DOE/NV/03624-0629

Source Physics Experiments at the Nevada National Security Site

Conducting Complex Underground Chemical Explosion Experiments for Nuclear Explosion Monitoring

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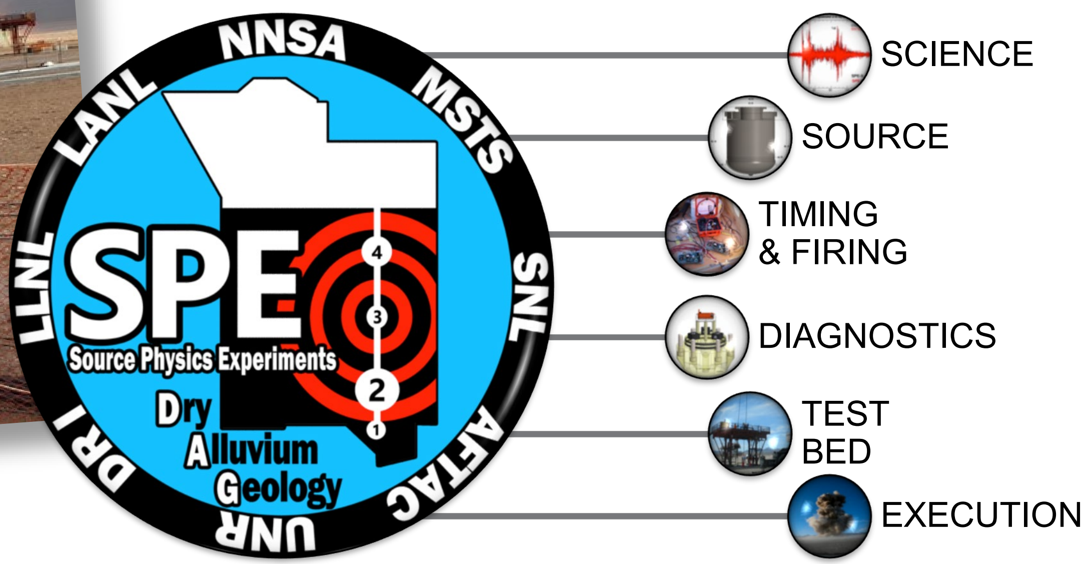
36th International Test and Evaluation Education Symposium
November 12-16, 2019

This work was done by Mission Support and Test Services, LLC, under Contract No. DE-NA0003624 with the U. S. Department of Energy

Purpose

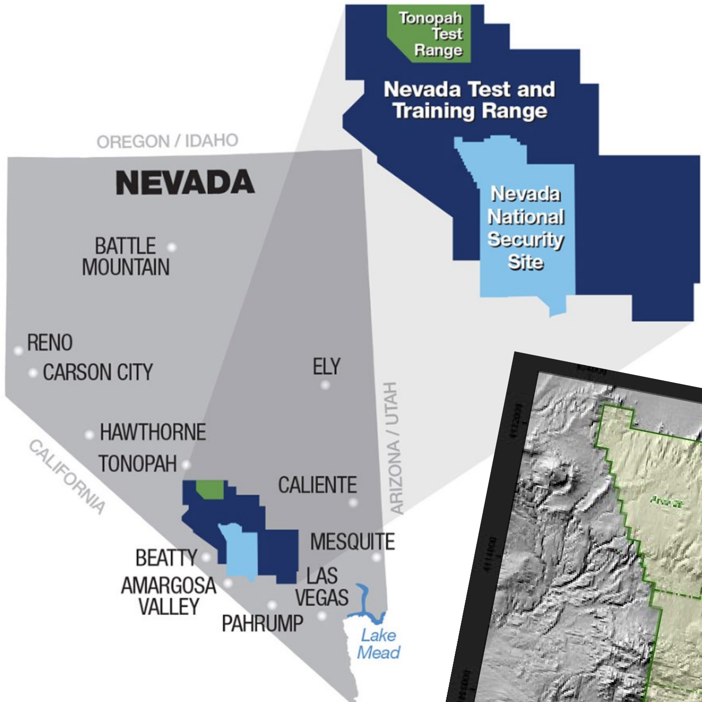
- Share some of the unique challenges associated with successfully executing the Dry Alluvium Geology (DAG) experiments at the Nevada National Security Site (NNSS).



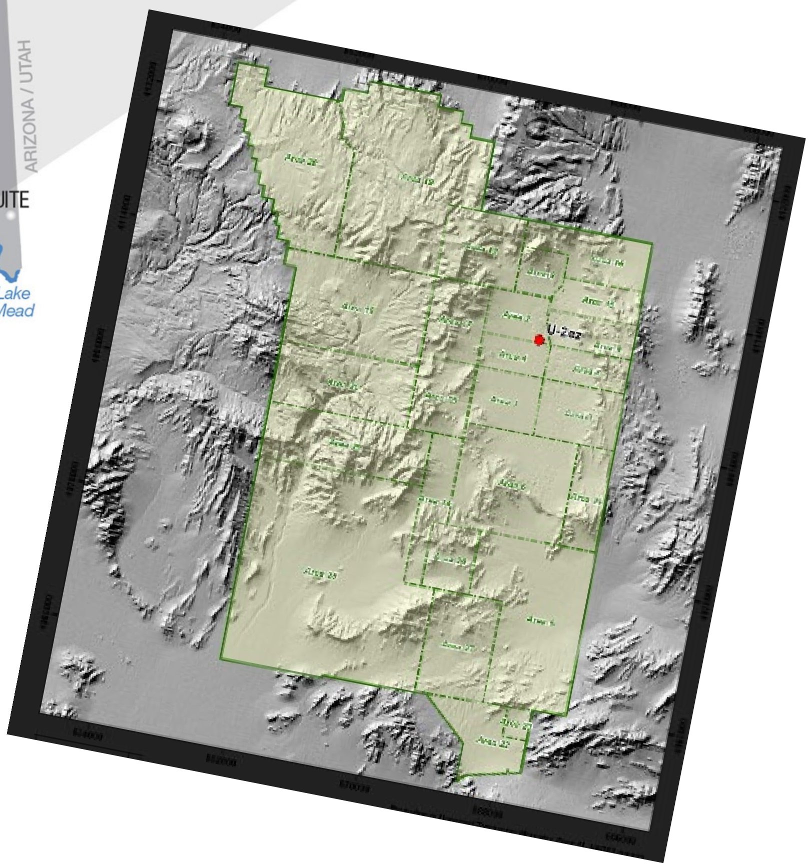
Experiment Summary

- The Dry Alluvium Geology (DAG) Project was a series of four chemical explosions detonated in alluvium geology in a well-instrumented test bed in 2018 and 2019.
- The goal of this experimental series is to improve U. S. nuclear explosion monitoring capabilities, particularly event identification and explosion yield estimation.
- The DAG test series emphasized collecting a wide range of explosion signatures to better understand the prompt-signal phenomenology of the explosion source, improve numerical modeling codes and improve confidence in monitoring future nuclear tests in new areas and emplacement conditions.
- The logistics of safely creating a complex testbed for large underground explosions and deploying a large variety of diagnostic sensors provided many opportunities for learning and creating efficiencies as the test series progressed.

Experiment Summary



- The Nevada National Security Site is 1,360 square miles - larger than the State of Rhode Island. The NNSS is located 65 miles northwest of Las Vegas.



- **Mission Support and Test Services**, an LLC consisting of Honeywell International, Jacobs Engineering Group and HII Nuclear manages operations at the NNSS.

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Dry Alluvium Geology Experiments

- Conducted in an 8-ft diameter, 1400-ft deep hole drilled in 1983 for nuclear testing but not used.
- Several nuclear tests were previously conducted within 1km of this site, providing a framework for comparison of seismic data.

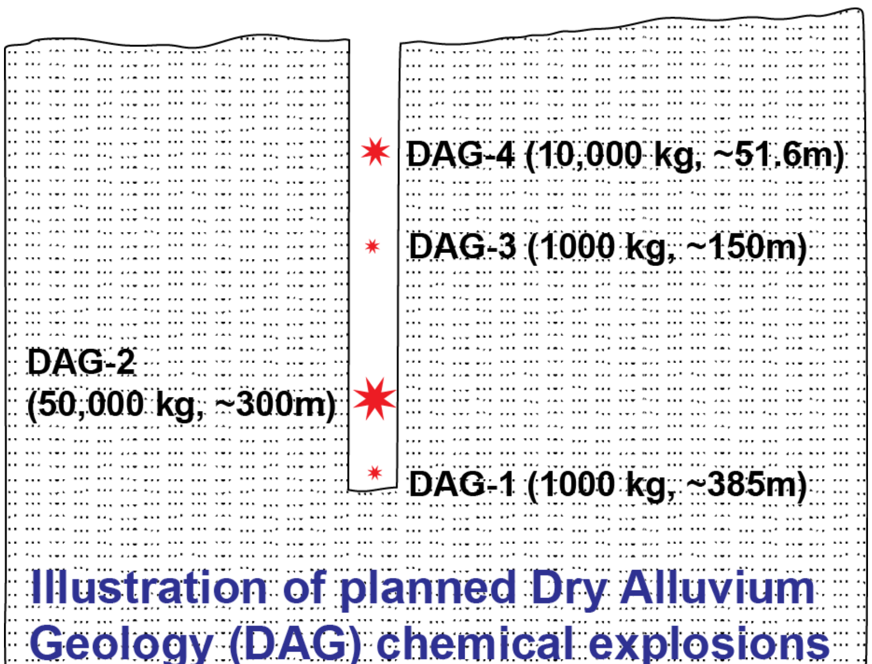
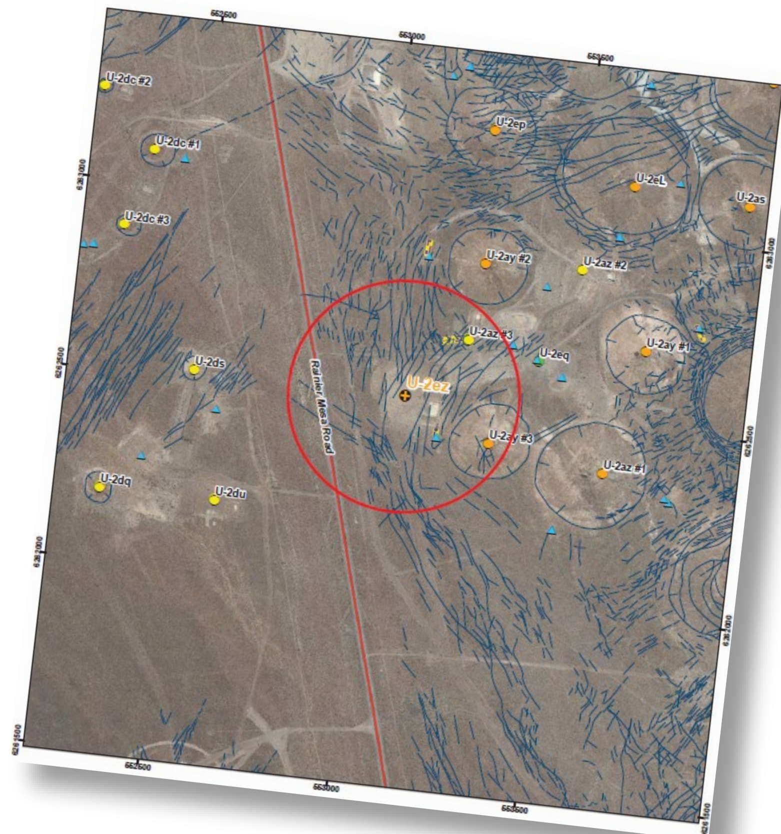


Illustration of planned Dry Alluvium Geology (DAG) chemical explosions



DAG Project Scope

- Timeline
  - 2017 – 2018: Ted Bed Development
  - 2018 – 2019: Experiment Execution
- Explosives
  - Storage and handling of >62,000 kg of Nitromethane
    - Process Safety Management
    - Nevada Chemical Accident Prevention Program
- Lifecycle Budget
  - >$30M
- Collaboration with multiple Program Partners for science and execution

DAG Venture Partners

Experiment Description

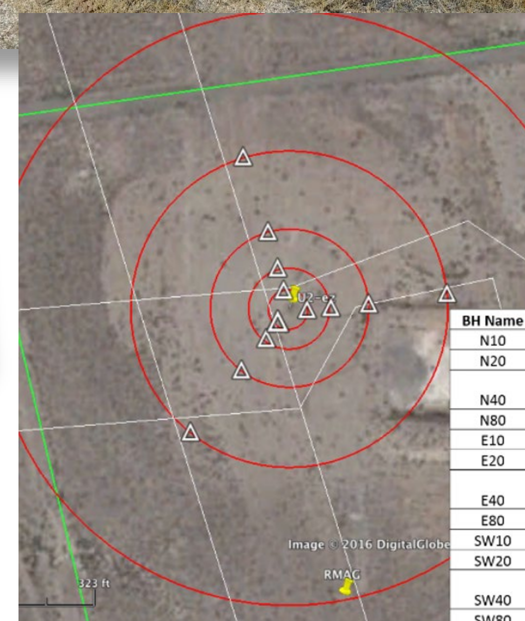
- Test Bed Development
  - Ground preparation, electrical, trailer park, loading dock, pad
  - Drilled twelve 1350+ foot-deep boreholes for accelerometers
  - Reconditioned legacy emplacement and stemming equipment
- Experiment Fielding
  - Timing and Firing Qualification
  - Canister insertion and filling with nitromethane
  - Emplacement
  - Stemming
- Field and Dry Run Diagnostics
- Experiment Execution
- Repeat

Site Preparation

- Site after grubbing and grading

- Emplacement and stemming equipment retrieved from storage and refurbished

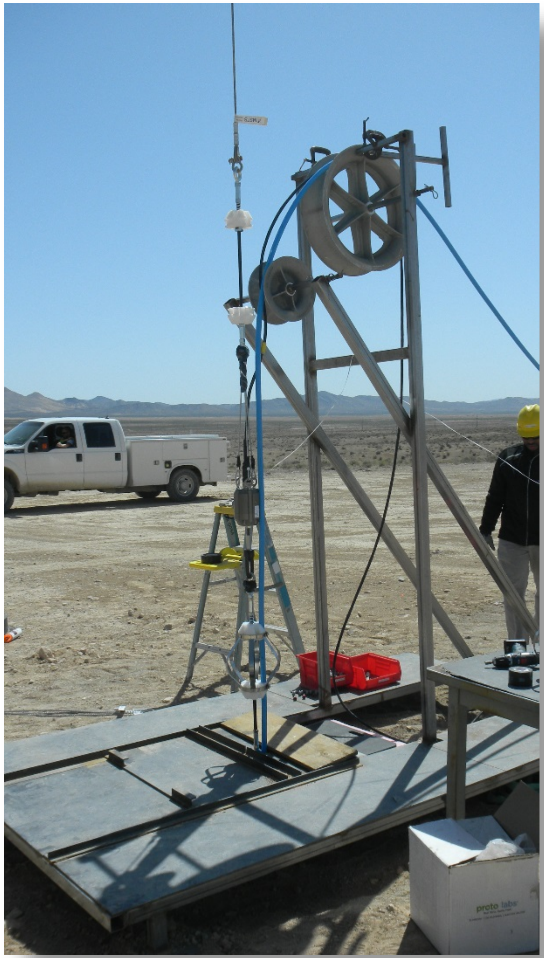
- Drilling boreholes

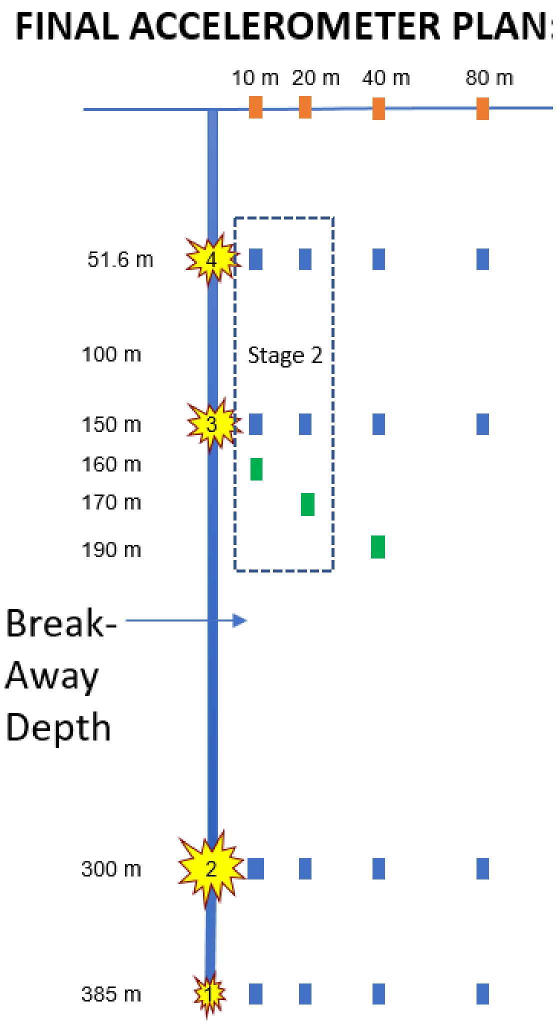


- Borehole array

Accelerometer Installation in Boreholes

- Rig built for accelerometer installation





- Accelerometer

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Experiment Fielding: Canister Handling

- Critical 2-crane lift required to upright canister

Accelerometer Installation in Boreholes

- Landing the canister at the top of the hole

- Filling the canister with nitromethane

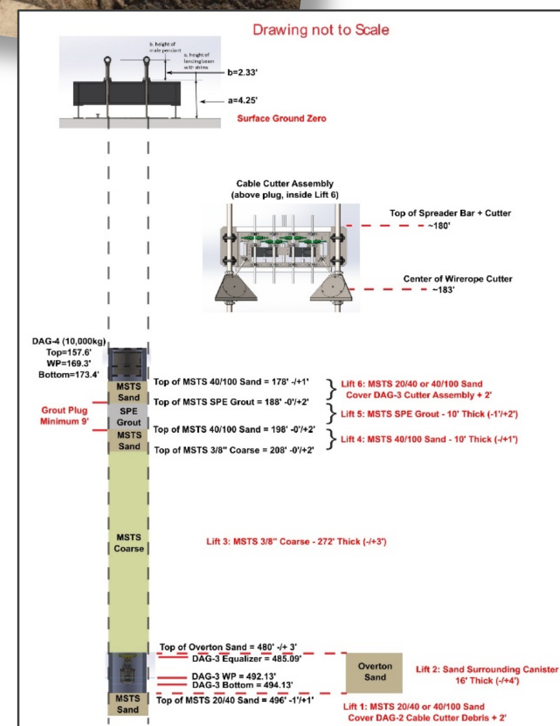
Emplacement

- 350T Crane, assist crane, 2-level platform, cable chute

- Cable handling during emplacement

Stemming Operations

- The hole was filled with sand, gravel and grout to confine the explosion



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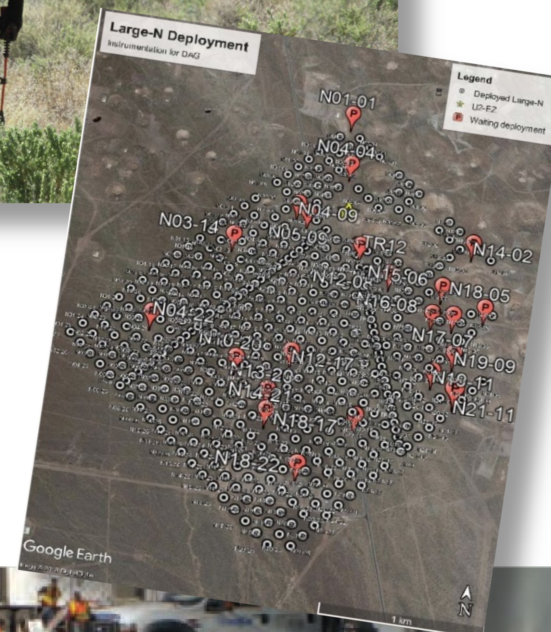
DAG Diagnostics

More than 600 individual diagnostics were deployed and recorded on more than 2000 data channels

- Borehole Accelerometers
- Surface Accelerometers
- Near-field Infrasound
- Distributed Fiber Optics
- Large-N Geophone Array
- Local Seismic Monitoring
- Borehole Microphone
- Broadband and Regional Seismic Stations
- Photogrammetry
- Video Synthetic Aperture Radar (and coherent change detection)
- Electromagnetic
- Video
- Heliotrope-based Infrasound
- Regional Infrasound
- Radon
- Atomic Magnetometer
- Pre- and post-experiment surface effects mapping

Diagnostic Installations



- Surface Infrasound Station

- Large N (500 nodes) geophone diagnostic array

Key Challenges in Fielding the DAG Experimental Series

- Environment
- Unique Testbed Hazards
- Multiple scientific goals
- Aerial Diagnostics
- Add-on Diagnostics

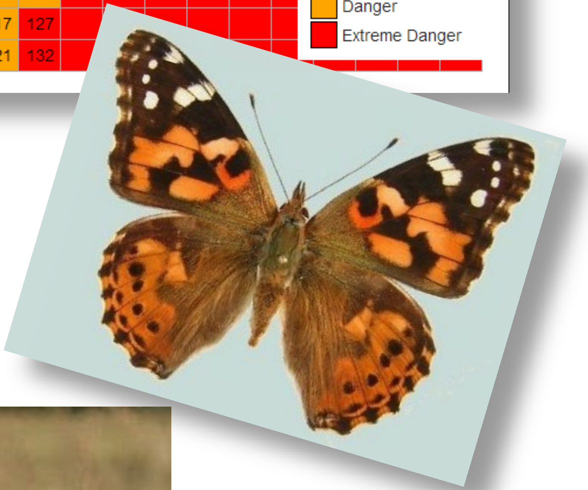
Environmental Challenges

- Environment
  - Wildlife
  - Weather Extremes
  - Blowing Sand (Silica)

NOAA national weather service: heat index

Relative Humidity (%)	temperature (°F) 80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
45	80	82	84	87	89	93	96	100	104	109	114	119	124	130	137	
50	81	83	85	88	91	95	99	103	108	113	118	124	131	137		
55	81	84	86	89	93	97	101	106	112	117	124	130	137			
60	82	84	88	91	95	100	105	110	116	123	129	137				
65	82	85	89	93	98	103	108	114	121	128	136					
70	83	86	90	95	100	105	112	119	126	134						
75	84	88	92	97	103	109	116	124	132							
80	84	89	94	100	106	113	121	129								
85	85	90	96	102	110	117	126	135								
90	86	91	98	105	113	122	131									
95	86	93	100	108	117	127										
100	87	95	103	112	121	132										

Caution
Extreme Caution
Danger
Extreme Danger



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Wildlife

- Ravens nesting on two-level platform

- Egret

- Coyote damage to radon diagnostic tubing

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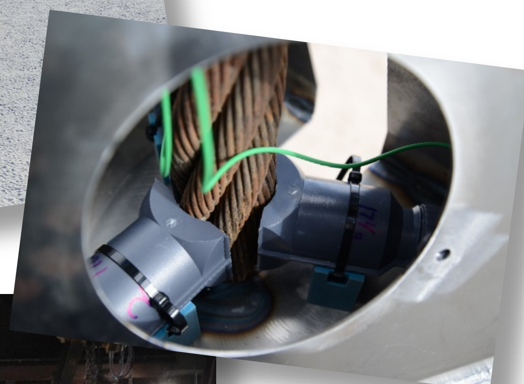
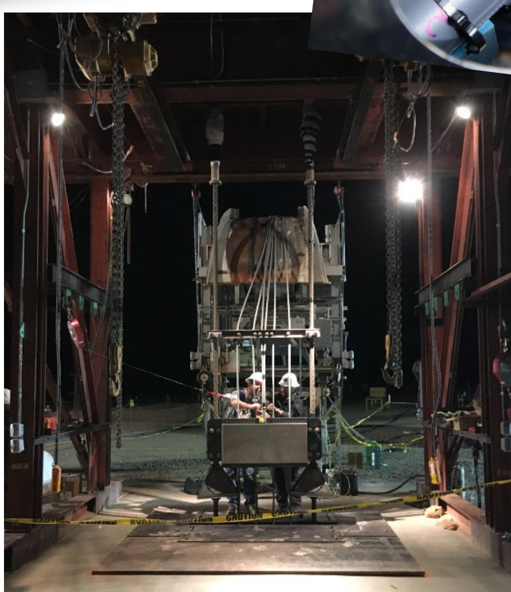
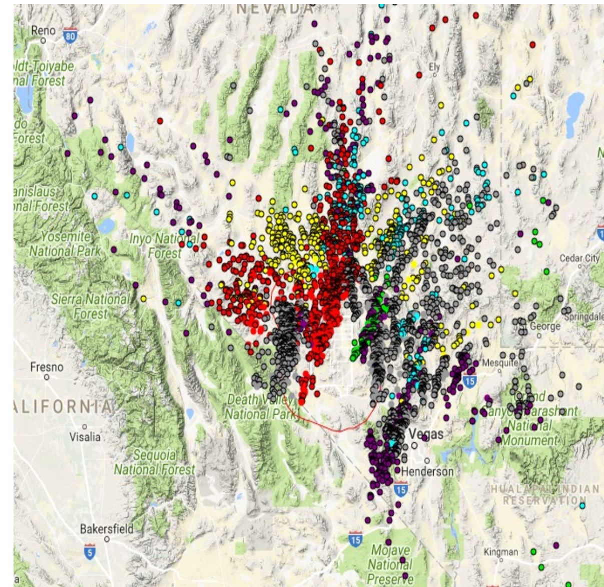
Weather







- Yes, it snows in the desert!
- More than 1000 man-hours lost to lightning alerts during HE operations
- Early winter darkness during cable cutter installation

Key Challenges: Unique Hazards

- Unique hazards
  - Working around an 8-ft diameter 1,350-ft deep hole
  - Post-experiment out-gassing
  - Road closures
  - Handling a 40-ft canister
  - Heavy crane lifts
  - Potential for subsidence

Heavy Crane Lifts

- DAG-2 experiment required the heaviest lift performed at the NNSS in more than 12 years
- Found that key crane safety features had not been fully documented
- Additional operational proficiency opportunities were implemented

Unique Hazards

- Main N-S Highway across NNSS closed more than 40 days during HE operations

- Potential subsidence post-experiment

- High CO levels at surface post-experiment

Company Form FRM-0239	INDUSTRIAL HYGIENE SURVEILLANCE FOR DIRECT READING INSTRUMENTS	02/22/18 Rev. 05 Page __ of __

SUPERVISOR NAME	AREA	BUILDING/FACILITY	DATE
Tom Sandoval	2	DAG	1/8/2019
SUPERINTENDENT/PROJECT MGR. Lisa Garner	SHOP ACTIVITY DAG Air Check Post-Shot		
CORRECTIVE ACTION REQUIRED? ☐ YES ☒ NO If Yes, see below	IH FOLLOWUP REQUIRED? ☒ YES ☐ NO If Yes, Specify: Continue Periodic Monitoring		

MONITORED AGENT	Acceptable Values	TIME 1	2	3	4	5	6	7	8
Oxygen	19.5%-23.5%	20.9	20.9	20.9	20.9	20.9	20.9		
LEL	<10%	0.0	0.0	0.0	0.0	3	4		
CO	<25 ppm	0.0	0.0	0.0	0.0	645	768		
H2S	<1 ppm (TWA)	0.0	0.0	0.0	0.0	1	0.0		
NO2	<0.2 ppm (TWA)	0.0	0.0	0.0	0.0	0.0	0.0		
HCN	<5 ppm	0.0	0.0	0.0	0.0	0.0	0.0		

Key Challenge: Aerial Diagnostics

- Dependent on weather conditions
- Environment is challenging for deployment
- Timing is critical and impacts all other elements of execution countdown
- Airspace clearance can be extremely challenging

Heliotrope-based Infrasound

Aerial Diagnostics

- Moored balloon-based Infrasound

- Video Synthetic Aperture Radar deployed via fixed-wing aircraft

Photo by Christian G. Andresen

- UASs for pre-, post- and real-time photogrammetry

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Key Challenge: Add-On Diagnostics

- Desire for more data led to approval of nearly all requests to add diagnostics
- The project did not have a rigorous process for evaluating readiness of add-on diagnostics
- Even “free” diagnostics require time and money to field

Lessons Learned

- 38 Lessons Learned were collected and evaluated prior to experiment execution
  - Source Physics Experiments
  - Integrated Systems Test
  - Unicorn Experiment
- Lessons Learned were collected, prioritized and implemented for each experiment prior to beginning the next experiment. A total of 244 Lessons Learned were documented during the project.
- DAG Lessons Learned are being applied to next experimental series

Diagnostics Lessons Learned

- Choose sensor network locations well and invest in proper emplacement (orientation)
- Predictive modeling should be done before deployment and used to inform and revise sensor layouts
- Document diagnostic station siting very well (meta-data are critical for analysis)

Outcomes

- Four experiments were successfully executed in less than 12 months
- >96% high quality data return
- DAG collaborators have published more than 32 articles in peer-reviewed journals, 52 poster sessions, 22 presentations, 5 reports and 27 talks at professional society meetings to date

DAG-4 Experiment Execution

Success Due to Outstanding Team

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Outcomes

- Execution of the DAG experiments required extensive planning, significant collaboration with experimental partners and resiliency in execution to overcome technological and operational challenges.
- Lessons learned have been thoroughly documented and evaluated for application to future experimental programs