ARPA-E/ASD(R&E) Hybrid Energy Storage Module (HESM) Technology Workshop Overview

19 May 2011

Mr. Donald Hoffman
DoD Program Manager

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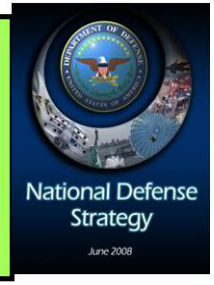
ARPA-E Program Manager

Getting More Fight with Less Fuel

"These are extraordinary times, and it calls for swift and extraordinary action. At a time of such great challenge for America, **no single issue is as fundamental to our future as energy**... Our scientists, businesses and workers have the capacity to move us forward. It falls on us to choose whether to risk the peril that comes with our current course or to **seize the promise of energy independence**... For the sake of our security, our economy and our planet, we must have the courage and commitment to change... Now is the time to meet the challenge at this crossroad of history by choosing **a future that is safer for our country, prosperous for our planet, and sustainable.** Those are my priorities..." *Remarks by the President on Jobs, Energy Independence, and Climate Change, East Room of the White House, January 26, 2009*

"...The **well-being of the global economy is contingent on ready access to energy resources.** Notwithstanding national efforts to reduce dependence on oil, **current trends indicate an increasing reliance on petroleum products from areas of instability** in the coming years, not reduced reliance. The [US] will continue to foster access to and flow of energy resources vital to the world economy. Further, the Department is examining its own energy demands and is taking action to reduce fuel demand where it will not negatively affect operational capability. **Such efforts will reduce DoD fuel costs and assist wider U.S. Government energy security and environmental objectives.**"

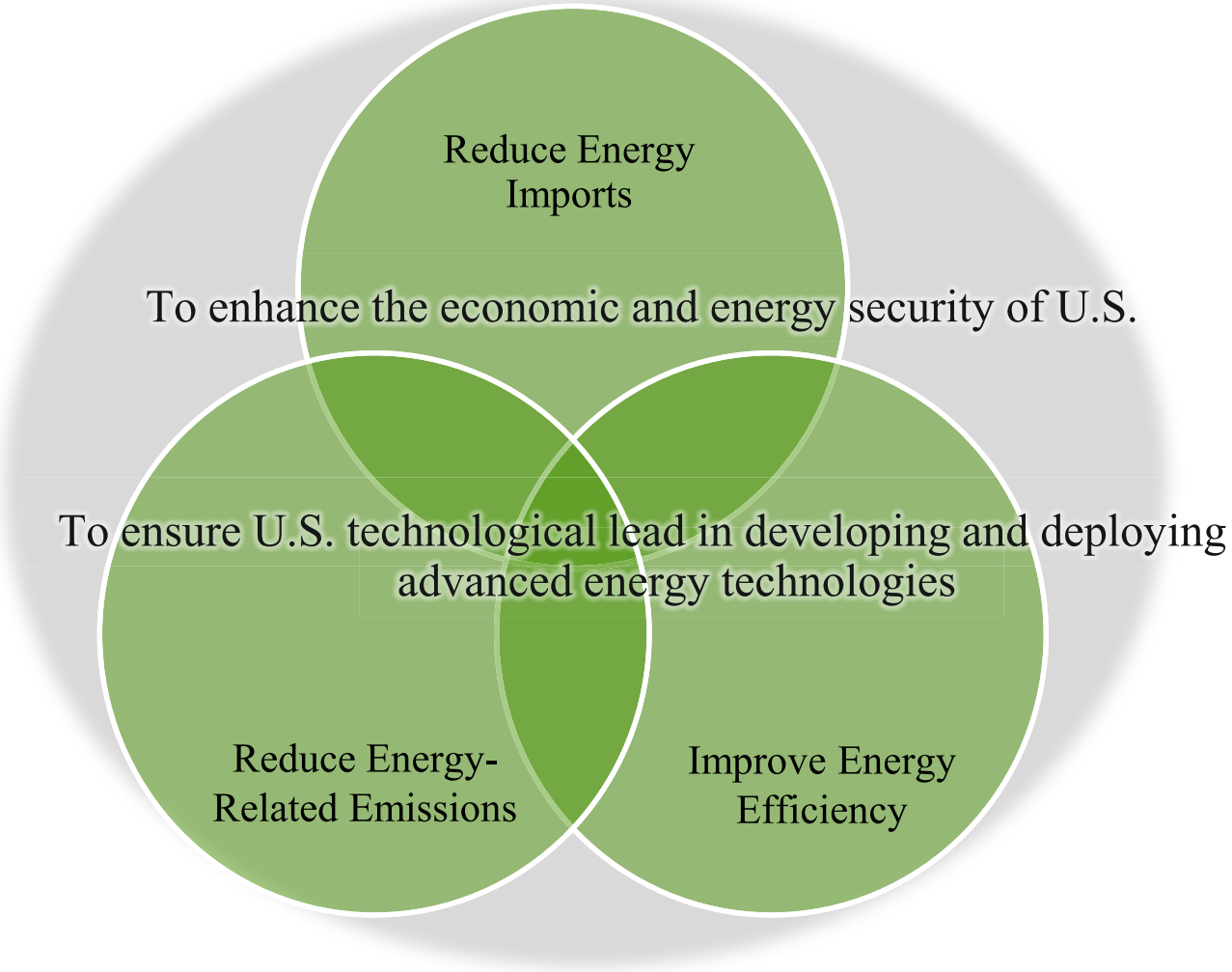
National Defense Strategy June 2008



U.S. Marine Corps Maj. Gen. Richard Zilmer, Al-Anbar Commander, submitted an **urgent request for renewable energy systems**, due to the vulnerability of American supply lines to insurgent attack by ambush or roadside bombs. The request said "**reducing the military's dependence on fuel for power generation could reduce the number of road-bound convoys.**" ...'Without this solution [renewable energy systems], personnel loss rates are likely to continue at their current rate. Continued casualty accumulation exhibits potential to jeopardize mission success...'"

Defense News, August 2006

ARPA-E's Mission



To overcome the long-term and high-risk technological barriers in the development of energy technologies.

(A) identifying and promoting revolutionary advances in fundamental sciences; **AND**

(B) translating scientific discoveries and cutting-edge inventions into technological innovations; **AND**

(C) accelerating transformational technological advances in areas that industry by itself is not likely to undertake because of technical and financial uncertainty.

Defense Payoff of ARPA-E S&T

Enables Advanced Long-Duration Unmanned Systems

Advanced Batteries (e.g. Li-ion & Metal-air)

Advanced Fuels

Thermal Mgmt.

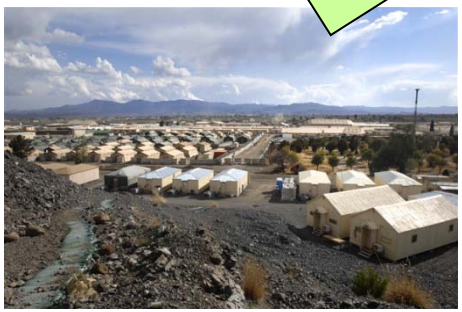
Micro-grid

Hybrid Energy Storage

Enables Fuel Flexibility & Long-Term Energy Security

Enables Operationally Longer-Duration Aircraft

Enables 4 x SOA Energy Dense Power Systems



Enables 25% FOB Fuel Reduction

Demonstrated 10% Fuel Reduction DDG 51

Enables Future Electric Weapons

Initial Announcement

Navy Secretary Mabus
March 2, 2011
at ARPA-E Energy Innovation Summit

"think about getting a gallon of gasoline to a Marine front-line unit in Helmand province in Afghanistan. First you've got to put it on a ship and go across one ocean - the Pacific or the Atlantic. Then you have to take it either up through Pakistan or down through the Northern Distribution Network, through the Baltics and across Russia. And when you get to Afghanistan, you have to go across the Hindu Kush from the south or the Amu Darya River from the north.

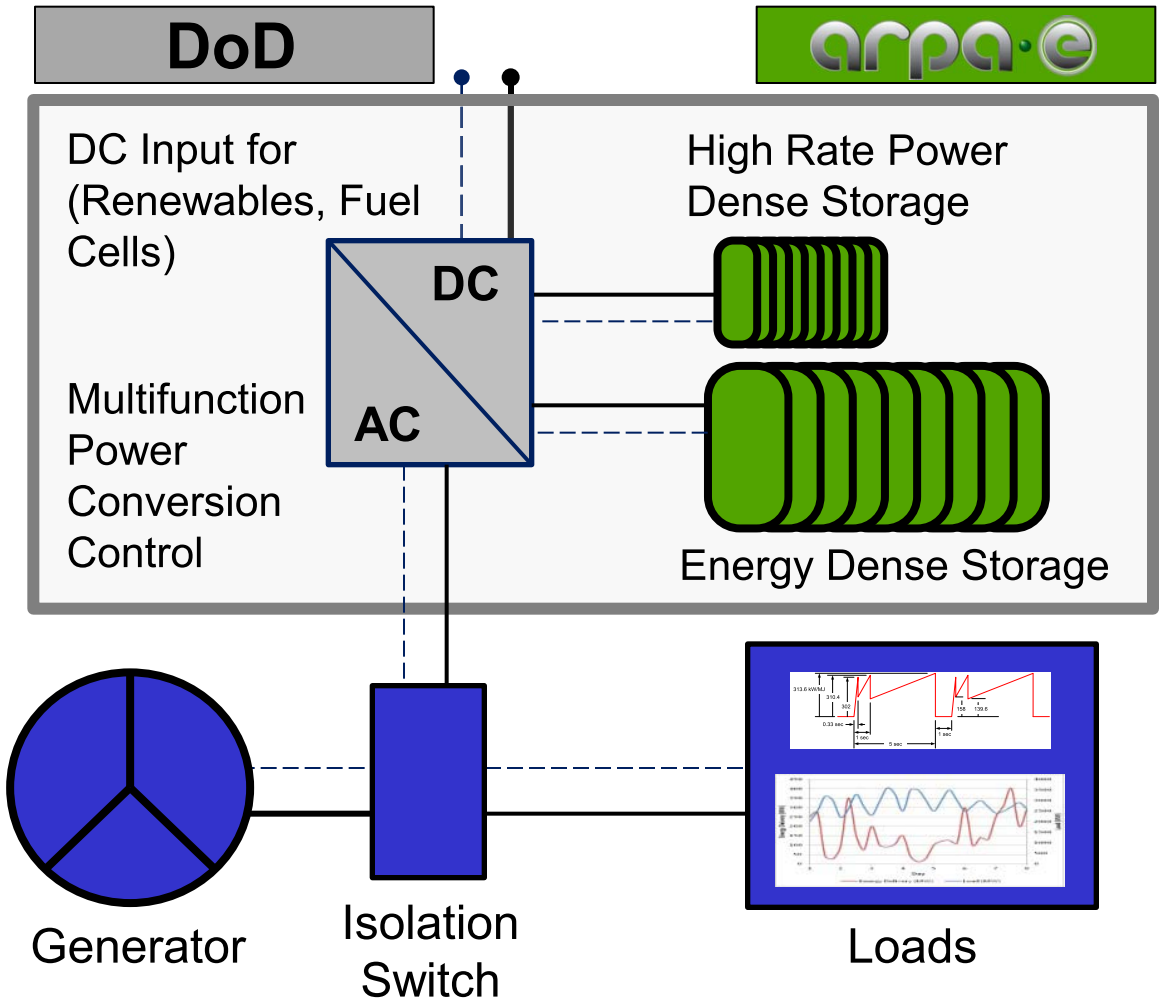
There are huge financial costs associated with it, but maybe, more important, there are huge other costs. The Army did a study that for every 24 convoys we'd lose a Soldier or a Marine, killed or wounded guarding that convoy. That's a high price to pay for fuel" …

"develop and build hybrid energy storage modules to provide long endurance, high-energy density materials in a small, modular and easily scalable package. The program's goals are to extend current levels of fuel duration by up to 30 percent while concurrently providing for batteries that rapidly charge and discharge big amounts of energy…. This means fewer Marines guarding convoys, less money, less effort getting fuel to the battlefield."

Sec. Mabus, … 78 days ago

Hybrid Energy Storage Module (HESM)

HESM Unit



Technologies

- **Storage**
  - **Advanced Energy Storage Device(s)**
    - **High Rate Batteries**
    - **Metal Air Batteries**
    - **High Energy Flywheels**
    - **Flow Batteries**
    - **Capacitors**
- **Multifunction Power Conversion Control**
  - **Multi Rate Control & Energy Storage Management**
  - **Thermal Tolerant Power Conversion for Continuous Operation**
  - **Energy Storage "Agnostic" Interface**
- **HESM System Design**
  - **Lightweight System Safety & Containment**
  - **Robust Thermal Architecture & Interface**

Hybrid Energy Storage Module Applications

Ships
Enables Future Electric Weapons & Sensors
Increases Shipboard Fuel Efficiency

HESM

Forward Operating Bases
Enables 30% Reduction in Fuel Use at Forward Operating Bases

Utilities
Increases Efficiency of Islanded Generators

Aircraft
Enables More Capable and Longer Duration Aircraft

Hybrid Energy Storage Module (HESM) Roadmap

- Joint Workshops (April, May 2011)
- Parallel Announcement (FY 2011)

ARPA-E: Advanced Energy Storage Devices Development

FY11 FY12 FY13 FY14

Proof of Concept Development

- Early Stage Technology Development
- Energy Storage (Batteries, Flywheels, …)
- Advanced Device Management Research

Continuous
"spiral Insertion"

DoD: Hybrid Energy Storage System Level Development

FY11 FY12 FY13 FY14 FY15 FY16

Sub Scale Validation

Full Scale Energy Storage Validation

- Develop Control/Logic
- Develop Fault Isolation
- Power Converter Design
- Advanced Thermal Mgt.

- Common Requirements Documents
- Full Scale System Fabrication(s)
- OEM Demonstration(s)
- In Field Demonstration(s)

Draft Output of Requirements Workshop
Product(s) Demonstration Areas

Tactical Energy Storage (kW – 10's kW)

- Operation close to power generation source
- Functionality: Energy Mgt, Power Quality
- DC Input for High Efficiency Renewables, Fuel Cell Generators

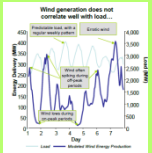
Commercial Application: Home Energy Management
DoD Application: Patrol Base, Combat Outpost, Austere FOB

Distributed Energy Storage (100's kW to MW)

- Operation distributed in electric architecture
- Functionality: Energy Mgt, Power Quality
- DC Input for High Efficiency Renewables, Fuel Cell Generators

Commercial Application: Utility Distributed Generators
DoD Application: FOB, Super FOB, Ships

Pulse Energy Storage



- Operation for specialty applications
- Functionality: Energy Mgt, Power Quality, High Pulse Capability

Commercial Application: Utility Grid Level Storage
DoD Application: Ships, Aircraft, Vehicles

Hybrid Energy Storage Module (HESM): Project Status

Task #	Description	Status
1	Establish Integrated Project Team (IPT)	✓
2	Define HESM Concept and Development Timeline	✓
3	Initial Survey of Energy Storage Applications from Army, Navy, Air Force, and Utility Industry	✓
4	Conduct Joint DOE-DOD HESM Workshop to Identify Army, Navy, Air Force, and Utility User Requirements	✓
5	Conduct Joint DOE-DOD HESM Workshop to Identify Technology Gaps	**Today**
6	Publish Coordinated BAA (DOD) and FOA (DOE) for Collaborative HESM Technology Development Programs	**Planned**

Mark Johnson ARPA-E IPT Lead

Don Hoffman DoD IPT Lead

IPT Members

- ARPA-E
- ASD (R&E)
- ASD (OEPP)

- Air Force (AFRLWP, AFRL Tyndall)
- Army (ARL, TARDEC)
- Navy (ONR, NSWC)

HESM IPT

Co Leads: Don Hoffman (DoD PM)/Mark Johnson (ARPA-E)

- **ARPA-E**
  - Srinivas Mirmira
  - David Danielson
  - Rusty Heffner
  - Leshika Samarasinghe
- **DoD**
  - Jack Taylor, ASD(R&E)
  - Jack Price, ASD(R&E)
  - Jillyn Alban, ASD(R&E)
  - Adam Rosenberg, ASD(OEPP)
  - John Pazik, ONR, Chair – EPCOI
  - Ed Shaffer, ARL
  - John Heinzel, NSWC Philadelphia
  - Erik Kallio, TARDEC
  - Miguel Maldonado, AFRL WPAFB, ASD(R&E)
  - Marcus Smith, AFRL Tyndall

Joint Workshop on Hybrid Energy Storage Module (HESM) Technology

Day 1: Morning: Introduction, including goals for DoD/DoE Collaboration
System Requirements and Needs
How Is Problem Solved Now

Afternoon: Technology Opportunities
Emerging Storage Module Technologies

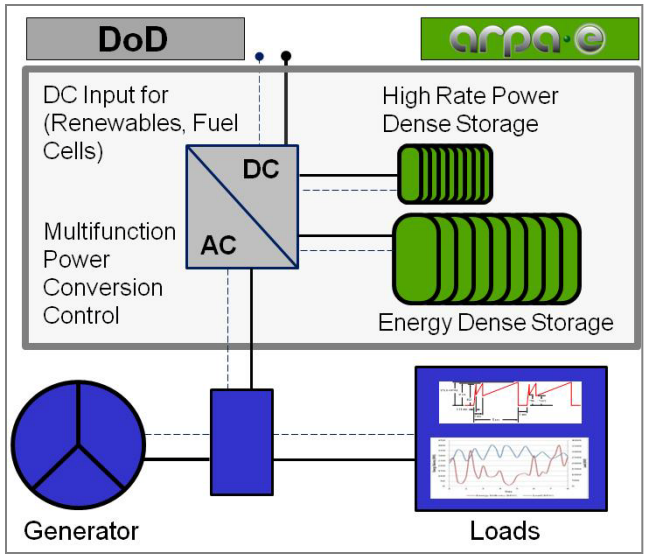
Break-out 1: Systems Approaches to HESM Storage
Report Back

Day 2: Morning: High Level Review on Day 1
Break-out 2: Technology Opportunities for HESM Storage
Report Back

Afternoon: One on One Sessions (Optional)

Workshop Focus Areas

Application Systems Perspectives

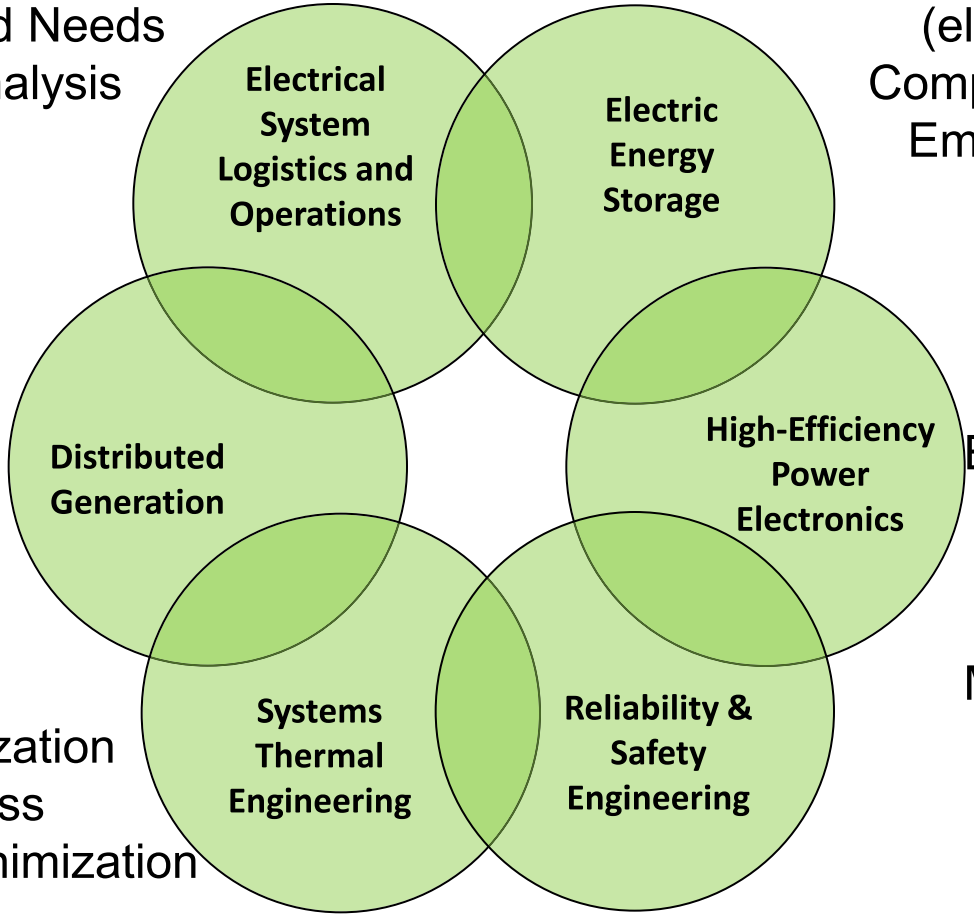


Enabling Technology Perspectives

Workshop Technical Communities

Statements of Problem
Current Solutions
Requirements and Needs
Systems Level Analysis

Storage Solution Sets
Technical Capabilities
(electrochem, mech, E/M)
Comparative Applications
Emergent Technology
and Science



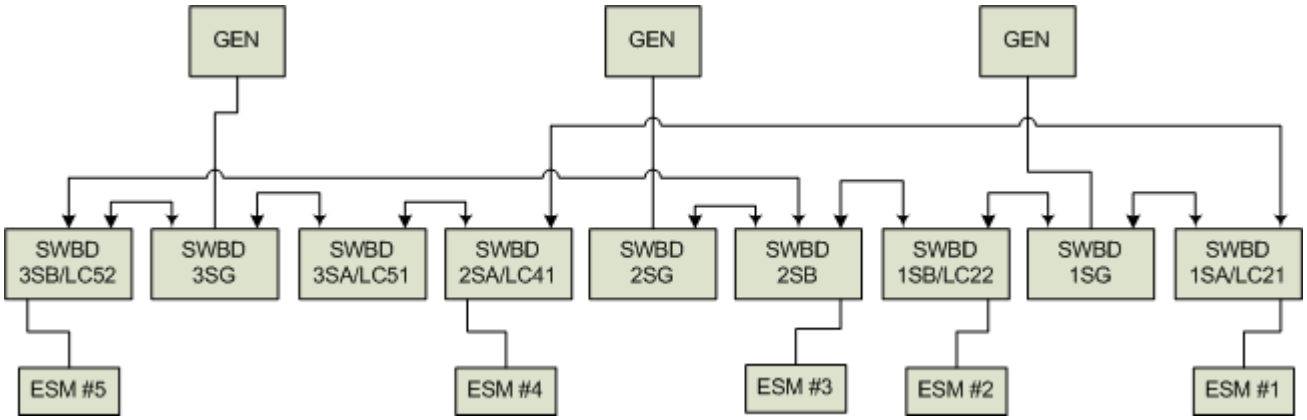
Current Limitations
Fuel Requirements
Size, Weight &
Power Trades

Efficient Bi-Directional
Electronics/PCS
Multifunctional Storage
Control
Multiservice Storage

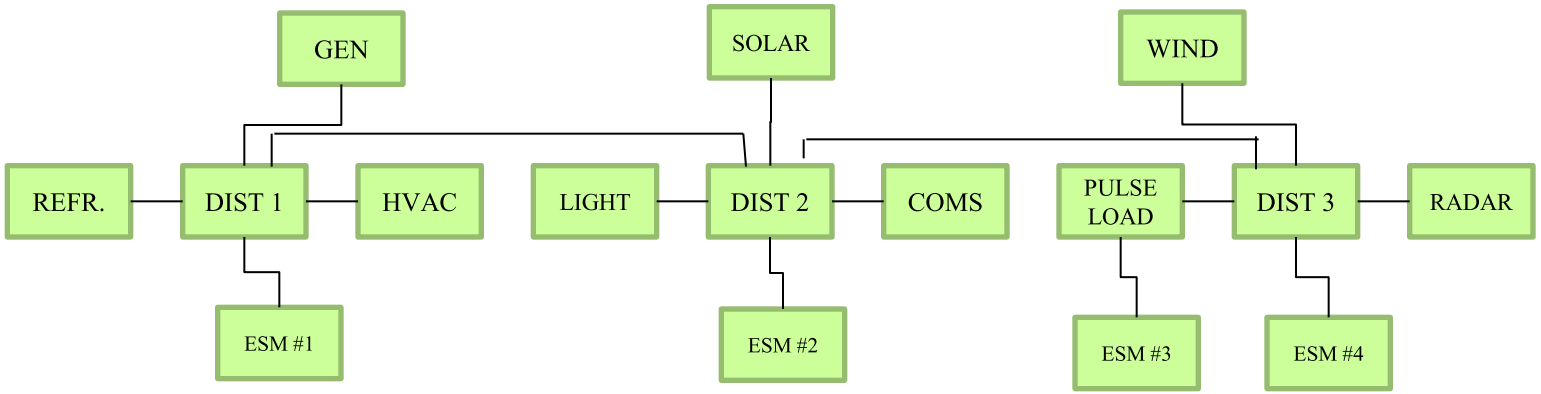
Efficiency Maximization
System Robustness
Size & Weight Minimization

Backup Slides

Application Similarities

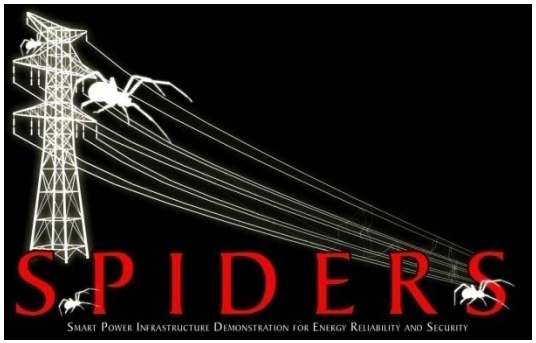


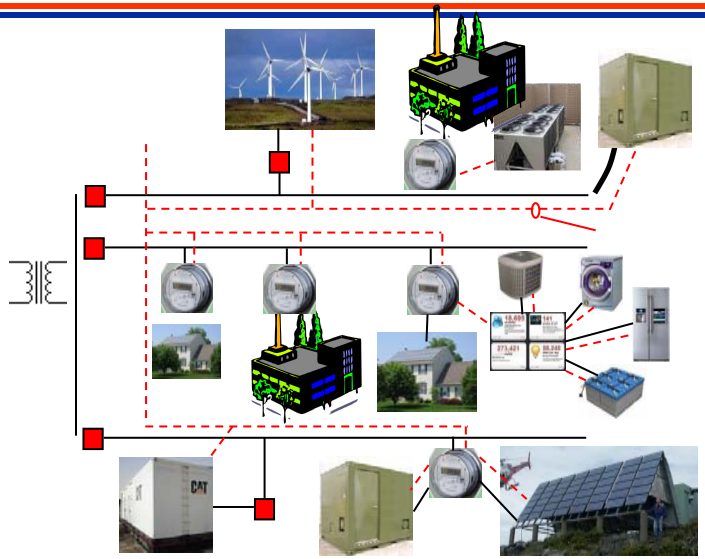
Ship Distribution / Large Microgrid



Microgrid w/Renewables

Complementary and Synergistic Activities

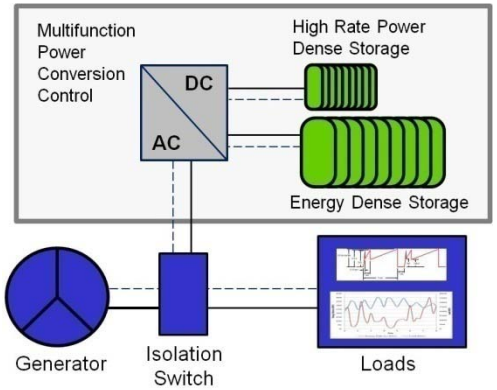




Reduce extended electric grid outages by developing the capability to "island" installations while maintaining operational surety & security

Smart Grid Technologies and Redundant UPS Power Surety

Hybrid Energy Storage Module (HESM)



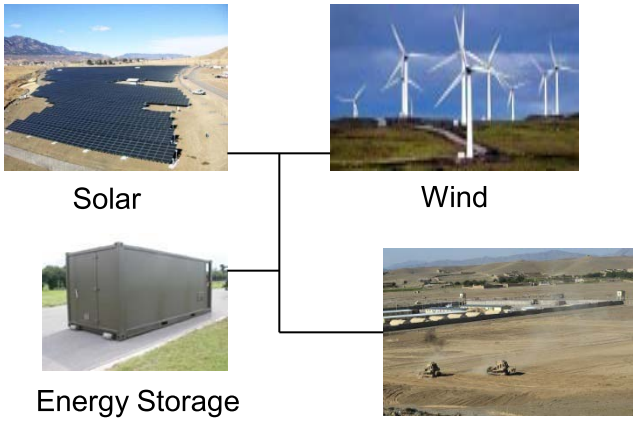
- **High Rate Power Dense Storage + Energy Dense Storage**
- **Multifunction Controls**
- **Tactical System Design**

- **Maximize Fuel Economy of Fossil Fuel Powered Microgrid**

- **Enable Increased Performance Capability for Multiple DoD Systems**

Complementary and Synergistic Activities

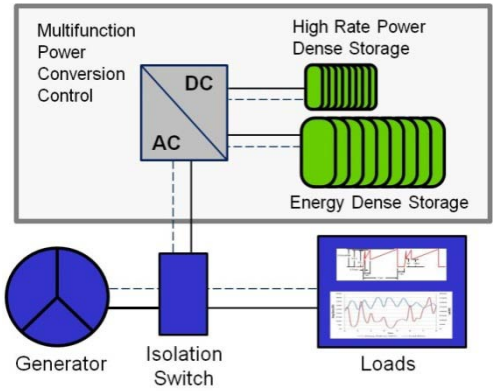
Deployed Energy Storage (DES) Program



High Density Storage For Solely Renewable Source Powered Forward Operating Base

Provides Reliable Fossil Fuel Free Microgrid

Hybrid Energy Storage Module (HESM)



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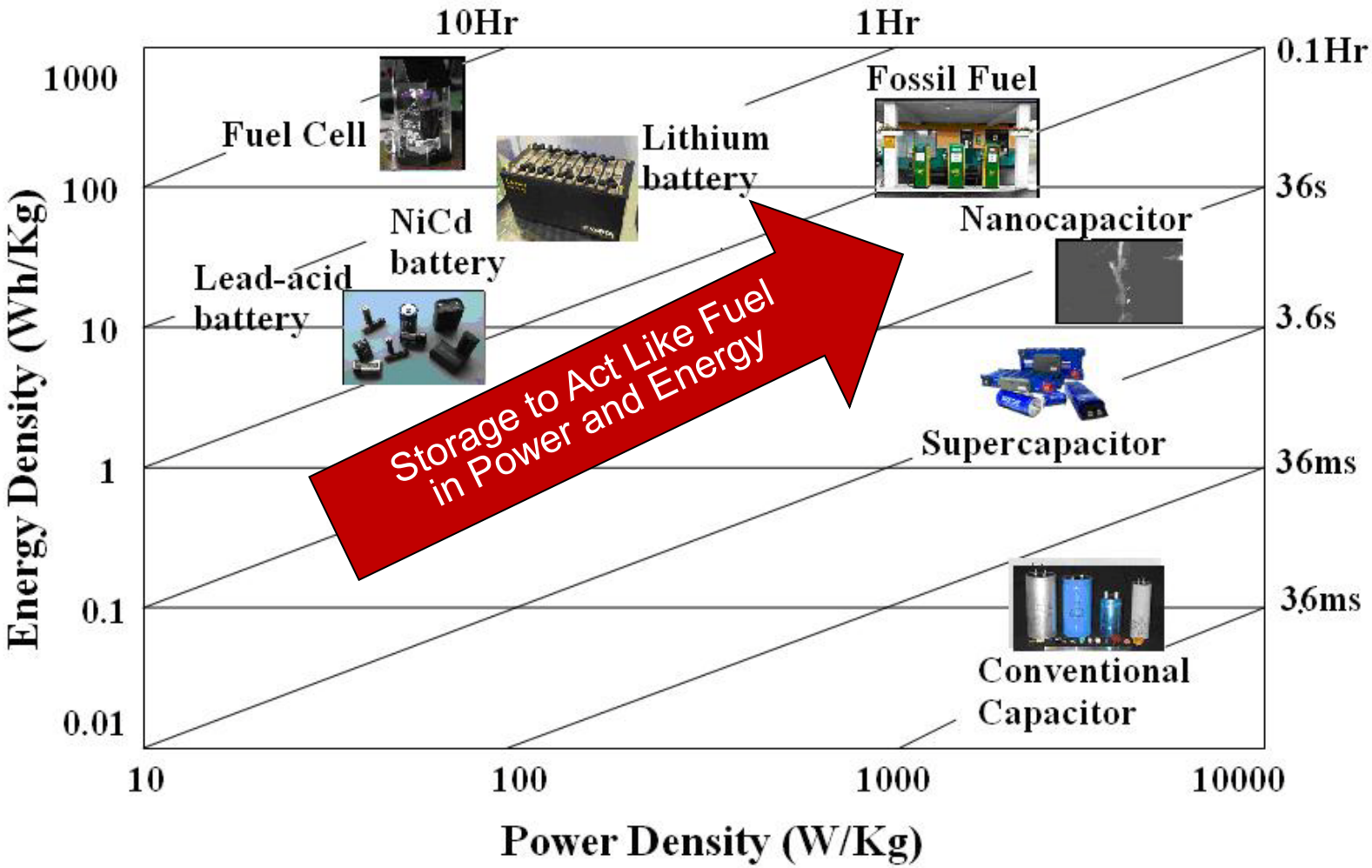
Technical Gap Area for Hybrid Energy Storage