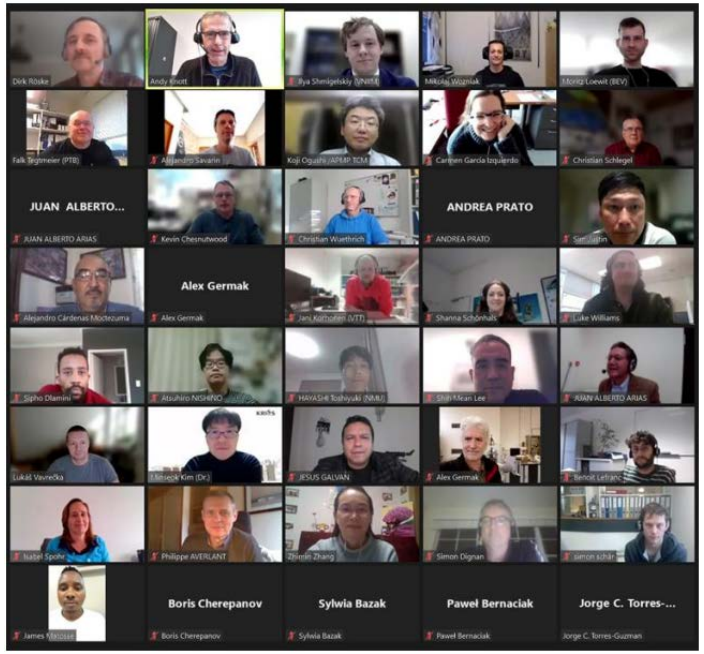
Report of the CCM Working Group on Force and Torque

Andy Knott

20th CCM meeting, 26-27 June 2025

WG Meetings



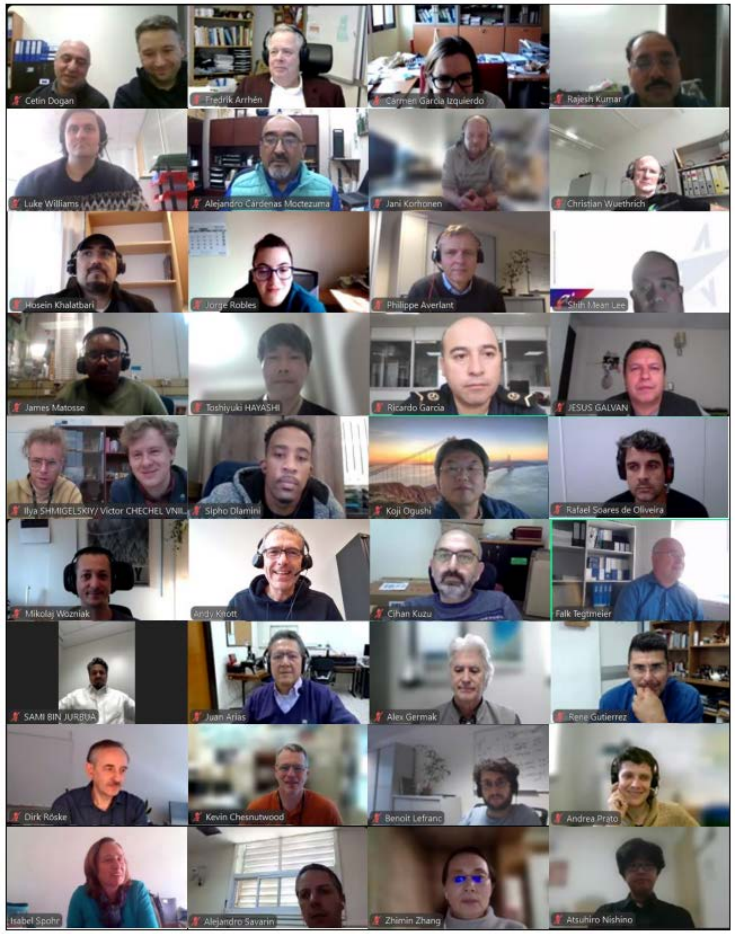
Past CCM-WGFT meetings

- 6-7 February 2024
- 18-19 February 2025

Future CCM-WGFT meetings

- February/March 2026

All virtual, via Zoom



Main actions and achievements

Ongoing organisation of KCs and publication of results

Preparation and publication of guidance on CMC submission and review

CMC submission and review guidance

2024-04-11
Version 1.1

Guidelines for Submission and Review of Calibration and Measurement Capabilities (CMCs)

Consultative Committee for Mass and Related Quantities (CCM)
Working Group on Force and Torque (CCM-WGFT)

Table 1: Force difficulty levels

Force traceability method	Force range	Difficulty level 1	Difficulty level 2	Difficulty level 3
Deadweight	$F \geq 1$ N	$W_{CMC} \leq W_1 = 0.005$ %	$W_1 < W_{CMC} \leq W_3$	$W_{CMC} > W_3 = 0.05$ %
	$F < 1$ N	$W_{CMC} \leq W_1 = 0.01$ %	$W_1 < W_{CMC} \leq W_3$	$W_{CMC} > W_3 = 0.1$ %
Hydraulic or lever amplification	all	$W_{CMC} \leq W_1 = 0.01$ %	$W_1 < W_{CMC} \leq W_3$	$W_{CMC} > W_3 = 0.1$ %
Single reference transducer	$F \geq 10$ N	$W_{CMC} \leq W_1 = 0.02$ %	$W_1 < W_{CMC} \leq W_3$	$W_{CMC} > W_3 = 0.2$ %
	$F < 10$ N	$W_{CMC} \leq W_1 = 0.05$ %	$W_1 < W_{CMC} \leq W_3$	$W_{CMC} > W_3 = 0.5$ %
Multiple reference transducers / build-up system	all	$W_{CMC} \leq W_1 = 0.02$ %	$W_1 < W_{CMC} \leq W_3$	$W_{CMC} > W_3 = 0.2$ %

Table 2: Torque difficulty levels

Torque traceability method	Torque range	Difficulty level 1	Difficulty level 2	Difficulty level 3
Deadweight + lever(s)	$T \geq 1$ N·m	$W_{CMC} \leq W_1 = 0.005$ %	$W_1 < W_{CMC} \leq W_3$	$W_{CMC} > W_3 = 0.05$ %
	$T < 1$ N·m	$W_{CMC} \leq W_1 = 0.01$ %	$W_1 < W_{CMC} \leq W_3$	$W_{CMC} > W_3 = 0.1$ %
Jockey weights + lever	all	$W_{CMC} \leq W_1 = 0.02$ %	$W_1 < W_{CMC} \leq W_3$	$W_{CMC} > W_3 = 0.2$ %
Load cell(s) + lever(s)	all	$W_{CMC} \leq W_1 = 0.02$ %	$W_1 < W_{CMC} \leq W_3$	$W_{CMC} > W_3 = 0.2$ %
Reference transducer	$T \geq 10$ N·m	$W_{CMC} \leq W_1 = 0.02$ %	$W_1 < W_{CMC} \leq W_3$	$W_{CMC} > W_3 = 0.2$ %
	$T < 10$ N·m	$W_{CMC} \leq W_1 = 0.05$ %	$W_1 < W_{CMC} \leq W_3$	$W_{CMC} > W_3 = 0.5$ %
Reference torque wrench*	all	$W_{CMC} \leq W_1 = 0.02$ %	$W_1 < W_{CMC} \leq W_3$	$W_{CMC} > W_3 = 0.2$ %
*used to calibrate torque wrench calibration equipment				

CMC submission and review guidance

Table 3: Technical evidence points values

Technical evidence	Points
CMC consistent with information from:	
Fully-documented uncertainty budget	16
Results of key or supplementary comparison	12
Onsite peer assessment reports	6
Publicly-available information on technical activities	4
Active participation in RMO projects	3
Other evidence of knowledge and experience	2

Table 4: Required points for difficulty levels

Difficulty level	Required points
1	36
2	31
3	28

CMC submission and review guidance

CIPM MRA Appendix C: Calibration and Measurement Capability (CMC) Declarations

Calibration or Measurement Service			Measurand Level or Range			Measurement Conditions/Independent Variable		Expanded Uncertainty					
Quantity/ Class	Instrument or Artifact	Instrument Type or Method	Minimum value	Maximum value	Units	Parameter	Specifications	Value	Units	Coverage Factor	Level of Confidence	Is the expanded uncertainty a relative one?	Evidence check
FORCE													
Force - tension and compression	Force measuring device		1	100	kN	Force application mode	incremental only	0.002	%	2	95%	Yes	CMC-F1
Force - compression only	Force measuring device		100	1000	kN			0.00005 F + 100 N;F in N	N	2	95%	No	CMC-F2
										2	95%	Yes	CMC-F3
										2	95%	Yes	CMC-F4
										2	95%	Yes	CMC-F5
TORQUE													
										2	95%	Yes	CMC-T1
										2	95%	Yes	CMC-T2

CMC submission and review guidance

Back to CMC

CMC metadata		CMC-F1	CMC-F2	CMC-F3	CMC-F4	CMC-F5	CMC-T1
Quantity		Force	Force	Force	Force	Force	Torque
Traceability		Deadweight	Hydraulic amplification				
Minimum force in N / Minimum torque in N m		1000 N	100000 N				
Minimum expanded (k = 2) uncertainty		0.002%	0.015%				
Difficulty level		1	2				
Required points		36	31				
Total points		37	32	0	0	0	0
Technical evidence	**Points**	**Supplied**	**Supplied**	**Supplied**	**Supplied**	**Supplied**	**Supplied**
Fully-documented uncertainty budget	16	Yes	Yes	No	No	No	No
Results of key or supplementary comparison	12	Yes	Yes	No	No	No	No
Onsite peer assessment reports	6	Yes	No	No	No	No	No
Publicly-available information on technical activities	4	No	Yes	No	No	No	No
Active participation in RMO projects	3	Yes	No	No	No	No	No
Other evidence of knowledge and experience	2	No	No	No	No	No	No

Progressing the state of the art

Methods for continuous and dynamic force calibration

Development and optimisation of technology including digitalisation

Digital SI and Digital Calibration Certificates (DCCs) in force and torque

Methods for realisation of low-range force and torque with direct traceability to fundamental constants

Traceability for time-dependent forces in different frequency ranges

Traceable machines for continuous and dynamic measurements for testing in industry and research

EMPIR 18SIB08 ComTraForce:
https://www.ptb.de/empir2018/comtraforce/home/

Progressing the state of the art - torque

Torque measurement under rotation and dynamic torque

Traceability for large torque in the MN·m range

Traceable methods for mechanical power measurements and efficiency determination

More interdisciplinary new topics for example in the field of renewable energy

EMPIR 19ENG08 WindEFCY:
https://www.ptb.de/empir2020/windefcy/home/

Liaison & stakeholders

IMEKO TC3 – Measurement of force, mass, torque, and gravity

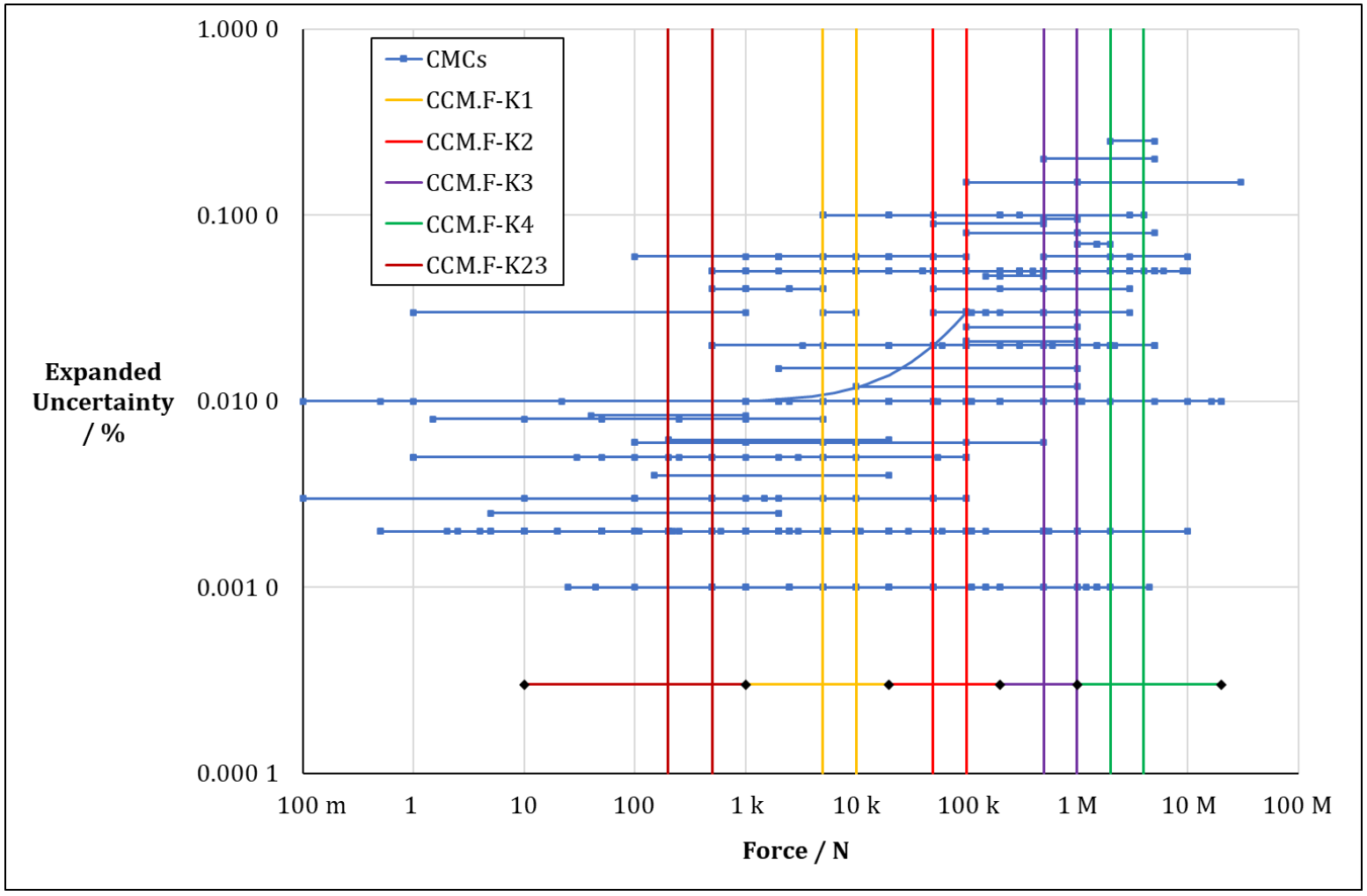
ISO/TC 164 – Mechanical testing of metals

- **ISO/TC 164/SC 1 - Uniaxial testing**
- **ISO/TC 164/SC 1/SG 1 - Continuous force traceability (ISO 376 and ISO 7500-1)**
- **ISO/TC 164/SC 4 - Fatigue, fracture and toughness testing**

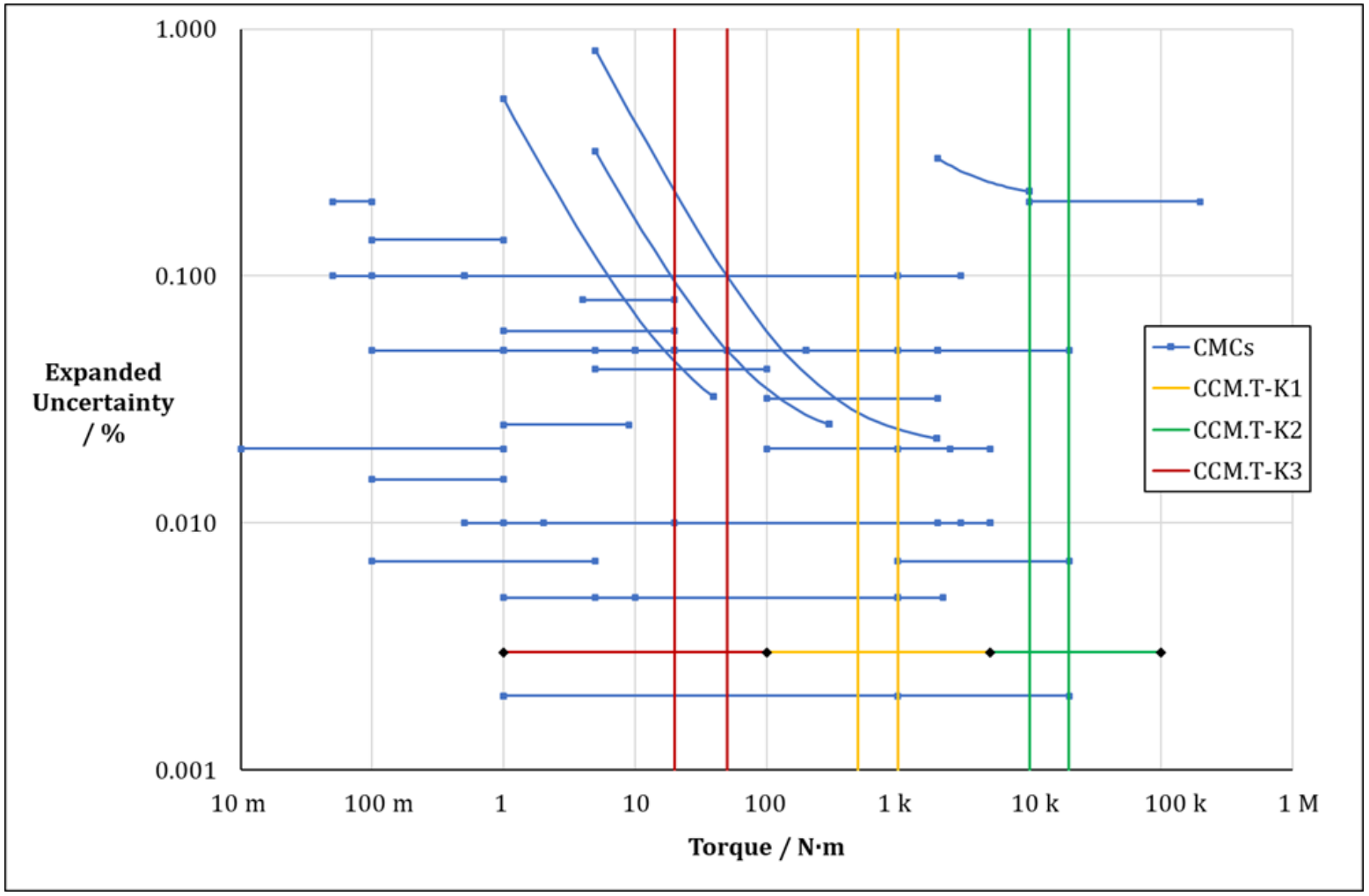
Industry

- **Manufacturers of force and torque measuring devices**
- **Manufacturers of testing machines and test benches**
- **Calibration and testing laboratories in force and torque**
- **Automotive, aerospace, materials, offshore, renewable energy industries**
- **Automation technology**
- **Medical measuring techniques**

CIPM MRA: KCs & CMCs



CIPM MRA: KCs & CMCs



CIPM MRA: KCs & CMCs

Completed KC

- **F-K23 (200 N, 500 N) – Pilot METAS**

Ongoing KC

- **F-K1.a.2022 (5 kN, 10 kN) – Pilot UME**

Planned KCs

- **F-K4 (2 MN, 4 MN) – Pilot NIST**
- **T-K1 (500 N·m, 1 kN·m) – Pilot CEM**
- **T-K3 (20 N·m, 50 N·m) – Pilot PTB**

CIPM MRA: KCs & CMCs

ID	Points	Range	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
CCM.F-K23	200 N, 500 N	10 N – 1 kN			X								
CCM.F-K1	5 kN, 10 kN	1 kN – 20 kN				X							
CCM.F-K2	50 kN, 100 kN	20 kN – 200 kN								X			
CCM.F-K3	500 kN, 1 MN	200 kN – 1 MN											X
CCM.F-K4	2 MN, 4 MN	1 MN – 20 MN							X				
CCM.T-K3	20 N·m, 50 N·m	1 N·m – 100 N·m								X			
CCM.T-K1	500 N·m, 1 kN·m	100 N·m – 5 kN·m							X				
CCM.T-K2	10 kN·m, 20 kN·m	5 kN·m – 100 kN·m										X	

Programme of work for the next 2 years

Complete ongoing KC

- **F-K1.a.2022 (5 kN, 10 kN) – Pilot UME**

Initiate planned KCs

- **F-K4 (2 MN, 4 MN) – Pilot NIST**
- **T-K1 (500 N·m, 1 kN·m) – Pilot CEM**
- **T-K3 (20 N·m, 50 N·m) – Pilot PTB**

Consider new KC at lower forces: 1 N to 20 N range

- **14 NMIs have expressed interest, 0.002 % < U_{CMC} < 0.01 %**
- **Issues with transfer standards, willingness to pilot**

Proposals (KCs, chairmanship, membership…)

No specific proposals

Thank you.

andy.knott@npl.co.uk