

# Progress in Measurement Science for Nuclear Test Monitoring Technologies

**Benoît Doury and PTS colleagues**

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Seismo-Acoustic Engineering Officer  
Comprehensive Nuclear-Test-Ban Treaty Organization  
Vienna International Centre  
1400 Vienna, Austria

# CTBT – The Treaty

## Comprehensive Nuclear-Test-Ban Treaty

### Article I

1. Each State Party undertakes not to carry out any nuclear weapon test explosion or any other nuclear explosion, and to prohibit and prevent any such nuclear explosion at any place under its jurisdiction or control.

Opened for signature on 24 September 1996

Near-universal – 186 signatures, 176 ratification

Entry-into-Force when 44 States listed in Annex 2 ratify the Treaty

8 Annex 2 States have not ratified the Treaty yet



The Preparatory Commission for the CTBT Organization is tasked with building up the verification regime and promoting the Treaty's universality

# The 4 Components of the **Verification Regime**

## 1. International Monitoring System

Collect, analyze and distribute data from the 337 monitoring facilities



## 2. Consultation and clarification

Highlight potential non-conformity through consultations



## 3. On-site Inspection

Clarify potential non-conformity through on-site inspection



## 4. Confidence-Building Measures

Prevent the wrong interpretation of data and support the calibration of monitoring tools



The Verification Regime is **central** to the Treaty



# The International Monitoring System (IMS): 337 facilities

4 monitoring technologies



**Seismic – 170**



Listening underground



**Hydroacoustic – 11**



Listening under water



**Infrasound – 60**



Listening above ground



**Radionuclide – 80 (+16)**

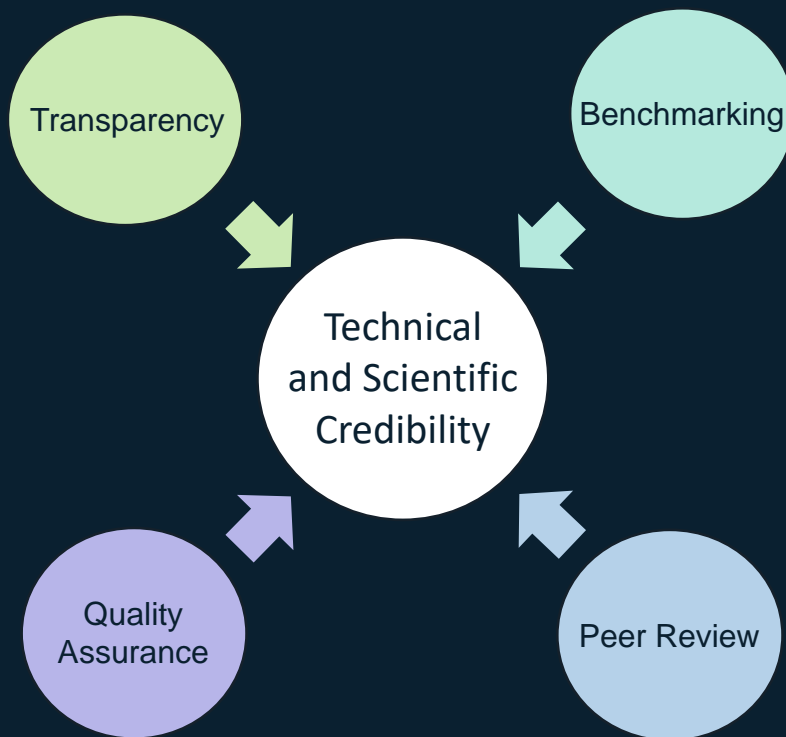


Sniffing for radiation

# 90% of IMS facilities already certified



# Quality assurance for IMS measurement systems



## Objectives

1. Demonstrate quality assurance in IMS measurements to ensure **trustworthiness** and **credibility** of IMS data
2. Ensure **consistency** in IMS measurements and **equivalence** in data produced across the IMS network
3. Ensure **continuity** and transparency of best practices **independent of changes** in instrumentation/service providers, or individual personnel

# The International Monitoring System: 337 facilities

4 monitoring technologies



Seismic – 170



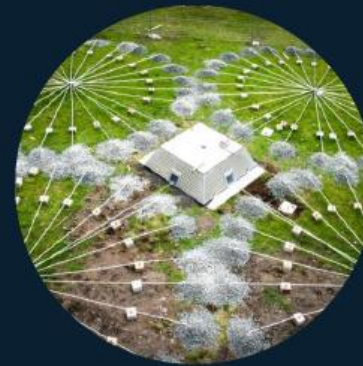
Listening underground



Hydroacoustic – 11



Listening under water



Infrasound – 60



Listening above ground



Radionuclide – 80 (+16)



Sniffing for radiation

2018

Need for **validated CMCs** across the IMS monitoring ranges

Measurement systems at stations  
cannot be sent back to laboratories for calibration



# CTBTO – BIPM Collaboration


- CTBTO gives invited presentations to CCAUV biennial strategic meeting since 2017
- CIPM invites CTBTO to the **26<sup>th</sup> General Conference for Weights and Measures**
- CTBTO describes **IMS needs** at the 26<sup>th</sup> CGPM
- BIPM and CTBTO identified **common goals** that provide the basis for a mutually beneficial relationship
- CTBTO traceability needs are included in **Strategy** documents of CCAUV and CCRI





# CTBTO – BIPM Collaboration

June 2021: A **practical arrangement** is signed between the BIPM and CTBTO on collaboration on the metrological traceability of measurements of infrasound, seismic activity and radioactivity.

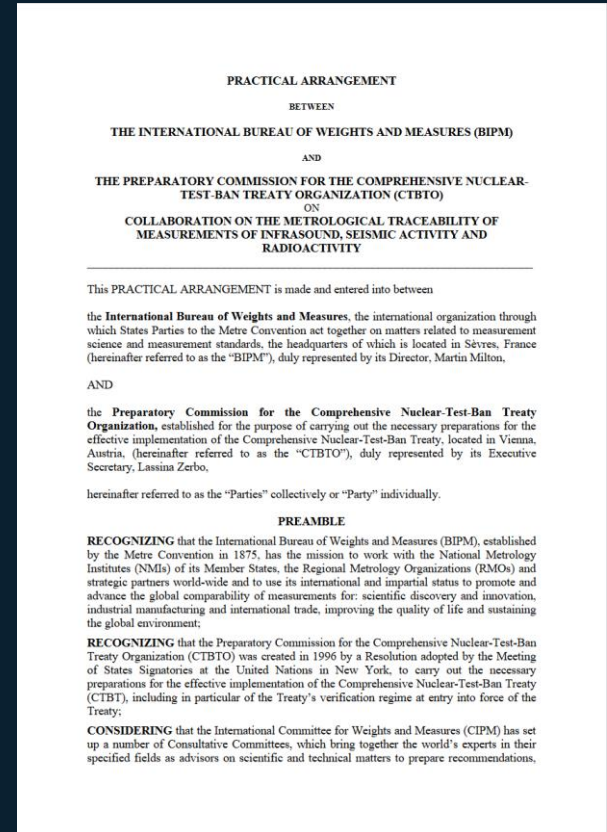


**CTBTO**  
PREPARATORY COMMISSION

**Bureau**  
International des  
Poids et  
Mesures

**The BIPM-CTBTO Practical Arrangement**

The BIPM-CTBTO Practical Arrangement was signed by Dr Lassina Zerbo, Executive Secretary of the CTBTO on 4 May 2021 and by Dr Martin Milton, Director of the BIPM on 10 June 2021.



CCAUV and CCRI are now **official liaisons** of CTBTO

# Metrological community captures low-frequency AUV needs

EURAMET research project **InfraAUV 2020 - 2023**

10 participants: NMIs and IMS service providers

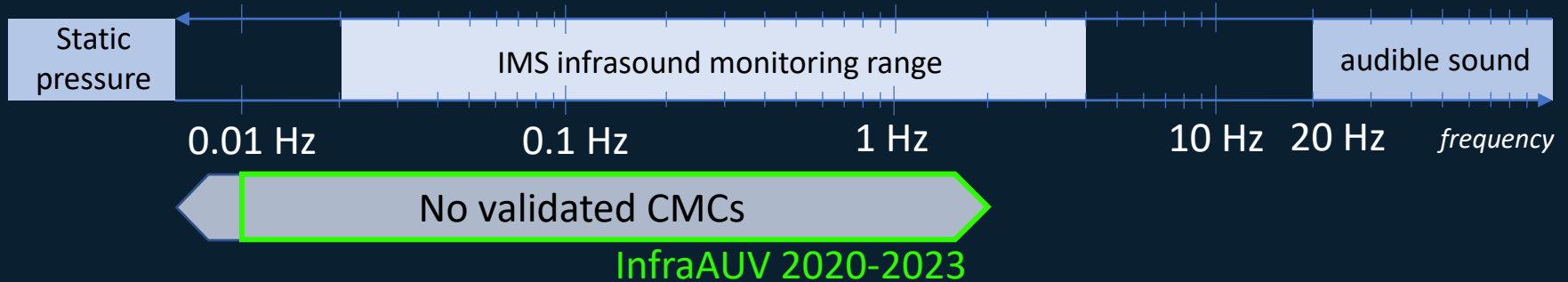
Extend the frequency ranges for **traceable** environmental measurements in the field of infrasound, underwater acoustics and seismic vibration to lower frequencies.

- Development of **calibration methods**
- Procedures for validation and dissemination
- **On-site** transfer to the actual applications at measurement stations

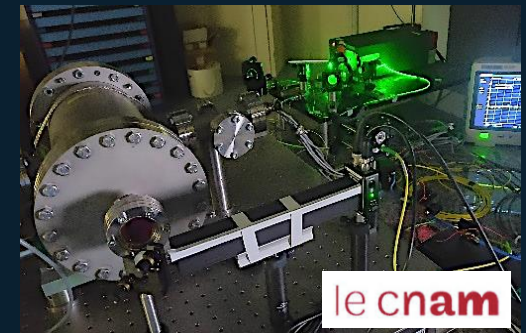
Close collaboration with CTBTO seismo-acoustic experts throughout the project



# Progress on **Infrasound** Technology

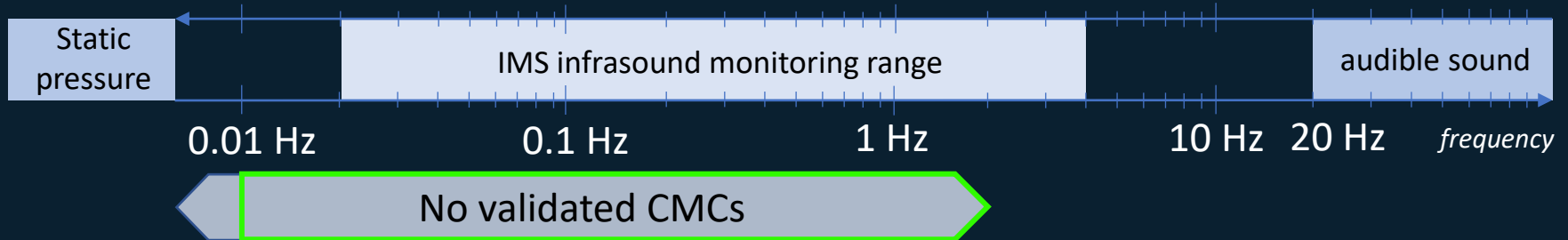


- Focus on **microbarometers** used by CTBTO, to be used as transfer standards
- Calibration concepts are developed, based on different **principles**, with **good agreement!**



Calibration concepts and methods under development at NMIs and IMS service providers in IMS passband

# Progress on **Infrasound** Technology



Primary and secondary **comparisons** within InfraAUV project

Development of methods to maintain traceability of deployed sensors **on-site**



IEC-61094-2 **revised** - primary microphone calibration by **reciprocity**

IEC-61094-10:2022 **alternate** calibration methods suited for **infrasound**



First **CMCs** are in preparation for submission to the BIPM



# Metrology applied by CTBTO community

CTBTO organizes Pilot studies with IMS service providers

Fruitful cooperation and knowledge exchange

*Measurands*

*Uncertainty budget*

*Expertise*

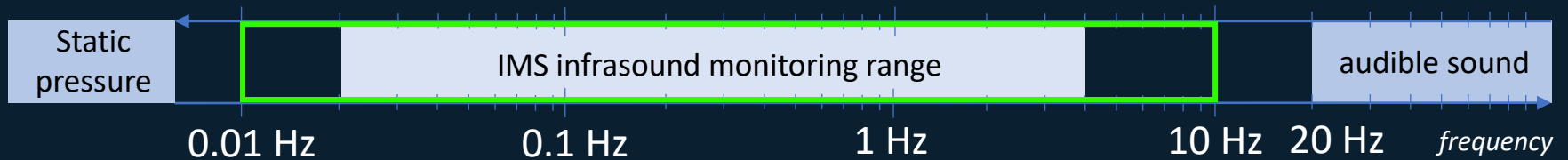
*Methodologies*

*Environment*



First CTBTO comparison in IMS infrasound monitoring range

# Metrology applied by CTBTO community



## CTBTO Comparison - Infrasound

### Measurands

Pressure Sensitivity  
Self-noise

0.01 to 10Hz



Barometer



Micro-barometer



Microphone

First time that **capability** of IMS service providers is formally **assessed**

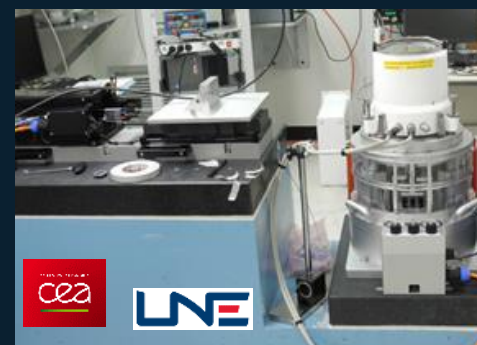
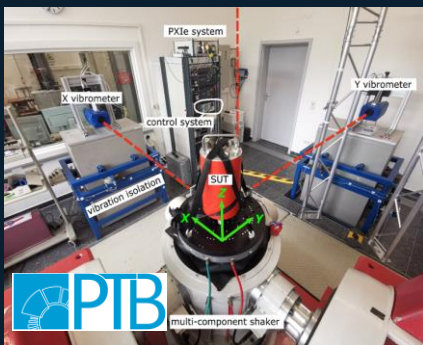
**Equivalence** demonstrated for majority of frequency range

Looking forward: extending efforts to the **seismic** technology

# Progress on Seismic Technology

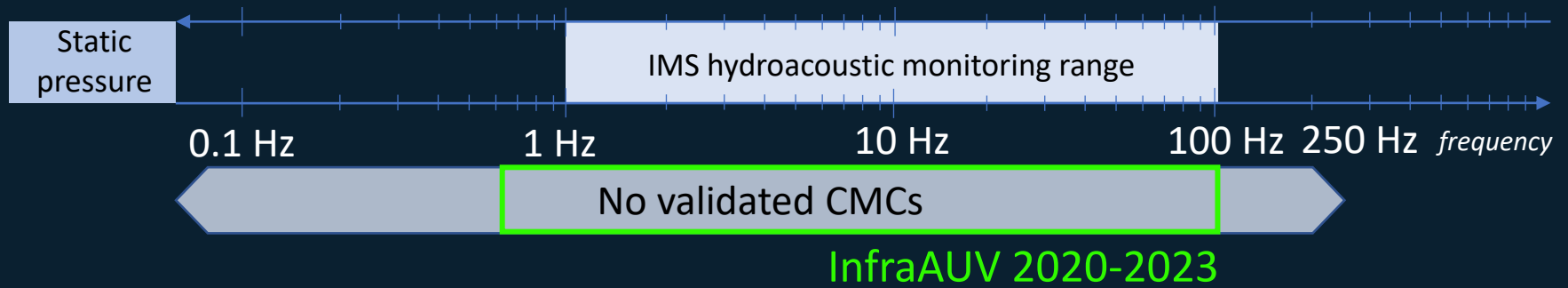


- Wide range of **seismometers** used by CTBTO and global seismic networks
- NMIs are adapting their workbench
- Development of methods to maintain traceability of **deployed** sensors

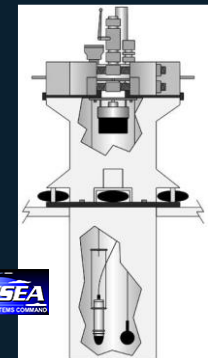
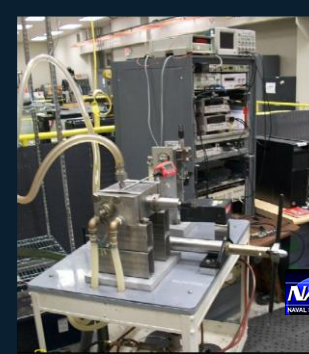
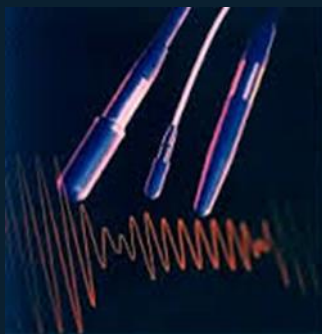


Calibration concepts and methods under development at NMIs and IMS service providers in IMS passband

# Progress on **Hydroacoustic** Technology



- First Calibration Concept covering the **full** IMS monitoring **range**
- **On-site** calibration is a challenge, research is on-going



Calibration concepts and methods under development at NMIs and IMS service providers in IMS passband



# Looking forward

Knowledge **dissemination** to CTBTO community, and beyond!



CTBTO will continue to collaborate with IMS service providers to address the needs for traceability **to the station**



Sensors deployed in harsh environments, for their **lifetime**

- Need to better understand the sensors **“in-service”**
- Need to know the impact of the **environment** on sensors characteristics

# Conclusion

- **Metrological traceability** for IMS measurements is key to further increase trust and sustain credibility in IMS data in the long term
- CTBTO has raised awareness of these needs, and the metrology community is **responding!**
- **BIPM** and CTBTO work on common goals and within a formal **practical arrangement**, already proving to be a mutually beneficial relationship
- The international metrological community has already started working on extending its **measurement and calibration capabilities** towards lower frequencies
- With the current rate of progress, **within a decade** most requirements will be fulfilled for seismic and acoustic!



A photograph of Earth from space, showing the curvature of the planet and a dense layer of white clouds. The sky is a deep blue, and the background is filled with numerous stars of varying brightness. The text "Thank you!" is centered in the middle of the image in a white, sans-serif font.

Thank you!