



1. General Aspects

This report summarises activities of the EURAMET Technical Committee for Acoustics, Ultrasound and Vibration (TC-AUV) for the time period 2022-2023.

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 CCAUV, EURAMET, technical activities cutting across all three AUV themes, and Research Programmes (EMPIR, EPM) 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).

The first term of Enver Sadıkoğlu from TÜBİTAK UME (Türkiye) as TC-AUV Chair is ending at the General Assembly in May 2023. He is willing to stand for re-election for the second term being supported by the Technical Committee.

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 of the project is DFM (Denmark) with the 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 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 range (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



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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 ÜME (Türkiye). Further partner outside of Europe is SASO-NMCC (Saudi Arabia). Pilot laboratory is HBK-DPLA (Denmark). Although the measurement stage within comparison has been completed long time ago, the Final Report of the comparison has been published on the BIPM KCDB in April 2023.

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 the 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 been completed and the Final Report has been published on the BIPM KCDB in August 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 ÜME (Türkiye), and METAS (Switzerland) is the second partner in the comparison. The measurement by TÜBİTAK ÜME was completed early in 2022, and the accelerometers has been transferred to METAS. However, after preliminary measurements METAS has declared that their calibration set-up is not suitable to generate reliable results for this type of accelerometers (Silicon Designs type 2240-005). Based on this fact and taking into account that it is not possible to run the comparison with the current composition of partners and the approved Technical Protocol, it was decided to abandon the comparison. This decision was implemented via KCDB 2.0 platform in January 2023.

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 Türkiye), along with USA, Russia, Brazil, China and South Africa (with an eighth participant from India as a guest participant). Although the measurement stage within comparison has been completed long time ago, the comparison has been completed just recently and the Final Report has been published on the BIPM KCDB in December 2022.

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 TÜBİTAK ÜME. Although delayed by COVID, the measurement phase was completed in February 2021. Evaluation of results and preparation of reports (Draft A and Draft B) have been done in 2022, including review and approval of comparison report by the CCAUV Key Comparison Working Group. The Final Report of the comparison has been published on the BIPM KCDB in January 2023.

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 2023.

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 kHz. 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 ÜME (Türkiye). A further non-EURAMET partner from GULFMET is SASO-NMCC (Saudi Arabia). Pilot laboratory is HBK-DPLA (Denmark). The comparison has been completed with the publication of the Final Report on the BIPM KCDB in April 2023.

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 has been completed and the Final Report has been published on the BIPM KCDB in August 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 ÜME (Türkiye), and METAS (Switzerland) is the second partner in the comparison. The measurements within the comparison have started as scheduled in the Technical Protocol. After monitoring of the stability of travelling standards and completion of the first stage of calibrations at TÜBİTAK ÜME, the accelerometers have been transferred to METAS. However, METAS has declared that their calibration set-up is not suitable to generate reliable results for this type of accelerometers (Silicon Designs type 2240-005). Based on this fact and considering that it is not possible to run the comparison with the current composition of partners and the approved

Technical Protocol, it was decided to abandon the comparison. This decision was implemented via KCDB 2.0 platform in January 2023.

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 comparison. Participants will include TÜBİTAK UME and GUM (the latter acting as linking laboratory).

4. CMCs

20 EURAMET NMIs and DIs have a total of 524 CMC entries approved and published on the BIPM KCDB. The distribution of CMCs by country and technical area is shown in the figures below. Of the 524 EURAMET CMCs, 318 are in Sound in Air, 185 are in Vibration, and 21 are in Ultrasound and Underwater Acoustics sub-fields. The total number of CMCs for 2023 shows an increase compared to the previous year (492). The change in the number of CMCs originate from 2 new CMCs from United Kingdom published on the BIPM KCDB late in 2022 and the decision of Ukraine to transfer their CMCs to EURAMET. The latest decision resulted to addition of 30 CMCs in the field of sound in air.

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.

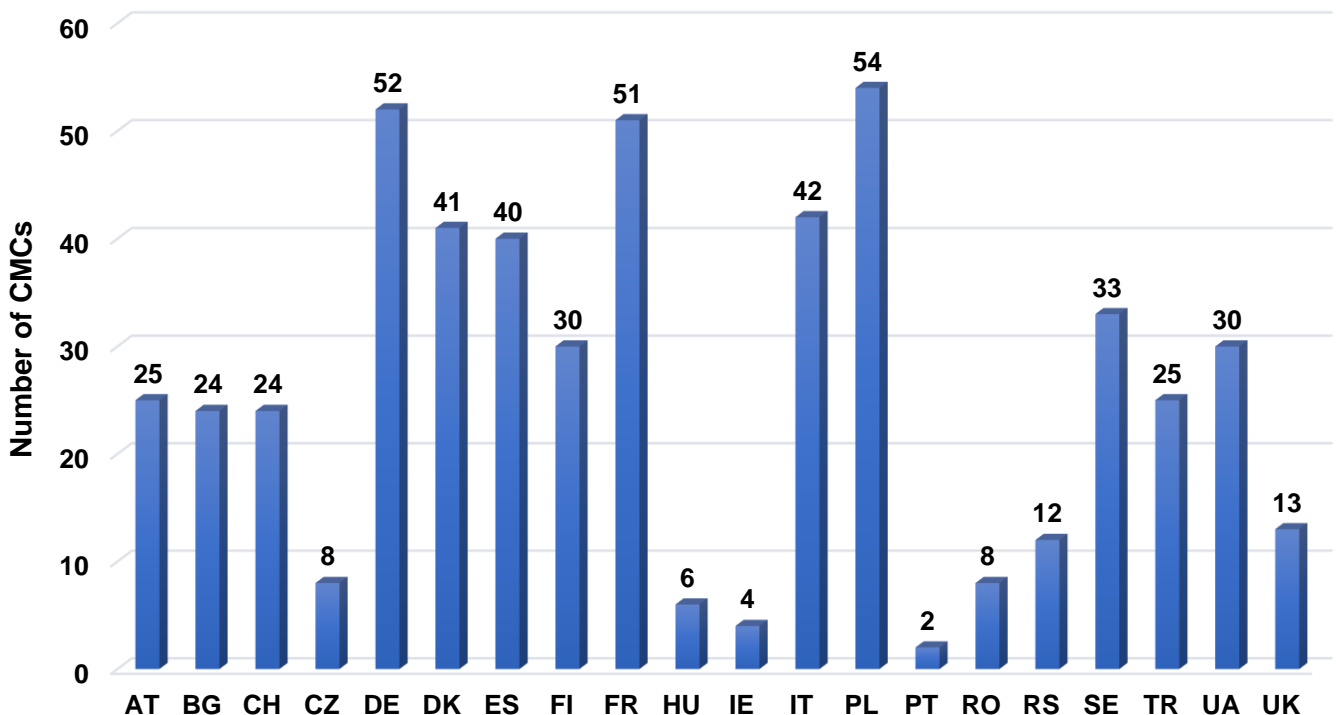


Figure 1. Distribution of EURAMET TC-AUV CMCs by country

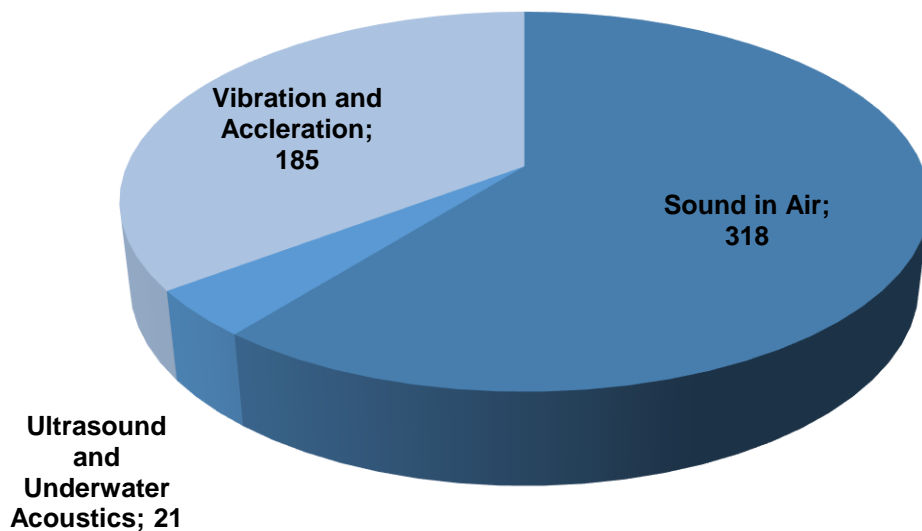


Figure 2. Distribution of EURAMET TC-AUV CMCs by sub-field

Vitality and validity of CMCs

The sound-in-air acoustic capability of **DMDM (Serbia)** was observed to be discrepant in EURAMET A-K5 comparison. 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 2023.

SMU (Slovakia) have requested that their greyed-out CMCs in air acoustics be restored and 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. The decision was implemented in 2022 and 6 CMCs in the field of sound in air has been deleted 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 (HBK-DPLA)	13
SC-U "Ultrasound and Underwater Acoustics"	Gianni Durando (INRiM)	6
SC-V "Vibration and Acceleration"	Thomas Bruns (PTB)	13

The number of members in each Sub-Committee presented above are written in accordance with the information registered by EURAMET Secretariat based on input form EURAMET members and associates. However, in reality number of NMIs and DIs with capabilities in AUV metrology is much higher, what could be easily monitored through the number of countries with CMCs published on the BIPM KCDB.

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 the meetings observers. As an example, although SC-U has only 6 official members listed on the EURAMET website, 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.

The term of Sub-Committees has been reviewed recently at the 21st BoD/TC Chairs/EMN Chairs/WG Convenors Joint Meeting on 15 February 2023, and Board of Directors has decided to renew the term of all 3 Sub-Committees under TC-AUV for the next 5 years until 2028.

6. Participation in EMRP/ EMPIR

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

EMPIR 18HLT06 RaCHy Project.

The aim of the project is to provide a reliable metrology framework for the evaluation of a class of radiation-based therapies coupled with hyperthermia induced by Therapeutic Ultrasound, conventional Electromagnetic Radiation, magnetic fluid hyperthermia mediated by (radioactive) magnetic nano particles. There are 11 partners in 5 different countries including some of the most influential therapeutic ultrasound groups in Europe. The project began on 1st June 2019 and has been completed successfully on 30 November 2022.

The project has developed and provided metrological support to achieve maximum synergistic advantage in the integration of radiotherapy (RT) oncology with different hyperthermia (HT) techniques, based on high intensity Therapeutic Ultrasound (TUS), Electromagnetic Radiation (EMR) and magnetic nanoparticles (MNPs) excited by AC magnetic fields. Heat delivery systems able to generate a uniform power deposition pattern in the target region with a closed-loop control which would maintain the defined temperature indefinitely have been developed and used for in vitro and in vivo tests. New systematic metrological approaches by using chemical metrology techniques such as FTIR spectroscopy as suitable non-invasive and non-ionising tissue diagnosis tools regarding chemical species combined with hyperspectral imaging (HSI) modalities at micrometre

resolution have been used for the biomedical evaluations. The techniques and methods have been tested in preclinical cases and they are now available for clinical evaluation.

14 open access articles have been published in peer-reviewed journals. The project has been presented at 52 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). An e-learning course has been completed and it is available on the RaChy project website: <https://rachy-project.eu/e-learning-course/>.

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 main objectives of the project are to 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 is currently on the last year of implementation. Development of several calibration facilities has been completed or are in advanced stages of development, across infrasound, vibration and underwater acoustics. 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 have been already demonstrated by a series of case studies and results published in scientific literature. 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 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, and outcomes will be communicate with EURAMET Capacity Building Officer. Some demand has been expressed for mentoring and this has been followed up. Currently two applications for Mentoring Scheme Award are under evaluation by BoD Capacity Building Working Group (CBWG). Both applications involve the same partners, NPL (United Kingdom) and GUM (Poland) and concerns with the development of calibration and measurement capabilities in the field of underwater acoustics at GUM and in the field of medical ultrasound (ultrasonic power and ultrasonic pressure) respectively.

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

9. Issues

CMC Review

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. Although the workload for CMC review in AUV field is manageable, number of experts willing to contribute to CMC review is limited in some fields (e.g. mechanical vibration). TC-AUV tries to encourage potential experts to join TC-AUV CMC Review Working Group to share the workload during intra and inter RMO CMC review process.

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. However, no progress on the preparation of the roadmaps was made. The work has been re-scheduled for 2023.

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. The plan will be reviewed again during TC-AUV annual meeting in May 2023.

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.

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

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