Highlights in the work of the BIPM during 2019

Dr Martin Milton
BIPM Director

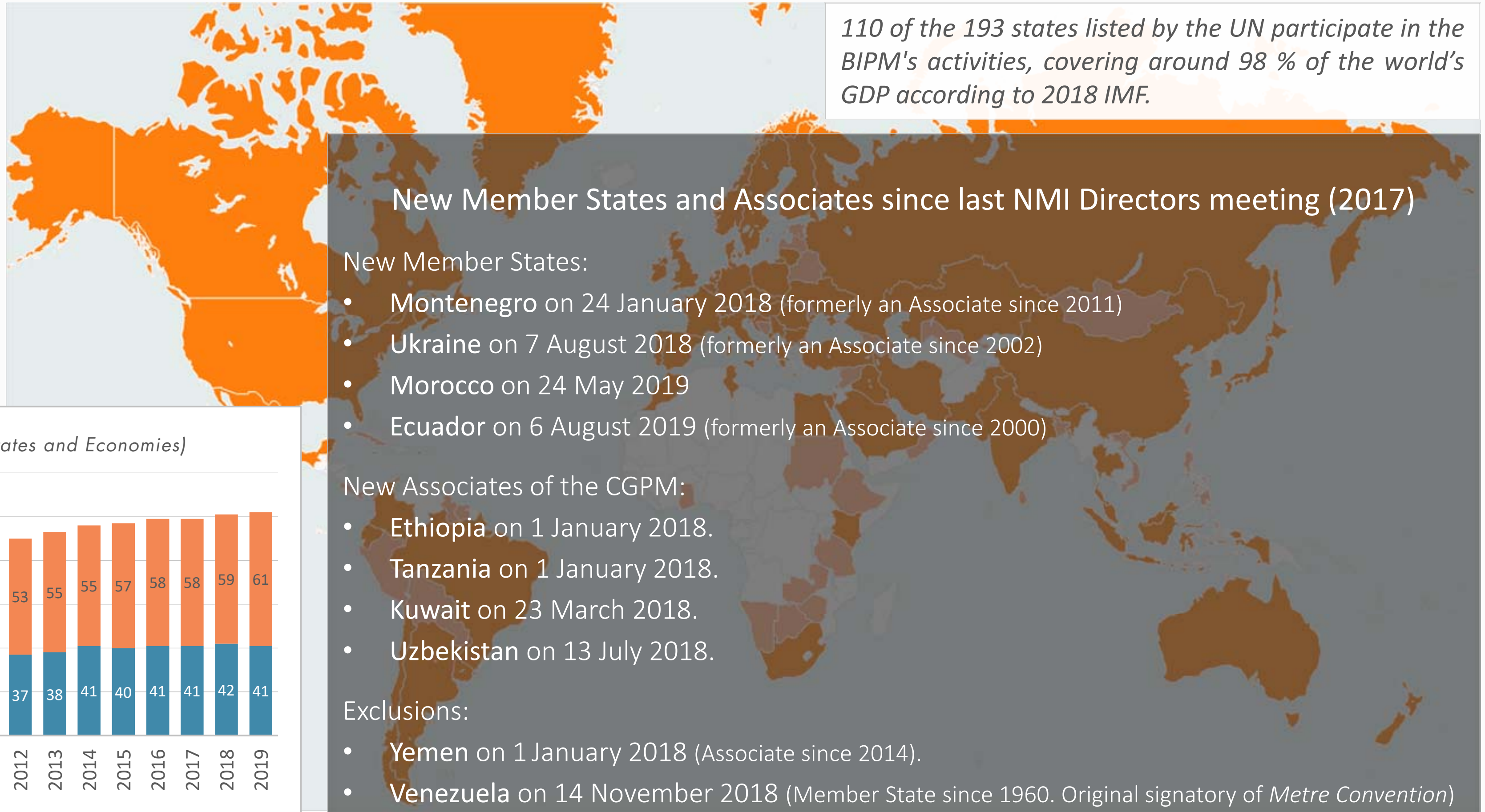
17 October 2019

Bureau
International des
Poids et
Mesures

Member States and Associates *(As of 06 August 2019)*

- 61 Member States*
- 41 Associates of the CGPM
  (States and Economies)

** The official term is "State Parties to the Metre Convention"; the term "Member States" is its synonym and used for easy reference.*



110 of the 193 states listed by the UN participate in the BIPM's activities, covering around 98 % of the world's GDP according to 2018 IMF.

New Member States and Associates since last NMI Directors meeting (2017)

New Member States:

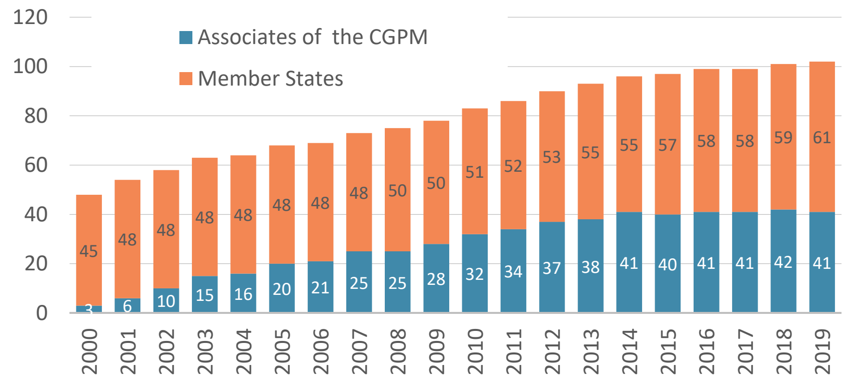
- **Montenegro** on 24 January 2018 (formerly an Associate since 2011)
- **Ukraine** on 7 August 2018 (formerly an Associate since 2002)
- **Morocco** on 24 May 2019
- **Ecuador** on 6 August 2019 (formerly an Associate since 2000)

New Associates of the CGPM:

- **Ethiopia** on 1 January 2018.
- **Tanzania** on 1 January 2018.
- **Kuwait** on 23 March 2018.
- **Uzbekistan** on 13 July 2018.

Exclusions:

- **Yemen** on 1 January 2018 (Associate since 2014).
- **Venezuela** on 14 November 2018 (Member State since 1960. Original signatory of *Metre Convention*)



*2019 data as of August 2019

BIPM highlights of 2019

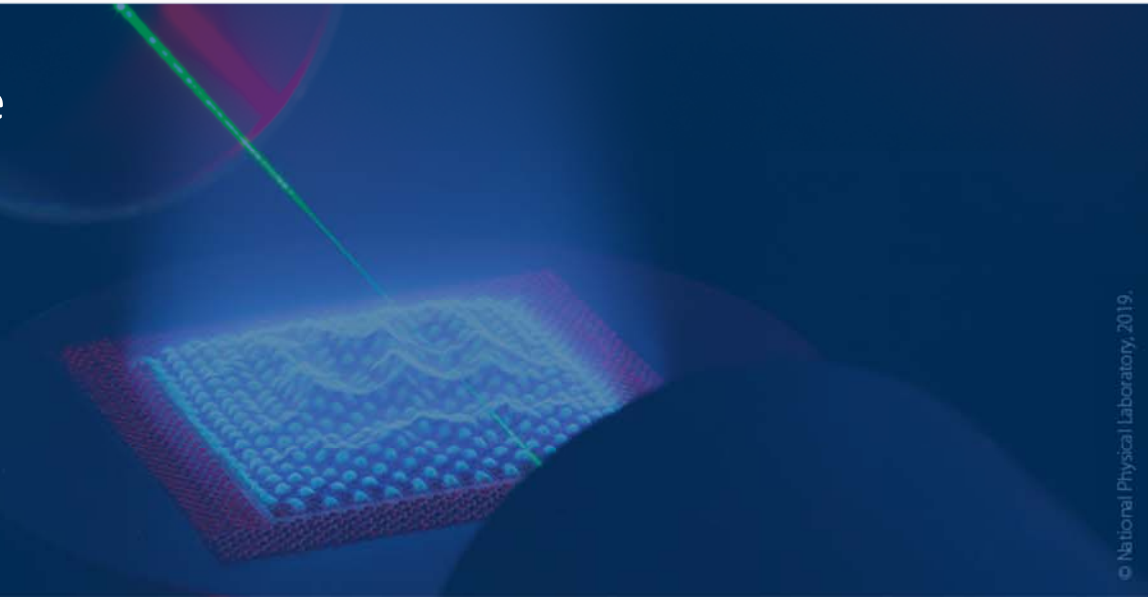
01 – Introduction to the work programme

02 – Liaison work

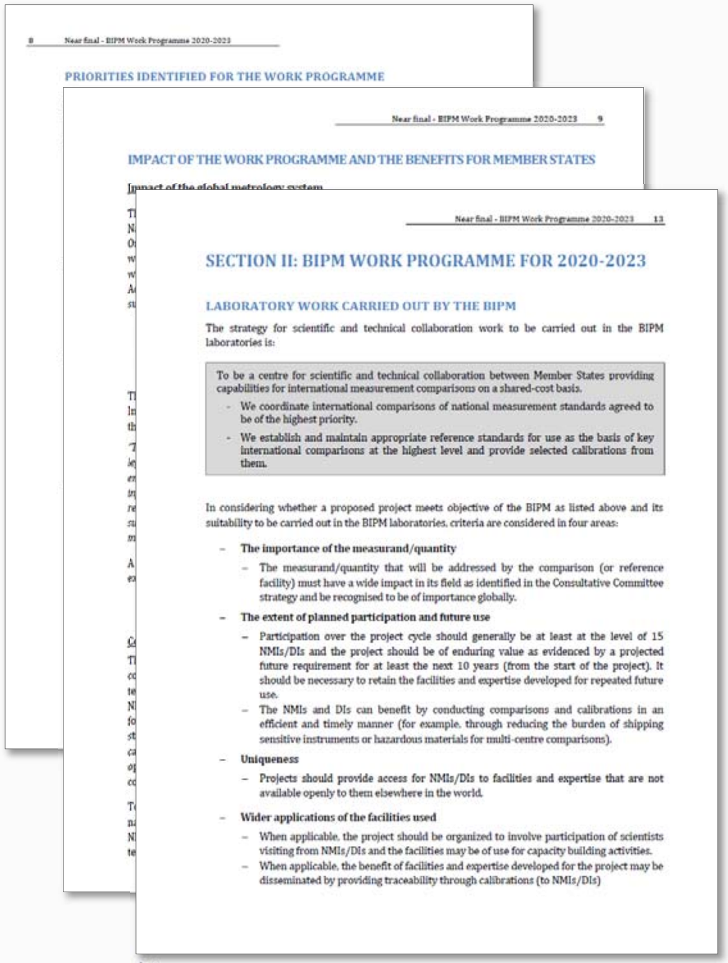
03 – Laboratory work

04 – Coordination work

05 – Finance and Operations



The BIPM work programme


8 Near final - BIPM Work Programme 2020-2023

PRIORITIES IDENTIFIED FOR THE WORK PROGRAMME

Near final - BIPM Work Programme 2020-2023 9

IMPACT OF THE WORK PROGRAMME AND THE BENEFITS FOR MEMBER STATES

Impact of the global metrology system

Near final - BIPM Work Programme 2020-2023 13

SECTION II: BIPM WORK PROGRAMME FOR 2020-2023

LABORATORY WORK CARRIED OUT BY THE BIPM

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

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

In considering whether a proposed project meets objective of the BIPM as listed above and its suitability to be carried out in the BIPM laboratories, criteria are considered in four areas:

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

Agreed by the CGPM for the period 2020-2023

- Covers all parts of our work: coordination, liaison, laboratories, meetings etc.
- Specific quantified milestones/deliverables agreed at the CGPM
- Will be delivered within the +1% pa budget increase
- Also receive grants from NMIs and RMOs for capacity-building and other specific projects.
- Openly available from the website.

Reporting

- Annual report of progress to the CIPM
- Annual visits to the labs by CIPM
- External audit (KPMG) against International Public Sector Accounting Standards (IPSAS)
- QMS – now reviewed through SIM

71 staff from 18 countries

- 23 PhD
- plus 10 full time equivalent secondees

5 Departments

- executing the work programme projects
- coordinating comparisons
- providing calibrations

Capacity Building and Knowledge Transfer - update

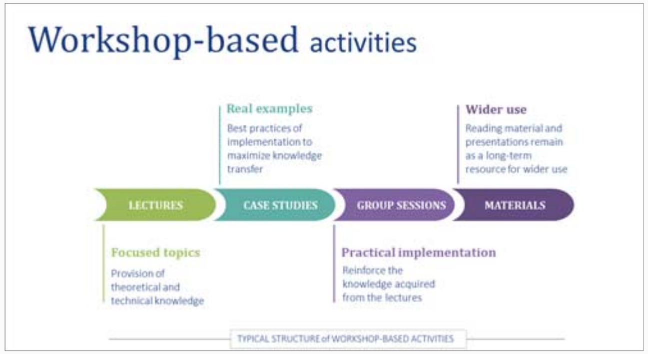
"to increase the effectiveness with which Member States and Associates engage in the world-wide coordinated metrological system"

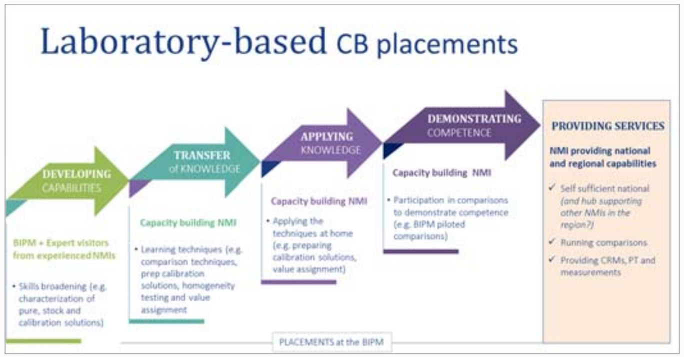
Over 75 % of Member States and Associates have participated in the CBKT Programme
(as trainees, lecturers and sponsors)

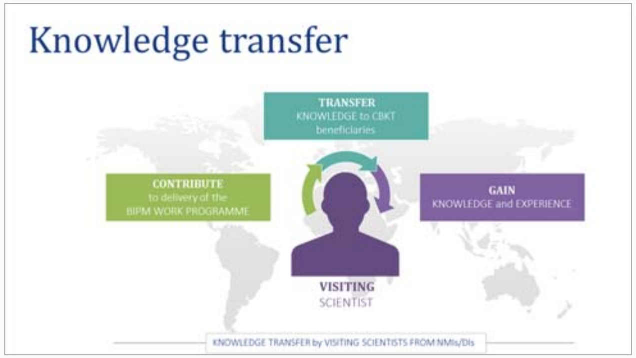
19 CBKT projects
- 16 Completed
- 3 Ongoing

384 people
from 85 countries have benefited

58 invited lecturers
from 28 countries have helped deliver the projects

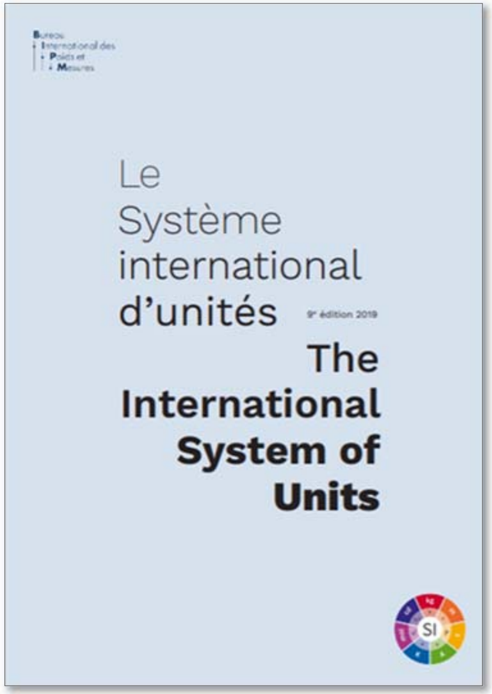






02 – Liaison work

Implementation of the SI



The 9th edition of the SI Brochure is available on the BIPM website.

The International System of Units (SI)

Introduction | Definition of the SI | SI base units | SI prefixes | The 2018 revision of the SI | How to realize the SI units | SI Brochure | History

→ The recommended practical system of units of measurement is the International System of Units (*Système International d'Unités*), with the international abbreviation **SI**.

The SI is defined by the **SI Brochure**, which is published by the BIPM.

In a landmark decision, the BIPM's Member States voted on 16 November 2018 to revise the SI, changing the world's definition of the kilogram, the ampere, the kelvin and the mole.

This decision, made at the 26th meeting of the General Conference on Weights and Measures (CGPM), means that from 20 May 2019 all SI units are defined in terms of constants that describe the natural world. This will assure the future stability of the SI and open the opportunity for the use of new technologies, including quantum technologies, to implement the definitions.

The seven defining constants of the SI are:

- the caesium hyperfine frequency $\Delta\nu_{Cs}$;
- the speed of light in vacuum c;
- the Planck constant h;
- the elementary charge e;
- the Boltzmann constant k;
- the Avogadro constant N_A; and
- the luminous efficacy of a defined visible radiation K_{cd}.

The SI was previously defined in terms of seven base units and derived units defined as products of powers of the base units. The seven base units were chosen for historical reasons, and were, by convention, regarded as dimensionally independent: the metre, the kilogram, the second, the ampere, the kelvin, the mole, and the candela. This role for the base units continues in the present SI even though the SI itself is now defined in terms of the defining constants above.

World Metrology Day 2019

"The International System of Units - Fundamentally better"

The 2019 poster was designed by the Standards and Calibration Laboratory, Hong Kong, China.

Innovation and Technology Commission

Standards and Calibration Laboratory, Hong Kong, China

- 18 languages (WMD poster was translated)

Information on national WMD activities is posted on the website:
http://www.worldmetrologyday.org

03 – Laboratory work

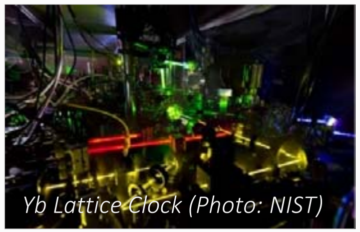
New frequency standards contribute to UTC

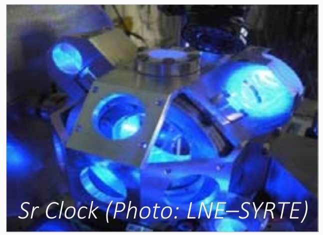
In August 2019 the relative accuracy of UTC with respect to the SI second was: $0.32 \pm 0.13 \times 10^{-15}$

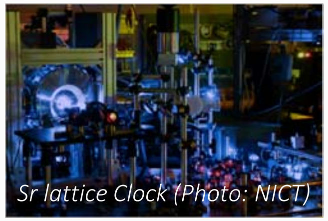

Cs fountain (Photo: NIM)

- The accuracy of UTC is based on the steering versus the **primary** realizations of the SI second.
  Primary realizations from NMIs are 10 Cesium fountains (accuracy 10^{-16}) and 2 traditional Cesium beam (accuracy 10^{-14}). 6 additional Cs fountains under development.

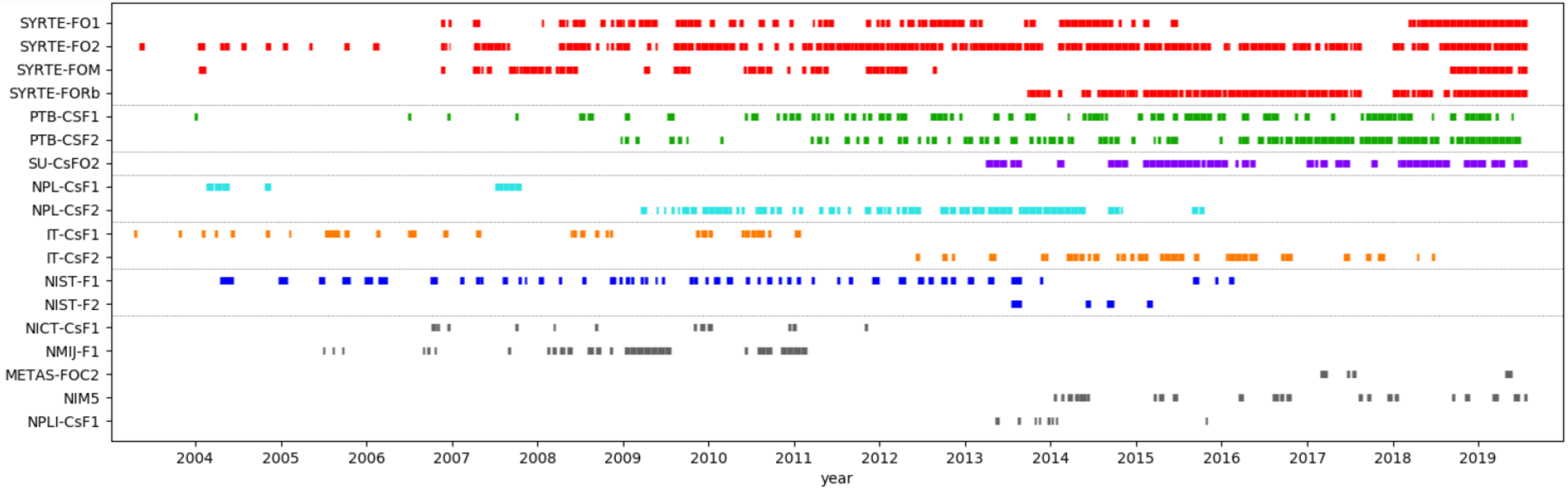
- Secondary representation of the second are also contributing:
  - **July 2015, first contribution** from the SYRTE Rb fountain
  - **March 2017, first results** from the SYRTE Strontium lattice standards
  - **Dec 2018**, the NICT and SYRTE Strontium standards and
  - **Feb 2019**, the NIST Ytterbium **lattice standard entered in the UTC computation**.


Yb Lattice Clock (Photo: NIST)


Sr Clock (Photo: LNE–SYRTE)

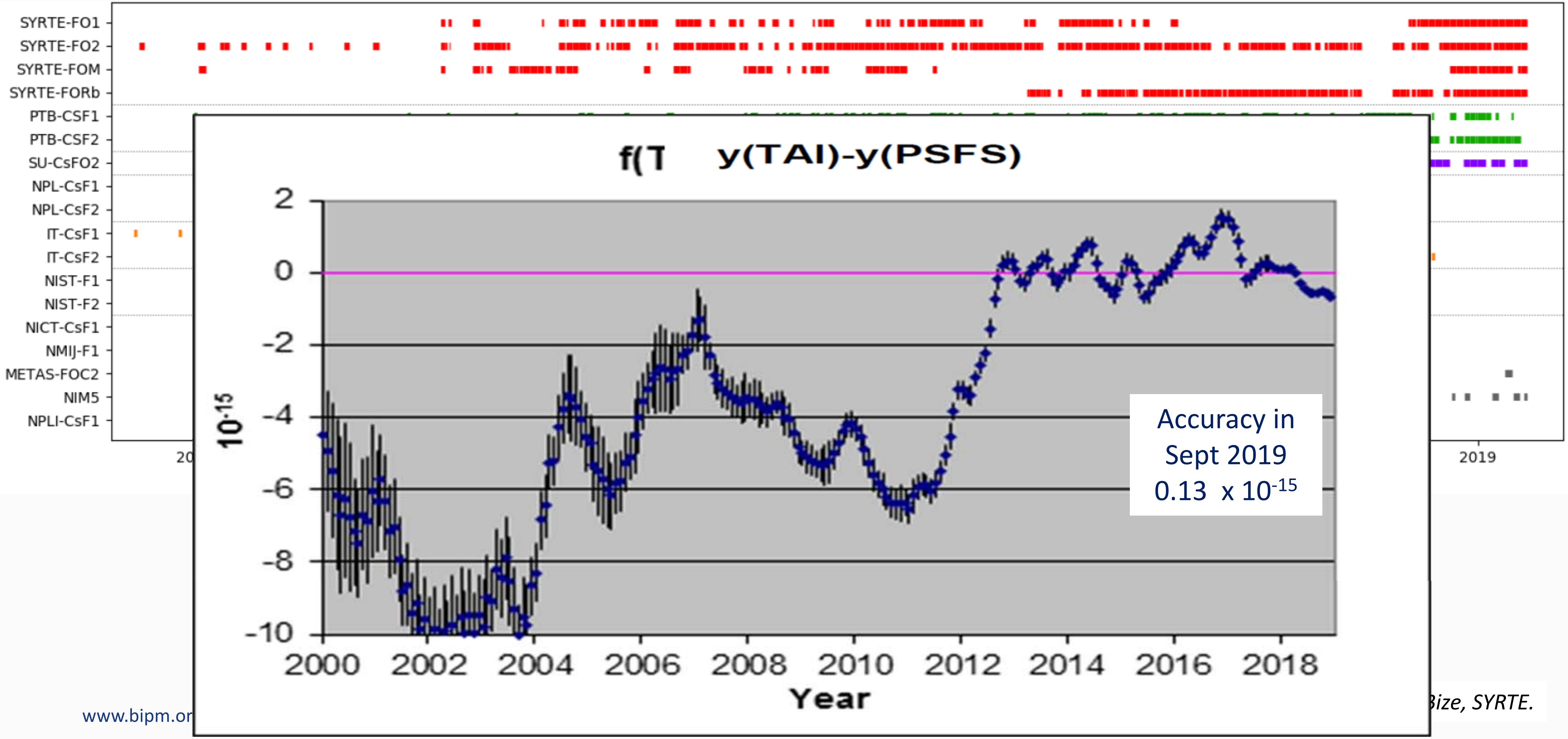

Sr lattice Clock (Photo: NICT)

Contributions to TAI by optical clocks and Cs-fountains



Courtesy of S. Bize, SYRTE.

Contributions to TAI by optical clocks and Cs-fountains



www.bipm.or

ize, SYRTE.

Capacity building in the time community

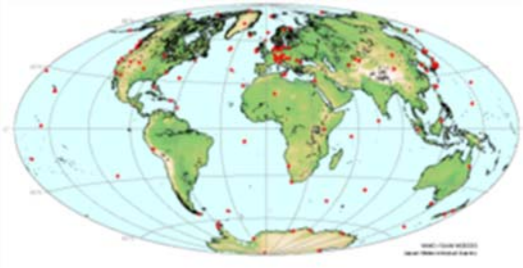
The Time Dept. is preparing a CBKT activity with different tools:

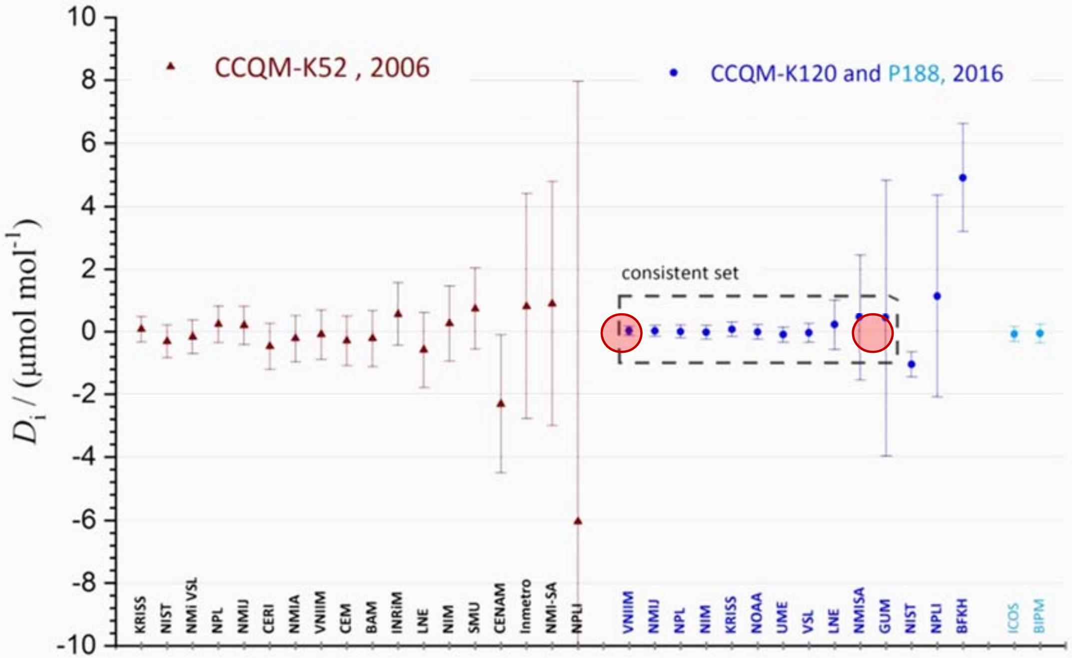
(with the support of *Y. Hanado*, secondee from NICT, Japan)

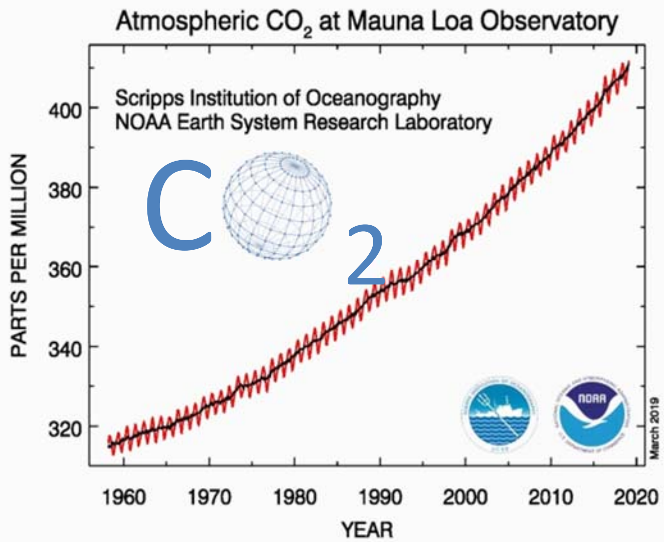
1. **Developing a course with tutorial lectures and training on time-scale and algorithm.**
   - It can be delivered at the BIPM or at RMO with the RMO lab support.
   - The targeted attendees are beginners who are/will be in charge of operating national standard time and participating to UTC.

2. **Planning additional activities:**
   - Practical exercise, simulations tools, and demonstrative videos.
   - These items will be offered during the course, and could be available for permanent (remote) training hosted on the BIPM web page.

Accuracy of Global CO_2 measurement scale demonstrated







WMO-CO_2-X2019 Scale

BIPM facility for on-going comparisons of CO_2 operating

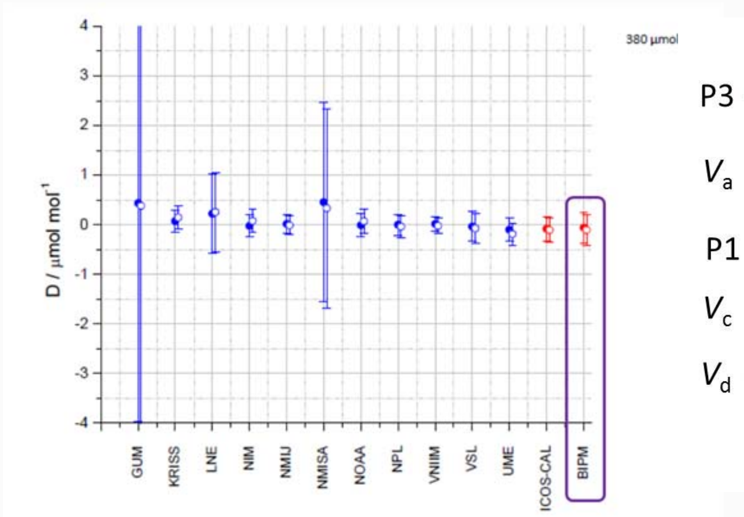
BIPM CO_2-PVT Reference System Established with visiting scientists from:

NIST

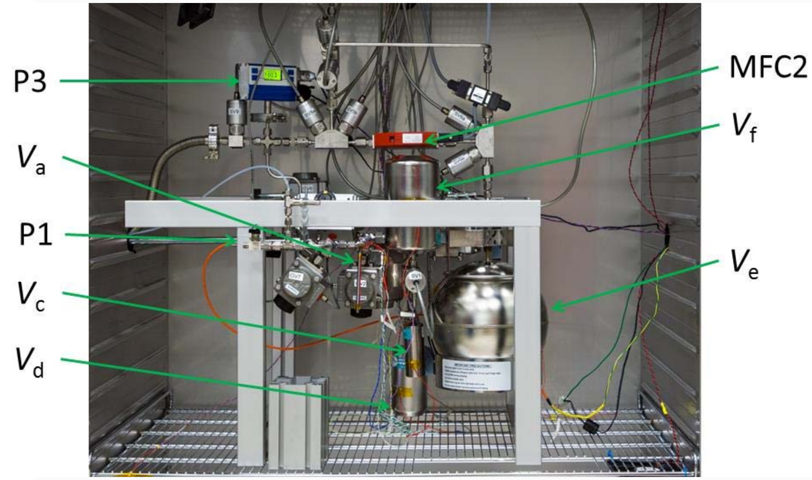
RISE

NMIJ

Performance in CCQM-P188



BIPM CO_2-PVT System



IOP Publishing | Bureau International des Poids et Mesures   Metrologia

Metrologia 55 (2018) S174–S181

SI traceability and scales for underpinning atmospheric monitoring of greenhouse gases

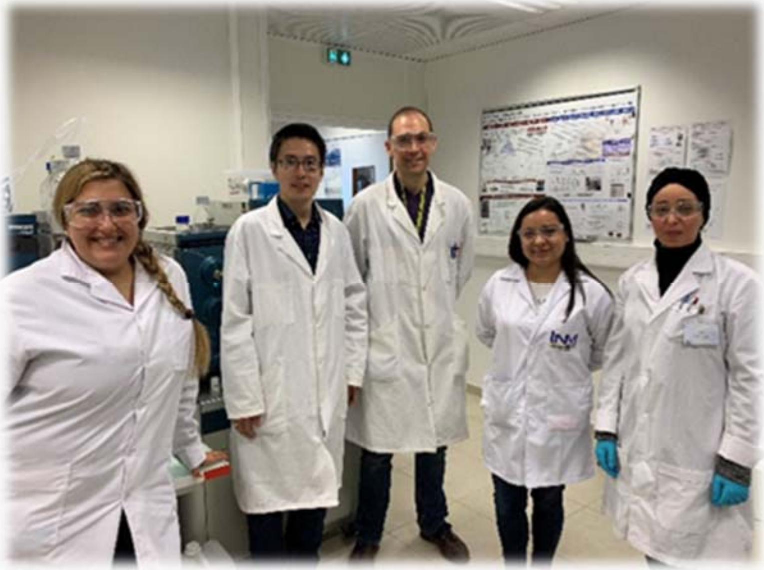
Paul J Brewer[1,4], Richard J C Brown[1], Oksana A Tarasova[2], Brad Hall[3], George C Rhoderick[4] and Robert I Wielgosz[5]

[1] National Physical Laboratory, Hampton Road, Teddington, Middlesex TW11 0LW, United Kingdom
[2] World Meteorological Organization, 7bis, avenue de la Paix, Case postale 2300, CH-1211 Geneva 2, Switzerland
[3] National Oceanic and Atmospheric Administration, 325 Broadway, Mail Stop R.GMD1, Boulder, CO 80305, United States of America
[4] National Institute of Standards and Technology, 100 Bureau Drive, MS-8393 Gaithersburg, MD 20899-8393, United States of America
[5] Bureau International des Poids et Mesures, Pavillon de Breteuil, F-92312 Sèvres Cedex, France

mole fraction of CO_2 in air standard

$$x_{CO2} = \frac{n_{CO2}}{n_{air}} = \left(\frac{V_s}{V_L}\right)\left(\frac{P_{CO2}}{P_{air}}\right)\left(\frac{T_{air}}{T_{CO2}}\right)\left(\frac{Z_{air}}{Z_{CO2}}\right)$$

Laboratory-based Capacity Building and Knowledge Transfer

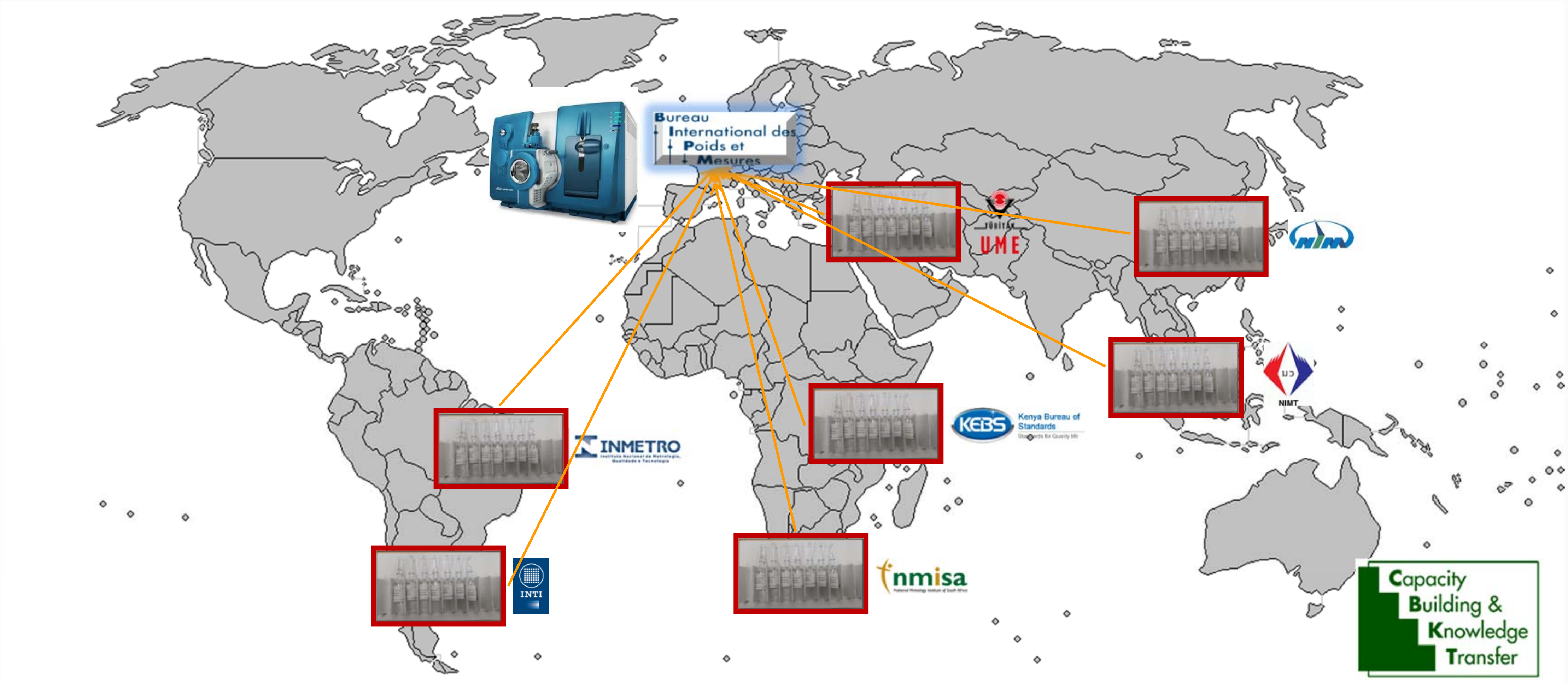


Established with support from

Support for 7 visiting scientists

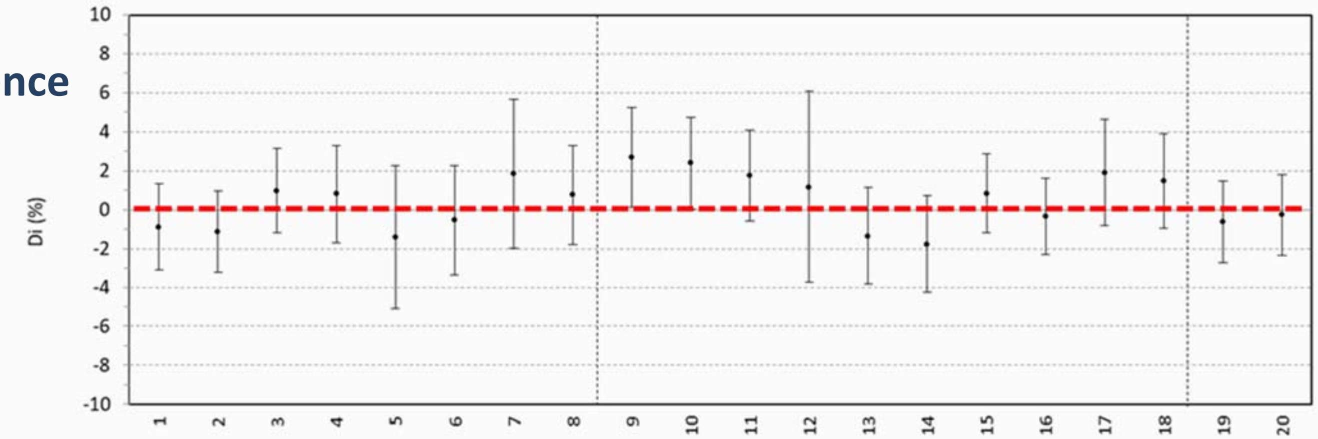
Capacity Building & Knowledge Transfer

Laboratory-based Capacity Building and Knowledge Transfer

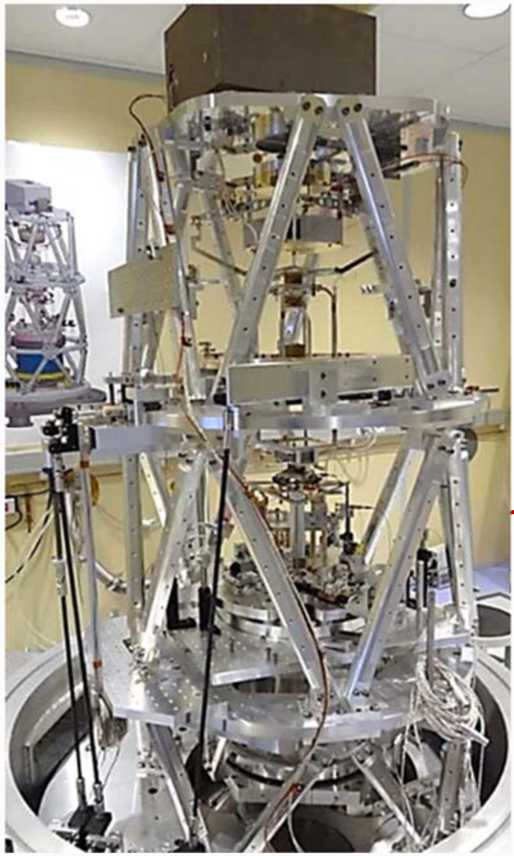


Laboratory-based Capacity Building and Knowledge Transfer

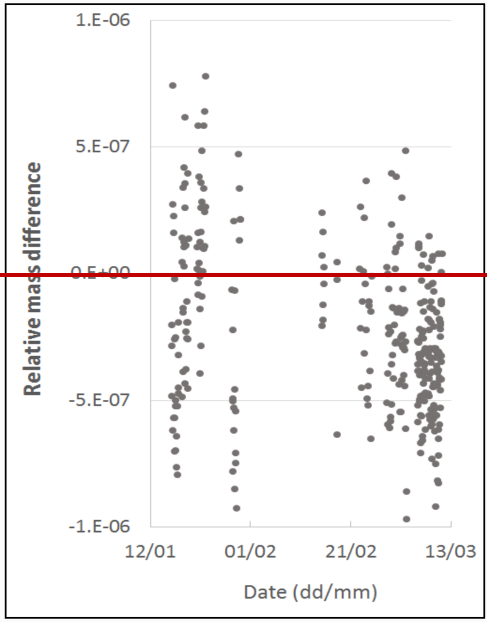
Demonstration of Competence
CCQM-K154.a – ZEN



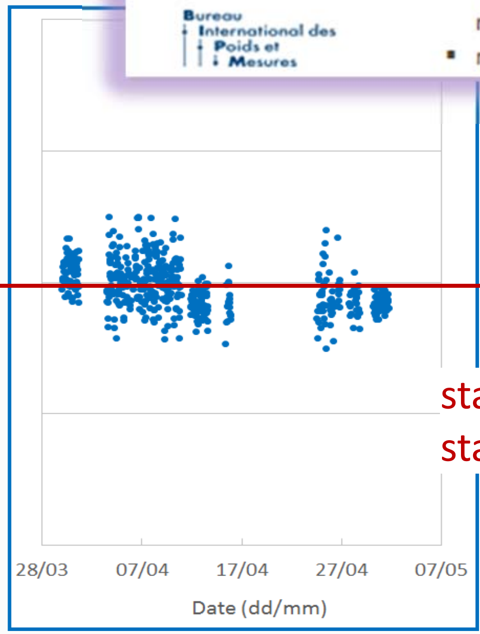
BIPM Kibble balance results



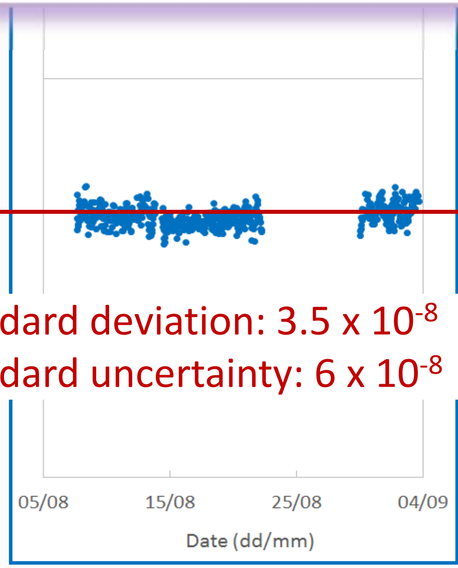
- fixing an electrical grounding issue on the suspension



January - March

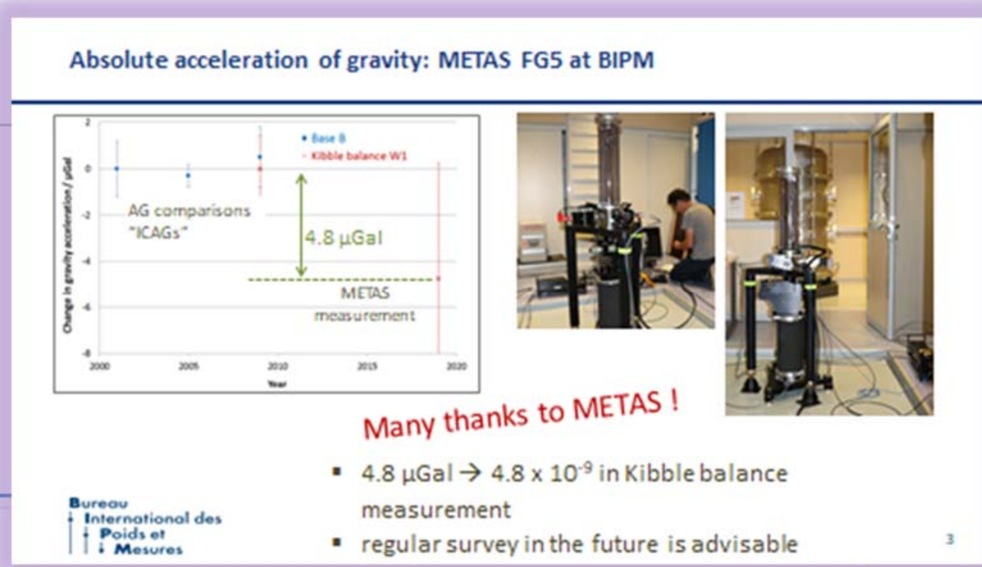


April - May



Aug - September

standard deviation: 3.5×10^{-8}
standard uncertainty: 6×10^{-8}



Coordinated R&D projects ***in radiation dosimetry***

Do ion chamber calibrations depend on the linear accelerator?

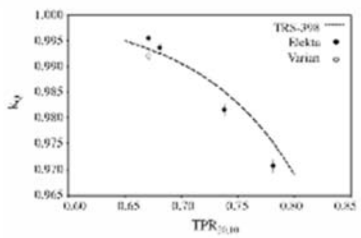


Figure 11. k_Q of modelled NE2561chamber with Varian 6 MV beam compared to ARPANSA Elekta beams.

A definitive experimental and modelling investigation using BIPM instrumentation on LINACS at DOSEO and the DTU (the final results are being analyzed at NRC).

NRC, LNHB & DTU

Are backscatter corrections correct for low-energy x-ray dosimetry?

Consistency of radiation dosimetry relies on IAEA TRS-398. This Code of Practice requires a correction factor for backscatter – this project provided new experimental data and Monte Carlo simulations.

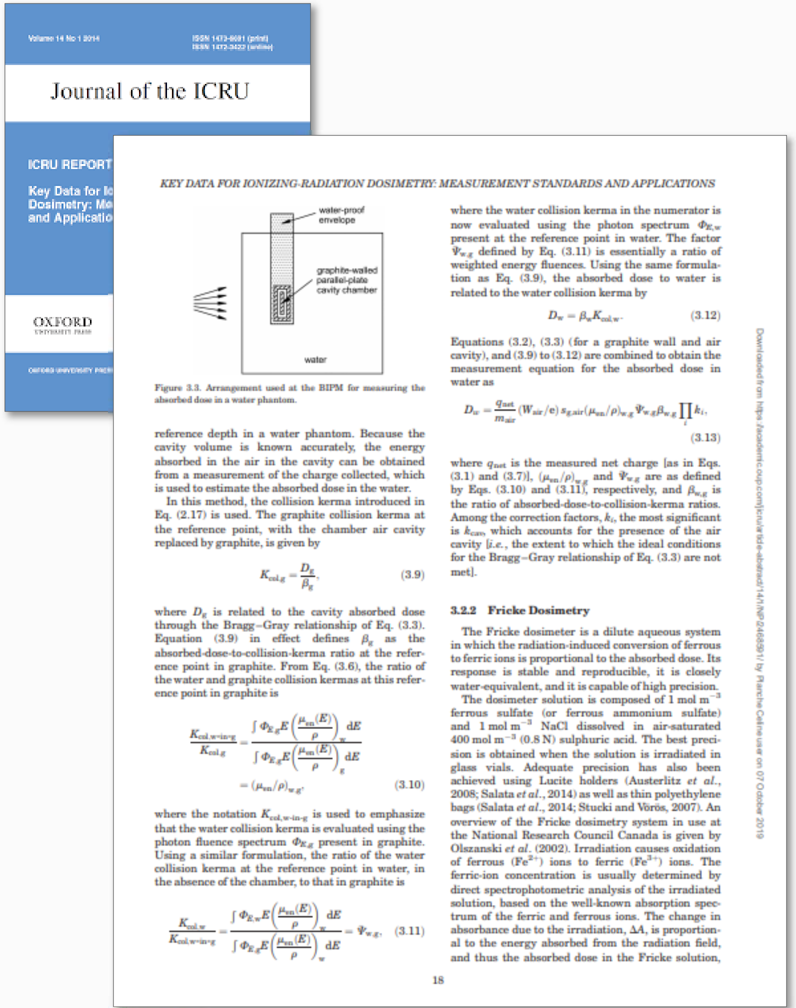
IAEA & consultant (Prof Andreo)

Improving the characterization of the reference qualities for low-energy x-rays.

This project expanded the range of comparison services and reduced measurement uncertainties.

VNIIM

Introduction of ICRU 90



KEY DATA FOR IONIZING-RADIATION DOSIMETRY: MEASUREMENT STANDARDS AND APPLICATIONS

Figure 3.3. Arrangement used at the BIPM for measuring the absorbed dose in a water phantom.

reference depth in a water phantom. Because the cavity volume is known accurately, the energy absorbed in the air in the cavity can be obtained from a measurement of the charge collected, which is used to estimate the absorbed dose in the water.

In this method, the collision kerma introduced in Eq. (2.17) is used. The graphite collision kerma at the reference point, with the chamber air cavity replaced by graphite, is given by

$$K_{col,g} = \frac{D_g}{\beta_g}, \quad (3.9)$$

where D_g is related to the cavity absorbed dose through the Bragg–Gray relationship of Eq. (3.3). Equation (3.9) in effect defines β_g as the absorbed-dose-to-collision-kerma ratio at the reference point in graphite. From Eq. (3.6), the ratio of the water and graphite collision kermas at this reference point in graphite is

$$\frac{K_{col,w\text{-}in\text{-}g}}{K_{col,g}} = \frac{\int \Phi_{E,g} E \left(\frac{\mu_{en}(E)}{\rho}\right)_w dE}{\int \Phi_{E,g} E \left(\frac{\mu_{en}(E)}{\rho}\right)_g dE} = (\mu_{en}/\rho)_{w,g}, \quad (3.10)$$

where the notation $K_{col,w\text{-}in\text{-}g}$ is used to emphasize that the water collision kerma is evaluated using the photon fluence spectrum $\Phi_{E,g}$ present in graphite. Using a similar formulation, the ratio of the water collision kerma at the reference point in water, in the absence of the chamber, to that in graphite is

$$\frac{K_{col,w}}{K_{col,w\text{-}in\text{-}g}} = \frac{\int \Phi_{E,w} E \left(\frac{\mu_{en}(E)}{\rho}\right)_w dE}{\int \Phi_{E,g} E \left(\frac{\mu_{en}(E)}{\rho}\right)_w dE} = \Psi_{w,g}, \quad (3.11)$$

where the water collision kerma in the numerator is now evaluated using the photon spectrum $\Phi_{E,w}$ present at the reference point in water. The factor $\Psi_{w,g}$ defined by Eq. (3.11) is essentially a ratio of weighted energy fluences. Using the same formulation as Eq. (3.9), the absorbed dose to water is related to the water collision kerma by

$$D_w = \beta_w K_{col,w}. \quad (3.12)$$

Equations (3.2), (3.3) (for a graphite wall and air cavity), and (3.9) to (3.12) are combined to obtain the measurement equation for the absorbed dose in water as

$$D_w = \frac{q_{net}}{m_{air}} (W_{air}/e)\, s_{g,air} (\mu_{en}/\rho)_{w,g} \Psi_{w,g} \beta_{w,g} \prod_i k_i, \quad (3.13)$$

where q_{net} is the measured net charge [as in Eqs. (3.1) and (3.7)], $(\mu_{en}/\rho)_{w,g}$ and $\Psi_{w,g}$ are as defined by Eqs. (3.10) and (3.11), respectively, and $\beta_{w,g}$ is the ratio of absorbed-dose-to-collision-kerma ratios. Among the correction factors, k_i, the most significant is k_{cav}, which accounts for the presence of the air cavity [*i.e.*, the extent to which the ideal conditions for the Bragg–Gray relationship of Eq. (3.3) are not met].

3.2.2 Fricke Dosimetry

The Fricke dosimeter is a dilute aqueous system in which the radiation-induced conversion of ferrous to ferric ions is proportional to the absorbed dose. Its response is stable and reproducible, it is closely water-equivalent, and it is capable of high precision.

The dosimeter solution is composed of 1 mol m^{-3} ferrous sulfate (or ferrous ammonium sulfate) and 1 mol m^{-3} NaCl dissolved in air-saturated 400 mol m^{-3} (0.8 N) sulphuric acid. The best precision is obtained when the solution is irradiated in glass vials. Adequate precision has also been achieved using Lucite holders (Austerlitz *et al.*, 2008; Salata *et al.*, 2014) as well as thin polyethylene bags (Salata *et al.*, 2014; Stucki and Vörös, 2007). An overview of the Fricke dosimetry system in use at the National Research Council Canada is given by Olszanski *et al.* (2002). Irradiation causes oxidation of ferrous (Fe^{2+}) ions to ferric (Fe^{3+}) ions. The ferric-ion concentration is usually determined by direct spectrophotometric analysis of the irradiated solution, based on the well-known absorption spectrum of the ferric and ferrous ions. The change in absorbance due to the irradiation, ΔA, is proportional to the energy absorbed from the radiation field, and thus the absorbed dose in the Fricke solution,

18

The most significant change in ionizing radiation dosimetry in many years

- New key data that impact primary standards
- Changes to standards and uncertainties
- The BIPM has implemented the changes for its standards and services, and published the impact (Burns and Kessler, Metrologia 2018)

Overview of services *(1 Jan. 2016 – 30 June 2019)*

427 Calibrations certificates and Study notes issued by the BIPM

376 Participations in comparisons coordinated by the BIPM

85/61 Participations in the TIME comparisons (*Circular T*/ UTCr)

WP overview *(1 Jan. 2016 – 30 June 2019)*

Technical Services

427 Calibrations certificates and Study notes issued by the BIPM

376 Participations in comparisons coordinated by the BIPM

85/61 Participations in the TIME comparisons (*Circular T*/ UTCr)

333 Participation in Workshop- based CBKT activities of the BIPM

51 Participation in Laboratory-based CBKT (25 placements at the BIPM)

43 WP Secondees assisted to deliver the Work Programme projects

04 – Coordination work

The coordination work of the BIPM

10 Consultative Committees

- CIPM Consultative Committees
- Plus 67 WGs etc.

4 Joint Committees

- JCGM
- JCRB
- JCTLM
- INetQI

3 international databases

- KCDB
- JCTLM
- IMRR

The BIPM Key Comparison Database (KCDB)

262 Institutes *(August 2019)*

- 102 National Metrology Institutes
  - *61 Member States*
  - *41 Associates*
- 4 International organizations *(ESA, IAEA, JRC, WMO)*
- plus 156 Designated Institutes

6 RMOs

Playing an important role to support mutual confidence in the validity of calibration and measurement certificates issued by participating institutes

1,613 comparisons

1039 key, 574 supplementary comparisons

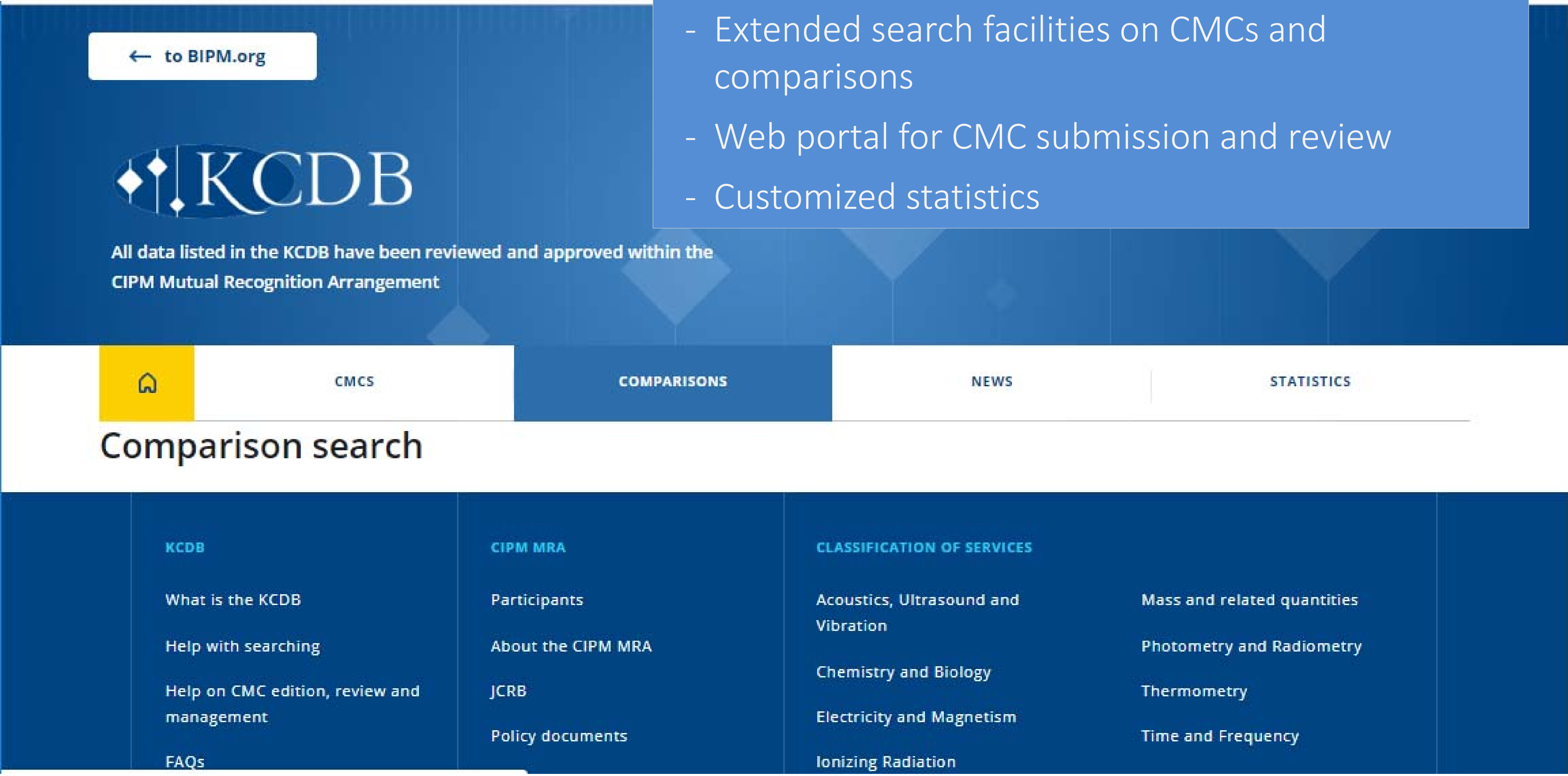
25 242 CMCs

regionally and internationally peer-reviewed CMC declarations

the **KCDB 2.0**

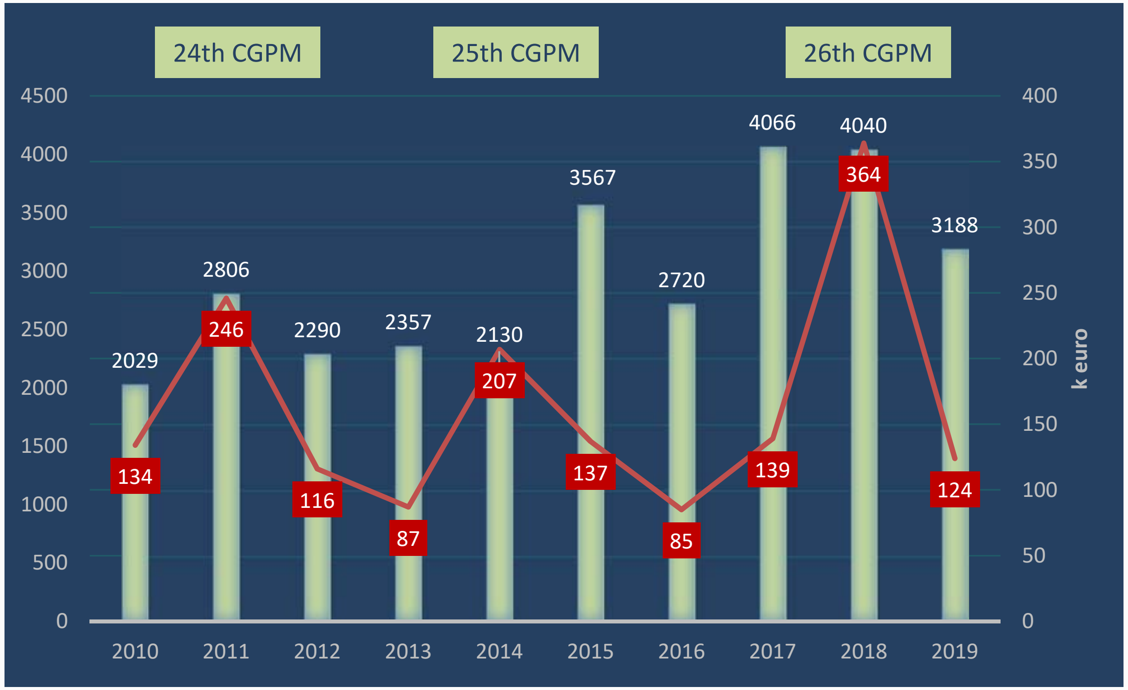
New features

- Extended search facilities on CMCs and comparisons
- Web portal for CMC submission and review
- Customized statistics



Hosting International meetings

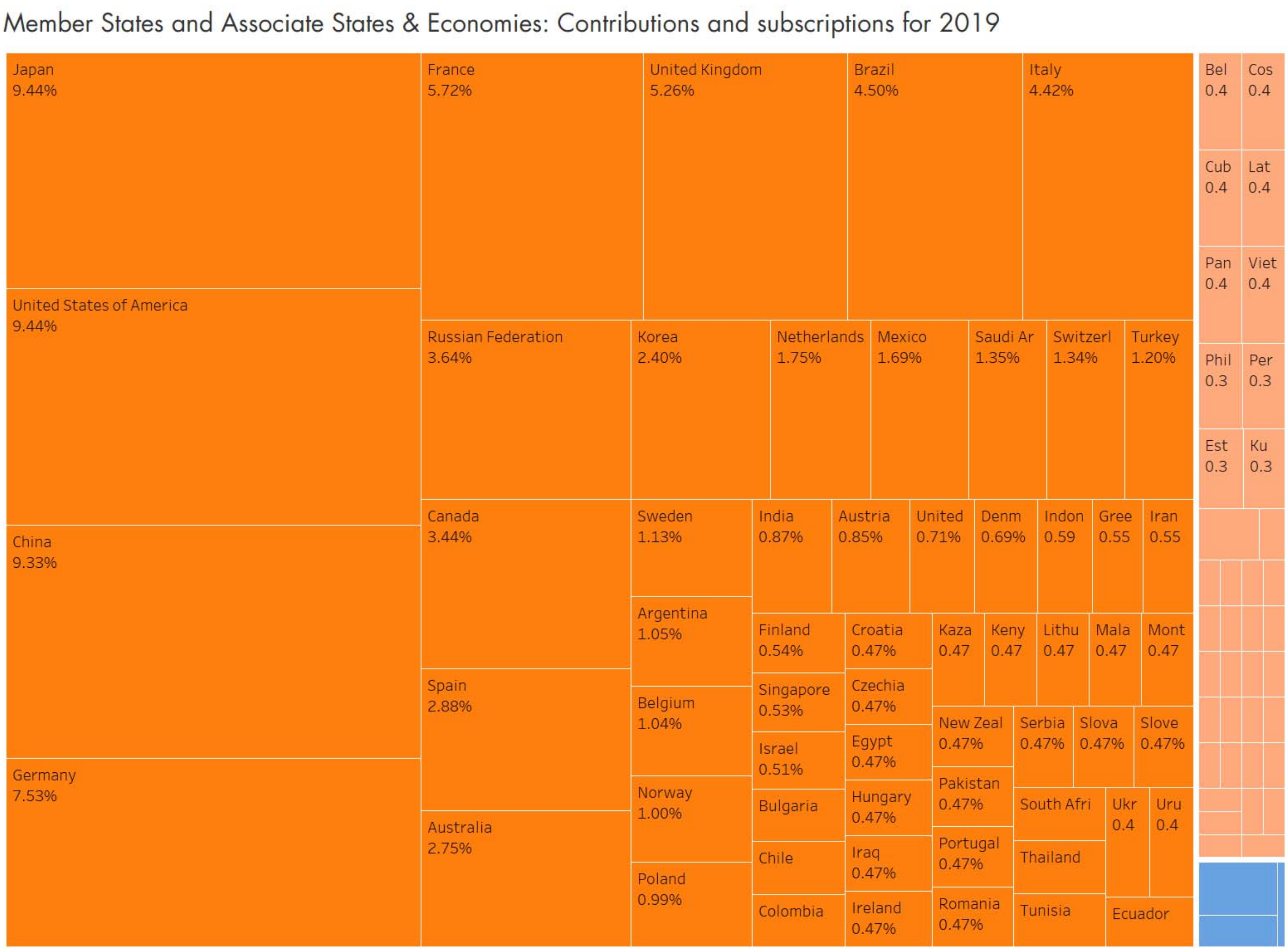
Daily meeting attendance /costs
(participants per day of meeting)



**2019 data as of October 2019*

05 – Finance and operations

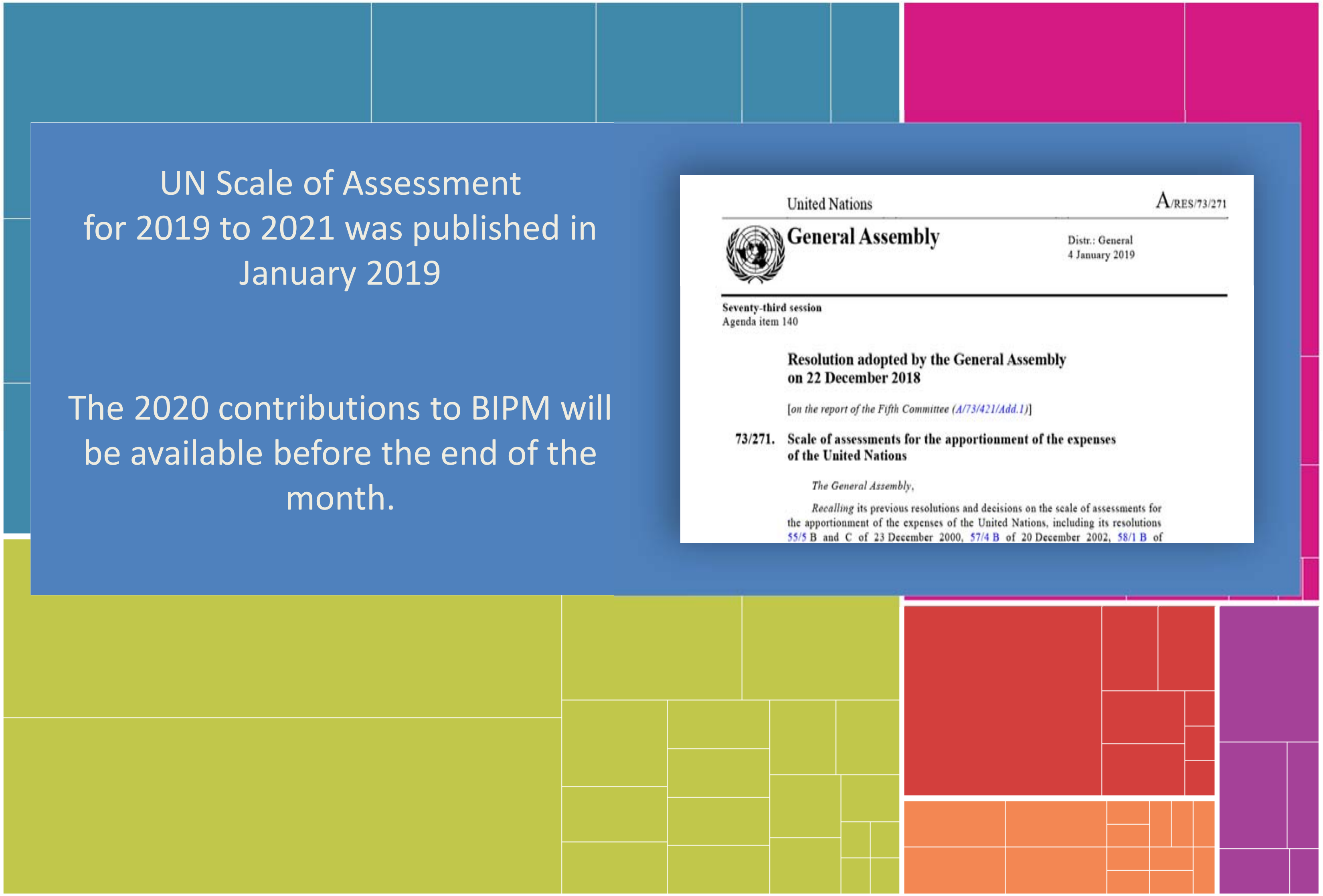
Source of Finance



Source of Finance

by RMO

Member States and Associate States & Economies: Contributions and subscriptions for 2019



UN Scale of Assessment for 2019 to 2021 was published in January 2019

The 2020 contributions to BIPM will be available before the end of the month.

United Nations A/RES/73/271

General Assembly

Distr.: General
4 January 2019

Seventy-third session
Agenda item 140

Resolution adopted by the General Assembly on 22 December 2018

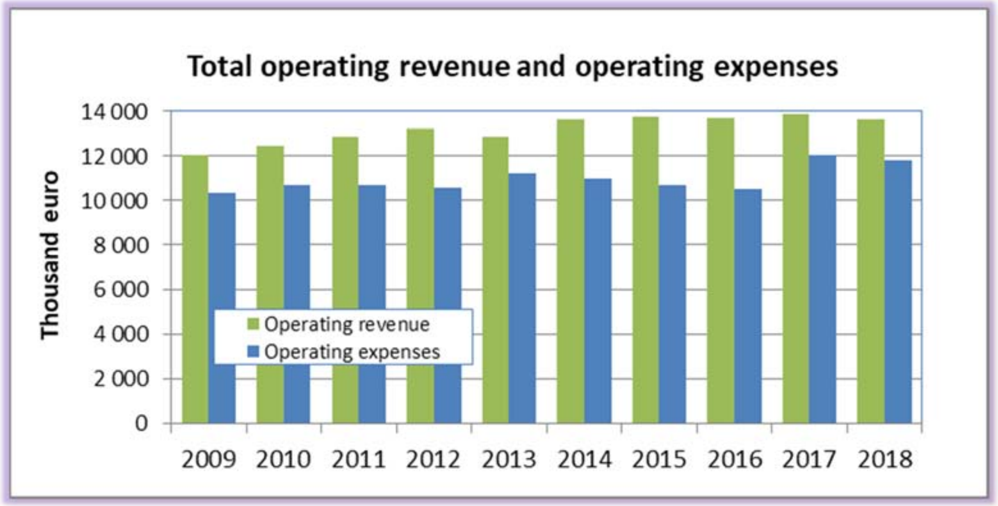
[on the report of the Fifth Committee (A/73/421/Add.1)]

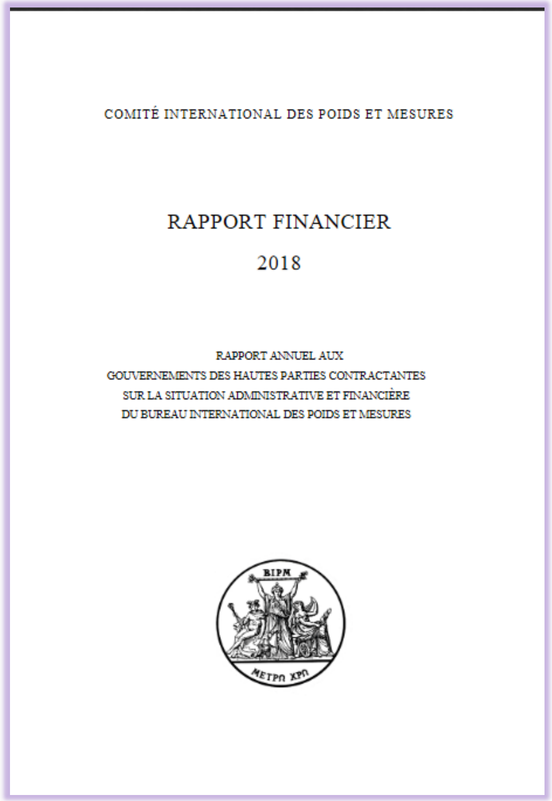
73/271. Scale of assessments for the apportionment of the expenses of the United Nations

The General Assembly,

Recalling its previous resolutions and decisions on the scale of assessments for the apportionment of the expenses of the United Nations, including its resolutions 55/5 B and C of 23 December 2000, 57/4 B of 20 December 2002, 58/1 B of

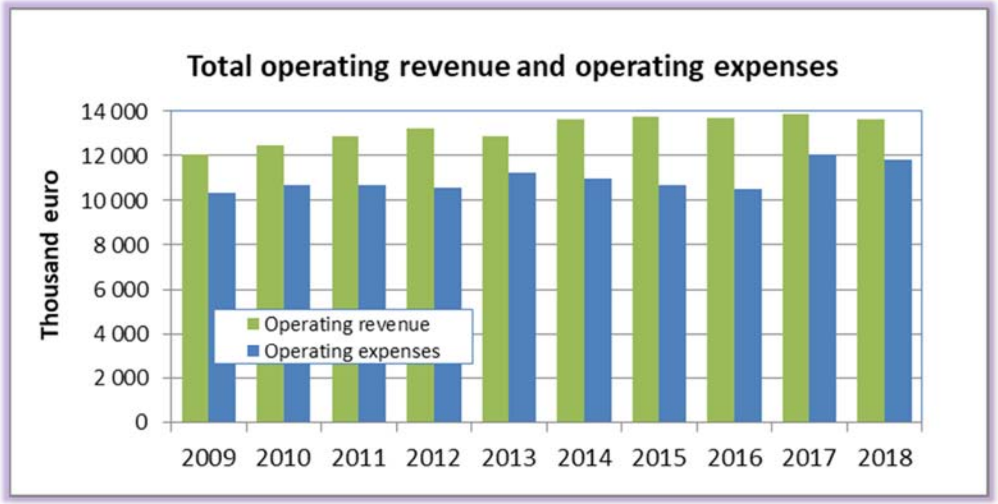
Financial outcomes for 2018

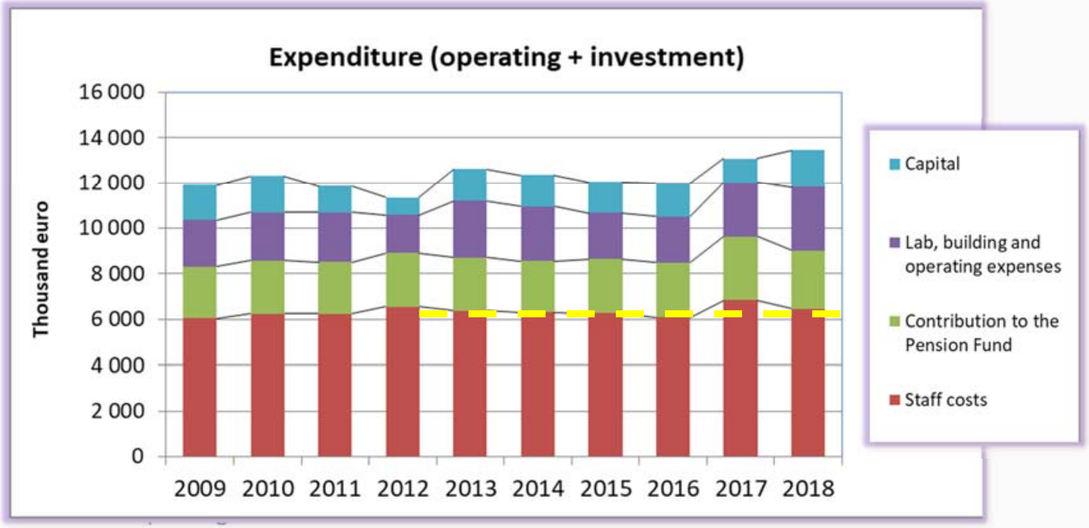


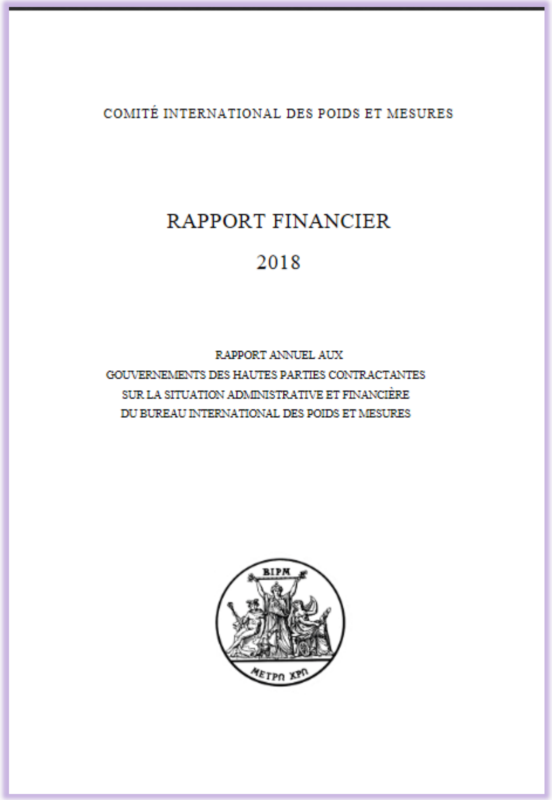


Published 31st May 2019

Financial outcomes for 2018

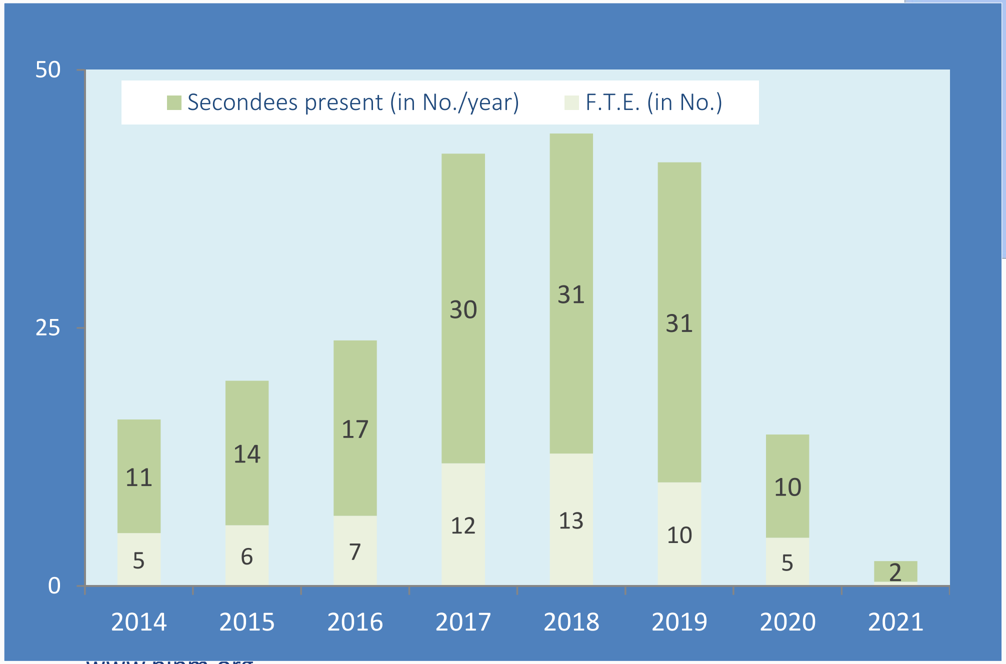






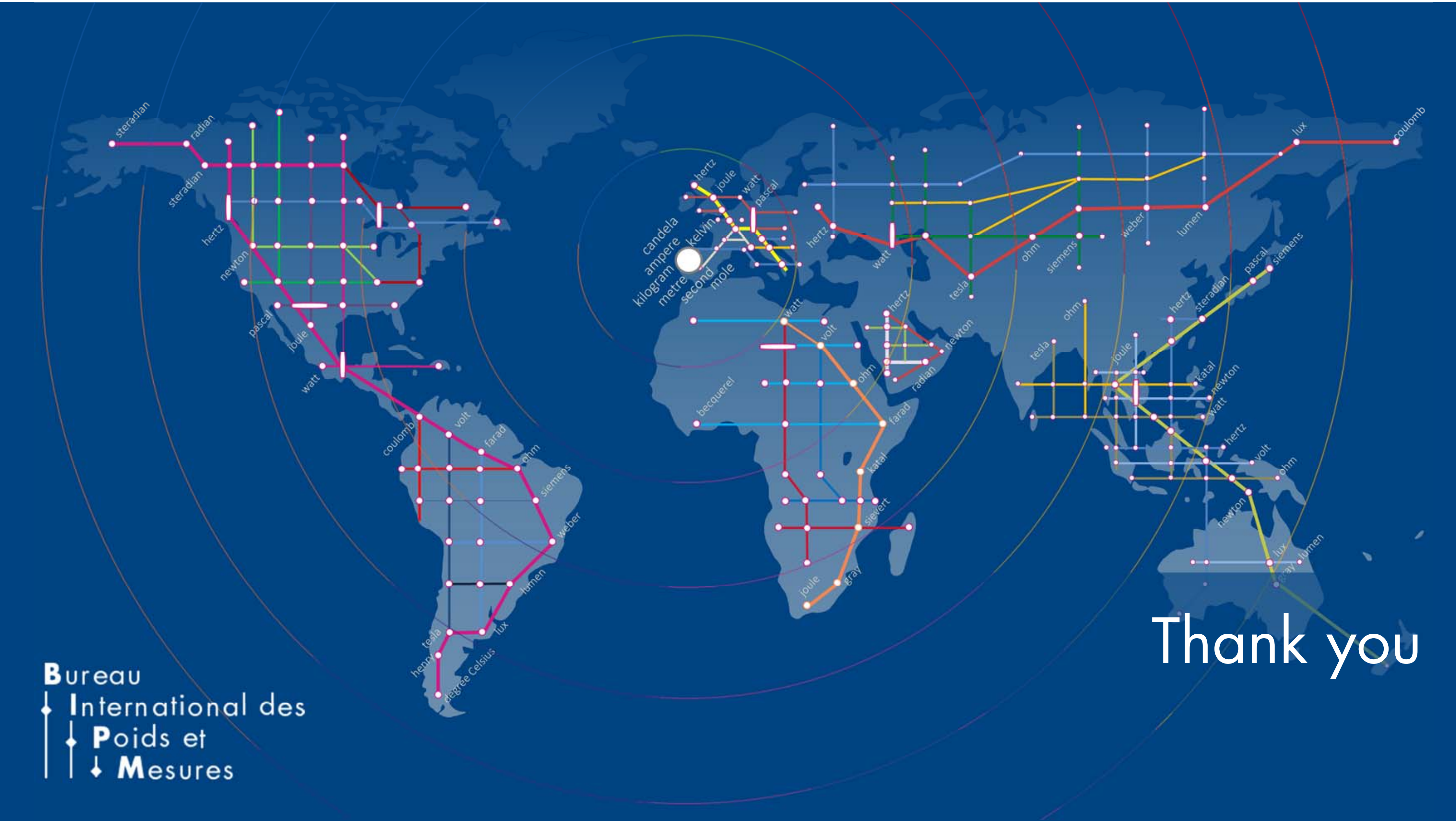
Published 31st May 2019

Secondees / Consultants from NMIs and DIs (2014-2021)



The 100th visitor

will arrive in Dec. 2019



Thank you

Bureau International des Poids et Mesures