

Bureau International des Poids et Mesures

Consultative Committee for Length (CCL)

Report of the 15th meeting
(19 – 20 September 2012)
to the International Committee for Weights and Measures



Comité international des poids et mesures

Note:

Following a decision of the International Committee for Weights and Measures at its 92nd meeting (October 2003), reports of meetings of the Consultative Committees are now published only on the BIPM website and in the form presented here.

Full bilingual versions in French and English are no longer published.

M. Milton,
Director BIPM

**LIST OF MEMBERS OF THE
CONSULTATIVE COMMITTEE FOR LENGTH**
as of 20 September 2012

President

Dr A. Sacconi, Member of the International Committee for Weights and Measures, Istituto Nazionale di Ricerca Metrologica, Turin.

Dr R. Thalmann, METAS, chaired the 15th meeting of the CCL.

Executive Secretary

Dr L. Robertsson, International Bureau of Weights and Measures [BIPM], Sèvres.

Members

Agency for Science, Technology and Research [A*STAR], Singapore.

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

Centre for Metrology and Accreditation/Mittatekniikan Keskus [MIKES], Espoo.

Centro Español de Metrología [CEM], Madrid.

Centro Nacional de Metrología [CENAM], Querétaro.

Conservatoire National des Arts et Métiers/Institut National de Métrologie [LNE-Cnam], La Plaine-Saint-Denis.

Czech Metrology Institute/Český Metrologický Institut [CMI], Brno.

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

Federal Office of Metrology/Office Fédéral de Métrologie [METAS], Bern-Wabern.

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

Istituto Nazionale di Ricerca Metrologica [INRIM], Turin.

JILA, Boulder.

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

National Institute of Metrology [NIM], Beijing.

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

National Measurement Institute, Australia [NMIA], Lindfield.

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/Ulusal Metroloji Enstitüsü [UME], Gebze-Kocaeli.

National Physical Laboratory [NPL], Teddington.

National Research Council of Canada - Measurement Science and Standards Portfolio [NRC],
Ottawa.

Physikalisch-Technische Bundesanstalt [PTB], Braunschweig.

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

VSL [VSL], Delft.

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

Observers

Instituto Português da Qualidade [IPQ], Caparica.

1. **OPENING OF THE MEETING; APPOINTMENT OF THE RAPPORTEUR; APPROVAL OF THE AGENDA**

The Consultative Committee for Length (CCL)* held its 15th meeting at the International Bureau of Weights and Measures (BIPM) headquarters, Sèvres, on Wednesday 19 and Thursday 20 September 2012.

The following delegates were present:

A. Balsamo (INRIM), R.H. Bergmans (VSL), H. Bosse (PTB), P. Cox (NMIA), J.C. de Oliveira (INMETRO), B. Eves (NRC), R. Fira (SMU), O. Ganioglu (UME), S. Gao (NIM), P. Gill (NPL), F.-L. Hong (NMIJ/AIST), J.-W. Kim (KRISS), P. Křen (CMI), O. Kruger (NMISA), M. Kühne (BIPM Director), A. Lassila (MIKES), Y. Lecoq (LNE-SYRTE), M. Matus (BEV), E. Prieto (CEM), F. Riehle (PTB), H. Schnatz (PTB), D. Sendoğdu (UME), J. Stone (NIST), T. Takatsuji (NMIJ/AIST), R. Thalmann (METAS), G.-P. Vaillau (LNE), M. Viliesid (CENAM), S. Wang (A*STAR), X. Zi (NIM) and M. Zucco (INRIM).

Guests: L. Erard (CIPM, President of the CCTF), J. Garnæs (DFM), Y.-P. Lan (CMS/ITRI), M. Lawn (NMIA).

Also present: A.O. Altan (JCRB Executive Secretary), A. Henson (BIPM), L. Robertsson (Executive Secretary of the CCL, BIPM), C. Thomas (BIPM).

Apologies: P. Juncar (LNE-Cnam), J.-A. Kim (KRISS), A. Sacconi.

Prof. M. Kühne, Director of BIPM, opened the session and welcomed participants to the 15th meeting of the Consultative Committee for Length (CCL). Prof. M. Kühne recalled the creation of the BIPM and how the length community is the oldest one linked to the work of the BIPM. Dr L. Robertsson mentioned a few items of housekeeping.

Dr R. Thalmann presented apologies on behalf of the CCL President, Dr A. Sacconi, for being unable to attend the meeting. Dr A. Sacconi had requested that the CIPM nominate Dr R. Thalmann to chair the 15th meeting of the CCL. Dr R. Thalmann expressed his best wishes to Dr A. Sacconi and his family, welcomed the participants and asked them to introduce themselves.

In the absence of Dr A. Lewis, Dr E. Prieto was appointed as Rapporteur after being proposed by Dr R. Thalmann.

The agenda was approved by attendees with no changes or additions.

The Minutes from the 14th meeting of the CCL in June 2009 had been approved by correspondence and published with no objections. Dr R. Thalmann thanked Dr A. Lewis for the detailed minutes.

* For the list of acronyms, [click here](#).

2. REPORT ON ACTIONS ARISING FROM THE JUNE 2009 MEETING

Dr R. Thalmann reviewed the actions list from the previous meeting of the CCL.

No	Action	Status
A.1	WGDM (now WG-MRA) to review the proposed FSWG single frequency list and suggest any additions to the list required for satisfying the needs of dimensional metrology.	<p>Pending.</p> <p>The list will be made available during this meeting.</p> <p><i>The WG-MRA will send additions to the list, if any (Action A.1).</i></p>
A.2	BIPM to take forward, via discussion with P. Tuckey, the possibility of a joint workshop between the CCL and the CCTF.	Completed
A.3	WGDM (now WG-MRA) to prepare a document, under authority of the CCL, to list 1) the values from Appendix 2 of the FSWG frequency list, 2) the approved text relating to the use of unstabilized lasers in dimensional metrology and 3) the proposed new standards for nanometrology.	<p>Points 1 and 2 completed.</p> <p>Point 3 pending.</p> <p><i>The WG-N will prepare a document proposing new standards for nanometrology</i></p> <p>(Action A.2).</p>
A.4	Dr F. Arias to make available on the CCL server as an open document the presentation given on the links between the MRA and consultative committees.	Completed
A.5	RMO TC-L chairpersons to recommend to the pilots of key comparisons, currently running or in the planning stage, that they arrange for independent refereeing of the final reports, by one of the participants (other than the pilot).	<p>Completed</p> <p>The WG-MRA has established a process of reviewing the final reports by all participants.</p>
A.6	sWG-CMC to investigate how to perform the review of CMCs supported by participation in CCL-K11.	Completed

A.7	Dr Bosse and Dr Dixson to prepare and distribute, via the CCL President, the proposed terms of reference for WG-N.	Completed
A.8	Dr Bosse and Dr Dixson to update the membership list for WG-N and forward to CCL for information.	Completed
A.9	WG-S, WG-MRA, sWG-CMC, sWG-KC and TG-L to elaborate their terms of reference, based on document CCL-09-30 and submit to CCL for approval.	Completed
A.10	The WG chairs to correspond to determine which parts of the agenda of the next meeting (of the CCL WGs) each WG will assume responsibility for.	Completed
A.11	BIPM to update the CCL membership list on the BIPM website to include A*STAR rather than SPRING, as member of CCL.	Completed
A.12	Ms Tan to determine the optimum meetings dates for the Meeting of the CCL Working Groups in Singapore in 2010.	Completed

Open items were carried forward to the action list for this meeting, and are listed in Appendix L3.

3. REPORT FROM THE WG-MRA

The 2012 WG-MRA meeting was held at the BIPM headquarters on 17-18 September, immediately before the 15th CCL meeting. Dr R. Thalmann, chairman of the CCL Working Group on the CIPM MRA (WG-MRA) presented the report from the meeting. Dr M. Matus (BEV) was thanked for acting as Rapporteur – no additional reports were prepared as the information is available directly from the minutes.

The report recalled the new structure of the CCL adopted 3 years ago, with different working groups (WG-MRA, WG-S, WG-N and CCL-CCTF FSWG), sub working groups (sWG-KC, sWG-CMC and TG-L) and discussion groups (DG1, DG2, DG3, DG4, DG5, DG6, DG7, DG8 and DG11). The discussion groups met together for the first time at this 15th CCL meeting. The general opinion among members of the WGs, sWGs and DGs is that the new structure is working very well.

To date, three meetings have been held: WG-MRA-1, on 10 June 2010 at the A*STAR, Singapore, WG-MRA-2, on 6-7 October 2011 at the METAS, Switzerland, and WG-MRA-3, on 17-18 September 2012 at the BIPM headquarters. Dr A. Lewis acted as Rapporteur for meetings 1 and 2, while Dr M. Matus acted as Rapporteur for the third meeting. Topics for discussion at the meetings included: RMO and KC reports, KC/SC planning and monitoring, CIPM MRA

activities (including CMCs and DimVIM), linking KCs, analysis of KC results regarding CMCs and monitoring corrective actions. Nanometrology was discussed in the WG-N.

In addition to these meetings, an intermediate “plenary” meeting was held on 11 June 2010 at the A*STAR, Singapore, where reports from the WGs, RMOs and DGs were discussed.

Between these meetings work on KC and SC progress (technical protocols, evaluation, discussion and approval of reports, equivalence tables and executive reports), discussions on linking issues (by the TG-L), CMC review and corrective actions (by RMOs coordinated by the sWG-CMC), and technical discussions within the DGs were conducted.

CCL Key Comparisons:

During the period 2009-2012, several KC and SC reports were finalized and the results published in the KCDB. All CCL-KC and the majority of RMO-KC reports from the first cycle of KC comparisons have been completed and published or are near publication. The second cycle has started (CCL-K1 and RMO-K1) or will start soon (K3, K4). For details, see document WGMRA-12-30_Changes to KCs each year.xls which is maintained by Dr A. Lewis.

Recent WG-MRA achievements:

The sWG-KC has developed an efficient tool for KC planning (document WGMRA-12-41_KC_planning-V1.19) which shows the historical record of the different KCs (K1 to K11) and participation of RMOs and NMIs. It permits checking if new KCs are needed or if a NMI needs to participate in a KC, by monitoring the established period to determine if it has been exceeded. This tool may be extended to other regions to monitor RMO members with respect to their participation in KCs.

A second achievement has been the creation of Guidance document GD1, which allows the monitoring of CIPM MRA comparisons in length metrology and their impact on CMCs. In addition, comparison log files prepared by Dr M. Matus allow monitoring of the progress of KCs to take place and the dates of the different stages to be recorded while the KC is progressing towards conclusion.

Templates for KC protocols and reports, and a plan to safely archive relevant KC data, to avoid loss of data, particularly when people retire, have been created.

At the sWG-CMC, a process for monitoring the impact of KC results on CMCs was developed. Maintenance of the DimVIM and its language versions, and coordination of CMC reviews by different RMO TCs present no major problems or delays.

Based on the requirements of the TG-L ToR “*work out appropriate ways of linking dimensional metrology key comparisons; support the DG moderators and KC pilots in linking the KCs*”, three linking schemes have been successfully applied, depending on the type of comparison: (a) Hierarchical, (b) Distributed and (c) “Common graph”.

There remain some topics for further work such as (a) correlation, (b) linking with different artefacts at different times and (c) practical implications of distributed linking on KCRV. Efforts will begin on a new task to reduce the amount of data for the KCDB by defining “super parameters”. This concept is particularly needed for comparisons such as K5, K6 and K7 where there is a large quantity of measurement results and information (tables and graphs) which make

the data difficult to handle. The action resulting from this anticipated task will be commented on later in this report.

WG-MRA issues for CCL approval:

1- Amending Terms of Reference:

WG-MRA requested the CCL to delegate the task to approve KC protocols and reports to WG-MRA. The reason for this is to simplify and accelerate the actual process and to avoid unnecessary duplicate consultation. This request was partly based on the fact that there has not been a single occasion where CCL consultation has raised any comment or concern.

CCL agreed in amending the WG-MRA ToR for CCL to delegate the task to approve KC protocols and Reports to WG-MRA (Decision D.1).

2- Problems with COOMET:

COOMET has participated in CCL KCs with unsatisfactory results, but no corrective action has been taken or reported, and the corresponding requests remain unanswered. As a consequence of this, the WG-MRA has requested that the CCL raise this issue with the Joint Committee of the Regional Metrology Organizations and the BIPM (JCRB) for clarification and corresponding action, possibly greying out of CMCs.

There was a short discussion with the participation of Dr J.C. Oliveira, Chairman of the sWG-CMC, Dr R. Thalmann, Dr C. Thomas and Prof. M. Kühne, where the difficulty of determining exactly how many CMCs are involved in these KCs was highlighted. This is because some CMCs are directly tested in the KC while others receive indirect confirmation from the KC results. It was recognized that the actual problem is that COOMET often does not answer requests from Dr J.C. Oliveira and the Pilots of such comparisons; this causes a lack of awareness of what is happening, ignorance of the existence of corrective actions and creates difficulties in taking decisions on their CMCs. It was emphasized that the chain of responsibility starts at the NMI and continues at the RMO (TC-Q), and then reaches the corresponding CC. In fact, this may be viewed as a Quality System problem operating incorrectly. This discussion led to the decision that:

CCL agreed that Dr J.C. Oliveira will inform officially (by writing) to Dr C. Thomas on the COOMET problems and the BIPM Director will raise this issue in the next JCRB meeting in March 2013 (Action A.3).

3- KC periodicity:

WG-MRA has noted that it is difficult to track the originally planned periodicity for KCs of 7 years and instead recommends a fixed maximum value of 10 years, which will apply to both the periodicity of KCs and the time interval an NMI is allowed to provide evidence for its CMCs in a KC topic.

Consequently, WG-MRA requested the CCL to support this recommendation and to mandate WG-MRA and the RMO TCs to enforce and monitor this requirement with appropriate diligence.

Dr F. Riehle explained that his impression was that the CIPM wanted to reduce the workload associated with KCs by reducing the number of comparisons, or increasing the periodicity. Mr L. Erard clarified that this was not a CIPM initiative by itself, but NMIs had contacted the CIPM explaining their interest in reducing the number of KCs for both economic and technical reasons. Dr P. Gill said that CCL-K11 may be an exception to the other KCs, in that it does not require lengthy checking or maintenance of the confidence on declared CMCs because it is a “continuous” KC.

CCL agreed in fixing a maximum value of 10 years applying to both the periodicity of KCs and the time interval a NMI needs to provide evidence for its CMCs in a KC topic (Decision D.2).

4- CMC for refractive index:

WG-MRA has been approached by the CCPR and its WG-CMC (Doc CCL/WG-MRA/12-53) to clarify the situation with regard to service categories and CMCs related to refractive index.

CCL agreed in proposing to CCPR to group all service categories related to refractive index in their classification scheme (Action A.4), thus to transfer DimVIM service 6.7.1 to CCPR, and to introduce new entries for spectral properties of materials.

Alternatively CCL would be ready to keep entry 6.7.1, but not intending to include materials properties.

5- WG-MRA chair:

The end of the Chairman’s mandate for WG-MRA is approaching. Dr R. Thalmann announced that he intends to step down as the WG chairman and nominated Dr A. Lewis (NPL) as the sole candidate for the upcoming WG-MRA chair. After agreement within WG-MRA, Dr R. Thalmann invited the CCL to formally elect Dr A. Lewis.

CCL agreed unanimously to Dr A. Lewis as the new WG-MRA chair after Dr R. Thalmann ends his mandate (Decision D.3).

6- Periodicity of WG-MRA meetings:

WG-MRA noted that most work is conducted before WG meetings and that regular meetings are therefore beneficial to the progress in KC activities. So,

WG-MRA asked CCL to support yearly meetings, in non-CCL years outside the BIPM headquarters, preferably in combination with a conference, possibly in the future also as a tele-conference (e.g. through webex).

CCL agreed (Decision D.4).

7- Writing rules for CMCs:

Although this point should have been discussed before the question of the WG-MRA chair, it was moved in the agenda because it was expected to lead to further discussions.

WG-MRA requests that the numerical value notation for CMCs be changed to quantity notation at the first possible opportunity. Therefore, WG-MRA requests the CCL to support a recommendation to the JCRB in line with the Draft document WGMRA-12-51 *Suggestion for conversion of numerical-value equations into quantity equations in uncertainty statements contained in CMCs of Length*, presented by Dr H. Bosse and prepared by René Schödel, with support from Stephan Mieke, Michael Krystek and Peter Franke, all of them from the PTB.

Prof. M. Kühne considered this more of an academic improvement than a real need, with no apparent positive effect, but instead predicts it will introduce a tremendous workload in requiring revisions of all CMCs held in the KCDB. Nevertheless, if approved by the CCL, he would take it to the next JCRB meeting.

Dr H. Bosse stated that the proposal originated in the PTB Precision Engineering Division and explained and defended the rationale behind it, which is included in the Draft document.

Dr C. Thomas opined that this should not be a recommendation but a proposal or advice to the CCL because it is not about CMCs but instead an expression of uncertainties in CMCs: CMCs involve much more than just uncertainties.

Dr R. Bergmans explained that the VSL is not only a NMI but also an accredited laboratory and therefore applies both expressions, one as a NMI and the other as an accredited laboratory, and this is unsatisfactory.

Dr C. Thomas recalled the historical implementation of CMCs, where NMIs were asked about the information they needed and how best to express it. Consequently, CMC uncertainties are now expressed as it was previously decided.

Prof. M. Kühne clarified that the issue had already been discussed at the most recent JCRB meeting but they were not in favour. Anyway, in case of approval by the CCL, he will raise the issue again at the JCRB for discussion.

Although not against the change in principle, Dr C. Thomas could not support it because of the work involved to update so many thousands of uncertainty expressions; remarking that Excel tools are not well adapted to implement these changes quickly. Dr C. Thomas thanked the PTB for its suggestion and exchange of information. Dr R. Thalmann stated that WG-MRA will continue to support this proposal until an improved method to electronically update uncertainties becomes available. Prof. M. Kühne added that if agreement is reached, it would be necessary to inform the other CCs, because of the implications on their CMCs.

CCL agreed to change the status of the document from Recommendation to Proposal, but leaving in the hands of the BIPM Director the actions to be taken, with the following wording (Decision D.5):

The Consultative Committee for Length (CCL),

considering that:

- the expression of existing CMC uncertainties entries are represented as numerical value equations, whereas several international standards and guideline documents strongly recommend to express the relationship between quantities by quantity equations, because quantity equations are independent of the choice of measurement units;

- the entry of data in the existing CMC numerical value equation format as well as the maintenance of the CMC entries is more error-prone compared to their expression as quantity equations;
- several ILAC MRA signatories (accreditation bodies) require from laboratories, which apply for accreditation according to ISO 17025 that the expression of the measurement uncertainties of the calibration laboratory has to be made by means of quantity equations. The use of numerical value equations is not allowed;

taking into account that:

- a change of the CMC writing rules from numerical value equations to quantity equations would affect all existing CMC entries of all CCs as well as several MRA related documents and thus would produce a bigger workload on the NMIs, the RMOs as well as on the BIPM KCDB office;
- the proposed changes of the CMC writing rules could probably not easily be handled within the existing system of CMC excel files and the KCDB data import and data handling capabilities;
- the proposed changes of the CMC writing rules are not time critical;
- a change of the CMC writing rules could most favourably be implemented in combination with other foreseen major revisions of the format of the CMC excel files and / or the KCDB capabilities;

proposes that:

- the director of BIPM considers the matter and takes appropriate actions.

4. REPORT FROM THE WG-N

The Report on Activities in Dimensional Nanometrology, prepared by Dr R. Dixon (NIST) and Dr H. Bosse (PTB), Chair and Co-chair of the WG-N respectively, was presented by Dr H Bosse in the absence of Dr R. Dixon.

Dr H. Bosse began by recalling previous WG-N meetings, the first on 8 June 2010 at A*STAR, Singapore, followed by a one-day symposium entitled “Challenges and Trends in Nanometrology”.

A second meeting had taken place on 19 September 2012, immediately before the 15th CCL meeting at the BIPM headquarters. Between meetings, informal contact was made between several WG-N members at different conferences, standardization meetings, joint research projects, etc.

Dr H. Bosse noted that prior “nano” comparisons organized by the predecessor group DG7, (NANO2 to NANO5) had been completed between 2001 and 2008, with the exception of NANO1 on photomask linewidth, which had not yet started. In 2006, Dr Orji (NIST) proposed a new linewidth comparison, Nano6, which was less ambitious in scope than Nano1, using atomic force microscopy (AFM) and measuring on a silicon wafer.

At present, NANO1 continues to be under preparation while a NIST-PTB bilateral comparison is in progress. NANO6 is under way and the Draft A report is expected in 2013.

Dr H. Bosse suggested the measurement of sub-100 nm pitch standards as a new potential topic, and the characterization of nano-roughness with AFM as a recently proposed activity.

In the field of nanoparticle (NP) characterization, Dr H. Bosse commented that the SC APMP.L-S5 is in progress (see document WG-N 12-43) and that the Draft A report is due in October 2012. Dr H. Bosse presented the results of the successful iMERA joint research project “Traceable characterisation of nanoparticles” (document WG-N 12-44) which resulted in the NPL Good Practice Guide 119 *Determination of the size distributions of spherical NP samples*, which can be downloaded from the NPL website. Ongoing investigations into NP are directed to method-dependent measurement results.

Dr H. Bosse informed of the recent publication of the JRC reference report *Requirements on measurements for the implementation of the European Commission definition of the term “nanomaterial”* (<http://publications.jrc.ec.europa.eu/repository/handle/111111111/26399>) and of new nanoscaled reference materials such as those produced by the NIST (SWCNT and TiO₂) and the IRMM (colloidal silica), and others available from the BAM website of nanomaterials (www.nano-refmat.bam.de).

The next agenda item was the **traceability to SI through Si Lattice**. Dr H. Bosse began with the report of the iMERA JRP “Nanotrace” (doc. WG-N 12-45) which had the aim to develop optical interferometers for displacement metrology with an accuracy of 10 pm and to verify their performance by using X-ray interferometry, required for semiconductor manufacturing, nanosensor characterization, surface science and NMI instrumentation. Dr H. Bosse presented some set-ups together with results of non-linearity measurements in the range of ± 5 pm obtained by the PTB interferometer.

Dr H. Bosse commented on the NIST linewidth metrology project, which has the goal to provide traceable width metrology of specific crystalline Si nanostructures, and the CCQM pilot study P38, which has the goal of comparing SiO₂ film thickness measurements by analyzing the similarities (use of transmission electron microscopy (TEM) and reference to the Si lattice to realize traceability) and fundamental differences (in the measurands) of both projects.

In the opinion of Dr R. Dixon, as chair of WG-N, (1) distributed properties such as film thickness fall within the scope of both the CCL and the CCQM, indicating a possible cooperation, (2) localized nanostructural metrology resides within the CCL WG-N space and (3) studies such as P38 illustrate important limitations of TEM traceability, although these issues are more limiting for film thickness applications than for structural metrology.

In conclusion, *Dr H. Bosse recommended that CCL WG-N with possible input and cooperation of CCQM, prepares a document stating a position on the use of TEM in dimensional nanometrology and realizing SI traceability through the Si lattice (Action A.5).*

This subject is connected with the broader question of intrinsic or atomically-defined standards, which were discussed during the Singapore WG-N meeting, where the idea of a *mise en pratique* for nano dimensional metrology was also proposed.

The presentation continued by commenting on some standardization aspects and the participation of some WG-N members in such tasks, mainly in ISO TC 229 & IEC TC 113, ISO TC 201 and ISO TC 202. Also, participation in other events was described, such as the BIPM-ISO Workshop on Nanometrology, held in February 2010 and at conferences such as NanoScale 2010, in October 2010 in Brno, Czech Republic, with 23 contributions and subsequent publication in a special issue of *Measurement Science and Technology*, 2011, **22**(9), for which Dr J. Garnaes (DFM) obtained the Outstanding Paper Award 2011. He was congratulated on this achievement by the WG-N.

Other conferences where WG-N members participated were SPIE DSS/Scanning 2011, 27-28 April 2011, Orlando, FL, USA, with AFM sessions where six NMIs (NMIA, MIKES, PTB, A*STAR/NMC, NMIJ and NIST) were represented and their contributions published in a special issue of the *SPIE Journal of Micro/nanolithography, MEMS, and MOEMS* (JM3) on AFM metrology, in January-March 2012.

A new conference, SPIE DSS/Scanning 2012, was held on 24-26 April 2012, in Baltimore, MD, USA, where five NMIs (NMIA, PTB, CMS/ITRI, NMIJ and NIST) gave presentations on AFM. Another event was the Workshop on Metrological AFMs (mAFM) which took place in February 2011 at the LNE, which was attended by 25 participant NMIs.

Dr Bosse announced that the NanoScale 2013 conference will be held on 25-26 April 2013 in Paris and invited the CCL, and more specifically, WG-N members to participate. The deadline for submitting abstracts is 1 November 2012.

Finally, Dr H. Bosse proposed that the CCL approve the following WG-N Terms of Reference:

- (1) *To serve as a forum in which NMI experts in dimensional nanometrology can share their experiences, discuss standardization needs, and identify developing trends and traceability needs in dimensional nanometrology.*
- (2) *To promote and rationalize the research into dimensional nanometrology, looking for improving calibration and measurement services within NMIs, so offering new accurate and traceable services as demanded by R&D institutions, industry and other stakeholders.*

(3) To coordinate (in cooperation with WG-MRA) the completion of previously agreed-upon pilot studies, supplementary, and key comparisons in dimensional nanometrology.

(4) To serve as a discussion and development forum for new comparison proposals in dimensional nanometrology and to make recommendations to the CCL when new comparisons are needed.

(5) To serve as a CCL nanometrology contact point for relationships with other CCs and organizations outside CCL.

The CCL agreed to the WG-N ToR and to their inclusion on the corresponding BIPM webpage (Decision D.6).

With respect to the CCL strategic plan 2013-2023, Dr H. Bosse indicated that nanometrology is a rapidly evolving field where disruptive step changes have already occurred and are likely to continue in the future.

At present, several issues of clear importance to the CCL are:

- (1) Intrinsically traceable standards, such as atomically-defined step height standards or TEM measurements calibrated with the silicon lattice. There is a growing need to reach consensus and develop practical guidelines for the use of these standards.
- (2) The challenge of methods divergence. The application-driven requirements on the uncertainty of dimension nanometrology are such that methods divergence – for example between AFM, SEM and optical metrology of linewidth – is becoming larger relative to individual method uncertainties, thus significantly complicating the interpretation of measurement results and of comparisons involving different techniques.
- (3) The related challenge of hybrid metrology in which measurements using multiple techniques are combined to estimate a measurand – for example, NIST has explored the integration of AFM and optical measurements. Such an approach requires rigorous modelling and uncertainty analysis, but it can be advantageous by allowing different measurement principles to complement each other's limitations.
- (4) A need for new comparisons. Photomask metrology, silicon linewidth measurements, and nanoparticle size are areas of significant need where new comparisons are under way or under development.

5. REPORT FROM THE FSWG. STATUS OF THE SINGLE LIST

The Report, prepared jointly by Dr F. Riehle and Dr P. Gill, was presented by Dr P. Gill. The different activities realized by the FSWG such as the list of recommended frequencies, the optical frequency ratios and the protocol for traceability of the metre directly from the Cs clock (K11; comb validation) were described.

Regarding the Joint Recommendations to the CCTF and the CCL, i.e. new entries in the list of recommended frequencies from 10-11 September 2012 will be addressed later.

Dr P. Gill presented the Terms of Reference (ToR) for the FSWG:

1. To make recommendations to the CCL for radiations to be used for the realization of the definition of the metre and to make recommendations to the CCTF for radiations to be used as secondary representations of the second;
2. To maintain together with the BIPM the list of recommended frequency standard values and wavelength values for applications including the practical realization of the definition of the metre and secondary representations of the second;
3. To take responsibility for key comparisons of standard frequencies such as CCL-K11;
4. To respond to future needs of both the CCL and CCTF concerning standard frequencies relevant to the respective communities;

Dr P. Gill then showed a graph with the recommended standard frequencies for secondary representations of the second, for the realization of the metre, and for optical communications. All the information may be found at www.bipm.org/en/publications/mep.html.

With respect to unstabilized 633 nm HeNe lasers, Dr P. Gill explained the inclusion of its frequency in the CCL-CCTF list of reference frequencies, which is complemented by the publication “Advice from the CCL on the use of unstabilized lasers as standards of wavelength: the helium-neon laser at 633 nm”, J.A. Stone, J.E. Decker, P. Gill, P. Juncar, A. Lewis, G.D. Rovera, M. Viliesid, *Metrologia*, 2009, **46**, 11-18.

Due to the many modifications and the new function of the list of frequencies, a complete list will be published in *Metrologia*, following the same general outline of the last complete list (T.J. Quinn, *Metrologia*, 2003, **40**, 103-133), based on the results from the 2001 CCL meeting. Modifications will also reflect the structure of the list of frequencies on the BIPM website. The existing Draft document still needs to be amended by including the 2012 CCTF and CCL recommendations, the uncertainties of the entries (after discussion), and frequency ratios. Submission of the final document is expected by the end of 2012.

Another question raised was the adaptation of the CCL-K11 protocol to include comb-based calibrations of laser frequencies. Regarding the need for protocol revision, discussions took place at the 2009 FSWG and CCL/CCTF meetings and a FSWG sub-group has been established to suggest revisions. The changes drafted comply with the adopted processes for K11 within the period 2009-2012 which have been completed. The Draft protocol has been placed on the FSWG document site. The minor modifications discussed during this meeting will be included.

One of the issues raised with respect to the draft document was the calibration via combs at “higher level of accuracy” i.e., relative uncertainties $<10^{-11}$. In this case, a self-confirmation via peer-reviewed publication is sufficient to demonstrate capability for KC and associated CMC statements, **only** if supported by equivalence of measurements from other NMIs. Another issue is the use of a transportable frequency stable laser as a comb capability validation device. This may be valid provided it is of high enough reproducibility and reliability, e.g. referenced to an atomic/molecular line.

With respect to Optical Frequency Ratios (f/r), Dr P. Gill explained that at the 2009 FSWG and CCL/CCTF meetings this had already been discussed and it was concluded that direct measurements were limited by the Cs realization, however optical frequency ratio measurements are possible with uncertainty less than 10^{-17} .

A FSWG sub-group, led by the NIST, was established to suggest how to utilize such ratio measurements. As a result, some f/r results for synthesized frequencies (already in use) have been obtained, and other f/r values are used for consistency checks $[(f1/f2)_1 / (f1/f2)_2 = 1]$. The long-term goal is to have all measurements versus Cs and f/r in a matrix by using standard algorithms. The issue of f/r will be discussed in a *Metrologia* paper.

Dr P. Gill then explained the list of recommended frequencies (LoR), and what it contains:

- New entries ($^{27}\text{Al}^+$, ^{199}Hg)
- Update of a value in the LoR ($^{171}\text{Yb}^+$ octupole, $^{171}\text{Yb}^+$ quadrupole, $^{88}\text{Sr}^+$, $^{40}\text{Ca}^+$, ^1H)
- Update of the value and uncertainty of a secondary realization of the second (^{87}Sr , $^{88}\text{Sr}^+$, $^{199}\text{Hg}^+$, $^{171}\text{Yb}^+$ quadrupole, ^{87}Rb microwave)
- New secondary representations of the second ($^{171}\text{Yb}^+$ octupole, ^{171}Yb , $^{27}\text{Al}^+$)
- No new realization of the definition of the metre.

A few uncertainties have been kept while some others associated with updated values have been enlarged by a factor 2 or even 3.

A short discussion took place on the interpretation of such enlarged uncertainties. Dr R. Thalmann asked if the new enlarged values were to be considered as standard uncertainties or not. Dr F. Riehle explained that the enlarged values are not exactly standard uncertainties because some other factors have to be taken into consideration. The discussion was concluded because no definitive consensus could be reached; it was decided to accept the list as it is, where uncertainties appear as relative uncertainties.

A proposal from the FSWG for a Recommendation to the CIPM for an updated list of reference frequencies as explained above was accepted at the last CCTF meeting on 11 September 2012, and was presented to the CCL for consideration. The Recommendation is included in Section 13 (see below).

CCL agreed on approving the updated list of frequencies.

Because within the list of eleven frequencies now presented for the approval of the CCL, the one inserted in the second bullet and related to the $^{199}\text{Hg}^+$ ion had not been included in the list when presented for the approval of the CCTF. Before the definitive approval by the CCL, the CCTF should send the CCL confirmation of the approval of the full list. (Action A.6) (Decision D.7)

Regarding other actions, Dr P. Gill explained (1) the set up of guidelines and papers for refereed publications and how to deal with the new values, (2) the development of a protocol for the traceability of the metre directly from the Cs clock (comb validation), (3) the evaluation of the implications of (optical) frequency ratios e.g. for inclusion in the LoR, and (4) the set up of a questionnaire about possible new BIPM activity to support comb validations.

With respect to a request by the CIPM that the procedure for the appointment of the chairperson of each WG should be defined within the Terms of Reference (ToR), the FSWG has added a 5th point to their ToR:

5. The chairperson is appointed by the CCL and the CCTF chairpersons for a period of four years (or at least two consecutive committee meetings) with the possibility of a second term.

Dr P. Gill concluded the presentation and thanked the audience for its attention.

6. STRATEGIC PLANNING

6.1. Outcome of the 24th meeting of the CGPM (2011)

Prof. M. Kühne, BIPM Director, took the floor and reminded attendees that of the ten Resolutions adopted at the 24th meeting of the CGPM (2011), there are only two which affect the CCL: Resolution 1 “on the possible future revision of the International System of Units, the SI”, and Resolution 10 “on the role, mission, objectives, long-term strategy and governance of the BIPM”.

Resolution 10 invited the CIPM to establish an *ad hoc* Working Group charged with conducting a Review of the role, mission, objectives, long-term financial stability, strategic direction and governance of the BIPM.

Such an *ad hoc* Working Group would present the findings of its Review to the CIPM, representatives of States Parties to the Metre Convention and NMI Directors in October 2012, and the CIPM would formulate proposed actions on the basis of the previous findings and implement those within its authority, subject to support from the representatives of States Parties to the Metre Convention and NMI Directors, during the 2013-2014 timeframe.

The CIPM would report later to the CGPM at its 25th meeting on the recommendations from the Review of the *ad hoc* Working Group, actions consequently taken by the CIPM, and proposals for additional actions that require the approval of the CGPM.

This process is known, in short, as the **Strategic Planning Process** which, as indicated above, has to be ready to be circulated to the NMI Directors in October 2012. Within the CCL, the WG-S is in charge of this issue and its valuable input will be presented later.

After this introduction, Mr A. Henson presented, as an aid to this process, a **template for information on Key Comparisons**, to include past comparisons, those in progress, and those scheduled for a future date, including not only the classical information on KCs, but also an estimate of resources in person-months (PM) for piloting and participants (per participant), the rationale for the comparison and how far the light shines, together with special aspects related to logistics.

The template consists of two Tables; Table 1 is a list of completed CC Key and BIPM comparisons, but excludes RMO Key or Supplementary Comparisons; this table should be consistent with the KCDB. Table 2 is a planning sheet for future comparisons for use by the CC (or dedicated CCWG). **This template is to be completed by all CCs.**

This initiative complements the template already created by WG-MRA although they do not handle exactly the same information. This issue and the question of how to act is repeated at the end of item “i”.

6.2. Report of the WG-S

Dr J. Stone, interim chair of the WG-S, described the creation of WG-S in 2009 and the two meetings held so far. The first meeting in Singapore in 2010 defined the ToR and outlined long-term planning strategies to make recommendations to the CIPM and NMIs about length R&D activities. The purpose was to ensure that critical items are not only addressed but also discussed. On this matter, roadmaps such as those elaborated by EURAMET provide valuable input.

As a reminder, within the ToR, bullet point 3 states:

(3) to propose long-term plans for future activities of the CCL over the next ten to fifteen years and to review and update these plans on a regular basis;

The second meeting took place in 2012, immediately prior to the commencement of the 15th Meeting of the CCL, its purpose was to formulate a “Strategy document for rolling programme development”. The work began by correspondence, in order to develop a draft agenda for discussion during the meeting, based on the background provided by Mr A. Henson, on the motivation to assist long-term planning via better coordination/communication between CCs, the BIPM and the NMIs. Reviewing the draft of this background (described later) accounted for most of the meeting.

The strength of the document is the broad agreement reached on baseline material that describes the CCL working groups and their achievements to date. More work is needed to describe the future direction in length metrology, something which requires both structural changes and more consideration of the details.

Dr J. Stone presented a very useful comparison planning document (document WGMRA-12-41_KC_planning) as an example of a work well done, which is intended to maintain the planning of actions for the future, formulated based on historical trends. In the near future the work will continue by correspondence; the deadline for completion is January 2013.

Dr J. Stone completed his presentation by referring to a second issue that was discussed in the 2nd meeting of the WG-S; the new definition of the metre (agenda item 12), in which WG-S expressed reservations (many are uncomfortable with the wording, a concept thought to be difficult to explain to the public) and advantages (WG-S recognized that the wording used fits into the broader framework of the new SI). No clear recommendation was reached.

i Strategic Planning Document

The deadline for receipt of the Strategic Planning Document by the CIPM is January 2013. This will allow distribution to NMI Directors to inform them of planned strategies and to allow the CIPM to prepare the BIPM Programme of Work for 2016-2019. Many countries face difficult economic times and NMI Directors should be updated at a regular interval of 2 years rather than the current interval of 4 years between the General Conferences, to enable them to maintain their support of the international metrological structure.

Dr J. Stone presented the Draft of the strategic planning document (document WGS_Strategy_Planning_Draft) which covers the relevant activities of the CCL and its various working groups: the CCL Working Group on Strategic Planning (WG-S), the CCL Working Group on the CIPM MRA (WG-MRA, with sub-working groups sWG-KC on key comparisons and sWG-CMC on CMCs), the CCL Working Group on Dimensional

Nanometrology (WG-N) and the joint CCL-CCTF Frequency Standards Working Group (FSWG), which has duties (among others) to develop guidance on the verification of optical frequency combs, a subject that impacts on the calibration of lasers for use in dimensional metrology. The work of the Task Group on KC linking, TG-L was briefly mentioned.

After referring to the number of members making up each WG and sWG, Dr J. Stone reminded the Chair of the names and mandate periods, the number of KCs organized between 1999 and 2012 (2 BIPM, 8 CCL and 29 RMO), together with 6 pilot studies in the nano area, most of which were reclassified as SCs, and of 1341 CMCs published in the KCDB and supported by CC activities.

The ToR of all groups were presented including those allocated to working groups and subgroups. Excluding support to comparisons and CMCs, a summary of **important achievements** was listed by Dr J. Stone:

- Establishment of Key Comparisons for length, with selection of the suite of comparisons based on the concept of “How far the light shines” (WGDM, sWG-KC)
- Development of the DimVIM, the CCL Length Services Classification scheme, which has been translated into 13 languages (WGDM, sWG-CMC)
- Development of the concept of CCL-RMO comparisons (interlinked RMOs in the same comparison) (WGDM)
- Writing of guidance documents on formatting of CMCs (WGDM, sWG-CMC)
- Developing methods of analysis, including hosting a workshop (WGDM Workshop on Analysis of International Comparison Results, 13 September 2005, Sèvres)
- Writing comparison protocols that have served as a model for subsequent comparisons (WGDM)
- Writing a detailed guidance document on conducting comparisons and evaluating impact on CMCs (sWG-KC, WGDM)
- Development of linking concepts, including a Workshop on Comparison Linking (Task Group on KC linking TG-L)
- Developed KC log files to assist in tracking the status of ongoing comparisons.

Also presented and described by Dr J. Stone were the **major changes in needs, technologies and areas of interest** since the last CCL meeting and their effect on the activities of the WGs and sWGs, cited as examples were: the advent of frequency combs, the increasing significance of nanotechnology, increasing accuracy in CMMs and their increased use for measurements at the NMI level. The **major challenges and difficulties encountered and issues that require resolution** presented by Dr J. Stone were: piloting and participating in KCs, the appropriate balance for deciding which KC to participate in, linking of CCL and RMO KCs with different artefacts conducted at different times, artefact stability and damage during shipment, customs and shipping problems, and challenges related to frequency combs.

Information on repeat frequencies of any comparison conducted to date was given. Detailed information on repeat frequencies is maintained by the sub-working group on key comparisons (sWG-KC) and is given in the document

“WGMRA-12-41_KC_planning-V1.19.xlsx”, with more detailed information available in “WGMRA-12-30_Changes to KCs each year.xlsx”.

The role of **stakeholders** on several levels (NMI members of the CIPM MRA, RMO certification bodies, standardization organizations, calibration laboratories, equipment manufacturers, military, government legislative and regulatory bodies, industries and consumers) was emphasized. In length metrology, some major industrial stakeholders include the automotive, aerospace, and semiconductor manufacturing sectors, but an exhaustive list would touch every aspect of manufacturing.

The presentation continued with a **Future Scan (2013-2023)**, a vision of the landscape and consequent requirements and measurement challenges anticipated in the future which identified the most likely ongoing requirements and the requirements that will appear or develop in the next 10 years, particularly potential major/disruptive step changes. This is a grey area, because of the difficulty in predicting many issues (evolution of nanometrology intrinsic standards?), CMMs (performance for a wide variety of tasks, free-form surfaces).

An overview of forthcoming measurement challenges (more than twenty) for industry and science were described by Dr J. Stone. These included many measurement challenges that might impact the work of the CCL. These are: intrinsically traceable standards and methods divergence in nanometrology, CMMs, laser trackers, articulated arms, x-ray computed tomography, scanning CMM probes, structured light systems, free-form surfaces, integration of comb technology into measurement systems, machine tools with direct traceability in harsh environments, future factories with metrology embedded in the manufacturing system, etc. This illustrates the potential for a significant expansion of DimVIM to suitably describe measurement tasks for different materials and measuring instruments.

The rationale for various activities planned for the period 2013-2023 were described. A discussion followed considering questions including, (a) what must be done to meet the developing challenges listed previously and (b) does the light from existing comparisons shine far enough to illuminate these new challenges? NMIs are encouraged to undertake research to address these questions, and it is expected that the CCL will play an active role in resolving the outstanding issues.

Based on the previous rationale, Dr J. Stone referred to the list of potential key comparisons and pilot studies required in the period 2013-2023. Dr J. Stone explained that the responsibility for planning future comparisons belonged to the WG-MRA. He also added that the document “WGMRA-12-41_KC_planning-V1.19.xlsx” does not currently include information beyond 2012; WG-KC will develop future strategies as part of actions (A12) agreed at the 2012 WG-MRA meeting.

Dr J. Stone described the frequency repetition of the comparisons considered as key comparisons including testing basic techniques, and the impact of increasing/decreasing their frequency. It was concluded that decreasing the repeat frequency has minimal adverse effect in principle, unless there were changes in staff or equipment. He also presented an estimate of resource implications for laboratories that pilot comparisons.

Discussion of KCs and CC-RMO comparisons took place from the point of view of the strategy. It was queried what would happen in the short term with K11 for instance, if nobody worked on it at the BIPM in the coming years. Prof. M. Kühne commented that although the BIPM had no length programme (this point had been previously noted by

Dr J. Stone), the BIPM could organize workshops of interest for the Length community, with the collaboration of other international organizations. It was noted that the WG-MRA could suggest to the BIPM such workshops and supporting programmes.

It was noted that both Mr A. Henson and Prof. M. Kühne were impressed by the work carried out and the Excel tables showing the comparison data prepared by WG-MRA and the BIPM to show the CIPM the KC strategy. Dr R. Thalmann invited members of the strategic group to continue to support Dr J. Stone in developing the document by sending suggestions for improvement. The document is posted on the restricted area of the WG-MRA webpage, because it is currently still a Draft document and not yet suitable for wider distribution. Dr A. Balsamo asked about the two different templates available which show the KC planning and evolution, one from Dr A. Lewis and the other from the BIPM, which were presented by Mr A. Henson. It was agreed that the information from the Dr A. Lewis' template will be moved by the WG-MRA, within a short time frame [unspecified], to the template designed by the BIPM. The final recommendation on the strategy document suggested by Dr R. Thalmann was to condense the ideas presented to facilitate the reading of the final document by NMIs Directors and other potential users.

Dr J. Stone completed the presentation by commenting on the anticipated schedule for revision of the document: 1 year for exceptions, 2 years for updating of all lists, and 4 years for major revision with extension of the period covered by the rolling programme.

ii BIPM programme of work for 2016 to 2019

As previously commented, the BIPM programme of work for 2016 to 2019 will be developed based on input received from the CCs. In particular, input from WG-MRA, through WG-S, will be included into the strategic planning document which is to be agreed by the CCL before it is sent to the CIPM.

The strategy planning document is currently the only input route to the BIPM programme of work for 2016 to 2019 by the CCL.

7. REPORTS FROM THE DISCUSSION GROUPS

Under this item, the different Discussion Group (DG) moderators presented short reports from their respective DGs.

DG1 - Gauge blocks. The report developed by Dr A. Lewis (NPL) was presented and commented on by Dr R. Thalmann (METAS). Dr R. Thalmann presented the membership list (23 members) and comparison activities including a list of papers on this topic.

Potential topics for discussion recommended by the DG included:

1. a move towards the use of double-ended interferometers for non-wrung gauge blocks, although this shows that other effects such as phase correction and alignment become more important;

2. the operation of precision interferometers for non-gauge block items, over extended temperatures;
3. updating of older styles of interferometer either to use lasers or phase-stepping techniques;
4. new phase-stepping algorithms being applied to gauge block interferometers;
5. studies on long-term trends and stabilities.

Dr R. Thalmann then described the “resurrection” at the NPL of a gauge-block interferometer that was taken out of service before the move to the new building. Dr A. Lassila (MIKES) added a note on a new upgrade that has been made to the NPL-TESA GB interferometer that it recently received.

DG2 - Thermal Expansion coefficient. Report presented by Dr T. Takatsuji (NMIJ) presented a report on CMCs linked to thermal expansion.

After conducting a survey, Dr T. Takatsuji found that there were 6 NMIs registering CMCs, 4 categories related to CTE in DimVIM [2.2.1 GBs (2 NMIs), 2.2.2 Length bar (4 NMIs), 6.3.1 thermal expansion artefact (2 NMIs)], while there are no NMIs with a service linked to CCT Thermometry.

No requests had been received to initiate a new international comparison for some time, but some members have expressed an interest in a new comparison. It may be possible for the NMIJ to prepare a supplementary comparison, but it was noted that the NMIJ instrument is not in good condition after the Tohoku earthquake on 11 March 2011.

Dr R. Thalmann invited Dr T. Takatsuji to contact CCT for a possible action with respect to possible common services (Action A.7)

DG3 - Angle standards and equipment. Report presented by Dr O. Kruger (NMISA).

Dr O. Kruger presented the different angular calibrations existing in CMCs and the DG3 member list.

Regarding **angle standards to be used in future comparisons**, after a survey it was clear that the most accurate calibrations in CMC database are angle **encoders** and that these could be the ideal artefact for future comparisons. **Polygons** are still used as standards but angle blocks are no longer used. With respect to the use of an **Autocollimator**, the conclusion of the EURAMET.L-K3 comparison is needed prior to the results being analysed and a decision reached. Nano-legs encoders were mentioned as possible comparison standards. Although the resolution is less than 1 μ rad, repeatability is not good, so more investigation is needed.

A comment was made about **possible overlap with the CCM with regard to hardness indenters geometry**.

An action for Dr M. Matus emerged (Action A.8) in order to clarify in DimVIM the possible overlap.

Within ongoing research in angle metrology (1) theodolites – angle calibration, (2) gyro theodolites – true north, and (3) EMRP angle project SRT-s10 were mentioned.

Dr R. Thalmann commented that his impression is that customers’ requirements for angle calibration were diminishing and asked if this trend was also occurring in other NMIs.

Dr O. Kruger had the same impression and after consulting other NMIs, concluded that the encoder field is becoming more interesting. Dr H. Bosse confirmed that at the PTB, autocollimators and encoders constituted the most demanding calibrations, while fewer requests were made for angle standards. Dr A. Balsamo explained how length and angle measurements related to CMMs and Laser Trackers are currently expanding. Encoders are important in these applications. Dr A. Lassila supported the previous comments remarking that MIKES calibrates some optical polygons, but most calibrations involve encoders and autocollimators, which confirms the lower importance of angle standards and for the prominence of autocollimators and encoders.

Dr O. Kruger asked *to include this conclusion in the strategic document and to think about the best standard(s) to satisfy angle needs (Action A.9).*

DG4 – Diameter standards. Report presented by Dr J. Stone (NIST)

Dr J. Stone referred to the measurement of diameter standards as a classical field and recalled the seven comparisons that the CCL and the RMOs have recently concluded, stating that three of the comparisons are at the ‘reports in progress’ stage. He referred to specific difficulties in fields such as small holes and also new challenges involved in the use of different techniques. These are probably useful in better characterizing the surface, just the boundary of the standard, which is very critical in contact methods.

Dr J. Stone then invited Dr T. Takatsuji to make a brief presentation on the growing importance and capabilities of computed tomography (CT) to calibrate diameters, spheres and other geometrical features.

Dr T. Takatsuji described X-ray CT measurements of internal/external features of a medical needle. These internal features are at the limit of measurement by conventional instruments. A test made on a “phantom” part constructed by Carl Zeiss, showed differences of less than 1 μm . The real challenge is to determine the boundary of parts in diameters. Dr J. Stone commented that as a first approximation, a difference of 1 μm is a good starting point. Nevertheless, the influence of the material and the surface achievement should be investigated further.

DG5 – Step gauges. Report presented by Dr E. Prieto (CEM)

The report followed the same format as those previously presented. The number of the DG members is 17; two substitutions were made, Dr Coveney (NPL) replaces Dr A. Lewis, and Dr Ganioglu (UME) replaces Dr Yandayan. The changes reflect new responsibilities related to step gauges at their respective institutions.

Dr E. Prieto presented the following comparison activities. EURAMET 2004 and APMP 2006 are concluded and reported, although the results of the latter are not yet on the KCDB, and APMP.L-K5.2006.1 which is in progress was registered on the KCDB in August 2012 as a follow-up bilateral comparison of the previous APMP 2006 between the NPLI (India) and the NMIJ (Japan). This occurred because the NPLI failed to demonstrate its CMC at that time.

Dr E. Prieto also commented on the process of commissioning of a second measurement rig to operate in tandem with the current system at the NPL and on the ongoing work for a new system, still at the design stage, also at the NPL, to measure the coefficient of thermal expansion of step gauges.

With regard to CMCs, Dr E. Prieto commented on 2 new submissions and 1 error correction in the KCDB by the NPL, the MKEH and the BEV respectively, as a result of the past EURAMET.L-K5.2004 comparison.

Regarding DG discussions, because the results of KCs with large data sets are difficult to represent in the results table of the KCDB, as is the case for K5, K6 and K7 comparisons, it is proposed that in future this problem will be addressed at the technical protocol stage by trying to obtain the KCRV and DoE from reduced data sets, perhaps using some type of “super-parameter” (as described in the proposal made by Dr R. Thalmann, document WGMRA-12-48_Results_to_KCDB.pdf). In the previous WG-MRA meeting an action was taken to create a specific group composed of Dr H. Bosse, Dr A. Balsamo, Dr P. Křen and Dr M. Viliesid to study this issue.

DG6 – Coordinate metrology. Report presented by Dr A. Balsamo (INRIM)

Dr A. Balsamo reported on the many participants in DG (21) and stated that it is increasing. A short activity summary informed of the establishment of a collective internet list, CCL-DG6@inrim.it, available to members to allow exchange of emails and documents.

Open issues highlighted were:

(1) Improvement of DimVIM 5.4.4 entry, reference software,

The rationale for this issue is that software is neither an Instrument or Artifact, nor a Measurand; the two column headings in DimVIM. The location and/or description of this entry is not correct in DimVIM. Although a consensus has not been yet reached, it seems that many members agree on changing “reference software” in the column of Instrument or Artefact, to “CMM software”, maintaining the measurand. It was considered to extend this to non-Gaussian features, and make the entry open to any feature; no further action is required.

Dr R. Thalmann considered the important issue of the terms “software validation” or “certification”, instead of “calibration” or traceability. Dr A. Balsamo commented that software is misplaced in DimVIM because it is a computation, and does not measure anything. There is no traceability in software but customers can ask for traceability of different tasks at CMMs. These tasks are very dependent on the software and measurement strategy.

Dr R. Thalmann added that DimVIM is not only for CMCs but that it has many other useful categories. After the meeting, Dr R. Thalmann emailed the argument that soft gauges could be also treated as a “standard reference material”, and that is what several NMIs deliver together with a certificate; also having corresponding CMCs. Testing software is the work of a certification or testing body. So there are two different arguments, and both can be justified. The issue has not yet been concluded and further reflection is needed.

(2) Possible reintroduction of K6

Another issue introduced by Dr A. Balsamo was the possible re-introduction of K6, based on the following rationale. K6 was taken off the list of KCs because of the high cost of ball plates; currently, all KCs are about 1D artefacts, while coordinate metrology covers 2D and 3D measurement. To date there has been no discussion on this topic and the issue is still open for future discussion.

(3) Possible broadening of CMM-related CMCs

Dr J. Stone explained the rationale behind this issue, which is that CMMs are flexible and reconfigurable, while CMCs are rigid and narrow in scope. ILAC regulations require that traceability to accredited laboratories is proven only by calibrations covered by registered CMCs. Some NMIs do provide traceability by means of CMMs which is outside the scope of current CMCs.

As an example consider a CMC as general as “1D gauge”, having several measurands - length, distance, size, ..., DimVIM is composed of two columns “Instrument or Artifact” and “Measurand”. Both columns are condensed into a single column in the CMC table; the next column being “Instrument type or method”. One proposal, still subject to discussion and consideration, is to make reference in this column to “CMM”, so solving the inevitable overlap with other CMCs, e.g. gauge blocks or step gauges. The eventual intent is to extend this facility even more, i.e. to 2D and 3D measurements. In order to start and progress step by step, the 1D artefact would be the first attempt.

Dr P. Gill, related to potential 3D artefacts, and asked about laser scanners. Dr A. Balsamo replied that it is no longer true that CMM is a unique machine, but the concept is now widely applied to laser scanners, articulated arms, laser trackers, micro-CT, etc., and artefacts are needed for all this new equipment. Dr J. Stone asked why not include a 1D artefact in DimVIM, while maintaining some caution with respect to unidirectional or bidirectional measurements. Dr M. Matus replied that this is possible. Dr A. Balsamo agreed on adding 1D artefact to DimVIM but explained this was not the end of the story, because of the implications for reviewing CMCs for instance.

Dr J.C. Oliveira asked if participating in a 1D artefact calibration would qualify the participant to calibrate ring diameters, spheres, etc. Dr E. Prieto considered that it is necessary to distinguish between artefact and measurand because both have a 1D, 2D or 3D nature. A 1D artefact should have at least a “main” 1D measurand, although it could have some others 2D or 3D. Dr R. Bergmans added that it would also be necessary to consider the measuring technique used. Dr A. Balsamo and Dr R. Thalmann insisted that CMCs could easily distinguish in the title the different machine/technique used for calibration.

Dr R. Thalmann proposed Dr M. Matus, the DimVIM keeper, to introduce a new input in DimVIM and to decide on the possible measurands.

*Dr M. Matus replied that he preferred to sum up all the changes needed in DimVIM, including those from other issues included in these minutes, and to make all changes at once. Therefore this action may be considered as already included in **Action A.4**.*

(4) Possible comparison of an industrial-like 3D artefact (possible pilot study, not KC).

This issue was raised by Euramet and Dr M. McCarthy in particular. The rationale for this issue is the complex geometry standards that have been developed recently, e.g. for free form, which may require calibration.

There was no discussion on this topic and the issue has been left open for future discussion, maintaining Euramet as the leading body.

Dr R. Thalmann argued that a proposal for a KC should be based on main techniques. A ball plate is an artefact. This should be investigated in more depth.

DG7 – Line Scales. Report presented by Dr H. Bosse (PTB).

Dr H. Bosse cited the number of members of DG7 (21). In the period since the previous meeting, few technical discussions have been undertaken.

Related to comparison activities, in February 2012 the final report on EURAMET.L-K7.2006 was issued. It was piloted by MIRS, Slovenia, with 31 participants and 2 loops in parallel. The Executive Report has been distributed. Currently, a line scale comparison using a 500 mm scale is being prepared by SIRIM, Malaysia, planned to start in 2013.

Other planned activities are comparison measurements on line, cross and circular features on 2D optical masks, this being of importance for **optical CMMs** and optical measuring microscopes including x-y-position, size and roundness (according to EN ISO 10360:7) of **features on transparent substrates** (masks, plates).

Dr H. Bosse included a list of useful papers related to the matter in his report; many of them were presented at the MacroScale 2011 conference.

As potential topics for discussion he mentioned the following were suggested:

1. To establish an infrastructure to improve the traceability chain for high precision optical size reference measurements on well defined structures (like e.g. photomasks), to optical CMM measurements on different type of measurement objects;
2. To extend the analysis of line scale comparisons with respect to condensed measurement, and the results to be used for linking, where possible. An example of a condensed measurement result is the deviation from nominal length, determined over all measured line positions of a line scale;
3. To extend the measurement capabilities of high precision line scale comparators, e.g. for determination of straightness or roundness deviations of features; standards with graduations calibrated for position and straightness may be valuable references for industrial 2D comparators as well as the recently developed 1.5D length encoder systems;
4. Calibration of length encoders in addition to classical line scales, maybe also by using a length encoder system as a transfer standard for DG 7 comparison measurements;
5. To take into account the application of interferometers, graduated standards and scale-based measurement systems for calibration and position feedback purposes in measurement instrumentation as well as manufacturing equipment, e.g. lithography wafer scanners and machine tools and to analyze the requirements from these applications on calibration aspects of graduated scales at the NMI and accredited laboratory level.

DG8 – Surface Texture. The report, prepared by Dr Baker, was presented by Dr P. Cox (NMIA).

DG8 is composed of 12 members representing all RMOs.

During the discussion, two international comparisons (APMP.L-K8 and EURAMET.L-K8) which are almost complete gave rise to the technical issue of whether to apply a correction of the measured profile due to the physical nature (size) of the stylus tip, which is also relevant to AFM measurement. Further discussion will take place on laboratory responses to intercomparison outcomes regarding outliers or uncertainties and eventual CMC claims. Many NMIs are now developing or purchasing machines for 3D measurement of surfaces, including areal stylus and a variety of optical techniques. These methods have technical issues and require individual standards documents, of which many have already been published. On a smaller scale, AFMs

can be used for roughness measurement. These three areas, which are relatively new, would benefit from properly designed intercomparisons.

The report included a list of recent standards and measurement guides, together with a list of recently published books and papers relevant to surface metrology. A list of upcoming events, of interest to DG8 members was presented.

Dr P. Cox finished his report by introducing some potential topics for DG discussion in line with the ideas presented at the start of his presentation:

1. Comparisons APMP.L-K8 and EURAMET.L-K8:

Linking of intercomparisons (possible CCL advice). How will laboratories respond to outliers?; Discussion on the effect of stylus tip (regarding NIST correction); Should other laboratories make this correction?; What effect will this have on accredited laboratories and manufacturers?; Should ISO 3274 be modified for stricter guidelines?; Review of uncertainties where good performance in key comparison indicates a claimed uncertainty could be reduced; Additional CMCs for many parameters.

2. Research into optical methods

Traceability - Direct interferometry or certified reference materials: steps, angles, optical resolution, Machine settings - wavelength corrections/bandwidth selection/amount of data, Uncertainty of measurement

3. Further development of Areal methods, artefacts and standards

3D parameters: definitions and standards being written, 3D soft gauges, uncertainty of measurement

4. Future intercomparisons

Various optical methods - Measure step heights, 3D parameters, resolution, bandwidth selection, effects of slope angle, different materials (refractive index), 3D Areal - Proposed EURAMET project by Ludger Koenders (PTB) for Spring 2013, AFM roughness - Proposed EURAMET project by Ludger Koenders (PTB) for 2013

5. Expand the contact list for representation of more NMIs.

DG11 – Lasers. Report presented by Dr M. Matus

The current membership of DG11 is 26; most are CCL members. Dr M. Matus referred to comparison activities, APMP.L-K11.1 which is finished, and CCL-K11, which is running with no serious problems, on which 3 final reports have been issued to date for the periods 2007-2009, 2010 and 2011. All three reports have been published in *Metrologia*.

Regarding CCL-K11, 27 NMIs plus 2 other laboratories have participated in CCL-K11 from all RMOs. The workload breakdown of the 5 node laboratories was: BEV (13), MIKES (4), NMIJ/AIST (8), NPL (0) and NRC (4). No participant failed because of incompatible results and no participant stated a higher uncertainty than those published in the CMC tables. There was therefore no need for corrective actions.

Dr M. Matus made the observation that according to the present version of the Technical Protocol, the comparison is open to different high quality standards of various wavelengths. Currently, only iodine stabilized He-Ne lasers emitting in 633 nm have participated, reflecting the situation with service category 1.1.1 of the DimVIM. Moreover, only half were conducted

according to the CIPM MeP. In others, the temperature of the iodine cell was not known and it had no traceability to ITS-90; also there were lasers using modulation transfer spectroscopy and/or frequency offset lasers, which exhibit an inferior performance but have advantages for dimensional metrology; even 3f lasers are increasingly not being operated according to the MeP. Dr M. Matus saw two possible options for the participants in CCL-K11.

- 1) Use the MeP value, parameter values and uncertainty. In this case, the measured frequency is corrected for working parameter deviations and the measurand is the frequency at MeP reference conditions. Responsibility is then assumed partly by the CIPM.
- 2) Calibrated or MeP value for the user's chosen working conditions. Often the measured frequency is not corrected, instead it is accounted for in the uncertainty. In this case, the measurand is the frequency under given stable conditions, not MeP conditions. The stability is then the responsibility of the NMI.

The main consequence of the previously described situation and options is, according to Dr M. Matus, that CCL-K11 final reports and results cannot be used as supporting evidence for the List of recommended Radiations (LoR).

Dr M. Matus presented as a potential topic for discussion the case of DimVIM 1.1.1 "stabilized laser of the MeP": if this is really the top level service and 1.1.2 "other stabilized lasers" constitutes a secondary level. According to the actual interpretation of DimVIM, many NMIs (not all) use for their top level calibration capabilities (combs), the service 1.1.2, reserving category 1.1.1 for specific instruments covered by the MeP, usually with higher uncertainties.

Among NMIs which use 1.1.1 as it is intended, there are still differences in the CMCs originating from the time they were applied for and participated in the corresponding BIPM comparison. The values and uncertainties in the MeP changed over time, but not the lasers.

Dr M. Matus explained that the choice of fitting a specific service either to 1.1.1 or 1.1.2 is arbitrary. Until now there has not been a real problem since the historical background is known, but Dr M. Matus advised that future users of App. C may encounter problems which would exacerbate the matter. A NMI operating a MeP-laser will be able to calibrate a customer's laser with a corresponding uncertainty. The same holds true for a NMI that uses a comb or a different kind of laser (even with high uncertainty) for its calibration service.

The possession of a MeP-laser does not justify a separate service category (otherwise we should include combs and probably other means as new service categories) CMC tables already have a column for the "instrument type or method". It was the opinion of Dr M. Matus, that the DimVIM should reflect calibration capabilities and not the maintenance of standards used for calibration.

A discussion topic may be the revision of DimVIM: aggregation of 1.1.1 and 1.1.2 to a new 1.1.1 (calibration of frequency stabilized lasers), hence dropping 1.1.2 and including present services to the new 1.1.1.

A discussion followed on the value of the CMC if calibrating a stabilized laser against a MeP laser. If so, the U should be higher than the MeP value. There was still some confusion; so, this is to be discussed even if CCL-K11 should be renamed.

As a consequence, an action emerged for Dr M. Matus: DG11 will prepare a proposal to modify the CCL-K11 protocol, if needed, and DimVIM categories (Action A.10).

8. RE-ELECTION OF THE WG CHAIRPERSONS

Dr R. Thalmann is due to stand down as WG-MRA chairman. Dr R. Thalmann proposed Dr A. Lewis to take over the role. There was a full agreement on the appointment of Dr A. Lewis as WG-MRA chairman.

The other WG chairpersons have another term in office and expressed their wish to continue in their roles. This was agreed, and does not require confirmation by the CCL.

9. CCL MEMBERSHIP AND MEMBERSHIP OF WORKING GROUPS. ACCEPTANCE OF TERMS OF REFERENCE OF WORKING GROUPS

Regarding membership of the CCL and Working Groups, Dr R. Thalmann reported no changes were required. However, formal approval of the Terms of Reference of the different WG and sWGs is needed. Most (but not all) of the Terms of Reference of WGs and sWGs have been published on the CCL website.

Dr R. Thalmann reported that:

the Terms of Reference of the joint CCL/CCTF working group on frequency standards FSWG were presented and formally approved (Decision D.8).

With respect to the ToR of WG-MRA, apart from a small variation in the 4th bullet, previously submitted and agreed, some minor changes to the ToR were already made.

Dr R. Thalmann asked CCL for approval of these variations. It was agreed (All variations are considered as integrated in Decision D.1)

As a result of this approval, one action emerged for Dr A. Lewis to:

Take note of this last version of the WG-MRA ToR (Action A.11).

ToR of the WG-N have remained unchanged since 2010. Dr R. Thalmann reminded the CCL of their approval and agreement of the ToR WG-N following the previous presentation made by Dr H. Bosse, the WG-N co-chair (see Decision D.6).

As a consequence of the previous decisions, a new action emerged: Dr Robertsson (BIPM):

To upload these modified/approved ToR into the CCL website. Dr Robertsson should also verify if the acronym FSWG is the official one or not and make the correction if needed (Action A.12)

10. REPORTS FROM THE REGIONS

Although the reports from the regions had already been presented at the WG-MRA meeting, the RMO TC-L Chairmen took the opportunity to emphasize areas of importance.

AFRIMETS (Dr O. Kruger):

Dr O. Kruger presented a map showing the Member States and Associates of the CGPM; and the top priorities of the length working group were outlined: comparisons to support CMC submission; assist countries entering CMCs into the database; sponsorship of comparison and R&D projects; and to identify training requirements. A list of 2012 comparisons in which AFRIMETS members are involved was presented, and a short summary of research activities was provided: a joint research project on gauge blocks (GB) measurements by interferometry using the phase stepping technique submitted by South Africa and Egypt. The AFRIMETS members only meet every two years and combine this meeting with workshops to encourage attendance.

APMP (Dr T. Takatsuji)

Dr T. Takatsuji referred to the 2011 Workshop on Nanoparticle Size Measurement held on 14-15 April 2011 at CMS, Hsinchu, Chinese Taipei, and the following:

The APMP Developing Economies' Committee (DEC) Workshop on Gauge Block Calibration by Interferometry, held on 26-29 September 2011 at NIMT, Thailand, and a second APMP DEC Workshop on Temperature Measurement for Precise Length Measurement, held on 30 October to 1 November 2012, also at NIMT, Thailand.

Dr T. Takatsuji reported on the most recent annual meeting/training/workshop held in Kobe, Japan, on 1-6 December 2011 and the forthcoming annual meeting/workshop which will be held in Wellington, New Zealand, on 24-27 November 2012. This workshop is dedicated to large scale dimensional topics and other topics of interest raised by member laboratories.

EURAMET (Dr A. Lassila)

Dr A. Lassila reported on the EMRP European Metrology Research Programme funded by EU and EMRP countries which has the goal to enhance co-operation between NMIs, industry and other institutes in metrological science. The success in the previous 2010/2011 calls was highlighted by presenting seven individual Joint Research Projects (JRPs) as examples. A list of nine selected proposals for the 2012 Call related to the Length programme was provided.

Future challenges in length metrology were proposed by referring to the EURAMET Roadmap update 2012.

The MacroScale 2011 Conference was very successful for the many NMI members of EURAMET. The forthcoming EURAMET TC-L meeting is to be held at GUM, Warsaw, Poland, on 22-24 October 2012.

SIM (Dr J. Stone)

Dr J. Stone summarized the current status and recent activities of SIM. These were: five active SIM comparisons, five ongoing CCL and other RMO comparisons with participation of SIM NMIs, and four other active comparisons since 2009. He highlighted that SIM

members appear to be in compliance with the 10-year rule agreed for participation in comparisons.

Regarding the updating of CMCs, a new CMC on length bar was submitted by INMETRO (Brazil) in 2012, adding to the five already submitted since 2009. Currently, there are two in the review process, from INDECOPI (Peru) and INTI (Argentina), and four more are planned in the near future by INTI, INDECOPI, and NIST.

Other recent developments highlighted related to technical exchanges, training and conferences: CENAM reported on several activities in 2012, Dr Pekelsky contacted INMETRO in 2011 regarding plane angle and length measurements, while NIST offered a tutorial “Intermediate Dimensional Metrology” during the 2012 NCLSI Conference held in Sacramento, USA, on 29 July to 2 August 2012.

11. PROPOSALS FOR NEW KEY COMPARISONS

No new proposals had been made.

12. THE NEW SI; ADVICE OF THE CCL ON RESOLUTION 1 OF THE 24TH CGPM “ON THE POSSIBLE FUTURE REVISION OF THE INTERNATIONAL SYSTEM OF UNITS, THE SI”

An invitation from the CCU (letter and presentation by Prof. I. Mills) was received by Dr R. Thalmann to discuss this proposal and to send the CCU a possible answer.

Dr C. Thomas presented and commented on the presentation sent by Prof. I. Mills (in fact an abbreviated version of the presentation). The next CCU meeting will take place in June 2013. A reminder that comments should arrive prior to the meeting was made.

Following this presentation, Dr R. Thalmann proposed that the full version of the new SI was not discussed but instead that the focus should be on the metre definition, its wording and the consequences for the length community. A comment was made by the sWG-S that they did not agree with the wording of the new definitions, but they understood the reasons behind such wording. Dr F. Riehle reported recent discussions within some groups regarding definitions of the second and Kelvin definitions but, again, it was stated that the reasons behind such wording were understood. As a result, no action is foreseen.

Agreed proposal: CCL to send a communication to Prof. I. Mills telling him that the CCL is not fully happy with the wording but the reasons behind it are understood. So, CCL takes note of the new definitions (Action A.13).

13. RECOMMENDATIONS TO THE CIPM

The CCL approved the text of the Recommendation presented by Dr Gill on new transition frequencies to be included or updated in the existing list of “Recommended values of standard frequencies for applications including the practical realization of the metre and secondary representations of the second”.

This list of frequencies had previously been presented and discussed at the CCL-CCTF (FSWG).

RECOMMENDATION CCL1 (2012)

Updates to the list of standard frequencies

The Consultative Committee for Length,

considering that

- a common list of “Recommended values of standard frequencies for applications including the practical realization of the metre and secondary representations of the second” has been established,
- the CCL-CCTF Frequency Standards Working Group (FSWG) has reviewed several candidates for inclusion into the list
- the CCTF has recommended these frequencies in its meeting in September 2012*

recommends that the following transition frequencies shall be included or updated in the list of recommended values of standard frequencies

- the unperturbed optical transition $3s^2\ ^1S_0 - 3s3p\ ^3P_0$ of the $^{27}\text{Al}^+$ ion with a frequency of $f_{27\text{Al}^+} = 1\ 121\ 015\ 393\ 207\ 857.3\ \text{Hz}$ and an estimated relative standard uncertainty of 1.9×10^{-15} .

This radiation is recommended to be endorsed by the CIPM as a secondary representation of the second.

- the unperturbed optical transition $5d^{10}6s\ ^2S_{1/2} - 5d\ ^96s^2\ ^2D_{5/2}$ of the $^{199}\text{Hg}^+$ ion with a frequency of $f_{199\text{Hg}^+} = 1\ 064\ 721\ 609\ 899\ 145.3\ \text{Hz}$ and an estimated relative standard uncertainty of 1.9×10^{-15} .

This radiation is recommended to be endorsed by the CIPM as a secondary representation of the second.

This radiation is already endorsed by the CIPM as a secondary representation of the second.

- the unperturbed optical transition $6s^2\ ^1S_0 - 6s6p\ ^3P_0$ of the ^{199}Hg neutral atom with a frequency of $f_{199\text{Hg}} = 1\ 128\ 575\ 290\ 808\ 162\ \text{Hz}$ and an estimated relative standard uncertainty of 1.7×10^{-14} .

* Some values of frequencies and/or uncertainties were not fixed at the FSWG meeting but were communicated later, before the approval of the present Report.

- the unperturbed optical transition $6s\ ^2S_{1/2} - 4f\ ^{13}6s^2\ ^2F_{7/2}$ of the $^{171}\text{Yb}^+$ ion with a frequency of
 $f_{171\text{Yb}^+}(\text{octupole}) = 642\ 121\ 496\ 772\ 645.6\ \text{Hz}$

and an estimated relative standard uncertainty of 1.3×10^{-15} .

This radiation is recommended to be endorsed by the CIPM as a secondary representation of the second.

- the unperturbed optical transition $6s\ ^2S_{1/2} (F = 0, m_F = 0) - 5d\ ^2D_{3/2} (F = 2, m_F = 0)$ of the $^{171}\text{Yb}^+$ ion with a frequency of
 $f_{171\text{Yb}^+}(\text{quadrupole}) = 688\ 358\ 979\ 309\ 307.1\ \text{Hz}$

and an estimated relative standard uncertainty of 3×10^{-15} .

This radiation is already endorsed by the CIPM as a secondary representation of the second.

- the unperturbed optical transition $5s\ ^2S_{1/2} - 4d\ ^2D_{5/2}$ of the $^{88}\text{Sr}^+$ ion with a frequency of
 $f_{88\text{Sr}^+} = 444\ 779\ 044\ 095\ 485.3\ \text{Hz}$
 and an estimated relative standard uncertainty of 4.0×10^{-15} .

This radiation is already endorsed by the CIPM as a secondary representation of the second.

- the unperturbed optical transition $4s\ ^2S_{1/2} - 3d\ ^2D_{5/2}$ of the $^{40}\text{Ca}^+$ ion with a frequency of
 $f_{40\text{Ca}^+} = 411\ 042\ 129\ 776\ 395\ \text{Hz}$
 and an estimated relative standard uncertainty of 1.5×10^{-14} .

- the unperturbed optical transition $1S - 2S$ of the ^1H neutral atom with a frequency of
 $f_{1\text{H}} = 1\ 233\ 030\ 706\ 593\ 518\ \text{Hz}$
 and an estimated relative standard uncertainty of 1.2×10^{-14} .

Note: This frequency corresponds to half of the energy difference between the 1S and 2S states.

- the unperturbed optical transition $5s^2\ ^1S_0 - 5s5p\ ^3P_0$ of the ^{87}Sr neutral atom with a frequency of
 $f_{87\text{Sr}} = 429\ 228\ 004\ 229\ 873.4\ \text{Hz}$

and an estimated relative standard uncertainty of 1×10^{-15} .

This radiation is already endorsed by the CIPM as a secondary representation of the second.

- the unperturbed optical transition $6s^2\ ^1S_0 - 6s6p\ ^3P_0$ of the ^{171}Yb neutral atom with a frequency of
 $f_{171\text{Yb}} = 518\ 295\ 836\ 590\ 865.0\ \text{Hz}$
and an estimated relative standard uncertainty of 2.7×10^{-15} .

This radiation is recommended to be endorsed by the CIPM as a secondary representation of the second.

- the unperturbed ground-state hyperfine transition of ^{87}Rb with a frequency of
 $f_{87\text{Rb}} = 6\ 834\ 682\ 610.904\ 312\ \text{Hz}$
and an estimated relative standard uncertainty of 1.3×10^{-15} .

This radiation is already endorsed by the CIPM as a secondary representation of the second.

Note: The value of the standard uncertainty is assumed to correspond to a confidence level of 68 %. However, given the very limited number of available data there is a possibility that in hindsight this might not prove to be exact.

and asks the CIPM for approval.

14. ANY OTHER BUSINESS

No information added.

15. NEXT MEETING OF THE CCL

It was proposed and agreed to hold the next CCL meeting approximately 3 years from now (2015).

Dr R. Thalmann and Prof. M. Kühne thanked all the participants for the excellent discussions and contributions.

The staff of the BIPM were thanked for their help both during the meeting and behind the scenes.

The meeting was closed on 20 September at 15:00, according to the scheduled agenda.

Appendix L 1

Working documents submitted to the 15th meeting of the CCL

Open working documents of the CCL can be obtained from the BIPM in their original version, or can be accessed on the BIPM website:

<http://www.bipm.org/cc/AllowedDocuments.jsp?cc=CCL>

Documents restricted to Committee Members can be accessed at the [restricted website](#).

Document

CCL/12-01	Agenda
CCL/12-02	Report from the 14th meeting
CCL/12-02.1	List of actions from the 14th meeting
CCL/12-03	WG-MRA report
CCL/12-04	FSWG report
CCL/12-05	WG-N report
CCL/12-06	WG-S report
CCL/12-7.1	DG1 report
CCL/12-7.2	DG2 report
CCL/12-7.3	DG3 report
CCL/12-7.4	DG4 report
CCL/12-7.5	DG5 report
CCL/12-7.6	DG6 report
CCL/12-7.7	DG7 report
CCL/12-7.8	DG8 Report
CCL/12-7.11.pdf	DG11 report
CCL/12-7.11.ppt	DG11 report
CCL/12-10.1	AFRIMET report
CCL/12-10.2	EURAMET report
CCL/12-10.3	APMP report
CCL/12-10.4	SIM report
CCL/12-12	PPT on new SI

Appendix L 2

List of decisions made at the 15th meeting of the CCL

This list is a summary of the decisions made at the 15th meeting of the CCL.

DECISION CCL 1 (2012) – Amending the WG-MRA ToR

CCL agreed in amending the WG-MRA ToR for CCL to delegate the task to approve KC protocols and Reports to WG-MRA and some other minor corrections in the Organization.

The final redaction is as follows:

Terms of Reference WG-MRA

1. Tasks

- To maintain links with the regional metrological cooperation organizations, seeking to ensure the involvement of member laboratories of the CCL in major comparisons in the field of length, thereby providing the means for assuring world-wide traceability and equivalence of length measurements at the highest levels of accuracy.
- To make recommendations to the CCL on the needs and priorities for additional international comparisons in length under the auspices of the CCL.
- To ensure the coordination of CCL and RMO key and supplementary comparisons.
- To approve the Length key comparison protocols and reports.
- To facilitate the inter-regional CMC Review Process, by:
 - a) Establishing and maintaining lists of service categories, and where necessary rules for the preparation of CMC entries;
 - b) Agreeing on detailed technical review criteria;
 - c) Coordinating and where possible conducting inter-regional reviews of CMCs submitted by RMOs for posting in Appendix C of the CIPM MRA;
 - d) Providing guidance on the range of CMCs supported by particular key and supplementary comparisons;
 - e) Identifying areas where additional key and supplementary comparisons are needed;
 - f) Coordinating the review of existing CMCs in the context of new results of key and supplementary comparisons.
- To report to the CCL.

2. Organization

The WG-MRA has the following sub groups and task group:

- a sub working group on key comparisons sWG-KC;

- a sub working group on CMCs sWG-CMC;
- a task group on KC linking TG-L.

3. Membership

- WG-MRA Chair is appointed by the CCL for a period of 4 years (renewable);
- membership includes members of the sub working groups and task groups, moderators of the discussion groups;
- Full voting Members are appointed by the CCL, and non-voting guests may be invited by the WG-MRA, through the Chair.

DECISION CCL 2 (2012) – Periodicity of KCs

CCL agreed in fixing a maximum value of 10 years applying to both the periodicity of KCs and the time interval a NMI needs to provide evidence for its CMCs in a KC topic.

DECISION CCL 3 (2012) – Election of the new WG-MRA Chairman

CCL agreed unanimously to Dr A. Lewis as the new WG-MRA chair after Dr R. Thalmann ends his mandate.

DECISION CCL 4 (2012) – Yearly meetings outside BIPM headquarters

CCL agreed to support the WG-MRA proposal for meetings, in non-CCL years outside the BIPM headquarters, preferably in combination with a conference, possibly in the future also as a tele-conference (e.g. through webex).

DECISION CCL 5 (2012) – Proposal for a new expression of the existing CMC uncertainties

The Consultative Committee for Length (CCL),

considering that:

- the expression of existing CMC uncertainties entries are represented as numerical value equations, whereas several international standards and guideline documents strongly recommend to express the relationship between quantities by quantity equations, because quantity equations are independent of the choice of measurement units;
- the entry of data in the existing CMC numerical value equation format as well as the maintenance of the CMC entries is more error-prone compared to their expression as quantity equations;
- several ILAC MRA signatories (accreditation bodies) require from laboratories, which apply for accreditation according to ISO 17025 that the expression of the measurement uncertainties of the calibration laboratory has to be made by means of quantity equations. The use of numerical value equations is not allowed;

taking into account that:

- a change of the CMC writing rules from numerical value equations to quantity equations would affect all existing CMC entries of all CCs as well as several MRA related documents and thus would produce a bigger workload on the NMIs, the RMOs as well as on the BIPM KCDB office;
- the proposed changes of the CMC writing rules could probably not easily be handled within the existing system of CMC excel files and the KCDB data import and data handling capabilities;
- the proposed changes of the CMC writing rules are not time critical;
- a change of the CMC writing rules could most favourably be implemented in combination with other foreseen major revisions of the format of the CMC excel files and / or the KCDB capabilities;

proposes that:

- the director of BIPM considers the matter and takes appropriate actions.

DECISION CCL 6 (2012) – Approval of the WG-N ToR

CCL agreed on approving the WG-N ToR and on their inclusion in the corresponding place of the BIPM webpage.

The WG-N ToR are as follows:

Terms of Reference WG-N

- (1) To serve as a forum in which NMI experts in dimensional nanometrology can share their experiences, discuss standardization needs, and identify developing trends and traceability needs in dimensional nanometrology.
- (2) To promote and rationalize the research into dimensional nanometrology, looking for improving calibration and measurement services within NMIs, so offering new accurate and traceable services as demanded by R&D Institutions, Industry and other Stakeholders.
- (3) To coordinate (in cooperation with the WG-MRA) the completion of previously agreed-upon pilot studies, supplementary, and key comparisons in dimensional nanometrology.
- (4) To serve as a discussion and development forum for new comparison proposals in dimensional nanometrology and to make recommendations to the CCL when new comparisons are needed.
- (5) To serve as a CCL nanometrology contact point for relationships with other CCs and organizations outside the CCL.

DECISION CCL 7 (2012) – Approval of the updated list of reference frequencies

(See item 13 of these Minutes)

CCL agreed on approving the updated list of frequencies proposed by the CCL-CCTF FSWG as a Recommendation to the CIPM, as presented in the item 13 of these Minutes.

NOTE: Because within the list of eleven frequencies presented for approval of the CCL, the one inserted in the second bullet and related to the $^{199}\text{Hg}^+$ ion had not been included in the list presented to the previous approval of CCTF, the definitive approval of CCL is conditional upon receiving confirmation from CCTF of its the full list approval. (see Action A.6)

DECISION CCL 8 (2012) – Approval of the CCL/CCTF FSWG ToR

CCL agreed on approving the Terms of Reference of the joint CCL/CCTF working group on frequency standards FSWG.

The CCL/CCTF FSWG ToR are as follows:

Terms of Reference CCL/CCTF FSWG

1. To make recommendations to the CCL for radiations to be used for the realization of the definition of the metre and to make recommendations to the CCTF for radiations to be used as secondary representations of the second;
2. To maintain together with the BIPM the list of recommended frequency standard values and wavelength values for applications including the practical realization of the definition of the metre and secondary representations of the second;
3. To take responsibility for key comparisons of standard frequencies such as CCL-K11;
4. To respond to future needs of both the CCL and CCTF concerning standard frequencies relevant to the respective communities.

Appendix L 3**List of actions resulting from the 15th meeting of the CCL**

This is a list of the actions decided upon during the 15th meeting of the CCL, including those carried forward from the 14th meeting.

No	Action	Status
A.1	The WG-MRA will send additions, if any, to the FSWG single frequency list.	
A.2	The WG-N will prepare a document proposing new standards for nanometrology.	
A.3	Dr J.C. Oliveira to inform officially (in writing) to Dr C. Thomas on the COOMET problems. Prof. M. Kühne, BIPM Director, will raise this issue in the next JCRB meeting	
A.4	<p>CCL shall propose to CCPR to group all service categories related to refractive index in their classification scheme, thus to transfer DimVIM service 6.7.1 to CCPR, and to introduce new entries for spectral properties of material.</p> <p>Alternatively CCL would be ready to keep entry 6.7.1, but does not intend to include material properties.</p> <p>Dr M. Matus to introduce a new input in DimVIM (1D artefact) and to decide on the possible measurands.</p>	
A.5	WG-N/CCL, with possible input and cooperation of the CCQM, to prepare a document stating a position on the use of TEM in dimensional nanometrology and realizing SI traceability through the Si lattice	
A.6	CCL-CCTF invited to confirm the approval of the full list of new recommended frequencies, before full approval by CCL	
A.7	Dr T. Takatsuji to contact CCT for a possible action with respect to possible common services.	
A.8	Dr M. Matus to contact CCM in order to clarify in DimVIM a possible overlapping with respect to hardness indenters geometry.	

A.9	WG-S to include in the strategic report the conclusion of Dr Kruger after the survey on angle standards and to consider which are the best standard(s) to satisfy angle needs.	
A.10	Dr M. Matus to prepare a proposal to modify CCL-K11 protocol, if needed, and DimVIM categories (merging 1.1.1 and 1.1.2 in a unique category 1.1.1?)	
A.11	Dr A. Lewis to take note of the last version of the WG-MRA ToR and as a consequence update the ToR	
A.12	Dr L. Robertsson (BIPM) to upload the modified/approved ToR to the CCL website and verify if the acronym FSWG is the official acronym, making the corresponding correction if needed	
A.13	CCL to send a communication to Prof. I. Mills (CCU) stating that the CCL does not fully agree with the wording of the new SI definitions, in particular the metre. The CCL recognizes the reasons for the new definitions and has taken note of these.	

Appendix L 4

Report of the meeting of the Frequency Standards Working Group

BIPM, Sèvres, 10 – 11 September 2012