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Exploring the Potential of a Barometer as a Transfer Standard for Infrasound Calibration

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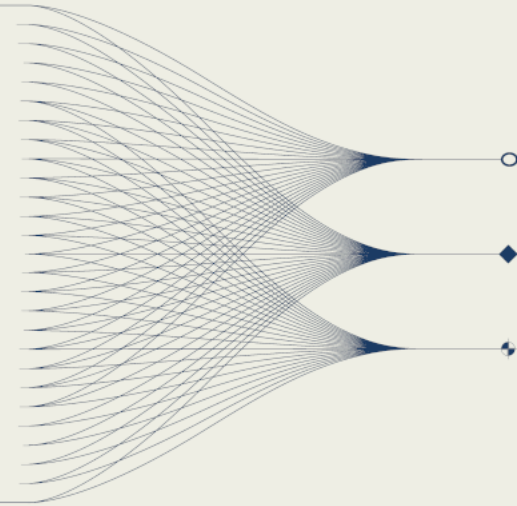

9th September 2025

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Motivation & Context

Quality assurance for IMS measurement systems

- CTBTO prepares to implement the Nuclear-Test-Ban Treaty.
- The International Monitoring System (IMS) is a key part of the verification regime.
- Ensuring data quality is essential:
  - Operational Manual (CTBT/WGB/TL-11,17/17/REV.7).
  - Quality assurance infrastructure for IMS infrasound measurements.
- Requires accurate and regularly calibrated instruments.

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Establishing measurement traceability for IMS infrasound measurements

Sandia National Laboratories

cea

National Metrology Institutes
Primary reference standard

Accredited / Expert Laboratories
Working standard

One site calibration laboratories
Travelling standard

Users
Measuring equipment

Need for reliable working/transfer standards

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Current Transfer Standards in Acoustics

- **Microphones:**
  - ✅ Well-established, robust, easy to deploy, traceable to primary standards
  - ❌ Limited below 0.1 Hz
- **Micro-barometers:**
  - ✅ Cover low-frequency range, robust, traceable to primary standards
  - ❌ Heavy and bulky, difficult to deploy
- **Barometers:**
  - ✅ Robust, stable, easy to deploy
  - ✅ Can bridge static and dynamic calibration domains

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Objectives & Device Under Test

- Investigate whether a barometer can serve as an infrasound transfer standard
  - Ability to bridge static and dynamic calibration domains
  - Compare static vs dynamic calibration methods

- The Device Under Test
  - Keller PAA33X static pressure sensor
  - Piezoresistive technology
  - Operating range : 800 – 1200 hPa
    - Analog interface ranged to 950–1050 hPa over 0–10 V output
    - Nominal sensitivity: -60 dB ref. 1V/Pa
  - Expected flat response up to ~20 Hz

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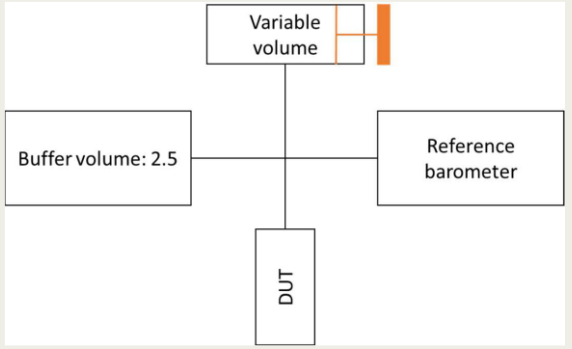
Calibration Methods Overview

- **Two calibration paths (same sensor):**
  - Static pressure calibration – reference barometer & buffer volume
  - Dynamic calibration – laser pistonphone
- **Two LNE laboratories involved:**
  - Static Pressure Lab
  - Acoustics & Vibration Lab
- **Comparison basis:**
  - Cross-compare static vs dynamic results under the same pressure range (100000 ± 20 Pa).



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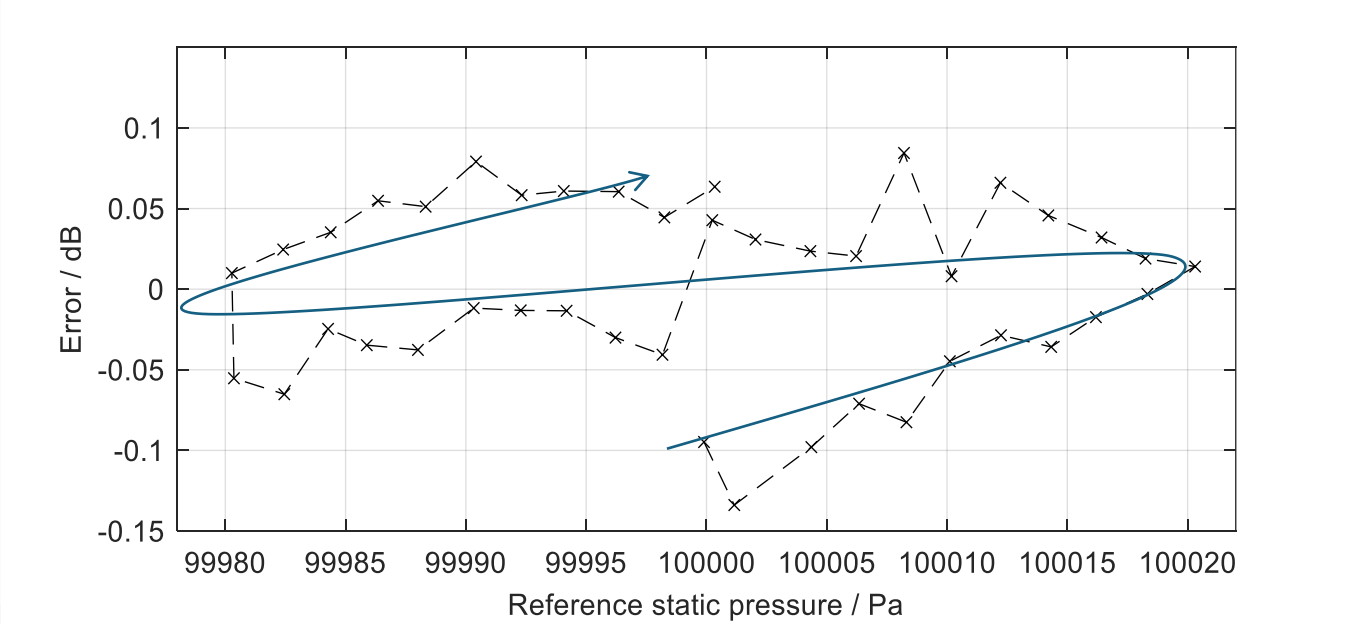
Static Pressure Calibration – Results

- Calibration cycle (2 Pa steps)
  - Simulates a sinusoidal pattern in DC
  - Sequence: 100000 → 100020 → 99980 → 100000 Pa

- Linear regression results:
  - Sensitivity M_p: **-60.034 dB re 1V/Pa**
  - Expanded uncertainty (k=2): **0.056 dB**



Deviation of the measured pressure from the expected pressure

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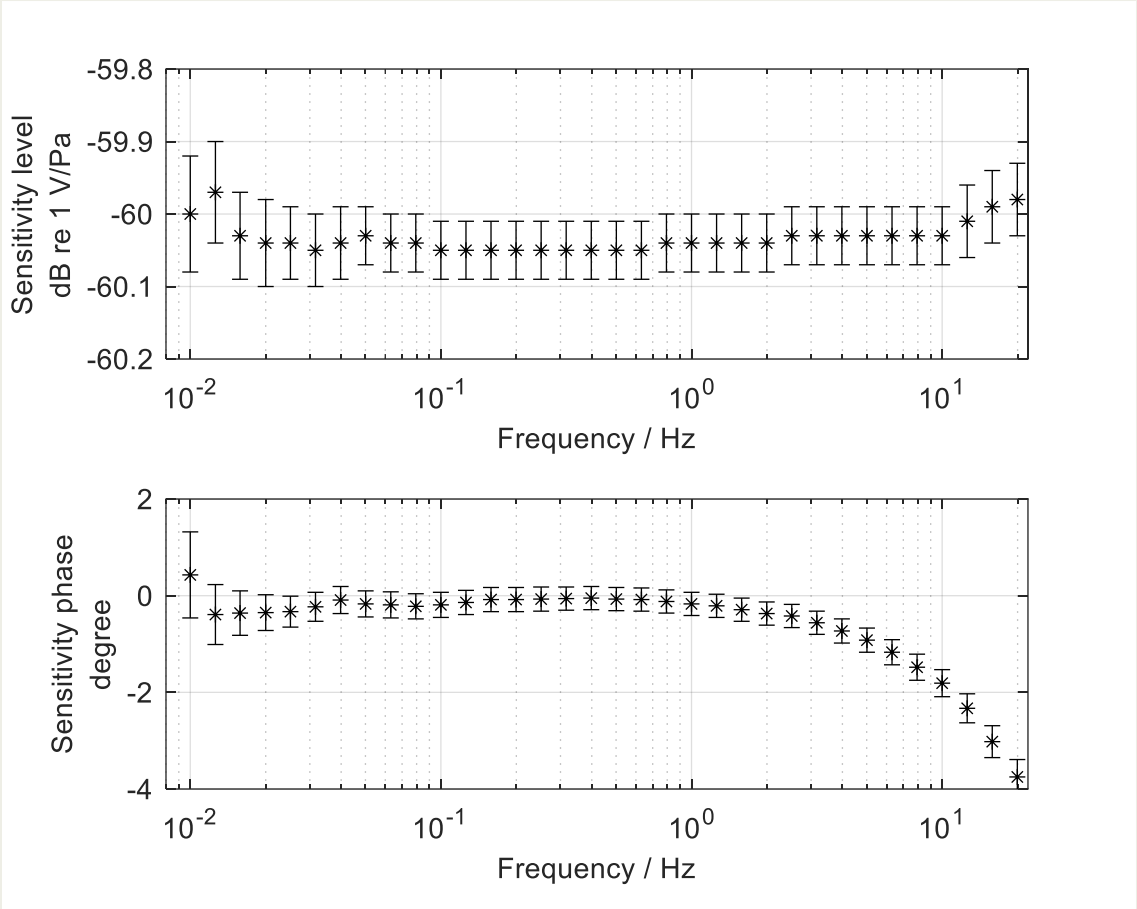
Dynamic Calibration – Results

- Method
  - Laser pistonphone (IEC TR 61094-10:2022)
  - Frequency range: 10 mHz – 20 Hz

- Results
  - Sensitivity M_p: ~ **-60.04 dB re 1 V/Pa** across range
  - Flat magnitude response (within uncertainty)
  - Phase tends to 0° at low frequencies

  - Expanded uncertainty (k=2):
    - From **0.04 dB** to **0.08 dB** for magnitude
    - From **0.24** degree to **0.89** degree for phase



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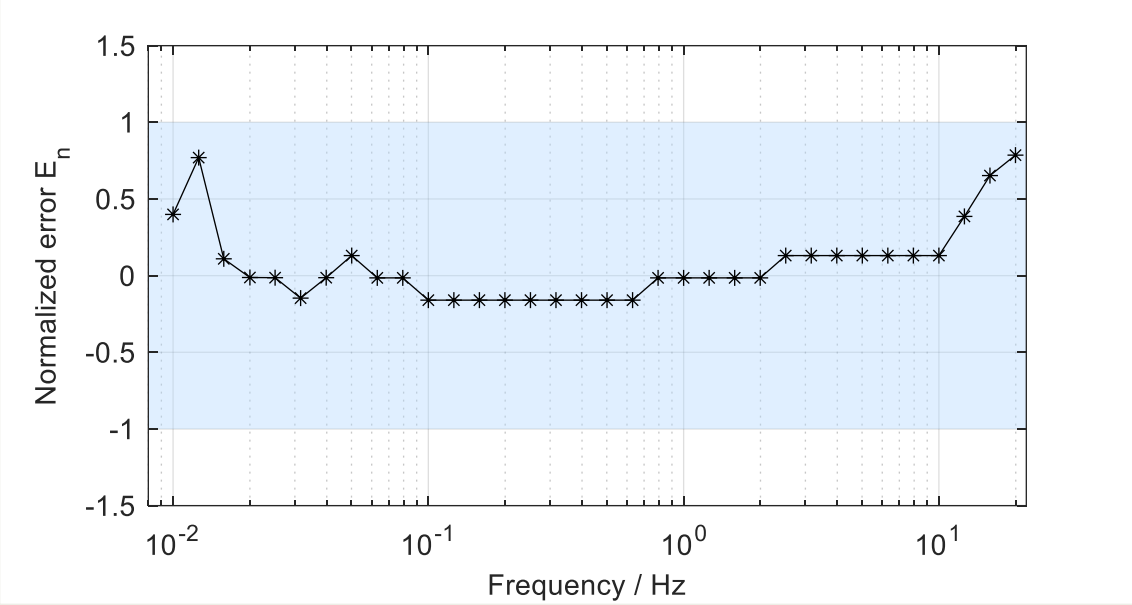
Comparison of Static vs Dynamic Results

- Results

Method	Sensitivity dB re 1 V/Pa	Expanded uncertainty in dB (k=2)
Static	–60.034	0.056 dB
Dynamic	~ –60.04	0.04–0.08 dB

- Sensitivities are in agreement within uncertainties
- Normalized error E_n: all values ≤ 1

→ Confirms good consistency between methods



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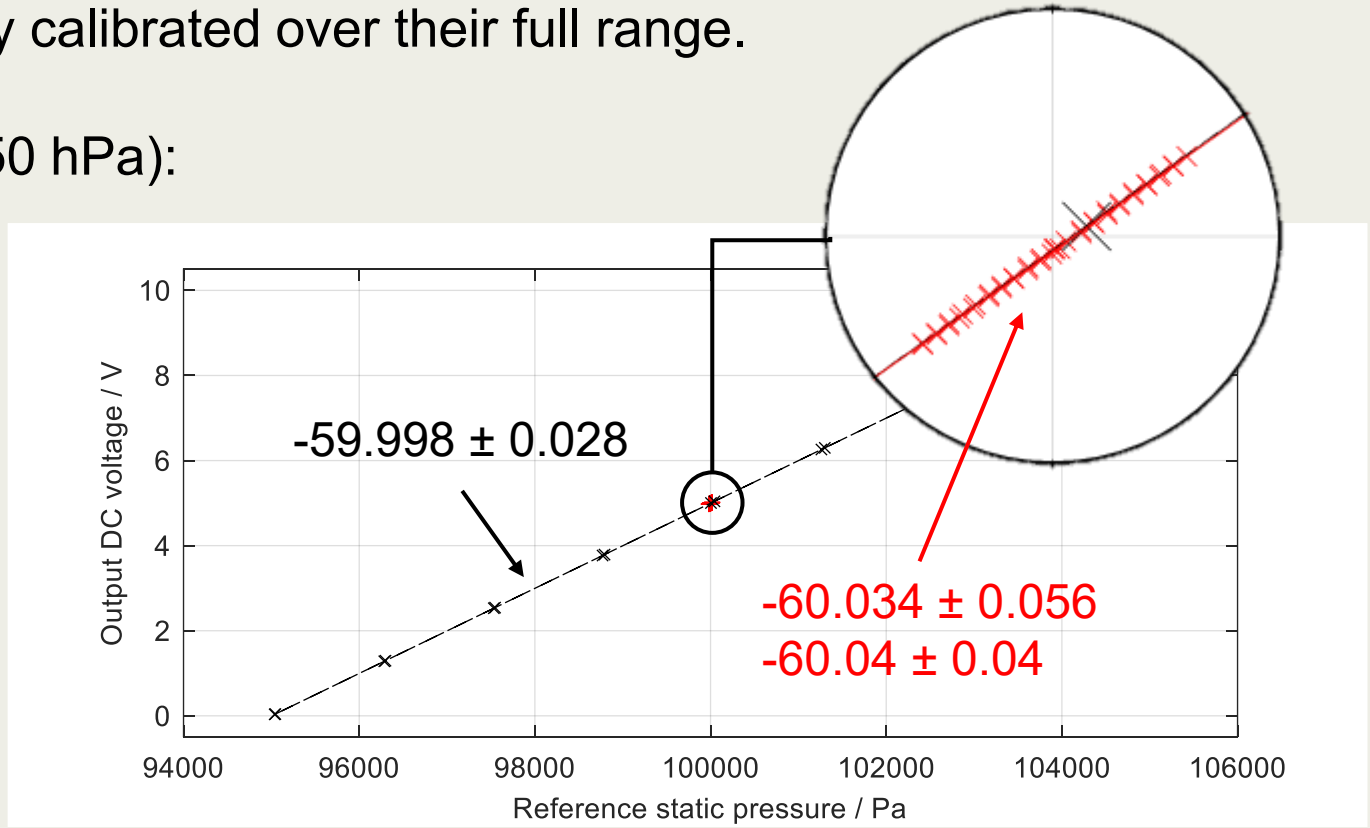
Discussion - Limits of Static Calibration

- Challenge: 2 Pa steps calibration over ~40 Pa range are difficult to achieve.
- Classical approach: barometers are usually calibrated over their full range.

- Extended range calibration (950 hPa – 1050 hPa):
  - Sensitivity M_p: **–59.998 dB re 1 V/Pa**
  - Expanded uncertainty (k=2): **0.028 dB**
- Results seems to be consistent.
- Risk: extended static calibration may underestimate uncertainty and give biased results → not fully representative of the real infrasound operating range (some tens of Pa).



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Conclusions & Perspectives

- **Key requirement**: define a transfer standard covering DC–20 Hz
- **Microphones**: reliable and traceable for frequencies above 0.1 Hz
- **Barometers:** promising for very low frequencies / near DC
  - Unique dual calibration paths
    - Static → accurate results near DC / very low frequencies.
    - Dynamic → essential at higher frequencies, when response may deviate from flat, and provides phase.
  - Complementary methods → combining both = more robust calibration
- **Next step**: extend study to other barometer models to strengthen consistency and robustness