



# **Power and Energy S&T Efforts Supporting Soldier and Basing at CERDEC**

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10-Sep-15



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- Operational Energy at CERDEC
  - Energy Informed Operations (Soldier & Basing)
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- Questions



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# Introduction

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## How We Fit In DOD



ASAALT



Army Material Command



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RFEC  
Atlantic

RFEC  
Pacific

RFEC  
Americas



**AMRDEC**  
Aviation &  
Missile  
Research,  
Development &  
Engineering  
Center



**ARDEC**  
Armaments  
Research,  
Development &  
Engineering  
Center



**ARL**  
Army  
Research  
Laboratory



**CERDEC**  
Communication-  
Electronics  
Research,  
Development &  
Engineering  
Center



**ECBC**  
Edgewood  
Chemical  
Biological  
Center



**NSRDEC**  
Natick Soldier  
Research,  
Development &  
Engineering  
Center



**TARDEC**  
Tank and  
Automotive  
Research,  
Development  
& Engineering  
Center



**CP&I**  
Command, Power & Integration



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# Introduction (Cont.)

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## CERDEC CP&ID Power Facilities



Test & Evaluation



System Integration



Rapid Prototyping

**Building 5100, APG, MD**

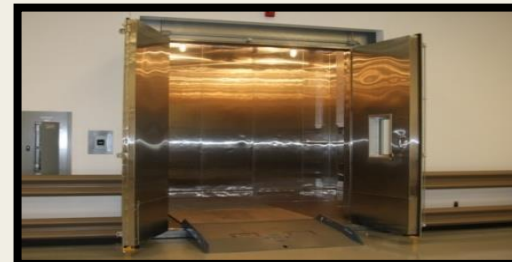
- 110,000 total ft<sup>2</sup>
- Over 60,000 ft<sup>2</sup> of lab space
- 30,000 ft<sup>2</sup> admin space
- 20,000 ft<sup>2</sup> of hardstand



Fuel Processing R&D



ECU Chamber



-68C to +79C Chamber



Abuse Test & HazMat Storage

- Rapid Prototyping, Materials Synthesis and Analysis, System Design and Fabrication
- Simulated Operational and Equipment Duty Cycles
  - ✓ Over 150 Programmable Test Channels, 0 - 48 V, 10uA - 200 A
  - ✓ Over 50 Environmental Chambers, 1 - 10,000 CuFt, -68C to 79C



**Power Generation & Conversion**

Components and processes for generating electricity:

- Generators
- Fuel Cells (and reforming)
- Energy Harvesting (Photovoltaic, Thermal Electric, Thermophotovoltaic, Kinetic)



**Energy Storage**

Components and processes for storing energy:

- Primary Batteries
- Rechargeable Batteries
- Packaged Fuels
- Hybrid storage



**Power Distribution**

Transmission of electric energy:

- Wireless (Induction, EM)
- Portable squad recharge kits
- Soldier worn power distribution

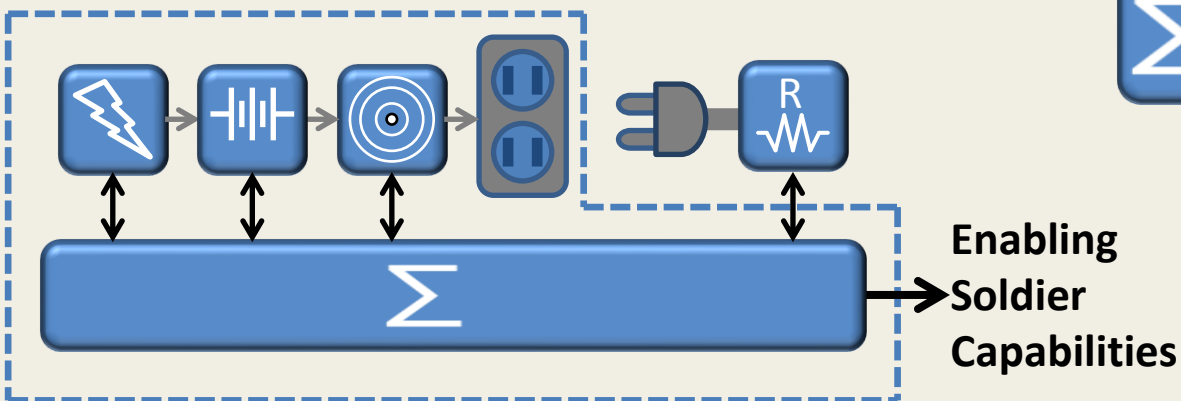


**Electrical & Thermal Load**

Consumer of the electricity:

- Communication s- Electronics Power (includes computers, sensors)
- Power Electronics Cooling
- Personal Heating & Cooling (wearable)

**Power & Energy Framework**



**Power Control & Management**

Integration of power sources, power generation, distribution grid and load management to provide electricity and energy status to Users.

- Source optimization
- Standard connectors
- Load management
- Non-Intrusive power distribution



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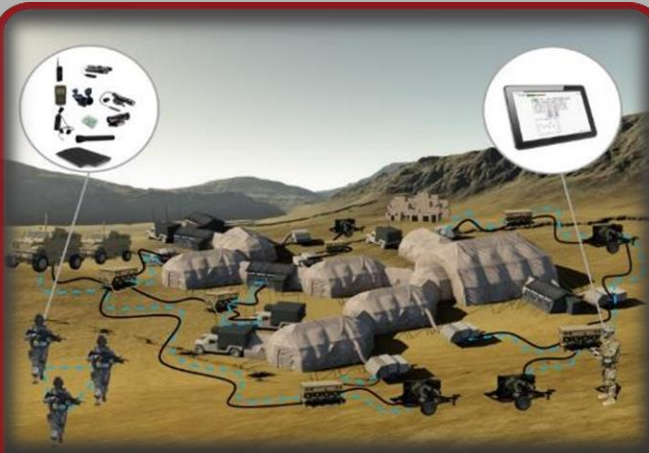
# Operational Energy Energy Informed Operations (EIO)

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## CURRENT

- No power monitoring or efficiencies, **total logistics dependence**
- **No optimization of power** and energy resources based on mission objectives
- One generator for each load with **high failure & maintenance required** – lowers overall power availability



## MID

- Reduced dependency on resupply and reduced logistics
- **Ability to tailor power system** based on operational environment and mission conditions
- **Increased power availability longer mean time between failures (MTBF) with lower maintenance**



## FAR

- Ability to use **any power, any where** - optimized for the given mission
- **Decreased deployment time/complexity** for tactical power systems
- Increased **renewable and alternative energy** solutions
- **Significant power availability – 97% up time**

OPTIMIZED POWER – INCREASED EFFICIENCY



*Schedule*     ◆ = TRL

Milestones	FY13	FY14	FY15	FY16
<b>Intelligent Power System Interface Standard Dev.</b>				
Intel. Power Distribution System Develop	5	6		
DRAFT Specification Releases	1	2	3	
Multi-voltage System incorporation		5	6	
TMSC Draft Standards Testing & Feedback				
<b>EIO Application Development</b>				
Application Development	2	3	4	
App/Power Integration and Test				
Application Enhancements			4	6
Integration with SPM				5
Final System Test & Demo				

**Purpose:**

Develop, implement, and support an intelligent power system interface standard and associated applications which allow optimization of power and energy resources based on mission objectives.

**Products:**

- Open Standards for Centrally Controlled Intelligent Power System Interfaces
- Applications for Awareness and Control of Power Resources

**Payoff:**

- Improved efficiency in operational energy to reduce to reduce cost and logistics burden of fuel resupply.
- Ability to prioritize and utilize power resources according to mission needs enabling commanders with information and flexibility to complete the mission in a resource constrained environment.
- More reliable and resilient energy network to ensure the availability of power across the battlespace.



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**Operational Energy**  
**Energy Informed Operations – Central (EIO-C)**

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## WHAT IS IT?

*Standards:* A scalable control standard for intelligent power distribution system interface, which allow optimization of power and energy resources based on mission objectives.

*Application:* The EIO application is a web base Single Page Application which allow the end users to monitor, manage and control power resources such as generator connect to a microgrid using the control standards.

## WHAT DOES IT OFFER?

*Standards:*

- Removal of a centrally controlled power management device eliminating a single point of failure for power and data transfer.
- Distributed control of hardware allows every device to be self-aware and conduct their own power & data management.
- Scalable architecture allows users to introduce new devices without the limitation imposed by fixed power management architectures.
- Provide the Warfighter with real time information about their power resources and its impact on their mission.

*Application:*

- Use knowledge base modules to Intelligently interpret

- power resource data and prescribe recommendations on how to use power efficiently during operational condition.
- Provide the Warfighter the ability to interactively monitor and manage power systems in order to optimize power availability, allowing the unit to maintain mission critical systems needed to achieve mission success.

## TECHNICAL APPROACH:

- Define a set of behaviors for various power resources types.
- Standardize the method by which data is exchanged.
- Fabricate prototypes to evaluate capability in hardware and software.
- Use real-time information generated from the intelligent power distribution systems, condition base maintenance data and mission objective prioritization to drive the implementation of capabilities that determine the best optimization strategies and provide power situation awareness.

### **Partners:**

MIT Lincoln Labs, Office of Naval Research, Army Corps of Engineers Research Labs, Army Research Labs, PM Expeditionary Energy & Sustainment Systems , PM Expeditionary Power Systems







*Schedule* ◆ = TRL

Milestones	FY16	FY17	FY18
<b>Control Stds for Distributed Power Systems</b> • Power System Simulation • Control Model Development • Power Hardware Development	◆3		◆5
<b>Energy Predictive Analysis Tools</b> • Prognostics & Diagnostics of Energy Systems • Power & Weather-Based Predictive Model Development • Hardware/Software Development	◆3		◆5
<b>Advanced Power Distribution</b> • Wireless Power Transfer: Near & Far-Field • E-Textiles • Higher Voltage AC/DC	◆2		◆5

**Purpose:**

Develop advanced power network control standards, and applications to enable high penetration of renewable technologies, ad-hoc arrangements and minimization wasted power in modular, scalable grids for self-sustaining Soldiers and base camps.

**Products:**

- Control Standards for Distributed Power Systems
- Prognostics and Diagnostics of Intelligent Power Sources for 91D, S4, and Smart Grid Apps
- Predictive Modeling to Optimize Energy Use During Mission Planning & Execution
- Advanced Power Distribution to include Wireless Power Transfer

**Payoff:**

- Reduced dependency on resupply and reduced cost and logistics burden of fuel and battery resupply.
- Ability to tailor power system based on operational environment and mission conditions
- More flexible and sustainable energy network to support extended missions with minimized logistics footprint.



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## EIO-D: Control Standards for Distributed Power Systems

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### WHAT IS IT?

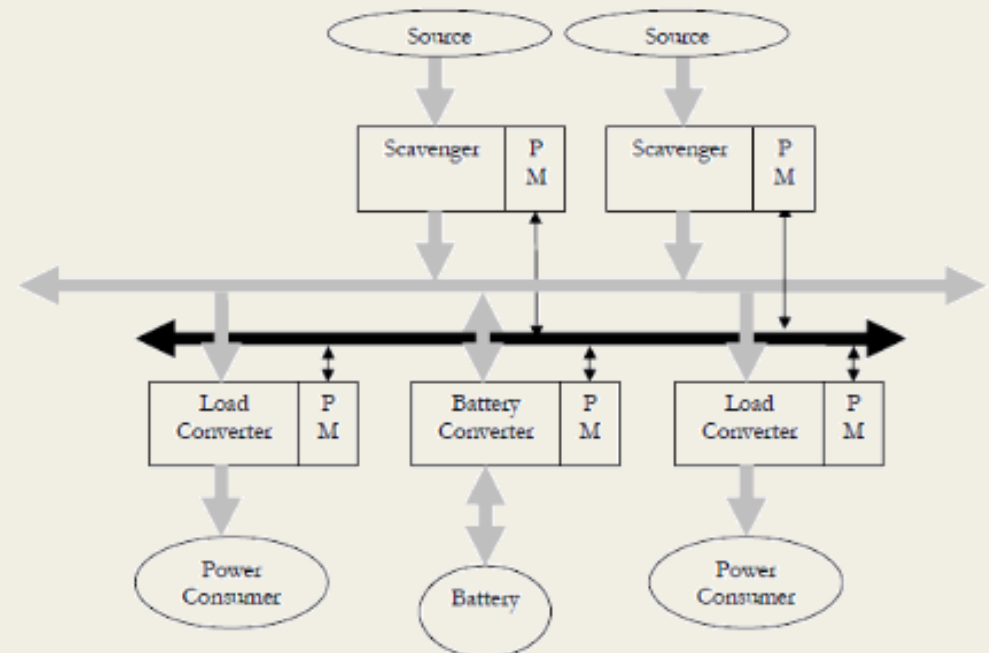
A scalable control standards architecture which enables devices to be controlled without the use of a central micro-controller. An intelligent power management module would reside within each device and be capable of automatically communicating with other powered devices.

### WHAT DOES IT OFFER?

- Removal of a centrally controlled power management device eliminates the single point of failure for power and data transfer.
- Distributed control of hardware allows every device to be self-aware and conduct their own power & data management.
- Reduction in weight and volume imposed by power management devices with a fixed number of ports.
- Scalable architecture allows Users to introduce new devices without the limitation imposed by a power management device with a fixed number of ports.

### TECHNICAL APPROACH:

- Define a set of behaviors for various power node types.
- Develop a breadboard to model power node performance in static & dynamic networks.
- Standardize the method by which data is exchanged.
- Fabricate prototypes to evaluate capability in hardware.





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# EIO-D: Energy Predictive Analysis Tools

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## WHAT IS IT?

A simulation model consisting of energy source/sink, mission and environmental variables capable of optimizing energy selection and use during mission planning and execution phases directly via the Users mobile device.

## WHAT DOES IT OFFER?

- Enables optimal selection of energy sources based upon a dynamically changing environment.
- Diagnostic & Prognostic modeling allows for the prediction of failures before they occur improving safety and efficiency.
- Allows intelligent control and switching of connected devices in a distributed network which maximizes energy efficiency.

## TECHNICAL APPROACH:

- Develop a framework in Simulink with all variables decomposed into discrete model blocks.
- Populate model blocks by testing energy source & load performance under various environmental conditions.
- Evaluate the performance of devices with respect to Soldier activities (March, Attack, Sleep, etc.)
- Incorporate capability into the existing Soldier architecture to aid in mission planning and execution.





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**EIO-D**

**Advanced Power Distribution**

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## WHAT IS IT?

Next Generation Power Distribution techniques to transmit power without the use of traditional cables during mounted and dismounted operations.

## WHAT DOES IT OFFER?

- Allows Soldiers to maneuver without becoming obstructed by physical cables.
- Elimination of cable failure caused by repeated bending & use.
- Ability to sustain long range items such as unmanned systems (UAS, UGV, etc.) to enable operational overmatch
- Reduced set up time of mission equipment.
- Reduction in power loss through improved distribution mechanisms to minimize overall energy demand.



## TECHNICAL APPROACH:

- Advance the development of E-Textile materials to eliminate snag hazards & improve mobility.
- Develop a path forward approach for using wireless to transmit power over short distances.
- Investigate the benefit of blending power source and power distribution components together to improve overall power distribution efficiency.
- Investigate technical feasibility of using higher power transmission technologies for long range wireless power transfer.
- Investigate the use of higher voltage transmission technologies to reduce cable infrastructure weight.





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# Operational Energy Tactical Power Generation (TPG)

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## CURRENT

- Too many different batteries with limited run-times
- Power generation severely limited by large amounts of battery swapping
- **Infantry Platoon carries 704 lbs of batteries for 72 hr mission require 39 battery swaps. (17 lbs per Soldier)**



## MID

- Reduced SWAP with high power & energy conformal wearable power sources integrated with Soldier Power Management
- Multi-fuel generators enable Squad battery charging
- **Infantry Platoon carries 261 lbs of batteries for 72 hr mission requires only 23 battery swaps. (6 lbs per Soldier)**



## FAR

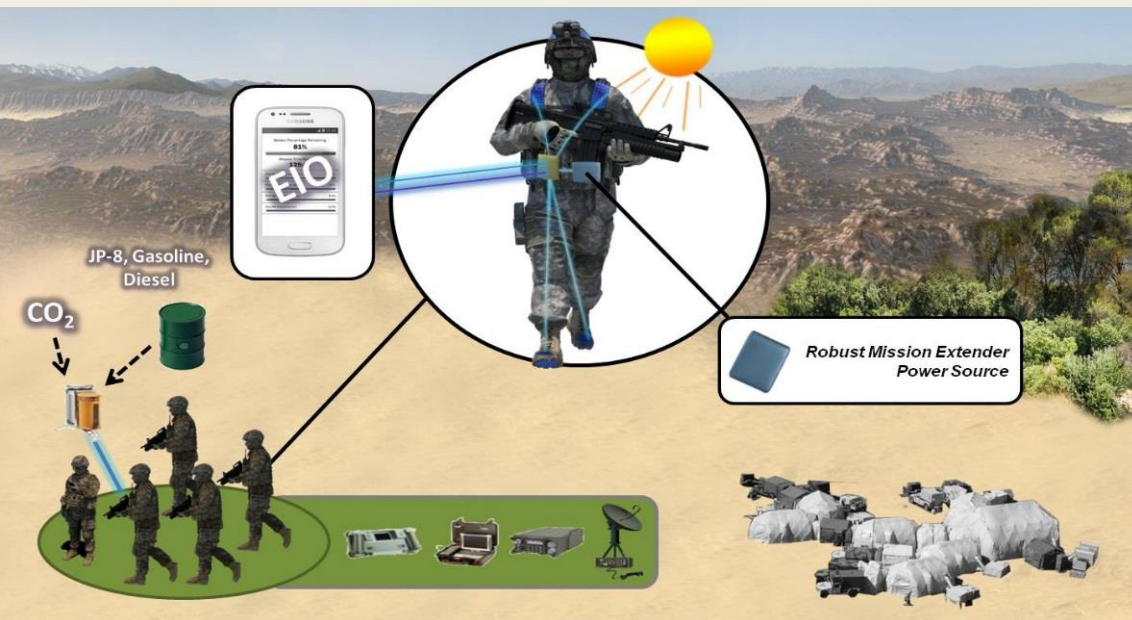
- Reduced SWAP through centralized sources w/ increased energy density and energy data awareness
- Reduced SWAP through high efficiency multi-fuel handling capability
- **Infantry Platoon carries 111 lbs of batteries for 72 hr mission requires only 5 battery swaps. (2.6 lbs per Soldier)**

OPTIMIZED POWER – INCREASED EFFICIENCY



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# Operational Energy Tactical Power Generation (TPG)



**Purpose:** Advance power & energy technologies that will result in products used to unburden the Soldier and Small Unit by significantly reducing swap, weight and costs of military unique batteries enabling self-sustainment for the future tactical force to continuously operate dismounted for multiple days in an austere net zero environment.

**Products:**

**Lightweight Portable & Soldier Power Sources (LPSPS):**

Develop power & energy technologies designed to lighten the load of the Soldier & Small Unit by reducing power sustainment footprint and extending mission duration through:

- Conformal wearable power sources (135 Wh/kg rechargeable; 350 Wh/kg primary; 20W hybrid power mission extenders)
- Multi-fueled portable power sources (≤30lb, 1kW)

**Advanced Integrated Soldier Power (AISP):**

Advance electrochemical materials and energy harvesting research & development to enable higher power & energy technologies with enhanced safety features for Soldier & Small Unit product integration through:

- Energy Harvesting Devices (kinetic energy harvesters)
- Advanced Electrochemical Materials (Li-Air, Li-S)

**Self-Sustaining Soldier Power (S<sup>3</sup>P):**

Optimize electrochemical materials and energy harvesting development that will enable future power & energy technologies with robust designs and reformed fuels to increase power generation capability for the Soldier & Small Unit through:

- Advanced Energy Harvesting Systems (soldier borne kinetic power generators)
- Robust Mission Extender Power Sources (700 Wh/kg)
- Reformed Fuel Power Sources (Efficient/High Yield CO<sub>2</sub> to Fuels)

**Payoff:**

- Reduces large quantities & swapping of expensive, bulky & heavy military batteries unburdening the Soldier as power sources get smaller, become wearable and significantly increase in energy.
- Provides Squad and Platoon level power generation for dismounted operations in remote areas as compact sources are implemented with high efficiency multi-reformed CO<sub>2</sub> to fuel handling capability.
- Enables net zero self operation and sustainment of dismounted Soldiers within Squad & Platoon level of operations during extended missions just beyond 72 hrs up to several days.

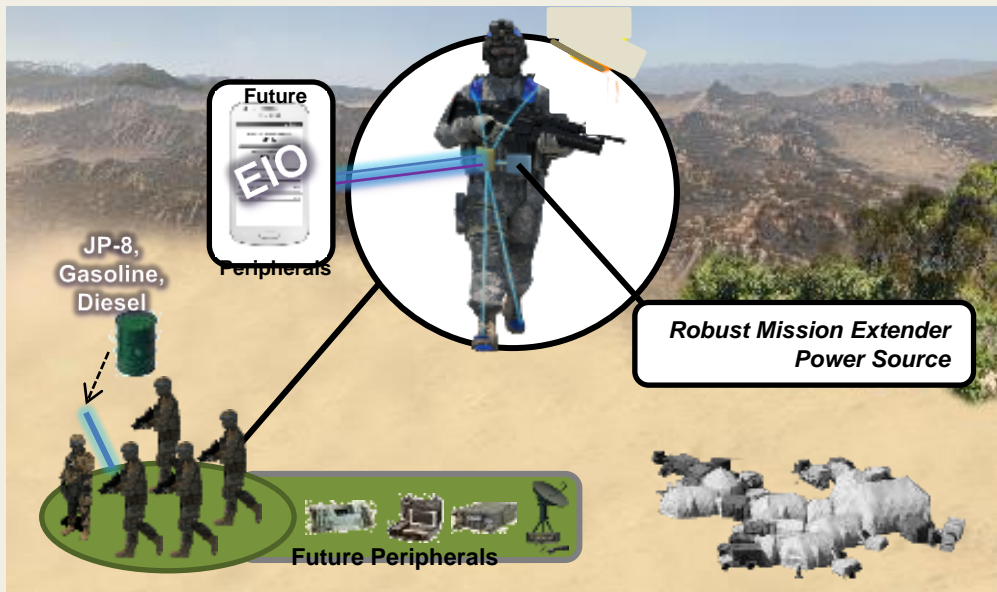
## Program Schedule

Milestones	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21
Lightweight Portable Soldier Power	4	6							
Advanced Integrated Soldier Power			2	5					
Self-Sustaining Soldier Power							4		
			Milestone Timeline						



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# Operational Energy Advanced Integrated Soldier Power



## Schedule

Milestones	FY16	FY17	FY18	FY19	
Kinetic Energy Harvesting	3	[Green bar]			5
Advanced Electrochemical Materials	2	[Green bar]			5
Compact Fueled Power Sources	1	[Green bar]			4

### Purpose:

Advanced electrochemical materials and energy harvesting component level research and development that provides more efficient Soldier and small unit power and energy technologies with enhanced safety features and the ability to be integrated into existing products.

### Products:

- Energy harvesting devices for Soldier power generation to include investigation of component level improvements for kinetic devices
- Advanced electrochemical materials for safe conformal wearable power sources to include both primary and rechargeable battery chemistries, and ultracapacitors
- Compact fueled power sources for increased energy on the move - includes novel fuel cell, microcombustion, and thermophotovoltaics materials, devices, and component development

### Payoff:

- Reduce Soldier burden: Nearly eliminates the large quantities of heavy military batteries further unburdening the Soldier as centralized power sources get smaller and significantly increase in energy
- Reduce logistical burden: Self-generation reduces the need for energy sustainment in austere locations
- Increased mission duration: Improved power densities and power generation while on the move enable extended operations beyond 72 hours



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**Operational Energy  
Advanced Integrated Soldier Power**

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## WHAT IS IT?

Development and demonstration of advanced Soldier and small unit power and energy technologies in 3 key areas:

- Energy harvesting: Kinetic energy harvesting devices that scavenge energy while on the move (CERDEC)
- Advanced Electrochemical Materials: Ultra-high energy primary and rechargeable conformal batteries (CERDEC/ARL)
- Compact fueled power sources: material and device development for novel fuel cells, micro combustion and thermophotovoltaics. (ARL)

## WHAT DOES IT OFFER?

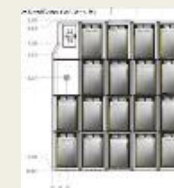
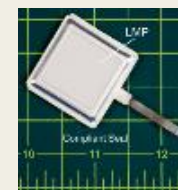
- Interoperable power solutions that maximize mission effectiveness, centralized power solution for increased power management and awareness
- On-the-move battery charging and power generation on the Soldier
- Physical weight burden reduction (>4X) for dismounted Soldier power; reduced need for spare batteries
- Significant increase in mission run times
- Wearable power in a conformal footprint

**Partners:** ARL SEDD, PM Soldier Warrior – Small Unit Power, ARL HRED/NSRDEC

## TECHNICAL APPROACH:

- Design and develop efficient kinetic energy power generation component technology for the Soldier
- Kinetic component material development and synergistic technology coupling, >0.09 J/step and 1.5 Ah per 2-3 miles walking
- Develop an ultra-high energy primary conformal battery materials with ~ 600 - 800 Wh/kg of energy
- Develop a high energy/power rechargeable conformal battery with up to 600 Wh/kg of energy
- Improve membrane conductivity and air electrode power density for Li-Air based designs
- Improve cycle life performance of Li-Sulfur designs
- Investigate and develop components for compact fueled power sources
- Development of cost effective fuel cell solutions with reduced balance of plant and higher efficiency

### *Energy Harvesting*



**Advanced electrochemical materials**

**Prototype  
Microcombustor**





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# Summary

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- Development, transition and fielding of advanced Power & Energy technologies have been, are, and will continue to be high priorities for the Army and DOD
- We cannot be successful in providing our soldiers with tactical power and energy superiority without the help of our academic, service and industry partners – all of you are critical
- Opportunities for innovation and collaboration will continue to present themselves well into the future for power and energy

## THANK YOU!