Consultative Committee for Length (CCL)
President I Castelazo, Executive Secretary G Panfilo

Meets every - 3 years **Last meeting** - June 2018 **Members/Observers** 25/4	**Working groups**: Nano, MRA, Strategy; Joint CCL-CCTF Frequency Standards WG; +12 Discussion groups		
Comparison activity	**Completed**	**In progress**	**Planned**
CCL KCs (& CC Supplementary)	8+ (4)	2	9
RMO KCs (& SCs)	31+ (52)	9+ (12)	3 + (no data)
BIPM comparisons	2	0	0
CC Pilot studies	4 (later upgraded to SCs)	0	0
CMCs	1641 CMCs in 102 service categories		

Pointers to the future, stakeholder needs and technological developments

- **Micro and Nanotechnology**: Application of Si lattice based length standards for traceability; methods divergence (*e.g.* difference of AFM, SEM and optical metrology of linewidth); hybrid metrology (AFM plus optical); nanoparticle size (multiplicity of standards *e.g.* 100+ definitions of diameter); scaling up of AFM and scaling down of coordinate metrology; integrated metrology for *e.g*. self-assembly; metrology enhancement of AFMs (traceability, speed, range).
- **Coordinate metrology**: Uncertainty estimation and performance verification for flexible systems (CMMs, laser trackers, laser scanners, X-ray CT); use of 'virtual instruments', refractive index limits in air, thermal compensation for T≠20 °C.
- **Optical frequency combs**: Widespread use of comb technology might require new verification methods.
- **Angle measurement technology**: Encoder technology taking over as traditional artefacts *e.g.* angle blocks diminish in importance. Previously neglected influences (*e.g.* air refraction, discovered by data mining a key comparison's results) becoming limiting factors.
- **Industrial demand for higher accuracy** in dimensional metrology: coordinate measurement *via* X-ray tomography, articulating arms, laser trackers & scanners, indoor GPS; digital manufacturing, GNSS impacting at macro scale, refractive index measurements in non-uniform environments (& thermal compensation on measurands to 20 °C), multi frequency/colour combs/lasers for absolute interferometry (departing from 633 nm helium neon), large areas assessment in manufacturing, intrinsically traceable metrology, in process metrology. Emerging needs include applications spanning a variety of length scales, such as particle accelerators (~10^3 m), aerospace (~10^2 m), pressure standards (10^{-1} m), fuel injectors (10^{-4} m), and nano-technologies (~10^{-9} m and smaller) - where nano-technology includes measurements of feature size, form, and/or location for semiconductor & nanoelectronics, nanoparticles, nano-structured surfaces, and nano-biological systems.

Workload Trend & Workload Management

- Currently 7 comparisons (gauge blocks, angle standards, cylindrical diameter, step gauges, line scales, surface texture and laser wavelength) test the principal techniques/skills using a matrix approach. The set may evolve/increase but no plans to reduce, it is considered a minimum set needed to test basic measurement techniques.
- 7 of the tentatively planned KCs are repeats only (1 ongoing). Thus, if the discussed new technologies do indeed lead to the need for comparisons, list may grow but the resources to participate in comparisons is relatively modest. Needs for new comparisons might be particularly anticipated in nanometrology and 3D flexible CMMs. Inter-RMO comparison schemes reduce the overall workload.
- With a set list supporting the basic techniques, possible increase in the workload depends on whether potential new measurement areas develop in the NMIs, requiring new comparisons.
- Lengthening the time between comparisons would in principle have little adverse effect, if the quality system is working properly. CCL already changed from 7 to 10 years with no adverse issues.
- There is already a lack of support in the NMIs for taking on the burden of piloting and/or the purchase of the required artefacts, which are often unusable after comparison circulation) – some high accuracy artefacts (needed to test SOA CMC claims) can be €5k-€30k value and suffer damage (due to monthly handling/measurement in KC, *cf.* 3-yearly use in 'real' use.
- Resources: piloting 1 pm, participation 0.25 pm (per lab). Values given are minimal, for repeating a well-established, small/medium comparison with no problems and measuring equipment ready on schedule at each NMI. Large, delayed comparisons with unstable artefacts, re-planning, detailed analysis can add 1 pm+ to the piloting.

BIPM – references to laboratory activity at the BIPM

- BIPM has no laboratory activity in Length so reference to historical BIPM comparisons only, there are no suggestions in the strategy for activity at the BIPM. Recommend continuation of educational activities.