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

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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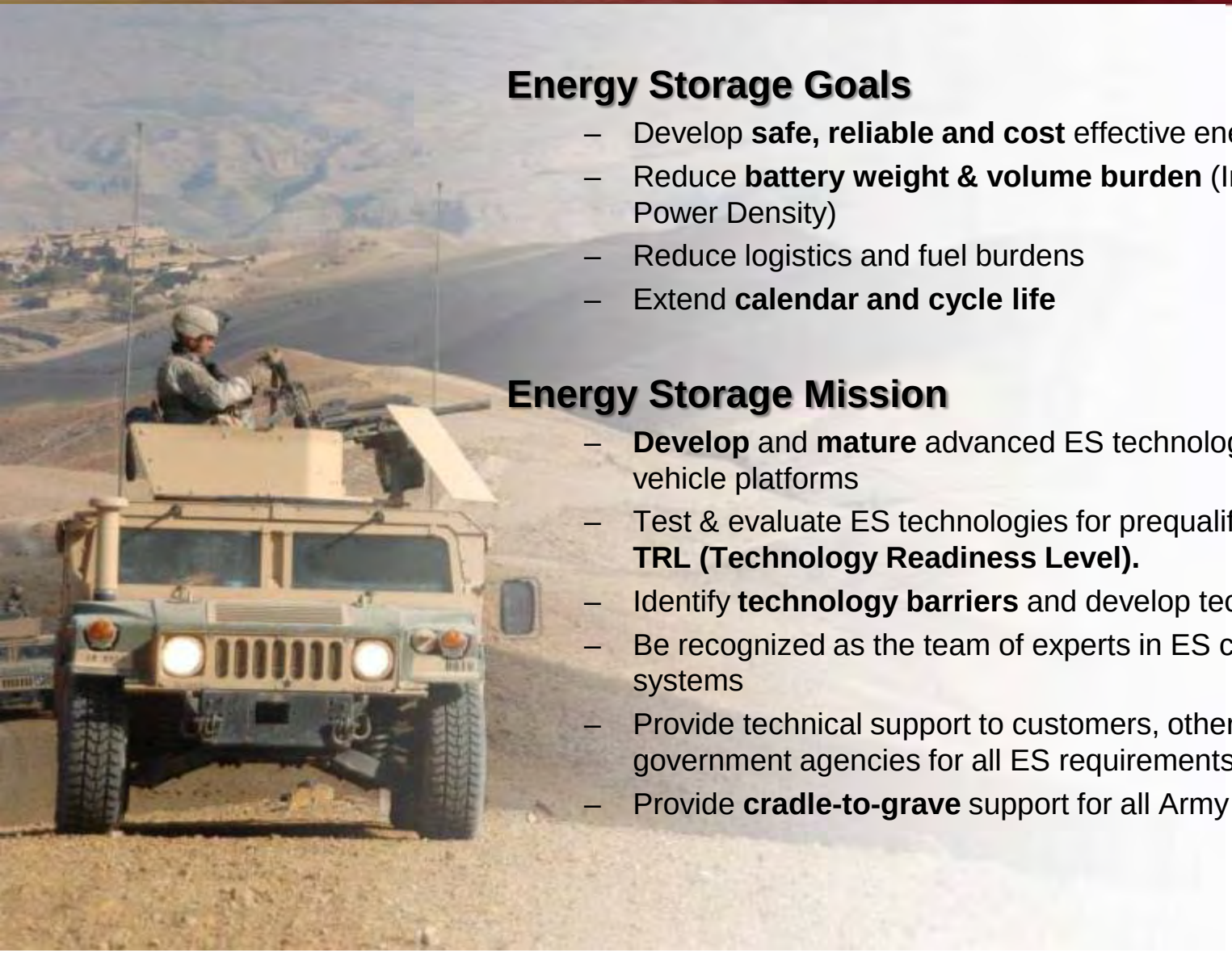
Overview

- **Energy Storage Goals & Mission**
- **Program Collaboration & DOD Customers**
- **DOD Power & Energy Requirements**
- **DOD Energy Storage R&D Challenges**
- **Army Applications & Approach**
- **Army Ground Vehicle Energy Storage R&D Programs**
  - Roadmap
  - Functional Breakdown/ Highlighted R&D Programs & Projects
- **Summary/Future Business Opportunities**

Energy Storage Goals and Mission



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
- 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

Program Collaboration & DOD Customers

PEO Soldier

DOD Customers

PEO GCS

PEO CS/CSS

DARPA

Battery Partners

CERDEC

Soldier

Material Developers

Battery Partners

TARDEC

Ground

OEMs (Commercial / Defense)

Industrial Developers

AFRL

Air

Battery Partners

DEPARTMENT OF DEFENSE

UNITED STATES OF AMERICA

Battery Developers

Material Developers

USABC

DOE

Universities

ANL

National Labs

ARL

Industrial Developers

NAVSEA

NAVAL SEA SYSTEMS COMMAND

Industrial Developers

Battery Partners

RDECOM

Technology to the Warfighter Quicker

DOD Power & Energy Requirements

RDECOM

TARDEC

Power (MW)

30MW

EM Rail Gun
(2020)

20MW

Free Electron Laser
(2020+)

2MW

Laser Weapon
(2016)

0.4MW

Active Denial
(2014)

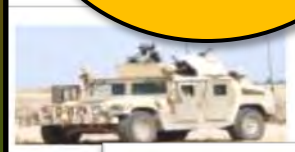
Single Engine Cruise

Commercial Hybrids
HEV: 5kWh
PHEV:16kWh
EV: 40+ kWh

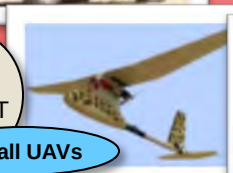
xEV: 40-60 kW

Abrams M1E3 Silent Watch

GCV Silent Watch



JLTV
SLI / 6T



Small UAVs

Soldier Power

Long Endurance UAV

Power (kW)

Energy (kWh)

Energy (MWh)

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Energy Storage Applications and Challenges

Major Applications

- Robotics
- Survivability
- Weapons Systems
- Electromagnetic Armor (EM Armor)
- Starting, Lighting and Ignition (SLI)
- Hybrid Vehicle Acceleration and Silent Mobility
- Silent Watch

Targeting Systems

Hit Avoidance

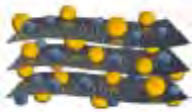
Challenges we have:

- Delivering reliable battery solutions in standardized military form factors
- Safety – Understanding thermal runaway process and its control, improved BMS and alternative cell technologies.
- Developing energy storage systems with higher energy and higher power densities (focus on designs and chemistries).
- Manufacturing process development, quality and cost control.

Where we need your help:

- Identify materials/designs/technologies to significantly improve safety
- Develop technologies to improve both energy and power density as well as life (calendar and cycle).
- Develop energy storage systems that focus on standardized form factors (6T, 4HN, Group 31 and Group 34).
- Cost reduction technologies

Energy Storage Functional Breakdown



Basic Research

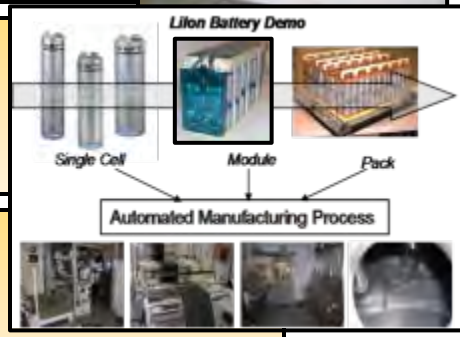
- Lithium plating phenomenon in Li-ion batteries
- **Study on the mechanism of thermal runaway in VRLA Batteries and Methods of Suppression**
- Study of electrode/current collector interface & safe separator for Li-ion batteries
- Development of high energy density anode materials for improved Li-ion 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

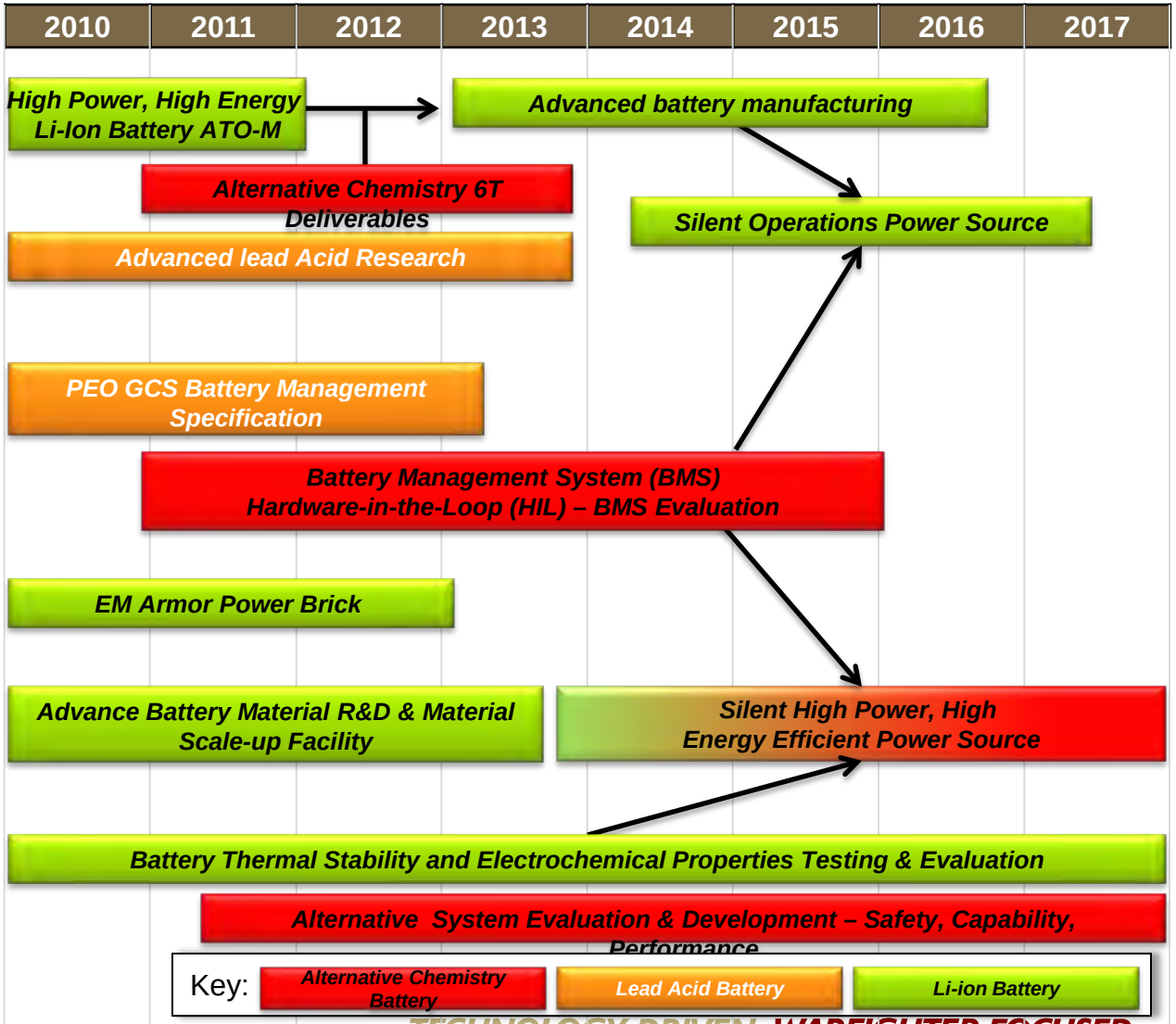
- **In-House BMS evaluation for PM HBCT & new laboratory**
- Universal BMS using novel algorithms for battery health
- Ballistic and abuse tolerance studies on cells, module and packs
- Development of advanced diagnostic tools for cycled cells

Alternative Systems

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

Projects Current & Future

- Manufacturable, Affordable, Safe, Reliable, Standardized High Energy Battery Packs
- Battery Electronics Control & Management
- High Power Batteries
- Ultra High Power & High Energy
- In house Research, Test, & Evaluation Capability



Advanced 6T Battery Roadmap

Military Lead-Acid 6T Batteries
40Wh/kg
400W/kg
~$350-400/kWh

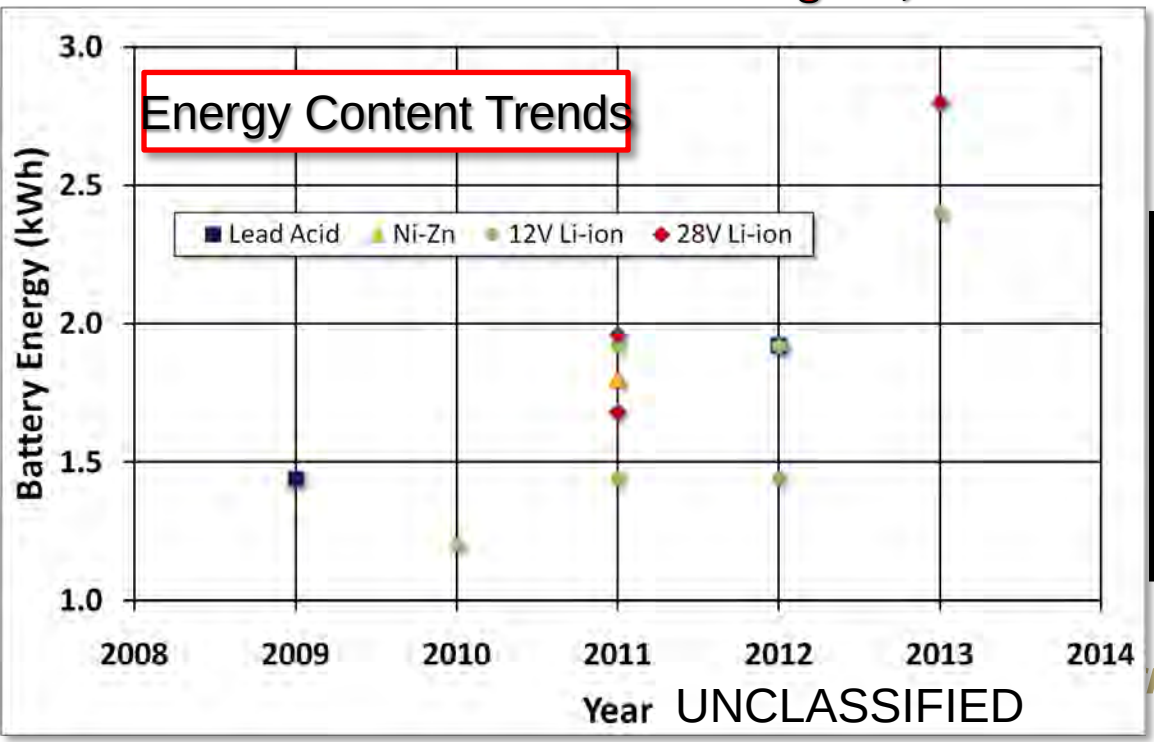
Baseline

Advanced (Ni-Zn or Li-ion) 12V 6T Battery
50-60Wh/kg
400-450W/kg
>$2000/kWhr

Lighter, 33% More Energy

Li-ion Military Battery Pack Target
>90Wh/kg
>920W/kg
<$800/kWhr

2-for-1 Drop-in Replacement
½ Volume



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	Advanced Battery Technologies Price Targets		
Battery Technology	Near-Term	Mid-Term Production	Long-Term High Volume
Lead Acid (12V)	$400/kWh	$350/kWh	$250/kWh
Ni-Zn (12V)	$500/kWh	$350/kWh	$200/kWh
Li-ion (12V or 28V)	$5,000/kWh	$1,000/kWh	$500/kWh

Laboratory Capability Current & Future

Current Capability

Battery Testing & Pre-Qualification

Advanced Battery Testing and R&D

- **Lead Acid Battery Laboratory (Bldg 7) -** Supports testing and pre-qualification for military lead acid batteries; 6 water baths, 31 circuits, 1 thermal chamber
- **Electrochemical Research & Analysis Lab (EARL) -** Supports small scale testing for advanced battery chemistries (Li-ion, Ni-Zn) at the cell and module level & battery R&D projects; Walk-in fume hood for safety, 2 explosion resistant thermal chambers, 15 circuits.

GSPEL
Ground Systems Power and Energy Laboratories

Battery Technology Roadmap

Future Capability

Battery Pack Storage & Shelf Life Testing

Battery Management Electronics Laboratory

GSPEL Battery Test Chambers

- **GSPEL Battery Chambers** – 3 Interior & 3 Exterior for safe testing from battery cell to pack level.
- **Battery Management Electronics Lab** – TRL BMS evaluation, Hardware-in-Loop simulation.
- **Battery Storage & Shelf Life Testing** – storage capacity for 26 battery packs or 600 6T batteries

Future Business Opportunities

Federal Business Opportunity Website:

www.fbo.gov

- **Broad Agency Announcement**
- **CRADA (Cooperative R&D Agreement)**
- **Education Partnership Agreement**
- **Ground Vehicle Gateway**
- **National Automotive Center**
- **Patent License Agreement**
- **SBIR Program**
- **Test Services Agreement**

Thank you – This concludes my presentation

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