Bureau International des Poids et Mesures

Forum on Metrology and Digitalization (FORUM-MD)

Report of the 1st meeting
(7-8 March 2024)
to the International Committee for Weights and Measures

Comité international des poids et mesures

LIST OF MEMBERS OF THE
FORUM ON METROLOGY AND DIGITALIZATION
as of 7 March 2024

Chair

J. Ullrich.

Vice-Chair

G. Macdonald, National Research Council of Canada [NRC], Ottawa, CIPM member.

Members

Centro Nacional de Metrología [CENAM], Querétaro.
Federal Office of Metrology [METAS], Bern-Wabern.
Instituto Nacional de Tecnología Industrial [INTI], Buenos Aires.
Measurement Standards Laboratory of New Zealand [MSL], Lower Hutt
National Institute of Metrology [NIM], Beijing.
National Institute of Standards and Technology [NIST], Gaithersburg.
National Measurement Institute, Australia [NMIA], Lindfield.
National Physical Laboratory [NPL], Teddington.
National Research Council of Canada [NRC], Ottawa.
Physikalisch-Technische Bundesanstalt [PTB], Braunschweig.
Russian Scientific Research Institute for Metrological Service, Rosstandart [VNIIMS], Moscow
The Director of the International Bureau of Weights and Measures [BIPM], Sèvres.

Observers

Central Office of Measures [GUM], Warsaw.
Centro Español de Metrología [CEM], Madrid.
CSIR National Physical Laboratory of India [NPLI], New Delhi.
Czech Metrology Institute [CMI], Brno.
D.I. Mendeleyev Institute for Metrology, Rosstandart [VNIIM], St Petersburg.
Instituto Nacional de Metrología de Colombia [INM Colombia], Bogotá.
Instituto Nacional de Metrologia, Qualidade e Tecnologia [INMETRO], Rio de Janeiro.
Korea Research Institute of Standards and Science [KRISS], Daejeon.
Laboratoire National de Métrologie et d'Essais [LNE], Paris.
National Institute of Metrology (Thailand) [NIMT], Pathumthani.
National Institute of Standards [NIS], Giza.
National Metrology Centre, Agency for Science, Technology and Research [NMC, A*STAR], Singapore.

National Metrology Institute of Japan, AIST [NMIJ/AIST], Tsukuba.

RISE Research Institutes of Sweden AB [RISE], Borås.

Saudi Standards, Metrology and Quality Organization/National Measurement and Calibration Center [SASO-NMCC], Riyadh.

VSL Dutch Metrology Institute [VSL], Delft.

Liaisons

Commission internationale de l'éclairage [CIE].

Committee on Data for Science and Technology [CODATA Task Group on Fundamental Constants].

International Electrotechnical Commission [IEC].

International Laboratory Accreditation Cooperation [ILAC].

International Measurement Confederation [IMEKO].

International Science Council [ISC].

International Organization for Standardization [ISO].

National Conference of Standards Laboratories International [NCSLI].

International Organization of Legal Metrology [OIML].

1 OPENING OF THE MEETING

The Forum on Metrology and Digitalization (FORUM-MD) held its first meeting at the International Bureau of Weights and Measures headquarters (BIPM), at Sèvres, and on-line, on Thursday 7 and Friday 8 March 2024.

The following attended:

Members: M. Ballico (NMIA), P. Blattner (METAS/CIE/CCPR/CCU), H. Brown (NIST), S. Chalmers (NPL), A. Charbonneau (NRC), O. De Feo (METAS), C. Denz (PTB), J.A. Fedchak (NIST), C. Galván-Hernandez (CENAM), A.A. García González (CENAM), B. Hall (MSL/NCSLI), F. Härtig (PTB), J.-L. Hippolyte (NPL), D. Hutzschenreuter (PTB), A. Kroshkin (VNIIMS), A.Y. Kuzin (VNIIMS), Z. Liu (NIM), Z. Liu (NIM), A. López-Celis (CENAM), G. Macdonald (FORUM-MD Vice-ChairNRC/CIPM), M.J.T. Milton (BIPM Director), A. Pankov (VNIIMS), A. Paul (NMIA), G. Stevenson (NMIA), K. Thomson (NRC), J. Ullrich (FORUM-MD Chair), R. White (NRC), L. Wright (NPL), X. Xiong (NIM).

Observers: R. Abdellatif (NIS), V.G. Achanta (NPLI/CIPM), K.G. Alghizzi (SASO, NMCC), R. Alyousefi (SASO, NMCC), A. Arce Criado (CEM), S.E.G. Bergstrand (RISE), S. Bin Qoud (SASO-NMCC), J. Buajarern (NIMT), R. Caballero Santos (CEM), N. Chanthawong (NIMT), W.-H. Cho (KRISS), S. Cui (NMC, A*STAR), E. Emardson (RISE), R.M. Gómez Rodríguez (INM Colombia), P. Guha (NPLI), K. Hosaka (NMIJ/AIST), A. Hussein (NIS), B. Koleva (BIM), M. Koval (CMI), J. Lefebvre (LNE-LNHB), M. Nawotka (GUM), Y. Nouel (LNE), S. Plumeri (LNE), L.L. Rivera Roa (INM Colombia), L.F. Rust (INMETRO), A. Sharma (NPLI), K. Shirono (NMIJ/AIST), M. Smid (CMI), F. van Booma - de Smit (VSL), R. Souza (INMETRO), K. Sung (KRISS), N. Taketoshi (NMIJ/AIST), M. Van Dijk (VSL), S. Yu (NMC, A*STAR), N. Zviagin (VNIIM).

Liaisons: I. Dunmill (OIML), S. Eichstädt (OIML), H. Gasca-Aragon (IMEKO), R. Gerasymchuk (ISO), J. Harben (NCSLI), S. Hodson (CODATA/ISC), M. Kuster (NCSLI), T. Menegotto (CIE), A. Reissert (IMEKO), K. Rodier (ISO), Z. Zelenka (IMEKO).

CIPM members: V. Coleman (NMIA), N. Dimarcq (CNRS, Univ. Côte d'Azur, Obs. Côte d'Azur), H. Laiz (INTI).

Representatives of Consultative Committees: T. Bruns (CCAUV), I. Budovsky (CCEM), R. Coulon (CCRI), S. Davidson (CCM), C. Gonzalez (CCQM), A. Lewis (CCL), C. Rieck (CCTF), P. Rourke (CCT).

Guests: J.G. Bartholomew (EMI), S. Chalk (UNF), R. Hanisch (NIST), P. Jivan (NMISA).

Also present: A. Cypionka (BIPM), F. Meynadier (BIPM), G. Panfilo (BIPM), P. Tavella (BIPM), S. J. Chalk (IUPAC).

J. Ullrich, Chair of the FORUM-MD, welcomed the participants to the 1st meeting of the Forum and thanked M. Milton, Director of the BIPM, and G. Panfilo who was the Secretary for the Forum and who gave some housekeeping information. J. Ullrich then moved to accept the tabled agenda [**F_MD_24_01**] which included a large number of reports in the initial session, followed by breakout sessions. The agenda was approved. A. Lewis (NPL) was appointed as Rapporteur after being proposed by J. Ullrich.

2 NEWS FROM THE CIPM AND THE BIPM

The CIPM President was unable to join the Forum so J. Ullrich would make this report later. M. Milton added his welcome. He mentioned that the CIPM had decided, so far, to apply formal rules to this Forum (similar to those of the Consultative Committees) but this may be reviewed later.

3 FORUM CHAIR'S REPORT

J. Ullrich gave the presentation of the Forum Chair [**F_MD_24_03.01**]. The presentation covered seven main topics.

1. Introduction

The Forum had been established by the CIPM to address the digital challenge: he gave a possible view of the future and foresaw that the regulatory aspects would naturally have a need for metrology.

2. Facing the digital challenge

J. Ullrich showed the Grand Vision for digitalization and highlighted progress through various milestones in facing up to the digital challenge: establishment of the CIPM Task Group and the Expert Group in 2019; formulating the Grand Vision; the International Workshop on the Digital SI Framework (785 participants, 33 talks); development of the SI Digital Framework; drafting and signing of the *Joint Statement of intent* (ISO, CIPM, ISC, CODATA, CIE, IEC, ILAC, IMEKO, OIML, NCSLi); all of which resulted in Resolution 2 of the 27th meeting of the CGPM ('…welcomes the recent efforts to articulate guiding principles for a digital transformation in metrology, welcomes the establishment of a flexible and inclusive governance structure supporting the development and implementation of that transformation'). J. Ullrich concluded that a large amount had been achieved by the Task Group and Expert Group and he thanked them for their work (the groups had achieved their goals and were closed).

3. The Forum on Metrology and Digitalization

J. Ullrich reminded the Forum that its existence was due to decisions by the CIPM:

Decision CIPM/112-12 – The CIPM approved the establishment of a forum on metrology in the digital world and noted the draft mission and structure proposed by the CIPM Task Group.

Decision CIPM/112-25 – The CIPM adopted 'Forum on Metrology and Digitalization' as the name for the horizontal forum on digitalization. It adopted the mission and structure of the forum, and approved the BIPM Headquarters' updated workplan on digitalization for 2023 and 2024.

4. Mission and Structure of the Forum

J. Ullrich reminded the meeting of the mission of this FORUM [**F_MD_24_03.03**] highlighting (shown in bold) certain aspects:

1. **To advise the CIPM** on the SI Digital Framework and the wider implications of the global digital transformation for metrology and for the international Quality Infrastructure including:

- the adoption of the FAIR principles (Findable, Accessible, Interoperable, and Reusable) for digital metrological data and metadata, ensuring that other communities recognize the critical importance of metrological traceability for measurement data, the latter being an established requisite for building trust,
- providing metrological input/thinking to increase confidence in areas impacted by the digital revolution including, but not limited to, examples such as:
    - systems metrology
    - trusted AI
    - the reproducibility of research results,
- the creation of the authoritative digital reference for core SI information,
- the digital transformation of services and products offered by the BIPM,
- the implications of digital transformation on the operation of the CIPM MRA including, but not limited to:
    - implementing the SI Digital Framework
    - digital calibration certificates
    - data integrity and authenticity (for example, digital signatures) of data for metrology and metrological services
    - relevant services and infrastructure in digital metrology.

2. **To harmonize internal processes** related to digitalization between NMIs, CCs, RMOs, and the BIPM headquarters.

3. **To act as a forum to exchange** information and to create synergies and opportunities for collaboration in this field, including, but not limited to, liaison with International QI Organizations, relevant International Organizations, international science organizations, relevant industry associations, and further relevant stakeholders in digitalization.

J. Ullrich was appointed to chair the first meeting and G. Macdonald was appointed as the vice-chair.

In terms of the membership of the Forum, the relevant membership terms are defined in CIPM-D-01 (as previously mentioned by M. Milton) thus we have: as Members, the Chair (who must be a CIPM Member), a Vice-chair (also a CIPM Member), one representative of any NMIs with up to two digitalization experts, additional CIPM members; as an *ex officio* member the Director of the BIPM Headquarters; as Observers, representatives of NMIs; and as Guests, digitalization representatives of the CCs, and of the RMOs; liaisons: organizations including the Joint Signatories and other organizations.

The CIPM had asked to update the membership rules for horizontal organizations to be more inclusive and so this was planned. The Forum structure contains:

- Chair
- Vice-chair
- Executive secretary from the BIPM Headquarters - G. Panfilo
- Strategy group (for steering): chairpersons, executive secretary, working group chairs, director of BIPM Headquarters
- Task Groups with individual Terms of Reference (for example, WG on metadata formats, on harmonizing work between CCs, *etc*.) (Task Groups had been chosen over Working Groups as their membership rules are more flexible).

5. The Joint Statement Signatory Round Table

J. Ullrich reminded the participants of the *Joint Statement of Intent* [**F_MD_24_03.04**], which sets out the reasons for undertaking a digital transformation and states that '*the undersigned undertake to support in a way appropriate to each organization the development, implementation, and promotion of the SI Digital Framework as part of a wider digital transformation of the international scientific and quality infrastructure'*.

There had been a proposal to establish a 'JSI signatory roundtable' to serve as a platform for discussion between the signatories and this had been welcomed by the CIPM (CIPM/112-40) and had led to the Workshop 'Towards Digital Quality Infrastructure' which had taken place at the BIPM Headquarters on 5–6 March 2024 immediately preceding the Forum.

6. The SI Reference Point: an Anchor of Trust

The SI Reference Point (SIRP) will be the authoritative digital Reference Point for the SI. It forms an essential part of the Grand Vision, the SI Digital Framework, Resolution 2 of the 27th CGPM (2022) and the Joint Statement. The SIRP will underpin the SI in the digital world to keep metrology data interoperable and make them machine-actionable (level 5, ISO/IEC). J. Miles (BIPM) had been working on the transition from the SI Brochure as a human readable PDF into machine readable data that is 'FAIR'.

The three basic pillars of the framework are already available online:

www.si-digital-framework.org/SI

www.si-digital-framework.org/constant

www.si-digital-framework.org/quantity

7. What is next?

J. Ullrich gave an outline of the plan for the remainder of the Forum and highlighted the four break-out sessions planned for the afternoon.

4 REPORTS FROM THE CONSULTATIVE COMMITTEES ON DIGITALIZATION ACTIVITIES

J. Ullrich invited the representatives from the CIPM Consultative Committees to give their reports on digitalization activities.

Consultative Committee for Time and Frequency (CCTF)

Mr Rieck presented the report from the CCTF [**F_MD_24.04.09**]. The continuous Key Comparison CCTF-K001.UTC computes Coordinated Universal Time (UTC) from ~ 420 atomic clocks kept in 87 laboratories world-wide and requires efficient machine-readable generation of data on a daily basis. Automation takes place both on the data source (NMI) side and the data sink (BIPM) side. The comparison uses standardized/agreed data formats: RINEX, CGGTTS, ITU-R TF.1153-4, IGS formats, RTCM, 3GPP, and outputs *Circular T*, with weights and rates. The lower level IP protocol transportation of data and results relies on FTP, HTTP, HTTPS, and SMTP. Many of the digitalization activities in the CCTF focus on time and frequency distribution such as Network Time NTP, IEEE-1588, high accuracy profiles, digital transformation of services, the use of digital infrastructure for dissemination. Time transfer over fibre is part of the digital framework and certified time using digital protocols is offered as a service.

Ongoing work focuses on: Application Programming Interface (API) access for UTC products and access to the CCL CCTF database of Recommended values of standard frequencies for realization of the metre and the second; modernization of Continuous UTC to keep it relevant and avoiding the leap second discontinuities, allowing a continuous time scale for the international synchronization of interconnected networks; SI Reference Point – work to engage the CCTF to develop time and frequency related metrological logic together with a project to link current API output to the SI Reference Point.

Future work will concern authenticity and security; chain of trust in (time) metrology, trustworthiness of data sources; securing access of communication channels; stimulating development of real-time TF comparison links; establishment of open methods and services; implementation of FAIR principles; provision of calibration data, CMCs, test vectors and algorithms.

S. Chalk asked whether the all the data was transferred in JSON or other formats? F. Meynadier responded that many of the formats are older than JSON but there are thoughts on how to improve this.

Consultative Committee for Photometry and Radiometry (CCPR)

P. Blattner presented the report from CCPR [**F_MD_24_04.07**]. The CCPR deals with measurands with high dimensionality often containing large data sets with correlations. Many different quantities are listed in the Key Comparison Database (KCDB) including many with dimension zero (for example, counts). Stakeholders are already carrying out digitalization tasks, and machine learning and artificial intelligence are already in use. The CCPR WG SP TG 15 had been studying the Impact of Digitalization on Matters Related to the CCPR by collecting information on activities at NMIs and clustering and prioritizing possible joint activities. At the highest priority level is support for the BIPM/CIPM, such as agreeing on 4-letter identifiers for KCDB quantities and harmonization of entries in the KCDB through work in CCPR-WG-CMC. Another high-priority item is looking at data formats: what are the needs from the stakeholders; how to bring the 'digital SI' to the many well-established file formats (for example, BIM, EO, sensXML, EULUMDAT); identifying gaps; and collaboration with CIE. Next in priority order is dealing with the problems associated with communication of correlations to the end user where it may be necessary to include covariance matrices (possibly up to 100 dimensions). The dimensionality issue could extend as far as data sets with over 1 million dimensions where it may be necessary to provide the full measurement model including the sensitivities of the input parameters. A final

example issue is how to proceed with digitalization of the 1924 CIE standardization of the human eye.

B. Hall asked about the correlations and the comparisons – how do the comparisons handle the correlations. P. Blattner added that the dimensionality of the comparisons was much lower. N. Zviagin asked about how AI is being used? P. Blattner responded that image processing tools now use AI and these can also be used for lighting analysis and control and require photometry information as inputs.

Consultative Committee for Units (CCU)

P. Blattner gave the report [**F_MD_24.04.01a**]. After reminding the participants of the Terms of Reference of the CCU he showed some activities of direct interest to the Forum. The CCU is responsible for the preparation of successive editions of the SI Brochure, including the 'Concise Summary of the SI'. The CCU has taken steps to support the progress of digitalization in metrology, in particular by providing definitions of core metrological terms, which are adequate for increasing levels of machine readability and interpretability. These are a set of terms defined in the VIM that are used in CGPM Resolutions, authoritative documentation globally and in national legislations. Examples include 'unit', 'quantity' and 'quantity value'. The CCU has created a Task Group of the CCU TG on Core Metrological Terms (WG-CMT); the CCU-WG-CMT has concluded that it is desirable to develop an axiomatic system for Core Metrology Terms (CMTs) which the TG thought would be useful to help to make the VIM (*etc*.) as unambiguous as possible, to 'sharpen' the definitions and become independent of the spoken language. The intention was to create a high-precision language that could, in addition, provide high-quality validated training material for AI and machine learning. The model focuses on logical relations between terms and no longer on what terms 'are'. The TG thought that this approach could be taken up subsequently by other vocabularies (ISO 80000-x, IEC 60050-x…). A layer scheme for machine actionable CMTs was shown. The definition of relations between terms is a work in progress.

P. Blattner foresaw further activities of the CCU WG: WG-CMT to become TG-CMT to allow expanded membership from outside the direct metrology community, and to use a similar approach on a wider number of CMTs; submission of a Proposed Research Topic (PRT) in the framework of the Call 2024 for Metrology Support for Digital Transformation of the European Partnership for Metrology (EPM); offering support to Milton for the 'digitalization' of the SI-Brochure. In addition the CCU and the CCQM jointly organized, in 2023, a workshop on 'Metrology of quantities which can be counted' leading to some proposed amendments to the SI Brochure.

R. White mentioned that the VIM lays out the formal system for us and asked if there are plans to extend the VIM using UML frameworks? P. Blattner agreed that this was a good proposal but cautioned that the critical part was how to go from the language to the mathematical approach. Miltonlton added that the challenge for NMIs was probably not strongly linked to the ISO approach – VIM3 had followed the ISO rules and this had caused most of the ensuing issues for the NMIs.

Consultative Committee for Thermometry (CCT)

P. Rourke presented the report [**F_MD_24.04.03**]. The digitalization activities of the CCT are concentrated within the CCT Task Group on Digitalization (CCT-TG-Dig, www.bipm.org/en/committees/cc/cct/wg/cct-tg-dig), which has 13 members. This Task Group

was created at the last CCT meeting (2022) and has been operating under its initial Terms of Reference which are: to identify information that should be machine readable in the documents related to the MeP-K, such as the ITS-90 text, Guide, appendices, *etc*; and to recommend an indexing and archiving approach for the documents. The Tasks of the CCT- TG-Dig are to: identify the relevant documents and advise BIPM staff on which documents need to be machine readable; identify equations, tables, *etc*. in the documents that are commonly implemented in software applications; recommend an indexing and archiving approach to make both current and former versions of the documents more findable, by internal and external search functions; and test beta versions of relevant documents and functions established by BIPM staff.

So far, ten key CCT documents related to the *Mise en Pratique* for the definition of the kelvin (MeP-K) have been reviewed and data extracted; these include the defining texts of the ITS-90 and PLTS-2000 temperature scales. A BIPM programmer has begun converting the extracted data into machine-accessible APIs to be hosted on the BIPM web server. The MeP-K itself has been restructured for improved machine (and human) readability, and its references have been updated. Core scientific content remains the same as in the present (2019) version. The restructured MeP-K will be presented to the CCT. A comprehensive indexing and archiving approach for CCT documents has been agreed within CCT-TG-Dig and will be recommended for adoption by the CCT at its plenary meeting, in May 2024. Consultations have been undertaken with BIPM staff on digital SI work. These have included disambiguation of temperature quantities to support KCDB digitalization upgrades, and discussions regarding Digital Object Identifiers (DOIs). BIPMBIPM expects to issue DOIs for CCT documents in 2024.

As the majority of the initial tasks of CCT-TG-Dig are nearly delivered, updated terms of reference will be proposed to the 2024 CCT meeting. How best can the global thermometry community be supported and what is the role of CCT in the digitalization ecosystem? Moreover, how soon will stakeholders be ready for given aspects of digitalization? P. Rourke welcomed any suggestions.

R. Hanisch asked how the mathematics was being encoded. P. Rourke responded that this was being handled by the BIPM and it was based on the SI Reference Point work.

Consultative Committee for Amount of Substance: Metrology in Chemistry and Biology (CCQM)

C. Gonzalez presented the report from the CCQM [**F_MD_24.04.05a**]. He outlined the benefits to using data digitalization to transform measurement services data to enable machine interaction with data sources: easier establishment of metrological traceability for customers; FAIR Data; public data becomes easier to use and search; easier conversion of data and units to formats needed by customers; easier for customers to access and ensure they are using current data; eliminates transcription errors; faster production of measurement services; reduces manual labour to create a certificate; easier and more secure delivery of certificates and reports to customers. Potential barriers could include: breaking barriers across disciplines; different WGs, different approaches; adopting data management standards; how to apply FAIR principles; what would identifiers look like; handling metadata; links to CMCs; coping with new technology; data sharing: ‘It is my data’; conveying the benefits; development and maintenance costs; workload; and metrics of success.

As a response to the challenges, the CCQM had decided to organize an online workshop on ‘Digital and FAIR Chemical and Biological Reference Data and Certificates: Challenges and Opportunities’, which will take place on 9–12 September 2024 [**F_MD_24.04.05**]. Thematic sessions will be held on: challenges with unique interoperable identifiers in the chem/bio area; digitalization of Certified Reference Material (CRM) certificates; best practice in developing

databases for chem/bio data that meet FAIR principles. A list of invited panellists was shown which included representatives from IUPAC, NPL, ISO/TC 215, BIPM, USP, IFCC, Leibniz Information Centre for Science and Technology, NIST, MERCK, NIM, NRC, LGC, Fujifilm-Wako, BAM, NIH, NLM, NCBI, NOAA, VSL, the Beilstein-Institut, and KIT.

D. Hutzschenreuter asked about CRMs and what kinds of data are included. Essentially this includes all the measurands provided to the stakeholders.

Consultative Committee for Mass and Related Quantities (CCM)

S. Davidson presented the report from CCM [**F_MD_24.04.08**]. There were several digital application areas across the CCM working groups. In *Gravimetry* there is internet integration of gravity observation sites and real-time cross validation (digital twin approach). In *Fluid Flow* – there is a wide range of characterization parameter and individual customer requirements. In *Mass* they are initiating a digital calibration certificate (DCC) interoperability project for (simple) mass certificates between ten NMIs and are using digital twins for realization experiments, with machine learning to investigate equivalence issues and define the kilogram. In *Force, torque, pressure (flow)* they facilitate monitoring of long-term performance of transducers over multiple calibrations together with easier mapping of decremental/incremental loading/hysteresis with respective interpolation equations; this enables digital traceability through a fully digital workflow from NMIs to accredited laboratories and further to industrial end users. There is also integration of data from sensor networks using machine learning to model processes.

The virtual pilot study of DCCs in the mass area involves comparisons between ten NMIs on calibrated mass values (PTB, NPL, MSL, UME, NMIJ, KRISS, NIM, INRIM, NRC, CENAM); the topic was chosen as being a ‘simple’ comparison of a single measurand with uncertainty. The first automated calculation of outputs from input DCCs is running and a paper will be presented at the IMEKO World Congress 2024. After the pilot study is completed, there will be an extension to areas involving more ‘complex’ certificates (force, pressure), digital Key comparison linking with Digital-SI, and interaction with the KCDB to update/validate CMCs leading to a machine actionable comparison infrastructure.

A Potential Research Topic had been submitted to the European Partnership on Metrology call entitled ‘An Interoperable Quality Infrastructure for Automated Interlaboratory Comparison’. The aims of the project would be to analyse requirements for implementing human-centric metrological expert software (MES) tools; to evaluate the best approaches to an interoperability framework for data, services and tools in a digital QI; to implement and verify MES tools in a testbed for interlaboratory comparison. The project partners would come from NMIs, standards and accreditation bodies, manufacturers and end users. Anticipated issues and discussion topics included integration with published standards (ISO, ASTM *etc*.) at a technical (CC) level, Digital-SI inclusion of fixed conversion factors (for example, lbf to N) or elsewhere, and does the use of DCCs for Certified Reference Materials raise any additional issues?

Consultative Committee for Ionizing Radiation (CCRI)

R. Coulon presented the report from the CCRI [**F_MD_24_04.06**]. Responding to the resolution of the CIPM on digital transformation, the CCRI Digital Transformation Task Group (DT-TG) had been created in March 2023 with two aims: to advise the CCRI on the SI Digital Framework; and to act as a forum to exchange information both inside the CCRI and outside including with the Forum. Several liaisons had been established so far (ICRU, DDEP, IAEA, CCRI(I-III), FORUM-MD). Several events had taken place: a kick-off meeting with introduction to the SI Digital Framework; an introduction to machine-readable key comparison data; a discussion of the

CCL-CCTF API Web Service; a workshop on running an interlaboratory comparison looking at automation of data analysis and reporting via the combined use of a MySQL dBase, Python; and a BIPM Webinar on 'Digital References for Metrology - data from CCRI(II) key comparisons: radionuclides' – this was now available on the BIPM YouTube channel.

The Task Group had identified aspects of digital transformation for IR metrology, including a list of the advantages and disadvantages of automation through digitalization. The Task Group had also examined reference data (and semantics) for use in IR metrology. Work was ongoing into investigation of the use of machine-readable formats for key comparison data with the idea being to link to the prototype of the SI reference point, use a digital representation of measurement, and link to KCDB Service category PIDs.

Consultative Committee for Length (CCL)

A. Lewis presented the report from the CCL [**F_MD_24.04.04**]. Much of the work had been performed jointly with CCTF and BIPM as mentioned earlier by C. Rieck. Starting with the inspiration for digitalization of the SI metre at the highest level, it was clear that in addition to the entry for the metre in the SI Reference Point, there would be a need for digital access to data in the *Mise en Pratique* for the definition of the metre, which contains much data and critical requirements. With the BIPM working on the SI Reference Point, the CCL joined with the CCTF to propose that the *Mise en Pratique* data in the list of recommended frequencies was converted into a database, with API access. Work between the NPL and BIPM defined an XML schema for data transfer (reusing elements of the Digital-SI XML exchange format). The API access was made live on 19 June 2023 and on 27 June 2023 a 'digital-ready' NPL reference laser used the API to access the relevant *Mise en Pratique* data and stored the returned values in its operating software. Recent work had begun looking into the CMCs in the length area and had revealed several issues such as: using up to 13 terms (in English alone) for the same measurand; CMCs which cover several deliberately different measurands, often with different units and dimensions; and CMCs for which there are multiple terms in different units but relating to the same feature – clearly there is much work remaining to make these interoperable.

Consultative Committee for Acoustics, Ultrasound and Vibration (CCAUV)

T. Bruns had tabled a written report [**F_MD_24.04.02**] but it was not presented.

Consultative Committee for Electricity and Magnetism (CCEM)

There was no report from the CCEM.

5 REPORTS FROM THE REGIONAL METROLOGY ORGANIZATIONS ON DIGITALIZATION ACTIVITIES

Asia Pacific Metrology Programme (APMP)

B. Hall presented the report from APMP [**F_MD_24.05.02**]. He highlighted that APMP includes laboratories from several developing economies which have specific needs. The APMP focus group on Digital Transformation in Metrology (DXFG) was established in November 2021 and now has 47 members from 19 countries; it has liaisons with three RMOs (EURAMET,

GULFMET, COOMET) as well as with NCSLI-MII and OIML-DTG (the list of liaison officers was shown). The DXFG had monthly sharing and information dissemination meetings throughout 2023, with 22 presentations of which eight were from outside APMP. The DXFG has Special Interest groups on: generic aspects of DCCs; automation; and DCC interoperability. DXFG members had attended several external events in 2023 (PTB-DCC3, OIML-TC6 webinar, AMCTM 2023, URSI GASS session, IC3K conference, and PTB-DCC4). The DXFG has organized workshops associated with the APMP General Assembly meetings: 2022 APMP-DXFG Webinar (https://apmp-dxfg.org/dxfg-eoy-webinar-2022.html); 2023 APMP-DXFG workshop for TC Chairs (https://apmp-dxfg.org/dxfg-tc-chairs-workshop-2023.html). Two workshops were organized and hosted by NIMT: 2022 Metrology for Digital Transformation (1-day online) on 'DCC—Applications and future developments'; and 2023 Digital transformation in metrology workshop (3-day in-person) on 'DCC for developer and its implementation in NQI'.

Intra-Africa Metrology System (AFRIMETS)

P. Jivan presented the report from AFRIMETS [**F_MD_24.05.01**]. The current status in the region is that digitalization and digital transformation are in the exploratory phase looking at the transition into business strategy, the technical need from industry, and the need for DCCs. A few laboratories have automated processes; however they are not fully automated from start to end and many labs are still focused on building infrastructure, capabilities and resources. There are several challenges such as priority and resource allocation - many laboratories are still in a developmental phase in their CMS and measurement capabilities; the human and financial resource pool is small and the priority on digital transformation is fairly low. Lack of knowledge on digital transformation means that the true meaning and future benefits of digital transformation are not understood by many. There has been no technical committee set up yet to discuss Intra-Africa digitalization efforts and any existing efforts are few and far between and generally are discovered when attending external meetings or conferences. Discussions are however under way on the need to establish a technical committee for the region on digitalization together with ideas on holding workshops to promote the benefits.

Euro-Asian Cooperation of National Metrological Institutions (COOMET)

The report from COOMET was presented by A. Pankov [**F_MD_24.05.03**]. A Concept document (Theme 825/RU-a/21) on Digital Transformation in COOMET has been developed with contents of: general provisions; principles of digital transformation; goals and objectives of digital transformation; digital transformation tools; stages of realization of digital transformation; creating conditions for digital transformation; and coordination of the implementation of digital transformation. Requirements had been identified for: digital document repositories; digital directories (codifiers, rubrics, *etc*.); a digital reference book of parameters of different groups of measuring instruments; DCCs; type descriptions for measuring instruments and digital certificates for CRMs; information and communication infrastructure between member countries; and a COOMET digital platform.

A. Pankov showed a 12-point roadmap starting in August 2023 and ending in December 2026. The stages within the roadmap and their states of completion are:

1 Development of the Terms of Reference for the creation of a unified information resource COOMET (completed).

2 Requirements for information and communication infrastructure to ensure information security of COOMET digital platform (completed). The document has eleven overall

requirements discussed: information protection, structural functions, security event registration, integrity assurance, user credentials and access management, operating modes, reliability, safety, patent purity, standardization and unification, and operation.

3 Discussion of the list and description of digital objects of COOMET member countries, recommended for inclusion in the unified COOMET information resource (completed).

4 Structure and requirements for digital descriptions of cards of groups of measuring instruments in COOMET member countries.

5 Structure and requirements for the digital classifier of measuring instruments in COOMET member countries.

6 Development of COOMET recommendation 'Structure and requirements for repositories of digital documents in COOMET member countries' (80 % ready). Currently, version 3.2.1 of the scheme includes 49 complex data types and ten simple data types (an example was shown in more detail). The recommended language is Russian and a set of structural elements had been defined.

7 Development of COOMET recommendation 'Structure and requirements for Digital Calibration Certificates for measuring Instruments used in COOMET member countries' (40 % completed). Two recommendations so far concern general requirements – characteristics of any data warehouse; and special requirements – specific for digital documents. Examples of identified requirements included: security and access control, scalability, performance, version control, search indexing, backup and restoring, full-text search on digital documents (DD), availability of visualization module, availability of the DD generator module, data export in machine-readable format, in addition to the presence of a permanent link to the DD+ generation of QR code, an API for reading repository data, presence of a validator of DD, signature verification functions if available, and availability of a unique identifier of the DD.

8 Development and launching of the unified COOMET information resource.

9 Structure and requirements for digital certificates for CRMs in COOMET member countries.

10 Structure and requirements for digital certificates and type descriptions of measuring instruments in COOMET member countries.

11 Structure and requirements for digital certificates of verification of measuring instruments in COOMET member countries.

12 Development of data exchange mechanisms between COOMET information resource and information resources of the participating countries.

European Association of National Metrology Institutes (EURAMET)

The EURAMET report was presented by L. Wright [**F_MD_24.05.04**]. Work within EURAMET on digitalization is undertaken in the Interdisciplinary Metrology Technical Committee (TC-IM) Working group on Metrology for Digital transformation (TC-IM WG M4D). Four implementation strands were being followed: EURAMET TC-IM for coordination with WG 'Metrology for digital transformation' (M4D) as a think tank'; dedicated projects in TC-IM for specific implementations and tasks under the coordination of WG M4D; EURAMET Technical Committees for field-specific expertise and developments; and EURAMET European Metrology Networks for topics driven by a clearly identified and coherent stakeholder community. L. Wright highlighted a particular link with the MATHMET network, which had made major contributions including

issuing guidance on software quality. The tasks and aims of TC-IM WG M4D are: to monitor relevant topics, analyse their relevance to EURAMET, and connect the individual developments; to enable and encourage synergies by improving communication and collaboration; to develop guidelines and strategic roadmaps; to identify suitable resources for EURAMET; to maintain an open exchange of ideas, suggestions and questions, and bring together expertise and activities; and to foster the uptake of individual developments by EURAMET members, EMNs and research projects. TC-IM WG M4D has 21 members from 12 NMIs and is running three projects (currently unfunded).

Project TC-IM 1448 is on *Development of digital calibration certificates*. It brings together DCC experts from EURAMET members with the general aim of harmonization of DCC to support uptake by calibration labs and customers. A small initiative 'DCC2GO' supported smaller and emerging EURAMET members in getting started with DCC. The project has close collaboration with the EURAMET secondee 'DCC Ambassador' to support Technical Committees.

Project TC-IM 1449 concerns *Research data management in European metrology*. It is designed to provide support for metrologists on research data management, especially European Metrology Partnership project leaders. It offers: templates for proposals and data management plans; a platform for automated data management plan generation; metadata for data publication and quantitative information; training and guidance documents; sample Research Data Management policy for European NMIs. Guidance is freely available from the project website (https://www.metrology-rdm.eu/home).

Project TC-IM 1551 is on *Challenges and opportunities in sensor network metrology*. It brings together experts across multiple application areas and links work being done in various European Metrology Partnerships projects, identifying challenges to feed into a roadmap.

Within EURAMET the Digital Transformation programme covers: generation, processing and storage of digital metrology data; sensor networks and internet of things; robustness and quality of Artificial Intelligence/Machine Learning; reference data requirements for validation; automated data quality assessment. A key aspect is the route to impact and end user engagement.

Two projects were started in 2023 (from the previous Digital call), one on virtual metrology, one on fundamentals of sensor network metrology. There is a new call running in 2024 and the initial proposal stage has just closed.

B. Hall asked about the requirement to follow the data management rules to be allowed to participate in the EU funded projects – he asked if this was filtered down to individual internal quality systems of the NMIs? L. Wright responded that her usual response is that in order 'to be kind to your future self' you need to setup and use appropriate data management systems.

Gulf Association for Metrology (GULFMET)

The GULFMET report was presented by J.G. Bartholomew [**F_MD_24.05.05**]. The GULFMET Digital Transformation Working Group was formed after its meeting in November 2021. Members of the WG are the laboratories of: United Arab Emirates, Oman, Bahrain, Kuwait, Saudi Arabia, Egypt, Hong Kong, and Republic of Korea. However, only the members from Saudi Arabia and the United Arab Emirates are currently active in Digital Transformation. The WG is tasked with: providing a central contact point for Digital Transformation in Metrology within GULFMET; supporting Technical Committees with information about Digital Transformation; supporting Technical Committees with information on CIPM and other RMO activities; and transferring digitalization knowledge between GULFMET members. To achieve these aims, the WG will: invite international experts to speak on digital transformation; provide a forum for discussion of

Digital Transformation between GULFMET members; propose joint projects on Digital Transformation and training activities to the General Assembly.

Two projects have been proposed: the first is on automation of the reading of handheld meters; the second project is to provide more information on digital transformation, such as: industry needs survey, DCC requirements, IT Requirements, a DCC Pilot, roadmaps for DCC implementation, investigation of AI applications in Metrology, a digital transformation session for the General Assembly, and an educational campaign for industry. Training proposals include monitoring and storing of data, automation of laboratory activities, broadening GULFMET members' knowledge, the format and generation of DCCs (a sort of DCC 'summer school').

However, J.G. Bartholomew cautioned that the Working Group is finding it hard to decide on the balance of work between the Technical Committees and the Working Group, and to identify the work the RMO should do collectively rather than the NMIs individually.

Inter-American Metrology System (SIM)

H. Gasca-Aragon presented the situation on digitalization in the SIM region [**F_MD_24.05.06**]. The SIM Metrology Working Group MWG14 – Metrology for Digital Transformation was established in 2021 (https://www.cenam.mx/m4dt-sim). Continuous activities included: informing members about the activities of the MWG14; an open call to collaborate; networking with other organizations (NMIs, RMOs, industry). Future activities of the Working Group will include: informing members about the activities of the CIPM Forum; contributing to a harmonized digital format of metrological data; identifying joint developments within the MWGs; developing digital platforms for metrological digital services; learning and sharing experiences in the field of machine learning; and outreach accredited laboratories and industry allies to support digital transformation. MWG14 has six sub-committees on: laboratory automation/digitalization (led by INACAL); cloud technologies (led by INMETRO); Digital Calibration Certificates development (led by CENAM); outreach industry and accredited laboratories (all); pilot projects Incubator (led by CENAM); and digitalization for reference materials (led by NIST). So far there had been 14 M4DT day awareness events; three M4DT Annual Conferences; development of measurement devices with digital capabilities; and sharing of experiences and networking with other RMOs.

J. Ullrich thanked all the RMO presenters and commented that many activities were already under way and hoped that all the RMOs could profit from each other's work.

6 REPORTS FROM LIAISON ORGANIZATIONS ON DIGITALIZATION ACTIVITIES

International Organization for Standardization (ISO)

R. Gerasymchuk gave the presentation and started by commenting that a small team is working on the SMART platform (www.smart-demo.iso.org). A short online demonstration was given. A dashboard shows the user the standards with which they are actively engaged. Looking at one specific standard, various fragments of the document are selectable using a menu. Additional information can be selected for linking. An extraction tool allows selection of fragments of existing documents for direct use or exporting. The self-assessment tool allows the user to review

their progress against the provisions of a selected standard. ISO was looking forward to collaborating with other stakeholders.

K. Rodier added further demonstration on a pilot regarding digitalization of terminology data. Various surveys of needs and future requirement had shown that terminologies were isolated and fragmented without interconnections to show use and reuse of terminology. This was a consequence of working using paper-based approaches. There is a need for a clear framework for terminology that reduced the level of over-definition and re-definition. Formal recommendations on using terminology would need to be issued to committee chairs.

J. Ullrich asked about the work with VIM WG2; would this be interconnected with the terminology work at ISO? K. Rodier commented that there was a clear need to work with Milton and other organizations working on terminology. J. Ullrich suggested collaborating with the team working on axiomatic terminology. M. Milton agreed and asked if BIPM and Forum members would get open access to the SMART platform? R. Gerasymchuk responded that this would happen in due time. M. Milton asked R. Gerasymchuk and K. Rodier to supply their relevant slides for the meeting information pack and R. Gerasymchuk responded that they would duly be in touch with the Executive Secretary.

International Organization of Legal Metrology (OIML)

S. Eichstädt of the **OIML** Digitalization Task Group (DTG) gave the presentation from the OIML [**F_MD_24_06.05**]. S. Eichstädt introduced the work and mission of OIML before describing the founding of the OIML DTG in May 2022. The DTG has 32 members from 19 different countries and two organizations in liaison. S. Eichstädt (Germany) is the Chairperson and Y. Ping (China) is the Deputy Chairperson. There is a sub-committee 'Smart Standards', with Convener K. Delak (USA). A recent OIML Seminar on 'The future of the OIML in the digital era' had resulted in a resolution which had approved the work plan of the DTG. A written report can be downloaded here: https://58ciml.oiml.org/ciml.html and an article on the Seminar outcomes is published in the OIML Bulletin dated January 2024 and can be accessed online at https://www.oiml.org/en/publications/bulletin/pdf/oiml_bulletin_jan_2024.pdf. Key findings from the seminar were that benefits and opportunities of digitalization included cost reduction and increased effectiveness, access and insights into information and data, new services and processes in legal metrology; there were expectations towards the OIML including training, guidance and exchange in legal metrology, harmonization and evolution of OIML technical work, and provision of OIML digital tools; and with regards to connection with regional and national initiatives, there would be knowledge sharing across regions, strengthening of partnerships and establishment of new ones, and making use of digital technologies.

The OIML DTG roadmap has elements on: establishing a training and education programme, including eLearning material, training activities and workshops; developing publication and communication material for different groups of stakeholders, including decision and policy makers; fostering the development of machine-readable information in legal metrology, including OIML-CS, smart standards, and digital test reports/certificates; and developing digital tools and platforms for digitalization in legal metrology, including a certificate database, digital OIML-CS, and verification services.

International Commission on Illumination (CIE)

T. Menegotto presented the report on digitalization from the International Commission on Illumination (CIE) [**F_MD_24.06.03**]. The CIE has 36 National Committees, Associate

Committees and 17 associate members. P. Blattner is the chair of the Task Group on Digital products, which has 15 members. The TG Terms of Reference are to draft CIE policies and procedures addressing digital products, covering toolboxes, data tables, databases, data-formats, 'Apps', and 'machine-readable standards'. In September 2023 a range of CIE datasets had been made available online (https://cie.co.at/news/cie-datasets-available-online). Several CIE Technical Reports and International Standards now include tables of data, provided by the CIE together with associated metadata based on the Datacite 4.4 schema. An example of a data element was shown, which included checksums created using the md5 hashing algorithm, allowing the user to check the validity of the data. Planned future work of the TG includes reference data for validating software (new TC); defining new data formats (for example, BRDF, luminaires, spectral data with correlation); transforming the e-ILV into a FAIR vocabulary and linking to the 'digital SI'; and transition to machine-readable documents.

Committee on Data of the International Science Council (CODATA)

S. Hodson gave the presentation [missing]. CODATA's vision and strategy were shown. The membership includes national data committees, scientific academies, scientific unions and other organizations. CODATA works with many partners including GO FAIR, RDA, WDS and BIPM. CODATA has four priority work areas: making data work; improving data policies; advancing data science; and enhancing data skills. Within the topic of Making Data work, the flagship initiative is that of WorldFAIR+ for which the main product will be the cross-domain interoperability framework (CDIF). Within the work of the topic Advancing the Science of Data and Data Stewardship, the flagship activities: include Data Science Journal, SciDatCon, international Data Week, Task groups on Fundamental Constants (TGFC) and Digital Representation of Units of Measure (DRUM).

The current membership of DRUM was shown (14 persons). Over the 2021–2023 period highlights included: several conferences and data summits: a *Nature Comments* paper ('Unclear units stymie science,' *Nature* **605** 222-224 (2022)) https://doi.org/10.1038/d41586-022-01233-w. Additionally there were now several web-based resources such as: Fundamental Constants web service: https://tinyurl.com/2p9h6nky; UMIS (Units of Measurement Interoperability Service): https://umis.stuchalk.domains.unf.edu/; and the units representation systems inventory https://tinyurl.com/3s9brkwn/.

DRUM's planned future activities are to: act on the Task Group reviewer's comments; increase diversity of the Task Group; GitHub repository containing an online version of the units inventory and resources for various disciplines on unit representation options; software tools and APIs for creating FAIR units, quantities, and fundamental constants; 'State of the Unit Representation' paper that includes a guide to good practices for unit representations; advise IUPAC on units representation for the Green Book (Quantities, Units, and Symbols in Physical Chemistry) and Gold Book (Compendium of Chemical Terminology); impact on AI, AI impact on units representations and interoperability; a Zenodo community for DRUM resources; an ongoing presence at SciDataCon, RDA and engagement in domain-specific conferences; and continued collaboration and coordination with the Digital SI initiatives of the CIPM.

S. Hodson finally wished to highlight three recent activities: digitization of fundamental physical constants, support for BIPM Digital-SI framework, and work within DRUM and on AI.

National Conference of Standards Laboratories International (NCSLI)

The report was presented by M. Kuster [**F_MD_24.06.04**]**.** The presentation showed the work of the Measurement Information Infrastructure (MII) and Automation Committee. A flow diagram of the measurement economy identified that in several steps there is a requirement for the exchange of standardized metrology data, for example, between specification of an instrument and the data provided to a measurement consumer. Work so far by the MII included: M-Layer - fundamental digital representations for quantities and units; measurand taxonomy of metadata for digital-document interoperability; high-level unified data models for quality and metrology data and processes; model processes and the associated informational components across the IQI, from the lowest to the highest level; documentation of technologically agnostic models to facilitate different implementations and information exchange independent of data formats; encouragement of Forum-MD members to develop, support, and implement digital processes and data derived from standardized models; and creation and population of FAIR reference-data systems with the metadata, taxonomies, and entities required to support IQI processes.

M. Kuster showed an example of an intelligent CMC search with an example use case. M. Kuster highlighted the upcoming First Annual Quality Infrastructure Modelling Workshop, which was proposed for Thursday 11 July 2024, immediately after the 6–10 July 2024 NCSLI Annual Workshop and Symposium (Denver, Colorado, USA)

D. Hutzschenreuter asked for more information about what NCSLI expected concerning digital transformation. M. Kuster responded that the goal was full machine-to-machine interoperability, taking over from human-based approaches.

International Measurement Confederation (IMEKO)

(This item was taken later in the agenda due to technical reasons).

H. Gasca-Aragon gave the report [**F_MD_24.06.02**]. Within the 25 technical committees of IMEKO, committee TC6 concerned digitalization and has as its aims to develop, organize, and disseminate fundamental concepts of measurement science that relate to digitalization and digital transformation in science, industry, and society; and to promote the accumulation and curation of knowledge in various forms relating to the digitalization of measurement methodologies and measurement outcomes. TC6 had organized three events: 1st International Conference on Metrology and Digital Transformation (M4Dconf) in September 2022, a joint webinar with the OIML Digitalization Task Group on ‘Blockchain technologies in metrology’ March 2023 and several sessions to be held at the IMEKO World Congress in August 2024. A working group had been established with members of all interested TCs. Its current activities included: informing about the activities of the CIPM Forum; identifying joint developments within the TCs; networking with other organizations (NMIs, RMOs, industry). It plans further activities such as contributing to a harmonized quality infrastructure; sharing experiences in the field of artificial intelligence; and supporting the CIPM/BIPM and standardization organizations.

M. Milton asked if there are any specific objectives under TC6 or plans to produce documents or guides. H. Gasca-Aragon responded that there is work on network of sensors. S. Eichstädt added that TCs in IMEKO are not the same as RMO TCs – IMEKO tends to focus on joint activities with other organizations rather than generating documents directly themselves.

7 REPORT FROM THE JOINT STATEMENT SIGNATURE HUB

J. Ullrich mentioned that there had been a meeting of the JSI Signatories on the preceding day, at the BIPM headquarters. The meeting had discussed the Joint Workshop (which had been held at the BIPM headquarters on 5–6 March 2024) and the organization of the round table. The workshop was well attended and appreciated by the attendees. The mixture of round tables and keynotes seemed to work well with a good mixture between science, metrology and industry approaches to digitalization. The next round table meeting with be in September 2024 – the position of chair and secretary will change each time – next time two volunteers are sought for a two year period. For the next meeting membership criteria will need to be discussed; the group should not be too large to enable efficient working. A decision will be taken on what topics may move from the Forum to the round table. On 11 July there would be a meeting at NCSLI and in August IMEKO may be able to host a session.

8 REPORT FROM THE BIPM-HEADQUARTERS ON THE BIPM ROADMAP AND EXECUTION STATUS

M. Milton gave the introductory presentation [**F_MD_24_08.01**]. The CGPM in 2022 had put in place many of the requirements through Resolution 2 its meeting ‘On the global digital transformation and International System of Units’. The KCDB was introduced for those not familiar with it – the KCDB is the property of 251 institutions thus individual requests are not possible to implement due to this large co-ownership.

SI Reference Point

M. Milton introduced the broad outline of the SI Reference Point in the context of the above introduction. The aim of the SI Reference Point is to provide a fully digital representation of the SI. It should provide the globally accepted anchor of trust for metrology in the digital era and facilitate the use of digital certificates and the adoption of the FAIR principles. The BIPM has enabled digital access to the BIPM databases (KCDB, UTC database) and had prepared the SI Reference Point digital service. The digitalization process makes use of external databases such as ROR, ORCID and InChl and a unit interoperability service is in preparation.

Within the SI Reference Point (v1.0) are digital references: units, prefixes, defining constants, quantities - used in the SI Brochure, CGPM decisions, CMCs, and measurement service categories for physics (excluding RI). SI Reference Point (v2.0), which is under development will add: measurement service categories for RI and chemistry, NMIs/DIs, quantities – used in the KCDB, fundamental constants, and further items. M. Milton handed over to F. Meynadier to continue the presentation.

Documentation may be viewed as belonging to five levels of digitalization:

- L0 analogue document
- L1 digital document
- L2 machine-readable document
- L3 machine-readable and -executable content
- L4 machine-interpretable content
- L5 machine-controllable content

The target was to take existing SI documents as far as L3+; this required the use of the building blocks of the semantic web. This would require addition of formal logic to the web, integration

with existing standards (to maintain compatibility), and using available collections of information (such as the SI Brochure).

Principal pillars of the SI Digital framework are: the SI units, SI prefixes, defining constants, selected quantities, and CGPM decisions concerning the SI. The information is built into knowledge graphs, which are serialized as TTL/JSON-LD in the format of triples: subject-predicate-object. F. Meynadier gave an example of constructing units from expressions using the newton as an example followed by an example of how an end user can link data to units in the SI Reference Point. Before proceeding with a live demonstration of the SI Reference Point, F. Meynadier concluded by showing the two main online locations: https://si-digital-framework.org/ which is the root URI and web endpoint; and https://github.com/TheBIPM/SI_Digital_Framework, which is the public GitHub repository where files and documentation are available, and issues can be raised. Comments on v1.0 of the SI Reference Point are welcome.

O. De Feo asked about compound units, and whether we should define such items as they are not primary. F. Meynadier responded that ideally that would be the case but actually these compound units are used by people who may not want to re-format their own data presentations for example, in tables, to use primary atomic entities. H. Laiz asked about how the linking would work. F. Meynadier responded that it could simply be an embedded link to the URI of the SI unit(s). By comparing what references two items are linked to, the items could be validated as being equivalent if they linked to the same location. This will require the BIPM to approach end users to inform them about the SI Reference Point and to ask them to start using it. P. Rourke asked about incorporating into the SI framework such things as GUM tree calculator and M-Layer. F. Meynadier responded that there could be bridges between these separate representations. It is necessary to consider reference to existing ontologies; in M-layer and QUDT it would be possible to include a direct link.

J. Ullrich summarized the situation – there are pioneering Key Comparisons and their communities should talk to each other; and there are clear links to take further with ISO on terminology. Several of these should now be the topics of the break-out sessions.

9 PRIORITY ACTIVITIES OF THE FORUM INCLUDING POSSIBLE PROJECTS, WGS AND TGS: INTRODUCTION OF PROPOSALS

J. Ullrich introduced the expectation from the breakout sessions. Several proposals had been tabled and were available in the meeting documents [**F_MD_24_09.xx**]. He recommended each session to have open and creative discussions and, ideally, he hoped to see the sessions make suggestions on TGs, WGs, *etc*. that are as concrete as possible. In addition, it would be useful to see whether there were items which were better suited to the JSI signatory round table. The four breakout session chairs briefly described the areas to be discussed in their session.

10 BREAK-OUT SESSIONS

There were four break-out sessions which commenced (for persons present at the BIPM headquarters only, no online attendance):

1. **Traceability, DCCs and DCRMs, Services and Applications**
2. **Interoperability and quality of data**
3. **RMOs, Capacity Building and interaction between CCs and the BIPM**
4. **Future Technologies.**

At 17:30 the break-out sessions were closed and the first day of the meeting came to an end.

11 REPORTING BACK FROM BREAK-OUT SESSIONS AND DISCUSSIONS

J. Ullrich welcomed all participants to the second day. He continued with the agenda. The first item was to report back from the breakout sessions. He asked the chairs of the sessions to give their summary reports.

Traceability, DCCs and DCRMs, Services and Applications

G. Macdonald reported that the discussions in this break-out session were on three topics:

1. Metrological traceability for digitalization

The conclusion was that this merits further discussion perhaps as a topic area for a FORUM-MD workshop or as a JSI roundtable activity.

2. Underpinning infrastructure for digitalization of metrology services

The conclusion was that this merits further discussion perhaps as a topic area for a FORUM-MD workshop or as a JSI roundtable activity.

3. Application – harmonizing DCCs and DRMCs

Here the session recommended the creation of a Task Group on Digital Calibration Certificates in order to explore harmonization, improve common understanding, develop user stories and value propositions, and write guidance documents. Suggested members would be from PTB, NIST, METAS, CMI, NPL.

D. Hutzschenreuter asked for further elaboration on the discussions on the underpinning infrastructure. O. De Feo responded that digital services are not just about defining standards but also working on the underpinning hardware, software *etc.* As soon as there is adoption there will be a need to for ongoing continuous improvement. J. Ullrich added it could be a good idea to have a Task Group to accompany the Digital SI work but was not sure if this was included. O. De Feo added that this was not part of the discussion and J. Ullrich added that he would consider adding this to the list of potential outcomes. R. White asked if the scope of the harmonization work would be discussed. G. Macdonald responded that when the Task Group would be launched, a first work item would be a scoping exercise, however the work on harmonization was to be strongly in line with ISO and accreditation requirements (for example, ISO 17025). J. Ullrich suggested that 'harmonizing' would be too strong a term and G. Macdonald suggested it was more 'exploratory'. B. Hall was pleased to see traceability at the top of the list – he was concerned about the difficulties of including traceability – he wished to see it given more priority. J. Ullrich suggested a workshop might be a good idea here.

Interoperability and quality of data

R. Hanisch reported. Three activity areas were discussed.

1. FAIR for metrology

- FAIR is a set of principles, not absolutes. How do we interpret FAIR for metrology?
- FAIR does not mean open. It must consider privacy and IP. Schema can be open while data therein are not (DCCs).
- Explore FAIR Digital Objects as vehicles for exchange of metrology data.

- What data attributes are important to carry with FAIR metrology data?
  - Uncertainty characterization.
  - Provenance.
  - Traceability.
  - Units.
- Data representation, data models, open formats.
- Data sharing policy for *Metrologia*?
- R. Hanisch, M. Ballico, F. Härtig, and M. van Dijk volunteered to be members of a Task Group.

2. Metrological semantics

- Terminology and semantics are inconsistent across NMIs.
- Need an overarching model for measurands.
- Need a standard way to describe parameter ranges for CMCs.
- Need to assure interoperability of DCCs, consistent understanding of metadata elements.
- CIPM MRA model/ontology
- Digital VIM.
- PIDs for everything.
- J.-L. Hippolyte, R. White, P. Blattner, K. Hosaka, S. Chalk, B. Hall, and F. Härtig volunteered to be members of a Task Group.

3. Data quality in metrology

- How to characterize data quality? Define principles for expression of DQ.
- DFFAIR expression of uncertainty.
- Fit for purpose.
- Build on Quality Infrastructure ISO 8000.
- Traceability contributes to Digital Quality.
- PIDs for everything (organizations, labs, instruments researchers).
- Quality data as inputs to AI/ML.
- S. Chalk, M. Ballico, B. Hall, M. van Dijk volunteered to be members of a Task Group.

O. De Feo mentioned that some companies have a policy on data quality covered by a data officer, usually this concerns the meta data – it is the application that determines the validity of the data. ChatGPT had proceeded without the quality aspects being discussed here. He suggested that the quality for use case should consider all possible end uses. R. Hanisch responded that FAIR data does not necessarily mean quality data (the data could be well tagged but noisy, for example). C. Denz added that in breakout session 4 it was pointed out that data can be singular, meta data, or many data items – the set of data may need additional qualities to the individual items. D. Hutzschenreuter wondered if it would be possible to split the work into the three groups, and asked if data fit for purpose was better expressed as data fit for use. R. Hanisch agreed that there may be overlap between results. He countered the fit for purpose question and had the opinion that this was still a valid item for discussion. J. Ullrich commented on the second suggested group – he thought that this discussion could eventually become a topic for the round table.

Future Technologies

C. Denz reported on the discussions. These had started with discussion of the four suggested topics tabled for the session.

- Blockchains as distributed technology: importance for smart contracts but needed no further discussion here.
- Digital twins: physics-informed virtual simulations – no further discussion needed.
- Artificial intelligence: Metrology for AI, AI methods for NMI tasks – it seemed there was a strong need here related to NMI tasks.
- Smart sensor networks: Metrology of emerging features.

There was then a discussion of overall challenges.

- Conceptual modelling of digitalization as a structured framework to streamline digital terms, processes and workflows.
- Capability of the CIPM to develop foresight processes in a dynamically changing future of digital technologies.

The discussion led to two overall conclusions.

1. Development of secure and trustworthy artificial intelligence

- Identification of uniform quality metrics for AI and workflows for AI.
- Quality of data: accuracy and uncertainties representativeness.
- Quality of algorithms: transparency, explainability, robustness.

Draft decision

The Forum on Metrology and Digitalization (FORUM-MD) decides to establish a Task Group on **Secure and trustworthy AI**. The Terms of Reference will be drafted by the Group to be approved in the next FORUM-MD Meeting. The FORUM-MD appoints PTB, NPL, and possibly NIST as Members of the Task Group.

2. Development of an overall metrology for complex sensor networks

- Harmonize metrics for networks of many and heterogenous sensors.
- Defining measures of networks of (smart) sensors as a whole.
- Uncertainty, traceability, calibrations, … control methods.

Draft decision

The Forum on Metrology and Digitalization (FORUM-MD) decides to establish a Task Group on Complex Sensor Networks. Terms of Reference will be drafted by the Group to be approved in the next FORUM-MD Meeting. The membership will be discussed.

R. White supported the idea on using a modelling approach using a structured framework which could be used to support the work in a more formalized fashion. Online question: when quality matrix for an AI is described what does this mean for metrology? C. Denz responded that for an AI we need a transparent algorithm than can be used for a metrological assessment. J. Ullrich added that guidance on allowed output ranges that an AI could be used for and C. Denz added that the risk class of an AI is included in the legal framework in the EU concerning the use of AI and this comes ultimately to metrology. F. Härtig asked about sensor networks – is this also a topic for

the GUM – should new approaches be developed for assessing the uncertainty of sensor ensembles? J. Ullrich agreed that this is needed due to high scaling of complexity with the number of sensors – it requires topological approaches. C. Denz added the example of sensors in autonomous cars where a failed sensor can be substituted by others. B. Hall re-stressed the need for traceability – engineers will make things work but the traceability is often missing. J. Ullrich concluded that a workshop may be necessary here.

RMOs, Capacity Building and interaction between CCs and the BIPM

H. Laiz summarized the discussions from this break-out session. Several questions had been tabled and then discussed.

Q: Which projects/activities under development in the RMOs could be shared with the other RMOs? How can we gain momentum from the common activities?

A: It would be valuable for all NMIs that the RMOs share the information of their capacity building activities and R&D projects on a regular basis to explore possibilities of cooperation.

Q: What is the role of the RMOs in the needed harmonization activities (*i.e.* DCCs)?

A: It would be good if the RMOs are involved **as RMOs** in these activities. This will provide an indirect link to NMIs that will not be directly involved in the Forum.

Q: Do we need an RMO-WG similar to that in most CCs?

A: Yes.

Actions:

- Provide a direct link between the Forum and every NMI (and their stakeholders).
- Exchange information on activities in regions to share knowledge transfer and explore synergies.
- Discuss the needs of the emerging NMIs.
- Transfer needs of the regions to the Forum, the CIPM, the BIPM and JCRB.

Members:

Chair of the corresponding TC in the RMO.

Q: What is the role of the CCs in support of digitalization?

Q: Are those tasks internal to the CCs or do we need a CC-WG in the Forum?

A: Yes, perhaps TG or *ad hoc* WG (not sure if these are permanent activities).

Actions:

- Exchange information on the approach of each CC to make Appendix C machine readable.
- Identify harmonization needs (if any).
- Identify best practices (publish guides).
- Organize seminars or workshops on common issues.
- Share experience, for instance, list of services updated for machine reading.
- Provide a common platform to link with the SIRP development.

Members:

Chair of the WG-D of each CC or representative appointed by the CC President.

Q: How should the capacity building activities be organized by the BIPM? How can we share the RMO's capacity building activities?

A: **BIPM**

- Capacity Building on the use of SI Reference Point and other digital services (urgent) using the e-learning platform.
- Awareness on the importance of the SI Reference Point as anchor of trust.

RMOs and BIPM

- Development of joint capacity building initiatives for stakeholders; take advantage of virtual activities of the RMOs.

S. Eichstädt asked if the activities were discussed as being limited to just the RMOs and TCs and asked if this could be opened to other organizations. He also asked if the capacity building work should also consider what were the needs from non-RMO/TC community. H. Laiz responded that the focus was different to what S. Eichstädt suggested, as the needs of the RMOs are very different therefore it should be a Working Group with TCs and RMOs as members, but this would then report back to the Forum to extend the discussions. F. Härtig asked about the common platform for SI Reference Point development and H. Laiz responded that this was a discussion platform rather than a software platform for using the SI Reference Point (which already exists).

F. Härtig asked about security of the SI Reference Point but this was not a topic for this session – it should be the consideration of the CIPM and BIPM. M. Milton commented on the cyber security approaches of the BIPM including distributed approaches – the BIPM and the NMIs will of course follow best practices. D. Hutzschenreuter added, and J. Ullrich agreed, that the capacity building work could be a round table discussion. C. Denz was not sure why there needed to be a different WG for the CCs which would work in parallel. H. Laiz thought that there were sufficient common issues across the CCs that they should have the opportunity to work together, though not as a permanent activity- this could be a Task Group, which is less permanent. T. Bruns mentioned the distribution of the SI Reference Point – he suggested an SI Reference Point 'to go' *i.e.* to have a version available that could be secure that could be used separately. M. Milton welcomed secondees, experts *etc.* to work reactively to benchmark issues of scope and functionality. J. Ullrich suggested that the various groups should meet before summer to discuss their terms of reference and their linkages. M. Smid commented that security was not part of the session discussions. He added that the key item is for the CCs to continue their job on CMCs and KCs, whereas the RMOs are key to the other digitalization activities.

Remarks from the online participants: coordination amongst CCs would be useful; important for NMIs to address traceability and calibration techniques of sensor networks.

L. Wright suggested that software quality was a good topic for capacity building, and M. Milton agreed.

Based on the earlier observation that the work on the digital SI Framework continues and needs its own forum, J. Ullrich tabled a suggestion for an additional Task Group.

The forum decides to establish a Task Group to accompany the further development of the Digital SI Framework and its adoption in services and tools of the wider scientific and quality infrastructure. The SI Reference Point is of particular interest and importance in the starting phase of the Task Group. The Terms of Reference will be drafted by the Group to be approved in the next Forum meeting. The membership and chair of the Group will be decided later.

This proposal was accepted.

J. Ullrich summarized the Working Groups/Task Groups:

1. Ad-hoc Task Group on SI Digital Framework
2. Ad-hoc Task group on Harmonizing DCC and DRMC
3. Ad-hoc Task group on FAIR for Metrology
4. Ad-hoc Task group on Metrological Semantics
5. Ad-hoc Task group on Data quality in Metrology
6. Ad-hoc Task Group on Secure and Trustworthy artificial intelligence
7. Working Group on Coordination between Consultative Committees
8. Working Group on coordination between Regional Metrology Organizations.

There were also two workshops which need to be organized on:

1. Complex Sensor Networks
2. Traceability.

There was discussion on the way forward regarding formal proposal of the new groups, and hosting of the workshops. J. Ullrich asked the session chairs to prepare formal worded proposals, however this was superseded by the decision to have one overall proposal, creating all the Groups. F. Härtig offered to host a face-to-face workshop at IMEKO – if it was limited to one day it could be offered for free. Online participant C. Shan, NMC A*STAR (Singapore) offered to organize the sensor network workshop. P. Blattner commented that the CIPM rules (CIPM-D-01) require further consideration, for example are the members the NMIs or specific people or are there limitations on the membership of Task Groups and Working Groups. M. Milton added that when the scope and chairs are clarified, the invitation will be opened for wider membership. S. Bergstrand proposed that the EURAMET TC-IM technical committee TC chair (Mr Gunn) is at least contacted, and M. Milton added that the RMOs are invited to send whoever they think is best suited.

12 CONCLUSION BREAK-OUT SESSIONS

J. Ullrich tabled the formal Decision on setting up the new Groups and organizing the workshops.

DECISION FORUM-MD-24-1

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 members M. Koval (CMI, Chair) X. Xiong (NIM), A. Sharma (NPLI), C. Galván-Hernandez (CENAM), N. Chanthawong (NIMT), A. Arce Criado (CEM), Per Olof Hedekvist (RISE), S. Schönhals (PTB), J. Fedchak (NIST), M. Bierzychudek (INTI), F. Prinsloo (NMISA);

FAIR for Metrology with members R. Hanisch (NIST, Chair), M. Ballico (NMIA), M. Van Dijk (VSL), R. M. Gómez Rodríguez (INM), S. Hacke (PTB), B. Maranville (NIST), Z. Liu (NIM);

Metrological Semantics with members R. White (NRC, Chair), J.-L. Hippolyte (NPL), P. Blattner (METAS), K. Hosaka (NMIJ/AIST), S. J. Chalk (UNF), B. Hall (MSL), S. E.G. Bergstrand (RISE), N. Zviagin (VNIIM), T. Menegotto (INMETRO), D. Hutzschenreuter (PTB), A. Sharma (NPLI), L. Mari (IEC), D. N. Coppa (INTI);

Data Quality in Metrology with members M. Ballico (NMIA, Chair), M. Van Dijk (VSL), S. E.G. Bergstrand (RISE), H. Gasca-Aragon (CENAM), D. Hutzschenreuter (PTB), Z. Liu (NIM), A. Sharma (NPLI), N. Chanthawong (NIMT), R. M. Gómez Rodríguez (INM Colombia), S. Yu (NMC, A*STAR), P. Jivan (NMISA), S. J. Chalk (UNF), B. Hall (MSL);

Secure and trustworthy AI with members L. Wright (NPL, Chair), R. Emardson (RISE), A. Charbonneau (NRC), S. Cui (NMC, A*STAR), L. Fernando Rust (INMETRO), H. Gasca-Aragon (CENAM), N. Chanthawong (NIMT), W. Zhang (NIM), S. Eichstädt (PTB), J. Rezac (NIST), A. Wunderlich (NIST), J. Hoffmann (METAS);

Coordination between RMOs with members N. Zviagin (VNIIM, Chair), and the chairs of the corresponding TC in the RMO, S. Schönhals (PTB), T. Krah (PTB);

Coordination between CCs with members P. Blattner (METAS, Chair), the chairs of the WG-D of each Consultative Committee or representative appointed by the Consultative Committee President;

SI-digital Framework with members A. Cypionka (BIPM, Chair), D. Hutzschenreuter (PTB), H. Laiz (INTI), C. Galván-Hernandez (CENAM), I. Budovsky (NMIA), P. Blattner (METAS), C. Sonntag (NMISA), X. Xiong (NIM), F. Meynadier (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), assisted by B. Hall (MSL), N. Chanthawong (NIMT) and H. Gasca-Aragon (CENAM), X. Xiong (NIM), J. Fedchak (NIST);

Complex sensor networks (organizer S. Cui (NMC, A*STAR), assisted by W.-H. Cho (KRISS), M. Koval (CMI), S. Eichstädt (PTB), N. Chanthawong (NIMT), A.A. García González (CENAM) and Z. Wei (NIM);

and **requests**

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

13 FORUM STRATEGY

J. Ullrich tabled the following draft, proposed by the current *ad hoc* Working Group [**F_MD_24.12.00**].

Draft Terms of Reference of Forum on Metrology and Digitalization (FORUM-MD) are to:

- propose a **long-term vision** for the FORUM-MD covering the **next five years** and establish as well as maintain a strategic planning document;
- ensure that **relevant developments in digitalization**, particularly in areas not covered by other Forum WGs, are monitored by the FORUM-MD and propose suitable actions;
- establish practices to ensure an effective **linkage between organizations in liaison** and in cooperation with the FORUM-MD;
- advise the FORUM-MD on the optimal **operational structure of the FORUM-MD** and its working groups; and
- prepare an outline agenda and main topics for **FORUM-MD plenary meetings** and propose **conferences** and other **events**.

The tabled Draft Terms of Reference for FORUM-MD were accepted.

Additionally, J. Ullrich reminded the participants that now that the kick-off meeting had been concluded there would be a formal **Working Group on Strategy** (WG-S), with a membership from the FORUM-MD: the Chair and Vice-chair, the Executive Secretary, the Chairs of the Working Groups and Task Groups, and the Director of the BIPM.

DECISION FORUM-MD-24-3

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**].

14 REVIEW OF MEMBERS, OBSERVERS AND LIAISONS

J. Ullrich commented that the membership was revised during the meeting and no further revisions needed to be discussed. The membership had been defined by decision CIPM/112-38, and all 27 parties who expressed an interest to participate may do so as *Observers*; there are eleven *Members* of the Forum (according to the D-01 criteria requiring Members to be institutions of Member States that are national laboratories responsible for national standards, with an active research and publications portfolio); and organizations from the international scientific and quality infrastructure, in particular Signatories of the JSI, are invited to participate as *Liaisons* to the Forum. Thus, CIPM had decided (CIPM/112-38) to approve CENAM, INTI, METAS, MSL, NIM, NIST, NMIA, NPL, NRC, PTB, and VNIIMS as Members of the Forum and invited J. Ullrich to chair the first meeting and appointed G. Macdonald as Vice-Chair.

15 ANY OTHER BUSINESS

J. Ullrich had prepared a list of items to be addressed as a reminder for future work.

- Contact ISO / IEC concerning terminology (↔ VIM, CCU-TG-CMT): P. Blattner, G. Macdonald.
- Until end of April: *ad-hoc* TG meetings.
  - Draft Terms of Reference.
  - Work Plan.
    Review members as needed.
- May: WG-S meeting: with new FORUM-MD Chair elected by the CIPM in March 2024.
  - Wrap-up of the Forum meeting.
  - Review of TGs' Terms of Reference, TG-Members
  - Report for the June CIPM meeting.
    Identification of priority themes.
- Revision of the D-01: members, observers, guest and liaisons.
- November / December: WG-S meeting.
  - Preparation of the next FMD meeting: February 2025.

H. Laiz thanked J. Ullrich for the work on championing the digital agenda and for his work throughout his entire time within CIPM. After applause from the floor, J. Ullrich thanked all and remarked that the help of everyone had made much of his time so enjoyable.

16 DATE OF THE NEXT FORUM MEETING

As discussed earlier, the next meeting of FORUM-MD will be decided in due course however the first meeting of FOURM-MD WG-S will be in May 2024 at a date to be confirmed.

At 11:30 J. Ullrich closed the meeting.

Appendix MD 1.

Working documents submitted to the FORUM-MD at its 1st meeting

Open working documents of the FORUM-MD can be obtained from the BIPM website (after logging in): https://www.bipm.org/en/committees/fo/forum-md. Note that not all documents were presented at the meeting.

Documents

F_MD_24_01	Draft agenda
F_MD_24_01.a	Breakout sessions and QR code for agenda
F_MD_24_03.01	Forum Chair slide pack
F_MD_24_03.02	CIPM Vision 2023 - SI for a Digital World
F_MD_24_03.03	Mission of the FORUM-MD
F_MD_24_03.04	Joint Statement of Intent
F_MD_24_04.01.a	CCU report
F_MD_24_04.01	CCU report to CGPM 2022
F_MD_24_04.02	CCAUV report
F_MD_24_04.03	CCT report (presentation)
F_MD_24_04.03.a	CCT report (document)
F_MD_24_04.04	CCL report
F_MD_24_04.05	CCQM report (document)
F_MD_24_04.05.a	CCQM report (presentation)
F_MD_24_04.06	CCRI report
F_MD_24_04.07	CCPR report
F_MD_24_04.08	CCM report
F_MD_24_04.09	CCTF report
F_MD_24_05.01	AFRIMETS report
F_MD_24_05.02	APMP report
F_MD_24_05.03	COOMET report
F_MD_24_05.04	EURAMET report
F_MD_24_05.05	GULFMET report
F_MD_24_05.06	SIM report
F_MD_24_06.01	CODATA report
F_MD_24_06.02	IMEKO report
F_MD_24_06.03	CIE report
F_MD_24_06.04	NCSLI report
F_MD_24_06.05	OIML report
F_MD_24_07	CIPM and OIML proposal
F_MD_24.08.00	BIPM progress report
F_MD_24.08.01	BIPM digital services
F_MD_24_09.00	BIPM report on digitalization survey

F_MD_24_09.01	VNIIM proposal
F_MD_24_09.02	NCSLI proposal
F_MD_24_09.03	NMIJ proposal
F_MD_24_09.04	KRISS proposal
F_MD_24_09.05	NIM proposal
F_MD_24_09.06	PTB proposal
F_MD_24_12.00	WG-S draft Terms of Reference
F_MD_24_13.00	Draft Decisions of FORUM-MD
F_MD_24_14.00	CIPM-D-01 Rules of procedure
F_MD_24_14.01	NIST digitalization progress
F_MD_24_14.02	METAS contribution
F_MD_24_14.03	PTB contribution