

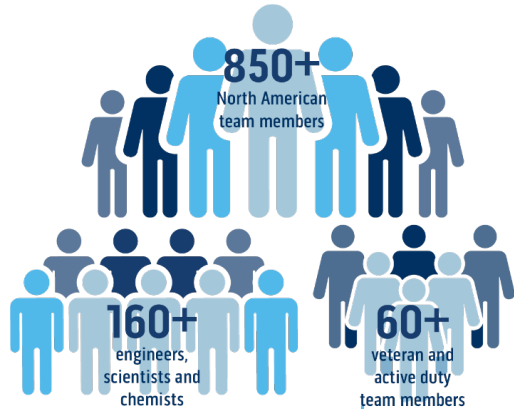
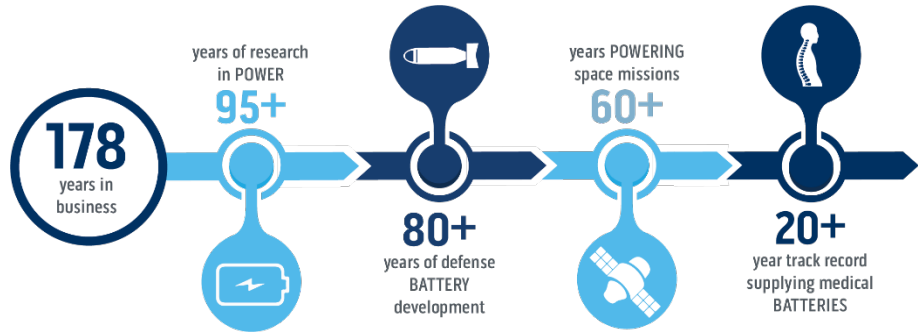
Design and Qualification of Family of Space COTS Batteries

Rob Gitzendanner, Richard Coffin,
Michel Lannes

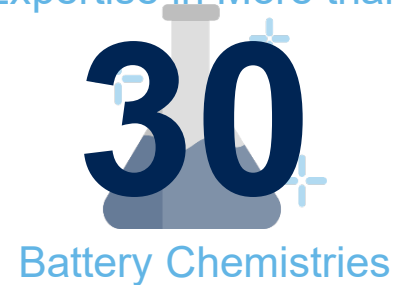
Space Power Workshop
(April 26-29, 2022 - Virtual)



EaglePicher at a Glance



Expertise in More than



The background of the image is a dark blue space scene. On the left, a portion of the Earth is visible, showing white clouds and blue oceans. In the center-right, a satellite is shown in orbit. The satellite has a central body with a circular antenna or sensor, and two long, rectangular solar panel arrays extending outwards. The overall tone is professional and technological.

EAGLEPICHER⁺
TECHNOLOGIES

EaglePicher in Space

A SUPERPOWER IN

BATTERY TECHNOLOGY

OUR PRODUCTS

POWERING MISSION SUCCESS

2, 9 6 5, 8 1 2, 3 9 6

Hours in space without a single failure. Mission accomplished!

*Approximate cell hours.

POWERING SOLUTIONS

FOR DIVERSE MARKETS

Lithium-ion Space Heritage



MARS

MER Rovers
2003

PHOENIX
2007

MSL
2011

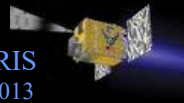
InSiGHT
2018

MAVEN
2013

Mars2020
2020



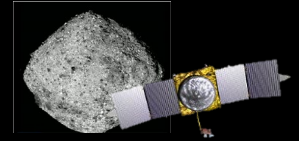
IRIS
2013



WISE
2009



GRAIL
2011



OSIRIS-REX
2016

NEXTSat
2007

ASTRO
2007

GPS
Block III
2018-2022

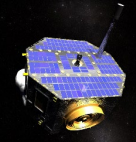


STP/SIV
STPSat 2 & 3

JWSD1
(TacSat 2)
2006

XSS-11
2005

IBEX
2008



ORION
2014/2019



STP-R1 STREAK
2005

MiTE_x
2006

JUNO
2011



DSX

X-37b
Various

PnPSAT



MISSE 5
2005



Planned
Launched



JUPITER

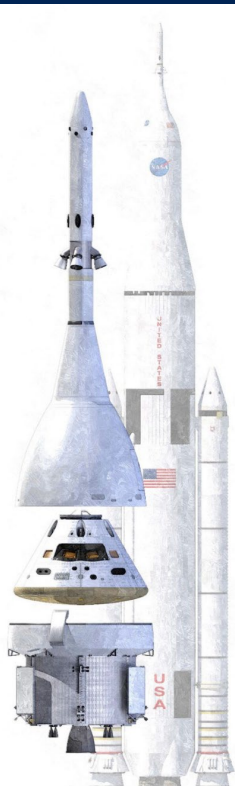
Custom Cells and Batteries



COTS Cell Battery Designs



NASA Orion – Crew Module Battery



- + Nominal 120V, 30Ah (14p32s)
- + Baseline NASA JSC Design
 - + EP completing design to meet environmental requirements
- + Thermal Runaway safety demonstrated – no propagation in testing

Modular Design

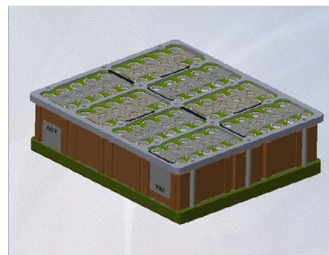
- + Cells arranged into 14p sub-bricks
- + 8s sub-bricks arranged on a thermal wall – super-brick
- + 4s super-bricks arranged in sealed aluminum structure



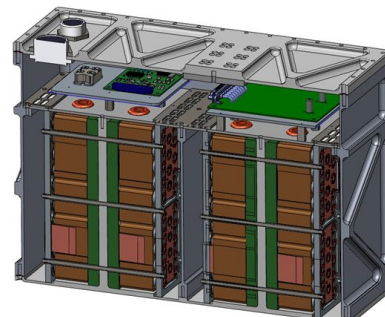
Cell



14-Cells in Parallel (Sub-Brick)

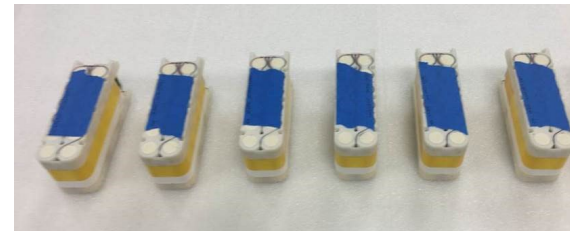


(8) Sub-Bricks in Series (Super-Brick)



Modular Battery Development

- + Several (non-space) applications developed with COTS cells, following similar design pathways
- + Performance-based cell selection, driven by application needs
- + Module Designs for Scalability
- + BMS architecture design to support large systems/arrays
- + Design in safety through best practices and demonstrated testing



Flexibility and Safety Foundation of Solutions

1. Cell Selection

- Performance characterization, validation, tracking

2. Design Modularity

- Flexible designs for rapid integration and scalability

3. Battery Management System

- Proven designs for performance and safety

4. Safety/Anti-Propagation

- demonstrated design safety and thermal management

Right Cell for Right Application

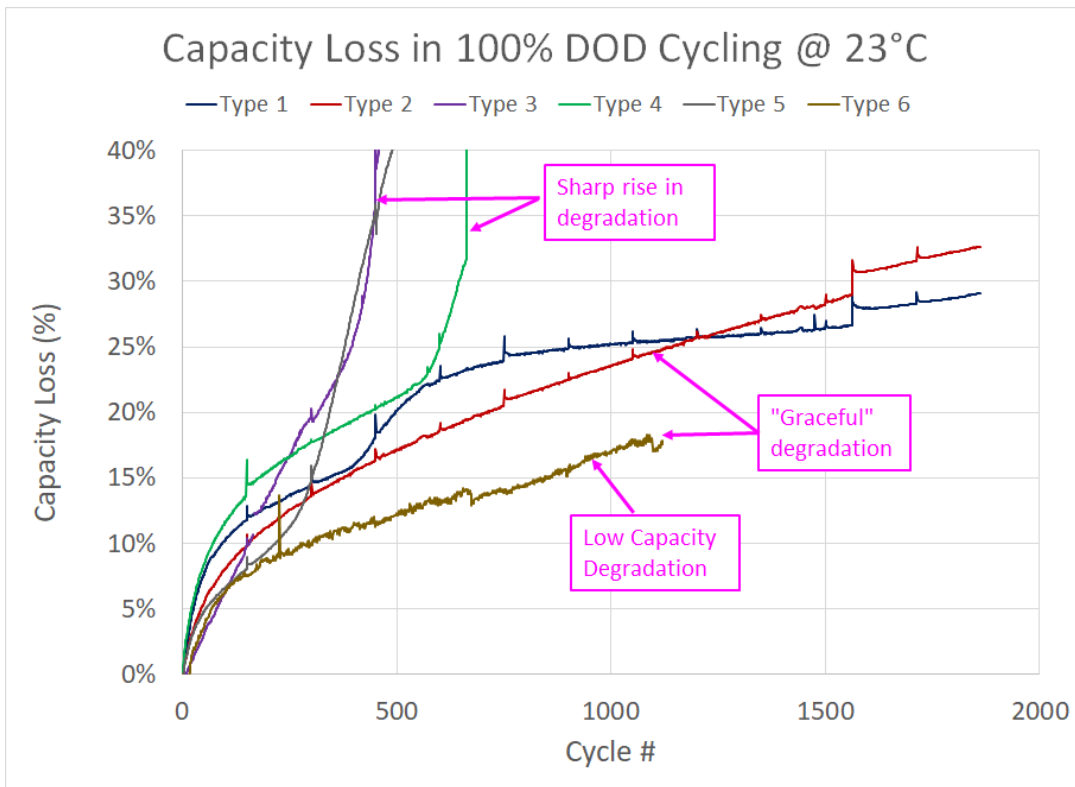
- + LEO missions favor cells that have the following characteristics:
 - + Capable of high charge and discharge rates
 - + Capable of high cycle count
 - + Stable voltage performance under load

- + GEO missions favor cells that have the following characteristics:
 - + High cell specific energy
 - + Leading to high battery mass efficiency by using less cells
 - + Low capacity degradation
 - + Under cycling and storage conditions (Time at SOC and temperature)
 - + Cells spend a large fraction of their time in orbit not being cycled

- + Always have to beware of Counterfeit Cells...

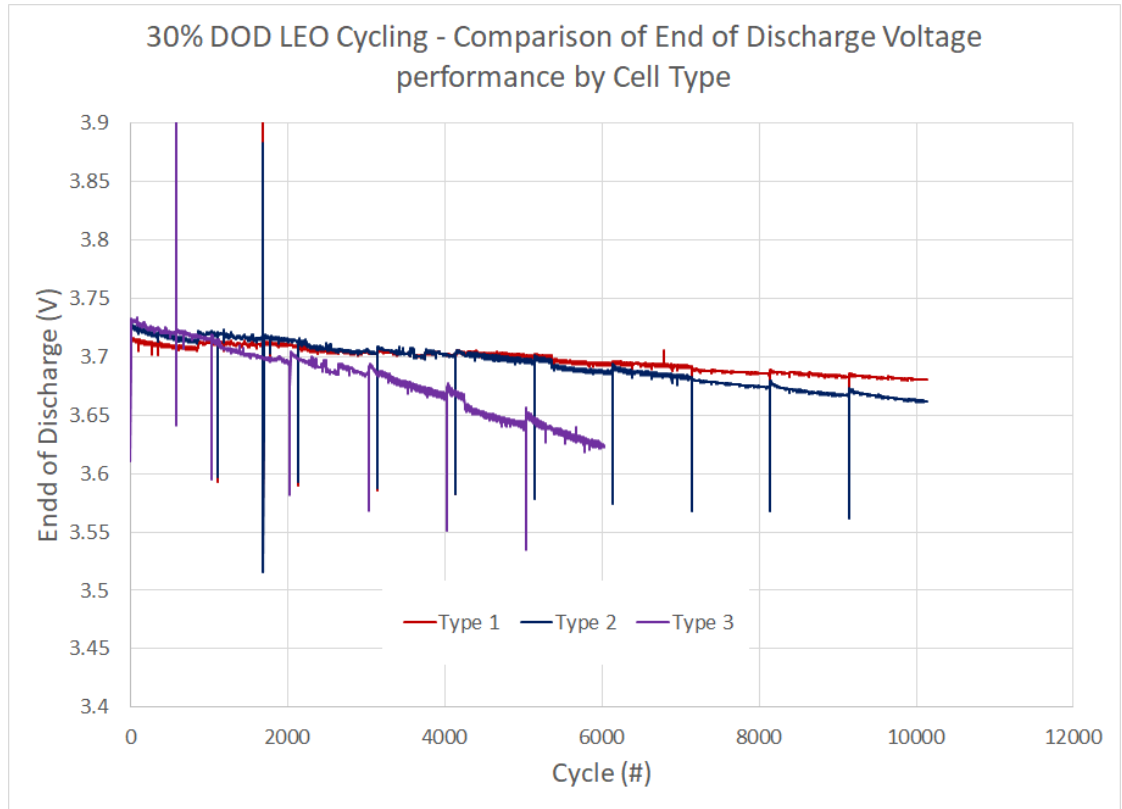
Characterization Testing

- + Cell robustness established through 100% DOD testing
 - + Eliminate cells that are designed to *optimize \$/kWh rather than cycle life*
 - + Cells that behave well in that test will perform well under high cycle count at low DOD
- + Type 2 cells are attractive for LEO missions
- + Type 6 cells good candidate for GEO missions



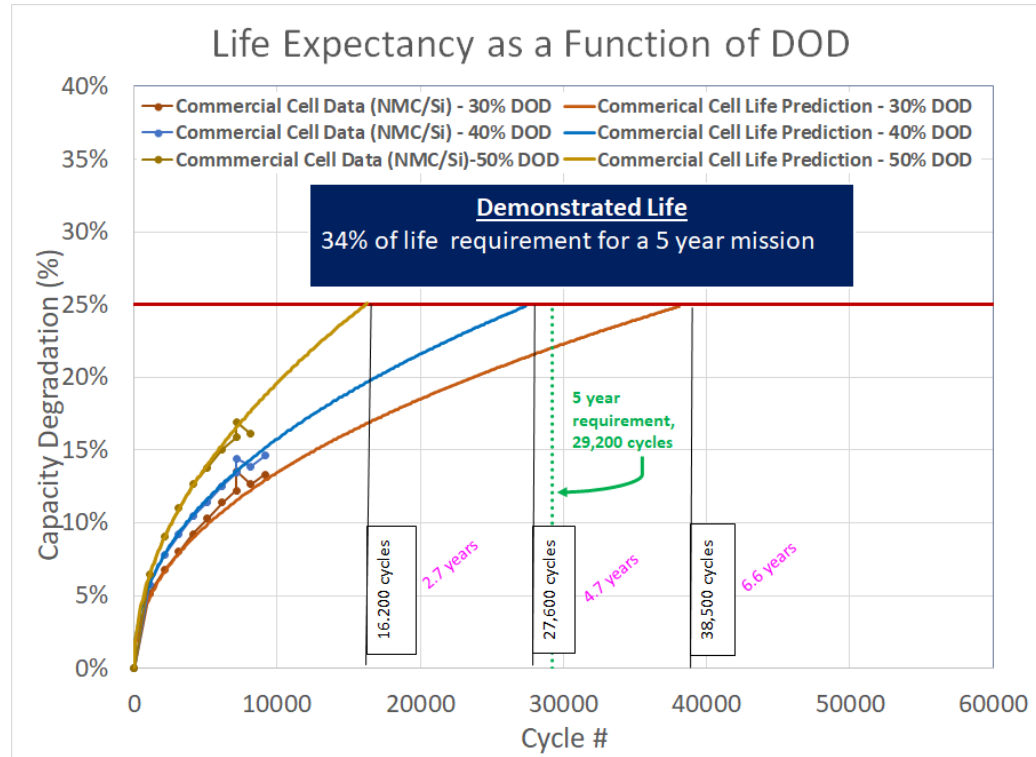
LEO Mission Life Testing

- + Up to 10,000 cycles accumulated on multiple cell types at 30%, 40%, and 50% DOD
- + Selection of cells through 100% DOD testing is confirmed by LEO test data



Life Characterization and Modeling

- + Models necessary to establish cell performance trend early
 - + A mission test often takes time and cannot be completed before launch
- + Life test data used to derive semi-empirical models
- + The combination of sufficient mission testing and high DOD testing provides confidence cells will meet mission requirements
 - + Life tests continue in parallel to flight to confirm long term performance



EAGLEPICHER⁺
TECHNOLOGIES



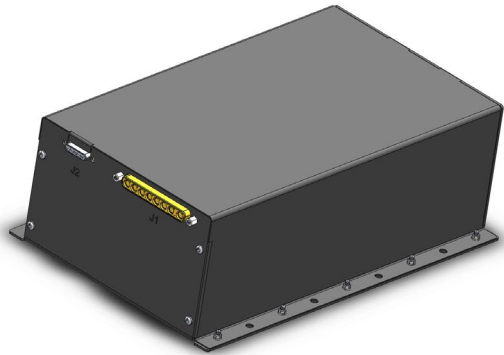
Family of Space COTS Batteries

Space COTS Battery Line

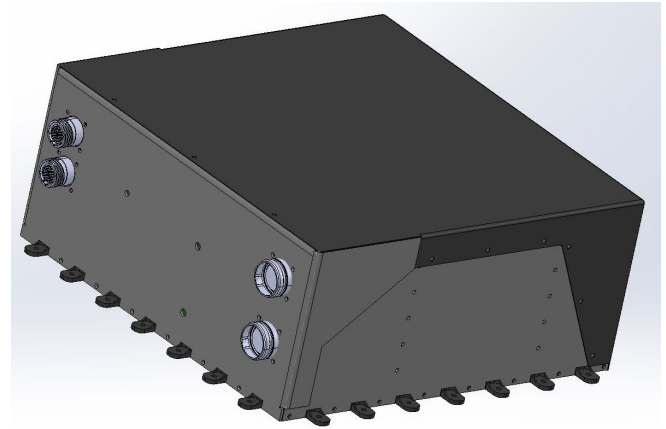
- + EaglePicher defined a “Family” of Space COTS batteries

- + All 28V Nominal – 8s Li-ion 18650 Cells

- + Nominal 1kWh Size – 8p, 10p or 12p



- + Nominal 6kWh Size – 63p



Internally Derived Specification

- + 'Envelope' experience from previous missions
- + Support LEO and GEO Missions

Spacecraft Battery

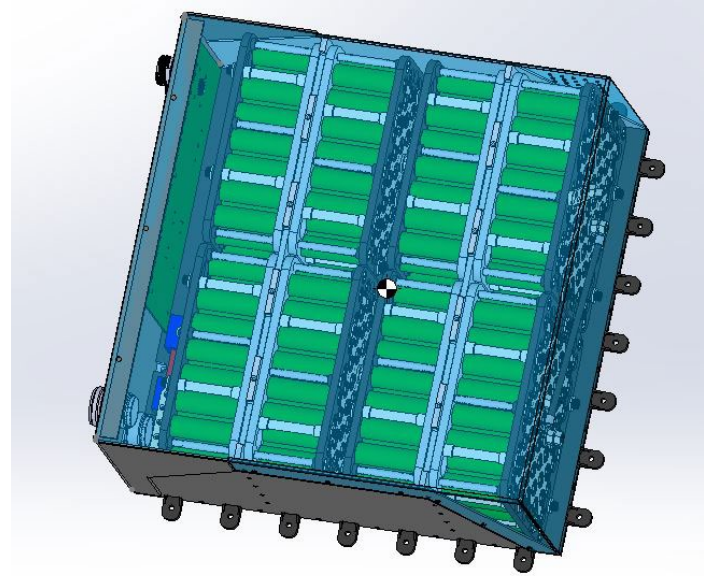
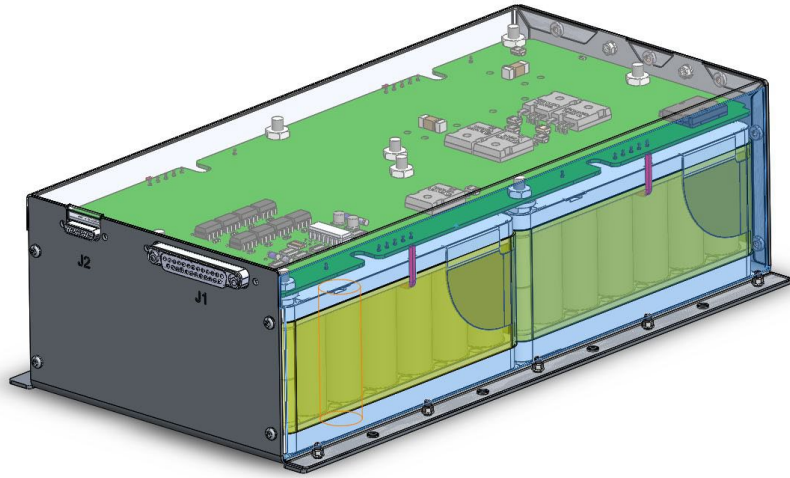
Technical Specification

EaglePicher Technologies
1215 W. C Street, Joplin, MO 64802
www.eaglepicher.com
DUNS # 78-810-4334
Cage Code: 81855

Document Date: May 5, 2021
Revision 1

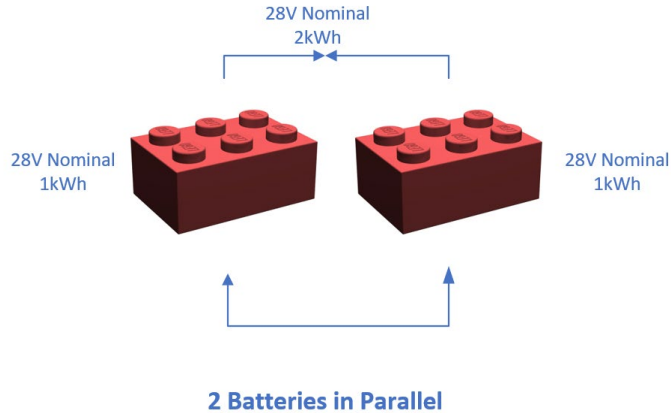
<u>Business Development</u> <u>Point of Contact:</u> Rick Meehan 401-234-6961 rick.meehan@eaglepicher.com	<u>Technical Point of Contact:</u> Richard Coffin 417-623-8000 richard.coffin@eaglepicher.com	<u>Contract Point of Contact:</u> Carol Baker 417- 208-1578 carol.baker@eaglepicher.com
--	--	---

Modular (Pack) construction

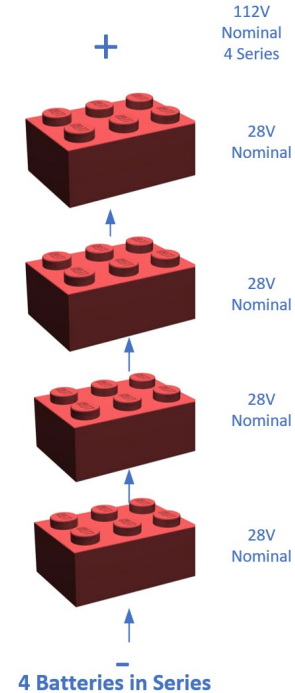


Battery Configuration Options

Increase Capacity

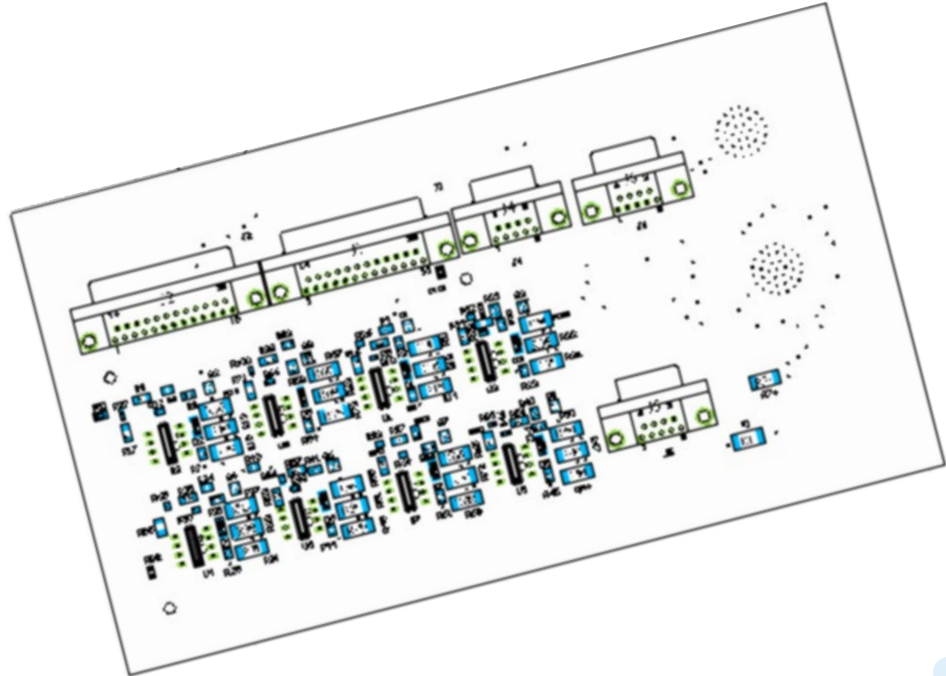


Increase Voltage



COTS-based BMS

- + Resistive Cell Balancing
- + Current, Voltage and Temperature Monitor and Reporting
- + Heater Control
- + Battery Isolation (optional)



Qualification Test Plan

- + Ground bonding
- + Isolation
- + Capacity
- + Electrical Performance
- + Impedance DC/AC
- + Temperature/TVAC
- + Shock and Vibe
- + EMI/EMC
- + Shipping UN/DOT 38.3

Baseline Schedule

- + Engineering Development Units complete – Delivering to customers
- + Critical Design Review (internal) Q2 2022
- + Qualification Complete early Q3 2022
- + Flight Units Delivered Q3/Q4 2022

Conclusion/Summary

- + EaglePicher has an extensive heritage in space applications
 - + Over 2 Billion Cell-hours operating in space, Over 14 years operational on Mars
 - + Deep knowledge-base on how to design for long endurance, high reliability missions
- + Developed internally designed Family of Space Batteries with COTS cells
 - + Low cost, configurable solutions
 - + Can be stocked for quick delivery
- + Flexible assembly line processing to reduce processing time and increase reliability and repeatability
- + Fully Qualified in Q3 2022

+ Thank You!

