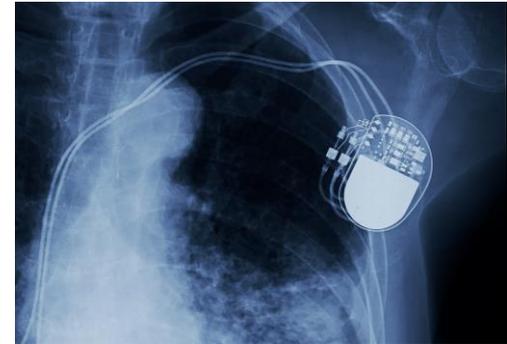


Energy Storage and Power Systems for Directed Energy Weapons Applications

June 2018



A dark blue silhouette of an F-35 fighter jet in flight, viewed from a low angle. The jet is positioned in the upper left and center of the frame, with its wings and tail visible. The background is a dark blue sky with a subtle, wavy pattern.

**EaglePicher Provides Reliable,
Flexible, Power Dense Solutions
for Directed Energy Weapons
Applications**

EaglePicher is the Market Leader in Defense Battery Solutions

Unmanned Aerial Vehicle (UAV):
Lithium-ion/ CF_x Batteries

Directed Energy Weapons: Lithium-ion Battery Systems

Aircraft Battery:
Lithium-ion Batteries

Satellite:
Lithium-ion Batteries

Precision Guided Munitions:
Thermal Batteries

Anti-Tank Missiles: Thermal Batteries

Ballistic Missile Defense:
Thermal Batteries

Shipboard Directed Energy Weapons:
Lithium-ion Power Systems

Torpedoes:
Silver Zinc Batteries

Portable Soldier Power:
Lithium-ion / CF_x Batteries

High Energy Laser Tactical Vehicle Demonstrator:
Lithium-ion Batteries

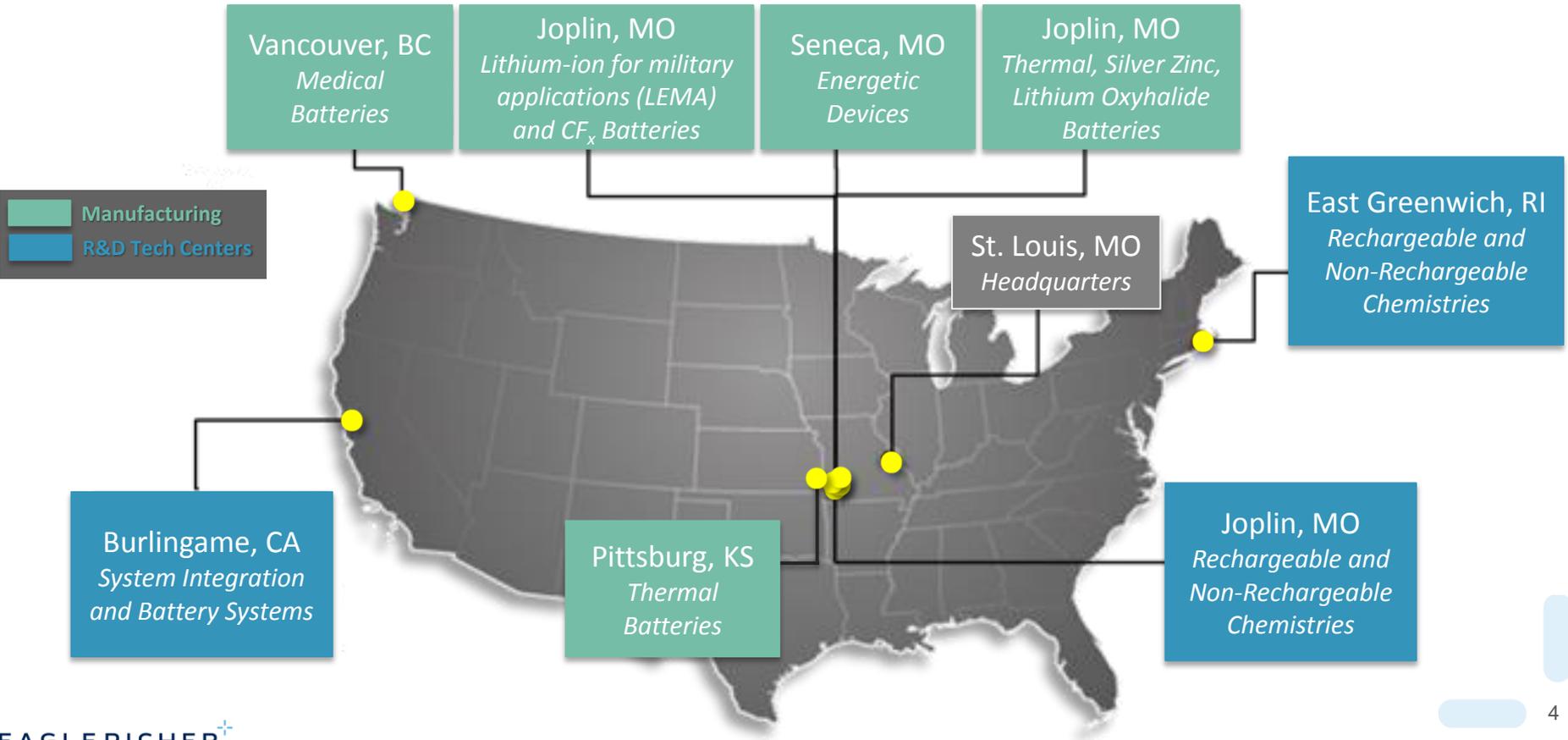
Diver Propulsion:
Lithium-ion Batteries

Military Radios:
Lithium-ion / CF_x Batteries

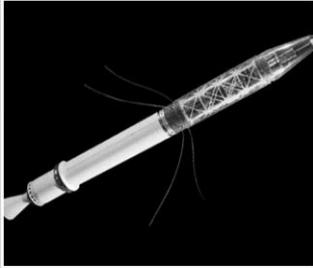
EaglePicher develops custom solutions to meet a wide range of defense application requirements including **Directed Energy Weapons**

 Currently Deployed
 In Development

Innovating, Investing and Growing in the United States



A Rich Heritage in Mission Critical Power Solutions



1958: Powers Explorer 1, the first U.S. satellite in space



1970: Provides power for the safe return of Apollo 13



1991: Powers first Tomahawk Cruise missile



1998: Provides primary power for International Space Station



2000: Delivers first Lithium-ion battery for military aircraft



2003: Supplies power for the Mars Rover which is still operational



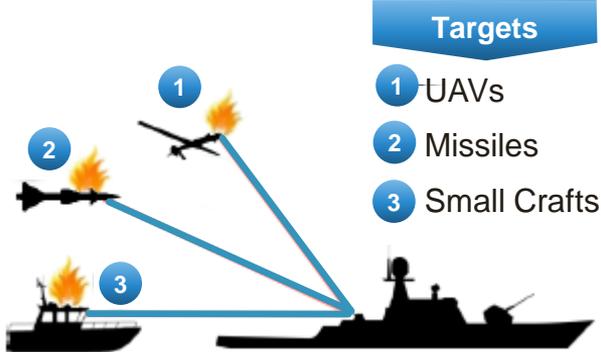
2017: Delivers High Energy Laser (HEL) prototype for Apache



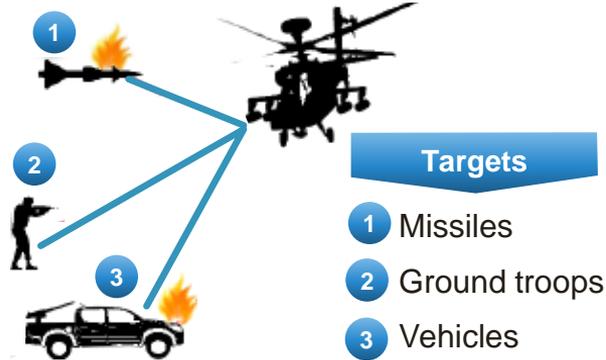
2018: Supplies high-power battery system for EML Navy

Summary of Directed Energy Programs

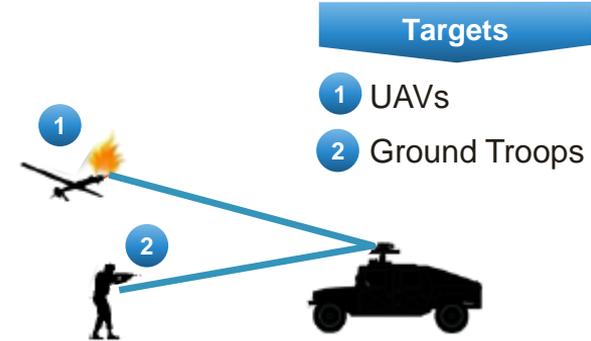
Sea-Based



Air-Based



Ground-Based



EaglePicher is Leading the Power Solutions for Directed Energy Weapons Applications

Energy Magazine Laser – SNLWS/HELIOS



Customer Challenges

- + Demonstrated safety
- + Ultra-high power
- + Minimize readiness time
- + Domestic production

EaglePicher Solutions

- + Leveraging the best chemistry available
- + Superior thermal management for maximum life
- + Containment for anti-propagation
- + Leveraging Lithium-ion for military applications (LIMA) facility for production
- + Battery management system (BMS) with redundant inputs and outputs (I/O) control, communications, balancing and protection

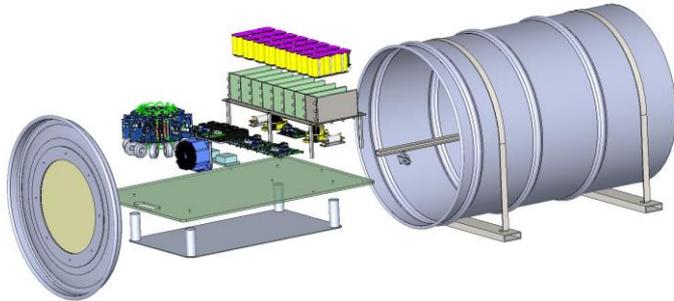


Missile Defense Agency Power Conversion



Customer Challenges

- + Demonstrated safety
- + Optimized for size weight and power (SWaP)
- + High power at the lightest weight possible
- + Highly regulated BUS
- + Integration with airframes
- + Very high altitude



EaglePicher Solutions

- + Superior thermal management
- + Multi-phase buck converter for voltage regulation
- + Flexible packaging of 5kW modules
- + All electronics rated for 65,000 feet

Apache Block 4



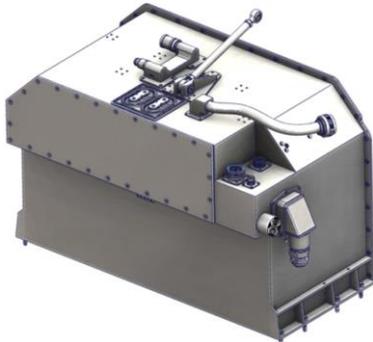
Customer Challenges

- + High power density
- + Maximum duty cycle
- + Airworthiness safety
- + Rotorcraft vibration

EaglePicher Solutions

- + Best available battery solution
- + Integrated liquid cooling
- + Module level containment
- + Rigid mounted modules

Tactical Aircraft – SHEILD



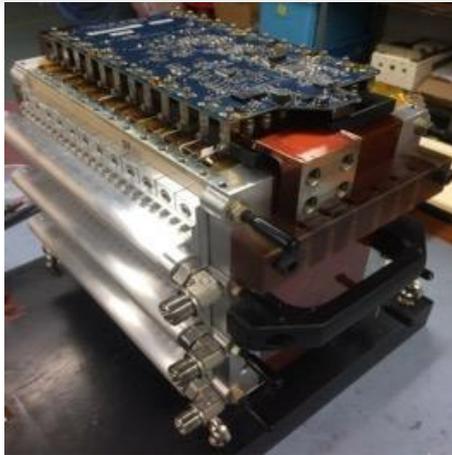
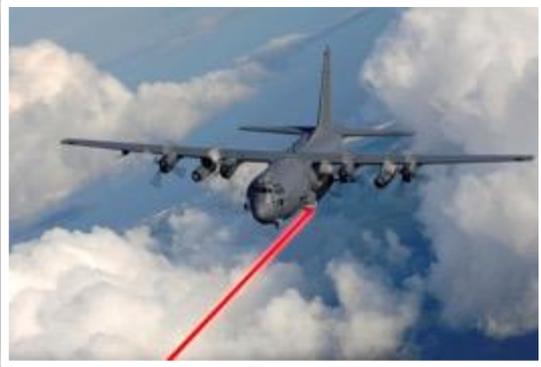
Customer Challenges

- + Very tight weight and volume
- + Integrated cooling
- + Integrated charger
- + Constrained installation space

EaglePicher Solutions

- + Best available battery solution
- + Liquid cooling for cells and charger
- + Module level containment, anti-propagation
- + Rigid mounted modules arranged in available space
- + Light weight internal truss structure

Airborne High Energy Laser – HEL-Maturation



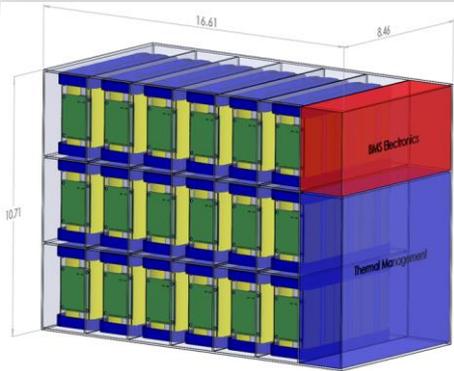
Customer Challenges

- + Demonstrated safety
- + Optimized for SWAP benefit
- + Highly regulated BUS
- + Integration with airframes

EaglePicher Solutions

- + Superior thermal management
- + BMS with complete I/O control, communications, balancing and protection
- + Demonstrated anti-propagation
- + Mission enabling, 50% duty cycle

High Energy Laser Tactical Vehicle Demonstrator



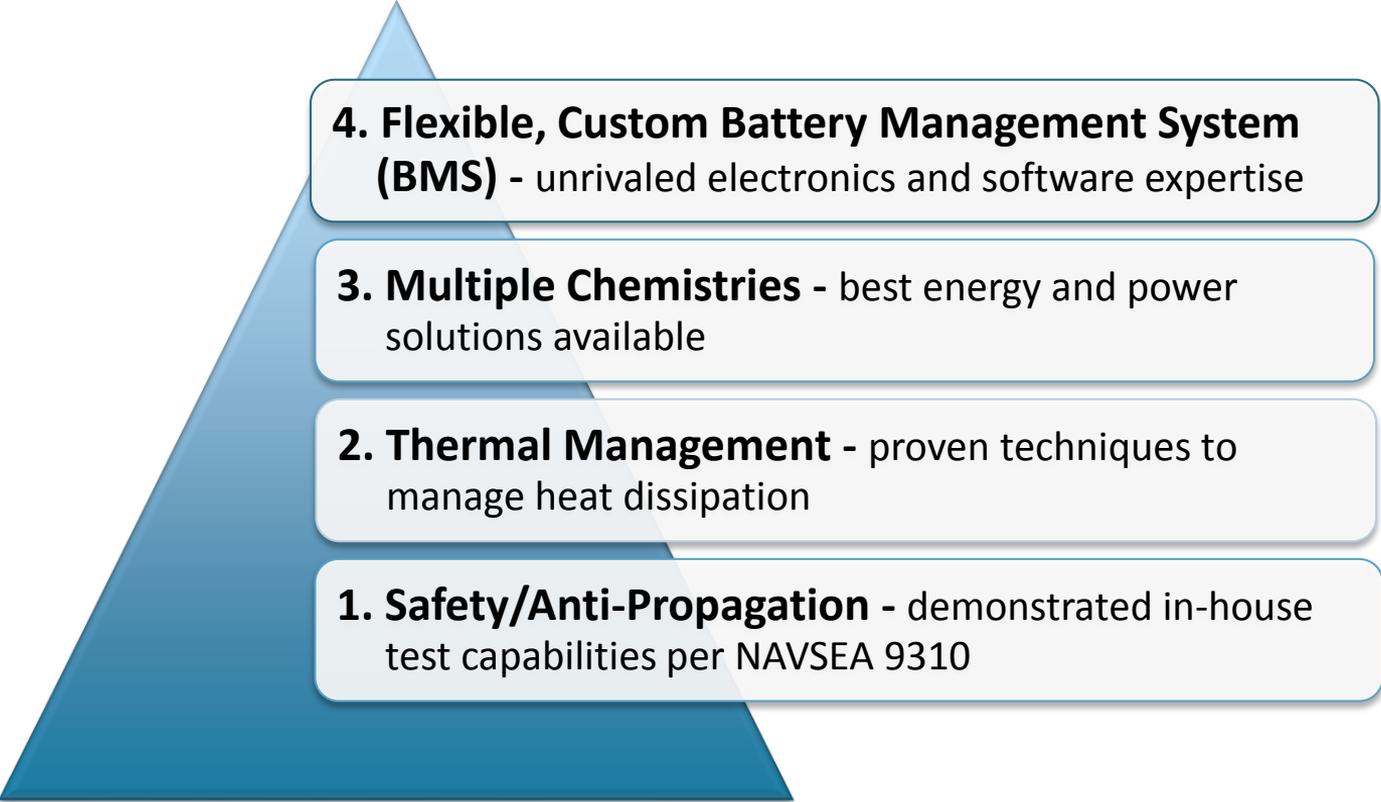
Customer Challenges

- + Demonstrated safety
- + Optimized for SWAP benefit
- + Vehicle environments
- + Cold storage temperatures

EaglePicher Solutions

- + Common BMS to other systems
- + Containment for anti-propagation
- + Integrated charger
- + Integrated thermal management (heating and cooling)
- + Robust modular structure

Safety is the Foundation for Our Solutions



4. Flexible, Custom Battery Management System (BMS) - unrivaled electronics and software expertise

3. Multiple Chemistries - best energy and power solutions available

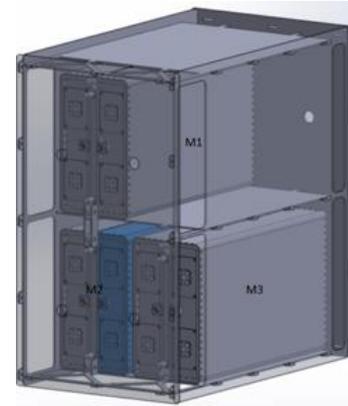
2. Thermal Management - proven techniques to manage heat dissipation

1. Safety/Anti-Propagation - demonstrated in-house test capabilities per NAVSEA 9310

Safety/Anti-Propagation

Anti-Propagation Design Pattern Re-use

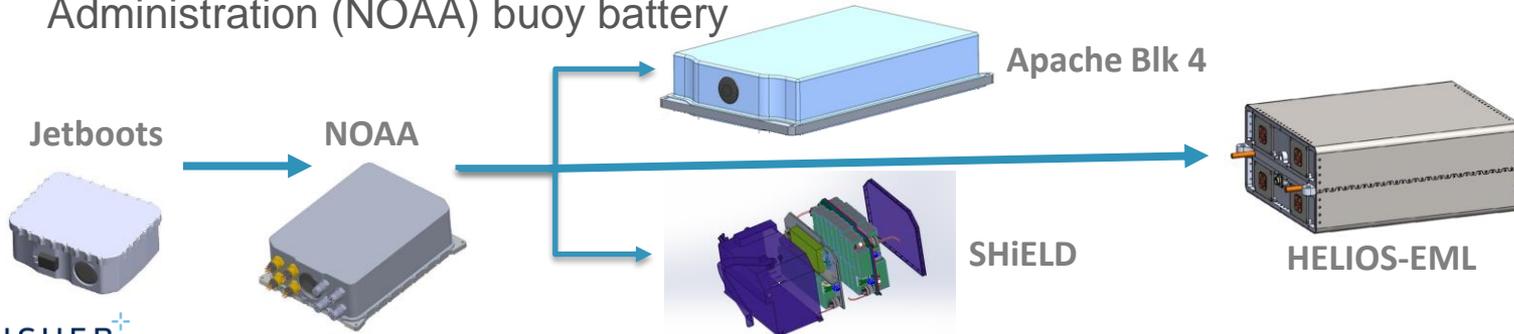
- + Safety is critical
- + Proven capabilities demonstrated over multiple projects
- + Demonstrated in-house NAVSEA 9310 testing
- + Reuse of learnings and continued refinement
 - + Jet-Boots battery
 - + National Oceanic and Atmospheric Administration (NOAA) buoy battery



In-house test capabilities demonstrated NAVSEA 9310



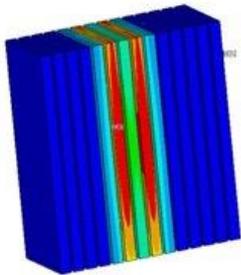
Post-test results met propagation requirements



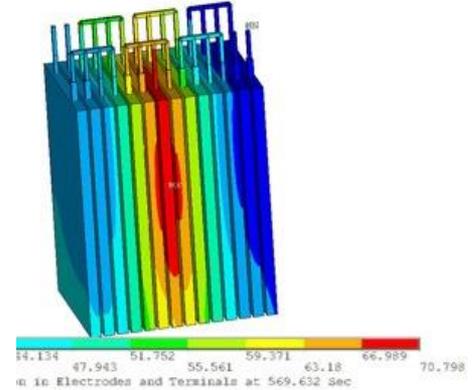
Thermal Management

Cell to Cell Propagation Limited by Pack Design

- + Cell thermal design keeps a cell cool during high power operation
- + Cell separation is key to prevent propagation
- + Applies to both prismatic and cylindrical cells
- + Advanced modeling for design optimization



**Two Concurrent Cell Failures
(6&8) at 500°C Neighbor Cell (7)
~150°C**

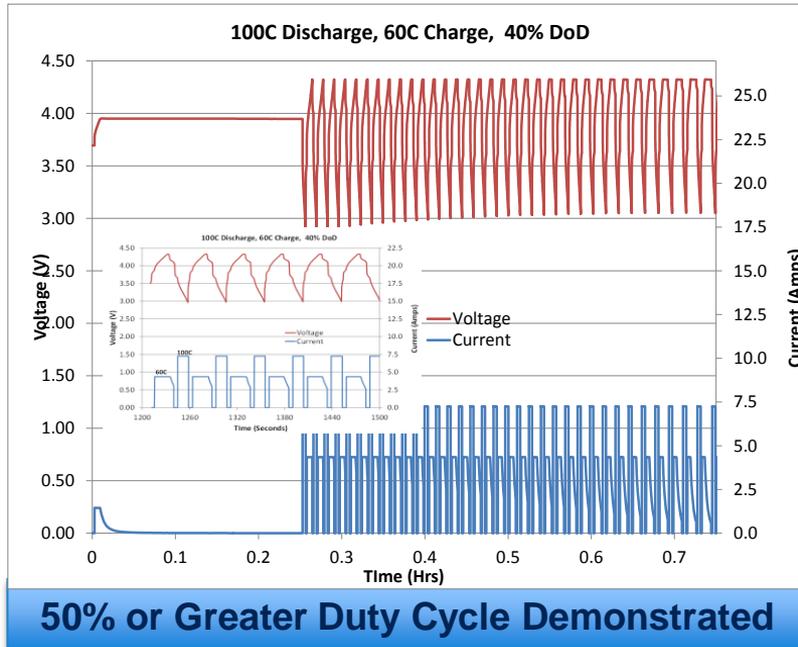


**Single Cell Failure at 500°C
Peak Neighbor < 90°C**

Multiple Chemistries

Proven High-Power Solutions

- + Over-charge tolerant
- + Demonstrated on numerous cell configurations
- + 2x power capacity per weight than competition



5Ah, Hard Cased Cell



14Ah Aircraft Cell

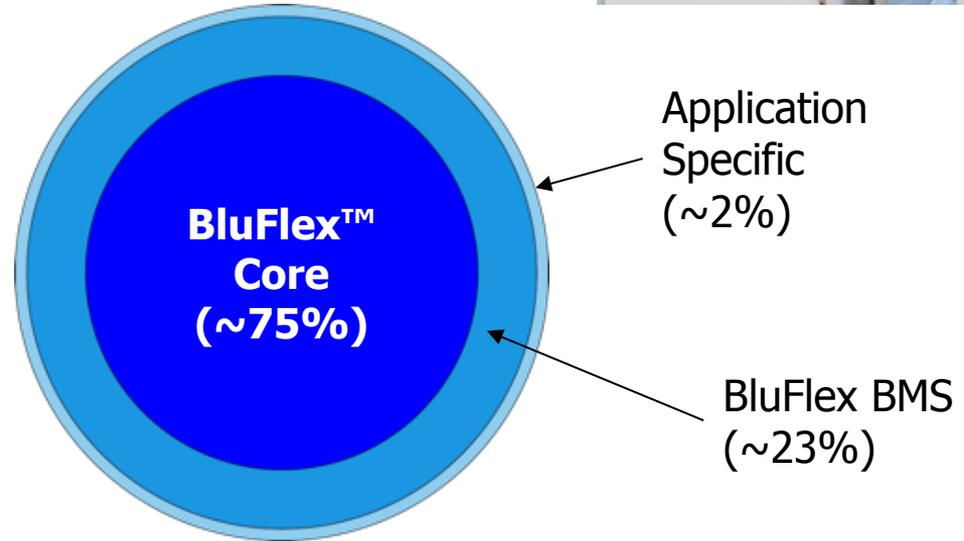


18Ah DEW Cell

Battery Management System (BMS)

BluFlex™ BMS High Performance Solution

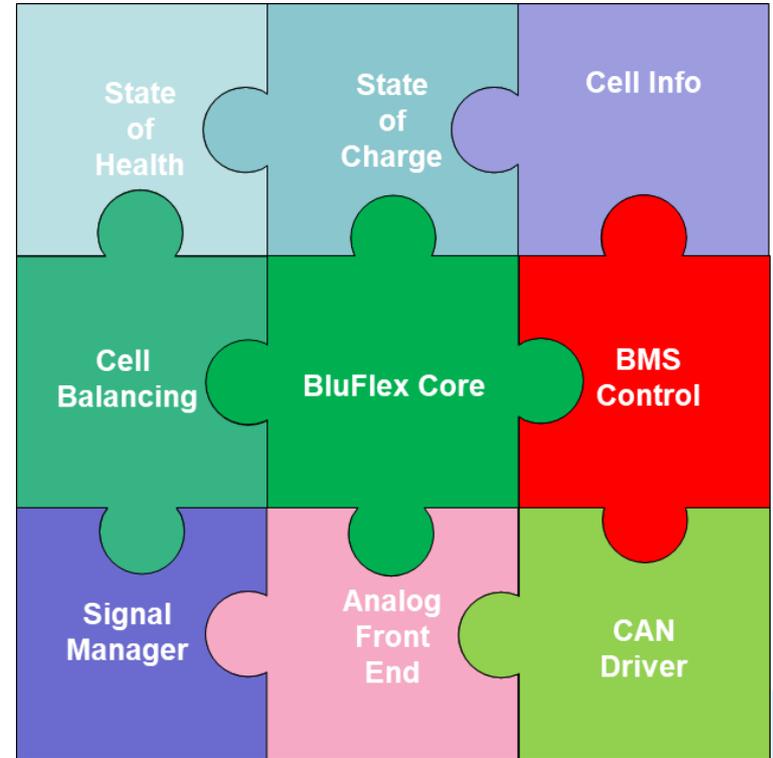
- + Robust Operations
 - + Safety
 - + Reliability
 - + Compatibility
- + Enables Critical Functions
 - + Protection
 - + Control
 - + Communication
 - + Charger management



Battery Management System (BMS)

BluFlex™ Flexible and Robust

- + Rapid development and implementation
- + Software stability and modularity
- + Hardware level modularity maps to software
- + Application specific modifications limited
- + Primary changes are lookup parameter values



EaglePicher Partnership

Proven:

- Currently on 17+ DEW programs

Reliable:

- Strong defense heritage and safety focus

Innovative:

- High performance batteries and flexible BMS

EaglePicher Provides Reliable, Flexible, Power Dense Solutions for Directed Energy Weapons Applications

INTERESTED IN ATTENDING?

Future weapons, including directed energy weapons have been in the Research & Development phase for the past several years. As the US armed forces, continue to develop and innovate in order to achieve battlefield overmatch and superiority, the Directed Energy weapon systems are making their way from the R&D phase to DoD and Military programs as the next step before acquisition and force integration.

Over the three-day summit we will examine the latest DE advancements, initiatives and plans regarding technology, acquisition and service roadmaps. This event will bring together thought leaders, acquisition executives, industry solution providers, and academia in order to tackle some of the challenges that face this community in the near, mid, and far term fight. We will look to gain insight and lessons learned from warfighter perspectives on the operational challenges and requirements of DES that will influence the capabilities of this game-changing technology.

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