# National Academy of Sciences Battery Conference

## Panel I: The Federal Outlook for the U.S. Battery Industry

## The Army Perspectives


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# Discussion Topics

- Army Ground Vehicle Perspective
- Vehicle Power and Energy Trends
- Warfighter Requirements
- Spectrum of Vehicle Electrification
- Systems Integration—From Component to Platform
- Energy Storage Technology Developments
- Challenges

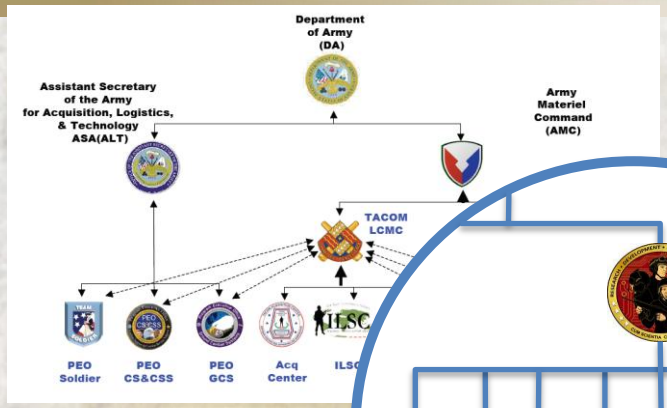
# It's All About the Warfighter

U.S. ARMY RDECOM



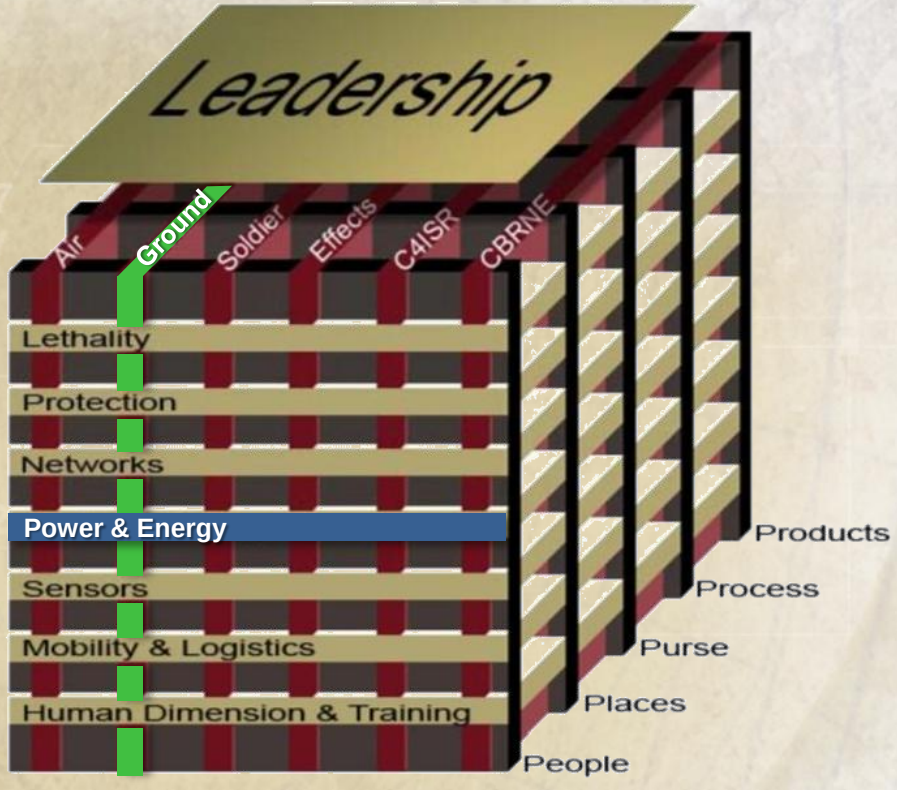
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

# Task Organized to Deliver Capabilities





- Technology – System Organizational Construct
- Multifunctional, Multidisciplinary Organization
- Cross-cutting System Engineering
- Incubating, Maturing, Transitioning Next Generation Technology




**Leveraging Resources & Investments to Deliver Capabilities**

# TARDEC Mission and Vision

U.S. ARMY RDECOM

- Provides full life-cycle engineering support and is provider-of-first-choice for all DOD ground combat and combat support vehicle systems.
- Develops and integrates the right technology solutions to improve Current Force effectiveness and provide superior capabilities for the Future Force.

***Ground Systems Integrator for the Department of Defense***

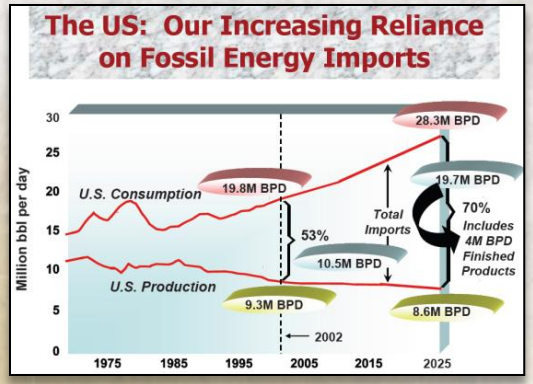
**Responsible for Research, Development and Engineering Support to *2,800* Army systems and many of the Army's and DOD's Top Joint Warfighter Development Programs**

# Power and Energy Trends

## The Challenges

### Battlefield consumption of energy increasing

- New C4ISR technologies
- IED Defeat Systems
- New weapons (EM guns, lasers)




### Energy security problematic

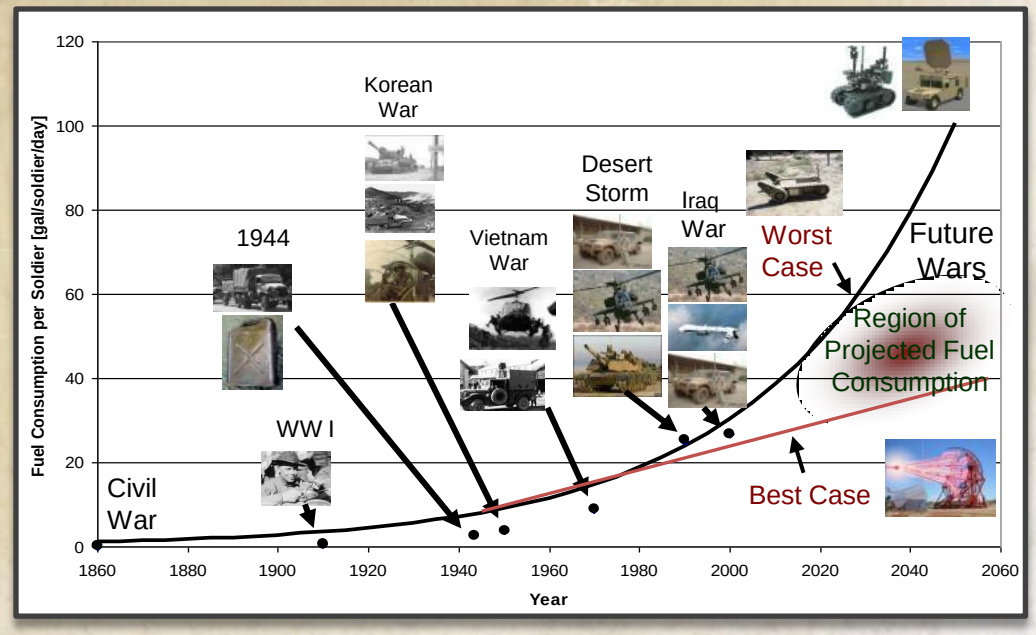
- Cost of fuel skyrocketing
- Alternative sources sought – wind, solar, bio-mass, waste to energy

### Operational issues

- Battery usage & limitations – energy & power density
- Demand for auxiliary power on-board vehicles
- Emphasis on silent (“quiet”) watch
- Unmanned vehicles (air/ground)
- Unattended sensors
- Inefficient management/ distribution of power
- Demand for soldier-wearable power

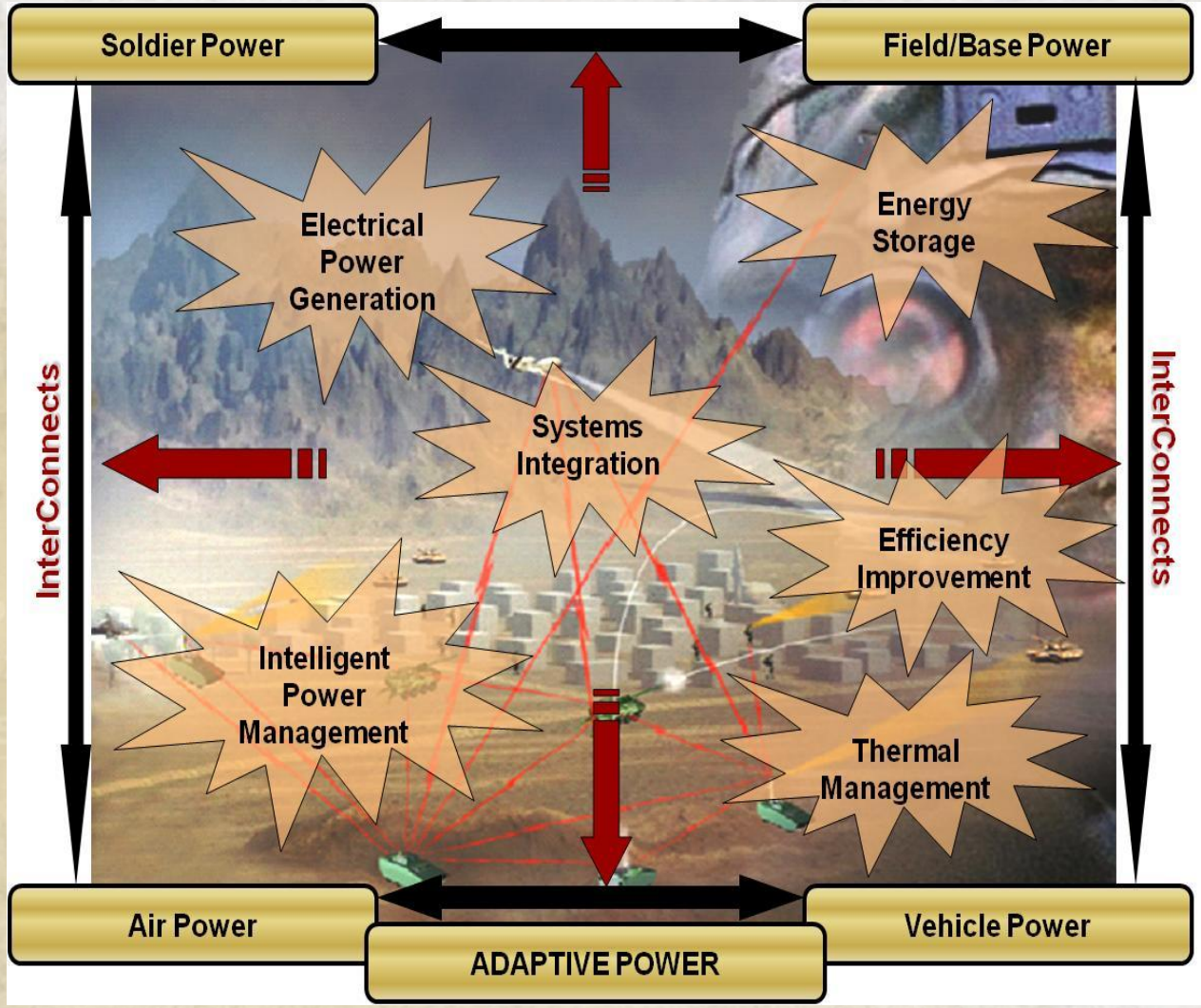
### Increased emphasis on system power metrics and energy efficiency

(KPPs, low consumption components)

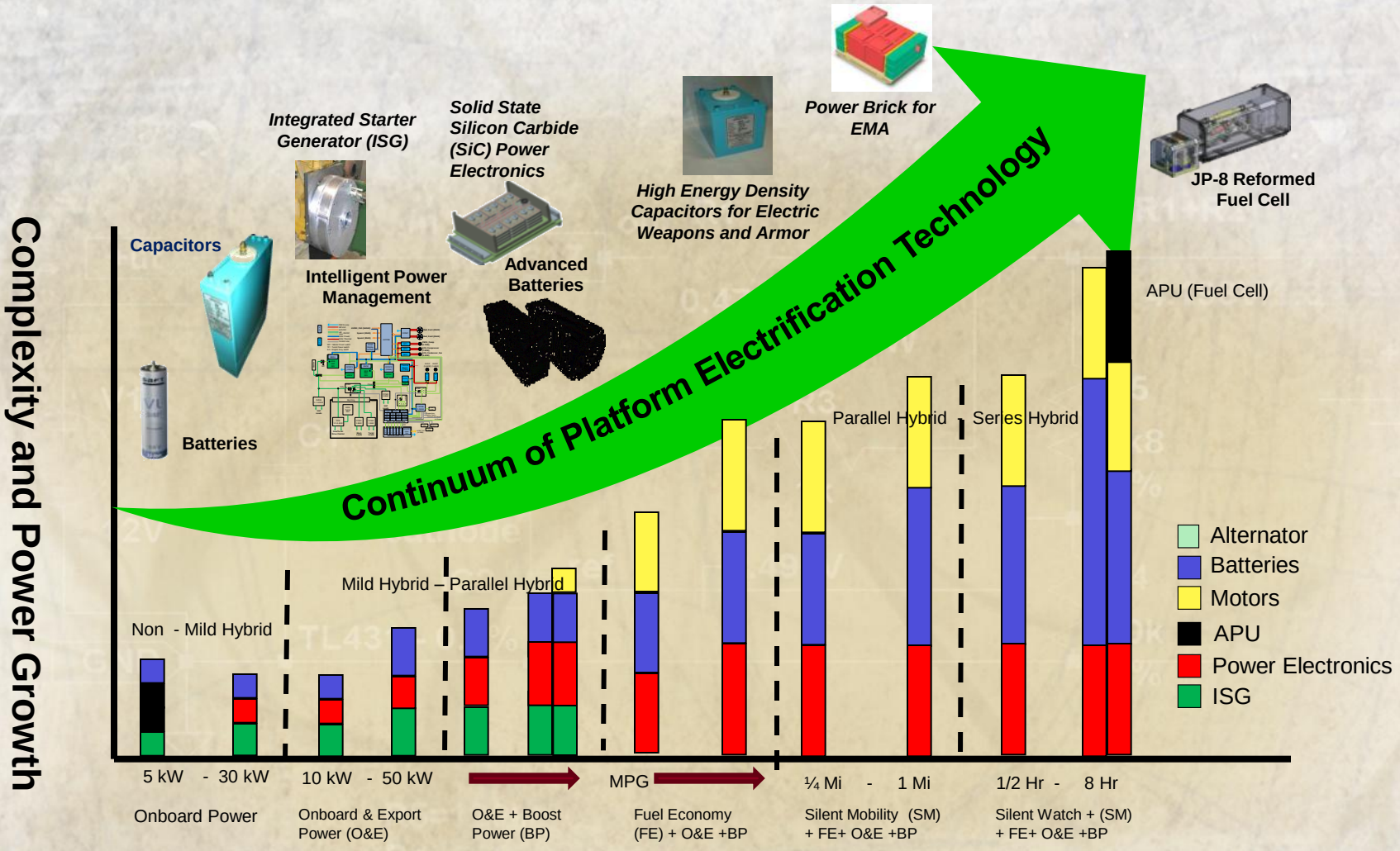


# Power and Energy Warfighter Outcomes

- **Enhance ground force effectiveness**, flexibility, protection and freedom of movement **by reducing the need to transport fuel**
- **Dramatically reduce sustainment footprint**, lighten soldier load and extend platform range/self-power endurance **by combining component functions**
- **Increase flexibility** by expanded capabilities to utilize **alternative energy** sources, **recycle energy, water and waste**, and to **redistribute resources among systems**
- **Reduce size and number** of Soldiers & systems required in forward areas **by deploying unmanned systems**
- **Integrate power & energy situational awareness and management functions with Mission Command** to **optimize energy use** and enable **"energy-informed operations"**



# Platform Electrification Technology




Menu of Capability

# Systems Approach Applied

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## Component

### Component Elements

DC/DC Converters

Motors

Batteries

### Subsystem Elements

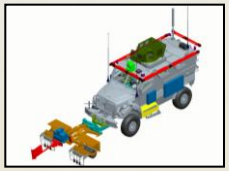
Engines

Engine Generator

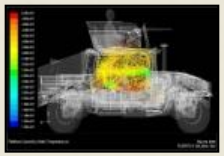
### High Temperature Electronics

High Temperature Power Electronics

## System Integration



Concepts



Analysis

Simulation

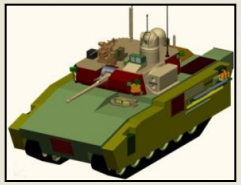
Testing

Systems Integration

## Platform Level

Fuel Efficiency ground vehicle Demonstrator

Autonomous Platform Demonstrator



Ground Combat Vehicle

Joint Light Tactical Vehicle

Parallel hybrid UVs

RSTV Series HE

Parallel Hybrid MSV

**Enabling Integration & Technology Development**

# Energy Storage Major Technology Increasing Energy Density

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## *Energy Density Improvements over time*

**2035-2050**
APU + High Energy Batteries
JP 8 Reformed Fuel Cell + Batteries

Future

**2012**
- Li-Ion Polymer
- 200 Wh/kg

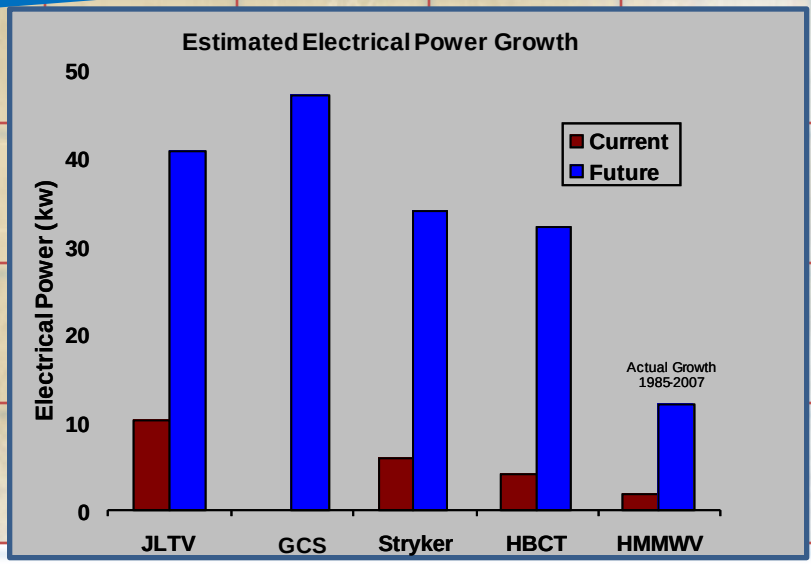
**2008**
- Li-Ion
- 145 Wh/kg



**2004**
- NiMH
- 120 Wh/kg

**1980**
- Nickel-Cadmium
- 60 Wh/kg

**1860**
- Pb-Acid
- ~30 Wh/kg

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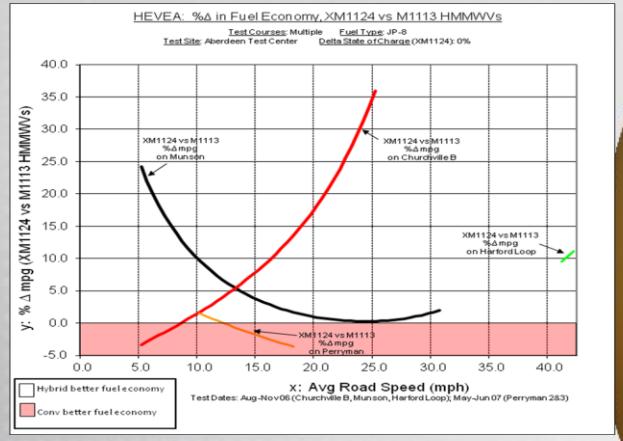
# Vehicle Electrification Challenges

Parallel Hybrid MSV

HMMWV Series HE

RSTV Series HE




- Military Duty Cycle and extreme environments
  - Very high torque and power demand
- Reliability and Safety
- Integration and packaging
- Thermal management and high temperature components (SiC)
- Development and advanced technology unit Cost
- Logistics and supportability
  - Expeditionary operations

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# Army Energy and Power: Battery Research and Investments


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# Discussion

- Defense and Army Strategic Energy Opportunity Areas
- Army Energy Strategy and Taxonomy
- Army Battery Investment Focus
- Battery Technology Programs
- Summary

# Defense Energy Strategic Opportunity Areas for Future Directions

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## Tactical Unit Energy Independence

UAV

UGS

## Autonomous Platform Power

## Adaptive Power Networks

## Energy Optimized Platforms

EM Launch

## Electric Weapons and High Power Sensors

# Power & Energy Strategy: Army Translation of Opportunity Areas

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## SOLDIER

Requirement:
72 Hour Missions


Technologies: High Energy Batteries, Hybrid Power Sources, Photovoltaic

Requirement:
Silent Power

## MOBILE

Technologies: Fuel Cell APUs, Reforming, Power MEMS

Requirement: Platform Surge Power , Weapon Pulse Power

Technologies: High Power Switching & Conditioning; Intelligent Power Management, Integrated Thermal Management

## PLATFORM & WEAPONS

| | | | |
|---|---|---|---|
| DOMAINS: | Soldier, C4ISR | C4ISR, Air, Ground | Ground, Effects |
| | MicroWatts to 10s of Watts | 100s of Watts to 100s of kW | Up to 1000s of MW |

# Army Strategic Opportunity Areas

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**Higher Energy Power Sources for Soldiers and Sensors**

**Unmanned Air and Ground Platforms**

Reformed Methanol Hybrid Fuel Cell

**Intelligent Energy Management Coupled with Alternative Energy Sources for Reduced Logistical Burden (Combat Outposts)**

Rucksack Portable Power System

**Ground Combat & Tactical Vehicles Vehicle Auxiliary Power and Quiet Watch Capabilities**

**High Energy Weapons**

# Power & Energy Taxonomy

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## Power and Energy Technology

### Electric Power Generation & Conversion

- Fuel Cells & Reforming
- Electro-mechanical Generation
- Alternative & Renewable Energy Conversion
- Micro Power/ Actuators/Motors

25.6%

### Energy Storage


- Primary Batteries
- Rechargeable Batteries
- Reserve Batteries
- Capacitors
- Fuel Storage

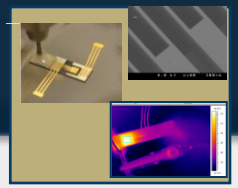
27.2%

### Power Control & Distribution

- Power Switches /Electronics
- Power Converters & Inverters
- Power Distribution
- Intelligent Power Management
- Magnetics/Other

16.6%

### Thermal Management



- Heating & Cooling
- Power Electronics
- Sub-System Thermal Management

30.6%

FY10 Investment → 6.1: 4.3% 6.2: 57.8% 6.3: 37.9% Total:100%

# Army Battery Investment Focus

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Army Technology Priority

Low ⟷ High

Investment Priority: High ↕ Low

## Commercial Market

**Lead Acid Rechargeable (SLI/HEV)**
Vehicle, critical backup, deep cycle applications, low cost electrical storage

**Alkaline Primary**
Non-critical applications

**Ni-MH Rechargeable**
Soldier power, HEV

**Li-$MnO_2$ Primary**
**Zinc-Air Primary**
Soldier power, sensors

**Li-FeS2 Primary**
Soldier power, sensors, long shelf life applications

## Commercial Chemistry Requiring Military Adaptation

**Hi Power Li-Ion Rechargeable**
Vehicles, critical backup, Soldier power, persistent surveillance, sensors

**Li-(CF)x Primary**
Soldier power, sensors

**Ni-Zn Rechargeable**
Vehicles, critical backup

## Military Unique Chemistries

**Li-Air Primary**
Soldier power, persistent surveillance, sensors

**Liquid Reserve**
Electric fuses for artillery, mortar, missiles, sub-munitions

**Thermal Reserve**
Electric fuses for artillery, missiles

**Pulse Power Li-Ion Rechargeable**
Weapons, GCV, 600V battery pack

**Li-SO2 Primary**
Soldier power, sensors

# High Voltage Li-ion Batteries

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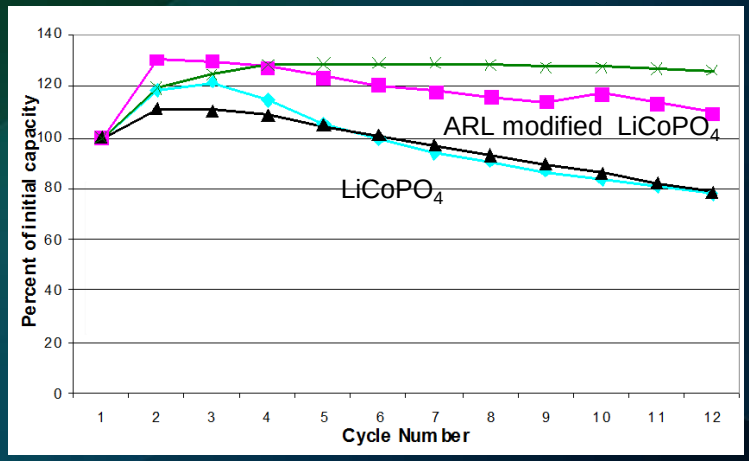
## OBJECTIVE

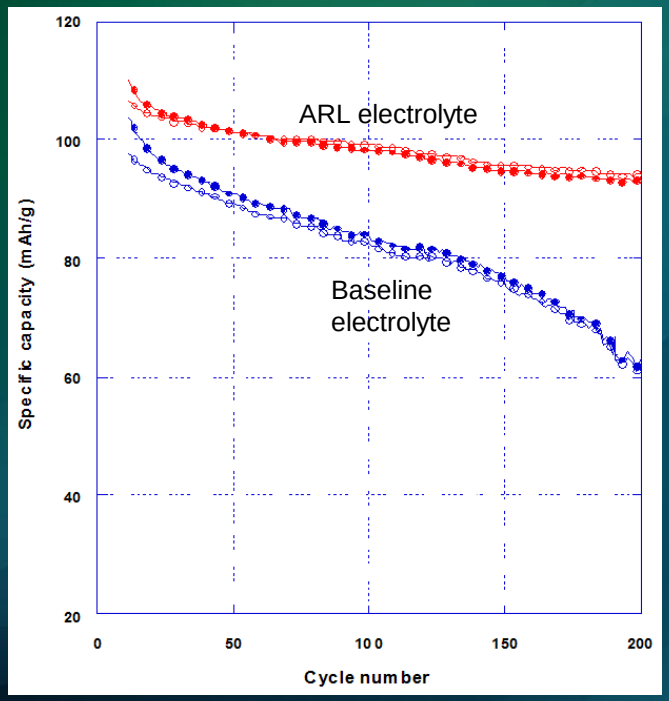
- Develop safe and higher energy-density Li-ion batteries

## CHALLENGES

- Cycling capability
- Electrolyte instability at higher voltages




*Cycling of structurally modified $LiCoPO_4$ vs. Li, 3.0 – 4.9 V*




*Cycling of $LiNi_{0.5}Mn_{1.5}O_4$ vs. Li, 3.0 – 4.95 V*

- Stabilized $LiCoPO_4$ by partially substituting Co with other metals with low capacity loss.
- Identified electrolyte additive that allows the cycling of high voltage cathodes with high capacity retention.

# Bio-inspired Materials for Enhanced Battery Performance

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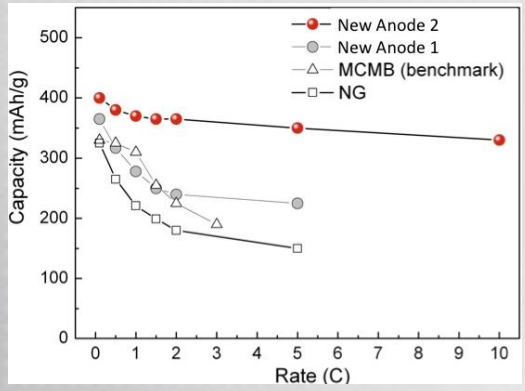
## High-performance Anodes For High Power, Lightweight Li-ion Batteries

- Bio-inspired catalytic synthesis grows tin nanoparticles inside graphite
- Higher metal electrical capacity that better accommodates swelling and shrinking during charge-discharge cycle
- Prevents metal disintegration and capacity loss seen with other anodes
- Result is higher energy and higher power density (excellent performance at 20C); suggests applications for lightweight electric vehicles and UAVs

**Retains High Capacity at High Rates**



# Battery Technology: Key Enabler for Networked Energy

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Improved Soldier Power

Energy Weapons

EM/Reactive Armor

Unattended Sensors

Non-propulsion Vehicle Apps

Increased life/ endurance

Increased Voltage

**Battery Technology**

Increased Capacity

Base/COP Back-up Energy

Safety

Improved Operating Characteristics (i.e., temperature, cycling)

Less Degradation

Intelligent Power Usage

Smart Grid

Battery Recharging

Off-peak Energy Storage

Energy Harvesting

Future systems, ever more power intensive!

Improving *energy* capability through holistic power sharing!

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