

*Cell-Level Anode Advances for SOC/SOH
Stability Under Space-Relevant PMAD
Conditions*

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LFP SOC Management: The Persistent PMAD Challenge

LFP is a growing chemistry for many space power applications, but its flat OCV plateau creates a systemic PMAD problem.

The LFP Electrochemical Constraint:

- OCV change across 10–90% SOC in LFP/graphite is approximately 0.1 V — **below reliable detection under load**
- BMS must rely on coulomb counting between calibration events
- Counting error accumulates with temperature variation, rate variation, and aging
- Recalibration via deep discharge is the standard fix — operationally disruptive and life-limiting

Downstream PMAD consequences:

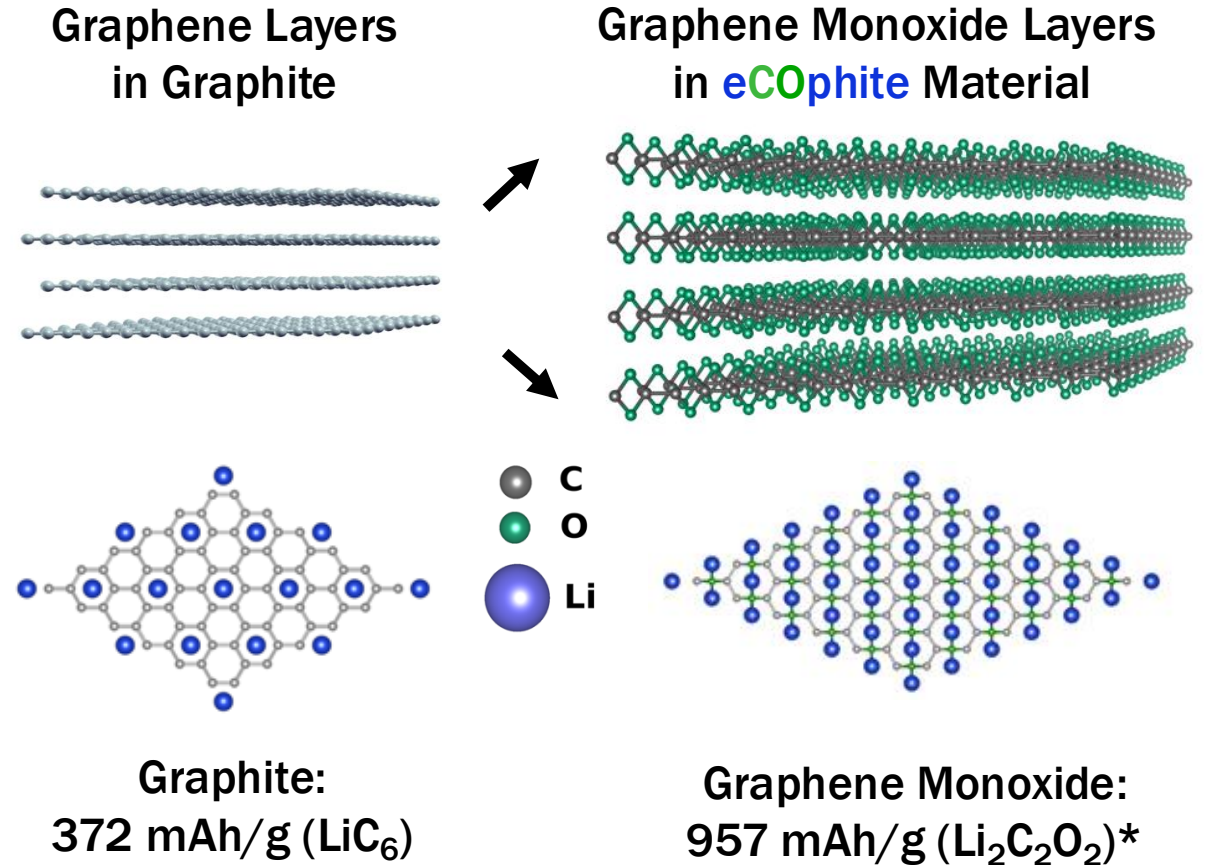
- **SOC margin padding** — Systems carry 20–30% SOC buffer to absorb uncertainty; direct mass and volume penalty
- **Cell balancing degradation** — Drifting SOC-voltage relationship causes inter-cell divergence to grow undetected
- **Fault detection ambiguity** — Low SOC signal-to-noise degrades isolation confidence in fault-tolerant architectures
- **Constrained operating profiles** — Pulsed EP loads, aggressive eclipse cycling, and fast charge acceptance all stress a system already operating with poor state observability

WHAT IS eCOphite™?

eCOphite™: A Graphene Monoxide Anode Material Derived from Lignin

Structural difference from graphite:

- Expanded interlayer spacing + oxygen functional sites → $\text{Li}_2\text{C}_2\text{O}_2$ stoichiometry → **957 mAh/g theoretical***
- **Larger d-spacing** reduces activation energy for Li intercalation; oxygen sites provide additional binding positions



**Enhanced SOC Monitoring, Fast-Charge Durability, and Cold-Temperature Performance for LFP Batteries.
Domestically Sourced, Cost Parity with Graphite at Scale.**

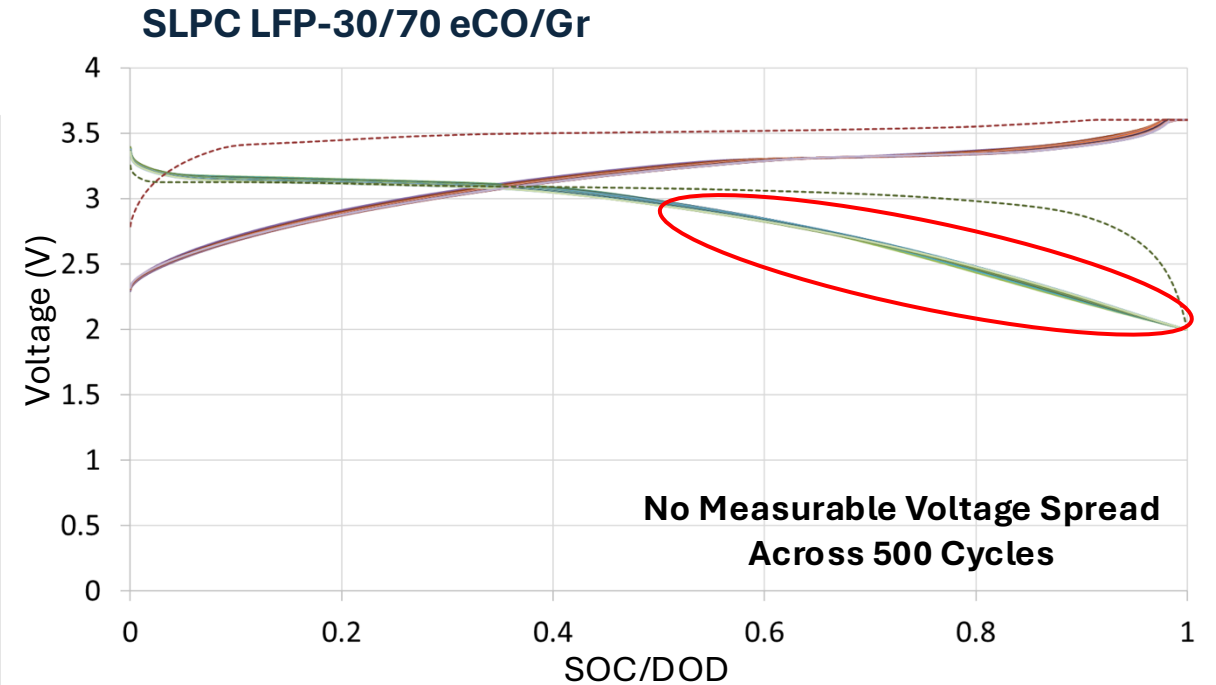
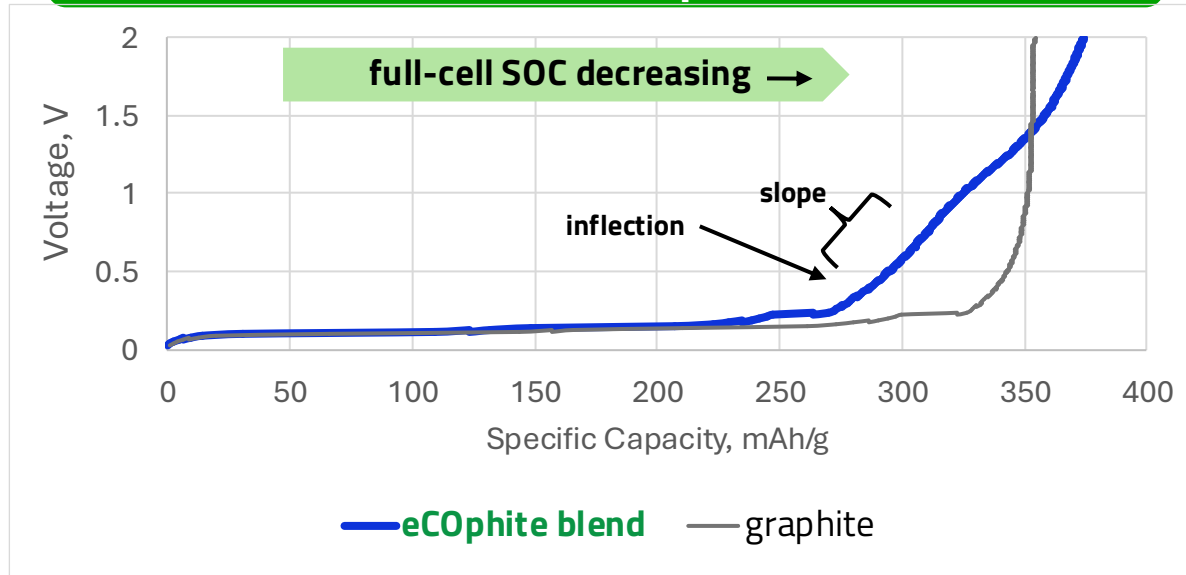


Key Result #1: SOC Voltage Stability

Cell Design: LFP Cathode, 70:30 Graphite / eCOphite Blend Anode

Single-layer pouch cells

Anode Delithiation Voltage Curve for eCOphite blend vs Graphite

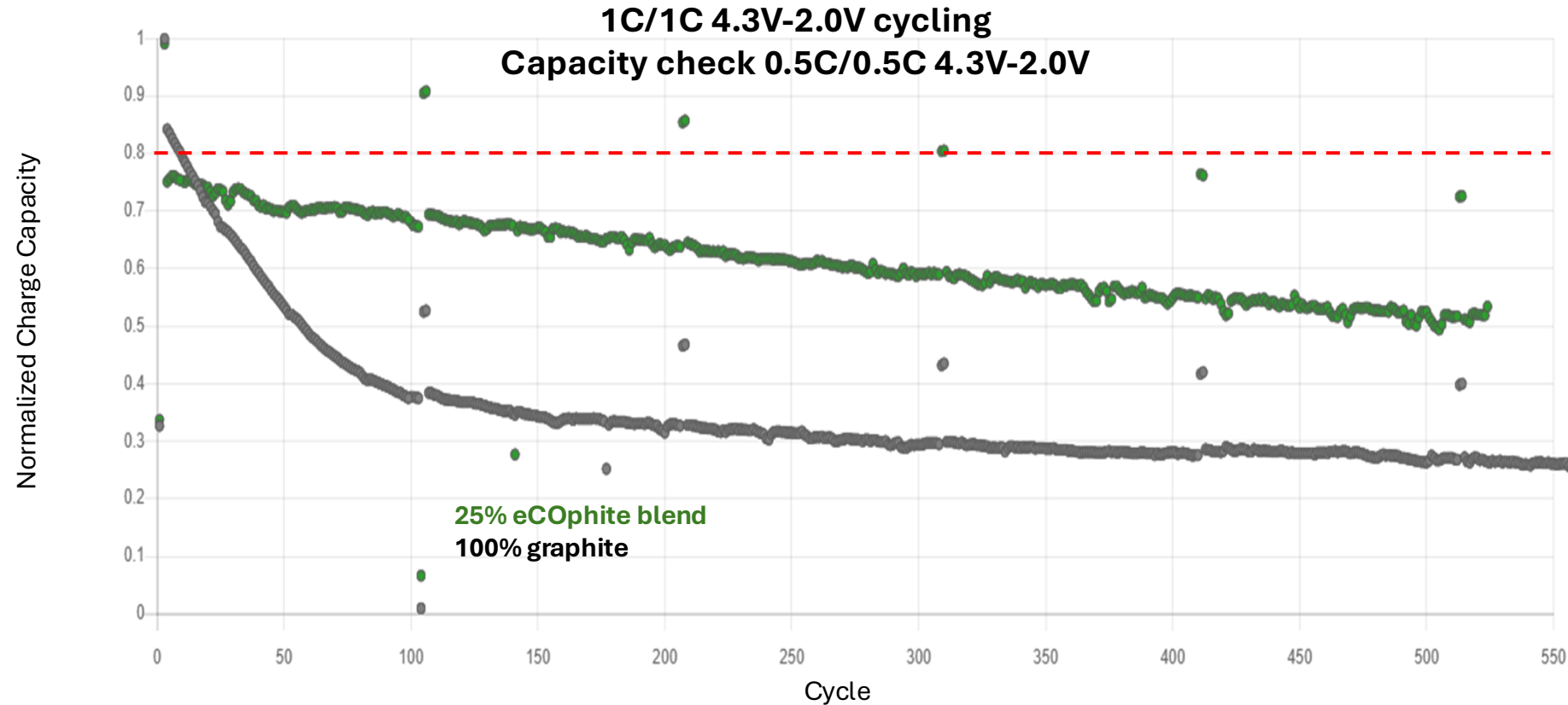


PMAD implication: A stable, detectable voltage inflection means the BMS can perform continuous voltage-based SOC correction without forced deep discharge.

Key Result #2: Fast-Charge Durability

Cycle Durability Under Fast-Charge Stress

NMC cathode | Single-layer pouch cells | Supporting data — LFP validation planned

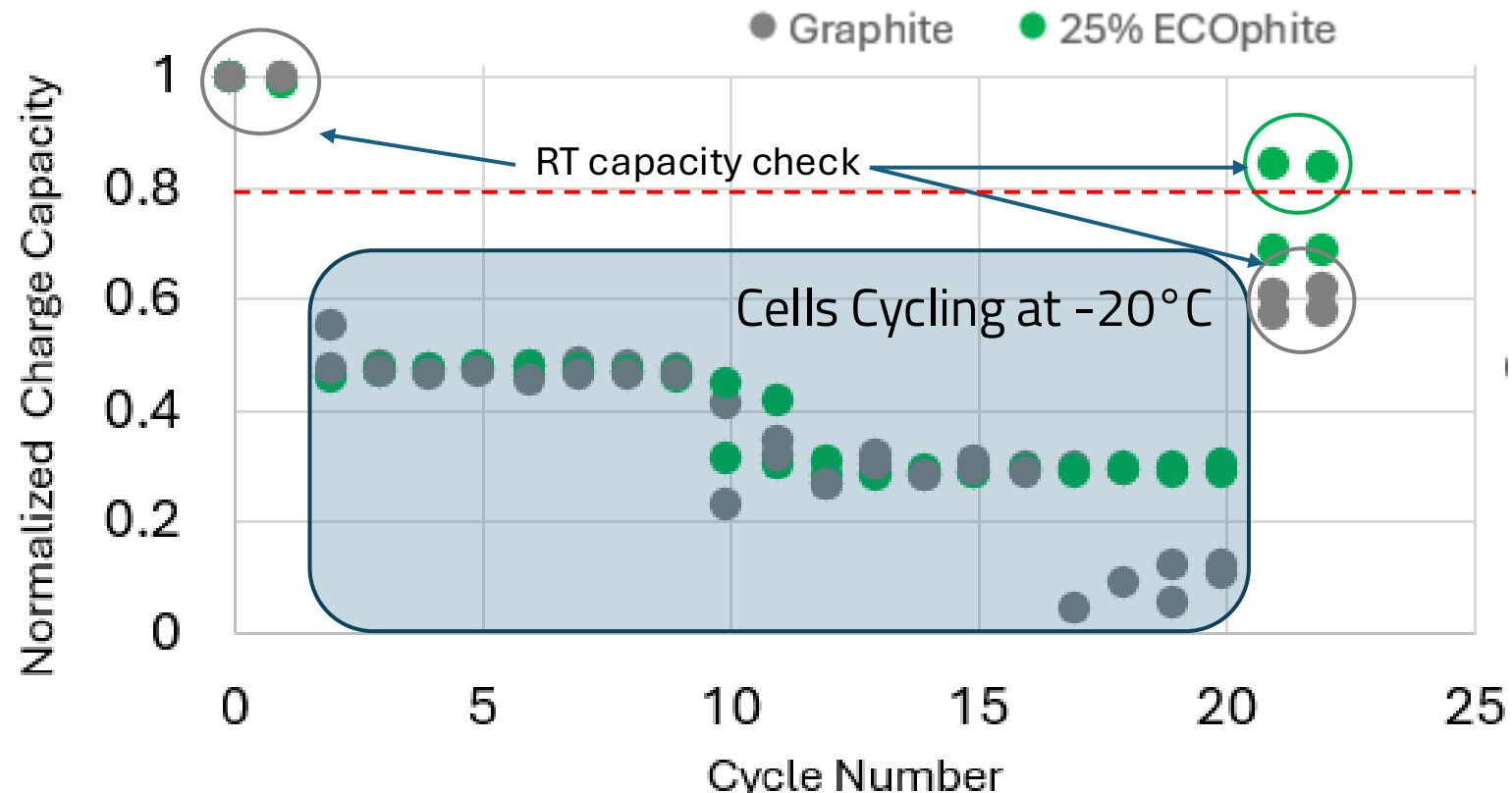


PMAD relevance: A cell that degrades rapidly under these conditions forces conservative charge rate limits.

Key Result #3: Cold-Temperature Performance

Low-Temperature Cycling Performance (-20 °C)

NMC cathode | Single-layer pouch cells | Supporting data — LFP validation planned



Space relevance: Eclipse periods in LEO range from 35 to 90 minutes depending on orbit. Cold-start performance without pre-heat directly affects power budget and thermal control mass.

Data Summary

Test	Cathode	Key Result	Status
OCV profile / SOC voltage inflection	LFP ✓	>0.25 V inflection at ~50% SOC; detectable under load	Confirmed
SOC voltage drift over 500 cycles	LFP ✓	<0.08 V (vs. 0.1–0.2 V for graphite)	Confirmed
EIS / cell resistance	LFP ✓	0.147 Ω (blend) vs. 0.156 Ω (graphite)	Confirmed
Cycle life under 1C stress	NMC*	~10× longer at 80% capacity retention vs. graphite	Supporting
Low-temperature cycling (–20 °C)	NMC*	>80% retention vs. <15% for graphite at 20 cycles	Supporting
SOC-voltage profile at 1C, LFP	LFP — not yet run	—	Planned
SOC-voltage profile at –20 °C, LFP	LFP — not yet run	—	Planned

** NMC data demonstrates material-level advantage over graphite. Cathode chemistry affects absolute values; relative comparison is the relevant signal. LFP validation is the immediate priority.*

System-Level Implications for PMAD Design

If the LFP SOC-voltage advantage holds across rate and temperature — what changes

SOC margin reduction: A stable, detectable voltage inflection enables continuous voltage-based state correction. The 20–30% SOC buffer typically carried to absorb coulomb counting uncertainty becomes compressible.

Balancing architecture: Stable SOC-voltage relationship (demonstrated: <0.08 V drift over 500 cycles, LFP) enables passive balancing during normal operation. Eliminates the periodic deep-discharge BMS reset that currently trades battery life for state accuracy.

Fault detection and isolation: Higher SOC signal fidelity improves the signal-to-noise available to fault detection algorithms. In fault-tolerant architectures with redundant strings, this reduces the probability of a false low-cell-voltage trigger causing unnecessary string dropout.

Pulsed and high-rate loads: Fast-charge durability data (NMC, supporting) suggests eCOphite blend cells tolerate aggressive charge profiles with less capacity fade. Relevant to EP thruster recharge cycles, radar and ISR duty cycling, and eclipse-to-sun charge transients.

Supply chain posture: Domestic lignin-derived pathway. Relevant to programs with domestic content requirements or foreign material restrictions.

Next Steps and an Invitation

What we are doing:

- Running LFP/eCOphite cells through the SOC-voltage characterization, fast-charge (1C) and low-temperature ($-20\text{ }^{\circ}\text{C}$) that is currently missing from our dataset
- Mapping SOC-voltage inflection point as a function of blend ratio (10–100% eCOphite)
- Scaling from single-layer pouch cell to multi-layer format

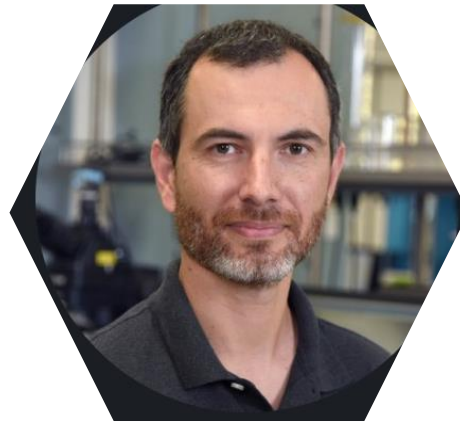
What would be useful from this room:

- Which operating conditions are most constraining for your PMAD architecture?
- Interest in co-designing the LFP test protocol around your specific rate and temperature profiles
- Modeled SOC-dependent PMAD behavior — we can provide the voltage inflection data as model inputs
- Interest in system-level validation once the LFP dataset is complete

Thank you / contact info



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