Defense Nuclear Nonproliferation Research & Development

Nuclear Explosion Monitoring Program Review

NEM 2019

Ground-based Nuclear Detonation Detection (GNDD): Waveform Sensors Research & Development

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Sandia National Laboratories

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GNDD Roadmap: Sensors

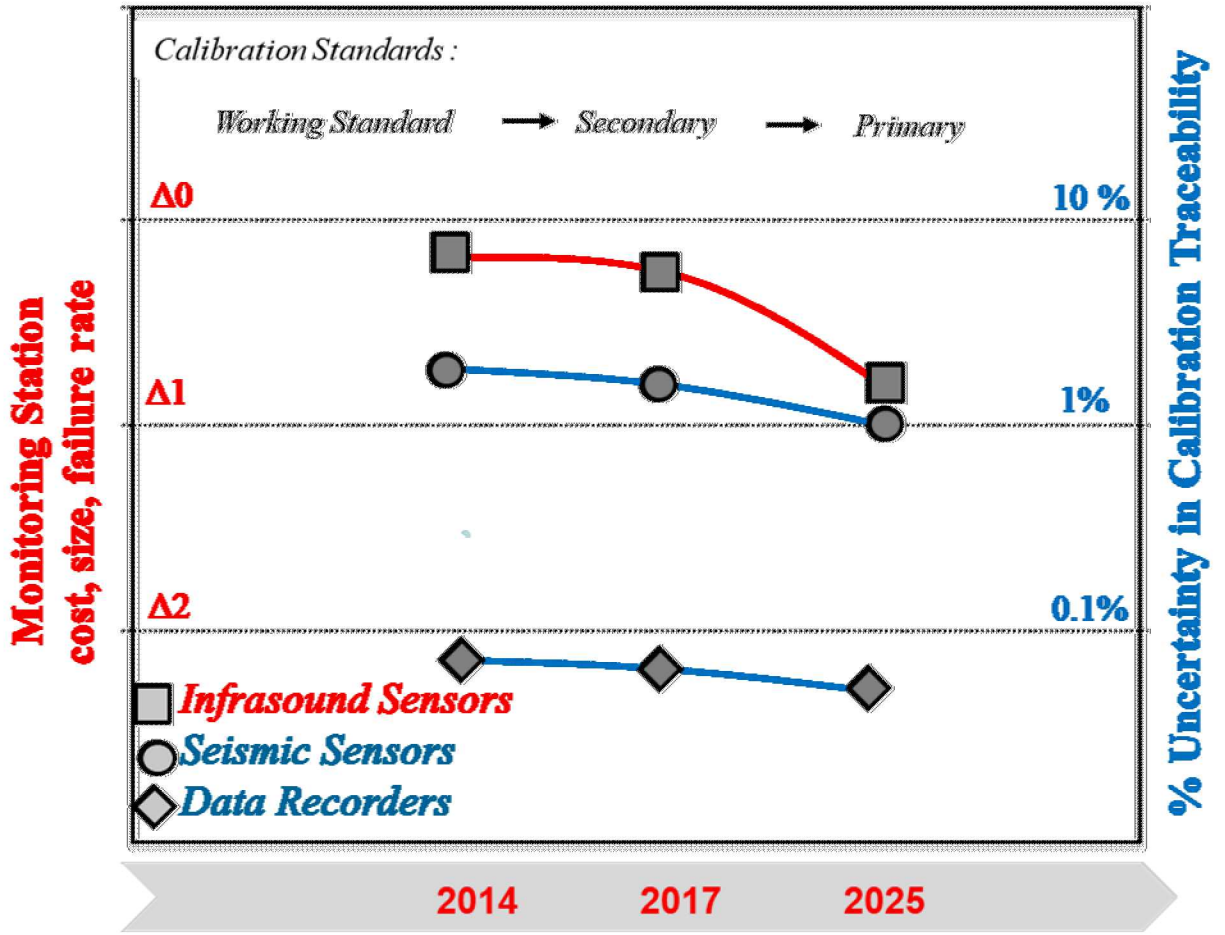
- **Sensors seeks to better understand and improve upon the instrumentation used in the monitoring system.**

- **Develop innovative sensors and monitoring systems with improved performance characteristics.**
- **Provide a source for independent, expert evaluations of monitoring system hardware.**

GNDD Sensors Metric

The major R&D for Sensors has evolved as monitoring instrumentation has become increasingly commercially available and requirements have moved to lower measurement uncertainties.

Waveform Sensors Metric: **Improve performance of the monitoring system through the development of improved sensor designs and sensor evaluation.**



GNDD Sensors Metric

The major R&D for Sensors has evolved as monitoring instrumentation has become increasingly commercially available and requirements have moved to lower measurement uncertainties.

Prior to the 1990s, the first implementations of sensors and digital data recorders were custom developed and required significant R&D.

Later developments resulted in significant improvements in cost, size, reliability, etc.

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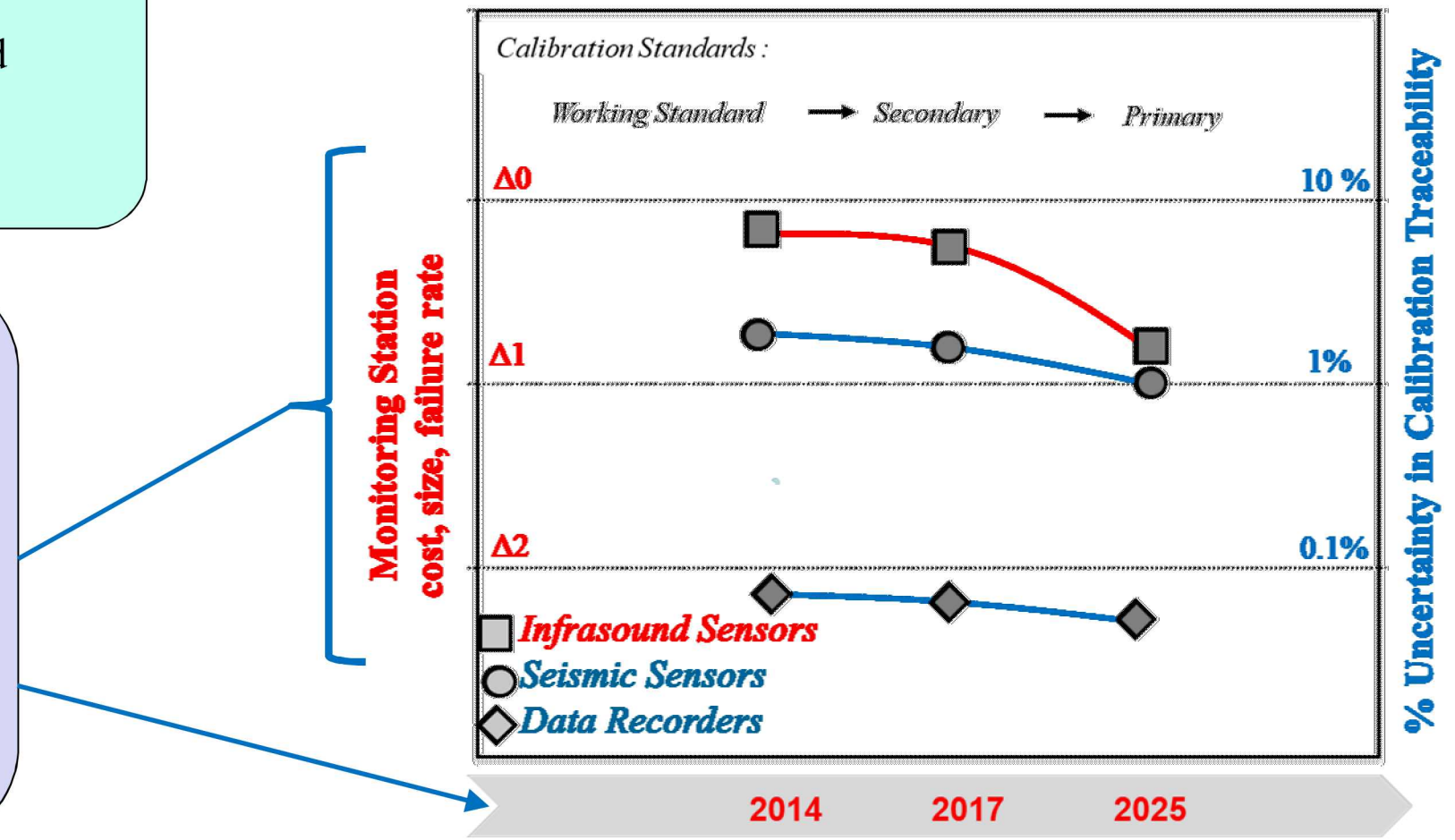

GNDD Sensors Metric

The major R&D for Sensors has evolved as monitoring instrumentation has become increasingly commercially available and requirements have moved to lower measurement uncertainties.

The priority within the program since 1990s has focused on improving the evaluations that are performed on instrumentation by providing traceable calibrations and reducing measurement uncertainty in the monitoring system.

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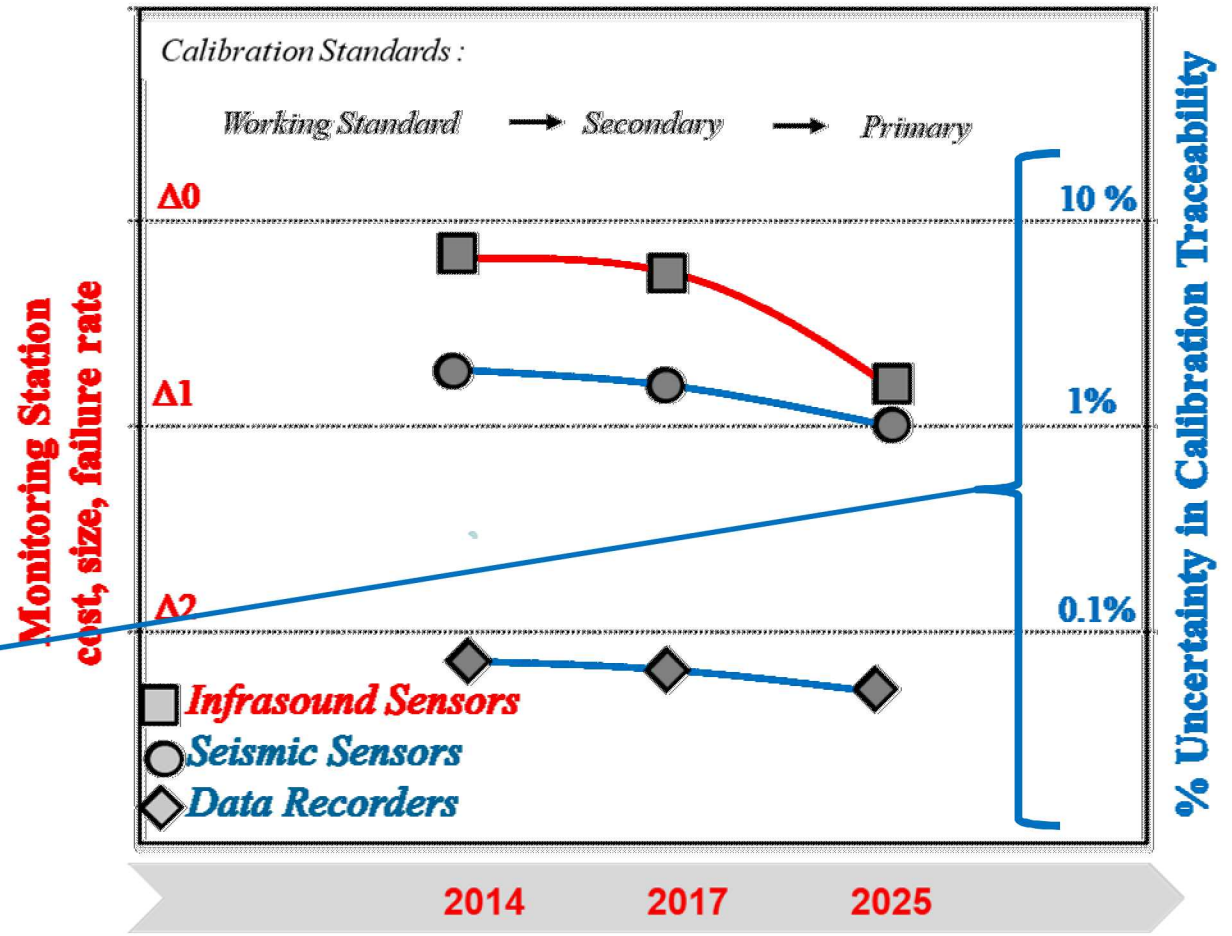


GNDD Sensors Metric

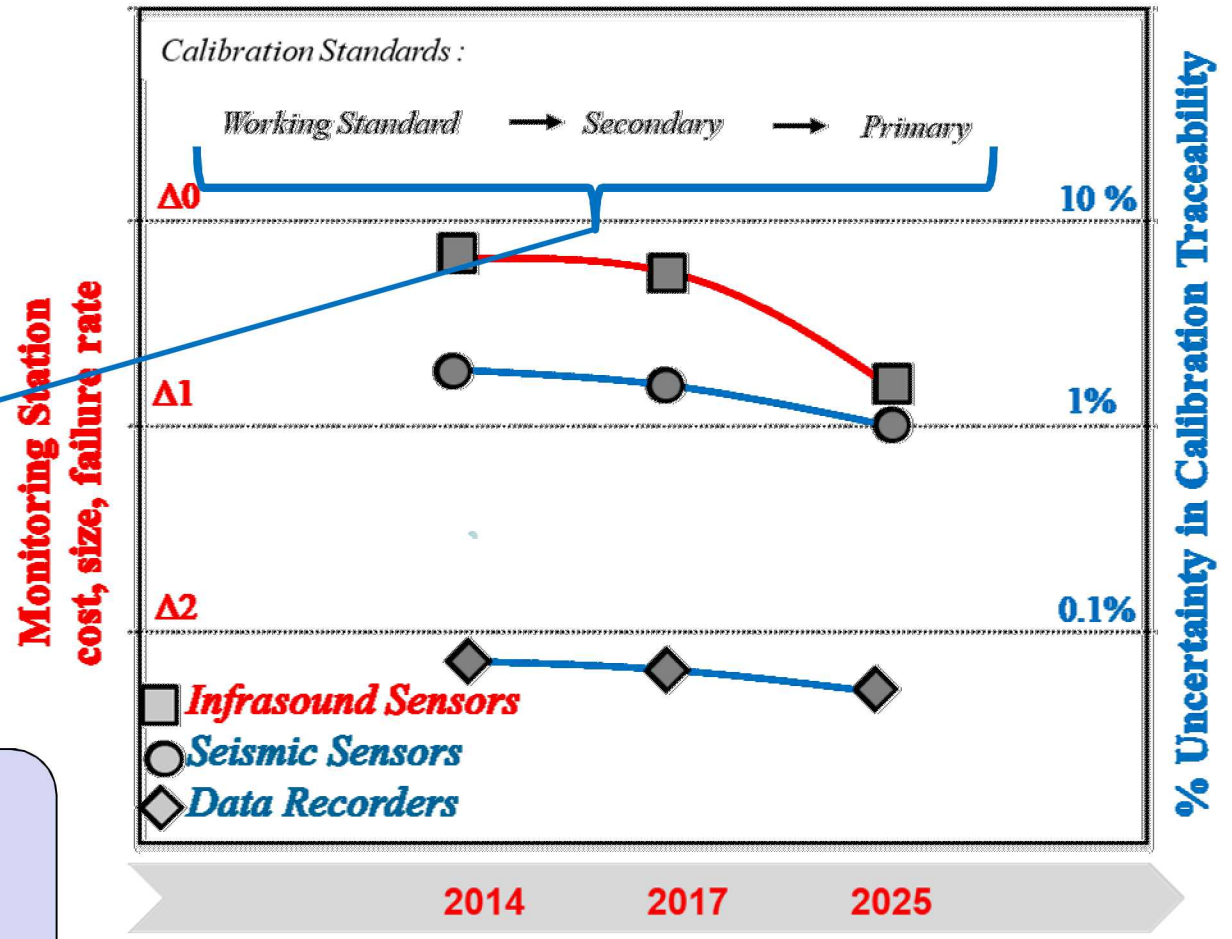
Waveform Sensors Metric: **Improve performance of the monitoring system through the development of improved sensor designs and sensor evaluation.**

The major R&D for Sensors has evolved as monitoring instrumentation has become increasingly commercially available and requirements have moved to lower measurement uncertainties.

The metrological standards used in laboratory calibrations have been evolving:

- Working Standard
- Secondary Standard
- Primary Standard

} includes uncertainty



Guide for the Uncertainty of Measurement (GUM)
https://www.bipm.org/en/publications/guides/gum.html

Bureau of International Weights and Measures (BIPM)

GNDD Sensors Metric

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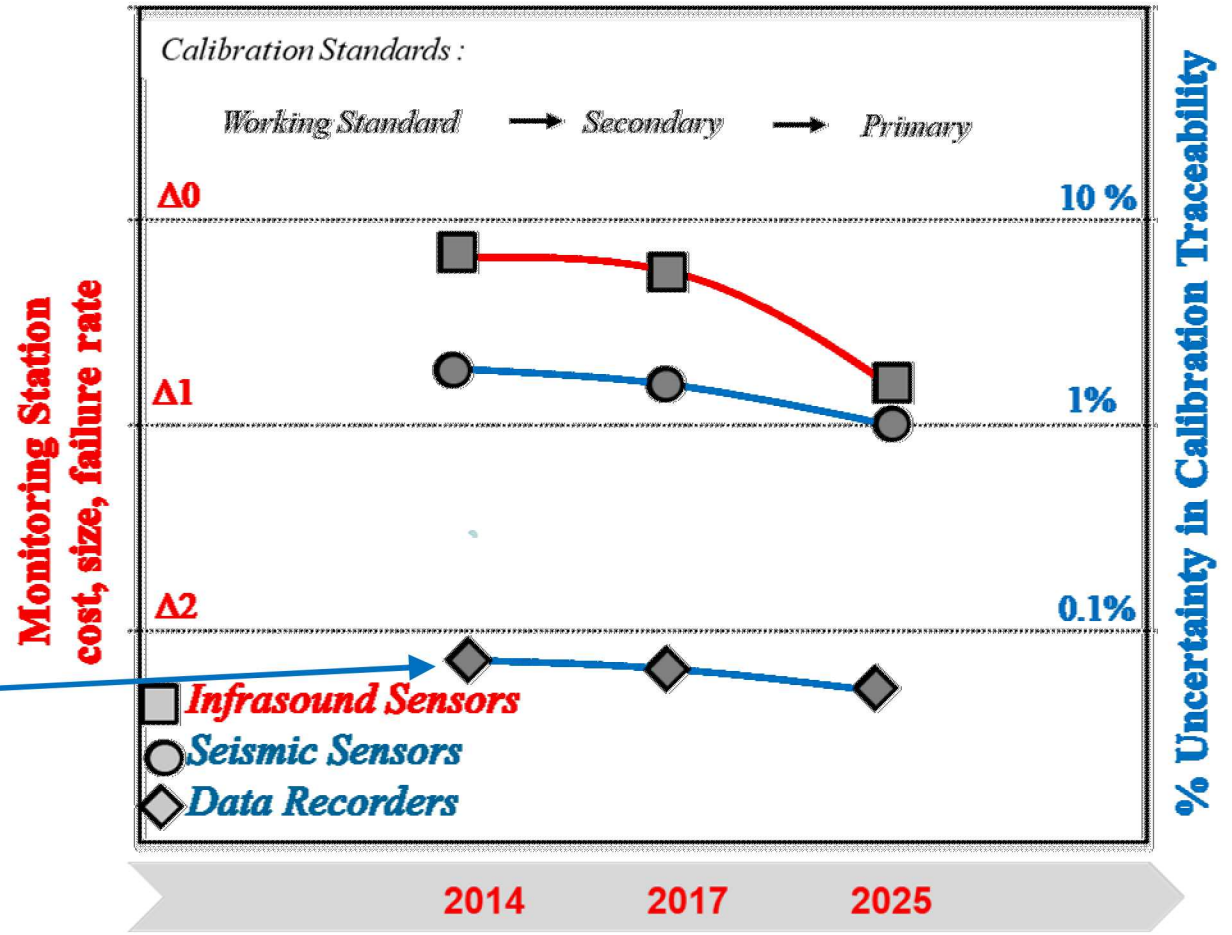
Digital Data Records have long had measurement uncertainties of less than 0.1%, due to calibration traceability to voltage being readily accessible, utilizing secondary references.

Waveform Sensors Metric: **Improve performance of the monitoring system through the development of improved sensor designs and sensor evaluation.**



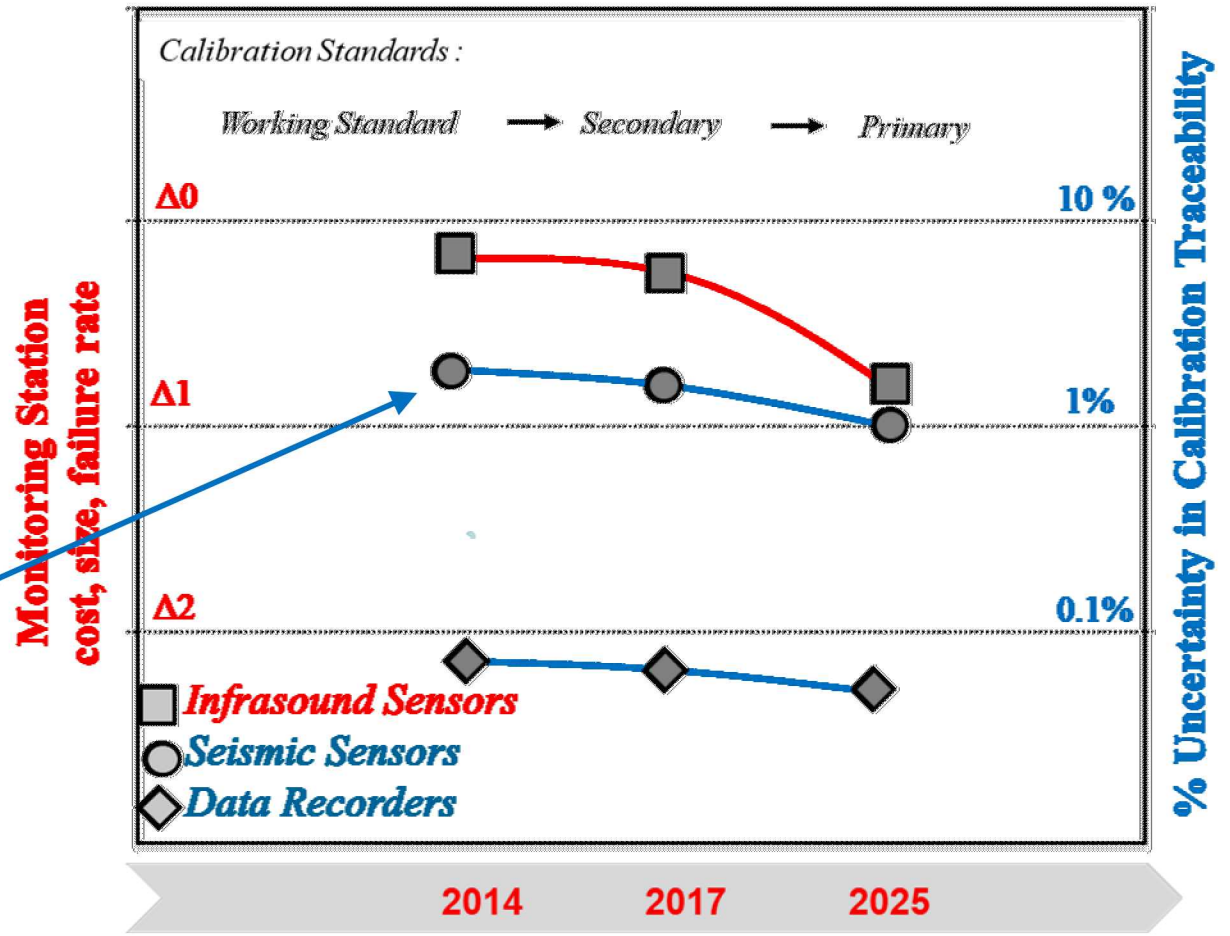
GNDD Sensors Metric

Waveform Sensors Metric: **Improve performance of the monitoring system through the development of improved sensor designs and sensor evaluation.**

The major R&D for Sensors has evolved as monitoring instrumentation has become increasingly commercially available and requirements have moved to lower measurement uncertainties.

Seismometer calibrations have improved over the past 10 years:

- Comparison against a working reference with unknown uncertainty.
- The addition of secondary traceability measurements.
- Recent primary calibrations with nearing 1% uncertainty.



GNDD Sensors Metric

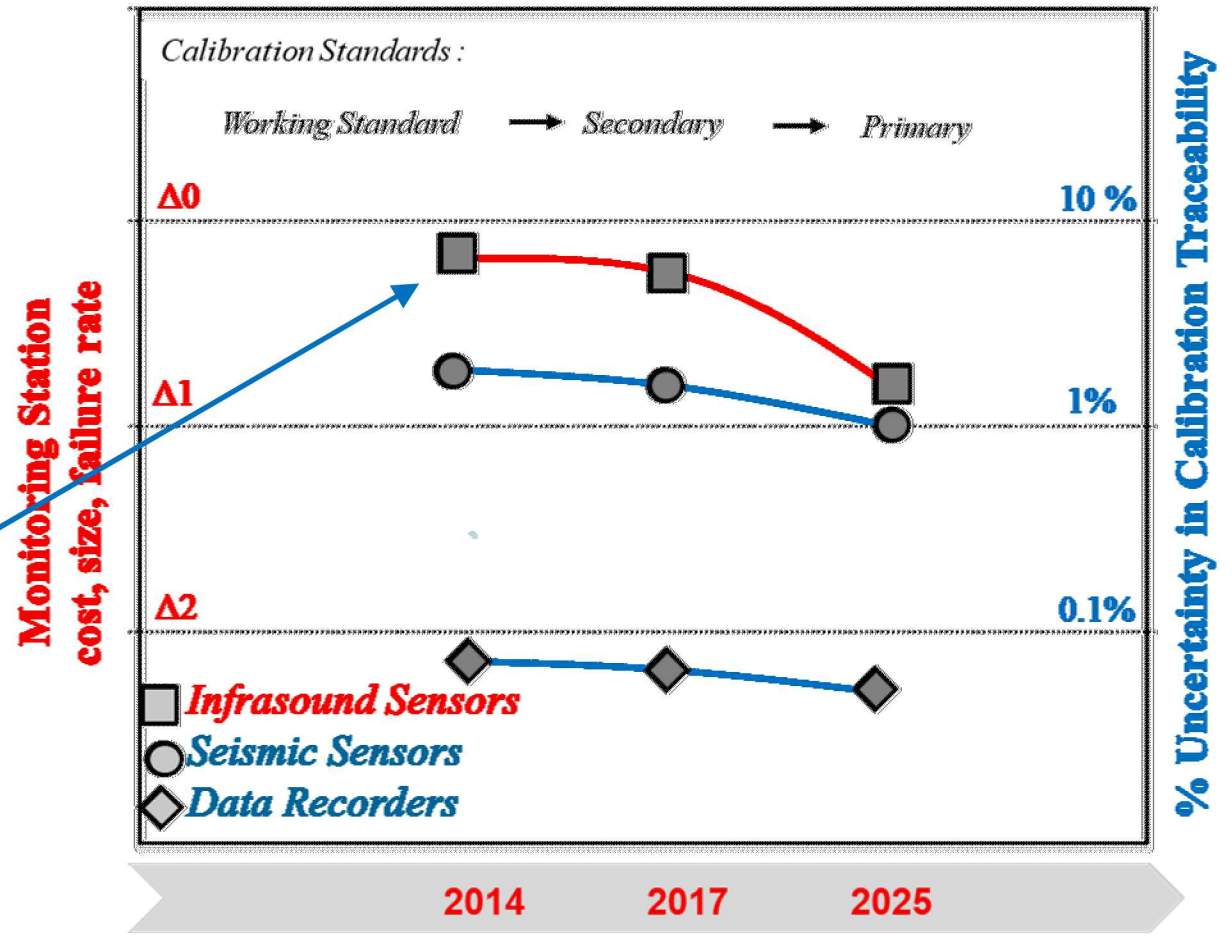
Waveform Sensors Metric: **Improve performance of the monitoring system through the development of improved sensor designs and sensor evaluation.**

The major R&D for Sensors has evolved as monitoring instrumentation has become increasingly commercially available and requirements have moved to lower measurement uncertainties.

Infrasound calibrations are evolving rapidly:

- Comparison against a working reference with unknown uncertainty.
- Recent addition of secondary traceability measurements.

- Future holds promise of primary calibrations with improved uncertainty.

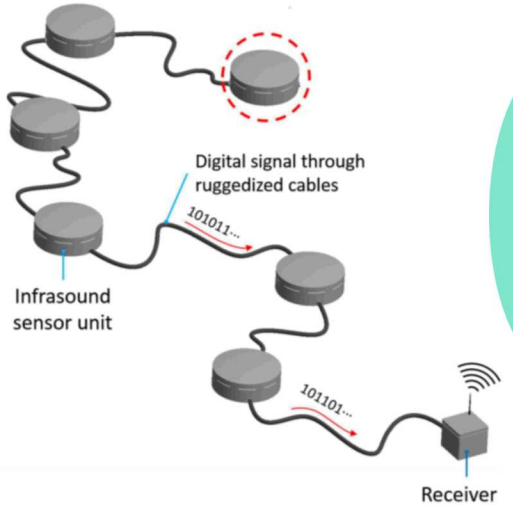


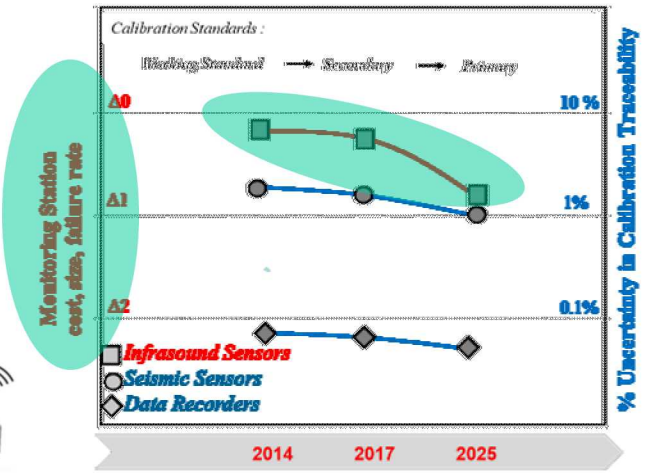
Silicon Audio Infrasound Sensor

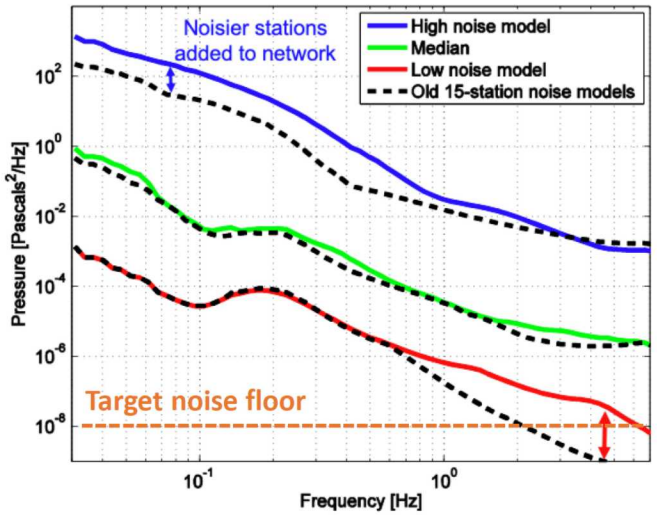
[improved sensor design]

Develop a modern, smart infrasound monitoring system

- Low-cost, low-noise sensing nodes.
- Modular design: support small and large arrays of nodes.
- Digital communication: deploy arrays in challenging terrain.
- Self-health monitoring and self-calibration.

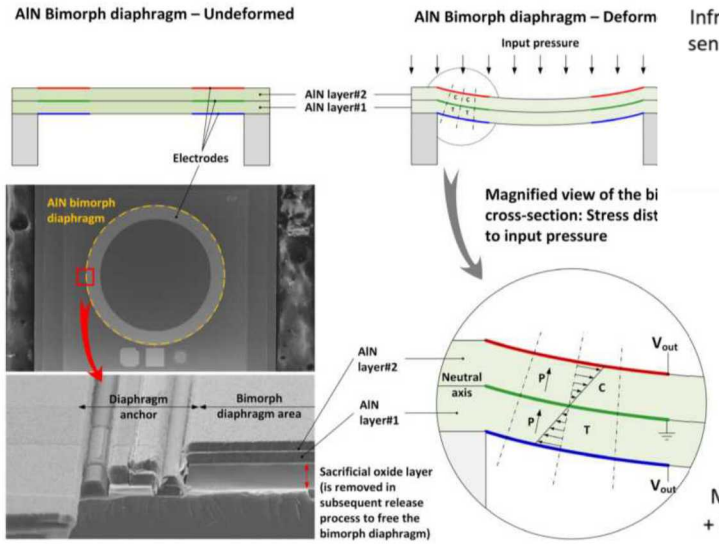


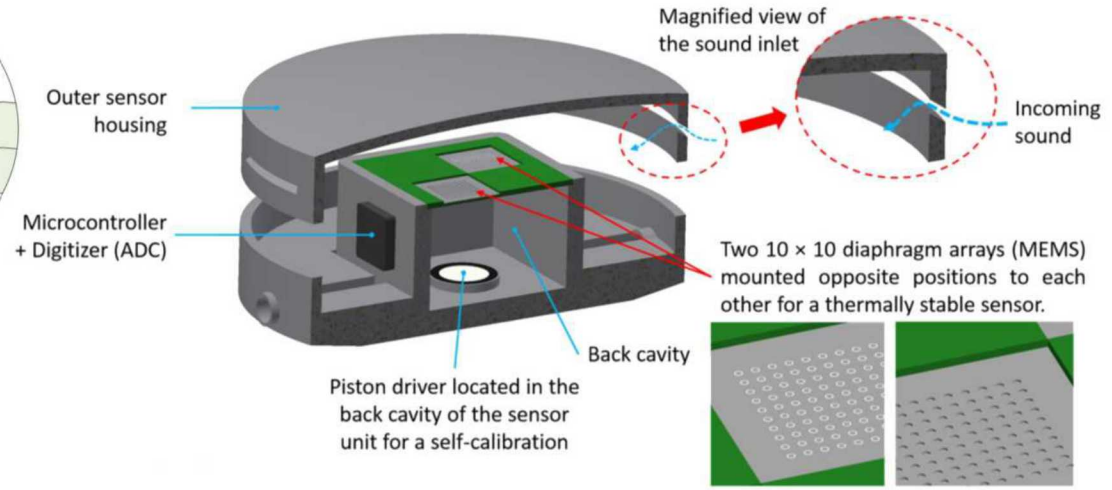




Median noise models similar

I55US removed from low-noise model (possible issues with snow and ice)





Operate an Evaluation Facility

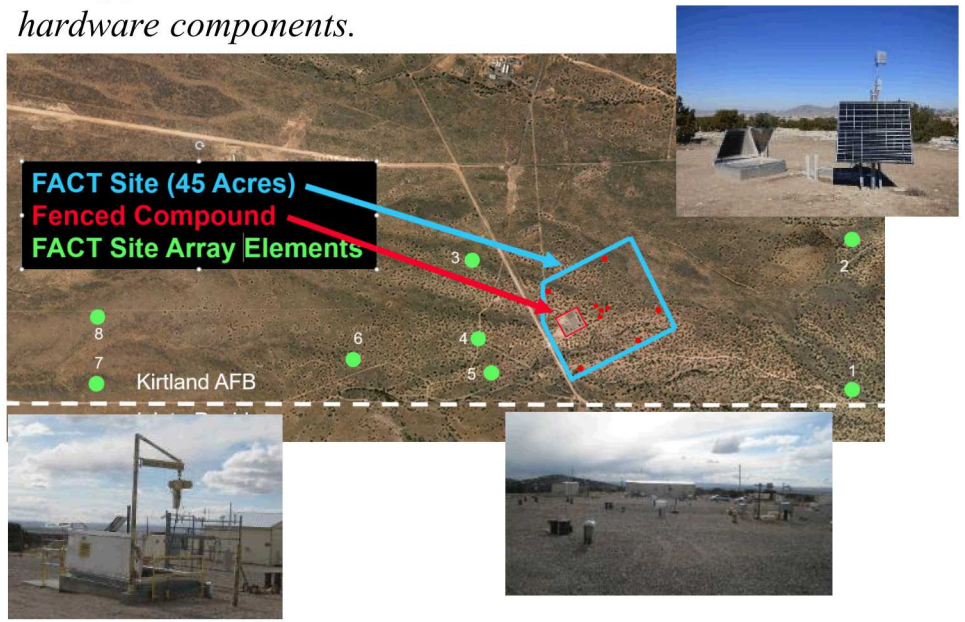
[improved sensor evaluation]

(IRP 7.35)

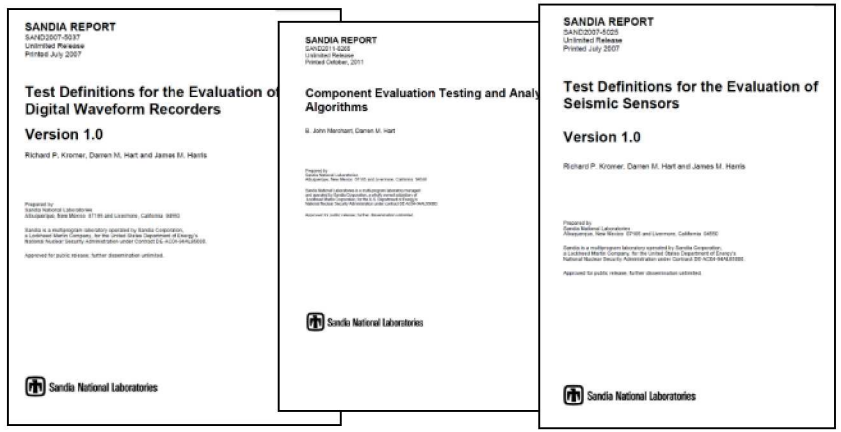
National Nuclear Security Administration
Defense Nuclear Nonproliferation

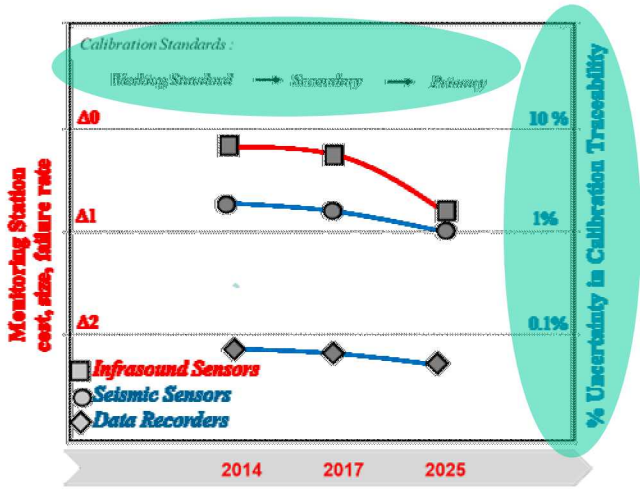
Provide independent evaluations of the primary hardware components (waveform recorders, seismometers and infrasound sensors) used by for monitoring for nuclear explosions.

Maintain facilities, knowledge, and experience of testing procedures to conduct evaluations on hardware components.



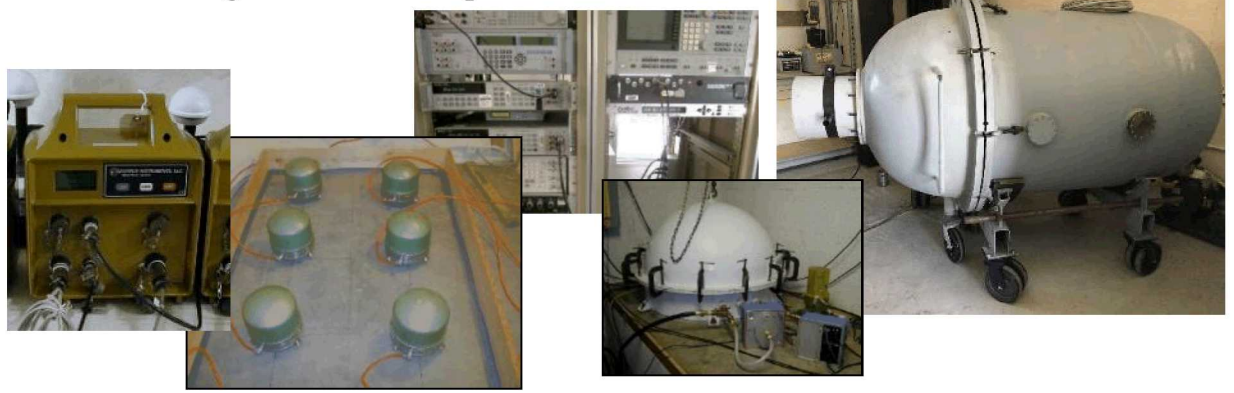
Provide evaluation reports to support U.S. Nuclear Treaty Monitoring interests





http://www.sandia.gov/fact/

Perform research in new methods and capabilities of testing hardware components.

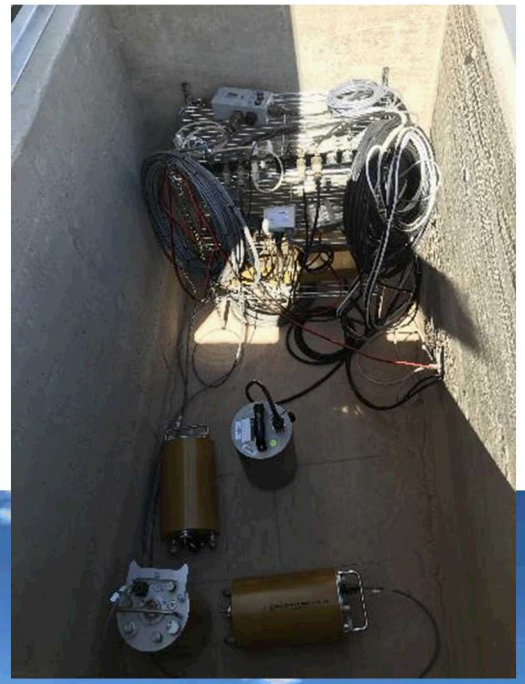


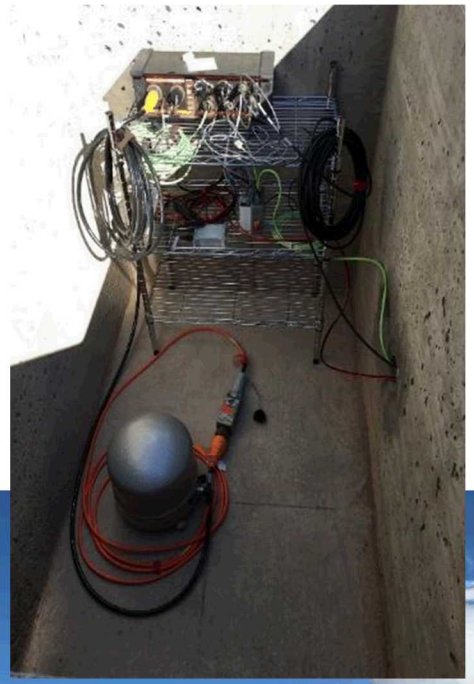
NA22 GNDD Sensors enables multiple sponsors:

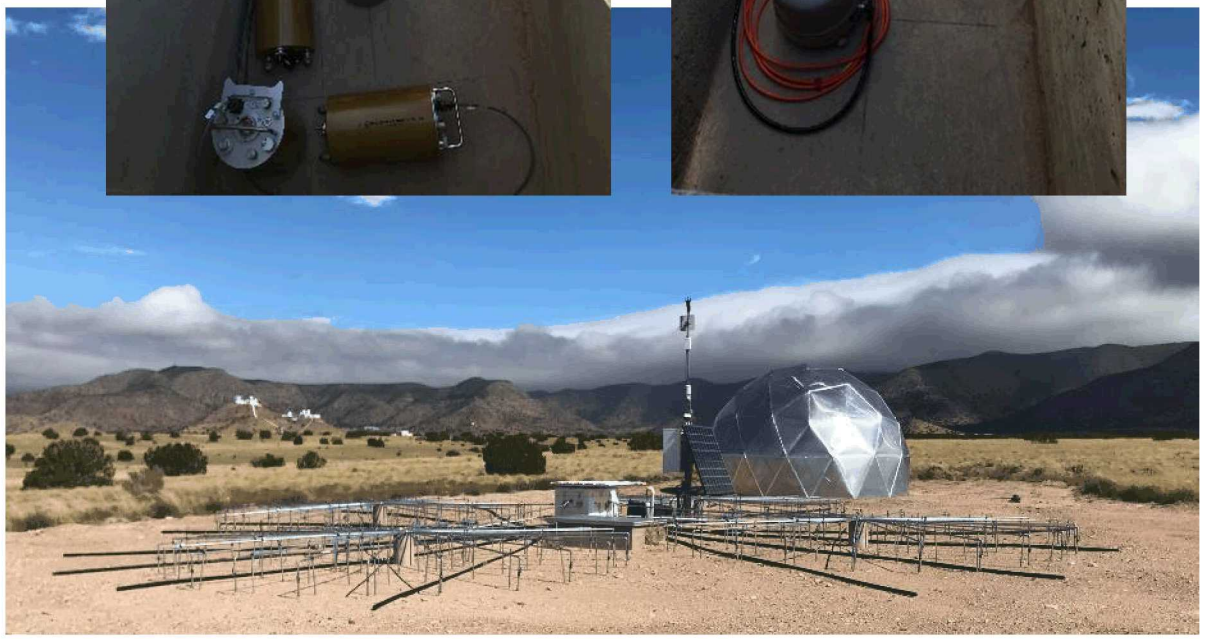
- AFTAC
- U.S. Department of Energy
- U.S. Department of State
- DTRA / NACT
- CTBTO

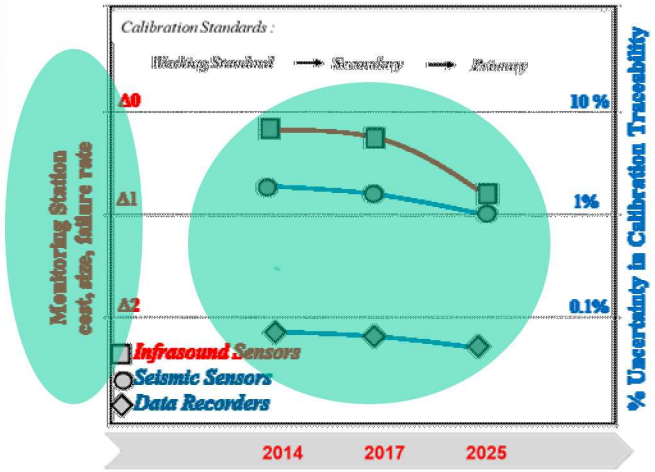
Field Site System Evaluations

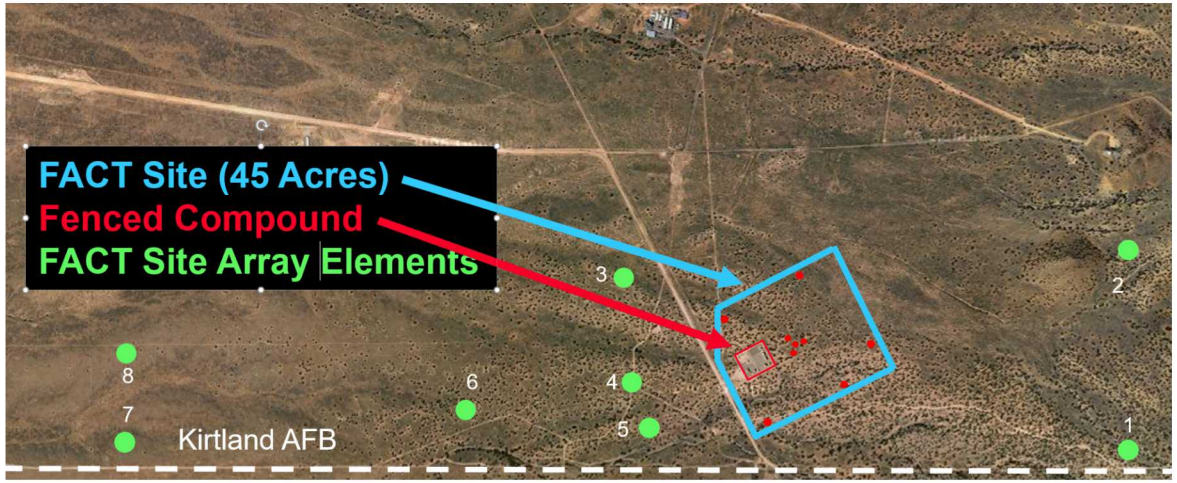
[improved system evaluation]











Infrasound Calibrations

[improved sensor evaluation]

National Nuclear Security Administration
Defense Nuclear Nonproliferation

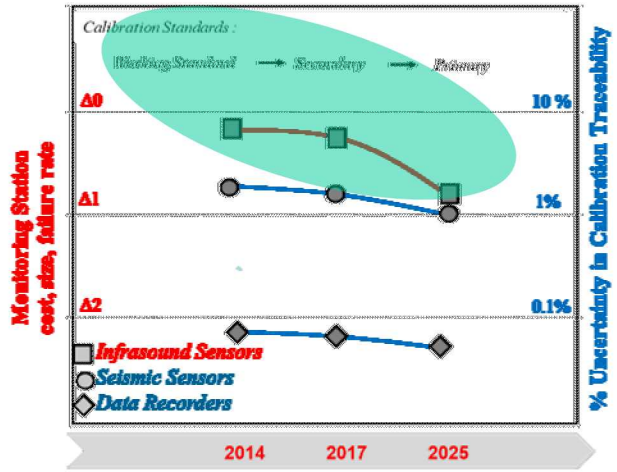
Transitioned to a new Infrasound Test Chamber for evaluations.

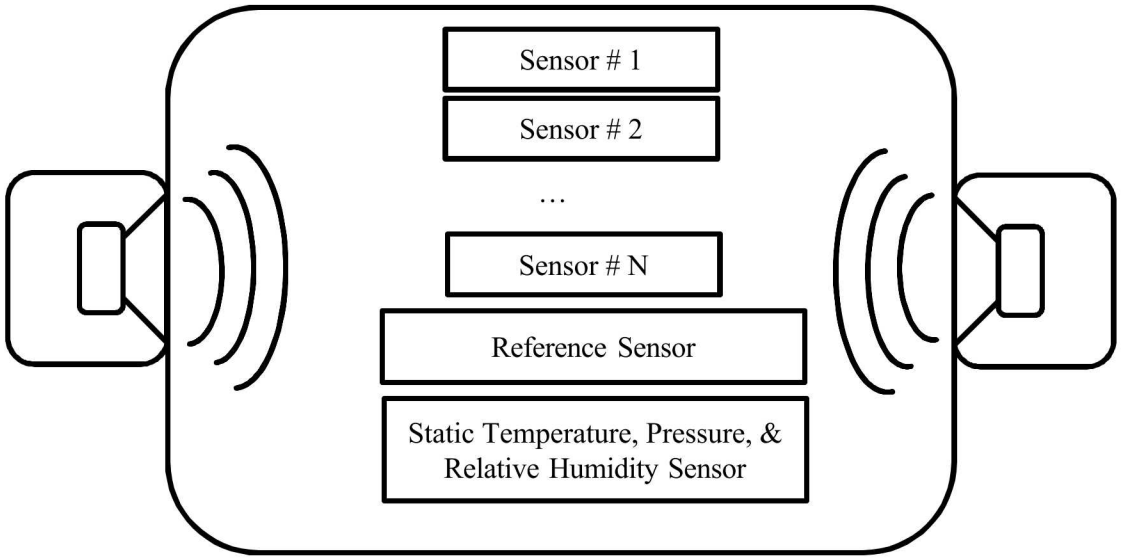
- Dynamic Pressures of 10 Pa, working to improve in FY19

Reference is an MB2005 (working standard), with ~ 4% uncertainty

Target is a secondary / primary standard, with ~ 1% uncertainty

- Reciprocity
- Laser measurement of speaker displacement





Seismometer Calibrations

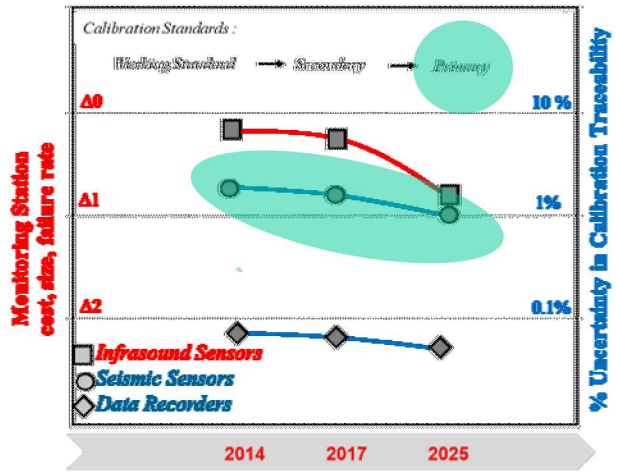
[improved sensor evaluation]

(IRP 7.35)

National Nuclear Security Administration
Defense Nuclear Nonproliferation

New Primary Seismic Calibrator

- ~1% measurement uncertainty
- Horizontal and vertical shakers
- Handles up to 50 kg
- 0.1 Hz – 160 Hz
- Used for evaluations of short-period and broadband seismometers



Underground Bunker

- Sensor comparison test
  - Relative response using a working standard as reference
- More thermally stable than the surface
- Removed from ambient surface noise
- Quiet environment suitable for short-period self-noise

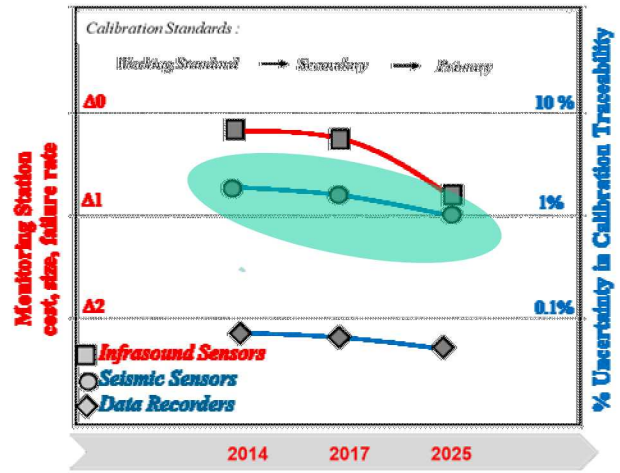
(IRP 7.35)

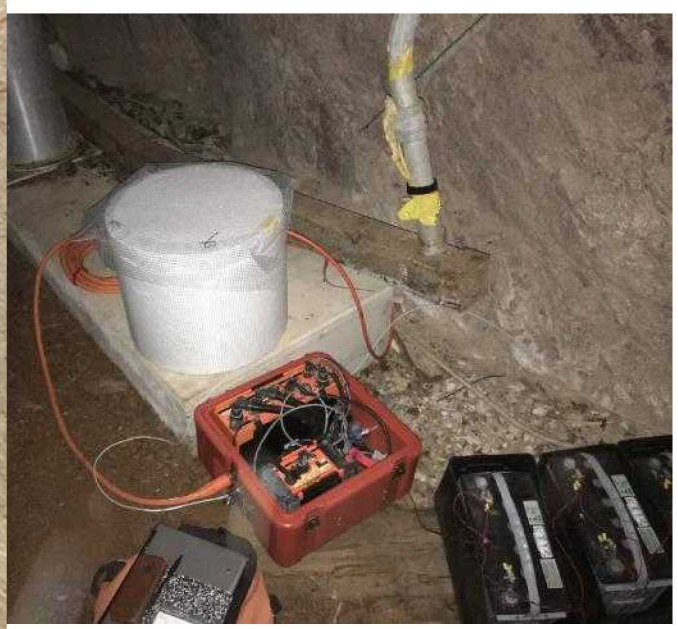
Report on facility for evaluating seismometer self-noise

[improved sensor evaluation]

National Nuclear Security Administration
Defense Nuclear Nonproliferation

- **Looking for a nearby location more suitable for measuring broad-band sensor self-noise: Quieter and thermally stable**
- **Manzano Mountain complex unsuitable due to equipment noise and proximity to the Interstate**
- **Re-entered a nearby mine in Fall 2018 (SNL property): "Frustration Mine"**
- **Previously used for seismometer testing, decommissioned decades ago.**
- **Evaluating background for seismometer low frequency self-noise measurement.**





FY19 GNDD Sensors Presentations / Publications

Presentations

- [11/5/2018] Infrasound Technology Workshop, poster on "Infrasound Sensor Testing Capability Advancements at Sandia National Laboratories"
- [12/16/2018] American Geophysical Union, poster on "Application of a Spectra CS-18 Seismic Calibration System at Sandia National Laboratories"

Upcoming publications (FY19)

- Guralp Affinity Evaluation for use in FACT Site's Infrasound Testbed
- Geotech GS13BH Seismometer Evaluation Report
- Evaluation Report of an alternate Hyperion wind shroud for improved wind noise rejection
- Design modifications to increase peak pressure in the Infrasound Testbed