

Annual Review: Supplement

Activities of the BIPM Departments

1 January 2020 – 31 December 2020

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This supplement reports activities on the projects detailed under the Work Programme (2020 – 2023).

The report is published annually and covers the calendar year.

Key achievements (1 January 2020 – 31 December 2020)

The Work Programme for 2020 – 2023 is described with 8 major activities which contain 65 projects and 93 tasks to the BIPM. Some of the key activities that took place during the reporting period are highlighted below:

LABORATORY WORK CARRIED OUT BY THE BIPM

• Physical Metrology

- The first CCM key comparison of realizations of the kilogram, organized by the BIPM, was completed, with participation from the BIPM Kibble balance.
- The first two bilateral BIPM key comparisons have been organized in the field of electricity with NMIs from GULFMET.
- Successful test of new graphene samples as possible candidates to be used in a future more compact and more economic quantum Hall resistance standard for on-site comparisons.

• Time Metrology

- Development and launching of an additional graphical information concerning the use of Primary and Secondary Frequency Standards (PSFS) in UTC.
- Successful use of the two-Way Satellite Time and Frequency Transfer, improved by the Software-Defined Radio (SDR) receiver, for *Circular T* calculation.

• Chemical Metrology

- Co-coordination of CCQM-P216 SARS-CoV-2 Antibodies.
- Mycotoxin Standard comparison report (CCQM-K154.a and a.1) for Food Safety CBKT.
- *Metrologia* publication on 'An optimized sampling system isotope ratio measurements ($\delta^{13}\text{C}$ and $\delta^{18}\text{O}$) of CO_2 , in support of CCQM-P204.
- Online workshop on Accurate Ozone monitoring and two webinars on 'Ensuring the reliability of measurements in response to the Covid-19 pandemic'.

• Ionizing Radiation Metrology

- Developed software for rapid publishing of results from comparisons of gamma emitters (SIR).
- Brand new service launched for comparisons of pure beta emitters (ESIR).
- A new calibration service for high-energy photon dosimetry has been started.
- New equipment commissioned for medium energy x-ray comparisons and calibrations.

INTERNATIONAL LIAISON

- Signing of the BIPM-ITU MoU in June 2020, and the BIPM-IFCC MoU in September 2020.
- Participation as a panelist in the OECD High-Level virtual Webinar: "International Organisations and their Members Facing the Global Crisis Together" held on 3 September 2020.

COORDINATION

- 40 videoconference session organized by the BIPM for 11 CCQM WGs to replace April 2020 face-to-face meetings.
- A Special Issue JCTLM newsletter on Reliability of COVID-19 testing produced and distributed.
- Revision of the CIPM MRA policy and guideline documents has been completed (editorial comments are being addressed).

CAPACITY BUILDING AND KNOWLEDGE TRANSFER

- The BIPM CBKT Programme extended to include REMOTE-LEARNING (allows to broaden and deepen). Eight online projects on core CBKT topics have been organized involving more than 600 participants.
- TÜBİTAK UME and BIPM extend Metrology for Safe Food and Feed CBKT activity to cover the measurement of veterinary drug residues in food.

COMMUNICATION AND PROMOTION

- A new COVID-19 repository was launched on the BIPM website. The repository lists examples of how the NMIs work is supporting the fight against the pandemic.
- The theme for 2020 was "Measurements for global trade". The poster was translated into more than 20 languages and information on 23 national celebratory events is published on WMD website.

Key figures *(as of 31 December 2020)*

• Member States and Associates

- 62 Member States* and
- 40 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.*

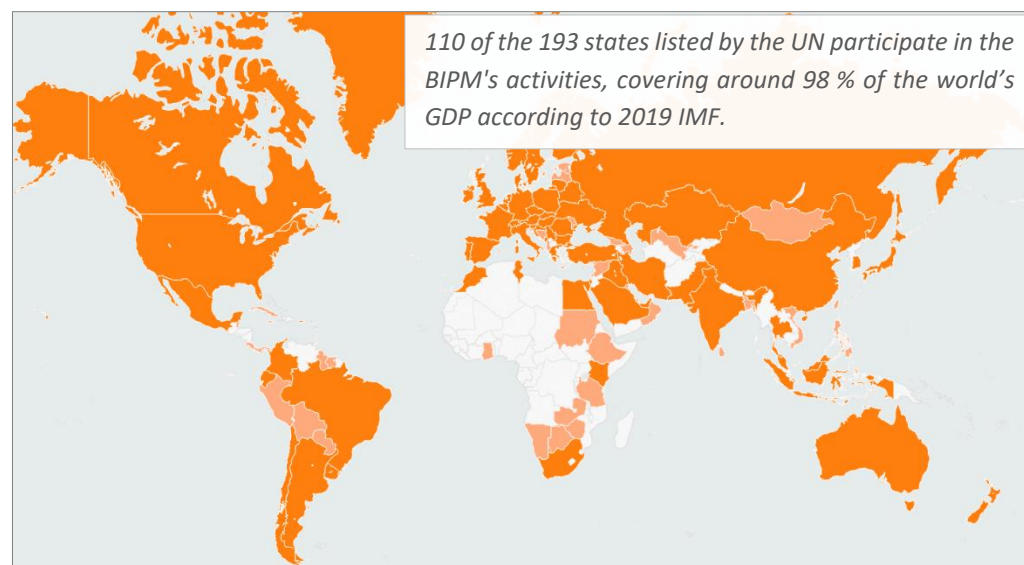
• KCDB data

258 Institutes

- 102 National Metrology Institutes
 - 62 Member States
 - 40 Associates
- 4 International organizations
(ESA, IAEA, JRC, WMO)
- plus 152 Designated Institutes

1 673 comparisons
1061 KCs, 612 SCs

25 726 CMCs
Peer-reviewed declarations



Report on the BIPM Work Programme for 2020-2023

Physical Metrology		
Project	Deliverables	Work performed in the period (1 January 2020 – 31 December 2020)
1. PMD-E1: INTERNATIONAL REFERENCE STANDARD for VOLTAGE		
E1.1: On-site comparisons of Josephson voltage standards (JVSs) <i>NMI Part.: 4</i>	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)	<ul style="list-style-type: none"> Drafting of the measurement report for the BIPM.EM-K10 comparison with MIKES. Pilot study with PTB on differential sampling of ac waveforms started in March in the BIPM laboratory, but interrupted due to outbreak of the Covid-19 pandemic. Electronics development: A backup bias source for the conventional dc Josephson standard and two switch systems for the ac Josephson standards. A presentation on ac voltage metrology was given at the CPEM conference. A joint KRISS-BIPM paper on differential sampling of ac waveforms was published in Metrologia. A paper on the metrology of secondary voltage standards at the BIPM was submitted for publication to Meas. Sci. Technol. (and accepted in 2021).
E1.2: Bilateral voltage comparisons using Zener diode transfer standards <i>NMI Part.: 4</i>	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)	<ul style="list-style-type: none"> Organization of a Zener voltage standard comparison BIPM.EM-K11 with NSAI and preparation of Draft A report. The BIPM Zener secondary voltage standards have been calibrated against the Josephson voltage standard.
E1.3: Calibrations of Zener diode secondary standards <i>Calibration for: 10 NMIs (12 certificates)</i>	1) Calibration of Zener diode secondary standards for NMIs without primary realization and for internal customers (Ionizing Radiation and Kibble balance)	<ul style="list-style-type: none"> Calibration of five Zener voltage standards from three NMIs (INM-Co, GUM, SMD). Support for the BIPM ionizing radiation department in the implementation of a new technique for the measurement of ultra-low currents from ionization chambers. A new version of the software for the automated Zener calibration setup was developed.
2. PMD-E2: INTERNATIONAL REFERENCE STANDARD for RESISTANCE		
E2.1: On-site comparisons of quantum Hall resistance (QHR) standards	1) Bilateral on-site comparisons of quantum Hall standards (including new graphene samples) as part of BIPM.EM-K12 with relative uncertainty 1×10^{-9}	<ul style="list-style-type: none"> Drafting and publication of the measurement reports concerning the BIPM.EM-K12 comparisons with NMIJ, NIM and KRISS. The comparison report with NMC-ASTAR is at draft A stage.

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Physical Metrology		
Project	Deliverables	Work performed in the period (1 January 2020 – 31 December 2020)
<i>NMI Part.: 4</i>	<ol style="list-style-type: none"> 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) 	<ul style="list-style-type: none"> • Characterization tests of two GaAs QHR devices provided by PTB, for ensuring the continuity of the services, taking into account the ageing of the LEP-514 samples still in use at BIPM. • Design and fabrication of a new cryo-probe for testing graphene devices from Graphene Waves (NIST technology). • Testing of two graphene devices from Graphene Waves for a future QHR standard: adjustment of carrier density by annealing and comparison with a GaAs device. • The basis for the realization of the farad from the QHR (E3.1) has been provided in January and July 2020. • Maintenance works on the electronics of the transportable 1Hz bridge used for BIPM.EM-K12. • Calibration of the resistance working standards of the BIPM (used for calibration and comparison services (E2.2 and E2.3). • Calibration of the power coefficients of the travelling resistors used for BIPM-EM.K12 comparisons. • Relocation of the QHR laboratory to a newly renovated laboratory and validation of correct operation.
<p>E2.2: Bilateral resistance comparisons using resistance transfer standards</p> <p><i>NMI Part.: 4</i></p>	<ol style="list-style-type: none"> 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) 	<ul style="list-style-type: none"> • Organization of three bilateral resistance comparisons BIPM.EM-K13 with EMI, INMETRO and NSAI. • Calibration traceable to the QHR of the resistors used as working standards for calibration services to NMIs.
<p>E2.3: Calibrations of resistance secondary standards</p> <p><i>Calibration for: 25 NMIs (150 certificates)</i></p>	<p>Calibration of resistance secondary standards for NMIs without primary realizations and for internal customers (Mass, Ionizing Radiation, Kibble balance)</p>	<ul style="list-style-type: none"> • 26 external resistance calibrations for 5 NMIs (INM-Co, INM-Ro, KazInMetr, NIMT, SASO) and 2 internal certificates (Ionizing Radiation Dept.).

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Physical Metrology		
Project	Deliverables	Work performed in the period (1 January 2020 – 31 December 2020)
3. PMD-E3: INTERNATIONAL REFERENCE STANDARD for CAPACITANCE		
<p>E3.1: Bilateral capacitance comparisons using capacitance transfer standards</p> <p><i>NMI Part.: 4</i></p>	<ol style="list-style-type: none"> 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) 	<ul style="list-style-type: none"> • Bilateral capacitance comparison BIPM.EM-K14 with SASO. • Two realizations of the farad from the ohm. • Monthly measurements for the surveillance of the capacitance bank of 10 pF capacitors. • Stability characterization of two 1 pF capacitors intended to be used in the future traceability chain linking the farad to the Calculable Capacitor. • Maintenance works in progress on the two-terminal-pair capacitance bridge. • Design of new thermostated ac resistance standards (12906.4 Ω and 51625.6 Ω) for use in the 4 terminal-pair resistance bridge and the quadrature bridge used to link the ohm to the farad. The fabrication of the 12906.4 Ω resistor has started. • Presentation on the determination of frequency dependence of resistors at the CPEM conference. Publication of the results regarding the renovation of the 4 terminal-pair bridge and of the characterization of the ac resistors currently in use in the quadrature bridge in the conference proceedings.
<p>E3.2: Calibrations of capacitance secondary standards</p> <p><i>Calibration for: 20 NMIs (110 Certificates)</i></p>	<ol style="list-style-type: none"> 1) Calibrations of capacitance secondary standards for NMIs without primary realizations 	<ul style="list-style-type: none"> • 38 standards calibrated for 9 NMIs (CEM, CENAM, CMI, EIM, KazInMetr, NIMT, NPLI, UME, UMTS).
<p>E3.3: ac quantum Hall effect</p>	<ol style="list-style-type: none"> 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 <i>mise en pratique</i> for the electrical units 	
<p>E3.4: Calculable capacitor</p>	<ol style="list-style-type: none"> 1) Completion of the calculable capacitor as a primary standard for capacitance to consolidate the BIPM measurement capabilities at the 	<ul style="list-style-type: none"> • Transfer of the stabilized laser from the Laser Building to the calculable capacitor laboratory and successful functional test.

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Physical Metrology		
Project	Deliverables	Work performed in the period (1 January 2020 – 31 December 2020)
	highest level and to help curating knowledge in this key technique	<ul style="list-style-type: none"> • Verification of the alignment of the main electrodes and preparation of a procedure for the alignment of the interferometer and guard electrode.
4. PMD-M1: MASS DISSEMINATION		
M1.1: Calibration of 1 kg national prototypes and mass standards <i>Calibration for: 25 NMIs (50 Certificates)</i>	<ol style="list-style-type: none"> 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. 	<ul style="list-style-type: none"> • Calibration of 3 Pt-Ir and 17 stainless steel mass standards for 8 NMIs (BIM, CMI, GUM, INM-Co, KazInMetr, MSL, SMD, VSL) • Determination of volume for one stainless steel standard (CMI) and of height of centre of gravity for two standards (INM-Co). • Mass values of BIPM working standards for current use monitored and adjusted against working standards for limited use. • Calibration campaign for 12 pressure gauges of the physical metrology department.
M1.2: Provision of 1 kg Pt-Ir prototypes <i>Fabrication for: 3 NMIs</i>	<ol style="list-style-type: none"> 1) Fabrication of 1 kg Pt-Ir prototypes for Member States. 2) Calibration of new 1 kg Pt-Ir prototypes including volume determination. 	<ul style="list-style-type: none"> • Final polishing of three new kilogram prototypes, nos. 113-115, has started. Quotations have been issued for all three prototypes to two NMIs (NSC IM, NIM).
5. PMD-M2: COMPARISONS of REALIZATIONS of the NEW KILOGRAM DEFINITION		
M2.1: Organization of a key comparison of kilogram realizations <i>NMI Part.: 10</i>	<ol style="list-style-type: none"> 1) Organization of a periodic CCM key comparison of all available kilogram realizations and participation in the determination of the consensus value, which during the first years after the redefinition will serve as the basis for dissemination for all participants to ensure world-wide uniformity of mass measurements. 2) Ongoing bilateral key comparison of kilogram realizations, linked to (1) 3) Update of the mass values attributed to the ensemble of reference mass standards (ERMS) and the Pt-Ir working standards, traceable to the reference value of the comparison of kilogram realizations. 	<ul style="list-style-type: none"> • The measurements for the first key comparison of kilogram realizations based on the new definition, CCM.M-K8.2019, are completed. Four institutes (incl. the BIPM) participated with Kibble balances, one with a joule balance, two with Avogadro spheres. • Writing the report of CCM.M-K8.2019, final report approved in October 2020. • The BIPM working standards and the standards of the ensemble of reference mass standards have been linked to the key comparison reference value. • The first CCM consensus value for the kilogram, which will be the basis for the dissemination of the kilogram from 1 February 2021, has been determined. • Study on the behavior of mass standards under air-vacuum transfer.

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Physical Metrology		
Project	Deliverables	Work performed in the period (1 January 2020 – 31 December 2020)
M2.2: Organization of a comparison of calibrations of stainless steel mass standards. <i>NMI Part.: 15</i>	<ol style="list-style-type: none"> 1) Organization of a new comparison of stainless steel 1 kg mass standards 2) Participation in related RMO comparisons. 	<ul style="list-style-type: none"> • New comparison of stainless steel standards planned to be organized by the BIPM during 2022/23.
M2.3: Maintaining the ERMS (ensemble of reference mass standards)	<ol style="list-style-type: none"> 1) Link of the ERMS masses with values from realization experiments. 2) Mass comparison of standards within the ERMS. 	<ul style="list-style-type: none"> • The mass standards of the ensemble have been linked with the key comparison reference value of the key comparison of realization experiments.
6. PMD-M3: KIBBLE BALANCE. <i>Developing and maintaining the Kibble balance</i>		
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.	<ul style="list-style-type: none"> • Work has started to improve the electrical circuit. First study leads to wider PJVS voltage-current plateaus which are moreover insensitive to connection/disconnection of other devices. • The stability of some critical alignments was regularly monitored. • Two independent data processing programs continued to be refined. • Development of a detailed uncertainty budget (4.9×10^{-8}). • Two presentations given at the virtual CPEM conference. • Publication of an article on the new interferometric system in IEEE Trans. Instrum. Meas.
M3.2:	Reengineering of critical mechanical subsystems to enable semi-routine operation.	<ul style="list-style-type: none"> • New middle and lower parts of the suspension for the mark II of the apparatus were designed and fabricated. The ensemble is now much stiffer and more easily adjustable than the previous system. • More stable mounts for optical fibers of the 3-axis interferometer were designed and integrated in the apparatus. • Design of a beam balance for the mark II Kibble balance apparatus.
M3.3:	Developing software and control system for full operation in vacuum.	<ul style="list-style-type: none"> • An automated data computing program was developed to facilitate the monitoring of the apparatus operation. • The frequency servo-control of the laser source for the 3-axis interferometer was 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 .	<ul style="list-style-type: none"> • A quick check of the spatial gradient in the balance laboratory was carried out using the CG5 relative gravimeter.

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Physical Metrology		
Project	Deliverables	Work performed in the period (1 January 2020 – 31 December 2020)
	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.	
M3.5:	Participate in the ongoing comparison of realizations of the kilogram (PMD-M2).	<ul style="list-style-type: none"> • Participation in the first key comparison of kg realizations CCM.M-K8.2019. Result agrees with key comparison reference value. • Measurement results including those used for the first comparison were published in <i>Metrologia</i>.
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.	

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II Time Metrology		
Project	Deliverables	Work performed in the period (1 January 2020 – 31 December 2020)
1. TIME-U1: GENERATION of TAI/UTC, STABLE and ACCURATE INTERNATIONAL REFERENCE		
<p>U1.1: Computation of UTC and KC for Time and Frequency transfer</p> <p><i>Participating laboratories: 80 (2017)</i></p>	<p>Monthly provision of the international reference time scales TAI, UTC, and the terrestrial Time (TT), continuously improving their metrological quality.</p> <p>This is obtained by computing the differences between UTC/UTC_r and the local real time realizations UTC(k) of the contributing laboratories. Results are published in the monthly BIPM <i>Circular T</i>, the weekly bulletin of the UTC_r, and providing data to the KCDB for the key comparison CCTF-K001.UTC.</p> <p>The process to obtain UTC and its validation is part of the BIPM Quality System.</p> <p>The Department also issues an annual report with a summary of the results.</p>	<ul style="list-style-type: none"> • Regular production of monthly UTC, CCTF-K001.UTC, and weekly Rapid UTC. • Computation of TT(BIPM19). • Several PSFS data available and used for the steering of TAI: new NRC Cs fountain, new NMJ Yb optical standard. • One of the TWSTFT links using the Software-Defined Radio technique (OP-PTB) has been calibrated, approved and entered in use as official link in UTC calculation. • Tests of a new SRS modem (initiated by NICT) have been conducted within TWSTFT WG. • Paper on “GNSS-to-GNSS Time Offsets: Study on the broadcast of a common reference time”. This deals with the proposal to use UTC as common pivo time scale to support GNSS interoperability. I. Sesia, G.Signorile, T. Thanh Thai, P. Defraigne, P.Tavella, “GNSS-to-GNSS Time Offsets: Study on the broadcast of a common reference time”, GPS Solutions (2021) 25:61, https://doi.org/10.1007/s10291-020-01082-y
<p>U1.2: Development and optimization of the UTC computation</p>	<p>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:</p> <ul style="list-style-type: none"> – 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. 	<ul style="list-style-type: none"> • New virtual machine system set-up and first steps of migration of all the nominal software routines for the automatic computation of UTC and UTC_r. • Centralisation and uniformisation of software routines for monitoring the automatic UTC lab data collection. A web page is under construction showing data availability. • New plot available and updated every month on the availability of PSFS in UTC https://webtai.bipm.org/database/show_psfs.html • Update of our GNSS calibration data base to also include the calibration on Galileo and future Beidou signals. • Participation to BIPM WG on scientific SW validation.
2. TIME-U2: IMPROVED ALGORITHMS for TIME SCALE and TIME TRANSFER DATA PROCESSING		
<p>ALGORITHMS</p>	<p>The algorithms developed, maintained, and continuously improved by the Time Department are devoted to:</p>	<ul style="list-style-type: none"> • Statistical analysis of H-Masers behavior showing their performance has allowed understanding possible changes in UTC algorithm with the aim of the long-term stability improvement.

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II Time Metrology		
Project	Deliverables	Work performed in the period (1 January 2020 – 31 December 2020)
	<ul style="list-style-type: none"> – the ensemble time scale formation, – the corrected processing of the time transfer measures, – the steering by the use of primary and secondary frequency standards. <p>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 secondee would be fundamental to ensure the necessary progress of these activities.</p> <p>The use of a GIT* laboratory capability within the frame of the TWSTFT WG so that software for software defined receiver (SDR) measurement technique can be developed through a collaborative effort with leading NMIs. This shared configuration will then be validated by a joint BIPM/NMI team and be made available for download as a service to NMIs (and other UTC time laboratories). Opportunities to use the capability for training and equipment monitoring will also be explored.</p> <p>*GIT is a free and open source distributed version control system</p>	<ul style="list-style-type: none"> • The paper describing the algorithm for the uncertainties on [UTC - UTC(k)] reported in Sec.1 of Circular T has been accepted for publication on <i>Metrologia</i>. • Work to prepare the future use of Precise Point Positioning techniques with new GNSS or with multi-GNSS, with R. Valceschini 2-month secondment. • Development of the SW and operational procedures for time and frequency transfer with Integer ambiguity Precise Point Positioning (IPPP). • Computation of IPPP results for worldwide comparison of primary and secondary frequency standards in collaboration with NMIs developing optical frequency standards. • Regular monthly computation of IPPP results for selected UTC links. <p>Papers:</p> <ul style="list-style-type: none"> • Panfilo G, Petit G and Harmegnies A (2020) A first step towards the introduction of redundant time links for the generation of UTC: the calculation of the uncertainties of [UTC-UTC(k)], <i>Metrologia</i>, accepted. • Petit G (2020) Sub-10-16 accuracy GNSS frequency transfer with IPPP. <i>GPS Solutions</i>, accepted. • Pizzocaro M et al. (2020) Intercontinental comparison of optical atomic clocks via very long baseline interferometry. <i>Nature Physics</i>, accepted. • Sekido M et al. (2020) A broadband VLBI system using transportable stations for geodesy and metrology - An alternative approach to the VGOS concept. <i>J. Geodesy</i>, accepted. • Tavella P and Petit G (2020) Precise time scales and navigation systems: mutual benefits of timekeeping and positioning. <i>Satell Navig</i> 1:10 https://doi.org/10.1186/s43020-020-00012-0
3. TIME-U3: CALCULATION and DISSEMINATION of RAPID UTC		
<p>RAPID UTC</p> <p><i>Participating laboratories: 57 (2018), 2023 target is to grow by 10 %</i></p>	<p>To meet the requirements of the NMI time labs and of other UTC users, a rapid approximation of UTC, called rapid UTC, is available weekly based on a subset of data. The automatization of the process and a reliable anomaly detection are in this case still more important and will be pursued in this WP, evaluating the possibility for a more frequent evaluation of the time scale.</p>	<ul style="list-style-type: none"> • Studies have been dedicated to minimize the difference between UTC and UTCr by adjusting the parameters used for UTCr. • Tests aimed to improve the robustness of UTCr have been implemented in particular to improve the procedure of data transfer from UTC to UTCr after the calculation of Circular T. • UTCr has been published without interruption every Wednesdays, the offset to UTC remains within +/- 2 ns.

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II Time Metrology		
Project	Deliverables	Work performed in the period (1 January 2020 – 31 December 2020)
	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	<ol style="list-style-type: none"> 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. 	<ul style="list-style-type: none"> • Update of GNSS delay measure guidelines, in consultation with the WG on GNSS. • Preparation of the BIPM traveling equipment B3TS for the 2020 Group 1 calibration trip. • Work on absolute delay measurement: Comparison of all known sources of absolute calibration (work with Pascale Defraigne as secondee). • Absolute delay measurement by the CNES of one new receiver (BP27) and comparison with the present reference for Group 1 trips.
D1.2: Realization of delay measurement campaigns for pivot laboratories (G1 labs)	<p>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:</p> <ul style="list-style-type: none"> – To organize the GNSS measurement campaigns (requiring the shipping of the BIPM travelling system without staff) to each of approximately ten contributing laboratories (G1 labs), a number that should expand with new RMOs. The whole process involves several circulating trips and is repeated every other year. 	<ul style="list-style-type: none"> • Determination of Galileo results for the 2018 Group 1 trip, after validation of a reference for Galileo delays by the WG on GNSS. • Start of the 2020 Group 1 trip with visits to the APMP G1 laboratories. Multi-GNSS data collection with results provided initially for GPS and Galileo. • A new mobile calibration box (dubbed B4TS) has been built around 2 multi-GNSS receivers, one of which has been independently calibrated by CNES. Sanitary measures affected work on this equipment, and delayed possible campaigns using it. Expected performance matches current SATRE modem specifications so we intend to use it for TWSTFT calibration trips.

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II		
Time Metrology		
Project	Deliverables	Work performed in the period (1 January 2020 – 31 December 2020)
	<ul style="list-style-type: none"> – 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. 	
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	<ol style="list-style-type: none"> 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. 	<ul style="list-style-type: none"> • Processing and validation of 15 Group 2 reports. Results introduced in the database.
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	<ol style="list-style-type: none"> 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. 5) Contribute to the discussion on the redefinition of the second. 	<ul style="list-style-type: none"> • The CCTF WGFS starts working in view of the CCTF meeting in March 2021 for the analysis and comparison of optical frequency standard measures to estimate the relative frequency values. Data are collected and meetings are organized for preliminary calculation and analysis. • Ongoing collaboration with the ACES-PHARAO mission team on development of the microwave link data processing software. • Collaboration with the CCTF on the redefinition of the second (see 8). Papers: <ul style="list-style-type: none"> • Roberts, B. M. et al., " Search for transient variations of the fine structure constant and dark matter using fiber-linked optical atomic clocks ", New Journal of Physics, Volume 22, Issue 9, id.093010, pp. 11. • Cacciapuoti, L et al., "Testing gravity with cold-atom clocks in space. The ACES mission", The European Physical Journal D, Volume 74, Issue 8, 2020, id. 164.

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II	Time Metrology	
Project	Deliverables	Work performed in the period (1 January 2020 – 31 December 2020)
<p>O1.2: Optimal use of optical standard measurements in TAI/UTC</p>	<p>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.</p> <p>To this aim, the Time Department need:</p> <ul style="list-style-type: none"> (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. <p>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:</p> <ul style="list-style-type: none"> (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. <p>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</p>	<ul style="list-style-type: none"> • Work with the WG on PSFS for introduction of one new Primary frequency standard (NRC-FCs2) and one new optical secondary frequency standard (NMIJ-Yb1) in TAI/UTC. • Work with the WG on PSFS for updating the procedure to report primary and secondary frequency standards and update of Circular T sec 3 on the PSFS uncertainty and regular reporting to TAI. • Study of a possible fiber connection with OP in order to practice White Rabbit time transfer. This activity is on halt since beginning of the sanitary measures.

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II	Time Metrology	
Project	Deliverables	Work performed in the period (1 January 2020 – 31 December 2020)
	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.	

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III Chemical Metrology		
Project	Deliverables	Work performed in the period (1 January 2020 – 31 December 2020)
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 <i>NMI Part.: 20</i>	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.	<ul style="list-style-type: none"> 2 bilateral comparisons performed in BIPM laboratories for ECCC (Feb. 2020) and METAS (July 2020). 8 key comparison reports published for (NMI, Measurement Date): NILU (Jan. 2018), NMC, A*STAR (July 2018), ISCIII (March 2019), KRISS (Apr. 2019), NIST (June 2019), JRC (July 2019), EAA (Sep. 2019) and UBA (Oct. 2019).
G1.2: <i>NMI Part.: 10</i>	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)	<ul style="list-style-type: none"> Modification of wiring of BIPM built new SRP electronic system prototype completed, to replicate new NIST wiring diagram. Test version of new NIST control software for electronics system implemented on BIPM instrument.
G1.3: <i>NMI Part.: 15</i> <i>(Measurements started in 2016-2019 BIPM Work Programme)</i>	Coordination of reactive gas/air quality comparisons (NO₂, HNO₃ 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.	<ul style="list-style-type: none"> CCQM-K74.2018 (NO₂ in nitrogen) Drafts A.1 and A.2 reports drafted and circulated to participants and discussed during two teleconferences with members of CCQM-GAWG in April 2020. A.3 report including more KCRV calculation options prepared and circulated to sub-group of GAWG, discussed in November teleconference and KCRV agreed. CCQM-P172 (HNO₃ spectroscopic methods) measurements completed and results compiled.
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: <i>NMI Part.: 20</i>	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.	<ul style="list-style-type: none"> BIPM CO₂-PVT (manometric) reference facility fully automated with a major update of control software developed and implemented (RGA, automated calculation, trapping and gas handling protocols). High trapping efficiency of BIPM developed series of 3 automated cryogenic traps validated for CO₂-PVT facility (internal report written). Standard deviation of 0.05 µmol/mol on measurements of CO₂ in air in the range 380 to 800 µmol/mol demonstrated

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III Chemical Metrology		
Project	Deliverables	Work performed in the period (1 January 2020 – 31 December 2020)
G2.2: <i>NMI Part.: 15</i>	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.	<ul style="list-style-type: none"> • Paper published : "An optimized sampling system for highly reproducible isotope ratio measurements ($\delta^{13}\text{C}$ and $\delta^{18}\text{O}$) of pure CO₂ gas by infrared spectroscopy" 2020, <i>Metrologia</i> 57 055004 • Internal training of two staff members the preparation of homogenous pure CO₂ aliquots for CCQM-P204 and their analysis by IRIS completed. • Collaborative measurements based on IRMS with IAEA completed and reported, demonstrating homogeneity and stability of CO₂ samples • 60 of 76 empty cylinders received from participants in CCQM-P204, for filling with BIPM SIRMGEN facility.
G2.3: <i>NMI Part.: 12</i>	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.	<ul style="list-style-type: none"> • New Isotope Ratio Mass Spectrometer received and installed (May 2020) and acceptance tests completed (December 2020) • Initial training of two staff members on IRMS system completed • Preliminary design for two sample preparation facilities completed: 1) automated cryogenic extraction system for CO₂ in air samples; 2) carbonate acid digestion facility, to enable traceability to international reference materials for isotope ratios. • Virtual Visiting Scientist contract established allowing knowledge transfer to BIPM staff and development of IRMS methods for pure CO₂ gas measurement.
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: <i>NMI Part.: 20 + 16 (Measurements started in 2016-2019 BIPM Work Programme)</i>	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.	<ul style="list-style-type: none"> • CCQM-K68.2019 (N₂O in air): measurements of 18 participants' standards with two analytical systems completed at the BIPM before March 2020 • Preliminary treatment of comparison results completed by the BIPM, based on indicative values provided by NMIs (final values require second measurement by NMIs following return of standards to them) • All 18 standards returned to NMIs before 15 September 2020 for second analysis.
G3.2:	Developed methods with reduced uncertainties for Greenhouse Gas comparisons, based on the improvement of cryogenic separation facilities for greenhouse gases and their quantitative operation in sample preparation for greenhouse gas mole fraction and isotope ratio measurements.	<ul style="list-style-type: none"> • Room S009 within the Laser Building refurbished for comparison of CO₂ in air standard ensembles • 4 videoconferences held with NMIs to develop protocols for future Greenhouse Gas Comparisons

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III		Chemical Metrology
Project	Deliverables	Work performed in the period (1 January 2020 – 31 December 2020)
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: <i>NMI Part.: 25 (Measurements started in 2016-2019 BIPM Work Programme)</i>	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.	<ul style="list-style-type: none"> Draft A.1 and A.2 reports, written and circulated to CCQM OAWG. Draft B report and KCRV agreed with WG in May 2020. Final Report circulated for CCQM approval in December 2020.
O1.2: <i>NMI Part.: 25</i>	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.	<ul style="list-style-type: none"> Oxytetracycline hydrochloride salt agreed by CCQM OAWG as material for comparison. NMR confirmation of material identity measurements completed qNMR first studies of material stability in acidic solution and methanol completed Trials of 2 LC-CAD methods for impurity quantification completed.
O1.3: <i>NMI Part.: 25</i>	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.	<ul style="list-style-type: none"> Project to start in 2022.
5. CHEM-O2: SMALL MOLECULE ORGANIC PRIMARY REFERENCE COMPARISONS (CALIBRATION SOLUTIONS)		
Coordination of comparisons standards and methods for organic calibrants.		
O2.1: <i>NMI Part.: 25</i>	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	<ul style="list-style-type: none"> Preparation of candidate comparison material, trifluralin and methoxychlor multicomponent solution, (270 units) completed. First trial of internal standard GC-MS method completed and applied in homogeneity study (7 units) and stability testing study (26 units) of candidate comparison material batch.

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III Chemical Metrology		
Project	Deliverables	Work performed in the period (1 January 2020 – 31 December 2020)
	purity measurement facilities, providing a core comparison for non-polar organic calibration solutions for NMIs.	
O2.2: <i>NMI Part.: 5</i>	Developed and published reference data for qNMR internal standards, based on BIPM's dedicated qNMR facility and in collaboration with NMII providing published reference data on qNMR internal standards, enabling the extension of the use of qNMR to accurate measurements with ¹⁹ F nuclei, and extending the scope of applicability of qNMR for SI traceable measurements on organic analytes, and support for NMI measurement services and their comparisons.	<ul style="list-style-type: none"> • Draft internal reports on two ¹⁹F qNMR materials completed. • First comparison study of <i>ab initio</i> modelling software for purity assessment completed using BIPM qNMR data on KHP.
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.	<ul style="list-style-type: none"> • Qualitative LC-hrMS method for triskelion impurity determination completed with support from NPL Visiting Scientist. • Triskelion candidate material received. Characterization by KFT (water), IC (TFA and anions) and elemental analysis with internal reports completed. • LC-hrMS, PICA and qNMR quantification methods completed. • Visiting scientist secondment completed with first draft of paper on compositional analysis of C3-triskelion prepared
O3.2: <i>NMI Part.: 15</i>	Completion of purity key comparison CCQM-K115.c C-HbA1c hexapeptide purity, CCQM-K115 repeat on HbA0 hexapeptide purity and CCQM-K115.b Oxytocin , based on mass-balance and protein impurity corrected amino acid analysis characterization performed at the BIPM, providing a core comparison of capabilities for value assignment of primary reference material straight chain peptides with molecular weights smaller than 5 kDa at NMIs, and underpinning reference measurements systems for glycosylated hemoglobin	<ul style="list-style-type: none"> • Draft B reports of CCQM-K115.b and parallel CCQM-P55.2.b written and accepted by PAWG. Final reports prepared and published in <i>Metrologia</i> and the KCDB. • BIPM comparison measurements based on mass balance, PICA and PICqNMR finalized and reports drafted, supporting the 13 NMI participations registered in CCQM-K115.c/P55.2.c (HbA1c hexapeptide (GE) purity). Comparison measurement results submitted by participants to BIPM by 18 September. • BIPM comparison measurements based on mass balance, PICA and PICqNMR finalized and reports drafted supporting the 14 NMI participations registered in CCQM-K115.2018/P55.2.2018 (HbA0 hexapeptide (VE) purity). Comparison measurement results submitted by participants to BIPM by 18 September.

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III	Chemical Metrology	
Project	Deliverables	Work performed in the period (1 January 2020 – 31 December 2020)
	and their development for diabetes diagnosis and patient monitoring.	<ul style="list-style-type: none"> • Comparison results of CCQM-K115.c/P55.2.c and CCQM-K115.2018/P55.2.2018 presented in video-conference with Draft A reports developed.
<p>O3.3: NMI Part.: 15</p>	<p>Coordination of CCQM-P216 on SARS-CoV-2 antibody quantification with NIM and NRC in response to the coronavirus pandemic.</p> <p>Method development for CCQM-K155.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.</p>	<ul style="list-style-type: none"> • BIPM established a comparison pilot group with NMIs in CCQM PAWG to work with NIM in developing the protocol for a CCQM pilot study on SARS-CoV-2 antibody quantification. 3 video conferences held and the protocol finalized and approved by the CCQM as CCQM-P216, to be coordinated by NIM, with BIPM and NRC. • First series of method development activities for amino acid and peptide tryptic digest analysis of monoclonal antibody material completed at BIPM.

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IV		Ionizing Radiation Metrology	
Project	Deliverables	Work performed in the period (1 January 2020 – 31 December 2020)	
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: <i>NMI Part.: 16</i>	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).	<ul style="list-style-type: none"> Comparisons have been completed for the NMIJ (Japan), GUM (Poland) and the VNIIM (Russia). 	
D1.2: <i>NMI Part.: 20</i>	Characterization and calibration of national standards, on request.	<ul style="list-style-type: none"> Calibrations have been completed for the IAEA. 	
D1.3:	Quality assurance of the BIPM primary standards for air kerma and absorbed dose to water, to confirm the long-term stability.	<ul style="list-style-type: none"> Quality assurance checks continued during the working restrictions. 	
D1.4:	Quality assurance and continual improvement of the BIPM international reference x-ray beam facilities.	<ul style="list-style-type: none"> A new medium energy x-ray generator has been installed and validated (see IR-D4). 	
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: <i>NMI Part.: 12</i>	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).	<ul style="list-style-type: none"> Comparisons have been completed for the GUM (Poland) and the BEV (Austria). 	
D2.2: <i>Calibration for NMIs: 25</i>	Calibration and characterization of national standards, on request.	<ul style="list-style-type: none"> Calibrations have been completed for the NMISA (South Africa), DTU (Denmark) and the CIEMAT (Spain). 	
D2.3:	Quality assurance of the BIPM primary standards for air kerma and absorbed dose to water, to confirm the long-term stability.	<ul style="list-style-type: none"> Quality assurance checks continued during the working restrictions. 	
D2.4:	Quality assurance and continual improvement of the BIPM international reference gamma-ray beam facility.	<ul style="list-style-type: none"> No changes to facility during this period. 	

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IV		Ionizing Radiation Metrology	
Project	Deliverables	Work performed in the period (1 January 2020 – 31 December 2020)	
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: <i>NMI Part.: 14</i>	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.	<ul style="list-style-type: none"> • Comparisons have been completed for the NRC (Canada). 	
D3.2: <i>Calibration for NMIs: 12</i>	Characterization and calibration of national standards, on request.	<ul style="list-style-type: none"> • Calibrations have been completed for the IAEA. 	
D3.3:	Quality assurance of the BIPM absorbed dose standard (graphite calorimeter and transfer instruments) to confirm their long-term stability.	<ul style="list-style-type: none"> • Quality assurance measurements were completed for the BIPM reference standards in the DOSEO facility. 	
D3.4:	Quality assurance and continual improvement of the measurement systems used at the DOSEO/BIPM high-energy photon beam facility.	<ul style="list-style-type: none"> • Improvements in data acquisition and analysis. 	
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.	<ul style="list-style-type: none"> • Study of current and future needs carried out, with particular reference to the long-term viability of existing facilities and services. 	
D4.2:	Specification, detailed design and modelling of a new reference standard for the priority identified.	<ul style="list-style-type: none"> • A new x-ray generator was installed and commissioned. The support system for the new x-ray tube has been designed, including collimator, shutter and automated filter wheel, and construction of the system is underway. 	

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IV		Ionizing Radiation Metrology	
Project	Deliverables	Work performed in the period (1 January 2020 – 31 December 2020)	
5. IR-D5: INTERNATIONAL REFERENCE SYSTEM for RADIATION PROTECTION DOSIMETRY (¹³⁷Cs)			
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: <i>NMI Part.: 16</i>	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 %).	<ul style="list-style-type: none"> An agreement had been reached with the IAEA in the previous programme to establish the BIPM-K5 service using a new ¹³⁷Cs irradiator at the IAEA Dosimetry Laboratory. Installation at the IAEA of the irradiator was delayed until early 2020 and has been further delayed due to the global pandemic. The instrumentation needed has been selected and purchased. 	
D5.2: <i>Calibration for NMIs: 20</i>	Characterization and calibration of national standards, on request.	<ul style="list-style-type: none"> No progress 	
D5.3:	Quality assurance and continual improvement of the BIPM primary standards, and the associated ancillary equipment.	<ul style="list-style-type: none"> No progress 	
6. IR-R1: INTERNATIONAL REFERENCE SYSTEM for GAMMA-EMITTING RADIONUCLIDES (SIR / SIRTl)			
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: <i>NMI Part.: 25</i>	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 %).	<ul style="list-style-type: none"> Delivery of sources for comparison exercises was disrupted by the impact of the global pandemic. The work during this period was focused on project R1.3. 	
R1.2: <i>Participating NMIs: minimum of two per year, six radionuclides per site visit</i>	On-site bilateral comparisons (BIPM.RI(II)-K4) of national standards of short lived gamma emitting radionuclides (SIRTl), using the high precision, high stability SIRTl scintillation counter (reproducibility better than 0.05 %). The SIRTl will be developed, so it can be operated remotely by NMI staff under the supervision of the BIPM staff.	<ul style="list-style-type: none"> No missions were possible during this period due to travel restrictions. The first comparison exercise had been planned with PTB for ¹⁸F at the end of 2020, together with validation measurements of ¹⁵³Sm and ¹²³I 	
R1.3:	Technical support for the SIR and SIRTl comparators (quality control checks and continual improvement including software updates). Development of a mathematical model for a second ionization chamber to enable KCRVs to be	<ul style="list-style-type: none"> Quality control checks continued throughout the period. New software has been developed and implemented to automate the data acquisition system for the SIR. A new Excel comparison reporting form has been developed and validated. 	

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IV Ionizing Radiation Metrology		
Project	Deliverables	Work performed in the period (1 January 2020 – 31 December 2020)
	duplicated without the need to measure all the radionuclides (collaboration with the NPL).	<ul style="list-style-type: none"> A study is underway to determine the feasibility of using mathematical modelling to transfer KCRVs from one ionization chamber to another, avoiding the need to measure samples of every radionuclide covered by the SIR.
R1.4:	Quality assurance and continual improvement of the high resolution gamma spectrometer for impurity checks and applications in health physics.	<ul style="list-style-type: none"> Quality assurance measurements have continued and the spectrometer 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.	<ul style="list-style-type: none"> Arrangements for the disposal of radioactive waste have continued, including the removal of the remaining legacy ^{60}Co sealed sources. The SIR laboratory has been refurbished. Extension of license obtained to hold the SIR ^{226}Ra sources, the ^{137}Cs-137 brachytherapy check source and the ^{241}Am TDCR check source. Compulsory training on radiation protection regulations was completed (via Zoom) for all staff in the department.
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.	<ul style="list-style-type: none"> Initial tests of an Ultra-Stable Low Current Amplifier (on loan from the PTB) are in progress.
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).	<ul style="list-style-type: none"> The replacement of ^{226}Ra by $^{166\text{m}}\text{Ho}$ sources has been delayed until 2021 as production of the raw material in laboratories in Switzerland was not possible during the pandemic.
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).	<ul style="list-style-type: none"> Planned for later in the programme.

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IV Ionizing Radiation Metrology		
Project	Deliverables	Work performed in the period (1 January 2020 – 31 December 2020)
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: <i>MI Part.: 25</i>	Bilateral comparisons (BIPM.RI(II)-Kx) 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%.	<ul style="list-style-type: none"> The planned ^{60}Co pilot comparison exercise was delayed due to the pandemic (delivery of sources was not possible during this period). The exercise has now restarted (September 2020).
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).	<ul style="list-style-type: none"> The specialist liquid scintillation counter used for the ESIR has been re-designed and constructed in the BIPM workshop. The instrument has been rebuilt and commissioning completed successfully. The first paper on the ESIR has been published in <i>Metrologia</i>. A second paper (on estimation of uncertainties) was submitted for publication in July. Seven procedures on the operation of the ESIR were drafted.
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.	<ul style="list-style-type: none"> As access to the BIPM site itself was not possible for several weeks, resources were diverted from this project onto new work related to digitalization: results from comparison exercises using the SIR were entered into a database and new software written to automate the production of reports. Software has also been written to convert the database into XLM format. The aim is to make the data accessible for studies of differences between standardization techniques and other applications.
R4.2:	Development and validation of report writing software.	<ul style="list-style-type: none"> No progress

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V International Liaison		
Project	Deliverables	Work performed in the period (1 January 2020 – 31 December 2020)
1. ILC-L1: LIAISON with MEMBER STATES, ASSOCIATES, the CIPM and RMOs		
ILC-L1:	<ol style="list-style-type: none"> 1) Support to Member States and Associates, CIPM and the BIPM Director; 2) Promotion of the <i>Metre Convention</i> and support to potential Member States and Associates; 3) Support for and representation to RMOs (AFRIMETS, APMP, COOMET, EURAMET, SIM and GULFMET). 	<ul style="list-style-type: none"> • As of January 2020 there are 62 Member States, and 40 Associates of the CGPM: <ul style="list-style-type: none"> – Belarus became a Member State as from 13 January 2020 being previously an Associate of the CGPM (since 2003) encouraged to accede to the <i>Metre Convention</i>. – Support/advice to the governments of Member States and Associates with outstanding contributions and subscriptions. • Support/advice to the governments of Cambodia to become an Associate State in 2021 (expected - subject to payment of its subscription) and Estonia to become a Member State in 2021 (Estonia is currently an Associate State). • Early-stage discussions/provision of information with other potential Member States/Associates. • Support to the CIPM strategy exercise. Most notably related to the following the CIPM strategy strands: <ul style="list-style-type: none"> – 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. • Supporting the implementation of the CIPM decision (CIPM/108-34) related to accumulated arrears. • Supported the CIPM President's initiative by compiling and publishing NMI examples of how their work is supporting the fight against the COVID-19 pandemic. A dedicated repository is available through: https://www.bipm.org/en/metrology-in-the-fight-against-covid-19
2. ILC-L2: LIAISON WITH STRATEGIC PARTNERS		
ILC-L2:	<p>Institutional liaison with International/intergovernmental/Quality Infrastructure:</p> <ul style="list-style-type: none"> – OIML, UNIDO, ILAC, ISO, OECD, WTO, World Bank; – Institutional liaison with other international organizations as required (BIPM liaises with around 30 international organizations). 	<ul style="list-style-type: none"> • BIPM-OIML cooperation: <ul style="list-style-type: none"> – The BIPM together with OIML heavily updated of the document OIML D1, <i>Elements for a Law on Metrology</i>, which will be adopted as a joint BIPM/OIML and is expected to be published with a new title reflecting the broader nature of the document: <i>National Metrology Systems - Developing the institutional and legislative framework</i>. – World Metrology Day activities (see project #ILC-CP5). • BIPM-WTO cooperation: <ul style="list-style-type: none"> – Submission of the BIPM statement to the WTO TBT Committee meetings in February, May and October 2020.

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V	International Liaison	
Project	Deliverables	Work performed in the period (1 January 2020 – 31 December 2020)
		<p>BIPM provided expert advice for two initiatives related to the development of the Quality infrastructure indexes (WTO/PTB and UNIDO initiatives). Expected to be published in 2021.</p> <ul style="list-style-type: none"> • BIPM-OECD cooperation: <ul style="list-style-type: none"> – Publication of the OECD/BIPM joint study within OECD IO Partnership <i>The Case of the International Bureau of Weights and Measures</i> in February 2020 – Director of the BIPM, together with heads of other IOs, participated as a panelist in the OECD High-Level virtual Webinar: "International Organisations and their Members Facing the Global Crisis Together" held as part of the 7th Annual IO Meeting held on 3 September 2020 within the context of the IO Partnership – Contribution to analytical work (Compendium of IO practices) through the IO Partnership for effective international rule-making (involving 50 IOs, country delegates and academics) in its five core focus areas (the BIPM is represented in WG2 (implementation), WG4 (evaluation) and WG5 (IO coordination – as a focal point). • BIPM-UNESCO cooperation: <ul style="list-style-type: none"> – Participation in the 6th Special virtual session the Executive Board of UNESCO, 8-9 June 2020. • Bilateral and multilateral agreements with liaisons: <ul style="list-style-type: none"> – Signing of the BIPM-ITU MoU (June 2020) – Signing of the BIPM-IFCC MoU (September 2020) • Drafting and negotiating MoUs with CTBTO, CODATA and OIML.
PMD-L1	<ol style="list-style-type: none"> 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) 	<ul style="list-style-type: none"> • Initiation of discussion on an MoU between the BIPM and CODATA TGFC. • Participation in discussions of the CPEM Executive Committee on selection of new members and on selection of the location of the 2026 conference.
TIME-L1 Coordination and promotion of time activities for the advancement in the development of time	<ol style="list-style-type: none"> 1) Dissemination of TAI/UTC/TT(BIPM) 2) GNSS time transfer 3) GNSS coordination 4) GNSS system time definition and realisation 5) GNSS dissemination of UTC 6) Need in Time and frequency transfer methods. 	<ul style="list-style-type: none"> • Work on the update of Circular T sec IV on the GNSS dissemination of UTC, extended to Beidou and Galileo systems in progress with several exchanges with CCTF GNSS WG. • A MoU with the ITU has been signed specifying different roles and areas of collaborations https://www.bipm.org/en/worldwide-metrology/liaisons/itu.html

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V		
International Liaison		
Project	Deliverables	Work performed in the period (1 January 2020 – 31 December 2020)
scales and their applications.		
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.	<ul style="list-style-type: none"> • Initiate activities of the new IAG Working Group Q.3 “Relativistic geodesy with clocks”, chaired by GP. • The liaison with the IAG and IUGG has been clarified and the IAG By-laws updated. The BIPM Time Dept is no more listed as an IAG services but as International Cooperation • G.Petit member of the IGS Directing Board (one meeting).
Chem-L1	1) Liaison activities with: IUPAC; ISO TC 212, IFCC, WMO, WHO, WADA, Codex, ISO TC 146.	<ul style="list-style-type: none"> • Review of Developments in Organic Purity Methods, developed by NMIs and BIPM, submitted to IUPAC for peer review and publication. • Liaison with IFCC to finalize draft text of MoU (approved by CIPM and signed 14/15 September) • Provisional planning for 2022 Climate Metrology workshop drafted in collaboration with the Chair of the European Metrology Network for climate and ocean observation
	2) Liaisons activities related to revision of Ozone standard reference method and global implementation.	<ul style="list-style-type: none"> • Meeting reorganized to online-workshop. Completed agenda and launched registrations for the workshop on Implementing an Ozone Cross Section change for worldwide surface ozone monitoring (On-line Oct. 2020). Survey on implementation of the ozone cross-section change for stakeholders, undertaken and presented during the workshop. Workshop completed successfully with recommendation to proceed with change in value of ozone cross section used in international comparisons, and a new task group to coordinate the change process over a 3 to 5 year period.
IR-L1	<ol style="list-style-type: none"> 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) 3) ISO (SC2 and working group meetings) 	<ul style="list-style-type: none"> • Participated (via Zoom) in the annual meeting of the ICRU. • Participated (via Zoom) in a meeting of the expert group revising the IAEA Code of Practice TRS-398. • Participated in the biennial meeting of the SSDL Scientific Committee, report published in the SSDL Newsletter. • Participated via Zoom in ICRM Life Science WG meeting.

Report on the BIPM Work Programme for 2020-2023

VI		Coordination
Project	Deliverables	Work performed in the period (1 January 2020 – 31 December 2020)
1. CIPM MRA		
ILC-C1:	<ol style="list-style-type: none"> 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 	<p>As of December 2020, the CIPM MRA has been signed by representatives of 102 institutes – from 62 Member States, 40 Associates States of the CGPM, and four international organizations – and covers a further 152 institutes designated by the signatory bodies.</p> <ul style="list-style-type: none"> • During the reporting period around 4000 CMCs were processed through the revised database – KCDB 2.0 (launched in late October 2019). • More than 55 new comparisons were registered via the new tools of the KCDB. • A new statistical tool was incorporated into the KCDB 2.0 early in 2020. • Continuous support of the KCDB user community (KCDB offline learning platform launched). • Published video tutorial, presentations, quick start guidelines to support the KCDB users. • March 2020 JCRB meeting was canceled, and appropriate action/decisions were addressed by correspondence. • Virtual JCRB meeting was held in September 2020 with participation of all six regions. • Revision of the CIPM MRA policy and guideline documents. Information maintained, but more effectively presented - 24 documents reduced to 6. This involved a multi-stage consultation exercise with RMOs and CCs: <ul style="list-style-type: none"> – Policy series of documents are approved and ready for publication (will be published as an integrated suite with the G documents once they are ready to be published). – Guidance documents approved in principle at the JCRB 42 (Sept 2020) and final editorial comments currently being addressed. – Suggestions that are beyond the revision aims of the P and G documents have been collated and are with the JCRB and will be considered going forward. <p>Publication is expected early 2021.</p> <p>Two training versions of the KCDB 2.0 database were developed to support the KCDB user community. They simulate all aspects of the CMC review and comparison registration processes. One version supports the training simulation and preloaded with suitable data for each course. The second allows the user community to experiment on their own.</p>
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.	<ul style="list-style-type: none"> • Full support to the JCGM-WG2 meetings held on 2-5 June 2020 and 8-11 December 2020 (via Webex) including publication of the meeting minutes. • Full support to the 23rd meeting of the JCGM meeting 7 December 2020 (via Webex), including publication of the meeting minutes.

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VI Coordination		
Project	Deliverables	Work performed in the period (1 January 2020 – 31 December 2020)
		<ul style="list-style-type: none"> • Participated in four JCGM-WG2 Focus Group meetings. • Proofread the VIM4 CD. • Participated in the meeting of Executive Secretaries on 11 June 2020.
IR-C1:	Provision of the Scientific Secretary for JCGM WG1 and support including: <ol style="list-style-type: none"> 1) <i>Rapporteur</i> 2) Two annual meetings. 	<ul style="list-style-type: none"> • Summary report of December 2019 meeting produced. • June meeting of JCGM-WG1 organized by teleconference.
3. JCTLM		
Chem-C3 Provision of JCTLM Executive Secretary in order to support:	Support for: <ol style="list-style-type: none"> 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 	<ul style="list-style-type: none"> • Report of the 21st Executive Committee meeting drafted and published. • Report of the December 2019 DBWG meeting drafted and distributed. • Videoconference of JCTLM Executive held in June and December 2020. • The 7th Issue of the JCTLM Database Newsletter edited and published; • A Special Issue JCTLM newsletter on Reliability of Covid-19 testing produced and distributed. • JCTLM Blood Cell Counting and Typing Review Team reestablished, with BIPM Principal Chemist as acting Review Team Leader. • BIPM Chemist appointed member of the JCTLM DBWG Proteins Review Team • Preliminary review of 80 nominations before distribution to the DBWG review teams completed • 30 new entries published in the JCTLM database • 70 JCTLM Review Team member reappointment forms processed for 12 review teams, ensuring resources for the JCTLM process for the next 5-years. • First draft of the technical specifications for new JCTLM Database structure and platform completed.
4. NMI DIRECTORS and RMO CHAIRS MEETING		
ILC-C3:	<ol style="list-style-type: none"> 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 <ol style="list-style-type: none"> a) <i>Development of a global perspective on key issues;</i> 	<ol style="list-style-type: none"> 1. Supported the reorganization of the 2020 NMI Directors meeting into an on-line format due to COVID-19. 2. No CC Presidents' meeting requested for 2020. 3. Support given to GULFMET as they adopt best practice. 4. Support for emerging states addressed via the CBKT programme.

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Coordination		
Project	Deliverables	Work performed in the period (1 January 2020 – 31 December 2020)
	<p>b) <i>Optimal support for states with emerging metrology systems</i></p> <p>c) <i>Facilitated by the BIPM convening annual meetings of the RMO Chairs</i></p>	
5. Support of CCs (including provision of Executive Secretaries)		
<p>PMD-C1 Provision of CCEM (Electricity and Magnetism) Executive Secretary in order to support:</p>	<p>Provision of CCEM (Electricity and Magnetism) Executive Secretary in order to support:</p> <ol style="list-style-type: none"> 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) 	<ul style="list-style-type: none"> • Preparation of a draft new version of the CCEM strategy document. • Updating the CCEM guidelines for CMC submission. • Review of several comparison reports. • Collecting the comments from members and WG chairs on the revised CIPM MRA guideline documents. • Early preparations for the 2021 CCEM meeting.
<p>PMD-C2 Provision of CCM (Mass and Related Quantities) Executive Secretary in order to support:</p>	<p>Provision of CCM (Mass and Related Quantities) Executive Secretary in order to support:</p> <ol style="list-style-type: none"> 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) 	<ul style="list-style-type: none"> • Following-up of the CCM action plan 2019-2020. • Simplifying the approval process of comparison reports by the CCM WGS. • Updating the <i>mise-en-pratique</i> document. • Coordinating the registration, approval and publication of the final reports of a large number of comparisons. • Collecting the comments from members and WG chairs on the revised CIPM MRA guideline documents. • Early preparations for the 2021 CCM meeting.
<p>PMD-C3 Provision of CCU (Units) Executive Secretary in order to support:</p>	<p>Provision of CCU (Units) Executive Secretary in order to support:</p> <ol style="list-style-type: none"> 1) Two CCU meetings 2) Pro-active interaction on strategy and communication 3) Coordination of CCU processes 	<ul style="list-style-type: none"> • Organization of two remote meetings of WG-CMT. • Participation in the development of a roadmap for introduction of new SI prefixes in the SI Brochure. • Correction of a number of editorial errors in the SI brochure. • Responding to questions received by the webmaster about SI and other units. • Coordination of the production of an XML version of the SI brochure.
<p>Time-C1 Provision of CCTF (Time and Frequency)</p>	<ol style="list-style-type: none"> 1) Organizing the CCTF bi/triennial meetings 2) Providing secretariat of CCTF and WGs 	<ul style="list-style-type: none"> • The CCTF celebrated its 22nd meeting with a first session in October 2020 (online) and a second session in March 2021 (online). The first online session focused on CCTF 'hot

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Coordination		
Project	Deliverables	Work performed in the period (1 January 2020 – 31 December 2020)
Executive Secretary in order to support:	<ol style="list-style-type: none"> 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 	<p>topics" with invited presentations stimulating the discussion before actions to be decided in the March session.</p> <p>Hot topics include:</p> <ol style="list-style-type: none"> 1. Update roadmap towards a new definition of the second 2. Need of a continuous UTC timescale 3. Promoting the mutual benefit of UTC and GNSS 4. CB activities and resource sharing to ensure the best performance of the global network of NMIs in producing UTC <ul style="list-style-type: none"> • Inside WG Strategic Planning a Task Force on the "updating the roadmap to the redefinition of the second" has been created • Inside WG on GNSS a Task Group on the "Traceability from GNSS measures" has been created. • Online meetings of the <ul style="list-style-type: none"> – WG GNSS – WG Algorithms – WG strategic Planning (6 meetings) – Joint WG CCL CCTF FS
Time-C2 Provision of CCL (Length) Executive Secretary in order to support:	<ol style="list-style-type: none"> 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 	<ul style="list-style-type: none"> • Organization of CCL SP WG meeting to organize the next CCL WG on MRA meeting foreseen before the end of 2020 • <i>Metrologia</i> Focus Issue on Length • CMC transformation to quantity equation
Time-C3 Provision of CCAUV (Acoustics, ultrasound and vibration) Executive Secretary in order to support:	<ol style="list-style-type: none"> 1) Biennial CCAUV meetings and three WG meetings 2) Pro-active interaction on strategy and communication 3) Development of strategic plans 	<ul style="list-style-type: none"> • Organization of CCAUV SP WG • Support the process of CCAUV approval and publication on KCDB of CC and RMO comparisons.

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VI		Coordination
Project	Deliverables	Work performed in the period (1 January 2020 – 31 December 2020)
	<ol style="list-style-type: none"> 4) Coordinate review of CC and RMO comparison reports before publication 5) Related liaisons with RMOs. 	
Chem-C1 Provision of CCQM (Amount of Substance) Executive Secretary in order to support:	<ol style="list-style-type: none"> 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 	<ul style="list-style-type: none"> • Coordination of arrangements following postponement of the CCQM plenary meeting planned for April 2020. Establishment of reduced agenda items, dealt with electronically, with comment forms for documents. • 76 videoconference session organized by the BIPM for 11 CCQM WGs to replace April 2020 face-to-face meetings. • Coordination of group organizing CCQM Covid-19 workshops, with 9 video conferences to prepare format, topics, find speakers and briefing for speakers. • 2 CCQM Webinars on Ensuring the reliability of measurements in response to the Covid-19 pandemic, run by the BIPM with over 200 participants attending live for each, with recordings publicly available. • Support for CCQM SPWG and CCQM in drafting and agreeing on: <ul style="list-style-type: none"> - CCQM vision and mission statements; - CCQM strategic aims for 2021-2023; - CCQM WG strategy document template; - CCQM Recommendation on Ozone cross sections - CCQM KCWG guidelines for integrating KCDB 2.0 processes
Chem-C2 Provision of CCPR (Photometry and Radiometry) Executive Secretary in order to support:	<ol style="list-style-type: none"> 1) Two CCPR plenary meetings and associated WG meetings 2) Pro-active interaction on strategy and communication 3) Coordination of review of CC and RMO comparison reports before publication 4) Development and review of CCPR documents and guidelines 	<ul style="list-style-type: none"> • Coordinated review and publication of 2 comparisons. • CCPR executive secretary has maintained contact with WG Chairs, and advised on availability of videoconference service organization from BIPM
IR-C2:	Provision of CCRI (Ionizing Radiation) Executive Secretary in order to support: <ol style="list-style-type: none"> 1) Biennial CCRI and sections I, II and III meetings 2) Regular meetings of seven working groups 3) Development of strategic plans 	<ul style="list-style-type: none"> • The CCRI strategy (published in 2019) has been reviewed in the context of discussions on the CIPM strategy. The CCRI community was consulted, including discussions with Section Chairs and RMO TC Chairs, and recommendations for changes to the CCRI strategy were developed. Further consultation is planned on these recommendations. • Two meetings were held of the new joint CCEM-CCRI Task Group on low electrical current measurement during the period.

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VI	Coordination	
Project	Deliverables	Work performed in the period (1 January 2020 – 31 December 2020)
	4) Co-ordination engagement with RMOs	<ul style="list-style-type: none"> • Meetings were held in September of the RMOWG, the KCWG(II) and the new Working Group on metrology for radiopharmaceutical therapy. • A new series of webinars will start in October 2020. • The CCRI Executive Secretary contributed to an APMP virtual workshop on submission of CMCs using the new KCDB.
IR-C3	Provision of CCT (Thermometry) Executive Secretary in order to support: <ol style="list-style-type: none"> 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 	<ul style="list-style-type: none"> • March 2020 CCT meeting was canceled. The 29th meeting of the CCT was held online in 5 separate sessions, first session held in October 2020.

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VII Capacity Building and Knowledge Transfer		
Project	Deliverables	Work performed in the period (1 January 2020 – 31 December 2020)
1. PLANNING and COORDINATION of BIPM CBKT PROGRAMME ACTIVITIES		
ILC-CBKT1	<ol style="list-style-type: none"> 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 <ul style="list-style-type: none"> – Liaison with RMOs to ensure coordinated CBKT delivery. 3) Development of remote learning capabilities: <ul style="list-style-type: none"> – online short courses. – online technical exchanges. – E-learning capabilities for CBKT. 	<ul style="list-style-type: none"> • Emergence of COVID-19 crisis in the first quarter of 2020 required complete re-evaluation of the delivery mechanisms of the CBKT programme, effectively requiring full redesign. • In May 2020 the BIPM CBKT Programme was extended to include a "remote-learning" capability, which provides on-line assistance to NMI/DI staff from Member States and Associates in their involvement in the CIPM MRA mechanisms. The "remote-learning" capabilities include online short courses (delivered in consultation with a particular RMO) and online technical exchanges (based on Q/A format and mainly focused on the KCDB 2.0). • Secured funding from METAS for the CBKT project planned in 2021. METAS is providing the financial support for the CBKT activities within 2020-2021. Due to current pandemic the fund for 2020 is transferred to 2021. • E-learning capabilities of the CBKT is under development. The scripts for two modules have been prepared. Launch is expected before mid 2021.
2. DELIVERY OF, and LECTURING on CORE BIPM CBKT ACTIVITIES		
ILC-CBKT2	<ol style="list-style-type: none"> 1) Delivery of, and lecturing on (including using the remote learning tools), core CBKT activities supporting the CIPM MRA: <ul style="list-style-type: none"> – 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'). 	<ul style="list-style-type: none"> • BIPM-EURAMET Workshop on "the KCDB 2.0" was organized at the BIPM in February 2020 with participation of 22 CIPM MRA experts from 11 EURAMET member institutes. • Seven young-unexperienced metrologists were able to complete their placements at TÜBİTAK UME laboratories within the frame of the joint project - 2020 "BIPM - TÜBİTAK UME project placements". • Eight online projects on core CBKT topics have been organized involving more than 600 participants: <ul style="list-style-type: none"> – Short course for COOMET TC Chairs on KCDB 2.0 (May 2020) – Technical exchanges for CMC writers in General Physics (June 2020) – Technical exchanges for CMC writers in Chemistry and Biology (June 2020) – Technical exchanges for CMC writers in Ionizing Radiation (June 2020)

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VII Capacity Building and Knowledge Transfer		
Project	Deliverables	Work performed in the period (1 January 2020 – 31 December 2020)
		<ul style="list-style-type: none"> – Technical exchanges for T Chairs and CMC reviewers in General Physics (Sept. 2020) – Technical exchanges for T Chairs and CMC reviewers in Ionizing Radiation (Sept. 2020) – Technical exchanges for Writers in Chemistry and Biology (October 2020) – Interactive simulation of JCRB review for Chemistry and Biology (October 2020)
3. VARENNA METROLOGY SCHOOL		
ILC-CBKT3	Delivery of joint Varenna metrology school for world class young scientists/metrologists - with the Italian Physical Society.	<ul style="list-style-type: none"> • The project is planned in 2023, however there is now some uncertainty on the timing.
4. Laboratory support for capacity building and knowledge transfer activities		
PMD-CBKT	Planning, coordination and delivery of the capacity building and knowledge transfer activities in the field of electricity and mass metrology.	<ul style="list-style-type: none"> • The project is planned in 2021-2023.
TIME-CBKT	Planning, coordination and delivery of the capacity building and knowledge transfer activities in the field of electricity and mass metrology.	<ul style="list-style-type: none"> • Postponement of the CBKT course organized in Thailand with the support of MEDEA project.
Chem-CBKT1 Metrology for Safe Food and Feed	<ol style="list-style-type: none"> 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 	<ul style="list-style-type: none"> • CCQM-K154.a.1 (ZEN mycotoxin calibrants) measurements completed and evaluated. Draft B reports of CCQM-K154.a and CCQM-K154.a.1 written and accepted by OAWG. Final report published in Metrologia and the KCDB. • Call and protocol for key comparison CCQM-K154.b (Afb1 Calibrant) written, accepted by OAWG and distributed to OAWG. Registration launched. • LC-DAD-MS/MS method development for patulin and potential impurities for homogeneity and stability testing completed with support from visiting scientist from NIM • Homogeneity studies for patulin calibration and stock solution (CCQM-K154.d candidate material) completed, with support from visiting scientist from NIM • Ochratoxin A material scale-up completed at NRC, as additional candidate materials for CBKT programme. • Collaborative project between UME and BIPM established to provide tetracycline materials to support CBKT activity in contaminant and drug residues in Food CBKT project. • 3 tetracycline materials in development at UME.

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VII Capacity Building and Knowledge Transfer		
Project	Deliverables	Work performed in the period (1 January 2020 – 31 December 2020)
	Collaborating NMI(s), for Pesticide materials, supporting CBKT program on Metrology for Safe Food and Feed.	
Chem-CBKT2&3 Metrology for Clean Air	<ol style="list-style-type: none"> 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 	<ul style="list-style-type: none"> • Training completed for 1 visiting scientist from KEBS (February 2020) on FTIR for gas standard analysis including B-FOS software operation • On-line assistance provided for NMISA on operation of B-FOS FTIR software following training in 2019 • User manual of B-FOS software update written
Chem-CBKT4 Metrology for Accurate Patient Care	<ol style="list-style-type: none"> 1. Development of E-training material on peptide pure material standard characterization and value assignment 	<ul style="list-style-type: none"> • Activity to start in 2022
ILC-CBKT	<ol style="list-style-type: none"> 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): <ul style="list-style-type: none"> – 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 	<ul style="list-style-type: none"> • EURAMET supported a joint workshop in 2020. The BIPM-EURAMET Workshop: "the KCDB 2.0", was organized on 17-19 February 2020 at the BIPM. • Due to COVID-19 crisis: <ul style="list-style-type: none"> – 2020 BIPM-SIM Training course: KCDB 2.0. Rescheduled for 2021. – 2020 BIPM-APMP Training course: Timescale and Algorithms. Rescheduled for 2021. – 2020 BIPM-COOMET Workshop: "the KCDB 2.0". Alternative online training was provided in May 2020.

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VIII		
Communication and Promotion		
Project	Deliverables	Work performed in the period (1 January 2020 – 31 December 2020)
1. PROVISION of BIPM INTERNET		
ILC-CP1:	<ol style="list-style-type: none"> 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. 	<ul style="list-style-type: none"> • Approximately 40k users visit the BIPM website every month. • The website currently hosts working documents for 242 different groups. • A new responsive version of the website- based on a new platform and with an updated graphic design - is under construction and scheduled for launch in late 2020.
2. FORMAL REPORTING & PUBLICATIONS		
ILC-CP2:	<p>Generating BIPM reports including drafting/minuting, editing, translation into French, typesetting and publication of CIPM and BIPM reports, publications and posters.</p>	<ul style="list-style-type: none"> • Drafted, edited, typeset and published the report of the 108th meeting of the CIPM (Session II, October 2019) • Published the BIPM Annual Review 2019/2020 • Published the Financial Report 2019 • Edited and published the Report of the 24th CCU meeting (2019) • Published the BIPM eNews • Edited, typeset and published the JCTLM Newsletter 2020 • Edited, typeset and published two JCTLM Newsletter Special Reports • Published the 'News from the BIPM laboratories 2019' • Designing new logos as required (for example CCs and CC WGs) • Published a bilingual version of the 2021 Notification
3. Metrologia		
ILC-CP3:	<p>Editing and publication of <i>Metrologia</i></p> <ol style="list-style-type: none"> 1. To ensure the success of <i>Metrologia</i> as the key scientific publication for high level metrology with an increase in impact factor. 2. To increase the number of annual issues of <i>Metrologia</i> from 6 to 10 3. Maintain a viable journal taking account of the trend towards "open access" for journals. 	<ul style="list-style-type: none"> • Sustainable editor team consisting of: • Editor Janet Miles (BIPM) • Dep. Eds: Sten Bergstrand (BIPM/RISE), Giovanni Mana (INRiM), Rod White (MSL). • Focus issues on Length, gravitational constant G, and mathematical methods under way. • 112 published articles (2019: 84 publ.) • 28 Open Access articles (2019: 31 OA) • Impact factor 3.058
4. LIBRARY		

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VIII		
Communication and Promotion		
Project	Deliverables	Work performed in the period (1 January 2020 – 31 December 2020)
ILC-CP4:	Journal subscriptions (on-line or hard copy) buy-per-view scientific articles and books for BIPM staff)	<ul style="list-style-type: none"> • Renewal of 10 journal subscriptions, one cancelled • Purchase of 11 books and 37 articles
5. WORLD METROLOGY DAY		
ILC-CP5:	<p>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:</p> <ol style="list-style-type: none"> 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 	<ul style="list-style-type: none"> • The project is run jointly by the BIPM and the OIML. The theme for 2020 was "<i>Measurements for global trade</i>". The theme raises awareness of the important role measurement plays in facilitating fair global trade - ensuring products meet standards and regulations, and satisfying customer quality expectations. • CIPM President's and BIPM Director's video messages were produced and published on the BIPM YouTube channel. • The 2020 poster was designed in collaboration with the AFRIMETS RMO and specifically with AA&W Legal Metrology Egypt. The poster was translated into more than 20 languages and information on 23 national celebratory events is provided on the 2020 World Metrology Day Resource Website http://www.worldmetrologyday.org/ • Participated NCSLI on-line event dedicated to World Metrology Day. • Participated in World Metrology Day on-line events organized by Member States and Associates. • Preparatory work – in collaboration with OIML - on WMD 2021 "Measurement in health", partnering with SASO via GULFMET, is ongoing.
6. IMPACT STUDY		
ILC-CP6:	Authoritative independent study highlighting the impact arising from metrology in the Quality Infrastructure.	<ul style="list-style-type: none"> • Ongoing discussions with OECD. • 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.	<ul style="list-style-type: none"> • Being discussed as part of the CIPM strategy exercise.

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BIPM - Pavillon de Breteuil F-92312 Sèvres Cedex FRANCE