Bureau International des Poids et Mesures

Report on the actions taken by the CIPM towards a “CIPM Strategy 2030+”

September 2022

CGPM

Executive Summary

The Metre Convention in 1875 introduced a measurement system that could be applied globally. Based on geodetic constants, a set of definitions was introduced that could be put into practice through physical artefacts as primary standards for the quantities of length, mass and time. Over 140 years the system expanded to include definitions for base units for temperature, luminous intensity and current. Other internationally agreed references were added to include almost all measurement fields and in 1960 this expanded system was named the "International System of Units" (SI). In 1974 the seventh base unit was added for the quantity amount of substance (the mole, symbol mol), establishing the unit system as we know it today. By this time most of the base units had been redefined in terms of physical constants such as the speed of light, but several were still defined in a relationship with the kilogram, whose definition was that of the mass of the International Prototype of the Kilogram, i.e., an artefact. A profound change to the system, decided by the General Conference on Weights and Measures (CGPM) in 2018, was implemented in 2019. This brought the SI in line with quantum concepts by defining the seven base units in terms of seven "defining" constants, making it truly universal. The current focus of the role players in the system (the BIPM, National Metrology Institutes (NMIs), Designated Institutes (DIs) and related parties) is to develop realizations of the units according to the present defining units, and to continue to develop a revision of the definition for the second.

This "Revised SI" is designed to address the demands of the modern world as we know it, and to "future proof" the SI system, at least for the immediate future, by decoupling the technology to realize the units from the definitions of the units. This opens exciting opportunities to, for example, reduce the measurement uncertainties of mass at the micro- and nanoscale, and with it the associated quantities such as force and pressure.

At the same time as the Revised SI was adopted in 2018, a new International Committee for Weights and Measures (CIPM) was elected by the CGPM. Since then, the CIPM has consolidated the coordination of work on the Revised SI, but at the same time, with renewed vigour, started to develop a strategy for the next horizon. What issues will scientific metrology have to address by 2030+? What disruptive technologies will shape our future? How will the organization have to adapt to address the future landscape? Will the system be digitalized and/or be virtual to an extent that the institute becomes more virtual? And how can we support the major challenges our societies are facing in for example ensuring good health and food quality, tackling climate change, and moving towards a sustainable energy infrastructure?

To meet the current and future scientific and societal challenges efficiently and effectively, the BIPM as the organization created by the States Parties to the Metre Convention, needs to constantly evolve towards better governance and to stay modern. As for membership of the organization, the current model accommodates just over 100 nations around the world that officially participate in the coordinated activities towards a global measurement system. Although these nations represent nearly 98 % of the world GDP, a further 83 UN Member States and other economies need to be accommodated in the official international measurement system to make it truly global.

In a world where the quality infrastructure is increasingly prominent as an integrated approach to ensure interoperability, food safety, environmental protection, effective healthcare and law enforcement, partnerships with other international organizations is paramount for the BIPM to deal with the challenges. This is the horizon that the CIPM is scanning for the updated strategy as a broad strategy for the future – that needs to distil to a focused and practical implementation plan – at least for the foreseeable future.

In March 2019 the CIPM drafted a plan as the first step in developing the strategy. Five themes were identified, and champions were assigned to lead the strategy development:

1. Responding to evolving needs for metrology.
2. Addressing key scientific challenges to advance the global measurement system.
3. Strategy for deepening engagement with other international organizations on measurement science issues.
4. Reviewing the strategy for the future membership of the organization.
5. Modernizing the operations of the organization.

Restrictions due to the Covid-19 pandemic meant that no physical meetings could be held by the CIPM during 2020 or 2021 to discuss and develop the themes further. However, the champions continued to work online to develop the strategy. In parallel they have worked on issues for which the CIPM already has a mandate from the CGPM (or is included in the founding convention), such as deepening the engagement with other international organizations and to modernize the operations of the organization. The activities leading up to the 27th CGPM meeting in 2022 and the steps in the process to publish the full Strategy 2030+ before the 28th CGPM in 2026, are summarized below.

A. Five main evolving needs in metrology were identified, together with two additional cross-cutting horizontal themes. For each of these seven needs, general sector challenges and particular metrology challenges were identified, and a report was prepared in which actions by the CIPM and BIPM Headquarters are proposed to promote and enhance international cooperation in these areas.
B. The key scientific challenges to advance the global measurement system were identified and are articulated in terms of current and future actions to better realize the SI.
C. The strategy for deepening engagement with other international organizations matured to implementation stage.
D. A way forward has been proposed to request the CGPM for a mandate to explore how future membership of the organization could be expanded.
E. Concrete actions were identified to modernize the organization and those that could be implemented by the CIPM in its role as the supervisory body of the International Bureau, have been implemented, such as Rules of Procedure and a Code of Conduct for the CIPM, while proposals on governance structures to address the strategy 2030+ are being developed. The report from the *ad hoc* Working Group of Member State representatives was noted and will provide input to further actions. The main outcome is anticipated to be by-laws for the organization to be presented to the 28th meeting of the CGPM (2026).

Draft resolutions addressing A, B and D are being tabled at the 27th CGPM with the aim of obtaining a mandate from the States Parties to the Metre Convention for the next steps of the strategy development. This report contains a summary of the progress to date on points A to E above. The detailed reports will be available on the BIPM website and will be circulated with this summary for comment by the metrology community after the Conference. This report and the draft resolutions, following adoption by the CGPM, will lead to the development of the final Strategy to be presented in 2025 at the occasion of the celebration of 150 years of the Metre Convention, with the aim to publish the final version in 2026.

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A. Report to address the evolving needs in metrology

1. Introduction

Confidence in the consistency and accuracy of measurement is critical for economies and societies across the globe. The International Measurement System therefore has the potential to impact every citizen and every business. This CIPM report seeks to identify changes and challenges in society and economies that are creating new needs for metrology; and to ask how best the CIPM can respond to ensure it can continue to realize this potential.

Historically, developments in science and technology, in business and in society, drove developments in metrology related to specific technical disciplines. At a national level, they were triggered by national needs that were addressed by development of a national measurement capability. At the international level, the response to these needs and technical developments could be coordinated through the discipline-based (vertical) CIPM Consultative Committees (CCs), with the international recognition of the related measurement capabilities assured through the implementation of the CIPM MRA.

In the 21st century, the evolving needs in metrology are notably different in character. They are frequently triggered by regional or even world-wide challenges. They also reflect the rapid development of technology (particularly the "digital revolution") and typically are of a horizontal nature, requiring the involvement of and integration across many disciplines. Addressing these "Grand challenges" will require greater cooperation between different areas of metrology, and between the metrology community and other stakeholders who are also seeking to address them. At the international level, this is an opportunity for the CIPM to foster and stimulate international cooperation (for example, between NMIs and relevant International Organizations).

This CIPM report identifies some of the most important evolving needs in metrology and makes recommendations on how to increase the international coordination role of the CIPM to address them; in particular to find mechanisms that reflect the multi-disciplinary nature of these "Grand Challenges".

Section 2 outlines some of the major changes and challenges that were identified by the CIPM; with seven "grand metrology challenges" described in more detail in Annex 1[1] as catalysts and "discussion starters" for future work.

Section 3 contains a proposal for implementation of the results of this report, particularly around piloting appropriate horizontal forums to shape and coordinate the metrology community's response to the identified grand challenges. Furthermore, it proposes the development of a new vision for the BIPM, building on this report, and seeks CGPM support for this development.

Draft Resolution A, presented to the 27th meeting of the CGPM, seeks a mandate to develop a new vision for the BIPM based on this report and the final Strategy to be tabled in 2025. As part of the next steps, annexes will be made available on the BIPM website that describe in more detail the seven "grand metrology challenges" that have been identified. Detailed suggestions for implementation of new horizontal forums addressing these challenges will also be included.

2. Evolving needs in metrology

Predicting the future at a time of rapid change is difficult, and the 21st century is clearly such a time. However, it is possible to identify three groups of drivers for future decision making globally, both technological and societal:

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[1] It should be noted that these seven summaries are not intended to be "definitive statements". They are complementary to the well-researched and detailed report "*Evolving Needs for Metrology in Trade, Industry and Society and the Role of the BIPM*", R. Kaarls, 2007 (https://www.bipm.org/en/impact-studies-international).

- **Well-being:** The health, security and safety of a growing population with evolving social attitudes and values.
- **Sustainability:** Reduced human impact on the climate and management of natural resources.
- **Enterprise**: Digital innovation to increase prosperity, productivity, and growth and also to enable equality and fairness.

These drivers, along with the rapid pace of technological change (particularly the redefinition of the SI along with digital and digitally-enabled technologies), will impact both "why" and "how" measurements will be made and will pose new challenges for metrology and for the international metrology system.

The 2020 global Covid-19 pandemic can be identified as a fourth driver that will change the speed of innovation (both positively and negatively) and will influence national and international priorities in the short and medium term. This pandemic took place during the development of this report and has had a significant impact on it. In 2020, the NMI community responded rapidly, to focus on their national priorities related to testing both personal protective equipment and hospital equipment, as well as vaccine development. Internationally, the CIPM facilitated the sharing of knowledge and experience as the impact of the pandemic increased across the world. It is clear that the international community can benefit from the lessons learned when responding to a global crisis and in adapting to rapidly changing priorities. The pandemic also brought some changes and new opportunities that are wider ranging, for example by accelerating the use of modern meeting and communication technologies and in adapting working practices. The boundaries of what is possible have been redefined and will have long-term and wide-ranging impacts that are reflected in this report.

Metrology will remain critical in enabling prosperity and well-being and addressing global challenges. However, to do so it must evolve and, in particular, metrologists from different disciplines will need to work together to support the new aims and to address these challenges.

In their evaluation of the evolving needs of metrology, the CIPM has identified five "Metrology Grand Challenges":

1. **Climate change and Environment**

   We live in the "Anthropocene", the geological epoch in which humanity is the dominant influence on the planet. Half of humanity's CO_2 emissions have been emitted in the last 30 years – since the first report of the Intergovernmental Panel on Climate Change (the IPCC). Furthermore, there is evidence that we have passed or reached several other "planetary boundaries" and with this we face an existential threat. Metrology is, and will continue to be, critical to ensuring we are able to base our monitoring of the global climate and broader environment, mitigation policies and their implementation on firm evidence.

2. **Health and Life Sciences**

   Global healthcare and life science activities are supported today by metrology across all of the CCs. The global measurement system is critical to the effective delivery of healthcare across the globe. The need for this support is expected to continue, evidenced by the present global pandemic. Healthcare costs represent a large proportion of national expenditure, so improvements in metrological capability and metrology-enabled innovations have the potential for significant social and economic impacts and benefits.

3. **Food safety**

   Food safety is a concern for all nations of the world, with governments overseeing systems and developing policies and regulatory frameworks to assure that food will not cause an adverse health effect for the consumer when it is prepared or consumed. The food system includes the production, processing, storage, distribution, marketing, acquisition, and consumption of food.

Unsafe food can pose a substantial global health threat. The risks of unsafe food are considerable. Food contaminants, such as harmful parasites, bacteria, viruses, prions, mycotoxins, pesticide residues, and other chemical or radioactive substances, cause more than 200 diseases – ranging from infectious diseases to cancers. Measurement plays an important role in food safety and ensuring that food is safe for human consumption and meets national and regional regulatory requirements that have been set to safeguard this.

4. **Energy**

   World energy consumption continues to grow. Demand is projected to increase by 37 % to 2040 and despite a significant growth in energy supply from renewables, fossil fuels presently still dominate supply across all regions. The challenges faced by governments, industries and societies across the world is succinctly encapsulated in the energy 'trilemma' of reducing carbon emissions whilst maintaining affordable energy and securing energy supply. Addressing the drivers of the energy trilemma together with providing world-wide access to energy will require significant investment in research and development. Metrology is a critical aspect of this investment providing underpinning measurement capabilities, standards and guidance needed to ensure that these policy and regulatory targets are met.

5. **Advanced Manufacturing**

   Advanced manufacturing, sometimes referred to as 'Industry 4.0', is the digital transformation of industrial processes, that involves deep productive and organizational transformations based on the incorporation of digital technologies. The processes, machinery, products and even parts or components are integrated into a company's information networks and communicate in real time, horizontally with each other and vertically with customers, users and suppliers. This transformational approach to manufacturing will require a similar transformation in the metrology on which it will rely. The efficient control of increasingly complex and, at the same time, flexible production processes typical in the advanced manufacturing framework requires detailed, real-time knowledge of the process parameters. The multitude of necessary sensors and measuring devices must deliver reliable and accurate measurement data with machine-readable metadata on units and data quality.

There are many ways in which the various challenges posed by the drivers of well-being, sustainability and enterprise can be articulated. Clearly, the above list is not comprehensive[2]. However, these examples do serve to identify and illustrate major challenges that will require coordinated input and support from metrology if they are to be addressed. These challenges are all global in nature, which highlights the need both for international coordination and for involvement from different regions and from economies at different stages of development.

In addition to these five "sectoral" challenges, impacting "why" measurements are needed, the CIPM also identified two "cross-cutting challenges" which reflect on the changes and challenges related to "how" we make measurements.

6. **Digital Transformation**

   We are amid a digital revolution that is challenging the metrology communities' working practices and paradigms for metrological traceability and reproducibility. It challenges us to both bring metrology to the digital world and to "digitalize" metrology, if we are to ensure consistency and confidence in measurement in this new world. Metrology can take advantage of such technological advancements to improve the productivity and quality of measurements. At the same time, the

[2] For example, this list does not include the major topics of Transportation and the Built Environment which appear on many lists of such grand challenges.

community can also contribute to the advancement by underpinning digitalized measurement using measurement science methodology to ensure the trustworthiness of the measurements done in society. There is a need for an internationally accepted and standardized infrastructure for the provenance of data, digital calibration certificates, accepted ontologies for machine-readable and machine-actionable information and data, and validation of artificial intelligence (AI) techniques such as machine learning (ML). These should be embedded within international standards and created through cross-disciplinary and cross-sectoral collaboration.

7. **"New" metrology**

Metrological traceability is one of the key principles in metrology: "the property of a measurement result, whereby the result can be related to a reference through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty"[3]. This principle of metrological traceability has proven to be extremely influential. However, looking forward, a number of impending technological advances could have an important "step-change" impact on the way metrological traceability can be realized in the future. These include the use of sensor networks, distributed instrumentation, intrinsic measurement standards, advances in measurement science enabled by the redefinition of the SI and the implications of AI/big data.

These two "cross-cutting" challenges clearly overlap with each other and link with the first five grand challenges. The CIPM is already beginning to tackle the challenge of the digital transformation through the Task Group on the Digital SI. The cross-cutting challenges can be reflected in three priorities for metrology in the coming decade:

- Putting in place a digitally enabled global measurement system, building on the redefinition of the SI, with shorter calibration chains and *in situ* calibration.
- Systems metrology: measurements to support a systems-understanding of the world where many often inter-related, non-standardized or unforeseen factors need to be considered and most are not part of the traditional SI system of measurement.
- Enabling confidence in decision making, particularly in situations with a multitude of data sources with different uncertainty.

The CIPM has drafted further background material that provides more details on each of these seven "metrology challenges", including an introduction to the theme, a description of the general sector, an identification of the specific metrology challenges and some recommendations to enhance the international coordination. As already indicated in section 1, the seven summaries given here serve as an introduction to the topic and together with the additional background material will be used to seed discussion in any forums that might be set up to take this work further.

3. Implementation of the results of this study

Whilst each of the seven metrology grand challenges identified above pose significant, and different, technical challenges for metrology, they also pose a common challenge for our community. The present CIPM structures, particularly the Consultative Committees that advise the CIPM, are organized and focused on 'vertical' metrological lines (for example, measurement of specific quantities/units or on unit definitions). The challenges identified above will require a multidisciplinary approach that addresses these challenges in a more holistic, 'horizontal' way.

Therefore, the CIPM proposes

to create appropriate forums to shape and coordinate the metrology community's response to the identified grand challenges with the objective to coordinate new possibilities for metrology to have

[3] VIM, 3rd Edition, JCGM200:210

an impact on global cross-cutting challenges.

The trends identified in this report will furthermore be one of the principal inputs into defining the future strategy and work of the BIPM. Recognizing that the agreement of the new definitions for the base units of the SI in 2018 was a milestone in world metrology and that 20 May 2025 will mark the 150th anniversary of the signature of the Metre Convention, the CIPM proposes to start to develop a new vision for the work of the BIPM that builds on this report and the Annexes, that should be consulted upon with the global metrology community before the 150th anniversary of the BIPM and for publication before the 28th meeting of the CGPM, expected to be in 2026. A resolution will be presented to the 28th meeting of the CGPM as an output of this process.

B. Report to address key scientific challenges to advance the global measurement system.

1. Introduction

With the revision of the International System of Units (SI) approved by the 26th meeting of the CGPM in 2018 and coming into force on 20 May 2019, the units in the SI are consistently defined by fixing the numerical values of so called "defining constants": the Planck constant; the Boltzmann constant; the Avogadro constant; the speed of light; the electron charge; the hyperfine transition frequency of the ^{133}Cs atom; and the luminous efficacy. Apart from the latter two, defining the SI units of time (the second) and of luminous intensity (the candela), as well as the Boltzmann and Avogadro constants, that may be considered as proportionality factors, the other defining constants are fundamental constants of nature. Thus, with this revision, the CGPM followed a suggestion by Max Planck in 1900 to define units by fixing the numerical values of fundamental constants. Such a system of units would be universal and valid "for all times and cultures".

Indeed, it seems that the revised SI, based on our present knowledge of the quantum nature of the Universe, will be valid for a very long time, perfectly serving all practical requirements in a system of units for global trade, science and society. Thus, one of the most important key scientific challenges in metrology coordinated under the auspices of the Metre Convention for many years, namely the requirement to measure the values of the defining constants with a precision that would be sufficient for all practical requirements, has essentially disappeared.

Fixing the numerical values of the Planck constant and the electron charge allows us to fully exploit the potential of electrical quantum effects for primary realizations. Furthermore, the Planck constant, the electron charge and the Boltzmann constant appear in many fundamental laws of nature. This reduces the overall uncertainties of all constants as listed in CODATA and allows totally new concepts for primary realizations based on such a law of nature anywhere on the scales, in contrast to the past, where the kilogram prototype and the triple point of water defined the unit at singular points on the scale.

Important tasks for all units remain and are addressed in section 2. Moreover, the unit of time, the second, the only base unit remaining to be redefined in the near future is posing key scientific challenges and opportunities for collaboration fostered under the Metre Convention that are outlined in section 3. Section 4 deals with the realization of the units in the revised SI. Finally, new scientific challenges are arising related to the metrological characterization of networks of huge numbers of heterogeneous sensors, for different quantities, with different sensitivities and uncertainties producing large amounts of interconnected measurement data. The metrological challenge connected with this development is addressed in Section 5 on "Systems Metrology".

2. Key scientific questions in the definition of the SI units

As outlined in the introduction, the key scientific challenge for the Metre Convention and its Member States as well as for the BIPM for many years has essentially disappeared. **Thus, only two key scientific challenges might be seen to remain, namely the redefinition of the second and of the candela. Both of the related defining constants have no fundamental character.**

For the ***candela***, there was an extensive discussion within the Consultative Committee for Photometry and Radiometry (CCPR) to consider a "photon-number based", more fundamental definition of the candela, i.e. a "quantum candela". This discussion has led to the photon-number based realization of the *candela* being described in the *mise en pratique* and becoming a topic in several NMIs; this was additionally the case because of the impact of photon-number states, for example in quantum technology. In conclusion, the present definition serves all practical requirements for global trade, science and society. Currently, there is neither any need for a redefinition nor a task for the Metre Convention in general and the BIPM in particular. All activities in photometry and radiometry ceased at the BIPM Headquarters a long time ago.

However, there is a key scientific challenge related to the fact that the defining constant, i.e., the luminous efficacy, linking the given photometric unit to the corresponding radiometric unit, has no fundamental character. Considering the progress achieved so far and foreseeable developments in vision science and Artificial Intelligence, there could, in a few years, be some changes in the photometric quantities because of a much better understanding of the luminous perception using the cone-fundamentals system. It is most likely this cone-fundamental based photometric system would need a new link between photometry (lm, cd, lx,…) and radiometry (W, W/sr, W/m^2…). This link and its nature are the key scientific challenges in the definition of the candela for the future.

For the ***second***, huge efforts are being undertaken by many NMIs to develop optical clocks with remarkable results: at least four laboratories are approaching the low 10^{-18} relative accuracy level; around a factor of a hundred improvement when compared to the present caesium standard. One laboratory has reached the 10^{-19} level and is projecting that it could reach 10^{-20} or even lower. This would have significant implications for many fundamental science questions: does the fine-structure constant vary with time (as predicted by some Grand Unified Theories), what are the Limits of Lorentz invariance, can we detect dark matter? to name just a few. Therefore, the second will be treated in detail in Section 3.

For all other units, future efforts will concentrate on increasing the precision in the realizations of the units, on developing novel technologies for their realization opened by the structure of the revised SI, as well as on improving their implementation. Here, primary standards might be operated outside NMIs, metrological traceability chains will possibly become significantly shorter, potentially changing the future role of the NMIs. As quantum technologies become increasingly robust, mature and user-friendly, they offer the potential to promote the use of self-calibrated measuring instruments beyond that in NMIs and to use these instruments for a wider range of measurement tasks.

Therefore, it was decided by the Consultative Committee for Units (CCU) and supported by the CIPM Sub-Committee on Strategy to conduct a questionnaire among Member State NMIs and Stakeholders addressing the following topics and questions concerning the implementation of the revised SI.

It is suggested that an online survey should be carried out involving:

- CCs and WG chairs, Regional Metrology Organizations (RMOs) and Technical Committee (TC) Chairs, NMI Directors.
- Accreditation and legal metrology bodies.
- World Meteorological Organization (WMO), World Health Organization (WHO).
- Academia and teaching organizations (for example academies, universities, schools, etc.) to be addressed through the NMIs in their countries.

The survey should address the following questions:

- To which degree has the revised SI been implemented?
- Are there issues with metrological traceability to the revised SI?
- What are the short-term and long-term challenges?
- What are the experiences and challenges related teaching the new SI in educational institutions and in industry?

Within a further survey to CC presidents and CCs, new scientific developments in the realization of the units and alternate metrological traceability paths enabled by the 2018 revision shall be addressed:

- Are there technological barriers in the implementation of the new SI?
- What are the emerging technologies in the field?
- What are alternate metrological traceability routes and what is the status of their development and implementation?

This questionnaire is planned to result in a publishable document with conclusions, possibly in combination with summarizing evolving needs in metrology. It is further recommended to repeat this effort within reasonable time spans (for example, within three years) to continuously keep track of the most recent developments concerning the realization, the dissemination of the units, of alternate metrological traceability paths as well as with challenges related in the teaching of the revised SI in educational institutions, industry, society and politics.

It is considered that this continuous effort is an important task for the CCU, supported by the BIPM, to keep the metrology community as well as the stakeholders informed, to establish continuous communication lines on fundamental metrology issues among them and to shape future efforts within the community.

3. On the future revision of the SI unit of time, the second

Optical frequency standards are now surpassing caesium primary standards, with measured relative uncertainties currently better by two orders of magnitudes. This assessment allows the metrology community to envisage a new definition relying on optical transitions, with the main goals as follows:

- Offer more accurate realizations of the unit with primary/secondary frequency standards, with an improvement by 10/100 in the short term after the redefinition (reaching 10^{-17} / 10^{-18} relative frequency accuracy) and a much larger improvement in the longer term.
- Ensure continuity with the current definition, which relies on caesium.
- Ensure continuity and sustainability of the availability of the new SI second through International Atomic Time (TAI)/Coordinated Universal Time (UTC), with a significant improvement of its frequency accuracy as soon as the definition is changed.
- Enable the dissemination of the unit towards wide categories of users.
- Be accepted by all NMIs and stakeholders.

The Consultative Committee for Time and Frequency (CCTF) has the task of updating the existing roadmap towards the definition of the second. This roadmap includes an ensemble of criteria which will be used as indicators to decide the most relevant option for the new definition, and the appropriate time to propose a change of the definition. These criteria are prioritized, from required conditions before changing the definition, to preferable criteria corresponding to works in progress at the time of the change in definition. The criteria cover various aspects:

- Frequency standards and options for the new definition.

  The aim is to ensure capability of optical frequency standards (level of performances, reliability and continuous operation, sustainable contributions to UTC).
- Time/Frequency dissemination techniques that support the high stability of optical clocks, time scales.

  The aim is to create the capability of T/F transfer techniques for frequency standard comparisons at the highest stability, the construction of UTC and the dissemination of the unit towards users by:
  - developing national and international networks of optical fibres,
  - developing high precision air/space microwave and optical links,
  - developing portable optical standards.
- Requests from user communities.

  The aim is to ensure the continuity with the present definition and the long-lasting capacity of the new definition, and also a broad access to the new definition.

As a conceivable long-term goal, it is recommended that space-qualified optical frequency standards are developed and the international communities and space agencies are brought together to launch a long-term plan for placing an optical-clock network on geostationary orbitals (GEO or MEO orbits) with inter-satellite links and time transfer links to the Earth. In terms of metrology, this would define an ultraprecise frame of reference for Earth and Space, comparing terrestrial clocks using clocks and links between satellites for optical Very Long Baseline Interferometry (VLBI) in Space. In addition, such a project would help explore some of the most prominent questions in science, such as observing gravitational waves in new frequency ranges, searching for dark matter, testing general relativity and the Einstein equivalence principle with highest accuracy ever, investigating quantum correlations and testing Bell inequalities for different gravitational potentials and relative velocities. As this would require considerable resources, the implementation of such a system would most likely have to be supported by an even broader range of applications that extend beyond metrology and science. Nevertheless, the Metre Convention with the Member State NMIs is in a leading position and predesignated for the international coordination of such a project as the best optical clocks today are exclusively operated by NMIs around the world.

In connection with the topic of the redefinition of the second, the CCTF is also engaged in other important activities:

- Strengthening training to improve the quality of UTC.
- Ensuring the promotion of the important benefits of the unique reference time UTC to the international scientific and industrial communities and strengthening the collaboration and the technical discussions with the International Telecommunication Union (ITU), the GNSS Providers, and related entities as the International GNSS Service (IGS) and International Committee on Global Navigation Satellite Systems (ICG).

It is essential that the present BIPM laboratory activities are continued in the future as laid down in the CCTF strategy document:

- To support the needs of the global time community by providing UTC of sufficient accuracy to progress the state of the art.
- To provide the unique, continuous time scale for world time coordination.
- To coordinate, support and promote training actions and sharing of resources in order to improve the International Timekeeping.
- To coordinate and support a redefinition of the second based on optical transitions and to adapt the infrastructure for time scale maintenance and dissemination to the new definition of the second.

4. Realization of the units in the revised SI

Here, challenges were identified concerning primary metrology outside the NMIs and its linkage to the wider quality infrastructure. It is recommended that the following are considered:

(1) Issues of accreditation, metrological traceability, remote calibration as well as the use of digital certificates (metadata) in accreditation and legal control.

(2) Real-time calibration in cases where measurement instruments and, thus, metrology is directly implemented in industrial processes and products, so called embedded measurements. This could even allow data to become publicly accessible in real time for example, for climate monitoring.

(3) Virtual measuring instruments, i.e., the exploitation of predictive models to calculate the calibration uncertainty or investigate the suitability of an instrument for a specific use. This might result in the improvement of the measurement process knowledge by the prediction of post-process metrology parameters by means of models and data sets, which characterize the processes. Further issues to be considered here are the confidence in models and data quality.

(4) Self-calibration devices ("NMI-on-a-chip") for example unstabilized He-Ne lasers exploiting the inherent stability of quantum effects. Here, the Consultative Committee for Length (CCL) declared that they do not need to be calibrated, because their intrinsic stability of 1.5×10^{-6} is sufficient for several applications. Other examples are self-calibrating photodiodes,

optomechanical temperature sensors and possibly more in the future.

(5) The lattice spacing of silicon has been identified and adopted by the CCL as a robust secondary realization of the metre in nanometrology. The challenge for NMI metrologists is to promulgate awareness of this secondary realization of the metre within the scientific and industrial communities.

5. Scientific foundation of systems metrology

Introduction and motivation

The unification of physical quantities in the international system of units (SI), beginning with the signing of the Metre Convention in 1875, was a fundamental basis for national and international trade. This international coordination is entirely lacking in the field of a digital quality infrastructure and for networked, intelligent and self-learning systems.

The complexity of future-oriented developments, such as autonomous vehicles or the supply system of the future in smart cities, illustrate the need for a novel systemic thinking in metrology. In this scenario, individual sensors and measurement procedures are no longer considered, but complex and heterogeneous networks are assessed in a holistic way. That is, the entire system of measurement procedures, sensors, software, AI-based control units and actuators are to be evaluated. Similarly, complex systems with hundreds of networked sensors and measuring methods, each with different measuring accuracy, reliability or weighting, will play an increasingly important role in the future as a basis for AI-based decisions to be made. An increasing number of research projects and the first commercial solutions are under development internationally. At the same time, very little is known, for example, about how measurement errors of individual sensors propagate in heterogeneous complex systems or how metrological principles can be applied to assess AI methods.

A sound metrological characterization is mandatory at an early stage of the product lifecycle. This holds especially true for regulated and/or safety-relevant areas. Based on fundamental metrology research, appropriate standards must be developed, legislation must be interpreted accordingly, and a certification and/or conformity assessment based on the latest state of the art must be prepared.

Metrological foundations for distributed systems and sensor networks

In numerous fields of application, complex systems consisting of networked sensors, digital twins and multimodal measurement quantities are increasingly becoming standard. Metrological principles for networked and autonomous systems need to be developed that make such systems comparable to each other, and which enable a quantitative assessment of their reliability and quality. These principles need to be applicable on the edge, fog and cloud part of internet of things (IoT) architecture in a flexible way. On this basis, evaluation methods, recommendations, standards and benchmarks, metrological assessment of complex systems and heterogeneous sensor networks can then be realized.

Distributed and networked systems, complex heterogeneous sensor networks and high-dimensional multimodal data for ML and AI require reliable and trustworthy procedures and tools for the storage and extraction of the associated metrological information. This is especially the case for the use of such information by AI, whereby information retrieval methods must be developed, which allow the reliable extraction of information such as units, measurement capabilities and measurement uncertainties in a machine-interpretable way. For this purpose, ontologies and semantic methods for distributed and networked systems, reference data sets and AI methods are to be developed. Ontologies and semantic references should be established that are similar to the existing International Vocabulary of Metrology (VIM), that serves as reference for many standardization and accreditation activities.

Thus, it is recommended that the following are considered:

(1) Methods and models for the propagation of measurement uncertainties of individual sensors in

distributed systems and sensor networks.

(2) Metrological approaches for co-calibration and remote X (calibration, diagnosis, maintenance, etc.) based on sensor networks.

(3) Development of practicable methods for the metrological evaluation of complex networked systems as a basis for the testing and certification of autonomous systems.

(4) Development of concepts for semantic information on metrological parameters such as data quality and measurement capabilities in distributed systems and sensor networks.

Methods and infrastructures for the validation of algorithms and AI

An important prerequisite for the approval of new AI methods is knowledge of the influence of the individual input variables and their uncertainty on the result. This knowledge can ultimately be used to define the reliability, robustness, and confidence of the complex system using the AI method. The assessment of AI methods requires different approaches than for classical mathematical methods. High-quality commonly acknowledged reference data sets are required to assess them, and finally to certify AI methods. At present, little fundamental knowledge exists about the requirements that must be met by these data sets in terms of their scope and the necessary quality for various applications. Metrology needs to provide principles, harmonized methods and standardized approaches for the development and evaluation of reference data sets. The resulting "gold standard" reference data sets will become what could be called "digital standards" for the metrological traceability needed for AI.

Regulatory bodies will consider a complete lifecycle assessment of AI methods (cf. DIN SPEC 92001[4]). This includes requirements and quantitative assessment of the training data sets and the AI algorithms. This requires fundamental metrology research on methods to evaluate robustness, explainability (transparency) and reliability of data and algorithms in AI. Similar to the guidelines on the evaluation of measurement uncertainty, that also serve as a reference in standardization and accreditation, guidelines on data quality and assessment of AI methods are required.

Thus, it is recommended that the following are considered:

- Development of harmonized requirements for reference data sets for simple and complex systems (for example distributed systems and AI applications).
- Use of digital twins as source of synthetic data in the development and validation of ML and AI methods.
- Development of basic concepts and methods for reference data sets as "digital standard" of a metrological traceability chain and basis of a "QI for AI".
- Development of concepts for new metrological services in the field of validation of algorithms based on reference data sets.

6. Where next?

Three resolutions are presented to the 27th meeting of the CGPM.

Draft Resolution C "On the extension of the range of SI prefixes"
Draft Resolution D "On the use and future development of UTC"
Draft Resolution E "On the future redefinition of the second"

Following the 27th CGPM, the Sub-Committee 2 on Strategy will continue towards the development of the final strategy to address key scientific challenges to advance the global measurement system.

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[4] DIN SPEC 92001-1:2019 Artificial Intelligence - Life Cycle Processes And Quality Requirements - Part 1: Quality Meta Model

C. Strategy for deepening engagement with other international organizations on measurement science issues

1. Introduction

In the modern era the BIPM is increasingly collaborating with other International Organizations (IOs). The CGPM encouraged these interactions with several resolutions:

Resolution 10 of the 20th CGPM (1995)

Future relations with the *Organisation internationale de métrologie légale*.

Resolution 1 of the 23rd CGPM (2007)

On the initiatives taken to strengthen the collaboration between National Metrology Institutes and recognized National Accreditation Bodies.

Resolution 2 of the 24th CGPM (2011)

On the importance of international collaboration so as to place measurements to monitor climate change on an SI traceable basis.

Acting on the resolutions during 2018 to 2022, the interactions that before this period were mostly at consultative committee or working group level, were elevated to organizational level and several formalizations of the liaisons took place. Memorandum of Understanding (MOUs) were concluded with:

- International Union of Pure and Applied Chemistry (IUPAC)
- International Telecommunication Union (ITU)
- Comprehensive Nuclear Test Ban Treaty Organization (CTBTO)
- Committee on Data of the International Science Council (CODATA)

A Declaration of Cooperation establishing the Joint Committee of Traceability in Laboratory Medicine (JCTLM) was re-signed with the International Federation of Clinical Chemistry and Laboratory Medicine (IFCC) and the International Laboratory Accreditation Cooperation (ILAC).

Relations with the International Organization of Legal Metrology (OIML) were further strengthened and a Joint BIPM-OIML task group was established by Decision CIPM/108-5 of March 2019[5].

This Joint Task Group, in collaboration with the CIPM Task Group on the Digital SI, concluded a Joint Statement of Intent *On the digital transformation in the international scientific and quality infrastructure* with the OIML and invited other IOs to sign the joint statement. To date CODATA, IMEKO, ILAC, ISO , IEC, IFC, IUPAC and IUPAP have joined the CIPM (for the BIPM) and CIML (for the OIML) in signing the Joint Statement.

2. Implementation of the Strategy

The CIPM concluded that the strategy for engagement with other IOs is mature and the CIPM oversight provides good governance. The BIPM International Liaison and Communication Department was strengthened to maintain the relationships and interactions, CIPM members were assigned to each strategic liaison to assist the staff with the strategic interactions, and the liaison arrangements are being put into practice.

[5] *The CIPM supported the establishment of a Joint Task Group at an operational level to further improve the cooperation between the BIPM and the International Organization of Legal Metrology (OIML), following the proposal made by the President of the International Committee of Legal Metrology (CIML).*

D. Reviewing the strategy for the future membership of the organization

1. Introduction

The fourth pillar of the CIPM Strategy has two components:

a) Responding to many resolutions of the CGPM that encourage the CIPM to seek broader membership for the organization, whilst reflecting on the fact that most, if not all, potential new Member States will be substantially below the minimum level of contribution.
   - Responding to Resolution 5 of the 24th CGPM (2011) for intergovernmental organizations.
   - Preparing a summary of the present state regarding engaging with the treaty.
   - Exploring alternative mechanisms to facilitate universal participation for future discussion.

b) Deepening of linkages with and amongst the RMOs, including addressing the challenge of NMIs that are not officially aligned with any RMO.

This report describes the history and current status of state participation, the formal resolutions and decisions related to universality of participation as well as consequent actions, including a summary of the present state regarding engagement. It proposes a draft resolution to be presented at the 27th meeting of the CGPM in 2022, with actions that reach out to the 28th meeting of the CGPM in 2026.

2. The concept of universality of participation

The idea of universality was embodied in the wording of the Metre Convention where the first page of the text signed by seventeen nations in Paris on 20 May 1875 talks of the High Contracting Parties desiring to ensure the international unification and the perfection of the Metric System, have resolved to conclude a convention to this effect. This ambitious aim of universality has been reinforced by the States Parties to the Metre Convention (Member States) many times since, notably via several Resolutions adopted by the CGPM that specifically advocate for greater, or universal, participation. These Resolutions call on Member States to encourage participation and the BIPM to undertake limited actions to facilitate it. In recent years the RMOs have also played an important role in encouraging their members that are not yet engaged in the activities of the BIPM, to participate. These efforts were aided by the support given to interested states by international organizations such as United Nations Industrial Development Organization (UNIDO) and the World Bank Group which encourage participation in their own policies and support programmes. Universality of participation is also supported by the World Trade Organization (WTO) in order to reduce and avoid trade barriers and facilitate mutual recognition of conformity assessment.

3. Current participation

Currently (September 2022) the BIPM has 64 Member States and 36 Associates participating; that is 110 of the 193 States listed by the UN as Member States (CARICOM, one of the Economies participating in the BIPM as an Associate, having eleven participating states).

Historical participation and initiatives to facilitate participation; The first hundred years

One hundred years after 17 States signed the original treaty, at the time of the 15th meeting of the CGPM in 1975, there were 44 Member States. Acceding states increased at a modest rate over the next twenty-five years to 48 by the end of the millennium, where it remained for several years.

The establishment of Associate Status and the CIPM MRA

The Associate State status was created in 1999 alongside the launch of the CIPM MRA. This allowed participation in the CIPM MRA, at significantly reduced cost for smaller[6] states. It was aimed at states that

[6] The use of ‘small’ in relation to states in this document refers to its economic size and state of development as captured by the UN coefficient, not to geographic size or population.

are not yet ready to fully participate as Member States, and was adopted on the basis that over time, as the metrology system in such states evolved, they would do so.

Encouraging Associate States to accede

The 20 years or so that have followed the turn of this Century have seen a significantly greater rate of growth in participation. By 2010 there were 51 Member States and 32 Associate States and Economies involved in the CIPM MRA. Currently there are 64 Member States and 36 Associate States and Economies.

Some Associate States were participating extensively in the CIPM MRA, yet still chose to remain as Associate States, presumably because the cost was so much less. Concerns were voiced by the Member States that the subscriptions for such Associate States (in most cases one tenth of that for a Member State) were disproportionally low related to both the benefits of participation and the cost of running the system from which they benefited. The CIPM therefore set criteria, and for those Associate States meeting those criteria, took the step of writing to several Associate States to suggest they acceded. Take-up in response to this initiative was however very limited, with just a single state responding.

Lifting of the Associate State base and introduction of the escalator - 2011

The CIPM was prompted to take a further measure regarding the Associate State status following a review of the situation in 2010 and 2011. As a consequence, the CGPM adopted Resolution 4 (2011). This Resolution had two key elements. Firstly, the minimum subscription for an Associate State was doubled (starting in 2013) from 0.05 % to 0.1 % of the BIPM Dotation. Secondly, the so called ‘escalator’ was introduced. Associate States, after five years of participation, were to be assessed against the criteria set by the CIPM, and if appropriate encouraged to accede. Those states that chose not to accede after being encouraged were give a further year’s grace, then their subscription rose in steps, over a five-year period, until it reached 90 % of that which the state would pay if it acceded and became Member States. These measures were effective with ten Associates States acceding through the encouragement and escalator mechanism.

The BIPM CBKT Programme in 2016

The need to effectively integrate new players into the CIPM MRA (as well as to encourage load sharing amongst the more experienced NMIs) led to the creation of the BIPM Capacity Building and Knowledge Transfer Programme (CBKT) in 2016. Until 2020 the programme relied upon sponsor support. From 2020, the core elements related to effective operation of the CIPM MRA were brought within the funded envelope, whilst the topic based CBKT initiatives continue to rely on sponsor support. This highly regarded programme demonstrates that as participation in the activities of the BIPM evolves, it has been necessary and very beneficial for the BIPM’s role to evolve in parallel. The programme enabled a number of Associate States that had ‘stalled’ in trying to develop CMCs to break through and successfully develop CMCs that are now published. It also vastly improved the quality of submissions from many of the Associate States and less experienced Member States.

Exemption from the escalator for countries with low UN coefficients - 2017

The pool of states is finite. As participation has evolved over time, new Member States and Associate States were increasingly countries with relatively smaller and smaller economies and often in development or transition. In recent years virtually all new participants have emerging metrology systems. Coupled with this is the trend of modern times such that Member State contributions and Associate subscriptions are paid by the Ministry responsible for the NMI or the NMI itself, rather than directly by the state via their Ministry of Foreign Affairs. These metrology institutes often consist of a handful of staff, and many found payment of their national subscriptions challenging, a situation that became far more difficult for them as they progressed up the escalator. Discussions with the NMI Directors involved highlighted that their institutes struggled to justify the year-on-year increases in terms of the benefits received from participation. They did not have the expertise or resources to be involved in the Consultative Committees, nor even to attend meetings of interest at the BIPM Headquarters, such as topic-based workshops and the NMI Directors meeting. The increasing amounts payable as a consequence of the introduction of the escalator led to discussions with some Associate States in which they indicated that they would very reluctantly have to withdraw. These discussions sat alongside an increasing number of Associate States falling into arrears and facing exclusion.

By late 2016 the CIPM came to the view that it needed to take action to address this situation or lose a number of Associate States. A wide variety of measures were considered and the most promising were modelled[7]. Options were benchmarked for effectiveness whilst still ensuring that overall, the Associate States would still fully cover the costs of their engagement for the BIPM. Finally, in October 2017 the CIPM were able to adopt a decision (Decision CIPM/106-20), which introduced favourable conditions for the smaller Associates States with emerging metrology systems. Those Associate States below 0.02 % on the UN scale would no longer be required to have their subscriptions elevated via the escalator mechanism, and any already on the escalator were exempt from future elevated payments. The CIPM were equally clear that accession was a sovereign right, and universal participation, ideally as Member States, by all states was surely beneficial.

The adoption of Decision CIPM/106-20 was successful in that it avoided the pending withdrawals and exclusions for Associate States struggling under the escalator. However, the CIPM recognized that this measure did not address the core future membership challenge. Many of the remaining states not yet engaged are far 'smaller' than any those addressed in the decision.

In round terms, looking the percentage of world GDP. [8]

- The 64 Member States account for over 93 %
- The existing 36 Associate States and Economies account for a little over 4.7 %
- The remaining 83 listed UN Member States, have a combined GDP of only around 2.3 % of the world total (and consequently lower and lower UN coefficients).

4. Where next?

It is clear that Associate State status with its current subscription structure was a major factor in widening participation in the CIPM MRA. The creation of the CIPM MRA, and the efforts of the CIPM, BIPM staff (where a dedicated position of liaison officer was created in 2010, in part to facilitate participation of new Member States and Associates), RMOs and individual Member States collectively helped to increase the number of both Member States and Associate States substantially over the last 20 years. These efforts were aided by the support given to interested states by international organizations such as UNIDO and the World Bank Group. The CIPM recognizes that there now remains a large block, currently consisting of 83 states that are almost exclusively developing countries. These states are users of the SI, but are not engaged either as Member States or as Associate States.

Some modest further organic increase in participation (almost certainly as Associate States) can still be expected with the present approach. Likewise, a limited number of Associate States are likely to accede via the escalator mechanism. However, for most of the remaining 83 states the size and construction of their economy, the resources allocated to metrology, and their existing capabilities are very limited. Existing

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[7] See CIPM Restricted paper 106/CIPM 17 – 18.1 https://www.bipm.org/cc/CIPM/Restricted/106/CIPM17-17.1-micro-CEEMS.pdf

[8] IMF DataMapper World Economic Outlook (Oct 2019) available at https://www.imf.org/external/datamapper/NGDPD@WEO/OEMDC/ADVEC/WEOWORLD For countries where data was not available IMF 2018 data or UN data.

options are not sufficiently attractive in terms of costs and benefits and consequently the majority are unlikely to find participation a viable option under these present arrangements. If the goal of universality is to be achieved, new models of participation are likely to be needed.

Motivation for non-participating states

The Sustainable Development Goals (SDGs), adopted by the UN nations in 2015, form the cornerstone of internationally agreed policy for developing countries. UNIDO, one of the UN agencies most deeply involved, have identified access to effective quality infrastructure as a prerequisite for developing countries if they are to meet the economic and social goals set out in the SDGs. UNIDO have further identified the need for such countries to have a Quality Policy related to the establishment of an effective Quality Infrastructure, and have recently developed Guiding Principles, a Technical Guide, and a practical Tool to help them[9]. These various documents and guidance identify effective engagement with the international organizations, including the BIPM and OIML, as one of the steps on the development road. Consequently, interest in participation in the activities of the BIPM are likely to increase in the coming years from such countries.

Notably to reduce poverty there is a need for developing countries to:

- Demonstrate compliance with ever tougher regulatory requirements set by the major trade blocks to enable market access (particularly regarding contamination requirements for food and feed stuff).
- Add greater value to products 'in country', particularly though the export of prepackaged goods rather than exporting bulk commodities.
- Meet export customer quality expectations.
- Improve attractiveness for inward investment within a country, or access to, QI capability to demonstrate conformity assessment meeting regulatory and quality expectations, and for this to be internationally recognized.
- Increase tourist revenue by offering safer drinking water, cleaner air, with hotels and restaurants able to put food on the plate that is safe to eat.
- Protect citizens by offering safer drinking water, cleaner air, with food availability that is safe to eat.
- Improve health services for citizens including laboratory medicine support.
- Ensure citizens are properly protected in trade transactions through an effective legal metrology system, properly underpinned by appropriate metrology standards capability.

Motivation for Member States

It is inherently obvious that a world-wide metrology system should be, world-wide. Beyond this there are identifiable reasons why it is in the interest of existing Member States to pursue universality, which:

- Aligns with national commitments to the 2030 SDGs.
- Facilitates the increase in prosperity in developing countries, and thus reduces economic migration pressure on high-wage countries.
- Facilitates the increase in prosperity in developing countries, and thus increases market opportunities for the major exporter countries.
- Helps ensure food and feedstuffs imported are of the appropriate quality and are free from contamination (as only sample checks are possible at border control).
- Helps ensure any imported products really do conform to regulatory and quality standards and raises the quality of those goods, thus increasing consumer choice.

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[9] https://www.unido.org/resources-publications-advancing-economic-competitiveness/quality-and-compliance-infrastructure

- Provides greater assurance of a healthy environment for citizens on holiday.
- Leverages many national and international aid programmes by facilitating sustainable development.

Considerations

An important aspect for existing Member States when considering potential changes to the participation model is that any proposal for change leads to a new model that is fair. Individual states and a number of international bodies run programmes directly aiming to support developing countries. It is important to recognize that it is not the remit of the BIPM to be an aid provider. Thus, on broad terms, each 'class' of participation should cover the costs incurred by the BIPM.

5. The way forward

The CIPM decided on a two-pronged approach:

- In the short term, to explore more fully what can be done under the current mandates (notably under Resolution 7 of the 23rd meeting of the CGPM (2007)) to increase engagement with those states that are neither Member States nor Associate States, notably the 23 states (predominantly in Africa) that are members of an RMO, and so have an identifiable interlocutor.
- To seek a mandate from the Member States, in the form of a draft Resolution presented to the 27th CGPM, to undertake a deep review of options and, if appropriate, propose a new participation model, or choice of models, with an associated fee structure. The aim will be to ensure a sustainable future for the intergovernmental organization, enhanced support to the existing Member States and Associates whilst providing the right platform to facilitate the next steps towards universal participation.

Change in the membership model might be facilitated by changes in the structure of the BIPM Work Programme allowing differing levels of access, which could also bring wider benefits, and a parallel work item would be needed to explore this direction.

Additionally, to work with OIML through the Joint Task Group on both short-term and longer-term objectives: the OIML faces very similar challenges and opportunities.

Draft Resolution F "On universal adherence to the Metre Convention", is presented to the Conference to obtain a mandate towards a potential solution with appropriate consensus built that could be presented as a draft resolution to the 28th meeting of the CGPM.

E. Modernizing the operations of the organization

1. Background

In 1875 twenty nations came together to agree on a unified measurement system for trade between them, which was based on the metric system. After much deliberation on the practicalities of how to implement such a system, the Metre Convention (MC) was signed by seventeen nations. In Article 1 of the Convention, they agreed to establish an International Bureau of Weights and Measures (BIPM) with its headquarters in Paris. It is under the supervision of the CIPM (the governance body), itself being under the authority of the CGPM. "The BIPM" was legalized in France as a Public Utility, thus giving it a legal personality under which it could sign agreements with the French Government such as the "Headquarters agreement" with which the CIPM was charged in the MC to put in place, and with the municipal authorities for the provision of utilities, to procure services and instruments. As entrenched further in the MC and its Annex as well as decisions of the CGPM, the CIPM can sanction agreements between the BIPM and entities at an international level between meetings of the CGPM, and propose to the CGPM any issues for which the signatories need to give approval. This includes what should be done in common that would have an impact on the contributions by the signatories, and logically any issues over and above the direct responsibility of the CIPM.

The founding parties showed great foresight in the establishment of an organization that could, with minor additions to its founding documents in 1921, grow to the organization it is today. Although there are diverging views on what the intent was in 1875, the current participants in the MC agree on the importance of the unified measurement structure for the world, and thus the crucial role played by the original BIPM, and everything introduced since. The development of the ten Consultative Committees of the CIPM, the CIPM MRA with its members the NMIs and DIs, that was established in 1999 and the structures introduced by it (the RMOs and their technical committees and the Joint Committee of the Regional Metrology Organizations and the BIPM (JCRB)), clearly could not have been foreseen in 1875. But the framework as developed then allowed the evolution of the organization to a truly international organization, and what is being done in common stretches to all corners of the globe.

Embracing both views on the original intent in 1875, the CIPM decided in 2019 at its first meeting after election at the 26th CGPM (2018), to focus on the modernization of the organization, within the boundaries set by the founding documents. An important task was to ensure governance with policies and procedures in place appropriate for a modern international organization. The first two issues to be addressed were:

- Rules of Procedure for the CIPM
- CIPM Code of Conduct.

These were developed amongst the constraints imposed by the Covid-19 pandemic, and took longer than anticipated. Plans for more actions had to be delayed until after the 27th meeting of the CGPM; this also allowed time to request a mandate from the conference to continue with the modernization of the organization.

2. The Way forward

The CIPM took note of the reports from the *ad hoc* Working Group of Member State representatives and its recommendations, and already took decisions that could reduce confusion over how to refer to the organs of the BIPM, with the most important being how to clearly indicate when the scientific and technical staff and facilities in Paris is meant, to distinguish it from the wider organization.

Decision CIPM/111-5 (2022)

The CIPM, considering the response to comments on the text for a draft resolution prepared by the ad hoc Working Group of Member State representatives in February 2022, and in accordance with the

First Article of the Metre Convention, the CIPM recalled its decision CIPM/107-06 and decided to recommend the use of the term “Headquarters” (in French “Siège”) whenever it is required (for example in formal or informal documents) to refer to the scientific and technical staff and facilities at the Pavillon de Breteuil.

The CIPM has started the development of by-laws for the organization (in line with such rules of procedure or by-laws that most modern IOs have introduced). Unfortunately, due to the restrictions imposed by the Covid-19 pandemic, this could not progress to the point of consultation with stakeholders and will be a task for the next CIPM elected in November 2022.

Anticipating discussions with representatives to the CGPM on the report of the Co-chairs of the *ad hoc* Working Group of Member State Representatives and further input from the Conference, the CIPM will continue to develop rules of procedure and by-laws for consultation with the shareholders, with the aim for them to be presented to the 28th meeting of the CGPM.