

## *Statistics at Sandia National Laboratories: From Atoms to Z Machine*

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# Acknowledgements

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# Framework for Presentation

- Brief History of Sandia
- Sandia Mission Areas Today
- Nuclear Deterrence Mission (Atoms)
- Statistical work supporting the Nuclear Deterrence Mission
- Global Security Mission
- National Security Mission
- Advanced Science and Technology Mission, some examples
  - Climate science
  - Health and Safety
  - Metrology
  - Covid-19 related research
  - Z machine
- University collaboration and teaching within Sandia
- Summary





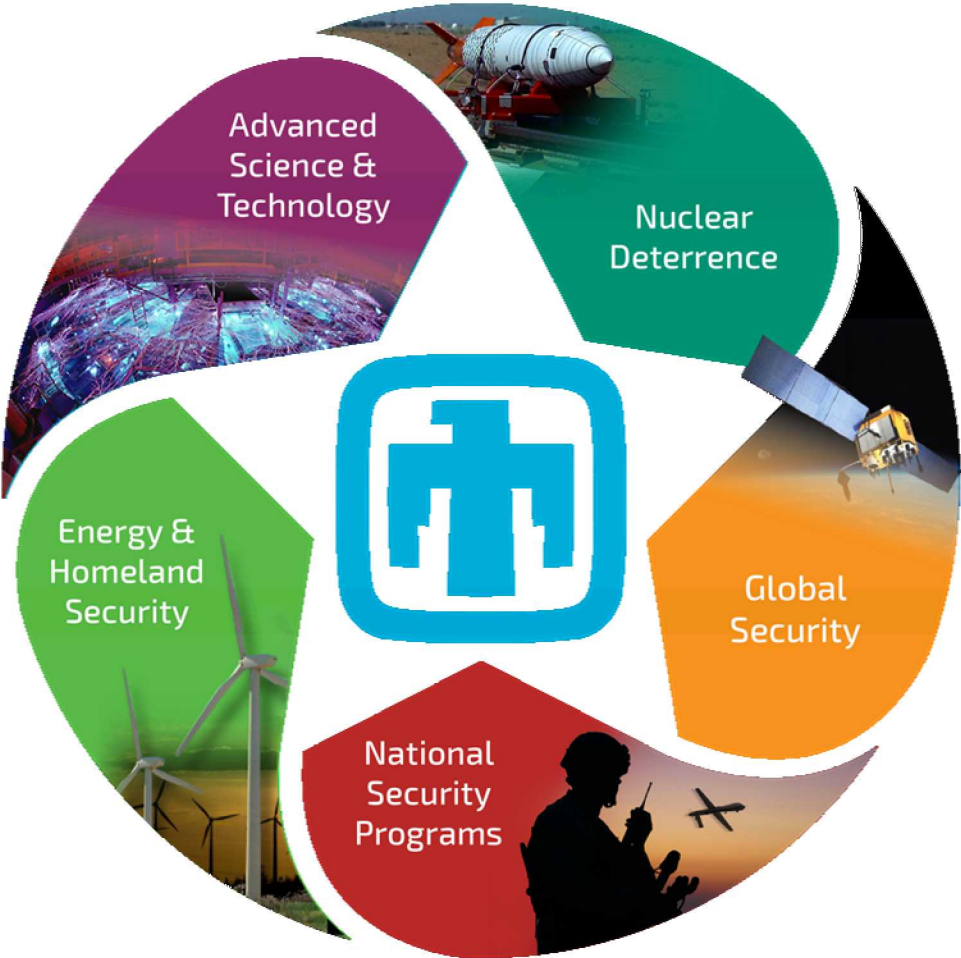
## Brief History of Sandia

- July, 1945. Los Alamos establishes Z division in Albuquerque, New Mexico.
- Z division handled the ordnance engineering, testing, assembly, and military activities for Los Alamos.
- June, 1946. First postwar nuclear tests done by Z division.
- November, 1949. Z division separated from Los Alamos and became Sandia.
- March, 1956. Second branch of Sandia opened in Livermore, CA.
- October, 1963. Sandia moves into test ban treaty verification with launch of Vela satellites.
- 1970's. Sandia expands to include research in areas like energy, terrorism
- February, 1998. Z machine produced 80 times world output of electricity for short burst of time.
- 2000's. Sandia expanded national security applications after 9/11.

Today: *Sandia develops advanced technologies to ensure global peace.*



# Sandia Mission Areas Today



Statisticians contribute in all mission areas at Sandia.



# Nuclear Deterrence Mission (Atoms)

- Sandia is responsible for the non-nuclear components of US nuclear weapons.
  - This is ***thousands*** of components
- Each weapon must work immediately if authorized by the president
- Each weapon must never go off if not authorized
- Weapons remain for decades in complex conditions and survive harsh environments.
- We want to say that we are X% confident that Y% of components will meet a requirement.
- We can't rely on experts state of knowledge
- Many sources of uncertainty that cannot be straightforwardly quantified
- Provide statistical modeling for weapons lifecycle decision support





# Support Work for Nuclear Deterrence Mission

- Suppose we have satisfied the conditions of the previous slide. There are other questions to consider. Such as-
- What if we have to move any type of weapon? How do we do that safely?
  - Statisticians are helping to advance secure transportation technologies robust to the new threats of the 21<sup>st</sup> century
  - Assess the overall reliability and uncertainty of new transportation designs due to materials and transport scenarios.



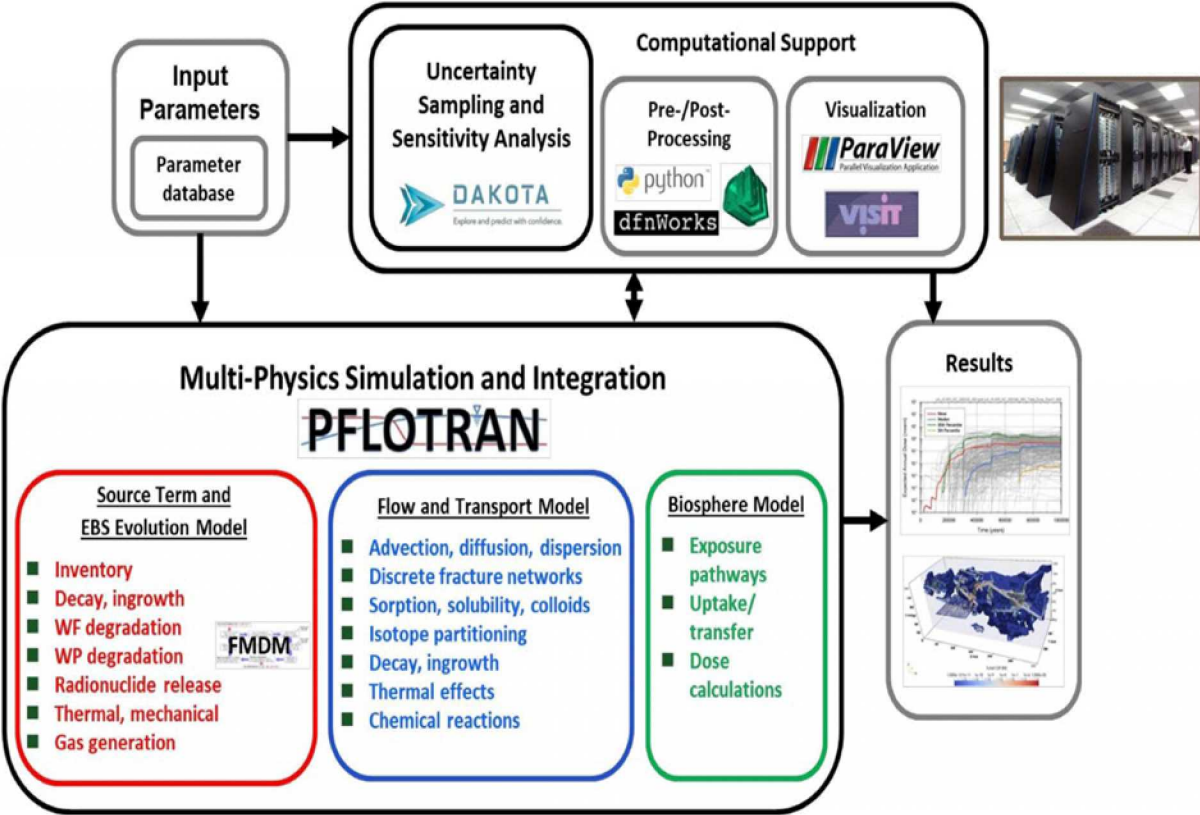


# Support Work for Nuclear Deterrence Mission

What about nuclear waste?  
How do we handle that safely  
if it is stored underground?

- Statisticians continue to develop methods and tools for uncertainty and sensitivity analysis for geologic disposal safety assessments, including variance-based sensitivity indices calculated based on surrogates (Gaussian processes), importance sampling, dimension reduction, and multi-fidelity UQ methods.

## (Geologic Disposal Safety Assessment) *GDSA Framework*





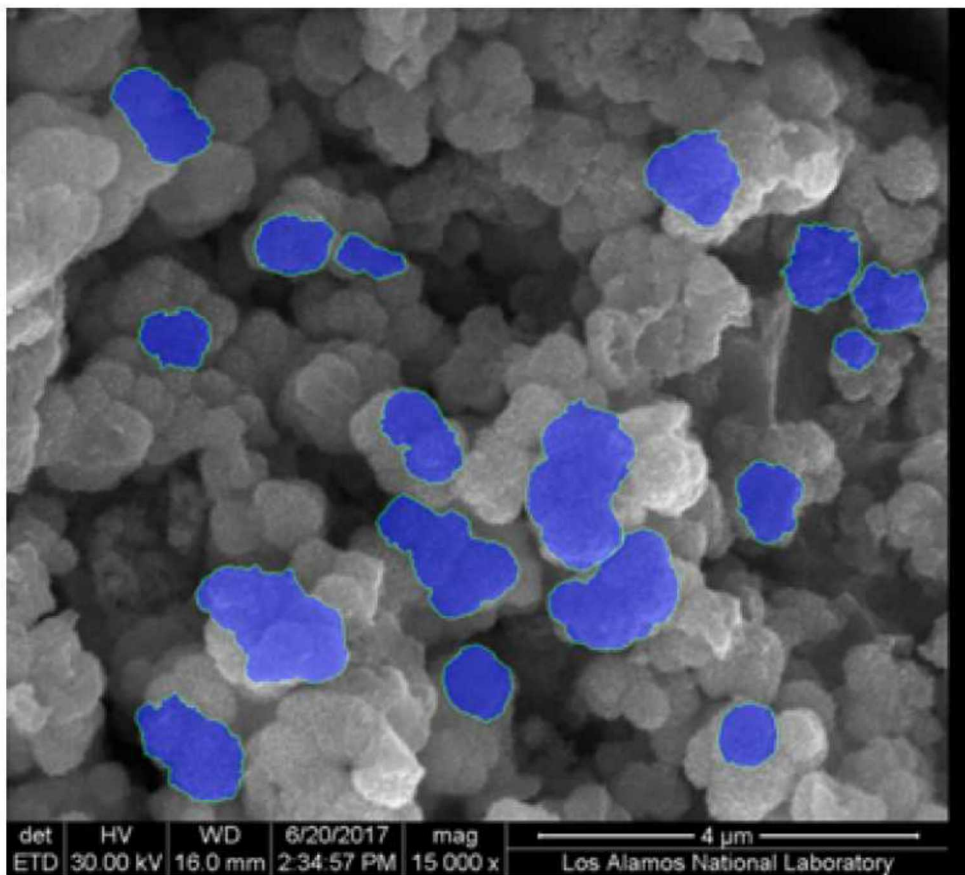


# Global Security

- Since the 1960's, Sandia has been involved in treaty verification
  - Sensors are deployed on Earth, in orbit, and seismically to detect foreign nuclear activities
  - Sandia statisticians play an important role in developing the detection and classification algorithms for the processing of remote sensing signatures.
  - Developing technologies to solve proliferation challenges
- Nuclear Forensics.
  - Suppose a piece of interdicted material is found. We would like to know where it came from.
  - Sandia statisticians are developing inverse prediction techniques for chemometrics, based on measured physical, chemical, and scanning electron microscope (SEM) features of materials, to detect signature characteristics associated with the pedigree of the material based on a statistically designed experiment.



# Global Security



**Figure 1.** SEM image from MAMA software. The blue shapes are the particles from which measurements such as vector area and pixel area are calculated.

## Nuclear Forensics Example

- Sample SEM image of particles
- We want to identify the processing conditions that created it.
- Knowing what type of material it is, we would like to know what conditions created it.

Characteristics from each of these blue segmented particles (like pixel area, grayscale, and major/minor ellipse) are used as a new potentially discriminating response for inverse prediction



# National Security

- Sandia statisticians have been involved in testing of US conventional weapons.
- Cybersecurity: Sandia conducts threat assessments, analyzes government, military and civilian networks, and develops protective technologies.
- Decision Support: tools and technologies to support decision making in complex national security mission areas.
- Intelligence Science: development of methods and technologies to detect and deter high impact events.

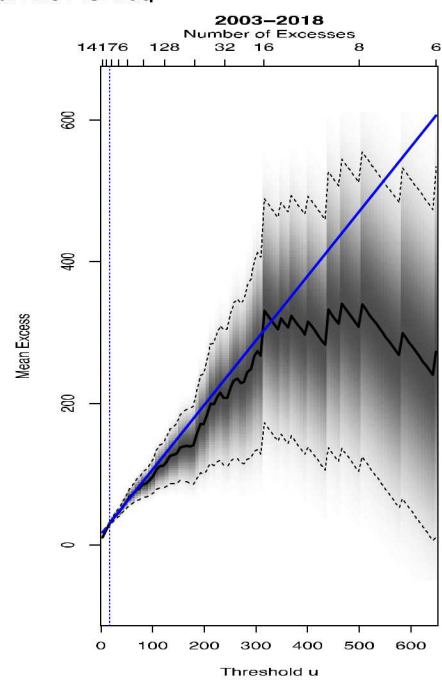
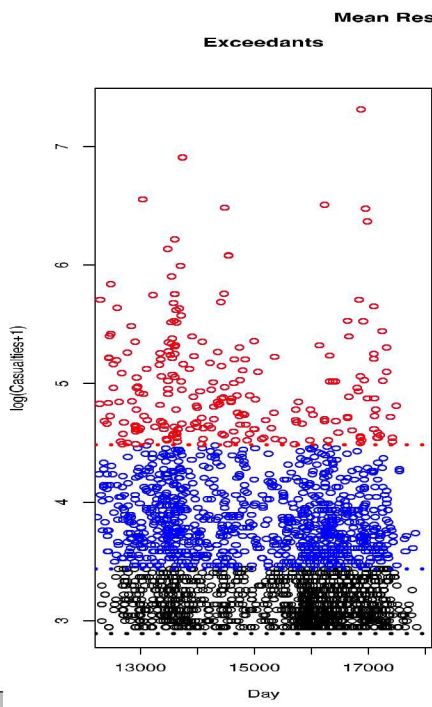
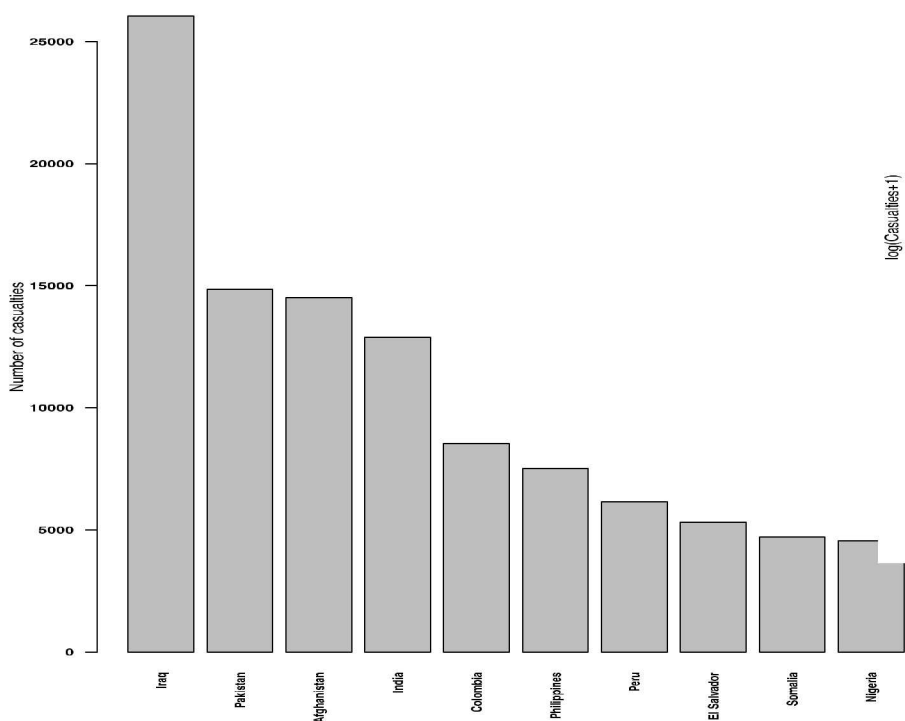




# National Security and Intelligence Science

- Sandia statisticians are assessing *extreme value analysis* to predict rare events with the *Global Terrorism Database* (JSM Session 366, 08/05/20, 10.00am).

- Histogram of casualties per country



- Iraq event exceedances 2003-2008



# Advanced Science and Technology

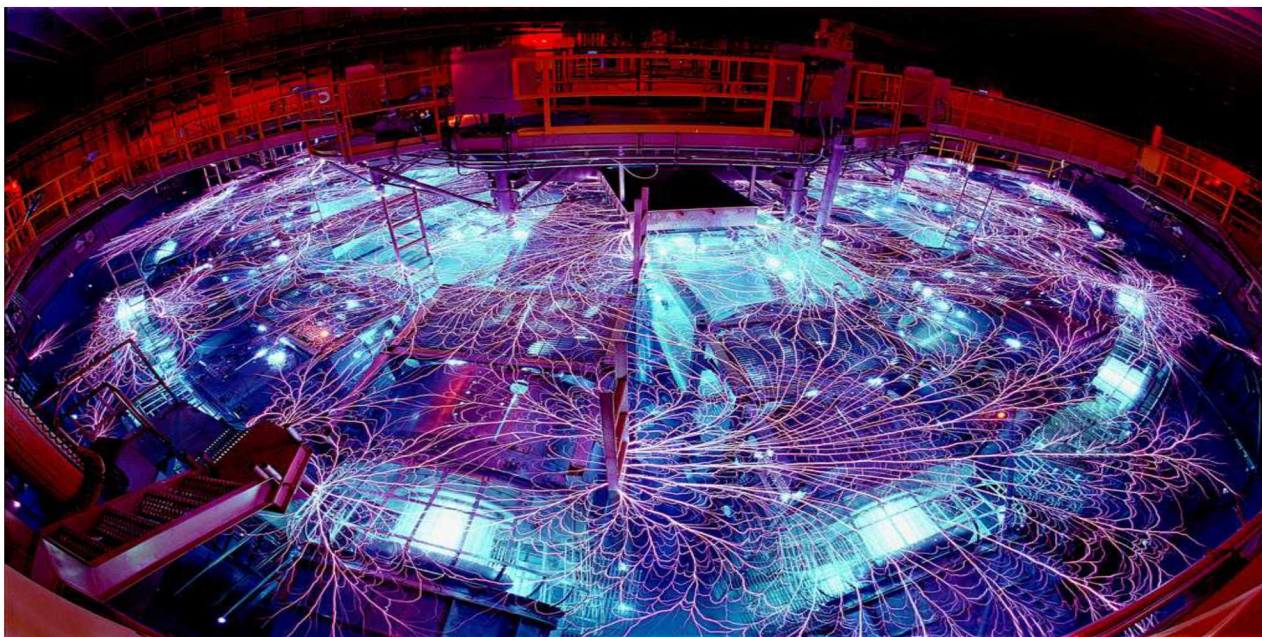
- Climate Science
  - Example: inferring from satellite imagery the longevity of ship-emitted aerosols and under what atmospheric conditions they form with aid of surrogate modeling (JSM session 73, 8/3/2020, 10.00am)
- Health and Safety applications
  - Example: predict physical fatigue using heart rate data from wearable devices using functional logistic regression
- Covid-19 related research
  - Covid-19 prediction modeling techniques
  - Developing new techniques for contact tracing
  - Helping medical teams develop guidelines for testing asymptomatic population
- Metrology: Quantifying uncertainty in measurement systems
- Z Machine





## Z Machine – what is it?

- Sandia's Z machine is Earth's most powerful pulsed-power facility and x-ray generator. Z compresses energy in time and space to achieve extreme power and intensity found nowhere else on Earth. The Z accelerator is an integral part of Sandia's Pulsed Power Program.
- Many different applications across the laboratory.

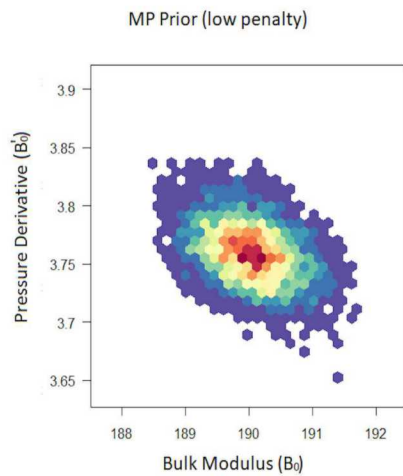
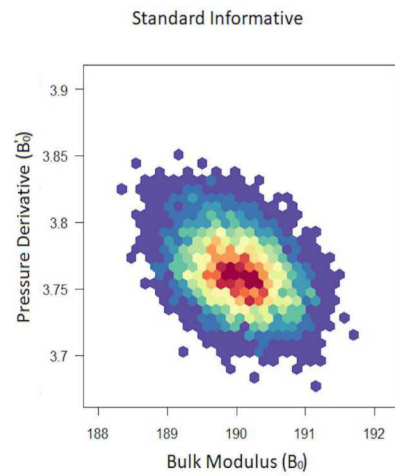
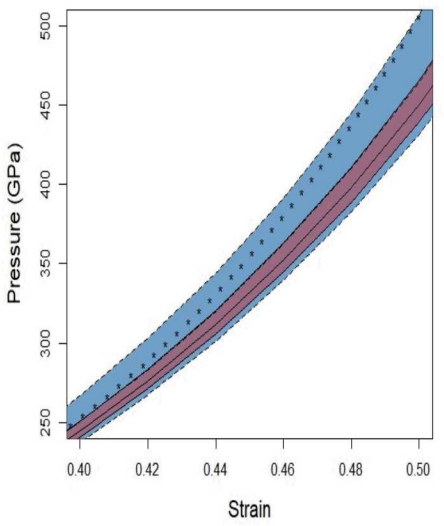
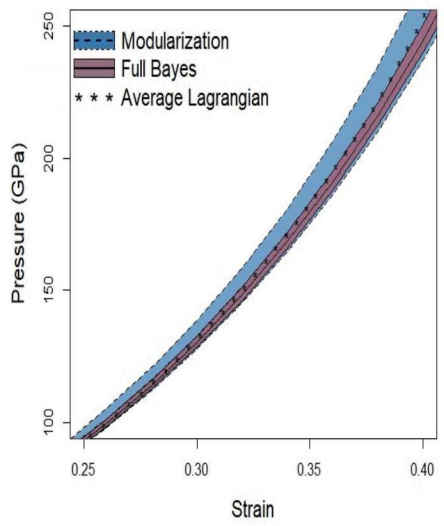
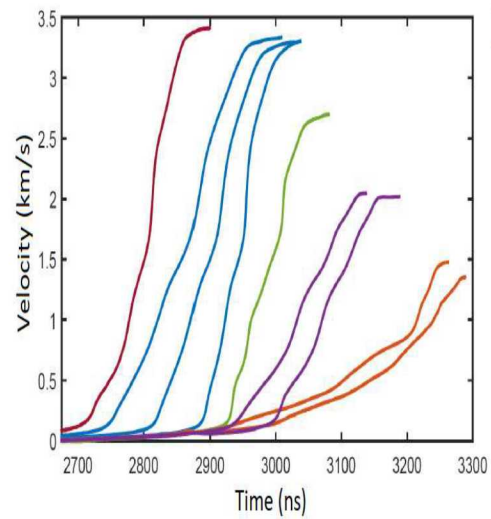
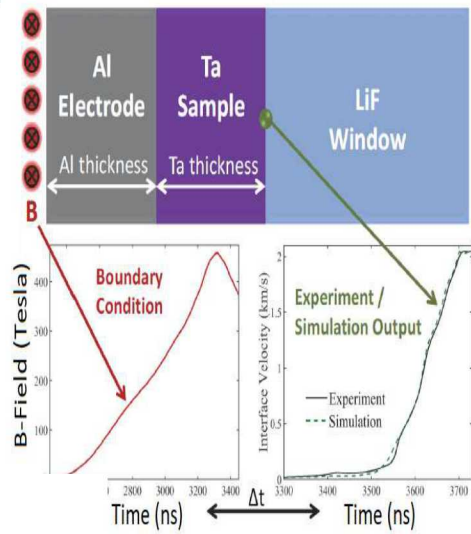






# Analysis with Z Machine

- Material sciences
  - Statisticians had been involved in the development of **uncertainty quantification** methods to predict important physical characteristics in material sciences by coupling experimental data and computer simulations from the *Z-machine*.





# University collaborations and Teaching

- Some of the universities Sandia statisticians have ongoing research collaborations with:
  - University of Illinois Urbana-Champaign
  - Ohio State University
  - Brigham Young University
  - Florida State University
  - University of Washington
  - University of New Mexico
- Sandia supports many students from universities all across the USA through internships (summer and year round).
  - Summer program this year is 100% virtual
- Teaching activities within Sandia
  - Data Analysis Techniques, Quantification of Margins and Uncertainties, Intro to R, Intro to Measurement Uncertainty, others



# Summary

- Statisticians are critical to many different areas at Sandia, including
  - Nuclear Deterrence and support of nuclear deterrence
  - Global Security
  - National Security
  - Advanced Science and Technology
  - University Research Collaborations, Internships, and Teaching

Come visit us at [www.sandia.gov](http://www.sandia.gov) and  
<http://www.sandia.gov/statistics/>





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