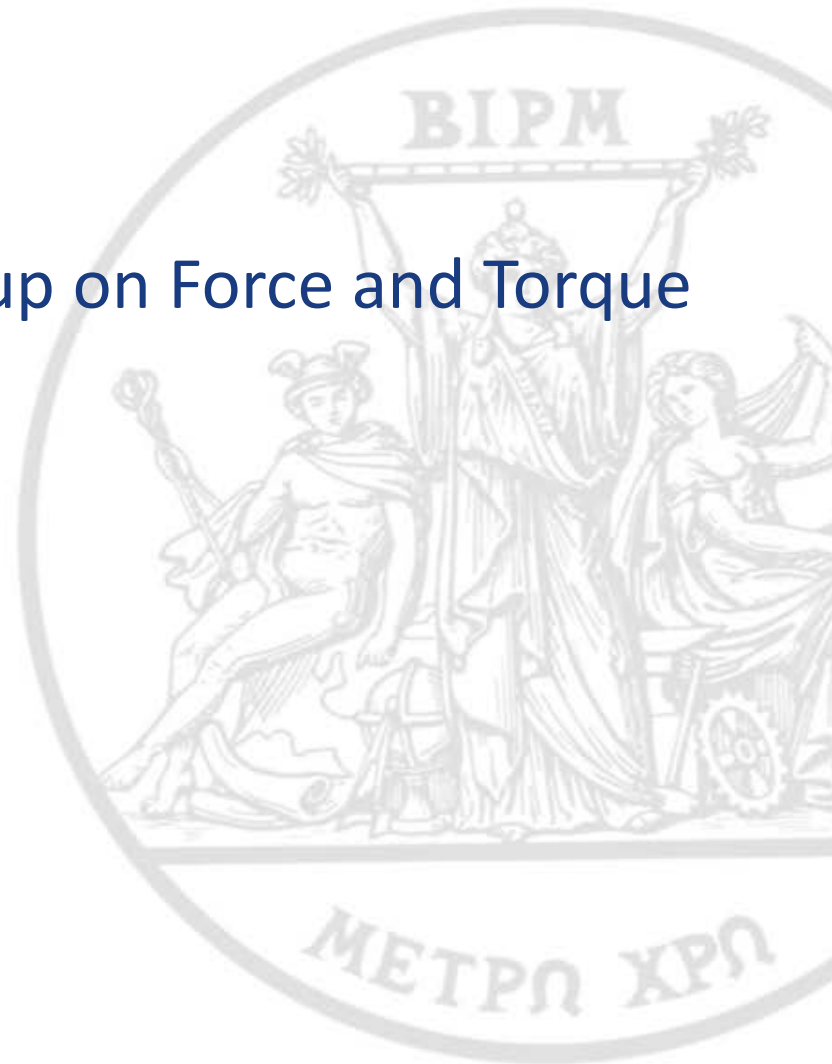


Report of the CCM Working Group on Force and Torque

Rolf Kumme

18th CCM meeting, 20-21 May 2021

Bureau
† **International des**
† **Poids et**
† **Mesures**



WG Meetings held since last CCM

- ◆ 20th April 2021 zoom meeting of 3 hours with 41 participants
- ◆ largest meeting which was ever held by CCM WGFT
- ◆ video conferences allow the participation of more members
- ◆ additional video conferences will be arranged

WG Meetings planned

- ◆ In September 2021 up to 3 video conferences planned, each meeting of about 2 hours related to following topics:
 - Preparation of next CCM.F-K1 (5 kN, 10 kN), pilot: UME, participants and procedure to be decided
 - Preparation of new CCM.T-K3 (20 N·m, 50 N·m), pilot, participants and procedure to be decided
 - Evaluation of CCM.F-K23 (200 N, 500 N)
 - CMCs in Force and Torque, Harmonisation and guideline for CMC review, other topics
- ◆ Autumn 2022 CCM WGFT meeting at NIST if possible or alternative video conference or hybrid meeting

Liaison & stakeholders

- ◆ IMEKO TC3 - Measurement of Force, Mass and Torque
- ◆ ISO/TC 164 Mechanical testing of metals
 - ISO/TC 164/SC 1 - Uniaxial testing
 - 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
 - Steel Industry
 - Car Industry, Aircraft & Space Travel Industry
 - Off-shore Industry
 - Wind Industry
 - Automation Technology
 - Medical Measuring Techniques

Terms of reference of CCM WG Force and Torque

- ◆ To study issues related to force and torque metrology, including dissemination, and to advise the CCM on these topics as well as on anticipated developments in this field;
- ◆ To review the results of completed key and supplementary comparisons and plan and support new comparisons;
- ◆ To facilitate the submission and review of CMCs by establishing technical review criteria and service categories and providing guidance on and coordinating the review process;
- ◆ To provide liaison at the technical level with ISO TC164/SC 1 and SC 4 and to maintain good links with IMEKO TC3.

Technology trends & challenges

- ◆ Methods for continuous force calibration in applications
- ◆ Methods for dynamic force calibration in applications
- ◆ Development and optimisation of technology including digitization
- ◆ Digital SI and Digital Calibration Certificates in Force and Torque
- ◆ Methods for realization of force and torque in the low range with direct traceability to fundamental constants and new SI definition
- ◆ Traceability for time dependent forces in different frequency ranges
- ◆ Traceable machines for continuous and dynamic measurements for testing in industry and research
- ◆ EMPIR 18SIB08: <https://www.ptb.de/empir2018/comtraforce/home/>

Technology trends & challenges

- ◆ 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 energies
- ◆ 19ENG08 WinDEFcy:
<https://www.ptb.de/empir2020/windefcy/home/>

Main actions taken and main achievements

- ◆ CCM.F-K23 (200 N, 500 N), Pilot: METAS
- ◆ Participants: CENAM, INRIM, KRISS, LNE, NIM, NIST, NMIJ, PTB
- ◆ All measurements performed in 2020/21 and completed
- ◆ New Principle: Each participant uses own force transfer standard
- ◆ Link realized by deadweight force standard machine from pilot
- ◆ Next CCM.F-K1 (5 kN, 10 kN), Pilot: UME, decided
- ◆ New CCM.T-K3 (20 N·m, 50 N·m) defined
- ◆ CMC harmonisation under discussion and on the way

Program of work for the next 5 years

Actual work:

- ◆ CCM.F-K23: Evaluation & Report
- ◆ CCM.F-K1: Planing, Measurements, Evaluation & Report
- ◆ CCM.T-K3: Planing, Measurements, Evaluation & Report
- ◆ Guideline for CMC Harmonisation in Force & Torque
- ◆ Guideline for CMC Review in Force & Torque

Discussion of New Topics:

- ◆ Traceable Methods for Dynamic Force & Torque
- ◆ Traceable Methods for Mechanical Power Measurement for Wind Industry, Electro Mobility & Engines
- ◆ Methods for Traceability in Small Force & Torque Range
- ◆ Digitisation in Force & Torque, D-SI, DCC, D-Twins

KCs Force & Torque, Measurement Points & Ranges

Quantity	KC-identifier	Measurement Points	Years	Year	Range
Force	CCM.F-K23	200 N, 500 N	15-20	2020/21	10 N – 1000 N
Force	CCM.F-K1	5 kN, 10 kN	15-20	2021/22	1 kN – 20 kN
Force	CCM.F-K2	50 kN, 100 kN	15-20	2027	20 kN – 200 kN
Force	CCM.F-K3	500 kN, 1000 kN	15-20	2030	200 kN – 1000 kN
Force	CCM.F-K4	2 MN, 4 MN	15-20	2024	1 MN – 20 MN
Torque	CCM.T-K1	500 N·m, 1000 N·m	15-20	2023	100 N·m - 5 kN·m
Torque	CCM.T-K2	10 kN·m, 20 kN·m	15-20	2025	5 kN·m - 100 kN·m
Torque	CCM.T-K3	20 N·m, 50 N·m	15-20	2022	1 N·m - 100 N·m

KCs Force & Torque, Future Time Schedule

year 20XX	20	21	22	23	24	25	26	27	28	29	30
CCM.F-K1		X									
CCM.F-K2								X			
CCM.F-K3											X
CCM.F-K4					X						
CCM.F-K23	X										
CCM.T-K1				X							
CCM.T-K2						X					
CCM.T-K3			X								

- ◆ CCM.F-K23 measurements completed in 2021
- ◆ CCM.F-K1 & CCM.T-K3 details will be planned in 2021

KCs in Force completed and underway

Summary of completed and approved KCs in Force

- ◆ CCM.F-K1.a (5 kN, 10 kN) & CCM.F-K1.b (5 kN), pilot: **MIKES**, 16 participants
- ◆ CCM.F-K2.a (50 kN, 100 kN) & CCM.F-K2.b (50 kN), pilot: **NPL**, 16 participants
- ◆ CCM.F-K3.a (0.5 MN, 1 MN) & CCM.F-K3.b (0.5 MN), pilot: **PTB**, 12 participants
- ◆ CCM.F-K4.a (2 MN, 4 MN) & CCM.F-K-4.b (2 MN), pilot: **NIST**, 8 participants

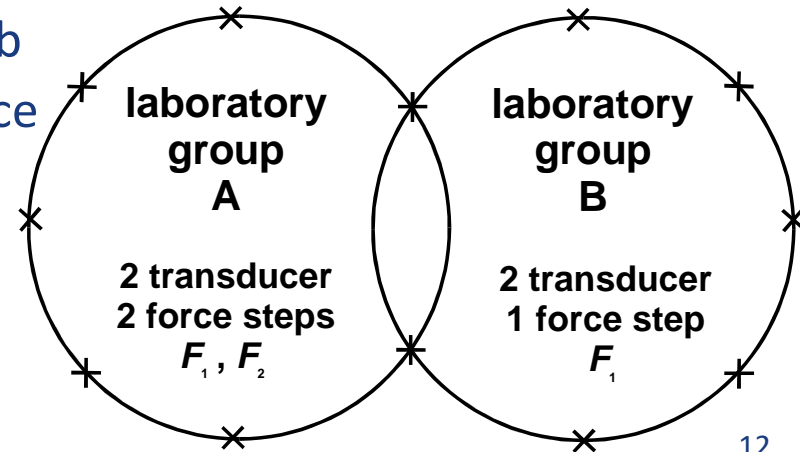
In all KCs each pilot selected 4 transducers which are circulated in star type formation.

= > excellent results, but a lot of work for pilot lab

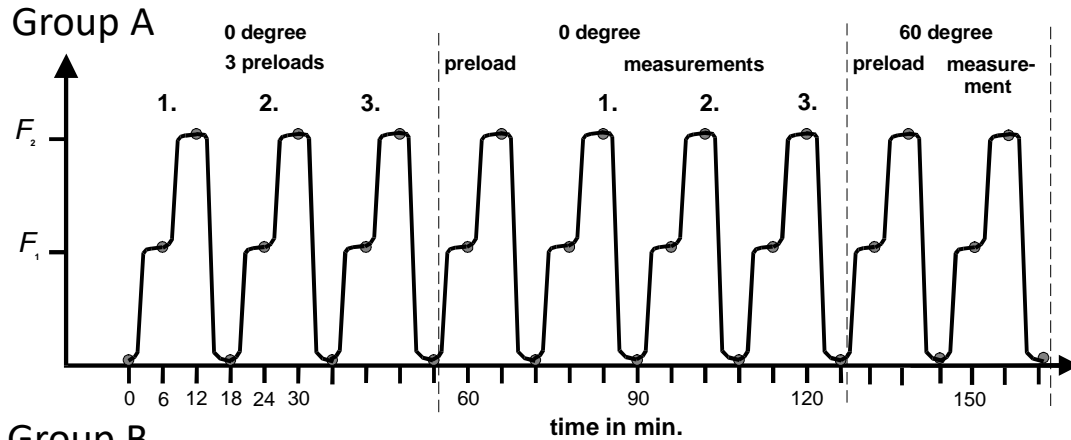
=> New method: each participant with own device

KCs underway

- ◆ CCM.F-K23 (200N, 500N), pilot: **METAS**
- ◆ CCM.F-K2.a.2 (5 kN, 10 kN, 50 kN, 100 kN, 200 kN), Report in progress (Draft A), **NPL**, **PTB**
- ◆ CCM.F-K3.1 (0.5 MN, 1 MN), **PTB**, **KRISS**
Report in progress (Draft A)

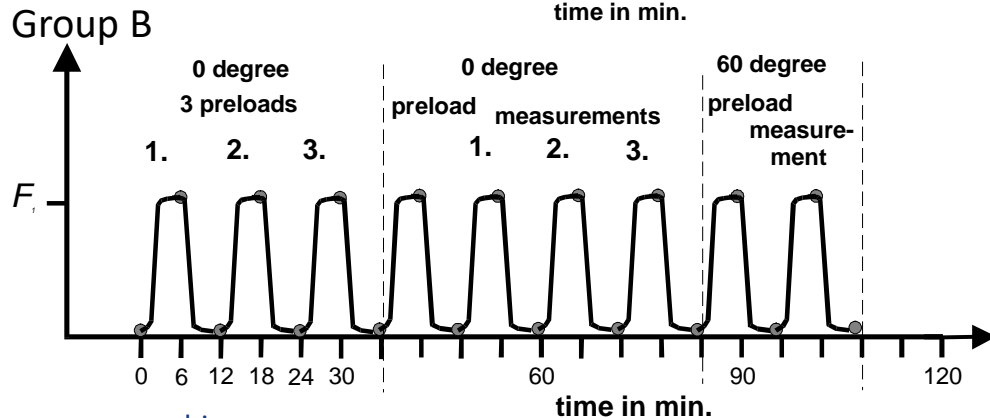


KCs completed and underway, Measurement principle



1 preload +
1 measurement
cycle in position

60°	60°
120°	120°
180°	180°
240°	240°
300°	300°
360°/0°	360°
1.rotation	2.rotation



Deflection = reading - zero signal

3 measurements in 0 degree positions
=> repeatability

12 measurements from 60 to 360 degree positions
=> mean value + reproducibility

KCs in Torque completed and underway

KCs completed

- ◆ CCM.T-K1 (500 N m, 1000 N m), pilot: PTB, 8 participants
- ◆ CCM.T-K1.1 (500 N m, 1000 N m), PTB, NPLI
- ◆ CCM.T-K1.2 (500 N m, 1000 N m), PTB, NIMT
- ◆ CCM.T-K1.3 (500 N m, 1000 N m), PTB, NIS
- ◆ CCM.T-K2 (10 kN m, 20 kN m), pilot: PTB, 4 participants

Same measurement principle like force comparison in group A.

For each KC the pilot selected 2 transducers which are measured in 2 torque steps clockwise and anticlockwise

⇒ excellent results obtained, but a lot of work for the pilot.

KCs underway

- ◆ CCM.T-K2.1 (10 kN m, 20 kN m), **NMIJ**, NMISA, planned
- ◆ CCM.T-K3 (20 N m, 50 N m), planned, pilot and participants to be decided in 2021

RMO Force key and supplementary comparisons

- APMP.M.F-K2.a and b (force transducer 50 kN, 100 kN), Pilot: **KRISS**, 13 participants
Approved for equivalence, Results available
- APMP.M.F-K3.a (force transducer 500 kN, 1000 kN), Pilot: **NIM**, 10 participants
Measurements completed, Draft A in preparation
- APMP.M.F-K3.b (force transducer 500 kN), Pilot: **NIM**, 4 participants
In progress, Measurements completed, Draft A in preparation
- APMP.M.F-K4.b (force transducer 2000 kN), Pilot: **NMIJ**
Approved for equivalence, Results available
- APMP.M.F-S1 (0.6 MN to 2 MN), **NMIJ**, PTB, approved
- APMP.M.F-S2 (10 kN to 100 kN), **NMIJ**, NIMT, approved
- APMP.M.F-S2.1 (force transducer 100 kN), Pilot: **KRISS**, VMI (Vietnam)
Planned
- APMP.M.F-S3 (500 N to 1 kN), **NMIJ**, RCM-LIPI, approved

RMO Force key and supplementary comparisons

- AFRIMET.M.F-S1 (force transducer 2 kN to 100 kN)
Participants: **KEBS** (Kenya), PTB, Report in progress.
- AFRIMET.M.F-S2 (force transducer 250 kN and 500 kN)
Participants: **KEBS** (Kenya), PTB, NMISA (South Africa), Approved
- COOMET.M.F-S1 (Force: 20 kN, 50 kN, 100 kN, 250 kN, 500 kN, 1000 kN and 2000 kN),
VNIIM, BelGIM, UkrCSM, Report in progress, Draft B
- COOMET.M.F-S2 (Force: 10 kN, 14 kN, 16 kN, 20 kN, 50 kN, 60 kN, 80 kN and 100 kN),
PTB, UkrCSM, Approved
- GULFMET.M.F.-S1 (force comparison 40 kN to 1 MN), Participants: **UME** (Turkey), SASO-
NMCC (Saudi Arabia), QCC-EMI (United Arab Emirates), Approved
- GULFMET.M.F-S2 (force comparison 0.4 kN to 100 kN), Participants: **UME** (Turkey), SASO-
NMCC (Saudi Arabia), Approved

RMO Force key and supplementary comparisons

- EUROMET.M.F-K1 (force transducer 5 kN, 10 kN), **MIKES**, 9 participants, Final report submitted
- EUROMET.M.F-K2 (force transducer 50 kN, 100 kN) , **NPL**, 12 participants, Approved for equivalence, Results available
- EUROMET.M.F-K3 (force transducer 500 kN, 1000 kN), **PTB**, 16 participants, Report (Draft A) in progress
- EURAMET.M.F-S1(supplementary force comparison 5 kN to 5 MN), **NPL**, NIS, approved
- EURAMET.M.F-S2 (supplementary force comparison of deadweight machines 5 N to 250 kN), **BEV**, PTB, Report (Draft A) in progress
- EURAMET.M.F-S3 (supplementary force comparison of deadweight machines), **NPL**, INMETRO, approved
- EURAMET.M.F-S4 (supplementary force comparison, 10 kN, 20 kN), **LNE**, KIM-LIPI (Indonesia), approved
- EURAMET.M.F-S5 (10kN to 500 kN), **NPL**, FSB-LIMS (Croatia), approved

RMO Force key and supplementary comparisons

- SIM.M.F-S1 (Calibration of a force testing machine in compression, Force: 10 kN to 100 kN)
IDIC, BSI, CENAM, CENAMEP AIP, IBMETRO, INDECOPI, INEN, INMETRO, INTI, INTN, LACOMET,
Approved and published
- SIM.M.F-S2 (Calibration of a force testing machine in compression, Force: 10 kN to 100 kN)
IDIC, Draft A, Participants: IDIC (Chile), CENAMEP AIP (Panama)
- SIM.M.F-S3 (Charpy V-notch reference specimen: 20 J and 100 J)
NIST, Report in progress, Draft B
- SIM.M.F-S4 (force transducer 50 kN, 100 kN)
IDIC, CENAM, INM (CO), LanammeUCR, approved
- SIM.M.F-S5 Comparison of force testing machines, 50 kN to 200 kN, **CENAM**, INDECOPI, INM (CO),
LanammeUCR, Approved and published
- SIM.M.F-S6 Comparison of force testing machines 10 kN to 100 kN
Draft A, Participants: **IDIC** (Chile), INTN (Paraguay)
- SIM.M.F-S7 (force comparison 500 kN to 1000 kN)
Measurements completed, Participants: **INMETRO** (Brazil), IDIC (Chile)

RMO Force key and supplementary comparisons

- SIM.M.F-S8 (comparison of force testing machines 20 kN to 100 kN)
Measurements completed, Participants: **IDIC** (Chile), IBMETRO (Bolivia)
- SIM.M.F-S9 (supplementary force comparison, force calibration, 200 kN force transducer, 20 kN to 200 kN, tension and compression), **IDIC** (participants: IDIC (Chile), INM (Columbia)), planned
- SIM.M.F-S10 (supplementary force comparison, calibration of force testing machine in compression), **IDIC**, Report in progress, Draft A

RMO Torque key and supplementary comparisons

- [APMP.M.T- K1](#) Pilot: KRISS, 6 participants
2015 – 2016, 500 N·m, 1000 N·m, Planned
- [APMP.M.T-S1](#)
2016, 1 kN·m to 2 kN·m, NMIJ, Approved and published
- [COOMET.M.T- S1](#)
2012 – 2014, 100 N·m to 2500 N·m, UNIIM, Approved and published
- [EURAMET.M.T- S1](#)
2008, 1 N·m, 5 N·m, 10 N·m, 50 N·m, 200 N·m, 500 N·m, and 1000 N·m,
PTB, Approved and published
- [EURAMET.M.T- S2](#)
2008, 10 N·m, 20 N·m, 40 N·m, 60 N·m, 80 N·m, and 100 N·m,), PTB,
Approved and published

RMO Torque key and supplementary comparisons

- [EURAMET.M.T- S3](#)
2010, 10 N·m, 20 N·m, ... 1 kN·m (torque wrenches), CEM, Approved and published
- [EURAMET.M.T- S4](#), LNE, PTB
2015, 5 N·m, ... 50 N·m, measurement completed
- [EURAMET.M.T- S5](#), LNE, PTB
2017, 5000 N·m, planned
- [SIM.M.T-S1](#)
2016, 10 Nm, 20 Nm and 50 Nm, CENAM, Report in progress (Draft A)
- SIM.M.T-S2 (Supplementary comparison in torque, Torque wrench calibration), CENAM, Participants: CENAM, INM (Colombia), approved

Proposed changes (membership, chairmanship, ToRs)

List of CCM WGFT members

FirstName	LastName	Country	Institute
		-	BIPM
Simon	Dignan	Australia	NMIA
Dietmar	Steindl	Austria	BEV
NN	NN	Belgium	Metrology Div
Rafael	Soares de Oliveira	Brazil	INMETRO
Juan Christian	Villarroel	Chile	IDIC (DI)
Zhimin	Zhang	China	NIM
Lukás	Vavrecka	Czech Republic	CMI
Aykurt	Altintas	Denmark	Force Technology (DI)
Khaled	Abd Elaziz	Egypt	NIS
Gouda	Mohamed	Egypt	NIS (Force Expert)
Jani	Korhonen	Finland	VTT MIKES
Philippe	Averlant	France	LNE
Rolf	Kumme	Germany	PTB
Dirk	Röske	Germany	PTB (Torque Expert)
S. Seela Kumar	Titus	India	NPLI
Alessandro	Germak	Italy	INRiM
Koji	Ohgushi	Japan	NMIJ
Toshiyuki	Hayashi	Japan	NMIJ (Force Expert)
Min Seok	Kim	Korea	KRISS
Yon-Kyu	Park	Korea	KRISS (Force Expert)
Jorge	Torres-Guzman	Mexico	CENAM
Janusz	Fidelus	Poland	GUM
Kamil	Cybul	Poland	GUM (Torque Expert)
Isabel	Spohr	Portugal	IPQ
Alexander	Ostrivnoy	Russia	VNIIM
Sipho	Dlamini	South Africa	NMISA
Shih Mean	Lee	Singapore	NMC/A*STAR
Nieves	Medina	Spain	CEM
Per	Nyfeldt	Sweden	RISE
Christian	Wüthrich	Switzerland	METAS
Bulent	Aydemir	Turkey	UME
Andy	Knott	UK	NPL
Olexander	Tsiporenko	Ukraine	Ukrmetrteststand(DI)
NN	NN	Uruguay	LATU
Kevin	Chestnutwood	US	NIST (Force Expert)
Zeina J.	Kubarych	US	NIST

◆ New Institutes in CCM WGFT:

- ◆ IDIC (DI), Chile
- ◆ Ukrmetrteststand (DI), Ukraine

◆ Changes of representatives in CCM WGFT:

- ◆ Juan Christian Villarroel, Chile, IDIC (DI)
- ◆ Janus Fidelus, Poland, GUM
- ◆ Shih Mean Lee, Singapore, A*STAR
- ◆ Olexander Tsiporenko, Ukraine Ukrmetrteststand (DI)
- ◆ Kevin Chesnutwood, US, NIST (Force Expert)
- ◆ Akobuije ChijiokeUS, NIST (Dynamic Force Expert)
- ◆ Kamil Cybul, Poland, GUM (Torque Expert)
- ◆ Min Seok Kim, Korea, KRISS
- ◆ Khaled Abd Elaziz, Egypt, NIS
- ◆ Gouda Mohamed, Egypt, NIS (Force Expert)

◆ Change of Chairmanship, to be decided next CCM meeting in 2023

◆ ToRs no changes

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