Annual Review: Supplement

Activities of the BIPM Departments

1 January 2023 – 31 December 2023

Bureau International des Poids et Mesures

Work Programme (2020 - 2023)

Contents

This report is published annually and covers the calendar year.

Key achievements *(1 January 2023 – 31 December 2023)*

The Work Programme for 2020 – 2023 is described in terms of 9 major activities, including 68 projects and 100 tasks for the BIPM. Some of the key activities during the reporting period are highlighted below:

LABORATORY WORK CARRIED OUT BY THE BIPM

- **Physical Metrology**
  - Following the second key comparison of kilogram realizations, organized by the BIPM and with participation of the BIPM Kibble balance, the second CCM consensus value for the kilogram was determined by the BIPM, approved by the CCM and implemented on 1 March 2023.
  - The new solid-state ac source developed at the CMI (Czechia) was investigated during a bilateral pilot study with KRISS and found to be suitable to be used as a transfer standard in the new BIPM.EM-K10 ac comparison.
  - A survey amongst CCEM member NMIs has shown a large interest for future bilateral comparisons of electrical quantum standards with the BIPM.
- **Time Metrology**
  - Support provided to the CCTF for the follow-up of CGPM-2022 resolutions 4 and 5. Work in collaboration with the International Telecommunication Union has lead to an endorsement by ITU World Radio Conference 2023 of Res 4 (CGPM 2022).
  - Work to update the Circular T with more adequate consideration of not calibrated GNSS equipment, and extending the evaluation of the broadcast prediction of UTC also to the Galileo and BeiDou systems.
- **Chemical Metrology**
  - CQM SARS-CoV-2 antibody quantification pilot study, CCQM-P216, was published as a Technical Supplement in Metrologia.
  - qNMR Internal Standard Reference Document on Benzoic Acid published, completing documentation on an octad of reference materials for qNMR.
  - Publication of Metrologia paper 'A high accuracy reference facility for ongoing comparisons of CO_2 in air standards' in preparation for BIPM.QM-K2.
- **Ionizing Radiation Metrology**
  - New primary standard for medium-energy x-rays tested and validated.
  - First comparison in ^{137}Cs by the BIPM using the IAEA facility.
  - Definition and validation by CCRI of the metrological scheme of the regional copies of the SIRTI linked to the SIR.
  - Conclusion of the ^{60}Co pilot study with the extension of the SIR and definition of 11 radionuclides, validated by CCRI, to open the ESIR K5 comparison in 2024.

INTERNATIONAL LIAISON

- 20 May of each was proclaimed as a World Metrology Day by the UNESCO General Conference.
- The BIPM delegation attended UNFCCC COP28 for the first time as an observer after admission in 2022.
- Based on mandates from the 27th CGPM, the ILC department supported the development of the future CIPM strategy.

COORDINATION

- The unique CMC identifiers in the KCDB are now displayed on the KCDB web interface.
- An online kick-off meeting of the CIPM's new Forum for Metrology and Digitalization was held in November 2023.

CAPACITY BUILDING AND KNOWLEDGE TRANSFER

- "BIPM/RMO forum: Supporting RMO Secretariats" was organized to support RMO Secretariats.
- The BIPM/OIML jointly published a Brochure on different aspects of National Metrology Systems.

COMMUNICATION AND PROMOTION

- The theme for World Metrology Day in 2023 was "*Measurements supporting the global food system*". The poster was shared by a record number of institutes/organizations (62) and information on 66 celebratory events is provided on the WMD website.
- The report of the 27th meeting of the CGPM (434pp) was drafted, edited and typeset in English and French and is ready for publication.

DIGITAL TRANSFORMATION

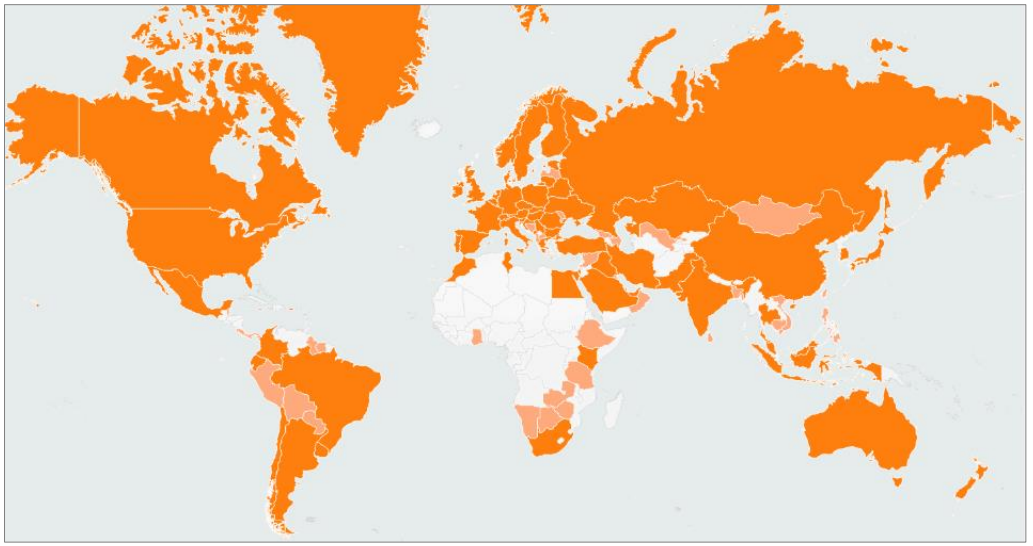
- Two BIPM digital services were launched on the SI Digital Framework site: Permanent links for CMCs; An ontologically enriched reference for the Service Categories in PHYSICS.
- The BIPM Time Department launched a beta-version of an API web service to provide machine-readable data on the recommended frequency standards for the practical realization of the metre.

Key figures *(as of 31 December 2023)*

- Member States and Associates

  - 64 Member States* and
  - 36 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

253 institutes in the CIPM MRA
The CIPM MRA has been signed by representatives of institutes from:
- 64 Member States
- 36 Associates States of the CGPM, and
- 4 international organizations

and covers a further 152 institutes designated by the signatory bodies.

1 841 comparisons	26 045 CMCs
1161 KCs, 680 SCs	Peer-reviewed declarations

I	**Physical Metrology**	
Project	Deliverables	Work performed in the period (1 January 2023 – 31 December 2023)
1. PMD-E1: INTERNATIONAL REFERENCE STANDARD for VOLTAGE		
E1.1: On-site comparisons of Josephson voltage standards (JVSs) *NMI Part.: 4*	1) Bilateral on-site comparisons at dc as part of BIPM.EM-K10.a/b and/or ac (new comparison) with relative uncertainty of 1×10^{-10} (dc) and below 10^{-6} (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)	• Following the distribution of a questionnaire to determine the interest in the extended BIPM.EM-K10 comparison, including ac voltages up to 1 kHz, the replies showed a large interest for this new type of measurement: 60% of the 27 replies expressed the wish to participate in the coming years. • Bilateral pilot studies were carried out with PTB (Germany) and with KRISS (Rep. of Korea) on differential sampling of ac waveforms. During the comparison with KRISS, the solid-state ac source developed at the CMI (Czechia) was investigated and found to be suitable to be used as a transfer standard in the BIPM.EM-K10 comparison. • The BIPM traveling quantum voltage standard was upgraded to receive a NIST 2 V array. This array is used for measuring 0.75 V signals and allows to achieve lower systematic errors related to leakage current than the previously used array. • Maintenance of the quality system associated with voltage services: no non-conformities identified in an internal audit in 2023.
E1.2: Bilateral voltage comparisons using Zener diode transfer standards *NMI Part.: 4*	a) Bilateral comparisons of Zener voltage standards as part of BIPM.EM-K11.a/b with relative uncertainty of 5×10^{-8} b) Participation in related RMO comparisons to link them to BIPM.EM-K11 c) Maintenance of the BIPM secondary dc voltage standards (Zeners), also supporting the calibration of Zener voltage standards for NMIs (E1.3)	• Comparisons of Zener voltage standards BIPM.EM-K11 are in progress with SASO (Saudi Arabia) and INRIM (Italy). Publication of the measurement reports for the comparisons with NPLI (India) and DEFNAT (Tunisia). • The BIPM Zener secondary voltage standards operated for BIPM.EM-K11 were maintained traceable to the BIPM primary voltage standard. • The number of bilateral Zener comparisons is still limited because of the shortage of liquid helium supply.
E1.3: Calibrations of Zener diode secondary standards *Calibration for: 10 NMIs (12 certificates)*	1) Calibration of Zener diode secondary standards for NMIs without primary realization and for internal customers (Ionizing Radiation and Kibble balance)	• 14 Zener voltage standards were calibrated for: Metrosert (Estonia), NSC IM (Ukraine), UDEC (Chile), INM (Colombia), ICE (Costa Rica), LPEE (Morocco), SIQ (Slovenia), UTE (Uruguay). The shortage of liquid helium still causes some delays in the service. • Support to the BIPM Kibble balance team operating a Josephson voltage chip in a cryocooler. A direct comparison against a 2 V chip belonging to the voltage calibration laboratory showed an agreement of 1 part in 10^9. This is sufficient for the Kibble balance, but not as good as expected. The work will continue.
2. PMD-E2: INTERNATIONAL REFERENCE STANDARD for RESISTANCE		
E2.1:	1) Bilateral on-site comparisons of quantum Hall standards (including new graphene samples) as	• The collaboration work started in 2020 with PTB and NMIJ (Japan) for the characterization of 1 ohm standard prototypes - developed by NMIJ and Alpha Electronics - continued until

I	**Physical Metrology**	
Project	Deliverables	Work performed in the period (1 January 2023 – 31 December 2023)
On-site comparisons of quantum Hall resistance (QHR) standards *NMI Part.: 4*	part of **BIPM.EM-K12** with relative uncertainty 1×10^{-9} 2) Providing the basis for the realization of the capacitance unit farad 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)	May 2023. Their low frequency dependence as well as their long- and short-term stability were studied with the objective of determining whether they could advantageously replace the 1 ohm standards currently used during **BIPM.EM-K12** comparisons. It was found that the technology used for the construction of these resistors, combined with an appropriate measurement configuration, allows near zero low frequency dependence, and that carefully selected resistors of this type could allow to reduce the uncertainties currently achieved during this comparison. • The new room temperature low frequency current comparator (LFCC), of ratio $R_H(2)/100\ \Omega$ (129.06), started in 2021, has been characterized through a comparison with the LFCC currently used in the 1 Hz bridge. The two LFCCs showed very similar performances and comparison results were found to be within a few ppb. This work takes place within the continuous maintenance process of the transportable 1 Hz bridge used for **BIPM.EM-K12** comparisons. A double current source for a new 1 Hz bridge is being developed. • The new cryo-probe designed in 2022 intended to be equipped with a new multi-winding superconducting cryogenic current comparator (CCC) and a recently bought SQUID, has been assembled and tested. Due to a malfunction of the SQUID it had to be sent back to the supplier for verification. This new CCC-probe should replace one of the two CCCs of the BIPM which has recently been found to be defective. • A collaboration agreement has been signed between BIPM and PTB for the long-term loan of quantum Hall devices based on graphene. Two first devices were recently provided to the BIPM and two other – able to be used in both dc and ac - should be provided later-on. A first series of characterization measurements of one of these devices showed its very good agreement with the reference GaAs-based QHR standards used for routine calibration at the BIPM. • Preparation work for **BIPM.EM-K12** comparison with LNE (France). This comparison, initially planned in 2022 was postponed by LNE and rescheduled for October 2023. Nevertheless, this comparison was again postponed by LNE a few weeks before the new planned date. A second comparison with INRIM (Italy), planned for April 2024, has also been recently postponed (in December 2023). As of today, no new dates have been set for these two comparisons, but they could be carried out in 2024 if LNE and INRIM are ready. • A survey of interest in future **BIPM.EM-K12** comparisons with the BIPM amongst NMIs resulted in more than 10 positive replies.
E2.2: Bilateral resistance comparisons using	1) Bilateral comparisons of resistance transfer standards as part of **BIPM.EM-K13.a/b** with relative uncertainty of 5×10^{-8}	• The calibration of the BIPM resistance reference base from the QHR has been carried out twice, in January and June. This reference is also the basis for the realization of the farad from the ohm (E3.1).

I	**Physical Metrology**	
Project	Deliverables	Work performed in the period (1 January 2023 – 31 December 2023)
resistance transfer standards *NMI Part.: 4*	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)	• Ongoing BIPM.EM-K13.a and b comparisons with INRIM (Italy). Publication of the measurement reports for comparisons with CEM (Spain) and INRIM (Italy). • Maintenance of the measuring bridges and standards used for resistance services. The resolution of several technical issues on the ageing electronics of the 1 Hz and CCC bridges was particularly time consuming during this year. • Maintenance of the quality system associated with resistance services which underwent an internal audit in 2023: no non-conformities detected.
E2.3: Calibrations of resistance secondary standards *Calibration for: 25 NMIs (150 certificates)*	Calibration of resistance secondary standards for NMIs without primary realizations and for internal customers (Mass, Ionizing Radiation, Kibble balance)	• 54 resistance standards calibrated for 13 NMIs : INM (Colombia), MSL (New Zealand), GUM (Poland), DEFNAT (Tunisia), NSC IM (Ukraine), SMD (Belgium), SIQ (Slovenia), Metrosert (Estonia), ICE (Costa Rica), LPEE (Morocco), SASO (Saudi Arabia), DMDM (Serbia), EMI (United Arab Emirates) and 6 internal certificates (for Mass and Voltage services).
3. PMD-E3: INTERNATIONAL REFERENCE STANDARD for CAPACITANCE		
E3.1: Bilateral capacitance comparisons using capacitance transfer standards *NMI Part.: 4*	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 January and July 2023. • Monthly measurements for the surveillance of the capacitance bank of 10 pF capacitors. • Maintenance of measuring bridges and standards used for capacitance services. • Maintenance of the quality system associated with capacitance services which was submitted to internal audit in June 2023. • Final report of ongoing BIPM.EM-K14.a and b comparisons with NMIM (Malaysia) published in June 2023. • Measurement of the frequency dependence of the ac-resistors of the quadrature bridge used for the realization of the farad from the QHR. This work, quite time consuming, is carried out every 5 years (a duration consistent with the expected stability of the frequency dependence of the type of resistors used).
E3.2: Calibrations of capacitance secondary standards *Calibration for: 20 NMIs (110 Certificates)*	1) Calibrations of capacitance secondary standards for NMIs without primary realizations	• 29 capacitance standards calibrated for 9 NMIs: UME (Turkey), BEV (Austria), SNSU BSN (Indonesia), DEFNAT (Tunisia), INTI (Argentina), ICE (Costa Rica), NPLI (India), SASO (Saudi Arabia), SIQ (Slovenia)

I	**Physical Metrology**	
Project	Deliverables	Work performed in the period (1 January 2023 – 31 December 2023)
E3.3: ac quantum Hall effect	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	• No work during this period.
E3.4: Calculable capacitor	1) Completion of the calculable capacitor as a primary standard for capacitance to consolidate the BIPM measurement capabilities at the highest level and to help curating knowledge in this key technique	• Study of the influence of the positioning of the probe bearing on the measurement of diagonal distances between opposite electrodes of the calculable capacitor. This study was made for both the invar and brass probes. Differences between the two probes were characterized and the best bearing positioning deduced. • Study of the influence of the positioning of the probe bearing on angular measurements for the invar probe. Differences lower than 0.15 mrad have been found. • Simulations have been realized using finite element analysis to determine the influence of lateral gap variations on the uncertainty of the calculable capacitor capacitance. This work is still in progress.
4. PMD-M1: MASS DISSEMINATION		
M1.1: Calibration of 1 kg national prototypes and mass standards *Calibration for: 25 NMIs (50 Certificates)*	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. 4) Calibration of pressure gauges, as an internal service necessary to support mass calibrations at the required uncertainty, and for other BIPM departments.	• Calibration of 5 Pt-Ir prototypes for NIMT (Thailand), PTB (Germany), NMC (Singapore), NIM (China), INM (Romania). • Calibration of 21 stainless steel mass standards for DZM (Croatia), INEN (Ecuador), SNSU BSN (Indonesia), Metrosert (Estonia), LATU (Uruguay), NIMT (Thailand), MIRS (Slovenia), BEV (Austria) , Singapore (NMC), INM (Romania). • Determination of the volume of 4 stainless steel mass standards for NIMT (Thailand) and INM (Romania). • Determination of centre of gravity for 6 stainless steel standards for INEN (Ecuador), MIRS (Slovenia), NIMT (Thailand), INM (Romania). • Mass values of BIPM working standards for current use monitored and adjusted against working standards for limited use. • Calibration campaign with 7 certificates for pressure gauges of the Physical Metrology Department. • Calibration of 3 hygrometers from the Physical Metrology Department.

I	**Physical Metrology**	
Project	Deliverables	Work performed in the period (1 January 2023 – 31 December 2023)
M1.2: Provision of 1 kg Pt-Ir prototypes *Fabrication for: 3 NMIs*	1) Fabrication of 1 kg Pt-Ir prototypes for Member States. 2) Calibration of new 1 kg Pt-Ir prototypes including volume determination.	• A quotation for a new Pt-Ir prototype was requested by an NMI. The quotation from Johnson Matthey for the Pt-Ir ingot showed a very significant increase in cost, the impact of which is under consideration.
5. PMD-M2: COMPARISONS of REALIZATIONS of the NEW KILOGRAM DEFINITION		
M2.1: Organization of a key comparison of kilogram realizations *NMI Part.: 10*	1) Organization of a periodic CCM key comparison of all available kilogram realizations and participation in the determination of the consensus value, which during the first years after the redefinition will serve as the basis for dissemination for all participants to ensure world-wide uniformity of mass measurements. 2) Ongoing bilateral key comparison of kilogram realizations, linked to (1) 3) Update of the mass values attributed to the ensemble of reference mass standards (ERMS) and the Pt-Ir working standards, traceable to the reference value of the comparison of kilogram realizations.	• Following the completion of the second key comparison organized by the BIPM, the second CCM consensus value for an internationally coordinated dissemination of the kilogram was determined by the BIPM, approved by the CCM TGPfD-kg and implemented by the CCM on 1 March 2023. • All BIPM mass calibration customers were informed about the implementation of the new consensus value and the actions to be taken. • Within the CCM TGPfD-kg the start date for the next key comparison of kg realizations was postponed from 2023 to 2024 to give NMIs time to look into the origins of the discrepancy between individual results.
M2.2: Organization of a comparison of calibrations of stainless steel mass standards. *NMI Part.: 15*	1) Organization of a new comparison of stainless steel 1 kg mass standards 2) Participation in related RMO comparisons.	• Next comparison of stainless steel standards planned to be organized by the BIPM between two comparisons of kg realizations, most likely starting in 2025.
M2.3: Maintaining the ERMS (ensemble of reference mass standards)	1) Link of the ERMS masses with values from realization experiments. 2) Mass comparison of standards within the ERMS.	• No work during this period.
6. PMD-M3: KIBBLE BALANCE. *Developing and maintaining the Kibble balance*		
M3.1:	Achieving a target uncertainty of 2 parts in 10^8 (corresponding to 20 µg at 1 kg) by further	• The 2 V PJVS array cooled down using a cryocooler system was successfully compared against the PJVS system belonging to BIPM voltage metrology with a relative agreement within 1.5×10^{-9} for a voltage of 1 V.

I	**Physical Metrology**	
Project	Deliverables	Work performed in the period (1 January 2023 – 31 December 2023)
	improvements of the apparatus and the development of a detailed uncertainty budget.	• Improved electronic boards for low emf switches were designed at BIPM and fabricated by an external company. • Replacement of the high voltage amplifier and related power supply used for the frequency stabilization of the interferometer laser source after its failure. • Two data processing programs were further reviewed and improved.
M3.2:	Reengineering of critical mechanical subsystems to enable semi-routine operation.	• No work during the period.
M3.3:	Developing software and control system for full operation in vacuum.	• No development or improvement is required during the period.
M3.4:	Develop a capability, in conjunction with NMIs that have a transportable gravimeter, for the determination of gravitational acceleration at the uncertainty level of a few parts in 10^9. This will require absolute gravimeter(s) to be brought to the BIPM from NMIs that have successfully participated in the most recent ICAG, accompanied by the NMI experts, for measurements in the BIPM Kibble balance laboratory.	• A study was started to investigate the possibility of linking the absolute gravitational acceleration values between BIPM and LNE using a relative gravimeter. The first measurements carried out early December using a CG5 relative gravimeter were very promising. This will be confirmed by new measurements planned in February 2024. • Calculation of the self-attraction correction due to the mechanical set-up based on a commercial FEA software was reviewed and compared to the value obtained using a simplified evaluation.
M3.5:	Participate in the ongoing comparison of realizations of the kilogram (PMD-M2).	• Measurements were carried out from February to May in anticipation of the next comparison which had initially been scheduled for the end of 2023. The work was stopped after the decision of the CCM made in July to postpone the comparison by one year.
M3.6:	Carry out a design study for a Kibble balance, taking advantage of the re-definition of the kilogram to realize directly masses below 1 kg, with smaller uncertainties than at present.	• The first prototype mechanism, based on an equal-arm double pan balance beam, was characterized on a test set-up in air. The key features of the first prototype design were successfully checked. The work was done with the support of a secondee from NMIJ starting in February. • A mass lifting device was made and integrated inside the set-up. • Additional control and acquisition programs were developed for characterizing the first prototype beam and for carrying out two measurement phases in a Kibble balance operation. • Improved current source and interfacing electronics were tested and integrated. • An improved design based on an equal-arm single pan beam was completed and is being fabricated by the BIPM mechanical workshop.

I	Physical Metrology	
Project	Deliverables	Work performed in the period (1 January 2023 – 31 December 2023)
		• A vacuum chamber was fabricated externally to improve the environmental measurement conditions in the future.

II	Time Metrology	
Project	Deliverables	Work performed in the period (1 January 2023 – 31 December 2023)
1. TIME-U1: GENERATION of TAI/UTC, STABLE and ACCURATE INTERNATIONAL REFERENCE		
U1.1: Computation of UTC and KC for Time and Frequency transfer *Participating laboratories: 87 (2022)*	Monthly provision of the international reference time scales TAI, UTC, and the terrestrial Time (TT), continuously improving their metrological quality. This is obtained by computing the differences between UTC/UTCr and the local real time realizations UTC(*k*) of the contributing laboratories. Results are published in the monthly BIPM *Circular T*, the weekly bulletin of the UTCr, and providing data 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. The Department also issues an annual report with a summary of the results.	• The regular collection of data, computation of UTC, rapid UTC, and the key comparison CCTF-K001.UTC continued without interruption. • Computation of TT(BIPM22). • Several PSFS data available, and used for the steering of TAI https://webtai.bipm.org/database/show_psfs.html • Selection process and training for a dept SW engineer was not successful and the position is still empty causing increased workload for current staff. • Contribution to several activities in the QMS: organization of internal audit, risk and opportunity policy. Publication of a report on the replacement of the Cs tube in the Cs atomic clock. • The publication of the Annual Report was discontinued in 2022 to be replaced by the increase of availability of machine-readable data in the dept database to be developed in the next years. • Three new labs entered in 2023 (IBM, UTE and UzNIM), 2 are in the pipeline (Croatia and Jamaica).
U1.2: Development and optimization of the UTC computation	The continuous improvement of UTC and related products is based on the development of appropriate SW tools and HW reliability. The goals of this WP are mostly based on: – Automatization of the computation system augmenting 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 data base structure for the time transfer and calibration data to provide user-friendly access to the results to the contributing NMIs.	• The development of a new dept IT infrastructure based on virtual machine is progressing. The automatic back up and revitalization of the VM has been accomplished. The migration from the old system is still on going. • Complete migration versus a VM with Win 10, abandoning the previous Win 7 desktop computer for the computation of UTC. All Win 7 desktop computers have been substituted. • Additional tools for the automatic checking of the UTC results are under development. A clock check module was developed to evaluate every month the behavior of the contributing clock, drawing plots, and alerting in case of anomalous behavior. Also, an automatic plot check for the consistency of the different PSFS contributions • A new plot on the calibration of TAI by PSFS, developed in collaboration with a CENAM seconded, has been created and it is available online. This helps the evaluation of the coherency of the historical contribution of PSFS to UTC, and also helps in monitoring the availability and accuracy of the contribution as requested by the roadmap to the redefinition of the second. https://webtai.bipm.org/database/d_plot.html • Extension of the availability of machine-readable data, by a demonstration API to get UTC data https://webtai.bipm.org/api/

II	Time Metrology	
Project	Deliverables	Work performed in the period (1 January 2023 – 31 December 2023)
		• Evolutions of UTC Circular T are almost ready for final publication. The UTC labs were informed of the new format at the end of 2023 and the new Circular will be published in June 2024. The updates concern: – Section 5, which reports the used time links, and their calibration information will evolve with a more adequate treatment of not calibrated GNSS equipment. Discussion with the concerned labs and with the WG TAI was extensively carried out. – Section 1, reporting the uncertainty of UTC-UTC(k) will be updated taking into account the not calibrated GNSS equipment and their correct treatment in the uncertainty propagation. – Section 4, which reports information on the prediction of UTC broadcast by GPS and GLONASS will be updated with the addition of the same information for the European Galileo and the Chinese BeiDou systems. • We have started the CCTF project on capacity building based on shared resources with Dr Bharat Vattikonda, a secondee from NPL India from Oct 2023 also supported by the IEEE UFFC Society. • Contribution to the development of the 'SI reference point" and related software. • Participation to the BIPM WG on Digitalization and the related communications to congresses and webinars as – Enjeux internationaux autour de la digitalisation des données de mesure, R. Coulon et al. Journée Technique CFM, France 2023 Support to the CCTF strategy towards a continuous UTC: • J. Levine, P. Tavella, M. Milton, "Towards a consensus on a continuous Coordinated Universal Time", Metrologia 60 (2023) 014001, https://doi.org/10.1088/1681-7575/ac9da5 • P. Tavella "Coordinated Universal time: an overview", in the ITU news Magazine 'The future of the Coordinated Universal Time", n 2, 2023, https://www.itu.int/en/itunews/Documents/2023/2023-02/2023_ITUNews02-en.pdf • P.Tavella, " Towards a continuous UTC", presentation at the Journées des Systèmes de Références, Nice, 2023.
2. TIME-U2: IMPROVED ALGORITHMS for TIME SCALE and TIME TRANSFER DATA PROCESSING		
TIME-U2: ALGORITHMS	The algorithms developed, maintained, and continuously improved by the Time Department are devoted to:	• From Jan 2023 we have a new Post Doc supported by the French FIRST TF network working on the Integer Precise Point Positioning. The project will last two years and aims to develop an IPPP suite able to compute IPPP link between two UTC laboratories with a friendly

II	Time Metrology	
Project	Deliverables	Work performed in the period (1 January 2023 – 31 December 2023)
	– the ensemble time scale formation, – the corrected processing of the time transfer measures, – the steering by the use of primary and secondary frequency standards. The goals are an algorithm for outlier and faults detection, monitoring of the data flow and link comparison, redundant links, multi-constellation GNSS time transfer, as well as algorithms treating each clock with adapted and modern statistical tools. The contribution of a ²secondee would be fundamental to ensure the necessary progress of these activities. The use of a GIT* laboratory capability within the frame of the TWSTFT WG so that software for software defined receiver (SDR) measurement technique can be developed through a collaborative effort with leading NMIs. This shared configuration will then be validated by a joint BIPM/NMI team and be made available for download as a service to NMIs (and other UTC time laboratories). Opportunities to use the capability for training and equipment monitoring will also be explored. *GIT is a free and open source distributed version control system	interface that can be used by UTC laboratories in autonomy. Work in collaboration with the French Space Agency CNES • first insight on a possible definition of a reference time scale for the Moon projects. Invitation by the European Space Agency to work in a joint group ESA-NASA for recommendations for the future navigation and communication projects. • Participation to BIPM WG on scientific SW validation contributing to the BIPM SW validation guideline. Publication and communication to congresses: • J. Milton and G. Panfilo, "The Maximum Weight in UTC: Proposal for a New Approach," in IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, vol. 70, no. 4, pp. 336-343, April 2023, doi: 10.1109/TUFFC.2022.3231084. • G. Panfilo, "Temps universel ou temps international ? ", Bachelard Studies, revision in progress. • Rosa Claudia Torcasio , Alessandra Mascitelli , Eugenio Realini, Stefano Barindelli, Giulio Tagliaferro , Silvia Puca, Stefano Dietrich , and Stefano Federico, "The impact of GNSS Zenith Total Delay data assimilation on the short-term precipitable water vapor and precipitation forecast over Italy using the WRF model", Accepted for publication 4 oct 2023 on Natural Hazards and Earth System Sciences, an EGU open access journal. • P. Defraigne, E. Pinat, G. Petit, F. Meynadier, "Monitoring of the offset between UTC and its prediction broadcast by the GNSS, Metrologia (submitted). • F. Meynadier, "Relativity for reference systems and time metrology", European Frequency and Time Seminar, Besançon, 2023. • F. Meynadier, "Atomic time scales", European Frequency and Time Seminar, Besançon, 2023. • P. Defraigne, F. Meynadier, P. Tavella, "Looking for a Lunar Reference Timescale", presentation at the, Journées des Systèmes de Références, Nice, 2023. Secondees and guests: • Antoine Baudiquez, January 2023 - December 2024, with a contribution by FIRST TF network. • Helen Margolis, 24 January – 17 February 2023. • Pascale Defraigne, 13-24 March 2023.

II	Time Metrology	
Project	Deliverables	Work performed in the period (1 January 2023 – 31 December 2023)
		• Maximilian Gruber, September -November 2023, with a contribution from PTB. • Bharat Vattikonda, October 23- September 24, with a contribution from the IEEE UFFC Society. • Francesca Collini, consultant, October 2023- September 2024. • Jiang Guo, ORB, Royal Observatory of Belgium, 23-27 October 2023. • Arianna Abis, Politecnico of Torino student, November 2023 – March 2024.
3. TIME-U3: CALCULATION and DISSEMINATION of RAPID UTC		
TIME-U3: RAPID UTC *Participating laboratories: 57 (2018), 63 (2022),* *2023 target is to grow by 10 %*	To meet the requirements of the NMI time labs and of other UTC users, a rapid approximation of UTC, called rapid UTC, is available weekly based on a subset of data. The automatization of the process and a reliable anomaly detection are in this case still more important and will be pursued in this WP, evaluating the possibility for a more frequent evaluation of the time scale. To be in pace with emerging user communities, as for example the GNSS navigation and timing systems, the Time Department will investigate the impact of reducing the delay in the publication of UTC and UTCr.	• UTCr is being published without interruption every Wednesdays, the offset to UTC remains within +/- 2 ns. • Additional check to evaluate the coherency between the data submission for UTC and UTCr are under development.
4. TIME-D1: CHARACTERIZATION of DELAYS in TIME TRANSFER EQUIPMENT OPERATED in TAI/UTC CONTRIBUTING LABORATORIES		
D1.1: Maintenance of BIPM GNSS travelling receivers and procedures for calibration	1) Characterization, study, and experimental tests of equipment compatible with those operated in NMIs. 2) Reliable/redundant travelling and fixed-reference standards. 3) Guidance documents and support for contributing NMIs. 4) Technical protocols for calibration. 5) Methods of calibration aimed at improving the time link uncertainty, which remains the largest component of the uncertainty of *UTC- UTC(k).*	• Maintenance of the BIPM traveling equipment B3TS and the other equipment for the 2022 Group 1 calibration trip. • Update of the GNSS calibration web site with the results for GPS and Galileo repeated calibration campaigns https://webtai.bipm.org/database/calib.html • The criteria to become G1 lab have been proposed and accepted by the CCTF WG GNSS and published. KRISS in the pipeline to become G1. Publications: • G.Petit and P. Defraigne, "Calibration of GNSS stations for UTC", Metrologia 2023 60 025009.

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Project	Deliverables	Work performed in the period (1 January 2023 – 31 December 2023)
	6) Maintaining a time lab supporting test and calibration of high accuracy microwave link. 7) Provision of a frequency reference to the other BIPM labs. The dissemination of this frequency signal and the related internal calibrations are part of the BIPM Quality System.	
D1.2: Realization of delay measurement campaigns for pivot laboratories (G1 labs)	This project ensures the calibration trips by GNSS receiver to the labs belonging to GNSS Group 1 or to other networks of labs. The different steps are: – To organize the GNSS measurement campaigns (requiring the shipping of the BIPM travelling system without staff) to each of approximately ten contributing laboratories (G1 labs), a number that should expand with new RMOs. The whole process involves several circulating trips and is repeated every other year. – to calibrate the TWSTFT networks by travelling GNSS receivers and by setting up additional dedicated travelling equipment with the aim to reach the best possible achievable uncertainty. – to check the receiver conditions and measure internal delays before and after the circulation. – to carry out the data analysis and issue the calibration report.	GNSS calibration exercise for G1 labs and the validation of results of the G2 labs were carried our almost regularly. • The 2022 G1 trip has continued after APMP to EURAMET (completed) and SIM (ongoing). • Russia was not included, in agreement with VNIIFTRI, due to impossibilities in the shipment of the equipment. The calibration of G1 lab in Russia and the sequent updated G2 calibrations in COOMET is delayed. • A guideline for the measurement of REFDELAY was prepared and will be part of the capacity building program of the Time Department.
D1.3: Coordinating with the RMOs for GNSS campaigns of G2 laboratories (labs which are not pivot labs) and linking results to the BIPM G1 reference	1) Provision of Guidelines. 2) Regular assessment of the values of the Type B uncertainty. 3) Validation of the G2 calibration reports and maintenance of the database. 4) Realization of differential calibration at the BIPM for G2 labs outside RMOs.	• The reports of 3 "Group 2" calibrations (RMOs calibrate equipment in other laboratories "Group 2") were validated, and the results are available in the database https://webtai.bipm.org/database/readme_clb.html
5. TIME-O1: USE of VERY ACCURATE OPTICAL FREQUENCY STANDARDS - SECONDARY REPRESENTATIONS of the SECOND		
O1.1:	1) Develop an operational algorithm for the analysis and comparison of optical frequency	• A CCL-CCTF digitalization project has been continued by adding: – XML output to the API which was in-house developed for CCL data,

II	Time Metrology	
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New time and frequency transfer techniques in TAI/UTC. Possible redefinition of the SI second and TT	standard measures to estimate the relative frequency values. 2) Study, develop, and make operational new algorithms for the processing of new and innovative time and frequency measures (optical fibres, 3-way by satellite). 3) Collaborate with NMIs and the CCTF for standardization of measurement process, data format; data treatment. 4) Promote the refinement of the Earth gravity potential as necessary for the comparison of optical frequency standards. 5) Contribute to the discussion on the redefinition of the second.	– All available information on input documents and CIPM updates for the CCTF secondary representations of the second. Work in strict collaboration with NPL CCL colleagues and the joint CCL CCTF WG. This is supporting the digitalization of the MeP of the meter and the second. API under test available here https://webtai.bipm.org/api/ccl-cctf/ • Very important collaboration with the CCTF on the redefinition of the second through the Task Force on the Roadmap to the redefinition of the second and its 3 subgroups (see Support to CCTF). • To help the monitoring of the CCTF criteria for redefinition two plots are automatically updated and published every month on the dept database, showing the availability of the PSFS contributions and also the accuracy of the submitted measurements https://webtai.bipm.org/database/show_psfs.html https://webtai.bipm.org/database/d_plot.html • Collaboration with the joint CCL CCTF WG for the estimation of the secondary representations of the second. The BIPM has developed an independent algorithm, working in parallel with NPL and NIST ones, for redundant checking o the obtained value. These algorithms allow the use of the correlation among measurements. Paper in progress: • The CIPM list "Recommended values of standard frequencies": 2021 update. H. S. Margolis, G. Panfilo, G. Petit, C. Oates, T. Ido and S. Bize. In progress for Metrologia submission. Publication and communication to congress: • Roadmap towards the redefinition of the second. N. DIMARCQ et al. 2024 Metrologia 61 012001. • P.Tavella, " Towards a continuous UTC", presentation at the Journées des Systèmes de Références, Nice, 2023.
O1.2: Optimal use of optical standard measurements in TAI/UTC	New optical standards as well as 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. To this aim, the Time Department need:	• Participation to the workshop on ACES-PHARAO mission to follow the advancement and the possibility of future use in UTC for clock comparison. • Recruitment of a secondee to support the analysis of PSFS was not successful in 2023. • The project to connect the BIPM time lab to the network of optical fibers in Europe is on hold due to budget reasons.

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	(a) to develop the correct statistical treatment of measures that may have peculiarities (dead time, long period of missing data, only frequency comparison…); (b) to adapt the TAI algorithm for the optimal introduction of the optical frequency standard measurements; (c) to study new optical transfer techniques and their technical constraints with the aim to appropriately estimate the uncertainty; (d) to set up calibration techniques and guidelines. The feasibility for the BIPM time lab to be connected to the network of optical fibres under construction by the NMIs will be explored. This would provide the possibility to: (a) validate the usual GNSS calibrations by independent and more accurate technique, (b) be connected to several of the new optical standards under development and to different UTC(*k*) time scales (c) provide training on the technologies of the future and explore the possibility for providing a hub for international PSFS comparison for NMIs. These additional activities 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 both in the data treatment, and in the set-up of the experimental fibre connection. In case this should not be available, only a minimal, un-optimized, and incomplete activity can be ensured.	• The possibility to get access to the fiber measurement routinely carried out between France and Italy is under evaluation and a draft agreement was submitted by the BIPM.

III	Chemical Metrology	
Project	Deliverables	Work performed in the period (1 January 2023 – 31 December 2023)
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 Part.: 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.	• 4 bilateral comparisons performed in BIPM laboratories for LNE (March 2023), FMI (March 2023), ISCIII (May 2023) and EMPA (June 2023). • 6 key comparison reports published for DMDM (Dec. 2022), NIST (March 2023), DHMZ (July 2023), LNE (July 2023), NIMT (Nov. 2023) and ISCIII (Nov. 2023).
G1.2: *NMI Part.: 10*	Update of SRP electronics system for National Ozone Standards, in collaboration with the NIST, enabling NMIs to extend the lifetime of their ozone standards (Note, costs included relate to upgrade and maintenance of the BIPM systems only, validation of upgraded standards included in BIPM.QM-K1)	• Electronics upgrade completed for LNE owned SRP at the BIPM Laboratories (March 2023).
G1.3: *NMI Part.: 15 (Measurements started in 2016-2019 BIPM Work Programme)*	Coordination of reactive gas/air quality comparisons (NO_2, HNO_3 and HCHO impurity comparison and spectroscopy studies), 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.	• NPL Joint Technical Project: stability study at the BIPM of six NO_2 in nitrogen standards at 10 µmol/mol, in three different cylinder types completed. Monthly measurements performed since February against the BIPM NO_2 dynamic reference facility. Five virtual meetings organized with NPL to identify the best transfer standards for the future on-going comparison BIPM.QM-K6. • 3 standards returned to NPL for start of repeated exchange of standards and measurements to test protocol for key comparison, following completion of reference method development at NPL.
2. CHEM-G2: INTERNATIONAL REFERENCE FACILITY for COMPARISON of STANDARDS and SCALES for CLEAN AIR Coordination of comparisons to determine and improve the international equivalence of radiative forcing gases		
G2.1: *NMI Part.: 20*	Coordination of BIPM.QM-K2 on Carbon dioxide in air (2020-2023), based on a unique manometric reference comparison facility maintained at the BIPM, providing an independent absolute analytical reference method for on-demand comparisons of gravimetrically prepared NMI standards for greenhouse gas and emissions measurement calibrations.	• CCQM-P225.a and b, Carbon Dioxide in air and nitrogen, ambient levels (350 µmol/mol to 800 µmol/mol) to validate BIPM CO_2-PVT facility completed, with 8 additional NMI standards measured at the BIPM, for a total of 28 measurements in the comparison. • Draft A and draft B report of CCQM-P225.a and b completed and reviewed by participants and CCQM/GAWG. Final report published in November.

III	Chemical Metrology	
Project	Deliverables	Work performed in the period (1 January 2023 – 31 December 2023)
		• Analytical measurements of the 18 CO_2 in air standards constituting the two future BIPM CO_2 scales completed with the Cavity Ring Down Spectroscopic analyser, demonstrating their consistency as two calibration ensembles. • CO_2 in air amount fraction measurements completed on the 18 standards with the BIPM CO_2-PVT facility. • Internal NIST review of BIPM CO_2-PVT facility completed, paper submitted to Metrologia in September and published in November. • BIPM report describing all parts of the BIPM CO_2-PVT facility published in November, supporting requests by other reference laboratories maintaining older systems and wishing to upgrade these.
G2.2: *NMI Part.: 15*	Completed homogeneity and stability studies on blended mixtures and coordination of CCQM-P204 on isotope ratios in carbon dioxide, and method development for reduced uncertainties, based on BIPM's high accuracy flow and cryogenic trapping system and optically based IRIS facility in collaboration with IAEA, demonstrating the state of the art in equivalence of CO_2 isotope ratio standards for atmospheric and point of origin measurement applications.	• Draft B report for CCQM-P204 prepared by the BIPM, reviewed by CCQM/GAWG (July 2023) and final report published in November 2023.
G2.3: *NMI Part.: 12*	Developed facility and methods for isotope ratio value assignment of CO_2 in air standards and coordination of CCQM-Pxx (2023) on isotope ratios in carbon dioxide, based on lowest uncertainty mass spectrometric and optically based measurements techniques at the BIPM, demonstrating equivalence of scale-based isotope ratio measurements and standards and relationship to SI traceable values.	• Completion of NPL visiting scientist secondment and validation measurements of isotopes of CO_2 in air in six standards prepared by NPL with the BIPM Air Trap system upstream of the IRMS, including correction for the interfering ions due to traces of N_2O, and demonstrating repeatable and reproducible results independently of the CO_2 amount fraction. • Completion of KRISS visiting scientist secondment of 3 months, including training on CO_2 in air isotopic analysis by IRMS and preparation of suitable standards of pure CO_2 for calibration. • 2 ensembles of 6 standards of pure CO_2 in 6 L canisters prepared with the BIPM Stable Isotope Reference Material Generation facility, for NPL and KRISS as part of Joint Technical Projects, covering the $^{13}C/^{12}C$ isotope delta scale required to underpin measurements in background and polluted atmosphere. Protocol for the CCQM pilot study on CO_2 in air isotope ratio measurements updated with CCQM GAWG and IRWG, and agreement to start in September 2024.

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Project	Deliverables	Work performed in the period (1 January 2023 – 31 December 2023)
3. CHEM-G3: INTERNATIONAL REFERENCE FACILITY for COMPARISON of STANDARDS AND SCALES for RADIATIVE FORCING GASES Coordination of comparisons to determine and improve the international equivalence of gas standards for radiative forcing gases.		
G3.1: *NMI Part.: 20 + 16 (Measurements started in 2016-2019 BIPM Work Programme)*	Completion of key comparison on nitrous oxide and coordination of methane in air standards comparison (CCQM-K82.2023), based on dedicated greenhouse gas standard comparison facilities at the BIPM with minimized analytical uncertainty to provide demonstration of continued improvement in the accuracy of radiative forcing gas standards world-wide for atmospheric monitoring.	• CCQM-K68.2019 (N_2O in air) and linked pilot study CCQM-P206 final reports published (April 2023). • CRDS system for CCQM-K82.2023 upgraded with new LabView software, including automatic data treatment to calculate comparisons results and uncertainties. • GC-FID system for CCQM-K82.2023 upgraded with new control software, new LabView software developed to automatize the data treatment up to the comparisons results, and facility re-validated with the same ensemble of 6 CH_4 in air standards used to validate the CRDS system. • Protocol for the CCQM-K82.2023 finalized and distributed to CCQM GAWG (Jan. 2023). Twenty-five CH_4 in air standards received from participants out of 30 expected (deadline October 2023 -last cylinder received on November 28). • The comparison measurements rescheduled to January 2024 due to delayed arrival of standards from some participating laboratories.
G3.2:	Developed methods with reduced uncertainties for Greenhouse Gas comparisons, based on the improvement of cryogenic separation facilities for greenhouse gases and their quantitative operation in sample preparation for greenhouse gas mole fraction and isotope ratio measurements.	• Best practice internal report on carbonate reaction procedure developed following IAEA laboratory visit for use of reference materials (IAEA-6XX series), to calibrate $^{13}C/^{12}C$ isotope delta measurements by IRMS directly on the VPDB scale. • Prototype of reaction chamber modification completed with gold plating, to ensure absence of corrosion when evolving CO_2 gas from reference materials made of carbonates. • 10 virtual meetings organized to progress for CCQM GAWG GHG Scale Comparison TG and Task teams guidelines on scales establishment and maintenance, and protocols for BIPM.QM-K5. • Terms of reference drafted for the future database for GHG Scale measurements and reference data, and first version of the software implementing an Error-In-Variables regression in the language *R* provided by VSL, as part of the Joint Technical Project with VSL.

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Project	Deliverables	Work performed in the period (1 January 2023 – 31 December 2023)
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 Part.: 25* *(Measurements started in 2016-2019 BIPM Work Programme)*	Completion of bisphenol A purity comparison CCQM-K148.a (non-polar organic (< 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 low polarity organic analytes.	• Activity completed in 2021.
O1.2: *NMI Part.: 25*	Coordination of CCQM-K148.b (polar organic (< 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 polar small molecule organic analytes.	• Results from 20 participating laboratories compiled and Draft A.1 completed and circulated to participants. • First online meeting to discuss results with participants organized and completed and potential sources of measurement bias in results identified. • Draft proposal of KCRV options completed. To be circulated and discussed in January 2024 OAWG meeting.
O1.3: *NMI Part.: 25*	Coordination of CCQM-K148.c organic purity (500 Da to 1000 Da) and method development, 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 larger small molecule analytes, together with the extension in methods for their characterization.	• Initial samples of Digitoxin material sourced and filled by UME received at the BIPM. • Preliminary purity measurements showed an unexpected significant impurity in UME material. The unknown impurity was identified by NMR to be 2,5-diphenyloxazole. Digitoxin purity only (523.1 ± 2.8) mg/g (k=2) by qNMR. UME contacted for an alternative source of material. • 4 months of GLHK secondment completed, and practical work for LC-DAD-MS/MS structurally related impurity method development finished and LC-DAD-CAD method development started. 2,5-diphenyloxazole impurity confirmed by LC-DAD-MS.
5. CHEM-O2: SMALL MOLECULE ORGANIC PRIMARY REFERENCE COMPARISONS (CALIBRATION SOLUTIONS) Coordination of comparisons standards and methods for organic calibrants.		
O2.1: *NMI Part.: 25*	Coordination of the calibration of solution comparison CCQM-K78.b (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	• Two online meetings organised to discuss the participant results and identify potential reasons for the observed bias in some results. • KCRV Proposal circulated to participants (November 2023). • Draft B report in preparation for distribution in January 2024.

III	Chemical Metrology	
Project	Deliverables	Work performed in the period (1 January 2023 – 31 December 2023)
	purity measurement facilities, providing a core comparison for non-polar organic calibration solutions for NMIs.	
O2.2: *NMI Part.: 5*	Developed and published reference data for qNMR internal standards, based on BIPM's dedicated qNMR facility and in collaboration with NMIJ providing published reference data on qNMR internal standards, enabling the extension of the use of qNMR to accurate measurements with ^{19}Fnuclei, and extending the scope of applicability of qNMR for SI traceable measurements on organic analytes, and support for NMI measurement services and their comparisons.	• Rapport BIPM-2023/02, qNMR Internal Standard Reference Data - Benzoic Acid [ISRD-08], published as part of Joint Technical Project with NIM China. • Measurements on ^{19} F vs ^{1}H qNMR bias completed as part of L. Santos (INTI) and W. Wollinger (INMETRO) secondments. Sources of bias identified and report and paper in preparation for November 2023. • Draft ISRD for 19F qNMR using BTFMBA circulated to external authors for comments. Expected publication in January 2024.
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:	Developed and published methods for the characterization of large molecule primary calibrators, based on high resolution mass spectrometry facilities at the BIPM, extending the application of mass spectrometric methods for the identification and quantification of structurally related impurities in peptide calibrators that are future candidates for comparisons to underpin NMI measurement capabilities.	• CITAC Best Papers Award 2022 for C3-triskelion *iscience* paper received. • Paper on Implementing metrological traceability of C-reactive protein measurement published in Clinical Chemistry and Laboratory Medicine (CCLM), 2023. • Validation of peptide/protein acid digestion method 80% completed.
O3.2: *NMI Part.: 15*	Completion of purity key comparison CCQM-K115.c C-HbA1c hexapeptide purity, CCQM-K115 repeat on HbA0 hexapeptide purity and CCQM-K115.b Oxytocin, 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 smaller than 5 kDa at NMIs, and underpinning reference measurements systems for glycated hemoglobin	• Activities completed in 2022.

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Project	Deliverables	Work performed in the period (1 January 2023 – 31 December 2023)
	and their development for diabetes diagnosis and patient monitoring.	
O3.3: *NMI Part.: 15*	Coordination of CCQM-P216 on SARS-CoV-2 antibody quantification with NIM and NRC in response to the coronavirus pandemic. Method development for CCQM-K115.d Primary peptide calibrator (5 kDa to 10 kDa) large organic molecule primary calibrator comparison, 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 greater than 5 kDa, cross-links and post-translational modifications for NMIs, and underpinning reference measurements systems for protein diagnostics.	• Part II of the CCQM SARS-CoV-2 antibody quantification pilot study, CCQM-P216, coordinated by NIM, with BIPM and NRC published in Metrologia Technical Supplement. • Onsite hybrid meeting held at the BIPM in February 2023 with NRC, NIBSC, CDC and IFCC to discuss PTH reference materials, methods and comparisons, and common approach to calibration hierarchy agreed. • PTH material from NIM received at the BIPM and initial screening method for related structure impurities completed. • PTH comparison discussed at the PAWG and approved by CCQM in April 2023. • PTH comparison protocol and call for participation drafted and discussed and agreed by PAWG in November 2023.

IV	Ionizing Radiation Metrology	
Project	Deliverables	Work performed in the period (1 January 2023 – 31 December 2023)
1. IR-D1: 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 comparisons and calibrations.		
D1.1: *NMI Part.: 16 (i.e. 4 per year)*	Bilateral comparisons (BIPM.RI(I)-K2, -K3, -K7) using high-stability (0.02 %) reference x-ray beams and high accuracy and stability primary standards (0.2 % for air kerma).	• 4 planned comparisons delayed or cancelled by the requesting NMIs. • 2 comparison reports were published in 2023: K2 (BFKH-2021), K3 (BFKH-). One remaining report, delayed while awaiting final data from the NMI.
D1.2: *NMI Part.: 20 (i.e. 5 per year)*	Characterization and calibration of national standards, on request.	• All requested calibrations and corresponding certificates have been completed for the ININ (Mexico), NIS (Egypt), NMISA (South Africa), NRPA (Norway) and IAEA; 21 calibrations corresponding to 16 NMI participations (with IAEA included).
D1.3:	Quality assurance of the BIPM primary standards for air kerma and absorbed dose to water, to confirm the long-term stability.	• Quality assurance checks continued all through the year.
D1.4:	Quality assurance and continual improvement of the BIPM international reference x-ray beam facilities.	• Studies on the beam characteristics of the new medium energy x-ray facility have been made using the new standard free air chamber.
2. IR-D2: INTERNATIONAL REFERENCE SYSTEM for GAMMA-RAY DOSIMETRY Underpinning the international equivalence of national standards for radiotherapy and radio-sterilization, through the provision of comparisons and calibrations.		
D2.1: *NMI Part.: 12 (i.e. 3 per year)*	Bilateral comparisons (BIPM.RI(I)-K1, -K4, -K5) using the BIPM ^{60}Co reference beam facility and high accuracy and stability primary standards (0.4 % for absorbed dose and 0.2 % for air kerma). *Comparisons of reference air kerma rate standards (-K8) of ^{92}Ir HDR source with a travelling instrument*	• All requested comparisons have been performed corresponding to 3 NMI participations in 2023: K1 and K4 for NIST (USA), K8 for PTB (Germany). • 4 comparison reports were published in 2023: K1 (BFKH-2021), K4 (BFKH-2021, NMIJ-2022) and K8 (NPL).
D2.2: *NMI Part: 25 (i.e. about 6 per year)*	Calibration and characterization of national standards, on request.	• All requested calibrations and corresponding certificates have been completed for the IST (Portugal), ININ (Mexico), NIS (Egypt), NMISA (South Africa) and the NRPA (Norway); 14 calibrations corresponding to 8 NMI participations.
D2.3:	Quality assurance of the BIPM primary standards for air kerma and absorbed dose to water, to confirm the long-term stability.	• Quality assurance checks continued all through the year.
D2.4:	Quality assurance and continual improvement of the BIPM international reference gamma-ray beam facility.	• Development of a new positioning system.

IV	Ionizing Radiation Metrology	
Project	Deliverables	Work performed in the period (1 January 2023 – 31 December 2023)
3. IR-D3: INTERNATIONAL REFERENCE SYSTEM for HIGH ENERGY PHOTONS Underpinning the international equivalence of national standards for high energy photons to meet the expanding need from the use of clinical linear accelerators for radiotherapy, through the provision of comparisons and calibrations.		
D3.1: *NMI Part.: 14 (i.e. about 4 per year)*	Bilateral comparisons (BIPM.RI(I)-K6) using the BIPM off-site facility at DOSEO, with the BIPM absorbed dose standard and high-stability beam monitoring system.	• All requested comparisons have been performed corresponding to 1 NMI participation in 2023 for K6: NIST (USA). • 1 K6 comparison report was published in 2023: ARPANSA-2022.
D3.2: *NMI Part: 12 (i.e. 3 per year)*	Characterization and calibration of national standards, on request.	• All requested calibrations and corresponding certificates have been completed for the NIS (Egypt), NMISA (South Africa) and the NRPA (Norway); 4 calibrations corresponding to 3 NMI participations.
D3.3:	Quality assurance of the BIPM absorbed dose standard (graphite calorimeter and transfer instruments) to confirm their long-term stability.	• Quality control checks continued throughout 2023 to ensure that the BIPM standards and radiation beams are stable. • Supporting calibrations for DOSEO in the BIPM Co-60 facility.
D3.4:	Quality assurance and continual improvement of the measurement systems used at the DOSEO/BIPM high-energy photon beam facility.	• Evaluation of impact of using the floating or non-floating method of applying the polarizing voltage during the calibration of chambers.
4. IR-D4: TOWARDS A NEW REFERENCE STANDARD for STATE-OF-THE-ART RADIOTHERAPY MODALITIES Preparations for the development of a new primary standard to meet future requirements for radiation dosimetry (for example, hadron beam dosimetry at an out-sourced facility, electron calorimetry, x-ray brachytherapy).		
D4.1:	Maintain the existing medium energy x-ray service (this involves installing a new x-ray generator and tube). Report on an investigation into future requirements for radiation dosimetry, identifying the priorities for the long term, taking into account feedback from NMIs and potential growth areas.	• Characterization of the new x-ray beams including field size, radial profiles and air attenuation. Studies of field size resulted in a new method of obtaining a circular field by independent adjustment of the inner and outer diameters of a conical aperture.
D4.2:	Specification, detailed design and modelling of a new reference standard for the priority identified.	• New primary standard instrument (free-air ionization chamber) for medium-energy x-rays beams installed and tested. Extensive studies of radiation shielding and penetration correction factors. • Comparisons between old and new standards.

IV	Ionizing Radiation Metrology	
Project	Deliverables	Work performed in the period (1 January 2023 – 31 December 2023)
5. IR-D5: INTERNATIONAL REFERENCE SYSTEM for RADIATION PROTECTION DOSIMETRY (^{137}Cs) Underpinning the international equivalence of national standards for radiation protection dosimetry using an off-site ^{137}Cs facility, through the provision of comparisons and calibrations.		
D5.1: *NMI Part.: 16*	Bilateral comparisons (BIPM.RI(I)-K5) using a BIPM-characterized and operated facility (to be restarted once the external facility is available) and high accuracy and stability primary standards (0.3 %).	• The comparison service has been re-established using the IAEA facility. • All requested comparisons have been performed corresponding to 2 NMI participations in 2023: K5 for BEV (Austria) and CIEMAT (Spain).
D5.2: *Calibration for NMIs: 20*	Characterization and calibration of national standards, on request.	• Re-establishment of the calibration service scheduled for 2024.
D5.3:	Quality assurance and continual improvement of the BIPM primary standards, and the associated ancillary equipment.	• Full validation of the BIPM dedicated measurement system at the BIPM before transportation to the IAEA, comprising both the hardware and the LabVIEW software to operate the system. Verification measurements on its return to the BIPM.
6. IR-R1: INTERNATIONAL REFERENCE SYSTEM for GAMMA-EMITTING RADIONUCLIDES (SIR / SIRTI) Provision of on-demand capability for bilateral comparisons of gamma-emitting radionuclides for applications in nuclear medicine, the nuclear industry, nuclear physics, environmental protection, radiation protection and nuclear forensics.		
R1.1: *NMI Part.: 25 (i.e. about 6 per year)*	Bilateral comparisons (BIPM.RI(II)-K1) of national standards of long lived gamma emitting radionuclides using the high precision, high stability, SIR ionization chambers (reproducibility better than 0.02 %).	• All requested comparisons have been performed corresponding to 9 NMI participations in 2023: Mn-54 (POLATOM), Co-57 (BEV), Ga-67 (CMI), Sm-153 (CMI), Lu-177 (CMI, KRISS), Tl-201 (CMI), Pb-203 (NPL) and Ac-225 (NIST). • 8 reports of K1 comparisons were published in 2023 for the following radionuclides: Ac-225 (POLATOM-2021) for which the first KCRV has been agreed, Ra-223 (POLATOM-2021), Y-88 (LNE-LNHB-2016) and BEV-2019), I-131 (BEV-2015, POLATOM-2015, NMISA-2017) including the link of the CCRI(II)-S6.I-131 and the EURAMET.RI(II)-K2.I-131 comparisons, Cs-134 (POLATOM-2014, NRC-2014, LMRI-IRD-2015 and PTB-2016), ^{60}Co (PTB-2020, NIST-2020, SMU-2020, BARC-2021, LNE-LNHB-2021, POLATOM-2021, ENEA-2021, NPL-2021, LNMRI-IRD-2021, NMISA-2022 and ANSTO-2022), ^{177}Lu (IFIN-HH 2013, LNE-LNHB 2014, IRA 2022), ^{22}Na (NMISA-2022).
R1.2: *Participating NMIs: minimum of two per year, six radionuclides per site visit*	On-site bilateral comparisons (BIPM.RI(II)-K4) of national standards of short lived gamma emitting radionuclides (SIRTI), using the high precision, high stability SIRTI scintillation counter (reproducibility better than 0.05 %). The SIRTI will be developed, so it can be operated remotely by NMI staff under the supervision of the BIPM staff.	• Two SIRTI comparisons were organized in 2023: a full remote comparison at the ANSTO for ^{123}I and a second one in hybrid mode at LNMRI-IRD. Due to radionuclide provision difficulties, only ^{18}F measurements were performed in 2023 and the other measurements have been postponed to 2024. • Validation by CCRI(II) on the traceability scheme of the RMO-SIRTIs, in development, to the BIPM SIRTI the latter one providing the link to the SIR.

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		• 2 reports of K4 comparison were published in 2023: ANSTO-2017 (^{99m}Tc, ^{64}Cu and ^{99m}Tc) and NRC-2017 (^{18}F, ^{64}Cu, ^{99m}Tc and ^{11}C).
R1.3:	Technical support for the SIR and SIRTI comparators (quality control checks and continual improvement including software updates). Development of a mathematical model for a second ionization chamber to enable KCRVs to be duplicated without the need to measure all the radionuclides (collaboration with the NPL).	• Quality control checks continued throughout the period. • Mathematical modelling to transfer KCRVs from one ionization chamber to another is still being developed to avoid the need to measure samples of every radionuclide covered by the SIR (3 meetings). • Developments of digital electronics for BIPM SIRTI: performance validation to better than 1 part in 1000 of a digital solution, using LabVIEW, able to replace the analog electronics currently used with the SIRTI (MTR2 module). • Technical support to future RMO pilot laboratories has been provided including provision of the SIRTI tripod and lead shielding.
R1.4:	Quality assurance and continual improvement of the high resolution gamma spectrometer for impurity checks and applications in health physics.	• The spectrometer has been mainly used for the measurement of leak test samples for sealed sources.
R1.5:	Tasks to ensure compliance with regulations, including radiation protection monitoring, safety testing of irradiators (for Dosimetry), arranging disposal of radioactive waste, and associated health and safety requirements.	• Continuous work to assure compliance with regulations, with support of an external radiation protection adviser. • Extension by the French Nuclear Safety Autority of the BIPM license to use the radium-226 sources with the SIR sources for an additional 18 months/5 years depending on the source. • First and successful audit of the BIPM radioactive waste management system.
7. IR-R2: DEVELOPMENT of the NEXT GENERATION INTERNATIONAL REFERENCE SYSTEM (SIR 2.0) The installation and validation of a new SIR based on state-of-the-art instrumentation for measuring low currents and reducing the dependence on sealed radioactive sources, drawing on the studies completed in the previous programme.		
R2.1:	Installation of a new ionization chamber and current measurement system, data collection and analysis software, using new technology for electrical current measurement and reducing the dependence on sealed radioactive sources as reference points.	• Purchase and reception of the new ionizing chambers and of the lead shielding of the system.
R2.2:	Validation of the new system including determining the long-term stability and precision of the system	• The purchased ^{166m}Ho solution was decontaminated from impurities by the supplier. • Transfer of the solution into ampoules by the LNE-LNHB is postponed, due to internal difficulties at LNE-LNHB, to mid-2024.

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	and confirmation of the linearity of the response (current versus activity).	
R2.3:	Bilateral comparisons of national standards of gamma-emitting radionuclides (in parallel with measurements on the SIR under BIPM.RI(II)-K1, to establish new key comparison reference values in terms of current versus activity).	• Delayed to next Work Programme.
8. IR-R3: INTERNATIONAL COMPARISON SYSTEMS for ALPHA- and BETA-EMITTING RADIONUCLIDES (ESIR) Provision and extension of the on-demand capability for bilateral comparisons of alpha- and beta-emitting radionuclides for applications in nuclear medicine, environmental protection, radiation protection and nuclear forensics, based on the ESIR established in the previous programme.		
R3.1: *MI Part.: 25*	Bilateral comparisons (BIPM.RI(II)-K5) of national standards of long lived pure alpha- and beta-emitting radionuclides, using the new ESIR comparator established in the previous programme with a reproducibility of better than 0.1%.	• Conclusion of the ^{60}Co pilot study – final report published in Applied Radiation and Isotopes. • Definition of 11 radionuclides, validated by CCRI, to open the ESIR K5 comparison in 2024.
R3.2:	Technical support and continual improvement of the new ESIR comparator including the development of additional software and hardware (such as extending the capability to cover additional radionuclides and the use of digital pulse processing systems).	• Development of a new code for impurities correction. • Definition of a PhD thesis work in collaboration with LNE-LNHB to implement the impurities correction in ESIR.
9. IR-R4: AUTOMATION of the PRODUCTION of COMPARISON REPORTS FOR the SIR Development of a machine-readable database of historical SIR data to enable rapid production of comparison reports for the SIR.		
R4.1:	Development of a database of historical SIR data.	• Work, with the KCWG(II) and the newly created CCRI digital transformation task group, to implement fair principle in machine readable data of K1 comparisons. • Thanks to the meta-analysis of the existing database, a survey of primary standards relevant to traceability of radionuclides in the environment is in preparation together with several institutes. • Two papers published on that topic: *Machine-readable data and metadata of international key comparisons in radionuclide metrology* (Meas. Sci. Technol) and *Evaluation of long-term robustness of the International System of Reference (SIR) used in radionuclide metrology based on the meta-analysis of its machine-readable database* (Metrologia).

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R4.2:	Development and validation of report writing software.	• Continuous upgrade of the software.

V	International Liaison	
Project	Deliverables	Work performed in the period (1 January 2023 – 31 December 2023)
1. 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) Support for and representation to RMOs (AFRIMETS, APMP, COOMET, EURAMET, SIM and GULFMET).	• As of December 2023, there are 64 Member States, and 36 Associates of the CGPM: – Support/advice to the governments of Member States and Associates with outstanding contributions and subscriptions. – Detailed support/advice to various governments as they progress towards accession. • Support to the *CIPM Sub-group on Strategy* for the implementation of Resolution 1 on *Evolving Needs in Metrology*: two surveys between member states were conducted and a draft strategy document prepared based on the material provided from CIPM members. • Support to the *CIPM Sub-group on Universal adherence to the Metre Convention* for the implementation of Resolution 6 *On universal adherence to the Metre Convention* adopted at the 27th meeting of the CGPM in November 2022 which gives a mandate to review the membership practices of other international organizations, to propose appropriate actions for consideration by the CGPM at its 28th meeting. As a result, the proposal of creation of *"Affiliate"* status was proposed and discussed at the 22nd meeting of the Partners/NMI Directors and State Party representatives in October 2023. • The Young Metrologists' 2050+ Vision was launched in July 2023 with the aim of complementing the CIPM Strategy by presenting visionary ideas for future opportunities and challenges from young metrologists who are looking ahead into the future. The foresighting exercise is being organized in consultation with RMOs. Eleven RMO Coordinators were appointed by their respective RMOs to run the project. The first webinar with young metrologists was organized for the SIM region on November 16, 2023. By December, we had received more than 100 responses to the questionnaire. Other five RMO webinars are planned for 2024. The consolidation workshop (in person) is scheduled for July 2024.
2. LIAISON WITH STRATEGIC PARTNERS		
ILC-L2:	Institutional liaison with International/intergovernmental/Quality Infrastructure: – OIML, UNIDO, ILAC, ISO, OECD, WTO, World Bank; – Institutional liaison with other international organizations as required (BIPM liaises	• BIPM-OIML cooperation: – World Metrology Day activities (see project #ILC-CP5). • BIPM-UNESCO cooperation: – In November 2023, the UNESCO General Conference, at its 42nd session, adopted a resolution proclaiming 20 May of each year as a world metrology day following 215 EX/Decision 41 World Metrology Day of the UNESCO Executive Board. The ILC Department continued liaising with Member States to support the final resolution.

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	with around 30 international organizations).	• BIPM-UNFCCC cooperation: – In November 2023, the BIPM delegation attended the Conference of the Parties (COP28) of the United Nations Framework Convention on Climate Change (UNFCCC) for the first time following the BIPM admission by COP27 as an observer organization to the UNFCCC in November 2022. • BIPM-UNECE cooperation: – In November 2023, the revised version of *Recommendation K on Metrological Assurance of Conformity Assessment and Testing* (including the Guidelines to its implementation) was adopted by the 33rd Session of the Working Party on Regulatory Cooperation and Standardization Policies (WP.6) of the United Nations Economic Commission for Europe (UNECE). The BIPM took the lead in the project updating Recommendation K under paragraph 10c of the Programme of Work of the WP.6. Recommendation K was written in 1998 and last revised in 2008. The project scope was to update Recommendation K with minor adjustments in order to modernize the language and to align it with current working methods and best practices (e.g., CIPM MRA), to update terms and references and develop a brief guideline to demonstrate how users can comply with the recommended practices. • BIPM-WTO cooperation: – Submission of the BIPM statement and representation of the BIPM at the WTO TBTC meetings in March (in person), June 2023 (virtual) and November 2023 (virtual). • BIPM-OECD cooperation: – In November 2023, the BIPM attended the 10th Annual Meeting IO Partnership (anniversary event). Discussions covered themes such as trust in international rulemaking, policies related to the climate crisis and artificial intelligence, and the challenges of multilateralism. The BIPM Director attended the high-level panel emphasizing the importance of strengthened cooperation within the IO Partnership, particularly through the partnership of IOs taking part in the international quality infrastructure during the session on Trust in International Rulemaking to Address Global Challenges. He also noted one of the BIPM key tasks to respond rapidly to meet the demands of new digital services and references. The BIPM moderated the session on inclusiveness. At this annual meeting, the BIPM successfully completed its

V	International Liaison	
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		role as a focal point of the Working Groups of the OECD IO Partnership. The BIPM has been a focal point of WG2: Inclusiveness (stakeholder engagement and IO coordination) since 2021. It has been a co-focal point of Working Group 5: IO Coordination since 2019. – In August 2023, the *Memorandum of Agreement for the loan of staff* was signed between the BIPM and OECD for the loan of the BIPM staff - Rahima Guliyeva to the OECD Regulatory Policy Division for two (2) full working days per week for a period of seven (7) months, from 7 September 2023 to 29 March 2024 to support the implementation of the OECD-PTB joint study *"Highlighting the Interrelations in Quality Infrastructure and Regulation"*. Interviews were held with some international and national QI partners and necessary preparations began for the drafting of the issues note which will serve as a basis for a future report (also see ILC-CP6). – In July 2023, the BIPM was invited to make a presentation during an open debate under Session 3: Strengthening Togo's quality infrastructure system to foster innovation, competitiveness and consumer's safety of the *Peer Learning Group Meeting* organized *in the framework of the Production Transformation Policy Review of Togo* held within the framework of the OECD initiative for policy dialogue on Global Value Chains, Production Transformation and Development. – In May 2023, the BIPM attended the IO Partnership's technical meeting. Topics included the future of the IO Partnership, the role of international rulemaking in a "disruptive" environment, overcoming barriers to collaboration among IOs, agility and impact of international instruments. At the meeting, the BIPM moderated the exchanges on stakeholder mapping and the session on inclusiveness, which main objective was to share insights and best practice regarding operational challenges of stakeholder engagement at different stages of rulemaking. – In May 2023, the BIPM attended the kick-off meeting of the OECD-PTB joint study *"Highlighting the Interrelations in Quality Infrastructure and Regulation"*. In March 2023, NCSL International signed the Joint Statement of Intent on the digital transformation in the international scientific and quality infrastructure.
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)	• Writing of the draft minutes of the TGFC meeting in 2022 • Meeting of the CODATA TGFC on 12-13 September 2023 • Writing of the draft minutes of the TGFC meeting in 2023 • Update of the CODATA TGFC website

V	International Liaison	
Project	Deliverables	Work performed in the period (1 January 2023 – 31 December 2023)
TIME-L1 Coordination and promotion of time activities for the advancement in the development of time scales and their applications.	1) Dissemination of TAI/UTC/TT(BIPM) 2) GNSS time transfer 3) GNSS coordination 4) GNSS system time definition and realisation 5) GNSS dissemination of UTC 6) Need in Time and frequency transfer methods.	Contribution to several meetings of international organizations and groups: • ICG annual meeting, 2023: Support to the use of UTC for GNSS interoperability, also related to the decision CIPM 108-41 and CCTF recommendation. Presentation of the CCTF activities related to the GNSS as continuous UTC, new circular T information, and traceability through GNSS measurements. • IGS: regular participation to trimester meetings of the governing board. • Participation to Working groups of the IGS (on clock products and on PPP-Ambiguity Resolution) and of the IAU (on Time metrology standards).
TIME-L2 Coordination and promotion of time activities for scientific applications.	TF metrological support to: 1) Space-time references, IERS Conventions 2) Timescales for astronomy/TT(BIPM)/Pulsar timescales 3) Geodetic and geophysical applications of TF metrology e.g. geodetic references, Earth gravity potential.	Collaboration with the ITU, following the MoU was signed between ITU-R and BIPM in 2020: • ITU-R and BIPM organized a special session at the 2nd ITU Inter-regional workshop on Definition of time scale and dissemination of time signals via radiocommunication systems (Res. 655 (WRC-15)) in Nov 2022 • ITU-R and BIPM produced an ITU News special issue on The future of Coordinated Universal Time, April 2023, https://www.itu.int/en/itunews/Documents/2023/2023-02/2023_ITUNews02-en.pdf • Meeting at the BIPM of the ITU-R WP7A dealing with time signals and frequency standard emissions, in June 2023 • Great effort devoted to networking with national and regional ITU delegations to explain the Res 4 (CGPM 2022) and the related discussion at the ITU World Radio Conference (WRC) in Nov 2023 • Participation to the ITU WRC 2023, in Dubai, Nov 2023 with the successful endorsement of Res 4 (CGPM 2022) by the ITU-R.
Chem-L1	1) Liaison activities with: IUPAC; ISO TC 212, IFCC, WMO, WHO, WADA, Codex, ISO TC 146.	• Report of the BIPM-WMO Workshop on Metrology for Climate action published (June 2023). • Presentation at WMO International Greenhouse Gas Monitoring Symposium (January 2023 and Workhsop October 2023) on Greenhouse Gas Scale Standards for an expanded Global Greenhouse Gas Monitoring Infrastructure. • Support of CIPM Sectorial Task Group on Climate Change and Environment (STG-CENV) created through decision CIPM/112-11 (2023) at its 112th meeting held on 21-23 March 2023. • Liaison with WMO Expert Team on Atmospheric Chemistry Measurement Quality maintained to advance the adoption of metrological concepts within the QS framework of WMO Global Atmosphere Watch program.

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		• Active liaison with ISO TC 146 maintained, including liaison report provided and virtual meeting attended to progress the amendment of ISO 13964 and ISO 10313 standards to replace the value of ozone absorption cross sections with the most accurate CCQM.03.2019 value recommended by the CCQM. • 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. • Active liaison with ISO TC 212 maintained. Lead role in the revision of ISO Standards 15193 and 15194 which are both at DIS voting stage and are the basis of the JCTLM review process for reference methods and materials. • Continued participation in the JCTLM review team for proteins and drugs. • Participation in the UN Climate Change Conference (UNFCCC COP 28).
	2) Liaisons activities related to revision of Ozone standard reference method and global implementation.	• Active support maintained for the CCQM-GAWG task group "Ozone cross-section change management" with Executive Secretary role held by BIPM (4 virtual meetings). • New website to communicate on the Ozone cross-section change launched by the BIPM for the *Communication team* of the CCQM-GAWG-TG-Ozone, and communication plan drafted. • New guidelines drafted by members of the CCQM-GAWG-TG-Ozone, to help technical staff and managers of ozone monitoring networks with the implementation of the new ozone cross-section value.
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 (SC2 and working group meetings)	• Participation in the report from the Consultancy Meeting of the IAEA on the analysis and dissemination of calibration coefficients for the linac installed at the IAEA dosimetry laboratory (DOL). • Membership of the consultants group revising the IAEA Code of Practice TRS-398 for external beam radiotherapy; revision in final stages of publication. • Participation in the work of the ICRU, notably the publication of ICRU Reports, Representation of 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, with preparation and participation in the 2023 ICRM conference in Bucharest (150 attendees).

VI	Coordination	
Project	Deliverables	Work performed in the period (1 January 2023 – 31 December 2023)
1. CIPM MRA		
ILC-C1:	1) Coordination of the CIPM MRA mechanisms through the JCRB 2) Provision of the KCDB database (Including Exec Sec of the JCRB). 3) Advising the CIPM MRA participants and mining the data for stakeholders	As of December 2023, the CIPM MRA has been signed by representatives of 100 institutes – from 64 Member States, 36 Associates States of the CGPM, and four international organizations – and covers a further 151 institutes designated by the signatory bodies. Two NMIs changed their names. • A new JCRB Executive Secretary was appointed on 1 June 2023 • During the reporting period around 1900 CMCs were processed (including greyed-out CMC) and 898 published in the KCDB. • 30 key and 20 supplementary comparisons were published in the KCDB. • The 46th and 47th meetings of the JCRB in March and September 2023 were organized as hybrid meetings. Participants representing all six RMOs and the CIPM took part. • KCDB reports to the JCRB in March and September 2023 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. • CMC PIDs were published on the KCDB website to support NMI/DIs for implementing direct linking of the Calibration certificates with their CMCs. • The unique CMC identifiers in the KCDB are now displayed on the KCDB web interface, and a digital service has been developed to provide a permanent reference for each CMC. A guideline document for the user community was made available on the webpage. • The following DIs were designated as participants of the CIPM MRA: – UNAL-CALAIRE - Laboratorio de Calidad del Aire - CALAIRE, of The Universidad Nacional de Colombia (UNAL), on 28 August 2023. – KACST - King Abdulaziz City for Science and Technology, on 18 September 2023. • Two DIs were excluded from the CIPM MRA: – Bureau of Radiation and Medical Devices, Department of Medical Science, Ministry of Public Health from Thailand. – MBW Calibration AG from Switzerland.

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2. JCGM		
ILC-C2:	Provision of JCGM Executive Secretary and rapporteur for WG2 (JCGM- one annual meeting, JCGM WG2 - two annual meetings), general support to JCGM, representation in JCGM WG2.	• The minutes of the 25th meeting of the JCGM, held on 12 December 2022, were published. • The minutes of the JCGM-WG2 meeting from 6-9 December 2022 were published. • Participated in WG2 Focus Group meetings throughout the period. • Support was provided to JCGM-WG2 during development of the VIM4 2CD. This included organizing the circulation of the VIM4 2CD to the JCGM Member Organizations and the NMIs during August 2023.
IR-C1:	Provision of the Scientific Secretary for JCGM WG1 and support including: *1) Rapporteur* 2) Two annual meetings.	• 2 JCGM-WG1 plenary meetings. • Review of the uncertainty evaluation of radioactive decay to be included in the JCGM GUM – Part 5: Examples in preparation.
3. JCTLM		
Chem-C3 Provision of JCTLM Executive Secretary in order to support:	Support for: 1) JCTLM Executive and WGs (eight meetings) 2) JCTLM Database entry/nomination review process 3) Maintenance of: JCTLM Database 4) Development of new platform and architecture for the JCTLM database, including machine readability, and replacing obsolete software	• Report of the 24th Executive Committee meeting drafted and published. • Report of the December 2022 DBWG meeting drafted and distributed. • Videoconference of JCTLM Executive held in July 2023. • The 10th Issue of the JCTLM Database Newsletter edited and published. • Update of JCTLM procedures. • Preliminary review of 111 nominations before distribution to the DBWG review teams completed. • 51 new entries published in the JCTLM database. • Completion of update of JCTLM Websites with the JCTLM TEP WG • Launch of JCTLM Survey on information and services provided, and processes used • Support for new JCTLM Task Group on Knowledge Transfer • Co-Chair role for the JCTLM Strategy Task group including organization of 5 online meetings and drafting of strategy document • Funding request for JCTLM database web interface project completed with 70 000 Euro raised. Development project to start in 2024. • Hosting of JCTLM Stakeholders' meeting and working group and Executive Meetings in December 2023.

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Project	Deliverables	Work performed in the period (1 January 2023 – 31 December 2023)
4. NMI DIRECTORS and RMO CHAIRS MEETING		
ILC-C3:	1) To work with the panel of NMI Directors to organize an annual meeting at the BIPM 2) Organization of the CC Presidents meetings 3) Access to and understanding of best practice in the operation of RMOs: *a) Development of a global perspective on key issues;* *b) Optimal support for states with emerging metrology systems* *c) Facilitated by the BIPM convening annual meetings of the RMO Chairs*	• The 22nd NMI Directors meeting was held as hybrid event on 19-20, October at the BIPM Headquarters . The main theme was "Measurements supporting the global food system" which covered various topics including food safety and climate change issues. • *BIPM/RMO forum "Supporting RMO Secretariats"* was organized at the BIPM Headquarters with participation of 21 individuals from RMO Secretariats and those who assist the RMO in various interactions with the BIPM. The aim was: to equip RMO Secretariats with appropriate knowledge that can assist in effective implementation of various interactions with the BIPM; to provide the basis for an ongoing forum supporting RMO Secretariats across the range of interface topics and fostering discussion with them; to provide a "toolbox" for RMO Secretariats indexing various BIPM and RMO interfaces.
5. Support of CCs (including provision of Executive Secretaries)		
PMD-C1 Provision of CCEM (Electricity and Magnetism) Executive Secretary in order to support:	Provision of CCEM (Electricity and Magnetism) Executive Secretary in order to support: 1) Two CCEM meetings 2) Annual working group meetings 3) Pro-active interaction on strategy and communication 4) Coordination of CCEM processes 5) Related liaison with RMO technical committees (4 meetings)	• Organization of the CCEM and its WG meetings in March as on-site meetings with the possibility to attend online. • Organization of two CCEM webinars. Preparations for CCEM webinar in early 2024. • Coordination of and participation in the review of comparison reports. • Writing of the CCEM summary to be included in the CIPM Strategy 30+. • Updating of the CCEM website.
PMD-C2 Provision of CCM (Mass and Related Quantities) Executive Secretary in order to support:	Provision of CCM (Mass and Related Quantities) Executive Secretary in order to support: 1) Two CCM meetings 2) Annual working group meetings 3) Pro-active interaction on strategy and communication 4) Coordination of CCM processes 5) Related liaison with RMO technical committees (4 meetings)	• Coordination of the registration, approval and publication of the final reports of KCs. • 19th CCM meeting and WG meetings in May 2023 (including the organization of a CCM Workshop, the organization and co-chair of the WGS meeting) • Drafting and follow-up of CCM action plan. • Organization of online WG meetings. • Involved in the TGPfD-kg work, especially on Consensus Value 2023 (writing and publication of summary notes and a news story etc.) • Organization of kick-off meeting of the TG on webinars & workshops

VI	Coordination	
Project	Deliverables	Work performed in the period (1 January 2023 – 31 December 2023)
		• Writing of the CCM summary to be included in the CIPM Strategy 30+. • Preparation of the CCM Strategy summary document. • Member of the Steering and Program Committees of the International Conference of Weighing 2023 (session chair on New kilogram). • Presentation at the EURAMET TC-M meeting. • Presentation at the APMP DEC – CMC Task Force meeting • Update of the CCM website (uploading WG documents; dealing with issues raised further to BIPM website's maintenance)
PMD-C3 Provision of CCU (Units) Executive Secretary in order to support:	Provision of CCU (Units) Executive Secretary in order to support: 1) Two CCU meetings 2) Pro-active interaction on strategy and communication 3) Coordination of CCU processes	• Organization of an online meeting of WG-S in September 2023. • Organization of six online meetings of WG-CMT and its focus group from January to June 2023. • Organization of two online meetings of TG-ADQSIB in February and March 2023 on how the text of the SI Brochure on angles could be clarified. • Creation of a focus group of TG-ADQSIB on counting and number quantities and consultation how the text of the SI Brochure on counting could be clarified. • Organization of an online meeting of the focus group of TG-ADQSIB in September 2023. • Organization of a joint CCU/CCQM online workshop on quantities which can be counted in March 2023 (> 300 participants). • Publication of a summary report on the CCU/CCQM workshop. • Planning for the CCU meeting in April 2024. • Responding to questions and comments received by the webmaster about the SI and units in general.
Time-C1 Provision of CCTF (Time and Frequency) Executive Secretary in order to support:	1) Organizing the CCTF bi/triennial meetings 2) Providing secretariat of CCTF and WGs 3) Pro-active interaction on strategy and communication 4) Coordinate CC processes including comparison and other MRA reports. 5) Key comparisons in time and frequency 6) Recommendation of standard frequencies as secondary representations of the second	• Continuation of the special focus on Metrologia on "Challenges in Time and Frequency Metrology" with 4 expected papers (3 published, 1 in progress) https://iopscience.iop.org/collections/0026-1394_challenges-in-time-and-frequency-metrology • Support and contribution to the CCTF WGs, Task Force and Task Group on the CCTF Hot topics and CCTF WG online meetings. • Re-organization of the Task Force for the redefinition of the second and related Kick Off meeting (sept 2023) • Preparation of the CCTF informative meeting on Nov 16, 2023

VI	Coordination	
Project	Deliverables	Work performed in the period (1 January 2023 – 31 December 2023)
		• Work toward the CGPM 2026 draft resolutions concerning redefinition of the second, and continuous UTC
Time-C2 Provision of CCL (Length) Executive Secretary in order to support:	1) CCL meetings 2) Participation in WGs 3) Pro-active interaction on strategy and communication 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 for the practical realization of the metre.	• Meetings of CCL WGMRA, CCL WGN and CCL WGS. • Communication and coordination between Russian institutions and CCL members to advance the organization and the reports of Key and Supplementary Comparisons. • API CCL-CCTF digitalization project, a first prototype has been published. • CMCs digitalization project started.
Time-C3 Provision of CCAUV (Acoustics, ultrasound and vibration) Executive Secretary in order 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.	• Meeting of CCAUV • Meetings of CCAUV KCWG, RMOWG and SPWG • Workshop: "The contribution of CCAUV to the Evolving needs in Metrology" • CMCs digitalization project started
Chem-C1 Provision of CCQM (Amount of Substance) Executive Secretary in order to support:	1) CCQM meetings (four plenary meetings) and eleven WG meetings (44 meetings in total) 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	• CCQM Plenary, 8 CCQM WG and 1 CCQM Task Group meeting organized and run at the BIPM in April 2023, with report of meeting published in June 2023 • Organization of CCQM workshop "Metrology for Viral systems as molecular tools" (January 2023) • Organization of CCRI-CCQM Workshop on the Use of Mass Spectrometry in Radionuclide Metrology: Opportunities and Challenges (February 2023) • Organization of CCU/CCQM Workshop on "The metrology of quantities which can be counted" (March 2023), and publication of summary outputs in Metrologia. • Support for CCQM Task Groups on: Microplastics Measurement Standardization; Metrology for pandemic Preparedness; Stakeholder Engagement. • Organization of CCQM website and BIPM YouTube channel with international video contributions for World metrology Day 2023 on food systems. • Active support and hosting TG Pandemic hybrid meeting.

VI	**Coordination**	
Project	Deliverables	Work performed in the period (1 January 2023 – 31 December 2023)
		• Support of organization of NMI Directors' meeting on food systems. • Support for establishment of new CCQM Task Group of Food Measurements and the steering committee for the CCQM Workshop on on Digital and FAIR Chemical and Biological Reference Data and Certificates: Challenges and Opportunities
Chem-C2 Provision of CCPR (Photometry and Radiometry) Executive Secretary in order 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	• Support provided to launch two new Task Groups of the CCPR-WG-SP : TG 15 on " The Impact of Digitalization on Matters Related to the CCPR" and TG16 on "Cone fundamentals". • Presentation given at EURAMET TC.PR meeting on activities of the BIPM. • Support provided for the publication of 1 new CCPR KC and 1 RMO comparison report in the KCDB. • Three hybrid meetings of the CCPR Working Groups at NPL (Sept. 2023) organized and hosted from the BIPM. • Hybrid workshop on Dark Uncertainty in CCPR Key Comparisons and its implication on CMCs organized and hosted from the BIPM.
IR-C2:	Provision of CCRI (Ionizing Radiation) Executive Secretary in order to support: 1) Biennial CCRI and sections I, II and III meetings 2) Regular meetings of seven working groups 3) Development of strategic plans 4) Co-ordination engagement with RMOs	• Organization and participation to the biennial CCRI and sections I, II and III meetings in May and June with production of the meetings reports. Section 1 meeting was hosted by IAEA. • CCRI webinar series: 5 organized webinars: *22/01 - Fast neutron reference fields above 20 MeV, 23/05 - Radon Metrology*, *05/07 - Ionizing radiation metrology at GULFMET*, *12/09 - Small field dosimetry for MRgRT, 28/11 - Synchrotron radiation beams: radiotherapy dosimetry and detector response*. • CCRI workshops: CCRI-CCQM Workshop on the *Use of Mass Spectrometry in Radionuclide Metrology: Opportunities and Challenges* – 14 to 16/02 (on-line), SSDL/CCRI(I) workshop *Strengthening Ionizing Radiation Metrology* – 31/05/2023 (on site at IAEA), *CCRI(II) Workshop on the Draft A results of the 2021 Cd-109 K2 Comparison* – 25 to 26/09 (on-line). • Chair of the CCRI communication Working Group (4 meetings in February, May, August and November): 5 webinars, 12 newsletters. • One meeting was held in April of the CCRI Radionuclide Therapy and Quantitative Imaging Working Group (CCRI-RTWG). • One meeting was held in May of the CCRI RMO Working Group on IR CMCs (CCRI-RMOWG). • Two meetings were held in May and June of the Key Comparisons Working Group of CCRI section II (CCRI-KCWG(II)). • Creation of a new Working Group on Digital Transformation (CCRI-DT-WG), chaired by BIPM, with 4 meetings in March, April, June and September.

VI	**Coordination**	
Project	Deliverables	Work performed in the period (1 January 2023 – 31 December 2023)
		• Co-pilot of the ^{109}Cd CCRI Section II comparison exercise: analysis of the comparison results and organization of a dedicated online workshop in September with 30 participants. • Help in piloting the SIM.RI(II)-K2.Zn-65 comparison and the EURAMET. RI(II)-S9 for radionuclides used in nuclear medicine (preparation of the protocole, the reporting form, analysis if the results). • Help in piloting of the thermal neutron CCRI(III).K8.2024 comparison – support to NIM and CMI in producing the protocol.
PMD-C4 (IR-C3)	Provision of CCT (Thermometry) Executive Secretary in order to support: 1) Biennial CCT meetings and twelve WG meetings 2) Pro-active interaction on strategy and communication 3) Coordinate review of CC and RMO comparison reports before publication 4) Related liaisons with RMOs	• Organization of the meetings of the CCT WGs on the occasion of the 10th Temperature Symposium (Anaheim, California, USA). • Organization of meetings of the CCT WG-Env and TG AirT. • Preparation of the CCT SP report to the CIPM in collaboration with the CCT President. • Publication of documents realized by the CCT TG on Digitalization. • Response to questions received from CCT WG chairs related to reviews of CCT documents to be posted on BIPM website, interactions with the webmaster on related issues. • Response to questions raised by participants in CCT comparisons and interactions on CMC submissions with the KCDB manager and JCRB Exec. Sec. • Guaranteeing the communication link between the VNIIM scientists involved in CCT comparisons with their partners. • Attendance of the CCT-WG-SP to prepare the agenda and the Convocation to the 31st CCT in May 2024.

VII	Capacity Building and Knowledge Transfer	
Project	Deliverables	Work performed in the period (1 January 2023 – 31 December 2023)
1. PLANNING and COORDINATION of BIPM CBKT PROGRAMME ACTIVITIES		
ILC-CBKT1	1) Planning, coordination and operation of core CBKT activities supporting the CIPM MRA and sponsor supported topic based CBKT activities, including scheduling, course design, call and selection processes (liaising with RMOs on prioritization of candidates), identification of speakers, funding of participants' costs where appropriate, provision of BIPM lecturers and sourcing of external RMO/NMI lectures together with all associated logistics. 2) Developing and managing of the BIPM RMO framework ensuring coordinated delivery of CBKT activities by BIPM and the RMOs – Liaison with RMOs to ensure coordinated CBKT delivery. 3) Development of remote learning capabilities: – online short courses. – online technical exchanges. – E-learning capabilities for CBKT.	• The Inter-American Metrology System (SIM) and Intra-Africa Metrology System (AFRIMETS) formally signed the practical arrangement to participate in the BIPM e-learning platform on 16 March 2023 and 20 October 2023 (www.e-learning.bipm.org). • As of December 2023, 20 courses have been provided by the BIPM and RMOs on the e-learning platform. • The BIPM e-learning platform has been upgraded from version 3.9 (launched in April 2021) to 4.1 in August 2023. The upgrade improved security and accessibility and provides new navigation and additional functions. • The joint project between the BIPM and OIML, aimed at developing e-learning courses and publication materials in support of the BIPM-OIML publication titled *'National Metrology Systems - Developing the Institutional and Legislative Framework,'* has been launched. This project is sponsored by METAS, the NMI of Switzerland. The first outcome of the project has been published as a set of brochures with six inserts. The storyboard for the e-learning modules of the project has been prepared, and the expected launch is planned in 2024." • Support from TÜBİTAK UME, NMI of Türkiye was secured for the joint BIPM and TÜBİTAK UME initiative to host ten talented metrologists from around the world.
2. DELIVERY OF, and LECTURING on CORE BIPM CBKT ACTIVITIES		
ILC-CBKT2	1) Delivery of, and lecturing on (including using the remote learning tools), core CBKT activities supporting the CIPM MRA: – 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').	• COOMET training course for TC Chairs and CMC reviewers within the CIPM MRA was organized with participation of more than 50 experts from COOMET member institutes in May 2023. • BIPM-APMP Workshop on *Sound Beginning in the CIPM MRA - APMP procedure and technique for peer review and CMC submission* was organized in hybrid mode in Mongolia in June 2023. The aim was to help developing NMIs to prepare their first submissions of CMCs and to correctly submit their first CMCs to the CMC peer review system. • A suite of brochures with six inserts was published. The content is based on the BIPM and OIML joint publication "*National metrology systems - Developing the institutional and legislative framework" (OIML D 1:2020*). These brochures were developed jointly by the BIPM and OIML to summarize key elements that should be considered when developing policies aimed at

VII	Capacity Building and Knowledge Transfer	
Project	Deliverables	Work performed in the period (1 January 2023 – 31 December 2023)
		developing national metrology systems, setting up institutions dealing with metrology, and drawing up national laws related to metrology. • Four online projects on core CBKT topics were organized with 516 participations: – KCDB 2.0 - CMC Writers in General Physics, Ionizing Radiation (23.03.2023), – KCDB 2.0 - CMC Writers in Chemistry and Biology (19.01.2023) – KCDB 2.0 – Comparisons pilots (08.01.2023) – KCDB 2.0 - TC Chairs in General Physics, Ionizing Radiation, Chemistry and Biology (16.06.2023) • CBKT courses were extended to include information about the BIPM's new digital services, for example, on how to link CMCs and CC service categories to NMI/DI documents on QMS and calibration certificates. Cumulative overview of the CBKT, as of December 2023: • 57 CBKT initiatives were organized: 29 projects at the BIPM and regions; 29 (+13 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 20 e-learning courses submitted by EURAMET, COOMET, GULFMET and the BIPM Scientific Departments available for metrology community. • Overall, 3544 participations from 125 countries in various CBKT initiatives: 558 participants at the BIPM and regions physically; 2986 participants in online sessions. About 950 participants from 116 countries are registered on the e-learning platform. • CBKT participation by RMOs: – 363 - AFRIMETS – 641 - APMP – 474 - COOMET – 987 - EURAMET – 357 – GULFMET – 722 - SIM
3. VARENNA METROLOGY SCHOOL		
ILC-CBKT3	Delivery of joint Varenna metrology school for world class young scientists/metrologists - with the Italian Physical Society.	• The project depends on available resources. Next school is scheduled for 2025.

VII	Capacity Building and Knowledge Transfer	
Project	Deliverables	Work performed in the period (1 January 2023 – 31 December 2023)
4. Laboratory support for capacity building and knowledge transfer activities		
ILC-CBKT	1. Delivery of, and lecturing on, sponsor supported topic based CBKT activities on courses (topics of interest chosen with the NMI/DI community and sponsors): – at the BIPM and – within the RMO Framework (i.e. at courses arranged in the regions by the RMOs), and aligned with NMI laboratory placements	• In 2023, the joint BIPM and TÜBİTAK UME initiative hosted ten talented metrologists from ten different countries (Colombia, Philippines, Poland, Uzbekistan, Egypt, Saudi Arabia, Malaysia, Kenya, Kazakhstan, Ukraine) from all RMOs; AFRIMETS, APMP, COOMET, EURAMET, GULFMET and SIM for a period of 1 to 3 months at the TÜBİTAK UME laboratories. The sixth cycle of the joint initiative was completed in December 2023.
PMD-CBKT	Planning, coordination and delivery of the capacity building and knowledge transfer activities in the field of electricity and mass metrology.	• The CCEM continued its series of webinars with a pedagogical approach to topics from electromagnetic metrology. Two webinars were held on theoretical and practical aspects of Josephson voltage standards (80 participants) and on electrochemical measurements for electrolytic conductivity and determination of biomarkers (30 participants). • The e-learning course on the dissemination of the kilogram was updated following the implementation of the second CCM consensus value.
TIME-CBKT	Planning, coordination and delivery of the capacity building and knowledge transfer activities in the field of time and frequency metrology.	• Start of the CCTF project on a CBKT program based on shared resources in collaboration with NMIs., with the CCTF WG on TAI and Algorithms, and a secondee from NPL India from October 2023. Project also funded by the IEEE UFFC society for the common aim of capacity building in time and frequency metrology • Meetings of the CCTF WG TAI as technical exchange" online
Chem-CBKT1 Metrology for Safe Food and Feed	1. Development and publication of purity evaluation and calibrant assessment guidelines for 4 mycotoxin standards 2. On-line laboratory training for NMI scientists in pure material and calibrant characterization methods 3. Coordination of 3 mycotoxin calibration solution key comparisons to support new NMI capabilities 4. Published Reference methods and data, with supporting reference materials from Collaborating NMI(s), for veterinary drug	• Draft BIPM Rapport – Purity Evaluation Guideline for Tetracycline completed • qNMR characterization of chlortetracycline and doxycycline materials completed at the BIPM as part of Joint Technical Project with TUBITAK-UME • Chlorpyrifos, acetamiprid and glyphosate material received from NIM China, as part of a Joint Technical Project on Pesticide Materials • qNMR characterization chlorpyrifos, acetamiprid and glyphosate materials completed at the BIPM as part of Joint Technical Project with NIM China • Endosulfan, dimethoate, carbofuran and atrazine material received from NIM China, as part of a Joint Technical Project on Pesticide Materials • CCQM-K154.d (PAT mycotoxin calibrant) results discussed in OAWG, Draft A, Draft B and final report completed and published in the KCDB and Metrologia.

VII	Capacity Building and Knowledge Transfer	
Project	Deliverables	Work performed in the period (1 January 2023 – 31 December 2023)
	materials, supporting CBKT program on Metrology for Safe Food and Feed 5. Published Reference methods and data, with supporting reference materials from Collaborating NMI(s), for Pesticide materials, supporting CBKT program on Metrology for Safe Food and Feed.	• Bilateral subsequent CCQM-K154.b.1 (AfB1 mycotoxin calibrant) measurements completed and Draft A prepared. • 70% of Ochratoxin A material characterization completed in preparation for CCQM-K154.e (OTA mycotoxin calibrant) • Organization of qNMR Summer School Programme at BIPM in June 2024 initiated. Instructors from NMIs recruited and external sponsorship obtained. Course development via regular online meetings has commenced together with online registration for the Summer School • e-Learning site established for the associated online qNMR course, to become active in 2nd half of 2024 at the conclusion of the Summer School,
Chem-CBKT2&3 Metrology for Clean Air	1. On-line training course on the use of FTIR for gas standards and metrology (6 month visiting scientist secondments planned for 2020 and 2021) 2. Development of on-line training course on dynamic methods for gas standards, including magnetic suspension balance and METAS REGAS system	• The On-line training course on the use of FTIR completed for scientists from PTB and UME resulting in operational facilities at both NMIs. • Continuation of Joint Technical Project with METAS on dynamic methods for NO_2 standards, with BIPM staff trained on the operation of a commercial permeation oven, and installed in BIPM's dynamic standards facility • Completion of upgrade of MSB dynamic NO_2 system at the BIPM with an additional dilution step and a CAPS detector to operate at 1 µmol/mol and (50 to 250) nmol/mol amount fractions for NO_2 in nitrogen. • The 2023-2024 online training course season on the use of FTIR for scientists from KRISS and NPLI commenced in September 2023.
Chem-CBKT4 Metrology for Accurate Patient Care	1. Development of E-training material on peptide pure material standard characterization and value assignment	• E-training material to be incorporated into the material for the BIPM qNMR summer school (2024). .
IR-CBKT	Planning, coordination and delivery of the capacity building and knowledge transfer activities in ionizing radiation.	• Participation in several Regional Metrology Organization (RMO) ionizing radiation technical committees. • Comments on the reports of various regional comparisons. • Organization of the CCRI webinars and Mass Spectrometry workshop: 800 attendees and 1400 YouTube views in 2023.

VIII	Communication and Promotion	
Project	Deliverables	Work performed in the period (1 January 2023 – 31 December 2023)
1. PROVISION of BIPM INTERNET		
ILC-CP1:	1. Provision of BIPM internet. 2. Website update - 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.	• The BIPM website continues to be the BIPM's primary means of communication and is supplemented by a number of 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. Unidentified users (without a login) have access to all open-access content, and restricted-access content is provided seamlessly (through the website and the search engine) to identified users. • The website contains more than 1000 official documents, more than 30000 working documents, and has over 10 000 individual user accounts (providing access to restricted content where appropriate). • The "webmaster" email address is shared by five BIPM colleagues, to ensure a rapid response to any queries. • In cooperation with the website external contractor, the architecture of the website was simplified to improve the web performance and the content management system was upgraded. • News stories are regularly published on the BIPM landing webpage, promoting the work of the BIPM, CIPM and CCs by covering topics such as: technical, liaison, digital transformation, CBKT, CIPM MRA, etc. The stories are sent periodically to registered users via email, by means of an external platform (MailChimp). • An icon was embedded into the BIPM website (bottom banner), enabling users to register to the BIPM eNEWS. Over 500 new subscriptions were recorded compared to 2022.
2. FORMAL REPORTING & PUBLICATIONS		
ILC-CP2:	Generating BIPM reports including drafting/minuting, editing, translation into French, typesetting and publication of CIPM and BIPM reports, publications and posters.	• The report of the 111th meeting of the CIPM (June 2022) was typeset and published in English and French. • The reports of Session I and II of the 112th meeting of the CIPM (March and June 2023) were drafted, edited, typeset and published in English. The report of Session III was drafted and edited. • The BIPM Annual Review 2022/2023 was published (revised layout).

VIII	**Communication and Promotion**	
Project	Deliverables	Work performed in the period (1 January 2023 – 31 December 2023)
		• The financial report 2022 was published in French and English. • The report of the 19th CCM meeting (2023) was edited and published. • The report of the 28th CCQM meeting (2023) was edited and published. • The report of the 33rd CCEM meeting (2023) was edited and published. • The report of the 27th meeting of the CGPM (434pp) was drafted, edited and typeset in English and French and is ready for publication. • A BIPM Rapport for the Chemistry Department was edited, typeset and published. • The report of the 'Metrology for Climate Action' workshop (September 2022) was edited, typeset and published. • The 2024 Notification was typeset and published in a bilingual version. • 43 news stories were published on the BIPM website. • The compilation of BIPM eNEWS was sent to registered users (7 issues) via MailChimp. • The *News from the BIPM laboratories 2022* was published. • The BIPM social media presence on LinkedIn was boosted. Our LinkedIn profile currently counts over 5500 followers. • The BIPM YouTube channel was significantly expanded (increased number of videos, playlists, followers) and the content was harmonized.
3. *Metrologia*		
ILC-CP3:	Editing and publication of *Metrologia* 1. To ensure the success of *Metrologia* as the key scientific publication for high level metrology with an increase in impact factor. 2. To increase the number of annual issues of *Metrologia* from 6 to 10 3. Maintain a viable journal taking account of the trend towards "open access" for journals.	• *Metrologia* has four open Focus issues: Challenges in Time and Frequency Metrology, Measurements of the Newtonian constant of Gravitation, Uncertainty in the Measurement of Transport Systems, and MATHMET 2022 • Three review papers were made openly available on publication, with the support of the BIPM CBKT initiative *'Knowledge Transfer through Metrologia'* • Published articles: 44 (2022: 77). • Open Access articles: 39 (2022: 41). • Receipt-to-1st Decision times: 46 days (2022: 31 days). • Accept-to-Online Publication times: 19 days (2022: 35 days). • Impact factor 2022: 2.4.
4. **LIBRARY**		
ILC-CP4:	Journal subscriptions (on-line or hard copy) buy-per-view scientific articles and books for BIPM staff)	• 6 journal subscriptions were renewed.

VIII	Communication and Promotion	
Project	Deliverables	Work performed in the period (1 January 2023 – 31 December 2023)
		• A few books and articles were purchased.
5. WORLD METROLOGY DAY		
ILC-CP5:	To build on the success of World Metrology Day, doubling participation through all media by 2022 (Project run jointly with OIML) with participation by at least 50 states. Provision of: 1. Website content, 2. Poster (in consultation RMOs and with selected NMI), 3. Directors messages, 4. Events listings for all participating countries 5. Press release 6. Participation in at least 4 national events in countries with emerging metrology systems	• The project is run jointly by the BIPM and the OIML. The theme for World Metrology Day in 2023 was "*Measurements supporting the global food system*". • The 2023 poster was designed in collaboration with SIM and specifically with the National Metrology Institute of Argentina (INTI). The poster was shared by 62 institutes/organizations and information on 67 • The celebratory events are provided on the World Metrology Day Resource Website http://www.worldmetrologyday.org/ • In collaboration with OIML, the WMD was successfully promoted on LinkedIn. The poster for 2024 will be designed by EURAMET.
6. IMPACT STUDY		
ILC-CP6:	Authoritative independent study highlighting the impact arising from metrology in the Quality Infrastructure.	• In August 2023 the *Memorandum of Agreement for the loan of staff* was signed between the BIPM and OECD for the loan of the BIPM staff - Rahima Guliyeva to the OECD within the OECD-PTB joint project on *"Highlighting the Interrelations in Quality Infrastructure and Regulation"* managed by the OECD Regulatory Policy Division for two (2) full working days per week for a period of seven (7) months, from 7 September 2023 to 29 March 2024 to support the implementation of the project. Interviews were held with some international and national QI partners and necessary preparations began for the drafting of the issues note which will serve as a basis for a future report (also see ILC-CP6).
7. WORKSHOPS ON KEY TOPICS		
ILC-CP8:	To identify (with the CIPM and NMIs) topics of importance to the metrology community (such as 'big data') to be addressed at BIPM Workshops.	• A BIPM webinar on Digital References for Metrology attracted 350 registrants. • Online meetings of the Signatories of the Joint Statement of Intent were held in February and September 2023.

IX	Digital Transformation	
Project	Deliverables	Work performed in the period (1 January 2023 – 31 December 2023)
1. DIG-D1: Machine-readable functionality for the KCDB 2.0 and JCTLM The path towards data meeting the FAIR agenda requires, in the first instance, that it should be "Findable and Accessible". Under this activity the first machine-readable functions for the principal data base products of the BIPM (KCDB 2.0 and JCTLM) will be developed and tested.		
D1.1:	Open new (digital) applications for the Key Comparison Data base by developing a "machine-readable" interface for the KCDB (by mid-2021). The interface will be "beta-tested" by experts nominated by the JCRB.	• The KCDB Application Programming Interface (API) for searching on published CMCs was improved, supported by detailed written guidance.
D1.2:	The revision of the software platform for the JCTLM database in underway. It will include an interface to facilitate machine readability as part of its specification.	• Development and publication of the application programming interface for the JCTLM database was completed in April 2023.
2. DIG-D2: Provision of BIPM documents and other text data in xml and other machine-accessible formats The BIPM publishes a number of important reference publications used by the metrology community. The actions proposed here will be the first steps towards providing true digital versions of these publications.		
D2.1:	Preparation of a version of the 9th-edition of the SI brochure in xml and support for JCGM/WG2 as they progress their JSON version of the annotated VIM 3.	• Work on an xml version of the SI Brochure has been completed as an exploratory exercise. JCGM-WG2 are working on a machine-readable version of the next edition of the VIM, which is currently with the JCGM Member Organizations as a second committee draft.
D2.2:	Development of a policy for allocating Digital Object Identifiers (DOIs) and necessary meta-data to publications (e.g. CIPM publications, selected CC documents). This requires the identification of the highest priority documents and the services of a DOI registration agency (e.g. Crossref.com). The policy will also consider the benefits of allocating DOIs to specific strings of text information (eg definitions, CMCs etc).	• The BIPM has joined Crossref and registered its first items for DOIs. • The project is running stepwise; in 2023 the official Resolutions of the CGPM and Recommendations of the CIPM were registered with DOIs.
D2.3:	Following the development and implementation of a policy for allocating DOIs to documents and to specific text strings it will be necessary to develop a specification for an open-access document repository (for implementation post 2022)	• The project to allocate DOIs to the BIPM's publications and develop a bibliographic API to facilitate finding and accessing them will resume in 2024.

IX	Digital Transformation	
Project	Deliverables	Work performed in the period (1 January 2023 – 31 December 2023)
3. DIG-D3: Support for Digital Transformation activities at the CIPM and the JCGM		
D3.1:	Support for the CIPM Task Group for the Digital SI in the preparation of the Workshop (February 2021) Support for the JCGM in the development of a policy for true digital publications and for WG 1 and 2 as they apply the policy to the GUM and the VIM.	• The BIPM provided Executive Secretary support for four meetings of the CIPM-TG-DIG, two meetings of the Signatories of the Joint Statement of Intent, and two meetings of the *ad hoc* Strategy Group for the CIPM's new Forum on Metrology and Digitalization. • An Online Briefing Session on the Forum on Metrology and Digitalization attracted over 450 registrants. • The Online Kickoff Meeting of the Forum on Metrology and Digitalization attracted over 220 registrants. • BIPM staff participated in the CIPM-TG-DIG Expert Group and the CODATA Task Group on Digital Representation of Units of Measurement, and these two groups jointly organized a session entitled "Progress on Digital Units Interoperability" at the CODATA SciDataCon 2023. • The BIPM hosted a Webinar on Digital References for Metrology, attracting over 350 registrants. • JCGM-WG1 members participated in meetings and webinars on digitalization. WG1 discussed the subject of machine learning and the potential need for definitions of new concepts and is considering what its role might be on this subject.
D3.2:	Development of a strategy for Digital Transformation activities in the 2024-27 WP to achieve data and document services that are "Interoperable and Re-usable" (i.e. "machine actionable") within the context of the FAIR framework. The strategy will include consideration of the future opportunities for the IMRR.	• The detailed Work Plan for the Digital Transformation work to be undertaken by the BIPM Headquarters in 2023 and 2024 was developed and given the full support of the CIPM-TG-DIG and the CIPM. • Several secondments were put in place to support the BIPM's Work Plan in this area. • A new digital platform has been established to allow machine (API/SPARQL) and human (web) access to the BIPM's digital services: si-digital-framework.org • As a first step towards improving the FAIRness of the data in the KCDB, a digital service has been published to provide a permanent reference for each CMC. • A KCDB Quick Start Guide was published on the BIPM website to promote use of the CMC identifiers, and the first NMI calibration certificates to include reference to the relevant CMCs have been issued. • Digital identifiers for the laboratories participating in the CIPM MRA, the JCTLM and UTC have been collated and introduced into the CMC service. • A digital service has been developed and published for the CC service categories in the fields of AUV, EM, L, M, PR, T and TF ('PHYSICS').

IX	Digital Transformation	
Project	Deliverables	Work performed in the period (1 January 2023 – 31 December 2023)
		• A fully semantic version of the SI Reference Point was developed and released for alpha-testing by a small team of users. The beta-testing version is scheduled for release in Q1 of 2024. • A beta-version of an API web service to provide machine-readable data on the recommended Standard Frequencies was launched. • Meetings were held with representatives of several CCs towards the identification of the kinds of quantities relating to the CC Service Categories. This work is in progress and is being interfaced with the SI Reference Point.

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