U.S. Army’s Ground Vehicle Energy Storage R&D Programs & Goals

Sonya Zanardelli
Energy Storage Team, US Army TARDEC
sonya.zanardelli@us.army.mil  586-282-5503
November 17, 2010
U.S. Army's Ground Vehicle Energy Storage R&D Programs & Goals

Sonya Zanardelli

US Army RDECOM-TARDEC 6501 E 11 Mile Rd Warren, MI 48397-5000, USA

Approved for public release, distribution unlimited

The original document contains color images.

<table>
<thead>
<tr>
<th>16. SECURITY CLASSIFICATION OF:</th>
<th>17. LIMITATION OF ABSTRACT</th>
<th>18. NUMBER OF PAGES</th>
<th>19a. NAME OF RESPONSIBLE PERSON</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. REPORT unclassified</td>
<td>SAR</td>
<td>11</td>
<td></td>
</tr>
</tbody>
</table>
Overview

- Energy Storage Goals & Mission
- DOD Power & Energy Requirements
- DOD Energy Storage R&D Challenges
- Vehicle Applications & Approach
- Army Ground Vehicle Energy Storage R&D Programs
  - Roadmap
  - Functional Breakdown/ Highlighted R&D Programs & Projects
- Summary
Energy Storage Goals

- Develop **safe, reliable and cost** effective energy storage systems
- Reduce **battery weight & volume burden** (Increase Energy & Power Density)
- Reduce logistics and fuel burdens
- Enhance performance, extend **calendar and cycle life**

Energy Storage Mission

- Develop and **mature** advanced ES technologies for transfer to vehicle platforms
- Test & evaluate ES technologies for prequalification and to **assess TRL** (Technology Readiness Level).
- Identify **technology barriers** and develop technical solutions
- Be recognized as the team of experts in ES components and systems
- Provide technical support to customers, other teams and government agencies for all ES requirements
- Provide **cradle-to-grave** support for all Army ES systems
**DOD Power & Energy Requirements**

- **Energy (kWh)**
  - 0.4MW: Energy (MW)
  - 2MW: Laser Weapon (2016)
  - 30MW: EM Rail Gun (2020+)

- **Power (MW)**
  - 0.4MW: Active Denial (2014)
  - 2MW: Laser Weapon (2016)
  - 30MW: EM Rail Gun (2020+)

- **Power (kW)**
  - Commercial Hybrids
    - HEV: 5kWh
    - PHEV: 16kWh
    - EV: 40+ kWh
    - xEV: 40-60 kW

- **Energy (MWh)**
  - Single Engine Cruise
  - Abrams M1E3 Silent Watch
  - GCV Silent Watch
  - Long Endurance UAV

- **Power (kW)**
  - JLTV SLI / 6T
  - Soldier Power
  - Small UAVs
  - Long Endurance UAV
Energy Storage Challenges:

- Cell & system safety & reliability
- Higher energy / higher power designs & chemistries
- Power vs. energy trade-off design optimization
- Manufacturing process development and cost control
- Thermal management
- System control and cell & battery management systems
- Alternative electrochemical improvements
- Thermal runaway process and its control
- Standardization of cells, modules and packs (logistics)
Army Applications & Approach

• Army Applications/Drivers:
  TARDEC - Ground
  – Major Applications
    ➢ Robotics
    ➢ Survivability
    ➢ Weapons Systems
    ➢ Electromagnetic Armor (EM Armor)
    ➢ Starting, Lighting and Ignition (SLI)
    ➢ Hybrid Vehicle Acceleration and Silent Mobility
    ➢ Silent Watch
  – Approach
    ➢ Standard Form Factor (6T)
    ➢ Ultra-capacitor/Battery/Fuel Cell Hybrid Power Sources

  – Energy Storage Team Focuses on Batteries:
    ➢ True silent watch and silent mobility
    ➢ Serves as reservoir to store energy to meet power demands and manage platform power
    ➢ Provide power source for advanced weapons.
Battery Roadmap: Battery Power and Energy Versus Time

Increasing Power & Energy Provides:
- Reduced Volume with Same Power OR
- Increased Power with Same Volume

Additional Capabilities for:
- Increased communication power
- Electronic Warfare
- Electric Weapon Systems
- Electromagnetic Armor

Lead Acid
- ~30-50 Wh/kg
- 150 W/kg

Nickel-Cadmium
- ~45-80 Wh/kg
- 200 W/kg

Nickel-Metal Hydride
- ~60-120 Wh/kg
- 250-1000 W/kg

Lithium-Ion

Improved Lithium battery

Advanced Energy Storage Systems

Power Cell
- 60 Wh/kg
- 16 kW/kg

Energy Cell
- 300 Wh/kg
- 500 W/kg

- 20 Year Life
- $300/kWh
- 5000 cycles

- >>400 Wh/kg
- (High Energy, Low Power)

- <$200/kWh

- 10 Year Life
- $1000/kWh
- 1000 cycles

- ~60-120 Wh/kg
- 250-1000 W/kg

- ~45-80 Wh/kg
- 200 W/kg

- 10 Year Life
- $1000/kWh
- 1000 cycles

- ~30-50 Wh/kg
- 150 W/kg

*Metrics are based on cell data
Energy Storage Technology
Trade-Offs & Capabilities

Ultra High Power Li-ion

Very High Power Li-ion

Very High Power Li-ion (LFP)

High Power Li-ion

Medium Power Li-ion

High Energy Li-ion

Ni-Cd

AgO-Zn

Ni-MH

Super Capacitor

High Energy Li-ion (LFP)
TARDEC Programs

Functional Breakdown

Energy Storage Functional Breakdown

Basic Research
- Lithium plating phenomenon in Li-ion batteries
- Study on the mechanism of thermal runaway in VRLA Batteries and Methods of Suppression
- Study of electrode/current collector interface & safe separator for Li-ion batteries
- Development of high energy density anode materials for improved Li-ion batteries
- Alternative electrolyte for use in lithium-ion batteries (higher voltage, improved performance)

Applied / Applications Research
- Electromagnetic Armor Power Maturation
- Nickel-Zinc 6T Battery Development
- Development of 6T battery for SLI and silent watch using Li-ion chemistries
- Absorbed Glass Matt lead acid battery for 24V military 4HN battery

Manufacturing
- High Power, High Energy Density Li-Ion Battery Manufacturing Program
- Lithium-Ion Cell/Battery Pack Manufacturing
- Advanced battery material scale-up facility

Battery Management / Safety
- In-House BMS evaluation for PM HBCT & new laboratory
- Universal BMS using novel algorithms for battery health
- Ballistic and abuse tolerance studies on cells, module and packs
- Development of advanced diagnostic tools for cycled cells

Alternative Systems
- Hybrid Power Module
- Lithium-Titanate Hybrid Vehicle Pack Integration
- Characterization of ultra-capacitors for SLI and high power applications

TARDEC has over 60 Projects & Programs

• High Power, High Energy Density Li-Ion Battery Manufacturing Program
• Lithium-Ion Cell/Battery Pack Manufacturing
• Advanced battery material scale-up facility

• Electromagnetic Armor Power Maturation
• Nickel-Zinc 6T Battery Development
• Development of 6T battery for SLI and silent watch using Li-ion chemistries
• Absorbed Glass Matt lead acid battery for 24V military 4HN battery

• In-House BMS evaluation for PM HBCT & new laboratory
• Universal BMS using novel algorithms for battery health
• Ballistic and abuse tolerance studies on cells, module and packs
• Development of advanced diagnostic tools for cycled cells

• Hybrid Power Module
• Lithium-Titanate Hybrid Vehicle Pack Integration
• Characterization of ultra-capacitors for SLI and high power applications
Summary

- Army has a diversified energy storage portfolio supporting a wide-range of customers
- Army has and is actively seeking collaboration with other Government Agencies, and Commercial & Military OEM’s
- Army has projects supporting several different functional areas in Energy Storage including: basic research, applied research & applications, manufacturing, battery management & safety, and alternative systems
- Army labs currently perform a wide variety of testing activities and has an established program for technology maturation and technology readiness level verification
- Army is actively involved in the development of battery standards and standard vehicle battery products
Thank you. Questions?