GVPM Energy Storage Overview

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Energy Storage

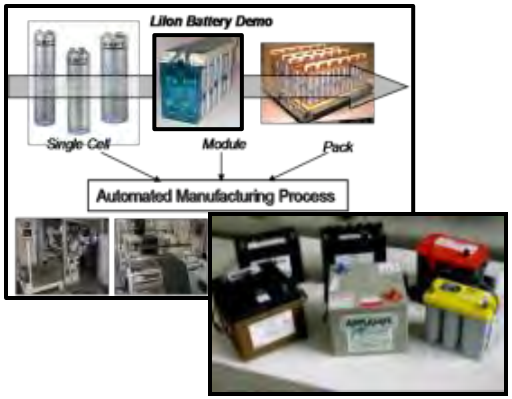
GVSETS
GROUND VEHICLE SYSTEMS ENGINEERING AND TECHNOLOGY SYMPOSIUM

Challenges we have:

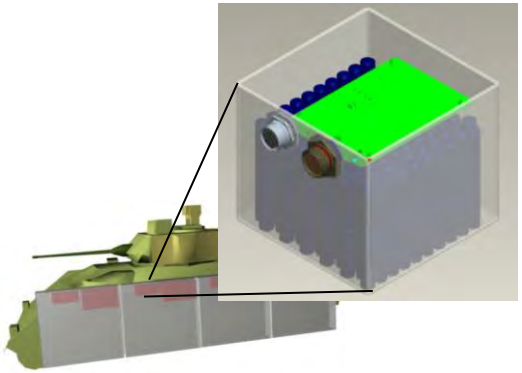
- Delivering reliable battery solutions in standardized military form factors
- Safety – Understanding thermal runaway process and its control, improved BMS and alternative cell technologies.
- Developing energy storage systems with higher energy and higher power densities (focus on designs and chemistries).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

Solutions we are investigating:

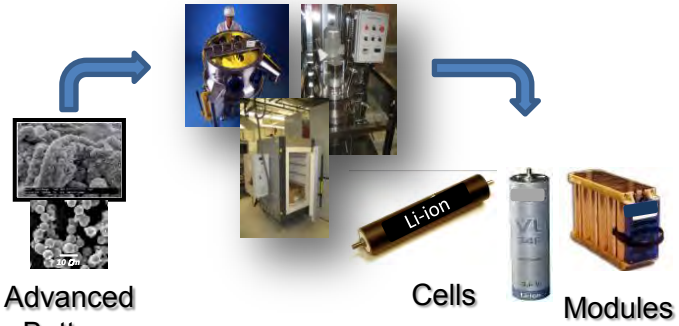
Development of advanced manufacturing technologies & form factor standardization



Develop of Power Brick battery for EM Armor and pulse power applications



R&D of new materials to improve performance and safety



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

Projects
Current & Future

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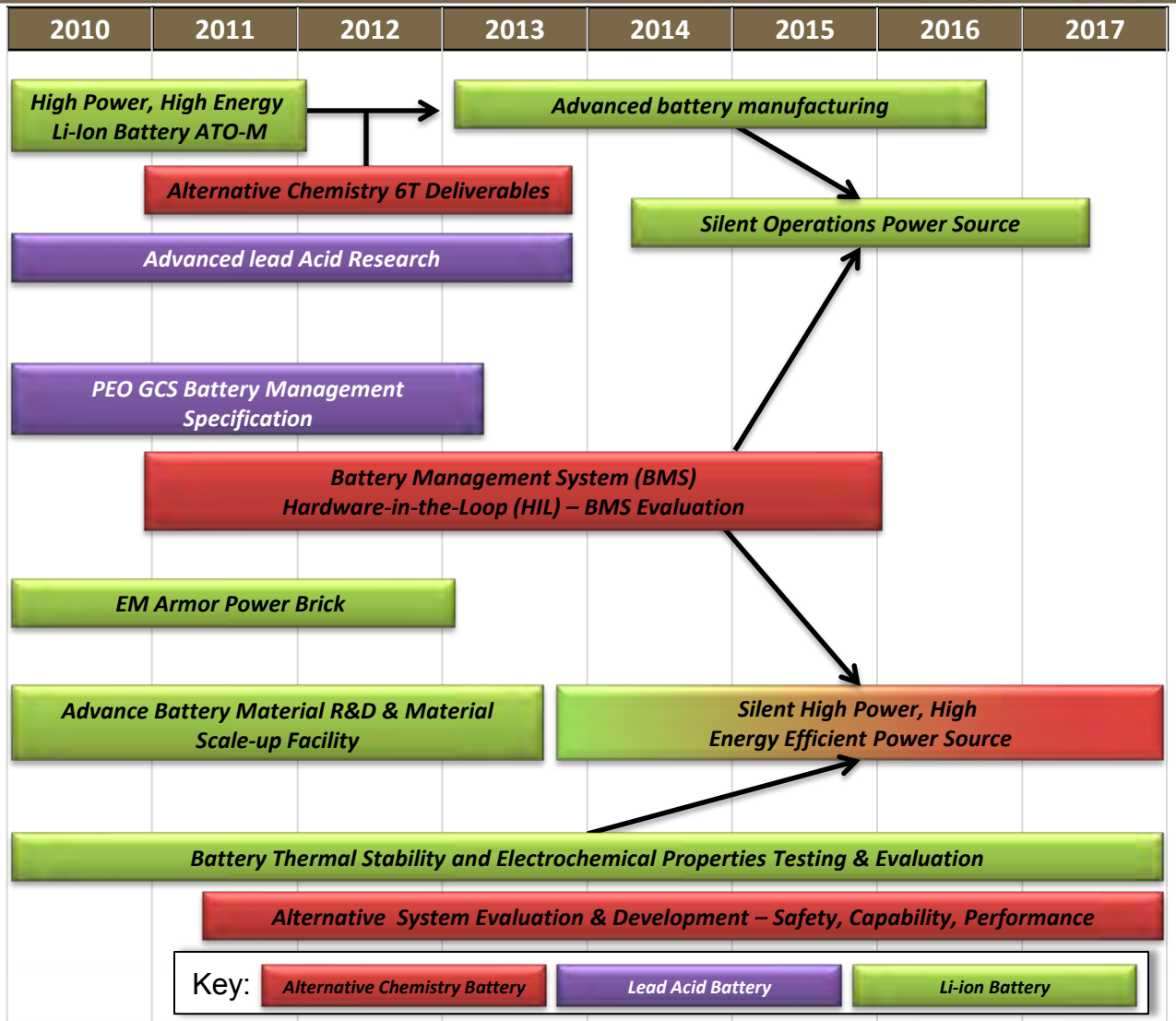
- Manufacturable, Affordable, Safe, Reliable, Standardized High Energy Battery Packs
- Battery Electronics Control & Management
- High Power Batteries
- Ultra High Power & High Energy
- In house Research, Test, & Evaluation Capability



Laboratory Capability Current & Future

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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

Advanced 6T Battery Roadmap

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

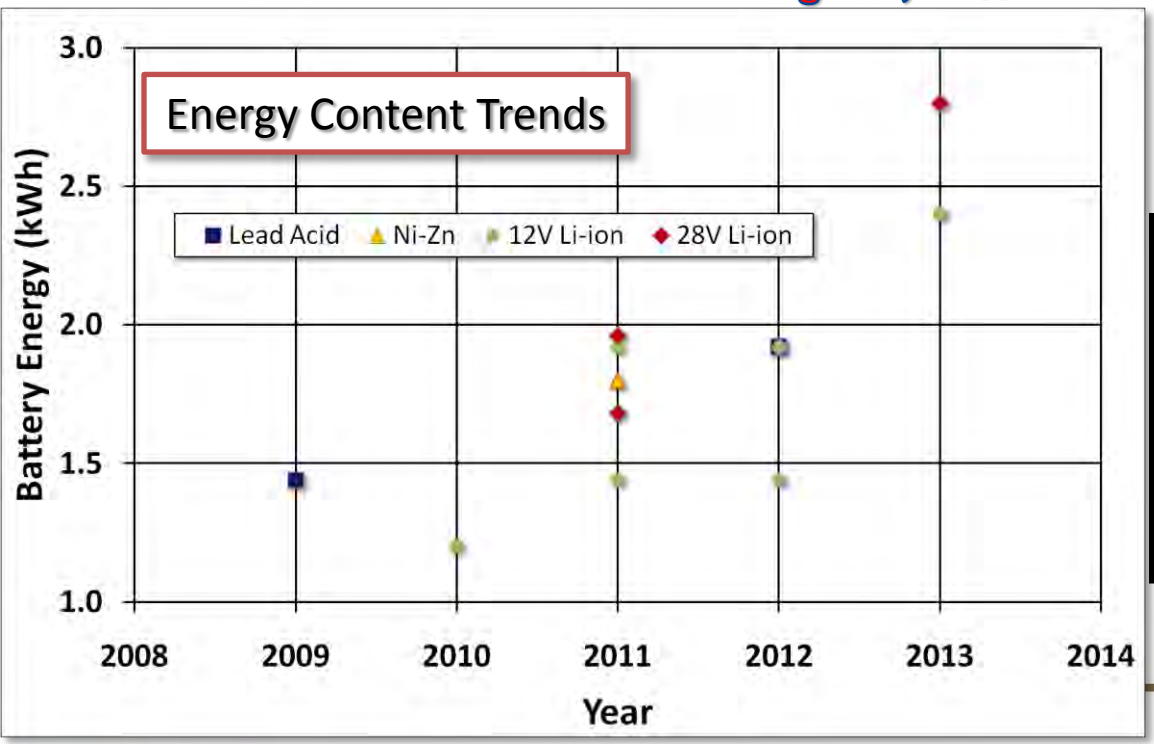
Baseline

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



Battery Technology	Advanced Battery Technologies Price Targets: 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