Annual Review: Supplement

Activities of the BIPM Departments

1 January 2022 – 31 December 2022

Bureau International des Poids et Mesures

Contents

The report is published annually and covers the calendar year.

Key achievements *(1 January 2022 – 31 December 2022)*

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 completion of 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 and implemented by the CCM WG-M on 1 March 2023.
  - The extension of the technical protocol for a BIPM on-site comparison of programmable Josephson voltage standards from dc to ac up to 1 kHz was approved by a task group of the CCEM.
- **Time Metrology**
  - Support to the CCTF for the preparation of the CGPM resolutions 4 and 5, and work in collaboration with the International Telecommunication Union and other industrial stakeholders to support continuous UTC.
  - Further development of the CCL CCTF database and related API for the MeP for the meter and the second allowing an XML output. Database now under test by related WGs of CCL and CCTF.
- **Chemical Metrology**
  - Coordination of key comparisons on food contaminant calibration solutions for mycotoxins, pesticides and veterinary drugs.
  - First laboratory-based knowledge transfer study completed on veterinary drug primary reference material characterization.
  - Reference facility for CO_2 in air standards comparisons validated with the CCQM-P255 study.
- **Ionizing Radiation Metrology**
  - New primary standard for medium-energy x-rays manufactured and assembled.
  - Development by BIPM of a complete measurement system for the re-establishment of ^{137}Cs services by the BIPM at the IAEA facility (1st comparison in 2023).
  - Record number of BIPM reports for radionuclide comparisons (13 reports).
  - Preparation of the RMO SIRTI project, i.e. regional copies of the SIRTI linked to the SIR.

INTERNATIONAL LIAISON

- UNESCO Executive Board took a key step towards recognizing World Metrology Day at their session.
- BIPM was admitted by the 27th session of COP27 held in Sharm-El-Sheikh, Egypt, as an observer organization to the UNFCCC.

COORDINATION

- The CIPM MRA Brochures were published to provide information and assistance on key roles and mechanisms within the CIPM MRA.

CAPACITY BUILDING AND KNOWLEDGE TRANSFER

- BIPM e-learning platform expanded to allow RMOs to publish their training material.
- Knowledge Transfer through Metrologia initiative was launched to make review papers openly available to metrology community.

COMMUNICATION AND PROMOTION

- The theme for World Metrology Day in 2022 was "*Metrology in the digital era*". The poster was translated into more than 20 languages and information on 30 national celebratory events is provided on the WMD website.
- Metrologia's Impact factor 2021: 2.748.

DIGITAL TRANSFORMATION

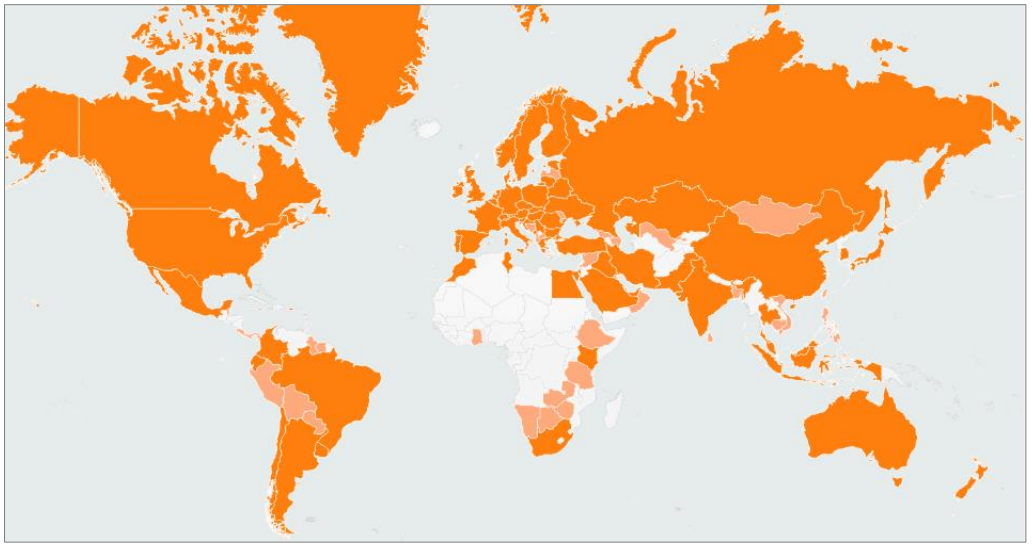
- A prototype version of a machine-actionable SI Digital Reference (the future digital version of the SI Brochure) was developed for discussion.
- The FAIR digital landscape for metrology has been outlined in terms of the main data to be rendered Fair and Accessible, and the principal additional components required to render them Interoperable and Reusable.
- The BIPM Time Department launched a beta-version of an API web service providing machine-readable time data through automated processes.

Key figures *(as of 31 December 2022)*

- 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

There are 251 institutes participating in the CIPM MRA, comprising 97 NMIs, 4 international organizations and 150 designated institutes.

1 801 comparisons
1137 KCs, 664 SCs

25 938 CMCs
Peer-reviewed declarations

I	**Physical Metrology**	
Project	Deliverables	Work performed in the period (1 January 2022 – 31 December 2022)
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)	• The draft of the updated BIPM.EM-K10 protocol including an extension to ac voltages was reviewed by the CCEM WGLF task group several times and agreement on a final version was obtained in June 2022. • A joint pilot study with PTB (Germany) and KRISS (Rep. of Korea) on differential sampling of ac waveforms took place in August 2022 at the PTB. The solid-state source developed at the CMI (Czech Republic) to be used as a transfer standard in the BIPM.EM-K10 comparison program was investigated and found to be suitable. • The cooperation with KRISS through a secondment to the BIPM extended until October 2022, leading to several improvements of the instrumentation and the software. • Maintenance of the quality system associated with voltage services which was submitted to both internal and external audits in 2022. • Two presentations were given at the 2022 CPEM Conference in New-Zealand.
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 were carried out with DEFNAT (Tunisia) and NPLI (India). Publication of the measurement report for the Zener voltage standard comparison with SMD (Belgium). • 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 had to be reduced 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)	• Two Zener voltage standards were calibrated for NIS (Egypt). A number of Zener calibrations had to be postponed to 2023 because of the shortage of liquid helium and an air conditioning failure of the calibration laboratory for six months. • Support to the BIPM Kibble balance team by the metrological validation of the new Josephson voltage chip to be operated in a cryocooler. The first test consisted of a direct comparison against a 2 V chip belonging to the voltage calibration laboratory. The results showed an excellent relative agreement to better than 1 part in 10^{10}.
2. PMD-E2: INTERNATIONAL REFERENCE STANDARD for RESISTANCE		
E2.1: On-site comparisons of quantum Hall	1) Bilateral on-site comparisons of quantum Hall standards (including new graphene samples) as	• Preparation work for BIPM.EM-K12 comparisons with LNE (France) and INMETRO (Brazil), which were finally both postponed by them for technical reasons and the current liquid

I	**Physical Metrology**	
Project	Deliverables	Work performed in the period (1 January 2022 – 31 December 2022)
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)	helium shortage. As of today, two comparisons will be possibly carried out in 2023 with INRIM (Italy) and LNE. Dates remain to be confirmed. • The characterization of 1 ohm standard prototypes developed by NMIJ (Japan) and Alpha Electronics continued to assess their stability at short and long term as well as their low frequency dependence. The objective is to identify the best 1 Ω transfer standard for on-site **BIPM.EM-K12** comparisons. The frequency dependence of 1 Ω resistors is the limiting factor of the uncertainties which can be achieved during these comparisons. A first round of measurements in early 2022 gave encouraging results but with some unexplained discrepancies at very low frequency for some measurement configurations. A second measurement round, started late 2022 and is still in progress. This work is performed in collaboration with PTB (Germany) and NMIJ. • The new room temperature low frequency current comparator, of ratio $R_H(2)/100$ (129.06), wound in 2021 is now assembled and its characterization is in progress. This work takes place within the continuous maintenance process of the transportable 1 Hz bridge used for **BIPM.EM-K12** comparisons. • A new cryo-probe for the new multi-windings superconducting cryogenic current comparator (CCC) wound in 2021 has been designed and fabricated. It is intended to replace one of the two cryogenic current comparators (CCC) of the BIPM which has recently been found defective. It will allow to ensure the continuity of services in case the currently used CCC would malfunction. • Design of a new digital double current source for use with the new CCC probe. Some parts of the electronics have been made. This work is still in progress.
E2.2: Bilateral resistance comparisons using resistance transfer standards *NMI Part.: 4*	1) Bilateral comparisons of resistance transfer standards as part of **BIPM.EM-K13.a/b** with relative uncertainty of 5×10^{-8} 2) Participation in related RMO comparisons to link them to BIPM.EM-K13 3) Maintenance of BIPM secondary resistance standards and related measurement chain, also for the calibration of resistance secondary standards for NMIs (E2.3)	• The calibration of the BIPM resistance reference base from the QHR has been carried out twice. This reference is also the basis for the realization of the farad from the ohm (E3.1). • Publication of the measurement report concerning **BIPM.EM-K13.a and b** comparisons with NPLI (India). • Ongoing **BIPM.EM-K13.a and b** comparisons with CEM (Spain) and INRIM (Italy). • Maintenance of the measuring bridges and standards used for resistance services. • Maintenance of the quality system associated with resistance services which was submitted to both internal and external audits in 2022.
E2.3: Calibrations of resistance secondary standards	Calibration of resistance secondary standards for NMIs without primary realizations and for internal customers (Mass, Ionizing Radiation, Kibble balance)	• 48 resistance standards calibrated for 11 NMIs (BIM (Bulgaria), NMIM (Malaysia), NMISA (South Africa), UTE (Uruguay), NIMT (Thailand), IPQ (Portugal), NIS (Egypt), VSL (Netherlands), INM (Columbia), NMC (Singapore), CENAM (Mexico)) and 2 internal certificates (Ionizing Radiation Department).

I	Physical Metrology	
Project	Deliverables	Work performed in the period (1 January 2022 – 31 December 2022)
Calibration for: 25 NMIs (150 certificates)		
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 February and July 2022. • 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 both internal and external audits in 2022. • Ongoing BIPM.EM-K14.a and b comparisons with NMIM (Malaysia).
E3.2: Calibrations of capacitance secondary standards *Calibration for: 20 NMIs (110 Certificates)*	1) Calibrations of capacitance secondary standards for NMIs without primary realizations	• 43 capacitance standards calibrated for 11 NMIs (CMI (Czech Republic), NRC (Canada), NMISA (South Africa), GUM (Poland), BIM (Bulgaria), NIMT (Thailand), IPQ (Portugal), NIS (Egypt), CENAM (Mexico), NMC (Singapore), CEM (Spain)). Study Notes were issued for two standards.
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	• Improvement of the characterization of a capacitive probe intended for the measurement of the angular position of the electrodes. This work allowed to improve the initial positioning of the electrodes' axes on the edges of a square to within ±0.3 mrad, and to reduce the skew angle to less than 1.4 mrad. These values correspond to an uncertainty of the order of 1 nF/F on the final realized capacitance value.

I	Physical Metrology	
Project	Deliverables	Work performed in the period (1 January 2022 – 31 December 2022)
		• Subsequent alignment of the cross-capacitor has allowed to adjust distances between opposite and adjacent electrodes to within less than 1 µm. • However, it was evidenced during the alignment process that the measuring probe used to measure the distances between adjacent electrodes has an accuracy limited to about 0.5 µm. Finer adjustments to the targeted 0.2 µm accuracy will require to improve this probe or design a new one. This point is currently under study. • Presentation of the work progress at the 2022 CPEM Conference in New-Zealand.
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 9 Pt-Ir prototypes for SMD (Belgium), NIM (China), NIS (Egypt), MIKES (Finland), NPLI (India), KEBS (Kenya) and IPQ (Portugal). • Calibration of 13 stainless steel mass standards for SMD (Belgium), NIS (Egypt), KEBS (Kenya), VSL (Netherland) and EMI (UAE). • Determination of the volume of two new prototypes for NIM (China). • Mass values of BIPM working standards for current use monitored and adjusted against working standards for limited use. • Calibration campaign with 14 certificates for pressure gauges of the Physical Metrology Department and the Chemistry Department. • Calibration of 3 hygrometers from the Physical Metrology Department.
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.	• The new prototypes n°s 114 and 115 were calibrated and delivered to NIM (China).
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.	• The second key comparison of realizations of the kg with Kibble balances and the XRCD method, with nine participants, has been completed and the results published in the KCDB (CCM.M-K8.2021, M. Stock et al., *Metrologia* **60** (2023) 07003). • The second CCM consensus value for an internationally coordinated dissemination of the kilogram has been determined by the BIPM and will be implemented by the CCM on 1 March 2023.

I	**Physical Metrology**	
Project	Deliverables	Work performed in the period (1 January 2022 – 31 December 2022)
	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.	• All BIPM mass calibration customers were informed about the implementation of the new consensus value and the actions to be taken.
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.	• New comparison of stainless steel standards planned to be organized by the BIPM during 2024/25.
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 improvements of the apparatus and the development of a detailed uncertainty budget.	• A reduction of the voltage measurement uncertainty by a factor of two was achieved thanks to the resolution of three unexpected issues. • To overcome the problem of liquid helium shortage, the liquid helium dewar for cooling the PJVS array was replaced with a cryo-cooler system. • A new 2 V PJVS array, kindly provided by the NIST, has been characterized and installed inside the cryo-cooler system. • Improved electronic boards for various sensors were fabricated and integrated. • Data processing programs were further reviewed and improved.
M3.2:	Reengineering of critical mechanical subsystems to enable semi-routine operation.	• A new device for adjusting the mass centre of the middle segment was built. The new device ensures a good repeatability of successive mass loadings and significantly shortens the alignment process. • An experimental set-up including the prototype beam mechanism and associated actuators and sensors was assembled and adjusted on a test bench. The mechanism serves as the basis for a compact Kibble balance for use at masses of 500 g and below (see M3.6).

I	**Physical Metrology**	
Project	Deliverables	Work performed in the period (1 January 2022 – 31 December 2022)
M3.3:	Developing software and control system for full operation in vacuum.	• Control and data acquisition programs were updated and improved.
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.	• No work during this period
M3.5:	Participate in the ongoing comparison of realizations of the kilogram (PMD-M2).	• The BIPM successfully participated in the second key comparison of realizations of the kilogram with a standard uncertainty of 4.1×10^{-8}.
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.	• To check some of the design features and to characterize the behavior of the new beam mechanical system, a home-made interferometer and several position sensors were developed. Two current sources and interfacing electronics for the generation of the magnetic force and for providing the beam swing were fabricated. • The system was interfaced with sensors. The control and the data acquisition software was completed. • First results of the characterization of the mechanism have been obtained. The work will be continued with the support of a secondee from NMIJ in 2023.

II	Time Metrology	
Project	Deliverables	Work performed in the period (1 January 2022 – 31 December 2022)
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, despite the difficulties in several NMIs to provide timely and validated data due to the sanitary situation resulting from the Covid-19 pandemic • In Jan 2022, the 400th Circular T was published https://www.bipm.org/en/-/2021-12-30-greetings • Computation of TT(BIPM21). • Several PSFS data available, and used for the steering of TAI https://webtai.bipm.org/database/show_psfs.html • The traditional annual report with a summary of the results has been discontinued with the aim of giving full availability of data and plots on the BIPM web pages to support the digitalization. • Selection process and training for a new physicist and a new SW engineer for the department • Contribution to several activities in the QMS in the transition to ISO 17025-2017. Update of the some QMS general procedure, organization of internal audit, risk and opportunity policy.
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.	• Progress in the project on a new IT system based on virtual machines. The machines are ready, the migration from the old system is in progress. • A SW for checking the availability and inconsistency of the submitted data for UTC and UTCr allowing early analysis and fault detection is under finalization. • Updated diagnostics are available for the UTC computation. The continuity of the links between labs and their clock measures are plotted on "continuity plots" automatically updated during the UTC computation, for an easy visual inspection of the results. Similarly, the measurements of the TAI frequency by the different PSFS are automatically plotted each month for internal inspection. • Important improvements of UTC Circular T are in progress. Section 5, which reports the used time links, and their calibration information will soon evolve, in collaboration to the relevant CCTF working groups, with the addition of more information and the complete treatment of non-calibrated receivers will allow an improvement of the estimation of the uncertainty of UTC-UTC(k), along the lines developed in 2020.

II	Time Metrology	
Project	Deliverables	Work performed in the period (1 January 2022 – 31 December 2022)
		• 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. • The management of the input files from external entities has been modified to correctly treat the filename changes of the IGS products that are used for the GNSS time transfer (precise satellite ephemerids, clocks, and ionospheric delay) • Participation to the BIPM WG on Digitalization • Publication and communication to congress: F Meynadier, "Machine-readable data within the context of disseminating the Coordinated Universal Time (UTC)", presentation at the SCIDatacon 2022. G. Panfilo, "Temps universel ou temps international ?", presentation at the meeting "Phénoménotechnique du temps", Besançon, 2022
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: – 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	• A collaboration with a PhD student of the University of Besancon has allowed the study of a possible method to detect anomalies on the UTC clock and link data. • An analysis of the UTC maximum weight definition, discussed with the CCTF WG on Algorithms, has led to a modification in the UTC algorithm configuration to slightly improve UTC stability. The possibility to use two different maximum weights has also been studied. • Additional developments in the application of Integer Precise Point Positioning (IPPP) to UTC links to improve current GNSS time links. This work was undertaken in collaboration with the CNRS (France), allowing the development of a preliminary tool for possible future routine use in UTC computation • Some aspects of other clock comparison techniques were also explored as the analysis of the diurnal component in the TWSTFT links, the ambiguity fixing in GNSS measures, and the instabilities in the TWSTFT and the GPS carrier phase time transfer systems Publication and communication to congress • Baudiquez and G. Panfilo, "Automatic jump detection in time transfer link for the calculation of UTC", presentation at the URSI AT-AP-RASC 2022, Gran Canaria • G Petit, F Meynadier, A Harmegnies, C Parra, « Continuous IPPP links for UTC", presentation at the URSI AT-AP-RASC 2022, Gran Canaria

II	Time Metrology	
Project	Deliverables	Work performed in the period (1 January 2022 – 31 December 2022)
	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	• J. Milton, G. Panfilo, "A new way to set the maximum weight in the weighting algorithm of UTC", presentation at the EFTF/IFCS 2022, Paris • F. Meynadier, "Understanding TWSTFT Diurnals ", presentation at the EFTF/IFCS 2022, Paris • G Petit, F Meynadier, A Harmegnies, C Parra, « Continuous IPPP links for UTC", presentation at the EFTF/IFCS 2022, Paris • J. Milton, G. Panfilo, "The maximum weight in UTC: proposal for a new approach", to appear on IEEE UFFC Trans, 2023. • G. Petit, F. Meynadier, A. Harmegnies, and C. Parra, "Continuous IPPP links for UTC", 2022 Metrologia 59 045007 DOI 10.1088/1681-7575/ac7687 • Parker T.E., Zhang V., Petit G., Yao J., Brown R.C., Hanssen J.L., "A three-cornered hat analysis of instabilities in two-way and GPS carrier phase time transfer systems", 2022, Metrologia, 59, 035007 • Tagliaferro G., Ambiguity fixing on geometry free like model using modernized GNSS signals, EGU General Assembly 2022, Vienna, Austria, 23–27, https://meetingorganizer.copernicus.org/EGU22/EGU22-4881.html • Panfilo G., "Temps universel ou temps international ?", presentation at the meeting "Phénoménotechnique du temps", Besançon, 2022 • Meynadier F., "Machine-readable data within the context of disseminating the Coordinated Universal Time (UTC)", presentation at the SCIDatacon 2022. • New Post Doc position supported by the French FIRST TF network. Recruitment and start of the activity in January 2023. • Participation to BIPM WG on scientific SW validation contributing to the BIPM SW validation guideline. Visitors: • Antoine Baudiquez, January – February 2022, June-July 2022 and • Pascale Defraigne, June -July 2022
3. TIME-U3: CALCULATION and DISSEMINATION of RAPID UTC		
TIME-U3: RAPID UTC	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	• UTCr has been published without interruption every Wednesdays, the offset to UTC remains within +/- 2 ns. • The SW routines for the computation of UTCr have been migrated on the new IT service with the necessary update for the improvement of the robustness of the system

II	Time Metrology	
Project	Deliverables	Work performed in the period (1 January 2022 – 31 December 2022)
Participating laboratories: 57 (2018), 63 (2022), 2023 target is to grow by 10 %	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.	
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).* 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.	• 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 • An overall analysis of the calibration results of the last years together with an analysis of the stability of the BIPM reference value for the G1 calibration has been accomplished and published in: – G.Petit and P. Defraigne, "Calibration of GNSS stations for UTC", *Metrologia* https://iopscience.iop.org/article/10.1088/1681-7575/acbd52
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	• GNSS calibration exercise for G1 labs and the validation of results of the G2 labs were carried our regularly. • The 2020 BIPM calibration of time transfer equipment in selected laboratories "Group 1" per region (G1) trip was completed, and the results of COOMET G1 laboratories (SU) published in the department database.

II	Time Metrology	
Project	Deliverables	Work performed in the period (1 January 2022 – 31 December 2022)
	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.	• The 2022 G1 trip has started and has recently concluded the visit in APMP G1 laboratories (NIM, NICT, TL).
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 26 "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: New time and frequency transfer techniques in TAI/UTC. Possible redefinition of the SI second and TT	1) Develop an operational algorithm for the analysis and comparison of optical frequency 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.	• A CCL-CCTF digitalization project has been developed: from the database conception, the database filling, up to the API creation. Work in strict collaboration with NPL CCL colleagues and the joint CCL CCTF WG. This is the first step toward the digitalization of the MeP of the meter and the second. • Follow the work of European collaborations leading to an almost continuous comparison of PSFS in Europe and evaluation on the possible inclusion in the UTC computation. • Active 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). • Secondment in June – Dec 2022 of Nelida Diaz from CENAM to support the publication of PSFS measures in an automatically updated and interactive plot https://webtai.bipm.org/database/d_plot.html

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	5) Contribute to the discussion on the redefinition of the second.	Publication and communication to congress: • G Petit, "Time metrology and the redefinition of the second: Some present and future challenges", Platinum Jubilee CSIR-NPL Jan 4, 2022.
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: (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.	• Participation to the workshop on ACES-PHARAO mission to follow the advancement and the possibility of future use in UTC for clock comparison. • Support to the use of new primary and secondary frequency standards in UTC along the roadmap to the redefinition of the second https://www.bipm.org/en/-/2021-12-21-record-tai Publication and communication to congress. • G. Petit and G. Panfilo, "Comparison of primary and secondary frequency standards used for TAI", presentation at the URSI AT-AP-RASC 2022, Gran Canaria. • Lewis and G. Panfilo, "Realizing the metre with a digital traceability chain for the recommended optical frequency values", presentation at the SCIDatacon 2022. Presentation of the CCTF roadmap to the redefinition of the second at the: • ROCIT workshop on Oct 19, 2022 (online). • CPEM on Dec 12, 2022, as invited plenary lecture (online).

II	Time Metrology	
Project	Deliverables	Work performed in the period (1 January 2022 – 31 December 2022)
	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.	

III	Chemical Metrology	
Project	Deliverables	Work performed in the period (1 January 2022 – 31 December 2022)
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 INRIM (Feb. 2022), NIST (June 2022), NPL (June 2022) and DMDM (Sept. 2022). • 3 key comparison reports published for CHMI (July. 2022), INRIM (Sept. 2022) and DMDM (Dec. 2022).
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 NPL owned SRP at the BIPM Laboratories (June 2022). • Publication of Rapport BIPM-2022/01 'Upgrade of the electronics modules of the BIPM Standard Reference Photometers for ozone and the effect on the on-going key comparison BIPM.QM-K1'.
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.	• The CCQM-P172 (HNO_3 spectroscopic methods) data analysis completed and final report published, with correction factor for spectroscopic measurements of HNO_3 established. • A Joint Technical project established with NPL for development of future on-going comparisons for NO_2 in nitrogen at 10 µmol/mol and 1 µmol/mol. • BIPM NO_2 dynamic MSB facility at 10 µmol/mol upgraded with new computer and FTIR operating software, with correction factor for HNO_3 from CCQM-P172 implemented into new version of system software. System operation validated with BIPM internally maintained static gas mixture standards.
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.	• BIPM CO_2-PVT (manometric) reference facility development completed and 1st draft of paper describing operation and uncertainty. • 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 initiated, with 20NMI standards measured at the BIPM. • Labview software for comparison of CO_2 in air gas standard ensembles completed and validated with a set of KRISS standards.

III	Chemical Metrology	
Project	Deliverables	Work performed in the period (1 January 2022 – 31 December 2022)
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.	• CCQM-P204 measurements completed, and results submitted to BIPM for analysis. • Draft A.1 and Draft A.2 reports for CCQM-P204 prepared by the BIPM and circulated to participants. • 3 online meetings, including pre-recorded presentations from participants, organized, and hosted by the BIPM, for discussion of the Draft A.2 report.
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.	• Modification of automated cryogenic extraction system for CO_2 in air samples completed with transfer line distances minimized. • 6 months of virtual visiting scientist contract completed with development of script for IRMS method for CO_2 isotope ratio in air measurement. • Completion of 3 months of NPL visiting scientist secondment and first set of validation measurements of CO_2 in air system completed. • Protocol for the CCQM pilot study on CO_2 in air isotope ratio measurements drafted and presented to CCQM GAWG and IRWG. • Paper on 'Minimum requirements for publishing HCNOS stable isotope delta results', published in *Pure and Applied Chemistry*.
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): KCRV method agreed with participants using dark uncertainty approach developed by NIST. Draft B circulated and agreed by the CCQM GAWG in October 2022. • Replacement CRDS system purchased, installed and validated for CCQM-K82.2023, using an ensemble of NPL developed standards. • Protocol for the CCQM-K82.2023 drafted and presented to CCQM GAWG.
G3.2:	Developed methods with reduced uncertainties for Greenhouse Gas comparisons, based on the improvement of cryogenic separation facilities for	• 1st design of carbonate reaction system for CO_2 isotope ratio system completed. • Leak testing completed and seal modifications introduced into design and prototype built.

III	Chemical Metrology	
Project	Deliverables	Work performed in the period (1 January 2022 – 31 December 2022)
	greenhouse gases and their quantitative operation in sample preparation for greenhouse gas mole fraction and isotope ratio measurements.	• Presentation for GGMT 20222 meeting on BIPM comparison and scale facilities for CO_2 in air. • Support for CCQM GAWG GHG Scale Comparison TG and Task teams input into 6 meetings to develop inputs into BIPM-WMO workshop and protocols for BIPM.QM-K5. • Presentation and poster submitted to BIPM-WMO Workshop on Metrology for Climate Action. • Initiation of Joint Technical Project with VSL to develop regression models for GHG Scale comparisons and a database design for GHG Scale measurements and reference data.
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.	• Oxytetracycline samples characterization and value assignment completed at BIPM. • Comparison protocol drafted and presented to CCQM OAWG. • Additional water sorption measurements completed at the BIPM and comparison protocol modified to include an increased range for relative humidity correction. • Comparison samples shipped to 18 participating laboratories.
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.	• Review of candidate materials for CCQM-K148.c completed with CCQM OAWG with Digitoxin as the material of choice.

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Project	Deliverables	Work performed in the period (1 January 2022 – 31 December 2022)
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 purity measurement facilities, providing a core comparison for non-polar organic calibration solutions for NMIs.	• Comparison samples distributed by BIPM to 23 participating NMIs. • Measurement completed and 21 results submitted to the BIPM. • Draft A.1 results collated by the BIPM and presented to the CCQM OAWG.
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.	• Characterization of benzoic acid for ISRD development with NIM China completed and ISRD drafted • Measurements for Internal Standard reference documents on three ^{19}F qNMR materials completed. Bias to ^{1}H demonstrated requiring further investigation.
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.	• Paper on compositional analysis of C3-triskelion published in *Iscience* • Study on prioritization of future peptide comparisons 2024-2027 completed with CCQM-PAWG meeting
O3.2: *NMI Part.: 15*	Completion of purity key comparison CCQM-K115.c C-HbA1c hexapeptide purity, CCQM-K115 repeat on	• Final reports of CCQM-K115.c and P55.2.c (HbA1c hexapeptide (GE) purity) completed and published.

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	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 and their development for diabetes diagnosis and patient monitoring.	• Final reports of CCQM-K115.2018 and P55.2.2018 (HbA0 hexapeptide (VE) purity) completed and published.
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.	• 3 video conference held to discuss results of part II of the CCQM SARS-CoV-2 antibody quantification pilot study, CCQM-P216, coordinated by NIM, with BIPM and NRC. Revision of draft report 25% complete. • 7 online meetings with NRC, NIBSC, CDC and IFCC to plan for the Parathyroid hormone (PTH) comparison, and onsite hybrid meeting to be held at the BIPM in February 2023

IV	Ionizing Radiation Metrology	
Project	Deliverables	Work performed in the period (1 January 2022 – 31 December 2022)
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).	• All requested comparisons have been performed corresponding to 4 NMI participations in 2022: K2, K7M and K7W for NIST (USA); K2 for ARPANSA (Australia). • 5 comparison reports were published in 2022: K2 (KRISS-2017, ARPANSA-2021, GUM-2021), K3 (KRISS-2017) and K7 (KRISS-2017).
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 SSM (Sweden), STUK (Finland) and the BARC (India) ; 7 calibrations corresponding to 6 NMI participations.
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.	• The beam of the new medium energy x-ray facility has been commissioned, requiring critical alignments, measurement of the radial profiles and new settings. • Refurbishment of the irradiation room.
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 5 NMI participations in 2022: K1 and K4 for NMIJ (Japan) and KRISS (Korea), K8 for NPL (UK). • 5 comparison reports were published in 2022: K1 (NMIJ-2022, KRISS-2022) and K4 (NRC-2020, NIM-2021, KRISS-2022).
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 IAEA, SSM (Sweden), STUK (Finland), BARC (India) and the SMU (Slovakia); 18 calibrations corresponding to 7 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.	• Refurbishment of the irradiation room.

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Project	Deliverables	Work performed in the period (1 January 2022 – 31 December 2022)
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 2022 for K6: ARPANSA (Australia). • Two K6 comparison reports were published in 2022: NRC-2020 and PTB-2021.
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 SSM (Sweden) and the BARC (India); 4 calibrations corresponding to 2 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 2022 to ensure that the BIPM standards and radiation beams were 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.	• Check of Beam profile at 10 MV. • Evaluation of k_Q factors for different high energy beams.
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.	• The x-ray tube for the new medium-energy x-ray facility installed and critically aligned to produce a horizontal radiation beam perpendicular to the measurement bench.
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 the medium-enery x-rays beams: o design finalized. o manufactured and assembled with first test measurements in January 2023.

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Project	Deliverables	Work performed in the period (1 January 2022 – 31 December 2022)
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 should be re-established in 2023 after the completion of the commissioning at the IAEA.
D5.2: *Calibration for NMIs: 20*	Characterization and calibration of national standards, on request.	• Scheduled end 2023.
D5.3:	Quality assurance and continual improvement of the BIPM primary standards, and the associated ancillary equipment.	• Full development of a dedicated measurement system, comprising both the hardware to be installed at the IAEA and the LabVIEW software to operate the system. • Validation in the BIPM ^{60}Co facility, preliminary tests successfully carried out in the ^{137}Cs beam at the IAEA.
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 11 NMI participations in 2022: Na-22 (NMISA), Cr-51 (POLATOM), Co-60 (NMISA, ANSTO), Zn-65 (LNMRI), I-125 (NPL), Ba-133 (PTB), Ce-139 (LNE-LNHB), Sm-153 (PTB), Tb-161 (NPL), Lu-177 (IRA). • 5 reports of K1 comparisons were published (11 draft B produced) in 2022 for the following radionuclides: Tl-201 (NIST-2011), Co-57 (POLATOM-2013, NMISA-2015, CMI-2021), Sn-113 (LNE-LNHB-2017), Ce-139 (NMISA-2019, LNE-LNHB-2022), Ba-133 (NRC-2016, TENMAK-2018, NMISA-2019, NIST-2019).
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.	• Full SIRTI remote comparison at the KRISS for ^{18}F, ^{64}Cu and ^{123}I. • As comparisons involve now much more radioisotopes that leads to hardly more than 1 comparison per year – to increase the number of comparisons, in 2022 started the development, by the RMOs (currently APMP and SIM) with BIPM support, of RMO SIRTI systems linked to the SIR. • 1 report of K4 comparison was published (2 draft B produced) in 2022 for the following radionuclides: ^{99m}Tc, ^{18}F and ^{64}Cu (POLATOM-2016).
R1.3:	Technical support for the SIR and SIRTI comparators (quality control checks and continual	• Quality control checks continued throughout the period.

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	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).	• Continuation of SIRTI remote measurements (started in 2021) of ^{153}Sm at PTB for linking of the SIRTI to the SIR. Linking values obtained in 2021 for ^{123}I agree within standard uncertainty giving confidence in the first ^{123}I key comparison that took place at KRISS • Development of software and procedure for remote SIRTI comparisons. • Mathematical modelling to transfer KCRVs from one ionization chamber to another is being developed to avoid the need to measure samples of every radionuclide covered by the SIR. Three possible methods are currently tested. • Developments of digital electronics for RMO and BIPM SIRTIs are underway and led to a dedicated workshop in June, organized by the BIPM, with more than 30 participants. A digital signal processing solution, using LabVIEW, has been developed by the BIPM showing preliminary performance equivalent to that of the analog electronics currently used with the SIRTI and of another LabVIEW digital solution developed at the NIST.
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. • Renewal by the French Nuclear Safety Autority of the BIPM authorisation to use ionizing radiation facilities and sources until 2027
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.	• Definition of the technical characteristics of the new SIR (named SIR 2.0): it will consist of two identical chambers measuring continuously in parallel, enhancing the measurement capabilities of the original system.
R2.2:	Validation of the new system including determining the long-term stability and precision of the system and confirmation of the linearity of the response (current versus activity).	• The purchased ^{166m}Ho solution was contaminated with impurities and had to return for a purification operation at the supplier postponing the tests to end 2023.

IV	Ionizing Radiation Metrology	
Project	Deliverables	Work performed in the period (1 January 2022 – 31 December 2022)
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%.	• The pilot study to validate the ESIR against the reference SIR with the use of ^{60}Co solutions standardized by 13 participating NMI/DIs has been completed successfully. • Draft A produced
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).	• Tests of a digital acquisition system were performed using a CAEN DT5730S module to process the signal leading to encouraging results (paper published in Applied Radiation Isotopes)
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.	• SIR data have been improved to follow FAIR principles allowing the publication in 2022 of the first key comparison report embedding machine-readable (XML and JSON) versions of the document, using the PDF/A-3 standard. • Thanks to the meta-analysis of the database, a survey of primary standards relevant to medical applications has been published as a joint paper with NPL, IAEA and NIST. • An equivalent survey of primary standards relevant to traceability of radionuclides in the environment is in preparation
R4.2:	Development and validation of report writing software.	• Continuous upgrade of the software • 22 reports published in 2 years (January 2021-January 2022)

V	International Liaison	
Project	Deliverables	Work performed in the period (1 January 2022 – 31 December 2022)
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 2022, there are 64 Member States, and 36 Associates of the CGPM: – Costa Rica became a Member State on 5 September 2022 having previously been an Associate of the CGPM since 2004. – Zimbabwe was reinstated as an Associate of the CGPM in February 2022 after being excluded on 1 January 2021. – Cuba and Sudan were excluded as an Associate of the CGPM on 1 January 2022. – Seychelles was withdrawn as an Associate of the CGPM on 1 January 2022. – 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 strategy exercise. Most notably related to the following the CIPM strategy strands: – responding to the evolving needs for metrology – strategy for deepening engagement with other international organizations on measurement science issues – reviewing the strategy for future membership of the organization. • Resolution *On universal adherence to the Metre Convention* adopted at the 27th meeting of the CGPM in November 2022 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.
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 with around 30 international organizations).	• BIPM-OIML cooperation: – World Metrology Day activities (see project #ILC-CP5). • BIPM-UNESCO cooperation: – UNESCO Executive Board adopted a decision towards recognizing World Metrology Day at their session on 13 October 2022 following the proposal presented by Kazakhstan (supported by the BIPM and OIML and 42 UNESCO Member States). The decision will need to be ratified by the 42nd session of the UNESCO General Conference to be held in November 2023. If all goes to plan, UNESCO will proclaim 20 May of each year as a UNESCO world day which will then be celebrated every year from 20 May 2024.

V	International Liaison	
Project	Deliverables	Work performed in the period (1 January 2022 – 31 December 2022)
		• BIPM-UNFCCC cooperation: – On 6 November 2022, the BIPM was admitted by the 27th session of the Conference of the Parties (COP27) held in Sharm-El-Sheikh, Egypt, as an observer organization to the United Nations Framework Convention on Climate Change (UNFCCC). • BIPM-WTO cooperation: – Submission of the BIPM statement and representation of the BIPM at the WTO TBTC meetings in March, July and November 2022. • BIPM-UNIDO cooperation: – The BIPM provided expert advice for to the development of the *UNIDO Quality Infrastructure for Sustainable Development (QI4SD) Index* published in 2022. • BIPM-OECD cooperation: – Director of the BIPM, together with heads of other IOs, shared a video message in the OECD and WOAH (founded as OIE) hosted event: *"International organisations: Supporting Countries to Anticipate, React and Rebuild in the Face of Global Disruptions"*. The event was held on 5 December 2022 as part of the 9th Annual IO Meeting within the context of the IO Partnership and welcomed heads of Secretariats of other international organisations (IOs). – Following the High-Level event, working-level technical meeting was held on 6 December 2022 and the BIPM as the Focal Point of the IOP WG2: Inclusiveness (merged WG: stakeholder engagement and IO coordination) moderated the session to discuss follow-up work of the IO Compendium regarding to stakeholder engagement and co-ordination across IOs.
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)	• Meeting of the CODATA TGFC on 12-14 September 2022 • Update of the CODATA TGFC website • Discussions on a new file format for digital data
TIME-L1 Coordination and promotion of time activities for the advancement in the development of time	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	• Contribution to the update of "1139-2008 - IEEE Standard Definitions of Physical Quantities for Fundamental Frequency and Time Metrology---Random Instabilities, to appear in 2023 • ICG annual meeting, Abu Dhabi, Oct 2022 (online). 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 and traceability through GNSS measurements.

V	International Liaison	
Project	Deliverables	Work performed in the period (1 January 2022 – 31 December 2022)
scales and their applications.	6) Need in Time and frequency transfer methods.	• IGS: Work with the governing board to support continuous UTC. IGS Statement on https://files.igs.org/pub/resource/IGS_LeapSecond_Statement_Final.pdf. • One member of the Time dept is a member of the IGS Governing Board with meeting on Dec 11, 2022 • Participation to Working groups of the IGS (on clock products and on PPP-Ambiguity Resolution) and of the IAU (on Time metrology standards) • EFTF Marcel Ecabert Award to G. Petit recognising his "long-standing involvement and key contributions in the timing activities of the BIPM and more generally in International time and frequency metrology." https://www.bipm.org/en/-/2022-05-16-gerard-award
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: • Attending the ITU WP7A meeting online in May and September 2022. Preparation by several discussions with the Chair and colleagues. • Meeting with ITU R Director and collaborators on Jan 2022 (online) and during CGPM Nov 2022 • Meeting ITU R Swiss delegation in April 2022 (online), ITU R Vatican delegation in March 2022 (online), ITU R Italian delegation in Rome, Sept 2022 • Support to the ITU-T on a liaison statement on continuous UTC • Attending the ITU European CEPT PTA meeting in Sept 2022 and submission of an informative doc on continuous UTC and CGPM draft resolution (online) • contribution to ITU Asia Pacific APG meeting in Aug 2022 and submission of an informative doc on continuous UTC and CGPM draft resolution • Contribution to the " Content and structure of time signals to be disseminated by radiocommunication systems and various aspects of current and potential future reference time scales, including their impacts and applications in radiocommunication", REPORT ITU-R TF.2511-0, https://www.itu.int/pub/R-REP-TF/en and the Note to the BR Director on continuous UTC. • Organization of the special session on Res 655 at the 2nd ITU-R interregional workshop, Dec 2022, Geneva, https://www.itu.int/en/ITU-R/conferences/wrc/2023/irwsp/Pages/2022.aspx
Chem-L1	1) Liaison activities with: IUPAC; ISO TC 212, IFCC, WMO, WHO, WADA, Codex, ISO TC 146.	• BIPM-WMO online Metrology for Climate Action Workshop organized 26-30 September, with over 1000 registered participants and 200 pre-recorded presentations producing over 100 recommendations.

V	International Liaison	
Project	Deliverables	Work performed in the period (1 January 2022 – 31 December 2022)
		• Active 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. • Active liaison with ISO TC 146 maintained, including new work items to revise ISO 13964 and ISO 10313 standards using most accurate value of ozone absorption cross sections 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, with continued revision of ISO Standards 15193 and 15194, and the basis of the JCTLM review process for reference methods and materials. • Participation and presentations at the ICSH General Assembly to strengthen collaboration within JCTLM. • Active liaison with ICSH to strengthen collaboration on Total Haemoglobin standardization between ICSH and CCQM and planning of joint meeting to be held at the BIPM in 2023 • IUPAC paper on Purity methods for Organic materials accepted for publication.
	2) Liaisons activities related to revision of Ozone standard reference method and global implementation.	• Management of CCQM-GAWG task group "Ozone cross-section change management" with Executive Secretary role held by BIPM staff J. Viallon. • Coordination of *Communication team* with leadership held by BIPM staff E. Flores and 6 meetings organized and draft website developed. • On-line information related to the task group activities updated on BIPM website. • Publication of BIPM Rapport BIPM-2022/02 'Units and values for the ozone absorption. cross section at 253.65 nm (air) with appropriate significant digits and rounding for use in documentary standards'.
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 a 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. • Participation in the work of the ICRU, including commenting on the final draft of the upcoming ICRU Report on dosimetry for radiopharmaceuticals. • Participation in an IEC/ISO (JWG 5) joint group with involvement in a new standard for radionuclide calibrators.

V	International Liaison	
Project	Deliverables	Work performed in the period (1 January 2022 – 31 December 2022)
		• Participation in the advisory board of the European provider of medical radionuclide (PRISMAP) • Vice presidency of the ICRM, with preparation of the 2023 ICRM conference (review of abstracts and participation in the Scientific board and Executive board meetings in Bucharest).

VI	Coordination	
Project	Deliverables	Work performed in the period (1 January 2022 – 31 December 2022)
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 2022, the CIPM MRA has been signed by representatives of 104 institutes – from 64 Member States, 36 associates States of the CGPM, and four international organizations – and covers a further 150 institutes designated by the signatory bodies. • During the reporting period around 1644 CMCs were processed via KCDB2.0 web platform and published. • There were 34 new key and 19 new supplementary comparisons registered in the KCDB in 2022. • The set of CIPM MRA brochures has been drafted and uploaded to the BIPM website. The brochures aimed to simply explain the benefits of the CIPM MRA to a variety of parties and describe how the data quality is assured. Printed versions of the brochures have been made available through the RMO Secretariats. • Organized the 45th meeting of the JCRB in March 2022 as online conferences. Participants were representing all six RMOs and the CIPM. • Publication and presentation of KCDB reports to the JCRB in March and September 2022; 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 of RMO in operation of the CIPM MRA processes, including support for RMOs TC Chairs, CMC Reviewers, comparison pilots and CMC writers. • Registration of DIs as participants of the CIPM MRA: One DI has been withdrawn as a participant of the CIPM MRA by the national authority, two have joined as a new DI, and two other ones have changed names.
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.	• Full support to the JCGM meeting held online on 12 December 2022, including publication of the meeting minutes. • Full support to the JCGM-WG2 meetings held online on 13-17 June 2022 and 6-9 December 2022 including publication of the meeting minutes. • Participated in WG2 Focus Group meetings. • Full support to JCGM-WG2 during development of the VIM4 2CD.
IR-C1:	Provision of the Scientific Secretary for JCGM WG1 and support including:	• Organization of the Joint Workshop of JCGM-WG1 and WMO-ET-MU on Measurement uncertainty in meteorology and climatology – 05-06 April 2022

VI	Coordination	
Project	Deliverables	Work performed in the period (1 January 2022 – 31 December 2022)
	1) Rapporteur 2) Two annual meetings.	• 3 JCGM-WG1:GUM meetings (2 on-line and 1 hybrid) in 2022 • Review and update of the JCGM-WG1 web pages and working documents on the new BIPM web site.
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 23rd Executive Committee meeting drafted and published. • Report of the December 2021 DBWG meeting drafted and distributed. • Videoconference of JCTLM Executive held in July 2022. • Onsite hybrid meeting of JCTLM Executive and DB WG held in December at the BIPM • The 9th Issue of the JCTLM Database Newsletter edited and published. • Organization of 4JCTLM Quality System Review Team meetings for updates to JCTLM procedures. • Preliminary review of 125 nominations before distribution to the DBWG review teams completed. • 40 new entries published in the JCTLM database. • Completion of development and publication of new version of JCTLM Database (October 2022). • Review and planning of updates of JCTLM Websites completed with the JCTLM TEP WG • Publication of report of the JCTLM Members and Stakeholders Meeting and Workshop on Overcoming challenges to global standardization of clinical laboratory testing: reference materials and regulation to be held 6-10 December 2021 in Clinical Chemistry and Laboratory Medicine (CCLM). • Co-organization and chairing of the JCTLM meeting on CRP standardization held in Milan in December 2022.
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;*	1. Organization of the 27th meeting of the CGPM. 2. No CC Presidents' meeting requested for 2022. 3. Support for emerging states addressed via the CBKT Programme.

VI	Coordination	
Project	Deliverables	Work performed in the period (1 January 2022 – 31 December 2022)
	b) Optimal support for states with emerging metrology systems *c) Facilitated by the BIPM convening annual meetings of the RMO Chairs*	
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)	• Preparation of the CCEM meeting in March 2023. • Update of the CCEM Guidelines on CMC submission. • Coordination of and participation in the review of comparison reports. • Presenting news from the CCEM and BIPM at the APMP TC-EM meeting. • Presenting news from the CCEM and BIPM at the EURAMET TC-EM meeting. • Launch of a series of CCEM webinars (see PMD-CBKT) and giving a presentation at the first webinar.
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)	• Update of two CCM guidance documents; 1 CCM Newsletter. • Update of CCM service scheme. • Drafting and follow-up of CCM action plan. • Coordination of the registration, approval and publication of the final reports of KCs. • Presentation at the EURAMET TC-M meeting. • Preparation of the CCM written report and CCM poster to the CGPM. • Steering and Program Committee of the International Conference of Weighing 2023 (12 meetings; review and selection of 20 abstracts). • Organization and co-chair of the WGS meeting; organization of online WG meetings. • Preparation for the 19th CCM meeting and WG meetings in May 2023.
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 remote meetings of WG-S in February 2022, of WG-CMT in May and September 2022 and of TG-ADQSIB in March 2022. • Organization of a series of four meetings of the WG-CMT focus group for early 2023. • Consultation of the members of TG-ADQSIB how the text of the SI Brochure about units for angles should be clarified. • Preparation of version 2.01 of the SI Brochure, including the new prefixes and a large number of minor editorial corrections.

VI	Coordination	
Project	Deliverables	Work performed in the period (1 January 2022 – 31 December 2022)
		• Organization of a joint CCU/CCQM workshop on quantities which can be counted in March 2023. • Preparation of the CCU written report and CCU poster to the CGPM. • 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	• Organization of the 23rd CCTF on June 29-July 1, 2022. The two CGPM 2022 draft resolutions and the other hot topics way forward were discussed with the CCTF, giving raise to 4 CCTF recommendations. • Preparation of a special focus on Metrologia on "Challenges in Time and Frequency Metrology". Two papers are already published, other two are 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 meetings. Publication and communication to congress • N. Dimarcq, P. Tavella, "Current activity of the CCTF to address the needs of time and frequency metrology and its applications", presentation at the EFTF/IFCS 2022, Paris • Gertsvolf M., Mileti G., Meynadier F., et al., "Task force on the Redefinition of the Second /Subgroup A: Impact on users and stimulus for the redefinition", presented at the EFTF/IFCS 2022, Paris. • Bize S., Peik E., Oates C., Petit G., "Current activities of CCTF to update the roadmap for a redefinition of the second: Options for the redefinition", presented at the EFTF/IFCS 2022, Paris. • Calonico D., Ido T., Panfilo G., "Time and Frequency Dissemination and Time Scales, Task Force on the Roadmap for the Redefinition of Second", presented at the EFTF/IFCS 2022, Paris. • J. Levine, P. Tavella, M. Milton, "Towards a consensus on a continuous coordinated universal time", 2023 Metrologia 60 014001. • Y. Koyama, P. Tavella, J. Levine, "Statements from International Union of Radio Science (URSI) on the Need for a Continuous Reference Timescale", URSI RADIO SCIENCE LETTERS, VOL. 3, 2021, DOI: 10.46620/21-0047, https://www.ursi.org/publications.php • Presentation of the CCTF roadmap to continuous UTC at the Time Appliances Project, Feb 2022 https://www.opencompute.org/wiki/Time_Appliances_Project (online).

VI	**Coordination**	
Project	Deliverables	Work performed in the period (1 January 2022 – 31 December 2022)
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 and CCL WGS. • Final publication of Metrologia Focus Issue on Length • Finalization of some guidance documents (coding documents and online voting) and starting discussion on possible improvement of KCDB during CCL WGS and CCL WGMRA meetings. • Communication and coordination between Russian institutions and CCL members to advance the organization and the reports of Key and Supplementary Comparisons.
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.	• Activity to reinforce CTBTO liaison with CCAUV and to finalize the CCAUV liaison with the joint WG ISO TC12/IEC TC25.
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	• On-line CCQM Plenary meeting organized and run over 3 successive days in April 2022, with report of meeting published in June 2022. • 44 videoconference sessions organized by the BIPM for 11 CCQM WGs in 2022. • Support for CCQM Task Groups on: Microplastics Measurement Standardization; Metrology for pandemic Preparedness; Stakeholder Engagement. • Hosting of CCQM online workshops on Microplastic Measurement Standardization and Particle Metrology. • Support of organization of CCQM Viral Workshop to beheld in 2023. • Support for CCQM SPWG meeting and CCQM inputs into the 27th CGPM meeting. • Identification and liaison with 4 speakers for the 27th CGPM meeting.
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	• Support for CCPR-WG-SP to perform and analyze a survey of CCPR members' needs (March 2022). • Support for CCPR-WG-SP to complete and publish the CCPR Strategy document in April 2022.

VI	**Coordination**	
Project	Deliverables	Work performed in the period (1 January 2022 – 31 December 2022)
	3) Coordination of review of CC and RMO comparison reports before publication 4) Development and review of CCPR documents and guidelines	• On-line CCPR Plenary meeting organized and run over 2 successive days in May 2022, with report of meeting published in August 2022. • Three on-line meetings of the CCPR Working Groups hosted in 2022. • Support for CCPR inputs into the 27th CGPM meeting (poster, presentation, report). • Support provided for the publication of 2 new CCPR RMO comparisons reports in the KCDB.
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	• CCRI webinar series: 8 organized webinars: *22/01- Needs and gaps in Metrology for Radionuclide Therapy, 17/02-Mass Spectrometry in Radionuclide Metrology, 10/03-Git for Metrology, 19/04-Radioactive sources in metrology, 31/05-x-ray machine spectrometry for dosimetry, 30/06-Carbon 14 analysis for dating and climate issues, 07/09-Beta radiation metrology, 24/11-International system for ionizing radiation metrology*. • Management of the work of the CCRI communication Working Group (4 meetings in February, March, June and September): 8 webinars, 7 newsletter, on-going analysis on e-learning needs. • Two meetings were held in May and October of the CCRI Radionuclide Therapy and Quantitative Imaging Working Group (CCRI-RTWG). • One meeting was held in June of the CCRI RMO Working Group on IR CMCs (CCRI-RMOWG). • Two meetings were held in April and December of the Key Comparisons Working Group of CCRI section II (CCRI-KCWG(II)). • Creation of a new Task Group on Radioactive Sources, with one meeting in May 2022 and a report awaited for mid 2023. • Co-pilot of the ^{109}Cd CCRI Section II comparison exercise: Data analysis and production of the Draft A of the comparison. • Co-pilot of the thermal neutron CCRI(III).K8.2024 comparison: dealing the issue of the main pilot unable to continue to play this role.
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	• The 30th meeting of the CCT was held as 2 separate online sessions in January and February 2022. A number of WG and TG meetings were also organized. • Minutes of each CCT session were drafted, where the CCT report to the CIPM is a summary of these. • Preparation of the CCT report and related poster for the CGPM • Preparation of the first meeting of the CCT-TG on Digitalization (April 2022).

VI	**Coordination**	
Project	Deliverables	Work performed in the period (1 January 2022 – 31 December 2022)
		• Responding to questions received by CCT-WGs chair related to broken links in CCT *Mise en pratique of the Kelvin* between the former website and the new one. Interactions with the webmaster on related issues. • TG on Body Temperature Measurements released guides on the best practice for the use of infrared ear and forehead thermometers. • Liaison with WMO is maintained by participation of CCT members and experts in the WMO expert groups. The CCT, and the CIPM, is also represented at the Global Climate Observing System Surface Reference Network Task Team (TT-GSRN).

VII	Capacity Building and Knowledge Transfer	
Project	Deliverables	Work performed in the period (1 January 2022 – 31 December 2022)
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.	• In 2022 the e-learning platform (www.e-learning.bipm.org) was expanded to enable it also to host the material from the interested RMOs. As of today APMP, COOMET, EURAMET and GULFMET have signed practical arrangement to join the e-learning initiative. The purpose of signing the formal arrangement is to ensure the ongoing reliability of the e-learning platform and publication of up-to-date material. • "Knowledge Transfer through Metrologia" was launched. This initiative is aimed to highlight the service rendered to the world-wide metrology community by senior scientists devoting time to publishing review papers on topics of interest and these papers being made openly available to all through Open Access publication in Metrologia. • Secured funding from METAS for the CBKT project planned in 2023. Currently, discussion is ongoing to launch the BIPM and OIML joint project on the development of e-learning courses and publication material in support of the BIPM-OIML publication: *National Metrology Systems - Developing the institutional and legislative framework.*
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').	• 2022 – GULFMET training course for Peer reviewers within the CIPM MRA was organized with participation of more than 60 experts from GULFMET member institutes. • 2022 - BIPM-SIM Training course: KCDB 2.0 was organized with participation of more than 200 staff from NMIs/DIs involved in the KCDB operation. This online training was the follow-up event to the global course entitled "Optimizing the CIPM MRA - the KCDB 2.0", organized at the BIPM in November 2019. • A suite of brochures was published under the auspices of the CBKT Programme to provide information and assistance on key roles and mechanisms within the CIPM MRA. • Seven online projects on core CBKT topics have been organized with 1162 participation: – KCDB 2.0 - CMC Writers in General Physics – KCDB 2.0 - CMC Writers in Ionizing Radiation

VII	Capacity Building and Knowledge Transfer	
Project	Deliverables	Work performed in the period (1 January 2022 – 31 December 2022)
		– KCDB 2.0 - CMC Writers in Chemistry and Biology – KCDB 2.0 – Comparisons – KCDB 2.0 - TC Chairs in General Physics – KCDB 2.0 - TC Chairs in Ionizing Radiation – KCDB 2.0 - TC Chairs in Chemistry and Biology Cumulative overview of the CBKT, as of 2022: • 50 CBKT initiatives were organized: 27 projects at the BIPM and regions; 23 (+11 repeated) projects online. More than 60 lecturers from NMIs/DI and IOs have been involved in delivery of the CBKT activities. • e-learning: there are 17 e-learning courses submitted by EURAMET, COOMET, GULFMET and the BIPM Scientific Departments available for metrology community. • Overall, 2998 participation from 120 countries in various CBKT initiatives: 527 participants at the BIPM and regions physically; 1223 participants in online sessions. Plus 730 registered participants from 116 countries in e-learning. • CBKT participation by RMOs: – 334 - AFRIMETS – 541 - APMP – 418 - COOMET – 802 - EURAMET – 305 - GULFMET – 598 - 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 is ad-hoc, organized based on available resources. Planned in 2025, however there is now some uncertainty on the timing.
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):	• Due to COVID-19 crisis: – 2020 BIPM-APMP Training course: Timescale and Algorithms. Postponed. • In 2022, the joint BIPM and TÜBİTAK UME initiative hosted ten talented metrologists from ten different countries (Ethiopia, Colombia, Tanzania, Philippines, Uzbekistan, Bosnia Herzegovina, Guyana, India, Indonesia, Kazakhstan) for a period of 1 to 3 months at the

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Project	Deliverables	Work performed in the period (1 January 2022 – 31 December 2022)
	– 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	TÜBİTAK UME laboratories. The geographical coverage in this cycle was wider than in previous cycles, welcoming participants from all RMOs; AFRIMETS, APMP, COOMET, EURAMET, GULFMET and SIM.
PMD-CBKT	Planning, coordination and delivery of the capacity building and knowledge transfer activities in the field of electricity and mass metrology.	• The CCEM launched a series of webinars with a pedagogical approach to topics from electromagnetic metrology. A first webinar was held in 2021 including a presentation of the work in the BIPM electricity laboratories. • Two e-learning courses on the realization and the dissemination of the kilogram following redefinition were developed and added to the e-learning platform.
TIME-CBKT	Planning, coordination and delivery of the capacity building and knowledge transfer activities in the field of time and frequency metrology.	• Shipment to the BIPM Frequency Comb to CENAM to contribute to the Length laboratory https://www.bipm.org/en/-/2022-02-03-frequency-comb-cenam • Collaboration with the CCTF and the CCTF WG on TAI and Algorithms to plan a CBKT program based on shared resources in collaboration with NMIs. • Contract of collaboration with the IEEE UFFC society for the common aim of capacity building in time and frequency metrology. The IEEE funded 50% of a secondee to be selected to coordinate the CB program in the Time Department.
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 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,	• CCQM-K154.b (AfB1 mycotoxin calibrant) final report completed and published in the KCDB. • CCQM-K154.c (DON mycotoxin calibrant) final report completed and published in the KCDB. • 10 NMI samples measured at the BIPM for the key comparison CCQM-K154.d (PAT mycotoxin calibrant) • 50% of Ochratoxin A material characterization completed in preparation for CCQM-K154.e (OTA mycotoxin calibrant) • Knowledge Transfer Study measurements on the purity evaluation of Tetracycline completed and results submitted to BIPM for evaluation. 3online meetings held with 14 NMI/DI participants to review results and summary presented to OAWG meeting. • Chlorpyrifos, acetamiprid and glyphosate material received from NIM China, as part of a Joint Technical Project on Pesticide Materials • Publication of Rapport BIPM-2022/03 [BIPM CAG-04] - Calibrant Assessment Guideline: Patulin (PAT) • Publication of Rapport BIPM-2022/04 [BIPM PEG-03] - Purity Evaluation Guideline: Deoxynivalenol (DON)

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Project	Deliverables	Work performed in the period (1 January 2022 – 31 December 2022)
	supporting CBKT program on Metrology for Safe Food and Feed.	• Publication of Rapport BIPM-2022/05 [BIPM PEG-04] - Purity Evaluation Guideline: Patulin (PAT)
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 NMISA and NIMT resulting in operational facilities at both NMIs. • Initiation of Joint Technical Project with METAS on dynamic methods for NO_2 standards and transfer of PermaCal system from METAS to BIPM • Completion of design of MSB dynamic NO_2 system at the BIPM to operate at 1 mmol/mol and (50 to 250) nmol/mol amount fractions for NO_2 in nitrogen
Chem-CBKT4 Metrology for Accurate Patient Care	1. Development of E-training material on peptide pure material standard characterization and value assignment	• Review of requirements completed, and e-learning module on qNMR for peptides to be developed in 2023.
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: 1371 attendees and 3225 YouTube views in 2022.

VIII	Communication and Promotion	
Project	Deliverables	Work performed in the period (1 January 2022 – 31 December 2022)
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 such as the KCDB, the JCTLM database, the BIPM e-learning platform, the BIPM SharePoint, the BIPM Time Department database, and the BIPM YouTube channel. • 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 and more than 26 300 working documents, and has over 10 000 individual user accounts (providing access to restricted content where appropriate). • In 2022 a special area was set up for the 27th CGPM, and the CBKT section was restructured in light of the growing number of CBKT projects. • The "webmaster" email address is shared by four BIPM colleagues, to ensure a rapid response to any queries. • A maintenance contract is in place with an external contractor to allow for the correction of bugs and the introduction of new facilities.
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.	• Typeset and published the report of the 110th meeting of the CIPM (June and October 2021) in English and French. • Drafted, edited, typeset and published the report of the 111th meeting of the CIPM (June 2022) in English and French. • Published the BIPM Annual Review 2021/2022. • Published the Financial Report 2021 in French and English. • Published version 2.01 of the SI Brochure (editorial changes). • Checked version 1.08 of the XML format of the SI Brochure. • Edited and published the Report of the 18th CCL meeting (2021). • Edited and published the Report of the 18th CCM meeting (2021).

VIII	**Communication and Promotion**	
Project	Deliverables	Work performed in the period (1 January 2022 – 31 December 2022)
		• Edited and published the Report of the 30th CCT meeting (2022). • Edited and published the Report of the 25th CCPR meeting (2022). • Edited and published the Report of the 27th CCQM meeting (2022). • Edited, typeset and published the CGPM Working Document, October 2022 (48pp). • Edited, typeset and published the Proposals for the Work Programme 2024-2027 (47pp) in French and English. • Edited, typeset and published the Strategic Plan for the Work Programme (2022) (25pp). • Edited, typeset and published the Draft Resolutions document (32pp) in French and English. • Edited, typeset and published the Report on the actions taken by the CIPM towards a "CIPM Strategy 2030+" (23pp). • Coordinated production of 23 CC and departmental posters for the CGPM. • Edited, typeset and published five Rapport BIPM for the Chemistry Department. • Published 30 news stories. • Published the BIPM eNews. • Edited, typeset and published the JCTLM Newsletter 2022. • Published the 'News from the BIPM laboratories 2021'. • Updating the BIPM social media presence on LinkedIn and Twitter. • Edited and published the 2023 Notification in English and French.
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.	• Sustainable editorial team comprising an Editor: Sten Bergstrand (RISE) and three Deputy Editors: Giovanni Mana (INRIM), Rod White (New Zealand), and Olav Werhahn (BIPM). • Open/recently completed Focus issues: Focus on Challenges in Time and Frequency Metrology, Measurements of the Newtonian Constant of Gravitation, MATHMET 2022. • New initiative: CBKT funding for Open Access publication of selected Review Papers. • Published articles: 77 (2021: 95). • Open Access articles: 41 (2021: 36). • Receipt-1st Decision times: 30 days (2021: 28 days). • Accept-Online Publication times: 34 days (2021: 38 days). • Impact factor 2021: 2.748.

VIII	Communication and Promotion	
Project	Deliverables	Work performed in the period (1 January 2022 – 31 December 2022)
4. LIBRARY		
ILC-CP4:	Journal subscriptions (on-line or hard copy) buy-per-view scientific articles and books for BIPM staff)	• Renewal of 8 journal subscriptions • Purchase of 6 books and 4 articles
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 2022 was " *Metrology in the Digital Era*". • The 2022 poster was designed in collaboration with the COOMET region and specifically with national Metrology Institute of Ukraine. The poster was translated into more than 20 languages and information on more than 30 national celebratory events is provided on the 2022 World Metrology Day Resource Website http://www.worldmetrologyday.org/ • Initial work has been launched for WMD 2023 with OIML and SIM including revamping to facilitate social media promotion of WMD. The theme for 2023 is "*Measurements supporting the global food system*".
6. IMPACT STUDY		
ILC-CP6:	Authoritative independent study highlighting the impact arising from metrology in the Quality Infrastructure.	• The study called *"Highlighting the interrelations in Quality Infrastructure and Regulation*" was proposed. • Discussion advanced with OECD around seconding a member of staff to assist working with the OECD Team. • INetQI ToR approved at its 10th Annual Meeting in December 2022. • Proposal to focus efforts and resources on INetQI "Single library" project is under consideration.
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.	• BIPM webinar on Developments Towards Interoperable Metrology (22 June 2022) with participation of around 90 experts. • BIPM-WMO online / virtual Workshop on Metrology for Climate Action (26-30 September 2022) with 1078 participation.

IX	Digital Transformation	
Project	Deliverables	Work performed in the period (1 January 2022 – 31 December 2022)
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.	• Continued maintenance and improvement of the KCDB Application Programming Interface (API) for searching on published CMCs, 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.	• First protype of the application programming interface for the JCTLM database completed, and testing initiated.
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.	• The emphasis for digitalizing the SI Brochure has evolved towards the publication of an "SI Digital Reference" point. A prototype machine- (and human-) readable reference point was developed by Janet Miles and Dr Stuart Chalk (University of North Florida, United States) during Dr Chalk's secondment to the BIPM (Jan-April 2022).
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).	• This work is ready to move forward in 2023, when the BIPM joins Crossref as a member, and register its first items for DOIs. • The project will run step-wise, such that the official Resolutions and Recommendations will be the first to be assigned 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 continue in 2023.

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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.	• With the other members of the CIPM-TG-DSI's Expert Group and members of the CODATA-DRUM, Romain Coulon and Susanne Picard coauthored a paper in Nature entitled "Stop squandering data: make units of measurement machine-readable". • Following her description of the SI Digital Reference, Janet Miles was invited to join the Expert Group and the CODATA-DRUM (on Digital Representations of Units of Measurement). • In conjunction with International Data Week and the CODATA SciDataCon, four coordinated sessions were organized on the subject of units. Outside the SciDataCon itself, a webinar dedicated to the CIPM and NMIs in the European region was hosted by CODATA, and a BIPM webinar on Developments towards Interoperable Metrology showcased some of the projects at the BIPM. • The survey on digital transformation needs across all the CCs was undertaken.
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" (ie "machine actionable") within the context of the FAIR framework. The strategy will include consideration of the future opportunities for the IMRR.	• The Work Programme of the BIPM Headquarters for 2024-2027 includes strategic directions on digital transformation and new digital services, for which the input of the CIPM-TG DSI and its Expert Group were taken into account. • Initial work packages for the implementation of the Strategy have been defined and secondments arranged to enable the necessary resources to be allocated for completion of the highest priority work packages. • Dr Stuart Chalk (University of North Florida) was seconded to the BIPM for three months spread over the period January to July 2022. • Dr Gregor Dudle (METAS) was seconded to the BIPM from the end of October 2022. • The FAIR digital landscape for metrology was outlined in terms of the main data that need to be rendered Fair and Accessible, and the principal additional components required to render the data Interoperable and Reusable. • The concept of a machine-actionable "SI Brochure" was presented to the CIPM-TG-DSI Expert Group early in the year, and a prototype of the machine-actionable SI Digital Reference (SIDR, pronounced "CIDER") was developed for discussion in collaboration with Dr Chalk. • Frédéric Meynadier and Gianna Panfilo (Time Department) developed an API to provide machine-readable time data through automated processes; this was made publicly available for testing.

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		• Gianna Panfilo, Aurélie Harmégnies et Frédéric Meynadier (Time Department) structured the data from the Recommended Standard Frequencies and produced a test version of an API for testing by the CCL-CCTF-WGFS. • Data for the *mise en pratique* of the kelvin were collated by the CCT-TG-DIG, who have itemized their requirements for digital services. • Romain Coulon (Ionizing Radiation Department) and colleagues published the first example of a key comparison report in PDF/A3 report, incorporating machine-readable data. • Appropriate external digital reference systems have been identified and are being collated for: laboratories, countries, scientists, chemical substances.

Bureau International des Poids et Mesures

BIPM - Pavillon de Breteuil F-92312 Sèvres Cedex FRANCE