Resilient Energy Systems Mission Campaign

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Mission Campaigns: Developing Key Capabilities and Overcoming High-Risk Technical Hurdles

Purpose: Mission Campaigns provide an agile, intentional process to bridge Science, Technology & Engineering (ST&E) R&D to mission application impact.

They are integrated, multi-disciplinary portfolios of LDRD-funded projects focused on addressing current and future national security needs.

The nation's energy and other critical infrastructure are under increasing threat of attack

"DOE is making financing available for projects that improve resilience and expand transmission capacity across the electrical grid, so we can reliably move clean energy from places where it's produced to places where it's needed most. [...] These investments will make our power system **more resilient against threats and more reliable** as we increase our clean energy capacity, creating thousands of jobs in the process."

– **Jennifer Granholm**, *Sec. Dept. of Energy, April 2021*

"Connecting forgotten communities, capping wells that are dangerous, **strengthening our power grid to make it more resilient to extreme weather changes:** These are investments — these are investments our country has never fully made. Now we are."

– **Joe Biden**

THREATS

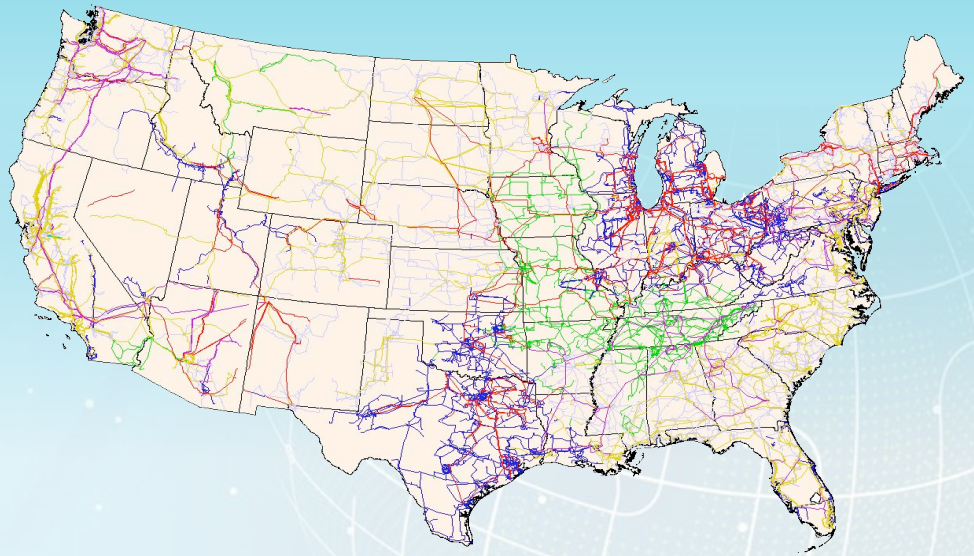
EMP/GMD

Cyber-Physical Attack

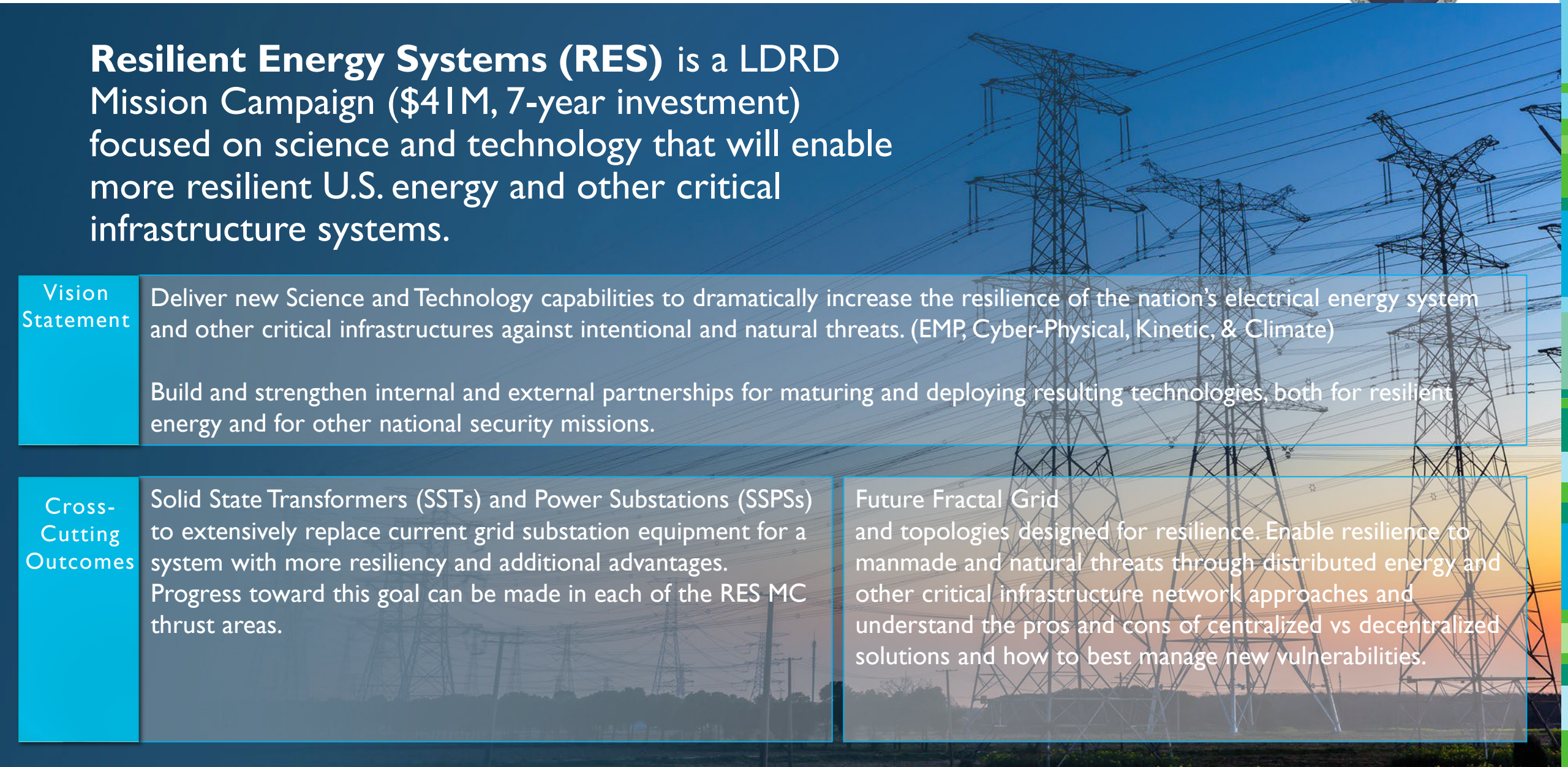
Kinetic Attack

Climate Change

US POWER GRID



RESILIENT ENERGY SYSTEMS MISSION CAMPAIGN



Resilient Energy Systems (RES) is a LDRD Mission Campaign ($41M, 7-year investment) focused on science and technology that will enable more resilient U.S. energy and other critical infrastructure systems.

Vision Statement	Deliver new Science and Technology capabilities to dramatically increase the resilience of the nation's electrical energy system and other critical infrastructures against intentional and natural threats. (EMP, Cyber-Physical, Kinetic, & Climate) Build and strengthen internal and external partnerships for maturing and deploying resulting technologies, both for resilient energy and for other national security missions.
Cross-Cutting Outcomes	Solid State Transformers (SSTs) and Power Substations (SSPSs) to extensively replace current grid substation equipment for a system with more resiliency and additional advantages. Progress toward this goal can be made in each of the RES MC thrust areas. Future Fractal Grid and topologies designed for resilience. Enable resilience to manmade and natural threats through distributed energy and other critical infrastructure network approaches and understand the pros and cons of centralized vs decentralized solutions and how to best manage new vulnerabilities.

RES Mission Campaign R&D Thrusts & Planned Outcomes

1. Science of Vulnerabilities

What are the vulnerabilities and physical failure mechanisms of node electrical hardware and control equipment for intentional and sophisticated kinetic, EMP, GMD, and cyber attacks?

2. Materials, Device, and Cyber Innovation

What novel materials, devices, and cyber advances will most cost-effectively increase resilience?

3. System-Level Threat-Informed Computational Science

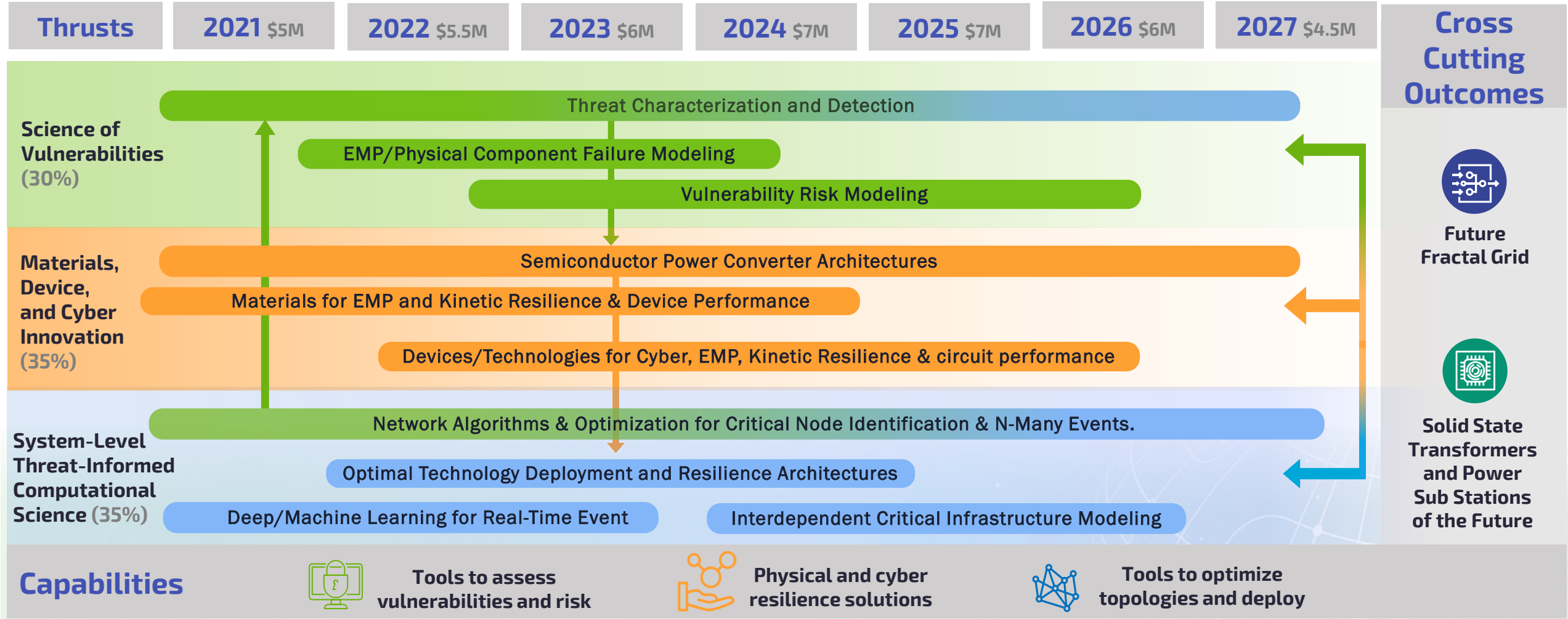
What are the critical elements of the electrical energy system, mechanisms of cascading failures, and potential approaches for a more resilient/secure architecture?

RESEARCH OUTCOMES:

1. *New tools to assess vulnerabilities and risk in the energy and critical infrastructure systems*
2. *Physical and cyber solutions to reduce those risks*
3. *Tools to analyze and assess how to optimize and deploy solutions for maximum benefit (economics, security, resilience)*

LEGACY: *An integrated portfolio of research across three thrusts* that will result in capabilities that can be harvested to *address this threat and others*

Current LDRD Roadmap & Portfolio



RES MC FY23 Project Portfolio

Project Ended
Continuing Project
New-Start Project

Thrust 1: Science of Vulnerabilities	**Thrust 2:** Materials, Devices and Cyber Innovation	**Thrust 3:** System-Level Threat-Informed Computational Science
ADROC: Advancing Resilience of Control Systems – Jamie Thorpe	LMI3 SST Technology – Jeff Koplow	Dynamics-Informed Optimization for Resilience – Bryan Arguello
Dynamic Monitoring to Analyze Grid Vulnerability to Fire – Holly Eagleston	HARMONIE SPS – Shamina Hossain McKenzie	Power-System Modeling for Grid Restoration – Kevin Stamber
Low-Cost HEMP Testing – Tyler Bowman	Signal-Based Fast-Tripping Protection Scheme – Matt Reno	REDLY – Mike Eydenberg
Hallucinating Canaries – Abe Clements	Nano Structural Granular Metals – Laura Biedermann	Critical Node Identification – Bryan Arguello
griDNA: Shamina Hossain-McKenzie	Discovery of New Materials by AI – Dale Huber	SHAZAM – Mike Ropp
Risk to Electric Power System Infrastructure from E2 – Ross Guttromson	AC to AC SST – Jack Flicker	Power System Vulnerability Identification & Defense through DRL – Drew Levin
OT GRITY: Moses Ike	SST Architecture & Control Compensation – Lee Rashkin	DRE: Designing for Resilience through Emulation – Jamie Thorpe
RHAPSODI: Adam Williams	STAHRS – Ryan Elliot	Dynamic & Uncertainty Aware Infrastructure Modeling – Kate Klise

Resilient Energy Systems Legacy

To make the R&D impactful we need to do more than just excellent research.

Partner	Test	Inform	Develop	Deploy
Leverage, collaborate and Integrate	Leave a legacy of enduring capability through RES Testbed development	Promulgate research results to a broad community	Cultivate new talent through a student pipeline	Mature and deploy technologies

Established multiple new areas of significant, impactful research:

1. Solid State Transformer (SST) R&D enabling a transformation to a new resilient energy system
2. Electromagnetic Pulse Protection (EMP) Device R&D
3. Cybersecurity for the grid

Secure Adaptable Grid Experimentation (SAGE) Facility - A unique large-scale medium voltage experimentation capability required to develop the next generation of grid/energy system components

Critical Internal and External partnerships

RES LDRD projects captures direct projected **follow-on funding totaling** **$100M**

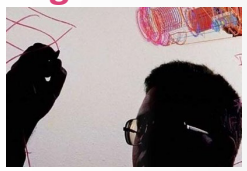
Key Programs:

Transformer Resilience & Advanced Components (TRAC)
Cybersecurity, Energy Security, Emergency Response (CESER)
Advanced Research Program Agency – Energy (ARPA-E)
DOE Office of Electricity Energy Storage Program

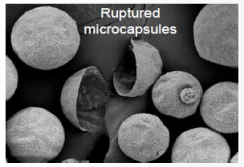
RES Mission Campaign Internal Partnerships

CIS

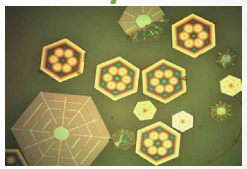
Engineer. Sci.



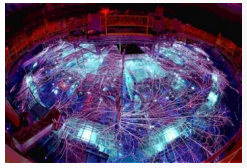
Material Sci.



Nano/Micro



REHEDS



SCIENCE OF VULNERABILITIES

Cyber Threat Characterization
- Information Operations (5600)
- Computation For National Security (8700)

EMP/Physical Component Failure Modeling
- Radiation & Electrical Sciences (1300)
- Weapons & Force Protection (6500)

Risk-based Methods for Vulnerabilities
- Computing Research (1400)
- Nuclear Fuel Cycle & Grid Modernization (8800)

MATERIALS, DEVICE, AND CYBER INNOVATION

Materials for Cyber, EMP & Kinetic Resilience
- Materials, Physical, & Chemical Sciences (1800)
- Chemical, Combustion & Materials Sciences (8300)

Device Technol. for Cyber, EMP & Kinetic Resilience
- Radiation & Electrical Sciences (1300)
- Microsystem Engineering & Science Applications (5200)

Semiconductor Power Conversion Architectures
- Materials, Physical, & Chemical Sciences (1800)
- Nuclear Fuel Cycle & Grid Modernization (8800)

SYSTEM-LEVEL THREAT-INFORMED COMPUTATIONAL SCIENCE

Algorithms & Optimiz. For Critical Node Identification
- Nuclear Fuel Cycle & Grid Modernization (8800)
- Computation For National Security (8700)

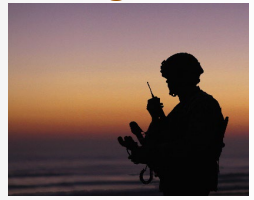
Resilience Architectures
- Computing Research (1400)
- Decision Support Systems (6300)

Deep/Machine Learning for Real-Time Events
- Applied Information Sciences (5500)
- Computing Research (1400)

Energy and Homeland Security

Global Security

National Security Programs



Nuclear Deterrence

Resilient Energy Systems
INTERN INSTITUTE

An innovative program focused on providing undergrad and graduate students with exciting and challenging opportunities to progress their science and engineering foundation. Students will support the Resilient Energy Systems Mission Campaign – a 7-year multimillion dollar investment involving brilliant minds across the labs to develop a more resilient U.S. electric grid to threats and attacks.

15 Student hires

8 Year-round conversions

2 staff hires

RESII Mission Statement

Hiring pipeline of students motivated to make an impact in National Security and Energy Resilience research.

Student Exposure

State-of-the-art:
- Facilities
- Laboratories
- Capabilities
- Research projects
- Research teams

RESII Core Disciplines

- Energy Resiliency
- Cyber Security
- Data Analytics
- Computer Science
- Materials Science
- AI/ML

Desired Qualifications

- Undergrad & Graduate Students
- Experience with Labview, Matlab, Python, etc.
- Systems Engineering
- Cyber Security
- STEM Degree: Engineering - ME, EE, NE, CE, etc. or Mathematics