Consultative Committee for Acoustics, Ultrasound and Vibration (CCAUV)

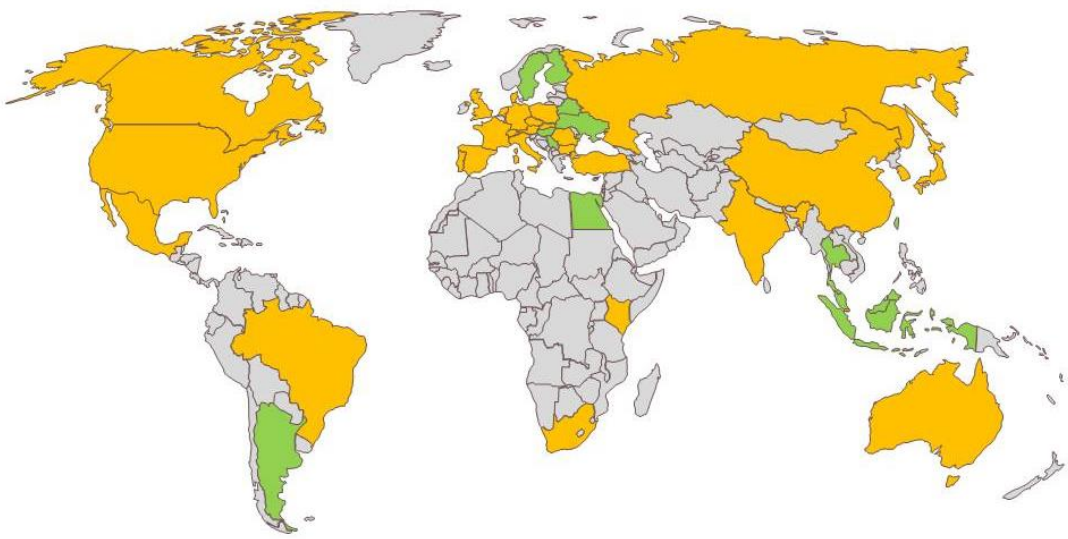
President: Prof. Dr Joaquín Valdés   Executive Secretary: Dr Susanne Picard

1. Executive summary

The CCAUV covers metrological aspects of mechanical waves: acoustics, ultrasound, vibration and underwater acoustics. The comparison phase demonstrating comparability of measurement capability within these fields has matured and reached a stage which is less based on frequent Key Comparisons. A feature of the CCAUV is the highly applied nature of its work and closeness to the stakeholder community. Clear routes for future planning of the activities of the CCAUV have been identified through the strategic planning process, revealing the **important impact on extensive health issues, the economy, environment and safety**.

2. Scope of the CCAUV

The remit of the CCAUV is to advise the CIPM on all scientific matters and issues that influence metrology in the fields of mechanical waves: **acoustics** (A), **ultrasound** (U), **vibration** (V) and **underwater acoustics** (W). It identifies and organizes Key Comparisons in these four fields to establish global compatibility of measurements and traceability to the SI. The CCAUV also acts as the focus and network for this diverse community, to discuss the results of latest research to support emerging areas, and to develop common aims and collaboration between national metrology institutes and designated organizations in Member States of the BIPM or with other relevant bodies.



Members and observers of the CCAUV (in yellow) and additional NMIs having participated in RMO key comparisons (in green).

3. Strategy

In 2012, the CCAUV undertook a radical review of its 2006 strategy that resulted in a global picture of the present and future needs in metrology for applications in A-U-V-W. As there is no activity carried out at the BIPM in these fields, the planning uniquely covers NMIs, DIs and their stakeholders, and the intention is that this will be updated regularly. The CCAUV has received positive feedback on the document from some NMIs, which consider it a valuable support document in the planning of their future activities.

Following the strategic planning process, it became clear that a large increase in the number of future key comparisons is not expected. The comparison phase within all four fields has matured and has reached a stage which is dominated by repeats. Additionally, these repeat key comparisons are characterized by broadened scopes, spanning increased frequency ranges, reflecting changing user demands.

To provide the highest efficiency and quality, the CCAUV is supported by its three Working Groups (WGs): the Key Comparison WG ensures that published comparison data are robust and representative; the RMO WG reviews the relevance of submitted entries for calibration and measurement capabilities; the Strategic Planning WG establishes the CCAUV strategy and maintains a watching brief on development and evolution in the scientific fields of relevance. The CCAUV has not identified any need or advantage in reducing the number of its working groups. Nevertheless, the SPWG and the KCWG have several issues in common, so joint meetings will be organized.

The CCAUV is the most recently created Consultative Committee. It has accumulated 15 years of experience and is now appropriately positioned to further push its strategy through a careful analysis of its actions within the framework of the CIPM MRA.

The published CCAUV Strategic Planning document gives a detailed analysis of each separate discipline. To offer a different perspective, section 5 of this document gives a shorter summary of the needs and impact of A-U-V-W within a selected number of significant areas.

4. Activities and achievements since the last meeting of the CGPM

The CCAUV has met twice since the 24th meeting of the CGPM (2011). As recommended by the CIPM *ad hoc* Working Group on Governance in 2012, the **RMO TC-AUV chairs were invited to the CCAUV meetings**, as well as to participate at the Key Comparison and Strategic Planning WG meetings. The **Actions and Decisions were identified** after each meeting and uploaded to the open CCAUV web pages **to rapidly make a summary publicly available** before the publication of the minutes. A **simplification in reporting Degrees of Equivalence** was adopted, which will save time for the institutes reporting comparisons. A **Key Comparison Working Group was established** and has contributed to clarifying important issues which need to be addressed before carrying out a key comparison, and to the **improved quality of published reports**. A **monthly newsletter** on CCAUV activities is communicated to all CCAUV participants.

Main activities

The CCAUV meets every two years. The group of metrologists within these areas represent a sparse and geographically-dispersed community. Therefore, the CCAUV meeting not only covers cooperation via comparisons but provides the focal point for individual participants to describe the latest research and demonstrate progress in the relevant fields, to create and maintain contacts with other specialists and to discuss current issues.

Contacts with stakeholders are to an extent accomplished by CCAUV links with several Technical Committees within the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC), maintained via CCAUV representatives.

The Kenyan Bureau of Standards (KEBS) became an observer of the CCAUV in 2014.

Challenges and difficulties

Contrary to many other Consultative Committees, the CCAUV does not maintain a base unit; units used are either derived (composed by several different base units), or represented by the well-known dimensionless unit *decibel*. For this reason, there is a need in the A-U-V-W areas to provide traceable measurements in a wide range of units. However, work is being focused on realizing sound pressure in terms of the SI unit *pascal*, which is already in place in Ultrasound.

Comparisons to accomplish traceability are made by circulating travelling standards, such as microphones, hydrophones or actuators, between the participants. This unavoidable way to proceed in A-U-V-W is often time consuming, where the next participant must wait for the previous, and where the conservation of artefact-quality critically affects the global comparison outcome. Unfortunately, transport problems are regularly encountered and are often exacerbated by national customs procedures. This can be particularly troublesome for the sensitive and fragile instruments involved.

The technical and scientific challenges are reported below.

5. Outlook in the short and long term

Health

Hearing is one of our most vital senses and impairment can lead to severe degradation in quality of life. Consequently, national healthcare programmes invest heavily in both hearing diagnostics through screening programmes and rehabilitation through the provision of hearing aids.

Early diagnosis and treatment of hearing disorders are realized today by new-born screening programmes in many countries. However, metrology underpinning hearing screening has not kept pace with modern audiological practices where there is a movement towards **objective methods** such as *oto-acoustic emission* (sound generated within the inner ear) and *evoked brainstem response* (measurable electrical activity in the brain to indicate hearing), for which there is a need for resources.

Hearing thresholds require new calibration methods traceable to national standards and improved methods for the determination of reference values of the ear. Further, continued generic science is necessary to **better understand and model the human auditory process**, particularly regarding hair cell damage by very high frequency sound and the bone conduction mechanism.

Therapy and Diagnostics: Ultrasound has become one of the most frequently used diagnostic tools in medicine. World-wide, there are 250 000 diagnostic ultrasound instruments and 250 million examinations per year. Safety-sensitive diagnostic applications will drive the continued development of improved metrological tools and prediction models. In particular, the last 15 years has seen a dramatic increase in quality and complexity of medical applications for early **routine cancer screening** through elaborate ultrasound imaging methods showing particular promise.

Novel therapeutic applications of ultrasound will continue to emerge, supporting drug delivery concepts based on high-intensity ultrasound or cavitation. Exploitation of the clinical potential of such methods requires the development of metrology for both existing and emerging quantities. To unlock the potential of therapeutic ultrasound and to better assess safety for diagnostic applications, metrology is essential for the development and validation of methods for determining *ultrasound dose*, supporting treatment planning and risk assessments.

For manufacturers, micro-bubbles coupled with therapeutics will drive developments of the next wave of ultrasound technology into clinical practice over the next 5 to 10 years. For example, **microbubble-based drug/gene delivery vehicles for cancer and Alzheimer therapies** promise significant advances in treatment.

Key factors in **assessing the safety of medical ultrasound** applications lie in methods of estimating *in-vivo* ultrasound levels, and its implications in terms of bio-effects. The ability to make such measurements is likely to find increasing application, for example in the evaluation of protein solutions, or assessment of nano-particles.

Environment

Underwater acoustic techniques are chosen for most marine applications requiring remote imaging, communication or mapping in sea water, where techniques based on electromagnetic waves suffer from a limited range due to their high levels of absorption.

Marine noise pollution generated by cargo ships or industrial activity in the marine environment, e.g. associated with oil and gas platforms or when installing wind-turbines, must be monitored using underwater acoustic techniques. Deep ocean measurements have reported that **marine noise doubles each decade**. Increasing legislation with regard to assessing and mitigating the exposure of marine life to noise pollution is one of the key drivers in this area. It is already subject to regional regulation.

Absolute acoustic techniques provide the potential for **monitoring carbon dioxide leakage** in carbon capture and storage applications. **Three-dimensional measurements of ocean currents** and temperature are achieved, representing important **indicators of climate change**. Other indicators may also be monitored such as acidification and methane seepage.

Deep ocean studies increasingly utilize autonomous underwater vehicles which are heavily dependent on acoustic systems. In shallow water, acoustic techniques are used in the study of sediment transport processes, important for **assessment of coastal erosion**.

Industry and Technology

Sensors, and the instrumentation used to produce meaningful outputs from them, underpin all acoustic measurements, starting with the realization and dissemination of the primary standard and finishing with hearing assessment, noise measurement or a description of sound quality. In many cases, the drivers for developments in acoustic instrumentation can be addressed through innovation in sensors and instrumentation. In this respect there is great potential to **exploit synergies with the consumer product sector**, where the demand for microphones now exceeds 2 billion units each year. With the proliferation of low-cost sensors, there is now scope for active management of the acoustic performance of sophisticated items and wireless, autonomous and intelligent operation. For example condition monitoring of machinery, vehicles, rail infrastructure and even domestic appliances could be implemented to maintain the acoustic performance designed into products, optimizing operating efficiency or simply monitoring the level of noise produced. These applications demand new metrology such as remote self-calibration of sensors and sensor networks, acoustic signature recognition and decision making based on multiple parameters.

Increasingly, the **acoustic performance of products** is becoming a distinctive added-value feature. Examples include luxury cars, laptop computers, and domestic products such as vacuum cleaners, fans, washing machines and lawn mowers. The first measurement consideration was the sound power produced by the product, but acoustic considerations have now evolved and its ***perceived*** **quality** is becoming increasingly important. Such applications are still unusual and create the demand for alternative metric types relevant to perception.

Industrial applications of ultrasound are extensive, where it is commonly applied as a means of bringing about macroscopic changes in materials, either within the bulk or at surfaces. Ultrasonic cleaning is the most widespread application of industrial ultrasound and such technology is used for the cleaning of surgical and dental instruments. There is a need for broadband measurement methods capable of spatially resolving non-uniformities in acoustic field distributions, and to underpin improved understanding of influencing factors. This will enable **high-power ultrasound to be further applied in an economically viable way** in a wide range of technical fields in industries such as food (crystallization control, pasteurization), pharmaceuticals (particle size control) and biofuel production.

The areas of **vibration measurement**, such as automotive, aerospace and testing, have not changed drastically over the last decade. However, new requirements are growing within these stakeholder groups and demands are expected for angular vibration (**automotive safety**) and shock acceleration measurements over an extended range.

The emerging metrological activity in the field of **dynamic measurement of mechanical quantities**, like force and torque, has revealed a whole new area where linear and angular acceleration become base quantities for traceability of the derived quantities. One well known area is automotive crash testing for which dynamic measurements are essential. Although widely accepted international standards exist, the results are in many cases not strictly comparable due to the lack of appropriate calibrations and in-depth understanding of the dynamic metrology. The metrology infrastructure currently in place for dynamic mechanical quantities, namely vibration and shock, lags a long way behind that established for acceleration measurements. A recent BIPM workshop identified that collaboration with other Consultative Committees would be of benefit to harmonize terminology and uncertainty estimates.

A substantial underwater acoustics industry supports off-shore applications. In **oil and gas**, there is a clear trend toward working in deeper water as the shallower coastal waters become heavily exploited. This is setting **new challenges for acoustic systems required to work at greater depths** and over larger ranges. In particular, hydrophones and materials are required with consistent acoustic performance over a range of different water temperatures and depths.

Society and Safety

Noise produced by a variety of sources such as transportation (road, rail, air), industrial plant and wind farms, neighbourhood noise, sports and entertainment venues, is also detrimental to the environment and quality of life. Many processes described in national and regional noise directives are repeated every five years providing scope for ongoing improvement in the mandates. One criticism is that its results bear little resemblance to the noise levels experienced at a given location at any particular time. It has been further criticized for relying totally on prediction with no requirement for validation by actual measurement. This is due to the costs of employing existing technology. **New metrology for cost-effective and widespread distributed noise measurement** is needed to redress this deficiency.

Requirements for traceability and mutual recognition of measurement results are needed for **workers' safety**. The **human response to mechanical vibration**, where a dose concept is applied, represents one issue, and hearing is commonly put at risk from excessive exposure to man-made noise. Measures to reduce these hazards impose huge expenses annually. The widespread screening of work-force or personal noise dose-monitoring will demand **new approaches and innovative instrumentation**.

Low-frequency vibration transducers are widely used for **monitoring earthquakes**. The demand for earthquake monitoring systems has increased following a number of major seismic incidents. Special sensors provide traceability to thousands of seismometers and hundreds of observation stations in the Global Seismographic Network which provide an **immediate alert** to the population, demanding calibrations at ultra-low-frequencies.

Underwater acoustic technology is employed for the **protection of ports and harbours** from mines and potential terrorist threats.

Annex: CCAUV Data

CCAUV set up in 1998
President: J. Valdés — Executive secretary: S. Picard
Membership: 17 members and 15 observers
List of CCAUV members and observers: http://www.bipm.org/en/committees/cc/ccauv/members_cc.html

Meetings since the 24th CGPM meeting: 13-14 June 2012 / 29-31 October 2013
Full reports of the CCAUV meetings: http://www.bipm.org/en/committees/cc/ccauv/publications_cc.html

3 Working Groups: http://www.bipm.org/en/committees/cc/ccauv/working_groups.html
Key Comparisons (KCWG)
RMO Coordination (RMOWG)
Strategic Planning (SPWG)

CCAUV Comparison activity	Completed	In progress	Planned [2015-2018]
CCAUV key comparisons (and supplementary comparisons)	13	3	4
BIPM comparisons	0	0	0
CC pilot studies	1	0	3
CMCs	1084 CMCs in 51 service categories registered in the KCDB		