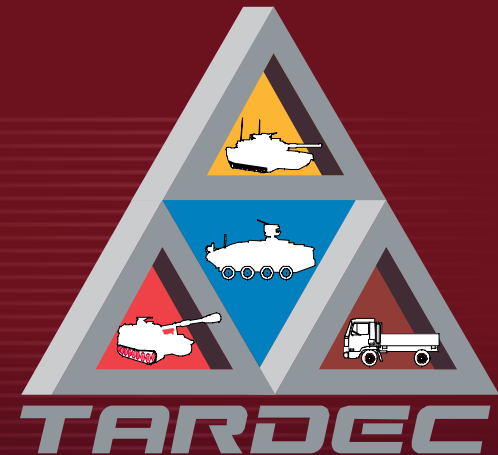




2nd Annual Ground-Automotive Power & Energy Symposium

Sonya Gargies & Marta Tomkiw



TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

TARDEC Battery Efforts

August 8, 2007

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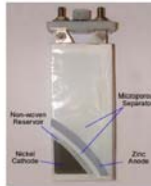
Efforts Supporting Future Force

– Lithium-Ion Technology

- High Power, High Energy Li-Ion Battery Manufacturing
- Large format prismatic cells with integrated liquid cooling development
- Lithium-Iron Phosphate Battery Safety Improvements
- Ultra High Power Cells for Pulse Power
- Advanced Battery Architecture using Hybrid Solutions for Low Cost
- Ballistic Impact Test and Evaluation for Liability Assessment
- Thermal Runaway Studies for safety improvements



L-i-Ion Battery Module (50V)



NiZn Cell

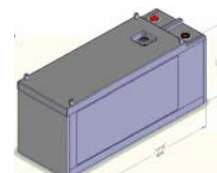


Li-Ion Cell



Li-Ion Prismatic Cell

- Integration, Testing, & Evaluation of Battery Packs in vehicle demos
- Nickel Zinc Battery Development
- Advanced Lead Acid Battery Technology Enhancement



Li-Ion/Ultracap Hybrid Energy Storage

- Safety and Reliability
- Cost maturation of Li-ion continues
- Li-Ion investment is needed because it exhibits the most desirable performance characteristics (power and energy density) for commercial and military applications
- A need exists to explore other battery chemistries for their superiority over that of lithium ion in terms of
 - cost
 - extreme temperature performance
 - operational safety
- Battery selection is very application-specific.

- **Directed Energy**
 - High Power Microwave for Active Denial (Air & Ground based)
 - Lasers
 - Electric Gun
 - Electric Armor

- **Mobility for on board Hybrid Electric Vehicles**
 - Full Hybrid:
 - 30kWh – 250kW continuous power by 2009
 - Silent watch/mobility requirement
 - Mild Hybrid:
 - 5kWh – 250kW
 - Fuel Economy requirement and no silent watch

- **Electromagnetic Launch**

- **Emergency Power for Aviation**

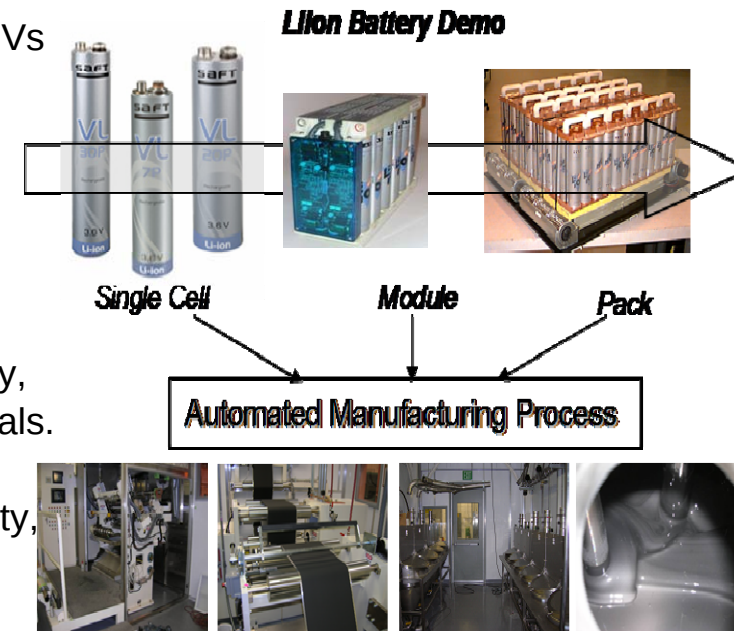
High Energy High Power Battery Manufacturing Technology Objective (MTO)

Purpose:

- Improve the current limited manufacturing capability of the 30 Amp-hr battery cells
- Provide affordable Li-Ion battery pack for the FCS and the current Ground Vehicle Programs

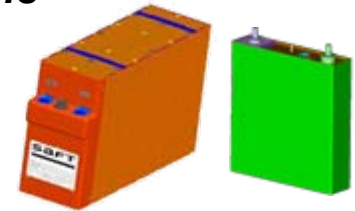
Objectives:

- High power, high energy Li-ion battery pack production for HEVs
- \$115K per 30kW-hr pack (per vehicle) to \$58K
- Accelerate the technology and automate the manufacturing process
- Parallel ATO will improve the technology in temperature stability, improve safety and performance and develop enhanced materials.
- MTO will produce affordable battery packs for HEV dash mobility, silent watch, and pulse power for weapons.



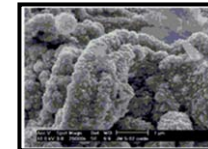
Prismatic Lithium-ion batteries and Integrated Liquid Cooled Module

- Develop large format prismatic lithium - ion cells optimized for liquid cooling
- Investigate and implement a liquid cooled Li-ion battery module
- Demonstrate feasibility of managing the heat transfer
- Extend operating temperature range



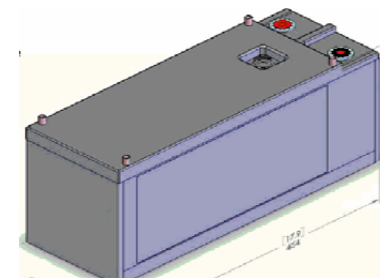
Lithium Iron Phosphate (LFP)

- New material is being investigated and scaled for hybrid electric vehicle applications to improve safety and performance for lighter, more affordable batteries.
- R&D targeted towards a module with LFP cathode material
- Improves safety and reliability



Battery Architecture

- Develop, build, and test an advanced configuration hybrid energy module
- Integrated dc-dc converters for power management control between the two sources of power and energy
- Architecture will be compared with battery-only and/or ultra capacitors only systems





CMU UGCV

- Full BPC
- 14 VL30P modules (168 cells)
- Average voltage 302V; 18.4kWh; 210kW pulse power
- Vehicle mileage with the battery: more than 1000 miles



DRS-TEM

Hybrid HMMWV

- Full BPC
- 14 VL30P modules (168 cells)
- Average voltage 302V; 18.4kWh; 210kW pulse power
- Vehicle mileage with the battery more than 2500 miles



**BAE (United Defense)
NLOS-C**

- 14 VL30P 12 Cell Modules in Series
- 18 kWh. 600 Volts

Li-Ion Compact High Power System Capabilities

Assumption: 1 CUBIC METER OF BATTERY about 2000 kg

Option	Yesterday	Today	Tomorrow
Battery Energy (Assuming 80% of usable energy)	75 kWh 270 MJ	54kWh 194 MJ	50kWh 180 MJ
Battery Discharge Power MW Pulse 0.2 sec Pulse 2 sec Pulse 18 sec	6.8 4.2 2.7	13.4 10.4 6.7	40 30 20
Applications (Continuous & Pulse)	•HEV Power •Silent Watch •Electric Weapons (laser, ETC, etc.) •Survivability (sensor defeat, EM Armor, etc)	•HEV Power •Silent Watch •Laser Targeting •Laser Sensor Defeat •Defeat Light Armor •Tactical Aircraft Missile Defense •ETC's	•HEV Power •Silent Watch •Laser Targeting •Laser Sensor Defeat •Defeat Heavy Armor •Tactical Aircraft/Missile Defense •Theater Long Range Missile Defense •ETC's EMG's/Counter Kinetics/HPM's

- **Thermal Runaway (the fundamental process and its control)**

- Commercial Market slow to bring these into markets due to high cost and limited manufacturing capability and technical challenges such as:

- **Cell Design Optimization**

- Power vs. Energy Trade-off
- Cell Configuration
- Manufacturing process development and cost control
- Cell Safety & Reliability



- **Battery Architecture Optimization**

- System energy vs. Power Optimization
- Thermal management
- System control and cell management
- Power conditioning & Integration with DC/DC Conversion
- System Reliability and Safety

- **Alternative Anode, Cathode, Shutdown Separator, Electrolyte Improvements**

- **Integrated Prototype Vehicle Evaluation (Battery Integration and Field Testing)**

- **Hybrid Solutions (e.g., Capacitor Assisted Battery)**

- **Battery designs are application specific:**
 - **Silent Watch**
 - **Dash Acceleration**
 - **Pulse Power**
- **Battery designs are tailored to specific market demands**
- **Battery designs intended for niche markets tend to be expensive**



**VRLA
Batteries**



**Advanced
Lead-Acid**



**On-Board
Vehicle
Power**

- Improve Energy Storage
- Display Battery Status
- Increase Power at Idle
- Minimize Costs

**Battery
Monitoring**



MIL-PRF-32143A Batteries

- Answer immediate need for “engine off” power for Aux./C4ISR equipment.
- Direct replacements for the standard 6TMF flooded military vehicle batteries.
- Offers improved performance and “deep cycle” capabilities that 6TMF batteries lack.



MIL-PRF-32143A Battery

- QPL item
- Two sources of supply on QPL
- Others in Qualification testing process
- Seeking additional suppliers
 - 6T (VRLA)
 - 2HN (VRLA)
 - 4HN (VRLA)



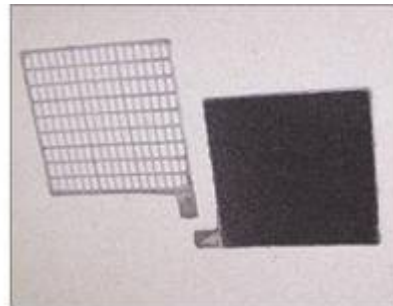
Firefly Energy's Grid Coating Technology

- Coating applied to traditional lead-acid battery grids designed to increase cycle life and reduce self-discharge
- Batteries assembled with coated grids under test in TARDEC Battery Lab



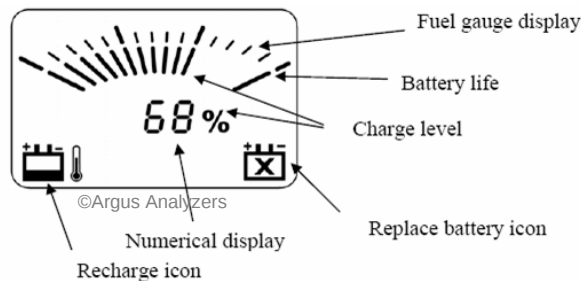
Firefly Energy's Composite Grid Technology

- FE developing advanced lead-acid batteries using high surface area foam grids.
- Development contract for “hybrid” batteries utilizing traditional and composite grids, and batteries with all composite grids.
- Deliverable batteries to be tested by TARDEC.



Battery Monitoring Technology

- Battery Monitoring provides a means to display or communicate battery status information to users and maintainers
 - Includes battery “fuel gauge” to monitor State of Charge
 - Indicates battery State of Health
- TARDEC is planning to test the more promising battery monitoring solutions in the laboratory to verify their accuracy for military applications



Efforts Supporting Current Force

- On Board Power Kits for the M1114 & the RG 31 in response to a JUONS for more vehicle electrical power at engine idle
- TARDEC given lead on project
- Worked with CERDEC, PM LTV, PM AMS, USMC, and Niehoff to implement a solution in 120 day time frame

Efforts Supporting Future Force

- Move into Phase two of the On Board Power JUONS to develop and integrate near term and long term power solutions

