



## 1. General Aspects

This report summarises activities of the EURAMET Technical Committee for Acoustics, Ultrasound and Vibration (TC-AUV) for 2021-2022.

Three Sub-Committees (SCs) are organised under the Technical Committee covering three different technical areas: sound in air, ultrasound and underwater acoustics, vibration and acceleration.

The SCs assume responsibility for technical activities within their own specialisms and are coordinated by an appointed Convener, whereas the TC is concerned with general issues including aspects coming from EURAMET, technical activities cutting across all three AUV themes, and EMPIR activities.

TC-AUV also has a Working Group (WG) consisting of members from each Sub-Committee for review of CMCs (within EURAMET and between RMOs).

As the term of Stephen Robinson (NPL, United Kingdom) at the position of the TC-AUV chair has been ended in June 2021, Enver Sadıkoğlu from TÜBİTAK UME (Turkey) has taken the responsibility being elected by EURAMET General Assembly late in 2020. Enver Sadıkoğlu will act as a TC-AUV Chair for the term from 2021 to 2023.

## 2. Projects

**Project 1281** *Reference data for pressure reciprocity calibration according to the standard IEC 61094-2:2009.*

Pressure reciprocity calibration is the most widespread method for realising the unit for acoustic pressure, the pascal (Pa), via the determination of the sensitivity of a microphone and is described in the international standard IEC 61094-2. To validate the changes for the latest version of the standard, a set of reference data can be introduced in the measurement software to compare the obtained sensitivity to the “reference” sensitivity. This research project should allow to validate the correct implementation of the physical models involved in the reciprocity calculations (such as the model taking into account the thermal conductivity as well as the viscosity of the gas affecting the low frequency behaviour) and to check the degree of equivalence of the implementation of the calculations. The project started in 2013 has been delayed somewhat by lack of available resources, but work is still ongoing. Coordinating Institute: DFM (Denmark); Participating Partners: HBK-DPLA (Denmark), CEM (Spain), INRIM (Italy), LNE (France), METAS (Switzerland), PTB (Germany). Non EURAMET partners include INMETRO (Brazil), NMIJ (Japan), NMISA (South Africa), NRC (Canada).

**Project 1481** *Secondary calibration of accelerometers at medium frequencies*

The specific task of this comparison is the measurement of the magnitude of the sensitivity of two single-ended accelerometers in medium frequency domain (10 Hz to 10 kHz). The project is registered in the KCDB as EURAMET.AUV.V-S1. The sensitivity shall be calculated as the ratio of



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the amplitude of the output of the accelerometer to the amplitude of the acceleration at its reference surface with secondary means in accordance with ISO 16063-21:2003 "Methods for the calibration of vibration and shock transducers - Part 21: Vibration calibration by comparison to a reference transducer". The project is led by BEV (Austria) and has the following partners: BIM (Bulgaria), CMI (Czech Republic), IPQ (Portugal), METAS (Switzerland), MIKES (Finland). A further non-EURAMET partner from AFRIMETS is KEBS (Kenya). The project started in September 2019 and was completed in March 2022 with the final report published on the BIPM KCDB.

#### **Project 1418 *Primary calibration of accelerometers in medium and high frequencies***

This comparison involves the measurement of the magnitude and phase of the complex voltage sensitivity of two accelerometers, one single-ended and one back-to-back, in medium and high frequency domain (10 Hz to 20 kHz). This comparison will be linked to the key comparison CCAUV.V-K5 which was completed in 2021. The voltage sensitivity shall be calculated as the ratio of the amplitude of the output of the accelerometer to the amplitude of the acceleration at its reference surface with primary means in accordance with ISO 16063-11:1999 "Methods for the calibration of vibration and shock transducers - Part 11: Primary vibration calibration by laser interferometry". The project started in 2017 and the participating laboratories are: HBK-DPLA (Denmark), LNE (France), CEM (Spain), CMI (Czech Republic), GUM (Poland), INRIM (Italy), METAS (Switzerland), MIKES (Finland), PTB (Germany), RISE (Sweden), TÜBİTAK UME (Turkey). Further partner outside of Europe is SASO-NMCC (Saudi Arabia). Pilot laboratory is HBK-DPLA (Denmark), and the work is scheduled for completion by the end of 2022. The project is on track with all partners having completed measurements. Following the approval of the Draft A report by all participants, the Draft B report of the comparison has been prepared and submitted to CCAUV Key Comparison Working Group for review and approval early in 2022.

#### **Project 1537 *Bilateral supplementary comparison on calibration of accelerometers***

The specific task of this bilateral comparison is the measurement of the magnitude of the sensitivity of one single-ended accelerometer in the medium frequency range (10 Hz to 10 kHz). The sensitivity shall be calculated as the ratio of the amplitude of the output of the accelerometer to the amplitude of the acceleration at its reference surface with secondary means in accordance with ISO 16063-21:2003 standard. The project is led by BEV (Austria), and METAS (Switzerland) is the second partner in the comparison. The comparison has reached its final stage with Draft B report of the comparison prepared and submitted to CCAUV Key Comparison Working Group for review and approval in May 2022.

#### **Project 1542 *Bilateral key comparison on calibration of accelerometers at low frequencies***

The specific task of this bilateral key comparison is the measurement of the magnitude of the complex charge sensitivity of two accelerometers in the frequency range from 0.2 Hz to 40 Hz. The sensitivity of accelerometer shall be calculated as the ratio of the amplitude of the output of the accelerometer to the amplitude of the acceleration at its reference surface with primary means in accordance with ISO 16063-11:1999 "Methods for the calibration of vibration and shock transducers - Part 11: Primary vibration calibration by laser interferometry". The project is led by TÜBİTAK UME (Turkey), and METAS (Switzerland) is the second partner in the comparison. The measurement stage within the comparison is in progress.

### 3. Comparisons

#### CCAUV Key Comparisons

**CCAUV.W-K2** *Comparison of free-field hydrophone calibrations in water.* This key comparison of hydrophones covers an extended frequency range of 250 Hz – 500 kHz and is piloted by NPL (United Kingdom). It has seven participants including two from EURAMET (UK and Turkey), along with USA, Russia, Brazil, China and South Africa (with an eighth participant from India as a guest participant). After some delay, the comparison passed to reporting stage and the Draft B report of the comparison will be circulated by June 2022.

**CCAUV.V-K5** *Comparison of calibrations of accelerometers in the frequency range from 10 Hz to 20 kHz.* This is a comparison of calibrations of accelerometers in the frequency range from 10 Hz to 20 kHz with three accelerometers used, Brüel & Kjaer (B&K) type 8305, type 8305-001 and type 4371 as transfer standards in the comparison. Participants of the comparison are: PTB (pilot), HBK-DPLA, CEM, METAS, NIST, CENAM, INMETRO, NIM, NMIJ, NMIA, NMC/A\*STAR, NMISA, SE "Ukrmetrteststandard" and VNIIM. The comparison is currently complete, and the final report has been published in the KCDB in September 2021.

**CCAUV.A-K6** *Comparison of calibration of LS2P microphones in the frequency range from 20 Hz to 25 kHz.* LNE (France) is piloting the key comparison CCAUV.A-K6 on calibration of LS2P microphones in the frequency range from 20 Hz to 20 kHz with an option to make calibrations down to 2 Hz and options for phase calibrations, with 12 participants calibrating microphones in accordance with the IEC 61094-2:2009 standard. EURAMET is represented by four participants in the comparison: LNE, GUM, METAS and UME. Although delayed by COVID, the measurement phase was completed in February 2021. Draft B of the comparison report has been submitted to CCAUV Key Comparison Working Group for review and approval in May 2022.

#### Future Key Comparisons

DFM (Denmark) will pilot the key comparison CCAUV.A-K7 on free – field calibration of LS2p microphones in the frequency range from 1 kHz to 40 kHz (repeat of CCAUV.A-K4). Preparations for comparison will start late in 2022.

#### RMO Key and Supplementary Comparisons

**EURAMET.AUV.V-K5** (EURAMET Project 1418) *Primary calibration of accelerometers in medium and high frequencies.* This comparison involves the measurement of the magnitude and phase of the complex voltage sensitivity of two accelerometers in the frequency range from 10 Hz to 20 000 Hz. This comparison will be linked to the key comparison CCAUV.V-K5. The comparison started in 2017 and the participating laboratories are: LNE (France), HBK-DPLA (Denmark), CEM (Spain), CMI (Czech Republic), GUM (Poland), INRIM (Italy), METAS (Switzerland), MIKES (Finland), PTB (Germany), RISE (Sweden), TÜBİTAK UME (Turkey). A further non-EURAMET partner from GULFMET is SASO-NMCC (Saudi Arabia). Pilot laboratory is HBK-DPLA (Denmark), and the work is scheduled for completion by December 2021. Draft B report of the comparison was submitted to CCAUV Key Comparison Working Group in February 2022, and review comments were received in March 2022. The document is under revision by pilot laboratory.

**EURAMET.AUV.V-S1** (EURAMET Project 1481) *Secondary calibration of accelerometers in medium frequencies (10 Hz to 10 000 Hz).* The sensitivity shall be calculated as the ratio of the amplitude of the output of the accelerometer to the amplitude of the acceleration at its reference surface with secondary means in accordance with ISO 16063-21:2003 "Methods for the calibration of vibration and shock transducers - Part 21: Vibration calibration by comparison to a reference transducer". The project is led by BEV (Austria) and has the following partners: BIM (Bulgaria), CMI (Czech Republic), IPQ (Portugal), METAS (Switzerland), MIKES (Finland). A further non-EURAMET partner from AFRIMETS is KEBS (Kenya). The comparison was completed in March 2022 with the final report published on the BIPM KCDB.

**EURAMET.AUV.V-S2** (EURAMET Project 1537). *Secondary calibration of accelerometers (10 Hz to 10 000 Hz).* The specific task of this bilateral comparison is the measurement of the magnitude of the sensitivity of one single-ended accelerometer in the medium frequency range (10 Hz to 10 kHz). The sensitivity shall be calculated as the ratio of the amplitude of the output of the accelerometer to the amplitude of the acceleration at its reference surface with secondary means in accordance with ISO 16063-21:2003 standard. The comparison is piloted by BEV (Austria), and METAS (Switzerland) is the second partner in the comparison. Draft B report of the comparison was submitted to CCAUV Key Comparison Working Group for review on 6 May 2022.

**EURAMET.AUV.V-K3.1 (EURAMET Project 1542)** *Key comparison on calibration of accelerometers at low frequencies.* The specific task of this bilateral key comparison is the measurement of the magnitude of the complex charge sensitivity of two accelerometers in the frequency range from 0.2 Hz to 40 Hz. The sensitivity of accelerometer shall be calculated as the ratio of the amplitude of the output of the accelerometer to the amplitude of the acceleration at its reference surface with primary means in accordance with ISO 16063-11:1999 "Methods for the calibration of vibration and shock transducers - Part 11: Primary vibration calibration by laser interferometry". The comparison is piloted by TÜBİTAK UME (Turkey), and METAS (Switzerland) is the second partner in the comparison. The measurement stage within the comparison is in progress.

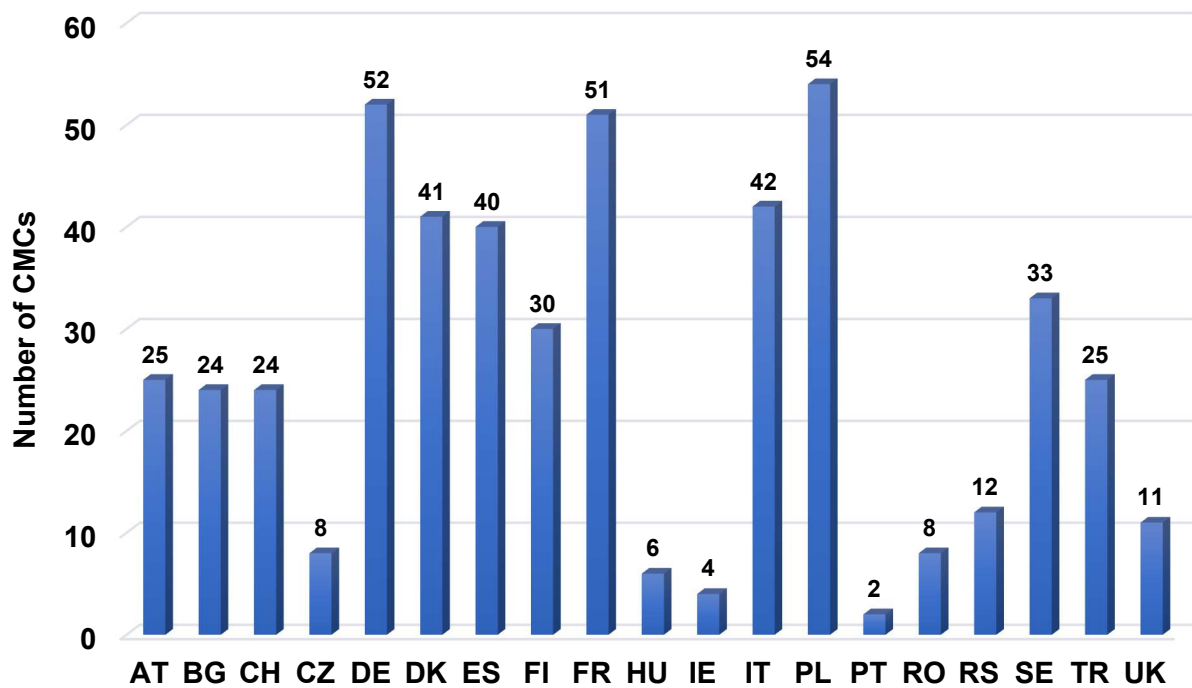
#### **Future RMO comparisons:**

A trilateral comparison will be set up to underpin justification of CMCs for DMDM after discrepancies in the DMDM performance in EURAMET.AUV.A-K5. Participants will include TÜBİTAK UME and GUM (the latter acting as linking laboratory).

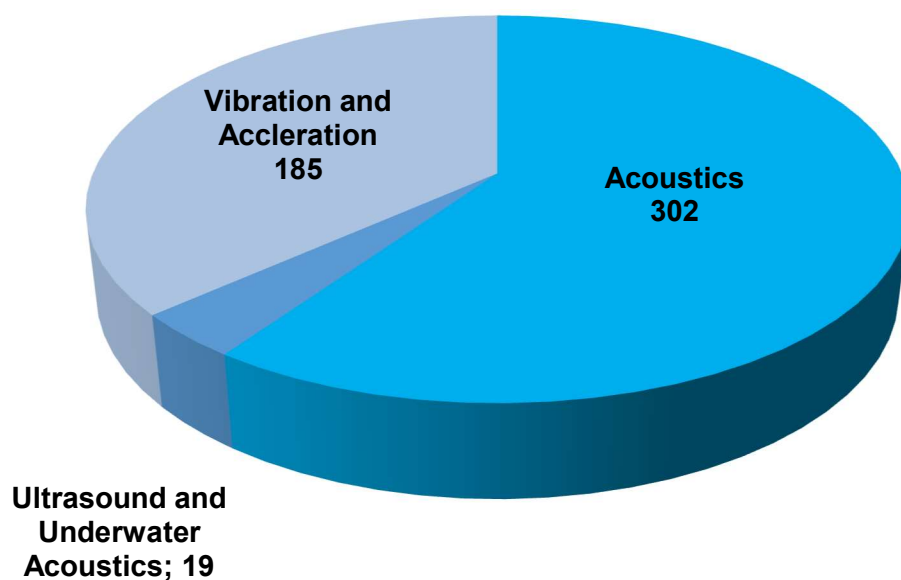
## **4. CMCs**

A total of 19 EURAMET NMIs and DIs have a total of 492 CMC entries approved and published on the BIPM KCDB. The distribution by country and technical area is shown below in the figures below. Of the 492 EURAMET CMCs, 288 are Sound in Air, 185 are for Vibration, and 19 are for Ultrasound and Underwater Acoustics. The total number of CMCs for 2022 shows a slight decrease compared to the value for the previous year (511) after the revision of the CMC entries for some NMIs.

Those countries having submitted updated CMCs in the 2021-2022 period include France, UK, Turkey and Austria. All submitted CMCs with except from those from UK has passed the full review cycle and published on the KCDB. Overall, the number of CMCs appearing for review is not excessive, and the situation is manageable. However, TC-AUV's position is to resist expansion of the service categories into tertiary application area as sometimes promoted by other RMOs.



**Figure 1.** Distribution of EURAMET TC-AUV CMCs by country



**Figure 2.** Distribution of EURAMET TC-AUV CMCs by sub-field

### Vitality and validity of CMCs

The questions raised about the CMCs in Vibration for **BIM (Bulgaria)** due to loss of expert staff have been addressed within SC-V. TC-AUV agreed an action plan for the verification of their capability and to ensure the validity of services including: (i) participation in a comparison; (ii) submitting to peer review; and (iii) engaging in capacity building actions. EURAMET project 1464 addressed the issue by providing for a bilateral comparison with GUM (EURAMET.AUV.V-K2) the results of which have now been accepted for equivalence in the KCDB. Revision of CMCs has been made by BIM to reflect the scope of the comparison with the current scope of service.

The sound-in-air acoustic capability of **DMDM (Serbia)** was observed to be discrepant in EURAMET A-K5. After investigation under the auspices of the SC-A Convener, the cause was found to be inexperienced staff undertaking the calibrations for the comparison after a key member of staff had left. After some administrative changes and review of the quality assurance system, new staff for calibrations were hired and successfully trained, and the DMDM capability has been restored. To demonstrate the restored capability, a trilateral comparison with TÜBİTAK UME and GUM, linking to CCAUV.A-K5 through EURAMET.AUV.A-K5, is being arranged. With a positive outcome of the comparison, the CMCs can be considered valid. The comparison will be initiated in the second half of the year 2022.

**SMU (Slovakia)** have requested that their greyed-out CMCs in air acoustics be restored now that they have obtained sufficiently expert staff to cover the required metrology area. SMU staff attended the TC-AUV meeting and the SC-A meeting in 2021, and an action plan submitted by SMU to cover the restoration process was discussed by at the SC-A meeting. A further meeting was arranged with TC-Q, TC-AUV Chairs and SMU management to agree the way forward. However, agreed action plan for re-instatement of CMCs was not implemented in time. Therefore TC-AUV decided to contact KCDB office for permanent deletion of SMU's CMCs in the field of sound in air from the KCDB.

## **5. Activities of the Subcommittees**

The activities of each Sub-Committee are coordinated by the appointed Convener. The Sub-Committees are:

<u>Sub-committee</u>	<u>Convener</u>	<u>Number of members</u>
SC-A "Sound in Air"	Erling Sandemann-Olson (DPLA)	16
SC-U "Ultrasound and Underwater Acoustics"	Gianni Durando (INRIM)	6
SC-V "Vibration and Acceleration"	Thomas Bruns (PTB)	15

The level of membership in Sub-Committees varies significantly, and it is common for invited guests from other RMOs and additional technical experts to attend as observers. As an example, although SC-U has only 6 official members listed on the EURAMET web-site, typically 10 or more people attend the SC-U meetings, frequently including guests from COOMET. Each Sub-Committee meets annually. The work of the Sub-Committees is reflected in the variety of past collaborative TC-projects.



## 6. Participation in EMRP/ EMPIR

There are currently three projects funded by EMPIR which have AUV content.

### EMPIR 18HLT06 RaCHy Project.

The aim is to provide a reliable metrology framework for the evaluation of a class of radiation-based therapies coupled with hyperthermia induced by Therapeutic Ultrasound (TUS), conventional Electromagnetic Radiation (EMR), magnetic fluid hyperthermia mediated by (radioactive) magnetic nano particles (MNPs). There are 11 partners in 5 different countries including some of the most influential therapeutic ultrasound groups in Europe, and the project began on 1st June 2019. In general, the cancer research community will be provided with metrological tools that are able to perform reliable, repeatable and transferrable tests of ultrasound-based methods for quantitative determination of temperature profiles. The findings of the project will also be discussed at the annual IEC TC87 meetings, which gather all the relevant NMIs and ultrasound equipment manufacturers throughout the world. Advances in modelling and the development of comprehensive heat delivery thermal models will reduce the time and the effort necessary for planning and delivery, which at the moment represent the bottleneck for fast and reliable treatment. To achieve the target, the standardization of methods to evaluate and report the results will be made immediately available to the scientific community. Outcomes, such as best practice guidelines based on the expertise and experience of leading centres throughout Europe can be collected to improve recommendations, and will be more widely disseminated. Furthermore, the ability to leverage long-term outcomes by centres in different countries strengthens the evidence-base, accelerating clinical uptake.

Up to now, new experimental and modelling methodologies were developed to enable the prediction of power deposition and temperature profiles within tissue-mimicking materials and biological media during TUS, EMR and MNPs based hyperthermia. The temperature profile will be measured during exposure, to ensure a safe and effective treatment.

A system based on HIFU transducers using the far field properties was developed. With this approach it will be possible to treat by hyperthermia the cancer tissue with 10 mm diameter, without using the motorized positioning translator coupled with HIFU transducer. The system was tested by measuring the temperature induced by US field and it is currently used for *in vivo* test. An ultrasound numerical tool, based on the Westervelt equation, for the simulation of the ultrasound propagation in heterogeneous media like fluids or tissues and the calculation of power deposition was developed. An RF applicator based on a coaxial TEM system with well-focused heating was designed and fabricated for EMR hyperthermia. This enables to generate a uniform power deposition pattern and a controlled temperature rise in a target region with 1 cm<sup>3</sup> size, at a frequency of 434 MHz. Tests have demonstrated the suitability of the RF applicator to be used as a calibrated setup in hyperthermia tests on tissue-mimicking materials, 3D cell cultures and tumour organoids.

Magnetic hyperthermia experiments were conducted with a custom laboratory setup on a set of samples, comprising Fe<sub>3</sub>O<sub>4</sub> nanodisks suspended in liquid. Fe<sub>3</sub>O<sub>4</sub> nanodisks were incorporated in tissue-mimicking phantoms for further thermometric characterization, to mimic a condition more similar to tissue heating. The found results demonstrated that a larger concentration of MNPs in phantoms is needed to obtain a temperature rise comparable to the one measured in liquid.

11 open access articles in peer-reviewed journals have been published. Project activities have been presented at 30 international and national conferences. One training activity has been carried out regarding the TUS application in hyperthermia (12 participants from one stakeholder of the project).

More than 70 people participated at second project stakeholder hybrid workshop on the subject “A combined approach for the treatment of tumours” held in November 2021.

#### EMPIR 19ENV03 Infra-AUV: Metrology for low-frequency sound and vibration

Low frequency Acoustics, Ultrasound and Vibration (AUV) phenomena in air, water and ground are used to detect major natural events such as earthquakes, tsunamis and volcanic activity. Low frequency AUV is also used by the International Monitoring System (IMS) to check compliance with the Comprehensive Nuclear-Test-Ban Treaty. However, the majority of the frequency ranges used for AUV detection are not covered by current measurement standards, limiting the reliability of data obtained. IMS stations are also often located in extreme environments posing additional challenges for assuring the accuracy of AUV sensors. The project will develop new primary calibration methods for airborne and underwater AUV sensing systems down to, and below, the low frequency range of 0.1 Hz. Secondary calibration methods for working standards will also be developed to enable traceability and reliability of sensors deployed in live environmental monitoring networks. Following the end of the project, these are expected to be incorporated in new international standards and aid more accurate and traceable measurements for both natural and man-made environmental events.

The project has recently passed the half-way point, with a successful mid-term review. Development of several calibration facilities has been completed or are in advanced stages of development, across infrasound, vibration and underwater acoustics. Preparations are in-hand for a series of interlaboratory comparisons to validate the new primary and secondary facilities. The project is also focussing on autonomous on-site calibration with an investigation of potential calibration stimulus and specification of reference sensors. New metrology capabilities will be demonstrated by a series of case studies, one of which on measurement of low frequency noise around a wind park, has already been completed and a report published. Strong inputs into standardisation are also planned and some successes have already been achieved. The project is generally running to plan and is fully expected to achieve all of its objectives.

### **7. Capacity Building: Activities of the last year and future needs**

Due to restrictions because of the COVID-19 pandemic, no further EURAMET training courses for air acoustic metrology have been scheduled since the courses held at GUM in Poland in June 2019. The possibility of further courses will be investigated after the travel restrictions are lifted. Some demand has been expressed for mentoring and this is been followed up, though the travel restrictions have prevented visits to participating laboratories. GUM have offered to mentor NSAI in air acoustic metrology, and once the travel restrictions are lifted, NPL will follow up opportunities for mentoring for GUM in underwater acoustic metrology.

### **8. Meetings**

The TC-AUV and the three Sub-Committees meet at minimum on an annual basis. In recent years, the meetings of the TC and all SCs have been held together, providing greater opportunities for cross-theme discussions and greater exposure of all delegates to wider EURAMET issues. The COVID-19 pandemic has severely restricted the ability to hold face-to-face meetings in 2021 and 2022, and so all recent meetings have been held online.

The TC-AUV meeting in 2022 was held on May 5th and 6th 2022. The TC-AUV meeting provided an opportunity for cascading of EURAMET news by Gregor Dudle (METAS, EURAMET BoD



member), Dagmar Auerbach (EMPIR Programme Manager) and Tanasko Tasic (EURAMET Capacity Building Officer).

The next TC-AUV meeting as well as meetings of SCs are scheduled to May 16<sup>th</sup> and 17<sup>th</sup> 2023. The meetings will be hosted by BEV (Austria). NSAI NML (Ireland) offered to host TC-AUV and SCs meetings in 2024.

## **9. Issues**

### KCDB 2.0

The new KCDB 2.0 is now being used for CMC submission and key comparison registration. All national TC-AUV delegates for AUV were encouraged to register as in the “writer” category. All pilots of comparisons are registered in the “pilot” user category. The members of the TC-AUV Working Group for CMC Review have all been registered in the “reviewer” user category. Some errors were discovered in the transfer of CMC data for the recently approved CMCs of PTB and GUM, and these have been cleared in 2021. Some troubles in using KCDB were reported by TC-AUV delegates, and discovered problems were solved in cooperation with the BIPM KCDB Office.

### European Metrology Networks

Currently TC-AUV does not have strong interactions with and an involvement in any operational European Metrology Networks. Some of the subjects are far from activities covered by the TC-AUV. However, in some cases scope of EMNs has kept relatively narrow, what prevents TC-AUV involvement. The issue could be overcome somehow by means of better communication with EMNs. Furthermore, closer look at the development of EMNs could be managed at the very early stages to have better connection between EMN and TC-AUV. TC-AUV would like to apply this approach to the development of proposal on EMN concerning with medical devices, where there should be strong link between TC-AUV and EMN, as TC-AUV activities are connected with audiometry and ultrasonic medical devices used both for treatment and therapy.

### Digital Transformation

The issue on digital transformation is on agenda of CCAUV as well as EURAMET. TC-AUV is involved in various activities concerned with digital transformation. Digital Calibration Certificates, distributed sensor network, calibration, and characterisation of sensors/devices with digital outputs are few topics to be mentioned as examples. Although the importance of joint efforts on these topics is well known, the clear picture on actions to be implemented does not exist. The current situation was discussed during internal workshop on “AUV activities toward digital transformation”, which was held in March 2022. Based on the outcomes from the workshop and following further discussion at TC-AUV meeting in May 2022, TC-AUV decided to create ad-hoc working group for preparation of roadmap for digital transformation and identify activities to be carried out by means of joint projects, either as EURAMET projects or as projects within European Partnership on Metrology.

## **10. Strategic Planning**

### Strategic plan for comparisons

A strategic plan for comparisons within EURAMET has been prepared in 2021. This is based on the CCAUV strategic plan which was developed in 2020 (EURAMET members had significant input into

the CCAUV strategy) and further revised late in 2021. The Strategic Plan was reviewed by the TC Chair and reviewed by the SCs at the May 2021 TC-AUV meeting.

### Road maps

The technical road maps for Airborne Acoustics, Ultrasound, Underwater Acoustics and Vibration are currently being updated, with some progress made since the last TC-AUV meeting. SC-U has prepared updated road maps for Medical Ultrasound and for Underwater Acoustics in 2021. Updated road maps are in preparation for air acoustics, and for vibration.

## **11. Outlook for 2022/2023**

TC-AUV is planning to establish roadmap for digital transformation and identify activities to be carried out by means of joint projects, either as EURAMET projects or as projects within European Partnership on Metrology.

Furthermore, the forthcoming years will keep TC-AUV busy with follow up of CIPM key comparisons to be completed in 2022.

One of the main objectives of TC-AUV in 2022 and 2023 is to establish stronger interactions with European Metrology Networks. This will probably trigger some new activities within TC-AUV.