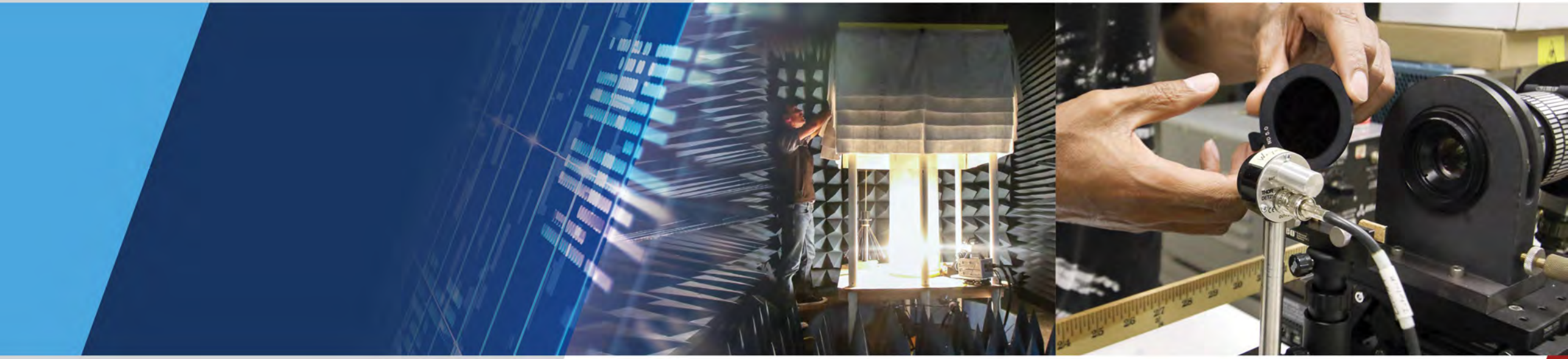
NEVADA NATIONAL NNSS SECURITY SITES

WE SECURE AMERICA'S FUTURE

Paul Guss, PhD

SDRD Program Manager



The SDRD Program at the NNSS

Nevada National Security Sites is managed and operated by MSTS under contract number DE-NA0003624.

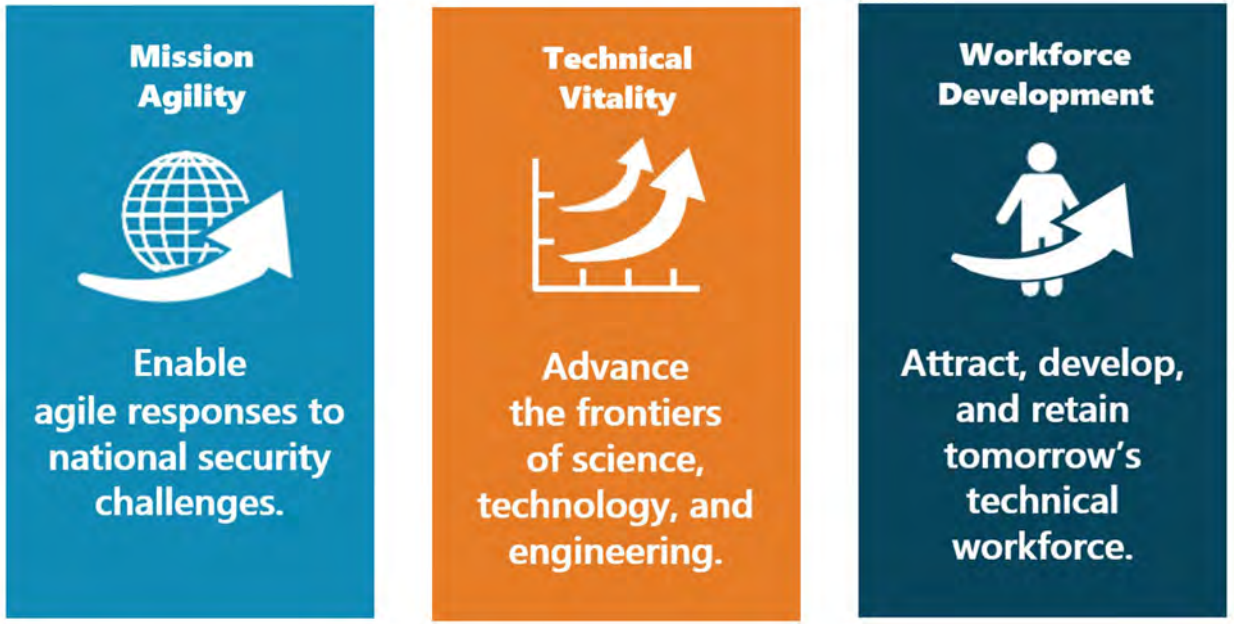
This work was done by Mission Support and Test Services, LLC, under Contract No. DE-NA0003624 with the U.S. Department of Energy, the NNSA Office of Defense Programs, and supported by the Site-Directed Research and Development Program. DOE/NV/03624—1871.

Site-Directed Research and Development Program (SDRD)

NEVADA NATIONAL NNSS SECURITY SITES
WE SECURE AMERICA'S FUTURE

What is SDRD?

- Internally funded Research and Development program
- Project durations from 1 to 3 years
- 40–60 projects in a given year
- Competitive process, projects are scored by a review committee
- Opportunity to be creative, try new things, take risks
- For many, SDRD offers the best opportunity for publication, conference attendance, etc.
- SDRD enables the mission execution of Science, Technology, and Engineering



SDRD Alignment into Mission Focused Thrust Areas is a Focused, Long-Term Technical Investment

Objectives for the STTAs

- Strengthen technical capabilities in the near term
- Enhance readiness of our core competencies in the long term
- Make us more agile and adaptable to new global threats

Strengthen existing and develop new technical capabilities throughout the NNSS in support of future NNSA-10/20/80 missions, as well as SPP/SIPP

- Align SDRD investments to better support NNSA missions
- Focus programmatic R&D efforts with a goal of enhancing or enabling new capabilities
- Deepen our scientific and engineering benches within these focused areas

SDRD Alignment to the STTAs

- Focus areas for Exploratory Projects
- Strategic initiatives

Strategic Response Toward NNSS Future Technology Preparedness

FY24 SDRD DHS-Relevant Projects

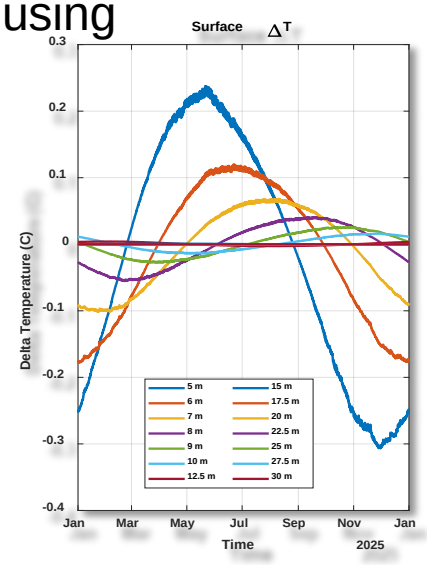
PID	Title	PI	STTA
23-016	Computational Fluid Dynamic Simulations for Critical Infrastructure (CFD-SCI)	Breckling, Sean	Communications and Computing
23-002	Mass-Selective Photoionization Detector	Manard, Manuel	Enabling Technologies for Autonomous Systems and Sensing
23-009	Low SNR, High Clutter UAS Detection and Tracking	McKenna, Ian	Enabling Technologies for Autonomous Systems and Sensing
23-010	Multi-Modal Remote Vibrometer for Infrastructure Interrogation	Koppenjan, Steven	Enabling Technologies for Autonomous Systems and Sensing
23-014	Optical comb techniques for hyperfine spectroscopy	Trainham, Clifford	Enabling Technologies for Autonomous Systems and Sensing
23-024	Measurements for combined gamma-ray and video modalities	Burt, Christopher	Enabling Technologies for Autonomous Systems and Sensing
23-034	Surface Gas Sampling Payload for Autonomous Underwater Vehicles	Priest, Cameron	Enabling Technologies for Autonomous Systems and Sensing
23-075	Microwave Detection Through Thin Films	Tarvin, Hilary	Enabling Technologies for Autonomous Systems and Sensing
23-081	AR/VR CBRN Solution for Emergency Responders	Richardson, Brian	Enabling Technologies for Autonomous Systems and Sensing
23-114	Spatially Aware Multi-modal Directional Radiation Detection Swarms	Essex, James	Enabling Technologies for Autonomous Systems and Sensing
24-117	Cloud-Based Meta-Analysis with Adaptive Learning for Massive Sensor Networks	Schuetze, Carson	Enabling Technologies for Autonomous Systems and Sensing
23-019	Additive manufacturing of structural and pixelated/discriminating scintillators	Staska, Matthew	Neutron Technologies and Measurements
23-032	Novel photon-counting detector concept for high-resolution radiographic imaging.	Miller, Stuart	Radiographic Systems Imaging and Analysis
23-007	Fundamental Experiments for Detonation Signature Modeling	Kimblin, Clare	User-Centered Remote Testing and Operations
23-062	Incorporation of Geologic Data into Centralized Database	Smith, Devon	User-Centered Remote Testing and Operations
24-076	Optical Remote Sensing for Facility Monitoring: An Integrated Approach to Modeling, Simulation and Sensors.	DiBenedetto, John	User-Centered Remote Testing and Operations
23-095	Spatial Spectral Observations from Near and Far	Howard, Michael	User-Centered Remote Testing and Operations
23-120	Feasibility of reoccupying historic testbeds for future experiments	Bortins, Ian	User-Centered Remote Testing and Operations

Enhancing Deep Cavity Detection Using Orthogonal Measurement Techniques (Completed FY23)

Project Scope

Characterize the foot print of an underground facility using thermal imaging techniques.

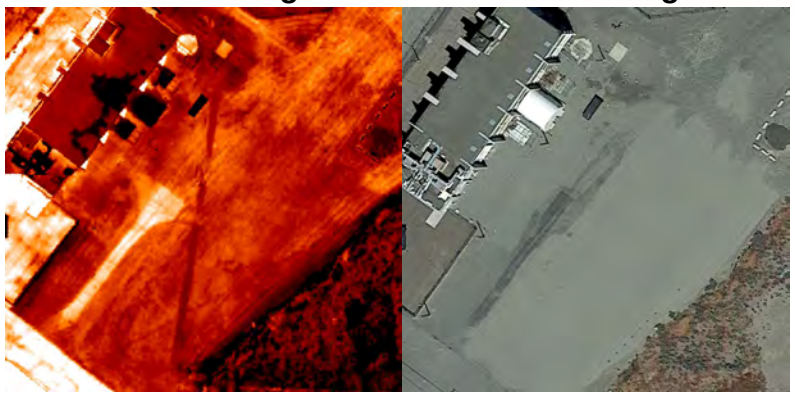
Knowledge of existence and location of subterranean targets is important to national security. A technique was developed to improve the likelihood of detection and mapping of subsurface voids with thermal remote sensing supplemented by geophysically-derived density structure.

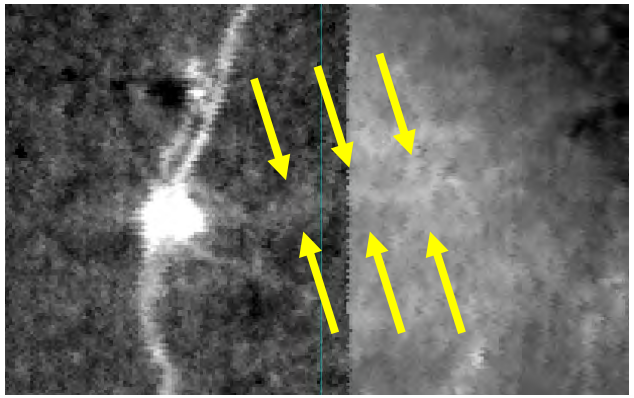


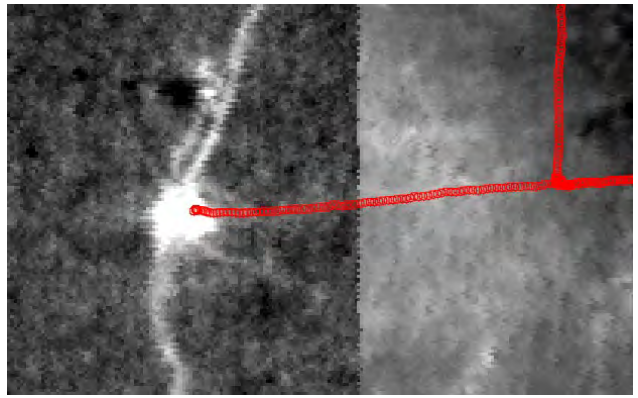
Heat flow model predicted optimum acquisition times to maximize thermal contrast of subsurface void

Thermal Image

Visible Image



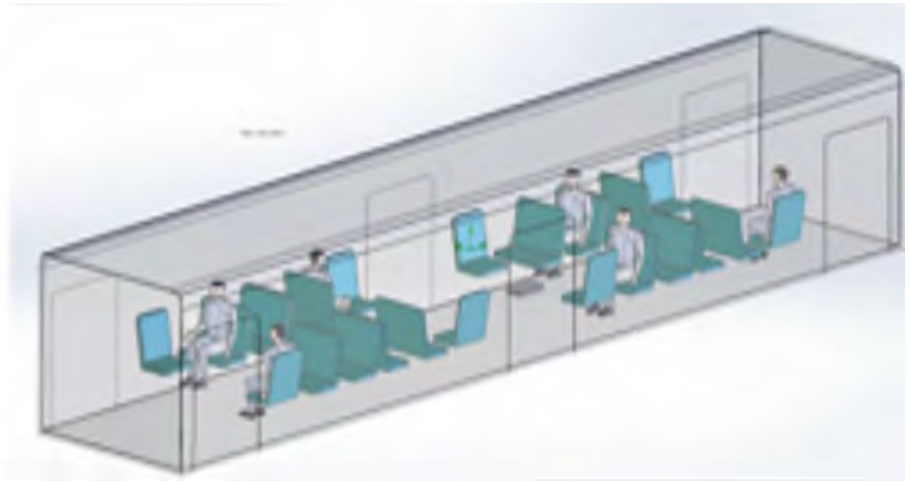


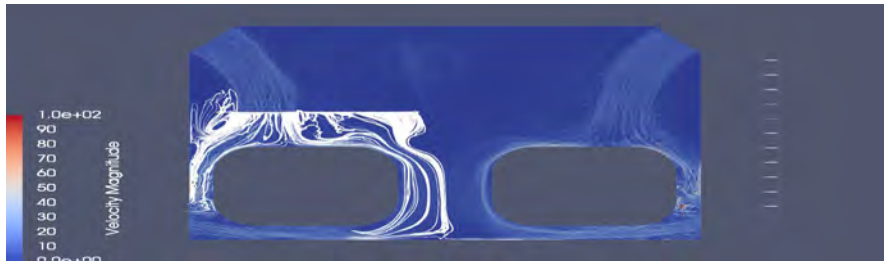


Computational Fluid Dynamic Simulations for Critical Infrastructure

Project Scope

- Develop in-house capability to numerically simulate fluid flow physics in incompressible regimes common to HVAC systems
- Construct a proof of concept HVAC/internal flow model surrogate using Continuous Data Assimilation (CDA) + Reduced Order Models (ROM)
- Validate new capabilities against previous and future physical experiments
- Develop techniques to assimilate physical measurement data (e.g., chemical species concentration, temperature, pressure) into numerical simulations.

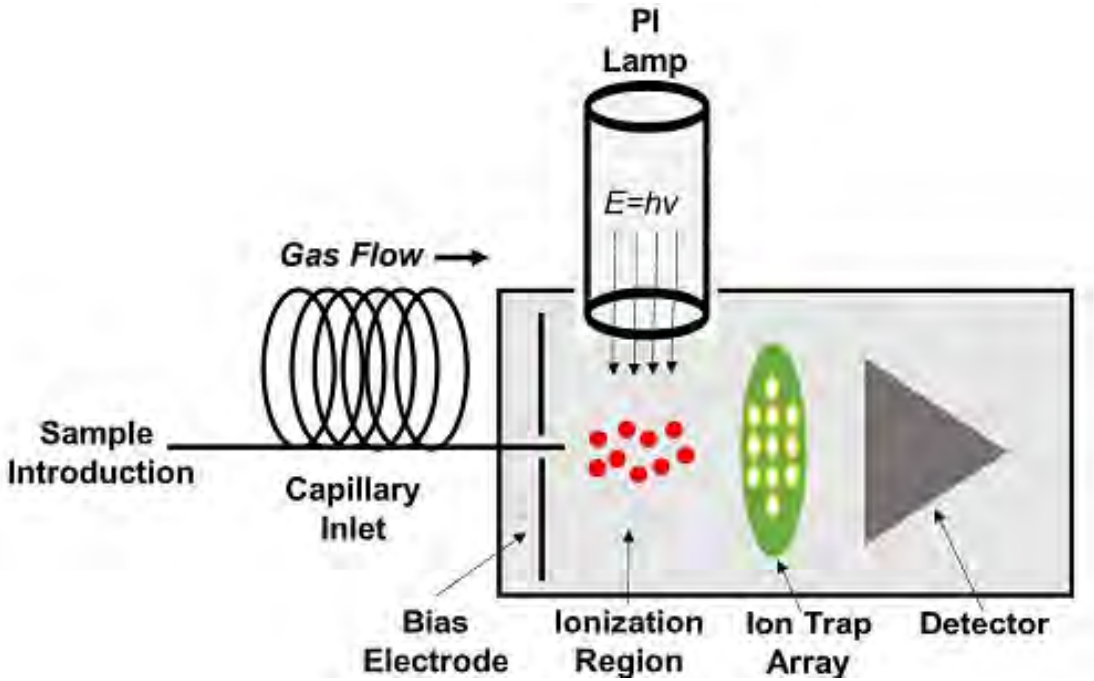


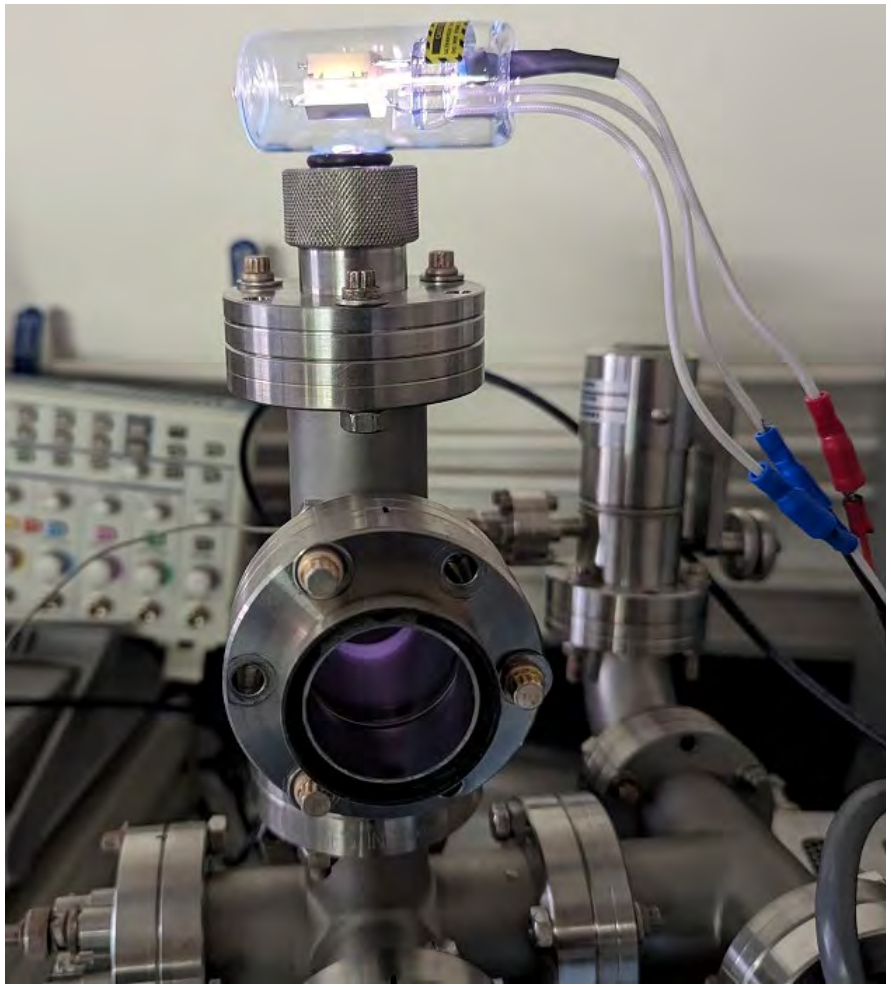


Mass-Selective Photoionization Detector

Project Scope

- Design, build, and test a proof-of-concept instrument that couples a photoionization (PI) lamp with an array of ion traps to provide mass spectra of chemical species in real time

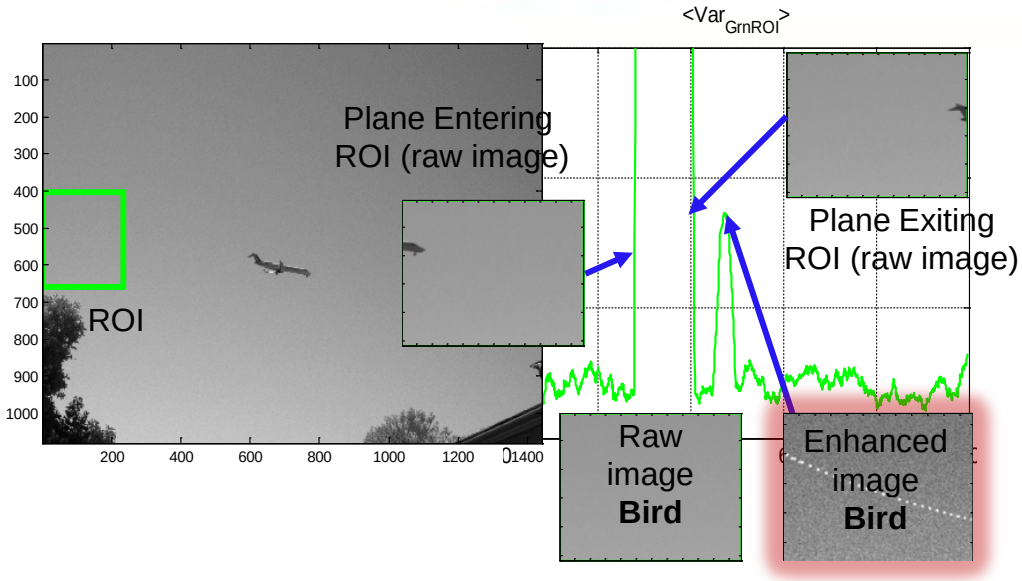


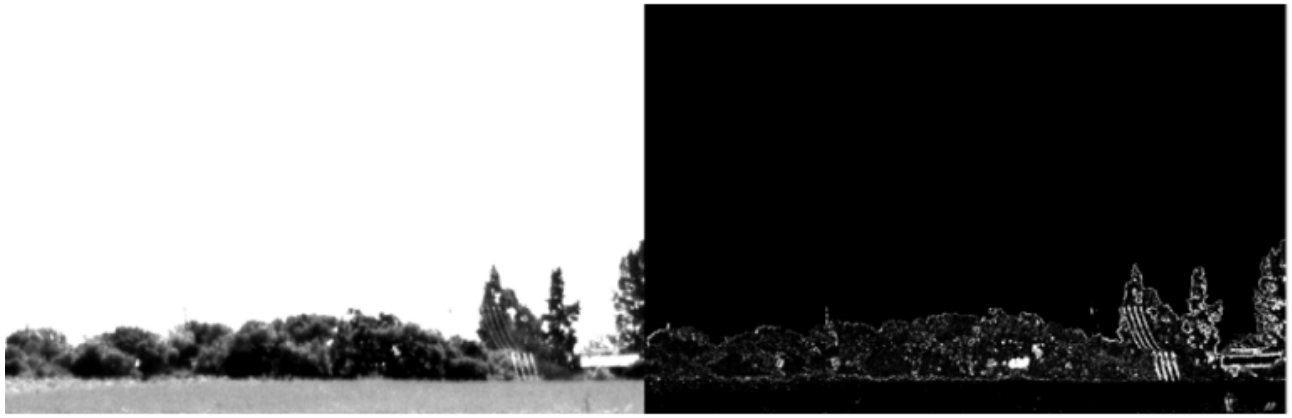


Low SNR, High Clutter UAS Detection and Tracking

Project Scope

- Develop methods to detect and track small unmanned aircraft systems (UASs) in complex environments
  - Leverages existing NNSS developed IP and algorithms
  - Develop sensor model to assist in understanding scaling
- This work directly addresses the need to detect and characterize small UASs
- Sensor agnostic algorithms may allow implementation with existing hardware
- Expands our knowledge and understanding of UAS detection

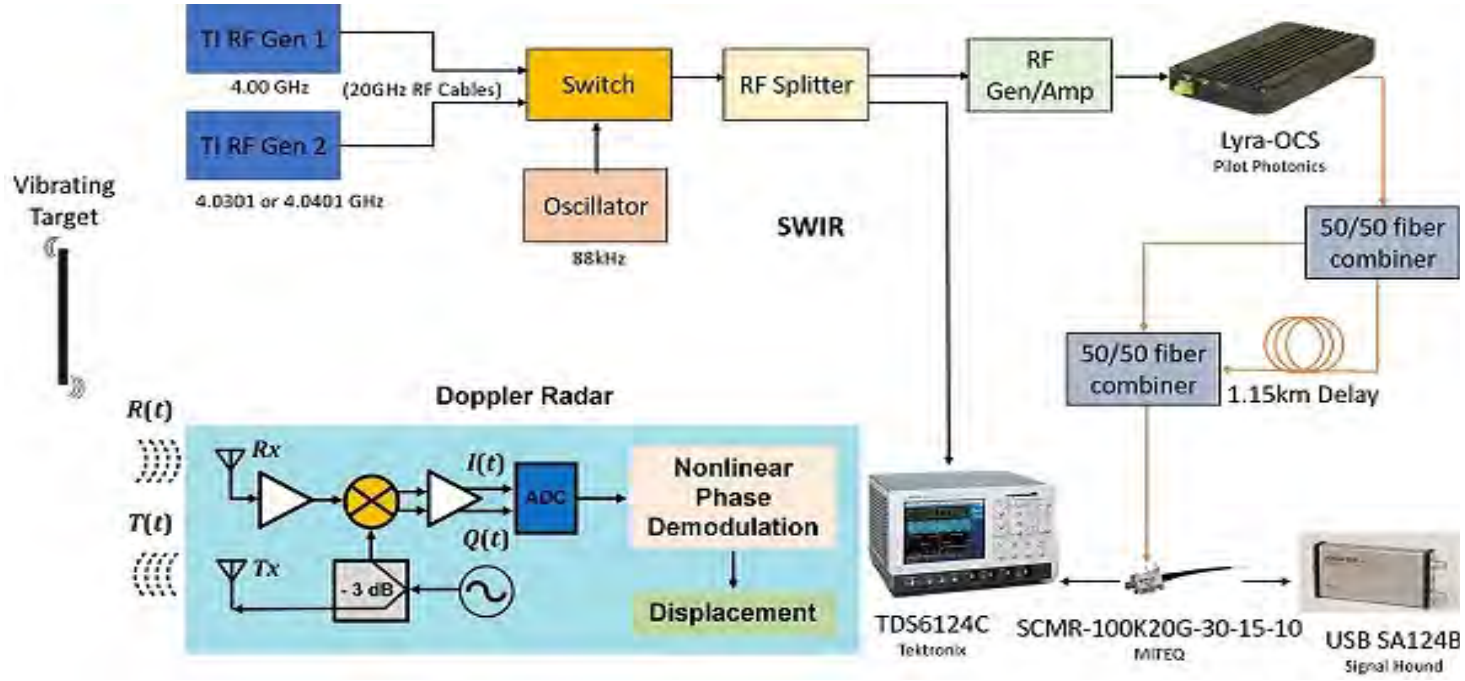




Multi-Modal Remote Vibrometer for Infrastructure Interrogation

Project Scope

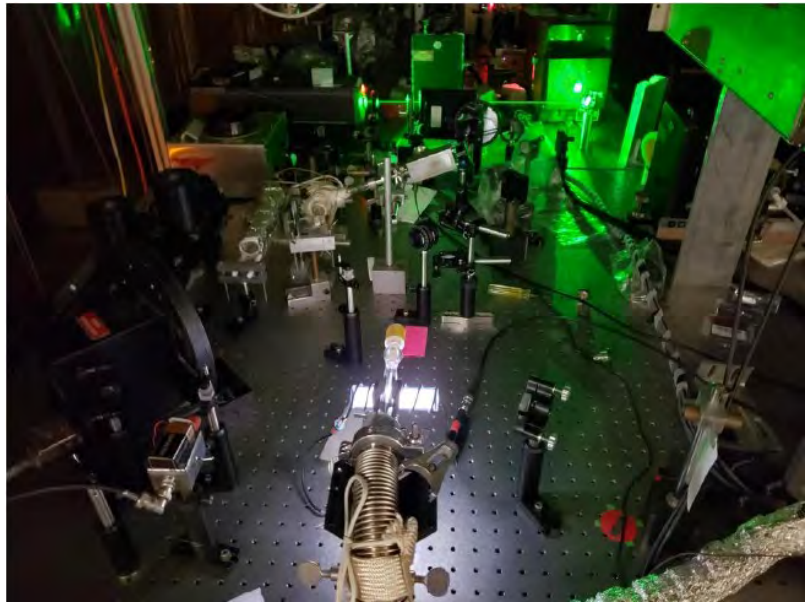
- Develop a next generation detection system to improve methods of remotely characterizing facilities of interest and increase standoff from hundreds of meters to multi-kilometer ranges
- Plan to extract unique signatures versus machinery operation levels; correlate to Patterns-of-Life.
- Combine temporal data analysis for more effective characterization of weak signals
- The Multi-Modal Remote Vibrometer for Infrastructure Interrogation combines active dual comb laser techniques, turbulence mitigation and micro-doppler radar
- This effort will move lab bench scale Dual Comb Spectroscopy techniques to the field and is directly related to the NNSA mission and treaty verification

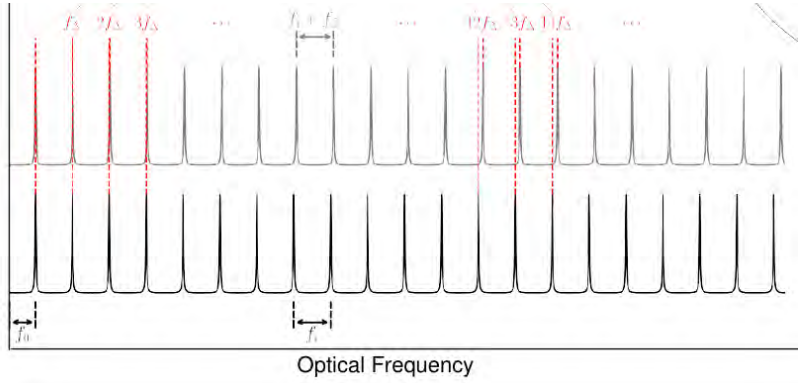


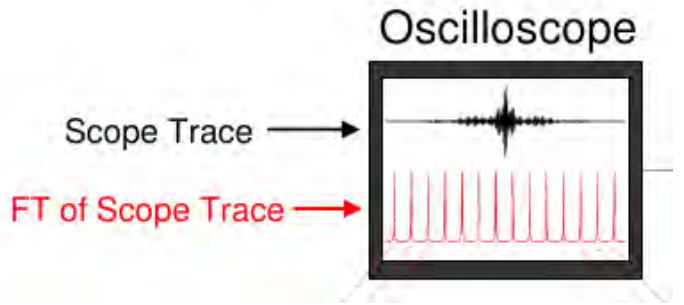
Optical Comb Techniques for Hyperfine Spectroscopy

Project Scope

- Measurement of atmospheric noble gases for radioactive isotopes, (radio-Xenon in particular) is an important tool in the detection of nuclear proliferation activities
- Measure isotopic abundances of Xenon samples by means of optical hyperfine spectroscopy
- The apparatus utilizes a Ti:sapphire laser that is large, complex, and expensive
- Comb techniques offer simplification of laser scanning, with an eye on portability for field deployment (in a van or aircraft).



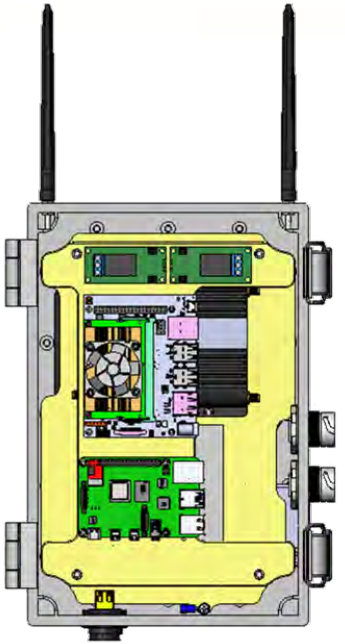




Measurements for Combined Gamma-Ray and Video Modalities

Project Scope

- Combine contextual video classification and weather information data with Nevada National Security Site (NNSS) in-house gamma identification algorithms to aid in convolution neural network source identification
- Provide rich stationary and mobile datasets for gamma identification algorithm training
- Extend applicability space of NNSS's Northern Virginia Radiation Sensor Array (NoVArray) from dataset generation to information generation
- Refurbish old nodes with current comms and edge compute hardware
- Contextual video classification and weather information to aid in convolutional neural network (CNN) source ID



Surface Gas Sampling Payload for Autonomous Underwater Vehicles

Project Scope

- Develop a gas sampling payload for an autonomous underwater vehicle (AUV)
- Focus on the method of sampling – not sample analysis, not host platform
- Challenge is to autonomously control this system at the sea/air interface in real-world open water conditions – must ensure we collect clean samples

Autonomous Underwater Vehicle (AUV)

Microwave Detection through Thin Films

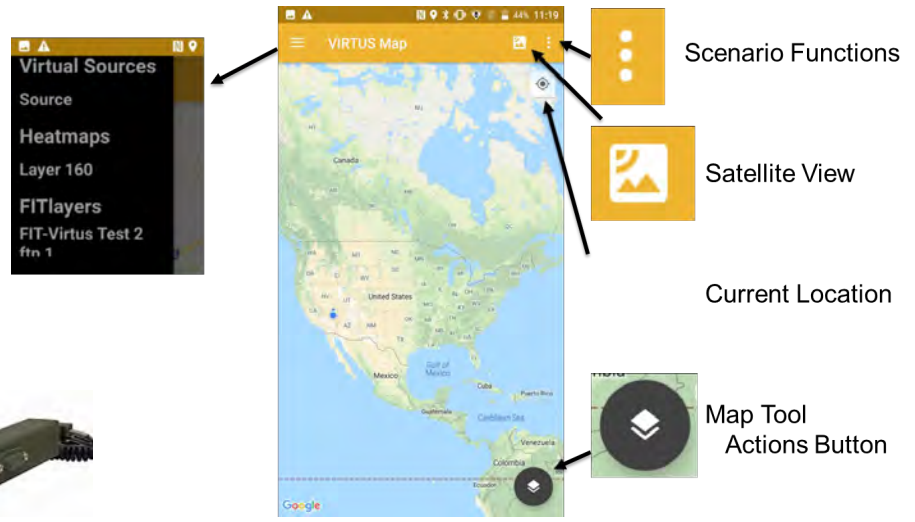
Project Scope

- Exposure to microwaves in certain power/frequency regimes can cause harmful health effects
- Electronic microwave detectors require calibration and are cost prohibitive for issuance to a large workforce or in device limited areas
- We hope to leverage a microwave catalyzed reaction that results in thin film deposition with an associated physical color change to create a TLD-like badge for microwave exposures

AR/VR CBRN Solution for Emergency Responders

Project Scope

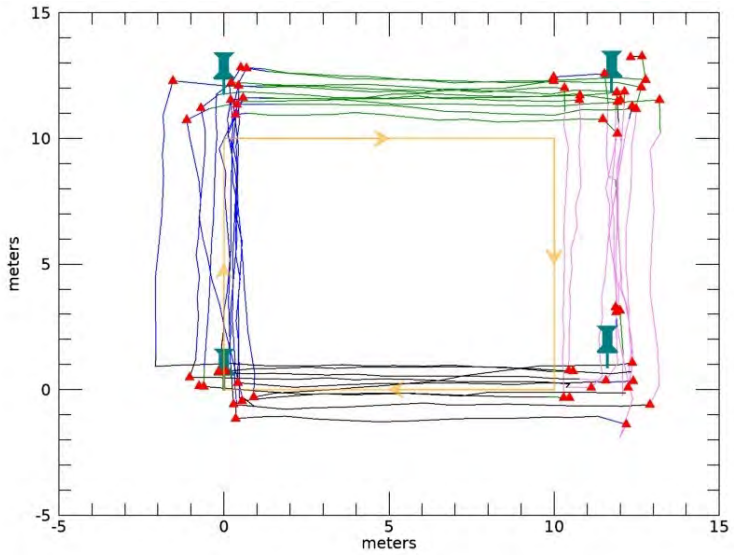
- Use Android smart device sensors and systems to create low-cost, external probes used by First Responders to more accurately and completely simulate chemical, biological, radiological, nuclear, and high explosive detection in virtual and augmented reality training programs

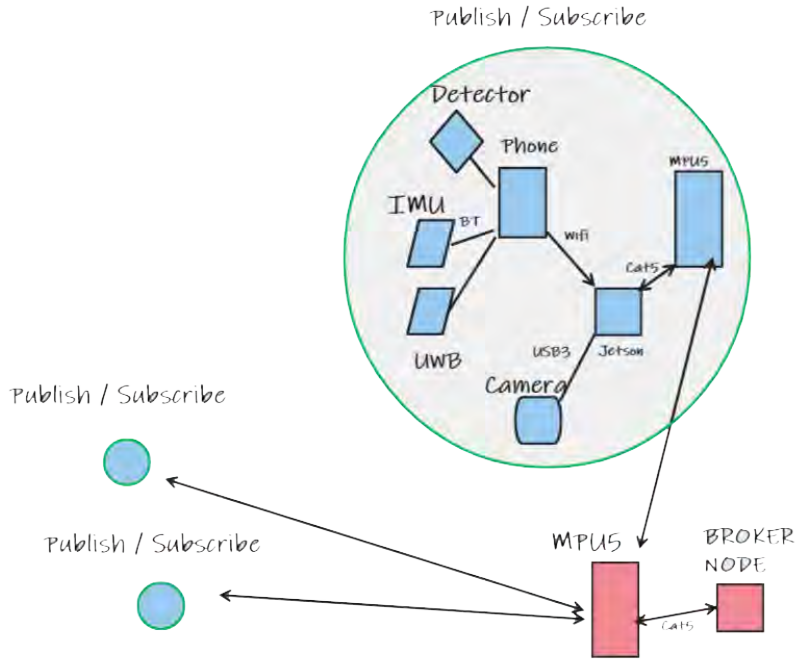


Spatially Aware Multi-Modal Directional Radiation Detection

Project Scope

- Explore spatially aware platforms that combine multiple inputs to estimate detector measurement locations and protocols for data exchange between sensors to develop methods to optimize detection and localization of radiation sources
- Improve anomaly detection and 2D radiation-source localization for both gamma and neutron radiation sources
- GPS-denied environments are most relevant, but tracking solutions that are adequately sophisticated will redefine the state of the art.





Cloud-Based Meta-Analysis with Adaptive Learning for Massive Sensor Networks

Project Scope

- Search sensor data aggregation and performance optimization by integrating historical data, fusing data and results from existing detection algorithms, and statistical analysis.

- Use meta-analysis and machine learning to quickly identify equipment abnormalities, optimize model parameters, autonomously adjudicate and prioritize anomalies... thus increasing threat detection probability and analyst sensor throughput.

- Migrate sensor analytics from the edge to the cloud. We will not be focusing on cloud computing yet... Focusing first on optimization.

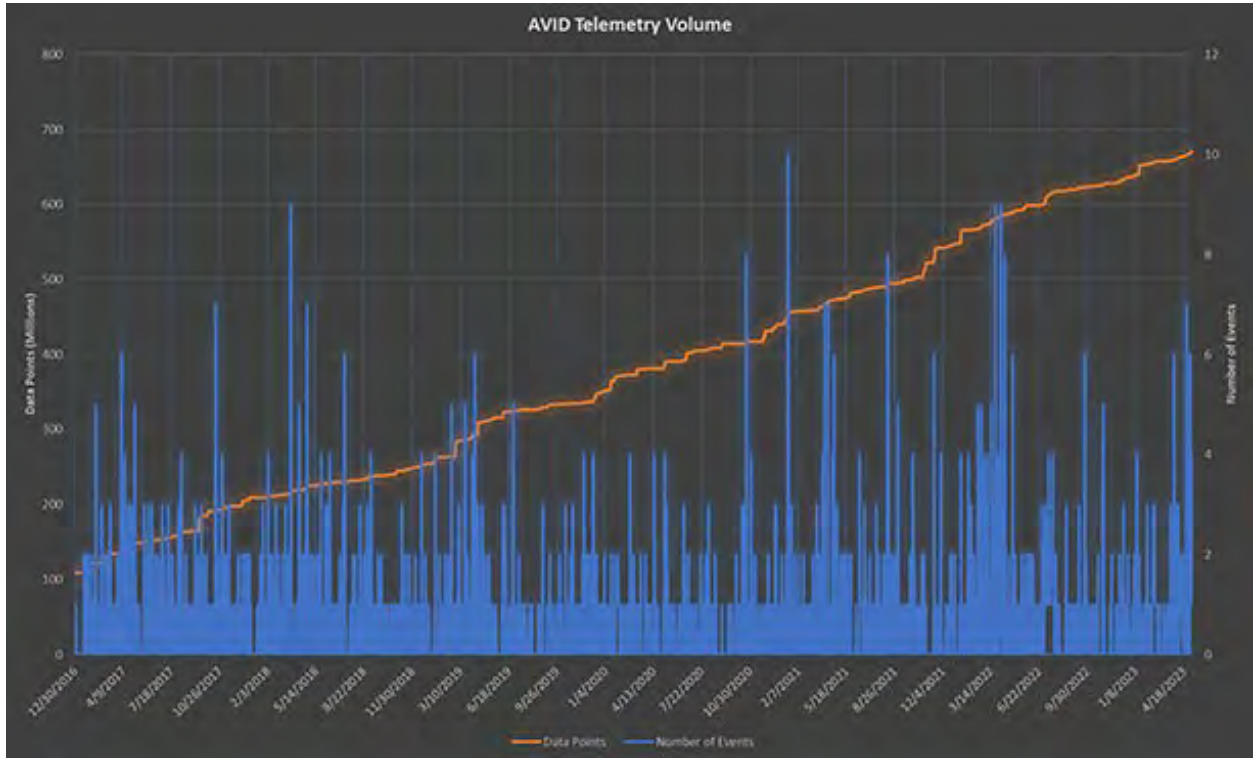


Figure depicts frequency of use and sensor data archive volume over last decade for the NNSS-managed Microsoft Azure cloud environment utilized for the NNSA's federal nuclear emergency response teams. Currently no analytics utilize any of this data, and instead anomaly detection assessments are made on time series snippet from a single sensor. This system is ripe for the application of meta-analysis and adaptive learning.

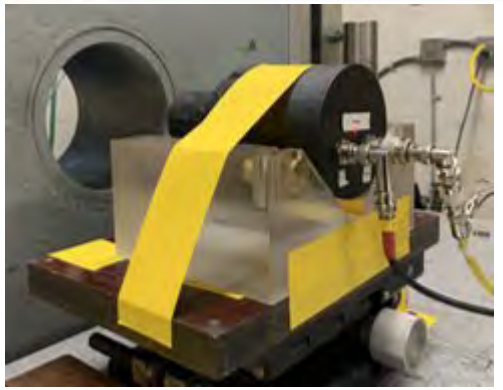
Additive manufacturing of structural and pixelated/discriminating scintillators

NEVADA NATIONAL NNSS SECURITY SITES

Project Scope

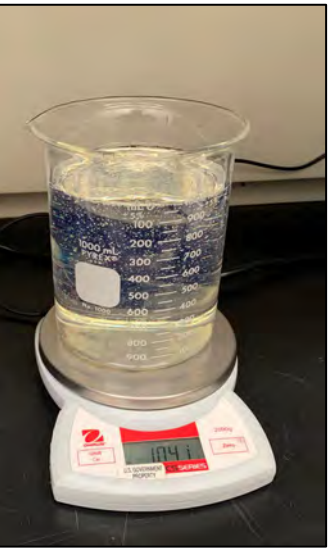
- To develop a capability at the NNSS that can AM plastic scintillators for prototyping and quick turnaround mission requirements

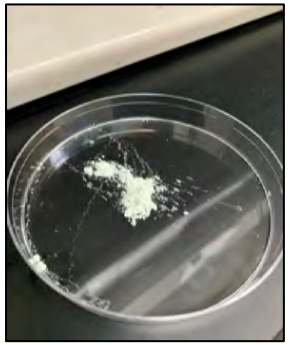
- To prove reliability of AM scintillator designs that could be used in imaging and radiation detection systems

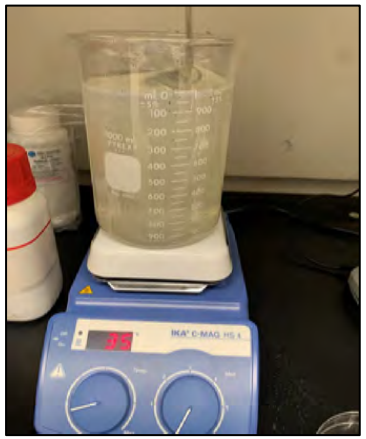


AM Scintillator in Source Range Testing in NLV

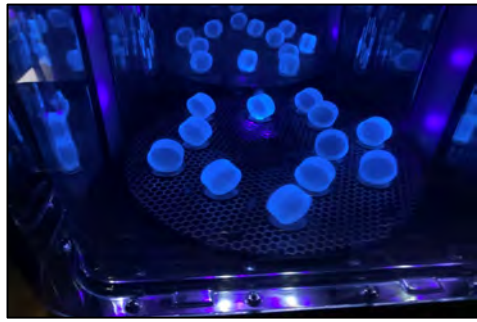
Resin and dopant mixing →







Resins were then loaded into the 3D printer

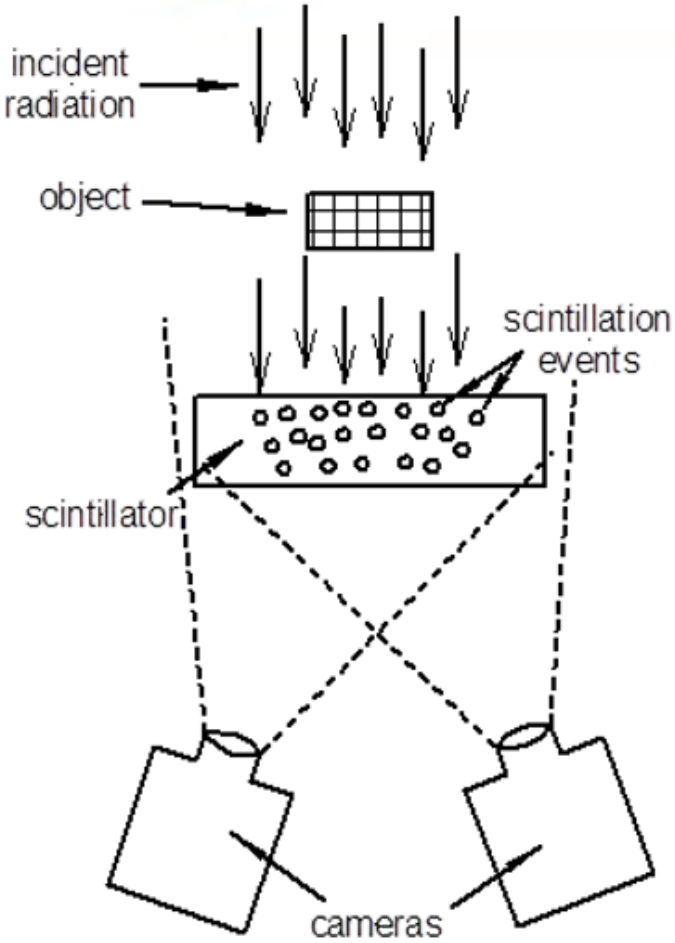


Novel photon-counting detector concept for high-resolution radiographic imaging

NEVADA NATIONAL NNSS SECURITY SITES

Project Scope

- Demonstrate The Concept
- GEANT4 simulations: gammas, neutrons (thermal/fast)
- Laboratory with EMCCD cameras and Xcitex software
- Image construction methods

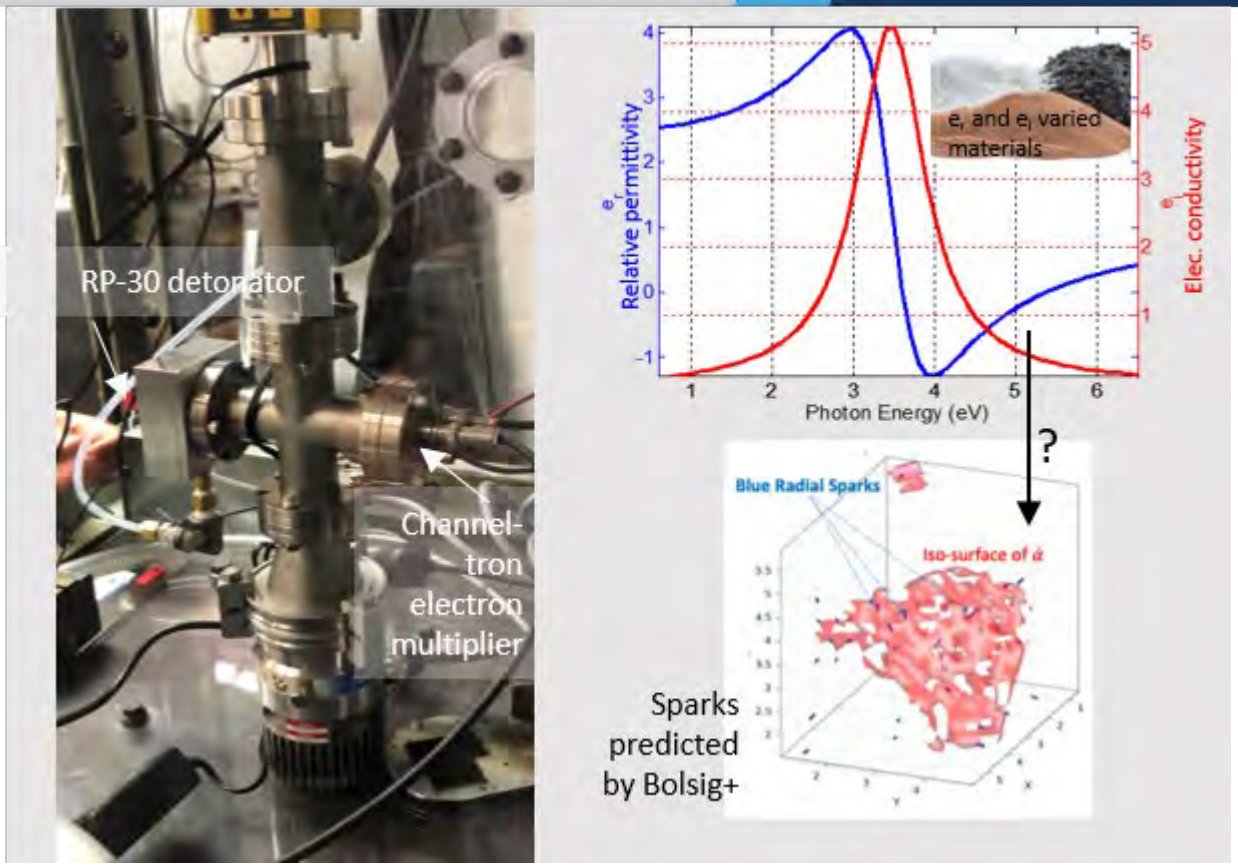


Neutron imaging is important to DNN, NA-22, and Global Security applications

Fundamental Experiments for Detonation Signature Modeling

Project Scope

- Particulate shock tube studies
- Multi-material studies to include metals, metal oxides, semiconductors to explore impacts of fundamental material characteristics, such as permittivity, conductivity and breakability, on discharge production and optical reflectance and extinction
- Develop MSTS supersonic gas modeling capabilities
- High Explosive Mass Spectrometry (HE-MS)
- Pairing detonation chamber (DC) with mass spectrometer (ToF) to permit direct measurement of detonation particle (DP) mass-to-charge ratios (m/z) milliseconds post-detonation



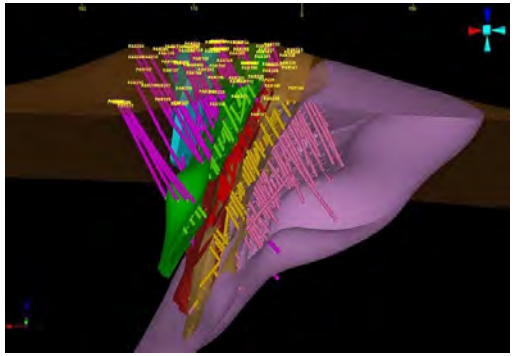
LHS: Proof of concept testing of prompt detonation particle charge with detonation chamber (using RP30-detonator) and Channeltron, in STL acrylic boom box. RHS: Dispersion model output showing material dependent relative permittivity and conductivity as a function of photon energy (O'Neill). Output from Bolsig+ showing sparks predicted by MAUI and Bolsig+ (Chris Kueny, LLNL). .

Incorporation of Geologic Data into Centralized Database

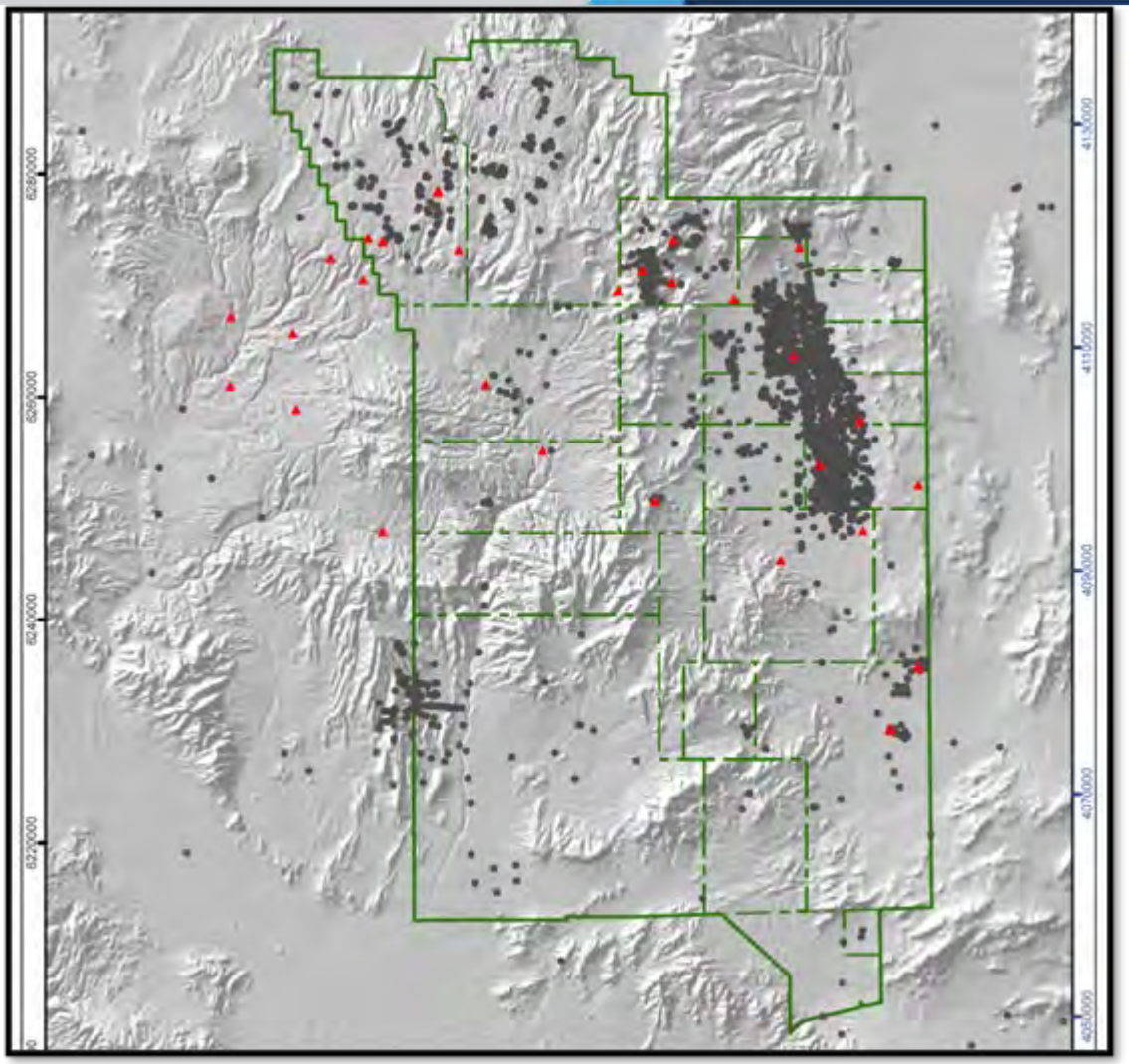
Project Scope

- compile the data into a centralized database, preserving the data and making it accessible to our scientists and stakeholders
- Establish SQL Importer for Geophysical Logs
- Migrate the Data
- Digitize and Import Paper Logs
- Migrate Access Data
- Modify our database

Database software



3D geologic model

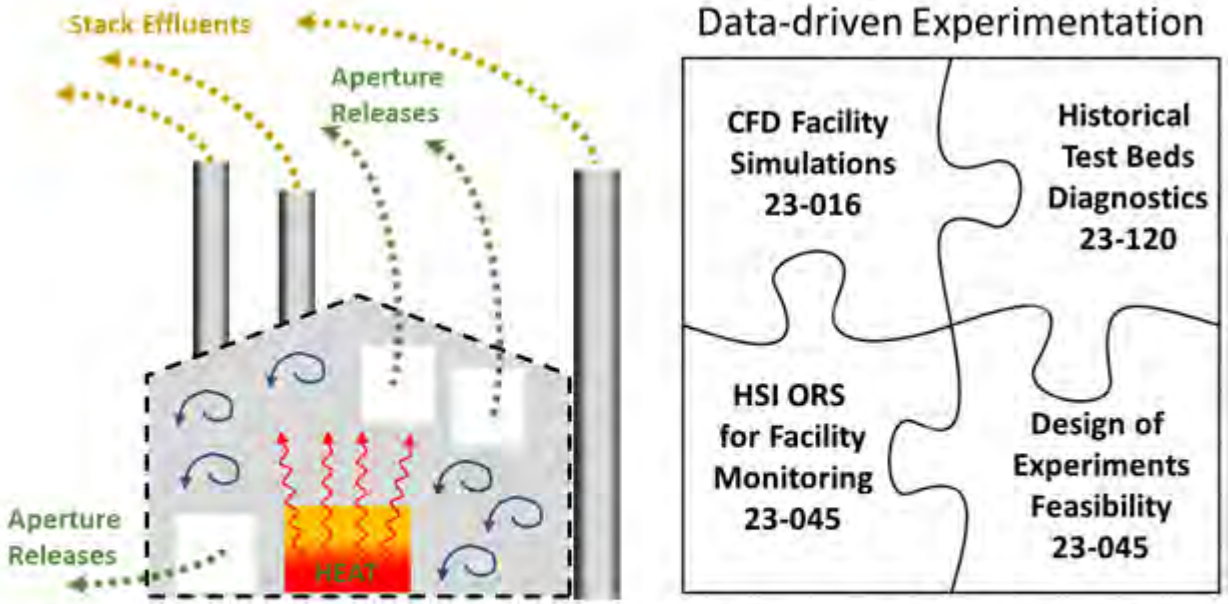


Geologic data is a key parameter for advanced nuclear treaty monitoring

Optical Remote Sensing for Facility Monitoring: An Integrated Approach to Modeling, Simulation and Sensors

Project Scope

- Create an integrated remote sensing capability for facility and test bed characterization.
- Develop an integrated approach that combines simulation and modeling of facilities with our airborne and ground-based sensing capabilities to predict activities at surrogate NP sites.
- Integrate two GOTS HSI sensors into airborne and ground-based configurations.
- Create a optical radiometric spatial/spectral simulation of an NNSS Test Bed.
- Multi-sensor data collection at NNSS: Goal = enhanced quantification.



23-016	Computational Fluid Dynamic Simulations for Critical Infrastructure (CFD-SCI)
23-120	Feasibility of reoccupying historic testbeds for future experiments
24-045	Enabling Science and Research with NNSS Experimental Feasibility
24-076	Optical Remote Sensing for Facility Monitoring: Sensor Simulation and Integration

Completed initial BG8 bench test setup. In process of cabling and verify connections with undocumented hardware.

Figure (left) shows a simplified model of activities at a production facility. Aperture releases are heat and effluents fugitive releases. Effluent releases are from stacks. Heat generated in processes and interior turbulence impact what is observed externally just as exterior forces impact internal air flow. Figure 1 (right) shows the relationships between two existing and two proposed FY24 projects regarding facility monitoring.

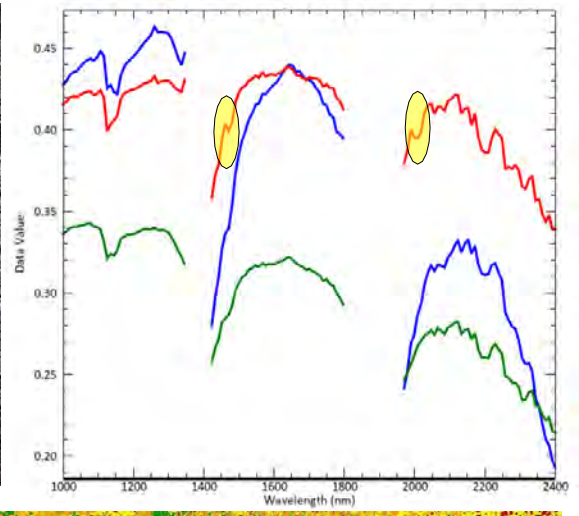
Spatial Spectral Observations from Near and Far

Project Scope

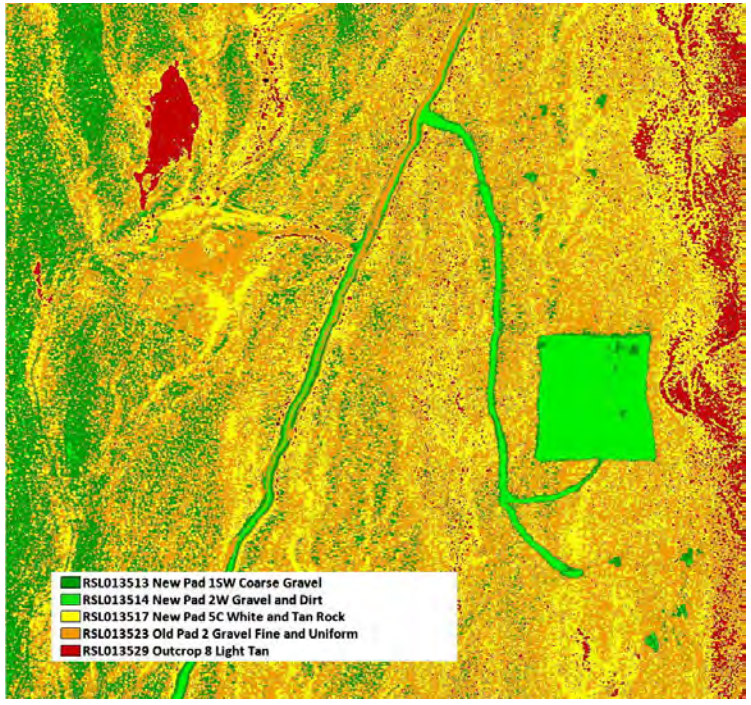
- Identify spatial and spectral signatures of surface materials that characterize the experimental design and proliferation intention of underground weapons testing in vertical emplacement shafts.

- Collect coordinated airborne imaging and ground-based spectral measurements of emplacement shaft construction site during construction, testing, and shutdown to identify spatial-spectral characteristics.

- Using the high spectral resolution test data, simulate satellite- based and high-altitude aircraft-based surveillance optical imaging systems to gauge their utility in remote detection and assessment of underground weapons testing construction.



Hyperspectral image analysis of RVDC testbed



Feasibility of reoccupying historic testbeds for future experiments

Project Scope

- Deployable capability for ground truthing remote sensing systems in areas where open air gas plume releases are not allowed.
- NNSS remote sensing testbed asset.
- Develop an optical target with controllable variables (temperature differential, concentration) for improved sensor calibration.


Questions?

Backup Slides – NNSS Capabilities

NEVADA NATIONAL NNSS SECURITY SITES
WE SECURE AMERICA'S FUTURE

NNSS Capabilities by Location

Location Missions

- **The Site:** Supports the stewardship of the nation's nuclear deterrent, provides emergency response capability and training, contributes to key nonproliferation and arms control missions, supports national security customers through strategic partnership programs and addresses the environmental legacy of the Cold War though environmental management programs.

- **North Las Vegas Facility:** Provides management, administration and mission support services (including the Machine Shop) for the Site and related facilities.
- **Remote Sensing Laboratory – Nellis:** Provides support for a number of National Nuclear Security Administration missions, including radiological emergency response, securing nuclear materials domestically and abroad from terrorists and criminals, preventing nuclear proliferation to rogue states and terrorist organizations, and making radiological sensing systems more easily deployable to real-world events.
- **Remote Sensing Laboratory – Andrews:** Provides the same support mission on the East Coast as RSL-Nellis provides on the West Coast, but with additional emphasis on activities protecting the nation's capital.

Location Missions

- **New Mexico Operations (Los Alamos & Sandia offices):** Provides on-site support for Los Alamos National Laboratory and Sandia National Laboratories, primarily involving stockpile stewardship experimentation and related activities to be conducted at the NNSS and on lab platforms.
- **Livermore Operations:** Provides on-site support for Lawrence Livermore National Laboratory, primarily involving stockpile stewardship and related activities to be conducted at the NNSS and on lab platforms.
- **Special Technologies Laboratory:** Provides support for national security missions, particularly involving the intelligence community.
- **Counterterrorism Operations Support – New York:** New York-based staff provide nuclear and radiological incident response training to first responders throughout the country.

Special Technologies Laboratory

Capabilities at The Site: Big Explosives Experiment Facility (BEEF)

BEEF is a site at which NNSA can conduct high explosives experiments without using special nuclear materials

- Up to 50,000 lbs TNT-equivalent
- Stockpile stewardship
- Counter terrorism
- More than 200 high-explosive tests since the 1992 moratorium

Capabilities at The Site: Baker Site

The NNSS Baker Site is a facility that supports high explosives (HE) activities. This site ensures the availability and capability to safely and securely receive HE shipments, store HE, and assemble units that are used in experiments at the NNSS. It is composed of a series of bays, bunkers, office areas, and a machine shop. Baker Site can be used as a DOE facility for warhead maintenance, storage, and dismantlement. Baker Site would permit testing technologies in a bunker/assembly bay environment.

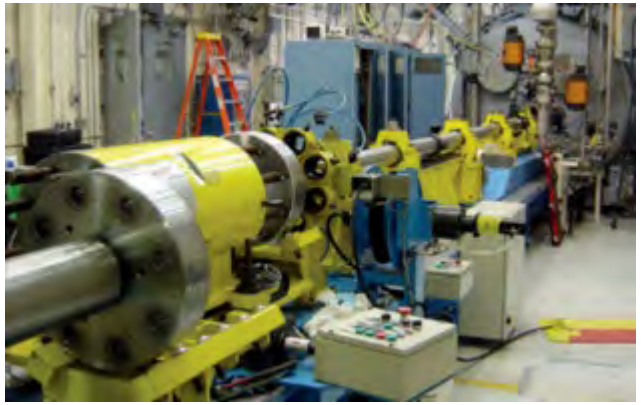
Capabilities at The Site: JASPER

Joint Actinide Shock Physics Experimental Research facility

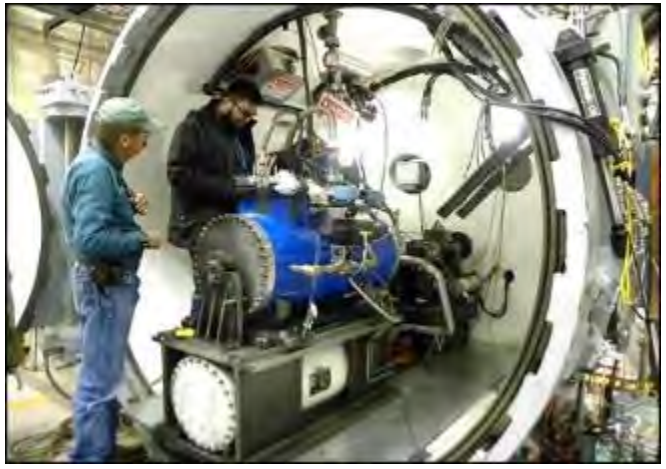
"The data are crazy good."

– Pat Ambrose, LLNL Principal Investigator

JASPER control team and gunners



JASPER gas gun



Secondary and primary containment chamber

Breach

Remote Sensing Laboratories (RSL) - Nellis Air Force Base and Joint Base Andrews

- 24/7/365 Nuclear Incident Response Assets
- On-Call Teams for Radiological Emergencies
- Deployable Field Teams / Home Team Reachback
- Aircraft – Unique Aerial Detection Capabilities

Nuclear Response Division (NRD) Support to National Security

Training and Exercises

- Interoperability – WINGS, etc.
- National Level Exercises
- Monthly proficiency exercises
- Regular exercises with interagency partners
- Advanced training for RAP

Real World Events

- Lost or Stolen Sources
- Nuclear Power Plant accident – Fukushima Japan Response
- Disasters – Hurricane Katrina, Cerro Grande Fire, Woolsey Fire

National Special Security Events (NSSE) and high-SEAR events

- Presidential Inaugurations
- Annual State of the Union
- Political Conventions
- Super Bowl
- Boston Marathon

International Outreach

- Training events
- Technical exchanges
- CONUS or OCONUS locations
- Over 800,000 miles traveled in a typical year
- Interaction with 20+ countries per year

Special Technologies Laboratory (STL)
Santa Barbara Campus

STL 5520 HQ (TS)
- Mission Support
- Engineering Development
- Electronics Manufacturing
- SCIF
- Secure Communications

STL 5540
- Science Laboratories
- Software Engineering
- Mission Support

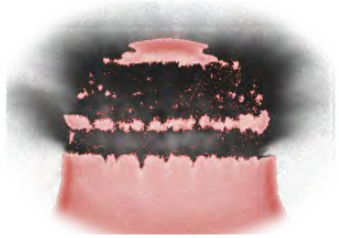
Building 226 Complex
Test & Evaluation Facility
- Laser Range
- Shielded Radiation Facility
- Explosives Facility
- Chemistry Labs
- Shipping & Receiving

35

Capabilities at STL

Proliferation Detection

- o Remote sensing technology
- o Optical systems R&D
- o Explosion signatures research
- o Enabling materials
- o Advanced analytics
- o Treaty verification research
- o Chemical trace detection
- o Simulation and modeling
- o Ground truth and source term measurement



Dynamic Experiments

- o Prompt diagnostics development
- o Spectroscopic and optical techniques
- o Experimental physics
- o Stockpile experimentation
  - ➢Modeling
  - ➢Mechanical design
  - ➢Fabrication and metrology
  - ➢Execution
  - ➢Analysis

Information Sciences

- o Software and cyber
- o Supply chain assurance
- o Operational technology
- o Consequence driven assessments
- o Physical system security

Systems Research & Development

- o RF & communications systems
- o System development and integration
- o Custom packaging
- o Electronic and mechanical prototyping
- o Reverse engineering
- o Low-power embedded electronics
- o AI/ML at the low-power edge
- o Assembly and fabrication

Capabilities of Los Alamos, Livermore, and Sandia Operations

Los Alamos Office
Los Alamos, NM

- High-speed electro-optical instrumentation
- Optics and fiber-optic systems
- Modeling and data analysis
- Photonics and electronic imaging
- Data Analysis

Livermore Operations
Livermore, CA

- National Institute of Standards and Technology accredited x-ray, optical, and high energy laser calibration labs supporting High Energy Density (HED) diagnostics
- Sole U.S. capability for custom photomultiplier tube fabrication
- Calibration source development
- Modeling and data analysis

Sandia Office
Albuquerque, NM

- Radiographic source development
- Mechanical design for Z containment
- Shock physics diagnostic development
- Velocity Interferometer System for Any Reflector (VISAR) and radial Photonic Doppler Velocimetry (PDV) development and fielding