Current and Future Thrusts for Dismounted Warrior Power

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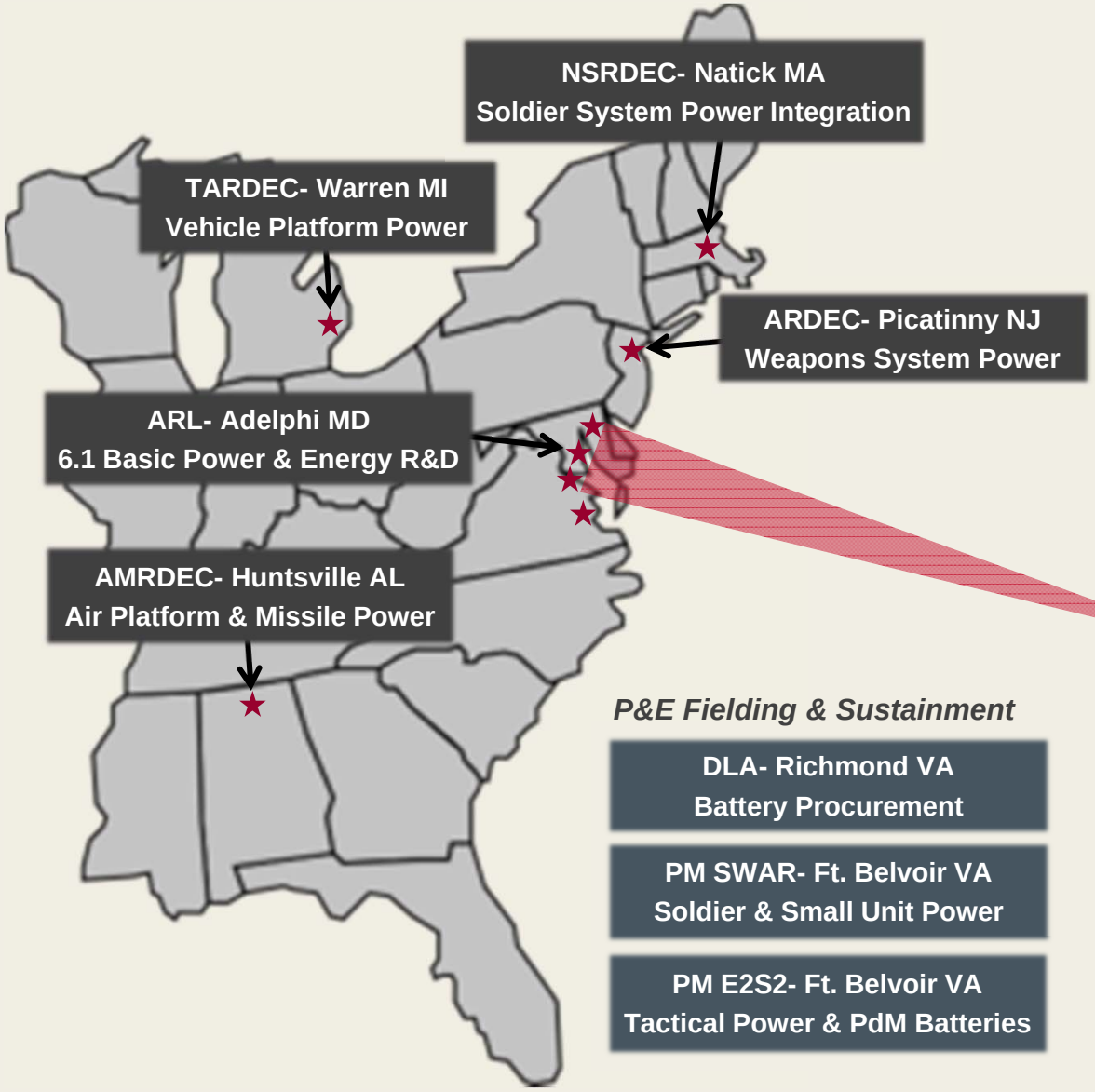
US Army RDECOM CERDEC CP&ID
NDIA Manufacturing Division Meeting Jan 2017

25 Jan 2017

Army P&E Community



P&E Fielding & Sustainment

DLA- Richmond VA
Battery Procurement

PM SWAR- Ft. Belvoir VA
Soldier & Small Unit Power

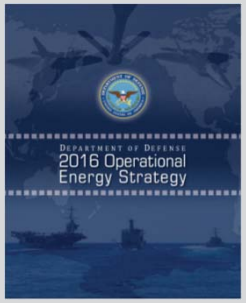
PM E2S2- Ft. Belvoir VA
Tactical Power & PdM Batteries

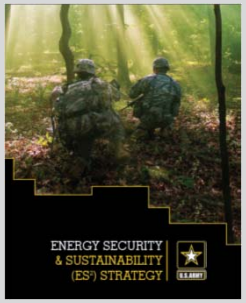
RDECOM ▪ CERDEC
CP&ID
COMMAND, POWER & INTEGRATION DIRECTORATE

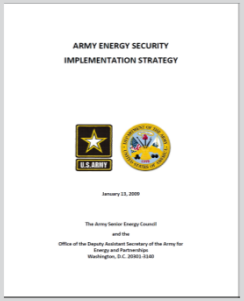
Power Division

6.2 Applied Power & Energy R&D
C4ISR, Soldier & Tactical Power

Operational Energy Strategic Guidance and Goals







Strategic Guidance

- Increase Future Warfighter Capability
- Identify and Reduce Risks
- Enhance Mission Effectiveness
- Inform Decisions – Leverage Army Culture
- Optimize Use – Increase Efficiencies
- Assure Access – Provide Reliable Availability
- Build Resiliency – Advanced Capabilities
- Drive Innovations – Encourage New Concepts

Operational Energy Goals

- Reduce Energy Consumption
- Increase Energy Efficiency across Platforms and Facilities
- Increase Use of Renewable/Alternative Energy
- Assure Access to Sufficient Energy Supplies
- Reduce Adverse Impacts on the Environment

U.S. ARMY RDECOM

Operational Energy Focus

CERDEC US ARMY – RDECOM

Technology Focus Areas

Power Sources
Batteries Capacitors

Power Generation
Fuel to Electricity Conversion

Renewables

Energy Harvesting

Power Distribution
Wireless Power

Power Management & Control

Soldier & Small Unit (up to 2kW)

Portable Power Generation

Conformal Wearable Battery

Wireless Power

Kinetic Energy Harvesting

Intelligent Tactical Micro-Grids (up to 360kW)

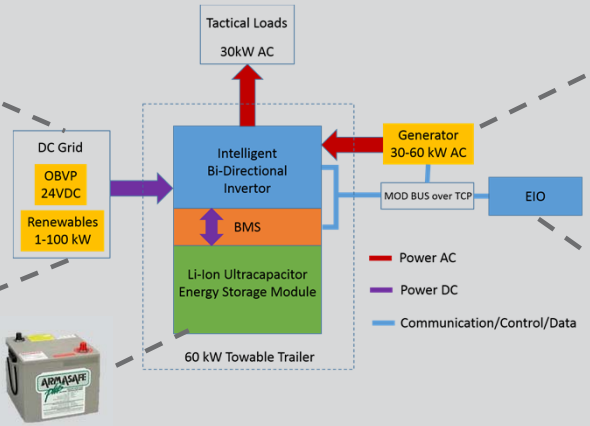
Advanced Medium Mobile Power System Generators

On Board Vehicle Power

Renewables

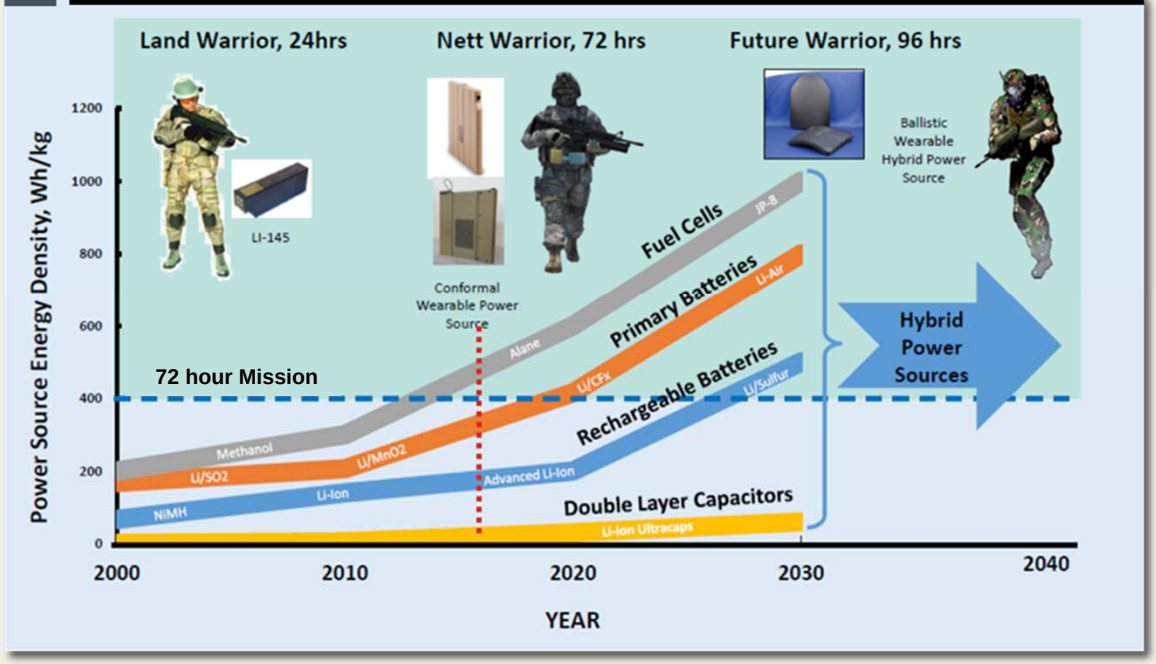
Energy Storage

Energy Informed Operations

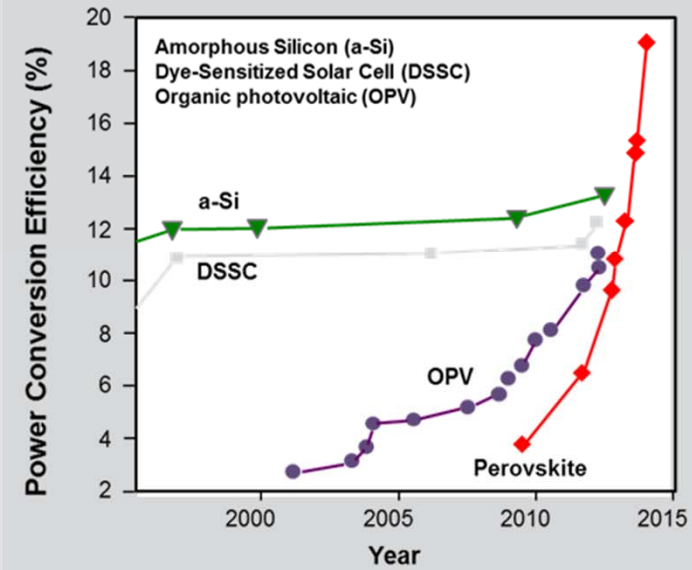


Operational Energy Trends

Soldier Power Trends



Renewable Energy Trends



Operational Energy Requirements

	High Level Required Capability	Capability Gaps	Specific Need	S&T Efforts
NEAR TERM (18-22)	Lighten the Soldier load	Maneuver Center of Excellence (MCOE) Small Unit Power CDD	Platoon - Provide sufficient power to recharge and power all Platoon equipment and fulfill residual power gaps at the Squad and Soldier level. Squad - Provide sources of power in austere environments where no power source exists. Soldier - Provide supplemental power to the conformal battery thus extending time between battery exchanges. Soldiers will require the ability to seamlessly interface their systems with a variety of energy sources and have the ability to monitor individual and SUP systems and energy status.	Advanced Integrated Soldier Power (AISP) Self-Sustaining Soldier Power
	Use power and energy resources efficiently	Army P&E Strategy WP – Grand Challenges 1, 2, and 3 Army Warfighting Challenge 16 CASCOM Technology and Capability Objectives for Force 2025 and Beyond	Significantly reduce requirements to transport fuel in an expeditionary environment. Maintain freedom of movement Provide intelligent power management and distribution	Ad hoc, In-Situ Power Management Wireless Power
	Understand the impact of energy on mission	Operational Energy ICD CASCOM Technology and Capability Objectives for Force 2025 and Beyond	Provide Soldiers and leaders a means to manage – measure, monitor and control energy status, usage and system performance; prioritize and redistribute resources. Integrate ability to generate, collect, control and analyze energy demand and consumption with Mission Command.	Expeditionary Mission Command – Energy Informed Operations

Field Based Risk Reduction

Opportunity to evaluate the Readiness of Capabilities in an Integrated Environment beyond the Traditional Lab Setting



Army Expeditionary Warrior Experiment (AEWE)
Maneuver Center of Excellence (MCOE), Fort Benning, GA

Maneuvers Fires Integration Exercise (MFIX)
Maneuvers Fires Battle Lab, Fort Benning, GA

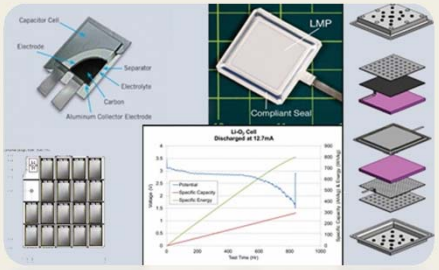
CERDEC Ground Activity
Joint Base Mcguire-Dix-Lakehurst, NJ

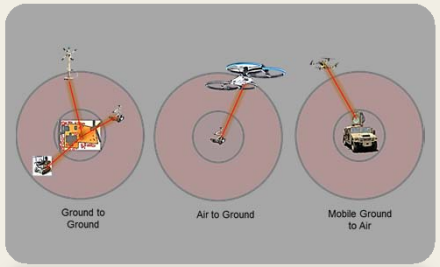
Base Camp Integration Lab (BCIL)
PM Force Sustainment Systems (PM FSS),
Fort Devens, MA

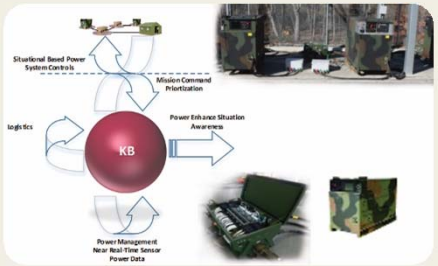

Contingency Basing Integration Technology Evaluation Center (CBITEC)
Maneuver Support Center of Excellence (MSCOE),
Fort Leonard Wood, MO


Network Integration Event (NIE) and Army Warfighting Assessments (AWA)
Brigade Modernization Command, Fort Bliss, TX

Summary of Challenges







Electrochemical Materials

- Primary Batteries: >600 Wh/kg
- Rechargeable Batteries: >300 Wh/kg
- Supercapacitors: 60 Wh/kg and 10kW/kg

Energy Harvesting

- Kinetic Energy
  - Capturing Low Frequency Motion
  - Capturing Instantaneous Strike Energy
  - >2.5 W/kg, continuous DC
  - Goal: 10W with 1kg
- Solar
  - Goal: > 25% Efficient PV

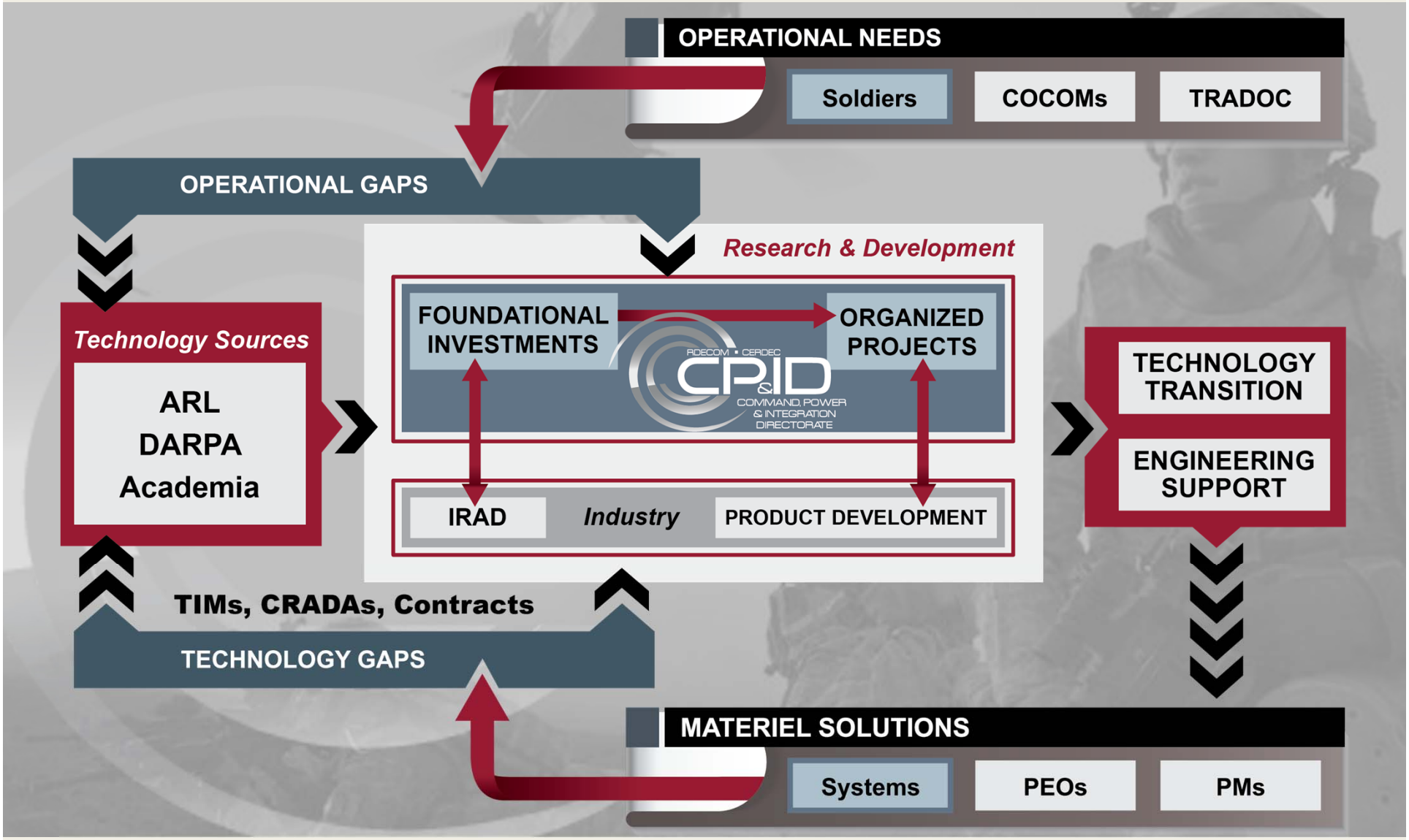
Wireless Power

- Receiving Diode
- Safety
- SWAP
- Goals:
  - >100W
  - >500m

Micro-Grids

- Tactical Grid-Tied Inverter w/ Anti-Islanding Controls
- Grid Stability and Controls
- Generator Tuning
- Secure Wireless Communications
- Grid Prognostics and Diagnostics
- Load Sharing Methodology

CP&ID Business Strategy
Concepts to Capabilities



Recommended Resources

- https://www.fbo.gov/
- www.sbir.gov
- Cooperative Research and Development Agreement (CRADA)
- Test Services Agreement
- Patent License Agreement
- http://www.cerdec.army.mil

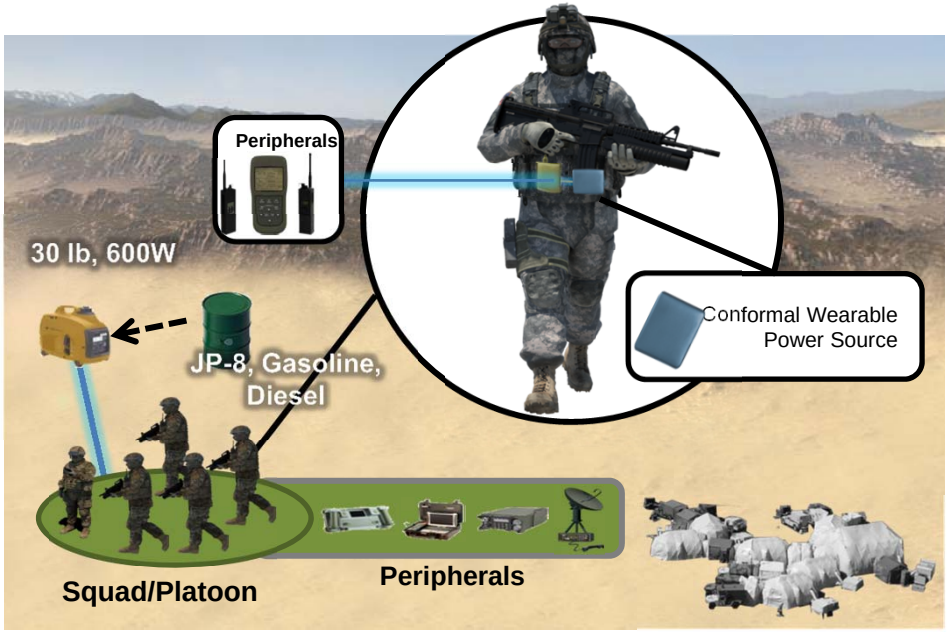
Focus Areas & Products

Goals & Drivers	Product Focus Areas
• Reduce battery SWAP-C* • Reduce battery spares • Enable extended operations	Energy Storage
• Generate power on the move • Enable Net-Zero operations • Reduce need for re-supply	Power Generation
• Optimize power distribution • Minimize energy consumption • Reducing battery burden / logistics	Soldier Power Management

**SWAP-C: Size, Weight and Power - Cost*

Advanced Integrated Soldier Power (AISP)

Advanced Integrated Soldier Power



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 to include novel fuel cell and component development and compact portable combustor for electric power

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

AISP: Energy Storage Advanced Electrochemical Materials

What is it?

Research that seeks to mature in-house & externally developed electrochemical materials to support component-level scale up for very high power & energy wearable power sources.

Advancements will enable battery technologies to reach up to 600-800 Wh/kg, which is a 4-6X increase over the current lithium ion batteries.

What does it Offer?

- Technology knowledge products that can influence component scale up for power sources
- Physical weight burden reduction (>4X) for power for dismounted Soldiers
- Significant increase in mission run times
- Provides wearable power in a conformal fightable footprint
- Faster recharging capability
- Reduces the need for various spare batteries

Technical Approach:

- Optimize Li-S cell components through Sulfur encapsulation techniques, Li protection layers, surface modified nanoclays and additives & co-solvents
- Improve cycle life performance of Li-S designs
- Develop robust materials for Silicon Anode and improve cycle life performance
- Investigate novel materials and processes to lower the cost of CFx
- Improve membrane conductivity and air electrode power density for Li-Air based designs.
- Report results of findings via applicable knowledge sharing forums

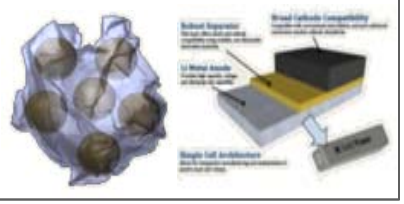
Technology Knowledge Products

Patents

Journal Articles

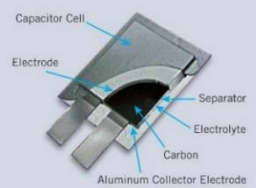
Licenses

Materials Research



4.5X Reduction in Soldier Battery Weight for 72 hrs

Cell scale up



Battery scale up

AISP: Kinetic Energy Harvesting

What is it?

Kinetic energy harvesting devices provide power to the Soldier by scavenging energy while on the move (i.e. walking, running).

Goal is to develop components that can be integrated into Soldier wearable and man packable applications to reduce quantity of carried batteries.

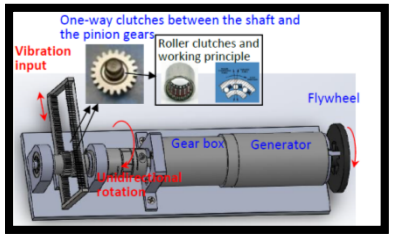
What does it Offer?

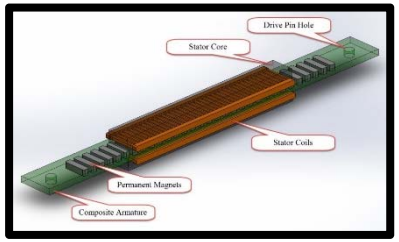
- On-the-move battery charging
- Interoperable power solutions that maximize mission effectiveness
- Reduced Soldier physical burden
- Power at remote locations with minimized resupply
- Tactical sustainment costs are reduced

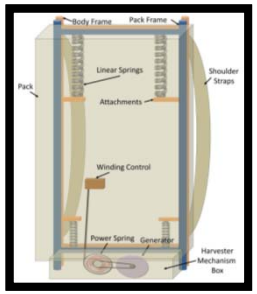
Addresses PM SWAR KPP to Provide Power Generation Capability on the Soldier

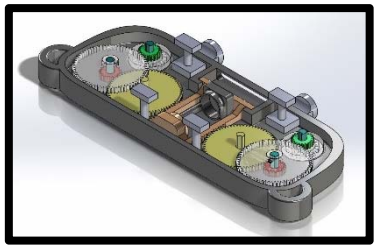
Technical Approach:

- Design rugged lightweight electromechanical components to harvest energy from Soldier center of mass motion that will enable sufficient power through put
- Design and build a Mechanical Motion Rectifier that harvests and converts bidirectional vibrations into unidirectional rotation, yielding greater efficiency and a significant increase in output power
- Design electromechanical components tuned to Soldier center of mass motion to increase power output and minimize the pack load burden on the Soldier

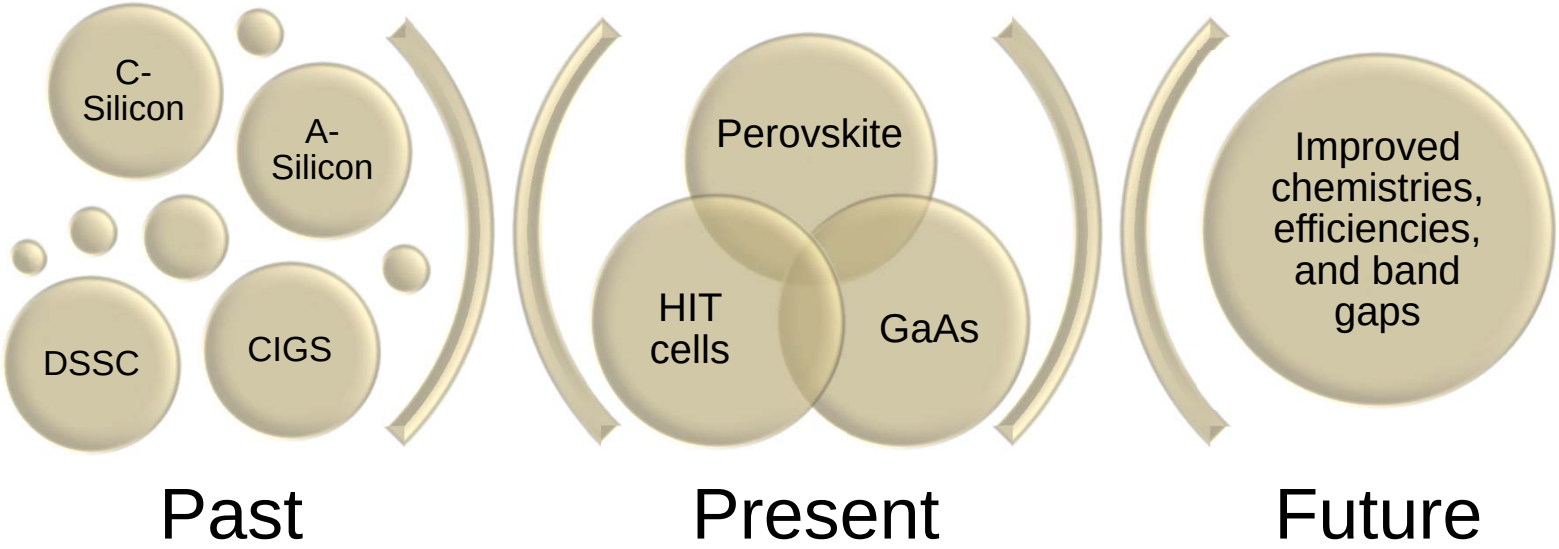








Solar Technologies



Advanced 100W Solar Blanket

What is it?

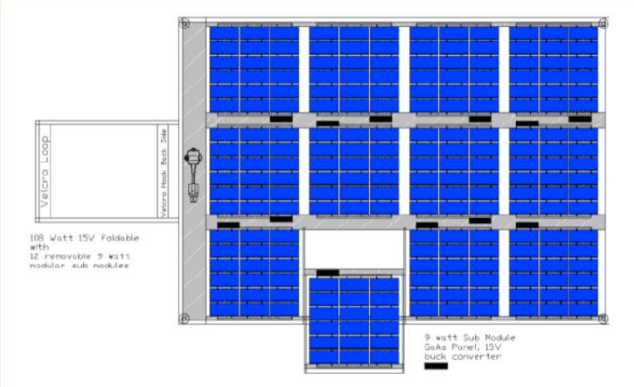
Solar panels utilizing advanced cell & electrical interconnect designs to improve overall performance.

What does it Offer?

- Use of higher efficiency materials will enable increased recharge capability
- Modules enable scalability, load distribution & minimal damage to the array
- Improved manufacturing methods to reduce cost and programmatic risk

Technical Approach:

- Define optimum module layouts
- Optimize power electronics performance
- Define optimum interconnect methods
- Define optimum encapsulation and interconnect design
- Conduct hybrid system analysis



Soldier Power Management & Distribution

Distributed Expeditionary Energy Management (DEEM)*

*Customer-funded effort

Distributed Expeditionary Energy Management (DEEM)*

Purpose:

Develop a lightweight multi-path, cable-less distribution architecture leveraging next generation power and data standards, and energy tools to optimize the selection of energy sources worn by Soldiers and Small Units.

Products:

- Matrix Architectures for Power Systems
- Energy Optimization Tools

Payoff:

- Awareness of energy assets allows Soldiers to be more self-reliant with reduced dependency on resupply of energy sources.
- Ability to intelligently select energy sources based on the operational environment and mission conditions ensures optimal sources are used.
- Flexible and configurable distribution system allows direct transfer of mission command capability from one Soldier to another.
- Multi-path, cable-less distribution architecture allows for a lighter, more reliable power and data flow due to redundant connection points and paths.

*Customer-funded effort

DEEM: Matrix Architectures for Power Systems*

What is it?

A scalable Power and Data architecture which enables devices to be intelligently controlled without the use of a central micro-controller or traditional cables on the tactical vest. An intelligent power management module would reside within each device and be capable of automatically communicating with other powered devices.

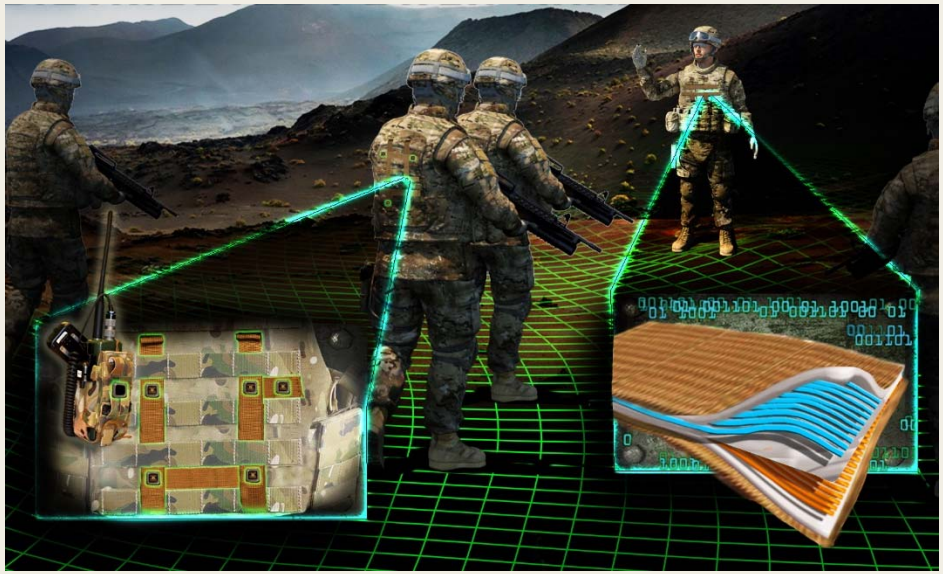
What does it Offer?

- 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.
- Universal and Scalable architecture allows Users to introduce new devices without the limitation imposed by a power management device with a fixed number of ports.

Gaps, Requirements Trace: SQD CBA 9.01, 9.02; OEfSGO ICD Priorities 2, 6 & 7

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.



Energy Optimization Tools

What is it?

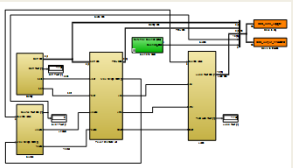
A mobile application which brings together data regarding the energy load, mission and environmental variables to optimize energy selection and use during both planning and execution phases of the mission.

What does it Offer?

- Enables optimal selection of energy sources based upon the operational environment and mission profile.
- Diagnostic & Prognostic modeling allows for the prediction of failures before they occur improving safety and efficiency.
- Allows Users to see the impact of energy needs before actually starting the mission.

Technical Approach:

- Develop a software framework with all variables decomposed into discrete model blocks for energy sources/loads and power management control.
- 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.

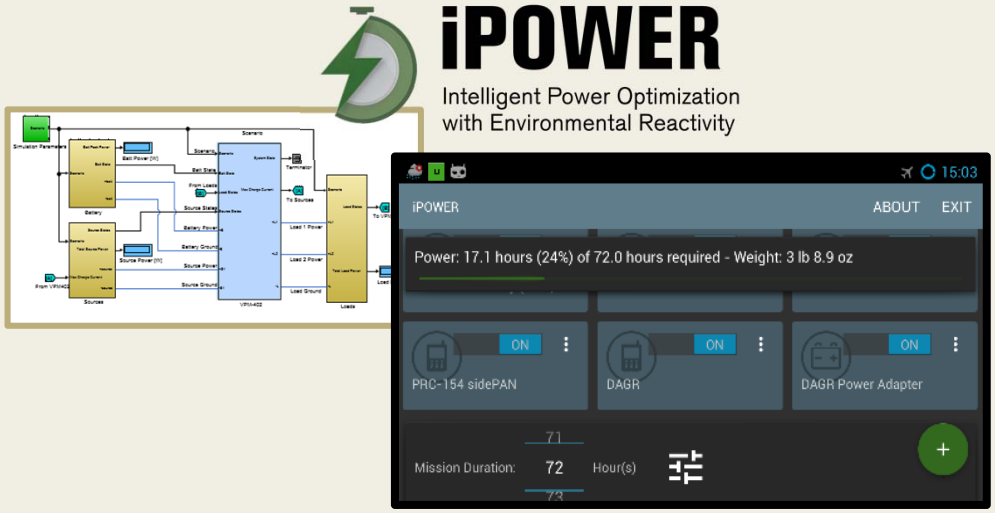


Gaps, Requirements Trace: SQD CBA 9.01, 9.02; OEfSGO ICD Priorities 2, 5, 7, & 11

Intelligent Power Optimization with Environmental Reactivity (iPOWER)

Purpose:

Develop an energy planning tool to optimize the selection of energy sources by bringing together device, mission, and environmental data to recommend an equipment load-out and estimate mission endurance for Soldiers and Small Units.



Results/Products:

Energy Optimization Tool with the following features:

- Mission Optimizer to select optimal energy sources based an embedded energy analysis code.
- Mission Block to allow the Soldiers to build their anticipated mission.
- Environmental Reactivity functionality to recommend the use and employment of solar panels based on optimal times.

Payoff:

- Reduces excess weight and volume by optimizing the selection of energy sources based upon the operational environment and mission profile.
- Guides mission planning by showing Users the energy impact of their choices before starting the mission.
- Provides Users with a recommendation to deploy energy harvesting at optimal times based upon environmental factors which enhances the amount of scavenged energy during a mission.

Future Proposed Work

USB 3.x Power Delivery

What is it?

USB 3.x is the current interface standard for power and data transfer between commercial C4ISR devices. It offers power distribution and control with higher data rates (bandwidth) allowing future devices to leverage this higher bandwidth and still support legacy data transfer from previous USB standards.

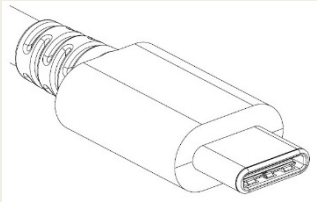
What does it Offer?

- Allows devices to negotiate power from the existing +5V,1.5A USB power wire.
- Negotiation of 5V, 12V, 20V up to 5A
- Up to 100W bidirectional power & data over 4 wires (device can power host)
- Reduced procurement cost as well as cable and connector weight
- Commercial standard implementation (not recreating the wheel)

Gaps, Requirements Trace: SQD CBA 9.01, 9.02; OEfSGO ICD Priorities 2, 5, & 11

Technical Approach:

- Review USB-IF standards.
- Conduct lab evaluation of chip vendor offerings.
- Simplify connector pinout from USB type C to MIL STD connector.
- Lay out conceptual Soldier system architecture elements.
- Develop function specifications for system components.



USB Type C plug

Data Over Powerlines

What is it?

Uses electrical wiring to simultaneously carry both data, and power. Communications signal modulated over AC or DC powerline. Narrowband (3-500 kHz) FFT sampling with multiple channels and provides up to 500 kbps data.

What does it Offer?

- Position CERDEC as subject matter experts in emerging technology space.
- Reduce weight in cabling and connectors for Soldiers, vehicles, basing, and aircraft.
- Reduce command post setup and tear down time.
- Guarantee interoperability of Army microgrids with worldwide public grid infrastructure.
- Universal and Scalable architecture allows Users to introduce new devices without the limitation imposed by a power management device with a fixed number of ports.

Gaps, Requirements Trace: SQD CBA 9.01, 9.02; OEfSGO ICD Priorities 2, 5, 7 & 16

Technical Approach:

- Evaluation of Powerline Communication technology.
- Concept demonstration through integration with EIO Microgrids.
- Demonstrate applicability to Soldier power management systems.