



# Explosion Data Fusion of Acoustic, Barometric, and Accelerometric data collected on

September 2021

*Changing the World's Energy Future*

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**September 2021**

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**<http://www.inl.gov>**

**Prepared for the  
U.S. Department of Energy  
Under DOE Idaho Operations Office  
Contract DE-AC07-05ID14517**



Office of Defense Nuclear Nonproliferation  
Research and Development

**University Program Review (UPR) 2021 Meeting**

**Explosion Data Fusion of Acoustic, Barometric,  
and Accelerometric data collected on  
Smartphones**

**Consortium for Monitoring, Technology, and Verification (MTV)**

September 2021

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September 8 - 10, 2021



# Introduction, Motivation, Relevance



## NNSA Mission

- Prevent and reduce threat of nuclear weapons.

## TA3. Nuclear Explosion Monitoring

- Explosion monitoring and forensic analysis are traditionally relevant mission across DOE, DOD, and other US and international agencies (e.g. CTBTO).

### TA3.1. Infrasound

- Address diversity of emplacement conditions and delivery systems for low, high, and nuclear explosives.
- Apply new blast pulse scaling and parametrization to near-surface and airborne stationary, subsonic, supersonic, and hypersonic explosive sources.





# Introduction, Motivation, Relevance



## Big picture, what are the underlying reasons for the work?

- Create standardized multimodal dataset of explosions
- Use dataset for explosion detection and yield estimation

## What is the fundamental problem you are trying to solve?

- Lack of easily accessible explosion data for analysis
- Detect and classify explosion events

## How does this work, and the problem you are trying to solve, relate to the NNSA mission?

- Growing dataset of explosions allows for "Big Data"
  - o Array Processing
  - o Machine Learning





# Technical Work and Results - 1



## Data Collection Collaboration

- Idaho National Labs
- Nevada National Security Site

## Deployed Smartphones with RedVox App

- Recording acoustic, barometric, and accelerometric sensors in phone





# Technical Work and Results - 2



## Dataset Overview

- 123 sets of explosion data collected from 13 explosion events
  - o Each set contains, acoustic, barometric and accelerometric data
  - o Set also includes meta data about the phone and event
- Range of explosion yields
  - o 2 kg to 1800 kg TNT equivalent
  - o Effective yield correction for surface explosions
- Range of distances / scaled distances
  - o Distance: 160 m to 140 km
  - o Scaled Distance:  $47 \text{ m} / \text{kg}^{1/3}$  to  $32,000 \text{ m} / \text{kg}^{1/3}$



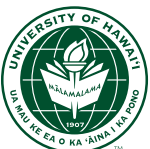
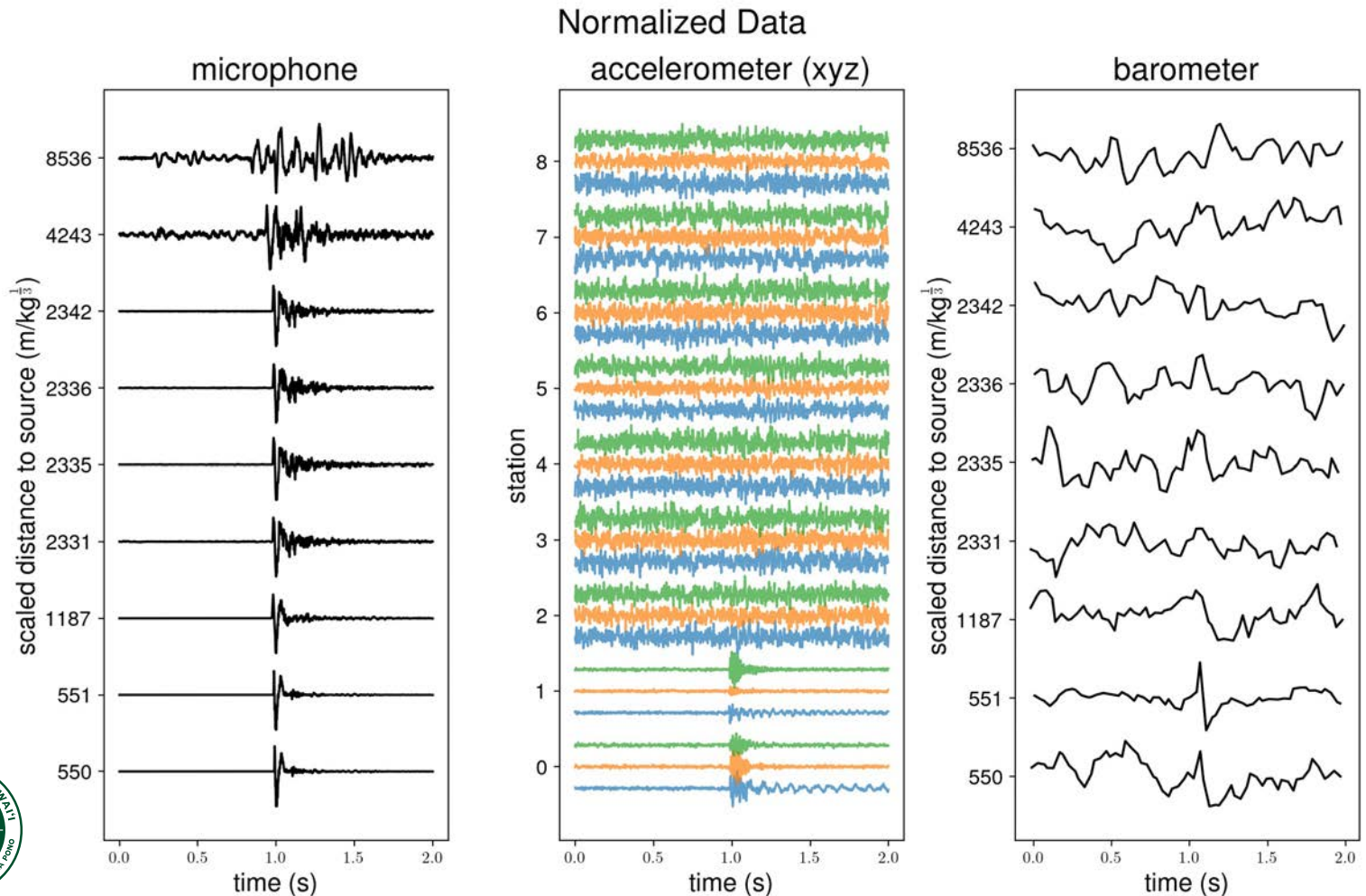


# Technical Work and Results - 3



## Acoustic, Accelerometric, Barometric Signal Highlights

– All sensors extracted from frame based on acoustics



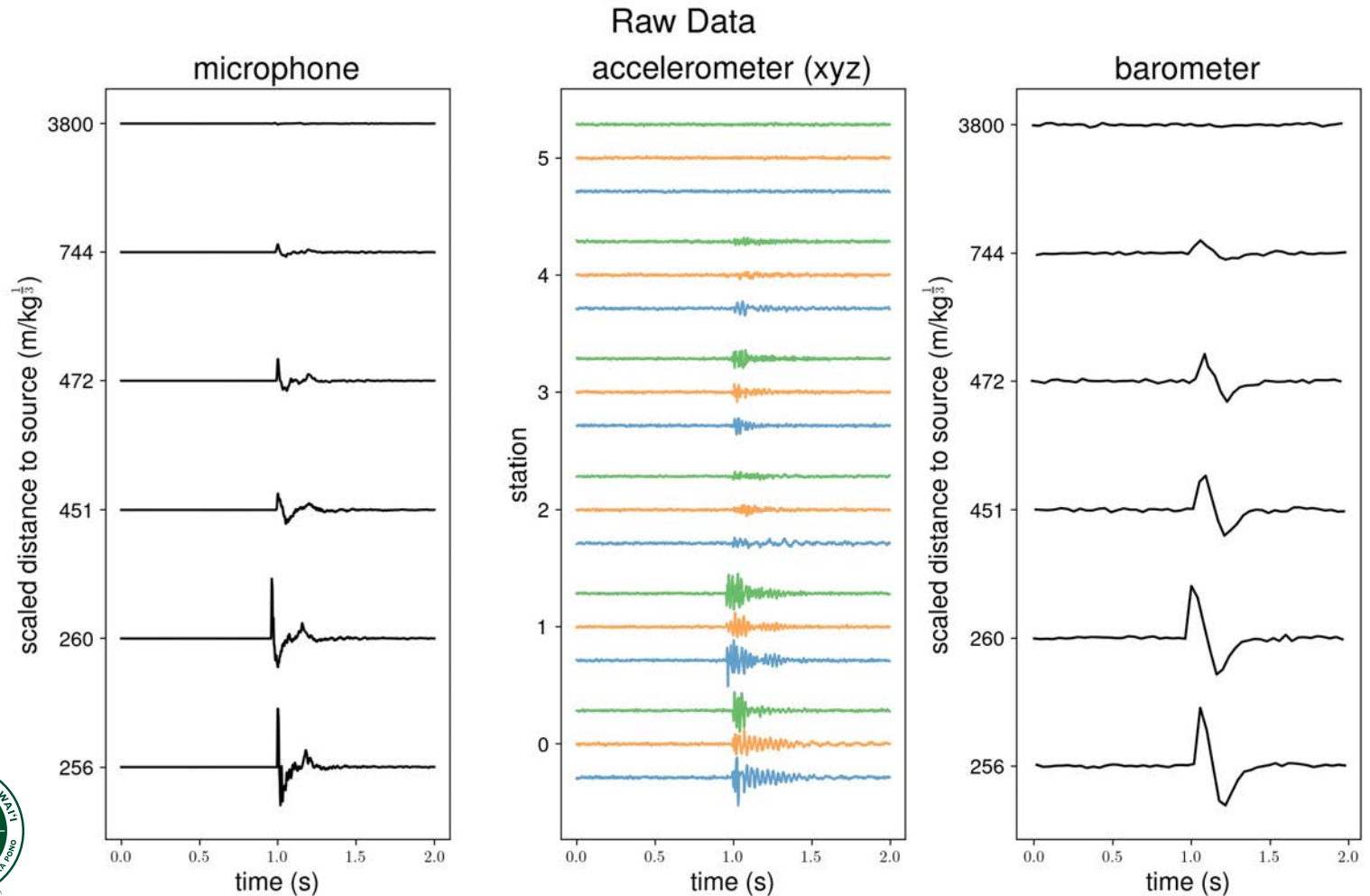


# Technical Work and Results - 4



## Acoustic, Accelerometric, Barometric Signal Highlights

– Accelerometric data shows air-coupled surface waves





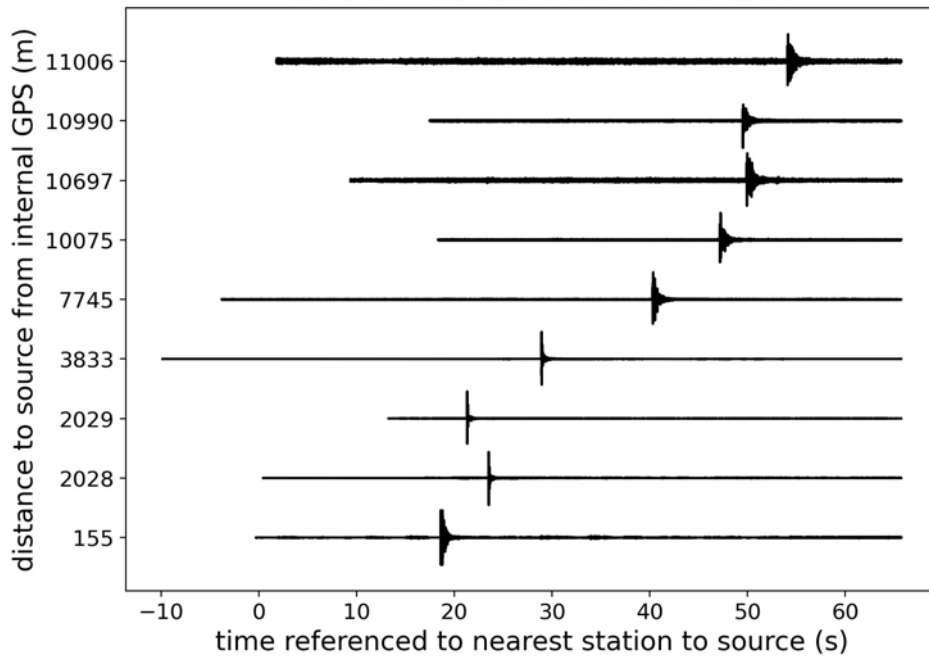
# Technical Work and Results - 4



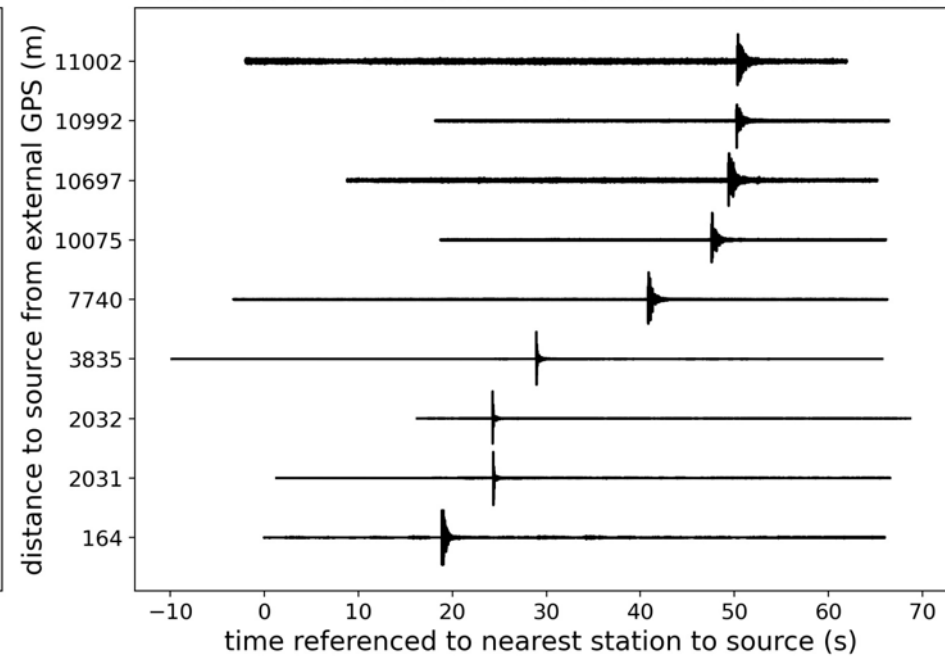
## Time and Location Highlights

- Timing correction model using tri-message
- Location model using phone GPS (compared with external GPS)

Normalized Acoustic Waveform



Normalized Acoustic Waveform: Time Corrected





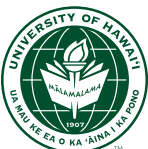
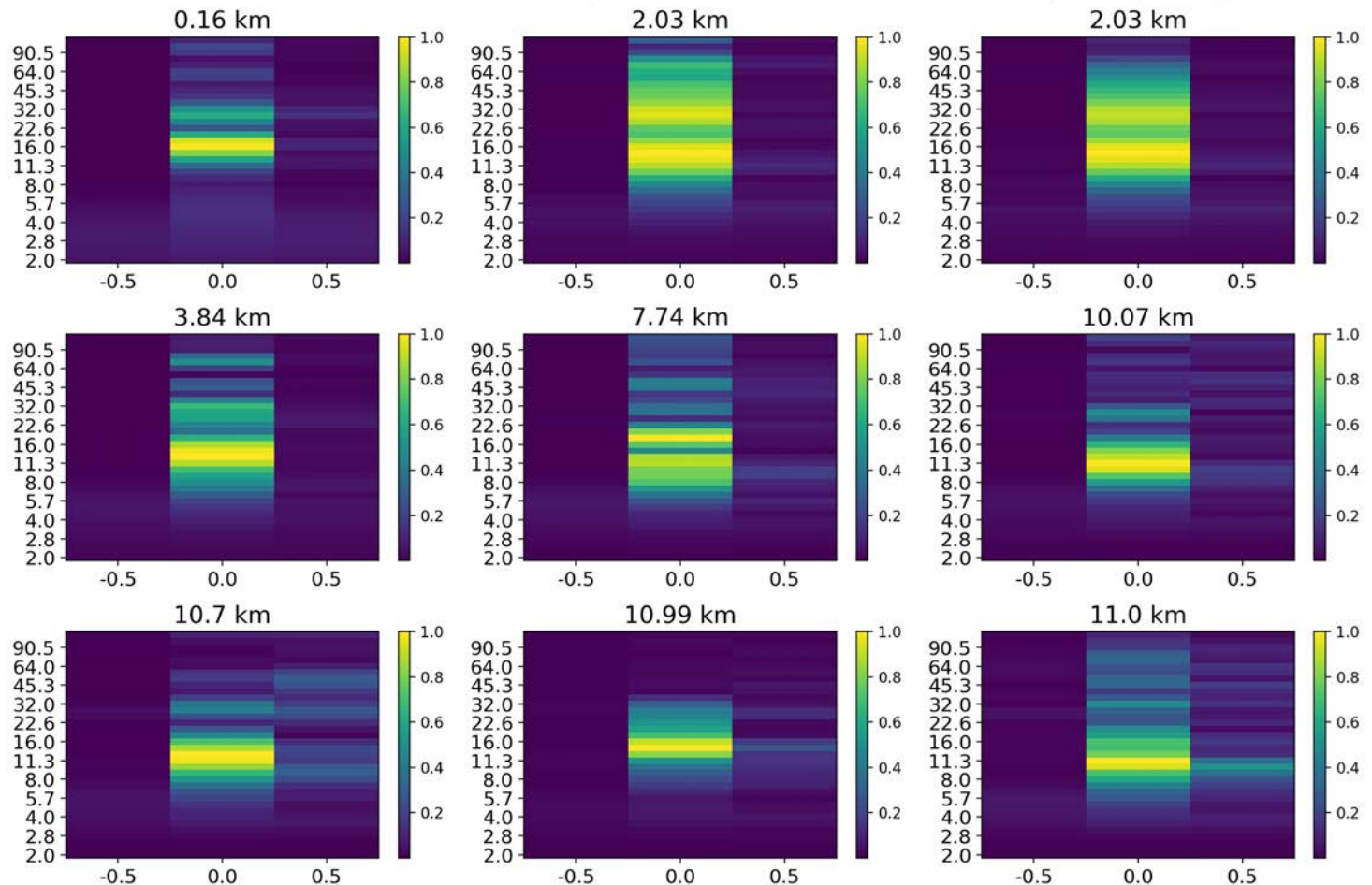
# Technical Work and Results



## Time Frequency Representations

- CQT with 6<sup>th</sup> order octave frequency bands

Constant Q Transform of Microphone (title: distance, x: time, y: frequency)





# MTV Impact



- **What is the impact of the MTV on your development?**
  - Collaboration with national labs for data collection
- **Plans for future relationship with national labs**
  - Continued data collections scheduled with INL and NNSS.
  - Sanitized explosion dataset release with LLNL.
- **Technology transitions**
  - Data collection: INL, LLNL, NNSS, SNL
  - Data analysis: University of Michigan (Dr. Hero's Team)





# Conclusion



## **Created a curated multi-sensor explosion dataset**

- Data is available and ready for analysis
  - o Yield Estimation
  - o Detection / Classification
  - o Modeling / Machine Learning

## **Created a standardized Time Frequency Representation**

- Reduces storage space and computation time
- Sparse representation of explosion signal

## **Please visit my poster for an example of the dataset in use**

- Effective Yield Classification using Machine Learning Methods

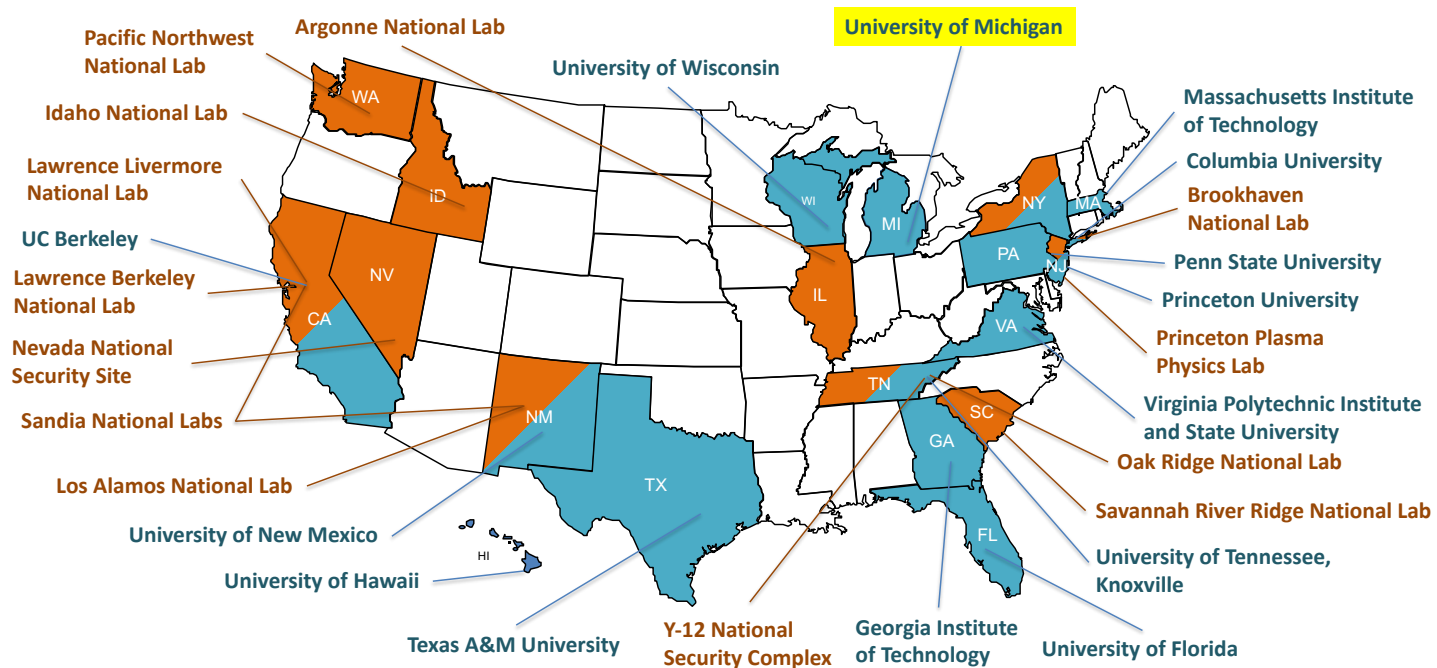




# Acknowledgements



The Consortium for Monitoring, Technology, and Verification would like to thank the NNSA for the continued support of these research activities.



This work was funded by the Consortium for Monitoring, Technology, and Verification under Department of Energy National Nuclear Security Administration award number DE-NA0003920

