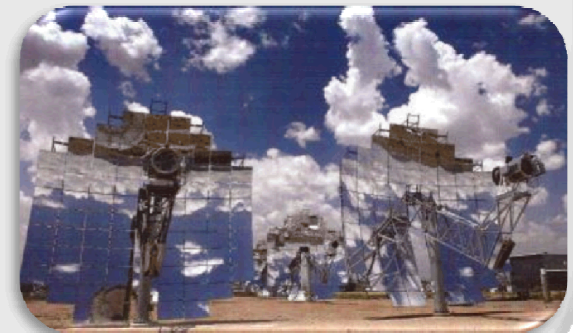# Energy & Infrastructure Future Group Overview
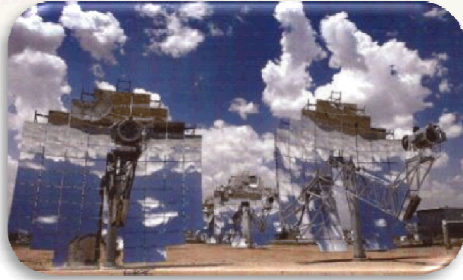
Jeff Nelson, Manager

Materials, Devices, and Energy Technologies Department

Sandia National Laboratories

jsnelso@Sandia.gov

(505)-284-1715

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Laboratories

Energy & Infrastructure Future Group

6330
Energy & Infrastructure Future
Rush Robinett

6337
Concentrating Solar Power
Joe Tillerson

6335
Photovoltaics and Grid Integration
Charles Hanley

6333
Wind & Hydro Power Technology
Jose Zayas

6331
Geothermal Research
Douglas Blankenship

6336
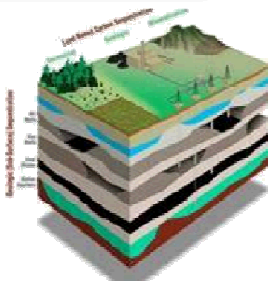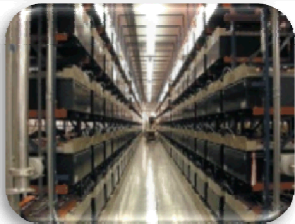**Energy Infrastructure & DER**
John Boyes

6332
Energy Systems Analysis
Juan Torres

6338
**Materials, Devices and Energy Technologies**
Jeff Nelson

6339
Emerging Energy Technologies
Ellen Stechel

Sandia National Laboratories

Wind Energy Technology

- **Blade Technology**
  - **Materials and Manufacturing**
  - **Structural, Aerodynamic, and Full System Modeling**
  - **Lab - Field Testing and Data Acquisition**
  - **Sensors and Structural Health Monitoring**
  - **Advanced Blade Concepts**

- **System Reliability**
  - **Industry Data Collection**
  - **Improve reliability of the existing technology and future designs**

- **System Integration & Outreach**
  - **DOE/Wind M&O**

3
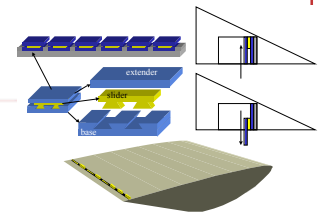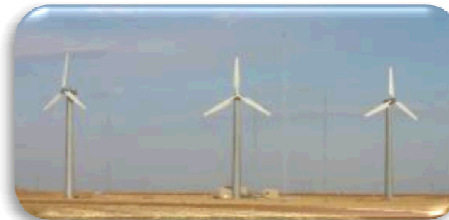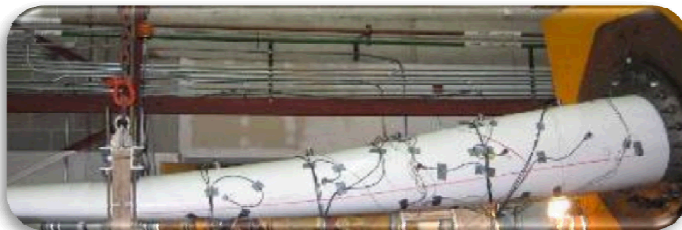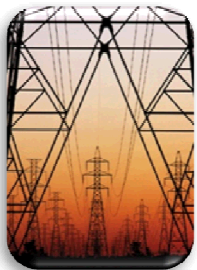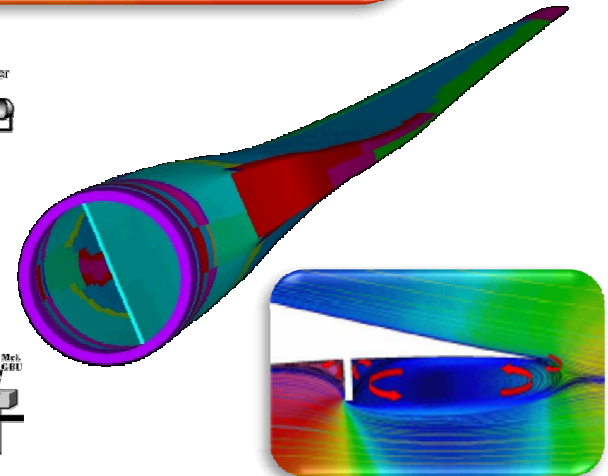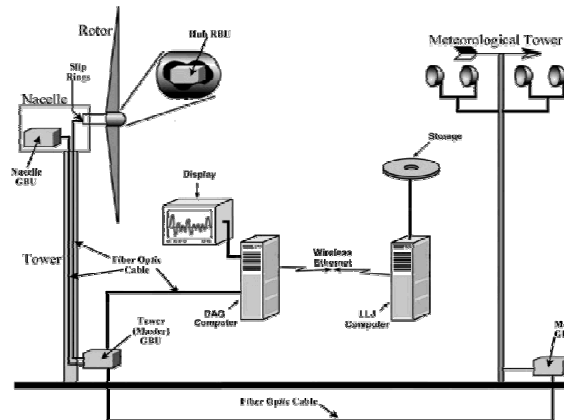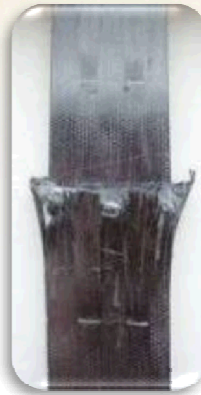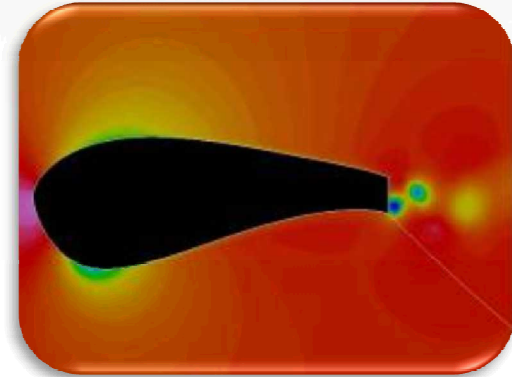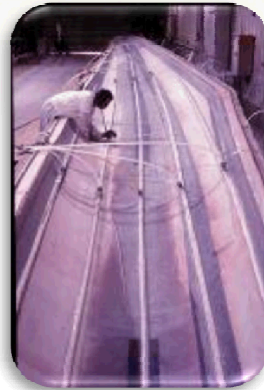
Geothermal Research
Drilling and Monitoring in Harsh Environments

- **Geothermal Well Construction**
  - **High-Temperature Electronics**
  - **Diagnostics-While-Drilling**
  - **Rock Reduction Technologies**
  - **Wellbore Integrity and Lost Circulation**
  - **Drilling Dynamics Modeling and Simulation**
  - **Vibration Mitigation**

DRILLER
Optimizes drilling process using real-time data

DRILLING ADVISORY SOFTWARE combines surface conditions with downhole information

CONTROL SIGNALS

HIGH-SPEED DATA LINK

DOWNHOLE SENSORS

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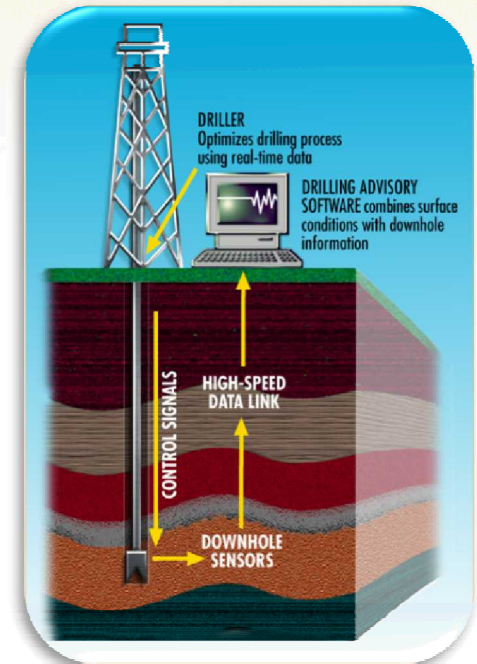
Energy Infrastructure and Distributed Energy Resources

S&C Purewave UPS System

- Distributed energy resources
- Power electronics
- Energy storage
- Energy Surety Microgrid

1.2 MW, 7.2 MWh Distributed Energy Storage System in Chemical Station, North Charleston

12kV / 480V Transformer   PCS   NAS Battery

Started Operation on June 26th, 2006

AEP APPALACHIAN POWER
A unit of American Electric Power

NGK Insulators Ltd
S&C Electric Co.
DOE / SANDIA

Application of Energy Storage
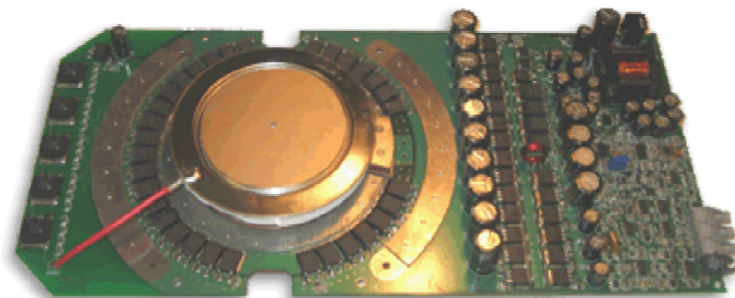
R&D 100: ETO High Power Switch

Energy Systems Analysis

- ## Competencies:
    - Power grid (generation, transmission, distribution) operations, modeling
    - Energy transport security (pipelines, power grid, marine, railways)
    - SCADA and control systems analysis and Cyber security
    - Energy system vulnerability, safety, and risk assessment
    - Energy system modeling and simulation
    - Energy systems analysis
    - Energy-Water Nexus issues
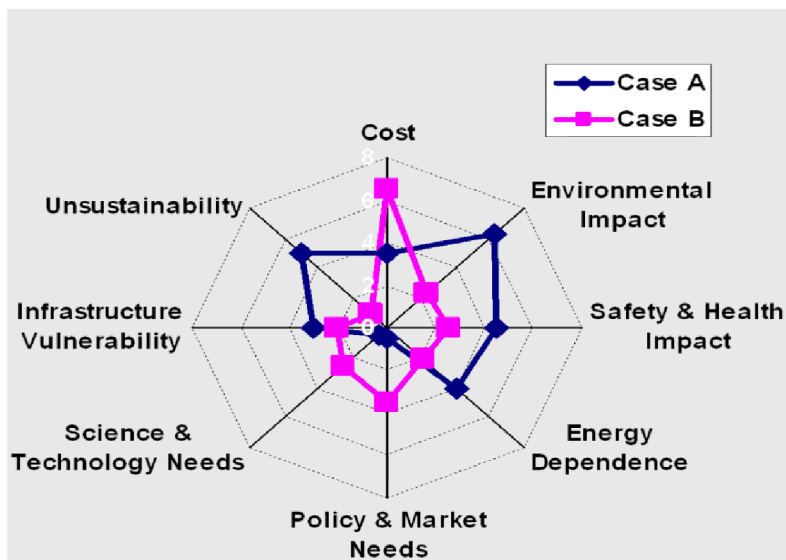
Materials, Devices, and Energy Technologies
Department-6338 (Jeff Nelson)

- **Materials Membranes & Coatings**
  - **Synthesis & Characterization**
    - Inorganic
      - **Ceramics, Glasses, Metals**
    - Organics
      - **Synthetic & Natural Polymers**
    - Hybrids
    - Nanomaterials
  - **Wide Range of Applications**
  - **System Level Assembly & Testing**

- **Thin-Film Reliability Studies (PV)**
- **High Temperature Solar Coatings (CSP)**
- **Solar Fuels**
- **CO2 Capture and Reuse**

Solar Technology

Technologies:

Photovoltaics
- Cells/Modules/Arrays
- Inverters/BOS
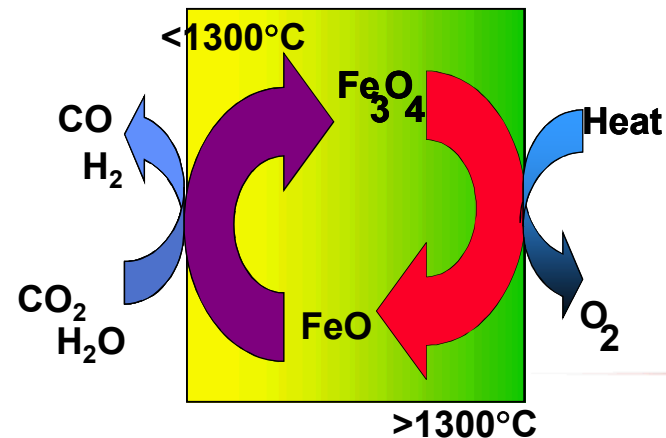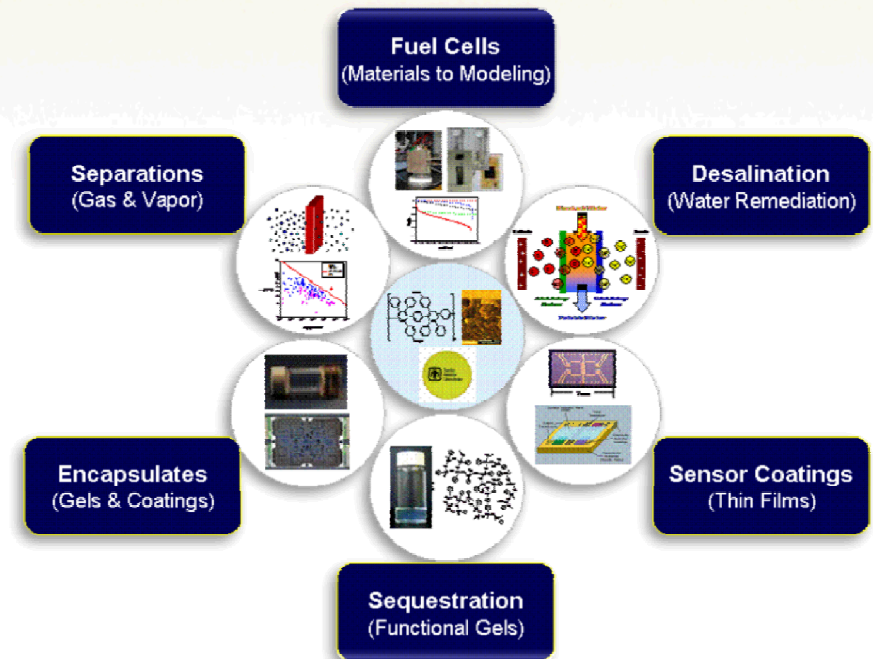- Controls/Communication
- Systems

Concentrating Solar Power
- National Solar Thermal Test Facility (Tower)
- Troughs
- Dishes

Solar Hot Water

Activities:

Advanced R&D
- CSP Thermal Storage Materials and Systems
- Dish Stirling Systems
- Advanced Towers and Receiver Designs
- Advanced Heliostats
- Optical and Mechanical Analysis
- New systems integrations
- Solar Fuels, Hydrogen Production
- High Efficiency PV Cell Technology
- New "Smarts": Controls, Communications, Power Conversion, Energy Management

Modeling – performance prediction

Reliability engineering

Evaluations/characterizations of new components/products

In field performance evaluation

Barrier removal: codes, standards, certification, design assistance, technical support

Market Transformation

Customers:

DOE/EERE/OE …
DOD
Industry
NASA

The Distributed Energy Technology Laboratory

Grid

Center for Control System Security

480V Microgrid

Other Remote DER sites

Distributed Energy Resources

Various Loads

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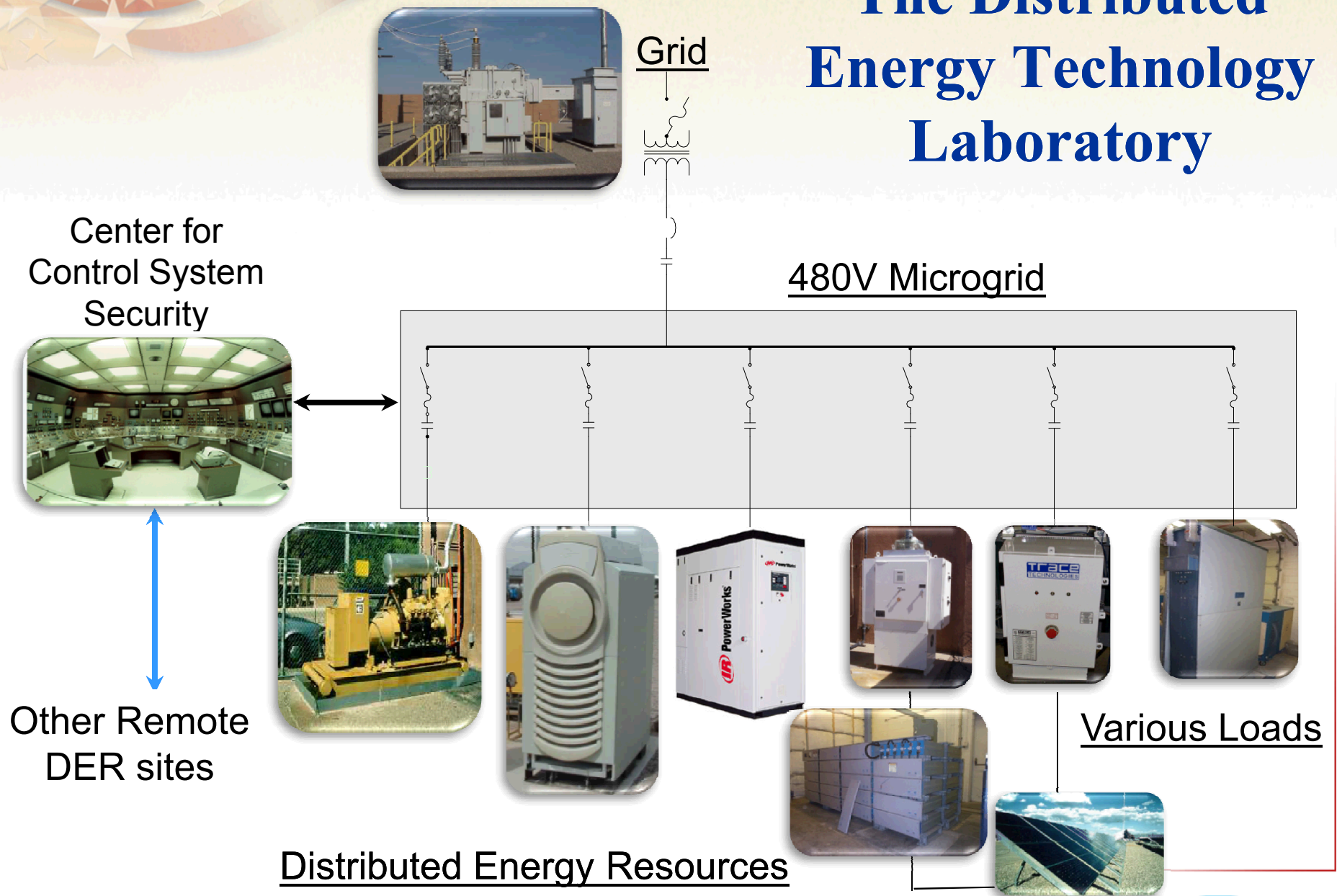
SEGIS - Solar Energy Grid Integration System
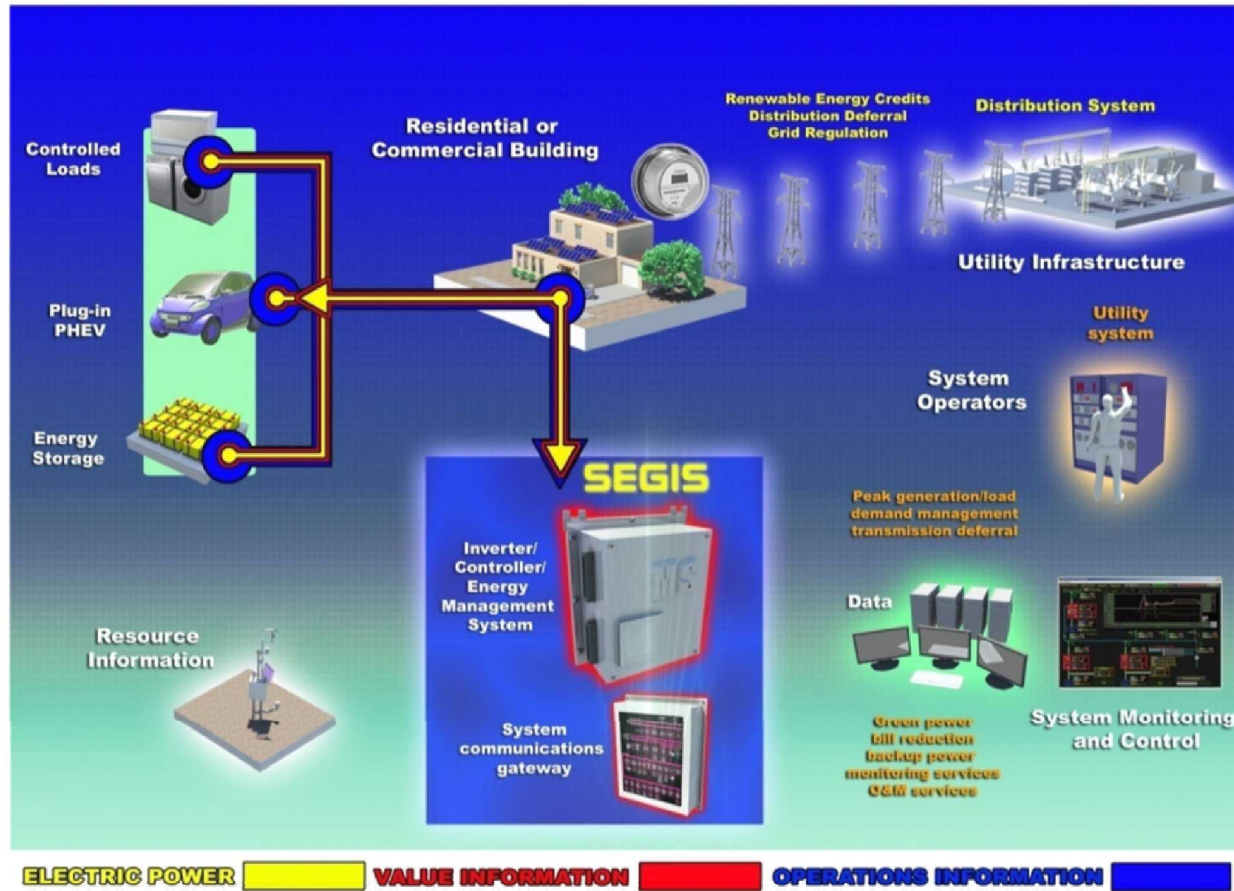
SEGIS focus is to develop the intelligent hardware that interconnects PV to the evolving "Smarter" electrical grid

Internal Grid Integration R&D

- **Focused on advanced architecture, hardware and controls for optimized grid management with high penetration PV**

1. Intelligent Power Controllers for Self-Organizing MicroGrids

✓ Develop open, fully controllable converter platform capable of hosting advanced controls, variable sources and storage

2. Innovative Control of a Flexible, Adaptive Energy Grid

✓ Develop scalable closed-loop nonlinear control concepts and analyses based on exergy/entropy, as applied to systems that contain variable sources and energy storage

3. Scalable Micro-grids

✓ Develop revolutionary control architecture for future micro-grids

✓ Develop low cost sensors using micro-systems technologies
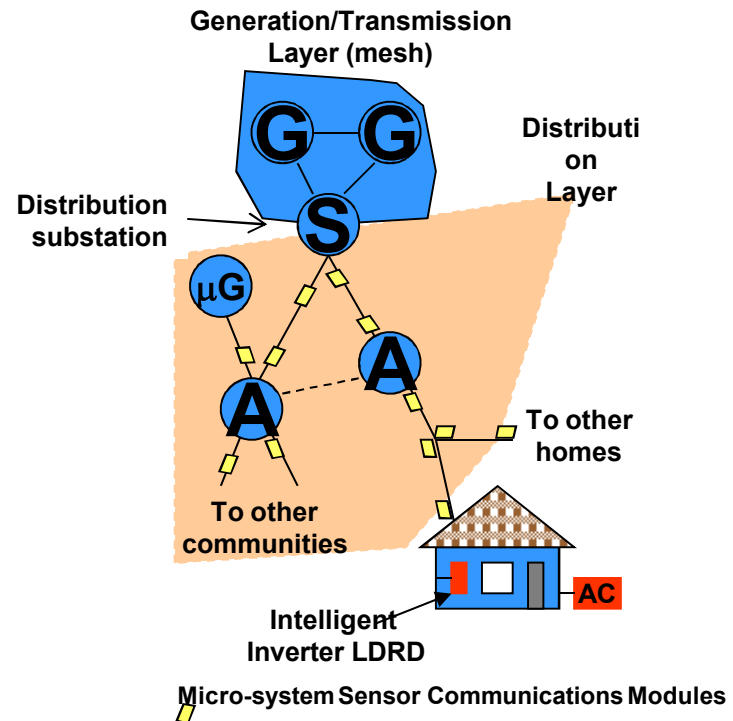
Cyber Security for the Smart Grid

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National
Laboratories

Trends Impacting Power Grid Cyber Security

- **Interconnected to Other Systems**
  - **Connections with enterprise networks to obtain productivity improvements and information sharing**
- **Common Operating Systems**
  - **Standardized computer platforms increasingly used to support control system applications**
- **Reliance on External Communications**
  - **Increasing use of public telecommunication systems, the Internet, and wireless for control system communications**
- **Increased Capability of Field Equipment**
  - **"Smart" sensors and controls with enhanced capability and functionality**

COMMON VULNERABILITIES IN CRITICAL INFRASTRUCTURE CONTROL SYSTEMS

Roadmap to Secure Control Systems in the Energy Sector

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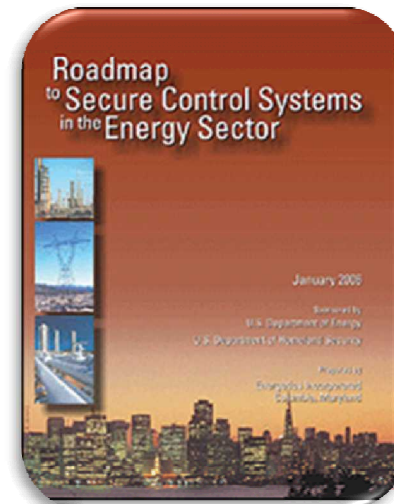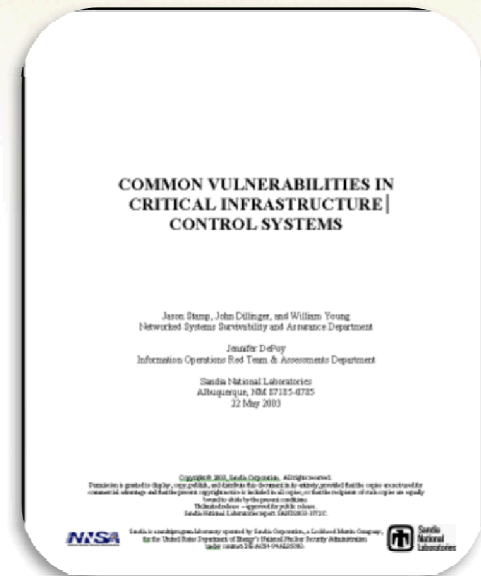
Vulnerability and Scenario Analysis: Virtual Control System Environment (VCSE)

- **High fidelity modeling environment**
- **Simulation and analysis of control system devices and network communications**
- **Execute cyber attacks and assess control system impacts –** *cyber-to-physical bridge*
- **Enables real-time, hardware/software-in-the-loop analysis**
- **Current capabilities:**
  - **SCADA communication protocols (Modbus, DNP3)**
  - **Real and virtual remote terminal units (RTUs)**
  - **Static and dynamic power system simulation**

Physical — Attacker — Operator — AREVA
Emulation — Cisco Systems — Network
Simulation — PLC Device — Power System

Possible Threats → Threat Analysis → Cyber Effect Analysis → System Impact Analysis → Consequence Analysis → Risk Analysis

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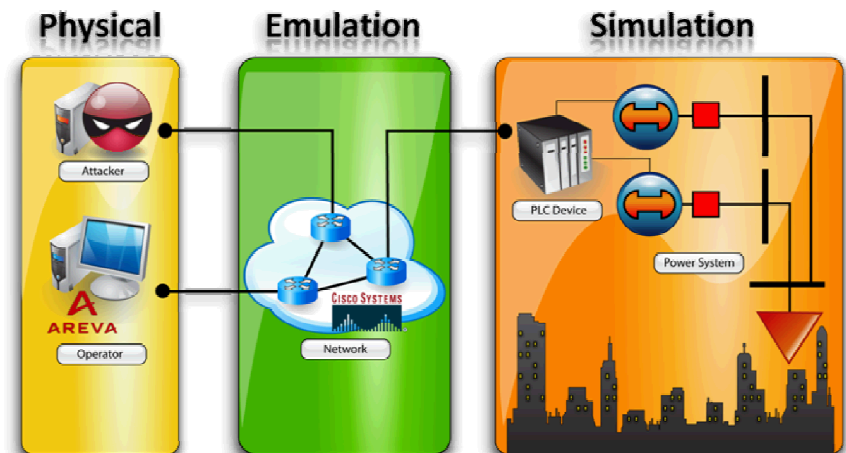
VCSE Use Case Examples

- ## Analyze Cyber Vulnerabilities in the Power Grid
  - **Smart Grid Advanced Metering Infrastructure Attack (March 2009)**
    - Leverage wireless mesh network to launch an attack on the grid
  - **Known Vulnerability Analysis (April 2009)**
    - US-CERT announced vulnerability in Domain Name System (DNS)
  - **Life-cycle Rogue Software Attack (June 2008)**
    - Rogue software planted during routine maintenance upgrade
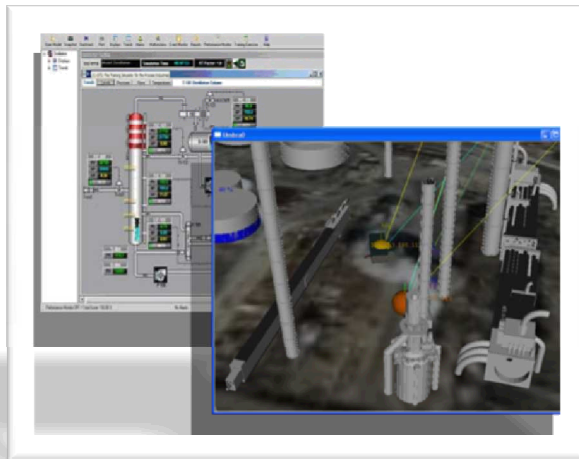
- ## Training Simulator for Oil & Gas
  - **Interactive cyber training simulator for control system operators**
  - **Simulates a cyber attack on an oil refinery and leads the 'student' through a series of events before an explosion occurs**
  - **Adversary attack graph is automated and the shortest path to the target is constantly being calculated**

Possible Threats → Threat Analysis → Cyber Effect Analysis → System Impact Analysis → Consequence Analysis → Risk Analysis

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The Green Grid

Making New Mexico a national leader in developing and demonstrating the next-generation "Green Grid" - a smart energy grid with variable and intermittent renewable energy

Thomas Bowles
Science Advisor to Governor Richardson

NM Green Grid Sites

Los Alamos
Suburban w national lab;
hi elevation mountainous terrain;
Municipal Utility: residential use of fossil and hydro;
Smart grid with > 30% solar and storage; smart grid model home.

Mesa del Sol (Albuquerque)
Largest NM urban center;
hi elevation semi-arid desert;
State's largest IOU; average commercial demand; mostly fossil fuel generation;
Site Objectives: Energy efficient buildings, smart grid with 30-100% solar PV and storage.

Taos / Taos Pueblo
Rural county and Pueblo;
hi elevation mountainous terrain
Rural Electric Cooperative Utility;
summer cooling/winter heating;
mostly fossil generation;
Site Objectives: smart grid with > 30% solar with 10 MW PV and storage.

Roosevelt County
Rural agrarian community;
open flat plains;
Rural Electric Cooperative Utility;
irrigation water pumping demand;
currently mix of fossil and wind;
Site Objectives: smart grid with > 30% wind/pumped water storage.
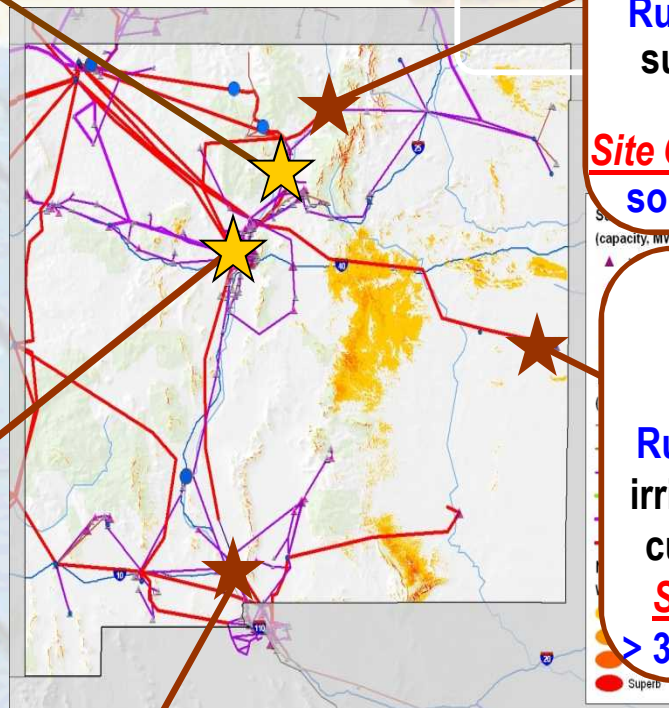
NMSU / Las Cruces
University campus; semi-arid desert;
University-owned/operated utility with IOU provider;
summer cooling demand; currently nuclear and fossil;
Site Objectives: smart grid w advanced controls.

⭐ **NEDO Sites**
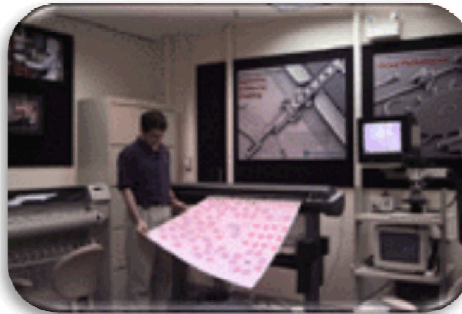
Sandia State-of-the-Art Facilities
Microelectronics, Materials, and Nanotechnology

Microelectronics and Semiconductor Materials Processing

Microelectronics Development Lab (MDL)

Microelectronics Development Lab (MDL)

Microsystems & Engineering Science Applications (MESA)

Materials Sciences and Nanotechnology Technology

Center for Integrated Nanotechnology (CINT)

Process & Environmental Technology Laboratory (PETL)

Integrated Materials Research Lab (IMRL)

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