Bureau International des Poids et Mesures

# Proposals for the Work Programme

of the International Bureau of Weights and Measures
for the years 2024-2027

This document presents proposals for the Work Programme for the years 2024 to 2027 for the BIPM Headquarters.

It addresses the objectives agreed by the CIPM in the "Strategic Plan for the BIPM Work Programme (2022)".

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# Contents

# EXECUTIVE SUMMARY

This document presents proposals for the BIPM Work Programme for the years 2024 to 2027 that will address the objectives agreed by the CIPM in the BIPM Strategic Plan (2022).

The programme includes projects in four technical areas:

***Physical Metrology***

- Coordinate the comparison of primary realizations of the kilogram according to the new definition and maintain the consensus value on the BIPM working standards.
- Disseminate the unit of mass by establishing metrological traceability from the BIPM Kibble balance based on the new definition of the kilogram.
- Organize a new comparison of AC voltage standards based on the Josephson effect.
- Develop a new approach to providing traceability for capacitance standards based on the AC quantum Hall effect.

***Time Metrology***

- Optimize the use of high-accuracy frequency data from optical clocks into UTC calculation and support the CCTF roadmap towards a new definition of the second.
- Study and test new, or extended, time and frequency transfer processing techniques with the goal of comparing optical frequency standards without degrading their stability.
- Implement new automatic checks on input data and on the results to reinforce the metrological quality and the robustness of the monthly computation of UTC and the weekly computation of Rapid UTC, also supporting the NMIs in their realization of high-quality UTC($k$) time scales.
- Extend the availability of digital data from the computation of UTC and Rapid UTC in new machine-readable formats to support the digital transformation of NMI services and for other users of timing data.

***Chemical Metrology***

- Provide on-demand comparisons of carbon dioxide in air standards needed by NMIs to support internationally-agreed data quality objectives for atmospheric monitoring and emissions verification.
- Provide on-demand comparisons for NMIs delivering surface ozone and nitrogen dioxide calibration services and standards for air quality networks and emission measurements.
- Provide comparisons for the 15 NMIs world-wide that are most involved in delivering peptide and protein calibrants and reference measurement services for *in-vitro* diagnostic applications and knowledge transfer programmes for those developing such services.
- Expand laboratory-based knowledge transfer programmes on organic standards to cover pesticide and veterinary drug residues and a broader range of mycotoxins.

### *Ionizing Radiation Metrology*

- Extend the comparison and calibration services provided from off-site facilities to include high-energy electrons, in response to the increasing use of these radiation fields in radiotherapy.
- Implement new low-current measurement technologies in the next-generation International Reference System (SIR) for comparing standards of gamma-emitting radionuclides, for applications in nuclear medicine and environmental monitoring.
- Expand the capabilities of the Extended SIR (ESIR) to compare standards of low-energy beta and alpha-emitting radionuclides, including the use of digital pulse processing systems.

### *Liaison, Coordination, Communication and Promotion*

The BIPM Work Programme 2024-2027 also proposes activities for coordination, liaison and communication that will address objectives agreed in the BIPM strategy. These activities will be managed in a way that will allow them to respond effectively and in a timely way to opportunities (and threats) that may arise amongst the stakeholder community for metrology and measurement science.

The coordination tasks within the CIPM MRA will continue, with a focus on the implementation of the FAIR *(Findable, Accessible, Interoperable and Reusable)* principles by providing KCDB data that is compatible with the wider digital framework developed by the CIPM.

Highlights among the liaison activities include increased interactions with the Regional Metrology Organizations (RMOs) and other relevant international bodies, in order to promote the benefits of the world-wide metrology infrastructure delivered through the international quality infrastructure. The liaison activities are broad, and the BIPM will remain agile in terms of its activities as liaison partners respond to their changing needs. The liaison activities will be focused, in conjunction with the CIPM, on exploring models that facilitate participation of those states not yet participating in the activities of the BIPM.

The BIPM will continue its close collaboration with the OIML as both organizations strive to present 'one voice' for metrology to the outside world. Additionally, the BIPM will continue to promote the importance of the global comparability of measurements with international organizations of strategic importance to the mission (including the OIML, ILAC, ISO, WTO-TBT) and to work closely towards better coordination and recognition of "Quality Infrastructure" (QI), aided by the INetQI – International Network on Quality Infrastructure.

### *Digital transformation and new digital services*

Implementing the CIPM "Grand Vision" for the SI Digital framework will require the BIPM to add new capabilities that enable the Digital Transformation of the BIPM databases and services so that they will be machine-readable.

Activities in the Work Programme will support the digital transformation through the creation of a digital hub in which BIPM, RMO and NMI data can be accessed in a form that meets the FAIR data principles. As this field of activities evolves and expands it is foreseen that there will be a number of iterations and revisions to ensure that the facilities meet stakeholder needs.

All the BIPM's documents will be made Findable and Accessible according to the FAIR guidelines.

### *Capacity Building and Knowledge Transfer (CBKT)*

The CBKT Programme, which was started following the 24th meeting of the CGPM in 2014 has been widely welcomed and has evolved rapidly to become a pillar supporting both national and regional metrology activities. Nowadays, the programme has a highly appreciated portfolio that continues to expand.

The activities of the BIPM CBKT "Remote-learning" initiative have been extended by the addition of e-learning capabilities. In 2022, the e-learning platform was expanded to enable it to host material from interested RMOs. The CBKT activities will continue to be important in the new programme with significant additional capabilities being proposed.

### *Visiting scientists*

The proposed activities in the Work Programme 2024-2027 are ambitious and depend on the work of visiting scientists and specialists working alongside BIPM staff for their delivery. The participation of visiting scientists reduces costs, brings in specific expertise when it is needed, injects new ideas, and provides greater flexibility in staffing. The proposals also include capacity building and knowledge transfer activities, some of which depend on the BIPM securing sponsorship from NMIs, Member States, RMOs or other bodies.

In summary, all Member States have access to the facilities, services and the know-how of internationally recognized and independent metrology laboratories at the BIPM.

The projected numbers of NMI and DI participations in comparisons coordinated by BIPM staff and calibrations delivered by BIPM staff for 2024-2027 are shown in the table below. These numbers represent a significant increase on those planned for the 2020-2023 Work Programme.

| **BIPM Scientific Department** | **Projected participations in comparisons and calibrations delivered by the BIPM staff** |
|---|---|
| Physical Metrology | 340 |
| Time* | 83 |
| Chemistry | 287 |
| Ionizing Radiation | 192 |
| **Total** | **902** |

**the participations indicated for the Time Department correspond to the monthly determination of UTC.*

# SECTION I: INTRODUCTION

The Work Programme 2024-2027 addresses the objectives agreed by the CIPM in the BIPM Strategic Plan (2022). We repeat here the Vision, Mission and Objectives of the BIPM:

***THE VISION AND MISSION OF THE BIPM***

The BIPM is an intergovernmental organization established by the Metre Convention, through which Member States act together on matters related to measurement science and measurement standards.

**Its vision** is to be universally recognized as the world focus for the international system of measurement.

**Its mission** is to work with the NMIs of its Member States, the RMOs and strategic partners world-wide and to use its international and impartial status to promote and advance the global comparability of measurements for:

- Scientific discovery and innovation,
- Industrial manufacturing and international trade,
- Improving the quality of life and sustaining the global environment.

***THE OBJECTIVES OF THE BIPM***

**To represent the world-wide measurement community - aiming to maximize its impact.**

- We liaise with relevant intergovernmental organizations and other international bodies in order to develop opportunities for the application of metrology to global challenges.

**To be a centre for scientific and technical collaboration between Member States providing capabilities for international measurement comparisons on a shared-cost basis.**

- We coordinate international comparisons of national measurement standards agreed to be of the highest priority.

- We establish and maintain appropriate reference standards for use as the basis of key international comparisons at the highest level and provide selected calibrations from them.

**To be the coordinator of the world-wide measurement system ensuring it gives comparable, fit-for-purpose and internationally accepted measurement results.**

- We coordinate activities between the NMIs of Member States and the RMOs, including the provision of technical services to support the CIPM MRA and the infrastructure for the development and promotion of the SI.

Fulfilling our mission and objectives is underpinned by our work in:

- **capacity building**, which aims to achieve a global balance between the metrology capabilities in Member States.
- **knowledge transfer**, which ensures that our work has the greatest impact.

## PRIORITIES IDENTIFIED FROM THE STRATEGIC PLAN

The BIPM Strategic Plan (2022) was approved by the CIPM in October 2021. It includes a set of agreed priorities that set the context for the development of the strategic plan. Some of these priorities are specifically relevant to the work programme and were considered in developing the proposals presented here.

The most relevant of these priorities will address:

- the challenges and opportunities afforded across all areas of the BIPM triggered by digital transformation, ranging from the provision of data that meets the FAIR principles through to the enhanced needs for data quality and curation,
- the increased focus on sectorial challenges and the need to support new mechanisms that facilitate cross-sector working in order to communicate effectively with sector actors,
- the impending technological advances that will have an important step-change impact on the way metrological traceability can be realized in the future,
- the opportunities identified in the consultative committee strategies including the provision of knowledge transfer from the BIPM laboratories,
- the emphasis on measurement science as an essential tool for economic growth after the impact of the global pandemic, as well as the continued need to operate in a way that is both “COVID safe” and takes note of the likely emergence of a “new normal” by using new ways for BIPM staff to interact with NMIs, RMOs and other key stakeholders.

# BASIS FOR COSTINGS AND THE INVOLVEMENT OF SECONDED STAFF

The programme includes a number of projects that depend significantly on seconded staff for their success. These projects will only be completed if the additional resources can be secured.

### Seconded staff contributing to delivery of the Work Programme

The total staff resources required for programme delivery (including visiting scientists and other specialists) are:

| **BIPM Department** | **BIPM staff** *(person months)* | | **Staff seconded from NMIs/DIs for programme delivery** *(person months)* |
|---|---|---|---|
| | *Programme delivery* | *Dep. management* | |
| Physical Metrology | 465 | 15 | 30 |
| Time | 316.2 | 15 | 128 |
| Chemistry | 489 | 15 | 120 |
| Ionizing Radiation | 369 | 15 | 60 |
| International Liaison and Communication | 417 | 15 | 108 |
| IT Services | 89 | 7 | - |
| **Total** | **2145.2** | **82** | **446** |

***Notes:***

*Seconded staff benefitting from the CBKT activities are not included above.*

# SECTION II: BIPM WORK PROGRAMME FOR 2024-2027

## LABORATORY WORK CARRIED OUT BY THE BIPM

The strategy for scientific and technical collaboration work to be carried out in the BIPM laboratories is:

> To be a centre for scientific and technical collaboration between Member States providing capabilities for international measurement comparisons on a shared-cost basis.
>
> – We coordinate international comparisons of national measurement standards agreed to be of the highest priority.
>
> – We establish and maintain appropriate reference standards for use as the basis of key international comparisons at the highest level and provide selected calibrations from them.

In considering whether a proposed project meets the objectives of the BIPM listed above and whether it is suitable to be carried out in the BIPM laboratories, criteria are considered in four areas:

- **The importance of the measurand/quantity**
  - The measurand/quantity that will be addressed by the comparison (or reference facility) must have a wide impact in its field as identified in the Consultative Committee strategy and be recognized to be of importance globally.
- **The extent of planned participation and future use**
  - Participation over the project cycle should generally be at least at the level of 15 NMIs/DIs and the project should be of enduring value as evidenced by a projected future requirement for at least the next 10 years (from the start of the project). It should be necessary to retain the facilities and expertise developed for repeated future use.
  - The NMIs and DIs can benefit by conducting comparisons and calibrations in an efficient and timely manner (for example, through reducing the burden of shipping sensitive instruments or hazardous materials for multi-centre comparisons).
- **Facilitating access**
  - Projects should provide access for NMIs/DIs to facilities and expertise that are not readily accessible to them elsewhere.
- **Wider applications of the facilities used**
  - When applicable, the project should be organized to involve participation of scientists visiting from NMIs/DIs and the facilities should also be of use for capacity building activities.
  - When applicable, the benefit of facilities and expertise developed for the project may be used to disseminate traceability through calibration services (to NMIs/DIs).

# PHYSICAL METROLOGY

**Strategy for physical metrology**

To support the comparison programme of the CCEM to demonstrate the capabilities of the NMIs and for knowledge transfer by scientists conducting on-site comparisons using dedicated travelling quantum standards.

- *To support the CCEM strategy delivering a programme of on-site comparisons using a new generation of more efficient and versatile quantum standards to increase the impact of the service with NMIs.*
- *Provide knowledge transfer services to NMIs that are developing new quantum standards capabilities.*

To support NMIs that have no access to quantum standards by providing calibrations for electrical quantities and by knowledge transfer.

- *Adapt the portfolio of calibration services to the NMI's needs.*
  - *Pioneer the implementation of digital calibration certificates for BIPM services.*
- *Provide knowledge transfer on electrical quantum standards for emerging NMIs.*

To support the *mise en pratique* of the kilogram by coordinating CCM key comparisons of primary realizations held by NMIs.

- *To support the CCM strategy by coordinating key comparisons of primary realizations of the kilogram and of secondary mass standards according to the mise en pratique.*
- *Maintain the BIPM Kibble balance for realizing the kilogram.*

To support the dissemination of the kilogram by providing calibrations of mass standards to NMIs that have no access to a primary realization.

- *Implement digital calibration certificates and provide knowledge transfer in the fields of the realization (Kibble balance) and dissemination of the kilogram.*

### Activities in the field of electrical metrology

The BIPM electricity laboratories ensure that NMIs have continued access to means of comparing or calibrating their national primary standards, with the lowest possible uncertainty, for the most fundamental electrical quantities – voltage, resistance and capacitance. From these quantities, most other electrical quantities can be derived. For these purposes, the Physical Metrology Department maintains and develops international reference facilities: transportable Josephson voltage standard, transportable quantum Hall resistance standard, calculable capacitor, and the associated measurement systems. The existing set of comparisons is extended by a comparison of ac signals using Josephson voltage standards. In addition to demonstrating the capabilities of the NMIs, the comparisons often have an aspect of knowledge transfer. The importance of the quantum electrical standards has increased following the revision of the SI in 2019 because they have become direct realization methods for electrical units. The request for calibrations is slowly increasing with the number of Member States. Another important task is the continued support for the Kibble balance and other BIPM departments in the field of electrical measurements.

| N | Project Code | Deliverables and Activities |
|---|---|---|
| **International reference standard for voltage** | | |
| **1.** | **PMD-E1** | **E1.1: Bilateral on-site comparisons of Josephson voltage standards (JVSs)**<br>Direct comparison of JVSs at dc and/or ac using the BIPM transportable JVSs to obtain the lowest possible uncertainty<br>*NMI Participations: 6* |
| | | 1. Bilateral on-site comparisons at dc and/or ac as part of **BIPM.EM-K10.a/b** with relative uncertainty of $1 \times 10^{-10}$ at dc and less than $1 \times 10^{-7}$ at ac.<br>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). |
| | | **E1.2: Bilateral voltage comparisons using Zener diode transfer standards**<br>For NMIs not possessing JVSs, and as a first step before an on-site comparison of JVSs (E1.1)<br>*NMI Participations: 6* |
| | | 1. Bilateral comparisons of Zener voltage standards as part of **BIPM.EM-K11.a/b** with relative uncertainty of $5 \times 10^{-8}$.<br>2. Participation in related RMO comparisons to link them to BIPM.EM-K11.<br>3. Maintenance of the BIPM secondary voltage standards (Zeners), also supporting the calibration of Zener voltage standards for NMIs (E1.3). |
| | | **E1.3: Calibrations of Zener diode secondary standards**<br>For NMIs not possessing a primary voltage standard, as for most of the new Member States, using measurement systems already in place for comparison activities<br>*Calibration for: 6 NMIs (12 certificates)* |
| | | Calibration of Zener diode secondary standards for NMIs without a primary realization and for internal customers (Ionizing Radiation Dept. and Kibble balance). |
| **International reference standard for resistance** | | |
| **2.** | **PMD-E2** | **E2.1: Bilateral on-site comparisons of quantum Hall resistance (QHR) standards**<br>Direct comparison of QHR standards using the BIPM transportable standard, to obtain the lowest possible uncertainty<br>*NMI Participations: 6* |
| | | 1. Bilateral on-site comparisons of quantum Hall standards (including new graphene samples) as part of **BIPM.EM-K12** with relative uncertainty of $1 \times 10^{-9}$.<br>2. Providing the basis for the realization of the capacitance unit farad (E3).<br>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). |
| | | **E2.2: Bilateral resistance comparisons using resistance transfer standards**<br>As a first step before an on-site comparison and for NMIs not possessing a QHR standard<br>*NMI Participations: 6* |
| | | 1. Bilateral comparisons of resistance transfer standards as part of **BIPM.EM-K13.a/b** with relative uncertainty of $5 \times 10^{-8}$.<br>2. Participation in related RMO comparisons to link them to BIPM.EM-K13.<br>3. Maintenance of BIPM secondary resistance standards and related measurement chain, also for the calibration of resistance secondary standards for NMIs (E2.3). |

| | | |
|---|---|---|
| **3.** | | **E 2.3: Calibrations of resistance secondary standards**<br>For NMIs that do not possess a primary resistance standard, as for most of the new Member States, using measurement systems already in place for comparisons<br>*Calibration for: 20 NMIs (130 Certificates)* |
| | | Calibration of resistance secondary standards for NMIs without primary realizations and for internal customers (Mass, Ionizing Radiation, Kibble balance). |
| | | **E 2.4: Development of a graphene-based QHR standard**<br>For a more compact and economic QHR standard, operating at higher temperature (5 K) and lower magnetic field (< 5 T) |
| | | Development of a QHR standard based on a graphene sample, replacing the GaAs QHR standard to simplify QHR implementation during on-site comparison and to reduce costs. |
| **International reference standard for capacitance** | | |
| **4.** | **PMD-E3** | **E3.1: Bilateral capacitance comparisons using capacitance transfer standards**<br>For NMIs wishing to demonstrate their capabilities in capacitance calibrations<br>*NMI Participations: 4* |
| | | 1. Bilateral comparisons of capacitance transfer standards as part of **BIPM.EM-K14.a/b** with relative uncertainty of $5 \times 10^{-8}$.<br>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). |
| | | **E3.2: Calibrations of capacitance secondary standards**<br>For NMIs that do not possess a primary capacitance standard, as for most of the new Member States<br>*Calibration for: 20 NMIs (100 Certificates)* |
| | | Calibrations of capacitance secondary standards for NMIs without primary realizations. |
| | | **E3.3: Development of the ac quantum Hall effect into an impedance standard**<br>To develop a primary method to realize ac impedances according to the revised SI |
| | | 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.<br>2. Direct comparison of the ac quantum Hall effect and the calculable capacitor, for verification of the validity of the equation for the von Klitzing constant at the $10^{-9}$ level, supporting the *mise en pratique* for the electrical units. |

## Activities in the field of mass metrology

The role of the BIPM in the field of mass metrology has evolved as a consequence of the redefinition of the kilogram. The existence of independent realizations of the kilogram at several NMIs using Kibble balances, a joule balance or isotopically enriched $^{28}$Si spheres is a fundamentally new situation for mass metrology. The BIPM plays an important role in ensuring the world-wide uniformity of dissemination of the kilogram by organizing biennial comparisons of the NMIs' kilogram realizations. During a transition period, the consensus value determined from the outcome of these comparisons will serve as the basis for dissemination from the participating NMIs and the BIPM to ensure world-wide uniformity. The BIPM provides a stable mass reference for these comparisons. The department continues to maintain and improve the Kibble balance, to support a robust international system for the realization and dissemination of the kilogram. The BIPM will continue to provide mass calibrations for NMIs which do not realize the mass unit.

| N | Project Code | Deliverables and Activities |
|---|---|---|
| **Mass dissemination** | | |
| **5.** | **PMD-M1** | **M1.1: Calibration of 1 kg national Pt-Ir prototypes and stainless steel mass standards**<br>*Calibration for: 25 NMIs (50 Certificates)* |
| | | 1. Calibration of existing 1 kg national Pt-Ir prototypes in air or under vacuum.<br>2. Calibration of 1 kg stainless steel national mass standards, including volume and centre-of-gravity determination, if requested.<br>3. Monitoring of the mass evolution of the BIPM working standards. Providing stable linkage between successive key comparisons (M1.3) to allow the calculation of the consensus value.<br>4. Calibration of pressure gauges, as an internal service necessary to support mass calibrations at the required uncertainty, and for other BIPM departments (Chemistry, Ionizing Radiation). |
| | | **M1.2: Provision of 1 kg Pt-Ir prototypes**<br>*Fabrication for: 2 NMIs* |
| | | 1. Fabrication in the BIPM workshop of 1 kg Pt-Ir prototypes for Member States.<br>2. Calibration of new 1 kg Pt-Ir prototypes including volume determination. |
| | | **M1.3: Organization of two CCM key comparisons of kilogram realizations**<br>*9 NMI participants (twice)* |
| | | 1. Organization of two key comparisons of kilogram realizations with Kibble balances, joule balances and the XRCD method, CCM.M-K8.<br>2. Calculation of a new consensus value after each comparison. |
| **Kibble Balance** | | |
| **6.** | | **Developing and maintaining the Kibble balance**<br>International reference facility for realization of the new definition of the kilogram on a long-term cost-shared basis |
| | **PMD-M2** | **M2.1:** Evaluate the performance improvement to the Kibble balance by use of an equal-arm balance mechanism in order to reach a target uncertainty of $2 \times 10^{-8}$ at the 1 kg level (see also new application for this technology in M2.5). |
| | | **M2.2:** Maintain and refine operation of the BIPM Kibble balance on the established design to sustain "turn-key" performance as an international reference facility for realization of the new definition of the kilogram at $5 \times 10^{-8}$ and as the platform for the improved equal-arm balance design (see M2.1). |
| | | **M2.3:** Contribute the results of an independent Kibble balance determination to the biennial comparison of realizations of the kilogram (CCM.M-K8) and host the meeting of the international Kibble balance collaboration of NMIs on one occasion during the period of the work programme. |
| | | **M2.4:** Determine the gravitational acceleration in the Kibble balance laboratory in collaboration with NMIs. This will require absolute gravimeter(s) to be brought to the BIPM from NMIs that have successfully participated in the most recent comparison of absolute gravimeters, CCM.G-K2.XXXX. To verify the stability of the spatial gravity gradient in the laboratory; the replacement of the relative gravimeter is planned. |
| | | **M2.5**: Design and construct a prototype apparatus that implements the equal-arm balance (see M2.1) design as the basis for a compact Kibble balance for use at masses of 500 g and below. (For planned CBKT activities see PMD-CBKT2). |

# TIME METROLOGY

### Activities in the field of time metrology

The main mission of the BIPM in the field of time is the realization and dissemination of Coordinated Universal Time (UTC), based on the computation of International Atomic Time (TAI) with the contribution of about 450 atomic clocks maintained in about 80 laboratories distributed world-wide. UTC is the international reference time scale, and it ensures approximate agreement with the time derived from the irregular rotation of the earth.

Continuous improvements are carried out to realize TAI, UTC and its rapid approximation (UTCr), at the best level of accuracy and stability, whilst taking advantage of the clocks and time transfer techniques developed by NMIs and RMOs. Research activities are carried out in the Time Department, including the maintenance of a time laboratory which is able to provide reference GNSS receivers for the measurement of the NMI time transfer equipment delays.

During the Work Programme 2024-2027, research on the improvement of UTC will include support towards the development and optimal use of optical frequency standard measures and their high accuracy comparison at distance. This will lead to a significant improvement in TAI and UTC as well as to a possible redefinition of the SI second which, in turn, will require an improved knowledge of the Earth's gravitational potential. In addition, the department will pursue an increase in the reliability of the computation process as well as the distribution of the results in digital, machine readable, formats.

The quality of UTC is based on the quality of the input data from the contributing laboratories. To underpin this principle, the department participates in the CBKT activities to support accurate and reliable realizations of the local approximations UTC($k$), from which a more accurate and reliable UTC can result.

The Time Department promotes the use of UTC as unique reference time scale by all countries, all GNSS providers, and in the different applications including digital networks and space systems, in liaison with other international organizations and committees related to time scales and timekeeping activities.

The drivers of the research and development of the department are established in line with the roadmap and strategy of the CCTF.

**Strategy for time metrology**

- To calculate, disseminate, and improve the world reference time scale UTC through the integration of data from atomic clocks and time transfer measurements at the NMIs (including tests and inclusion of new types of standards and their comparison at long distance).
- To support the development and best use of the new optical frequency standards and their high stability measurements at distance for the improvement of UTC and to support the future redefinition of the second.
- To promote the importance and benefits of a unique reference time scale ensuring traceable access to the SI second to the international industrial and scientific communities and other involved international organizations.

| N | Project Code | Deliverables and Activities |
|---|---|---|
| **Generation of TAI/UTC, stable and accurate international references** | | |
| **1.** | **Time-U1** | **U1.1: Computation of UTC, $UTC_r$, TT, and KC for Time and Frequency transfer**<br>*Participating laboratories in UTC: 83 (2022)*<br>*Participating laboratories in $UTC_r$: 58 (2022)* |
| | | *Monthly* provision of the international reference time scale UTC, through the computation of International Atomic Time, and the distribution and publication of all the related reference data, continuously improving the metrological quality.<br>The results giving the differences between UTC and the local real time realizations UTC(*k*) of the contributing laboratories are published in the monthly BIPM *Circular T*. Data are also provided to the KCDB for the key comparison CCTF-K001.UTC. The process to obtain UTC and its validation is part of the BIPM Quality System.<br>*Weekly* provision of a rapid solution called UTCr computed and published on Wednesdays on a subset of UTC laboratories sending data daily.<br>*Annual* provision of the Terrestrial Time, TTBIPM, with optimized long-term accuracy, *a posteriori*, for the studies requiring the best performance over the long term. |
| | | **U1.2: Development and optimization of the algorithms and tools for UTC and other time product computation** |
| | | The algorithms developed, maintained, and continuously improved by the Time Department are devoted to:<br>– the ensemble time scale formation,<br>– the accurate processing of the time and frequency transfer measures,<br>– the steering by the use of primary and secondary frequency standards.<br>The main goals for the development are related to the jump detection, link comparison and switching, redundant and multi-constellation GNSS time transfer, with optimal processing of GNSS phase measurements, as well as optimization of the individual clock statistical model.<br>The use of a GIT(*) laboratory capability will be consolidated within the CCTF-WGTWSTFT for collaborative work on the SDR software development and validation. A similar tool will be used for the CBKT programme.<br>The experience on time transfer based on optical fibres, their calibration, and comparison with other time transfer techniques will be consolidated.<br>The contribution of a secondee would be fundamental to ensure the necessary progress of all these activities.<br>The continuous improvement of UTC, UTCr, and related products is also based on the development of appropriate software tools, ensuring reliability of the available computational resources. To this aim the main goals are:<br>– further automation of the computation system to augment the automatic checks on input and output data to improve the reliability of the results,<br>– Use of a redundant and secure ensemble of servers based on virtualization technology,<br>– Use of a database structure for the time transfer and calibration data to provide machine readable access to the results to the contributing NMIs.<br>**GIT is a free and open-source distributed version control system* |

| | | |
|---|---|---|
| **Characterization of delays in time transfer equipment operated in UTC contributing laboratories** | | |
| **2.** | **Time-D1** | **D1.1: Maintenance of BIPM travelling receivers, measurement reference, and procedures for calibration. Realization of delay measurement campaigns for specific laboratories (GNSS G1, TWSTFT, others)** |
| | | A set of (absolutely) calibrated reference GNSS receivers is maintained to ensure the overall coherency of the time transfer delay calibration in the UTC time links (GNSS, TW, others, …) of all the contributing laboratories. Some of these reference receivers are continuously travelling to selected laboratories for on-site delay comparison. This activity requires:<br>1. Characterization, study, and experimental tests of equipment compatible with those operated in NMIs.<br>2. Guidance documents for the travelling box installation and measurement for the delay measurement of UTC laboratory equipment (G1 GNSS, TW, others).<br>3. Organization of the travelling campaigns (requiring the shipping of the BIPM travelling system without staff) to about 10-15 selected laboratories, usually every other year.<br>4. data analysis, uncertainty evaluation, publication of the report and application to UTC computation.<br>Access to a "dark fibre" will be rented to connect the BIPM to the nearest point in the NMI network to facilitate improved calibration of receiver delays, high-stability measurement of PSFS, and comparison with other high-stability time transfer techniques. The establishment of this link involves operational costs that will depend on telecom suppliers in the Sèvres area. It will only be realized if a good balance between costs and benefits can be reached.<br>The time laboratory also ensures the provision of a frequency reference to the other BIPM laboratories. The dissemination of this frequency signal and the related internal calibrations are part of the BIPM Quality System. |
| | | **D1.2: Coordinating measurement campaigns with the RMOs for GNSS G2, linking results to the BIPM G1 reference, and other BIPM coordinated campaigns** |
| | | For the UTC laboratories subsequently visited by the previous group of G1 laboratories, the BIPM has the role to:<br>– Provide guidelines,<br>– Validate the calibration reports and their application in UTC computation. |
| **Use of very accurate optical frequency standards - Support to the redefinition of the SI second** | | |
| **3.** | **Time-O1** | **O1.1: Optimal use of optical standard measurements in TAI/UTC, support to NMIs and CCTF in the development of optical frequency standards and advanced time and frequency transfer techniques in TAI/UTC** |
| | | New optical standards as well as a new time and frequency comparison in the optical domain call for an update of the TAI/UTC data processing to optimize the contribution of these new measures. In particular:<br>a. Development of the statistical treatment of measures that may have peculiarities (dead time, long period of missing data, only frequency comparison…) and the uncertainty evaluation.<br>b. Adaptation of the TAI algorithm for the optimal introduction of the optical frequency standard measurements.<br>c. Collaborate with NMIs and the CCTF for standardization of measurement process, data format, and to set up calibration techniques and guidelines.<br>These additional activities would require additional effort that the BIPM staff could ensure only at a very basic level. To face the new challenges with appropriate resources and optimizing the use in TAI/UTC, the support of a full time secondee is necessary. In case this support should not be available, only a limited activity can be ensured.<br>The department will also contribute to the activities illustrated in the CCTF roadmap for the redefinition of the second. |

# CHEMICAL METROLOGY

### Activities in the field of Chemistry

The BIPM chemistry laboratory activities support the CCQM 2021-2030 strategy through the provision of comparisons for laboratories with established metrology programmes and knowledge transfer programmes for those with programmes in development. Its activities also include provision of reference data for the application of chemical reference methods. The facilities maintained within the department support these activities for gas standards for air quality and global atmospheric monitoring, and primary calibrators for clinical chemistry and laboratory medicine, food analysis, environmental analysis, forensics and pharma.

The development and provision of unique on-demand comparison services for NMI gas standards for air quality and global atmospheric monitoring is a focus within the Work Programme 2024-2027, and a response to evolving requirements at the national level. The period will also see an expansion of the laboratory-based knowledge transfer programmes offered on organic standards to cover pesticide and veterinary drug residues and a broader range of mycotoxins in response to global growth in NMI programmes addressing food safety measurement requirements. There will also be a continued focus on comparisons for peptide and protein calibrants for *in vitro* diagnostic applications and knowledge transfer programmes for those developing such services in response to globally increased requirements for accurate *in vitro* diagnostic testing.

**Strategy for chemical metrology**

To provide and coordinate comparisons of national measurement standards for:

- **greenhouse gases**, demonstrating consistency at levels required to support national energy and environmental priorities.
- **major air quality gases**, demonstrating consistency at levels required to support national health and environmental priorities.

To provide the basis for metrological traceability for organic and biochemical measurements by coordinating comparisons of primary reference materials for:

- **small organic molecules**, demonstrating consistency at levels required to support reference measurement systems for laboratory medicine, food safety, forensics, environmental analysis and pharma.
- **peptides and large organic molecules**, demonstrating consistency at levels required to support reference measurement systems for laboratory medicine and health care sectors.

To provide the knowledge transfer activities in the fields where it coordinates comparisons, providing support for national metrology programmes addressing:

- **Food Safety,**
- **Laboratory Medicine,**
- **Clean Air.**

To promote and develop the use of SI traceable standards and measurements (available from the NMIs) with intergovernmental stakeholders.

## International equivalence of gas standards for air quality and global atmospheric monitoring

| N | Project Code | Deliverables and Activities |
|---|---|---|
| **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<br>*NMI Participations: 50* | | |
| **1.** | **Chem-G1** | **G1.1:** 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.<br>*NMI participations: 20* |
| | | **G1.2:** Installation and validation of new SRP electronics systems for **National Ozone Standards**, on request from NMIs participating in BIPM.QM-K1. |
| | | **G1.3:** Coordination of reactive gas/air quality comparisons (development and implementation of on-going comparison on **$NO_2$ standards, BIPM.QM-K6**), based on state-of-the-art dynamic standard reference facilities at the BIPM, enabling NMIs to demonstrate equivalence of their standards for air quality and vehicle emission verification measurements.<br>*NMI participations: 30* |
| **International reference facilities and comparisons of GHGs** | | |
| Coordination of comparisons to determine and improve the international equivalence of radiative forcing gases<br>*NMI Participations: 52* | | |
| **2.** | **Chem-G2** | **G2.1:** Coordination of **BIPM.QM-K2.a and b** on Carbon dioxide in air and nitrogen**,** based on a unique manometric reference comparison facility maintained at the BIPM, providing on-demand comparisons of gravimetrically prepared NMI standards for greenhouse gas and emissions measurement calibrations, and core comparisons for NMIs developing binary gas mixtures.<br>*NMI participations: 20* |
| | | **G2.2:** Establishment and coordination of **BIPM.QM-K5** on $CO_2$ in air GHG Scale comparisons, providing on-demand comparisons for NMIs developing and maintaining GHG scale standards for background, emission and flux determinations, based on scales and facilities maintained at the BIPM, with SI value assignment provided through the BIPM manometric facility and a database consultable for scale and standard relationships.<br>*NMI participations: 12* |
| | | **G2.3:** Coordination of $CH_4$, $N_2O$ GHG comparisons, and completion of **CCQM-K84.2023** on methane at ambient levels, based on comparative measurements undertaken at the BIPM, and supporting NMI standards for greenhouse gas and emissions measurement calibrations.<br>*NMI participations: 20* |

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| **International reference facilities and comparisons for isotope ratios** | | |
| Coordination of comparisons to support the international infrastructure for isotope ratio standards including for measurements on radiative forcing gases.<br>*NMI Participations: 52* | | |
| **3.** | **Chem-G3** | **G3.1:** Establishment and coordination of **BIPM.QM-K3** on $CO_2$ isotope ratios in pure $CO_2$ gas, based on dedicated $CO_2$ gas sample generation facilities and an IRMS-based comparison facility with traceability to carbonate reference methods and international standards, supporting NMIs providing carbon isotope ratio scale standards, highest accuracy $CO_2$ amount fraction standards with on demand comparison and calibration services.<br>*NMI participations: 40* |
| | | **G3.2:** Establishment and coordination of **BIPM.QM-K4** on $CO_2$ isotope ratios in $CO_2$ in air mixtures, based on cryogenic separation and IRMS reference facilities maintained at the BIPM with traceability to carbonate reference methods and international standards, supporting NMIs providing $CO_2$ in air isotope ratio standards and amount fraction standards, with an on-demand comparison service.<br>*NMI participations: 12* |
| | | **G3.3:** Develop methods for reduced uncertainties for isotope ratio measurements and comparisons of $CO_2$, based on preparation of $CO_2$ mixtures with well-established equilibration properties, and characterization by IRMS and IRIS methods as pure gases and in air matrix, and development of models to deal with non-stoichiometric distributions of isotopes in standards samples. Methods to be applied to on-going comparisons for $CO_2$ isotope and amount fraction, and support of NMI activities in development of reduced uncertainties in SI traceable values. |

## International equivalence of organic primary calibrators for clinical chemistry and laboratory medicine, food analysis, environmental analysis, forensics and pharma

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| **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.<br>*NMI Participations: 40* | | |
| **4.** | **Chem-O1** | **O1.1:** Completion of purity comparison **CCQM-K148.c** (MW 500-1000 Da) with, Draft A, B and Final Reports completed and providing a core comparison enabling NMIs to demonstrate capabilities and continued improvement in providing SI traceability for small molecule organic analytes.<br>*NMI participations: 20* |
| | | **O1.2:** Coordination of **CCQM-K148.a.1** (Non-polar organic (MW 75-500 Da) with mass-balance and qNMR value assignment at the BIPM, and homogeneity and stability analysis, providing a core comparison enabling NMIs to demonstrate capabilities and continued improvement in providing SI traceability for small molecule non-polar organic analytes.<br>*NMI participations: 20* |
| | | **O1.3:** Development of purity evaluation guidelines for pesticide, drug and mycotoxin samples, supporting knowledge transfer and BIPM on-line e-learning, modules and comparisons for NMIs with developing programmes in metrology on organic analysis in support of food safety. |

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| **Small molecule organic primary reference comparisons (calibration solutions)** | | |
| Coordination of comparisons standards and methods for organic calibrants.<br>*NMI Participations: 60* | | |
| **5.** | **Chem-O2** | **O2.1:** Coordination of calibration solution comparison **CCQM-K78.a.1** (Multi-component aqueous solution), based on BIPM gravimetrically prepared samples with multi-component polar analytes, with the mass fractions of primary reference materials quantified within the BIPM purity measurement facilities, providing a core comparison for polar organic calibration solutions for NMIs.<br>*NMI participations: 20* |
| | | **O2.2:** Coordination of calibration solution comparison **CCQM-K78.b.1** (Multi-component, non-polar), based on BIPM gravimetrically prepared calibration solutions with multi-component non-polar analytes, with the mass fractions of primary reference materials quantified within the BIPM purity measurement facilities, providing a core comparison for non-polar organic calibration solutions for NMIs.<br>*NMI participations: 20* |
| | | **O2.3:** Coordination of **CCQM-K154.e** (Ochratoxin A), and development of calibrant assessment guidelines, and qNMR internal standard reference documents, providing support to NMIs developing and providing measurements standards in support of food safety and extending the scope of applicability of qNMR for SI traceable measurements on organic analytes, and support for NMI measurement services and their comparisons.<br>*NMI participations: 20* |
| **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<br>*NMI Participations: 45* | | |
| **6.** | **Chem-O3** | **O3.1:** Completion of **CCQM-K155.d** Primary peptide calibrator (5 kDa to 10 kDa), based on mass-balance and protein impurity corrected amino acid analysis characterization performed at the BIPM, providing a core comparison of capabilities for value assignment of primary reference material straight chain peptides with molecular weights between 5 kDa to 10 kDa at NMIs, and underpinning reference measurement systems for parathyroid hormone (PTH) measurements and their development for diagnosis and patient monitoring.<br>*NMI participations: 15* |
| | | **O3.2:** Coordination of peptide/protein purity key comparison **CCQM-K115.e**, intact proteins MW > 10 kDa, based on methodologies developed in running CCQM-P216, on SARS-CoV-2 monoclonal antibody quantification, and providing a core comparison of capabilities for value assignment of primary reference methods for proteins with molar masses of greater than 10 kDa at NMIs, and underpinning reference measurement systems diagnosis and therapeutics.<br>*NMI participations: 15* |
| | | **O3.3:** Coordination of peptide/protein purity key comparison **CCQM-K115.a.2**, 1 kDa < peptide < 5 kDa **,** based on mass-balance and protein impurity corrected amino acid analysis characterization performed at the BIPM, providing a core comparison of capabilities for value assignment of primary reference material peptides with molecular weights between 1 kDa and 5 kDa, and underpinning reference measurement systems for protein diagnostics.<br>*NMI participations: 15* |

# IONIZING RADIATION METROLOGY

**Activities in the field of ionizing radiation metrology**

The vision of the Ionizing Radiation Department is to reduce the burden of piloting comparisons, to build on the successful and established traceability schemes, to be the focal point to reduce the need for large scale comparison exercises and to work closely with strategic partners to increase the regional reach of the work. This work programme's focus is on moving to the next generation of techniques for comparing standards and realizing primary standards, working with stakeholders to optimize use of expensive facilities, adopting new technology to future-proof the methods used by the department and providing an efficient service for NMIs and DIs at the CCRI and RMO levels.

The external drivers for ionizing radiation metrology continue to evolve and expand. Nuclear medicine development is driven by the need for early diagnosis and the demand for better cancer therapies; the world-wide market for nuclear medicine is predicted to grow from 7.4 billion USD in 2021 to 14 billion USD in 2026. Decommissioning of the first-generation nuclear power reactors (199 power reactors have already shut down and between 200 to 400 reactors are scheduled for decommissioning in the next 20 years) as well as the development of the nuclear forensics, lead to growing needs in radionuclide metrology for both environmental and nuclear safety considerations.

The rising incidence of cancer (the World Health Organization estimates that the number of new cases of cancer per year will increase by 70 % over the next 20 years) is driving expansion in the use of external beam radiotherapy, which uses increasingly complex technologies, and brachytherapy, with a shortfall of several thousands of radiotherapy machines in the developing world. The International Atomic Energy Agency (IAEA) has noted that developments in imaging technology are fundamentally changing radiation therapy. Proton therapy is predicted to expand, with the global market reaching 3.6 billion USD by 2026, as well as new approaches such as FLASH radiotherapy using high-energy electron beams.

These societal challenges are placing increasing demands on NMIs/DIs for accurate primary standards in ionizing radiation and for their dissemination to secondary standards held by reference laboratories, hospitals, the nuclear industry and security services. The demands are international, with clinical trials of new radiopharmaceuticals, for example theranostics and targeted alpha therapy, being carried out in several countries, and the safe disposal of radioactive waste being of global concern (radioactive waste knows no borders). The need to demonstrate the equivalence of primary standards has never been more pressing but NMIs/DIs that volunteer to pilot comparison exercises face a unique problem: the regulatory, logistical and practical burden of shipping hazardous materials or delicate reference standard instruments. This is one of the key drivers behind the development of remote-controlled systems and robust transportable instruments, including digital electronics, such as the SIRTI.

The BIPM will continue to find creative solutions in exploring the possibility of new dosimetry services at off-site facilities. The development of standards allowing the BIPM to provide comparisons and calibrations targeting the changing demands of new radiotherapy technologies and treatment methods will be investigated. In the field of radionuclides, the number of isotopes of interest for NMIs and DIs is both increasing and becoming significantly more challenging, as these institutes establish and provide more and more services addressing short-lived elements and low energy beta- and alpha-emitters.

## Strategy for ionizing radiation metrology

Provide the high-precision / high accuracy services that enable metrology institutes to compare or calibrate national standards that underpin global metrology for healthcare and radiation protection dosimetry, with an increased emphasis on supporting emerging metrology institutes and dosimetry for new treatment modalities such as radionuclide therapy.

- *To expand the use of the comparison and calibration dosimetry services for low-, medium- and high-energy photons and for brachytherapy, particularly for emerging metrology institutes.*
- *To coordinate comparison services for NMIs in the emerging field of dosimetry for radionuclide therapy.*

Work with the CCRI and the RMOs to develop new services to demonstrate the equivalence of standards of new radionuclides for nuclear medicine and difficult-to-measure radionuclides. For existing services, the focus is on improving operational efficiency.

- *To develop new high-precision comparison services to cover difficult-to measure radionuclides such as electron capture radionuclides and radionuclides in complex decay chains, designing new instrumentation where existing instruments are not suitable.*
- *To work with Regional Metrology Organizations to introduce regional implementations of the SIRTI and exploit recent developments in portable TDCR, to provide a regional network of instruments to ensure comparability of radioactivity standards.*

Work with stakeholders including other international organizations and RMOs to provide capacity building / knowledge transfer opportunities, particularly for countries and economies with emerging metrology systems.

- *To expand the service for coordinating / co-piloting comparison exercises, particularly for developing institutes and where access to major external facilities is needed (for example proton therapy, mass spectrometry, quantitative imaging).*
- *To work with stakeholders (such as the IAEA and the RMOs) to develop a comprehensive capacity building / knowledge transfer programme for ionizing radiation metrologists.*
- *To continue the programme of secondments including the use of part-time virtual secondments.*

| N | Project Code | Deliverables and Activities |
|---|---|---|
| **Radiation Dosimetry** | | |
| **1.** | **IR-D1** | **International reference system for x-ray dosimetry**<br>Underpinning the international equivalence of national standards for radiotherapy, diagnostic x-rays, mammography and radiation protection, through the provision of comparison and calibration services.<br>*Participation: 25 NMIs* |
| | | **D1.1:** Validation of national primary standards through bilateral comparisons and traceability of national secondary standards through calibrations: air kerma for low energy (BIPM.RI(I)-K2), medium energy (-K3) and mammography (-K7); absorbed dose to water for medium energy (-K9).<br>**D1.2:** Quality assurance to demonstrate the high accuracy and long-term stability of the BIPM primary standards and reference x-ray beams for air kerma and absorbed dose to water. Continual improvement of the BIPM standards and x-ray facilities to assure long-term reliability and compliance with evolving regulations and norms.<br>**D1.3**: Development of a new reference low energy x-ray facility to improve the efficiency and assure the long-term provision of the existing service. |

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| **2.** | **IR-D2** | **International reference system for gamma-ray dosimetry**<br>Underpinning the international equivalence of national standards for radiotherapy, brachytherapy, radiation protection and radio-sterilization through the provision of comparison and calibration services.<br>*Participation: 40 NMIs* |
| | | **D2.1:** Validation of national primary standards through bilateral comparisons and traceability of national secondary standards through calibrations:<br>– BIPM $^{60}$Co beam: air kerma (BIPM.RI(I)-K1), absorbed dose to water (-K4),<br>– Off-site $^{137}$Cs beam (IAEA): air kerma (-K5),<br>– Off-site $^{192}$Ir HDR source: travelling instrument for comparisons of reference air kerma rate standards (-K8).<br>**D2.2:** Quality assurance to demonstrate the high accuracy and long-term stability of the BIPM primary standards and reference gamma-ray beams for air kerma and absorbed dose to water. Continual improvement of the BIPM standards and gamma-ray facilities to assure long-term reliability and compliance with evolving regulations and norms. |
| **3.** | **IR-D3** | **International reference system for high-energy radiation dosimetry**<br>Underpinning the international equivalence of national standards for high-energy radiation beams to meet the expanding and emerging needs in dosimetry for radiotherapy, through the provision of comparison and calibration services.<br>*Participation: 15 NMIs* |
| | | **D3.1:** Validation of national primary standards through bilateral comparisons and traceability of national secondary standards through calibrations at the off-site DOSEO facility: absorbed dose to water for high-energy photon beams (BIPM.RI(I)-K6).<br>**D3.2:** Quality assurance to demonstrate the high accuracy and long-term stability of the BIPM primary standard (graphite calorimeter) and transfer instruments for absorbed dose to water. Continual improvement of the BIPM standards and equipment to assure long-term reliability.<br>**D3.3**: Development of a new calorimeter standard for high-energy photons, with a smaller core aimed to reduce uncertainties.<br>**D3.4:** Extension of the comparison and calibration services to high-energy electrons at the off-site DOSEO facility, using the new calorimeter. |
| **Radionuclide Metrology** | | |
| **4.** | **IR-R1** | **International reference system for activity measurements of gamma-ray emitting radionuclides (SIR)**<br>Underpinning the international equivalence of national standards of gamma-ray emitting radionuclides for applications in nuclear medicine, the nuclear industry, nuclear physics, environmental protection, radiation protection and nuclear forensics, through the provision of BIPM key comparisons.<br>*Participations: 40* |
| | | **R1.1:** Provision of BIPM key comparisons (BIPM.RI(II)-K1) of national activity standards of gamma-ray emitting radionuclides using the high precision, high stability, SIR ionization chambers.<br>**R1.2:** Quality assurance and continual improvement to demonstrate the high precision and long-term stability of the SIR services and assure compliance with evolving regulations and norms.<br>**R1.3:** Transfer of the SIR services to the updated SIR device and measurement method, based on state-of-the-art instrumentation for measuring low currents, assuring the long-term continuity of the international equivalence of national standards. |

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| **5.** | **IR-R2** | **International reference system for activity measurements of short-lived gamma-ray emitting radionuclides (SIRTI)**<br>Underpinning the international equivalence of national standards of short-lived gamma-ray emitting radionuclides for particular applications in nuclear medicine and other domains, through the provision of BIPM key comparisons.<br>*Participations: 10* |
| | | **R2.1:** Provision of BIPM key comparisons (BIPM.RI(II)-K4) of national activity standards of short-lived gamma-ray emitting radionuclides using the high precision, high stability SIRTI scintillation counter, in remote or on-site modes.<br>**R2.2:** Quality assurance and continual improvement to demonstrate the high precision and long-term stability of the SIRTI services and assure compliance with evolving regulations and norms.<br>**R2.3:** Duplication of the SIRTI to a second device equipped with dedicated digital electronics, assuring the long-term continuity of the SIRTI services, and transfer of the SIRTI method to several RMOs.<br>**R2.4:** Extension of SIRTI services to new (3) radionuclides requiring metrological studies and cross-calibration with the SIR. |
| **6.** | **IR-R3** | **International reference system for activity measurements of alpha- and beta-particle emitting radionuclides (ESIR)**<br>Underpinning the international equivalence of national standards of alpha- and beta-particle emitting radionuclides for applications in nuclear medicine, environmental protection, radiation protection and nuclear forensics, through the provision of BIPM key comparisons.<br>*Participating NMIs: 25* |
| | | **R3.1:** Provision of BIPM key comparisons (BIPM.RI(II)-K5) of national activity standards of medium- and high-energy beta-particle emitting radionuclides using the high precision, high stability ESIR liquid scintillation counter based on the TDCR method.<br>**R3.2:** Quality assurance and continual improvement to demonstrate the high precision and long-term stability of the ESIR services and assure compliance with evolving regulations and norms.<br>**R3.3:** Extension of the services to cover additional radionuclides, low energy beta and alpha emitters, thanks to digital pulse processing systems. |

## COORDINATION AND INSTITUTIONAL LIAISON

**Coordination** activities aim to ensure the world-wide measurement system gives comparable, fit-for-purpose and internationally-accepted measurement results. The coordination tasks within the CIPM MRA will continue with a focus on the implementation of the FAIR *(Findable, Accessible, Interoperable and Re-usable)* principles by providing KCDB data that is compatible with the wider digital framework developed by the CIPM.

**Liaison** activities aim to foster cooperation with international organizations whose missions depend on sound measurement or who are part of the quality infrastructure and to promote the world-wide comparability of measurement. These activities will be managed in a way to respond effectively and in a timely way to opportunities (and threats) arising amongst the stakeholder community for metrology and measurement science. Highlights among the liaison activities will include increased interactions with the Regional Metrology Organizations (RMOs) and other relevant international bodies, in order to promote the benefits of the world-wide metrology infrastructure delivered through the international quality infrastructure. The liaison activities will be focused, in conjunction with the CIPM, on exploring models that facilitate participation of those states not yet participating in the activities of the BIPM. The trend of working ever more closely within a quality infrastructure framework is expected to continue.

**Strategy for coordination and institutional liaison**

To work with the CIPM to improve and promote the mutual recognition of national measurement standards and of calibration and measurement capabilities (CMCs) issued by NMIs (the CIPM MRA), particularly by operation of the KCDB and supporting the JCRB.

- *To provide the underpinning for the FAIR data and metadata, specifically focusing on the support necessary from the KCDB for digital calibration certificates, including evolution of the database and its machine-readable interfaces.*

To liaise with the NMIs of Member States, Associates and the Regional Metrology Organizations (RMOs).

- *To work with the CIPM and the Member States Representatives with a particular focus on liaising with existing Member States and the RMOs as models are explored and, potentially, implemented to facilitate participation of those states not yet participating in the activities of the BIPM.*

To work with the CIPM to promote the importance of the global comparability of measurements with international organizations of strategic importance to the mission (including the OIML, ILAC, ISO, WTO-TBT) and to work with them and others through Joint Committees.

- *To work towards better coordination and recognition of "Quality Infrastructure" (QI) and the central role of metrology within it amongst International Organizations and their stakeholders.*
- *To implement a strategy of shared representation with partner organizations.*

## Coordination activities

| N | Project Code | Deliverables and Activities |
|---|---|---|
| **Support for CCs (including provision of Executive Secretaries)** | | |
| **1.** | **PMD-C1** | Provision of CCEM (Electricity and Magnetism) Executive Secretary to support:<br>1. Two CCEM meetings<br>2. Annual working group meetings<br>3. Pro-active interaction on strategy and communication<br>4. Coordination of CCEM processes. |
| **2.** | **PMD-C2** | Provision of CCM (Mass and Related Quantities) Executive Secretary to support:<br>1. Two CCM meetings<br>2. Annual working group meetings<br>3. Pro-active interaction on strategy and communication<br>4. Coordination of CCM processes. |
| **3.** | **PMD-C3** | Provision of CCT (Thermometry) Executive Secretary to support:<br>1. Two CCT meetings<br>2. Annual working group meetings<br>3. Pro-active interaction on strategy and communication<br>4. Coordination of CCT processes. |
| **4.** | **PMD-C4** | Provision of CCU (Units) Executive Secretary to support:<br>1. Two CCU meetings<br>2. Annual working group meetings<br>3. Pro-active interaction on strategy and communication<br>4. Coordination of CCU processes. |
| **5.** | **Time-C1** | Provision of CCTF (Time and Frequency) Executive Secretary to support:<br>1. Organizing the CCTF bi/triennial meetings and more frequent meetings of the CCTF WG on Strategic Planning<br>2. Providing secretariat for CCTF and WGs<br>3. Pro-active interaction on strategy and communication<br>4. Key comparisons in time and frequency and other MRA activities<br>5. Contribution to the estimation of the recommended frequencies for the secondary representations of the second. |
| **6.** | **Time-C2** | Provision of CCL (Length) Executive Secretary to support:<br>1. CCL meetings<br>2. Participation in WGs<br>3. Pro-active interaction on strategy and communication<br>4. Coordination between NMIs for length related activities. Key comparisons in length, support to comparisons of stabilized lasers piloted by NMIs<br>5. Recommendation of standard frequencies and wavelength for the practical realization of the metre. |
| **7.** | **Time-C3** | Provision of CCAUV (acoustics, ultrasound and vibration) Executive Secretary to support:<br>1. Biennial CCAUV meetings and three WG meetings<br>2. Pro-active interaction on strategy and communication<br>3. Development of strategic plans<br>4. Coordinate review of CC and RMO comparison reports before publication<br>5. Related liaisons with RMOs and CTBTO. |
| **8.** | **Chem-C1** | Provision of CCQM (Chemistry and Biology) Executive Secretary to support:<br>1. Annual CCQM meetings (four plenary meetings) and meetings of eleven WGs (in presence and on-line) |

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| | | 2. Pro-active interaction on strategy and communication<br>3. Coordination of review of CC and RMO comparison reports before publication<br>4. Development and review of CCQM documents and guidelines<br>5. Organization and coordination of CCQM workshops. |
| **9.** | **Chem-C2** | Provision of CCPR (Photometry and Radiometry) Executive Secretary to support:<br>1. Two CCPR plenary meetings and associated WG meetings<br>2. Pro-active interaction on strategy and communication<br>3. Coordination of review of CC and RMO comparison reports before publication<br>4. Development and review of CCPR documents and guidelines. |
| **10.** | **IR-C1** | Provision of CCRI (Ionizing Radiation) Executive Secretary to support:<br>1. Biennial CCRI and sections I, II and III meetings<br>2. Regular meetings of seven working groups<br>3. Development of strategic plans<br>4. Co-ordination of engagement with RMOs. |
| **CIPM MRA coordination and provision of the KCDB** | | |
| **11.** | **ILC-C1** | 1. Coordination of the CIPM MRA mechanisms through the JCRB<br>2. Provision of the KCDB database and API (including Exec. Sec. of the JCRB)<br>3. Maintenance and minor updates for KCDB<br>4. Publication of comparison data and interventions on CMCs<br>5. Advising the CIPM MRA participants and mining the data for stakeholders. |
| **12.** | **ILC-C2** | Provision of JCRB Executive Secretary (Secondee position) to support:<br>1. Organization and participation in biannual JCRB meetings<br>2. Pro-active monitoring the JCRB CMC review process<br>3. Analysis and reporting on the efficiency and effectiveness of the JCRB CMC review process<br>4. Maintenance of the CIPM MRA documents suite, JCRB database, DI registry etc.<br>5. Interface with the KCDB office<br>6. Provision of assistance to CIPM MRA participants and RMOs. |
| **JCGM** | | |
| **13.** | **ILC-C3** | Provision of JCGM and JCGM WG2 Executive Secretary and rapporteur (JCGM - one annual meeting, JCGM WG2 - two annual meetings), general support to JCGM, representation in JCGM WG2. |
| **14.** | **IR-C2** | Provision of the Scientific Secretary for JCGM WG1 and support including:<br>1. *Rapporteur*<br>Two annual meetings. |
| **JCTLM** | | |
| **15.** | **Chem-C3** | Support for:<br>1. JCTLM Executive and WG meetings (in presence and on-line)<br>2. JCTLM Database entry/nomination review process<br>3. Maintenance and continued development of the JCTLM Database<br>4. JCTLM Stakeholder meetings<br>5. Development of on-line programmes on JCTLM nomination and review processes. |

## Institutional liaison

| N | Project Code | Deliverables and Activities |
|---|---|---|
| **Liaison with Member States, Associates, the CIPM and RMOs** | | |
| **16.** | **ILC-L1** | 1. Support to Member States and Associates, CIPM and the BIPM Director<br>2. Promotion of the Metre Convention and support to potential Member States and Associates<br>3. Supporting the CIPM in its activities towards universal adherence to the Metre Convention<br>4. Support for and representation to RMOs (AFRIMETS, APMP, COOMET, EURAMET, GULFMET and SIM). |
| **17.** | **PMD-L1** | 1. Representation of the BIPM in the CODATA Task Group on Fundamental Constants (4 meetings)<br>2. Representation of the BIPM in the Executive Committee of the CPEM (Conference on Precision Electromagnetic Measurements) (4 meetings)<br>3. Representation of the BIPM in RMO Technical Committee meetings in Mass, Electricity and Thermometry (8 meetings). |
| **18.** | **Time-L1** | Coordination and promotion of time activities for the advancement in the understanding, development, and applications of time scales.<br>Importance of a unique world-wide reference time scale and the correct implementation in all applications, including scientific projects, and industrial systems, for example digital networks and satellite systems.<br>1. Work with scientific organizations such as the IGS, and ICG in the GNSS field, and the IAU, IUGG, IERS, URSI<br>2. Work with industrial application organizations as the ITU. |
| **19.** | **Chem-L1** | 1. Maintain working relationships with IFCC, ICSH, ISO TC 212, WHO, IUPAC, IAEA, WMO, ISO TC 207, ISO TC 146, WADA, Codex in support of CCQM and JCTLM activities<br>2. Support liaison activities required for the CCQM Task Group for Ozone Cross Section to facilitate global implementation of CCQM recommended cross section values for surface ozone monitoring world-wide<br>3. Support liaison activities required for the CCQM-GAWG Task Group on GHG Scale Comparisons to facilitate expansion of the global measurement infrastructure for atmospheric GHG measurements in support of emission inventory verification<br>4. Support liaison activities required in support of CIPM Sector Task Group initiatives in the field of: health, food safety, and environment and climate. |
| **20.** | **IR-L1** | 1. International Commission on Radiation Units (ICRU) (Commissioner and sponsor of Report Committees)<br>2. International Atomic Energy Agency (IAEA) (SSDL Scientific Committee)<br>3. International Committee for Radionuclide Metrology (ICRM)<br>4. ISO (TC 85/SC 2 and working group meetings). |
| **Supporting NMI Directors meeting and RMO Chairs/Secretariat** | | |
| **21.** | **ILC-L2** | 1. To work with the panel of NMI Directors to organize an annual meeting at the BIPM<br>2. Development of a global perspective on key issues<br>3. Provide focused support for states with emerging metrology systems<br>4. Facilitate annual meetings of the BIPM and RMO Chairs. |

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| **Liaison with strategic partners** | | |
| **22.** | **ILC-L3** | Institutional liaison with International/intergovernmental organizations/Quality Infrastructure players:<br>– INetQI, OIML, UNIDO, UNESCO, ILAC, ISO, OECD, WTO, World Bank,<br>– institutional liaison with other international organizations as required. |
| **Young metrologists' foresighting exercise** | | |
| **23.** | **ILC-L4** | Facilitating visionary ideas for future opportunities and challenges via workshops, debates and interviews with young metrologists to encourage strategic thinking on long-term issues and challenges.<br>This exercise will be conducted bottom-up in collaboration with RMOs before being brought into a common perspective for presentation at the 150th anniversary of the signing of the Metre Convention (20th May 2025). |

# COMMUNICATION AND PROMOTION

**Strategy for communication and promotion**

**To communicate effectively (with Member States, potential new Member States and other key stakeholders) about the Metre Convention and the SI.**

- To follow the CIPM's policy on "open access" BIPM and CC documents.
- To build on the success of World Metrology Day, doubling participation through all media.
- To promote the achievements of the BIPM over 150 years and to launch the CIPM strategy for 2030+ at a major event on the 150th anniversary of the signing of the Metre Convention (20th May 2025).

**To inform the science community, the wider scientific public and decision makers on matters related to metrology and its benefits through publications, meetings and the BIPM website.**

- To identify (with the CIPM) topics of importance to the metrology community to be addressed at BIPM Workshops and/or Focus Issues of *Metrologia.*
- To adapt effectively to the rapidly changing world of electronic media to ensure that the BIPM continues to deliver services effectively and remains up to date with evolving technologies (including on-line meetings, ensuring the authenticity of documents and signatures, enabling on-line voting, etc.)
- To ensure the success of *Metrologia* as the key scientific publication for high-level metrology and to broaden its reach by attracting metrological papers from disciplines that have not historically looked to publish in *Metrologia*; to monitor and adapt to the move towards "open access" for journals.

| N | Project Code | Deliverables and Activities |
|---|---|---|
| **Promotion, reporting, publications and the BIPM website** | | |
| **1.** | **ILC-CP1** | Provision of BIPM internet:<br>1. Continue to adapt effectively to the rapidly changing world of electronic media to ensure that the website continues to deliver services effectively and portrays an up-to-date image of the BIPM.<br>2. Develop web services as required to meet the needs of the BIPM, CIPM and CCs.<br>3. Adapt the site to display landing pages for documents published by the BIPM and identified with DOIs (see ILC-DT1.2). |
| **2.** | **ILC-CP2** | Promotion and Enhancement:<br>1. Creation of newsletters, posters, and videos in support of the BIPM's programmes.<br>2. Creation of a repository of BIPM images.<br>3. Work with the Communications teams of the RMOs to pool resources and maximize the impact of both regional and world-wide campaigns.<br>4. Develop the BIPM's presence on social media such as YouTube, LinkedIn and Twitter. |
| **3.** | **ILC-CP3** | Publications:<br>1. Publish meeting reports - including drafting/minuting, editing, translation into French, typesetting, and printing as required – for the BIPM, CIPM, and CGPM as well as the Joint Committees.<br>2. Editing, translation into French if required, typesetting and publication of other key reports and documents.<br>3. Editing of papers by the BIPM staff for publication in the scientific literature.<br>4. Register the BIPM's publications in an external repository, to improve their Findability and Accessibility (see ILC-DT7). |

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| **4.** | **ILC-CP4** | 1. Editing and publication of *Metrologia*<br>2. Ensure the success of *Metrologia* as the key scientific publication for high-level metrology, with a robust editorial team and appropriate publishing partner.<br>3. Liaise with the CIPM and CCs to identify topics of interest, as well as publications that should be included in the *Guides, Standards and Conventions* section.<br>4. Produce Focus Issues on key topics of interest.<br>5. Maintain the journal's viability taking account of evolving trends such as towards open-access publishing.<br>6. Encourage the publication in *Metrologia* of open-access review papers by senior scientists, through funding the Article Processing Charge for selected papers.<br>7. Celebrate the journal's 60th anniversary in 2025, alongside celebrations of the anniversary of the *Metre Convention*.<br>8. Provision of external Deputy editor support. |
| **5.** | **ILC-CP5** | Journal subscriptions (on-line or hard copy); pay-per-view access (or rental) of individual scientific articles; reference books for BIPM staff. |
| **World Metrology Day** | | |
| **6.** | **ILC-CP6** | Build on the success of World Metrology Day (WMD), doubling participation through all media (Project run jointly with OIML):<br>1. Provision of WMD Website content:<br>– Poster (in consultation RMOs and with a selected NMI)<br>– Directors' messages and press release<br>– Poster and events listings for all participating countries<br>2. Participation in at least four national events and hosting events at the BIPM for Embassy Representatives.<br>3. Promoting World Metrology Day with International, Regional and National Stakeholders via social media. |
| **Workshops on key topics** | | |
| **7.** | **ILC-CP7** | To identify (with the CIPM and NMIs) topics of importance to the metrology community to be addressed at BIPM Workshops. |

# DIGITAL TRANSFORMATION AND NEW DIGITAL SERVICES

Our aim is to develop expertise to become an anchor of trust for the digital transformation in metrology both in our own services and through support for the work of the CIPM and the wider community.

**Strategy for digital transformation**

**To develop a set of new high-quality web services that provide access to the data and on-line tools provided by the BIPM.**

- To support the needs for interoperable and reusable data services that are machine actionable.
- To develop and publish an Appendix to the SI Brochure addressing Core SI Data topics.
- To establish a working group to progress the digital transformation of BIPM services amongst the BIPM staff and including seconded experts from NMIs and liaison organizations when possible.

**To support the continuous development of the FAIR SI Digital Framework and other CIPM initiatives addressing the digital transformation of global measurements.**

- To develop a web portal based on the International Metrology Resource Registry (IMRR) to be able to meet needs for access to FAIR metrological data, Digital Calibration Certificates (DCCs) and other digital information that is key to the world-wide metrology community. To support the CIPM with the development of consensus on guidelines for FAIR implementation of data and metadata in metrology. To develop appropriate services of benefit for a wide section of the metrology community and their stakeholders – to become an 'anchor of trust'.

**To support the development of the NMI community by building the global capacity for digital transformation.**

- Organize and deliver capacity-building events focusing on digital transformation.
- Promote the CIPM's work on the use of the FAIR principles at NMIs.
- Hold regular webinars on topics of digital transformation.
- Work with the RMOs to facilitate the sharing of best practice (including case studies) amongst NMIs.

***Note on the proposed Digital Transformation projects***

*The requirements for Digital Transformation have been growing rapidly whilst this Work Programme has been developed. Many of the new requirements have been developed under the supervision of the CIPM's Task and Expert Groups on the SI Digital Framework. As these new digital functionalities have been conceived and specified, so have the opportunities for new and extended BIPM services. The following projects have been drafted to best capture these requirements and opportunities as they have been understood at the time of writing.*

*Two of the deliverables shown below have been marked "XXX" in place of an allocation to any of the BIPM Departments. This is because the scope and skills of the staff resources needed for them cannot yet be planned. They will be planned and agreed with the CIPM after the start of the Work Programme when the requirements have been defined.*

## Development of SI digital references

| N | Project Code | Deliverables and Activities |
|---|---|---|
| The basis for the SI Digital Framework proposed by the CIPM will be the provision of the reference data in digital format that provide the essential definition of the SI. These data will be a digital representation of the data that are currently included in the SI Brochure which includes all of the decisions made by the CGPM and the CIPM that underpin the SI. Additionally, databases and associated APIs will be developed in collaboration with Working Groups of each of the CCs to facilitate machine access to the *mises en pratique* for the base SI units. | | |
| **1.** | **DT1** | **ILC-DT1.1**: Development of the Unique SI Digital Reference Point. This will be the digital (machine-readable) resource from which all of the information about base units, derived units, prefixes and units accepted for use with the SI can be accessed digitally. |
| | | **ILC-DT1.2:** Development and maintenance of digital identifiers for key reference texts underpinning the Unique SI Reference Point (e.g., definitions, resolutions, CMCs, etc.) |
| **2.** | **DT2** | **Time-DT2**: Work with representatives of the CCL and the CCTF to provide machine-readable access to the standard frequencies that underpin the *mise en pratique* of the metre and the secondary representations of the second. The work will require the development of a special database and a custom API for each community. |
| | | **PMD-DT2**: Work with representatives of the CCT to provide machine-readable access to the agreed data for the fixed points of the ITS-90 that are specified in the *mise en pratique* of the kelvin. The work will require the development of a special database and a custom API. |
| | | **XXX-DT2:** Machine-readable access to the *mise en pratique* for the other base units will be put in place during the Work Programme. All of this activity will be undertaken in collaboration with working groups of each of the CCs involved to ensure that the facilities developed meet the needs of each user community. |

## Development of new digital services

| N | Project Code | Deliverables and Activities |
|---|---|---|
| The digital references developed by the activities above will provide the basis for new metrology services at the BIPM, in the NMIs and amongst sectors of society that use the SI. Such services will enable data to be available for analysis; they will improve data quality and increase reliability in its use. The projects below describe the actions planned to develop some of these new digital services at the BIPM. | | |
| **3.** | **DT3** | **ILC-DT3:** Undertake actions necessary to ensure that the KCDB data environment can provide machine readable data.<br>1) Upgrade of the KCDB database and creation of a back office to provide "Digital CMCs" (DCMCs) and support for DCCs.<br>2) Development and maintenance of an API for DCMCs. |
| **4.** | **DT4** | **Time-DT4:** Undertake actions necessary to ensure that the UTC and UTC-rapid data, and other services currently available from the BIPM Time Department database are available in a machine-readable format. |
| **5.** | **DT5** | **Chem-DT5:** Maintain machine readability of the JCTLM Database. Continue to deliver machine readability of the database with future operational updates. |
| **6.** | **DT6** | **ILC-DT6:** Develop new digital services, as required by the CIPM and CCs, including an extension of the machine-readability for the KCDB to access the results of key and supplementary comparisons (Appendix B). |

## Development of new data portal and support for components of the "Interoperability and reusability" resource layer

| N | Project Code | Deliverables and Activities |
|---|---|---|
| In order to provide efficient user access to the new digital services described in the projects above, they will be accessible directly and through the International Metrology Resource Registry (IMRR). This is already hosted on the BIPM website as a result of a collaboration with NIST. The project work proposed here will greatly extend the functionality of the IMRR to enable direct access (via APIs) to data held within the resources in its registry.<br>Additionality, this project will support the development of the interoperability and reusability resource layer of the SI Digital Framework. This layer includes the mapping, translation and ontology services needed to develop the "I" and the "R" of FAIR. | | |
| **7.** | **DT7** | **ILC-DT7:** Strengthen the International Metrology Resource Registry (IMRR) through liaison with the CCs to identify key data that could usefully be shared across the metrology community; encourage the inclusion of supporting data for digital calibration certificates (DCCs); further develop the IMRR in accordance with the FAIR principles to provide direct mining of resources through APIs. |
| **8.** | **DT8** | **XXX-DT8**: Enable the interoperability of representations of units of measurement in the community through development of a unit mapping service between broadly adopted unit of measurement representation systems (UMRSs) aligned with SI units; enable semantic representation of core concepts in metrology through development of ontologies as appropriate; develop metadata and a metadata schema ('m-layer') in support of digital translation between units and quantity kinds; support the JCGM-WG2 in their revision of the annotated VIM to meet the demands of machine readability, and machine-actionability where possible/appropriate. |

## Other Digital Transformation activities including support for the CIPM

| N | Project Code | Deliverables and Activities |
|---|---|---|
| **9.** | **DT9** | **PMD-DT9:** Development and support of DCCs for calibrations undertaken by all BIPM scientific departments (led by the Physical Metrology Department). |
| | | **ILC-DT9**: Coordination of the "Digital Discussion group" amongst BIPM staff working on Digital Transformation projects to ensure effective collaboration on these topics. |
| **10.** | **DT10** | **ILC-DT10:** Support for the work and meetings of the CIPM Digital EG and TG.<br>External consultancy to support the digital transformation activities described above. |

# IT SERVICES

**Activities in the field of Information Technology**

The BIPM activities are supported by a fully operational IT infrastructure and services (2 full-time equivalents).

Due to obsolescence and lifetime guarantee expiration, parts of the IT internal infrastructure, such as network infrastructure and the phone system, will have to be replaced during the work programme. This task will take into account new technologies such as phone integration with collaborative tools, Cloud storage, network technology evolution and security measures.

BIPM hosted web services, such as Web databases, need to be accessible to the outside world on a permanent and secure basis. This will require a reliable internal Web and database architecture.

The use of collaborative software, based on Cloud services, which significantly increases the opportunities for Working Group members to share information and documents, will be increased. The use of Cloud-based services for long-term archiving of data will also be considered.

In addition to these tasks, the typical spectrum of hardware, software, application maintenance and helpdesk services for scientific, financial and administrative computing, and computerized instrument operation as well as electronic communication will continue to be covered by IT services.

**Strategy for IT Services**

1. To provide essential IT infrastructure that is secure, reliable and affordable in the framework of increased use of Cloud-based services and collaborative work.
2. To help scientific departments in their move to digitalization and digital services by providing the necessary core environment, including secure and efficient software platforms.
3. To support the needs for remote calibration and remote computer-based experimentation by using communication standards, secure protocols, remote audio-video and collaborative tools and automated processes.
4. To provide a reliable infrastructure for a set of Web services for the metrological community, which give access to open-data, based on searchable criteria and which can be processed by any computer application in a fail-safe environment.
5. To continue to offer a high level of support, application maintenance and helpdesk quality to BIPM staff.

## IT Infrastructure; network, storage and security Infrastructure

| N | Project Code | Deliverables and Activities |
|---|---|---|
| **Network infrastructure**<br>Due to product lifetime and warranty expirations, parts of the BIPM IT datacentre infrastructure will have to be renewed during the period 2024-2027. The network core and edge devices, installed in 2013, are running out of maintenance contracts and need to be replaced in 2024. | | |
| **1.** | **INF-NNA** | **NNA.1:** Network core infrastructure |
| | | **NNA.2:** Network Edge infrastructure |
| | | **NNA.3:** Licenses and services |
| **Storage infrastructure**<br>Taking into account the increased use of Cloud-based storage as a major solution to host external data, the internal network storage, which hosts the IT services and the internal network data, will have to be updated in 2027 | | |
| **2.** | **INF-NSA** | **NSA.1/NSA.2:** Storage infrastructure |
| | | **NSA.3:** Backup infrastructure |
| | | **NSA.4:** Licenses and services |
| **Security infrastructure**<br>The network security infrastructure, which includes access control, application security, firewalls, virtual private networks (VPN), behavioural analytics, intrusion prevention systems, and wireless security will be reviewed, and parts of the infrastructure will be renewed. A security audit is planned for 2026. | | |
| **3.** | **INF-SEC** | **SEC.1:** Firewall Cluster and Intrusion Prevention System devices |
| | | **SEC.2:** Anti-virus Cloud Service |
| | | **SEC.3:** Multi-factor authentication services and devices |
| | | **SEC.4:** Licenses and services |
| | | **SEC5:** IT External Security review |

## IT Services; Web, databases, scientific and Cloud services

| N | Project Code | Deliverables and Activities |
|---|---|---|
| **Servers and virtualization platform for hosting services**<br>BIPM Web and all Intranet services rely on a virtualized platform that operates on dedicated hardware servers in a disaster recovery scheme. This allows redundancy of services as well as load balancer dispatch Web traffic among several virtual servers. As the five-year lifetime of hardware servers is the standard, they should be renewed in 2026. | | |
| **4.** | **SRV-SER** | **SER.1/2:** Virtualization platform and hardware hosts |
| | | **SER.3:** Load balancer Servers |
| | | **SER.3:** Licenses and services |

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| **Phone system services**<br>In the framework of revamping its phone service in 2024, IT services will prioritize a strong interaction between the classic phone service and O365 services in order to get a full cloud-based telephony solution that will offer new business services. | | |
| **5.** | **SRV-PH** | **PH.1:** Core infrastructure |
| | | **PH.2:** Dedicated Data Link |
| | | **PH.3:** Phone set |
| | | **PH.4:** Licenses and services |
| **Database, scientific and Cloud services**<br>Among other Web services, databases have a major role in serving the world-wide metrology community. The goal is to consolidate all these databases into a single repository which can be searchable and findable by the community.<br>O365 cloud services have a key role in sharing information among BIPM stakeholders, such as working groups. It has improved communications and provides new services that offer productivity gains. Other Cloud services will be implemented such as long-term data archiving and on-line web firewalling. | | |
| **6.** | **SRV-DB** | **DB.1:** Database core infrastructure |
| | | **DB.2:** Database infrastructure integration |
| | | **DB.3:** Licenses and support |
| **7.** | **SRV-NI** | National instruments site license and other sitewide scientific software licenses |
| **8.** | **SRV-O365** | **O365.1:** O365 Development |
| | | **O365.2:** Licenses and support |
| **9.** | **SRV-WEB** | **WEB.1:** Cloud Infinite archiving system |
| | | **WEB.2:** Web service firewall and security |

## Other activities: user helpdesk and application support - infrastructure administration and support

| N | Project Code | Deliverables and Activities |
|---|---|---|
| IT services provides a helpdesk with a high level of expertise for staff members in their daily use of IT materials and manages more than two hundred and fifty computers and peripheral devices. IT services, through application support, deliver the expected quality of service for all internal and external IT applications. | | |
| **10.** | **IT-HELP** | User helpdesk and application support |
| IT infrastructure and maintenance covers the entire IT network, storage and services by managing all the underlying platforms, preparing maintenance plans and upgrading schedules, identifying and resolving technical issues for more than forty services hosted on sixty virtual servers. | | |
| **11.** | **IT-ADM** | Infrastructure administration and maintenance |

## CAPACITY BUILDING AND KNOWLEDGE TRANSFER

The BIPM Capacity Building and Knowledge Transfer Programme aims to increase the effectiveness with which Member States and Associates engage in the world-wide coordinated metrological system. The Programme encompasses both core activities where building capacity for one participant brings clear benefits to the wider NMI community, and more focused activities, often topic-based, where the benefits rest primarily with the recipients of the activity. The CBKT Programme includes a wide range of delivery options including, but not limited to: workshop-based activities organized at the BIPM and at NMIs, usually in consultation with the RMOs; remote-learning on-line activities (on-line short courses, on-line technical exchanges and e-learning platform); and placements organized at the BIPM laboratories and at partner NMIs.

Activities are classed as capacity building when individual participating (and consequently their laboratories) are the prime beneficiaries. Where those involved have greater expertise, the knowledge flow is bi-directional. An example would be secondees working on the BIPM Work Programme, and such activities are classed as knowledge transfer. The boundaries between capacity building and knowledge transfer are not rigidly defined.

**Strategy for capacity building and knowledge transfer**

**To reinforce the international metrology system and to "balance the load" amongst the NMIs and support effective engagement with the international metrology community in developing countries. To support the efficient operation of the global measurement system.**

- To agree and implement a sustainable and balanced funding model that facilitates effective load sharing, based on programme funding and sponsorship for CBKT activities that can address different levels of need related to both the metrology system (CIPM MRA, JCTLM, UTC etc) and also specific laboratory expertise from the BIPM laboratories.
- Adapt the funding model in response to the CIPM's proposed initiative to encourage engagement by the remaining 80 or so nations that do not currently participate. This will be done in close collaboration with the RMOs.

**To support NMIs from Countries and Economies with Emerging Metrology Systems (CEEMS) to engage appropriately and effectively with the international measurement system.**

- To respond to the expected CGPM initiative to increase world-wide participation in the activity of the BIPM.
- To explore, with the RMOs, the concept of an integrated mentoring tool.

**To sustain a programme for visiting/seconded scientists to (and from) the BIPM.**

- To promote a timetable of opportunities for visiting scientists to take part in the work of all the BIPM laboratories. To develop laboratory-based knowledge transfer activities in the BIPM laboratories.

| N | Project Code | Deliverables and Activities |
|---|---|---|
| **BIPM CBKT Programme level strategy, development, and operation, including associated web and e-learning platforms and coordination with stakeholders**<br>*Over 80 % participation of Member States and Associates (as participants and lecturers)* | | |
| **1.** | **ILC-CBKT1**<br>– *4 workshop-based activities (BIPM and RMOs)*<br>– *4 cycles of laboratory-based placements at partner NMIs*<br>– *30 remote learning on-line activities*<br>– *100 workshop-based participants (BIPM and RMOs)*<br>– *40 metrologists at laboratory-based placements at partner NMIs*<br>– *400 participants in on-line activities*<br>– *500 e-learning participants* | 1. Maintaining the CBKT strategy that aims to increase the effectiveness with which Member States and Associates engage in the world-wide coordinated metrological system: assessing needs of stakeholders; identifying appropriate CBKT instruments; implementing activities; evaluating the CBKT Programme activities; adapting/adjusting the Programme activities to the needs of stakeholders.<br>2. Technical aspects associated with the management, operation and maintenance of the CBKT remote learning capabilities (including licenses and contractor relations):<br>– on-line KCDB 2.0 CBKT training platform<br>– on-line short courses<br>– on-line technical exchanges<br>– CBKT webpage of the BIPM website<br>– e-learning platform (including RMO e-learning sectors).<br>3. Developing and managing the BIPM/RMO CBKT framework (including cross-RMO on-line activities and e-learning). Liaison with RMOs to ensure coordinated CBKT delivery.<br>– Operation and management of a BIPM/RMO advisory group for the CBKT Programme (including liaison with OIML CEEMS Advisory Group).<br>4. Exploring support from and liaison with appropriate international organizations with an interest in relevant capacity building and knowledge transfer activities. |
| **Planning, coordination, support, logistics and delivery of the core CBKT activities (CIPM MRA, JCTLM and UTC)** | | |
| **2.** | **ILC-CBKT2** | 1. Planning, coordination, support, logistics and delivery of the core CBKT activities (CIPM MRA, JCTLM and UTC): scheduling, course design, call and selection processes (liaising with stakeholders on prioritization of candidates), identification of speakers, funding of participants' costs where appropriate, provision of BIPM lecturers and sourcing of external RMO/NMI lecturers together with all associated logistics.<br>2. Delivery of the CIPM MRA courses (when necessary) to cover:<br>– Future leaders (aimed at new and potential RMO TC/WG Chairs)<br>– Sound beginning (aimed at new participants in the CIPM MRA)<br>– Orientation for new RMO TC/WG Chairs<br>– Participation in the activities of the *Metre Convention* (including orientation for 'newcomers').<br>3. Supporting JCTLM and UTC CBKT initiatives through:<br>– Workshop-based CB activities<br>– Laboratory-based CB placements<br>– Knowledge transfer activities<br>– Remote-learning on-line activities (on-line short courses, on-line technical exchanges, and provision of the e-learning platform). |
| **Planning, coordination, support, logistics and delivery of the topic-based CBKT activities** | | |
| **3.** | **ILC-CBKT3** | 1. Planning, coordination, support, logistics and delivery of the topic-based CBKT activities: finding sponsors, scheduling, course design, call and selection processes (liaising with stakeholders on prioritization of candidates), identification of speakers, provision of BIPM lecturers and sourcing of external lecturers.<br>2. Delivery, supporting of and lecturing in the topic-based CBKT initiatives through:<br>– Workshop-based CB activities<br>– Laboratory-based CB placements<br>– Knowledge transfer activities |

| | | |
|---|---|---|
| | | – Remote-learning on-line activities (on-line short courses, on-line technical exchanges, and provision of the e-learning platform).<br>3. Delivery of joint Varenna metrology school for world-class young scientists/metrologists – in collaboration with the Italian Physical Society. |
| **Laboratory-led capacity building and knowledge transfer activities** | | |
| **4.** | **PMD-CBKT1** | Planning, coordination and delivery of the capacity building and knowledge transfer activities in the field of electricity. |
| **5.** | **PMD-CBKT2** | Plan and deliver knowledge transfer activities using a compact prototype Kibble balance apparatus to NMIs seeking opportunities for scientists to experience hands-on involvement in Kibble balance technology. |
| **6.** | **Time-CBKT** | Planning, coordination and delivery of the capacity building and knowledge transfer activities in the field of time metrology according to the CCTF plans by developing e-learning tools and GIT repository, and by the continuous day-to-day support to the UTC laboratories.<br>This activity relies on the contribution of a secondee with the role of promoting the coordination and efficient use of the CBKT material. Without a secondee this activity will be limited. |
| **7.** | **Chem-CBKT** | Planning, coordination and delivery of the capacity building and knowledge transfer activities (including on-line activities) in the field of chemical metrology. |
| **8.** | **Chem-CBKT1**<br>Metrology for Safe Food and Feed | Delivery of on-line material and knowledge transfer courses supported by short workshops at the BIPM related to:<br>a. Mycotoxin standards<br>b. Pesticide standards<br>c. Drug residue standards. |
| **9.** | **Chem-CBKT2**<br>Metrology for Clean Air | Delivery of on-line material and knowledge transfer courses supported by short workshops at the BIPM related to:<br>a. FTIR for gas standards and metrology<br>b. Dynamic methods for reactive gas standards<br>c. $CO_2$ isotope ratio traceable measurement.<br>On-line support for a mentoring programme for the new coordinating laboratory for the CCQM-K137 repeat comparison on nitrogen monoxide standards. |
| **10.** | **Chem-CBKT3**<br>Metrology for Accurate Patient Care | Delivery of on-line material and knowledge transfer courses supported by short workshops at the BIPM related to:<br>a. Peptide primary reference material value assignment methods, < 5 kDa<br>b. Peptide primary reference material value assignment methods, > 5 kDa and < 10 kDa. |
| **11.** | **IR-CBKT** | Planning, coordination and delivery of the capacity building and knowledge transfer activities in ionizing radiation. |

– ***Summary of the core funded CBKT Programme activities***

We estimate that the opportunities for NMI/DI staff to benefit from CBKT workshops and courses delivered at the BIPM/RMOs and through remote learning activities are as follows: (These CBKT activities are funded through the Work Programme 2024-2027)

| **Core CBKT activities** | **CBKT beneficiaries** *(Number of recipients)* | | **Remote learning courses** | |
|---|---|---|---|---|
| | *Delivered at the BIPM* | *Delivered in the regions as part of the integrated framework with RMOs/NMIs* | *Delivered through on-line courses (Number of recipients)* | *Delivered through e-learning platform (Number of registrations)* |
| Core CBKT activities | **80** | **360** | **400** | **500** |

– ***Summary of projected sponsor supported CBKT Programme activities***

We estimate that the opportunities for NMI/DI staff to benefit from CBKT activities in the BIPM laboratories are as follows: (The success of these projects depends on securing sponsorship).

| BIPM Department | Seconded staff (to the BIPM) | | | e-learning courses |
|---|---|---|---|---|
| | Typical length of placement *(months)* | Number of recipients visiting the BIPM | Total *(person months)* | Number of registrations |
| Physical Metrology | 6 | 2 | 12 | Under discussion |
| Time | - | - | - | Under discussion |
| Chemistry | 0.25 | 64 | 16 | 250 |
| Ionizing Radiation | 6 | 1 | 6 | Under discussion |
| **Total** | - | **67** | **34** | **250** |

***Note:*** *To ensure best use of opportunities arising and optimal impact, a degree of flexibility is necessary for sponsor-based CBKT activities.*

## Knowledge transfer activities from visiting scientists/specialists seconded to the BIPM

As indicated in the laboratory work programme of the BIPM, a significant number of projects depend on seconded staff for their success. Visiting scientists/specialists seconded to the BIPM contribute to the delivery of the programme projects; benefit from the work at the BIPM laboratories and also help to ensure knowledge transfer to the CBKT beneficiaries.

The total number of visiting scientists/specialists required to contribute to delivery of the Work Programme is:

| BIPM Department | Staff seconded from NMIs/DIs for programme delivery *(person months)* | |
|---|---|---|
| | **2020-2023** | **2024-2027** |
| Physical Metrology | 44 | 30 |
| Time | 108 | 128 |
| Chemistry | 132 | 120 |
| Ionizing Radiation | 42 | 60 |
| International Liaison and Communication | 76 | 108 |
| **Total** | **402** | **446** |

***Notes:***

*To ensure best use of opportunities arising and optimal impact a degree of flexibility is necessary for visiting scientist placements.*

# CORPORATE SUPPORT

**Strategy for corporate support services**

- To provide the highest level of corporate support and governance.
- To follow "best practice" in staff training and development.
- To increase the skill mix and experience available at the BIPM.
- To develop and implement best practice in the support of the Consultative Committees and Joint Committees through the provision of Executive Secretaries.

### The Directors Office: Finance, Legal and HR

The Finance team prepares the annual accounts and financial statements, medium- and long-term plans and the annual budget. They have initiated a programme of putting all financial services on-line. They carry out a range of financial management functions to meet corporate needs as well as those of the scientific departments, which includes cash management, purchasing and pay role. They manage the transport of artefacts to and from the BIPM with international shipping agents. The preparation of the annual financial reports is carried out by an external accountancy company and is subject to a full external audit.

The BIPM Legal Office addresses all legal issues including those related to the BIPM Regulations, Rules and Instructions applicable to staff members and the Regulations and Rules of the BIPM Pension and Provident Fund, agreements such as Memoranda of Understanding and complex purchase contracts and agreements, international institutional law and international law.

The Human Resources Office carries out all the processes needed to provide the staff benefits specified in the BIPM Regulations, Rules and Instructions. The Human Resources Office:

- manages the staff reporting and leave processes.
- manages communications with beneficiaries of the BIPM Pension Fund.
- has initiated a programme of putting all HR services on-line.
- liaises with the National French authorities relating to staff employment and visas for visitors and seconded staff.
- supports the recruitment and installation of all staff and secondees.

The BIPM Director's time together with the Executive Office is included within the Director's Office (2 full-time equivalents).

### The Meetings Office

The Meetings Office is responsible for the operation of all meetings held on the site (for example the CIPM, the Consultative Committees, the Joint Committees and various BIPM workshops). It also organizes a growing number of on-line meetings and webinars as well as the CGPM every fourth year. The work includes support for the Executive Secretaries as well as visiting delegates.

# TECHNICAL SERVICES

**Strategy for technical services**

- To develop the laboratory environment to sustain the BIPM Work Programme.
- To ensure that the BIPM meeting facilities, which support the CCs and WGs, continue to be "best in class".
- To maintain the heritage buildings and estate at a level consistent with the mission of the BIPM.

In order to optimize the cost-effectiveness of providing technical services, the BIPM is implementing a policy of reviewing requirements when staff retire from these areas and considering the cost-benefit of replacing them by external contractor services.

### Grounds and Security

The quality and occupational health and safety system is administrated by a fully-qualified *chargé de prévention.* Occupational health and safety is audited internally and subject to a variety of external technical controls (following French law) related to key sources of safety risks such as electrical, pressure, ionizing radiation, lightning protection and fire hazards.

The BIPM is located in the *Domaine national de Saint-Cloud*, a historic site granted to the BIPM by the French Government. The Pavillon de Breteuil and the six other buildings erected since the creation of the BIPM, range in date from the seventeenth century to the present day. Their maintenance requires a wide range of skills and techniques which are largely provided by external suppliers. The BIPM employs staff with experience in the maintenance of buildings, electrical facilities, and gardens. They are supported by staff from the mechanical workshop (see below).

The BIPM has a site guardian whose work is supplemented by external contractors who provide security at weekends and outside working hours. The operation of the Reception Office is contracted to an independent supplier.

Housekeeping services combine BIPM staff with contracted staff to clean offices and laboratories. They support meetings held on site (including by the provision of catering).

### Workshop

A mechanical workshop service is maintained at the level needed to support the planned laboratory work programme. The service designs and manufactures components for research instrumentation and commissions work externally that cannot be performed in-house. The mechanical workshop also produces platinum/iridium copies of the kilogram prototype against reimbursement of cost. This is a service that is uniquely available to Member States.

# ACRONYMS USED IN THE PRESENT VOLUME

| | |
|---|---|
| AC | Alternating current |
| AFRIMETS | Inter-Africa Metrology System |
| API | Application Programming Interface |
| APMP | Asia/Pacific Metrology Programme |
| BIPM | International Bureau of Weights and Measures |
| CB | Capacity building |
| CBKT | Capacity Building and Knowledge Transfer |
| CC | Consultative Committee of the CIPM |
| CCAUV | Consultative Committee for Acoustics, Ultrasound and Vibration |
| CCEM | Consultative Committee for Electricity and Magnetism |
| CCL | Consultative Committee for Length |
| CCM | Consultative Committee for Mass and Related Quantities |
| CCPR | Consultative Committee for Photometry and Radiometry |
| CCQM | Consultative Committee for Amount of Substance: Metrology in Chemistry and Biology |
| CCQM-GAWG | CCQM Working Group on Gas Analysis |
| CCRI | Consultative Committee for Ionizing Radiation |
| CCT | Consultative Committee for Thermometry |
| CCTF | Consultative Committee for Time and Frequency |
| CCTF-WGTWSTFT | CCTF Working Group on Two-Way Satellite Time and Frequency Transfer |
| CCU | Consultative Committee for Units |
| CEEMS | Countries and Economies with Emerging Metrology Systems |
| CGPM | General Conference on Weights and Measures |
| CIPM | International Committee for Weights and Measures |
| CIPM MRA | CIPM Mutual Recognition Arrangement |
| CMC | Calibration and Measurement Capability |
| CODATA | Committee on Data of the International Science Council |
| Codex Alimentarius | Commission under the Joint FAO/WHO Food Standards Programme |
| COOMET | Euro-Asian Cooperation of National Metrology Institutions |
| CPEM | Conference on Precision Electromagnetic Measurements |
| CTBTO | Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization |
| DCCs | Digital Calibration Certificates |
| DCMCs | Digital Calibration and Measurement Capabilities |
| DI | Designated Institute |
| DOI | Digital object identifier |
| DOSEO | Doseo technology platform CEA SACLAY |
| ESIR | Extended SIR |
| EURAMET | European Association of National Metrology Institutes |
| FAIR | Findable, Accessible, Interoperable and Re-usable |
| FTIR | Fourier-transform infrared |
| GHG | Greenhouse gas |
| GNSS | Global Navigation Satellite System |
| GULFMET | Gulf Association for Metrology |
| HDR | High dose rate |

| | |
|---|---|
| HR | Human resources |
| IAEA | International Atomic Energy Agency |
| IAU | International Astronomical Union |
| ICG | International Committee on Global Navigation Satellite Systems |
| ICRM | International Committee for Radionuclide Metrology |
| ICRU | International Commission on Radiation Units and Measurements |
| ICSH | International Council for Standardization in Haematology |
| IERS | International Earth Rotation and Reference Systems Service |
| IFCC | International Federation of Clinical Chemistry and Laboratory Medicine |
| IGS | International GPS Service |
| ILAC | International laboratory Accreditation Cooperation |
| IMRR | International Metrology Resource Registry |
| INetQI | International Network on Quality Infrastructure |
| IRIS | Isotope Ratio Infrared Spectroscopy |
| IRMS | Isotope Ratio Mass Spectrometry |
| ISO | International Organization for Standardization |
| IT | Information Technology |
| ITS-90 | International Temperature Scale of 1990 |
| ITU | International Telecommunication Union |
| IUGG | International Union of Geodesy and Geophysics |
| IUPAC | International Union of Pure and Applied Chemistry |
| JCGM | Joint Committee for Guides in Metrology |
| JCGM WG1 | JCGM Working Group on the Expression of Uncertainty in Measurement |
| JCGM WG2 | JCGM Working Group on the International Vocabulary of Metrology |
| JCRB | Joint Committee of the Regional Metrology Organizations and the BIPM |
| JCTLM | Joint Committee for Traceability in Laboratory Medicine |
| JVS | Josephson voltage standards |
| KCDB | BIPM key comparison database |
| MeP | *mise en pratique* |
| NMI | National Metrology Institute |
| OECD | Organisation for Economic Co-operation and Development |
| OIML | International Organization for Legal Metrology |
| PSFS | Primary and Secondary Frequency Standards |
| PTH | Parathyroid hormone |
| QHR | quantum Hall resistance |
| QI | Quality infrastructure |
| qNMR | quantitative Nuclear Magnetic Resonance |
| RMO | Regional Metrology Organization |
| SDR | Software-Defined Radio |
| SI | International System of Units |
| SIM | Inter-American Metrology System |
| SIR | International Reference System for gamma-ray emitting radionuclides |
| SIRTI | Transfer Instrument of the SIR |
| SRP | Standard Reference Photometers |
| SSDL | Secondary Standards Dosimetry Laboratory |
| TAI | International Atomic Time |
| TC | Technical committee |

| | |
|---|---|
| TDCR | Triple-to-double coincidence ratio |
| TT | Terrestrial Time |
| TWSTFT | Two Way Satellite Time and Frequency Transfer |
| UMRS | Unit of Measurement Representation System |
| UNESCO | United Nations Educational, Scientific and Cultural Organization |
| UNIDO | United Nations Industrial Development Organization |
| URSI | International Union of Radio Science |
| UTC | Coordinated Universal Time |
| UTCr | rapid UTC |
| VIM | International Vocabulary of Basic and General Terms in Metrology |
| VPN | Virtual private network |
| WADA | World Anti-Doping Agency |
| WG | Working group |
| WHO | World Health Organization |
| WMD | World Metrology Day |
| WMO | World Meteorological Organization |
| WTO | World Trade Organization |
| WTO-TBT | WTO Committee on Technical Barriers to Trade |
| XRCD | X-ray crystal density |