



Report from the CCM Task Group on the Phases for the Dissemination of the kilogram following redefinition (CCM-TGPfD-kg)

Stuart Davidson
19th CCM meeting, 25-26 May 2023

CCM-TGPfD-kg Report

- The work of the Task Group
- The 2023 consensus value for the kilogram
- CCM recommendation to address the discrepancy between current realisations of the kilogram

CCM-TGPfD-kg - Membership

Chair

Dr Stuart Davidson

National Physical Laboratory
United Kingdom

Members

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

Phases of Dissemination of the kilogram

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

- Traceability to the IPK (but taking into account the additional uncertainty coming from the new definition) (May 2019 to February 2021),
- Dissemination of the consensus value (from February 2021),
- Dissemination of individual realizations (in the future)

<https://www.bipm.org/en/committees/cc/ccm/wg/ccm-tgpfd-kg>

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CCM-TGPfD-kg - Terms of Reference

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,
- Propose 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.

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Meetings of the CCM-TGPfD-kg

– Three meetings of the CCM-TGPfD-kg

- Monday 3rd October 2022
- Friday 21st April 2023
- Wednesday 25th May 2023

Meeting (3rd October 2022)

– Discussion

- Review of results of CCM.M-K8.2021 KC of realisation experiments
- Calculation of the new Consensus Value
- Recommendations to WG members and NMIs
- Implementation date for new CV
- Provisional schedule for next KC

Meeting (21st April 2023)

– Discussion

- Draft CCM recommendation to address the discrepancy between current realisations of the kilogram
- Ongoing schedule for Key Comparisons of realisation experiments
- Proposal to change way the KC results contribute to the next Consensus Value
- Discuss strategy to address the discrepancy between realisations

Meeting (24th May 2023)

– Discussion

- Review draft CCM recommendation to address the discrepancy between current realisations of the kilogram
- Ongoing schedule for Key Comparisons of realisation experiments (2024 vs. 2023)
- Proposal to change way the KC results contribute to the next Consensus Value
- Discuss strategy to address the discrepancy between realisations

All minutes at: <https://www.bipm.org/en/committees/cc/ccm/wg/ccm-tgpdf-kg>



The 2023 Consensus Value for the kilogram

Stuart Davidson
19th CCM meeting, 25-26 May 2023

CONSULTATIVE COMMITTEE
FOR MASS AND RELATED QUANTITIES

2021 (first) Consensus value

- The consensus value is calculated as an arithmetic mean of the last 3 “results” for the value of the kilogram
- The consensus value is relative to the mass value of the International Prototype Kilogram (IPK)
- The uncertainty in the consensus value has been fixed as 20 μg ($k = 1$)
- 2021 required no adjustment to mass scale but an increase in CMCs to accommodate the uncertainty needed to be made

	Value (1 kg +) / μg	Standard Uncertainty / μg
International Prototype Kilogram	0	10 [†]
Pilot Study Reference Value (2017) [2]	12.4	11.4 [†]
Key Comparison Reference Value (2020) [3]	-18.8	7.5 [†]
Calculated Consensus Value (arithmetic mean)	-2.1	20[‡]

2023 Consensus value

- The consensus value is now entirely based on the results of the realisation experiments
- 2023 consensus value differs significantly with respect to the value of the IPK
- An adjustment to the mass scale (-7 micrograms relative to the IPK) was required (no further adjustment to CMC required)

	Value (1 kg +) / μg	Standard Uncertainty / μg
Pilot Study Reference Value (2016)	12.4	11.4 [†]
KCRV of the first CCM.M-K8 (2019)	-18.8	8.1 [†]
KCRV of the second CCM.M-K8 (2021)	-15.2	7.4 [†]
Calculated Consensus Value (arithmetic mean)	-7.2	20[‡]

Action required

("Calculation of the Consensus Value for the Kilogram 2023")

- To achieve consistency with the 2023 consensus value, all NMIs would need to reduce the mass value of their national as-maintained mass unit by 7 μg with respect to the mass value based on the IPK or by 5 μg with respect to the consensus value of 2021.
- It is recommended to all NMIs to state clearly on their certificates the traceability to the Consensus Value 2023, for example, using the following sentence "The calibration results stated in this certificate are based on the Consensus Value of the kilogram commencing 1st March 2023."
- The adoption of the consensus value of 2023 requires no further adjustment to the published CMCs of NMIs.

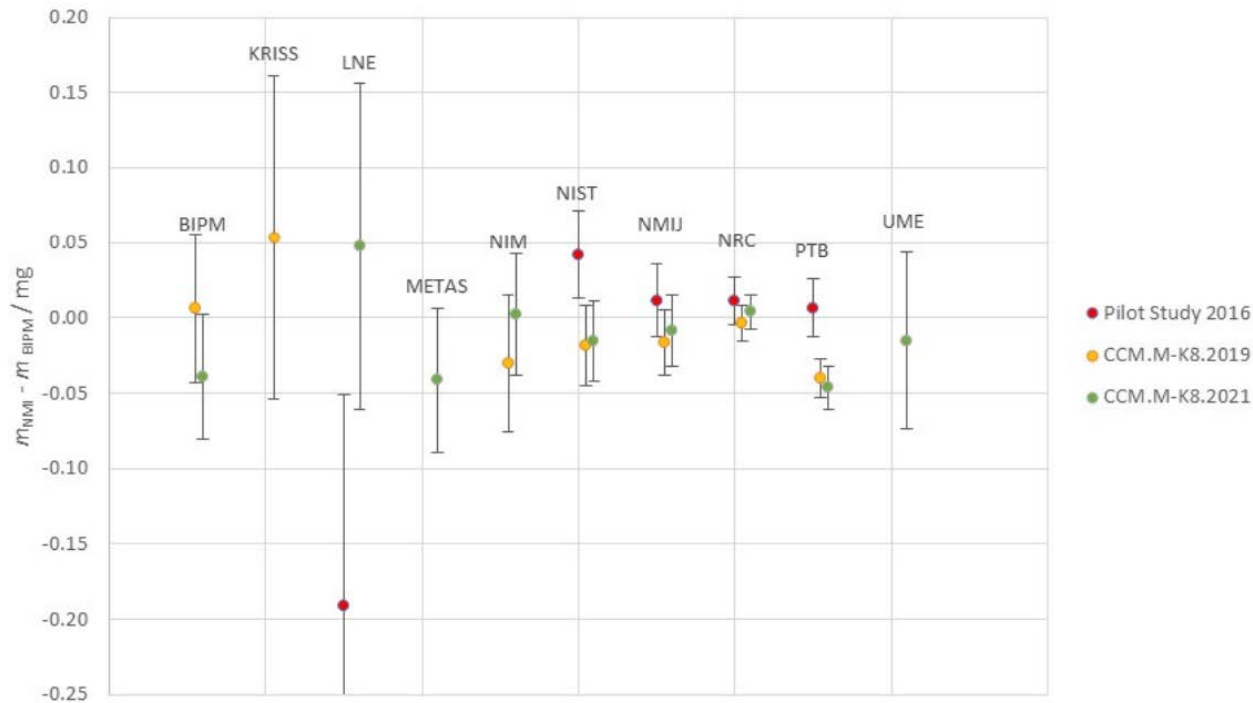


CCM recommendation on addressing lack of agreement in the realisation experiments

Stuart Davidson
19th CCM meeting, 25-26 May 2023

Background

- Experiments are evolving, uncertainties are improving but agreement is not getting significantly better



Background

- Use of Consensus Value for the kilogram ensures global consistency but the value is changing each time a KC is completed
- The ultimate aim of the redefinition process is for reliable and consistent dissemination from **individual realisation experiments** to be possible
- This will allow transition to Phase 3 (sovereign dissemination from individual realisation experiments).

	Value (1 kg +) / μg	Standard Uncertainty / μg
Pilot Study Reference Value (2016)	12.4	11.4 ^t
KCRV of the first CCM.M-K8 (2019)	-18.8	8.1 ^t
KCRV of the second CCM.M-K8 (2021)	-15.2	7.4 ^t
Calculated Consensus Value (arithmetic mean)	-7.2	20^f

Rational

- There is a need to acknowledge the discrepancies in the experiments
- We need to encourage activities to specifically investigate these discrepancies
- A roadmap and/or strategy document will be produced to accompany the recommendation and give more detail of the specific activities intended to investigate the discrepancies (examples later).

The recommendation - context

recalling the redefinition of the kilogram in terms of a fixed numerical value of the Planck constant on 20 May 2019 and the “CCM detailed note on the dissemination process after the redefinition of the kilogram” outlining phases for the implementation of the redefined kilogram,

recognizing the work of NMIs to improve experiments and to develop new experiments but noting the results of Key Comparisons CCM.M-K8.2019 and CCM.M-K8.2021 which show a lack of agreement between realization experiments,

The recommendation - context

considering

- the approval of the final version of the mise en pratique for the realization of the new definition of the kilogram and its future dissemination,
- that as many (consistent) realizations of the kilogram as possible should be available to NMIs,
- that the following conditions to allow sovereign realizations of the kilogram have been outlined in the “CCM detailed note on the dissemination process after the redefinition of the kilogram”:
 - 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
 - At least three of the realization experiments meeting the above criteria should have uncertainties less than or equal to 20 parts in 10^9
 - The consistent set of experiments must include two independent methods of realizing the SI unit of mass (e.g. Kibble balance, joule balance and X-ray crystal density experiments)
 - The difference between the Consensus Value for the kilogram (determined from the three last Key Comparison results) and the KCRV for the final Key Comparison is less than 5 parts in 10^9

The recommendation

encourages all National Metrology Institutes to continue research and further improve experiments in support of primary realizations of the SI unit of mass at appropriate levels of accuracy and at different mass values suitable for current and anticipated applications,

requests those National Metrology Institutes having a realization of the kilogram to engage in targeted activities to directly investigate any lack of agreement between individual NMIs' realizations of the kilogram,

reminds members of the CCM that all Member States not having realizations of the new definition of the kilogram will have direct access to traceability to the same consensus value as determined by the ongoing comparison through the calibration services of the BIPM,

recommends that the CCM Task Group on the Phases for the Dissemination of the kilogram following redefinition outlines a strategy and coordinates a structured approach to the global advancement of realization experiments and to addressing any lack of agreement between experiments.

Thank you.

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