ERDC-CERL Microgrids at Fixed Installations: Security and Economics

Melanie Johnson
ERDC-CERL

TCIPG Seminar
2 March 2012

US Army Corps of Engineers
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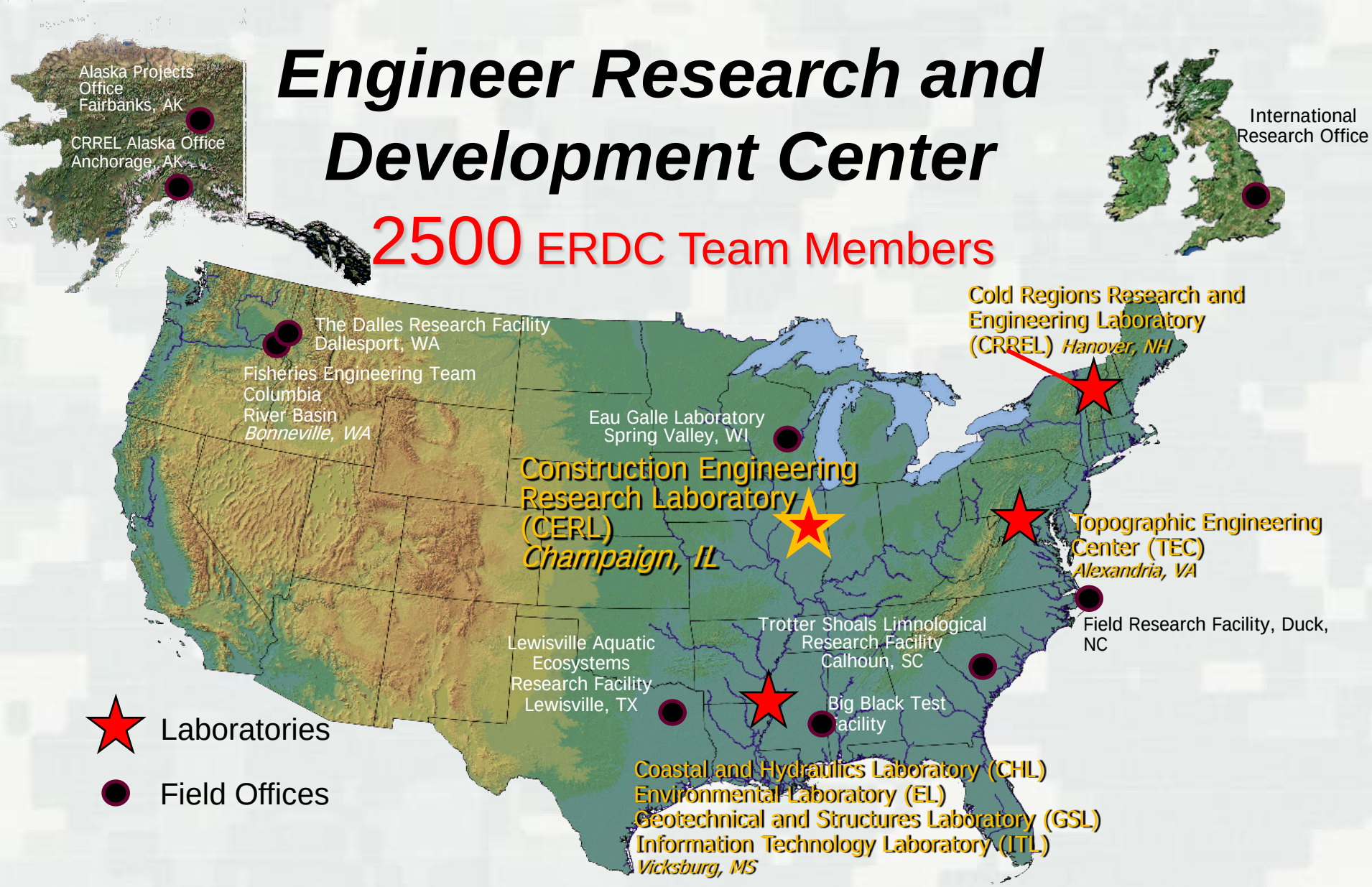
Engineer Research and Development Center

2500 ERDC Team Members



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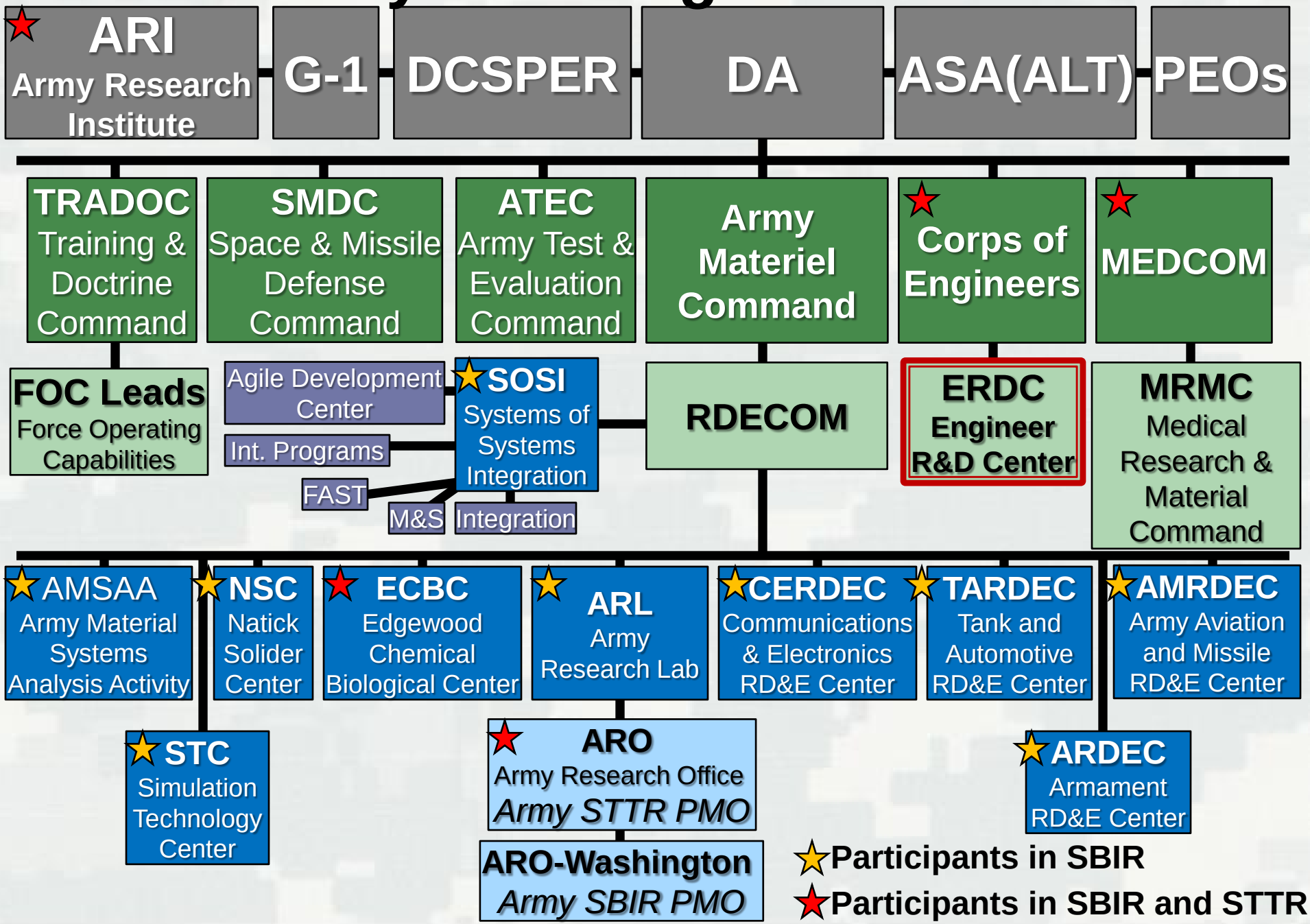
Army R&D Organizations



Microgrid Technology

An islandable dynamic power distribution system capable of optimizing multiple power generation assets and loads through advanced controls and communication.

- Two modes of operation: grid-tied and islanded
- Advanced Control Systems
  - System stability
  - Economic optimization
  - Distributed for graceful degradation
  - Control techniques accommodate reduced “inertia”
- Dynamic and reconfigurable distribution enhances reliability and energy security

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Army Microgrid Motivation

- DoD Policy Goals
  - EISA 2007, EPAct 2005, Ex. Order 13514
- Energy Security
  - **A**rmy **E**nergy **S**ecurity **I**mplementation **S**trategy
  - Surety, Survivability, Supply, Sufficiency, and Sustainability
- Renewables Integration
  - Economic Optimization
  - Islanded Operation
- Evolving Energy Market Participation
  - Demand Response, Peak Shaving
  - Real Time Pricing
  - PHEV, BEV Integration

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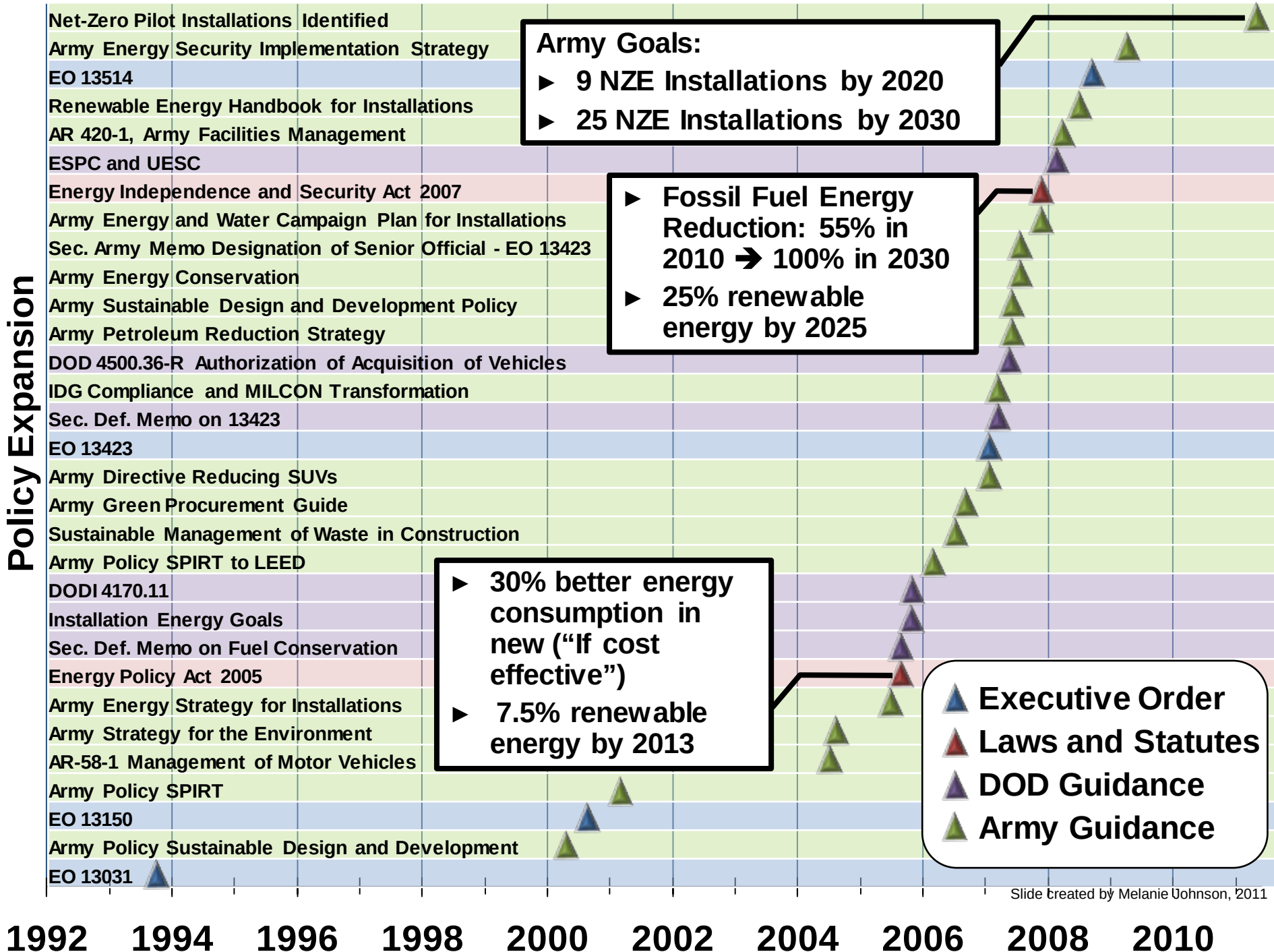
Policy Expansion
Net-Zero Pilot Installations Identified
Army Energy Security Implementation Strategy
EO 13514
Renewable Energy Handbook for Installations
AR 420-1, Army Facilities Management
ESPC and UESC
Energy Independence and Security Act 2007
Army Energy and Water Campaign Plan for Installations
Sec. Army Memo Designation of Senior Official - EO 13423
Army Energy Conservation
Army Sustainable Design and Development Policy
Army Petroleum Reduction Strategy
DOD 4500.36-R Authorization of Acquisition of Vehicles
IDG Compliance and MILCON Transformation
Sec. Def. Memo on 13423
EO 13423
Army Directive Reducing SUVs
Army Green Procurement Guide
Sustainable Management of Waste in Construction
Army Policy SPIRT to LEED
DODI 4170.11
Installation Energy Goals
Sec. Def. Memo on Fuel Conservation
Energy Policy Act 2005
Army Energy Strategy for Installations
Army Strategy for the Environment
AR-58-1 Management of Motor Vehicles
Army Policy SPIRT
EO 13150
Army Policy Sustainable Design and Development
EO 13031
Army Goals:
► 9 NZE Installations by 2020
► 25 NZE Installations by 2030
► Fossil Fuel Energy Reduction: 55% in 2010 ➔ 100% in 2030
► 25% renewable energy by 2025
► 30% better energy consumption in new ("If cost effective")
► 7.5% renewable energy by 2013
Executive Order
Laws and Statutes
DOD Guidance
Army Guidance
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1992
1994
1996
1998
2000
2002
2004
2006
2008
2010

Microgrid Scalability

Tactical

99% Islanded, 1% Grid Tied

10s of kWs

Highly Portable

Operational

Forward Operating Bases

100s of kWs

Power Sharing

Installation

99% Grid Tied, 1% Islanded

10s of MWs

Flexible Distribution

Microgrid Scalability

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Renewable Sources | **Energy Storage** | **FF Generation** | **Grid**

Power and Data

Microgrid Control and Optimization

User Control and Interface

Power and Data

Mission Critical Loads | **Mission Priority Loads** | **Electrified NTVs**






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Determining a Microgrid

Energy Security Assessment

- Identify Critical Mission Loads
- Identify Critical Infrastructure Supporting CMLs
- Identify Risk and Mitigations

Islanding Plan

- Select Subset of Critical Infrastructure to Island
- Identify Infrastructure Upgrades Required to Island
- Develop Potential Generation Portfolio

Microgrid Implementation

- Implement Upgrades, Generation Recommendations
- Establish microgrid in phases across the installation

Microgrid Challenges:
Systems of Systems Integration

- Variety of systems:
  - Power Distribution, Industrial Control, Building Automation, Information Network, Utility Communication
- Interconnecting is a significant challenge.
  - Proprietary Protocols/Tools
  - Legacy Equipment
  - New vulnerabilities (network connectivity)
- Standards can mitigate this challenge.
  - NIST/SGIP
  - DHS/INL ICS Procurement Language
  - Roadmaps

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Microgrid Challenges:
Information Assurance/Cyber Security

- Extensive communication
  - Energy production
  - Usage
  - Pricing data
  - Protection
- Network connectivity
  - Installation Network (DIACAP, NEC)
  - Internet Connection
- New vulnerabilities
  - Existing SCADA
  - More sophisticated control devices

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Cyber Security Challenges:
IT v. Power Systems

Information Technology World	Power Systems World
Equipment refresh every 2 years	Equipment refresh every 20 years (maybe)
Weekly patch/system reboot is no problem	100% uptime requirement
3:00 AM: good time for a virus scan	3:00 AM or 3:00 PM: no “good” time
Implicit assumption: fail-safe means deny	Implicit assumption: fail-safe means allow
Confidentiality – Integrity – Availability	Availability – Integrity – Confidentiality
IT Department	Operations Department

- IT technologies offer both new capabilities and new vulnerabilities to control systems.
- Reconciling these two paradigms is a challenge!

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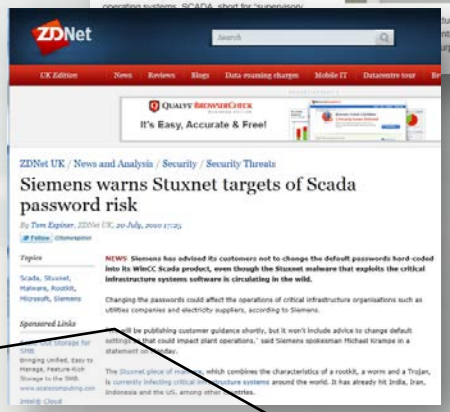
Cyber Security Challenges: Operational Capabilities

- Security measures can impede system operation
  - Particularly in contingency situations
- Control Systems Vendors include known default passwords.
  - Allows easy access:
    - Especially for the good guys in a pinch!
    - …and especially for malicious intent!
  - Vulnerabilities like this are required for system operation.
- Good security practices can have dramatic operational impact.



"We will be publishing customer guidance shortly, but it won't include advice to change default settings as that could impact plant operations," said Siemens spokesman Michael Krampe in a statement on Monday.

The Real Question:

Why connect critical military infrastructure to the internet?

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Cyber Security and Economics

- Communication with a utility/ISO/RTO facilitates realization of microgrid economic capabilities.
  - ► Not just peak-shaving

- Funding for large-scale microgrid projects is scarce.
  - ► Alternative financing is desirable.

- Introducing new vulnerabilities largely eliminates the benefits of the microgrid.
  - ► Layered defense is needed.

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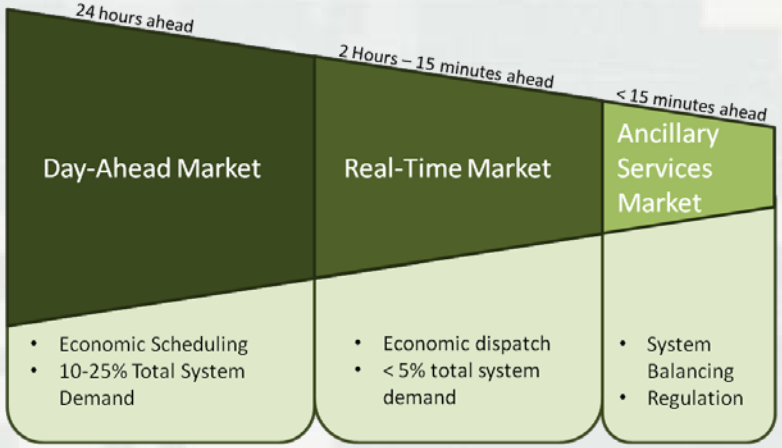
Microgrid Economic Opportunities

- Peak Shaving: Reduce peak demand utilizing resources "inside the fence"

- Demand Response: Reduce demand in response to grid conditions or energy prices

- Energy Arbitrage: Charge batteries (Or EVs)when energy prices are low and discharge batteries when energy prices are high



Graphic Concept: USDOE 2006

- Ancillary/Grid Services: Act as grid resource for regulation and/or reserves

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Microgrid Economic Opportunities

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Microgrid Economic Capabilities

	Peak Shaving	Demand Response	Energy Arbitrage	Ancillary Services	Real time pricing
Prioritized Load Shedding	✓	✓		✓	✓
Intentional Islanding	✓	✓			✓
Control	✓	✓	✓	✓	✓
Communication	✓	✓	✓	✓	✓
Renewables Integration	✓				✓
Energy Storage	✓	✓	✓	✓	✓
Internal Generation	✓			✓	✓

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Energy Market Comparison

	Fort Carson	Fort Bliss	Fort Irwin
Peak Shaving (Demand Reduction)	✓	✓	✓
Demand Response		✓	✓
Energy Arbitrage			✓
Ancillary Grid Services			✓

- **Fort Carson:** Vertically Integrated, no capacity constraints
- **Fort Bliss:** Vertically Integrated, summer capacity constraints
- **Fort Irwin:** Energy Market, expanded opportunity.

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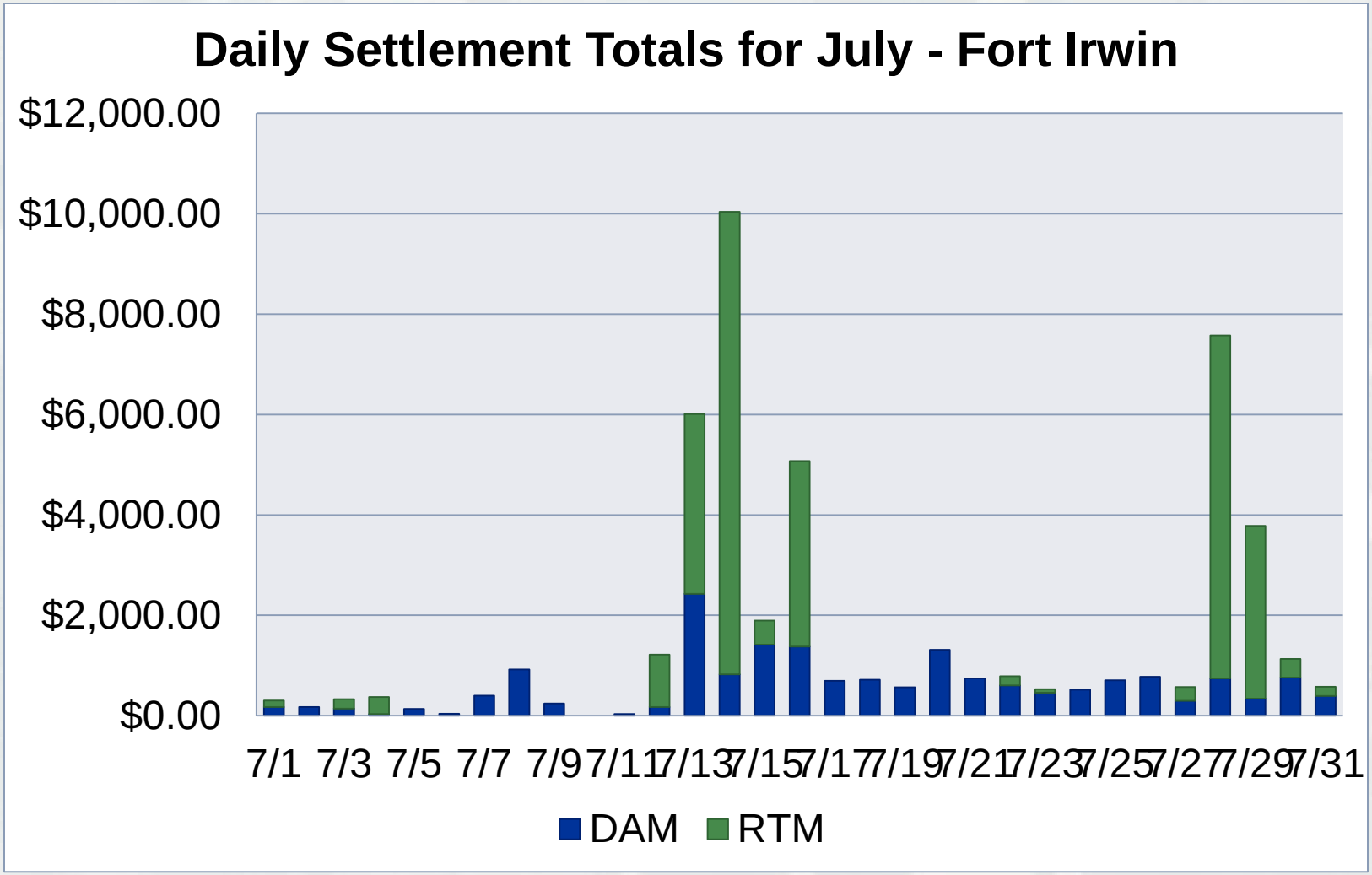
Demand Response Simulator



Study funded by IMCOM-W FY2010.

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Demand Response

- Simulator Caveats:
  - Baseline calculation
  - Guaranteed bid acceptance
  - No non-performance penalties
  - Estimated non-critical loads
  - No service fees

- Additional Challenges: Need 3rd party aggregator to assume risks of market participation.
- Study led to ESTCP to demonstrate Open ADR protocols at Fort Irwin with Honeywell.

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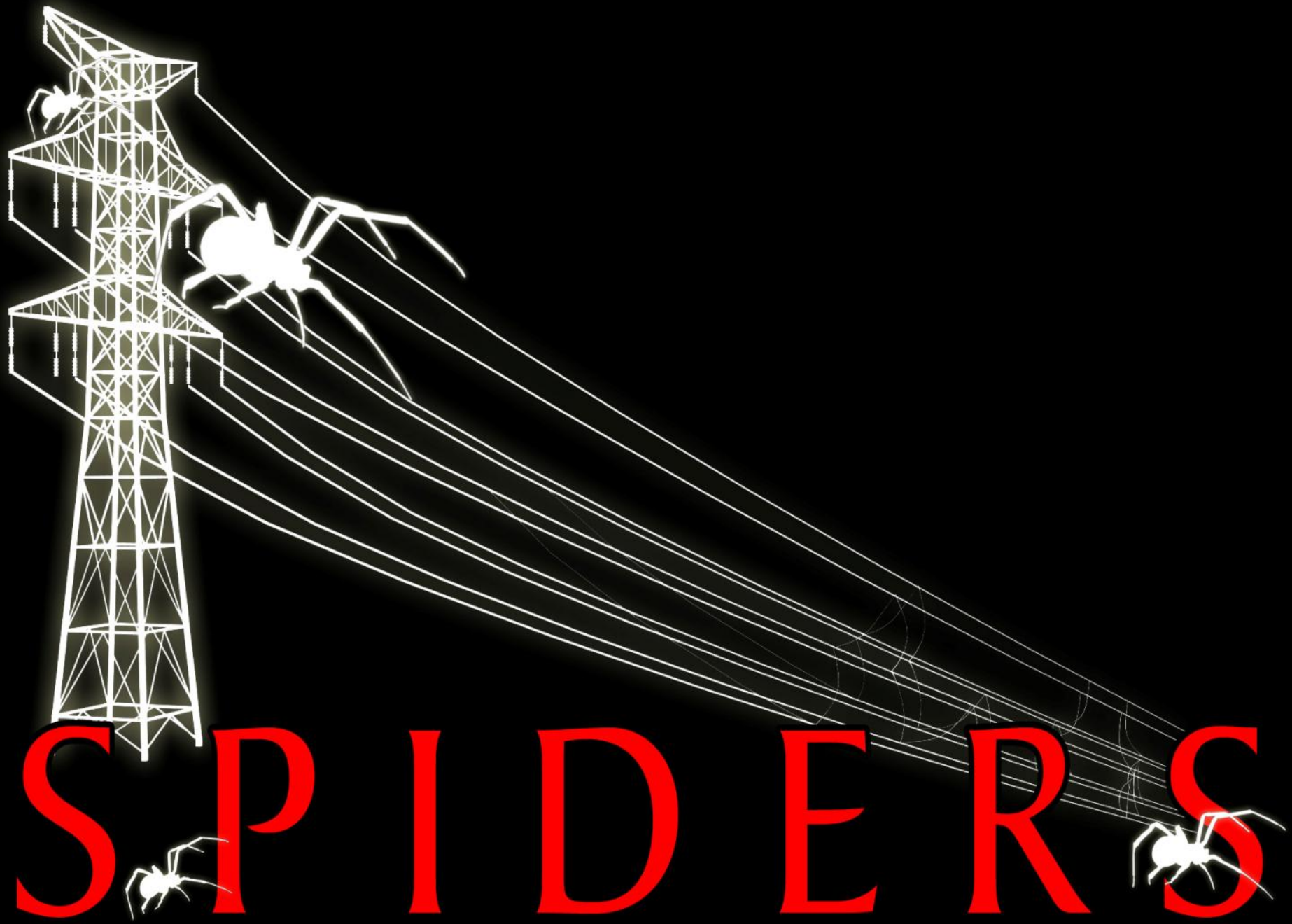

Smart Power Infrastructure Demonstration for Energy Reliability and Security

SPIDERS JCTD Objectives

- **Cyber-security**
  - Layered in-depth defense
  - Information assurance
- **Smart Grid Technologies & Applications**
  - Automated load balancing,
  - Two-way communication,
  - Smart-metering,
  - Automatic system re-configuration
  - Demand side management/Load shedding
- **Islanded Micro-grid**
  - Entire installation to island
  - Extended continuity of operations
  - Seamless disconnect/reconnect
- **Distributed & intermittent renewable sources**
  - Off-grid availability
  - Reduce fossil fuel consumption and carbon boot-print

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SPIDERS Participants

- USPACOM, USNORTHCOM, DOE, and DHS
- DOE - 5 Nat'l Labs
- USACE ERDC – Construction Engineering Research Lab (CERL)
- Military Services
- Navel Facilities Engineering Cmd
- Local Utility Companies
- States of Hawaii & Colorado

JCTD SPIDERS Overview

Phase1: JB Pearl-Hickam Circuit Level Demonstration

- Renewables
- Storage
- Energy Management

Phase 2: Fort Carson Microgrid

- Large-Scale Renewables
- Vehicle-to-Grid
- Smart Microgrid
- Critical Assets
- CONUS Homeland Defense Demo
- COOP Exercise

Phase 3: Camp Smith Energy Island

- Entire Installation Smart Microgrid
- Islanded Installation
- High Penetration of Renewables
- Demand Side Management
- Redundant Backup Power
- Makana Pahili Hurricane Exercise

Beyond: Transition

- Template for DoD-wide Implementation
- CONOPS
- TTPs
- Training Plans
- DoD Adds Specs to GSA Schedule
- Transition to Commercial Sector
- Transition Cyber Security to Federal Sector and Utilities

Cyber-Security Solution Development

- **Intended End Result of SPIDERS:**
  - **First Complete DoD installation with a secure, smart, islandable microgrid**
  - **Template for DoD-wide installation energy security**
- **Technical Manager: U.S. Army ERDC-CERL, Deputy TM: Sandia National Laboratory**

Slide content courtesy of Juan Torres, SNL

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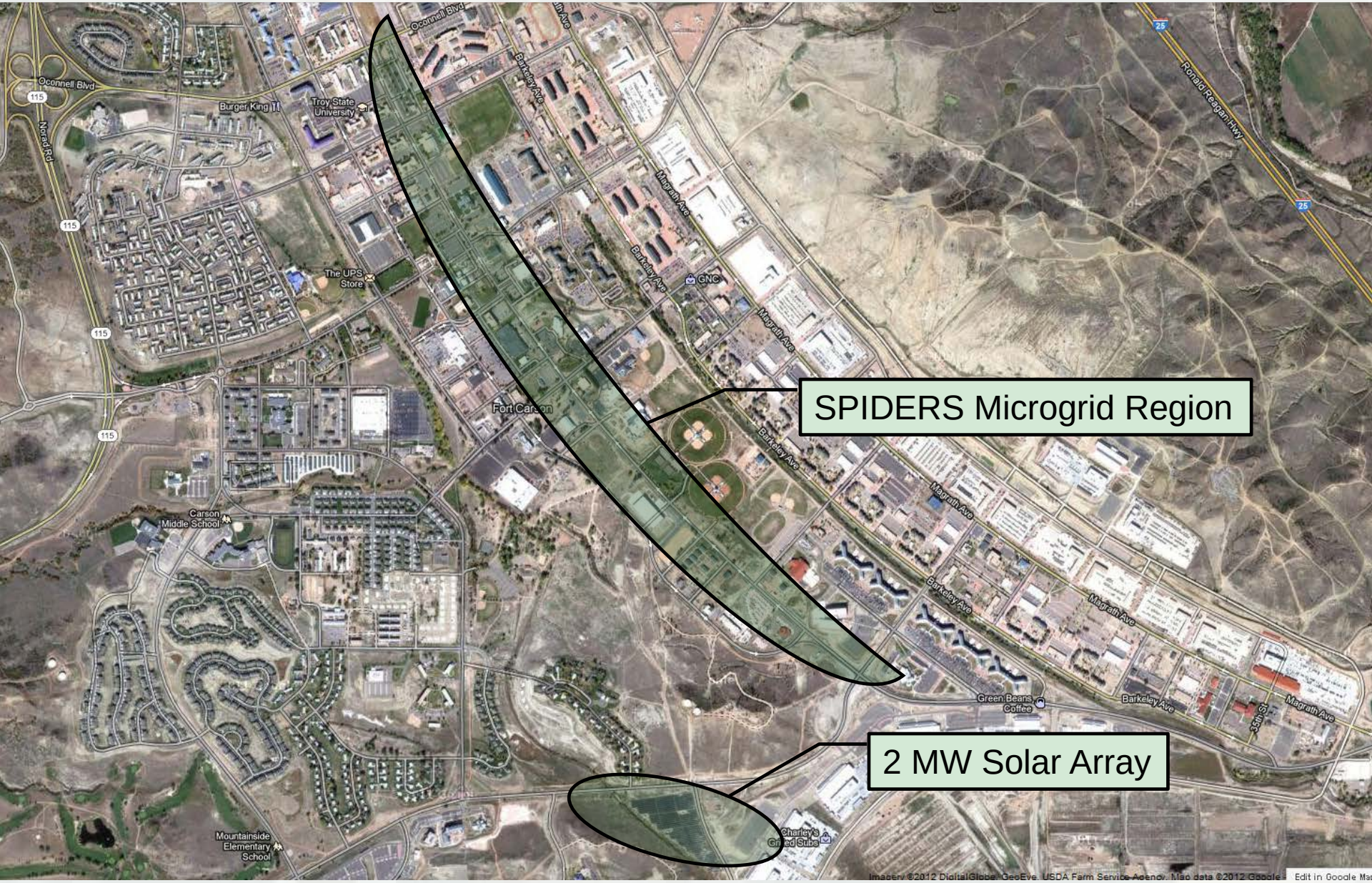
The SPIDERS Microgrid at Fort Carson



Phase 2: SPIDERS @ Fort Carson

Loads

- **Tier 1**: Loads/buildings that are critical to the mission of Fort Carson. 100% served by islanded microgrid.
  - **1.1 MW**
- **Tier 2:** Loads/buildings that are nice to have, but that can be switched on or off the microgrid at the garrison commander's discretion.
  - **1 MW**
- **Tier 3:** Loads/buildings that will not be powered during islanded microgrid operation

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Phase 2: SPIDERS @ Fort Carson

Generation Assets:

- **Diesel Generation:**
  - 4 Generators - 3.225 MW(3.5 MVA)
- **Renewables:**
  - 2 MW Solar Array
- **Energy Storage:**
  - Smith Electric Vehicles: 440 kWh
  - Additional: 500-750 kW for one hour

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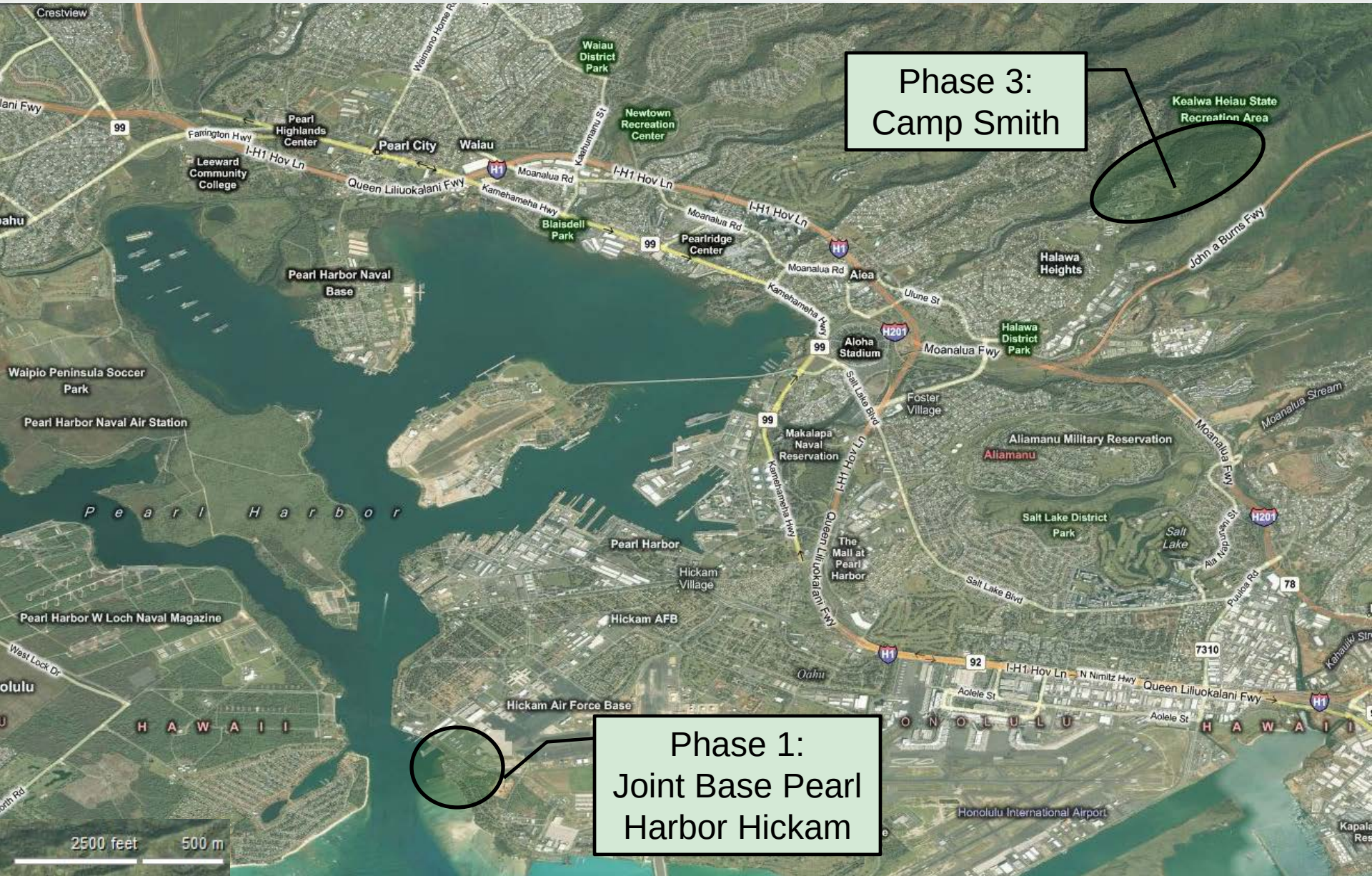
SPIDERS Microgrids On Oahu



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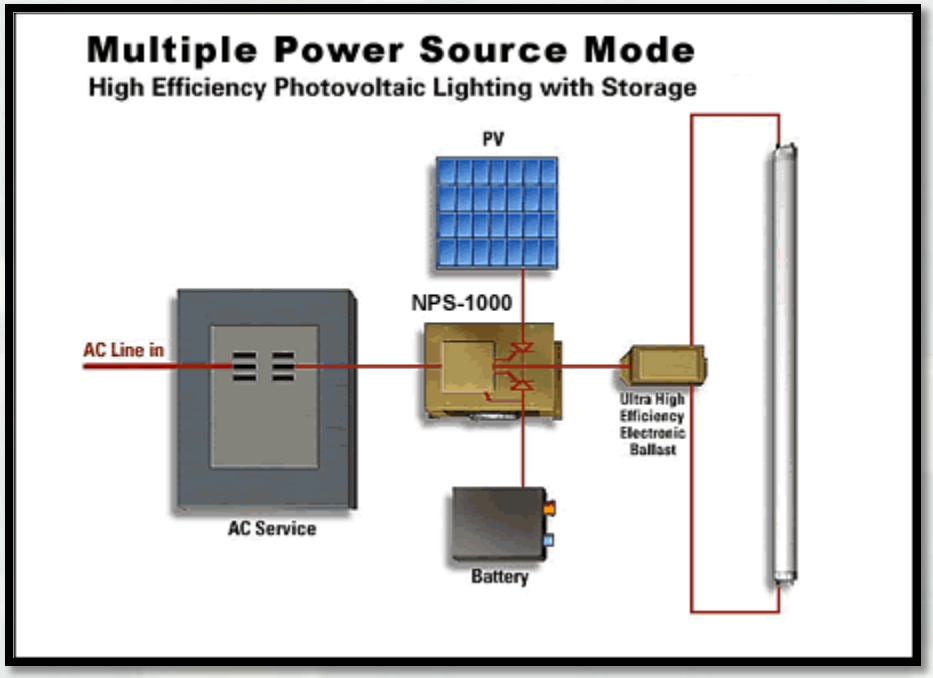
Fort Sill Field-Scale Microgrid Demonstration

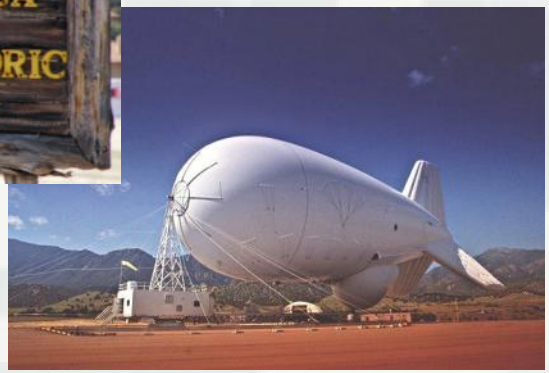
- Generation:
  - 2 – 210kW Natural Gas Generators
  - 30 kW PV
  - 2.4 kW Wind
  - 500 kWh/250 kW ZnBr Flow Battery
- Loads: Chiller Loop
- Features:
  - Adjustable trip-curve breakers
  - Microgrid Interface Switch

- Demonstration:
  - Seamless transition
  - Extended islanded operation

Nextek DC Power System

- Expect efficiency gains through eliminating multiple AC/DC conversions
- 24V DC Power Distribution
- Generation:
  - 7 kW PV
  - Energy Storage
  - Power Grid
- Load:
  - Fluorescent Lighting with DC Ballasts
  - Electronics





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Other Projects

- Fort Bliss Microgrid Demonstration:
  - Dining Facility supported by existing backup diesel, high penetration renewables, and energy storage.
  - Partnership with Lockheed Martin
  - ESTCP Funded

- OpenADR Protocol Demonstration:
  - Pilot tariff and protocol demonstration at Fort Irwin, CA for automated demand response
  - Partnership with Honeywell
  - ESTCP funded

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Wrap Up

- Microgrids offer higher reliability and efficiency through the use of advanced control and communication.
- Control and communication make it possible to have substantial and autonomous market interaction.
- Overlaying communication network on critical infrastructure introduces new vulnerabilities and culture clashes.

Questions?

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