Bureau International des Poids et Mesures

Consultative Committee for Length (CCL)

Report of the 19th meeting
(10–11 October 2024)
to the International Committee for Weights and Measures

Comité international des poids et mesures

LIST OF MEMBERS OF THE
CONSULTATIVE COMMITTEE FOR LENGTH
as of 10 October 2024

President

Dr V. Coleman, Member of the International Committee for Weights and Measures.

Executive Secretary

Dr G. Panfilo, International Bureau of Weights and Measures [BIPM], Sèvres.

Members

Bundesamt für Eich- und Vermessungswesen [BEV], Vienna.

Centro Español de Metrología [CEM], Madrid.

Centro Nacional de Metrología [CENAM], Querétaro.

Czech Metrology Institute [CMI], Brno.

D.I. Mendeleyev Institute for Metrology, Rosstandart, [VNIIM], St Petersburg.

Federal Institute of Metrology [METAS], Bern-Wabern.

Instituto Nacional de Metrologia, Normalizaçao e Qualidade Industrial [INMETRO], Rio de Janeiro.

JILA, Boulder.

Korea Research Institute of Standards and Science [KRISS], Daejeon.

Laboratoire National de Métrologie et d'Essais [LNE], Paris.

National Institute of Metrological Research/Istituto Nazionale di Ricerca Metrologica [INRiM], Turin.

National Institute of Metrology [NIM], Beijing.

National Institute of Standards [NIS], Giza.

National Institute of Standards and Technology [NIST], Gaithersburg.

National Measurement Institute, Australia [NMIA], Lindfield.

National Metrology Centre, Agency for Science, Technology and Research [NMC, A*STAR], Singapore.

National Metrology Institute of Japan, Advanced Institute of Science and Technology [NMIJ/AIST], Tsukuba.

National Metrology Institute of South Africa [NMISA], Pretoria.

National Metrology Institute of Turkey/ TÜBITAK Ulusal Metroloji Enstitüsü [UME], Gebze-Kocaeli.

National Physical Laboratory [NPL], Teddington.

National Research Council of Canada [NRC], Ottawa.

Physikalisch-Technische Bundesanstalt [PTB], Braunschweig.

Slovak Institute of Metrology/Slovenský Metrologický Ústav [SMU], Bratislava.

VSL Dutch Metrology Institute [VSL], Delft.

VTT Technical Research Center of Finland Ltd, Centre for Metrology / Mittatekniikan Keskus [MIKES], Espoo.

The Director of the International Bureau of Weights and Measures [BIPM], Sèvres.

Observers

Central Office of Measures [GUM], Warsaw.

Industrial Technology Research Institute/Center for Measurement Standards [CMS/ITRI], Hsinchu.

Instituto Nacional de Tecnología Industrial [INTI], San Martín, Prov. Buenos Aires.

Instituto Português da Qualidade [IPQ], Caparica.

National Institute of Metrology (Thailand) [NIMT], Pathumthani.

National Scientific Centre "Institute of Metrology" [NSC IM], Kharkiv.

FIRST SESSION, THURSDAY 10 OCTOBER

The Consultative Committee for Length (CCL) held its 19th meeting online on Thursday 10, and Friday 11 October 2024. Three sessions were held, 09:00 – 13:00. 14:00 – 18:00 on day one and 09:00 – 12:30 (times are UTC+1).

The following delegates were present:

Members: D.G. Abdelsalam Ibrahim (NIS), M. Aksulu (UME), A. Arce Criado (CEM), M. Aşar (UME), F. Assi (METAS), A. Baker (NMIA), P. Balling (CMI), A. Balsamo (INRIM), Y. Bitou (NMIJ/AIST), H. Bosse (PTB), L. Carcedo Cerezo (CEM), V. Coleman (CCL President, CIPM), T. Coveney (NPL), P. Cox (NMIA), M. Motta de Souza (INMETRO), R. Dixson (NIST), B. Eves (NRC), R. Fira (SMU), R. França (INMETRO), S. Gagné (NRC), A. Hirai (NMIJ/AIST), Y. Huang (NIM), F. Hungwe (NMISA), N. Huntemann (PTB), C.-S. Kang (KRISS), N. Kononova (VNIIM), R. Koops (VSL), P. Křen (CMI), O. Kruger (NMISA), A. Küng (METAS), A. Lassila (MIKES), R. Le Targat (LNE-SYRTE), I.D. Leroux (NRC), A. Lewis (NPL), C. Lisdat (PTB), M. Matus (BEV), M.J.T. Milton (BIPM Director), A. Moskalev (VNIIM), J.J. Park (KRISS), M.d.M. Pérez Hernandez (CEM), M. Pisani (INRIM), J.-A. Saldago (LNE), O. Sato (NMIJ/AIST), D. Sawyer (NIST), Y. Shi (NIM), J.R. Stoup (NIST), M.R. Viliesid Alsonso (CENAM), S. Wang (NMC, A*STAR), J. Wu (NIM), D. Xu (NMC, A*STAR), A. Yacoot (NPL), S. Yu (NMC, A*STAR), G. Zechner (BEV), M. Zucco (INRIM).

Official Observers: L. Álvarez (INTI), K.B. Bastida (INTI), J. Buajarern (NIMT), J.D. Campbell (INTI), D. Czulek (GUM), W.-E. Fu (CMS/ITRI), O. Kostrikov (NSC IM), S. Peingbangyang (NIMT), F. Saraiva (IPQ).

Representatives from Member State invited to attend as Observer: M. Al Senaidi (EMI), C. Bore (KEBS), D. Moldybayev (RSE "KazStandard").

Guests: F. AlQahtani (SASO-NMCC), S.EG. Bergstrand (RISE), S. Bize (LNE-SYRTE), B.P. Gandah (NMI-SIRDC), C.W. Tang (SCL), Z. Xue (NIM).

Also present: I. Ahmed (JCRB Executive Secretary), G. Panfilo (Executive Secretary of the CCL, BIPM), S. Maniguet (KCDB Coordinator, BIPM), Frédéric Meynadier (BIPM).

1 WELCOME BY THE DIRECTOR OF THE BIPM

Dr Milton, Director of the BIPM welcomed the participants to the 19th meeting of the CCL and gave a special welcome to the new President of the CCL, Dr Coleman.

2 INTRODUCTION BY THE CCL PRESIDENT

Dr Coleman, President of the CCL, welcomed the participants to the 19th meeting of the CCL and thanked Dr Milton, Director of the BIPM for the introduction. She was pleased that the CCL was meeting face to face again as a community. She asked everyone to introduce themselves.

Dr Coleman gave some housekeeping information.

3 APPOINTMENT OF THE RAPPORTEUR AND APPROVAL OF THE AGENDA

Dr Lewis (NPL) was appointed as Rapporteur after being proposed by Dr Coleman; Dr Coveney was assisting him. Dr Coleman referred to the tabled agenda. The GULFMET report would be taken on day one and, due to a number of CCL decisions which would need be taken; a discussion on decisions will take place ahead of item 13 in the agenda. No other business was tabled. The agenda was approved by the attendees with no further changes or additions.

4 REVIEW OF ACTIONS ARISING FROM THE SEPTEMBER 2021 CCL MEETING

Dr Coleman presented the action list from the previous meeting of the CCL together with the updated status, as reported in the following table.

No	Action	Status
A.1	All presenters to ensure that up to date versions of their presentations or working documents are supplied to Dr Panfilo for inclusion with the meeting documents online.	Completed.
A.2	Dr Lewis to discuss critical and practical aspects of digitalizing the metre realization with the WG-N (through Dr Yacoot), DG11 and CCTF colleagues, and to report to CCL within one year.	Completed.
A.3	Dr Lewis to supply a copy of the working draft of the NPL good practice guide on angle measurement to Dr Prieto.	Completed.
A.4	Dr Castelazo to contact Dr Lewis, Dr Matus, Dr Leroux, Dr Bosse, and Dr Panfilo to form a Task Group to discuss the format of laser frequency data for submission to the CCL-CCTF-WGFS, taking into account the needs of the digitalized SI metre initiative.	Completed.

A.5	Dr Prieto to share the EURAMET guidance information on converting CMCs to quantity equations (specifically the significant digits conversion rules) with Dr Xue.	Completed.
A.6	Dr Yacoot and Dr Lewis to contact the authors of the outstanding articles for the *Metrologia* Focus issue to see how soon they can be submitted, or otherwise take a decision on closing the issue.	Completed.
A.7	WG-S to continue discussions on the periodicity of sWG chair positions, and alignment of periods of office with CCL meetings or otherwise.	Completed.
A.8	Dr Bize to communicate with Dr Dimarcq regarding the recommendation to set up a task group on digital MeP data formats in time and length metrology.	Completed.

The actions were all complete and approved. There were no outstanding actions.

5 REPORTS FROM CIPM AND BIPM

Dr Milton gave the presentation for the BIPM. He said that there are 64 Member States and 36 Associates of the CGPM; the most recent state to join was Costa Rica (in September 2022). UNESCO had designated 20 May "World Metrology Day" as being an official "world day" every year. In 2024, World Metrology Day included 56 individual national posters and 35 additional events. An initiative to encourage wider participation in the work of the BIPM was under way following a resolution of the CGPM in 2022. The BIPM had noted that there were 85 UN Member States which were neither Member States or Associate States of the Metre Convention. A new status of 'Observer' had been proposed. Observers would be able to attend meetings of the CGPM as an Observer and would be able to access specific capacity building activities and information resources. No fee would be required for Observer status. Evidence will need to be submitted by Observer states in order to join, and there would be other requirements including use of the SI and UTC. Observer status will also be available to intergovernmental organizations which perform work related to that of the BIPM.

The year 2025 will be the 150th anniversary of the signing of the Metre Convention and events are being planned – information will be available on the BIPM website. There will be a new book on the history of the BIPM, a new postage stamp will be issued by *La Poste* , and there will be additional talks at events around the world.

October 2024 is the 25th anniversary or the CIPM MRA and November 2024 will be the 25th anniversary of the KCDB; the first set of CMCs in the KCDB were 286 CMCs from length metrology. Dr Milton mentioned several examples of the impact of the CIPM MRA such as specific mentions by the Federal Aviation Administration, ISO/IEC and ILAC.

The CIPM had recently elected three new members, as well as new Presidents of Consultative Committees including Dr Brown as CCU President and Dr Ripper as CCAUV President.

Dr Coleman informed the delegates of news from the recent meetings of the CIPM and BIPM.

At the CIPM meeting in March 2023, Dr Wynand Louw and Dr Takashi Usuda had been returned as CCL President and Secretary, respectively; Dr Jim Olthoff had been returned as Vice President; Dr Philippe Richard was newly elected as Vice President; Dr Victoria Coleman was appointed CCL President (succeeding Ismael Castelazo, retired from CIPM); and Dr J.-T. Janssen was appointed as CCRI President (succeeding Dr Martyn Sene, retired from CIPM). With the passing of Prof. Pavel Neyezhmakov, and the retirement of Dr Yuning Duan and Professor Joachim Ulrich, three new CIPM members were appointed in March 2024: Hans Arne Frøystein (JV, Norway), Dr Jieng Qu (NIM, China), and Prof. Cornelia Denz (PTB, Germany). The updated list of Consultative Committee Presidents and Forum Chairs was shown.

The current CIPM work plan includes: a focus on Governance and Strategy; responding to resolutions of the 27th CGPM and preparing resolutions for the 28th CGPM; redefinition of the second; establishment of (the first) horizontal forums; developing a proposal for universal adherence; and developing the strategy 2030+.

At the 27th CGPM (2022), several Resolutions had been adopted:

- Resolution 1 On the report prepared by the International Committee for Weights and Measures on the "Evolving Needs in Metrology".
- Resolution 2 On the global digital transformation and the International System of Units.
- Resolution 3 On the extension of the range of SI prefixes.
- Resolution 4 On the use and future development of UTC.
- Resolution 5 On the future redefinition of the second.
- Resolution 6 On universal adherence to the Metre Convention.

In addition, there was an election at the CGPM for the CIPM members for the period 2023–2026.

Regarding the horizontal forums, a new Sectorial Task Group on Climate Change and Environment (STG-CENV) was established, which held its first meeting in September 2024 as well as a Forum on Metrology and Digitalization (FORUM-MD), which will hold its 2nd meeting on 17–21 February 2025 (BIPM) - Andrew Lewis is participating in the Forum's WG-CC on behalf of the CCL.

Based on the 'Evolving needs in metrology', there were additional plans for forums in: health and life sciences; food safety – already active WG in CCQM; energy; advanced manufacturing; and 'New' metrology (sensor networks, distributed instrumentation, intrinsic measurement standards, advances in measurement science enabled by the redefinition of the SI and the implications of AI/big data). There had been a BIPM Workshop on Accelerating the adoption of Quantum Technologies through Measurements and Standards, held at the BIPM on 21–22 March 2024.

With regard to the CIPM strategy 2030+, the CIPM is looking to release its next strategy in association with the 150th Anniversary of the Metre Convention. It will be based on the document presented to the 27th CGPM (2022) and will include input from the Young Metrologists 2050+ Vision. Work is being led by Chingis Kuanbayev and Kanyoung Sung (BIPM) with a team of young metrologists from the RMOs. An update to the CCL future strategy is also to be considered/requested.

A search for the next BIPM Director is under way as Dr Milton will retire in 2025. The next meeting of the CIPM (Session III, 113th meeting) will be held on 14-16 October at the BIPM headquarters. There will be a Director's workshop 17–18 October – topics include redefinition of

the second, AI, and Quantum technology. Over the period 20–22 May 2025 the BIPM will hold the 150th Anniversary Celebrations of the signing of the Metre Convention. Dr Coleman ended her presentation by remarking that the 28th meeting of the CGPM would be in 2026.

6 SI DIGITAL FRAMEWORK

a. CCL digitalization work with the BIPM

Dr Lewis showed the work undertaken in collaboration with the BIPM which linked together the *Mise en Pratique* information from the List of Recommended Frequencies, the SI Reference Point, and a download schema in XML for data encapsulation. The NPL had designed an XML schema and worked with the BIPM to use the schema in their Application Programming Interface (API) calls to download formatted metadata regarding metre realization laser operation. The schema was available from a repository (https://doi.org/10.5281/zenodo.6412020) and utilized the Digital-SI schema (https://doi.org/10.5281/zenodo.3826517) developed in the EU-funded *SmartCom* project. A paper has been published (https://doi.org/10.1088/1681-7575/ac7fce) on the work.

Dr Lewis showed the use of the API call to find and download metre realization data for the popular 633 nm (474 THz) iodine stabilized laser, which is used to provide traceability for dimensional metrology. He would be demonstrating a simple graphical user interface for this download at the next FORUM-MD WG-CC meeting and would make the simple Python code available. The system had already been implemented in one of the new iodine stabilized lasers at the NPL. The XML schema repository contains additional example code in Python.

Dr Coveney asked if the approach was restricted to just the iodine lasers within the length community. Dr Lewis said that the schema could be extended to cover the silicon lattice approach and had heard that the Consultative Committee for Thermometry (CCT) was now starting work on a similar approach to high-level metadata traceability for ITS-90.

b. Report on FORUM-MD

Dr Lewis gave a presentation on the first meeting of the CIPM Forum on Metrology and Digitalization (FORUM-MD) which he attended on behalf of the CCL. The Forum had met at the BIPM headquarters on 7–8 March 2024, with delegates from the official Members present, together with Observers from other Member States and from external organizations (CEI, CODATA, IEC, ILAC, IMEKO, ISC, IAO, NCSLI, and OIML). The Forum was established as the result of the decisions CIPM/112-12 and CIPM/112-25. After receiving reports on digitalization from: the Consultative Committees, the Regional Metrology Organizations, liaison organizations, and from the Joint Statement Signature Hub, the Report from the BIPM and its roadmap were shown, including status updates on the digitalization roadmap and the SI Reference Point.

Several break-out sessions followed on: traceability; DCCs and DCRMs; services and applications; interoperability and quality of data; RMOs, capacity building and interaction between CCs and the BIPM; and Future Technologies.

The Forum made three official Decisions.

DECISION FORUM-MD-24-1 – Task Groups, Working Groups

The Forum on Metrology and Digitalization (FORUM-MD) decides to establish the following *ad hoc* Task and Working Groups on:

Harmonizing DCC and DRMC with chair M. Koval (CMI);

FAIR for Metrology with chair R. Hanisch (NIST);

Metrological Semantics with chair R. White (NRC);

Data Quality in Metrology with chair M. Ballico (NMIA);

Secure and trustworthy AI with chair L. Wright (NPL);

Coordination between RMOs with chair N. Zviagin (VNIIM);

Coordination between CCs with members P. Blattner (METAS, chair), the chairs of the WG-DIG/TG-DIG of each Consultative Committee or representative appointed by the Consultative Committee President (including A Lewis for CCL);

SI-digital Framework with chair A. Cypionka (BIPM);

and requests the provisional Chairs to draft Terms of Reference and submit them to the Chair and Executive Secretary of the Forum by end of April 2024.

DECISION FORUM-MD-24-2

The **Forum on Metrology and Digitalization** (FORUM-MD) **decides** to organize workshops on:

- **Metrological Traceability** (organizer F. Härtig (PTB);
- **Complex sensor networks** (organizer S. Cui (NMC, A*STAR);

and **requests** the designated persons to **prepare** a formal proposal and **submit** it to the Chair and Executive Secretary of the Forum.

DECISION FORUM-MD-24-3 – WG Strategy

The **Forum on Metrology and Digitalization** (FORUM-MD) **decides** to establish a Working Group on Strategy (WG-S). The FORUM-MD **approves** the Terms of Reference as tabled [F_MD_24.12.00]. The first meeting of FORUM-MD WG-S will be in May 2024 at a date to be confirmed.

The membership of FORUM-MD WG-CC, in addition to the chair (Dr Peter Blattner, METAS) is: Dr Thomas Bruns (PTB), Dr Ilya Budovsky (NMIA), Dr Romain Coulon (BIPM), Dr Stuart Davidson (NPL), Dr Calos Gonzalez (NIST), Prof. Andrew Lewis (NPL), Dr Thiago Menegotto (INMETRO), Mr Carsten Rieck (RISE), and Dr Patrick Rourke (NRC).

After several meetings, the FORUM-MD WG-CC has now decided on its draft Terms of Reference:

Name: FORUM-MD WG "Coordination between CCs"

Membership: Membership of the WG-CC

- Chair of the TG/WG-D of each CC or representative appointed by the CC President
- Guests can be invited by the chair on a one-off basis.

Chairperson: Chair of the WG-CC (2024-2028): Dr Peter Blattner METAS

- The TG/WG chairperson is appointed by the Chair of the FORUM-MD, with the agreement of the FORUM-MD.
- The chair of WG-CC should rotate among Chair of the TG/WG-D of each CC or representative appointed by the CC President.
- The mandate of the chairperson is 4 years.

Area: The purpose of this group is to exchange information and coordinate activities between the CCs and to provide feedback to the FORUM-MD on opportunities, challenges, requirements, and digital activities from the CCs, for example in respect to digital services of the BIPM.

Activities:

- To define the interactions and responsibilities with respect to other FORUM-MD WG/TGs;
- to collect generic needs from BIPM services to the CCs and vice versa;
- to support the CCs in progressing digital transformation in a harmonized way through sharing information, resources, and best practices amongst the CCs;
- to regularly meet to exchange information on dedicated topics.

Dr Lewis indicated that the WG-CC chair had made available several tools (based on Microsoft Excel) which use the KCDB API calls to obtain specific data from the KCDB into an Excel file. A ZIP file of these tools was uploaded to the CCL meeting documents and may prove to be useful for the CMC FAIR work about to take place.

c. KCDB FAIR

Dr Lewis showed work undertaken by TG-DIG and the BIPM on the next stage of digitalization, related to the KCDB and CMCs. The CCL had made great progress in being the first Consultative Committee to formalize a CMC service category list – the DimVIM, which now has official translations into several languages. The DimVIM informs CMC writers where their CMC fits into the definition framework, so that it can be found together with other CMCs of the same measurand. The results of KCDB searches are easy to read for humans; but at the moment, machines cannot process them because they use terminology, which is undefined and, in some cases, conflicting.

Some service categories have multiple measurands – this is fine provided it is clear what their measurands are and whether or not the measurands are different. What is not clear is whether similarly named measurands in one category are of the same quantity in another category, or even

if measurands in the same category, in different CMCs, are the same quantity. In a single service category, a KCDB search may return three CMCs, one for central length, one for variation in length, and one for thermal expansivity. Do they have compatible and comparable quantities?

Working with the BIPM, a set of 4-letter quantity labels has been defined, which can be used to report almost all the quantities for the length CMCs and the service categories have been allocated the relevant quantities. There are some CMCs, such as for coordinates, where the quantity is not scalar and is not yet captured in quantities. There is a larger issue in that CMC writers have not always followed the suggested text in the DimVIM, resulting in multiple text terms being used for the same measurand. For example, searching for the central length of a gauge block, category 2.2.1, will return CMCs which describe the same measurand in thirteen separate ways. As far as machine readability is concerned, that is not interoperable. Work will be needed to harmonize the text in the CMCs and ensure consistency across the languages.

Dr Eves commented that it would be easier to reduce the large number of descriptions for a single measurand if the KCDB data entry was restricted to a pre-selected list. Dr Lewis agreed that a drop-down list of pre-defined terms would be useful.

Dr Milton said that this work on making the KCDB FAIR was very important and added that the suggestion from Dr Eves could be possible but noted that when the CIPM MRA was initiated 25 years ago there was pressure to keep these fields open; but now it was realized that these fields should be more restricted and standardized - he noted that the CCL had gone further than other Consultative Committees in standardizing these terms.

Dr Balsamo felt that the standardization of terms already existed within the DimVIM, but this standardization required translating into the KCDB.

d. SI Reference point

Dr Lewis handed over to Dr Meynadier. The motivation of the next stage of digitalization is to provide trusted knowledge bases to describe metrological information for machines. This entails the preparation of existing documents for so-called L3+ in which the content of the documents is completely discovered. As the basis for this, there are five pillars: SI units; SI prefixes; defining constants; selected quantities; and decisions concerning the SI. The formal approach to this is to encode data in knowledge graphs. This is all part of the digital framework linking items such as CMCs, NMIs, units, prefixes, *etc*. An example knowledge graph for the unit newton (N) was shown, to show how units can be constructed from expressions based on their unit equation. To link data, such as values in CMCs, to units, requires all the previously stated pillars, plus selection of the correct quantity.

The work heavily relies on contributions from outside the BIPM and feedback on the Digital Framework is requested. The FORUM-MD is gathering feedback and will be steering the development, in coordination with decisions concerning the SI brochure.

Dr Meynadier gave a live demonstration of the Framework and asked for further feedback.

e. PTB work on DCCs

Dr Bosse reported the PTB's work on Digital Calibration Certificates (DCCs). He said that the PTB's work had focused on four measurands, firstly gauge blocks, and then coordinate metrology items such as hole plates, bearing rings and reference spheres. He noted that Shanna Schönhals, who is responsible for delivering this work at the PTB is a member of the FORUM-MD TG-H-DCC/DRMC.

Dr Bosse showed links to various relevant websites with information on the PTB's work in this area as well as expert reports prepared by DKD expert groups. A presentation on the work had been given at the IMEKO World Congress 2024.

A DCC schema definition is being developed at the PTB. Dr Bosse gave several examples of schema encoded data, starting with the data for calibration of a reference sphere. This was followed by data of a diameter calibration certificate where Dr Bosse highlighted a clear mapping from the value on the paper/text certificate and the value encoded in the XML. Further examples were shown for roundness, and parallelism error in ring gauges. For hole plates, there were additional challenges such as uncertainty representation and representation of coordinates.

Further work is planned for DCCs for measurement standards in length metrology; DCCs for coordinate measuring systems; and DCCs as input and output of a D-MT (Virtual CMM). Dr Bosse expected an expert report to be available on this work early in 2025.

Dr Bosse commented that there is pressure from accredited laboratories noting that in Germany there are 60 different companies that are providers of calibration certificates, but only a few of them are requesting DCCs. Dr Coleman asked whether there was an increasing trend of requests for DCCs. Dr Bosse agreed that this was the case.

Mr Sawyer asked what the appropriate mixture of technical staff to data staff was for this work as he had found communication issues could arise in discussions with the technical staff. Dr Bosse responded that it was different depending on the NMI; at the PTB there was a group already working in this area.

7 REPORTS FROM THE WORKING GROUP CHAIRS

a. Report from CCL-WG-MRA

The Chair of the CCL Working Group on the CIPM MRA (WG-MRA) Dr Balsamo presented the report. He reminded the meeting of the WG-MRA terms of reference, structure, and current membership. A number of officers will be leaving their posts over the next three years and a list of positions requiring new candidates was presented.

A summary of the past and future meeting schedule was shown. The next meeting of the WG-MRA will be held alongside the MacroScale conference, which is expected to be hosted in either Turin (Italy) or Buenos Aires (Argentina). Since the previous CCL meeting there have been 57 comparisons active: 24 key comparisons and 33 supplementary comparisons. The status of currently running comparisons was shown.

Dr Balsamo detailed the challenges of linking dimensional key comparisons and detailed some of the work the Task Group on Linking has done to meet these challenges by proposing and using

three linking schemes: numerical linking; visual linking; and distributed linking. A summary of the current linkage status for length comparisons was given.

The WG-MRA maintains a number of guidance documents on behalf of the CCL and the current status of these were shown. New versions of GD-3 (Guide to preparation of Key Comparison Reports in Dimensional Metrology) and its related templates and GD-4 (Key comparison planning) have been issued in 2024 and the new GD-9 document on Voting by correspondence in the CCL and CCL-WGs was issued in 2023. A new version of GD-1 on Running CIPM MRA comparisons in length metrology and monitoring their impact on CMCs is being prepared to include significant changes resulting from new MRA documents issued by the CIPM.

The status of the transition of CMCs to quantity equations was reported. Good progress has been made, with APMP and GULFMET complete. EURAMET is complete with the exception of two institutes who have recently joined from COOMET and are yet to change their CMCs to the new format. The work in SIM and AFRIMETS is ongoing, and no update had been available from the COOMET region.

Dr Balsamo reported on some work being carried out within DG6 on the reinstatement of the K6 comparison topic to support coordinate metrology. The discussion has shown that there is an underlying issue with CMCs in coordinate metrology which has to be resolved before addressing the issues around reinstating K6; more information was given in the DG6 report.

Dr Balsamo mentioned that there were three Recommendations to the CCL from WG-MRA concerning: approval of the updated and new GDs; renovation of officers and moderators; and linking of COOMET.

b. Report from the CCL-WG-N

Dr Yacoot, the Chair of the Working Group on Dimensional Nanometrology (WG-N) gave the presentation. There had been ten meetings of CCL-N to date, with the latest meetings in October 2023 at VTT MIKES (Finland), and October 2024 at the BIPM headquarters. The Terms of Reference of WG-N were shown – they had not been updated since the previous CCL meeting. In terms of comparisons, the WG-N predecessor group DG7 had planned and conducted five comparisons – all were complete except the NANO1 comparison on photomask linewidths, which had entered the planning stage in 2019. Recently the NANO6 comparison on AFM measurements of silicon linewidth had completed the measurement circulation. Some details of the NANO1 comparison were shown including a tentative list of participants and a draft schedule.

A comparison on surface roughness measurements by AFM, registered as EURAMET project number 1239, is at the Draft A reporting stage. There is a tri-lateral pilot study comparison on nanoscale 3D standards involving the PTB, NPL and NMIJ and the status of the comparison was shown – the circulation in under way and the samples are at the NPL.

A EURAMET supplementary comparison (EURAMET.L-S4.1.n01) was underway with the circulated artefact being a 300 mm diameter precision optical flat.

Regarding the secondary realization of the metre, the lattice spacing of silicon had been adopted as a secondary metre realization in the 2019 revision of the SI. Three traceability routes had been identified and associated guidance documents had been prepared along with the *Mise en Pratique*: X-ray interferometry for micro/nano displacement metrology; calibration of lattice-resolving TEM on crystalline silicon nanostructures by reference to the Si lattice parameter; and step height

standards based on the lattice constant. The adoption of a formal secondary realization based on silicon had been one of the biggest recent changes for the CCL since the metre was redefined based on *c* in 1983. Since the original publication of the documents only minor corrections and updating of references had been undertaken in 2022.

There are many standardization activities under way in nanotechnology and Dr Yacoot mentioned that the details are available in the tabled slide pack.

The Consultative Committee for Amount of Substance: Metrology in Chemistry and Biology (CCQM) President has given approval for the CCQM Working Group on Surface Analysis (SAWG) and CCQM Working Group on Inorganic Analysis (CCQM-IAWG) to form a joint Task Group on particle metrology, coordinated by Dr Minelli at the NPL. Input to the Working Group has been requested from the CCL and in particular from WG-N; participation from Jariya Buajarern (NIMT), Victoria Coleman (NMIA), Andrew Yacoot (NPL) was planned.

Dr Yacoot showed information about the 2023 NanoScale conference, which had taken place in Helsinki in October 2023. NanoScale takes place every three years and Dr Yacoot invited people to attend the next NanoScale, which would be hosted by the NPL, Teddington (UK) in October 2026. Information about the location, access and facilities was shown.

c. Report from the CCL-CCTF-WGFS

The CCL Chair of the joint CCL-CCTF Working Group on Frequency Standards (WGFS), Dr Matus, presented the report. He reminded the meeting that this was a joint working group with the CCTF and the presentation would be in two parts.

The Working Group had met earlier in the week and this had been the first face-to-face meeting for some time. The Terms of Reference had not been changed since the previous meeting. The membership of the Working Group was shown: there were ten members plus the co-chairs and the CCL Executive Secretary.

A review of past recommendations to the CCL and CCTF was shown; there had been three recommendations to the 22nd CCTF, one recommendation at the 23rd CCTF and three recommendations were made at the 18th CCL.

Progress on work to adopt the HCN transition frequencies as a recommended standard frequency was reported. These frequencies are already in use in the telecoms industry and have applications in dimensional metrology such as use in frequency scanning interferometry.

Measurements of the frequencies started in 1990 but to date there is only one high precision measurement, so WGFS will wait for additional results before recommending this transition for inclusion in the MeP.

While experimenting with the new API calls for *MeP* data, it had been found that one of the entries in the frequency list is incorrect ($^{13}C_2H_2$). The error is present in the API-accessed data from the database and also in the original PDF file. There was a CCL Decision in 2007 on this topic, but it was never converted to a Recommendation to the CIPM. The original Decision has been reworded as a Recommendation to the CIPM and tabled for this CCL meeting.

Dr Matus showed a graph of data from the running laser comparison under the responsibility of the Working Group, CCL-K11; this is running smoothly and no updates to the guidance

documentation are required. This comparison could be a suitable candidate for experimenting with a digital workflow.

Regarding the work on updating values in the List of recommended Frequencies, the Working Group was considering sources whose output frequency can be linked to a standard from the recommended list, operating under known conditions (no "black boxes"). Candidate data measured independently would help monitor the ongoing validity of the recommended frequencies. However, this data usually cannot be published. Data should be submitted in response to the WGFS' periodic requests for new data to inform updates to the recommended radiations. The next survey will be circulated in December 2024, and CCL members with relevant data are encouraged to contribute to it. (Sensitive client data may be uploaded to the BIPM FTP server instead).

Dr Matus mentioned that there were two recommendations from the WGFS to the CCL on: correcting the entry in the list of standard frequencies for acetylene; and the promotion of the WGFS survey of measurements of wavelengths, including those which cannot be published in a peer reviewed journal.

Dr Matus handed over to Dr Bize for the CCTF part of the report.

Dr Bize gave more details of the recommendations made to CCTF by WGFS since the last CCL meeting. At the 22nd CCTF three recommendations were submitted. These included: an update to the CIPM list of standard frequencies, with 12 values updated including eleven secondary realizations of the second (further information can be found in *Metrologia* **61**, 035005 (2024) https://doi.org/10.1088/1681-7575/ad3afc); the handling of dead time uncertainty and frequency transfer uncertainty by laboratories operating optical frequency standards; and recommendations for operating, comparing and reporting frequency standards to improve TAI and to prepare for a redefinition of the second by optical transitions.

At the 23rd meeting of the CCTF, there was a Recommendation on the redefinition of the second, which included specifications of criteria for readiness, options for consideration, and anticipated timeline. This had led to Draft Resolution E 'On the future redefinition of the second', adopted at the 27th CGPM (2022). Further information could be found in the publication *Metrologia* **61**, 012001 (2024) DOI: 10.1088/1681-7575/ad17d2.

Recent activities included preparation for the next update of the CIPM list to be presented at the 24th CCTF in September 2025 and contribution to the monitoring of the fulfillment level of criteria for the redefinition of the second. Dr Bize showed a graph summarizing the contributions of SRS to the calibration of the TAI scale interval.

Dr Milton added that in 2024 only two optical clocks had been contributing data, those at KRISS and NPL. This was not a good situation for redefinition – the NMI Directors' meeting would be discussing this in the next few weeks.

d. Report from the CCL-WG-S

Dr Coleman reported on recent work in the Working Group on Strategic Planning (WG-S), which had met online in recent years and then in person during the days preceding the CCL meeting. The membership and Terms of Reference were shown; no changes were proposed. There had been a discussion on the CCL strategy document and the structure of the CCL.

It had been noted that there was a lack of meaningful activity within the Discussion Groups in the period between CCL meetings. Therefore, five changes were proposed for the endorsement of the CCL:

1. Noting the overlap with CCL-CCTF-WGFS, DG11 should be closed and the members who are not in WGFS should transfer to WGFS but with the proviso that the membership should not be too large – it is a Working Group and not a Discussion Group.
2. Noting the growing scientific interest in aspects of coordinate metrology, DG6 should transition, over the coming 12 months, to a Working Group on Coordinate Metrology (WG-CM) to enable greater scientific exploration of coordinate metrology.
3. The WG-N chair should become an *ex-officio* member of WG-MRA, as should the chairs of WG-CM and TG-DIG.
4. The CCL should revitalize the remaining discussion groups by including them more in the CIPM MRA processes, technical discussions, and comparison report reviewing; and then review the effectiveness of Discussion Groups at the next CCL plenary.
5. The Terms of Reference of WG-CM, WG-N and WGFS should be updated to include provision of ongoing support for the CCL strategy document.

On the proposal to form WG-CM, a transition will take place over the next 12 months, with DG6 considering the establishment of a new key comparison(s) to support coordinate metrology. Dr Balsamo has agreed to become the chair of the new WG-CM. WG-CM will establish Terms of Reference and will mirror the membership rules of WG-N.

There will be a broad scope update to the CCL Strategy document: to reflect the proposed changes to structure; to accurately reflect the current competence matrix; and to reflect current trends in digitalization (with assistance from TG-DIG).

Dr Coleman used a slide from the WG-MRA report to highlight the pending changes in CCL leadership of the sub-structures. There was an unprecedented change in officers anticipated over the next two to three years due to retirements and other changes, so there will be an open call to the CCL for leadership positions in the CCL following retirement/departure of many Chairs/Moderators before the next CCL plenary in 2027. There will also be a call for interested members to join DGs, WG-CM and TG-DIG.

Dr Balsamo noted that a candidate for the DG3 moderator position had already been identified and asked whether the CCL should formally nominate that candidate now. Dr Coleman said that since there were a number of candidates to be found it made sense to nominate these together. Responding to a question from Dr Zucco, Dr Matus and Dr Coleman confirmed that the discussions within DG11 would continue in WGFS.

Recommendations for the endorsement of CCL

There will be formal Recommendations on: approval to close DG11 and move existing members to the WG-FS (noting the overlap with CCL-CCTF-WG-FS); approval for DG6 to become WG-CM over the next 12 months with Alessandro Balsamo as the interim Chair; and approval for WG-N, WG-CM and TG-DIG Chairs to be *ex-officio* members of WG-MRA. There will be Recommendations on: remaining discussion groups to revitalize themselves over the next three years, with effectiveness reviewed at the next CCL plenary in 2027; DG6 to consider key

comparison(s) to support coordinate metrology; WG-CM to establish Terms of Reference, which include regular input to the CCL strategy document; WG-N and TG-DG update their Terms of Reference to include input to the CCL strategy document; the CCL President to call for nominations for open positions within the CCL and for membership of DGs, WG-CM an TG-DIG; and to update to the CCL strategy document for review within next 12 months.

e. Report from the CCL-TG-DIG

[NOTE: Items 7.e and 7.f were taken earlier in the meeting before item 7.a].

Dr Coleman reported that the last meeting of TG-DIG was in 2021. The Task Group had noted the increase in interest in digitalization activities in NMIs and the need for two-way information exchange between FORUM-MD and Consultative Committees such as the CCL (concerning CMCs, KCDB, comparisons, DCCs *etc*…). Dr Coleman and the Task Group had welcomed the appointment of Dr Lewis as the CCL representative to the FORUM-MD WG-CC, however he is likely to retire within the next few years and the Task Group had suggested that a co-chair, Dr Buajarern from NMIT be appointed as well. The Task Group would need to include the RMO TC-L chairs as well, and may need to co-opt experts as necessary. The Task Group would need to formulate its Terms of Reference as one of its first activities.

f. Outcome of the workshop

Dr Coleman showed the list of topics presented at the previous day's CCL Workshop on Latest Developments in Length Metrology. In addition to the onsite attendees there were around sixty attendees online. She thanked the organizers and presenters from the workshop. In non-CCL years the Working Group meetings were usually associated with technical conferences, however it is perhaps important to consider making time for technical presentations during the CCL plenary week.

8 REPORTS FROM THE DISCUSSION GROUPS

DG1 Gauge blocks

Dr Lewis, the moderator of DG1 gave the report. He presented the membership list, noting members who have left the group and new members who have joined. He listed some discussions which have recently been concluded within the group on: uncertainties for measurands other than central length; the use of accredited laboratories to perform calibrations on equipment measuring auxiliary influence quantities; and the supply of laser tubes for interferometers.

Ongoing topics of discussion included: the use of mechanical measurements with low uncertainties which could be a better fit for industry whilst noting that an update would be needed to ISO 3650 due to the difference in measurands; a discussion on what should be considered as the world best CMC, including what was considered to be the best available artefact (typically a

zero CTE gauge); the terminology used for CMCs to ensure that they would fulfil the requirements of the FAIR initiative; a survey on the amount of time necessary to train new operators; and the gathering of issues for the next update of ISO 3650.

There are a several ongoing comparisons in the K1 topic and a consortium of EURAMET labs have submitted a normative project call, which includes double-ended interferometry. A comprehensive list of publications and journal papers is maintained within DG1.

Dr Lewis noted that some colleagues at other institutes had enquired whether the familiar NPL gauge block interferometer (GBI) that is used by many laboratories world-wide was still available and/or supported. Dr Lewis had confirmed within DG1 that the GBI is still sold and supported by both its commercial manufacturer and the NPL and added that further information can be found at https://hexagon.com/products/product-groups/primary-calibration-equipment.

DG2 Thermal expansion coefficient

Dr Hirai, the moderator of DG2 gave the report. She showed the membership list, highlighting the new members who had joined since the last meeting. There are now 18 members from 15 NMIs. The main topic for discussion has been issues arising from the difference between thermodynamic temperature and ITS-90. The revision to ISO 1 to explicitly refer to ITS-90 has resolved these issues. However, there are discussions ongoing within the CCT regarding changes to ITS-90 and it is important for the CCL to be included in these discussions.

There are currently 13 CMCs in the area of thermal expansion within length, primarily focused on end standards. The last comparison in this area was completed in 2004, so a new comparison is being prepared with PTB acting as the pilot and DG2 members contributing to the development of the technical protocol. Gauge blocks made of low CTE material were considered as artefacts but this has been dropped due to little demand.

Dr Bosse added further information regarding the planned comparison: the planned participants were BEV, NMIJ, NPL, VSL, and PTB. The artefacts will be a 100 mm steel gauge block, 100 mm ceramic gauge block, a 30 mm ceramic gauge block and a 100 mm line scale. Dr Bosse added a request for further participants to send information to him or the PTB pilot, Dr Guido Bartl, by end of October 2024. Dr Wu said that NIM would be interested in participating, which Dr Bosse welcomed.

Dr Coleman asked whether any CCT members were members of DG2. Receiving an answer in the negative she asked whether this could be arranged. Dr Hirai agreed this would be useful and Dr Coleman offered to talk to the CCT president to arrange this.

Dr Balsamo expressed caution regarding the possible change to ITS-90, noting that a significant impact had been seen when ITS-90 was originally adopted. He felt that it was important to ensure that the importance of the temperature range around 20 °C was made clear, since CCT covers a much wider range of temperatures, but this range of around 20 °C was especially of concern to CCL due to ISO 1.

DG3 Angle standards and equipment

Dr Kruger presented the report. He started with a list of the DG members. Not many technical discussions have been undertaken in the period since the last CCL meeting. The main topics of emails have been the organization of the international comparisons for CIPM MRA purposes. DG3 covers sections 3.1 to 3.5 of the DimVIM. There are three comparisons active at the moment: CCL-K3.n01 (polygons); EURAMET.L-K4.2021 (polygon and angle encoder); and AMPM.L-K3.n01 (angle blocks). An analysis of the number of CMCs in the KCDB had been used to determine which artefacts to include in the key comparisons. Recently published or discovered papers included work on encoders and linked to Intercomparisons. There were papers showing recent research from NIST, PTB, INRIM (EURAMET) and the APMP region (KRISS, NMIJ *etc*.). There was research into the use of phase shifting interferometers and high-accuracy encoders driven by, among others, NRC and INRIM.

Dr Eves commented that it was important that the CCL recognizes that the fact that CCL laboratories do not realize the angle units using the definition in the SI brochure; they mainly use circular closure. Dr Balsamo asked whether it was the definition or the *MeP* for the radian which was problematic – Dr Eves responded that it was definition that was the problem as it was not related to the way that CCL members realized the unit of angle.

Dr Bergstrand noted that the 9th edition of the SI Brochure, version 3.01 had been issued recently in which the expression of the radian in table 4 is presented in a new way; section 5.4.7 has been renamed and section 5.4.8 which previously provided the definition of the radian has been removed completely. He suggested that this strengthened the case regarding the CCL not relying on the definition of the radian in the SI Brochure. Dr Balsamo added that through his membership of CCU he was familiar with the discussions, which were complicated because the discussion was extended to other dimensionless units, as well as the issue of the specifics of the radian definition.

Dr Eves asked whether there was consensus within the CCL on the definition of the angle, and if not, this should be established first before progressing the discussion to the CCU. Dr Bergstrand suggested that DG3 was the best forum for the discussion of angular units within the CCL. Dr Coleman agreed this was the best way forward.

DG4 Diameter standards

Dr Viliesid, the moderator of DG4 gave the report. He showed the membership list and noted there had not been much activity since the previous CCL meeting. A pilot study on measurements of a piston cylinder ensemble from a deadweight pressure balance is being prepared by NIST. Interest in participating has been expressed by NMIJ, NPL, CEM, NIST, NRC-CNRC, and CENAM. Possible topics of interest include characterization of piston cylinder ensembles, high accuracy contact and non-contact sphere measurements, and the application of different techniques and using data fusion.

Current comparison activities are the CCL-K4.2015 and EURAMET.L-K4.2015 comparisons. The CCL comparison should reach the Final report stage by end of October 2024.

Dr Kruger asked about the fact that the CCM runs deadweight pressure balance comparisons and whether there was a conflict with the proposal to run the pilot study in length. Dr Viliesid responded that he understood CCM did not include the dimensional aspects of the cylinders in their comparisons and the request for high-accuracy dimensional measurements of the cylinder

came from the pressure community. Both Dr Kruger and Dr Bosse confirmed that dimensional measurements form part of the traceability path for deadweight pressure measurements.

DG5 Step gauges

Dr Coveney, the moderator of DG5 gave the report. He presented the membership list, noting those members who had left the group since the previous CCL meeting. He reminded the meeting that DG5 is an open forum and welcomed the nomination of new members. He showed the group's centralized email address which is managed by the CCL executive secretary. The terms of reference of DG5 were shown.

There have been discussions about the instability of step gauges as artefacts. While this has generally been assumed to be due to damage in transit it was noted that there is no definitive evidence of this, so a proposal was made to use logging devices to monitor shipments for shocks, temperature changes and other environmental effects. To date this proposal has not been taken forward.

Noting DG5's terms of reference a further discussion has been around the lack of a standardized definition of the term 'step gauge', despite the term appearing in several standards and the DimVIM. Consultation was extended to other bodies, including working groups of ISO/TC 213 which confirmed this status. In nanometrology, for example the term 'step gauge' usually refers to a height standard, so is potentially in conflict. The issue has been flagged as a need for future standardization and DG5 will continue to monitor and input to this process. A summary of comparison activities was also presented.

Dr Balsamo added that WG6 of ISO TC213 is well aware of this lack of standardization - work could start already but a leader for this was needed to drive a standard forward. Dr Coleman and Dr Coveney welcomed any volunteers from DG5.

DG6 Coordinate metrology

Dr Balsamo gave the report, starting with a list of members, the collective email address, and the Terms of Reference. The second bullet point of the task on producing a working document on principal uncertainty components was still a challenging topic due to the wide range of techniques in use.

Comparison topic K6 (ball and hole plates) was discontinued by CCL at its 11th meeting in 2003 following a recommendation of the WGDM. The comparison found it was too expensive to purchase, donate and transport artefacts (size and weight); the artefacts were not widely used for CMMs and so the last K6 Key Comparison was APMP-K6 (with measurements between May 2006 and October 2008). A discussion is ongoing whether K6 should be reinstated in its previous or modified form to support CMCs in coordinate metrology. A guidance document CCL-GD-6 (2018) had been prepared on CMCs of category "Standards of 1D point-to-point dimensions". Despite this, there no such CMC registered in the KCDB at the moment.

Recent discussions were around two topics: possible reinstatement of K6 to improve the competence matrix; and use of digital test parts, given their importance in industry. The revision of the Competence Matrix done by WG-S and led by Dr Eves highlighted that the entire coordinate metrology topic is covered by no Key Comparisons. The need for this discussion was recognized

at the last WG-MRA meeting (October 2023) but the discussion within DG6 was initiated only recently in preparation of this year's meeting of the CCL. The moderator had circulated a document within DG6 a few days ago to kick off the discussion and no replies had yet been received. The issue was raised at the recent meeting of WG-MRA and some discussion had followed.

The following are key points of the discussion.

Key Comparisons are in support of CMCs: before deciding any action on KCs we need to be clear on CMCs. CMCs related to coordinate metrology currently listed in the DimVIM are about artefacts (ball bars, …) for which there is no problem, which is similar to all other CMCs, and "CMMs" and "laser trackers" with measurands "error of indicated [size; location; shape]". This is a very poor definition of the measurands: is any size or location or shape covered?

Coordinate Measuring Systems (CMSs) are versatile and reconfigurable but the uncertainty varies enormously for different measurement tasks and must be evaluated case by case. If a CMC is restricted to a specific artefact and measurand, then the CMC is about that artefact rather than the CMS. If it is not restricted, how can one express the uncertainty claim?

Mr Sawyer had raised the topic of digital test parts. Coordinate metrology is likely the most widely used approach to dimensional measurement in industry. Measurements are mostly done for inspecting parts to verify conformance to tolerances specified in drawings and CAD models. Software plays a very important role, often working as a complex black box largely out of the user's control. The interpretation of the drawing is a complex task that requires knowledge and experience; the derivation of the measurand is not supported by official guidance documents. A question arose at the recent WG-MRA meeting asking if this should be addressed because of its importance and impact to industry, even if the CCL is the top level body of length, DG6 was tasked to look into this point.

Dr Balsamo ended the presentation by reminding people of the task of compiling the working document on principal uncertainty components in coordinate metrology. This is a scientifically challenging task which has so far not been addressed.

Mr Sawyer added that he appreciated bringing up his concern – he felt that some of the experts at the CCL are the right audience for working on this topic and he hoped that his request would start discussions at the NMIs on this. Dr Balsamo added his agreement.

DG7 Lines scales

Dr Bosse gave the report. The list of members was shown, noting that some members could no longer be contacted at the email addresses supplied. A summary of comparison activities for the last decade was presented, and planned activities include: comparisons on measurements of line, cross and circular features on 2D optical masks, including x-y-position; and size and roundness of features on transparent substrates, which are required for tests in ISO 10360:7. Further details were shown of the plans for EURAMET.L-K7.n01 which is just getting under way and will cover 31 participants from five RMOs.

Recent discussion topics and activities included:

the Nano1 comparison supporting infrastructure for an improved traceability chain for high precision optical size reference measurements on well-defined structures (for example photomasks) to optical CMMs;

extending analysis of line scale comparisons with respect to condensed measurement results to be used for linking, where possible;

extending the measurement capabilities of high precision line scale comparators, for example the determination of straightness or roundness deviations of features;

calibration of length encoders in addition to classical line scales;

application of interferometers as well as graduated standards for calibration and position feedback purposes in measurement instrumentation as well as manufacturing equipment;

line width and from edge-to-edge distances with line scale calibration - these would be useful for calibration of vision CMMs; and

the potential to use new types of line features for metrology, which are promising to be more robust against contamination and easier to be cleaned and offer good optical contrast.

Dr Coveney commented that the roundness of optical features on photomasks was an important topic as the NPL had been receiving many enquiries and he welcomed information from anyone who can perform such measurements. Dr Bosse replied that one DKD laboratory can do this using stepping around a circular feature using what is effectively a 2D CMM, but it was different to the classical continuous approach for roundness measurement. Dr Balsamo recalled that when ISO WG10 published standards in this area, they recommended NMIs to set up this capability, but it is still an open issue as not many facilities had been established.

DG8 Surface texture

Dr Cox presented the report on behalf of the DG8 Moderator Andrew Baker. The membership list had been revised as several members were no longer active. Potential topics for DG8 discussions included: linking of APMP.L-K8 (2021), EURAMET.L-K8 (2020) and other comparisons; measurement of areal parameters across a range of instruments and associated difficulties in comparisons; simplification of CMC listings which had too many parameters; addition of 3D Areal parameters to KCDB and DimVIM; industry needs, such as NMI level support for additive manufacturing; the impact of stylus tip correction on 2D stylus intercomparison key comparison reference values and outliers; use of crystalline and self-assembled structures as length standards (for example, https://www.ptb.de/emrp/sib61-home.html); application of recent new standards ISO 21920-1, 21920-2 and 21920-3 (2021); having scheduled meetings for DG8 members with approved agenda, perhaps scheduled prior to CCL meetings.

A list of completed comparisons was shown followed by the currently active comparisons which are EURAMET.L-K8.n01 and APMP.L-K8.n01, which were both close to the end of artefact circulation. Four comparisons in areal standards had been completed and a further nine comparison activities are planned. The report concluded with a list of recently published or discovered papers and guides.

DG11 Lasers

Dr Matus gave the report, showing the terms of reference and membership of DG11 and the collective email address. Dr Matus noted that a lot of the items covered in the terms of reference were now undertaken in the DimVIM or WGFS. He noted that there were no discussions during the period since the last comparison and added that the relevant topics overlap considerably with those of CCL-CCTF-WGFS. Historically the issues discussed were around the use of frequency combs and the operation of the CCL-K11 comparison. Both these issues have been resolved in discussions in WGFS. CCL-K11 is the only comparison activity in the area, this an ongoing comparison organized differently to other length comparisons and the organization and history of the comparison was shown. In light of decisions discussed earlier, Dr Matus concluded by noting that this will be the last report from DG11.

9 REPORTS FROM THE KCDB, JCRB AND REGIONAL METROLOGY ORGANIZATIONS

a. JCRB and KCDB

JCRB

The JCRB Executive Secretary, Ibrahim Ahmed, gave the report. At the 48th meeting of the JCRB, held at the BIPM headquarters in September 2024, all RMOs had been represented with delegations (physical and online) and RMO reports to the JCRB including annual QS reports had been discussed. The March and September 2024 KCDB reports had been published online, https://www.bipm.org/en/cipm-mra/kcdb-reports, and the Executive Secretary's report on the system's performance and addressing of the issues arising from the 47th meeting of the JCRB had been discussed. There were additional discussions on progress at the BIPM, the RMO's CIPM MRA activities, the KCDB and its performance, digital transformation of BIPM services, the capacity building programme and a proposal to indicate validity on CMCs after subsequent comparisons.

There were specific actions from the JCRB meeting:

Action JCRB/48-1

> "The JCRB supported the request from EURAMET to provide open-access to information about the confirmation of CMCs including the technical evidence used and the dates of confirmation. The JCRB requested EURAMET to develop a detailed proposal including an outline timetable for implementation for consideration at the 49th JCRB."

Action JCRB/48-2

> "The JCRB Executive Secretary was requested to send a list of comparisons older than 5 years to the CCs and RMOs that are overseeing them. The JCRB requests the CCs and RMOs to review the status of each of their comparisons in this category and to report to the 49th meeting of the JCRB on the cause of the delays and the actions they will take to address the delays."

The JCRB noted two forms developed by the JCRB Executive Secretary. The JCRB requests RMOs: to encourage CMC Writers to make use of the CMC checklist before submitting CMC claims for Intra-Regional review; and to use the revised form for the nomination of Designated

Institutes. The JCRB approved the inclusion of a note at the end of section 5.2 of document CIPM MRA-G-13 addressing the automatic 3-week extension when RMO TC/WG Chairs do not declare interest on the KCDB web platform and/or relinquish their right to review a CMC.

Regarding CMC reviews, JCRB review durations have remained low over the year; 85 days in KCDB 2.0 as compared to 140 days in the old system. More than five metrology areas have Intra-RMO reviews for CMCs of >200 days in the short term. The CCL has the longest, at 522 days. JCRB review durations are impressive; <100 days for all metrology areas. The CCL has 43 in the long term and 53 in the short term. There had been only nine instances of the loss of rights to review CMCs within the length CMC submissions.

A 3-point checklist has been developed on preparation of quality CMCs and guidance on supporting evidence. RMOs were advised to improve on the intra-RMO reviews to resolve most of the issues before submission for JCRB review. Reviewers, Writers, TC Chairs and other stakeholders were regularly reminded of this in Consultative Committee meetings and CBKT technical exchanges.

Since the 47th meeting of the JCRB, 12 CMCs had “slipped” through the JCRB review phase due to various factors.; the CMCs were subsequently reviewed post submission to the KCDB Office. Five length CMCs are on the verge of slipping through by 22 October 2024 if no RMO reviews them.

KCDB

Stéphanie Maniguet presented the current status of the KCDB. The platform is used daily and there are 1 700 individual user accounts. So far, 41 000 users have viewed the website.

In length there are 2 966 CMCs of which 630 CMCs had been published since the last CCL meeting, the majority were the subject of editorial modifications only. There are 76 length key comparisons and 101 supplementary comparisons in the database.

There is a continuous improvement programme for the web platform based on user feedback; this has led to the addition of special user accounts for NMI secretaries, RMO Secretaries, new functionalities to support the review process and the ability to display a KCDB CMC Permanent ID (PID) on the CMC advanced search, which will be released soon.

Regarding the API access to the KCDB, it is now possible to carry out menu-based or keyword-based searches for CMCs on the KCDB using the API. Machine readable CMCs with queries and results in XML or JSON are possible.

Towards digital CMCs and interoperability, work is under validation to update the KCDB API to: include PID for NMI/DI (ROR, Wiki data); include PID for Service Category; and extend search on CMCs with all statuses, namely Archived, Greyed out, Deleted. The idea is that the API will follow the life cycle of a CMC by being able to access obsolete data.

The BIPM is progressing work on a review of the kind of quantities and units used in the CMCs with respect to the defined service category, to extend the list of quantities of the SI Reference Point. The next steps will be for the KCDB Office to look at how to integrate the SI Digital Reference for unit and kind of quantity for CMCs, whilst taking into account the KCDB technical constraints, impact on CMCs and web submission form.

Device Under Test

Mr Ahmed gave a presentation regarding the concern that the uncertainty contribution of the device under test (DUT) in comparisons was not being properly implemented in accordance with the guidance documents. A study has been performed to establish how each Consultative Committee implemented the guidance. In CIPM MRA-G-13 it is recommended to exclude the uncertainty contributions caused by the client's device. Guidance on this matter varies across Consultative Committees, with only the CCM, CCT (for some services) and CCTF having supplementary guidance documents. Others use a variety of strategies and different nomenclature. Out of 26 000 CMCs only 145 mention DUT influence. Examples of CMCs which do include DUT were shown. Several actions have been proposed to move forward on this issue:

- Consultative Committees to adopt a harmonized common term for DUT;
- where necessary, Consultative Committees to develop supplementary guidance material on DUT effect on CMCs;
- Consultative Committee to conduct CBKTs on the developed guides for harmony among their communities; and
- Consultative Committee to deliberate on how to handle service categories with DUTs having different uncertainty contributions.

Dr Eves, noting that length calibrations typically report "on the day" values, asked whether the uncertainty due to the DUT refers to the longer-term stability of the device (between calibrations), or whether it was properties of the artefacts at the time of the test that caused the uncertainty. Mr Ahmed confirmed that it was the properties of the artefacts at the time of the test that was the issue. Dr Eves said that this presents a challenge for length as properties such as gauge material, CTE and quality vary widely but have a large effect on CMCs. Dr Bergstrand echoed this point and commented that the stability of the artefact was what was shown in the Note 5 of CIPM-MRA-G-13, whereas the 'best existing device' may only exist for a short period in time. He was also concerned that including the "on the day" effect of the device under test could be a big problem for length metrology as many CMCs are subject to material-based issues.

Dr Milton acknowledged the difficulty but stated that it must be addressed due to the agreement with ILAC on the consistency of the term 'CMC'. Dr Milton suggested that the guidance allowed each organization to agree on a best existing device to be used, so the CCL could define their own rules in this area.

Dr Eves stated that each RMO has its own view on "best" so there would be difficulty reaching an agreement across the regions. Maybe the CCL would prefer to keep things as they are. Dr Milton suggested that the CCL could potentially develop its own solution but would need to be transparent in what it decides.

Dr Balsamo noted that some uncertainty contributions, such as form errors, are universally bad so can be easily dealt with. However, other terms are not so easy to deal with, such as material, which can depend on circumstance. There is also a risk that with each NMI taking their own decision, CMCs will not be comparable.

Dr Kren added that the specification of what was the best artefact could be based on the relevant ISO standard related to the device being calibrated. Dr Bergstrand added that there was also a question of sending around artefacts of different materials in comparisons, due to the different properties and allowing the participants to demonstrate their best CMC. Dr Balsamo asked what

the term ‘best’ meant in this context. It would be up to the client. Dr Eves responded that there was a danger the NMIs would only circulate zero CTE artefacts and no longer bother to measure temperature,

Dr Yandayan (attending online with Dr Asar) added that in comparisons he had to quote an uncertainty higher than the CMC claim due to the artefact properties. Dr Coveney responded that even if low CTE artefacts were circulated, the order of participation would be important as artefacts are progressively damaged, so some participants may still not be able to demonstrate their CMC claim.

Dr Coleman suggested that this would be best discussed in the WG-MRA. Dr Balsamo agreed noting that sWG-CMC was the ideal body within WG-MRA for this discussion.

b. Regional Metrology Organizations

i. AFRIMETS

The report from AFRIMETS was presented by Dr Gandah, the TC-L vice chair. The last meeting of AFRIMETS TC-L took place in July 2024 with 12 countries represented. Seven length comparisons have been completed since the last CCL meeting, all of which are approved and published in the KCDB and in *Metrologia*. Information on ongoing and planned comparisons, CMCs and international recognition was given. Training activities have been ongoing and some current research projects were shown, including upgrades of the tape calibration systems at TBS and KEBS. A proposal has been submitted for an angle calibration knowledge sharing workshop and the setting up of angle calibration systems. This is awaiting funding approval.

ii. APMP

The report from APMP was presented by Dr Xue. Thirteen comparisons have been run since 2018. Three are newly registered, eight have completed circulation and two are at the draft B report stage. The changes in the numbers of CMCs since the last CCL meeting were shown and the number of CMCs published or claimed in 2024 was also shown. MASM (Mongolia) had submitted their first CMCs to the KCDB in 2024. The number of active CMCs was reduced in 2024 due to a number of CMCs being greyed out. Dr Xue discussed the plan for peer reviews in 2024 with six labs needing peer review, three of them having exceeded the five year limit for peer reviews. Corrective actions have arisen for APMP.L-S5.2.n01 which are under discussion with the labs involved. Some labs have a number of greyed out CMCs which require corrective actions to clear and these were presented.

Pilot studies on rotary encoders and areal surface texture are planned to start over the next year. For the rotary encoders NMIJ, NIM, NIMT, CMS and VMI plan to participate. The participant list for the areal surface texture study is not yet finalized.

Since the previous CCL meeting, workshops have been held on: EDM comparisons, DEC Future Proofing Task Force - practical realization and how to assure measurement traceability of the Metre; optical techniques application in geometric metrology; and dimensional metrology enabling advanced manufacturing.

Dr Xue noted that her term as chair is ending and Dr Shihua Wang of NMC A*STAR (Singapore), has been elected to replace her, starting in 2025. Dr Coleman expressed the thanks of the CCL to Dr Xue for her services as TC-L chair of APMP.

iii. COOMET

The report from COOMET was presented by Dr Andrew Moskalev on behalf of Dr Chekirda. The status of COOMET comparisons were shown, with particular detail given to COOMET.L-S20, which has been running for more than 5 years. There were 13 comparisons ongoing. One of the issues for the region was operation after the withdrawal of Ukraine from the RMO. Technically Moldova is within the COOMET region but there is little contact with them. Comparison proposals developed by COOMET TC 1.5 were shown, which covered angle standards, iodine stabilized He-Ne lasers and measurement of tapes.

Dr Balsamo indicated that the WG-MRA had recommended closer participation between COOMET and the CCL to ensure success of the CIPM MRA. Dr Moskalev thanked Dr Balsamo for the comment and expressed agreement that closer cooperation between COOMET and the CCL and its Working Groups was desired. Dr Balsamo commented on the issue of renumbering of comparisons and Dr Moskalev mentioned that although he was not the TC-L chair, he would pass on the necessary information. Dr Korolev commented that he had reviewed the situation of the participation of the Ukraine laboratories in the COOMET comparisons. Dr Moskalev would update the situation and send the updated list to the secretary.

iv. EURAMET

The report from EURAMET was presented by Dr Bergstrand. He reported that Ukraine and Georgia have joined EURAMET since the previous CCL meeting, Kazakhstan has been granted observer status and NIS and COOMET are no longer observers. Dr Kruger has personal Observer status. Details of activities since the 18th CCL meeting were given, including the annual TC-L meetings (NPL (UK) in 2022, MIKES (Finland) in 2023), the NanoScale 2023 conference and joint research projects in the EMPIR research programme, of which further details were presented. The future calls for the Metrology Partnership programme will be: Health, and Integrated European Metrology in 2025; Fundamental, and Industry in 2026; and Green Deal in 2027. Normative and Research Potential calls are open each year. The annual TC-L meeting would take place at DMDM (Serbia) over 21-23 October 2024. An Advanced Manufacturing Worksop, which will take place during the annual TC-L meeting is open for all to attend online – please contact Dr Bergstrand for information. Dr Bergstrand showed the status of EURAMET running comparisons and provided a breakdown of the distribution of CMCs by DimVIM area (as required in MRA-G-13). There are no spectral lamp CMCs, and no CMCs listed in the hand tools category, although some institutes are delivering services in this area. Details of the European Metrology Networks were provided.

Dr Lassila commented on the low-accuracy CMCs such as hand instruments; in the early years there was an agreement to not include the lower level CMCs, just the higher level ones. He asked if this situation needed revising. Dr Bergstrand responded that the situation may be changing as some customers are requesting CIPM MRA logos on certificates. Dr Matus added that at BEV there were some other instruments in other categories where there were CMCs. Dr Balsamo agreed

that there was no need for laboratories providing higher services to include lower-level services especially as this required further underpinning quality systems work. There was then the question of whether or not the DimVIM categories were still needed. However, a local need may be found to establish such services at NMIs and these should not be rejected – we should simply not encourage the larger NMIs to submit such services. Dr Matus wished to keep the lower-level service categories in the DimVIM because it is used for other purposes outside of the CIPM MRA.

v. GULFMET

The report from GULFMET was presented by Mr AlQahtani. GULFMET has six NMIs and associate members from Bosnia and Herzegovina Egypt, Türkiye, South Korea, and Hong Kong, China.

GULFMET TC meetings are held twice a year. The new term for chairperson and secretary began in 2022. Details of GULFMET comparisons were shown with a new K1 comparison planned soon. No corrective actions have arisen from the two comparisons completed within GULFMET.

The numbers of CMC from GULFMET and statistics on the JCRB review process were shown.

SASO-NMCC had taken part in the ProbeTrace EURAMET EMPIR project as an unfunded partner. A practical session on CMC writing and KCDB use was conducted during the GULFMET 15th TC-L meeting in June 2023. SASO-NMCC hosted a training programme in Dimensional Metrology on 12–14 February 2024.

vi. SIM

The report from SIM was presented by Dr Bastida. She noted that the SIM TC-L chair would transfer to Ian Leroux from the NRC. The current SIM TC-L vice chair is Dr Eves. The list of members and contact persons was shown. Projects on “Improvement and updating of interferometric systems for traceable dimensional nanometrology at SIM”, “Large-scale dimensional metrology” and “Calibration of standard reference material for use in calibrating the magnification or scale of optical microscopy and scanning electron microscopy” have been completed. Three projects under the Digital Transformation programme were coming to a conclusion (gauge calibrations, tomography, nano scale). Details of the 2024 SIM school were given. The current statuses of SIM comparisons, a history of participation in gauge block comparisons and the status of corrective actions from the region were presented: the SIM.L-S2.2.n01 and the SIM.L-S2.2.n02 were running. The situation for gauge block measurement by comparison shows several laboratories participating in the comparison but not yet having CMCs and for those with CMCs, there is a mixture of CMC formats, some not yet converted to quantity equation format.

Dr Coleman thanked Dr Bastida for her long-term service as TC-L chair for the region.

10 REPORTS FROM INTERNATIONAL OBSERVERS AND INTERNATIONAL MEETINGS

a. ISO/TC213

Dr Balsamo gave a presentation, detailing the key personnel and scope of ISO/TC 213, which is responsible for the systems of standards ISO GPS Geometrical Product Specifications. TC/213 is assigned to the UK – the Committee manager is Sarah Kelly (BSI), and Chair is Iain Macleod. Dr Balsamo showed the structure of the committee's sub-groups and working groups; Dr Balsamo is responsible for WG4 on uncertainty of measurement and decision rules. He detailed the link between the ISO GPS and metrology, with ISO GPS providing definitions and standard values, while metrology provides measurement units, traceability, concepts, and experience. In recognition of this a formal liaison agreement exists between CCL and ISO/TC 213. The ISO GPS is currently being reorganized into a hierarchical structure due to its significant growth requiring simplification. A hierarchical structure is being implemented, which is at early stage; documents are categorized as:

Level 0: Outside the ISO GPS (constraints; includes the ISO 1)
Level 1: Foundations (terms, tenets, principles; *e.g.*, ISO 8015, ISO 17450-1 & -2)
Level 2: Fundamentals (*e.g.*, filtering, partitioning, uncertainty)
Level 3: Practical (most of the current ISO GPS matrix)
Level 4: Pedagogical (illustrative)

Dr Balsamo concluded by showing a list of relevant standards published over the last few years.

11 CCL MEMBERSHIP AND MEMBERSHIP OF WORKING GROUPS

Application for observer status

There was an application for observer status from SCL (Hong Kong, China) represented by Dr Tang who made a presentation.

SCL was established in 1984, renamed in 1997 and became part of the Innovation and Technology Commission in 2000. Their functions are:

- establishing and maintaining the reference standards of physical measurement traceable to the International System of Units (SI) for Hong Kong, China;
- ensuring these standards are recognized world-wide;
- providing calibration services to disseminate the values of these standards and proficiency testing services to demonstrate the technical competence of calibration laboratories in Hong Kong, China; and
- disseminating metrological knowledge.

The organization chart of SCL was shown. SCL maintains a primary standard iodine stabilized helium-neon reference laser to realize the metre. Major equipment used in the length lab included: four iodine-stabilized He-Ne lasers; six laser interferometer measuring systems; a line scale measuring system; two gauge block comparators; two Horizontal Length Measuring Machines;

two precision indexing tables; two autocollimators; a roundness measuring machine, a surface measuring machine, a coordinate measuring machine and six step gauges in various sizes, which are used to support the a measurement service providing ISO 10360 CMM verification to external customers.

In 1997 SCL became a full member of APMP. Hong Kong, China, became an Associate of the CGPM in 2000. SCL became an associate of GULFMET in 2014 and observers of CCEM and CCPR in 2016 and an observer of CCT in 2021. SCL is a signatory to the CIPM MRA and has 194 CMCs including 15 in length. They have participated in 13 comparisons, with details of participations since 2014 shown. All comparison results shown were either comparable or pending. The quality system of SCL is accredited to ISO/IEC 17025:2017 and ISO/IEC 17043:2010. Accreditation is currently carried out by HKAS. Calibration services provided by the length lab include: line scales; stage micrometers; gauge blocks; long gauge blocks and length bars; pin and plug gauges; roughness specimens; CMMs (verification in accordance with the ISO 10360 series); extensometer calibrators; laser distance meters; and thermal anemometers.

Publications included a range of scientific papers and conference proceedings.

SCL had organized several seminars and symposia including a metrology symposium, a metrology workshop, and a workshop on calibration of general equipment used in testing.

SCL will be relocating in 2025 towards the north-east in order to benefit from a lower vibration environment – they hoped to then be able to operate a gauge block interferometer and a frequency comb system.

There was an active outreach programme and photos of public visits were shown.

Mr Sawyer asked about the last slide showing a large CMM – Dr Tang clarified that this was an on-site CMM verification at a customer's site.

Membership status: INTI and RISE

There were two applications for Member status, from INTI and RISE.

INTI

Dr Bastida made a presentation on research and development activities in Length Metrology carried out at INTI (Argentina). INTI has four sites around Argentina with length activities split between the sites in Córdoba and Buenos Aires. At the Córdoba site activities include calibrations of: gauge block by mechanical comparison, diameter (spheres, internal and external cylinder), line scales, roundness, angle, and stage micrometers (the latter not yet covered by a CMC). Activities at the Buenos Aires site include calibrations of gauge blocks by interferometry, long gauges blocks by mechanical contact, roughness (greyed out), laser frequency, flatness (no CMC yet), and a frequency comb (no CMC yet).

INTI operates three Caesium clocks to contribute to the national time network, and a physics thesis is in process. The laboratory is developing a metrological IR stabilized laser system. Starting from the pumping of an IR laser, designing the best configuration to link the frequency to an iodine-absorbed frequency in a doubling glass. Another thesis is in progress in this area.

Short gauge block calibration is done using an NPL type gauge block interferometer. As part of the digital transformation of the SIM NMIs, INTI has a project which aims to develop open-source

software to automate data collection, data processing, and uncertainty estimation when measuring gauge blocks using phase-stepping interferometry (PSI). The software will emit measurement results in a digital format more suitable for automatic processing than the current paper calibration certificates. It will be adaptable to a range of experimental setups that are being built or upgraded in the SIM region. This is a joint project with NMIs from Colombia, Mexico, and Canada. The project is delayed in its execution, but INTI has made some progress with the software development alongside the design of the DCC certificate in collaboration with the DCC working group from INTI.

INTI has just completed a project on calibration of standard reference material for use in calibrating the magnification or scale of optical microscopy, scanning electron microscopy and photogrammetry. The instruments most widely used are photogrammetry systems, Optical Microscopes (OM) and Scanning Electron Microscopes (SEM). The purpose of this project has been to develop procedures to calibrate these kinds of standards. It was a joint project with INM from SIM, as well as INMETRO and CENAM.

There are additional projects related to improvement and updating of interferometric systems for traceable dimensional measurements such as cross-validation of flatness measurement systems; instrument verification for large scale dimensional metrology; a study of different optical 3D measuring systems; and high-accuracy measurements of the optical rotation angle.

RISE

Dr Bergstrand gave the presentation. Sweden was one of the original signatures on the Metre Convention and the metrology developments had continued since then including merging of various institutes into SP. In 1975 there was a relocation to Borås. After separation into several laboratories, and transformation into a governmental limited company, it was merged into the RISE structure in 2017. RISE has over 3000 employees, but the Measurement part is relatively untouched by the changes.

The three pillars of RISE include a geometry pillar (large volume metrology services focusing on energy, manufacture and automotive); a length pillar (the main NMI activities); and a research pillar (project-based, working on GNSS, fundamentals).

The length area has five plus one full-time employees. In the KCDB, RISE has 31 comparisons, 37(33) CMCs, individually linked to the service website at RISE (closed loop pending) and more available but not yet included (*e.g.,* DimVIM 6.1.x). They are seeing increasing demand for CIPM MRA logos on certificates.

The geometry area has three (plus one) full time employees. They focus on large volume measurements, with equipment such as a laser tracker, a laser scanner, a total station, a structured light system and a GNSS-RTK. The focus is on solving industry's problems. A particular highlight is performing volumetric calibration of large transfer vessels with volumes in the order of 1×10^4 m^3. The team has a flexible accreditation for measurements up to 200 m × 200 m × 200 m.

The research/project area has seven full time employees. Current focuses include GNSS, AT/ADAS and Fundamental research. There is close cooperation with other departments within RISE, such as Time and Frequency, and also Industry and academia. Individual funding opportunities are available. Two recently completed PhD projects were in surface metrology and a chip-size frequency comb. Ongoing projects include optical clocks, GNSS, and spectrometry.

A number of research papers published in the length field from 2015-2024 were shown.

The applications were discussed whilst the representatives of the applicants were not present.

The Conclusion of the discussions was unanimous support for all three applications.

12 REPORTS FROM INTERNATIONAL OBSERVERS / MEETINGS

IMEKO

Dr Bosse tabled a report on IMEKO 2024 which had taken place from 26–29 August 2024 in Hamburg (Germany). The event included 25 technical committees, over 1 100 participants, 470 talks and 153 posters. Three workshops were held, covering topics of digitalization, quantum metrology and UN-sustainable development goals. Dr Bosse reported the winners of various awards announced at the conference. Seven technical visits took place to scientific and industrial sites in the surrounding region and there was also a visit to PTB.

NanoScale

This item was taken earlier in the agenda under the report from WG-N – of note is that NanoScale 2026 will take place at the NPL, Teddington (UK), in October 2026.

MacroScale

Dr Balsamo noted that the organization of MacroScale is handled by PTB. There are two proposals for hosting the next edition of the conference in 2025, one from Turin (Italy) and one from Buenos Aries (Argentina). Dr Coleman asked when a decision on the host will be made. Dr Bastida and Dr Bosse both indicated that a decision would be made by the middle of November 2024.

European Metrology Network for Advanced Manufacturing

Dr Bosse tabled a report presenting details on the European Metrology Network (EMN) for Advanced Manufacturing. The EMN was formally established in October 2021, formed of 18 NMIs/DIs. It is organized into three sections, Advanced Materials, Smart Manufacturing Systems and Manufactured Components and Products. There are representations from across Europe, including NMIs, DIs, research institutes, companies, universities, agencies, associations, and initiatives. The first draft of the strategic research agenda was published on the EMN website in 2022. There have been several stakeholder engagement events, including meetings and workshops, and liaisons have been formed with a number of organizations. The next AGM of the EMN will be held on 23–24 October 2024, with an open meeting on the first day.

Dr Coleman asked whether observers from other regions were welcome? Dr Bosse said that full membership was only available to EURAMET members but other options such as associated membership were available and that interested parties could contact him.

13 CCL DECISIONS AND RECOMMENDATIONS FROM THE 19TH MEETING

RECOMMENDATION CCL 1 (2024)

On the approval of updated and new guidance documents

The CCL,

recognizing the importance of the CCL Guidance Documents made publicly available through the BIPM website;

and **considering** that comparison planning information needs updating significantly more often than the usual periodicity of CCL meetings;

approves the updated and new guidance documents tabled at the 2024 meeting of the CCL WG-MRA:

- GD-3 v1.7 2024 Guide to preparation of KC Reports in Dimensional Metrology
- GD-3.1 v3 2024 CCL KC – Technical Protocol (template)
- GD-3.2 v2 2024 CCL KC– Report (template)
- GD-3.2b v2 2024 CCL KC– Report (for bilaterals, template)
- GD-3.3 v2 2024 CCL KC– Executive report (template)
- GD-9 v1 2023 Voting by correspondence in the CCL and CCL-WGs

RECOMMENDATION CCL 2 (2024)

On engagement with the COOMET RMO on comparison activities

The CCL,

recognizing the importance of the global reach of the CIPM MRA for ensuring world-wide equivalence in metrology;

and **considering** that there has been a significant period of time since COOMET NMIs and DIs participated in CCL key comparisons or other linked CIPM MRA comparisons;

requests that the COOMET TC-L chair takes action to rectify this situation and ensures that COOMET NMIs and DIs with length CMCs are appropriately linked within the CIPM MRA.

RECOMMENDATION CCL 3 (2024)

On updating the $^{13}C_2H_2$ (n1 + n3) P(16) entry in the list of recommended frequencies

The CCL,

considering that

an inconsistency has been detected in the specified frequency modulation width required to realize the acetylene $^{13}C_2H_2$ (n1 + n3) P(16) stabilized laser frequency standard at 1.54 μm; and

the frequency modulation conditions appropriate for laser stabilization to the b_{10} component of the $^{127}I_2$ R(106) 28-0 transition at 543 nm do not take account of detection techniques different to 3f detection;

decides that

the frequency modulation width relevant to the acetylene $^{13}C_2H_2$ (n1 + n3) P(16) stabilized laser frequency standard at 1.54 μm is changed to:

frequency modulation width, peak-to-peak of 1.5 $\pm$ 0.5 MHz (for 3f detection cases)

and the following sentence is added after the stated 3f frequency modulation width relevant to the $^{127}I_2$ R(106) 28-0 transition at 543 nm:

"Other techniques such as FM or modulation transfer detection can be used to realize the standard, provided the value can be shown to remain within the stated uncertainty";

and **informs** the CIPM of the change.

RECOMMENDATION CCL 4 (2024)

On measurements of transitions and frequency standards relevant for the practical realization of the metre

The CCL,

considering that

recommended values for the frequencies emitted by standardized devices such as stabilized lasers may be affected by changes in materials and manufacturing techniques, and thus should be regularly revalidated; and

the ongoing CCL-K11 comparison is now solely devoted to the support of CMCs, and is no longer designed to gather data suitable for the validation and refinement of the recommended standard frequencies; and

CCL-CCTF-WGFS regularly conducts a survey compiling measurement data relevant to the List of Recommended Values of Standard Frequencies;

requests that

member laboratories should, whenever possible, submit information on measurements of transitions and frequency standards relevant for the practical realization of the metre to the WGFS survey; and

in cases where the measurements are ineligible for inclusion because they will not be published in a peer-reviewed journal, member laboratories contact the CCL Secretary for information on uploading those measurement results to a dedicated private folder that has been created on BIPM servers, so that they can be reviewed and considered by CCL-CCTF WGFS in its ongoing maintenance of the List of Recommended Values of Standard Frequencies.

RECOMMENDATION CCL 5 (2024)

On merging CCL discussion group 11 and CCL-CCTF Joint Working Group on Frequency standards

The CCL,

recognizing that there is significant overlap between the activities of CCL-CCTF-WGFS and CCL-DG11, and that CCL-DG11 has reported no discussions since the last CCL meeting;

and **considering** that membership of a working group must not be too large to function effectively;

nominates members of CCL-DG11 as members of CCL-CCTF-WGFS;

closes CCL-DG11;

instructs CCL-CCTF-WGFS to manage its membership list to ensure functionality as a working group;

and **informs** CCTF of this recommendation.

RECOMMENDATION CCL 6 (2024)

On the formation of a working group on coordinate metrology

The CCL,

recognizing that there is growing scientific interest in aspects of coordinate metrology;

and **considering** that CCL-DG6 has previously been tasked with establishing new key comparisons in support of coordinate metrology and that there is ongoing activity within CCL-DG6;

establishes a Working Group on Coordinate Metrology (CCL-WG-CM); and

approves the appointment of Dr Balsamo as chairperson of CCL-WG-CM; and

instructs

CCL-DG6 to transition activities into CCL-WG-CM over the next 12 months;

CCL-WG-CM to continue the activity on developing key comparison proposals to support coordinate metrology CMCs;

CCL-WG-CM to develop terms of reference, which must include a requirement for regular input to the CCL strategy document, for approval at the next CCL meeting;

and **closes** CCL-DG6, once the transition of activities is complete.

RECOMMENDATION CCL 7 (2024)

On internal coordination between WG-MRA and other Working Groups

The CCL,

recognizing that co-ordination between the working and discussion groups is vital for delivery of the CCL strategy; and

considering that CCL-WG-MRA acts as a forum for such cooperation outside of CCL years;

recommends updating the membership rules of CCL-WG-MRA to include the chairs of CCL-WG-N, of CCL-TG-DIG, and of the newly-formed CCL-WG-CM as *ex officio* members of CCL-WG-MRA.

RECOMMENDATION CCL 8 (2024)

On interactions between CCL Working Groups on Strategic planning activities

The CCL,

recognizing that the CCL strategy document requires updating from time to time and that such an update is currently required; and

considering that the input of CCL Working Groups to the strategy document is of particular importance, and that the current terms of reference of some Working Groups do not cover this activity;

requests CCL-WG-N and CCL-TG-DG to update their Terms of Reference to include regular input to the CCL strategy document.

RECOMMENDATION CCL 9 (2024)

On revitalizing the CCL Discussion Groups

The CCL,

recognizing that:

the CCL Discussion Groups provide a useful forum in which experts in particular fields can collaborate on topics of mutual interest; and

as open forums, the CCL Discussion Groups can reach a wider range of interested parties than the necessarily smaller CCL Working Groups;

and **considering** that reports of activities coming from the Discussion Groups have shown that recent activity in these groups is lower than expected;

encourages all CCL Discussion Groups to revitalize discussions in their area, with particular reference to actions arising from the CCL and CCL Working Group meetings in 2024; and

will **review** the effectiveness of Discussion Group activities at the next CCL Plenary in 2027.

RECOMMENDATION CCL 10 (2024)

On succession planning for CCL working group officers and discussion group membership

The CCL,

recognizing that

a large number of officers from several working and discussion groups will leave their posts over the next three years;

and that membership of some discussion groups is low;

and **considering that**

succession planning and role handovers are vital for smooth transitions;

wider participation and engagement in the discussion groups is beneficial; and

some roles will require a new office holder to be in post before the next CCL Plenary meeting;

calls for

nominations for posts expected to become vacant over the next three years; and

nominations for experts to join discussion groups (with particular encouragement to institutes with no current representation);

and **establishes** a recommendation for handover procedures for the smooth transition of roles.

RECOMMENDATION CCL 11 (2024)

On updating the structure and role of CCL-TG-DIG

The CCL,

recognizing the increased interest in digitalization activities in NMIs;

and **considering** that that there is 2-way information exchange between FORUM-MD and CCL and that Dr Lewis is the CCL representative to the FORUM-MD WG-CC;

updates the membership of CCL TG-DIG to include the RMO TC-L chairs;

approves the appointment of Dr Lewis as the chair of CCL TG-DIG and Dr Buajarern as co-chair;

calls for interested parties wishing to become members of CCL TG-DIG to contact the CCL executive secretary; and

instructs the CCL TG-DIG to prepare Terms of Reference for approval at the next CCL.

14 RECOMMENDATIONS TO THE INTERNATIONAL COMMITTEE FOR WEIGHTS AND MEASURES (CIPM)

Dr Coleman asked Dr Lewis to show a draft recommendation that had been discussed in the meeting. The draft text was shown, discussed and agreed.

RECOMMENDATION CCL 1 (2024)
On new applications for Member and Observer status at the CCL

The Consultative Committee for Length (CCL),

considering that

an application for Observer status at the CCL has been received from SCL (Hong Kong, China);

an application for Membership of CCL has been received from INTI (Argentina); and

an application for Membership of CCL has been received from RISE (Sweden);

and **noting** that all members of CCL unanimously approved these applications when presented at the 2024 CCL plenary meeting;

recommends that

SCL be made an Observer at the CCL;

INTI be made a Member of the CCL; and

RISE be made a Member of the CCL.

15 ANY OTHER BUSINESS

Metrologia – Revitalizing ties with the CCL

Dr Bergstrand showed a presentation on the journal *Metrologia*, of which he is the editor. The history of the journal, which is owned by the BIPM, was shown. It is the leading international journal in pure and applied metrology. It has an editorial board of NMI experts. From 2024 it has been published in electronic format only and it is published by the Institute of Physics (IOP), as is the similar *Journal Measurement Science and Technology* with which *Metrologia* cooperates. A discussion of the difference in scope between the two journals was shown. Dr Bergstrand encouraged all members to consider publishing their work in *Metrologia* noting the journals ambition to publish the world's leading metrological research. He recommended publishing open access to increase impact, noting that all ten of the current most read papers were open access. All authors should have a registered ORCID ID since this helps SI digitalization and is becoming mandatory. He also noted that Focus issues, such as the Focus issue on length, were useful, provided sufficient high-quality papers were available in a reasonable time frame.

Dr Bergstrand showed the Editorial board membership and noted that since the retirement of Dr Rudolph Thalmann there has been no length specialist on this board, and while Dr Bergstrand endeavours to represent the length community it would be beneficial to have another expert join the editorial board.

Dr Coleman asked whether members interested in joining the editorial board should contact Dr Bergstrand? He agreed that this should be the course of action.

Comment on membership changes

Dr Coleman said that the CCL membership would look very different when it next met with several longstanding members retiring or leaving before the next plenary meeting. She asked the CCL to thank all members who would be leaving, noting the significant contributions members have made over many years. The meeting gave a round of applause, for those members who would be leaving over the next three years.

16 DATE OF NEXT MEETING

Dr Coleman expected that the next time the CCL would meet will be in 2027, at the BIPM headquarters, probably in the third quarter. The exact date would be confirmed in due course. Working groups will likely meet in 2025, associated with the Macroscale conference.

17 CLOSING THE MEETING

Dr Coleman thanked everyone for their participation.

The CCL President closed the meeting at 12:45.

Appendix L 1.

Working documents submitted to the CCL at its 19th meeting

Open working documents of the CCL can be obtained from the BIPM website (after logging in): https://www.bipm.org/en/committees/cc/ccl/

Documents

CCL-24-03	Agenda for 19th CCL meeting
CCL-24-04	Actions from the 2021 CCL meeting
CCL-25-05	Reports from CIPM and BIPM
CCL-24-06	Report on the SI Digital Framework
CCL-24-06.01	Report on CCL digitalization work with the BIPM
CCL-24-06.02	Report on FORUM-MD
CCL-24-06.03	KCDB FAIR
CCL-24-06.04	SI Reference Point
CCL-24-06.05	Development of Digital Calibration Certificates for dimensional metrology at PTB
CCL-24-07.01	Report from WG-MRA
CCL-24-07.02	Report from WG-N
CCL-24-07.03	Report from CCL-CCTF-WGFS
CCL-24-07.04	Report from WG-S
CCL-24-07.05	Report from TG-DIG
CCL-24-07.06	CCL 2024 Workshop outcome
CCL-24-8.1	Report from DG1
CCL-24-8.2	Report from DG2
CCL-24-8.3	Report from DG3
CCL-24-8.4	Report from DG4
CCL-24-8.5	Report from DG5
CCL-24-8.6	Report from DG6
CCL-24-8.7	Report from DG7
CCL-24-8.8	Report from DG8
CCL-24-8.11	Report from DG11
CCL-24-9.01	Report from JCRB and KCDB
CCL-24-9.01.03	Report on DUT
CCL-24-9.2.1	Report from TC-L AFRIMETS
CCL-24-9.2.2	Report from TC-L APMP
CCL-24-9.2.3	Report from TC-L COOMET
CCL-24-9.2.4	Report from TC-L EURAMET
CCL-24-9.2.5	Report from TC-L GULFMET
CCL-24-9.2.6	Report from TC-L SIM
CCL-24-10.1	Report from Liaison of CCL to ISO-TC213
CCL-24-11	CCL and WG membership
CCL-24-11.01	INTI report and request for membership
CCL-24-11.02	RISE report and request for membership
CCL-24-11.03	SCL report and request for observer status
CCL-24-12	Reports from international observers/meetings
CCL-24-12.01	IMEKO
CCL-24-12.03	MacroScale

CCL-24-12.04	EMN Advanced Manufacturing
CCL-24-13	Recommendations to the CIPM
CCL-24-14	Metrologia

Appendix L 2.
List of actions resulting from the CCL 19th meeting

This is a list of the actions decided upon during the 19th meeting of the CCL.

No	Action	Status
A.1	All presenters to ensure that up to date versions of their presentations or working documents are supplied to Dr Panfilo for inclusion with the meeting documents online.	
A.2	All to consider nominations for upcoming officer and moderator positions in Working groups and Discussion groups, in particular the role of chair sWG-CMC.	
A.3	Dr Coleman to contact the president of CCT to discuss adding a liaison member to CCL-DG2	
A.4	CCL-DG3 to discuss and prepare a consensus position on plane angles.	
A.5	sWG-CMC to discuss the issue of the on-the-day uncertainty of the Device Under Test (DUT) being included in CMC claims and propose a harmonized approach for recommendation to CCL on how length CMCs should take this into account.	
A.6	WG-MRA, and particularly sWG-CMC to consider the issue of NMIs submitting CMCs for low level services such as hand instruments and using MRA logos for these services.	