



Eos DawnOS™

How Eos redefined control—and unlocked the full power of zinc

By Pranesh Rao

One outlier battery cell shouldn't take down a system.

But in most energy storage systems, it could. A single imbalanced cell can radically reduce the output of an entire system. Not because the system lacks energy, but because it lacks the ability to use it.

That's how battery management systems (BMS) have always worked. Control happens at the system or string level. The usable capacity of the entire group is constrained to the capacity of its weakest cell. One underperforming cell in a battery module doesn't just reduce its own output—it drags down the output of every cell in every module it's grouped with.

Accommodating system imbalance is one of the biggest drivers of upsizing requirements. Where some may have accepted it as an inherent limitation of battery energy storage systems, Eos approached it as a problem to solve.

About the author

Mr. Rao is a Senior VP of Storage Systems Engineering at Eos. He is a power systems and IoT / IIoT expert with more than 25 years' experience in conceptualizing, developing, and commercializing embedded, stand-alone and networked products and software for the utility and industrial market.

Over decades of development, dominant battery technologies have influenced assumptions across every layer of energy storage system design—not just the BMS. Inverter settings, communications protocols, and safety procedures are calibrated to lithium’s characteristics.

But the Eos battery technology is built upon its proprietary long-duration zinc-halide chemistry. It’s fundamentally different. Different voltage, different depth of discharge. It’s extraordinarily resilient—able to take significant abuse—and largely self-healing. These aren’t minor configuration differences. They’re characteristics that improve electrochemical performance. They make a different level of control possible. And that demanded a different system.

Eos didn’t start with DawnOS. It got there through rapid, iterative innovation.

Phase 1: Validating the tech with system-level control.

The first-generation Eos Cube, launched in 2018—with its Eos 2.3 battery modules housed inside a standard shipping container—used a proprietary, Eos-built BMS aligned around its zinc chemistry with control at the full system level. It proved viability. But it exposed a well-known problem: any imbalance, anywhere, impacted system output.

Every phase solved a problem. Every problem revealed the next one.

The evolution of battery management at Eos.

	Phase 1 Starting point	Phase 2a	Phase 2b	Phase 3
Problem exposed	Zinc-halide chemistry validated. No controls designed for it.	Any imbalance, anywhere in the system, impacted everything.	Lithium-based controls didn't fit zinc chemistry. Constant adaptation required.	String-level control still took entire strings offline for one module's imbalance.
What Eos built	System-Level Gen 1 Cube · 2.3 Proprietary BMS aligned to zinc chemistry. Proved the technology was viable	String-Level (Off-the-Shelf) Gen 2 Cube · Z3 Adopted an industry-standard lithium-ion BMS. Isolated issues to strings. Faster to market.	String-Level (Purpose-Built) Gen 2 Cube · Z3 Purpose-built string-level BMS designed from the ground up for zinc. Costs down, performance up.	Module-Level Gen 2 Cube & Indensity Core · Z3 · DawnOS DawnOS manages at the module level. <1% energy loss from a module imbalance. Self-healing. Autonomous recovery.

Phase 2: Meeting the industry’s string-level standard.

By 2023, Eos had already shifted to its new Z3 modules, and its second-generation Cube, with a smaller, custom-made steel housing. The advancements doubled energy in half the footprint. With it, Eos moved to string-level control—isolating balancing issues to smaller groups. Initially, this meant adopting an industry-standard BMS originally designed for lithium-ion systems. It was a pragmatic decision to drive speed to market and a meaningful improvement in performance. But it came with a hidden cost.

Those controls weren’t designed for the Eos zinc chemistry. The mismatches were fundamental—lithium operates at approximately 3V per cell, Eos zinc modules operate at 40V; lithium safely cycles within a 20% to 80% depth of discharge window, while zinc can operate from 0% to 100% without impact to system health or longevity. This means the operating voltage window of the system is fundamentally larger for Eos compared to lithium. Eos engineered the BMS around these differences. Every deployment required adaptation. Every update carried added complexity.

It amounted to a continuous engineering tax. And it made one thing clear: adapting someone else's controls would always limit what zinc could do. It ultimately drove Eos back to a purpose-built approach. By 2024, it had designed a string-level BMS from the ground up specifically for its zinc chemistry. Performance was maintained. Costs came down. And it revealed how much more the chemistry could deliver with even finer-grained control.

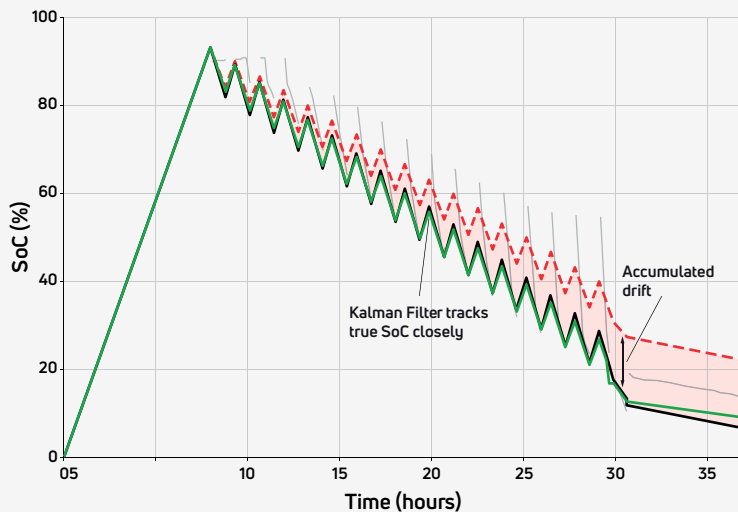
Phase 3: The breakthrough—manage at the module level.

With DawnOS, Eos rebuilt its control system from the ground up—not as a refinement of string-level management, but as a fundamentally different architecture. The system can see and manage modules, in real time. Custom switching boards route around imbalances, keeping the rest of the string in operation. A custom DC/DC converter regulates the varying voltage output of the zinc-halide chemistry—which shifts across its full 0% to 100% discharge range—and delivers stable, consistent voltage to the inverter, balancing many strings connected in parallel. Custom State of Charge and State of Health algorithms, written specifically for the zinc-halide electrochemical behavior—validated to accuracy levels comparable to aerospace-grade systems—track the condition of each module, rather than inferring it from string-level averages.

State of Charge: Why accuracy matters

Single-cycle test showing how Eos's Kalman Filter algorithm tracks true SoC while coulomb counting drifts.

- Eos: Kalman Filter
- Coulomb counting (conventional)
- Voltage
- True SoC (lab measured)



Source: Eos laboratory cycle test data

Conventional method

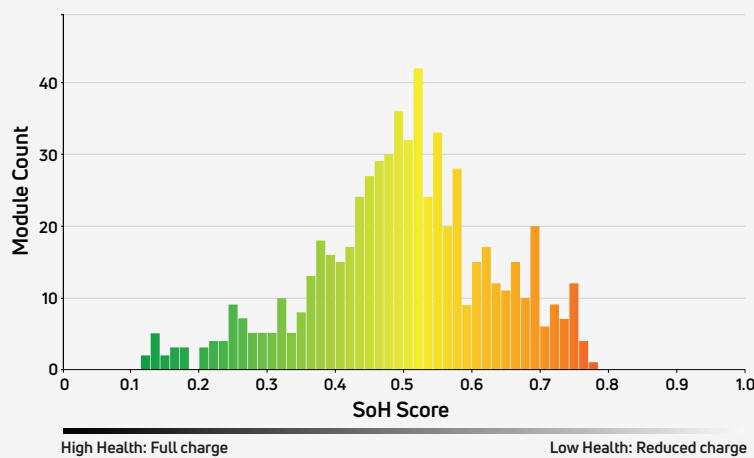
Coulomb counting tracks current in and out—like estimating fuel consumption by counting miles driven. Errors accumulate across cycles. By the end of this test, more energy is reported than actually remains.

Proprietary Eos approach

The Eos Z3 zinc-halide chemistry has a distinctive voltage curve that enables the Kalman Filter to correct continuously using voltage, current, and temperature—tracking true SoC closely across the full cycle with no accumulated drift.

State of Health (SoH)

DawnOS reads each module's health and makes nuanced adjustments to charging levels—like a dimmer switch, not an on/off button.



Source: Eos laboratory cycle test data

What the score measures

How much available capacity a module has—how big the fuel tank is. A lower score means more capacity.

How DawnOS responds

DawnOS sets each module's charge level individually. The healthier the module, the fuller the charge.

Why it matters

Module-level charging keeps every module at optimal output based on its health. The result: more usable energy overall.

That level of real-time, module-level management is only possible because the underlying chemistry is stable enough, flexible enough, and resilient enough to support it. A chemistry that degraded under deep cycling or required narrow voltage control couldn't sustain it. The zinc-halide chemistry can—and does.

What a module-level BMS delivers.

Imbalances no longer spread.

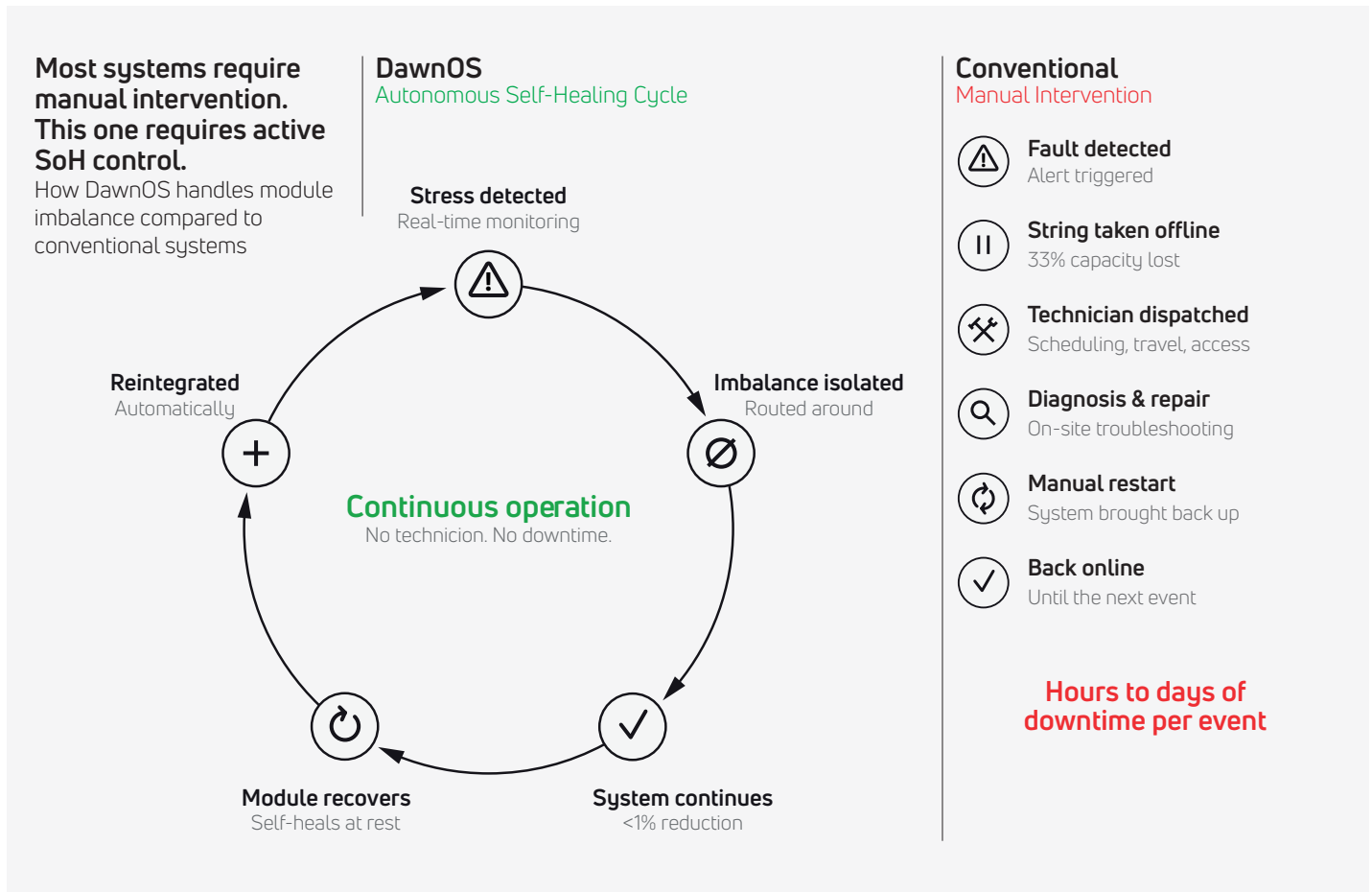
When a module falls out of balance, DawnOS isolates and routes around the issue, and the string continues to deliver energy—with a less than 1% reduction. The imbalance is effectively contained.

Systems heal themselves.

The Eos zinc-halide modules, because of the chemistry's inherent resilience, will more often than not recover on their own based on the Eos state of health algorithm. DawnOS monitors imbalanced modules continuously. When state of charge and health indicators return to operating parameters, the system automatically reintegrates isolated modules—no technician dispatch, no manual restart, no extended downtime. The system can manage its own recovery.

More installed capacity becomes usable capacity.

In conventional architectures, systems are often oversized to account for the energy that is lost due to balancing and string-level constraints. When the system can use virtually all its installed capacity—because it's no longer penalized by its weakest module—the economics shift.



Built into the future. Already in the field.

Fully realized in Eos Indensity™.

The Eos Indensity system is built from Indensity Cores—each an approximately 5-foot by 5-foot unit housing a single string of 112 modules. That physical architecture matters for module-level management. A single string means there is a direct relationship between the DawnOS control layer and every module in the unit. Access is immediate—a technician can reach any individual module without navigating the complexity of a multi-string container. The control system and the physical system are aligned by design, not adapted after the fact.

Available for deployed Cubes with Z3.

The Eos team has developed DawnOS with remarkable speed, creating a capability gap between new and deployed units in the Eos fleet more typically seen over much longer product cycles. Rather than accept that gap, reserving innovation just for new deployments, Eos is closing it. All shipped Cubes with Z3 modules can be brought to full DawnOS performance with relative ease, ensuring existing hardware and controls upgrades work together to unlock trapped energy in systems already in the field.

This is what zinc makes possible.

Energy storage has long been constrained—not just by chemistry, but by control. Systems were designed to manage limitations. DawnOS removes one of the most fundamental of those limits.

It changes how energy storage systems operate—at every level. It shifts the operating model from the string to the module, from system-wide impact to isolated events, from accepted loss to near-complete utilization, and from manual intervention to autonomous recovery.

The outcome is that more energy is available, more systems stay online, and more value is realized from every installed asset.

DawnOS represents a fundamentally different approach for energy storage control—one that is only possible because of the unique characteristics of zinc.