

**International Regulatory Co-operation
and International Organisations**



The Case of the International Bureau of Weights and Measures (BIPM)



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By Juan (Ada) Cai



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Foreword

The case study of the International Bureau of Weights and Measures (BIPM) builds on OECD long-standing work on regulatory policy and governance, as set out in the *OECD 2012 Recommendation of the Council on Regulatory Policy and Governance* (Recommendation). It was developed in the framework of OECD work on international regulatory co-operation (IRC) (Principle 12 of the Recommendation), within the Partnership of International Organisations for Effective International Rulemaking (IO Partnership). It is part of a series started in 2014 that provides detailed overviews of the structure, governance, instruments and processes of international organisations (IOs) in support of international rulemaking and standard-setting. To date, the series includes the cases of the OECD, the International Maritime Organization (IMO), the Food and Agriculture Organization of the United Nations (FAO), the International Organization for Standardization (ISO), the International Organization of Legal Metrology (OIML), the United Nations Economic Commission for Europe (UNECE), the World Health Organization (WHO), Facilitating Trade Through Regulatory Co-operation: the Case of the WTO TBT/SPS Agreements and Committees, and the study on the World Organisation for Animal Health (OIE) Observatory on the Implementation of Standards.

The case studies complement broader analytical work conducted by the IO Partnership that compares the governance modalities and rulemaking processes of 50 IOs, annual meetings and technical discussions within five working groups. The work on international regulatory co-operation and IOs is conducted under the auspices of the OECD Regulatory Policy Committee, whose mandate is to assist both members and non-members in building and strengthening capacity for regulatory quality and regulatory reform.

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The study was prepared by Juan (Ada) Cai, Senior Engineer of the National Institute of Metrology (NIM), China, whilst on secondment to the BIPM. She conducted her research under the direction of Andy Henson, Director, and Rahima Guliyeva, International Liaison Officer, of the BIPM International Liaison and Communication Department.

The OECD prepared the common structure used to develop the studies and organised the regular meetings to discuss progress made and challenges faced in the research and drafting phases. In addition, the OECD ensured the quality control by reviewing the different drafts of the case study and managing the circulation of the final draft to OECD delegates and the 50 IOs involved in the work.

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Acronyms and abbreviations

AfCFTA	African Continental Free Trade Area
AFRIMETS	Intra-Africa Metrology System
APMP	Asia Pacific Metrology Programme
BIPM	International Bureau of Weights and Measures
CCs	Consultative Committees
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
CCRI	Consultative Committee for Ionizing Radiation
CCT	Consultative Committee for Thermometry
CCTF	Consultative Committee for Time and Frequency

CCU	Consultative Committee for Units
CGPM	General Conference on Weights and Measures
CIPM	International Committee for Weights and Measures
CIPM MRA	CIPM Mutual Recognition Arrangement
CMCs	Calibration and Measurement Capabilities
COOMET	Euro-Asian Cooperation of National Metrological Institutions
DIs	Designated Institutes
EASA	European Aviation and Safety Agency
EURAMET	European Association of National Metrology Institutes
FAA	U.S. Federal Aviation Administration
GATT	General Agreement on Tariffs and Trade
GULFMET	Gulf Association for Metrology
GUM	Guide to the Expression of Uncertainty in Measurement
IAEA	International Atomic Energy Agency
IAF	International Accreditation Forum
IEC	International Electrotechnical Commission
IFCC	International Federation of Clinical Chemistry and Laboratory Medicine
ILAC	International Laboratory Accreditation Cooperation
INetQI	International Network on Quality Infrastructure
IOs	International organisations
IRC	International regulatory co-operation
ISO	International Organization for Standardization

ITC	International Trade Centre
ITU	International Telecommunication Union
JCGM	Joint Committee for Guides in Metrology
JCRB	Joint Committee of the Regional Metrology Organizations and the BIPM
JCTLM	Joint Committee for Traceability in Laboratory Medicine
JRC	Joint Research Centre of the European Commission
NMIs	National Metrology Institutes
OECD	Organisation for Economic Cooperation and Development
OIML	International Organization of Legal Metrology
QI	Quality Infrastructure
RMOs	Regional Metrology Organizations
SI	International System of Units
SIM	Inter-American Metrology System
TAI	International Atomic Time
TBT	Technical Barriers to Trade
UNIDO	United Nations Industrial Development Organization
UTC	Coordinated Universal Time
VIM	International Vocabulary of Basic and General Terms in Metrology
WHO	World Health Organization
WMD	World Metrology Day
WMO	World Meteorological Organization
WTO	World Trade Organization

Introduction

The International Bureau of Weights and Measures (*Bureau International des Poids et Mesures*, BIPM) is the intergovernmental organisation through which Member States act together on matters related to measurement science and measurement standards. Together with the wider metrology community, as well as other strategic partners, the BIPM ensures that the measurement results from different states are comparable, mutually trusted and accepted.

The BIPM provides a forum for the creation and worldwide adoption of common rules of measurement. The international system of measurement that the BIPM co-ordinates worldwide underpins the benefits of international regulatory co-operation (IRC): increased trade and investment flows and additional GDP points; gains in administrative efficiency and cost savings for governments, businesses and citizens; and societal benefits such as improved safety and strengthened environmental sustainability. Accurate measurements are specifically necessary to regulators and legislators for establishing and enforcing regulatory limits, and an efficient worldwide measurement system is vital for IRC to avoid technical barriers to trade.

The BIPM's work concerns the international co-ordination of measurement science and measurement standards. It maintains a particularly close relationship with its sister organisation, the International Organization of Legal Metrology (OIML). The OIML, which was the subject of a previous study in the OECD series,¹ builds on the work of the BIPM, aiming to harmonise internationally the application of legal requirements to measurements and measuring instruments.

The objectives of this study are:

- to raise awareness of the role of metrology and the international measurement system, particularly for the regulatory community in the context of IRC;
- to explain the organisation, governance and performance of the international measurement system;
- to illustrate with in-depth examples the impact that the metrology community brings to the globalised world and each individual State.

This case study is structured around the following five chapters:

- “The context of regulatory co-operation” introduces metrology and its working mechanisms; the historical development of the Metre Convention and creation of the BIPM; and the institutional landscape that the BIPM works within, from the core area of metrology to the broader area of quality infrastructure (QI), and to the wider field involving all other organisations with which the BIPM liaises;
- “Main characteristics of regulatory co-operation in the context of the BIPM” describes the governance structure and operational modalities of the BIPM, and explains in detail the forms of regulatory co-operation provided by the BIPM to ensure worldwide uniformity of measurement;
- “Quality assurance, monitoring and evaluation mechanisms” summarises the measures and practices adopted by the BIPM to ensure the quality of its work, and the effective implementation of its mechanisms by Member States;
- “Assessment of the impact and success of regulatory co-operation through the BIPM” illustrates the economic benefits and societal impacts of metrology as a whole and of the BIPM generated through its work, with impact and case studies as supporting evidence;
- The final chapter draws conclusions from the study and looks ahead for future challenges.

The context of regulatory co-operation

Metrology and worldwide uniformity of measurements

What is metrology?

Measurement is the process of experimentally obtaining one or more quantity values that can reasonably be attributed to a quantity (JCGM, 2012). Ordinary measurements take place everywhere and every day in our life, be it checking the time, measuring body temperature, or weighing fruit in a supermarket. However, when it comes to manufacturing, trade, safety, regulatory administration, and quantitative research in many disciplines, measurements need to be highly accurate and consistent worldwide.

Metrology is the science of measurement and its application. It includes all theoretical and practical aspects of measurement, whatever the measurement uncertainty and field of application (JCGM, 2012). The objectives of the metrology community are to ensure that:

- Measurements are **accurate**
 - An expressed value can be as close to the true value as possible
- Measurements are **stable**
 - Long-term trends can be used for decision-making
- Measurements are **comparable**
 - Results from different laboratories can be brought together

- Measurements are **coherent**
 - Results from different methods can be brought together.

Metrology is of vital importance to human society (Figure 1). The intricate but invisible networks of services, suppliers and communications upon which we are all dependent are reliant on metrology for efficient and reliable operation. For example:

- The economic success of nations depends upon the ability to manufacture and trade precisely made and tested products and components.
- A common international time scale makes accurate positioning possible through satellite navigation, enabling electronic banking, the internet and telecommunications.
- Human health depends critically on the ability to make accurate diagnoses, in which reliable measurement is increasingly important.
- Consumers have to trust the amount of petrol delivered by a pump, and the metered amount of electricity or gas.
- The effective implementation of regulations and specifications relies on conformity assessment, and in many cases specifically on measurement and testing.

The metrology community works to ensure that internationally accepted and 'fit for purpose' measurement capability is available across the scope of human activity, and also to prepare for the next generation of needs. As the ability to measure is an enabling technology to control manufacturing and processes, improvements in metrology open new opportunities for innovators across many fields.

Figure 1. Measurement affects daily life



Source: BIPM, 2017.

How metrology enables worldwide uniformity of measurement

The objectives of metrology are achieved through the provision of a framework for metrologically “traceable” measurements, which contains the following three basic elements:

- The definition of internationally accepted units of measurement, for example the metre.
- The realisation of units of measurement by measurement standards, for example the realisation of a metre through the use of a laser wavelength.
- The establishment of a metrological traceability chain that transfers quantity values of measurement standards to measuring instruments, for example to calibrate a standard gauge block in a precision engineering workshop using a laser interferometer calibration system in a metrology laboratory.

Units of measurement

The International System of Units (*Système International d’Unités*), referred to as the SI, is a coherent system of units used throughout the world.² Definitions of the SI units are developed in collaboration under the auspices of the BIPM and are published by the BIPM through its publication, the SI Brochure.³ The SI consists of a set of base units,

prefixes and derived units. The base quantities are a choice of seven well-defined quantities, which by convention are regarded as dimensionally independent: time, length, mass, electric current, thermodynamic temperature, amount of substance, and luminous intensity, with their corresponding base units being the second, metre, kilogram, ampere, kelvin, mole, and candela. Derived units (such as for force, pressure, area, volume or speed) are formed by combining the base units according to the algebraic relations linking the corresponding quantities.

Measurement standards

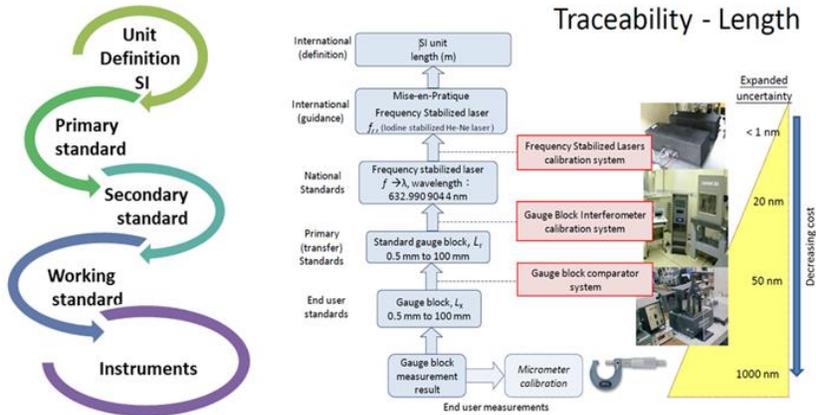
The realisation of a measurement unit is the conversion of its definition into reality. Definitions of the SI units are realised by measurement standards. Different from the “documentary standards” (for example ISO and IEC standards, OIML Recommendations, etc.) that provide requirements and specifications, measurement standards involve apparatus in physical areas, or reference materials with certified values in chemical areas. Box 1 provides examples of measurement standards. Details of practical realisation of the definitions of some important units are given in the SI Brochure.

Box 1. Example of measurement standards and the traceability chain

- The time frequency standard is a caesium atomic fountain clock with a relative standard measurement uncertainty of 2×10^{-15} .
- Standards for mass concentration of different proteins are reference materials providing these quantity values with measurement uncertainties.

The hierarchy of measurement standards starts with a primary standard, normally held at the national level at the apex and goes all the way down to working standards (Figure 2). The primary standards are known with the highest precision and are recognised by the national authority to serve as the basis for assigning values to other standards of the quantity concerned.

Figure 2. Example of measurement standards and the traceability chain



Source: BIPM, 2017, and courtesy of Stuart Davidson, NPL.

Metrological traceability chain and calibrations

Primary standards are used to calibrate secondary standards, and they in turn are used to calibrate working standards. These working standards are then routinely used to calibrate measuring instruments or reference materials found in science, manufacturing, trade, regulatory activities, etc. It is this chain of activity that is referred to as the metrological traceability chain.

At each step in such a traceability chain, a certain degree of precision is lost; this can be balanced against equipment becoming more robust, cheaper, easier and faster to use. Metrological traceability is important because it gives you confidence that your measurement results are “right”. The results can be used to provide calibrations, perform tests, or make conformity assessment decisions that affect operability, reliability and regulatory compliance.

The Metre Convention and creation of the BIPM

Although standardisation of weights and measures has been a goal of social and economic advances since very early times, it was not until the 18th century that there was a unified system of measurement. The

earliest systems of weights and measures were based on human morphology, for example the inch, the hand, the foot, and the yard or cubit corresponded to dimensions of the human body. Consequently, these units of measurement were not fixed; they varied from one town to another, from one occupation to another, and with the type of object to be measured.

This lack of a standardised system of measurements was a source of confusion, mistrust, error and fraud in commercial and social transactions, putting a brake on international commerce and preventing the development of science as an international endeavour. With the expansion of industry and trade, there was an increasing need for harmonisation of weights and measures between countries. Politicians and scientists proposed to resolve this situation by adopting a standard of measurement by comparison with a standard taken from nature.

The metric system began in France in the late 1700s. The first natural measure was the metre, defined as being equal to the ten-millionth part of one quarter of the terrestrial meridian.⁴ Such a unit was not arbitrary, being based on the size of the Earth. The utility of the French metric system attracted other countries as the 19th century progressed. However, those countries were dependent for their national standards on copies of the original prototypes. This dependence, together with the lack of uniformity in making copies, hindered adoption of this system.

To overcome these difficulties, a diplomatic treaty known as the Metre Convention was signed in Paris on 20 May 1875 by representatives of seventeen States.⁵ It established a scientific and permanent intergovernmental organisation,⁶ the *International Bureau of Weights and Measures* (BIPM), with its headquarters in Paris.⁷ It also laid down the way in which the activities of the BIPM should be financed and managed. The Convention remains the basis of international agreement on units of measurement and the worldwide measurement system.

Box 2. World Metrology Day (WMD)

To celebrate the signing of the Metre Convention, the date of 20 May is known as World Metrology Day (WMD). This is a key event to raise awareness of the importance of metrology. Originating in 2000, the annual WMD project is jointly organised by the BIPM and the OIML, with the participation of national metrology institutes and regional metrology organizations worldwide. In 2019, celebrations in more than 40 countries were listed on the WMD website (www.worldmetrologyday.org) and posters in more than 15 languages were published.

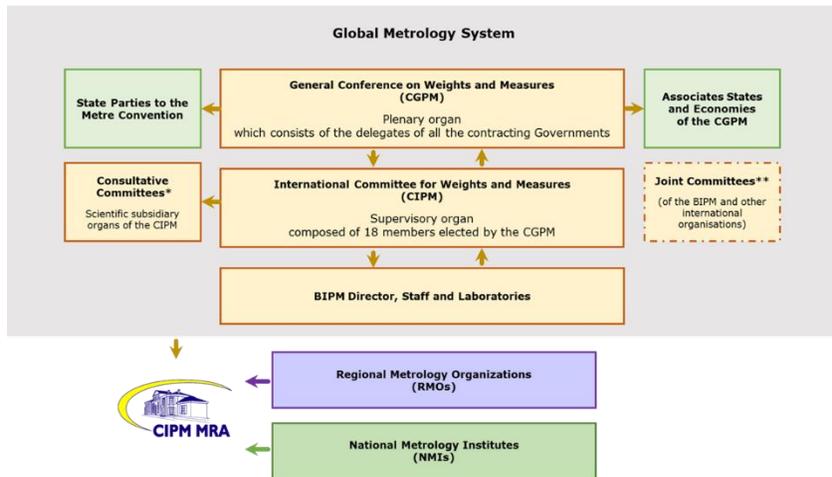
The institutional landscape for metrology

The institutional landscape for metrology can be considered from three perspectives: firstly organisations of the global metrology system; secondly how metrology fits into the wider quality infrastructure; and thirdly other international organisations for whom accurate and reliable measurements are important and with which the BIPM liaises.

Structure of the global metrology system

The global metrology system is the technical and administrative infrastructure maintained by the National Metrology Institutes (NMIs) in collaboration through the Regional Metrology Organizations (RMOs) and the BIPM that enables a comparable basis for measurements around the world (Figure 3).

Figure 3. Structure of the global metrology system



*There are currently ten Consultative Committees which advise the CIPM on scientific issues and the administration of the CIPM MRA.

**They include: Joint Committee for Guides in Metrology (JCGM), Joint Committee of the RMOs and the BIPM (JCRB), Joint Committee for Traceability in Laboratory Medicine (JCTLM), and International Network on Quality Infrastructure (INetQI).

Source: BIPM, 2020

National Metrology Institutes (NMIs)

An NMI has the responsibility of developing and maintaining national measurement standards and disseminating the SI units. To aid international recognition of national measurement standards and the associated measurement capabilities, NMIs participate in international comparisons of measurement standards under the CIPM MRA (Mutual Recognition Arrangement) framework (see next chapter). In some States, NMI functions are not restricted to a single entity. They may have a distributed system where a number of different metrology institutes develop and maintain national measurement standards in their own specialised fields and work collectively. Today, the NMIs of the industrialised countries serve as the national focus of measurement science, providing leadership to nationwide and worldwide scientific cooperation relating to metrology. The BIPM hosts (typically annual) meetings of NMI Directors and State Party Representatives to discuss metrological issues of worldwide concern.

Regional Metrology Organizations (RMOs)

RMOs are regional associations of NMIs. They have a wide range of activities, with perhaps the most important role being their participation in the operation of the CIPM MRA. In particular, they carry out regional comparisons corresponding to the international comparisons, establish and maintain quality oversight of participating institutes. Additionally, RMOs collaborate with the BIPM to organise capacity building and knowledge transfer activities for their members. Some RMOs, most notably EURAMET, run metrology research programmes. The RMO membership is wider than the BIPM membership (particularly in Africa), and thus countries with very limited metrological capacity in that region are also able to benefit from the “transfer down” of metrological knowledge (Table 1).

The BIPM works closely with the RMOs primarily through the Joint Committee of the Regional Metrology Organizations and the BIPM (JCRB) on the operation of the CIPM MRA, as well as through direct participation at the RMO General Assemblies and meetings of their technical working groups.

Table 1. RMOs recognised within the framework of the CIPM MRA

• AFRIMETS	Intra-Africa Metrology System
• APMP	Asia Pacific Metrology Programme
• COOMET	Euro-Asian Cooperation of National Metrological Institutions
• EURAMET	European Association of National Metrology Institutes
• GULFMET*	Gulf Association for Metrology
• SIM	Inter-American Metrology System

Note: *At the time of writing, the recognition of GULFMET by the CIPM is “provisional”.

Source: BIPM, 2020

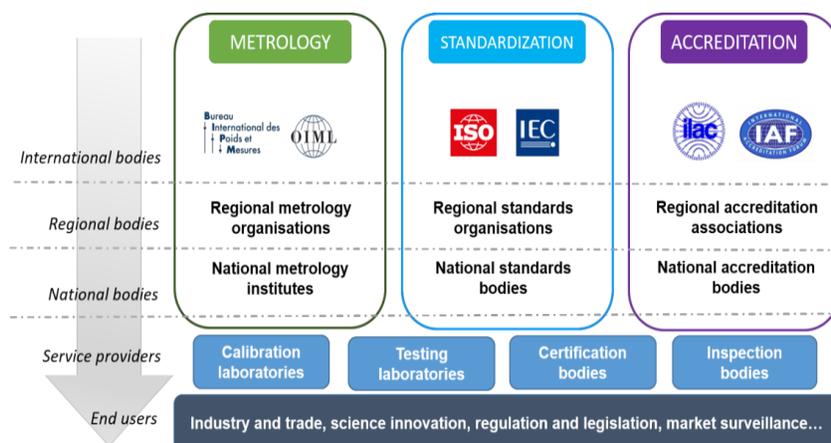
The network of quality infrastructure (QI)

Metrology is one of the key components of a quality infrastructure (QI), defined as “the system comprising the organisations (public and private) together with the policies, relevant legal and regulatory framework, and

practices needed to support and enhance the quality, safety and environmental soundness of goods, services and processes, relying on metrology, standardisation, accreditation, conformity assessment, and market surveillance.”⁸ Thus at the international level, the BIPM liaises closely with the other intergovernmental or international organisations in legal metrology, standardisation, accreditation and conformity assessment, to constitute the wider and very interdependent network of QI (Box 3).

The International Network on Quality Infrastructure (INetQI) is a grouping of twelve international organisations⁹ that are specialised in promoting and implementing QI activities. It meets annually and is the leading network in coordinating QI activities worldwide. Among all INetQI members, the OIML, ILAC and ISO are the closest collaborators with the BIPM to ensure the delivery of sound measurements to the ‘workforce’.

Figure 4. Key players in the QI system



Source: BIPM, 2020

Box 3. Highlights of cooperation between the BIPM and its key QI partners

BIPM and OIML (legal metrology)

The BIPM, the OIML (and UNIDO) signed a Memorandum of Understanding in 2008. The BIPM and the OIML interact at a senior level through annual bilateral and multipartite meetings to address metrological issues; they collaborate to promote WMD; the OIML is a member of the Joint Committee for Guides in Metrology (JCGM) operated by the BIPM (see the next chapter) and INetQI; they also collaborate on the potential participation of new States

BIPM and ILAC (accreditation)

The BIPM-ILAC Memorandum of Understanding was signed in 2001, reaffirmed in 2012 and in 2016. The two organisations collaborate through mutual observer/liaison status at meetings; ILAC is a member of the JCGM, JCTLM operated by the BIPM (see the next chapter) and INetQI; the BIPM is an active participant in the ILAC Accreditation Committee (ILAC AIC) and particularly the AIC WG2; the BIPM organises consultation with NMIs (via RMOs) on key ILAC documents; the BIPM and ILAC issue joint declarations and joint statements when appropriate.

BIPM and ISO (standardisation)

Many ISO documentary standards involve appropriate measurements and thus rely on the SI and the quality infrastructure. ISO interacts with the BIPM at senior level through an annual multipartite meeting at the BIPM (with ILAC and OIML); ISO is a member of the JCGM and INetQI; a number of ISO Technical Committees (TC) or Subcommittees (SC) participate in Consultative Committees of the BIPM. The BIPM has Liaison A status (organisations that make an effective contribution to the technical work) with several ISO TCs or SCs.

Other international bodies with which the BIPM liaises

In addition to international organisations involved in QI, the BIPM also liaises with some 20 international bodies¹⁰ whose missions depend on sound measurement.

Box 4. Examples of other liaisons

The BIPM and the International Atomic Energy Agency (IAEA) have worked closely in the field of radiation since 1972. The IAEA makes use of the BIPM's scientific expertise to calibrate its secondary standards used in Secondary Standard Dosimetry Laboratories (SSDLs). The IAEA participates in the Consultative Committee for Amount of Substance: Metrology in Chemistry and Biology (CCQM) and the Consultative Committee for Ionizing Radiation (CCRI).

The Time Department of the BIPM has close links with the International Telecommunication Union (ITU), which establishes the rules for dissemination of Coordinated Universal Time (UTC) through standard frequency and time signal services. The BIPM is a Sector Member of the ITU-Radiocommunication Sector (ITU-R), and reciprocally, ITU-R participates in the Consultative Committee for Time and Frequency (CCTF).

The BIPM works closely with the World Meteorological Organization (WMO) to ensure that measurements related to monitoring climate change are reliable.

In a fast changing world, the BIPM must remain agile in terms of its activities to be able to take advantage of new opportunities as liaison partners respond to their changing needs. Consequently, the BIPM maintains and updates individual strategic aims for its interactions with liaison organisations. The international liaison activities are undertaken by the International Liaison and Communication Department, and by four scientific departments of the BIPM for matters in specific fields.

Main characteristics of regulatory co operation in the context of the BIPM

Governance arrangements and operational modalities of the BIPM

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

Its mission is to work with the NMIs of its Member States, the RMOs and strategic partners worldwide 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 are to:¹¹

- Represent the worldwide measurement community, aiming to maximise its uptake and impact.
- Be a centre for scientific and technical collaboration between Member States, providing capabilities for international measurement comparisons on a shared-cost basis.
- Be the coordinator of the worldwide measurement system, ensuring it gives comparable and internationally accepted measurement results.

Fulfilling the BIPM mission and objectives is complemented by its work in:

- Capacity building, which aims to achieve a global balance between the metrology capabilities in Member States; and
- Knowledge transfer, which ensures that the work of the BIPM has the greatest impact.

Membership

Only States can accede and become States Parties to the Metre Convention (often referred to as Member States).¹² In 1999, the General Conference on Weights and Measures (CGPM) created the status of 'Associate of the CGPM'¹³ so that states not yet ready for membership, and some economic entities, could have limited participation in the activities of the BIPM through their NMI.

As of 13 January 2020, the BIPM has 62 Member States and 40 Associate States and Economies,¹⁴ which account for 110¹⁵ of the 193 UN Member States.

Member States

All States are able to accede to the Metre Convention. To become a State Party to the Metre Convention, a State must notify its national decision to accede to the Metre Convention to the French Ministry of Europe and Foreign Affairs. New Member States pay their first annual contribution plus a one-off entrance contribution (currently equal to the amount of the first annual contribution). The status of Member State accords a number of rights, in particular:

- to attend and vote at meetings of the CGPM;
- to obtain internationally recognised measurement traceability through the BIPM calibration services, at no additional cost;
- to purchase, at cost, a calibrated platinum-iridium kilogram;
- the potential opportunity for its experts to participate in the Consultative Committees created by the CIPM;
- a possible opportunity for its scientists to participate in various scientific programmes run by the BIPM;
- to participate in the CIPM MRA and have their internationally recognised national calibration and measurement capabilities

(CMCs) published in the CIPM MRA database, known as the KCDB;

- to attend the meetings of NMI Directors and State Party Representatives, organised by the BIPM;
- to participate in the BIPM Capacity Building and Knowledge Transfer (CBKT) Programme (BIPM, 2018a).

Associate States and Economies

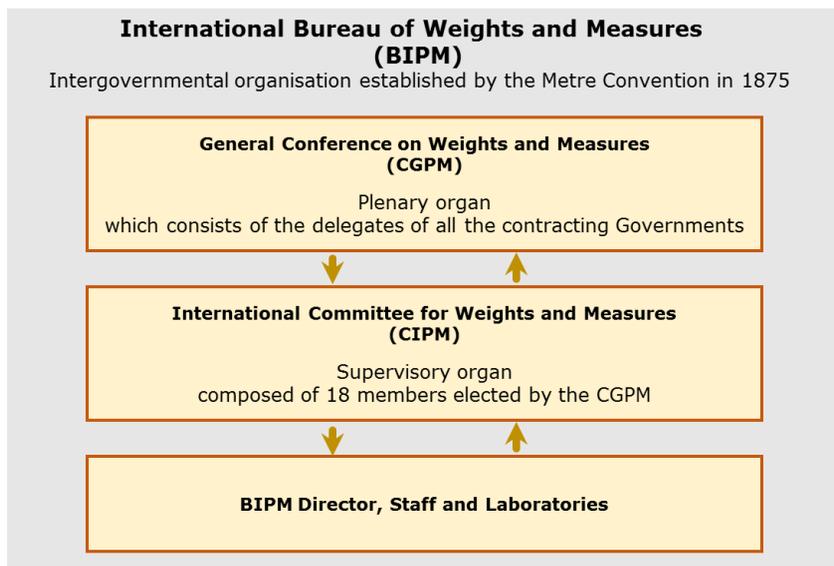
In 1999 the status of “Associate of the CGPM” was created, open to States and Economies without well-established national metrology systems, to enable such States and Economies to participate in the CIPM MRA.¹⁶ A State wishing to become an Associate may do so by application to the Director of the BIPM, and by the payment of the first annual subscription. As an Associate, a State or Economy cannot enjoy the first five rights of Member States as stated above (BIPM, 2018b).

The status of Associate State should be a possible first step to accede to the Metre Convention.

Organisational structure

The three organs of the BIPM are the CGPM, the CIPM and the scientific and administrative organ, often referred to in practice as the “BIPM”, which operates under the exclusive direction and supervision of the CIPM, itself placed under the authority of the CGPM (Figure 5).¹⁷

Figure 5. Organisational structure of the BIPM



Source: BIPM, 2020

General Conference on Weights and Measures (CGPM)

The CGPM is the plenary organ of the BIPM, which consists of the delegates of all the contracting Governments. Associates of the CGPM have the right to participate in meetings of the CGPM as non-voting observers. The General Conference receives the report of the CIPM on work accomplished; it discusses and examines the arrangements required to ensure the propagation and improvement of the SI; it endorses the results of new fundamental metrological determinations and various scientific resolutions of international scope; and it decides all major issues concerning the organisation and development of the BIPM, including the dotation of the BIPM. The CGPM meets in Paris, usually once every four years.

International Committee for Weights and Measures (CIPM)

The CIPM is the organ that exerts the exclusive direction and supervision of the BIPM. It is placed under the authority of the CGPM. It is composed of 18 members, each of a different nationality. The CIPM meets once or twice a year to, among other matters, discuss reports presented by its

Consultative Committees, oversee the progress of the decisions of the CGPM and the BIPM Work Programme, take decisions on various issues, and follows them up. A “bureau” of the CIPM is set up as a restricted collegial organ of the CIPM, composed of the President, the Secretary and two Vice-Presidents, and supported by the Director of the BIPM. Over the years, the CIPM has included a number of world-class scientists, including five Nobel Prize winners.

CIPM Consultative Committees (CCs) and Working Groups (WGs)

The activities under the framework of the Metre Convention, initially limited to measurements of length and mass, have been extended over time to address measurement of electricity (1927), photometry and radiometry (1937), ionizing radiation (1960), time scales (1988) and chemistry (2000). Accordingly, over the years, the CIPM set up a number of scientific subsidiary organs, known as Consultative Committees (CCs), to assist it on scientific and technical matters in these areas. The CCs have broadened as science and technology advances (Box 5).

The objectives of the CCs are to:

- Progress the state-of-the art by providing a global forum for NMIs to exchange information about the state of the art and best practices,
- Define new possibilities for metrology to have impact on global measurement challenges by facilitating dialogue between the NMIs and new and established stakeholders, and
- Demonstrate and improve the global comparability of measurements. Particularly by working with the RMOs in the context of the CIPM MRA to:
 - plan, execute and monitor KCs, and to
 - support the process of CMC review.

The presidents of the CCs are appointed by, and are normally members of, the CIPM. Membership of a CC is open to NMIs of Member States that are recognised internationally as most expert in the field, with other NMIs from Member States able to attend CC meetings as observers. The BIPM provides Executive Secretaries for these CCs. A substantial amount of CC work is carried out by its working groups established to deal with specialised topics.

Box 5. Consultative Committees 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
CCRI	Consultative Committee for Ionizing Radiation
CCT	Consultative Committee for Thermometry
CCTF	Consultative Committee for Time and Frequency
CCU	Consultative Committee for Units

The “BIPM” as the scientific and administrative organ

The BIPM headquarters (Director, staff and laboratories) are located at the Pavillon de Breteuil in Sèvres,¹⁸ France. The BIPM enjoys functional privileges and immunities by virtue of the Headquarters Agreement, signed between the CIPM and the French Government in 1969.

The Director of the BIPM is responsible to the CIPM for the running of the BIPM. The Director must be of different nationality to the President and the Secretary of the CIPM. The BIPM operates four scientific

departments/laboratories in the fields of physical metrology, time, ionizing radiation and chemistry. These laboratories coordinate international comparisons of national measurement standards that rely on specific, dedicated facilities and expertise, uniquely developed and maintained by the BIPM, and provide selected calibrations for Member States. In addition, there is an International Liaison and Communication Department, and various supporting sections. Currently there are around 70 permanent staff working at the BIPM, supported by an average of 13 full-time-equivalent secondees per year from various Member States.

Decision-making process

The CGPM adopts Resolutions and decisions on all matters within its attributions. The CGPM makes decisions based on votes made by Member States present at its meetings. The general majority rule at the meetings of the CGPM is that of absolute majority of represented voting Member States, apart from decisions concerning the increase of the dotation, the calculation of the contributions, and matters of the Treaty itself, for which there should be no votes against.

The CIPM adopts scientific and administrative unilateral acts in the form of decisions or recommendations during its sessions or by correspondence. It also decides and monitors the budgeting of the BIPM. The CIPM works generally by consensus; if there is a need to vote it is by majority. The Director of the BIPM has a vote in the CIPM although not being a member. In the case of an evenly split vote, the President has a casting vote.

Budget

The BIPM budget comes primarily from the annual dotation of the BIPM (contributions of Member States), as well as subscriptions from Associates and other minor income sources, totaling around 13 million euros. The dotation is decided by the CGPM through a Resolution normally once every four years, corresponding to the activities proposed and agreed for the forthcoming BIPM Work Programme.

The annual dotation of the BIPM is partitioned amongst the Member States based on the *Scale of Assessments for the apportionment of the expenses of the United Nations (UN)*¹⁹ adopted by the UN General Assembly every three years. However, the scale is adjusted to take

account of the differing membership of the two organisations, and of the caps adopted by the CGPM for the maximum and minimum contributions of Member States (BIPM, 2020). The subscription of Associates is calculated as a percentage of the dotation, again based on the UN Scale adjusted as for Member States, but subject to a lower minimum threshold, that is one fifth of that for Member States.

The annual budget of the Director of the BIPM, staff and laboratories is proposed by the Director of the BIPM based on the available budget, and is approved by the CIPM.

Forms of regulatory co-operation

In 2012, OECD countries adopted the Recommendation of the Council on Regulatory Policy and Governance, making international regulatory co-operation (IRC) a key ingredient of regulatory quality (OECD, 2012). IRC plays a strong role to “harness” and create the common rules of globalisation. It adapts rulemaking for an interconnected world. International organisations (IOs) play a growing role as standard setting bodies in supporting regulatory co-operation. OECD (2016) shows that IOs contribute to IRC by offering platforms for continuous dialogue on regulatory issues; facilitating the comparability of approaches and practices; providing member countries with flexible mechanisms to identify and adapt to new and emerging regulatory areas or issues; contributing to the development of a common regulatory language; and developing international legal and policy instruments.

In the field of metrology, there are two intergovernmental organisations contributing to IRC in this field. One is the BIPM created by the Metre Convention in 1875; the other is the OIML, which was created by the *Convention establishing an International Organisation of Legal Metrology* in 1955. While the BIPM focuses on coordinating common actions relating to measurement science and measurement standards, the OIML focuses on unifying the practice and process of applying statutory and regulatory structure and enforcement to metrology.²⁰

The BIPM contributes to the IRC objectives through providing a global forum for the creation and effective implementation of an internationally agreed system of measurement. The ‘forms of regulatory co-operation’ provided by the BIPM include:

- Relevant Resolutions of the CGPM and Decisions of the CIPM.
- International standards in the field of metrology, including:
 - the International System of Units, the SI, and
 - the international reference time scale (UTC).
- The CIPM MRA, the international arrangement established to enable the mutual recognition of national measurement standards and of calibration and measurement certificates issued by NMIs.
- The Guides in metrology provided by the JCGM, including the '*Guide to the Expression of Uncertainty in Measurement*' (known as the GUM) and the '*International Vocabulary of Basic and General Terms in Metrology*' (known as the VIM).
- The authoritative listing of available higher-order reference materials, measurement procedures and measurement laboratories maintained by the JCTLM. The JCTLM provides a worldwide platform to promote, and give guidance on, internationally recognized and accepted equivalence of measurements in laboratory medicine and traceability to appropriate measurement standards.
- Joint Declarations, MoUs and agreements on some concepts and principles.

Resolutions of the CGPM and Decisions of the CIPM

The fundamental principles of free consent and of good faith and the *pacta sunt servanda* rule, which is defined by Article 26 of the Vienna Convention on the Law of Treaties (1969) and which provides that “every treaty in force is binding upon the parties to it and must be performed by them in good faith”, are universally recognized as rules of international customary law. Consequently, as Parties to an international convention, Member States are bound by the Metre Convention and must execute it in good faith.

In addition, when Member States adopt binding decisions at the meetings of the CGPM, they have the obligation to execute them in good faith (BIPM, 2018c). Resolutions of the CGPM are fundamental decisions adopted by the CGPM.

Decisions of the CIPM can be on scientific or institutional matters. Even though the CIPM is an independent body, its decisions cannot be in

contradiction with the resolutions and decisions adopted by the CGPM. Some decisions may encourage actions by the wider community.

In addition, the BIPM also provides a forum for the development of a wide variety of scientific and technical publications. These documents and publications report work progress of the BIPM, study and disseminate developing trends and strategies, transfer knowledge to the world metrology community, and coordinate this community to act together on matters relating to metrology. Key documents and publications include:

- Documents of the CGPM:
 - Convocation to meetings of the CGPM
 - Proceedings of the CGPM (*Comptes Rendus*) which include the Resolutions
- Reports of the CIPM:
 - Annual Report to Governments
 - Notification of the contributive parts of the Contracting States
 - Reports of CIPM meetings (*Procès-Verbaux*)
 - Report of the President of the CIPM to the CGPM
- Reports from the BIPM:
 - Director's Report on the Activity and Management of the BIPM (officially presented to each meeting of the CIPM)
- Reports of the CIPM's CCs
- Metrology references:
 - SI Brochure
 - *Mises en pratique*: Instructions for practical realization of the SI units
 - *Metrologia*: the leading international journal of pure and applied metrology, publishing peer reviewed scientific papers in the field
 - *Circular T*, the monthly publication of the Time Department that provides traceability to UTC
- Recommended values of standard frequencies

The International System of Units (SI)

The BIPM is the custodian of the SI, which provides a universal language for measurement. Following an international inquiry by the

BIPM, which began in 1948, in addition to the *metre*, the *kilogram* and the *second*, the CGPM at its 10th meeting, in 1954, approved the introduction of the *ampere*, the *kelvin* and the *candela* as base units, respectively, for electric current, thermodynamic temperature and luminous intensity. The name “International System of Units”, with the abbreviation SI, was given to the system by the 11th meeting of the CGPM (1960). At the 14th meeting of the CGPM (1971), after lengthy discussions between physicists and chemists, the current version of the SI was completed by adding the *mole* as the base unit for amount of substance, bringing the total number of base units to seven. The SI and the guidance on practical realisations of the SI base units are published by the BIPM through the SI Brochure.

The BIPM also works closely with NMIs in further developing the SI. On 16 November 2018, the CGPM, at its 26th meeting, agreed perhaps one of the most significant revisions to the SI since its inception (Box 6). Research into new measurement methods, including those using quantum phenomena, underpin the change. The SI is now based on a set of definitions each linked to the laws of physics and which have the advantage of being able to embrace further improvements in measurement science and technology to meet the needs of future users for many years to come.

Box 6. Revision of the SI



Box 6. Revision of the SI (cont.)

In the revised SI four of the SI base units – namely the kilogram, the ampere, the kelvin and the mole – are redefined in terms of constants; the new definitions are based on fixed numerical values of the Planck constant (h), the elementary charge (e), the Boltzmann constant (k), and the Avogadro constant (N_A), respectively. Further, the new definitions of all seven base units of the SI are also uniformly expressed using the explicit-constant formulation. The new definitions of the SI base units came into effect on 20 May 2019.

See the BIPM website for more information.

Coordinated Universal Time (UTC)

The BIPM is responsible for generating the international reference time scale, Coordinated Universal Time (UTC), or in simple terms, the world standard time.

Physical realisations of UTC are maintained in National Metrology Institutes or observatories. About 500 atomic clocks in approximately 80 national laboratories around the world send their clock data to the BIPM. The weighted average of these readings contributes to the calculation of International Atomic Time (TAI). UTC is then derived from TAI by the application of the total number of leap seconds, and the time laboratories use UTC to steer their national disseminations of time, ensuring that ‘time’ is coherent worldwide (CCTF, 2016). Values of $[UTC - UTC(k)]$ at five-day intervals are published in the monthly BIPM *Circular T*, which gives official traceability to UTC to the world.

The quality of the data has increased dramatically over the years, as a result of the progress made in clocks and time and frequency transfer techniques, in parallel with the constant improvement in the treatment of the data at the BIPM.

The CIPM MRA

The CIPM Mutual Recognition of national measurement standards and of calibration and measurement certificates issued by national metrology

institutes (known as the CIPM Mutual Recognition Arrangement, or CIPM MRA) is the framework through which NMIs:

- Demonstrate the international equivalence of their measurement standards; and
- Accept the calibration and measurement certificates they issue.

The outcomes are:

- Recognised degrees of equivalence between national standards; and
- Peer-reviewed, approved and therefore internationally recognised CMCs of the participating institutes.

The outcomes are publicly available from the CIPM MRA database, known as the KCDB, maintained by the BIPM.

The CIPM MRA responds to the need for an open, transparent and comprehensive scheme to give users reliable quantitative information on the comparability of national metrology services and to provide the technical basis for wider agreements negotiated for international trade, commerce and regulatory affairs.

The CIPM MRA was launched on 14 October 1999, signed by NMI Directors from 38 Member States and two international organisations. The participation has since grown significantly and today there are more than 100 signatory institutes from all Member States and Associates and four international organisations; it further covers over 150 institutes designated by these signatory bodies.

The origins of the CIPM MRA

The backdrop to the CIPM MRA was the major increase in world trade triggered by the General Agreement on Tariffs and Trade (GATT),²¹ and the focus by the WTO on technical barriers to trade (TBT). The need to measure accurately and consistently, and to have those measurements accepted across trading partners, is fundamental to an increasingly globalised world.

In addition to these changes on the world stage, three different developments collectively reinforced the need for a comprehensive and coherent solution to establishing and demonstrating the degree of international equivalence at the NMI level. Firstly, in order to meet regulatory requirements, US companies operating worldwide as well as the

companies subcontracted to them had to send instruments back to the US for calibration, causing inherent delays, increased cost for the companies and increased workload for the US NMI. Secondly, the emerging accredited-laboratory sector wished to access NMI services in both their own country and aboard, and to have a simple way of assuring the quality of those services. Thirdly, from the late 1970s onwards, the emergence of regional metrology cooperation through the RMOs led to an urgent need to somehow tie together their regional comparisons with those of the CIPM and the BIPM (Henson, 2015).

In 1999, Resolution 2, adopted at the 21st meeting of the CGPM, formally paved the way for signature of the CIPM MRA. The CGPM invited:

- All Member States of the Metre Convention to participate in the arrangement by giving authority to the director of the designated national metrology institute in their country to sign the arrangement;
- All Member States to make every effort to implement the arrangement and to encourage other authorities in their country to recognise the equivalence of national measurement standards and calibration and measurement certificates thereby demonstrated;
- All States to use this arrangement as the basis for recognising the national measurement standards and calibration and measurement certificates of signatory national metrology institutes.

In parallel, following consultation with the WTO, consideration was given to ensure that the CIPM MRA did not itself become a technical barrier to trade. The CGPM created a new status of “Associate of the CGPM” to allow States that were not yet ready to become Member States (and in special cases Economies) the opportunity to participate in the CIPM MRA.

Participation in the CIPM MRA

The CIPM MRA is open to NMIs (and other designated institutes in States with a distributed metrology system) of Member States and Associates, and a limited number of international and intergovernmental organisations invited by the CIPM.²²

The engagement and mutual recognition rules are that NMI Directors sign the CIPM MRA with the approval of the appropriate authorities in their own country and thereby:

- Accept the process specified in the CIPM MRA for establishing the database;
- Recognise the results of key and supplementary comparisons as stated in the database; and
- Recognise the published CMCs of other participating NMIs and DIs, which further means that the traceability to this NMI or DI (demonstrated by the calibration certificates they issue) will be recognised by all the other signatory NMIs and DIs.

The overall coordination is by the BIPM under the authority of the CIPM. The CIPM's CCs, the RMOs and the BIPM are responsible for carrying out key and supplementary comparisons; and the RJCRB, which is chaired by the BIPM, makes policy suggestions on the operation of the CIPM MRA, and coordinates the activities among the RMOs.

Processes of the CIPM MRA

To obtain international recognition of their national measurement standards and measurement capabilities, a participating NMI needs to go through the following processes:

- Review of quality management systems. Participating institutes are required to operate an appropriate quality system covering the calibration and measurement capabilities that are to be declared through the CIPM MRA.
- Participation in international comparisons (Box 7). The recognised comparisons are:
 - *CIPM key comparisons*, which are top-level scientific comparisons carried out by CCs or the BIPM²³ internationally with participation by those NMIs of Member States having the highest level of skills in that measurement field;
 - *RMO key comparisons*, which are comparisons carried out at regional level to allow laboratories that are active in the field but have not participated in CIPM key comparisons to participate.

- *RMO supplementary comparisons*, which can be organised by a RMO when a regional comparison need is not covered by a key comparison, or when an NMI has missed a comparison cycle and needs to demonstrate its capabilities.
- *Declaration of CMCs*. Following satisfactory participation in appropriate scientific comparisons, the participating NMIs declare their CMCs.
- *Publication of CMCs in the KCDB*. Peer reviewed, approved and therefore internationally recognised CMCs will be published in the KCDB as being accepted by all other signatory NMIs.

Box 7. International key comparisons piloted by the BIPM

In order to operate the CIPM MRA, and in addition to its coordination role, the BIPM laboratories scientifically pilot a limited number of top level international comparisons. It focuses only on those comparisons that require specialised and dedicated scientific expertise and facilities available uniquely at the BIPM. This is the major focus of scientific work of the BIPM laboratories.

For example, the most accurate international comparisons in electricity are made by taking the BIPM transportable Josephson and quantum-Hall systems to those national laboratories which have comparable systems. In this way worldwide uniformity has been demonstrated at the level of a few parts in 10^{10} in voltage standards and a few parts in 10^9 in resistance standards. Other examples are that the BIPM has developed central facilities to run international comparisons of greenhouse gas (GHG) standards prepared by NMIs, for CO₂, methane (CH₄) and nitrous oxide (N₂O).

Outcome of the CIPM MRA - the KCDB

The KCDB (<https://kcdb.bipm.org/>) publishes all data of the CIPM MRA. Currently it covers more than 1 500 scientific comparisons, around two-thirds of which are key comparisons (KC) and one-third are supplementary comparisons (SC). Supported by these comparisons, the KCDB has

published over 25 000 peer-reviewed and internationally recognised CMCs submitted by about 70% of the signatory institutes, around 60% of which are in general physics, 15% in ionizing radiation, and 25% in chemistry. These CMCs cover the full set of metrological fields (acoustics, ultrasound and vibration, mass and associated quantities, length, photometry and radiometry, thermometry, time and frequency, electricity and magnetism, ionizing radiation, and chemistry),²⁴ which means the measurement capabilities that have realised mutual recognition at a global scale have covered all scientific disciplines. According to the BIPM statistics, the KCDB receives about 62 000 visits per month, by users around the world.

Guides in metrology

The JCGM, whose members are the BIPM, IEC, IFCC, ILAC, ISO IUPAC, IUPAP and OIML has two Working Groups:

- WG1 – that develops, maintains and promotes the use of the *Guide to the Expression of Uncertainty in Measurement* (known as the GUM). However, it also produces a series of documents to accompany the GUM, most notably for this study JCGM 106:2012 ‘*The role of measurement uncertainty in conformity assessment*’.
- WG2 – that develops, maintains and promotes the use of the *International Vocabulary of Metrology* (known as the VIM). In this vocabulary, a set of definitions and associated terms is given, in English and French, for a system of basic and general concepts used in metrology, together with concept diagrams to demonstrate their relationships. Additional information is given in the form of examples and notes under many definitions. This vocabulary is meant to be a common reference for scientists and engineers — including physicists, chemists, medical scientists — as well as for both teachers and practitioners involved in planning or performing measurements, irrespective of the level of measurement uncertainty and irrespective of the field of application. It also provides a reference for governmental and inter-governmental bodies, trade associations, accreditation bodies, regulators, and professional societies.

The GUM and its supplements, and the VIM, which are also published as ISO documents, are referenced in the competency standard ISO/IEC 17025, and as such are crucial documents for the 60 000 plus calibration and testing laboratories worldwide.

The JCTLM database for traceability in laboratory medicine

To respond to and underpin the enforcement of the IVD Directive (Directive 98/79/EC of the European Parliament and of the Council of 27 October 1998 on in vitro diagnostic medical devices), which requires that *“the traceability of values assigned to calibrators and/or control materials must be assured through available reference measurement procedures and/or available reference materials of a higher order”* (European Parliament, 1998), the JCTLM was established in 2002 through a *Declaration of Cooperation between the BIPM, the IFCC, and the ILAC*.²⁵ The JCTLM provides a worldwide platform to help IVD manufacturers identify and source appropriate higher order elements necessary to meet traceability requirements stated by the IVD Directive and IVD Regulation (Regulation (EU) 2017/746 of the European Parliament and of the Council of 5 April 2017 on in vitro diagnostic medical devices and repealing Directive 98/79/EC and Commission Decision 2010/227/EU). The output is the JCTLM database, publicly available at www.bipm.org/jctlm/ which provides free lists of:

- available higher order certified reference materials,
- available higher order reference measurement methods/procedures, and
- reference measurement services of laboratories.

This database is available for use by all parties involved in laboratory medicine, including the IVD industry, quality assurance organisations, regulatory authorities, international organisations, clinical laboratories, etc. Metrological traceability enables that even if laboratories necessarily use different measurement procedures and calibration standards, such differences will not produce different measurement results. The resulting reliable, repeatable and comparable measurement results are necessary for the effective diagnosis and treatment of disease.

Bilateral and multilateral agreements with other international bodies

The BIPM has concluded formal agreements or MoUs with a number of intergovernmental organisations or international bodies that are of strategic importance to the BIPM, including:

- Agreements:
 - CIE: International Commission on Illumination
 - WMO: World Meteorological Organization
 - UNESCO: United Nations Educational, Scientific and Cultural Organization
- MoUs:
 - IAEA: International Atomic Energy Agency
 - ILAC: International Laboratory Accreditation Cooperation
 - UNIDO: United Nations Industrial Development Organization
 - OIML: International Organization of Legal Metrology
 - VAMAS: Versailles Project on Advanced Materials and Standards
 - WHO: World Health Organization
 - IUPAC: International Union of Pure and Applied Chemistry

These agreements allow the BIPM to collaborate with other international bodies and promote its objectives, when such objectives are of common benefit to both parties. Primarily they allow the BIPM:

- to promote good measurement practice including use of the SI;
- to update the international community about BIPM activities and effectively disseminate information on metrology in the quality infrastructure context;
- to advocate on behalf of the NMI community such that the members of other international organisations can gain the best benefit at national level from the available national metrology resource for their missions; and
- to allow the exchange of knowledge in the use of measurement standards, development measurement techniques and methods, and agree on strategies for achieving common goals.

The BIPM, OIML, ILAC and ISO, as the four international bodies working most closely on metrology, accreditation and standardisation issues worldwide, issued in 2011 (reaffirmed in 2018) a *Joint Declaration on Metrological Traceability*. This Joint Declaration provides recommendations for whenever there is a need to demonstrate metrological traceability for international acceptance. It encourages the members of the four organisations, as well as others for whom traceability is important, to adopt it. It also encourages other bodies to declare their support for the principles and practices embodied in this Declaration wherever possible.

Another important joint initiative is that international organisations (including the BIPM) within INetQI adopted a common definition for quality infrastructure (QI) in 2017. This promotes a holistic approach considering metrology, accreditation, standardisation, and conformity assessment, as interconnected elements, collectively critical in promoting and sustaining economic development, as well as environmental and social well-being.

Supportive services

Providing calibrations to Member States in selected fields

The BIPM has the capability to provide calibrations of measurement standards in selected fields. These calibrations are provided to Member States free of charge. This particularly fulfils the needs of Member States that do not hold primary standards, due to either budgetary or technical difficulties. Examples of these calibration services are:

- mass calibrations;
- providing calibrations of resistors, capacitors and voltage standards (Zeners) to those Member States without Josephson voltage or quantum Hall resistance standards;
- providing calibrations and characterisations of NMI standards of air kerma or absorbed dose to water for low-, medium-energy and mammography; and
- providing calibrations of national ozone photometers.

BIPM Capacity Building and Knowledge Transfer (CBKT) Programme

The BIPM runs a Capacity Building and Knowledge Transfer (CBKT) Programme to help the worldwide metrology community obtain, strengthen and maintain capabilities needed to understand and participate in the international measurement system.

The Programme was launched in 2016 with the aim of increasing the effectiveness with which Member States and Associates engage in the worldwide coordinated metrological system. This aim further includes three specific goals:

- to enlarge the pool of developed NMIs so that more NMIs are capable of sharing the workload of operating the CIPM MRA;
- to help new participants engage effectively with the international measurement system; and
- to sustain the BIPM visiting secondment programme and promote exchange between participants.

This Programme is implemented through two main types of activities: short-term training, and long-term placements of visiting scientists at the BIPM or sponsoring organisations. Topics include core topics that focus on the operation of the CIPM MRA and other diverse topics that are of interest and benefit to participants. While core CBKT initiatives are funded by the BIPM, most activities under the Programme rely on sponsorship from Member States.

Box 8. Examples of the CBKT activities

Sound beginning in the CIPM MRA

This course provides effective training for inexperienced NMIs and DIs to achieve “right first time” submissions into the CMC review process. This has in turn reduced the burden on peers from the leading NMIs that review quality systems as well as CMCs of these NMIs and DIs.

Metrology for safe food and feed in developing economies

Mycotoxin contamination is the main cause of regulatory border refusal for food and feedstuffs. This project allows visiting scientist seconded by NMIs to work together to develop mycotoxin reference materials and proficiency testing materials, and provide knowledge transfer to NMIs developing capabilities in this area. These capabilities enable in-country/in-region testing networks to calibrate their instrumentation.

Note: See the BIPM website for more information

Quality assurance, monitoring and evaluation mechanisms

The BIPM undertakes a range of strategic planning, consultation, and evaluation activities to ensure that its work follows an agreed strategic direction, that decisions and mechanisms are appropriate and well accepted, are understood and can be effectively implemented. The processes aim to ensure that the main specific instruments are not only appropriately maintained, but also adapted and improved to meet changing or new demands.

The strategic direction of the BIPM's work

The BIPM undertakes strategic planning at different levels to ensure its work complies with developing trends in metrology and fits into the needs of Member States. The strategy documents include:

- *BIPM Mission, Role and Objectives*. A good example demonstrating the BIPM's cautiousness about its strategic correctness is the reformulation of its role and mission some years ago. Following a resolution adopted at the 24th meeting of the CGPM (2011), an *ad hoc* working group was set up to review and update the role, mission and strategic direction of the BIPM. The BIPM Compendium was generated as a compact, easily readable document of all currently applicable rules relating to the BIPM governance. The adoption of Resolution 3 '*On the objectives of the BIPM*' at the 26th meeting of the CGPM (2018) could be considered the completion of this process of reform.
- *BIPM Strategic Plan* is developed to implement its Mission, Role and Objectives. The current strategic plan includes strategic

priorities (2018–2019) as well as detailed strategic plans for the medium and long term (2020–2025).

- *BIPM Work Programme* is developed in the same cycle with the CGPM and is presented at each meeting of the CGPM to identify work priorities in the next four years and for consideration with the BIPM dotation.
- *Consultative Committee (CC) strategic documents* are developed by each CC under the request of the BIPM to review their areas of activity and plan for the future; they are complementary to the BIPM Strategic Plan.

The effective implementation of the BIPM instruments through consultation

Consultation with Member States and other stakeholders (Box 9) is one of the important measures taken by the BIPM to support accountability, to sustain confidence in the BIPM's instruments, and to allow these instruments to be more accessible and better implemented by them.

Box 9. Main consultation activities of the BIPM

Main consultation activities of the BIPM include:

- CGPM Resolutions: consultation made within the CIPM - then with NMI Directors and State Party Representatives.
- BIPM Strategy and Work Programme: consultation on early draft with CIPM and CCs - then publication for comments from Member States and other stakeholders.
- The ten CCs serve as formal consultative bodies to the CIPM, composed of the most knowledgeable experts around the world in that field and advising the CIPM on all scientific matters. CCs may prepare recommendations for adoption by the CIPM as draft Resolutions.
- The BIPM hosts (approximately annual) meetings of NMI Directors and State Party Representatives to discuss metrological issues of worldwide concern.

Box 9. Main consultation activities of the BIPM (cont')

- The BIPM organises meetings of the JCRB, usually twice a year, to discuss matters relating to the CIPM MRA and other related issues with the RMOs.

Monitoring and evaluation of instruments

The BIPM coordinates Member States and partners involved to conduct monitoring and evaluation of its instruments to ensure the quality and effectiveness of these instruments, for example the review of the effectiveness and efficiency of the CIPM MRA (Box 10), and the ongoing monitoring and evaluation related to the work of the JCTLM (Box 11).

Box 10. Review of the CIPM MRA

After a decade and a half of successful operation, the CIPM MRA had matured into a well- recognised pillar of the international quality infrastructure. To ensure its sustainability and improve its efficiency, Resolution 5 adopted at the 25th meeting of the CGPM (2014) launched the CIPM MRA review.

The review considered whether the CIPM MRA was still meeting stakeholder needs, and looked for opportunities to simplify the whole system, as well as opportunities to improve the efficiency of the processes, procedures and tools, including the KCDB. A Review Working Group was appointed to consider issues identified by the Workshop in further detail.

Box 10. Review of the CIPM MRA (cont')

The Working Group formulated a list of nine recommendations with twenty-eight sub-recommendations, and identified the key parties to act on each recommendation. A further CIPM ad hoc committee oversaw the implementation of the recommendations, most of which had been completed at the time of writing.

A notable change, among others, is that a new CIPM MRA database (the "KCDB"), was developed and implemented in 2019, aiming to greatly increase the efficiency of the operation of the CIPM MRA by integrating the whole process into one on-line platform and ending the need for manual transfer of data for review and publication.

Box 11. Monitoring and evaluation of the JCTLM

Another example is the oversight, monitoring and evolution of the JCTLM. The JCTLM Executive Committee oversees the operations of the JCTLM; provides oversight of the processes to evaluate entries in the JCTLM database against appropriate international documentary standards; and promotes the value and use of the JCTLM database.

A major review was undertaken, with the establishment of an ad hoc Working Group on JCTLM Future Structure, leading in 2016 to the modification of the 'Declaration of Cooperation' between the three collaborating organisations (BIPM, IFCC and ILAC), and to the amendment of the JCTLM structure and operation, such that additional organisations could be invited to join the Executive Committee provided they fulfilled defined criteria. At the same time the membership categories were modified to allow wider participation of stakeholders.

The Declaration of Cooperation was revised in 2019, to facilitate expansion of the JCTLM Executive Committee to include additional organizations in its membership from further branches of laboratory medicine, and re-signed in December 2019.

Assessment of the impact and success of regulatory co-operation through the BIPM

The impact of metrology and the BIPM's work in fostering better rules of metrology crosses all sectors and aspects of human endeavour. Much of this work is synergistic. For example, the work of the Consultative Committee for Electricity and Magnetism (CCEM) does not just benefit the electrical sector; it also benefits users of instrumentation found in every sector of industry, commerce and among the wider public.

Ironically, the impact of metrology and the BIPM is very difficult to quantify precisely, partly because it is ubiquitous, and partly because the benefits can rarely be attributed to metrology alone. This chapter will summarise some evaluations and case studies from two aspects – the overall impact of metrology, and the specific impact of the BIPM's work to help to illustrate this impact.

The overall impact of metrology - an enabler for everyday life

Metrology influences, underpins and drives much of what we do and experience in our everyday lives, though often unseen and beyond our awareness. Industry, trade, quality of life, regulation, science and innovation all rely on metrology to some extent, so metrology forms a natural and vital part of everyday life (Redgrave and Henson, 2005).

“When you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of meagre and unsatisfactory kind.”

Lord Kelvin, Scientist 1824-1907

Metrology for industry

High-performance products and manufacturing systems require accurate measurements for a wide range of parameters and in a wide range of production environments. For example, the biomedical, semiconductor and robotics industries need precision positioning techniques at the nano-scale to underpin the development and production of high-performance products.²⁶ Smart and embedded measurements also enable the development of emerging technologies and of novel products. For example, the future ‘smart factory’ has the potential of integrating design and manufacture into one single engineering process to enable the “right first time” fabrication of bespoke products. Metrology will be used to assess and guarantee the fit, performance and functionality of every part and supporting the targets of zero waste and a carbon neutral outcome (NPL, 2012).

Metrology for trade and commerce

The fast growing world trade and the implementation of the WTO TBT Agreement requires the mutual recognition of measurement and test results to avoid duplication of measurements and tests in exporting and importing countries, saving costs and reducing delays and the risk of disputes concerning the results. In addition, as an increasing number of manufactured goods contain components made in a multitude of countries, mutually accepted measurements have become vital elements to enable manufacturing and commerce. In response, international organisations such as the BIPM, OIML, ILAC, IAF, and ISO have all developed interdependent procedures with the same aim of “One standard, one test, accepted everywhere”. Metrology contributes to this target by providing an internationally recognised system of traceable and comparable measurements, which can ensure that equipment sold with calibration or test certificates is accepted and considered reliable not only in the country of origin but also in the final destination.

Metrology for quality of life²⁷

Measurements are essential for ensuring the quality of life of citizens. Food safety, be it chemical or microbiological contamination or the presence of genetically modified organisms, can only be examined with reference materials of these substances. Many modern advances in medical treatment, such as increased doses in cancer treatment, are only possible because improvements in measurement techniques and accuracy ensure that the treatment is effectively targeted at the diseased area, minimising damage to healthy tissue. Similarly, reliable and comparable measurements are required to identify and control pollution of water, air and soil. Metrology in the energy field contributes in several ways to the transformation of energy supply systems, for example, measuring the efficiency of renewable energy, and supporting development and control of the “smart grid”.

Metrology for regulation and legislation

Metrology is a requisite for effective legislation covering product quality, healthcare and safety, the environment and consumer protection, to name just a few. Metrology is required not only to enable an effective assessment of compliance, but also in the development of effective regulation and as an input to the data underpinning the rationale for the legislation. For example, it has enabled regulators to set “the maximum contaminant limit in foodstuff” at parts per million or even parts per billion and know that these limits can be reliably enforced. A study on the impact of the EMRP programme, a multinational metrology research programme of the European Union, shows that 42 EMRP projects out of the 119 funded have direct relevance to some 25 EU regulations and directives (Knee and Jarvis, 2017a).

Metrology for science and innovation

On one hand, new breakthroughs in science enable improvements in measurement techniques and metrological capability, for example the discovery of the Josephson effect led to new voltage standards. On the other hand, improved metrological capability provides new tools for scientists, researchers and innovators in all fields. For example, advances in atomic clocks enabled the development of Global Positioning Systems. Measurements are required to test hypotheses and

verify theories, establish consistency of results, determine fundamental constants and to investigate susceptibility of phenomena to external influences. The ability to move a scientific breakthrough or development, for example carbon nano-tubes, from an interesting scientific phenomenon to an industrial application often relies on metrological capability and advances (Redgrave and Henson, 2005).

Impact of the BIPM's work

In summary, the BIPM has played and continues to play a centrally coordinated role in establishing a global metrology system that delivers all the benefits of metrology. This system benefits Member States because it creates an internationally agreed framework within which the equivalence of measurements made in different states can be demonstrated. Additionally, involvement in this system provides a benchmark for the performance of NMIs and supports national agendas in scientific discovery and innovation, industrial manufacturing and international trade, improving the quality of life and sustaining the global environment. Furthermore, this global metrology system plays a crucial and underpinning role in the wider quality infrastructure.

This chapter will evaluate impact of the BIPM's work from the following two aspects:

- scope of coverage of the global metrology system coordinated by the BIPM
- impact of the regulatory co-operation provided by the BIPM

Indicator 1: Global coverage of the international measurement system

As of 13 January 2020, the BIPM has 62 Member States and 40 Associate States and Economies, spread broadly across the globe, from North and South America to Europe and Asia-Pacific. Each of these States and Economies participate in the CIPM MRA. These account for 110 of the 193 UN Member States, including all the industrialised countries and major traders in the world, covering around 98% of the world's GDP (2019).²⁸

This does not mean that all States participate equally in the CIPM MRA. Currently many have limited engagement as their metrology infrastructure

is still developing. One of the aims of the BIPM CBKT Programme is to facilitate their participation.

Indicator 2: Impact of the regulatory co-operation provided by the BIPM

The SI

The *International System of Units (SI)* adopted worldwide remains the basis of metric system and worldwide uniformity of measurements. The SI global coverage is much wider than the BIPM membership. Around 195 countries have adopted it as their official system of weights and measures. In practice, each State decides by legislation on the rules for the use of SI units at the national level. Measurement units not in the SI, but used in practice, have a fixed conversion to the SI.²⁹

Because of the importance of the SI (metric system) as an international standard, its use in product design, manufacturing, marketing, and labelling is essential for the success of all economies' industry in the global marketplace.

The world standard time

Coordinated Universal Time (UTC), which is the world standard time, is a continuous time scale produced by the BIPM based on the best realisations of the SI second. UTC provides a vital tool for operation of modern society, underpinning, in particular, trade, financing, telecommunications, sports, global navigation and positioning sectors, to name just a few.

A good example of the importance of a high-accuracy time standard is related to implementation of regulations in the financial sector. The Markets in Financial Instruments Directive (MiFID II)³⁰ applying from 3 January 2018 is the EU's legislation that regulates firms who provide financial services. It mandates operators of trading venues and their members or participants to synchronise their clocks to UTC³¹ to promote improved transparency and better deals for customers, and requires that trades need to be recorded in microseconds (a millionth of a second).

Another example of UTC's more critical role is that it supports the Smart Ledger (aka blockchain) Technology, one of the core technologies of the new fintech movement, which will enable financial market counterparties

to store financial assets in a shared ledger. In a ground-breaking experiment, researchers from the NPL (the NMI of the UK) and its partners have timestamped financial stock trades with UTC generated from NPL atomic clocks and recorded the trades directly on a distributed ledger.³²

Guides in Metrology

Guides in Metrology developed by the BIPM (GUM and VIM) are adopted worldwide. Crucially these allow the worldwide community, regulators and those needing to comply with and enforce regulation amongst them, to use common terminology and to understand how measurement uncertainty can be evaluated (vital for establishing compliance with regulatory limits). Each year there are more than 100 000 downloads of the documents in the GUM suite from the BIPM website, and the documents have been translated into several different languages.³³

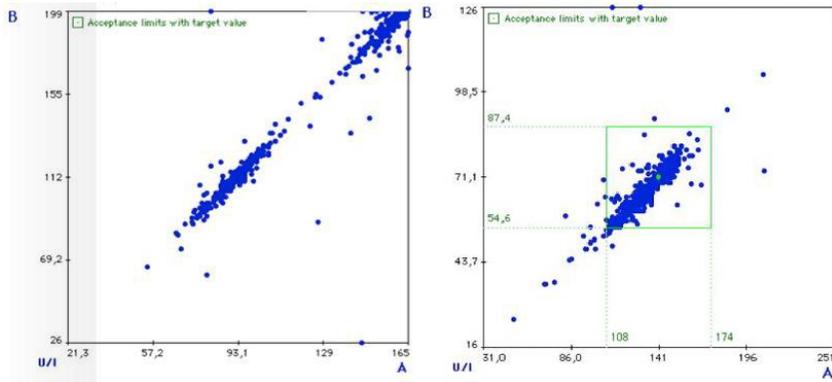
The JCTLM database

The number of entries in the JCTLM database has increased by an average of 10% annually. As of April 2019 it contained 303 entries for certified reference materials, 201 reference measurement methods, and 187 reference measurement services delivered by 19 reference laboratories. The past seventeen years have also witnessed a steady growth in the membership of the JCTLM. At the time of writing, there are nearly 60 member organisations from 20 countries, including various stakeholders in the field of IVD.

The JCTLM helps to provide “the quality behind the product”. The global *in vitro* diagnostics market was valued at about US\$61.1 billion in 2016 and is expected to grow at a compound annual growth rate (CAGR) of 6.8% to USD 84.6 billion by 2023, with Europe accounting for the second largest market share after North America (Kramer, 2017). If it is estimated that the JCTLM contributes to just 1% of the IVD market value in terms of meeting its requirement for traceability, it was worth USD 611 million in 2016, rising to USD 846 million by 2023. In addition, more and more evidence has shown that the quality of patient care is improved as a result of improved accuracy of testing results, which reduces between-method variability in laboratory medicine (Figure 6).

Figure 6. Accurate results for patient care

(impact of implementation of reference method for the enzyme GGT)



The CIPM MRA

Through the CIPM MRA the BIPM has created a unique mechanism enabling the formal recognition of national measurement standards and calibration capabilities in a fully international spectrum. It has made life simpler for conformity assessors, manufacturers, enterprises directly involved in trade, rule makers, and customers. The CIPM MRA remains the most far-reaching and iconic mechanism created by the BIPM to harmonise and simplify the use of measurement results. It surpasses other instruments of the BIPM in terms of size, complexity and impact. Many of the benefits of the CIPM MRA are difficult to summarise in number, but they are clearly important. This section illustrates its impact from two aspects: benefits to participating states, and benefits at a global level.

Benefits to participating states

The CIPM MRA has established a global system of mutual acceptance to replace the former regionally-or-bilaterally-based systems of recognition. It saves a participating State (or economy) an unimaginably large amount of cost by allowing it to participate in a centrally coordinated system rather than having to develop the same level of mutual recognition through numerous bilateral relationships. A KPMG Report on the potential economic impact of the CIPM MRA commissioned by the BIPM in 2002 concluded that the arrangement has resulted in a notional saving of EUR 75 000 per NMI in the cost of establishing and maintaining

mutual recognition with one other NMI at the 2002 price level (MacDonald, 2002a). It can be estimated accordingly that to obtain the same broad international recognition through bilateral arrangements would be prohibitively expensive.

In addition, many case studies have clearly indicated the huge economic and social benefits that the CIPM MRA has brought to participating States, for example:

- **It guarantees the equity of trade.** An example is that the CIPM MRA has enabled Kazakhstan to trust and accept all measurement data obtained from over 300 sets of measuring instruments used in the Central-Asian natural gas pipelines because they are calibrated by NIM, the NMI of China. These measurement data have guaranteed a natural gas trade of 47.5 billion standard cubic meters in 2018, 15% of the total natural gas consumption of China in that year.³⁴
- **It supports trans-national manufacturing.** An example is that the CIPM MRA has enabled the Russian acceptance of in-country calibration by KRISS, the NMI of the Republic of Korea, saving a Korean manufacturer contracted to develop, manufacture and deliver two offshore oil platforms to a consortium operating in the Russian Federation some USD 16 million.³⁵ Another example is that Boeing, with 20 000 diverse suppliers and partners worldwide,³⁶ uses the CIPM MRA to avoid the need to ship instrumentation home for calibration, reduce delays and downtime, and thus lower costs. The CIPM MRA also helps Boeing to utilise a calibration capability that exists only outside the US.
- **It supports effective implementation of regulations.** The U.S. Federal Aviation Administration (FAA) and the European Aviation Safety Agency (EASA) both accept the CIPM MRA,³⁷ facilitating in-country calibration of instrumentation for aircraft repair and maintenance facilities. This has enabled the service providers to avoid major costs from duplicated calibrations, disruptive downtime, or the alternative of duplicating sets of measuring instruments, and thus have cut the costs to airlines. The African Continental Free Trade Area (AfCFTA) Agreement that aims to create a “single continental market for Africa” officially encourages State Parties to participate in BIPM activities.³⁸

Benefits at a global level

More significant is the CIPM MRA's benefits to world trade as a well-recognised pillar of international quality infrastructure. For firms intending to export products into other countries, proving conformity with the regulatory requirements in importing markets is critical and costly (OECD, 2017). The CIPM MRA saves companies costs and risks caused by duplicated calibrations, and at the same time, guarantees the reliability of testing to monitor the quality of products and verify their fulfilment with the relevant regulatory requirements in importing markets. Referring to the most recent data for 2016, the total exports of goods, services and primary income (Balance of Payments, current USD) of 98 CIPM MRA signatories³⁹ is 2.29×10^{13} USD.⁴⁰ If the reduction of technical barriers can account for as much as a 10% net benefit, and even when only 0.1% net benefit is generated by the effects of the CIPM MRA (Kaarls, 2003), this gives a benefit of 2.29×10^9 EUR in 2016. This is viewed just as a conservative estimate.

In addition, the CIPM MRA has underpinned the IRC undertaken by many other international organisations. For example it provides a vital resource to the ILAC Mutual Recognition Arrangement (ILAC MRA), available to some 60 000⁴¹ accredited calibration and testing laboratories worldwide as a source of metrological traceability. The CIPM MRA and the ILAC MRA are complementary tools facilitating smooth and efficient global trade. It is also referenced in the 2017 revision of ISO/IEC 17025: *General requirements for the competence of testing and calibration laboratories*,⁴² the standard used by more than 50 000 calibration and testing laboratories worldwide, as well as the OIML Document D1 *Considerations for a Law on Metrology*,⁴³ a guide on drawing up national laws related to metrology.

Calibration services to Member States

The BIPM provides selected calibrations free of charge for Member States. This has a significant social impact because it provides traceability especially to Member States that do not maintain high-level measurement standards of their own. From the economic perspective, in the nineteen years from 2000 to 2019, the BIPM has issued nearly 1,800 calibration certificates to the NMLs of Member States. If the average cost of one calibration is estimated to be €1,000, this represents €1,800 000 of free calibrations for Member States, who would otherwise

need to seek traceability through a purchase order on another NMI. If we consider the amount that a beneficiary NMI would have to spend to establish a same-level measurement standard within its country, the costs would be much higher.

BIPM Capacity Building and Knowledge Transfer (CBKT) Programme

The past four years have witnessed the undeniable success of this programme. Twelve projects have been completed, four projects (in the form of visiting scientist projects) are ongoing, and four new projects are planned. By the end of 2019 more than 400 individuals from some 80 countries, covering all six RMOs, have participated in projects of various forms. A key aspect of the programme are the visiting scientists seconded to the BIPM for an average of six-month knowledge transfer placements. At the time of writing, over 75% of Member States and Associates have participated in the CBKT Programme (as trainees, lecturers and sponsors). This programme has effectively promoted the sharing of expertise, technologies and even facilities between developed and developing NMIs, promoting the initiation of the same kind of technical assistance activities at regional and national levels.

Conclusion

The worldwide uniformity of measurements has become ever more critical as a result of the expansion of global commerce and trade. The demand for a worldwide standardised system of measurements led to the creation of the BIPM by the signing of the diplomatic treaty known as the Metre Convention on 20 May 1875. In recent times an international coherent system of measurement has become just as essential in addressing quality of life challenges ranging from climate change to healthcare.

The BIPM contributes to the forms of regulatory cooperation identified by the OECD in a variety of ways. Its founding treaty, the Metre Convention brings Member States together to cooperate, on matters related to measurement science and measurement standards. Member States adopt Resolutions of the CGPM. These Resolutions, supported by the decisions of the CIPM, have resulted in some key “normative” international standards (for example the SI, UTC, and the Guides in Metrology) that are adopted worldwide. Likewise the CIPM MRA mechanism established by Resolution provides the worldwide framework for international recognition of measurement standards and certificates issued by NMIs.

The work of the BIPM has produced significant economic benefits and societal impacts. This impact is synergistic as it crosses all sectors and aspects of human endeavour, including supporting the development and implementation of effective regulation. Prof. Philippe Taquet, then President of the French *Académie des Sciences*, and President of the 25th meeting of the CGPM (2014), made an elegant summary of the BIPM’s merit:

“The BIPM is an organisation that is a perfect and magnificent example of a work of peace. The BIPM symbolises in a unique manner what people are able to

achieve when they pool their wills, their knowledge, their talents and their abilities. The BIPM was a precursor to this.”

However, the BIPM and its wider community also faces grand challenges in continuously pursuing the state of the art of metrology. The rate of change in metrology is driven by the need to sustain the performance of measurement standards at a level that supports users and is able to stay ahead of their requirements. Advances in scientific discovery, innovation and intensive R&D growth have led to a foreseeable dramatic change in industries and life style. Meeting these needs will demand continued evolution in metrological science and its application, including:

- **The new quantum standard.** The SI is revised to eradicate all physical artefacts and be linked to natural constants, the laws of physics. Since its inception, research into new measurement standards and methods, primarily those using quantum phenomena, will dominate the fundamental research of metrology.
- **New measurement solutions for applications.** New technologies and emerging industries require new measurement solutions that are beyond the boundaries of today’s measurement capability. For example: Assessment of product quality and safety will require measurement of the size and properties of nanoscale particles; precision medicine, an emerging approach for customised disease prevention and treatment, will need development of measurements and standards that can reflect an individual’s genes, environment and lifestyle;⁴⁴ measurement of properties and characterising behaviour may be conducted at timescales ranging from attoseconds to millennia (NPL, 2012).
- **Measurement at the frontiers.** Advances in science and technology push at the frontiers of what is possible for metrology. Advancements in measurement will be enabled by new capabilities in computing, software and communication technologies. Sensors based on quantum, bio and nanotechnologies may be integrated into measurement networks, making measurements smarter, faster and highly interconnected. Metrological capability might be embedded into products and systems exemplifying technological convergence.

- **“Upstream” metrology.** The worldwide metrology community and the systems in place are effective in providing the traceable measurements needed in industry, trade and regulation. However, there are questions as to whether more could and should be done to ensure the same rigorous approach to measurement by the wider scientific community when undertaking research. There is evidence that too often when research teams try to reproduce new and interesting scientific findings published by others in reputable scientific journals, they cannot do so. The reasons behind this so called ‘reproducibility crisis’ are complex. Nevertheless, there is an increasing view that a more rigorous adoption of the principles of metrological traceability measurement uncertainty by the research community, particularly the universities (where researchers tend to be less familiar with metrology), could bring substantive improvements. Thus, in this case the challenge is somewhat different, it is one of ensuring the adoption of existing best practice.

The BIPM also faces wider challenges. The changing perception of multilateralism affects all IOs including the BIPM. Increases in dotation funding are only possible if there is no objection by any Member State. This, in practice, is not always so easy to achieve.

Another challenge is ensuring effective participation in the CIPM MRA. All current Member States and Associates are signatories of the CIPM MRA, but there are still more than 80 UN Member States that are not yet part of this framework. Even among the current CIPM MRA signatories there are still some that do not yet fully benefit as their participation in the CIPM MRA remains marginal. As participation in the activities of the BIPM has expanded, this is reflected in the launch and formalisation of a role in CBKT for the BIPM, which brings challenges in terms of resources, skills, etc. Whilst the Metre Convention established the structure and processes through which we aim to obtain worldwide uniformity in measurement, there is still some way to go before the goal is fully realised.

The BIPM as a scientific and permanent intergovernmental organisation continues to evolve, so the story of the BIPM does not end here. You are welcome to follow us, exploring the diverse, dynamic and spectacular world of measurement science.

Notes

1. OECD/OIML (2016), “International Regulatory Co-operation and International Organisations: The Case of the International Organization of Legal Metrology (OIML)”, OECD and OIML.
2. Even in countries that still use “customary units”, the conversion rates to the SI units are fixed, such that there is a clearly identified relationship between the two systems.
3. The 9th edition of the SI Brochure was published in 2019 and is available on the BIPM website.
4. LNE website, “History of measurement”,
<https://metrologie-francaise.lne.fr/en/metrology/history-units> (accessed 23 January 2020).
5. Argentina, Austria-Hungary, Belgium, Brazil, Denmark, France, Germany, Italy, Peru, Portugal, Russia, Spain, Sweden-Norway, Switzerland, Turkey, the United States of America, and Venezuela.
6. There is no general conventional or jurisprudential definition of an intergovernmental or international organization, however public international law specialists define it as follows: “international organizations are defined as forms of cooperation founded on an international agreement usually creating a new legal person having at least one organ with a will of its own, established under international law” (Henry G. Schermers & Niels M. Blokker, *International Institutional Law*, 4th Revised Edition, Martinus Nijhoff Publishers, 2003). Another comparable definition is a “collectivity of States established by treaty, with a constitution and common organs, having a personality distinct from that of its Member States and being a subject of international law with treaty-making capacity” (Sir Gerald Fitzmaurice’s definition, *Ann. ILC*. 1956-II, p. 108).

7. Whilst the Metre Convention describes the BIPM headquarters as being in Paris, in reality the BIPM headquarters is situated in Sèvres, outside the formal boundary of Paris but in the western outskirts of the city.
8. This definition was adopted by INetQI at its 2017 meeting.
9. They include: the BIPM, the International Accreditation Forum (IAF), the International Electrotechnical Commission (IEC), the International Laboratory Accreditation Cooperation (ILAC), the International Organization for Standardization (ISO), the International Trade Centre (ITC), the International Telecommunication Union (ITU), the International Organization of Legal Metrology (OIML), the United Nations Economic Cooperation for Europe (UNECE), the United Nations International Development Organization (UNIDO), the World Bank Group (WBG), and the World Trade Organization (WTO).
10. See the BIPM website for more information.
11. Resolution 3 “*On the objectives of the BIPM*” adopted at the 26th meeting of the CGPM (2018).
12. The official term is “States Parties to the Metre Convention”; the term “Member States” is its synonym, and used for easy reference in this document.
13. The official term is “Associate States and Economies of the CGPM”, but for the sake of brevity the terms like “Associate”, “Associate of the CGPM”, “Associate States and Economies”, “Associate State” and, “Associate Economy” are used.
14. CARICOM (Caribbean Community) is an Associate Economy of the CGPM on behalf of eleven of its members: *Antigua and Barbuda, Barbados, Belize, Dominica, Grenada, Guyana, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago*.
15. The total participating states are: 62 Member States + 37 Associate States + 11 CARICOM members = 110.
16. Resolution 3 “*Associates of the Conférence Générale des Poids et Mesures*” adopted at the 21st meeting of the CGPM (1999).

17. See Article 3 of the Metre Convention.
18. Granted in the Concession Convention by the French Government (concluded in 1875).
19. The UN Scale for 2019, 2020 and 2021 is available at <https://undocs.org/en/A/RES/73/271>.
20. OECD/OIML (2016), "International Regulatory Co-operation and International Organisations: The Case of the International Organization of Legal Metrology (OIML)", OECD and OIML. p. 10.
21. For more information: www.wto.org/english/docs_e/legal_e/06-gatt_e.htm (accessed 23 January 2020).
22. There are currently four such organisations: The International Atomic Energy Agency (IAEA); the Joint Research Centre (JRC of the European Commission); the World Meteorological Organization (WMO) and the European Space Agency (ESA).
23. It happens when such a comparison depends on the specialised, dedicated facilities developed and maintained only by the BIPM, for example the transportable Josephson voltage system.
24. BIPM website, KCDB Statistics.
25. Available at the BIPM website.
26. European Metrology Research Programme delivering impact, available at www.euramet.org (accessed 23 January 2020).
27. More information can be found in the UNIDO-BIPM-OIML Joint Brochure explaining the role of metrology within the 2030 UN Sustainable Development Goals (SDGs), available at www.bipm.org/utills/common/liaisons/unido-bipm-oiml-brochure.pdf (accessed 23 January 2020).
28. International Monetary Fund (IMF) data as published in the World Economic Outlook Database, www.imf.org/external/datamapper/datasets/WEO (accessed 23 January 2020).

29. Davis R. and Fellag Ariouet C. (2018), Key events in this history of the International System of Units, in Made to measure the world's 7 units, Paris : Réunion des musées nationaux : Musée des Arts et Métiers.
30. https://ec.europa.eu/info/business-economy-euro/banking-and-finance/financial-markets/securities-markets_en (accessed 23 January 2020)
31. www.corvil.com/solutions/electronic-trading/solutions/rts-25-clock-synchronization(accessed 23 January 2020)
32. www.npl.co.uk/npltime (accessed 23 January 2020).
33. According to the BIPM's statistics.
34. www.cnenergy.org/yq/trq/201901/t20190114_752307.html (in Chinese) (accessed 23 January 2020).
35. Cf. Documents of the CIPM MRA Review Workshop: from users and stakeholders: Best practices (Republic of Korea), BIPM website <https://www.oneauthor.org/> (accessed 23 January 2020).
36. Boeing website, www.boeing.com/global (accessed 23 January 2020).
37. For more information: www.faa.gov/about/initiatives/atos (accessed 23 January 2020).
38. Compiled Annexes to the on the establishment of the continental free trade area, available at www.tralac.org/documents/resources/african-union/2163-compiled-annexes-to-the-afcfta-agreement-legally-scrubbed-version-signed-16-may-2018file.html(accessed 23 January 2020).
39. Not including Chinese Taipei and CARICOM whose data are not available, and Cuba, Iran, Syria and United Arab Emirates whose export data are not published at the time of writing.
40. International Monetary Fund (IMF) data as published in the World Economic Outlook Database, www.imf.org/external/datamapper/datasets/WEO (accessed 23 January 2020).

41. ILAC Website, facts and figures:
<https://ilac.org/about-ilac/facts-and-figures> (accessed 23 January 2020).
42. Available at www.iso.org/publication/PUB100424.html
(accessed 23 January 2020).
43. Available at www.oiml.org/en/files/pdf_d/d001-e12.pdf
(accessed 23 January 2020).
44. Cf. Precision Medicine, NIST website, available at
www.nist.gov/topics/precision-medicine (accessed 23 January 2020).

References

- BIPM (2020), Explanatory note: calculation of the individual contributions to the BIPM dotation for Member States, p. 3.
- BIPM (2018a), Compendium of main rules and practices applicable to the BIPM, pp. 6-8.
- BIPM (2018b), Compendium of main rules and practices applicable to the BIPM, p. 10.
- BIPM (2018c), Compendium of main rules and practices applicable to the BIPM, p. 7.
- BIPM (2017), Calibration and Measurement Capabilities in the context of the CIPM MRA (CIPM MRA-D-04), Version 5, pp. 18-20.
- CCTF (2016), CCTF Strategy Document, Period covered: 2006-2016, Version 0.6, updated May 2016, p.1.1
- Davis R. and Fellag Ariouet C. (2018), Key events in this history of the International System of Units, in *Made to measure the world's 7 units*, Paris : Réunion des musées nationaux : Musée des Arts et Métiers.
- European Parliament (1998), Directive 98/79/EV of The European Parliament and of the Council of 27 October 1998 on *in vitro* diagnostic medical devices, p. 16, available at <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31998L0079&from=EN> (accessed 23 January 2020).
- Henson A. (2015), The CIPM MRA: Past, Present and Future (Rapport BIPM-2015/01), p. 3.
- JCGM (2012a), International Vocabulary of Metrology – Basic and General Concepts and Associated Terms (VIM 3rd edition), JCGM 200:2012 (JCGM 200:2008 with minor corrections), term 2.1.

- JCGM (2012b), International Vocabulary of Metrology – Basic and General Concepts and Associated Terms (VIM 3rd edition), JCGM 200:2012 (JCGM 200:2008 with minor corrections), term 2.2.
- Kaaris R. (2003), Evolving needs for metrology in trade, industry and society and the role of the BIPM, p. 121.
- Knee P. and Jarvis D. (2017), Impact of the EMRP, EURAMET, Public Version 1.0, issued 26 September, p. 40.
- Kramer E. (2017), The European *In Vitro* Diagnostic Regulation: It's Time to Start Preparing, Nerac Analyst, p. 1.
- MacDonald M. et.al (2002), Potential Economic Impact of the CIPM Mutual Recognition Arrangement, KPMG Consulting, April 2002, p. 2.
- NPL (2012), Metrology for the 2020s, National Physical Laboratory (NPL), March 2012. OECD (2012), Recommendation of the Council on Regulatory Policy and Governance, www.oecd.org/gov/regulatory-policy/2012-recommendation.htm
- OECD (2017), International Regulatory Co-operation and Trade: Understanding the Trade Costs of Regulatory Divergence and the Remedies, OECD Publishing, Paris.
- OECD (2016), International Regulatory Co-operation: the Role of International Organisations in Fostering Better Rules of Globalisation, OECD, 2016. p. 58.
- Redgrave F. and Henson A. (2005), "Metrology...Who Benefits and Why Should They Care?", 2005 NCSL International Workshop and Symposium, p. 5-7.

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

The OECD is a unique forum where governments work together to address the economic, social and environmental challenges of globalisation. The OECD is also at the forefront of efforts to understand and to help governments respond to new developments and concerns, such as corporate governance, the information economy and the challenges of an ageing population. The Organisation provides a setting where governments can compare policy experiences, seek answers to common problems, identify good practice and work to co-ordinate domestic and international policies.

The OECD member countries are: Australia, Austria, Belgium, Canada, Chile, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Latvia, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The European Union takes part in the work of the OECD.

International Regulatory Co-operation and International Organisations

The Case of the International Bureau of Weights and Measures (BIPM)

The International Bureau of Weights and Measures (BIPM) is the intergovernmental organisation through which Member States act together on matters related to measurement science and measurement standards. Together with the wider metrology community, as well as other strategic partners, the BIPM ensures that the measurement results from different states are comparable, mutually trusted and accepted. The BIPM provides a forum for the creation and worldwide adoption of common rules of measurement. The international system of measurement that the BIPM co-ordinates worldwide underpins the benefits of international regulatory co-operation (IRC): increased trade and investment flows and additional GDP points; gains in administrative efficiency and cost savings for governments, businesses and citizens; and societal benefits such as improved safety and strengthened environmental sustainability. Accurate measurements are specifically necessary to regulators and legislators for establishing and enforcing regulatory limits. This case study describes how the BIPM supports international regulatory co-operation (IRC) – its institutional context, its main characteristics, its impacts, successes and challenges.

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www.oecd.org/gov/regulatory-policy/irc.htm