U.S. DEPARTMENT OF ENERGY

Office of Electricity Delivery & Energy Reliability

DOE Strategy for Energy Sector Cybersecurity

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Deputy Assistant Secretary, Cybersecurity and Emerging Threats R&D

September 14, 2017

Energy Sector Partners Are Critical to Success

Asset Owners/Operators (36)

- Ameren
- Arkansas Electric Cooperatives Corporation
- Avista
- Burbank Water and Power
- BPA
- CenterPoint Energy
- Chevron
- ComEd
- Dominion
- Duke Energy
- Electric Reliability Council of Texas
- Entergy
- FirstEnergy
- FP&L
- HECO
- Idaho Falls Power
- Inland Empire Energy
- NIPSCO
- Omaha Public Power District
- Orange & Rockland Utility
- Pacific Gas & Electric
- PacifiCorp
- Peak RC
- PJM Interconnection
- Rochester Public Utilities
- Sacramento Municipal Utilities District
- San Diego Gas and Electric
- Sempra
- Snohomish PUD
- Southern Company
- Southern California Edison
- TVA
- Virgin Islands Water and Power Authority
- WAPA
- Westar Energy
- WGES

Solution Providers (35)

- ABB
- Alstom Grid
- Applied Communication Services
- Applied Control Solutions
- Cigital, Inc.
- Critical Intelligence
- Cybati
- Eaton
- Enernex
- EPRI
- Foxguard Solutions
- GE
- Grid Protection Alliance
- Grimm
- Honeywell
- ID Quantique
- Intel
- NexDefense
- OPAL-RT
- Open Information Security Foundation
- OSIsoft
- Parsons
- Power Standards Laboratory
- Qubitekk
- RTDS Technologies Inc.
- Schneider Electric
- SEL
- Siemens
- Telvent
- Tenable Network Security
- Utility Advisors
- Utility Integration Solutions
- UTRC
- Veracity
- ViaSat

Academia (23)

- Arizona State University
- Carnegie Mellon University
- Dartmouth College
- Florida International University
- Georgia Institute of Technology
- Illinois Institute of Technology
- Iowa State University
- Lehigh University
- Massachusetts Institute of Technology
- Oregon State University
- Rutgers University
- Tennessee State University
- Texas A&M EES
- University of Arkansas
- University of Arkansas-Little Rock
- University of Buffalo - SUNY
- University of Illinois
- UC Davis
- UC Berkeley
- University of Houston
- University of Tennessee-Knoxville
- University of Texas at Austin
- Washington State

National Labs (10)

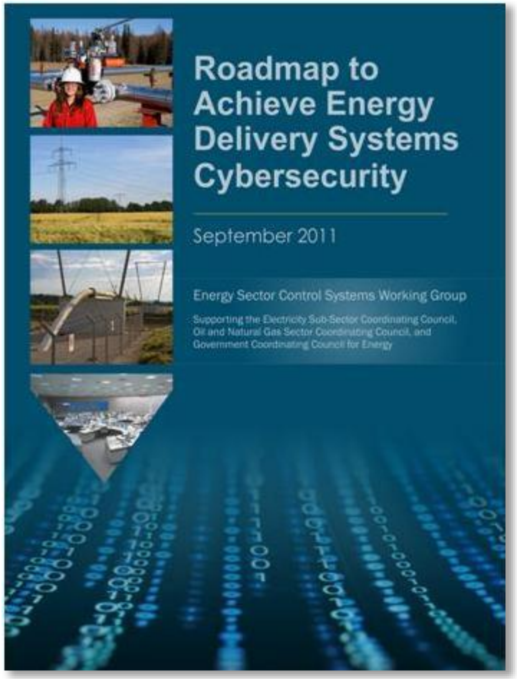
- Argonne National Laboratory
- Brookhaven National Laboratory
- Idaho National Laboratory
- Lawrence Berkeley National Laboratory
- Lawrence Livermore National Laboratory
- Los Alamos National Laboratory
- National Renewable Energy Laboratory
- Oak Ridge National Laboratory
- Pacific Northwest National Laboratory
- Sandia National Laboratories

Other (5)

- Energy Sector Control Systems Working Group
- International Society of Automation
- NESCOR
- NRECA
- Open Information Security Foundation

109 public-private partners drive R&D

Energy Sector Roadmap – Framework to Guide Public-Private Partnership



Roadmap to Achieve Energy Delivery Systems Cybersecurity

September 2011

Energy Sector Control Systems Working Group

Supporting the Electricity Sub-Sector Coordinating Council, Oil and Natural Gas Sector Coordinating Council, and Government Coordinating Council for Energy

- ***Energy Sector's*** synthesis of critical control system security challenges, R&D needs, and implementation milestones
- Provides strategic framework to:
  - Ensure public and private R&D is relevant and meets the needs of energy utilities
  - Stimulate investments in control systems security

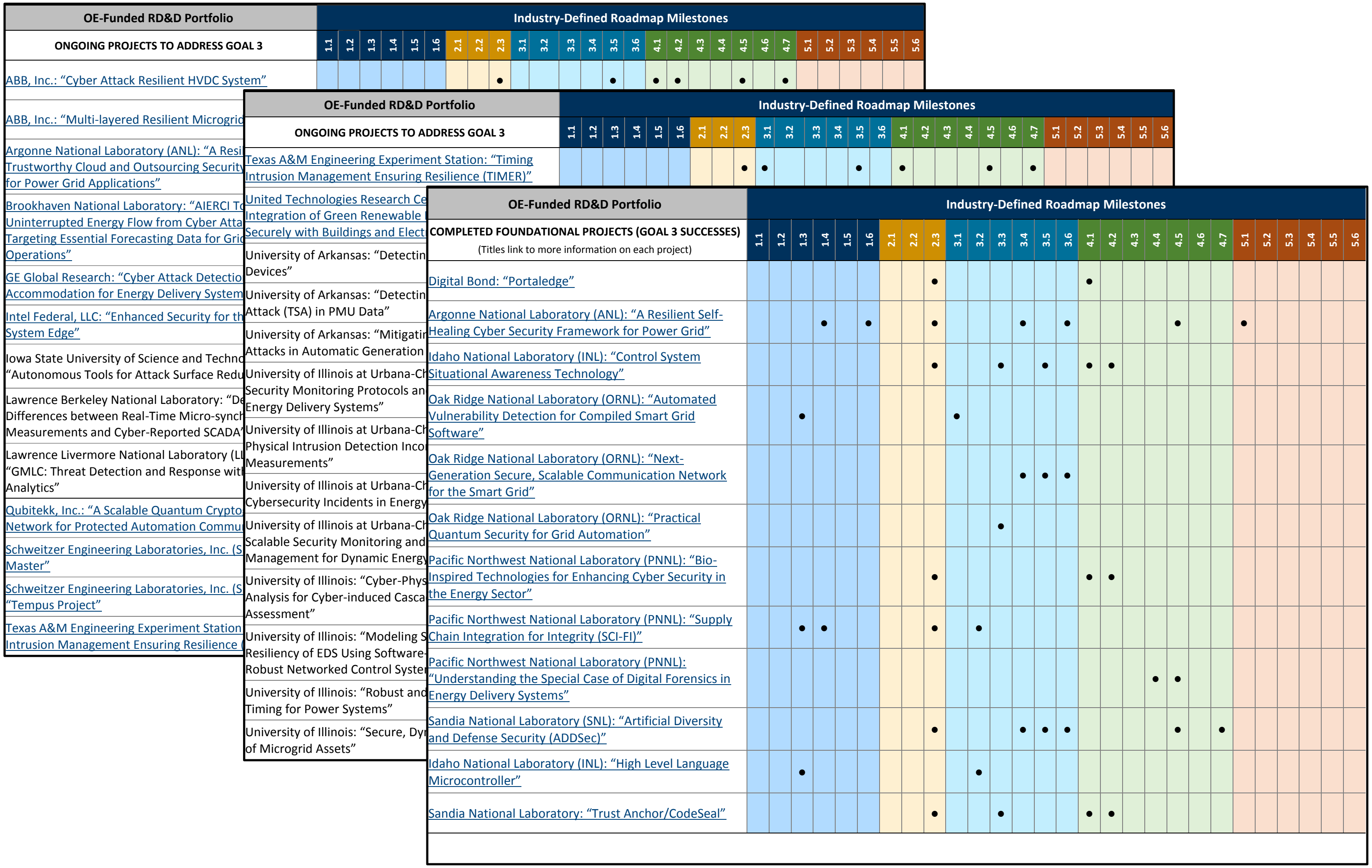
Roadmap Vision

Resilient energy delivery systems are designed, installed, operated, and maintained to survive a cyber incident while sustaining critical functions

Roadmap Milestones and Goals

	1. Assess and Monitor Risk	2. Manage Incidents	3. Develop and Implement New Protective Measures to Reduce Risk	4. Manage Incidents	5. Sustain Security Improvements
Near-term Milestones (By 2013)	1.1 Executive Engagement and support of cyber resilience efforts 1.2 Industry-driven safe code development and software assurance awareness workforce training campaign launched	2.1 Common terms and measures specific to each energy subsector available for baselining security posture in operational settings	3.1 Capabilities to evaluate the robustness and survivability of new platforms, systems, networks, architectures, policies, and other system changes commercially available	4.1 Tools to identify cyber events across all levels of energy delivery system networks commercially available 4.2 Tools to support and implement cyber-attack response decision making for the human operator commercially available	5.1 Cyber threats, vulnerability, mitigation strategies, and incidents timely shared among appropriate sector stakeholders 5.2 Federal and state incentives available to accelerate investment in and adoption of resilient energy delivery systems
Mid-term Milestones (By 2017)	1.3 Vendor systems and components using sophisticated secure coding and software assurance practices widely available 1.4 Field-proven best practices for energy delivery systems security widely employed 1.5 Compelling business case developed for investment in energy delivery systems security	2.2 Majority of asset owners baselining their security posture using energy subsector specific metrics	3.2 Scalable access control for all energy delivery system devices available 3.3 Next-generation, interoperable, and upgradeable solutions for secure serial and routable communications between devices at all levels of energy delivery system networks implemented	4.3 Incident reporting guidelines accepted and implemented by each energy subsector 4.4 Real-time forensics capabilities commercially available 4.5 Cyber event detection tools that evolve with the dynamic threat landscape commercially available	5.3 Collaborative environments, mechanisms, and resources available for connecting security and operations researchers, vendors, and asset owners 5.4 Federally funded partnerships and organizations focused on energy sector cybersecurity become self-sustaining
Long-term Milestones (By 2020)	1.6 Significant increase in the number of workers skilled in energy delivery, information systems, and cybersecurity employed by industry	2.3 Tools for real-time security state monitoring and risk assessment of all energy delivery system architecture levels and across cyber-physical domains commercially available	3.4 Self-configuring energy delivery system network architectures widely available 3.5 Capabilities that enable security solutions to continue operation during a cyber-attack available as upgrades and built-in to new security solutions 3.6 Next-generation, interoperable, and upgradeable solutions for secure wireless communications between devices at all levels of energy delivery system networks implemented	4.6 Lessons learned from cyber incidents shared and implemented throughout the energy sector 4.7 Capabilities for automated response to cyber incidents, including best practices for implementing these capabilities available	5.5 Private-sector investment surpasses federal investment in developing cybersecurity solutions for energy delivery systems 5.6 Mature, proactive processes to rapidly share threat, vulnerabilities, and mitigation strategies are implemented throughout the energy sector
Goals	**Continuous security state monitoring of all energy delivery system architecture levels and across cyber-physical domains is widely adopted by energy sector asset owners and operators**	**Energy sector stakeholders are able to mitigate a cyber incident as it unfolds, quickly return to normal operations, and derive lessons learned from incidents and changes in the energy delivery systems environment**	**Next-generation energy delivery system architectures provide "defense in depth" and employ components that are interoperable, extensible, and able to continue operating in a degraded condition during a cyber incident**	**Energy sector stakeholders are able to mitigate a cyber incident as it unfolds, quickly return to normal operations, and derive lessons learned from incidents and changes in the energy delivery systems environment**	**Collaboration between industry, academia, and government maintains cybersecurity advances**

49 DOE Technologies Contribute to 28 Milestones



OE-Funded RD&D Portfolio	Industry-Defined Roadmap Milestones																											
ONGOING PROJECTS TO ADDRESS GOAL 3	1.1	1.2	1.3	1.4	1.5	1.6	2.1	2.2	2.3	3.1	3.2	3.3	3.4	3.5	3.6	4.1	4.2	4.3	4.4	4.5	4.6	4.7	5.1	5.2	5.3	5.4	5.5	5.6
ABB, Inc.: “Cyber Attack Resilient HVDC System”									●					●		●	●			●		●						

ABB, Inc.: “Multi-layered Resilient Microgrid

Argonne National Laboratory (ANL): “A Resi
Trustworthy Cloud and Outsourcing Security
for Power Grid Applications”

Brookhaven National Laboratory: “AIERCI To
Uninterrupted Energy Flow from Cyber Atta
Targeting Essential Forecasting Data for Grid
Operations”

GE Global Research: “Cyber Attack Detectio
Accommodation for Energy Delivery System

Intel Federal, LLC: “Enhanced Security for th
System Edge”

Iowa State University of Science and Techno
“Autonomous Tools for Attack Surface Redu

Lawrence Berkeley National Laboratory: “De
Differences between Real-Time Micro-synch
Measurements and Cyber-Reported SCADA”

Lawrence Livermore National Laboratory (LL
“GMLC: Threat Detection and Response wit
Analytics”

Qubitekk, Inc.: “A Scalable Quantum Crypto
Network for Protected Automation Commu

Schweitzer Engineering Laboratories, Inc. (S
Master”

Schweitzer Engineering Laboratories, Inc. (S
“Tempus Project”

Texas A&M Engineering Experiment Station
Intrusion Management Ensuring Resilience

OE-Funded RD&D Portfolio	Industry-Defined Roadmap Milestones																											
ONGOING PROJECTS TO ADDRESS GOAL 3	1.1	1.2	1.3	1.4	1.5	1.6	2.1	2.2	2.3	3.1	3.2	3.3	3.4	3.5	3.6	4.1	4.2	4.3	4.4	4.5	4.6	4.7	5.1	5.2	5.3	5.4	5.5	5.6
Texas A&M Engineering Experiment Station: “Timing Intrusion Management Ensuring Resilience (TIMER)”									●	●				●		●				●		●						

United Technologies Research Ce
Integration of Green Renewable
Securely with Buildings and Elect

University of Arkansas: “Detectin
Devices”

University of Arkansas: “Detectin
Attack (TSA) in PMU Data”

University of Arkansas: “Mitigatir
Attacks in Automatic Generation

University of Illinois at Urbana-Ch
Security Monitoring Protocols an
Energy Delivery Systems”

University of Illinois at Urbana-Ch
Physical Intrusion Detection Inco
Measurements”

University of Illinois at Urbana-Ch
Cybersecurity Incidents in Energy

University of Illinois at Urbana-Ch
Scalable Security Monitoring and
Management for Dynamic Energy

University of Illinois: “Cyber-Phys
Analysis for Cyber-induced Casca
Assessment”

University of Illinois: “Modeling S
Resiliency of EDS Using Software-
Robust Networked Control Syster

University of Illinois: “Robust and
Timing for Power Systems”

University of Illinois: “Secure, Dy
of Microgrid Assets”

OE-Funded RD&D Portfolio	Industry-Defined Roadmap Milestones																											
COMPLETED FOUNDATIONAL PROJECTS (GOAL 3 SUCCESSES) (Titles link to more information on each project)	1.1	1.2	1.3	1.4	1.5	1.6	2.1	2.2	2.3	3.1	3.2	3.3	3.4	3.5	3.6	4.1	4.2	4.3	4.4	4.5	4.6	4.7	5.1	5.2	5.3	5.4	5.5	5.6
Digital Bond: “Portaledge”									●							●												
Argonne National Laboratory (ANL): “A Resilient Self-Healing Cyber Security Framework for Power Grid”				●		●			●				●		●					●			●					
Idaho National Laboratory (INL): “Control System Situational Awareness Technology”									●			●		●		●	●											
Oak Ridge National Laboratory (ORNL): “Automated Vulnerability Detection for Compiled Smart Grid Software”			●							●																		
Oak Ridge National Laboratory (ORNL): “Next-Generation Secure, Scalable Communication Network for the Smart Grid”													●	●	●													
Oak Ridge National Laboratory (ORNL): “Practical Quantum Security for Grid Automation”												●																
Pacific Northwest National Laboratory (PNNL): “Bio-Inspired Technologies for Enhancing Cyber Security in the Energy Sector”									●							●	●											
Pacific Northwest National Laboratory (PNNL): “Supply Chain Integration for Integrity (SCI-FI)”			●	●					●		●																	
Pacific Northwest National Laboratory (PNNL): “Understanding the Special Case of Digital Forensics in Energy Delivery Systems”																			●	●								
Sandia National Laboratory (SNL): “Artificial Diversity and Defense Security (ADDSec)”									●				●	●	●					●		●						
Idaho National Laboratory (INL): “High Level Language Microcontroller”			●								●																	
Sandia National Laboratory: “Trust Anchor/CodeSeal”									●			●				●	●											

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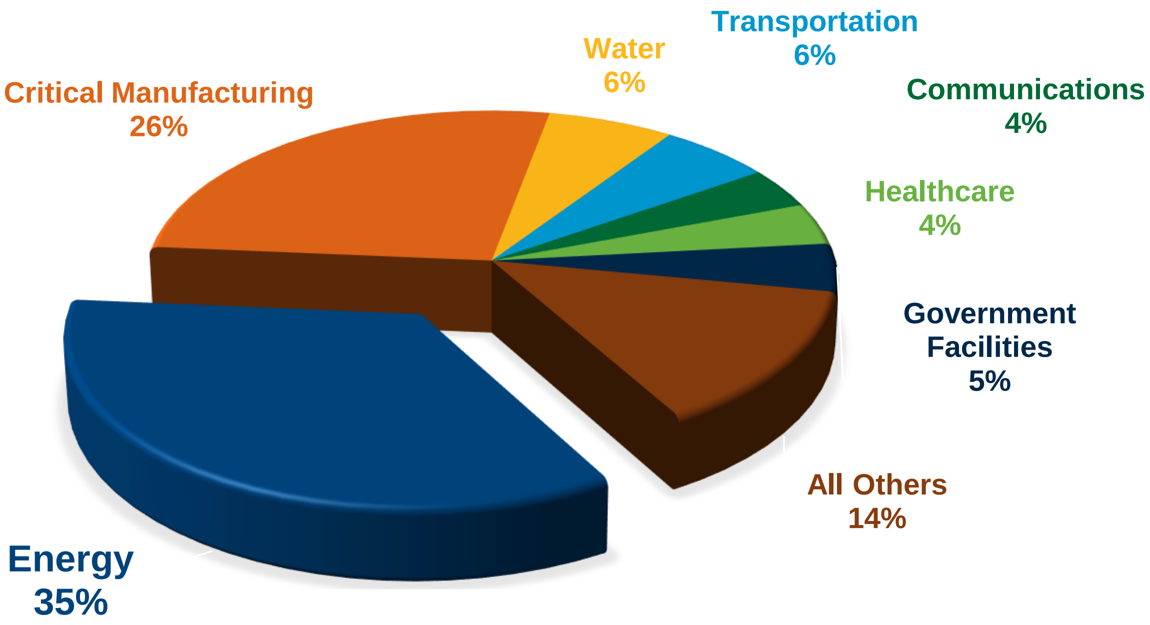
Energy Sector: A Major Target of Cyber Attacks

- → Aggressive attacks are outpacing defense
- → Growing attack surface of U.S. energy infrastructure
- → Public examples of attacks on foreign ICS demonstrate attack knowledge (Ukraine)

Cyber Incidents Reported to DHS ICS-CERT (2013-2015)

Total Reported Incidents: 796



Source: ICS-CERT Monitors (Oct-Dec 2013, Sept 2014-Feb 2015, Nov-Dec 2015)

More Targeted and Sophisticated Attacks

SHODAN
Developed in 2009

- Search engine to find Internet-connected devices (including control system field devices)
- Increase in IoT devices increases potential exploits

STUXNET
July 2010

- Advanced persistent threat (APT) attack on SCADA control systems in Iranian nuclear centrifuge facilities
- Relied on zero-day exploits
- OT centrifuge equipment irreparably damaged by operating out of bounds

METASPLOIT
October 2010 – First SCADA exploit

- Open-source penetration testing tool developed in 2003 to expose vulnerabilities
- First modules to exploit control system devices (PCS and SCADA) released 2011

SHAMOON
August 2012

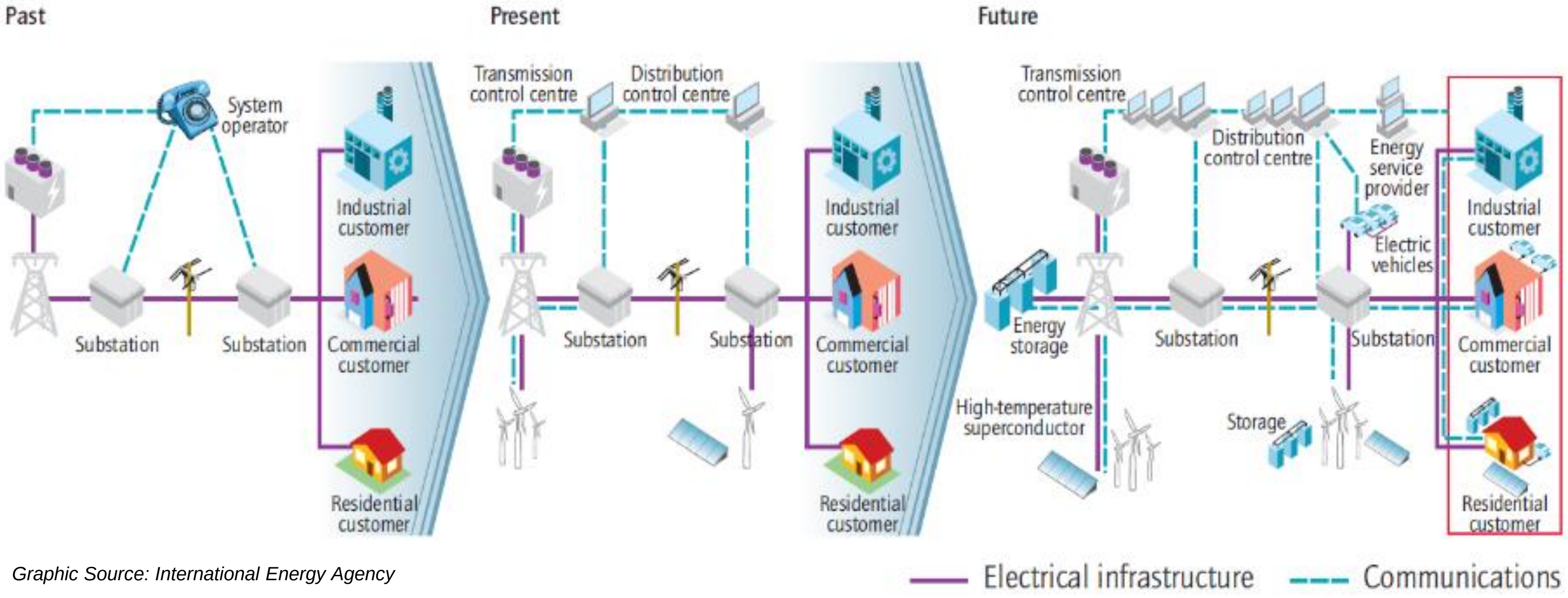
UKRAINE POWER GRID
December 2015

- 225,000 customers lost power in coordinated attack
- SCADA systems targeted and damaged
- Military-like planning and execution
- Utility companies infiltrated 9 months prior to attack
- Launched with easily available attack tools (malware and denial of service)

SHAMOON 2
January 2017

- Virus destroys data on workstations as means to disrupt operations
- 2012 weaponized malware hit 15 state bodies and private companies in Saudi Arabia, wiping >35,000 hard drives of Aramco oil supplier
- Iranian-backed hackers suspected
- 2017 version hit 3 state agencies and 4 private-sector companies in Saudi Arabia

Electricity Delivery System is Evolving to Meet Customer Needs and Changing Generation Mix



Graphic Source: International Energy Agency

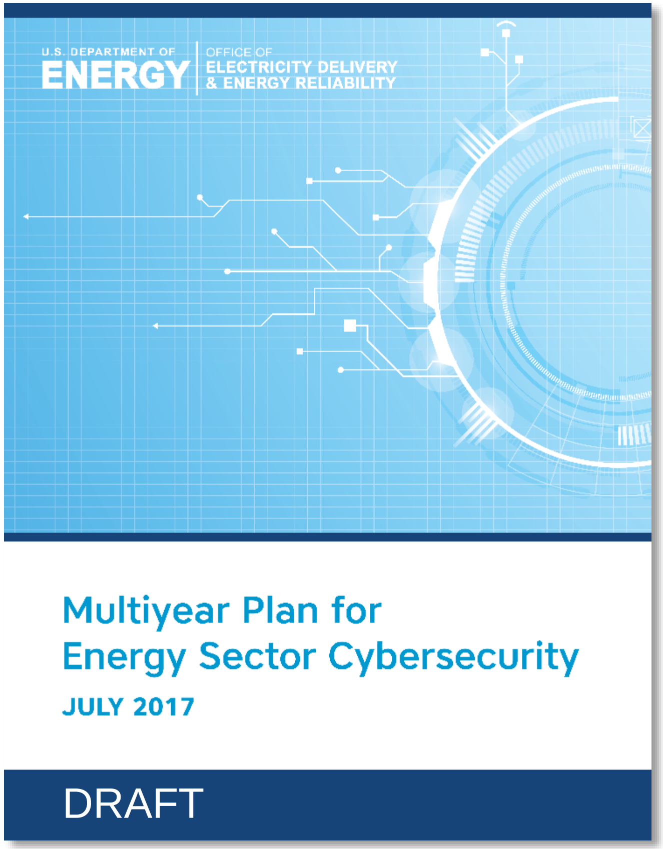
HISTORICAL

- *Human-based grid management*
- *Centralized generation/control*
- *One-way power and info flow*

EMERGING

- *Increasing distributed generation/control*
- *Multi-level coordination*
- *Increasing reliance on sensors and information and control technologies (ICT)*
- *Two-way power and info flow*

DOE Multiyear Plan for Energy Sector Cybersecurity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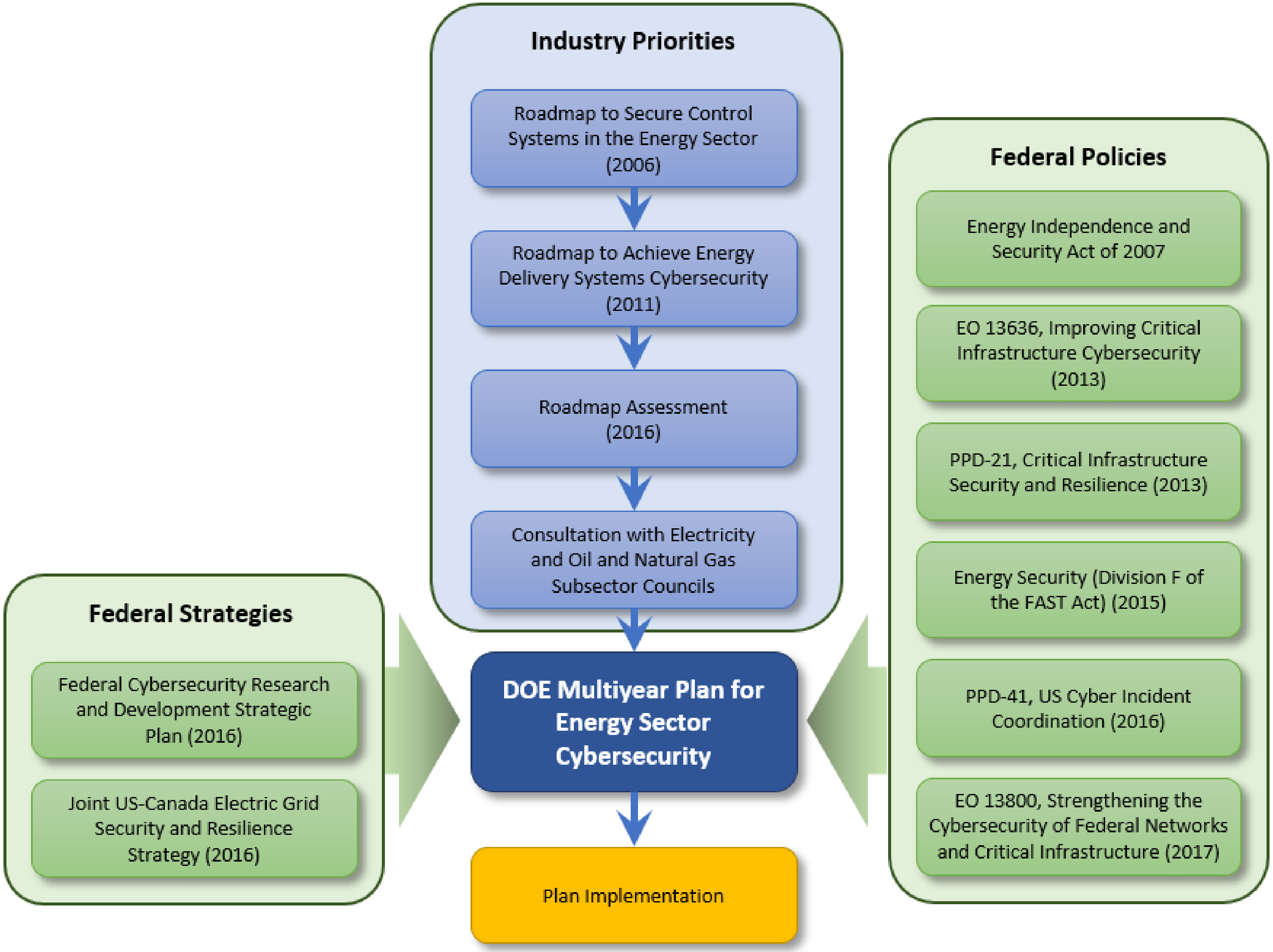
Multiyear Plan for Energy Sector Cybersecurity

JULY 2017

DRAFT

- **DOE's stratety/plan** for partnering with industry to enhance cybersecurity of U.S. energy system
- **Guided by direct industry input** on cybersecurity needs and priorities – complements the Roadmap
- **Market-based approach** encourages investment and cost-sharing of promising technologies and practices
- **Establishes goals, objectives, and activities** to improve both near- and long-term energy cybersecurity

Energy Sector Needs inform DOE Strategy



Industry Priorities

Roadmap to Secure Control Systems in the Energy Sector (2006)

Roadmap to Achieve Energy Delivery Systems Cybersecurity (2011)

Roadmap Assessment (2016)

Consultation with Electricity and Oil and Natural Gas Subsector Councils

Federal Strategies

Federal Cybersecurity Research and Development Strategic Plan (2016)

Joint US-Canada Electric Grid Security and Resilience Strategy (2016)

Federal Policies

Energy Independence and Security Act of 2007

EO 13636, Improving Critical Infrastructure Cybersecurity (2013)

PPD-21, Critical Infrastructure Security and Resilience (2013)

Energy Security (Division F of the FAST Act) (2015)

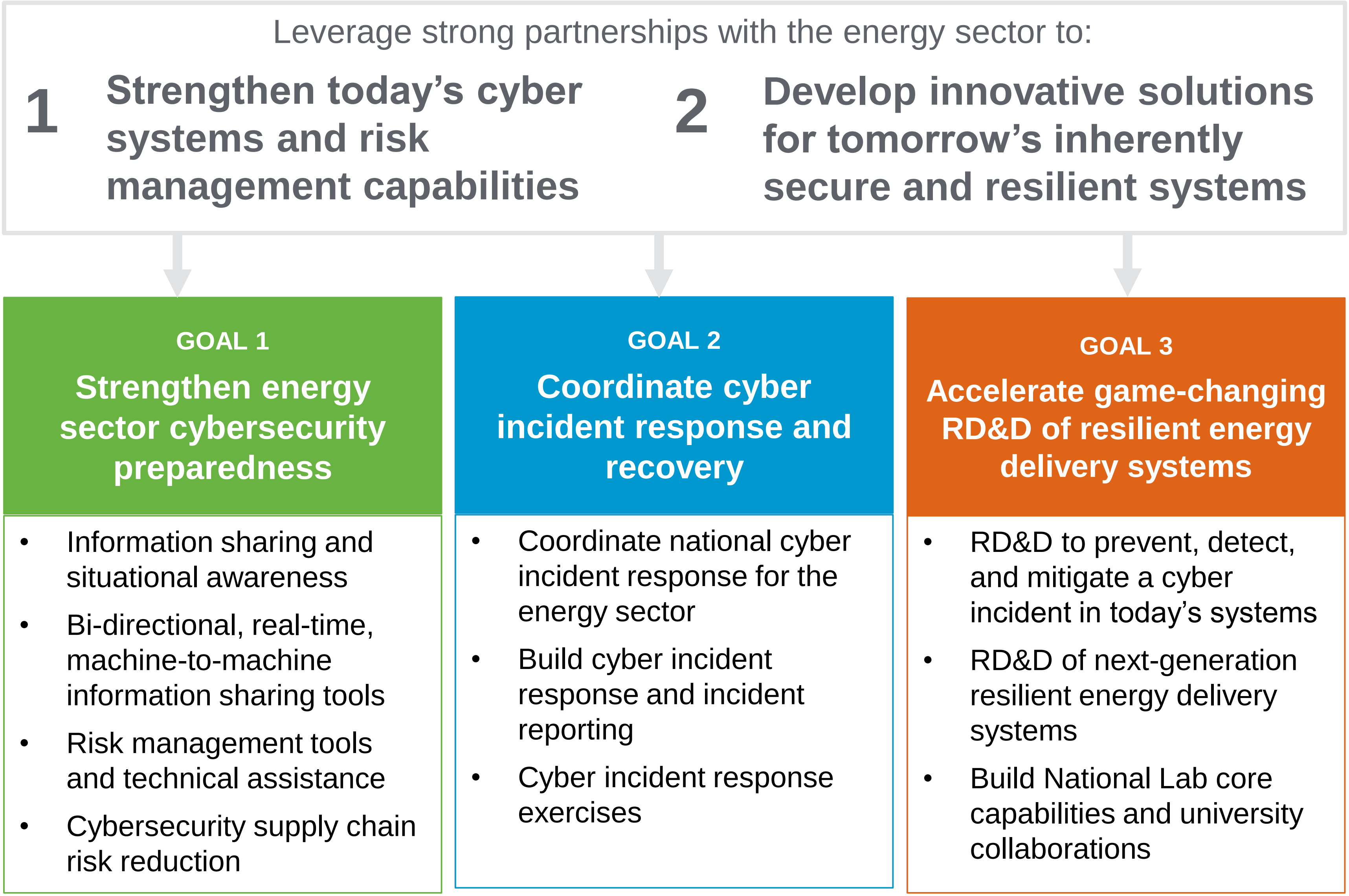
PPD-41, US Cyber Incident Coordination (2016)

EO 13800, Strengthening the Cybersecurity of Federal Networks and Critical Infrastructure (2017)

DOE Multiyear Plan for Energy Sector Cybersecurity

Plan Implementation

DOE’s Strategy for Energy Sector Cybersecurity



Leverage strong partnerships with the energy sector to:

1 Strengthen today’s cyber systems and risk management capabilities

2 Develop innovative solutions for tomorrow’s inherently secure and resilient systems

GOAL 1

Strengthen energy sector cybersecurity preparedness

- Information sharing and situational awareness
- Bi-directional, real-time, machine-to-machine information sharing tools
- Risk management tools and technical assistance
- Cybersecurity supply chain risk reduction

GOAL 2

Coordinate cyber incident response and recovery

- Coordinate national cyber incident response for the energy sector
- Build cyber incident response and incident reporting
- Cyber incident response exercises

GOAL 3

Accelerate game-changing RD&D of resilient energy delivery systems

- RD&D to prevent, detect, and mitigate a cyber incident in today’s systems
- RD&D of next-generation resilient energy delivery systems
- Build National Lab core capabilities and university collaborations

GOAL 1: Strengthen Energy Sector Cybersecurity Preparedness

PRIORITIES AND EXAMPLE OUTCOMES

1. **Enhanced situational awareness and information sharing**
   → Sensors to capture OT data for electricity and oil and natural gas, private-sector clearances, and intelligence information sharing

2. **Real-time, machine-to-machine cyber defense**
   → Distributed malware analysis platform that safely enables automated and manual analysis of malicious code

3. **Risk management tools, guidelines, and training**
   → Enhance state-federal coordination (Energy Assurance Plans) and planning (exercises and workforce), and update Cybersecurity Capability Maturity Model (C2M2); expand oil and gas emphasis

4. **Improved understanding of cyber supply chain risks**
   → Collaborative public-private partnerships to gain insight into systemic vulnerabilities

Cybersecurity Risk Information Sharing Program (CRISP)

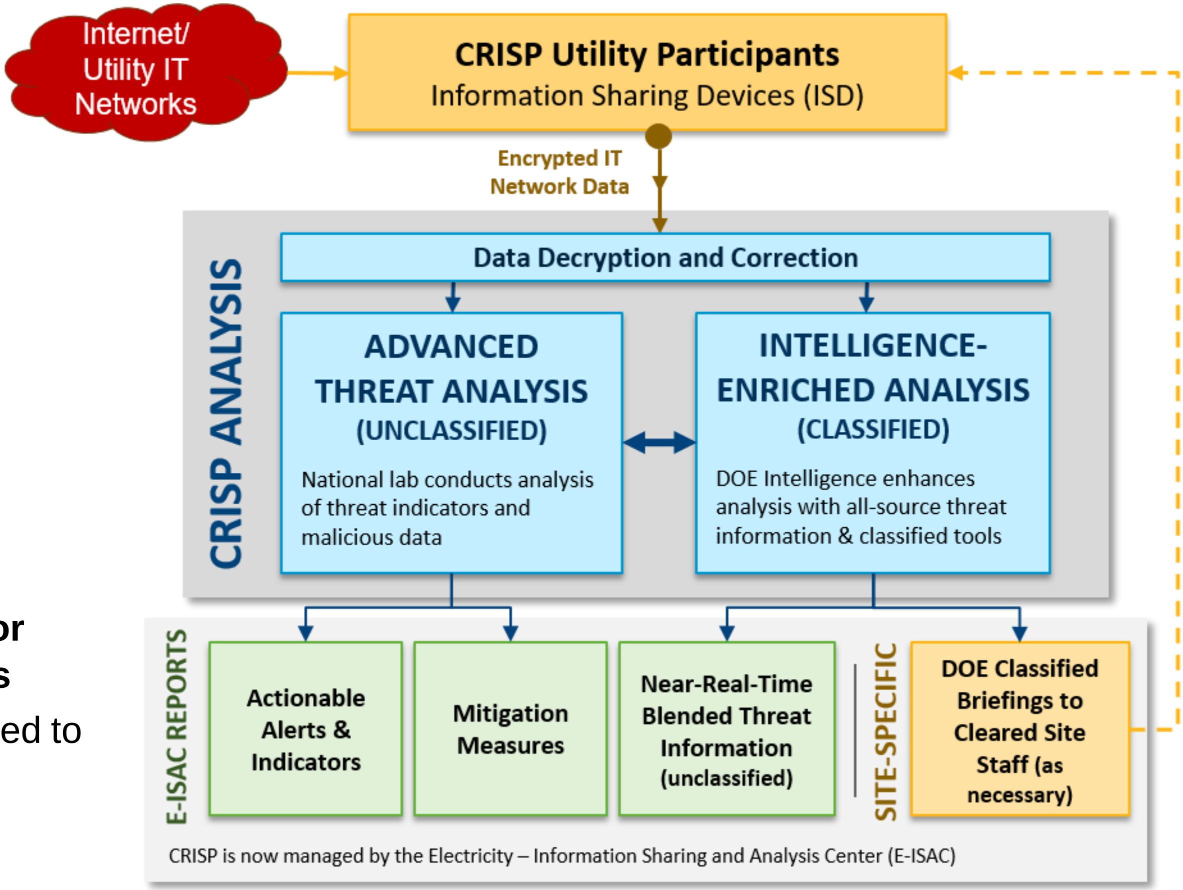
Identify threat patterns across the electric industry by analyzing real-time traffic using U.S. Intelligence capabilities

Approach

- Unique platform enables energy companies to voluntarily share IT network data
- Delivers cyber threat information – enriched with intelligence insights and tools – to help identify malicious activity and prioritize mitigation

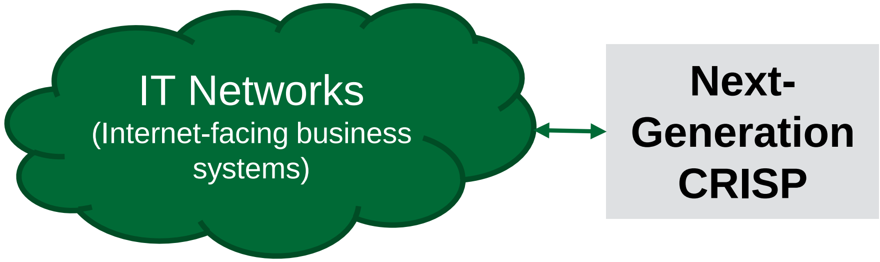
Industry Impact

- **Participating utilities account for ~75% of U.S. electric customers**
- Developed by DOE and transitioned to the E-ISAC starting in 2014
- Allows IT data sharing for threat mitigation


Internet/ Utility IT Networks
CRISP Utility Participants
Information Sharing Devices (ISD)
Encrypted IT Network Data
CRISP ANALYSIS
Data Decryption and Correction
ADVANCED THREAT ANALYSIS (UNCLASSIFIED)
National lab conducts analysis of threat indicators and malicious data
INTELLIGENCE-ENRICHED ANALYSIS (CLASSIFIED)
DOE Intelligence enhances analysis with all-source threat information & classified tools
E-ISAC REPORTS
Actionable Alerts & Indicators
Mitigation Measures
Near-Real-Time Blended Threat Information (unclassified)
SITE-SPECIFIC
DOE Classified Briefings to Cleared Site Staff (as necessary)

CRISP is now managed by the Electricity – Information Sharing and Analysis Center (E-ISAC)

Advanced Tools to Enhance Threat Detection and Information Sharing



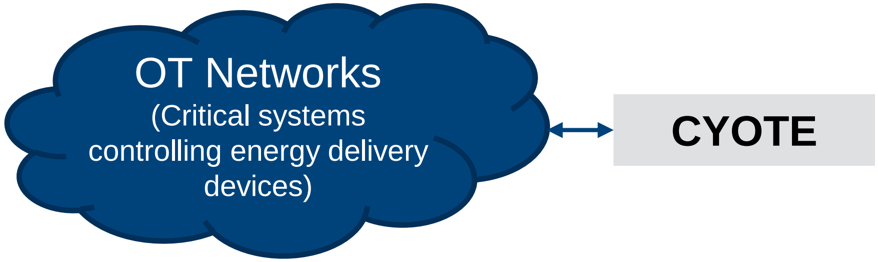
IT Networks

(Internet-facing business systems)

Next-Generation CRISP

Cyber Analytics Tools and Techniques (CATT)

- **Improve the speed, value, and cost of CRISP** analysis, reports, and mitigations
- **Improve IT threat detection** by adding new analytic tools and capabilities to CRISP platform (working with PNNL, INL, ORNL, ANL)
- **Better leverage U.S. Intelligence** by enabling direct analysis of CRISP data in secure government storage using unique and sophisticated intelligence tools



OT Networks

(Critical systems controlling energy delivery devices)

CYOTE

CYbersecurity for the Operational Technology Environment (CYOTE)

- **Pilot a two-way OT data sharing and analysis capability** (similar to CRISP) with 4 utilities for the complex OT environment – where threat monitoring and detection is not widespread
- **Map the OT cyber "kill chain"** – the attack pathways hackers could use to compromise utility OT systems
- **Identify OT network sensors** that monitor the right data and meet demanding OT network requirements

Working With Small and Medium-Sized Utilities (over 2,000) to Enhance Cybersecurity

Program Objectives

- Engage with public power distribution utilities to better understand cyber security posture and implement programs to improve

Industry Impact

- Support smaller distribution utilities that typically have limited resources invest in cyber resilience and stay ahead of rapidly evolving sophisticated cyber threats

Approach

- Work through leading trade associations to provide resources, training, and technical assistance to member utilities
- Conduct cyber security risk assessments
- Conduct onsite vulnerability assessments
- Pilot existing or emerging cybersecurity technologies
- improve/develop process to better share threat information

Partners

APPA – Trade association for >2,000 local- and state-owned utilities serving >48 million Americans

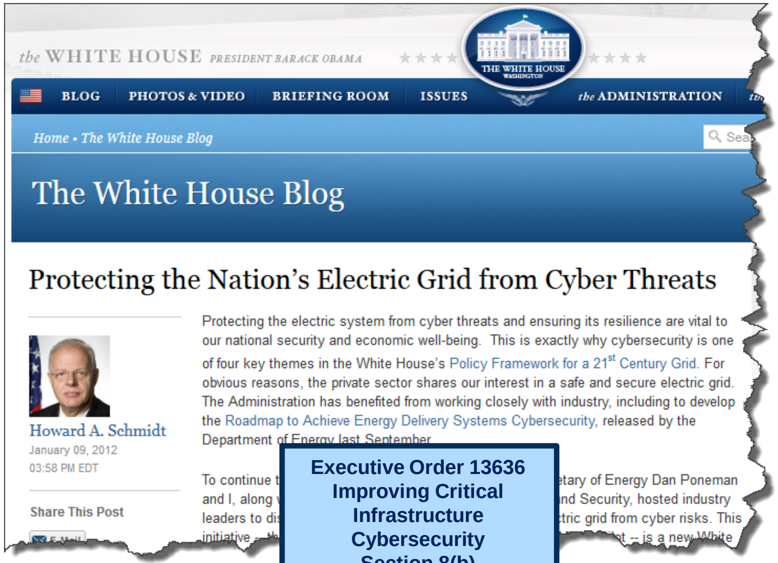
- APPA partners include Axio and Energetics, Inc.

NRECA – Trade association for >900 not-for-profit rural electric cooperatives and public power districts serving >42 million customers in 47 states

- **R3C – The Rural Cooperative Cyber Security Capabilities Program**
- Partners include Cigital and BlackByte Cyber Security LLC

Cybersecurity Capability Maturity Model (C2M2)

- Public-private partnership program to help energy sector asset owners and operators assess their capabilities and continuously improve their cybersecurity posture
- C2M2 strengthens organizational cybersecurity capabilities; shares best practices, and employs the National Institute of Standards and Technology (NIST) Cybersecurity Framework.
- The C2M2 helps organizations – regardless of size, type, or industry to evaluate, prioritize, and improve their own cybersecurity capabilities.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Protecting the Nation's Electric Grid from Cyber Threats

Howard A. Schmidt
January 09, 2012
03:58 PM EDT

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Protecting the electric system from cyber threats and ensuring its resilience are vital to our national security and economic well-being. This is exactly why cybersecurity is one of four key themes in the White House's Policy Framework for a 21st Century Grid. For obvious reasons, the private sector shares our interest in a safe and secure electric grid. The Administration has benefited from working closely with industry, including to develop the Roadmap to Achieve Energy Delivery Systems Cybersecurity, released by the Department of Energy last September.

To continue t … etary of Energy Dan Poneman
and I, along … nd Security, hosted industry
leaders to di … tric grid from cyber risks. This
initiative -- th … t -- is a new White

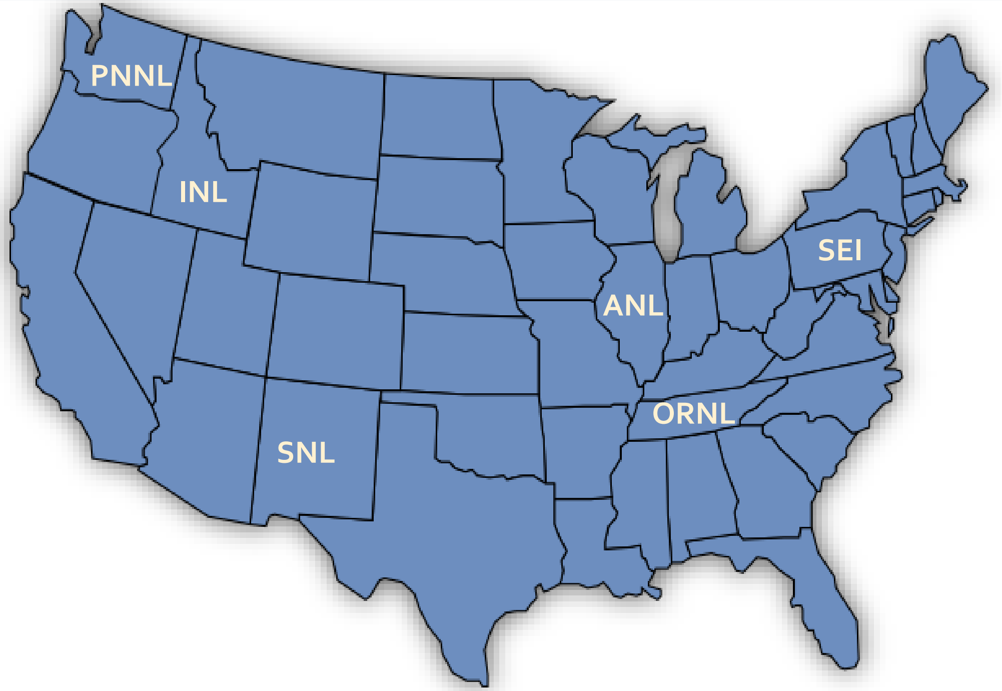
Executive Order 13636
Improving Critical Infrastructure Cybersecurity
Section 8(b)

"Sector-Specific Agencies, in consultation with the Secretary and other interested agencies, shall coordinate with the Sector Coordinating Councils to review the Cybersecurity Framework and, if necessary, develop implementation guidance or supplemental materials to address sector-specific risks and operating environments."

GOAL 2: Coordinate Cyber Incident Response and Recovery

1. **Coordinated national cyber incident response for the energy sector**
   - Fulfill our SSA responsibilities
   - Educate stakeholders on processes, roles, responsibilities, and resources; integrated into the DOE unified command structure
2. **Build additional Cyber incident response capability**
   - Build energy specific OT teams and capability to support cyber incident response
   - ESF-12 responders across the nation trained on coordination needs for intersection of cyber incidents and physical response through FEMA
   - Improve cyber incident reporting process for private-sector partners
3. **Annual cyber incident response exercises with industry and federal/state/local stakeholders**

DOE Cyber Response Partnership (CRP) Teams



Vision: Mission-ready access to energy sector specific cybersecurity expertise, capabilities, and resources for cyber incident response

- **Deliver expert assistance to industry cyber victims**
- **Establish energy sector cyber response structure and processes**
- **Agreements in place with 5 National Labs**
- **Scalable technical assistance capability**

GOAL 3: Accelerate Game-Changing RD&D of Resilient Energy Delivery Systems

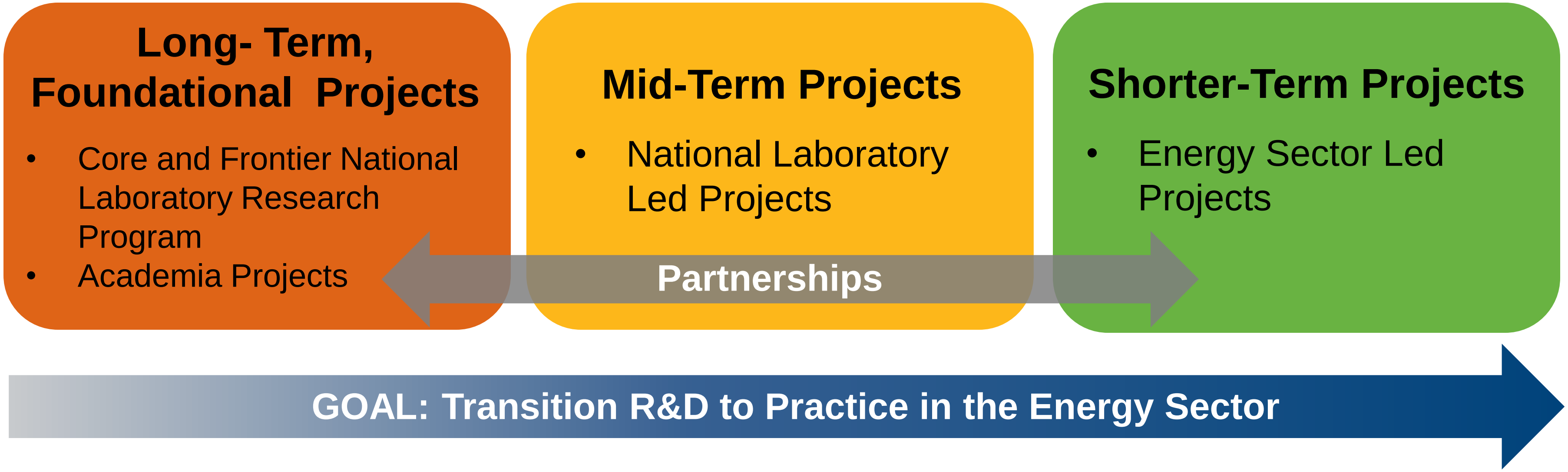
PRIORITIES AND PATHWAYS

Research, develop, and demonstrate tools and technologies to:

1. **Prevent, detect, and mitigate cyber incidents in *today's energy delivery systems***
   - Decrease the cyber attack surface and block attempted misuse
   - Decrease the risk of malicious components inserted in the supply chain
   - Enable real-time, continuous cyber situational awareness
   - Automatically detect attempts to execute a function that could de-stabilize the system when the command is issued
   - Characterize cyber incident consequences and automate responses

2. **Change the game so that *tomorrow's resilient energy delivery systems* can survive a cyber incident**
   - Anticipate future grid scenarios and design cybersecurity into systems from the start
   - Enable power systems to automatically detect and reject a cyber attack, refusing any commands/actions that do not support grid stability
   - Build strategic partnerships and core capabilities in National Labs

Cybersecurity for Energy Delivery Systems (CEDS) R&D Program Approach



Long- Term, Foundational Projects

- Core and Frontier National Laboratory Research Program
- Academia Projects

Mid-Term Projects

- National Laboratory Led Projects

Shorter-Term Projects

- Energy Sector Led Projects

Partnerships

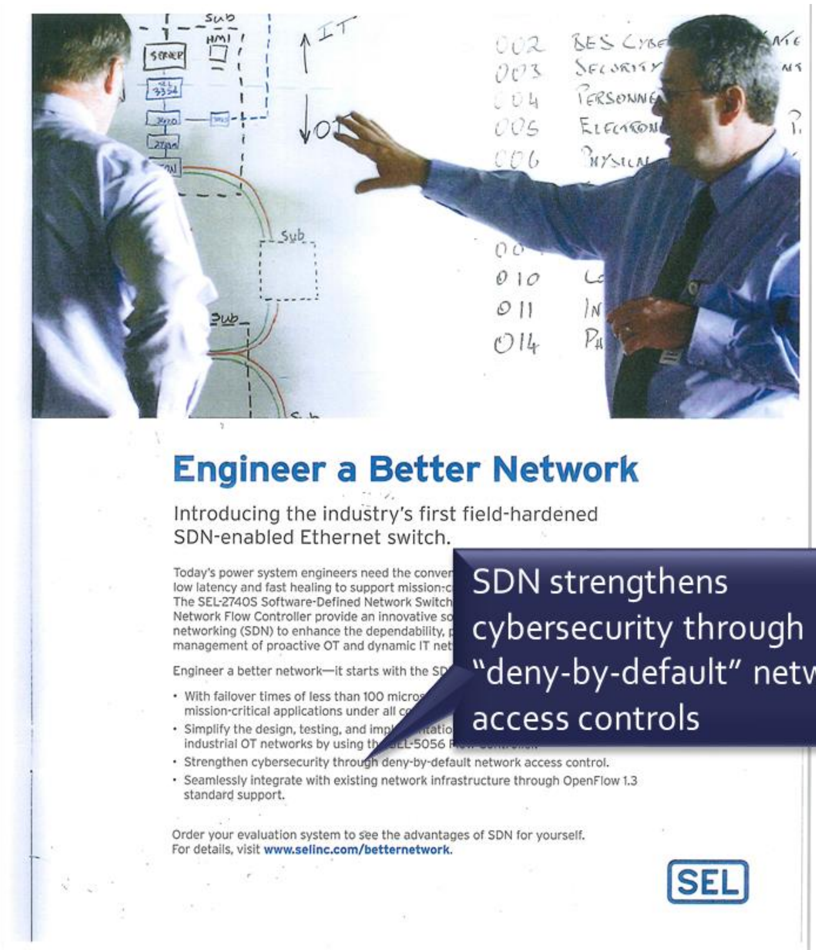
GOAL: Transition R&D to Practice in the Energy Sector

- Funds innovative R&D in areas critical for national security where the industry lacks a clear business case
- Builds R&D pipeline through partnerships with energy sector utilities, suppliers, universities and national laboratories

- **Successfully transitioned more than 30 tools and technologies used TODAY** to better secure U.S. energy infrastructure
- **Over 990 utilities in 50 states have purchased technologies developed by CEDS**

R&D Successes Include Advanced Technologies That Enhance Cybersecurity AND Lower Operating Costs

Commercially Available in FY16



Engineer a Better Network

Introducing the industry's first field-hardened SDN-enabled Ethernet switch.

Today's power system engineers need the conver
low latency and fast healing to support mission-c
The SEL-2740S Software-Defined Network Switch
Network Flow Controller provide an innovative so
networking (SDN) to enhance the dependability, p
management of proactive OT and dynamic IT net

Engineer a better network—it starts with the SD

- With failover times of less than 100 micros
  mission-critical applications under all co
- Simplify the design, testing, and imp ntatio
  industrial OT networks by using th EL-5056
- Strengthen cybersecurity through deny-by-default network access control.
- Seamlessly integrate with existing network infrastructure through OpenFlow 1.3 standard support.

Order your evaluation system to see the advantages of SDN for yourself.
For details, visit www.selinc.com/betternetwork.

SEL

SDN strengthens cybersecurity through "deny-by-default" network access controls

Reference: UTC Journal, 3rd Quarter 2016

Software Defined Networking (SDN):

- Monitors network traffic using a whitelist approach and quarantines unauthorized or suspicious devices
- Improves network performance with <100uS network heal times
- Market-ready solution resulting from strong partnerships and real-world demonstration

SEL-led research partnership with:

- Pacific Northwest National Laboratory (PNNL)
- University of Illinois at Urbana Champaign
- Ameren

SEL SCHWEITZER ENGINEERING LABORATORIES

Ameren

Pacific Northwest NATIONAL LABORATORY

Cybersecurity Intrusion Detection and Monitoring for Field Area Networks

- **Detects anomalies and attacks in smart grid wireless mesh networks** for smart meters and distribution automation
- Demonstrated at 4 utilities and commercialized as SecureSmart technology

- **Now used today** to give operators great visibility into critical smart grid networks
- Deployments -

PROJECT LEAD

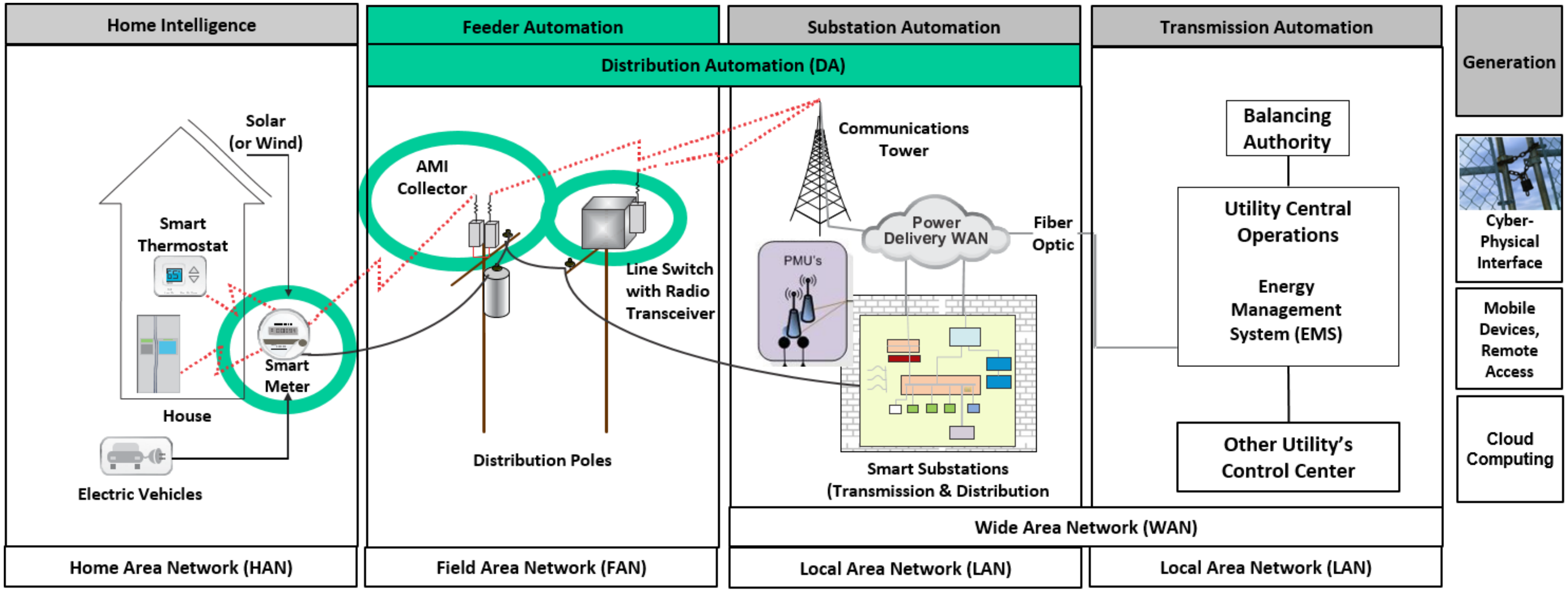
Applied Communication Sciences

Now Vencore Labs

PARTNER

SMUD Sacramento Municipal Utility District

The Power To Do More.®



Using Physics of Electric Power Flow to Thwart Cyber Attacks

CODEF – Collaborative Defense of Transmission and Distribution Protection and Control Devices

- **Automatically detects and rejects malicious commands** that could jeopardize physical grid operations if acted on
- Anticipates the effects of each command and only enacts those that will **support grid stability**
- **Demonstrated transmission level cybersecurity functions** at Bonneville Power Administration
- Four CODEF functions detected and blocked cyber attacks targeting substation circuit breakers and intelligent electronic devices

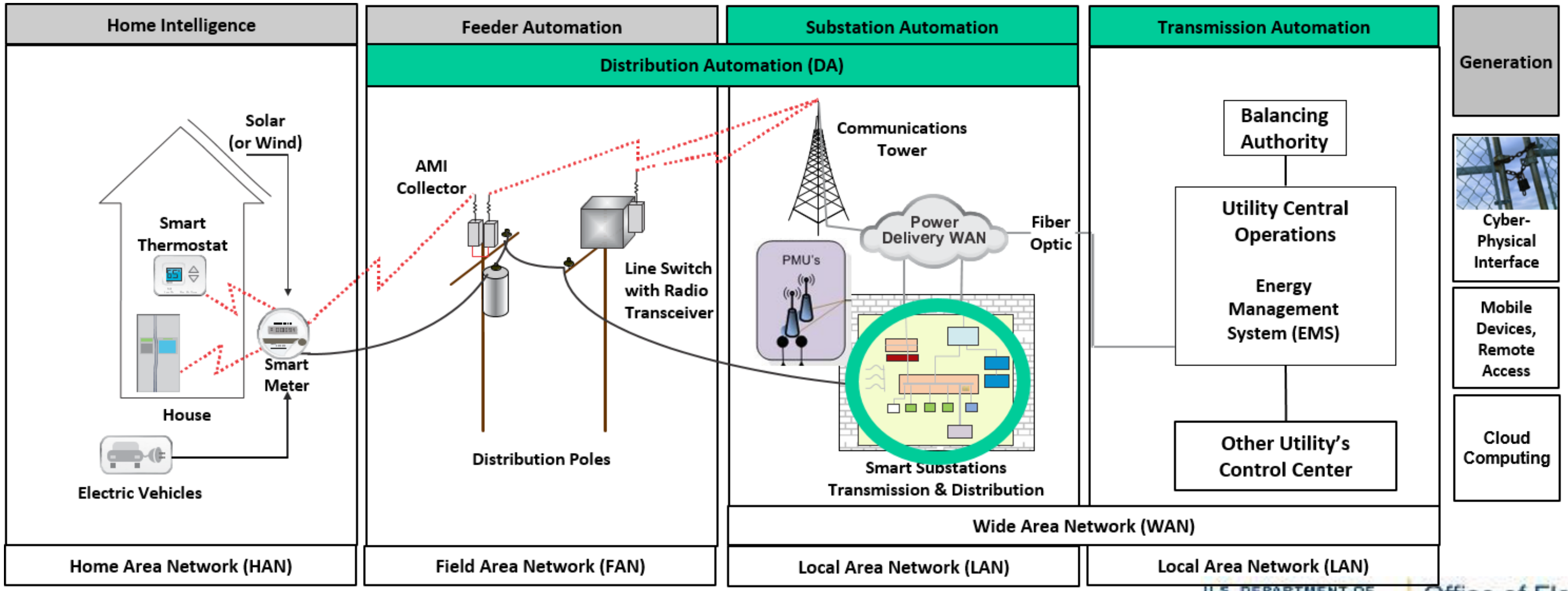
PROJECT LEAD

ABB

PARTNERS

Bonneville POWER ADMINISTRATION

ILLINOIS



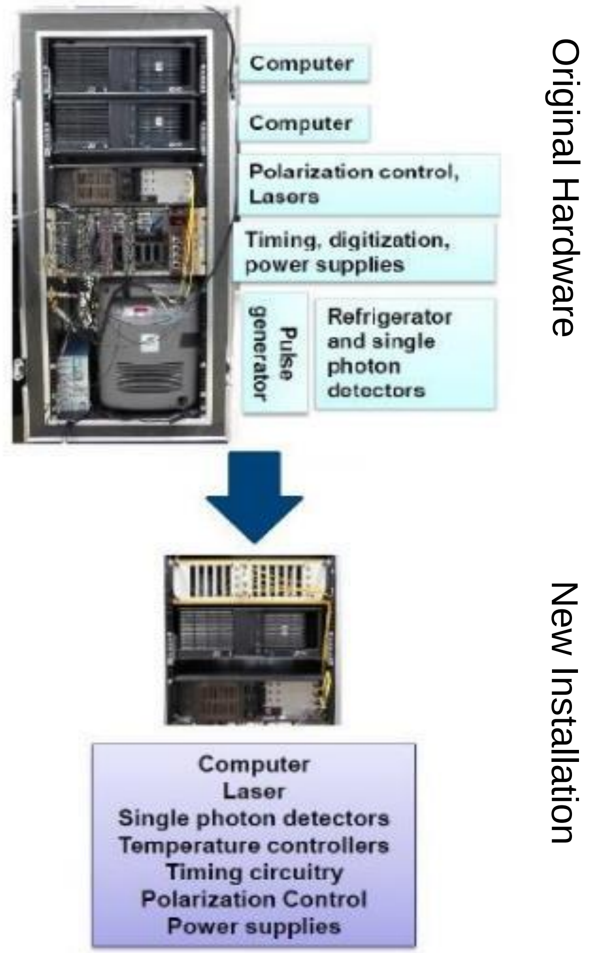
Quantum Encryption Key Distribution Techniques

Quantum Key Distribution Benefits:

- **LANL is developing Quantum Security Modules (QSMs) that securely transmit and receive data from grid control devices encrypted with quantum keys**
- **When an adversary attempts to intercept an encryption key, it causes an unavoidable distortion in the signal that alerts operators**
- **Recent technology advances reduced the facility footprint and improved the performance:**
  - Size of the installed hardware reduced by a factor of five
  - Operating range doubled and increased the key generation rate by 73%

Los Alamos
NATIONAL LABORATORY
EST.1943

Reduced Footprint of Quantum Communication System



Original Hardware

Computer

Computer

Polarization control, Lasers

Timing, digitization, power supplies

Pulse generator

Refrigerator and single photon detectors

New Installation

Computer
Laser
Single photon detectors
Temperature controllers
Timing circuitry
Polarization Control
Power supplies

Developing Strategic Cybersecurity Core Capabilities at DOE National Laboratories

National Laboratory	CEDS R&D Strategic Core Capability Examples
ANL	Power system applications that are cyber-aware
BNL	Cybersecurity for energy sector forecasting data
INL	Cyber-informed development and engineering for next generation resilient energy delivery systems.
LANL	Quantum Key Distribution (QKD) for the energy sector
LBNL	Detecting cyber incidents in the distribution-level grid
LLNL	Reliable active mapping for operational networks
ORNL	Detecting adversarial presence in energy delivery control systems
PNNL	Enhanced situational awareness using federated power system data
SNL	Energy delivery systems that confront the adversary with a moving target

DOE Awards for Next Generation Cybersecurity Technologies and Tools

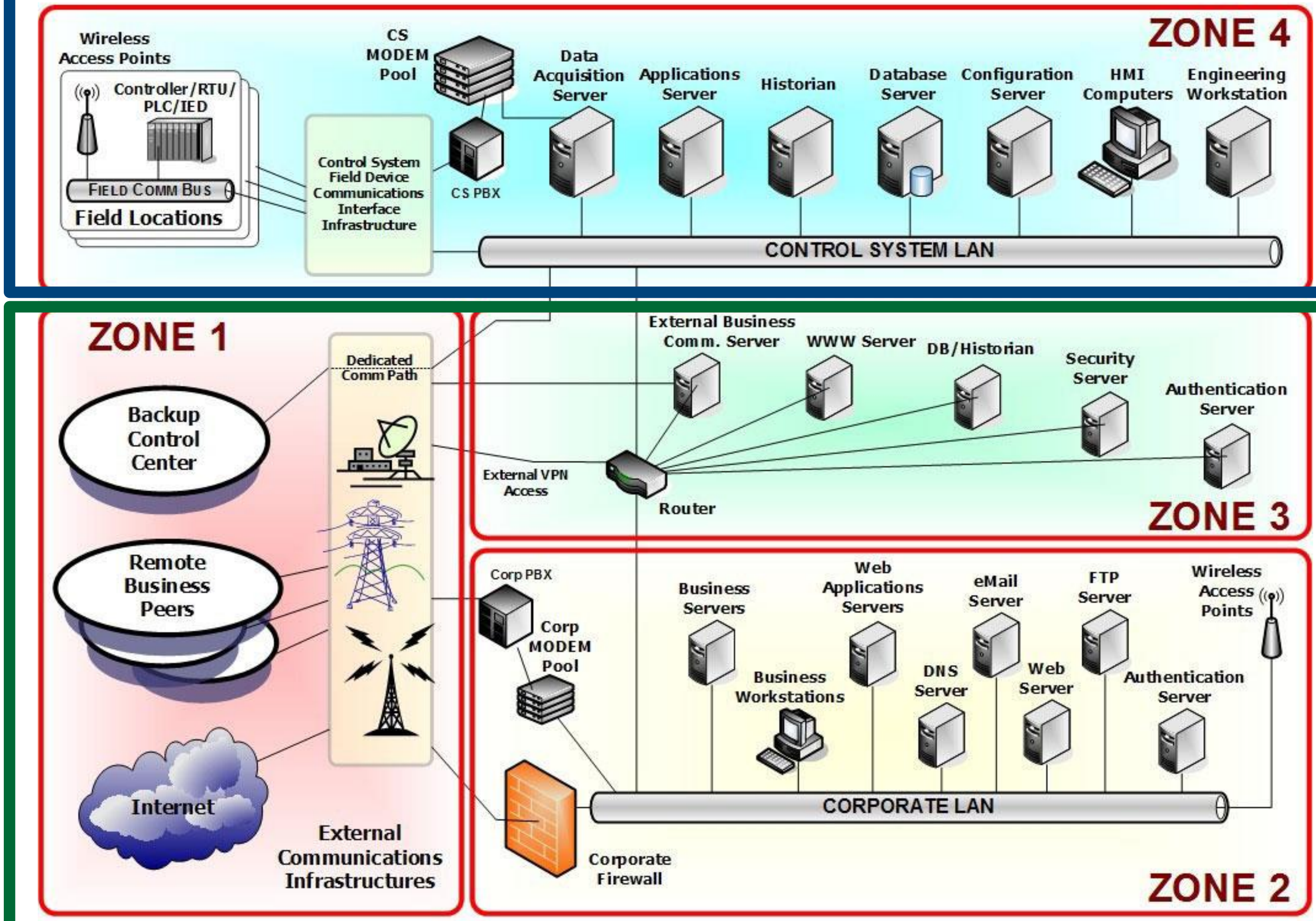
DOE awarded $20 million for 20 new projects to

- Support critical early stage R&D of next-generation tools and technologies
- Build capacity throughout the energy sector for day-to-day operations such as cyber-threat information sharing

- **Next-Generation Attack-Resilient Electricity Distribution Systems**
- **(FIT) Firmware Indicator Translation**
- **Adaptive Control of Electric Grid Components for Cyber-Resiliency**
- **Cyber Interconnection Analysis for High Penetration of DER**
- **GPS Interference Detection**
- **Secure SCADA Protocol Characterization and Standardization**
- **Quantum Key Distribution for the Energy Sector: Trusted Node Relays and Networks**
- **(Module-OT) Modular Security Apparatus for Managing Distributed Cryptography for Command & Control Messages on Operational Technology (OT) Networks**
- **DarkNet**
- **Quantum Physics Secured Communications for the Energy Sector**
- **Energy Delivery Systems with Verifiable Trustworthiness**
- **Malware Operational Mitigation (MOM)**
- **KISS (Keyless Infrastructure Security Solution)**
- **MEEDS (Mitigation of External-exposure of Energy Delivery System Equipment)**
- **SASS-E (Safe & Secure Autonomous Scanning Solution for Energy Delivery Systems)**
- **SDN4EDS (Software Defined Networking for Energy Delivery Systems)**
- **UUDEX (Universal Utility Data Exchange)**
- **VERITAS (Vulnerability, Exploit, and Risk Identification Toolset and Source)**
- **Containerized Application Security for Industrial Control Systems**
- **Survivable ICS**

THE END

Today's Energy Delivery Systems: More Complex with an Increasing Attack Surface



Operational Technology (OT) Environment

Controls physical energy delivery processes

Information Technology (IT) Environment

Includes Internet-connected business networks

Managing Cyber Risks Must Be a Shared Responsibility

Security Roles and Responsibilities for Physical and Cyber Risks

Physical Risks

Fed Govt.

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Private Sector

- Nuclear Attack
- Natural Disasters
- Active Shooter
- Insider Threats
- Accidents
- Theft and Vandalism

Cyber Risks

- Nation-State Attack
- Terrorists
- Organized Crime
- Hacktivists
- Script Kiddies
- Accidents

Fed Govt.

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Private Sector

Source: NIAC Cyber Scoping Study, February 2017