# Lithium Ion Technology Overview

April 2013

EaglePicher™ Technologies, LLC
An OMG Company

Where SAFETY and QUALITY come first.

## Company Overview

# EPT Company Profile

EaglePicher™ Technologies, LLC
An OMG Company

## Leader in Batteries, Battery Chargers & Energetic Devices for Defense, Space, Commercial, and Medical Applications

- EaglePicher Technologies, LLC (EPT) is an OM Group (NYSE: OMG) company
- EPT is headquartered in Joplin, MO with 10 plants in Joplin, MO; Seneca, MO; Pittsburg, KS, Vancouver, B.C.; Rothenbach, Germany (JV)
- Over 375,000 sq-ft of manufacturing space (500,000 total)
- Three Strategic Business Units
  - Aerospace Systems: Aircraft, Satellites, Missiles, Special Applications, Missiles, Commercial Power, Alternative Energy Storage
  - Defense Systems: Missiles, Launch Vehicles, Portable Power, Portable Power, Energetic Devices
  - Medical Power: Implantable Devices

EPT Headquarters - Joplin, Missouri

Dual certification to ISO 9001:2008 and AS9100B

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# EPT Market Segments

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**Fixed wing, Rotorcraft, UAV's for Commercial & Military**
- Batteries
  - Lithium Ion
  - Primary Lithium
  - Special Packaging
- Electronics & BMS

**Aerospace Systems**

**Defense Systems**

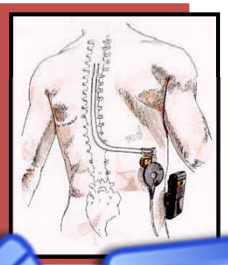
**Missiles, Launchers, Portable Power**
- Batteries
  - Lithium Ion
  - Lithium Primaries
  - Thermal
  - Silver Zinc
- Energetic Devices

**Market Segments**

**Hybrid Power Storage Systems Enable:**
- Grid Stabilization
- Improved asset utilization
- High penetration of renewables
- Enhanced reliability


**Alternative Energy Storage**

**Medical Power**



**Medical Devices**
- Batteries
  - Lithium Ion
  - Lithium Primaries
  - Microcell
  - Nickel Cadmium

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# Lithium Ion Battery Chemistries

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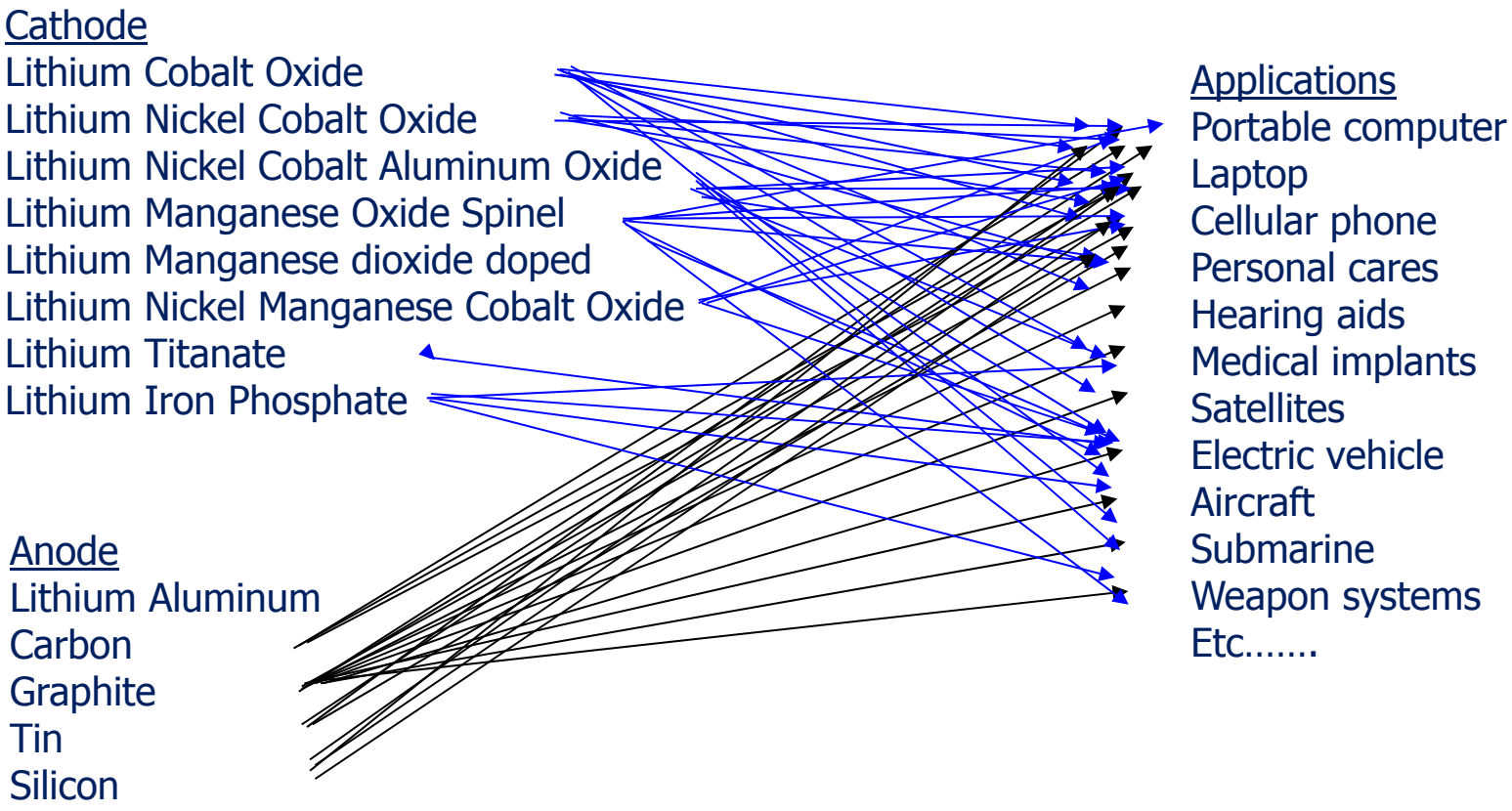
Which Li-Ion for which application? That depends…

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# Lithium-ion Experience

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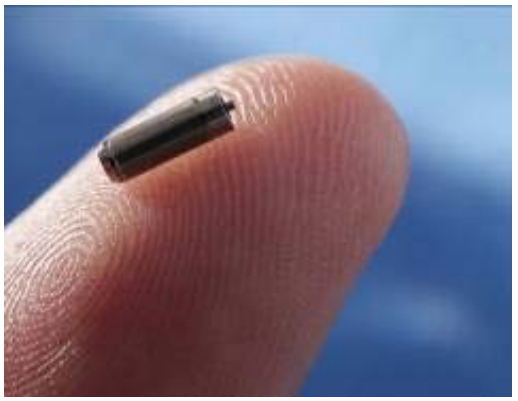
- Began Li-ion Battery Activity in 1994
- EaglePicher has a 24,000 sq. ft. facility in Joplin, dedicated to the development/manufacture of Lithium-ion products (2006)
- EPT Lithium-ion batteries in space – Total of 10 currently in orbit
  - Nameplate – 200Ah, 32V
- EPT was the first to market Lithium-ion batteries for use in implantable medical devices
- Delivered over 100 Aircraft Backup Stair Actuator Batteries since 2006
  - Nameplate – 6Ah, 28V
- Contract for MAR-9516 - Main Engine Start Battery to Certify and Deliver 2013
  - Nameplate – 30Ah, 28V
  - Includes EP Designed Battery Management System (BMS)

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# Lithium-ion Experience (Cont.)

EaglePicher™ Technologies, LLC
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- Research Contract for Next Generation Lithium-ion Cells
  - High and Low Temperature Electrolyte
  - Non-flammable Electrolyte

- High Power Lithium-ion Pouch Cell Designs in development
  - Chemistry Options: NCA, NCM, Spinel and LiFePO4

- Ultra High Power System
  - Output Power = 50kW
    - ✓ Voltage ≥ 230 Volts, Current ≤ 210 Amps
  - Input Power = 208Vac, 20A, 3 phase
  - Water cooled
  - EP Designed BMS

- Alternate/Grid Energy Storage System
  - Output Power = 1MW
    - ✓ Voltage 480Vac, 3-phase
  - 2MWHr of energy storage
    - ✓ 10% Lithium-ion
    - ✓ 360AH/480V Lithium-ion Battery

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# Lithium-ion Aircraft Product Overview

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| Usage` | Capacity (Ah) | Voltage | Weight (lb) | Volume (in) | Config | Chem | Certifications | Cells | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Capacity (Ah) | Config |
| Main | 30 | 28 | 38 | 8.34x10.44x7.85 | 13P8S | Phosphate | Type Certificate for commercial VLJ application – ECD 2013 | 2.3 | 26650 |
| Main | 45 | 28 | 50 | 10.25 in (h) x 12.25 in (l) x 9.25 in (w) | 21P8S | Phosphate | TSO through FAA and EASA | 2.3 | 26650 |
| Emer Stair Act | 6 | 28 | 6.5 | 6.25x3.50x5.50 | 3P8S | NCA | Environmental and EMC per DO-160D – received 2006 | 2 | 18650 |
| UAV Main Start | 19 | 19 | 6.5 | 7.4″H x 4.22″ W x 3.46″D | 8P5S | NCM | | 2.4 | Prismatic Pouch Cell |
| Main | 34 | 26 | 35 | 7.02x6.49x12.13 | 1P7S | NCM | Project Complete | 34 | Prismatic (Al Case) |
| Main | 50 | 26 | 42.3 | 8.81x7.69x10.66 | 1P7S | NCM | ECD Q1 2013 | 50 | Prismatic (Al Case) |

**Main Engine Start**

**Emergency Stair Actuator**

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# EP's Approach to Aircraft Battery Safety

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- Lithium Ion cells are susceptible to thermal runaway
  - Cell/battery design must mitigate the chances of internal propagation
  - Battery design must mitigate the chances of external propagation
- Cell Design
  - Metallic Case: Lowers possibility of cell to cell propagation
  - LFP Cathode: Lower energy density/less reactive with electrolyte
  - Small cell format: Lowers energy content released in a single cell event
- Battery Design
  - Thermal barrier material: Isolates cell from other battery components
  - Battery Case: Not hermitically sealed to prevent pressure buildup
- Protection from external abuse is be accomplished by a Battery Management System (BMS)
- Our approach has been proven by testing
  - Passed Explosion Containment per DO-311
  - Passed External Short Circuit with Protection Disabled per DO-311

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# Lithium-ion Aircraft Battery Design

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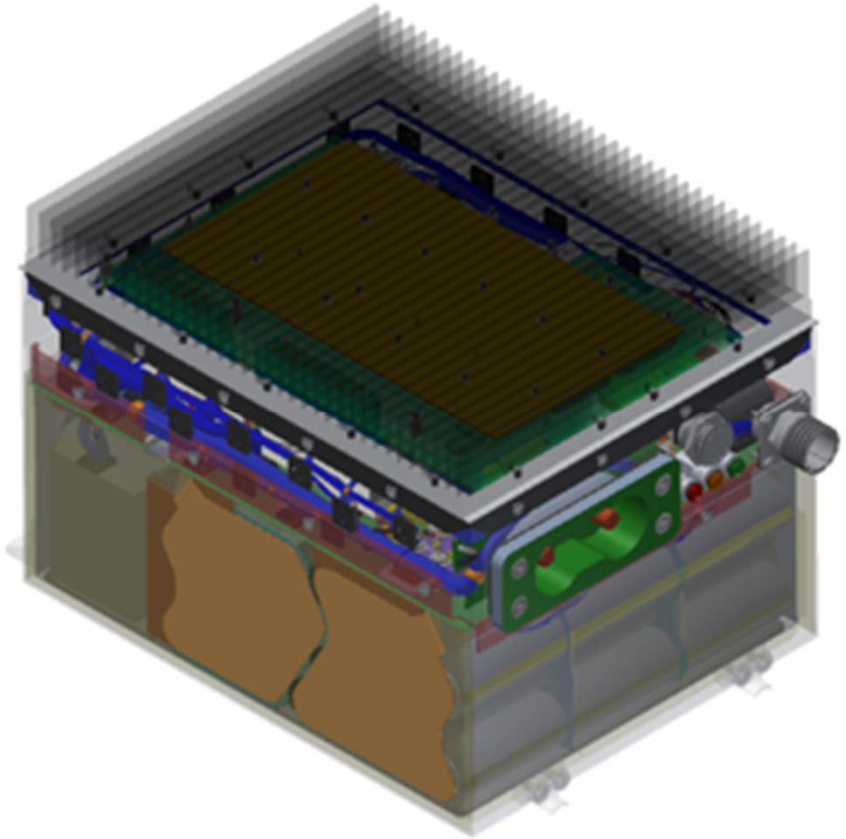
- Cell Stack
- Cell Heaters
- Protection & Isolation Switches
- Charge Isolation Diodes
- Transient Suppression Diodes
- Battery Management System
- Redundant Protection Board
- Peripheral Support Board



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# Battery Architecture - Electronics

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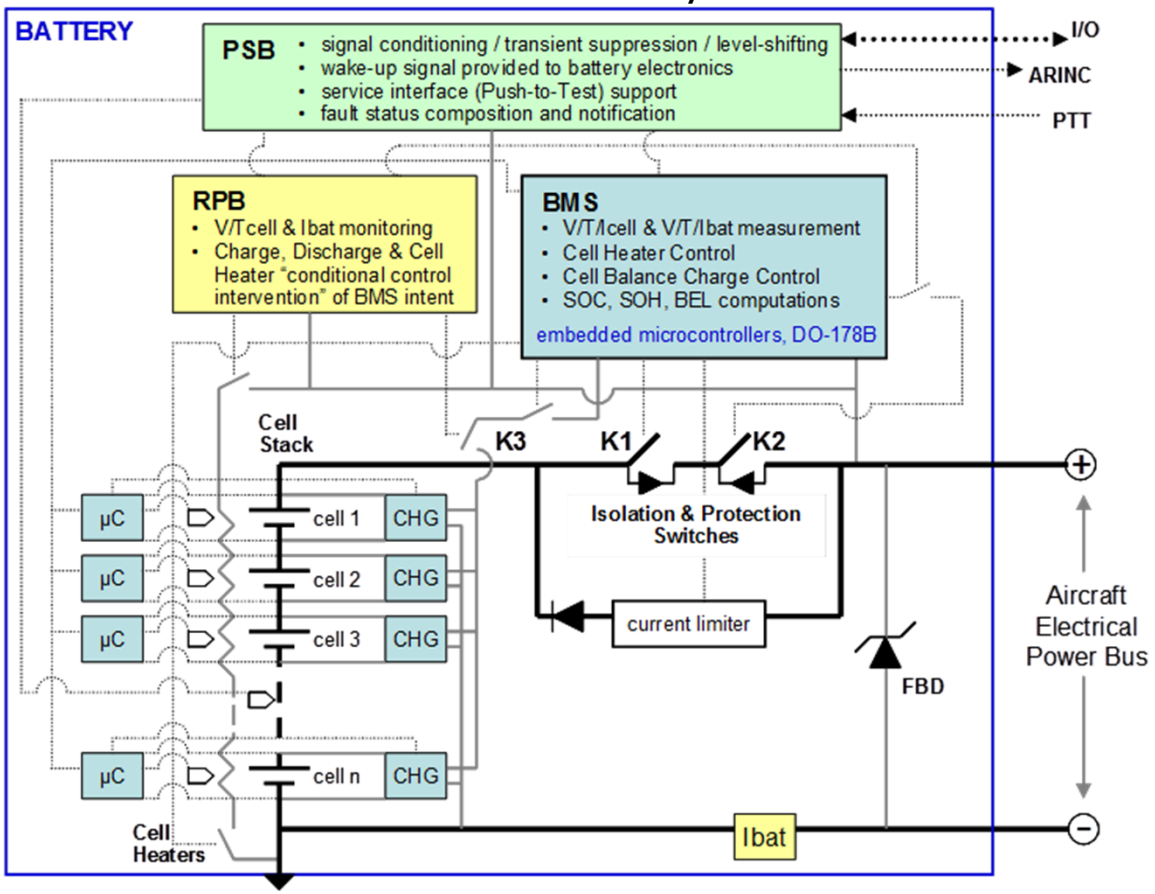
## Battery Composed of Four (4) Major Electronics Sub-Systems:

1. **BMS** – primary oversight; cell heater control; charge control; protections
2. **RPB** – secondary layer of cell protections - independent & dissimilar from BMS
3. **PSB** – airframe-specific I/O, communications & fault composition
4. **Protection Switches** – solid-state relays to isolate Cell Stack from aircraft bus

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# Summary

EaglePicher™ Technologies, LLC
An EnerSys Company

- **EPT has been a industry leader in specialty batteries for over 90 years**
- **We see Li-Ion as the future for many applications**
- **Have made a significant investment in Lithium-ion battery system development**
- **Provide entire battery solution (cells, battery, BMS)**
- **Have overcome the stringent DO-311 requirements**
- **Expect to have first certified battery by the end of 2013**

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