JCTLMDB, API, ...) , O365 services and Internal Services.
IT-ADM:	Infrastructure administration and maintenance	• Yearly maintenance for 2024-2027.

IX	Capacity Building and Knowledge Transfer	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
1. BIPM CBKT PROGRAMME LEVEL STRATEGY, DEVELOPMENT, AND OPERATION, INCLUDING ASSOCIATED WEB AND E-LEARNING PLATFORMS AND COORDINATION WITH STAKEHOLDERS *Over 80 % participation of Member States and Associates (as participants and lecturers)*		
ILC-CBKT1: – *4 workshop-based activities (BIPM and RMOs)* – *4 cycles of laboratory-based placements at partner NMIs* – *30 remote learning on-line activities* – *100 workshop-based participants (BIPM and RMOs)* – *40 metrologists at laboratory-based placements at partner NMIs* – *400 participants in on-line activities* – *500 e-learning participants*	1) Maintaining the CBKT strategy that aims to increase the effectiveness with which Member States and Associates engage in the world-wide coordinated metrological system: assessing needs of stakeholders; identifying appropriate CBKT instruments; implementing activities; evaluating the CBKT Programme activities; adapting/adjusting the Programme activities to the needs of stakeholders. 2) Technical aspects associated with the management, operation and maintenance of the CBKT remote learning capabilities (including licenses and contractor relations): – on-line KCDB 2.0 CBKT training platform – on-line short courses – on-line technical exchanges – CBKT webpage of the BIPM website – e-learning platform (including RMO e-learning sectors). 3) Developing and managing the BIPM/RMO CBKT framework (including cross-RMO on-line activities and e-learning). Liaison with RMOs to ensure coordinated CBKT delivery. – Operation and management of a BIPM/RMO advisory group for the CBKT Programme (including liaison with OIML CEEMS Advisory Group).	• Support from TÜBİTAK UME, NMI of Türkiye was secured to run the cycles in 2024-2025. The joint BIPM and TÜBİTAK UME initiative to host ten talented metrologists from around the world. The survey for the TUBITAK UME project placement initiative was organized, and the feedback was taken into account when developing the seventh cycle. • The survey to identify the needs of RMO TC/WG Chairs has been completed; the programme outline on the role of RMO TC/WG Chairs is under development. The expected launch of the webinar is the beginning of December 2024. • The survey was conducted to understand the needs of the potential pilot laboratories within the CIPM MRA. The survey results will be used in the development of the programme to support potential pilots of comparisons within the CIPM MRA. • A meeting with the RMO CBKT officers was organized in March and December 2024. The aim of the meeting was to share capacity building and knowledge transfer practices, support each other where possible, and build joint initiatives designed to support the CIPM MRA user community.

IX	Capacity Building and Knowledge Transfer	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
	4) Exploring support from and liaison with appropriate international organizations with an interest in relevant capacity building and knowledge transfer activities.	
2. PLANNING, COORDINATION, SUPPORT, LOGISTICS AND DELIVERY OF THE CORE CBKT ACTIVITIES (CIPM MRA, JCTLM AND UTC)		
ILC-CBKT2:	1) Planning, coordination, support, logistics and delivery of the core CBKT activities (CIPM MRA, JCTLM and UTC): scheduling, course design, call and selection processes (liaising with stakeholders on prioritization of candidates), identification of speakers, funding of participants' costs where appropriate, provision of BIPM lecturers and sourcing of external RMO/NMI lecturers together with all associated logistics. 2) Delivery of the CIPM MRA courses (when necessary) to cover: – Future leaders (aimed at new and potential RMO TC/WG Chairs) – Sound beginning (aimed at new participants in the CIPM MRA) – Orientation for new RMO TC/WG Chairs – Participation in the activities of the *Metre Convention* (including orientation for 'newcomers'). 3) Supporting JCTLM and UTC CBKT initiatives through: – Workshop-based CB activities – Laboratory-based CB placements – Knowledge transfer activities 4) Remote-learning on-line activities (on-line short courses, on-line technical exchanges, and provision of the e-learning platform).	• The joint BIPM and OIML e-learning course, which includes 5 Modules based on the BIPM and OIML joint publication - *'National Metrology Systems - Developing the Institutional and Legislative Framework,'* was launched in July 2024. Currently 108 users are enrolled on the course. This project is sponsored by METAS, the NMI of Switzerland. A paper on this initiative has been published in the OIML Bulletin. • Three technical exchanges on the KCDB (CIPM MRA) for Writers, TC Chairs and Comparisons pilots were organized, with a total participation of 565 NMI/DI experts: – KCDB 2.0 - TC Chairs in Chemistry and Biology (15.02.2024) – KCDB 2.0 – Comparisons pilots (26.03.2024) – KCDB 2.0 - CMC Writers in General Physics, Ionizing Radiation (04.04.2024) Cumulative overview of the CBKT, as of September 2024: • 61 CBKT initiatives were organized: 30 projects at the BIPM and regions; 31 (+15 repeated) projects online and webinars organized with RMOs. More than 65 lecturers from NMIs/DI and IOs have been involved in delivery of the CBKT activities. • e-learning: there are 24 e-learning courses submitted by EURAMET, COOMET, GULFMET and the BIPM Scientific Departments available for metrology community. • Overall, 4109 participations from 125 countries in various CBKT initiatives: 558 participants at the BIPM and regions physically; 3551 participants in online sessions. About 1600 participants from 116 countries are registered on the e-learning platform. • CBKT participation by RMOs: – 372 - AFRIMETS – 787 - APMP – 564 - COOMET – 1118 - EURAMET – 376 – GULFMET – 892 - SIM

IX	Capacity Building and Knowledge Transfer	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
3. PLANNING, COORDINATION, SUPPORT, LOGISTICS AND DELIVERY OF THE TOPIC-BASED CBKT ACTIVITIES		
ILC-CBKT3:	1) Planning, coordination, support, logistics and delivery of the topic-based CBKT activities: finding sponsors, scheduling, course design, call and selection processes (liaising with stakeholders on prioritization of candidates), identification of speakers, provision of BIPM lecturers and sourcing of external lecturers. 2) Delivery, supporting of and lecturing in the topic-based CBKT initiatives through: – Workshop-based CB activities – Laboratory-based CB placements – Knowledge transfer activities – Remote-learning on-line activities (on-line short courses, on-line technical exchanges, and provision of the e-learning platform). 3) Delivery of joint Varenna metrology school for world-class young scientists/metrologists – in collaboration with the Italian Physical Society.	• Seventh cycle of the joint BIPM and TÜBİTAK UME initiative has been completed. Ten young metrologists from ten countries (Ethiopia, Uzbekistan, Azerbaijan, Kenya, Saudi Arabia, Argentina, Egypt, Costa Rica, Indonesia, Russian Federation) from all RMOs have submitted their project reports based on their placements at the TÜBİTAK UME laboratories (for a period of 1 to 3 months). • EURAMET-BIPM training course on National time scale and dissemination of time and frequency has been launched. The joint knowledge transfer initiative at the *Real Instituto y Observatorio de la Armada (ROA)*, Spain, will be from 29 to 31 October 2024. The project is open to all RMOs.
4. Laboratory-led capacity building and knowledge transfer activities		
PMD-CBKT1	Planning, coordination and delivery of the capacity building and knowledge transfer activities in the field of electricity.	• Not planned during the reporting period
PMD-CBKT2	Plan and deliver knowledge transfer activities using a compact prototype Kibble balance apparatus to NMIs seeking opportunities for scientists to experience hands-on involvement in Kibble balance technology.	• Not planned during the reporting period
Time-CBKT:	Planning, coordination and delivery of the capacity building and knowledge transfer activities in the field of time metrology according to the CCTF plans by developing e-learning tools and GIT repository,	The CCTF CBKT project has started with several eLearning tools published and under test, thanks to the support of a secondee from NPLI, India. Three courses are now available: 1. Time Transfer Through GNSS Pseudorange Measurements 2. Time and Frequency Capacity Building By Resource Sharing

IX	Capacity Building and Knowledge Transfer	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
	and by the continuous day-to-day support to the UTC laboratories. This activity relies on the contribution of a secondee with the role of promoting the coordination and efficient use of the CBKT material. Without a secondee this activity will be limited.	3. CCTF Technical Exchanges on Time and Frequency Best Practice in NMIs Another three are under development. This activity is greatly appreciated by the UTC laboratories and will be additionally promoted and schools will be organized with the support of a secondee from NIST. In 2024 the CCTF CBKT programme contributed to the EURAMET and the APMP training schools. In 2025 a contribution to a SIM school as well as the organization of a BIPM summer schools is in progress. *Publications and presentations:* • B. Vattikonda, G. Tagliaferro, P. Tavella, "CCTF Capacity Building for Time & Frequency Metrology- Overview and First Results," presented at the European Frequency and Time Forum (EFTF), 2024
Chem-CBKT:	Planning, coordination and delivery of the capacity building and knowledge transfer activities (including on-line activities) in the field of chemical metrology.	• Chemistry Department CBKT activities are planned and coordinated as indicated in the projects: Chem-CBKT1; Chem-CBKT2; Chem-CBKT3
Chem-CBKT1 *Metrology for Safe Food and Feed*	Delivery of on-line material and knowledge transfer courses supported by short workshops at the BIPM related to: a. Mycotoxin standards b. Pesticide standards c. Drug residue standards.	qNMR Summer Schoool at the BIPM Headquarters • qNMR Summer School Programme at the BIPM was delivered in June 2024 , for twelve NMI participants from 11 countries with support from 4 NMI experts and 3 BIPM staff. • Development of an online version of the qNMR course based on the Summer School lectures has been completed and was launched through the BIPM e-learning site in October 2024.
Chem-CBKT2: *Metrology for Clean Air*	Delivery of on-line material and knowledge transfer courses supported by short workshops at the BIPM related to: a. FTIR for gas standards and metrology b. Dynamic methods for reactive gas standards c. CO_2 isotope ratio traceable measurement. On-line support for a mentoring programme for the new coordinating laboratory for the CCQM-K137 repeat comparison on nitrogen monoxide standards.	CO_2 isotope ratio traceable measurement CBKT • eLearning modules on introduction to $\delta^{13}C$ and $\delta^{18}O$ standards and measurements in CO_2 developed as part of 3-month secondment, and launched in October 2024. CBKT on dynamic methods for NO_2 mixtures in nitrogen with amounts fractions below 1 µmol/mol • 1st characterization of operation of BIPM MSB facility over ranges (500 to 1100) nmol/mol and (70 to 500) nmol/mol completed, with Labview automation on-going. • METAS calibrated permeation tubes installed in BIPM operated PermaCal device for comparison with BIPM facility over (70 to 500) nmol/mol range. • Preparation of 2 standards at 1 µmol/mol completed at the LNE, for comparison with BIPM MSB facility over ranges (500 to 1100) nmol/mol range.

IX	**Capacity Building and Knowledge Transfer**	
Project	Deliverables	Work performed in the period (1 January 2024 – 31 December 2024)
Chem-CBKT3: *Metrology for Accurate Patient Care*	Delivery of on-line material and knowledge transfer courses supported by short workshops at the BIPM related to: a. Peptide primary reference material value assignment methods, < 5 kDa b. Peptide primary reference material value assignment methods, > 5 kDa and < 10 kDa.	• Activity in planning stage.
IR-CBKT:	Planning, coordination and delivery of the capacity building and knowledge transfer activities in ionizing radiation.	• Organization of the CCRI webinars and workshop: 1500 attendees and 2500 YouTube views in 2024. • Training of LNMRI/IRD (Brazil) staff on using a SIR transfer instrument for RMO short-lived radionuclides comparisons.

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