The Consensus Value for the kilogram

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

- Members;

Dr Hao Fang (BIPM), Dr Dorothea Knopf (PTB),
Ms Maria Nieves Medina (CEM), Dr Lars Nielsen (DFM),
Dr Philippe Richard (METAS), Dr Alan Steele, Dr Michael Stock (BIPM)

- Alan Steele has retired from NRC and will be replaced by Richard Green
- New members joined from NIST and NMIJ (to ensure to global reach of the TG)
- Philippe Richard will step down as a member of the TG
- Thanks to Horst Bettin and Estefanía de Mirandés for valuable contributions

Phase	Time scale	Description	Source of traceability	Uncertainty of BIPM mass calibrations	Role of realization experiments	Dissemination of mass from NMIs with realization experiments
0	Until 20 May 19[1]	Traceability to the IPK	$m_{IPK} \equiv 1$ kg $u_{m_{\text{IPK}}} \equiv 0$	$u_{\text{stab}}(t)$	Measurement of h	Dissemination from national prototype traceable to IPK
1	20 May 19 - date 1[2]	Traceability to the Planck constant via the IPK, with additional uncertainty from the (new) definition	$m_{IPK} = 1$ kg $u_{m_{\text{IPK}}} = 10\ \mu g$	$\approx \sqrt{u_{m_{\text{IPK}}}^2 + u_{\text{stab}}^2(t)}$	Contribute to Key Comparison (KC), improve and resolve discrepancies	Dissemination from national prototype traceable to IPK, with 10 µg added uncertainty
2	date 1 – date 2[3]	Traceability to the Planck constant, dissemination from a consensus value[4] (CV)	Consensus value (CV)	$\approx \sqrt{u_{\text{CV}}^2 + u_{\text{stab}}^2(t)}$	contribute to CV (via KC), improve experiments and resolve discrepancies	Dissemination from consensus value with uncertainty ≈ $\sqrt{u_{\text{CV}}^2 + u_{\text{stab.NMI}}^2(t)}$
3	from date 2	Traceability to the Planck constant, dissemination by individual realizations	Fixed value of *h* u(h) ≡ 0	(Uncertainty of BIPM realization experiment)	Realization of the unit of mass, Participation in KCs to demonstrate equivalence	Dissemination from validated realization experiments with the uncertainty of the experiment. The terms of the CIPM MRA are applicable.

Rationale for the Consensus Value

- (Continuing) discrepancy between the Kibble balance and X-ray crystal density (XRCD) experiments means individual realisations are not equivalent.
- BUT we want traceability to the Planck constant.
- To ensure the continuity, temporal stability and equivalence of the SI unit of mass the use of a consensus value for the kilogram after its redefinition was agreed by the CCM at the 16th meeting in May 2017.
- The use of a consensus value will facilitate the smooth transition from traceability derived from the International Prototype kilogram (IPK) to a point where individual realization experiments can be used for sovereign realization and dissemination of the unit of mass.

Calculation

- The initial consensus value will be calculated based on an arithmetic (non-weighted) mean of three sets of data;

1. data directly traceable to the IPK (taking into account the additional uncertainty of 10 micrograms and a contribution for the temporal stability of the BIPM working standards).
2. extant data from the CCM Pilot Study of realization experiments (corrected for the shift of 17 parts in 10^9 in *h* introduced by the CODATA 2017 adjustment)
3. the KCRV of the first CCM Key Comparison (after removal of outliers)

Calculation

- The next consensus value will be calculated based on an arithmetic (non-weighted) mean of three sets of data;

1. extant data from the CCM Pilot Study of realization experiments (corrected for the shift of 17 parts in 10^9 in *h* introduced by the CODATA 2017 adjustment)
2. the KCRV of the first CCM Key Comparison (after removal of outliers)
3. the KCRV of the second CCM Key Comparison (after removal of outliers)

Calculation

- The ongoing consensus value will be calculated based on an arithmetic (non-weighted) mean of three sets of data;

1. the KCRV of the first CCM Key Comparison (after removal of outliers)
2. the KCRV of the second CCM Key Comparison (after removal of outliers)
3. the KCRV of the third CCM Key Comparison (after removal of outliers)

Uncertainty

Standard uncertainty in the consensus value is 20 µg throughout Phase 2 (unless a statistical analysis following a Key Comparison shows that this value should be increased). This value was recommended by the CCM Task Group on the Phases for the Dissemination of the kilogram following redefinition (CCM TGPfD-kg).

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2	1 Feb 21 – date 2[3]	Traceability to the Planck constant, dissemination from a consensus value[4] (CV)	Consensus value (CV)	$\approx \sqrt{u_{\text{CV}}^2 + u_{\text{stab}}^2(t)}$	contribute to CV (via KC), improve experiments and resolve discrepancies	Dissemination from consensus value with uncertainty ≈ $\sqrt{u_{\text{CV}}^2 + u_{\text{stab.NMI}}^2(t)}$
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Uncertainty

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- Typical uncertainty of “mature” realization experiments such as those at NIST, NMIJ, NRC and PTB
- The target uncertainty of newer realization experiments which are predicted to be completed in the next 10 years
- Setting the expectations on future uncertainties from individual realization experiments (Phase 3) at the beginning of Phase 2.
- 20 µg was the target uncertainty that the CCM established to proceed with the redefinition of the kilogram

Timetable

- The Key Comparison of realisation experiments will take place approximately every 2 years
- The Consensus value for the kilogram will be reviewed after each KC

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

- A minimum of five consistent realisation experiments which:
  - Achieve Key Comparison results with a relative standard uncertainty of 40 parts in 10^9 or better
  - Demonstrate consistency with the KCRV
  - Demonstrate stability by producing consistent (equivalent) results for two consecutive Key Comparisons
- At least three of the realisation 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 realising the SI unit of mass (e.g. Kibble balance and X-ray crystal density experiments)
- 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.

Conclusions

- Traceability is to the Planck constant, via the consensus value which will be maintained by the BIPM
- Since traceability is the same for all NMI, equivalence demonstrated in past KCs is still valid (the additional uncertainty due to the use of a consensus value is correlated between all NMIs)
- All the "hard work" with respect to the transition has been done, no further changes to CMCs should be necessary
- Transition to Phase 3 (dissemination from individual realisation experiments) will take place once the equivalence and stability of enough experiments has been demonstrated

https://www.bipm.org/documents/20126/49759984/Calculation+of+the+consensus+value+2020/99498411-54a2-ddfd-5054-4d7beb1ae45f

Thank you for your attention

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Adjustment of CMCs to account for the uncertainty in the Consensus Value

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Rationale

- The standard uncertainty in the Consensus Value is 20 µg (Phase 2)
- The (previous) standard uncertainty in the IPK (Phase 1) was 10 µg (plus drift uncertainty) so;
- The CMCs of a number of NMIs need to be updated to take into account the increase in uncertainty
- Uncertainties < 80 µg at 1 kilogram ($k = 2$) needed to be adjusted (31 NMIs affected)

Adjustment

$$(\text{new CMC}/2)^2 = (\text{existing CMC}/2)^2 - 10^2 + 20^2$$

Progress

- Adjustments were made by an ad-hoc Task Group of the CCM and sent to NMIs for approval
- 29 of the 31 NMIs have approved the revisions
- Revisions are now with the KCDB Coordinator for uploading to the KCDB

Thanks

- Thanks to Zoltan Zelenka and Susanne Picard for help with this process
- Thanks to the NMIs involved for cooperation and (generally) quick replies

Thank you for your attention

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Timetable for the next comparison of realisation experiments CCM.M.K8.2021

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Proposed timescale for CCM.M-K8.2021

June 2021	Call for participation
June/July 2021	Agreement on technical protocol (similar to K8.2019)
September – December 2021	Measurement of travelling standards at NMIs
January – March 2022	Comparison measurements at BIPM
April-May 2022	Stability checks at NMIs after return of standards
June 2022	Draft A
September 2022	Final report