# New Mexico Research Spotlight Forum

10.17.2019 Grid Resiliency

# Overview: Grid Modernization Research at Sandia


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Sandia National Laboratories
Program Overview


Sandia National Laboratories is a multi-mission laboratory managed and operated by National Technology and Engineering Solutions of Sandia LLC, a wholly owned subsidiary of Honeywell International Inc. for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525. SAND2019-12739 O
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U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

# SANDIA'S ENERGY PROGRAMS HAVE GROWN FROM OUR CORE CAPABILITIES

Safe Nuclear Waste Disposal

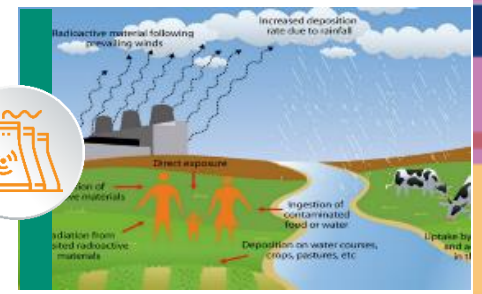
Solar Tower


Water Distribution Systems

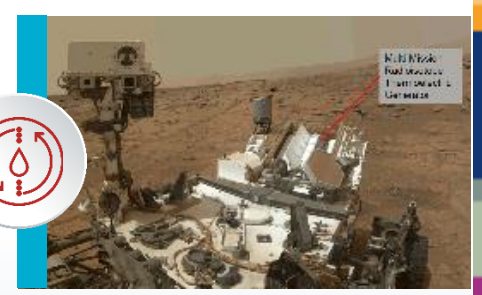
Energy Storage Integration to the Grid


Borehole Integrity

Off-Site Consequences of Radioactive Atmospheric Release Modeling



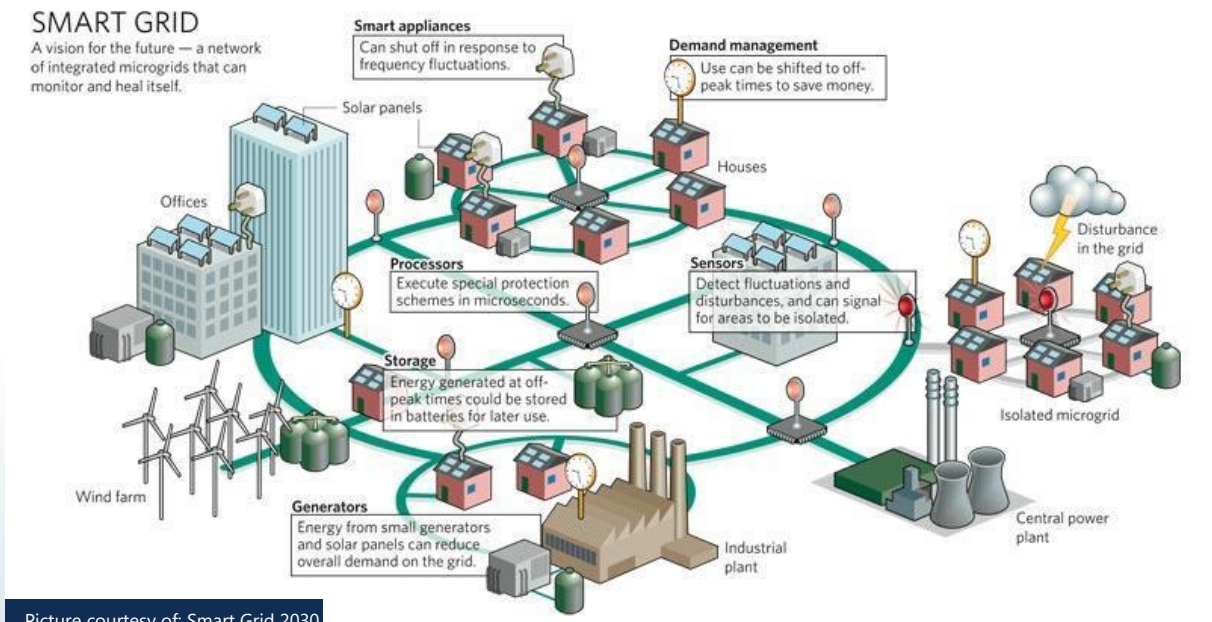
Safety Analysis of MARS 2020



Advanced Nanomaterials for Energy Efficiency

# VISION

*A world of interdependent and variable distributed systems that are optimized at multiple scales – including transmission – to maximize local resources in providing secure, resilient, and clean energy to all users at all times.*



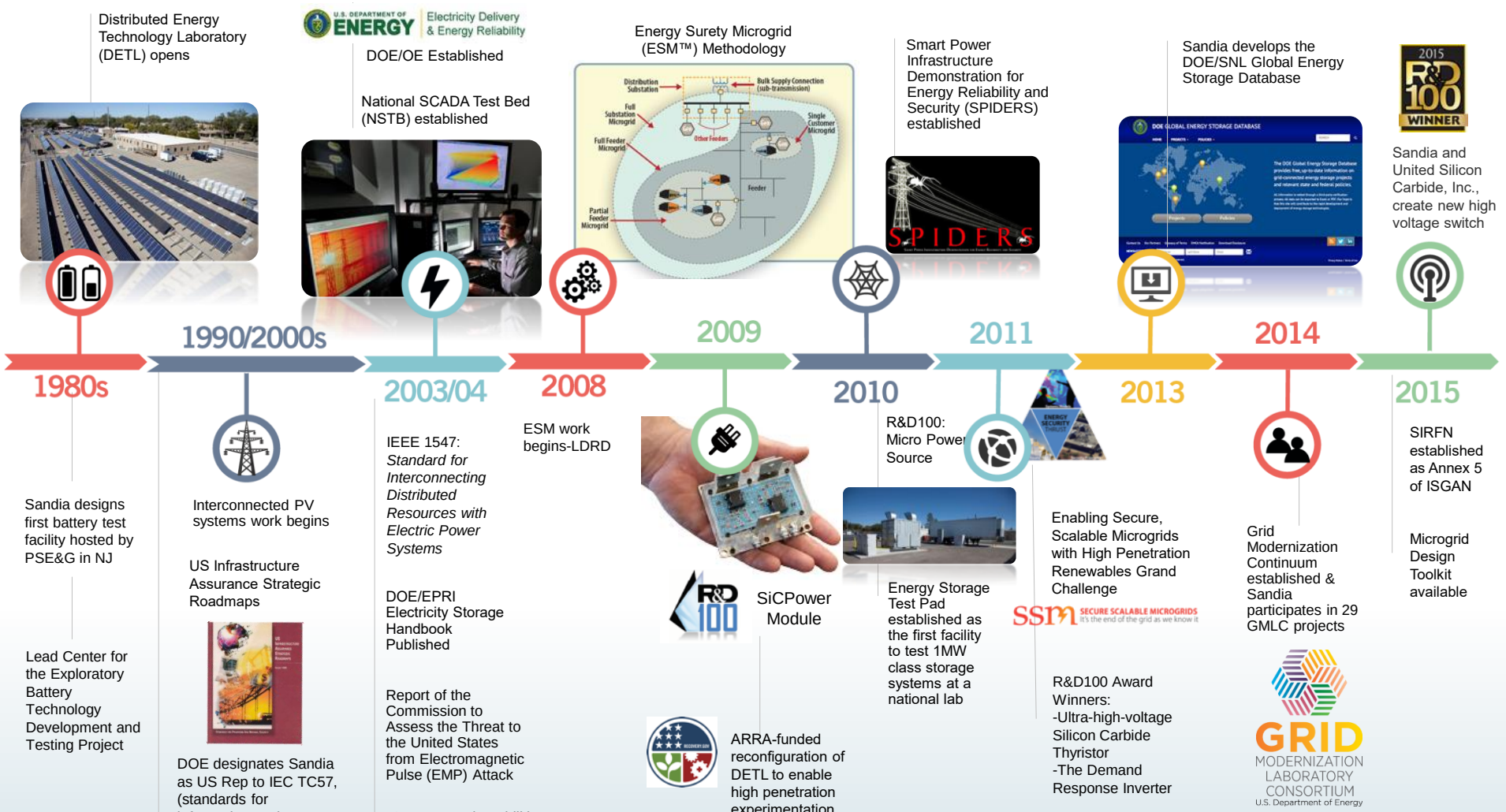

Picture courtesy of: Smart Grid 2030

Our capabilities support this vision:

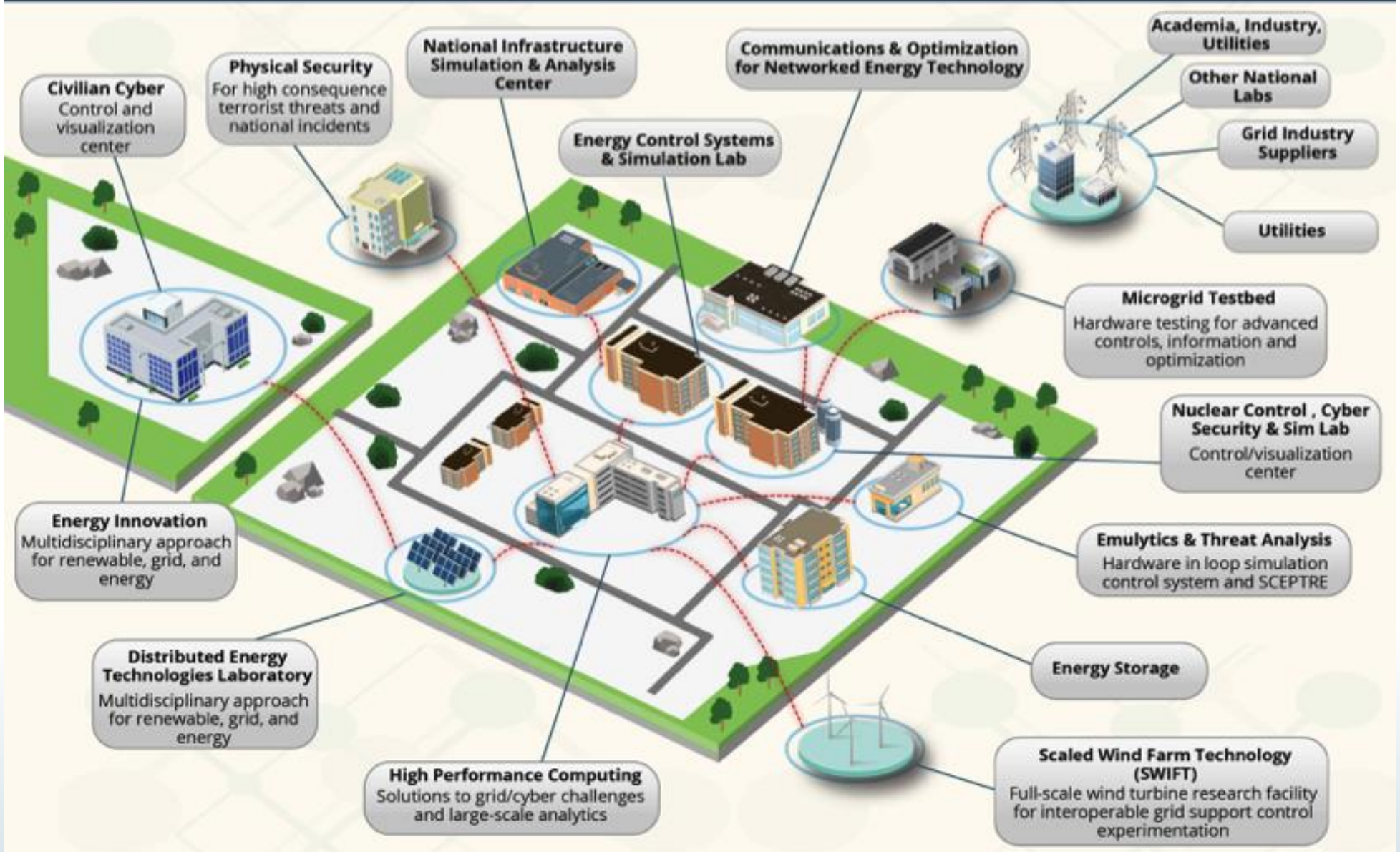
- DER and renewable energy integration
- Power electronics and controls
- Secure and scalable microgrids
- Advanced grid analytics/complex systems
- Infrastructure interdependencies
- Cyber and physical security
- Embedded sensors, information processing, and secure manufacturing
- Energy storage systems

# SANDIA GRID MODERNIZATION AND ENERGY STORAGE
## Program Leadership

# **TIMELINE:** SANDIA GRID MODERNIZATION



# Sandia's Integrated Energy Control System R&D Campus



# Sandia's approach to resilience combines capabilities that cover the full threat spectrum

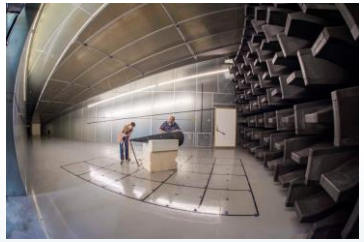
- Integrated cyber-physical
- Combining models and physical systems
- Probabilistic and consequence-based


# Sandia's Electromagnetic Pulse (EMP) Facilities

***Unique EM Test/Experiment Capabilities are Required for our Mission Space***

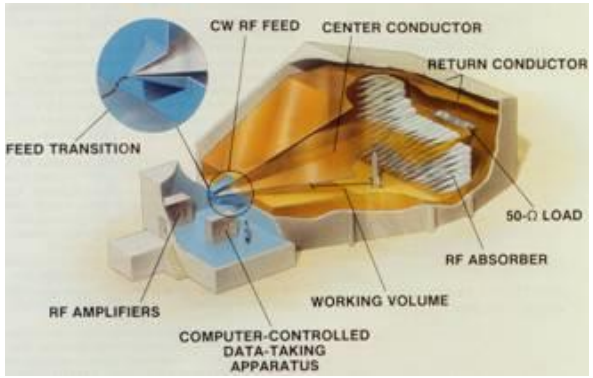
**Mode-Stir Chamber**

- **CW (220 MHz – 40 GHz)**



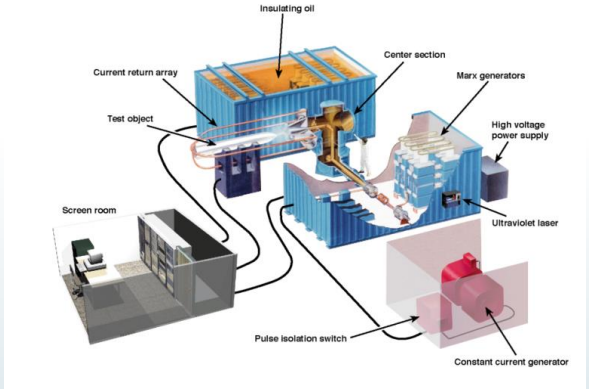
**Gigahertz Transverse ElectroMagnetic (GTEM)**

- **CW (DC – 1GHz) >130 V/m**
- **EMP (1 ns risetime) > 130 kV/m, HPM**




**EMES Facility**

- **CW (100 kHz – 250 MHz)**
  **125 V/m**
- **EMP (1 ns risetime)**
  **250 kV/m**




**Extreme Lightning Simulator**

- **200 kA peak**
- **Two pulse w/ continuing current (600 A)**

# EMP/GMD Mitigation Strategies Being Developed

## Operational Mitigation

**Real-time control to limit power outages**

Automated protection relay schemes (w/GATech)

Heuristic solution of reconfigured network dynamics

## Grid Black Start and Restoration

**Plan restoration to maximize grid resilience**

SOS models for inter-dependent infrastructures

Role of renewables and storage

Restoration scheduling, inventory, and energization

Feasibility heuristics

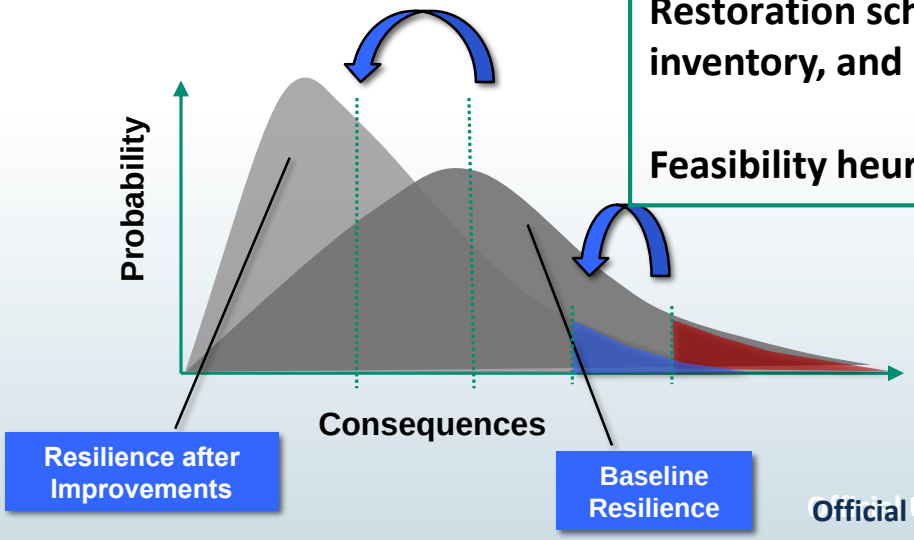
## Technology Deployment

**Plan deployments that mitigate EMP risks**

SOS models integrating operational mitigation and restoration

Multi-objective optimization with uncertainty

Surrogate optimization with algebraic approximations




**Leveraging**: Resilience models, SOS infrastructure models, power grid models, Pyomo and JEGA optimization software

# Machine Learning for Grid Stability

## Objectives

- Build decision-support tool to restore grid from near blackout
- Use machine learning to map grid state to stability margins

## Novelty of Approach

- Reinforcement learning facilitates near optimal restoration of the grid
- Also allows us to characterize potential grid vulnerabilities

## Recent Accomplishments

- Using Mini-WECC grid model
- Building deep neural network for continuous space model of grid state/stability margin mapping

## Key Partners

- Southern Company

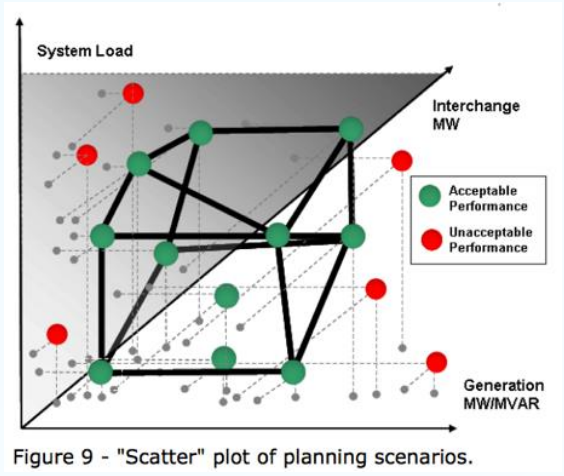
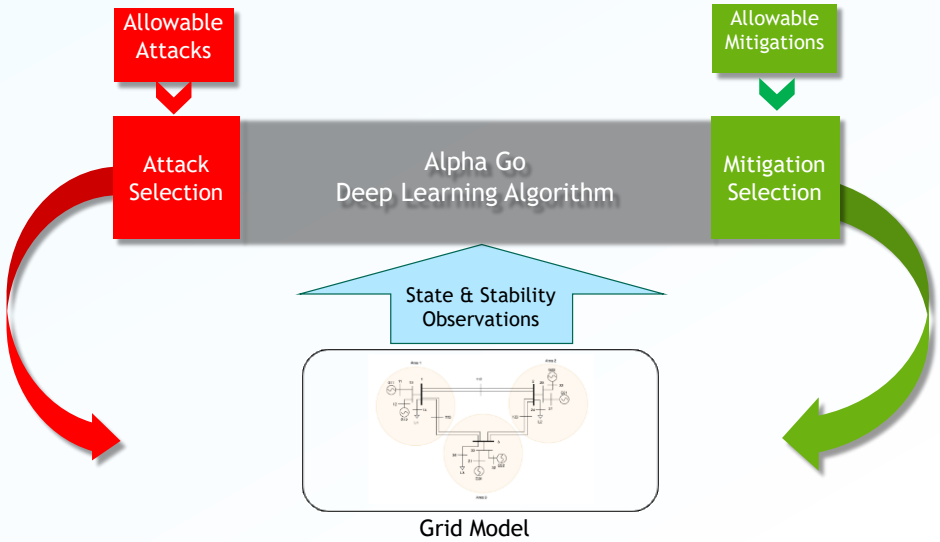



Figure 9 - "Scatter" plot of planning scenarios.

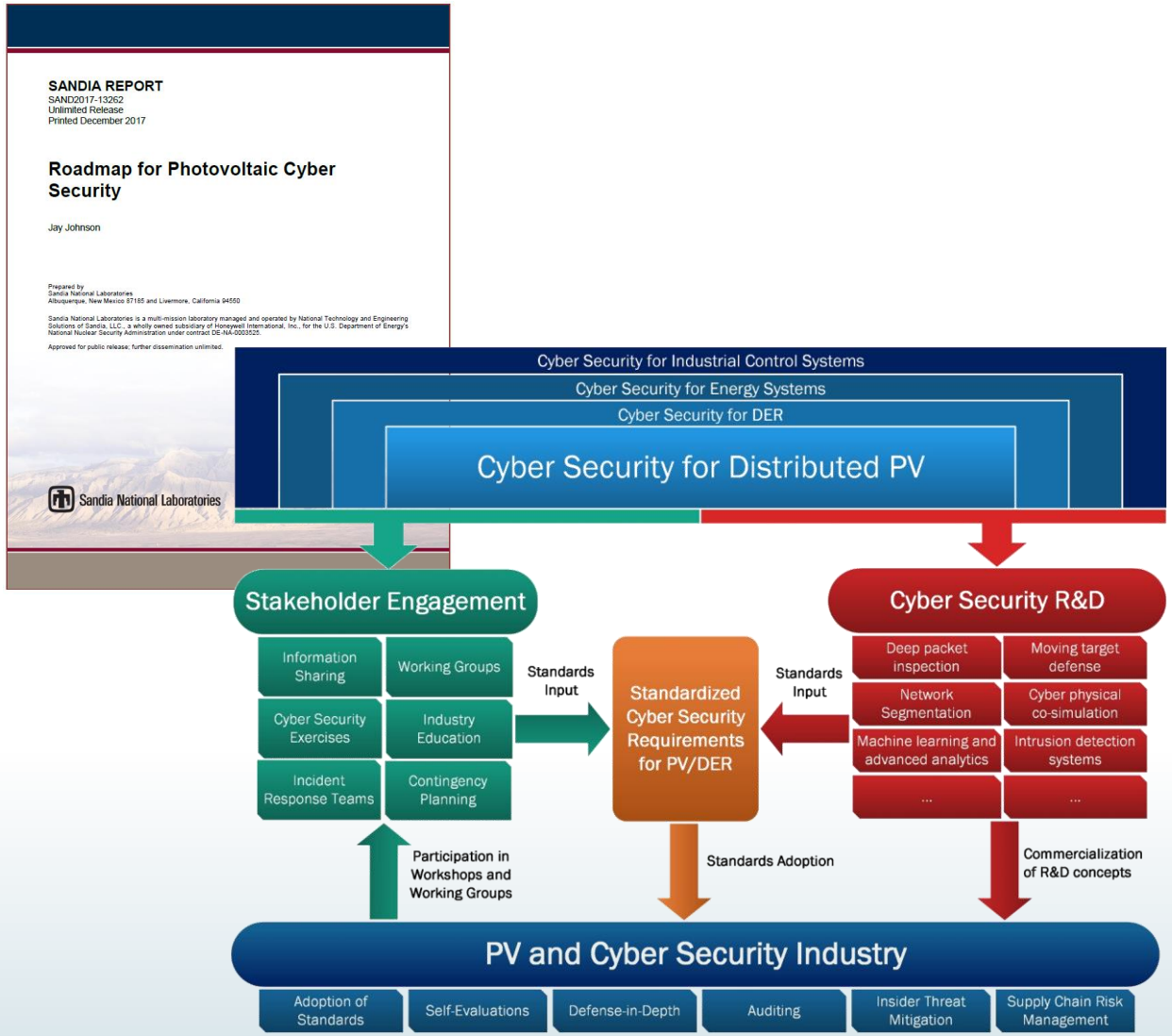
**Decision-support tool for situations outside normal operation**




**Proposed reinforcement learning framework for grid restoration decision support**

# Providing New Pathways for Distributed Resources and Cybersecurity

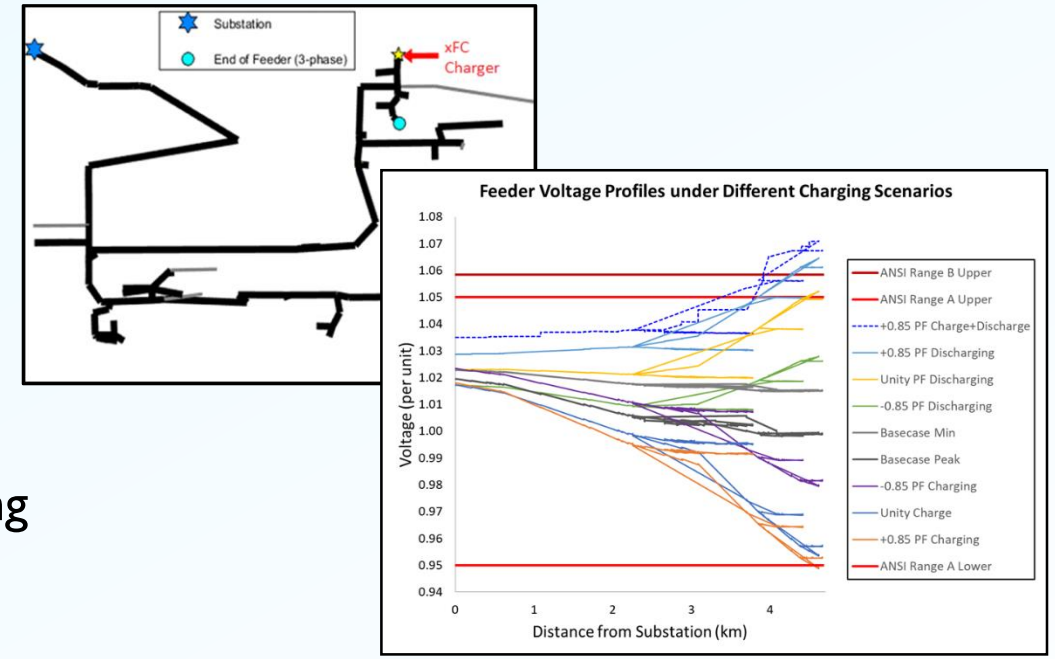
- Cybersecurity roadmap developed for distributed PV is being adapted across DOE renewable programs
- Methods to study complex interactions of power/cyber/controls of distributed energy systems
  - Aggregators, adaptive networks, restoration
- Apply capabilities in information and operational technology (IT/OT) security to develop new grid security paradigms
  - Data analytics, machine learning, HPC



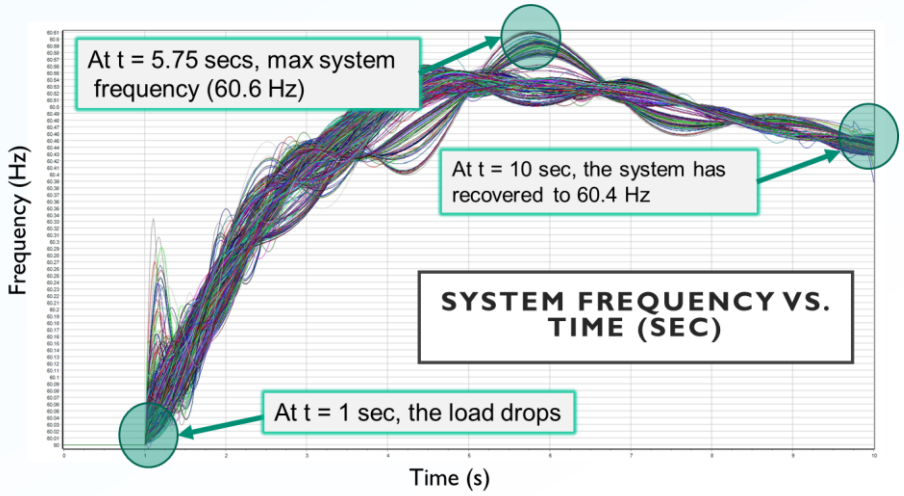

Proposed cybersecurity R&D framework for distributed systems

# Securing Vehicle Charging Infrastructure

- Objective: Create a cybersecurity threat model and perform a technical risk assessment of electric vehicle supply equipment (EVSE)
- Novelty of Approach: Team is conducting red team assessments of EVSEs and analyzing power system impact for different attack scenarios
- Recent Accomplishments:
  - Drafted data flow model for EV charging
  - Completed first distribution and transmission simulations for coordinated EV cyber attacks
  - Completed reconnaissance of EVSE production environment
- Key Partners: PNNL, ANL, BTCPower, NMFTA, DOT

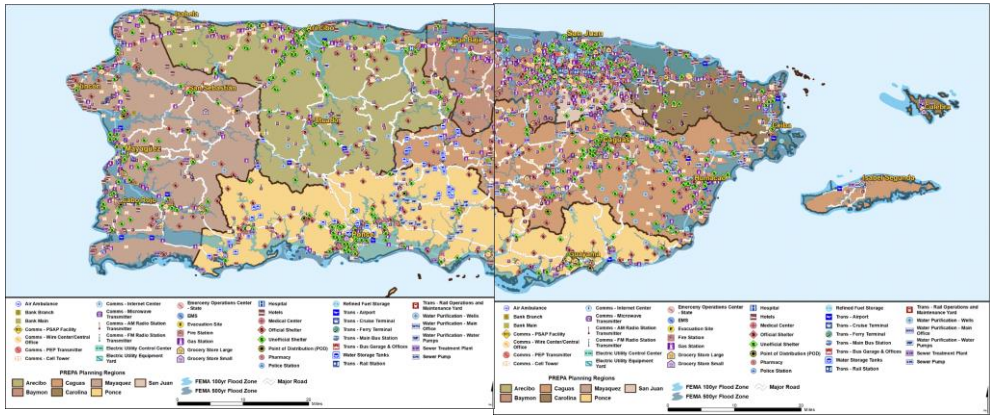



**Distribution Simulations of EV Cyber Attacks**

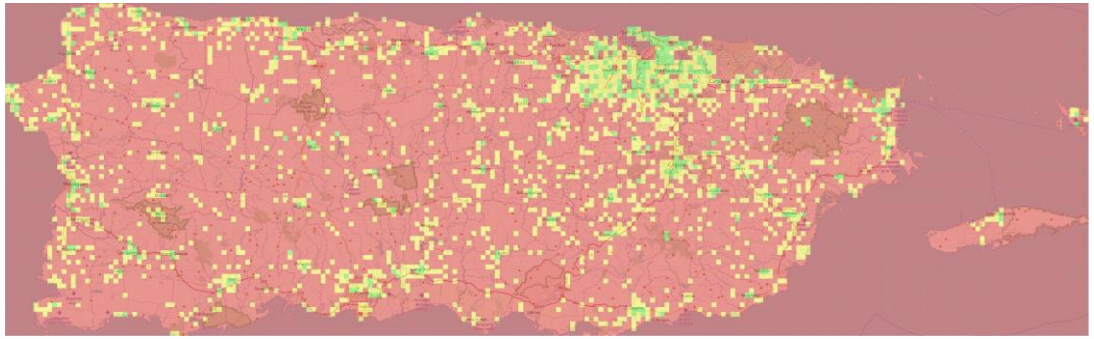


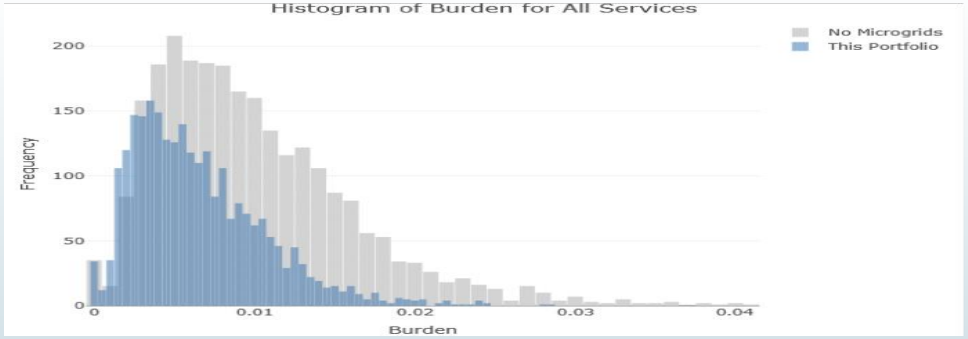

**Transmission Simulations of EV Cyber Attacks**

# Puerto Rico: Critical Infrastructure Locations for Resilient Microgrids



100-yr Flood

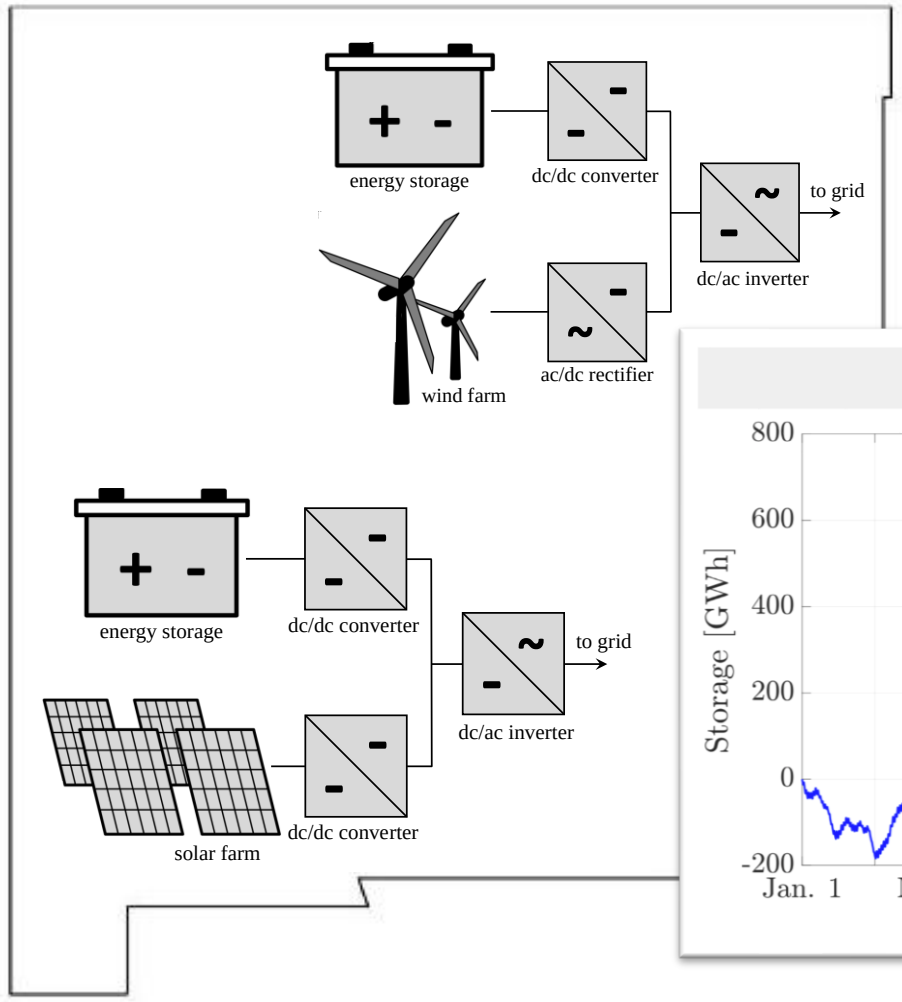





- Create 3-D rendition of critical infrastructure, service locations
- Develop maps of optimal microgrid locations under various threat scenarios
- Compare histograms of consequence or "burden" impacts

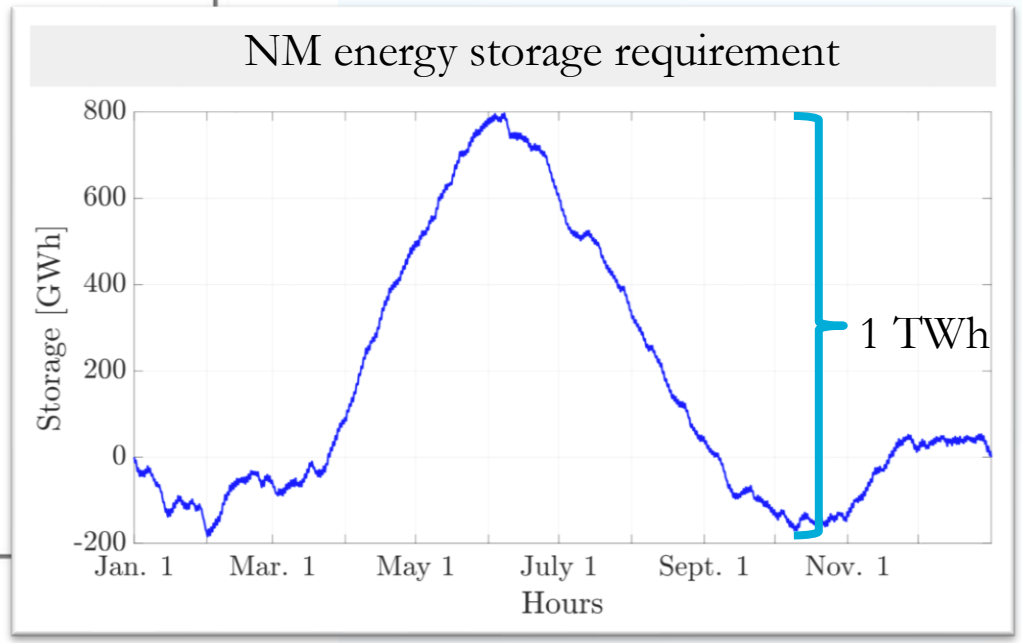
# 100% Carbon-Free New Mexico Analysis

**New Mexico aiming for 100% carbon-free electric generation by 2045.**




Significant changes required to mitigate renewable intermittence and stochastic demand:

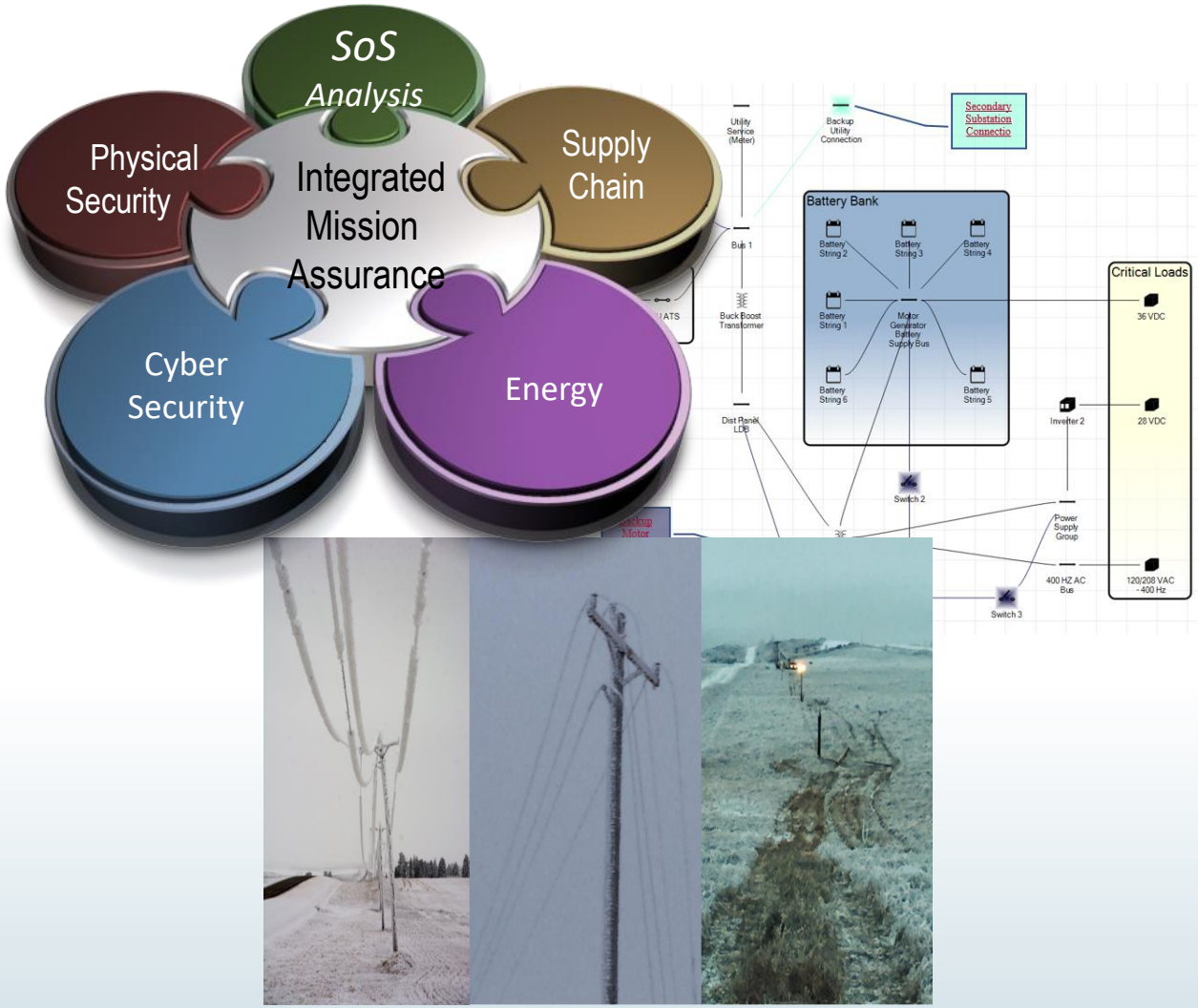
- What should the generation mix be (solar/wind)?




- Where to site resources and build transmission infrastructure?
- How much energy storage?

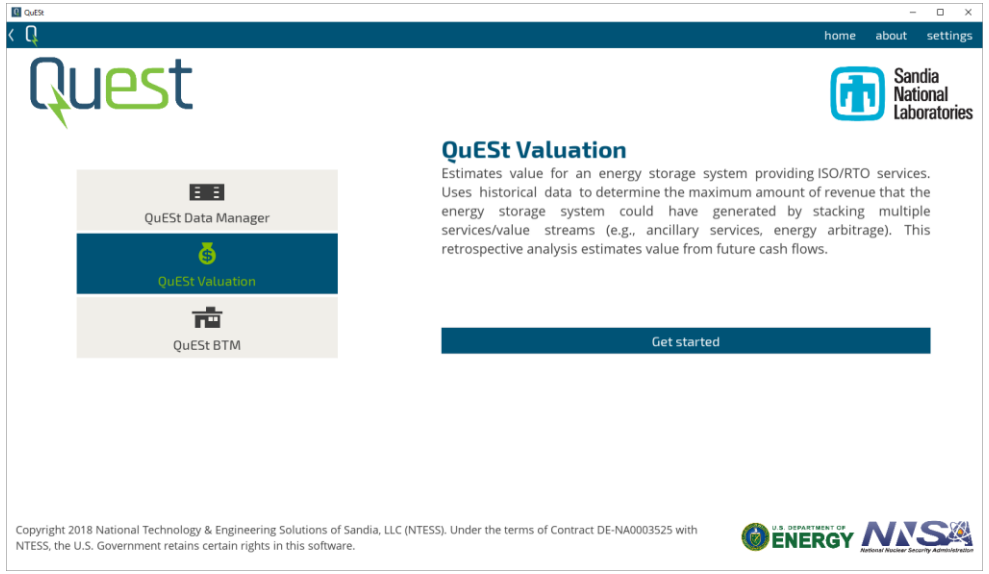
# Integrated Mission Assurance with DOD Partners: Malmstrom Missile Silo Energy Surety – 60 Day Study

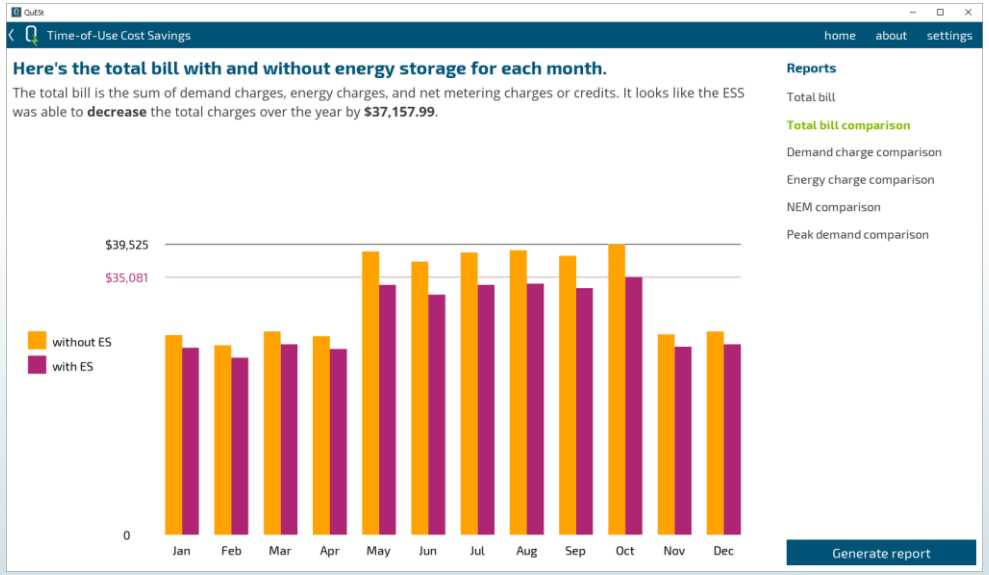
- Objectives
  - Investigate use of Sandia's Resilience Analysis Methodology for energy security of the ICBM Missile Launch sites assigned to Malmstrom Air Force Base
- Novelty of Approach
  - Use of Sandia's Microgrid Design Toolkit
  - Address both site and utility issues
  - Consider resilience (high consequence, low probability) events.
- Recent Accomplishments
  - OUO Study Completed and recommendations made
- Key Partners
  - NNSA
  - Malmstrom Air Force Base
  - Air Force Nuclear Weapons Center
  - Air Force Global Strike Command

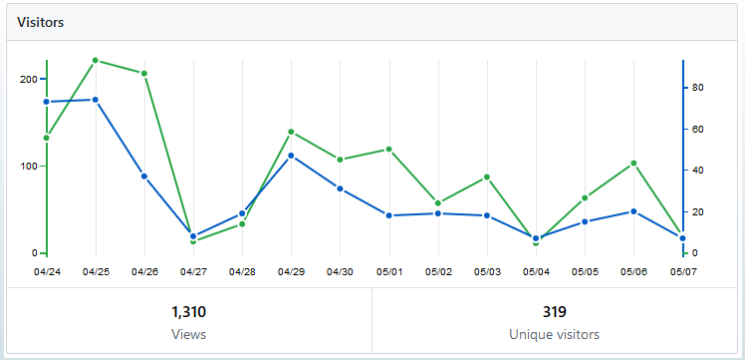


# QUEST: Open Source Energy Storage APP Suite

- A free, open source software tool for energy storage valuation designed to be run from the desktop
- Initially released in September 2018 with update releases in November and March
- Uses public domain data to estimate value potential of energy storage via retrospective analysis of value stacking
  - Energy arbitrage
  - Ancillary services
  - Other ISO/RTO services
- Latest version includes QuESt BTM with a tool for estimating cost savings for time-of-use customers using energy storage
  - Demand/energy charge reduction; net metering credits
  - Onsite solar + storage facility configurations



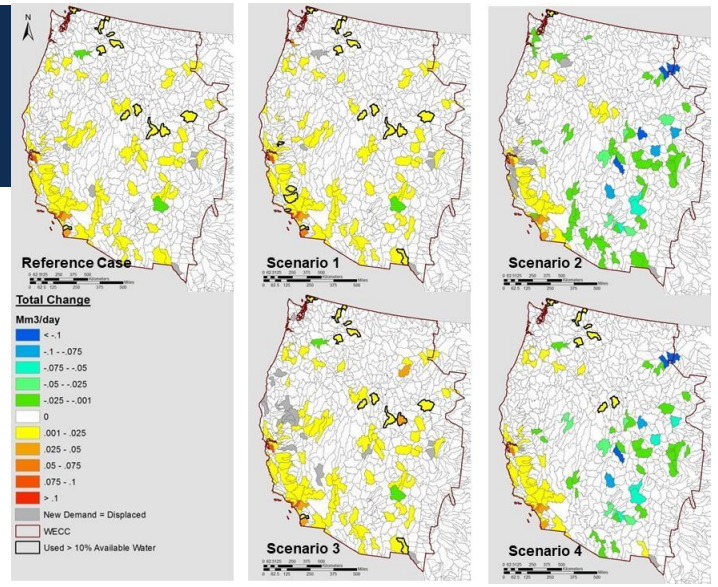



# Energy-Water Dynamics and Grid Resilience

*Limiting the impacts of an uncertain water future on the reliability and resilience of the electric power system*

**Water footprint of different WECC transmission expansion scenarios**



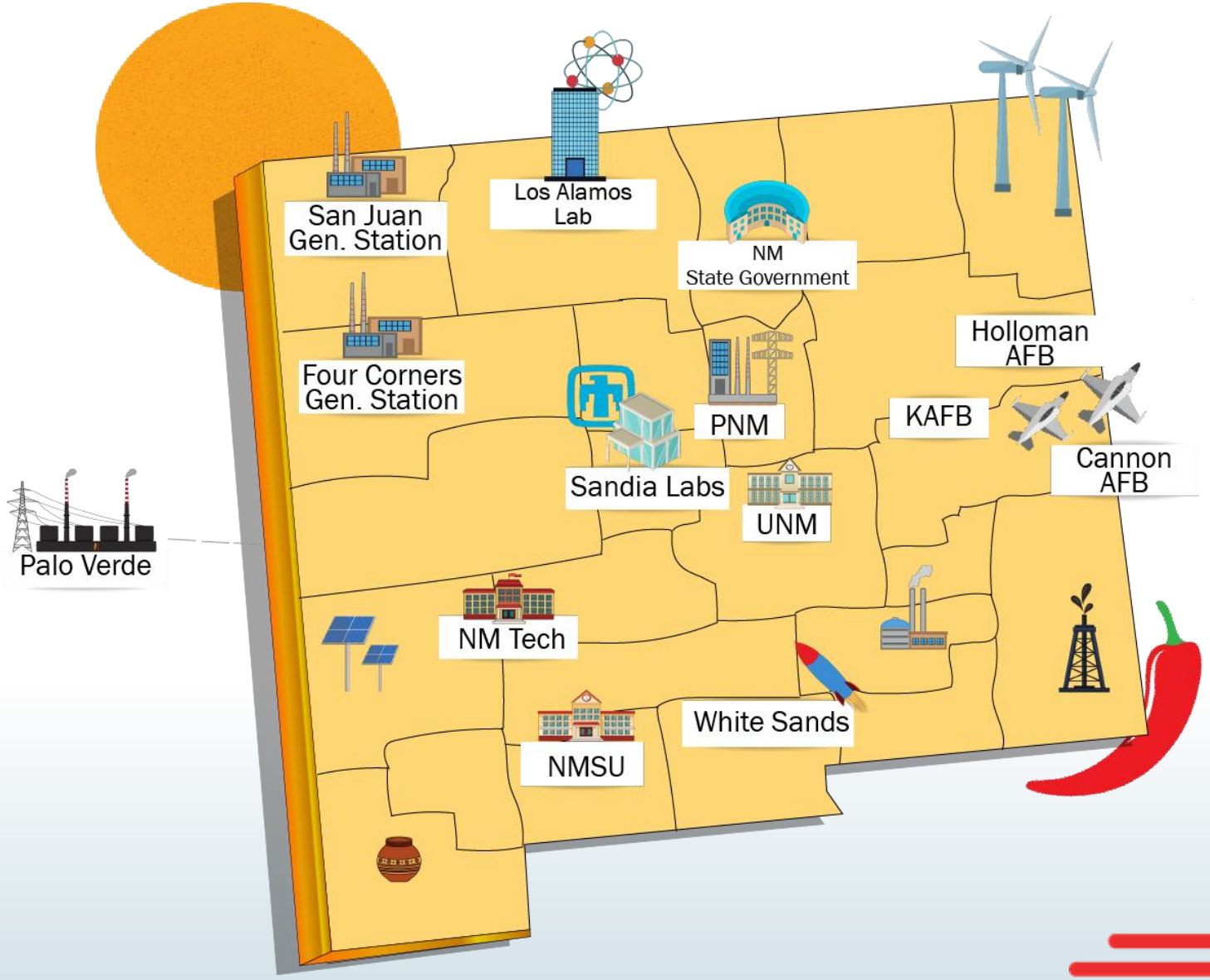

- Developing advanced technologies to make new sources of water available at competitive costs.
- Supporting the nation's interconnections with integrating water into their long-term transmission planning.
- Modeling and analysis to improve the resilience and reliability of coupled energy-water systems.
- *Water Atlas*, a database of critical water supply, demand and policy information.
- Tools for water distribution system resilience to natural and human-caused events.

# New Mexico Can be a National Security Model
## Leadership in Clean Energy, Water Security, Education, and Job Creation

RESILIENT ENERGY:
- Physical Security
- Cyber Security
- Energy/Resource Security

TECHNO-ECONOMIC APPLICATIONS:
- Energy Storage
- Microgrids
- Blackout Recovery
- Fossil Retirement
- Renewables Integration
- Energy/Water Infrastructure
- Disaster Response (natural/human caused)
- Transportation
- Hydrogen

BUILDS ON SANDIA WORK:
- California
- Alaska
- Hawaii
- Puerto Rico/US Virgin Islands
- Texas



# Collaborative Research Opportunities

- **Multi-Scale Energy Storage Technologies:**
  - Develop, deploy, and assist in the scale-up of safe, reliable storage systems to enable a grid transformation.
- **Control Systems and Optimization:**
  - Integrated controls and optimization across transmission, distribution, and advanced microgrids to employ new operational paradigms and asset aggregation schemes.
- **Power Conversion Systems:**
  - Employing advanced power devices and controls in highly efficient converters that provide greater autonomy at multiple physical scales.
- **Grid Security:**
  - Apply Sandia's extensive capabilities in information and operational technology (IT/OT) security to develop new grid security technologies; apply our technology developments in physical security for nuclear and defense installations for the grid.
- **Resilience Methods:**
  - Develop and deploy data-analytical methods to measure and improve overall resilience for communities, defense installations, and other stakeholders.
- **Electromagnetic Pulse and Geomagnetic-Induced Currents:**
  - Lead the nation in determining potential impacts of EMP/GMD and effective mitigation strategies.