



U.S. Army's Ground Vehicle Energy Storage

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TARDEC 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

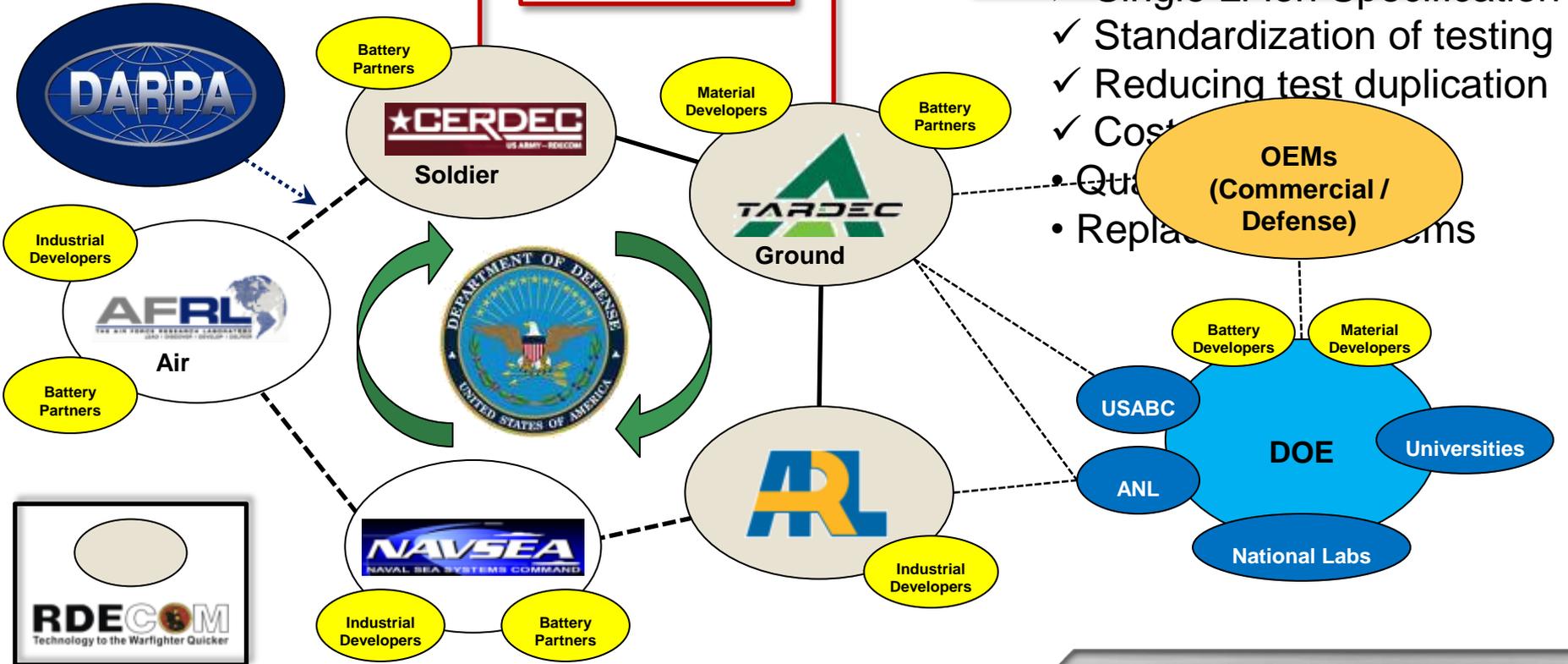
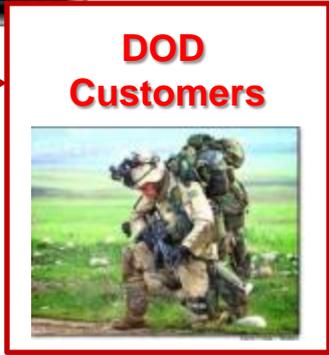
- **Develop** and **mature** advanced ES technologies for transfer to vehicle platforms
- Test & evaluate ES technologies for prequalification and to **assess TRL (Technology Readiness Level)**.
- Identify **technology barriers** and develop technical solutions
- Be recognized as the team of experts 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





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Program Collaboration & DOD Customers





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Energy Storage Applications and Challenges



Major Applications/Drivers

- Increased Electrical Power Draw
- Robotics
- Survivability
- Advanced Weapons Systems
- Electromagnetic Armor (EM Armor)
- Starting, Lighting and Ignition (SLI)
- Hybrid Vehicle Acceleration and **Silent Mobility**
- Silent Watch



Hit Avoidance



Targeting Systems



Communications



Energy Storage Challenges:

- Delivering reliable battery solutions in standardized military form factors (logistics/sustainability/compatibility)
- 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 and quality (Reliability & Safety)
- Cost control (balancing \$ with ↑ performance & ↑ durability)
- Thermal Management

Batteries represent one of the top ten ongoing maintenance costs in theater.



- Current Lead acid battery: ~\$300/kWh
- Current Lithium ion battery: \$2000-\$5000/kWh
- Target price for Li-ion battery is \$500/kWh

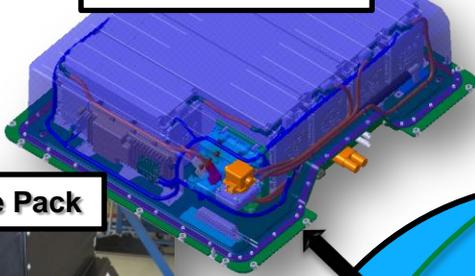


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Commercial vs. Military Energy Storage Requirements



Heavy Duty Truck Demo Pack



Automotive Pack

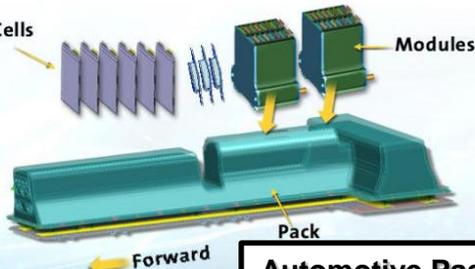


Automotive Pack



>200 Cells

Modules



Automotive Pack

Divergence of Military and Commercial Requirements:



Extreme operating environments

Commercial Focus

- Fuel Economy/Hybridized vehicles
- Increased energy – EV applications
- Increased power – HEV applications
- Cost (\$250/kWhr)
- Life (cycle/10-15 year calendar life)
- Safety
- SAE Standards
- Operation from to -20°C to +55°C

Military Requirements:

- ✓ Operating Temperatures: -46°C to 71°C
- ✓ Storage Temperatures: -54°C to 88°C
- ✓ Electromagnetic Interference: MIL-STD-461F
- ✓ Ballistic Shock: MIL-STD-810G
- ✓ Live Fire: MIL-STD-810G
- ✓ Explosive Environment: MIL-STD-810G
- ✓ Altitude to 60,000ft: MIL-STD-29595
- ✓ Explosive Decompression: MIL-STD-810G
- ✓ Salt fog: MIL-STD-810G
- ✓ Sand and Dust requirements: MIL-STD-810G

Additional Military Focus:

- ✓ NATO **Standardized** Form Factors (i.e. 6T)
- ✓ Maximized Power AND Energy density
- ✓ Sustainability and Logistics issues
- ✓ Silent Watch/Silent Mobility
- ✓ On-board Electric Power

Commercial

Military



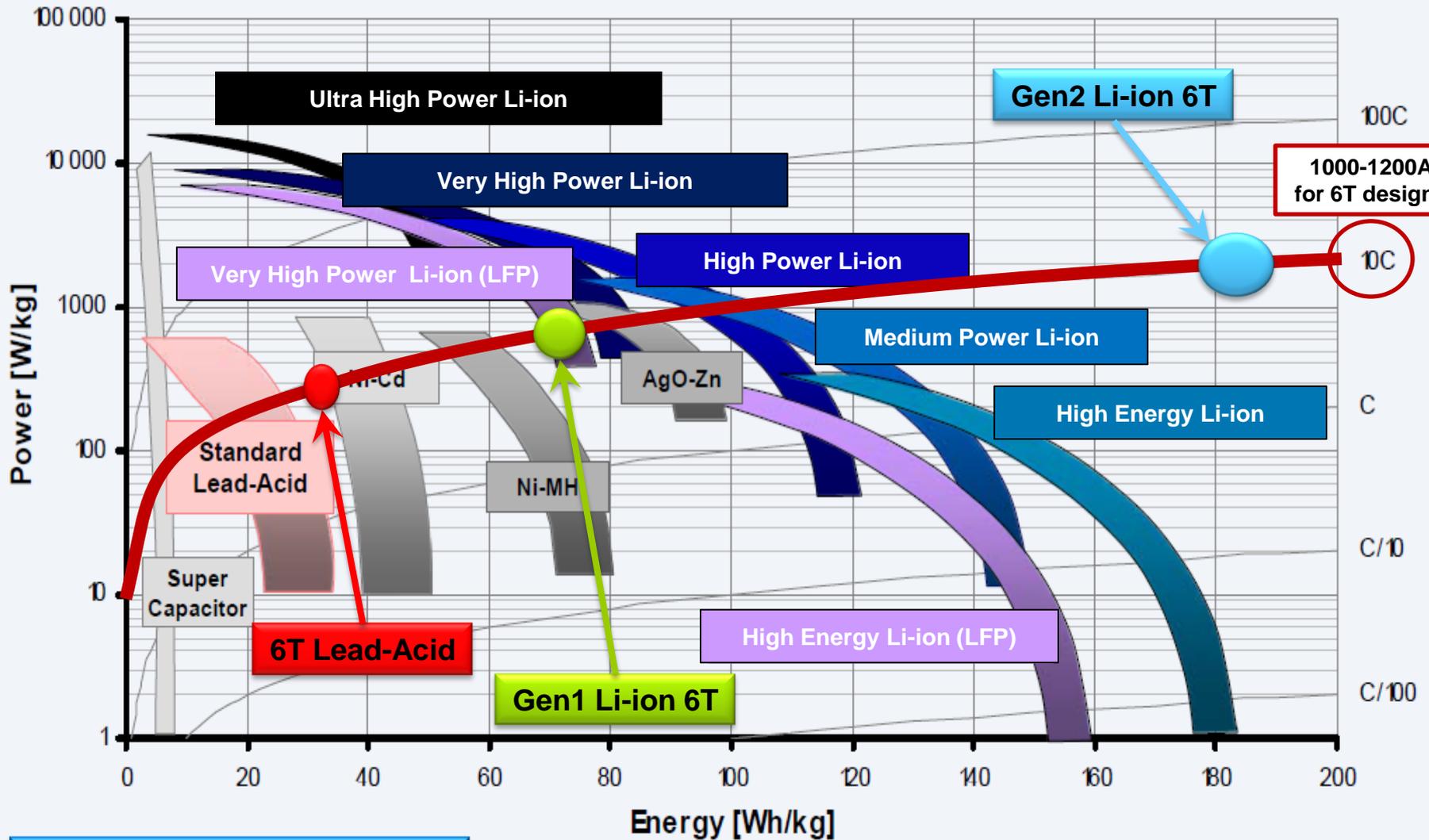
Standardized Military Batteries (i.e. 6T)
Used in 95% of Military Vehicles





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Energy Storage Technology: Ragone Plot (with Military Pack Targets)



Where are we today...

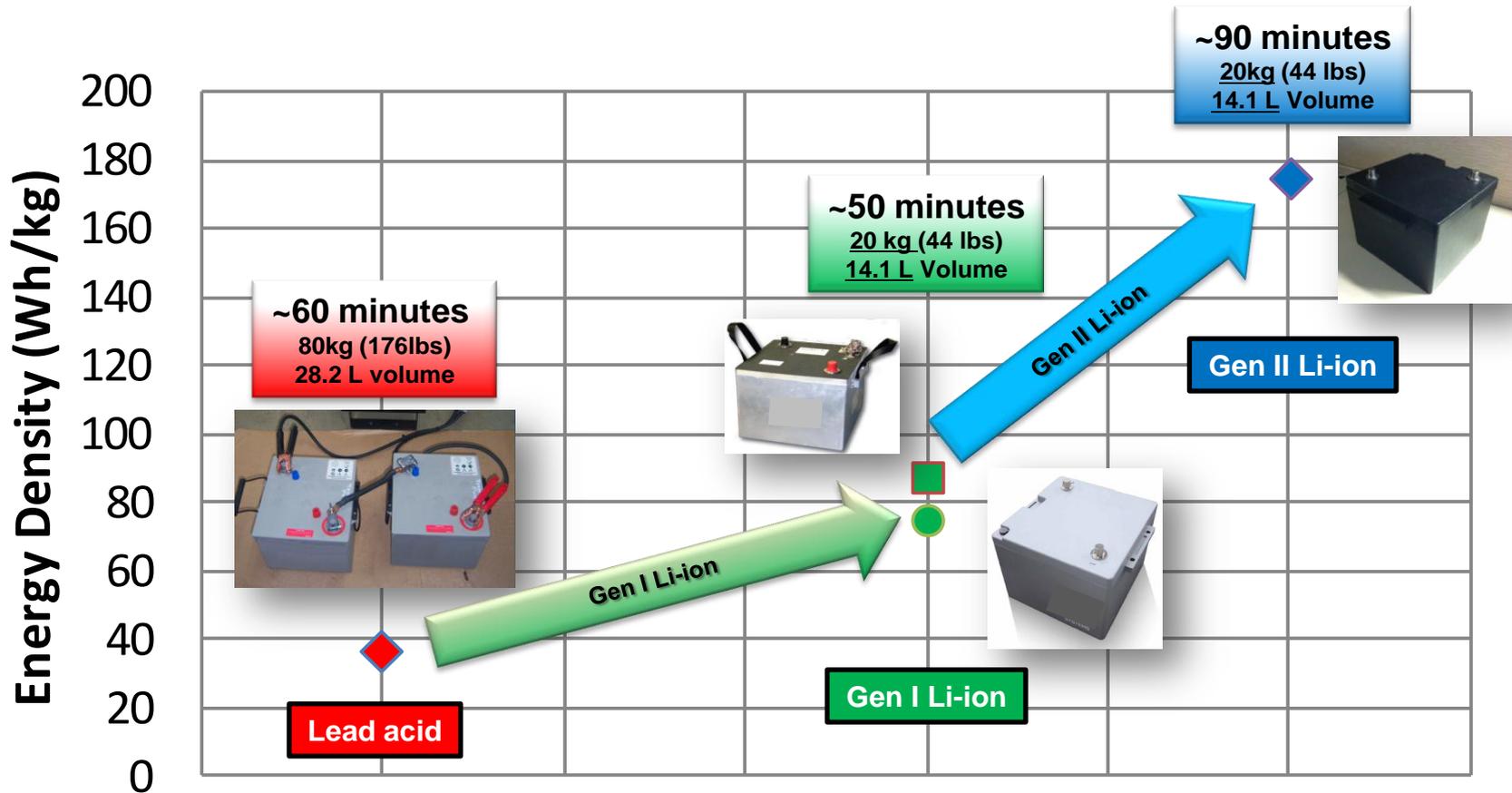


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Advanced Technology Solutions Li-ion Development



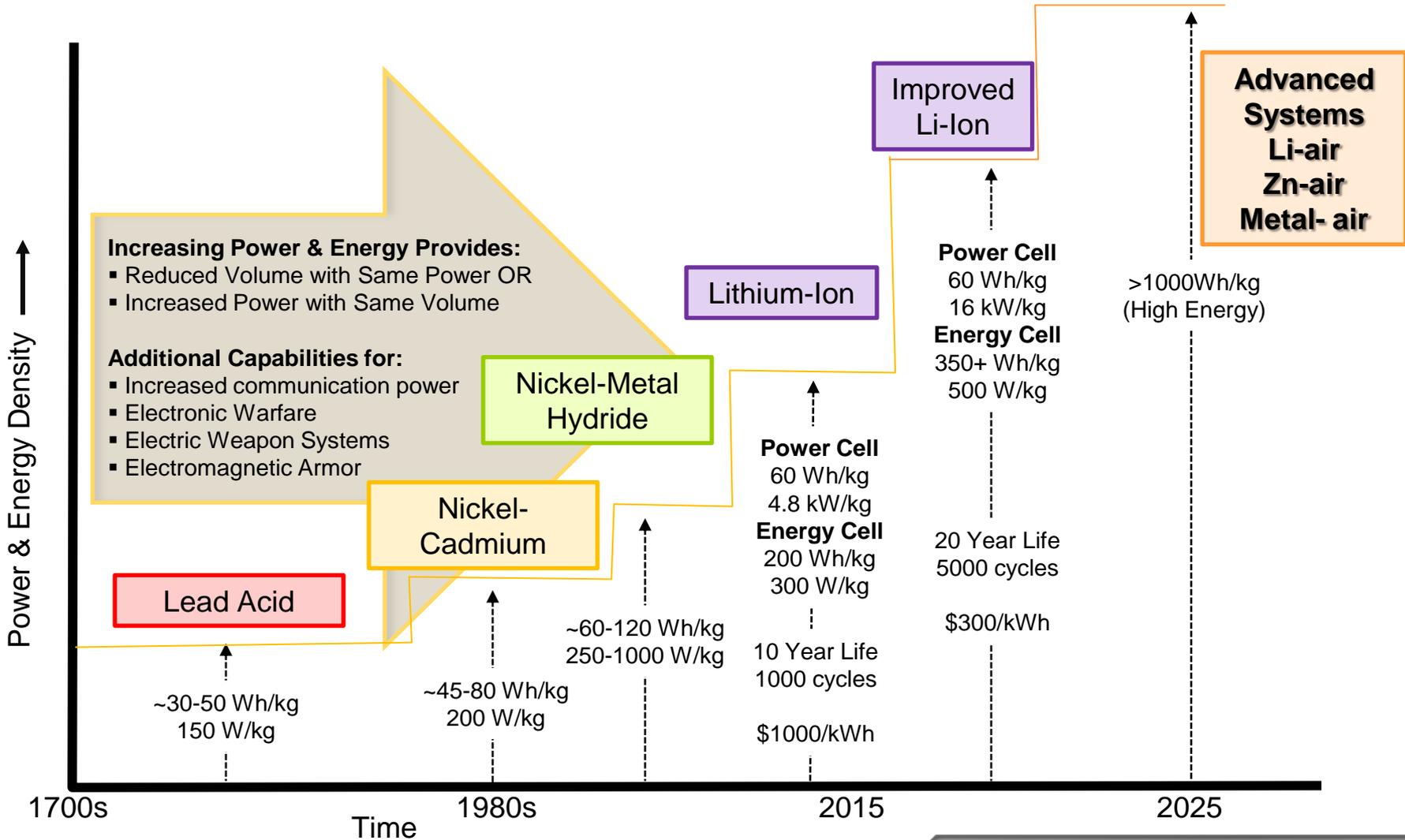
Assume a continuous silent watch load of 2kW...





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Battery Roadmap: Battery Progression Versus Time





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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



groundvehiclegateway@conus.army.mil



Back-up Info



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TARDEC's Role in Army Batteries



The TARDEC Energy Storage Team is the single point of accountability to provide full service lifecycle engineering and integration support (cradle-to-grave) for Energy Storage systems for Army Ground vehicle platforms.

- TARDEC Energy Storage Team Role is the Engineering Support Activity (ESA) to ensure conformance with the specification & recommendation for QPL acceptance.
 - TARDEC Standardization Team Role is the Qualifying Activity that maintains the modifications to the MIL-PRF 32143B and QPL.
-
- ✓ First Article in-house Testing & Qualification Test Issues
 - ✓ Develop, publish, and maintenance of battery standards and performance specifications
 - ✓ Participate with DLA on audits of production facilities
 - ✓ Establish vendor qualification criteria
 - ✓ Provide technical expertise on energy storage systems for all stakeholders
 - ✓ Project Management
 - ✓ Preparing and updating Tech Manuals
 - ✓ Provide SMEs for Analysis of Alternatives (AOAs)
 - ✓ Provide sustainment and fielding support of batteries
 - ✓ Research, develop, and mature advanced energy storage technologies for enhanced capability
 - ✓ Establish and leverage collaborative projects, battery working groups, MOUs/MOAs with other government agencies





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Ground Systems Power and Energy Laboratory (GSPEL)



Capabilities

- Provides steady state and transient (mission profile based) testing
- Ability to test current and emerging classes of ground vehicles
- 32,000 ft² of laboratory space
- Environmental chamber able to test between -60° to 160°F with winds up to 60 mph
- Provides 10 dynamometers to allow testing of up to 5 axle wheeled vehicles



Grand Opening April 11, 2012

**Certified Leadership in Energy and Environmental Design (LEED) Silver
in accordance with the US Green Building Council (USGBC)**



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TARDEC Energy Storage Labs: GSPEL Energy Storage Lab



Purpose:

The GSPEL Energy Storage Lab is TARDEC's testing laboratory and will be used to safely analyze, evaluate and test battery and other electrochemical technologies at the cell, module level, and pack level.

Capabilities:

- Characterize and evaluate advanced technologies (lithium-ion, nickel-zinc, lead acid, ultra capacitors families, and any future new chemistry that is developed)
- Centrally controlled and monitored cyler circuits of varying current and voltage capabilities
- Characterization at different charge/discharge rates/temperatures/life cycling/pulse power/stand testing/& drive profile cycling
- Temperature test ranging from -73°C to 200°C .
- Lead acid batteries battery life analysis



Water Baths



Cell, Module and Battery Cycling Equipment



Equipment:

- 3 blast proof rooms
- 2 pack external battery pack test chambers
- ~100 cell level cyler channels
- ~100 (0-60V) module/pack level cyler channels
- 6 pack test cyler channels (AV900)
- 12 environmental chambers
- 6 water baths for testing Pb Acid batteries
- Accelerated rate calorimeter

Internal Cell/Module Test Rooms



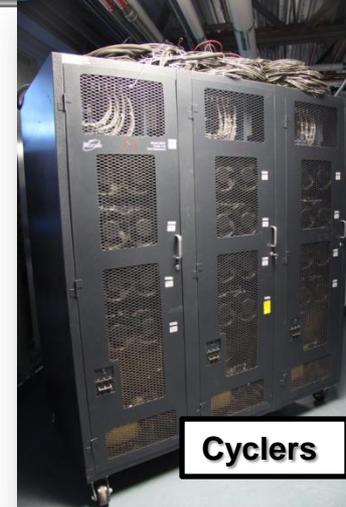
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TARDEC Energy Storage Labs: GSPEL Energy Storage Lab Safety Features



Safety Features:

- The rooms are designed to withstand 25 psi
- Room and doors are designed to withstand this pressure and actually hold it for a controlled release.
- Walls are ~8 inches thick concrete and are re-enforced with tie rods.
- 100% air is replaced 8 times per hour. In emergency, air changes increase to 24 per hour.
- All air is passed thru a scrubber located on the roof.
- Sensors include heat, smoke, hydrogen, and organic vapors
- Fire suppression includes - Nitrogen/Argon gas fire suppression, water sprinkler system, and capability to flood the room
- E stops located in the control room, test chamber, and outside the rooms shut down all electrical equipment operating in the room and feeding the room from the mezzanine.
- Spill containment is located under the floor to contain and control spills.





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TARDEC Energy Storage Labs: Electrochemical Analysis & Research Laboratory



Purpose:

The EARL is TARDEC's testing laboratory for analyzing and evaluating battery and other electrochemical technology at the cell & module level. Testing in this laboratory aids TARDEC in understanding new breakthrough technologies for Army ground vehicle energy storage systems.

Capabilities:

EARL contains a number of battery cyclers for charging and discharging batteries, along with thermal chambers and a centralized control system that enables assessment of electrochemical cells with a variety of tests including:

- Characterization at different charge/discharge rates and temperatures
- Life cycling
- Hybrid pulse power characterization
- Stand testing
- Tests are monitored with thermocouples and video feed

Equipment:

Three Battery Cyclers

- 16 & 4 Channel Bitrode, 4 Channel Maccor
- Two Solartron SI 1287 Electrochemical Impedance Spectrometers
- Parstat 2273 Potentiostat
- Walk-in Hood with 4 chamber fire suppression system
- Three Tenny thermal chambers
- Centralized Control System



**Battery Cycling
Equipment**



Thermal Chambers & Exhaust Hood



**Electrochemical
Characterization**



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TARDEC Energy Storage Labs: Battery Management System Lab



**Hardware-in-the-loop
(HIL) Battery Simulator**

Purpose:

The Battery Management System (BMS) laboratory is TARDEC's Lab for analyzing and evaluating prototype, near production ready, and commercial-off-the-shelf BMS units for lead acid and Li-ion batteries. BMS evaluation in this lab supports the PM/PEO to determine if the system is ready for fielding. Testing also aids TARDEC in updating the BMS specification that is used by the customer for battery management qualifications that will be used in fielded vehicles.

Capabilities:

The BMS lab contains

- BMS Hardware-In-the-Loop (HIL) which can simulate a battery profile
- Thermal chambers
- Analog and digital input/output (I/O)
- Centralized control system

Equipment Specification:

- BMS HIL – Independently simulate and control up to 180 cells from 0 to 5 volts.
- Pack voltages up to 750V can be simulated.
- Large Thermal Chamber – 8 cubic feet, remotely programmable from -73°C to 200°C.
- Two Small Thermal Chambers – 1 cubic foot, remotely programmable from -73°C to 200°C.
- Independent Data Acquisition (I/O)
 - 16 channels of digital input
 - 16 channels of digital output
 - 16 channels of analog input
 - 16 channels of analog output
 - 16 channels of thermocouple
- Centralized Control System – control all lab equipment



Thermal chambers



**Centralized data
acquisition & control
system**