Bureau International des Poids et Mesures

Consultative Committee for Acoustics, Ultrasound, and Vibration (CCAUV)

Strategy 2016 to 2026

Consultative Committee for Acoustics, Ultrasound, and Vibration (CCAUV)

Dr. Takashi Usuda (NMIJ), CCAUV President
Dr. Gianna Panfilo (BIPM), Secretary

Strategic Planning Working Group (SPWG)

Dr. Michael Gaitan (NIST), Chairperson
Dr. Salvador Figueroa (DFM), Co-Chair (Acoustics)
Dr. Bajram Zeqiri (NPL), Co-Chair (Ultrasound)
Dr. Stephen Robinson (NPL), Co-Chair (Underwater Acoustics)
Dr. Thomas Bruns (PTB), Co-Chair (Vibration and Shock)

Mission of the CCAUV SPWG

- Establish a view on emerging requirements for CCAUV metrology, the way these are driven by societal and industrial stakeholder needs and the key enabling technologies providing solutions to the highlighted challenges;
- Provide input within the area of AUV into the CC Strategy Document; “Future Needs in Metrology” documents;
- Provide expert input and advice to the CC Strategy Document identifying future pilot studies and Key Comparisons;
- Advise the CCAUV on the optimal operational structure, e.g. for information gathering, collation and dissemination;
- Share information on national priorities (e.g. roadmapping) for emerging metrology helping NMIs to formulate improved metrological programmes;
- Identify areas suitable for collaboration, thereby allowing impact to be accelerated;
- Monitor and respond to developments within other CCs, including the future of the SI, which might impact on the area of CCAUV;
- Identify developments needed for AUV measurement of properties relevant to “Materials Metrology”.

Organization of the Report

- Executive Summary
- Terms of Reference
- Baseline
- Stakeholders
- Future Scan
- Rationale for Various Activities
- Required Key Comparisons and Pilot Studies
- Resource Implications for Piloting Laboratories
- Summary
- Document Revision Schedule
- Bibliography and Supporting Documents

Schedule of SPWG Activities

- Assignment of Chair, CCAUV Meeting, November 2015
- Assignment of Co-Chairs and Responsibilities, Kickoff Teleconference, Spring 2016
- Preparation of Draft Sections of the Report, by email correspondence, Early Spring 2017
  - Future Scan
  - Update of Baseline and Stakeholders
  - Rational and Schedule for Key Comparisons
  - Stakeholders and Resource Implications
- Preparation of Draft Report, by email correspondence, Summer 2017
- Meeting of the SPWG to Review the Report, CCAUV Pre-Meeting, September 2017
- *Presentation and discussions, Main CCAUV Meeting, September 2017*
- Submission of Report, End of CCAUV Meeting, September 2017

General Information of CCAUV

- Established in 1999
- President: Dr. Takashi Usuda (NMIJ), since 2014
- 17 members and 14 observers
- Meets every 2 years
- Last meeting was held 25 to 27 November 2015
- 46 participants at last meeting (experts included)
- 15 CC-KCs and 26 RMO-KCs carried out from 1999 to 2016
- 2 Pilot Studies were carried out from 1999 to 2016
- There are 51 types of CMCs. 1174 CMC entries are published in KCDB of which 870 are linked to a Key Comparison supported by the CCAUV

Terms of Reference

"Though the measurement units that the CCAUV supports are not fundamental units of the International System of Units (SI), they have a direct relationship to public safety, health, and national security."
Executive Summary

- Endow traceability by international collaboration and coordination;
- Identify, plan and execute key comparisons of national measurement standards;
- Harmonize contacts between Regional Metrology Organizations (RMOs) and survey issues related to CMCs in the framework CIPM MRA (cf. RMOWG);
- Identify advances in physics and engineering that directly influence acoustic and acceleration metrology;
- Provide a vision for short- and long-term strategy (cf. SPWG);
- Provide expertise to maintain AUV metrology at its highest level (cf. KCWG);
- Prepare recommendations for discussion at the CIPM.

Baseline: A-U-V Designations

(A)	**Acoustics**	
	Airborne Sound	Airborne sound is sound that is transmitted through the air.
(U)	**Ultrasound and Underwater Acoustics**	
	Ultrasound	Ultrasound is sonic energy having a frequency above the human hearing range. These applications have primary use in industrial and medical applications.
	Underwater Acoustics	Underwater acoustics is the study of the propagation of sound in aquatic environments.
(V)	**Vibration**	
	Sinusoidal Acceleration	Acceleration measurements using sinusoidal steady state mechanical vibrations
	Shock Acceleration	Acceleration measurements using transient impact
	Inertial Acceleration (under consideration)	Acceleration measurements by static positioning in the gravitational field or held at continuous rotation rate.

Baseline: Stakeholders

Stakeholder	**Application**
Metrological bodies	High precision metrology Precursor to other stakeholders
Health	Hearing assessment Objective audiology Diagnostics (imaging) Therapy (e.g. drug delivery in cancer and Alzheimer therapies, treatment enhancement for strokes) Cleaning and materials processing Occupational Safety Patient Safety
Industry	Industrial design Equipment manufacturers Automotive Aerospace Testing (e.g. bulk materials and surfaces) Health and safety Cleaning procedures
Consumer Electronics	Mobile devices Fitness Tracking
Trade	Added value in performance of products

Baseline: Stakeholders (Continued)

Stakeholder	**Application**
Environment	Marine noise pollution Climate change monitoring Air-borne environmental noise Earth quake monitoring Carbon capture and storage
Society	Environmental protection Psychological influence and human health
Energy	Offshore oil and gas Marine renewable energy Biofuel production Wind
Defense	Defense and security Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO)
Ocean science and marine applications	Ocean processes (e.g. currents and temperature) Hydrographic mapping Positioning, Navigation Communication Sonar Echo-sounding Geophysical survey

Future Scan: Inertial Acceleration

Inertial acceleration is included in this future scan, motivated by the significant global market for inertial sensors based on Microelectromechanical Systems (MEMS). Yole Development (a market study organization) reported in 2016 that the global market for MEMS-based inertial sensors was $3.4B and expected to continue to grow with a compound annual growth rate (CAGR) of 9.6% for inertial combos. Other market studies forecast even higher growth rates.

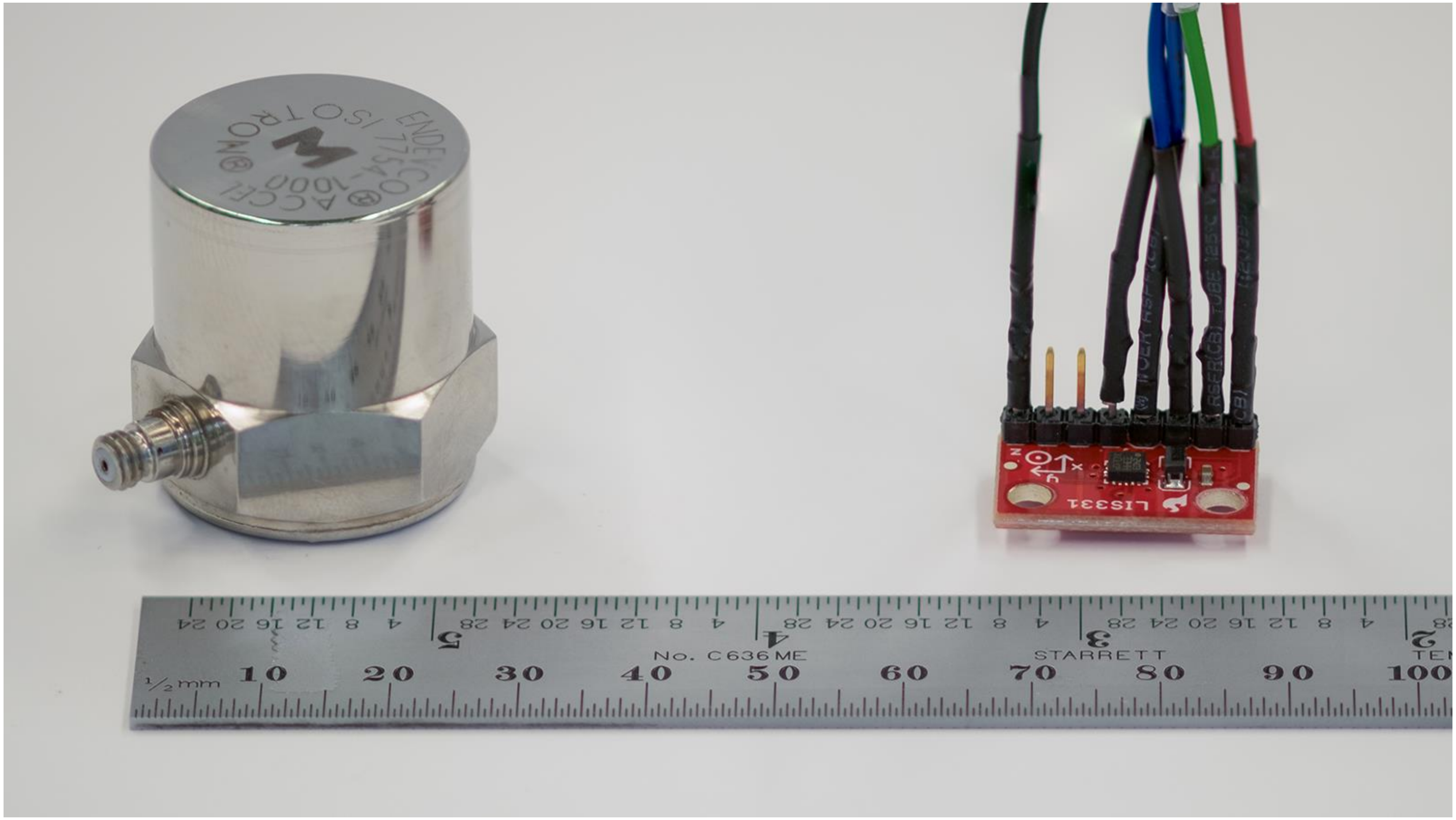
Future Scan: Inertial Acceleration

These technologies are multi-axis accelerometers and gyroscopes called inertial combos … Inertial Measurement Units (IMUs) are a type of inertial combo integrating three-axis accelerometers, gyroscopes, and magnetometers into a single integrated device.

Future Scan: Digitization

A majority of inertial sensor combos, as well as microphones, utilize digital data interface standards such as I2C or SPI. The CCAUV's key comparisons do not include the use of reference transducers with digital interfaces. Although in principal the testing of transducers with digital interface devices could follow a similar procedure as their analog cousins, in practice interfacing with them is likely not straightforward.

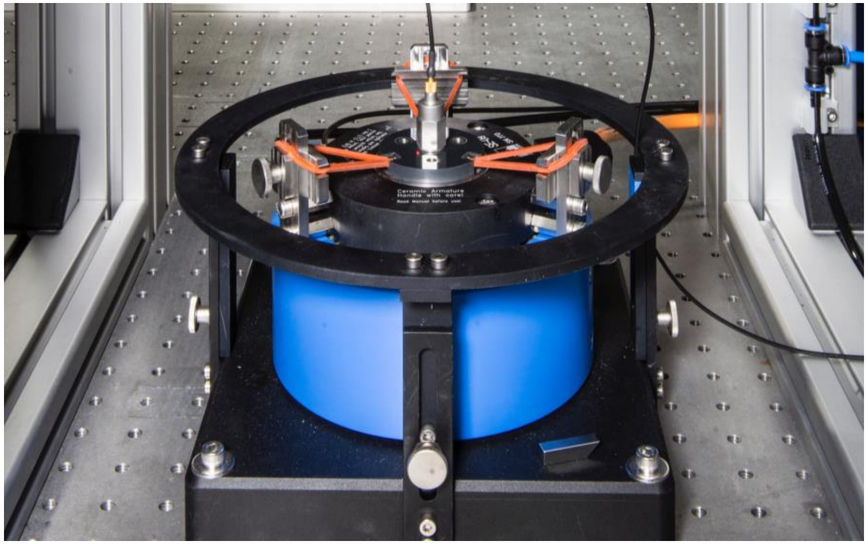
Example

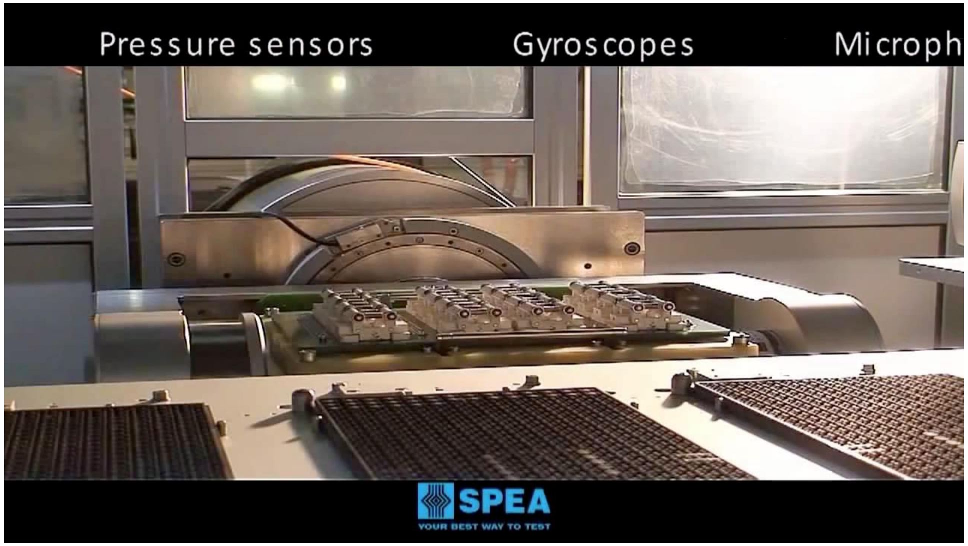


Example Reference Accelerometer
(Endevco 7754-1000)
Single Axis, Analog

Example MEMS Accelerometer
(ST LIS331HH)
3 Axis, Digital (SPI or I^2C)

Test and Calibration Equipment





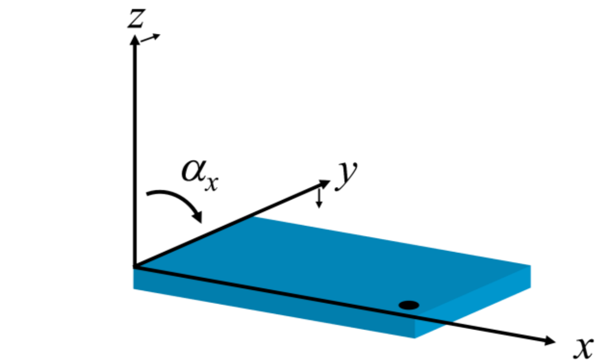
Source: https://www.youtube.com/watch?v=cZAJdkxdkHo

Example: Air Bearing Shaker for Primary Calibration of Reference Accelerometers

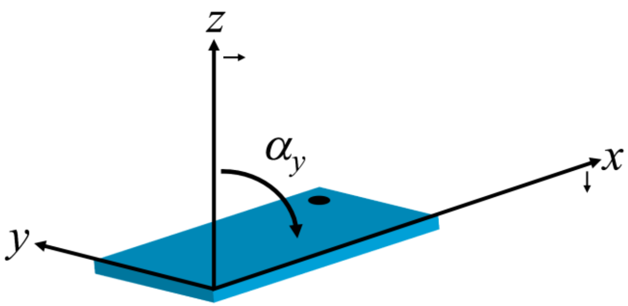
Example: High Throughput Test Equipment for MEMS Accelerometers

Disclaimer: NIST does not endorse any products shown in this presentation; they are only depicted as examples of what is commercially available.

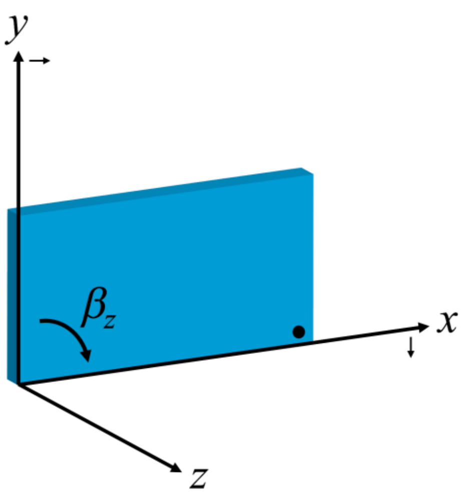
Testing Protocol Used at NIST



1. Rotation around the x-axis

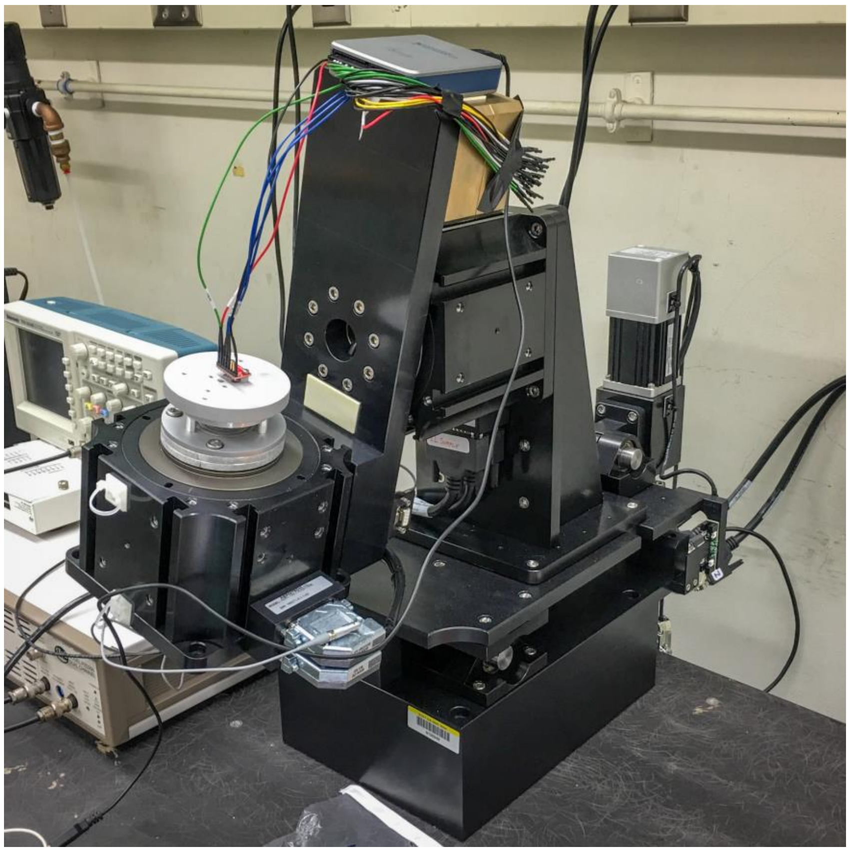


2. Rotation around the y-axis

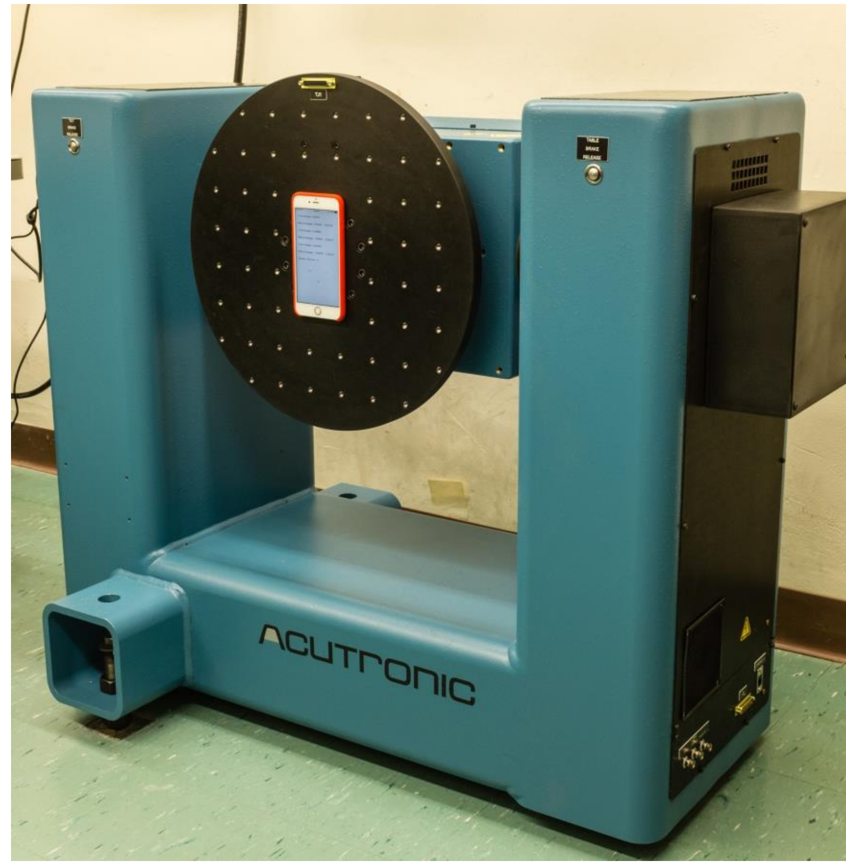


3. Rotation around the z-axis

Exciters Used at NIST

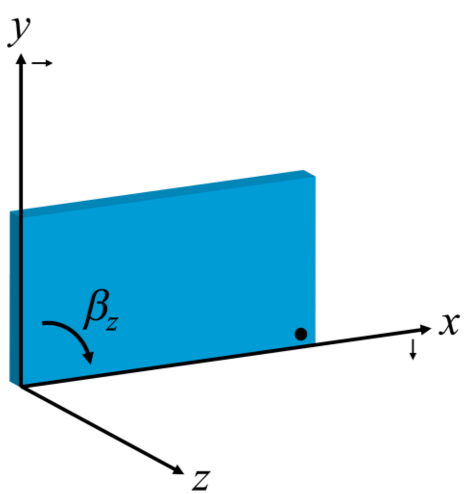


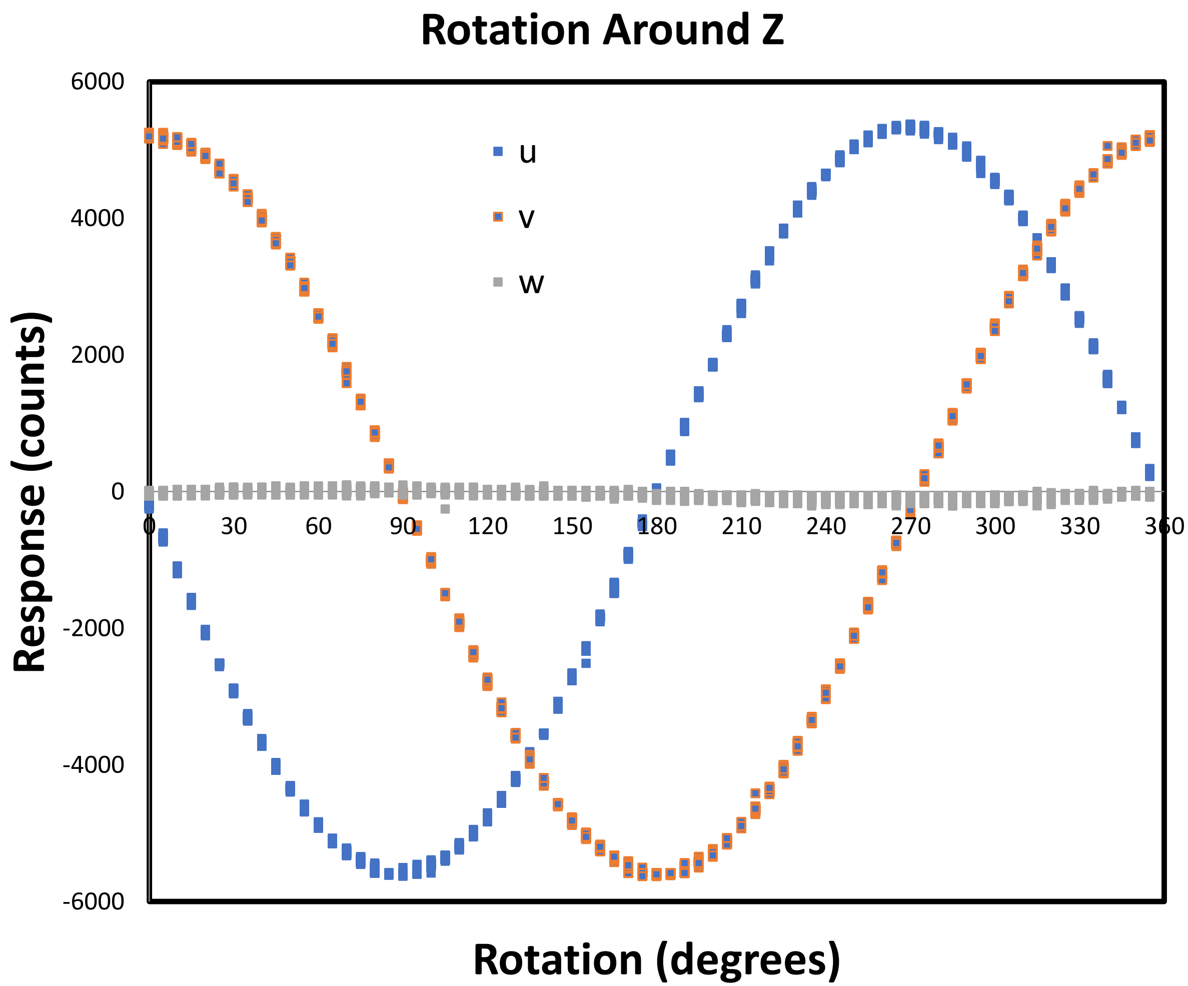
2 ½ DoF gimbal
Packaged Device



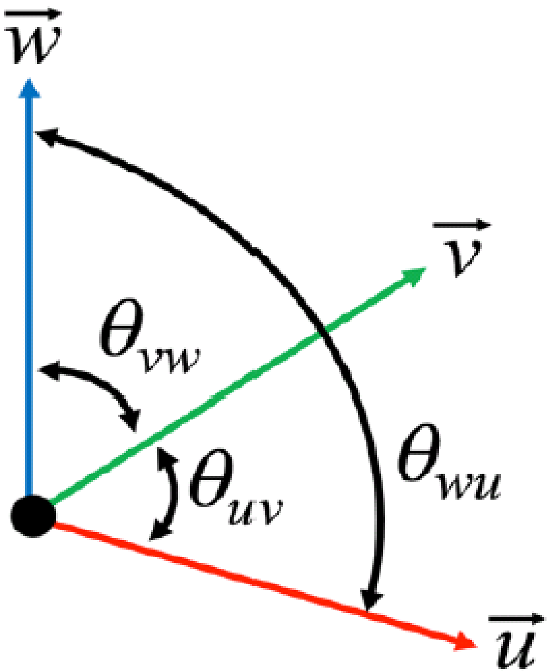
2 ½ DoF position and rate table
Smartphone

Example: Accelerometer Response Data





Example: Measurement Results



Intrinsic Properties

u	=	5448
v	=	5386
w	=	5503
		(counts)/(g_n)

θ_{uv}	=	88.7
θ_{vw}	=	89.3
θ_{wu}	=	88.5
		(degrees)

Gravity-Based Characterization of Three-Axis Accelerometers in Terms of Intrinsic Accelerometer Parameters, Jon Geist, Muhammad Yaqub Afridi, Craig D. McGray, Michael Gaitan, Published July 13, 2017
http://nvlpubs.nist.gov/nistpubs/jres/122/jres.122.032.pdf

g_n refers to the average acceleration produced by gravity at the Earth's surface (sea level), 9.80665 m/s2 (value published by the Committee on Data for Science and Technology (CODATA) for international use)

Future

- Discovery of international needs, and interest and collaboration between NMIs (at this meeting)
- Development of Standards (ISO)
- Bilateral Comparisons
- Pilot Studies
- Key Comparisons

Key Comparisons: Airborne Sound

Sub-area/ Reference No.	Description	Rationale	How far the light shines	Expected start
Airborne sound	Comparison of Laboratory Standard Microphones type LS2	Repeat of CCAUV.A-K3 and extending frequency range	Pressure sensitivity in the frequency range 2 Hz to 30 kHz	2018
Airborne sound	Comparison of Laboratory Standard Microphones type LS2	Repeat of CCAUV.A-K4	Free-field sensitivity in the frequency range 1 kHz to 30 kHz	2020
Airborne sound	Comparison of Laboratory Standard Microphones type LS1	Repeat of CCAUV.A-K5	Pressure sensitivity in the frequency range 2 Hz to 20 kHz	2022
Airborne sound	Comparison of Working Standard Microphones type WS3 (Pilot study)	Extension of the frequency range up to 150 kHz	Free-field sensitivity in the frequency range 10 kHz to 150 kHz	2020
Airborne sound	Comparison of Laboratory Standard Microphones type LS1/LS2 (pilot study)	Calibration in a diffuse field	Diffuse-field sensitivity in the frequency range 2 Hz to 20 kHz	2020
Airborne sound	Calibration of LS1/LS2/WS3 microphones (pilot study)	Calibration using optical techniques	Pressure and free-field sensitivity in the combined frequency range 1 Hz to 200 kHz	2022

Key Comparisons: Ultrasound

Sub-area/ Reference No.	Description	Rationale	How far the light shines	Expected start
Ultrasound	Ultrasonic power	Repeat of CCAUV.U-K3	Transducer electro-acoustic radiation conductance and transducer ultrasonic output power, 0.01 W – 15 W*	2023
Ultrasound	Comparison of reference hydrophone calibrations	Repeat of CCAUV.U-K4	End-of-cable loaded hydrophone sensitivity, in nV/Pa, over the frequency range 2 MHz – 20 MHz*	2024

Key Comparisons: Underwater Acoustics

Sub-area/ Reference No.	Description	Rationale	How far the light shines	Expected start
Underwater Acoustics	Comparison of pressure calibration of hydrophones	Extension of CCAUV.W-K2 to low frequencies	Free-field hydrophone sensitivity in V/Pa over the frequency range 2 Hz to 1 kHz	2019
Underwater Acoustics	Comparison of free-field calibrations vector sensors (pilot study)	Comparison of particle velocity standards	Free-field sensitivity in $Vm^{-1}s$ over the frequency range 20 Hz to 10 kHz	2022
Underwater Acoustics	Comparison of free-field calibrations of hydrophones	Repeat of CCAUV.W-K2	Free-field hydrophone sensitivity in V/Pa over the frequency range ~250 Hz to 2 MHz	2025
Underwater Acoustics	Comparison of pressure calibration of hydrophones	Extension of CCAUV.W-K2 to low frequencies	Hydrophone pressure sensitivity in V/Pa over the frequency range 2 Hz to 1 kHz	2026

Key Comparisons: Sinusoidal Acceleration

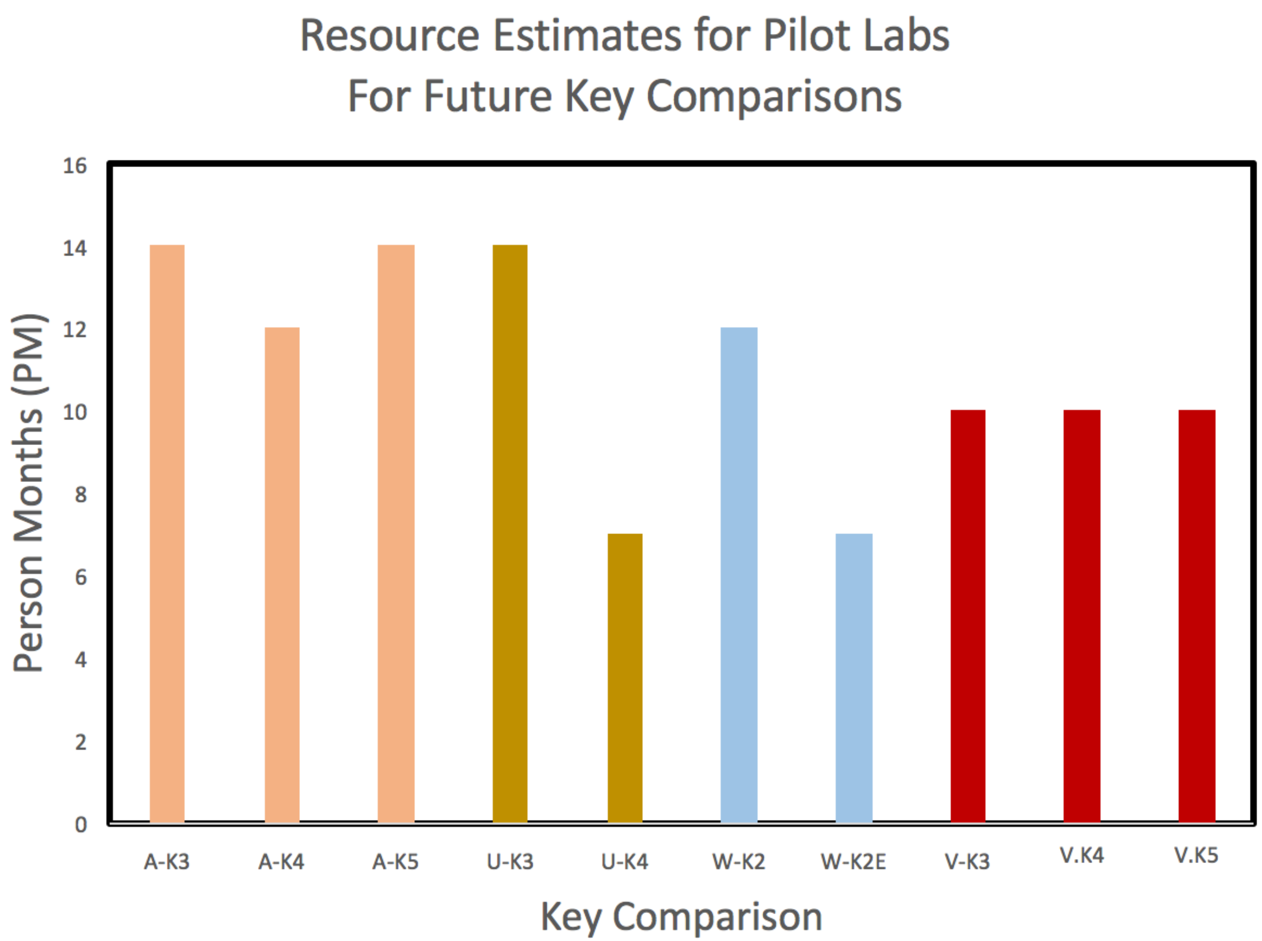
Sub-area/ Reference No.	Description	Rationale	How far the light shines	Expected start
Sine-excitation	Comparison of primary calibration of magnitude and phase	Coverage of traditional calibration services in acceleration	10 Hz to 20 kHz This will be a regular KC to be repeated in 10 y intervals	2017
Sine-excitation	Comparison of primary calibration in magnitude and phase	Coverage of traditional calibration services in acceleration	0.1 Hz to 40 Hz This will be a regular KC to be repeated in 10 y intervals	2025
Sine-excitation	Comparison of primary calibration of magnitude and phase	Coverage of traditional calibration services in acceleration	10 Hz to 20 kHz This will be a regular KC to be repeated in 10 y intervals	2027
Angular vibration	Primary calibration of magnitude	Increasing number of NMIs with the capability and demand for CMCs	Depending on the global demand this may become a regular KC	2020

Key Comparisons: Shock

Sub-area/ Reference No.	Description	Rationale	How far the light shines	Expected start
Shock excitation	Primary calibration according to ISO 16063-13 (peak ratio)	Increasing number of NMIs with the capability and demand for CMCs	500 m/s^2 to 5000 m/s^2 This will ultimately be a regular KC to be repeated in an 10-year interval.	2026
Shock excitation	High intensity primary calibration according to ISO16063-43 (pilot study)	The parameter identification is needed for broad band excitation calibration	A pilot study is needed to ensure the applicability of the parameter identification for KC. This will enable subsequent KCs.	2020

Resource Implications

The purpose of this section is to base our arguments of lessons learned from previous key comparisons to improve protocols and schedule optimization for our key comparisons.



Thank You!

Please continue to contribute your ideas during this meeting.