



Report of the CCM Working Group on Mass (inc. CCM-TGPfD-kg)

Stuart Davidson

20th CCM meeting, 26-27 June 2025



WG and TG Meetings



- **WG Mass meetings held 24 June 2025**
- **CCM Webinar outlining the work of WG Mass held 30 April 2024**
- **Meeting of the CCM Task Group on the Phases for the Dissemination of the kilogram following redefinition (CCM-TGPfD-kg)**
 - July 2023
 - July 2024
 - April 2025
 - June 2025

Report from the last meetings of the (CCM-TGPfD-kg)



Report from the last meetings of the (CCM-TGPfD-kg) **CCM**

Task Group Members

- Dr Stuart Davidson, NPL (Chair)
- Dr Hao Fang, CCM Executive Secretary, BIPM
- Dr Richard Green, NRC
- Dr Dorothea Knopf, PTB
- Dr Naoki Kuramoto, NMIJ/AIST
- Dr David B. Newell, NIST
- Dr Lars Nielsen, DFM
- Dr Michael Stock, BIPM
- Selected to give balance of realisation experiments and RMOs
- All members happy to continue
- New member(s) proposed to include more NMIs without realisation experiments

CCM-TGPfD-kg Terms of Reference



The dissemination of the kilogram after 20 May 2019 is taking place in three consecutive phases:

- Traceability to the IPK (taking into account the additional uncertainty from the new definition) (May 2019 to Feb 2021),
- **Dissemination of individual realizations (in the future).**
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Based on "the *mise en pratique* of the definition of the kilogram" and on "the CCM short note on the dissemination process after the proposed redefinition of the kilogram" the task group will:

- Ensure the correct implementation of the present traceability across the period of the redefinition of the kilogram,
- a detailed calculation of the consensus value and its uncertainty and oversee the transition for the "present traceability" to the use of the consensus value,
- Propose methods to maintain the best possible stability of the consensus value over time (including comparison periodicity),
- Propose clear criteria for moving from the consensus value dissemination phase to the individual realization dissemination phase,
- Maintain a detailed document describing the three dissemination phases for the CCM and the mass community. This document includes the calculation of the consensus value, its uncertainty and time scale as well as any other relevant information related to the dissemination of the kilogram,
- Provide advice to the CCM-WGM in all questions regarding traceability of the kilogram during the first two phases above.

2023 CCM recommendation on improving agreement in the realisation experiments



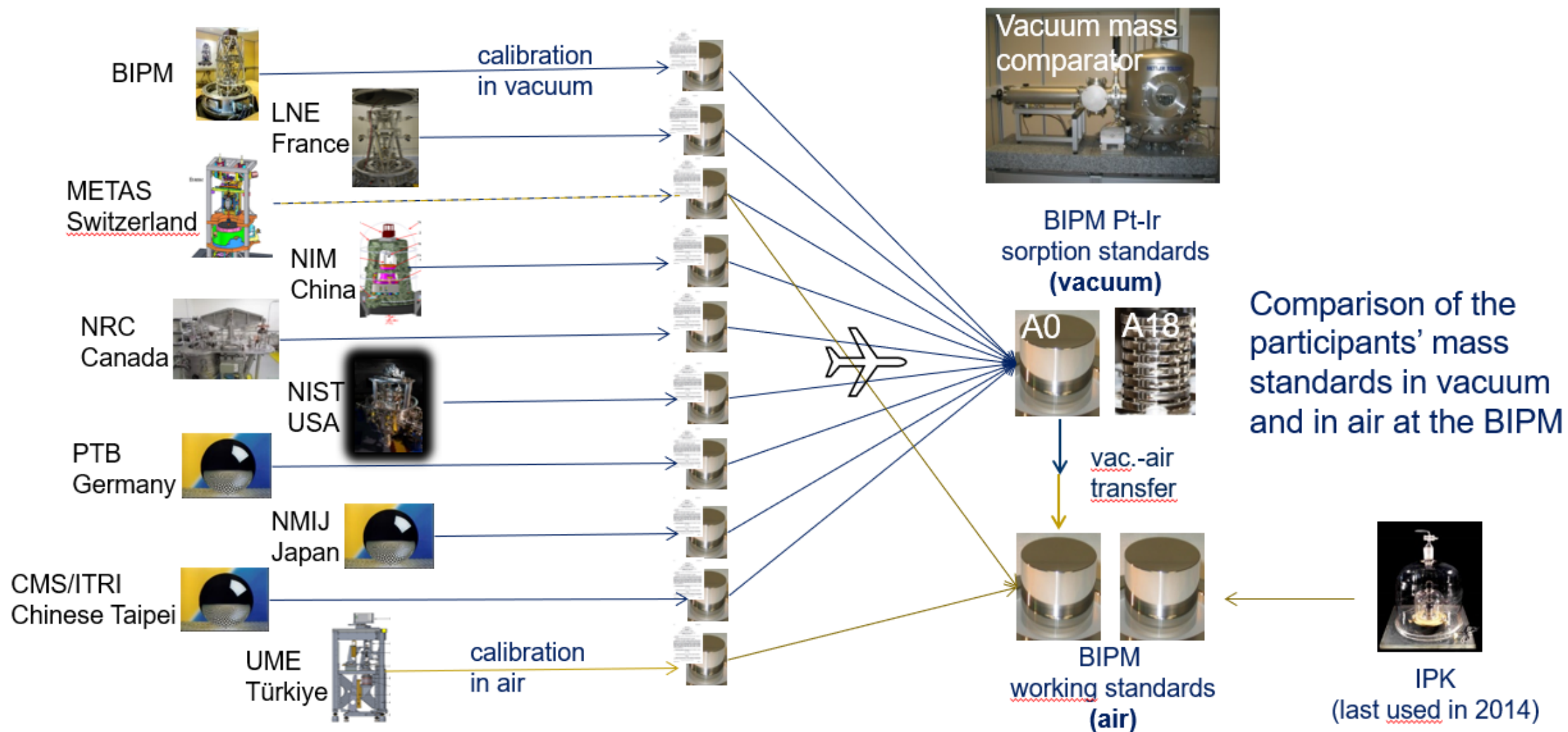
encourages all National Metrology Institutes to support of primary mass values suitable for the kilogram, requests those National Metrology Institutes to direct activities to direct the kilogram, reminds member states that the kilogram will have comparison through the kilogram, recommends that the redefinition outline realization experiments

	2023	2024	2025	2026	2027	2028
BIPM Kibble		Continuing reproducibility check		Dynamic S/N, Laser alignment, electrical noise Work (with NIST) on compact KB		Mech. improvement to minimize parasitic coil motion
	Mass Comparison of Si spheres (inc. sorption effects)					
PTB XRCD				Improvement/check of material measures Further research on lattice parameter with partners (EURAMET, IAC, ...)		
	Comparison of volume and surface characterisation	Comparison of Si sphere by XRCD and KB		Comparison of volume and surface characterisation		
NMIJ XRCD				Improvement of volume measurement		
NIST Kibble	Investigation of "dark" uncertainties inc. vibration effects			100 g NMI level Kibble balance Comparison with Si sphere Collaboration with RISE on 100 ohm QHR array		
	Comparison of alternative weights (500 g to 100 g) on Kibble balance					
NRC Kibble	Repair to QHR, investigate sorption			Operational Improvements Control system upgrades Investigate high-temperature voltage standard		

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CCM.M-K8 Comparison of Realisation Experiments

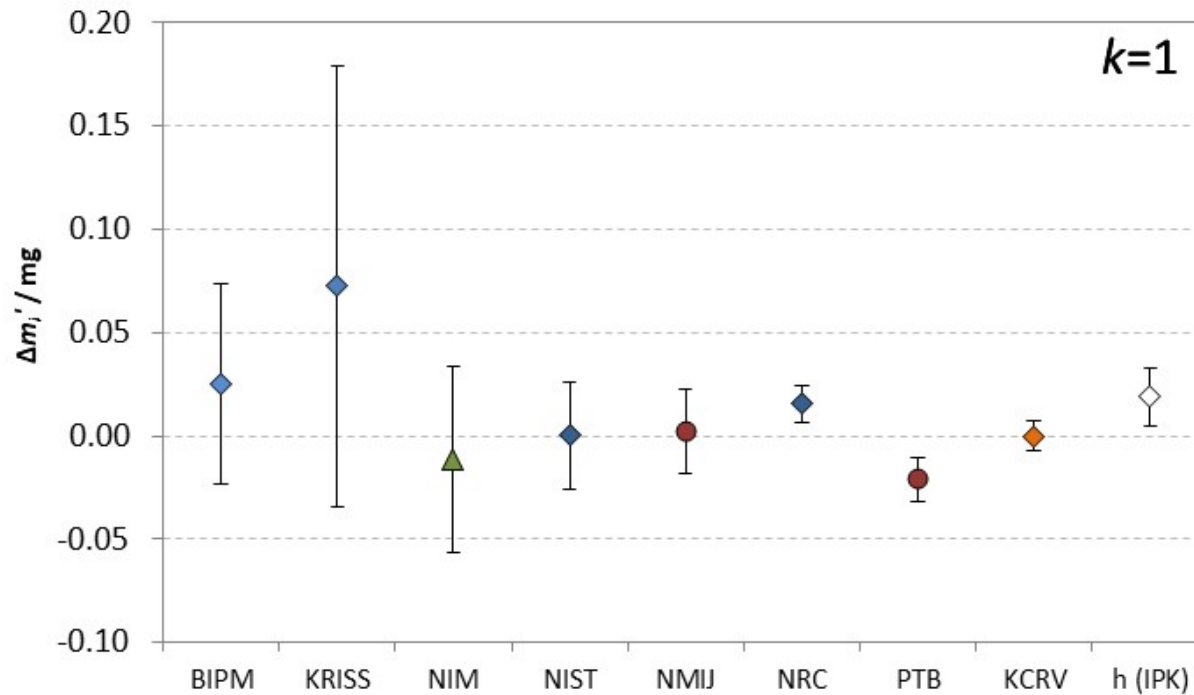


CCM.M-K8.2024

Reminder of the two previous comparisons



CCM.M-K8.2019

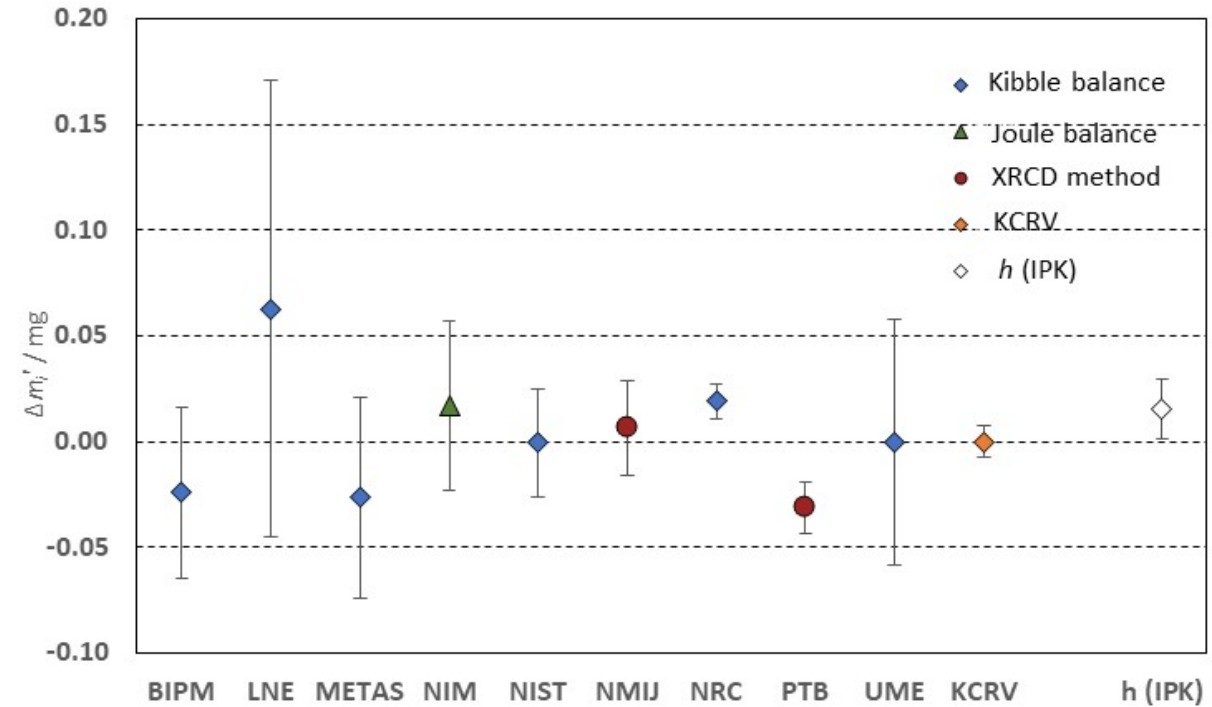


7 participants

KCRV = -0.0188 mg, $u = 0.0075$ mg

NRC – PTB = 0.0364 mg

CCM.M-K8.2021



9 participants

KCRV = -0.0152 mg, $u = 0.0074$ mg

NRC – PTB = 0.0501 mg

Report from the last meetings of the (CCM-TGPfD-kg)



Highlights

- Ongoing organisation of key comparison of realisation experiments
 - CCM.M-K8.2024 measurements complete
 - Significant improvement in agreement of results
 - Next Comparison 2027
- Ongoing assessment and adjustment of the Consensus Value of the kilogram (based on the results of the K8 comparisons)
 - Likely change – 5 μg , end 2025
- Finalisation of a guide to the Consensus Value of the kilogram (aimed at mass end users)

The Consensus Value of the kilogram

CCM-TGPfD-kg*

a) 1889-2019



b) 2019-Present



c) Post Consensus Value



The **Consensus Value of the kilogram** (CV-kg) is the one-kilogram reference for the SI mass unit based on the fixed value of the Planck constant. It is represented by an aggregate of measurements performed by experiments at the **Bureau International des Poids et Mesures** and **National Metrology Institutes** (NMIs) from around the world that can **realize** the kilogram directly from the **Planck constant**. It can be considered as the global **realization** of the kilogram within the International System of Units (SI).

Criteria for moving to Phase 3 (individual realisations)



CCM detailed note on the dissemination process after the redefinition of the kilogram

4.3.1 Criteria for transition from Phase 2 to Phase 3 of the dissemination process

- a) A minimum of five consistent realization experiments which:
 - I. Achieve Key Comparison results with a relative standard uncertainty of 40 parts in 10^9 or better
 - II. Demonstrate consistency with the KCRV
 - III. Demonstrate stability by producing consistent (equivalent) results for two consecutive Key Comparisons
- b) At least three of the realization experiments meeting the above criteria should have uncertainties less than or equal to 20 parts in 10^9 .
- c) The consistent set of experiments must include two independent methods of realizing the SI unit of mass (e.g. Kibble balance and X-ray crystal density experiments).
- d) The difference between the Consensus Value for the kilogram (determined from three last 3 Key Comparison results) and the KCRV for the final Key Comparison is less than 5 parts in 10^9 .

How will Phase 3 (individual realisations) be implemented



Options include

- Dissemination from “validated” realisation experiments (at the uncertainty of the individual experiments)
- Dissemination from an “international mean kilogram” (at the BIPM)
 - Uncertainty of 20 μg (as for Consensus Value)
 - With the uncertainty of the last KCRV ($< 10 \mu\text{g}$)

SI at point of need

- SI realisations by end users - how will these need to be validated



Report from the WG Mass



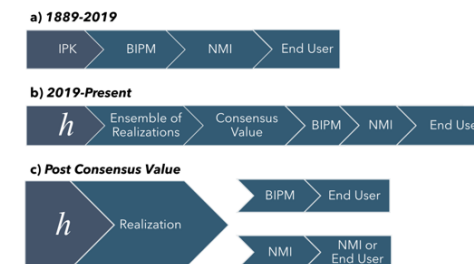
Main actions and achievements

- Recommendation on addressing discrepancy in realisation experiments published
- Roadmap to address realisation experiment discrepancy developed
- Measurements complete for CCM.M-K8.2024 comparison of realisation experiments
- Progress has been made in addressing the lack of agreement between realisation experiments
- Guide to the Consensus value completed
- Guide to CMC submission and review completed
- Coordination of digitalisation projects



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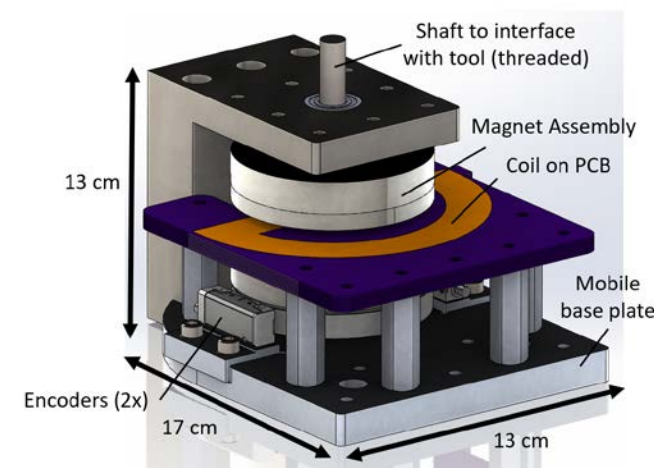
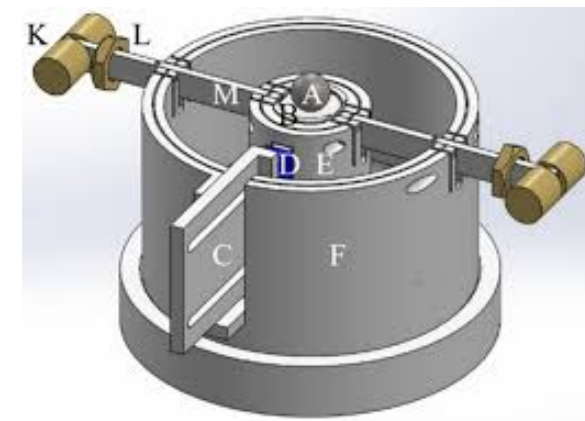
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NMI XRCd	Comparison of volume and surface characterization	Comparison of Si sphere by XRCd and KB		Comparison of volume and surface characterization Improvement of volume measurement		
NIST Kibble	Investigation of "dark" uncertainties and vibration effects			100 g KMM level Kibble balance Comparison with Si sphere Collaboration with NIST on 100 gram QM array		
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Progressing the state of the art



Realisation experiments

- Improvements in uncertainties of realisation experiments and increase in number of experiments
- Progress in addressing the lack of agreement between realisation experiments
- Application of Kibble balance technology to develop:
 - Commercial and table-top balances
 - Micro-Kibble balance
 - Torque realisation instruments
 - Radiation force balance



Progressing the state of the art



Digitalisation

- Completed automated evaluation of a virtual comparison of mass using the Digital Calibration Certificate (DCC) schema
 - 10 Participants: PTB, NPL, MSL, UME, NMII, KRISS, NIM, INRIM, NRC, CENAM
 - Measurement: Sensors, Volume 38, Supplement, May 2025, 101361
 - Next step to use more “complicated” comparison (multiple weights, density) and to increase functionality (e.g. automatic check of results against CMCs in KCDB)
- Addressing Interoperability of mass DCCs
 - Cross RMO collaboration
 - Partners include end users (Mettler-Toledo, Sartorius)
- BIPM Forum on Digital Metrology (FORUM-MD) includes WG on coordination between CCs



Liaison & stakeholders



- IMEKO TC3, OIML, weight and balance manufacturers
- BIPM Forum on Digital Metrology (FORUM-MD) includes WG on coordination between CCs
- Work on DCCs across RMOs and with end users (Mettler-Toledo, Sartorius)
- Presentation of CCM strategy delivered to CCQM Task Group on Food Measurement (CCQM-TG-FOOD)

Improved liaison

- Webinars on areas of special interest (e.g. digitalisation) and for training will be planned
- Interim meeting of Working Group to be scheduled (on-line or with Kibble balance technical meeting)
- Regular meetings with RMO TC chairs scheduled to ensure effective coordination of KCs and SCs and dissemination of information

CIPM MRA: KCs & CMCs



Measurements Completed	CCM.M-XX	Mass Values of Travelling/Transfer Standards				
1998	K1				1 kg	
1999	K2	100 mg	2 g	20 g	500 g	10 kg
2009	K3					50 kg
2012	K4				1 kg	
2003	K5	200 mg	1 g	200 g	2 kg	
2013	K6					50 kg
2015	K7	500 mg	5 g	10 g	100 g	5 kg
2020	K8.2019				R-1 kg	
2022	K8.2021				R-1 kg	
2025	K8.2024				R-1 kg	
2026	K2 2024	100 mg	2 g	20 g	500 g	10 kg
2026	K4.2026				1 kg	
2028	K8.2028				R-1 kg	

CIPM MRA: KCs & CMCs



- CCM.M-K2.2024 sub-multiples of the kilogram scheduled to start end 2025, complete 2027
- CCM.M-K4.2026 comparison of SS kilogram standards
 - Last run 2013
 - Pilot BIPM scheme will involve participants sending their own (suitable) transfer standards to the BIPM (same model as the K8 comparison of realisation experiments)
- CCM.M-K8.2027 comparison of realisations experiments to be repeated every 3-4 years
- CCM.M-K6 comparison of 50 kg last performed 2013 needs to be repeated
- Proposed Pilot studies for Centre of Gravity and Magnetic Susceptibility measurements



Program of work for the next 2 years



- Complete Draft A and Draft B of CCM.M-K8.2024
- Adjustment of the Consensus Value of the kilogram
- Publish guide on Consensus Value of the kilogram
- Publish guide and submission and review of CMCs
- Complete and publish guidance, examples and spreadsheets on rationalisation (reduction on number) of CMC entries
- Complete CCM.M-K2.2024 sub-multiples of the kilogram
- Aim to Complete CCM.M-K4.2026

Proposals (KCs, chairmanship, membership...)



- WG Mass - Stuart Davidson (Chair) Richard Green (Vice-Chair)
- CCM-TGPfD-kg - Stuart Davidson (Chair) Additional member(s) proposed
- WG Mass new members
 - KEBS, Kenya
 - NIMT, Thailand
- Comparisons
 - CCM.M-K4.2026 Stainless Steel kilograms
 - CCM.M-K8.2027 Realisation experiments
 - Pilot Study – determination of Centre of Gravity
 - Pilot Study – Measurement of magnetic susceptibility of mass standards

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Thank you.

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