SnT 2019
CTBT: SCIENCE AND TECHNOLOGY CONFERENCE

Explosion Monitoring Research at the Nevada National Security Site

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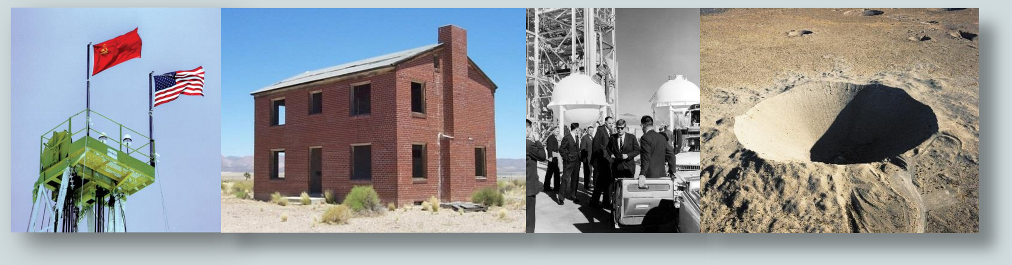
T2.1-P13

*Our objective is to enhance capabilities (**physical** models, numerical codes, data) to monitor and verify nuclear explosions at increasingly lower yields with improved confidence.*

Nevada National Security Site

History

- US President Truman established the Nevada Proving Grounds in 1950. It later became the Nevada Test Site and was renamed the Nevada National Security Site (NNSS) in 2010.
- January 1951: First atmospheric nuclear test detonated at the NNSS
  - 1951-1962: 100 atmospheric tests conducted
- August 1963: Limited Test Ban Treaty – led to underground testing
  - 1961-1992: 828 underground tests conducted
- 1988 Joint Verification Experiment (JVE)
- 1992 Last nuclear explosive test detonated



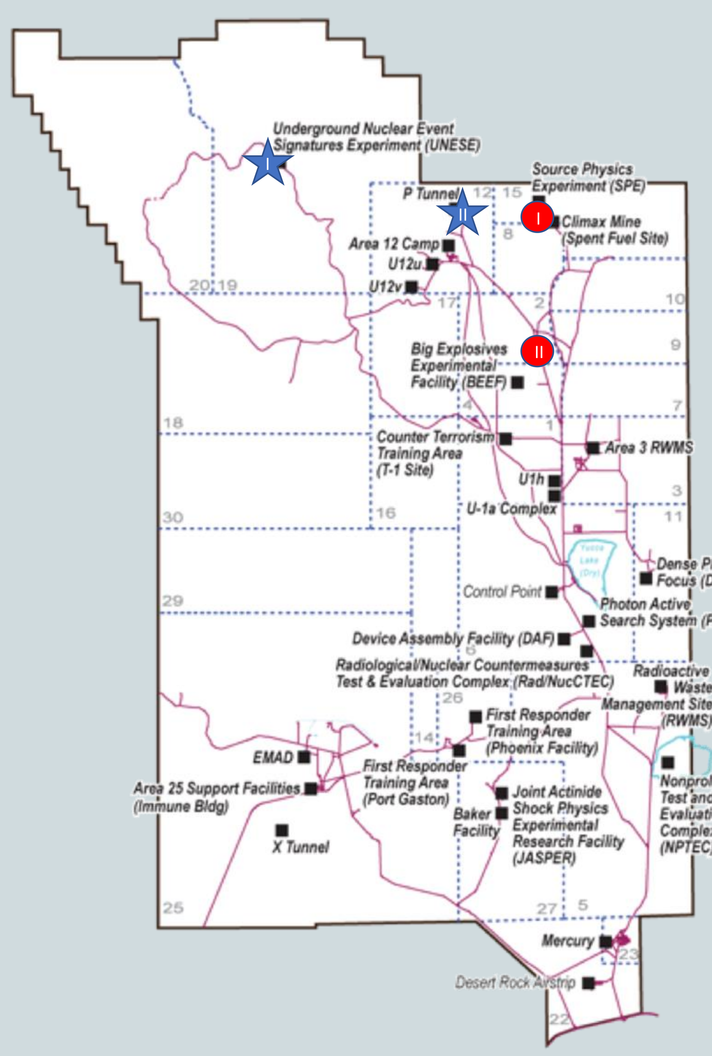
Today

- The NNSS is currently conducting experiments and research and development efforts that:
  - Support Stockpile Stewardship
    - Deterrence, safety, & security
  - Conduct global security research
  - Provide emergency response capability and training
  - Contribute to key nonproliferation and arms control initiatives
  - Support environmental management
- Outstanding safety record
- 3,522 square kilometers
- Since 2010, the NNSS has supported nuclear non-proliferation R&D with **the Source Physics Experiment (SPE)** and the **Underground Nuclear Explosion Signatures Experiment (UNESE)**

Stockpile Stewardship

Global and Homeland Security

Environmental Management



- Source Physics Experiment (Phase I or II)
- Underground Nuclear Explosion Signatures Experiment (Phase I or II)

Source Physics Experiment (SPE)

Phase I: Granite (SPE)

Phase II: Dry Alluvium Geology (DAG)

Conducting Chemical Explosions

- SPE Phase I explosions ranged in yield from 200 lbs to 5 tons. DAG explosions have ranged from 1 to 50 tons.
- The SPE/DAG series are unique, in that experiments in each series are all detonated in the same borehole
  - Allows the same sensor networks to be used for each experiment
  - Simplifies comparisons between experiments
- The experiments are designed to address specific knowledge gaps in explosion source physics
- Experiments provide excellent opportunities for current and next generation engineers and system design teams to develop critical skillsets

Image Courtesy of Beth Dzenitis, LLNL

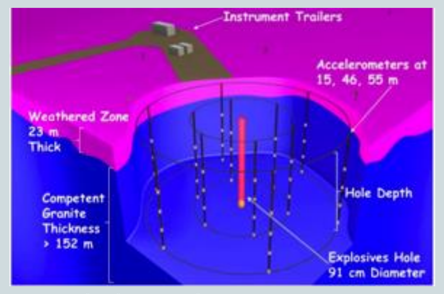
Emplacing a SPE chemical explosion canister (0.2 tons)

Image Courtesy of J.A. Vigil, LANL

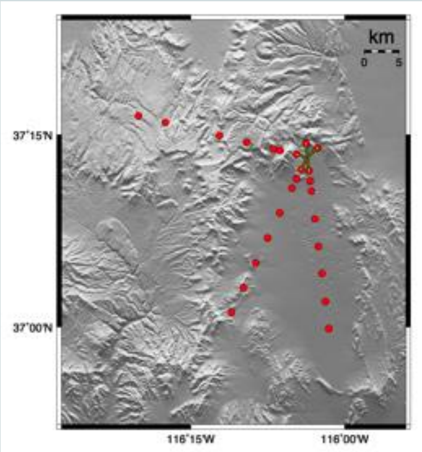
Emplacing a DAG chemical explosion canister (50 tons)

Acquire High Quality Data

- A priority for meeting science objectives was the development of high quality sensor networks for SPE and DAG
- The SPE series has already generated one of the most comprehensive non-nuclear explosion data sets in existence
- SPE explosions are also recorded by:
  - Accelerometers
  - Seismic networks
  - Infrasound arrays
  - Hi-speed video
  - Electromagnetic sensors
  - Remote sensing methods
  - Photogrammetry
- Includes opportunities to introduce students to non-proliferation data collection and analysis
- Data are released to the scientific community approximately 2 years after the experiment

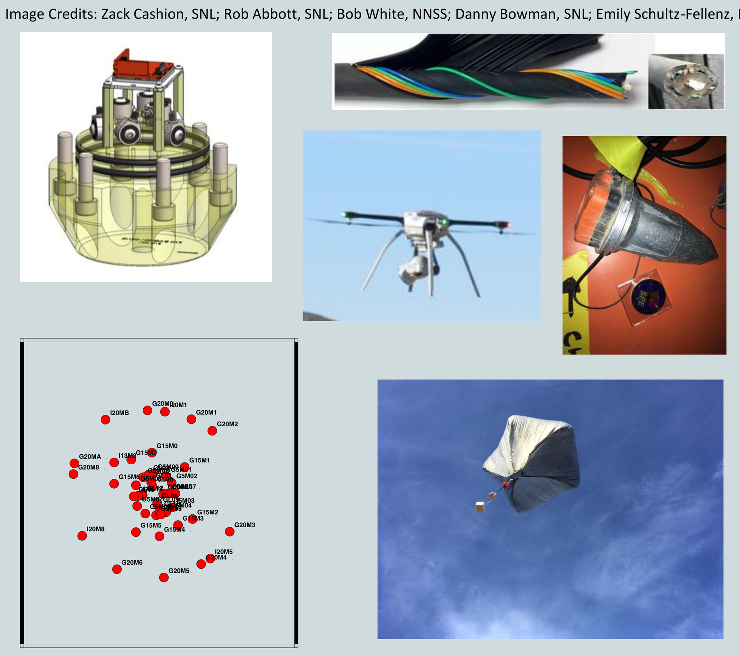


Borehole accelerometers at SPE



NNSS seismic networks recording SPE explosions

Image Credits: Zack Cashion, SNL; Rob Abbott, SNL; Bob White, NNSS; Danny Bowman, SNL; Emily Schultz-Fellenz, LANL

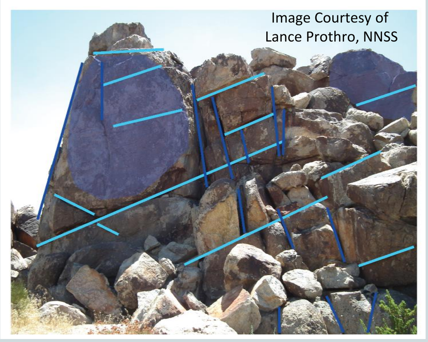


Diagnostics for DAG include fiber optics, geophones, heliotropes, seismo-acoustic, accelerometers, photogrammetry, and other technologies

Geologic Characterization

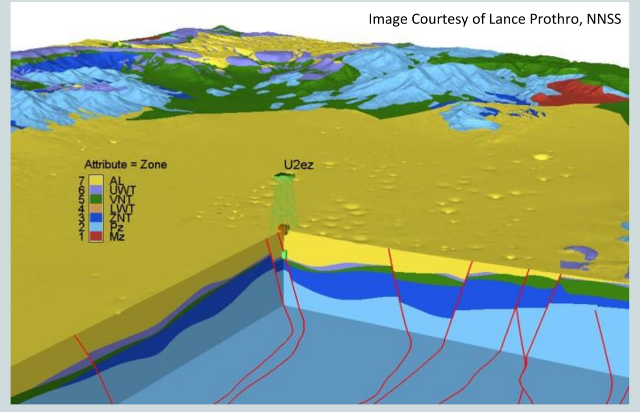
- The type of rock in which an explosion is detonated is very important to the phenomenology
- An explosion detonated in hard rock will transmit more seismic energy to the earth and have larger waveform amplitudes than an explosion conducted in soft rock
- SPE explosions were designed to include chemical explosions in a wide range of geologic settings (Granite vs Dry Alluvium)
- Our research teams have conducted extensive studies to characterize the emplacement media for the SPE explosions

Image Courtesy of Lance Prothro, NNSS



Granite outcrop near the SPE test site. Geologists have interpreted the picture with lines that represent the joints in the granite.

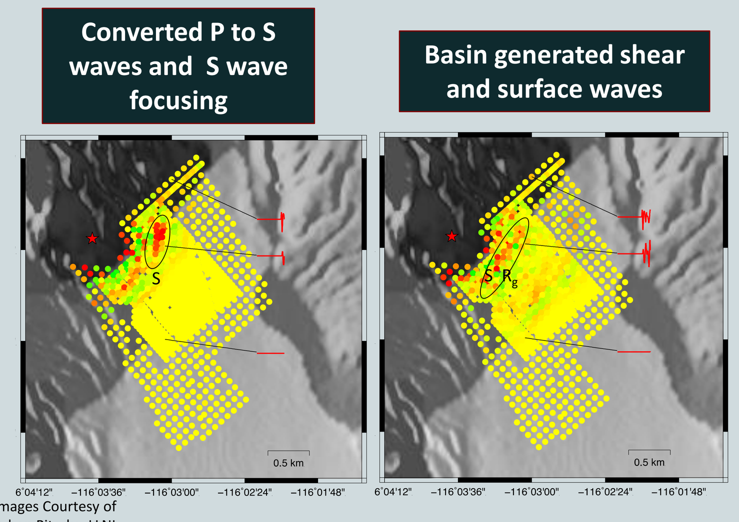
Image Courtesy of Lance Prothro, NNSS



Geologic Framework Model shows the alluvium (yellow) and basement rocks (blues)

Analysis, Modeling, and Simulation

- A fully coupled source-to-sensor modeling capability is being developed and applied to address the major scientific goals of the SPE
- To capture the processes that occur during an underground explosion, hydrodynamic modeling simulates the physics of the explosive burn, the rock damage/deformation around the explosion, and the shock wave generation
- The National Labs have also developed efficient numerical codes to propagate these simulated shock waves to hundreds of kilometers where nuclear monitoring stations are often located
- The SPE data allow these codes to be validated and applied to nuclear explosion problems with confidence



Images Courtesy of Arben Pitarka, LLNL

Large-N array data clearly show strong propagation effects on S waves generated in the source region and at structural boundaries, and Rg waves.

Image Courtesy of Scott Phillips, LANL

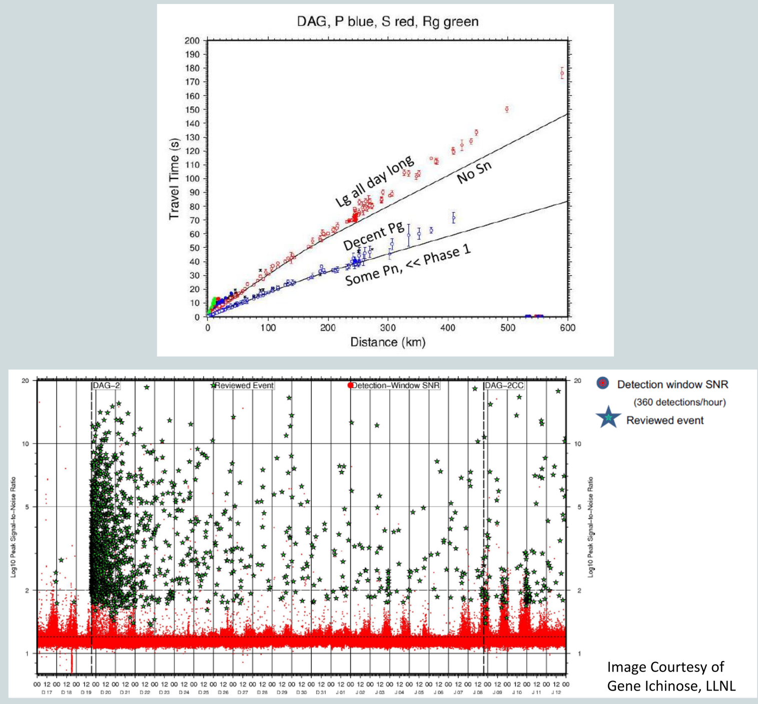


Image Courtesy of Gene Ichinose, LLNL

(Top) DAG-2 phase detections vs distance
(Bottom) DAG-2 aftershock detections with time after the explosion

Underground Nuclear Explosions Signatures Experiment (UNESE)

Focusing on Non-Prompt Signals

- Goals:
  - Advance underground nuclear explosion (UNE) detection
  - Develop a national test bed
  - Target development of new technologies
- Collaborative research partnership across numerous institutions
- Deliverables include remote and ground-based datasets; model development and refinement; interim and final reports
- Capability improvements for detection and identification of UNEs
- Focused on two emplacement scenarios
  - Phase I: Vertical Shaft (BARNWELL)
  - Phase II: Tunnel (DISKO ELM)

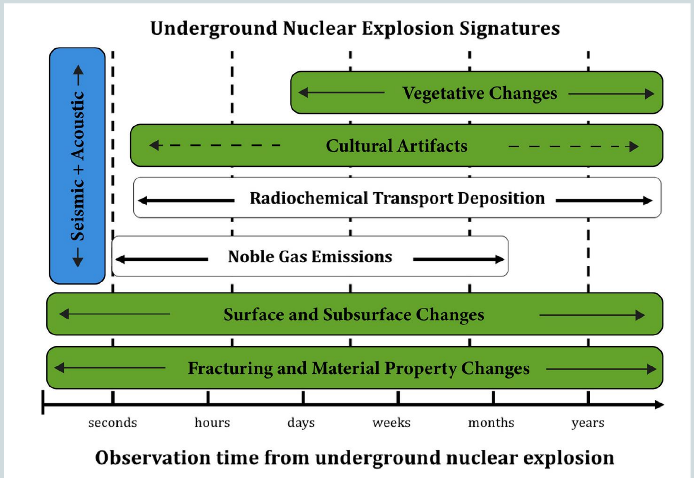


Image Courtesy of Liz Miller, LANL

Subsurface Modeling and Simulations

- Subsurface models and damage simulations based on geologic parameters are critical integrative tasks to link physical and radiochemical signatures.
- Imaging of large-scale subsurface damage using geophysical data, such as passive seismic and gravity surveys, help refine subsurface structure and damage models.
- A geologic framework model allows visualization and interpretation of surface and subsurface physical signature datasets.
- Damage simulations provide hydrodynamic prompt damage fracture networks in gas migration flow code.

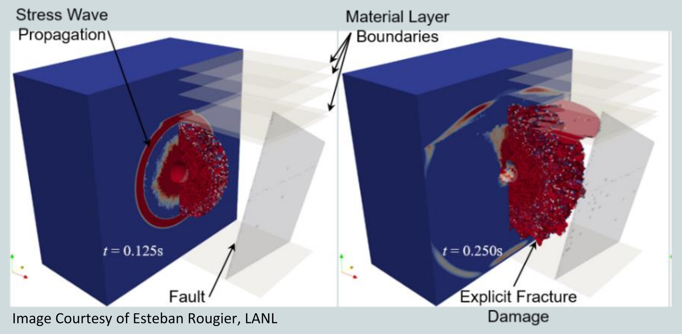


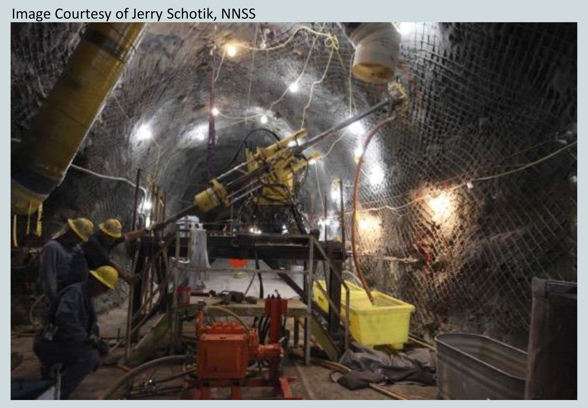
Image Courtesy of Esteban Rougier, LANL

Modeling fracture networks from an explosion

Chimney and Tunnel Investigations via Drilling

- Drilling into the chimney from the tunnel and from surface produced a 3D view of UNEs

Image Courtesy of Jerry Schotik, NNSS



Angled drilling into a historic nuclear explosion chimney

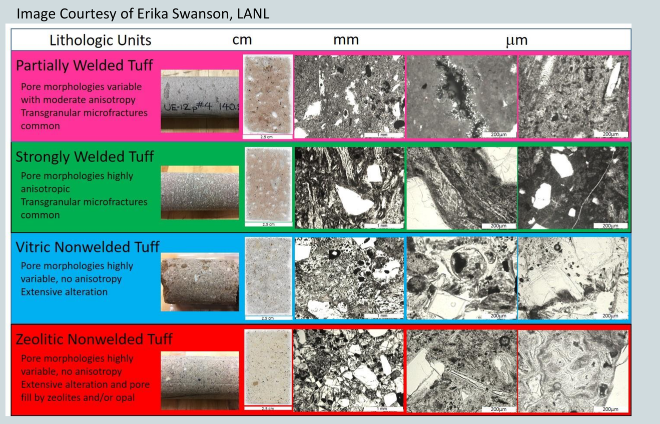
Image Courtesy of John Benner, LANL

Surface drilling for installation of gas monitoring sensors

Radiochemical Modeling & Gas Migration

- Material and fracture properties are determined from core sample analyses.
- Tracer gas migration studies include detection of radionuclides at the surface and in nearby boreholes, indicative of a UNE decades after it occurred.
- We used noble gas tracers to estimate transport processes in the test cavity and surrounding containment regime.
- We investigated the spread of airborne gases following a UNE to quantify realistic download concentrations and determine optimal sensor deployment.

Image Courtesy of Erika Swanson, LANL



Lithologic analysis of rock types studied by UNESE

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