# SMC Qualification of New Battery Chemistry using AIAA S-144-202X in Support of SMC S-017 and the SMC Battery Roadmap Rev. 11, 11/21/19

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# Overview



- **Problem: New Battery Chemistry Doesn't Find its Way into SMC Systems**
- **Solution**
- **SMC Battery Roadmap**
- **AIAA S-144-202X**
- **Rapid Innovation Fund Demonstrator**

# Problem: New Battery Chemistry Doesn't Find its Way into SMC Systems



## In Satellites:

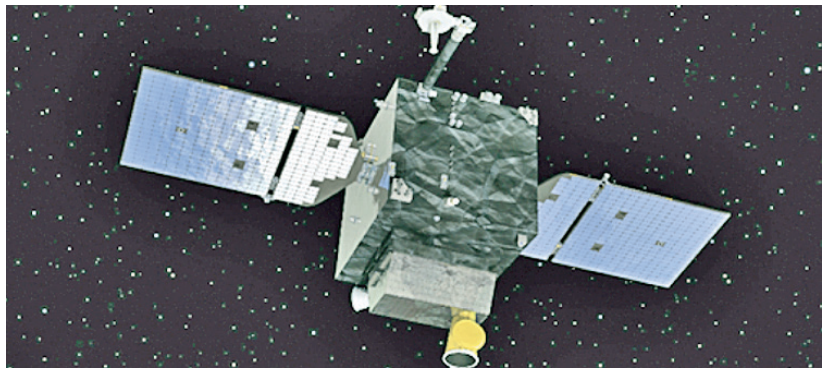
- Non-standardized battery modules – can't use commoditized cells
- Non-standard-sized cells – sole source risk
- New chemistry introduced approximately every 15 years due to existing qualification requirements

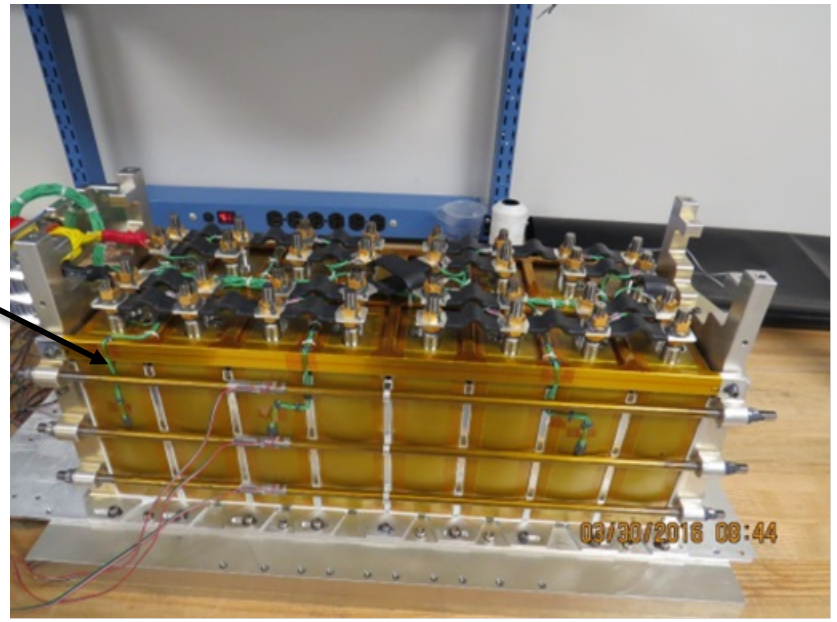
**Sole-source designs regularly create schedule and cost risks to space misssions and prevent rapid new chemistry introduction into energy storage systems**

# For Batteries the Technology Transfer Vehicle is the Cell - STPSat 6 Example



| | |
|---|---|
| Constellation | Air Force Space Command |
| Program | STPSat-6 Vehicle – Authority: ERB |
| System | Electric Power System – Authority: ERB |
| Subsystem | Energy Storage – SMC S-017 Specification |
| Assembly | BMS and Battery Module – SMC S-017 Specification |
| Subassembly | Battery Module (Assy of Cells) SMC S-017, better way AIAA S-149 |
| Part | 5781173 Battery Cell – SMC S-017, better way AIAA S-144 Qualification |
| Refined Materials | MCMB (MesoCarbon MicroBeads) – Title III |
| Raw Materials | Coal Tar Pitch – Title III |





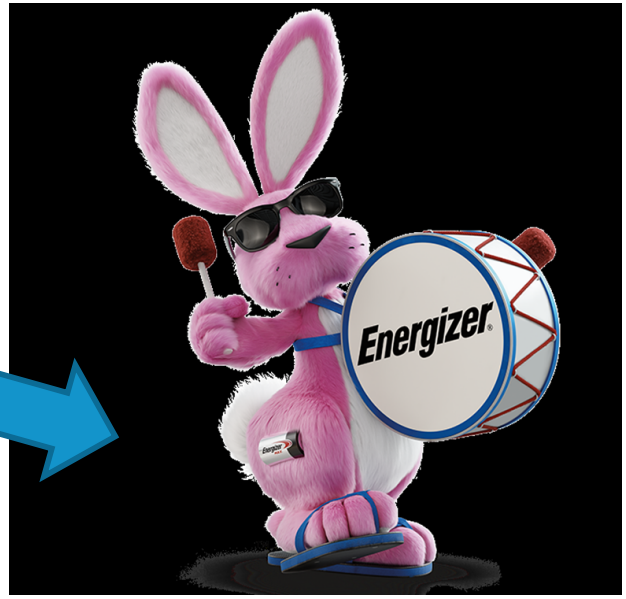
# Solution: Insert New Battery Chemistry into SMC Systems using Terrestrial Approach



## Apply Terrestrial Battery Improvement Approaches to Space Satellites using AIAA S-144 and S-149



AIAA S-144 Qualified, Standard-Size Battery Cell




Satellite with AIAA S-149 Qualified Battery Box that Accepts AIAA S-144 Qualified, Standard-Sized Cells

# Seven Benefits of AIAA S-144-201X



- Provide standard-sized cells from multiple manufacturers, reducing program office costs and schedule delays
- Enable modular/scalable batteries, minimizing customer costs by reducing need for changes in mission-specific battery design, assembly, documentation, requalification
- Standardize minimum set of qualification and acceptance tests, satisfying all international requirements for all cell sizes
- Standardize reports and reporting formats, improving customer awareness of alternatives for new missions

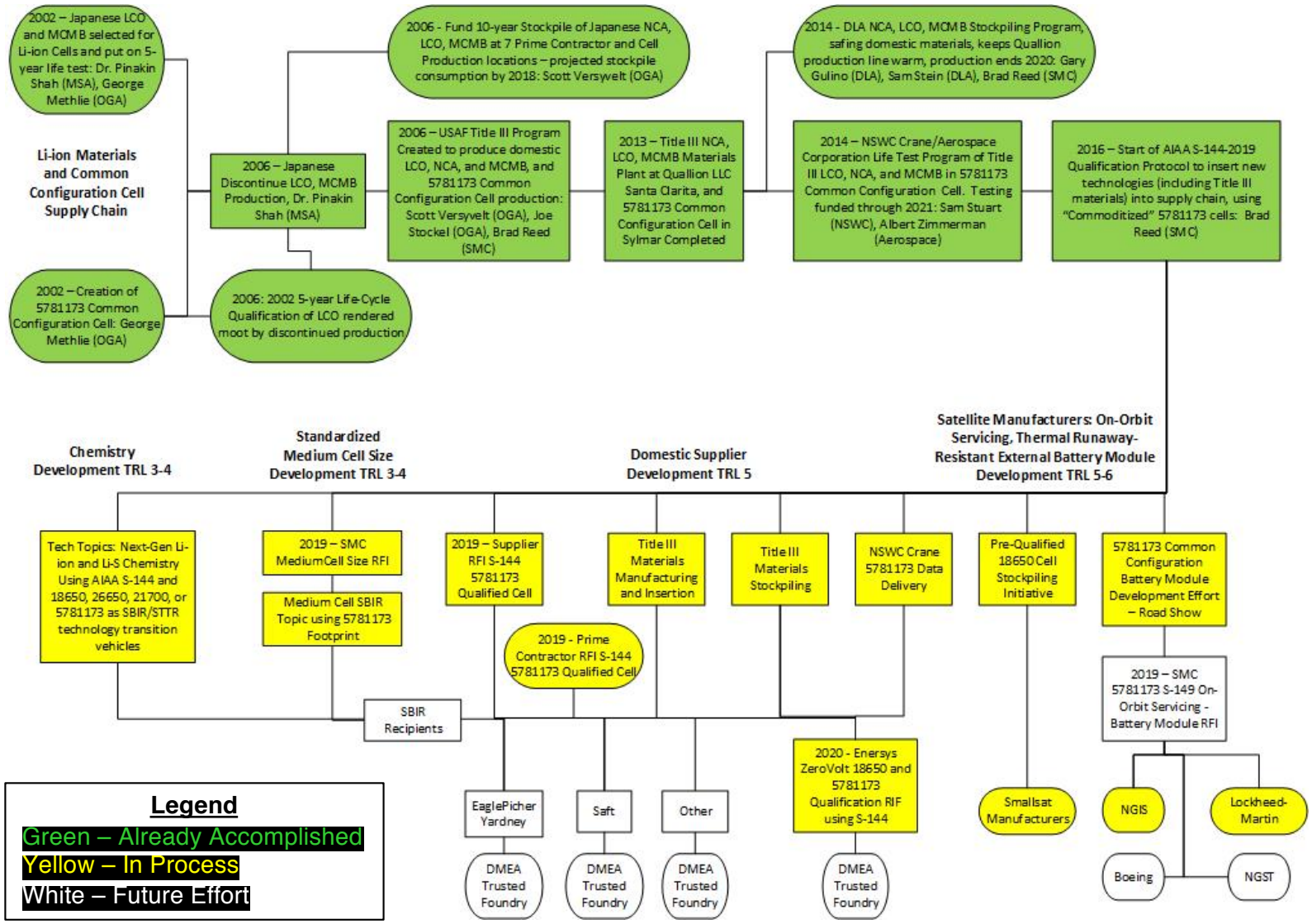
# Seven Benefits of AIAA S-144-201X (cont'd)



- Require manufacturer transparency to resolve issues that affect parts, materials, and processes, or form, fit, and function
- Encourage dual-source parts to reduce sole-source, single-source, and foreign-source risks
- Establish standardized cell sizes:
  - 18650, 26650, and 21700 sizes already standardized
  - New cell for proposed 20 A-h market (goal)
  - 5781173 size standardized in the 50-75 A-h market

# SMC Battery Roadmap





# SMC Battery TRL "Valley of Death" Mitigation Roadmap



- New Chemistry Development Through SBIR/STTR (TRL 3-4)
  - Baseline: Li-ion
  - Develop enhanced Li-ion, Li-S, other Zero Volt chemistries through normal SBIR/STTR process and set productization path through "commoditized" 18650, 26650, 21700, 5781173 tech transfer vehicles; Explore other government agency synergies/intersections
- Intermediate Cell Size Development Through SBIR (TRL 3-4)
  - Baseline "Commoditized" Sizes Standardized by AIAA S-144-2019: 18650, 26650, 21700, 5781173
  - SMC submit RFI to determine "next" best A-h cell size
  - SBIR Topic – use 5781173 footprint with Li-ion A-h size requirement
  - Execute SBIR – develop design with government IP rights
  - Government share design with cell manufacturers
  - Government fund 5-year Li-ion testing program to support "Space Force" architecture (fund mechanism TBD); Explore other government agency synergies/intersections

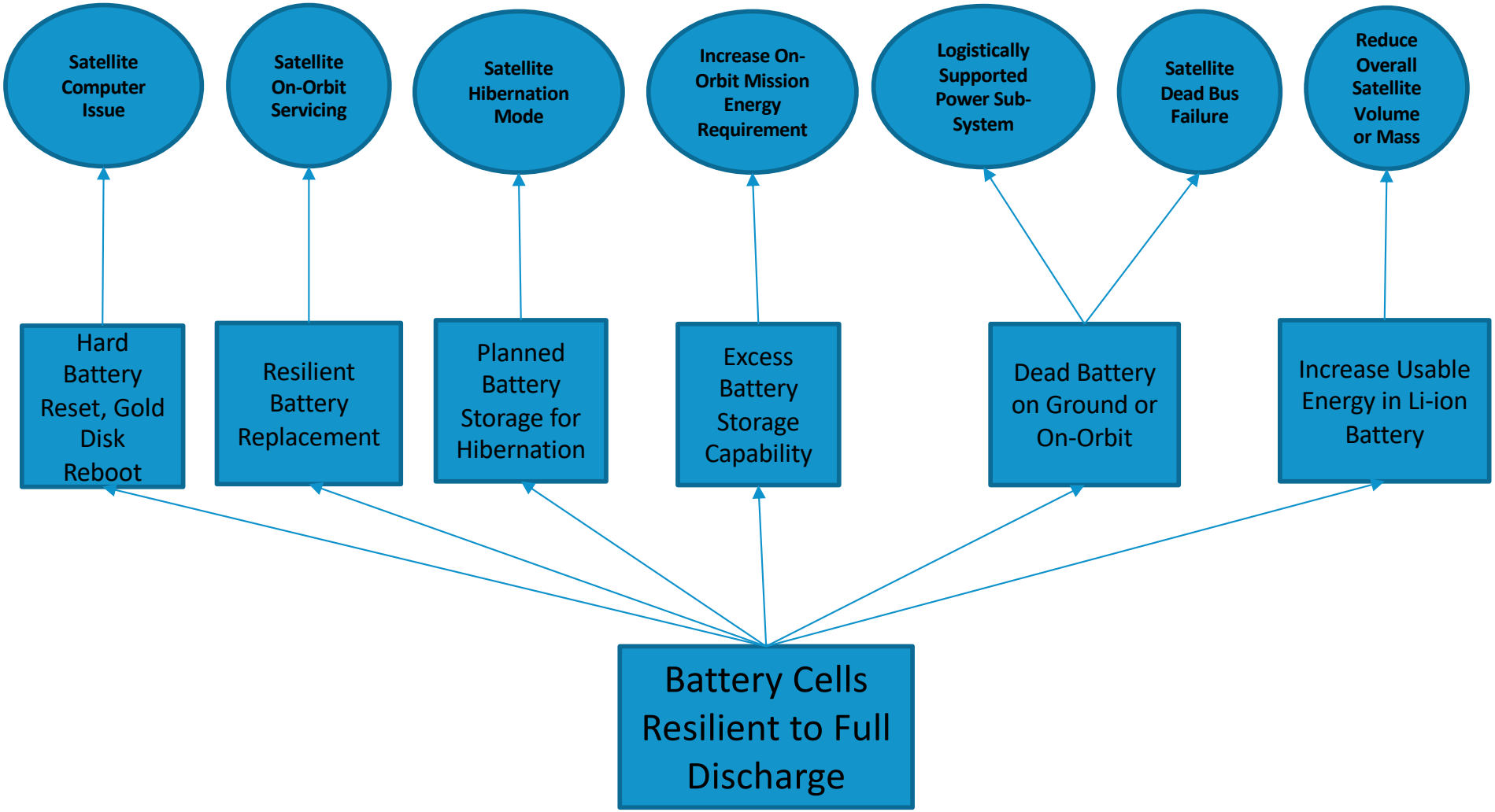
# SMC Battery TRL "Valley of Death" Mitigation Roadmap (cont'd)



- 5781173 Supplier Development Through Prime Contractor Partnership (TRL 5)
  - SMC RFI to determine number of vendors in "commoditized" 5781173 market
  - Government/Supplier Partnership to Fund Qualification data gap (fund mechanism TBD); Explore other government agency synergies/intersections
- Prime Contractor "Standard" External Battery Module Development (TRL 5-6)
  - SMC RFI to understand which prime contractors will start modular design approach based on "commoditized" cells
  - Aerospace goal of thermal runaway mitigation to stimulate new module development
  - SMC goal of "on-orbit servicing"

# MBSE Battery Problem Roadmapping: New Battery Chemistry Solution





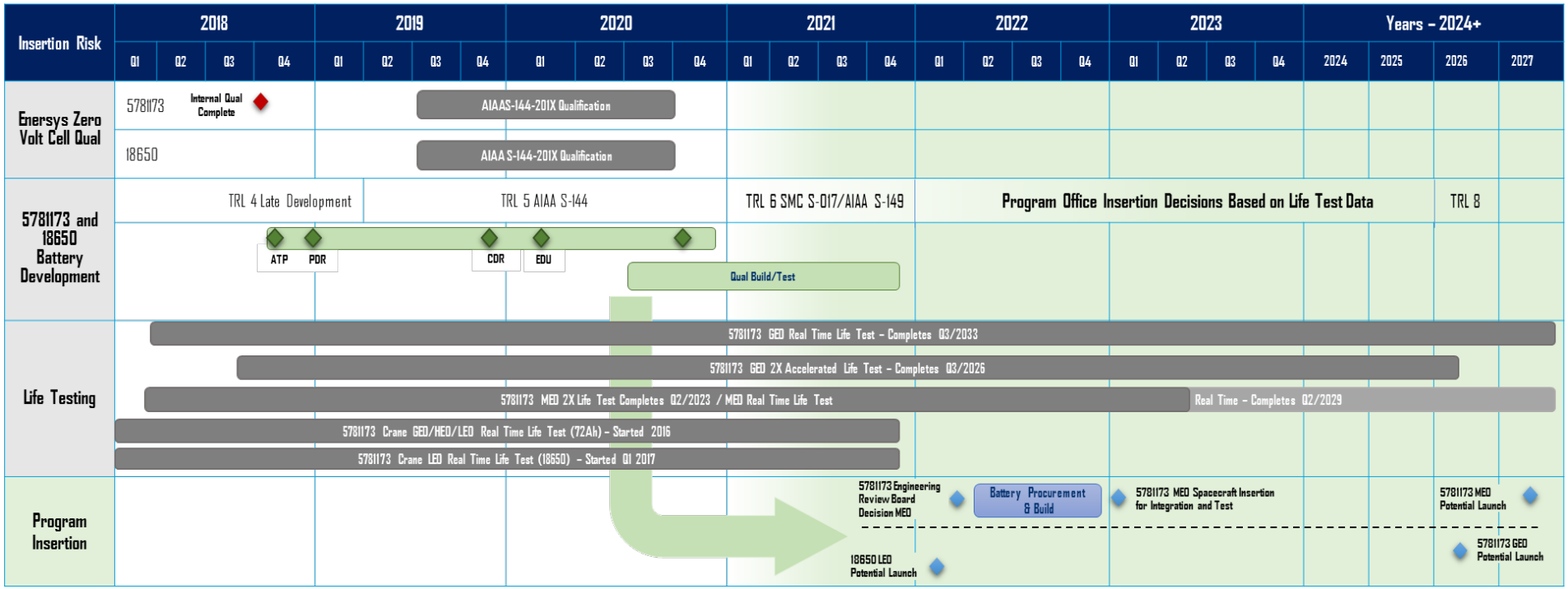
# Rapid Innovation Fund Program Demonstrator



- **Characterize and Qualify new battery chemistry resilient to full-discharge environments using AIAA S-144**
- Demonstrate new cell qualification standard AIAA S-144-201X for 18650 and 5781173 cells
- Develop criteria for standardized AIAA S-149-202X battery qualification
- Transition the new chemistry to a SMC program of record through AIAA S-149-202X and SMC S-017

# RIF Program: Enersys Title III Cell 18650 and 5781173 Supply Chain Insertion Timeline





# 18650 Cost Comparison Example: Notional 5-Year LEO Satellite Mission Based on EOL Energy Requirements



- **With the current lack of standards, it is difficult to provide an apples-to-apples comparison like the below:**
- ZeroVolt 18650 one-time S-144 qualified = $55/unit[1]
- LG Chem 18650MJ1 ($8) + S-144 qual ($40) = $48/unit[1]
- EOL 5 years at LEO (27,375 cycles) and C/2 charge/discharge
  - LG Chem 18650 capacity at 5 years: 0.96 Ah (high capacity fade)
    - Energy per cycle 3.7 V x .96 Ah x .4 DOD = **1.4 Wh per cycle**
  - ZeroVolt 18650 capacity at 5 years: 1.24 Ah
    - Energy per cycle 3.7 V x 1.24 Ah x .6 DOD = **2.8 Wh per cycle**
- **In this theoretical battery, one can use approximately half the number of ZeroVolt cells at 60% DOD as opposed to LG Chem cells at 40% DOD, reducing the battery cell cost by approximately 40% for the same EOL usable energy**. In addition, the ZeroVolt feature allows battery-level capability to solve the on-orbit problems LG Chem cells can't accommodate, and reduction of battery volume and mass in the satellite.
- **AIAA S-144 provides the framework to allow such a comparison**

[1] Approximate Cost based on bulk buy of LG Chem COTS cells, as opposed to JIT production of ZeroVolt cells and does not factor in amortized ZeroVolt qualification costs over time or qualification of new COTs cell lots.

# Potential ZeroVolt/Title III Material Commoditized Cell Adopters

## Satellite Organizations



**Adcole, Angstrom, Astro Digital, Blue Canyon, Boeing, ExoTerra, General Atomics Electromagnetics Systems, Hera Systems, Innoflight, Jet Propulsion Laboratory, L3/Harris, Lockheed Martin, Maxar, Micro Aerospace, Millenium Space, NearSpace, Northrop Grumman, NovaWurks, Planetary Systems, Pumpkin, Sierra Nevada, Space Micro, Spire Global Systems, SRI International, Tyvak, York**

# Summary

- SMC is executing a methodology through its battery roadmap and AIAA S-144 to introduce new battery chemistries into SMC missions
- The Enersys RIF and the ZeroVolt chemistry is the first demonstration of this methodology
- A new “standard” cell size will be developed to address the need for a “standard” intermediate-sized cell