Serviceability

How Eos leveraged zinc to reimagine the energy storage service model

By Dana Brown and Dr. Jeff LaPoint

An energy storage project's success rests on its ability to deliver at nameplate capacity, each and every day, over the long term.

But the reality of conventional battery energy storage system (BESS) chemistry and design requires that owners put costly strategies in place to ensure output meets contracted commitments. Any shortfall in availability or capacity can result in substantial financial losses and/or penalties.

Degradation rates and depth of discharge (DoD) limitations are the primary, well-documented challenges. They are traditionally addressed through initial upsizing and staged augmentation, adding to cost, complexity, and risks over the lifetime of a project.

Servicing downtime is a third, less widely discussed but increasingly important issue. Over the past decade, the size of individual BESS units has grown significantly. Today, a fault in a single unit can take a meaningful portion of an installation's capacity offline. For owners, that means mean time to repair (MTTR) is becoming a mission-critical metric.

With the commercial launch of its zinc-halide chemistry in 2018, in the first-generation Eos Cube, the company reset expectations around battery technology flexibility and longevity. In designing the Eos Indensity Core™, Eos saw an opportunity to apply the same thinking to serviceability—redefining the industry model, with a goal of restoring an installation to full capacity by the next cycle following a Core repair or maintenance event.

The Eos Z3™: Zinc chemistry that maximizes capacity

Eos' foundational battery technology, the zinc-halide chemistry of its Eos Z3 modules, was developed to overcome inherent limitations of conventional BESS systems. Among those limitations are the interrelated challenges of rapid degradation and constrained DoD and their impact on usable system output.

Shallow cycling can maintain battery health for longer, but it reduces usable energy in the near term. Deep cycling increases usable energy but typically accelerates capacity degradation fade. Neither approach provides an efficient path to maintaining nameplate capacity over time. As a result, it has become an accepted industry practice to address capacity loss through some combination of initial upsizing and staged augmentation. Upsizing can add, in general, 15% or more to a project's initial size. While ITC credits lessen the impact, that overbuild may only be enough for the first 5 years. At that point, augmentation is likely required—and will be again at years 10 and 15—when ITC credits may not be available and equipment costs are unknowable. Overall, the practice increases capital expense, current and future footprint requirements, construction and commissioning events, and long-term service costs, and exposes the project to greater inflation and commodity risk.

Eos Z3 technology renders that industry practice obsolete. Its chemistry is designed for deep cycling with exceptionally low degradation, retaining approximately 96% of maximum capacity after 25 years —even when operating at 100% DoD. This creates a fundamentally different capacity proposition. Eos still designs for degradation, but it does so inside the Indensity Core and Cube solutions, at the factory, building in the margin needed to hold to nameplate over time. With Eos storage systems built around the Z3 modules, owners get what they buy: usable energy remains closely aligned with original capacity. There is no need to build around anticipated degradation or add capacity later to compensate for it.

That shifts the serviceability equation, too. When the underlying battery chemistry maintains capacity over decades, the only intervention a system needs is the occasional repair. The question is no longer how to compensate for predictable capacity loss, but how quickly capacity can be restored when a component needs attention.

Figure 1
Usable discharge range: Eos Z3 vs. incumbent chemistries*
Incumbent chemistries are typically cycled within a window of roughly 20% to 80% to slow degradation, which leaves only about 60% of installed capacity usable. Eos Z3 is designed to cycle from 0% to 100%.

* Operating windows are indicative; incumbent ranges vary by chemistry, warranty terms, and application.

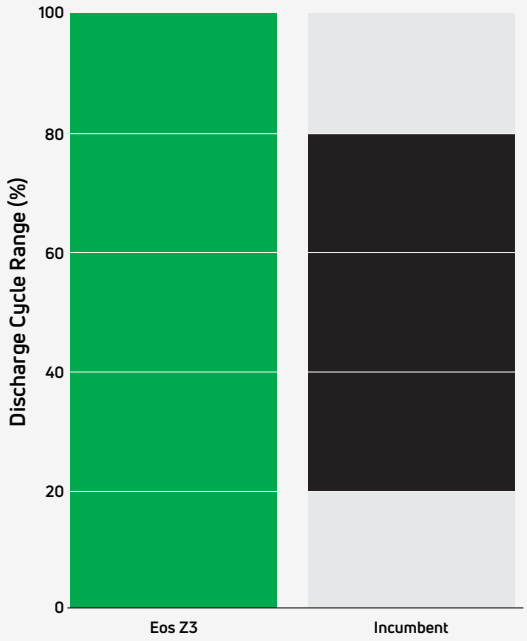
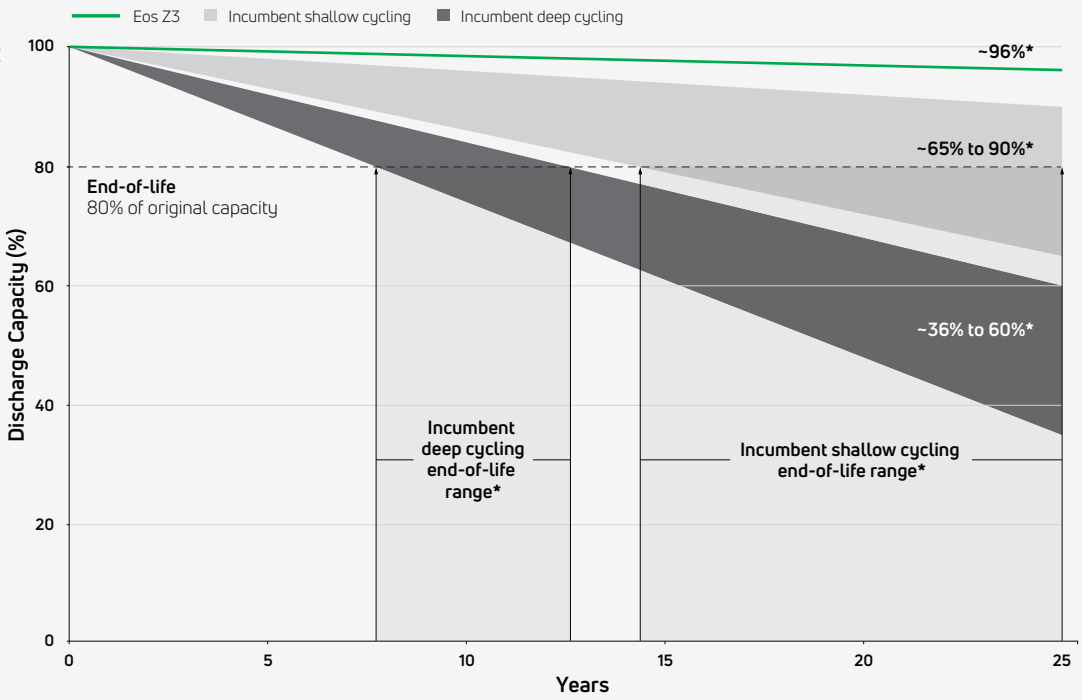


Figure 2

Projected module capacity over 25 years: Eos Z3 vs. incumbent chemistries*

Cycled deeply, incumbent chemistries are projected to reach the 80% end-of-life threshold in roughly 8 to 13 years; cycled shallowly, in as early as 14 years. An Eos Z3 module is projected to retain about 96% of its capacity at year 25 and never reaches the end-of-life line.

* Projections are indicative; actual results depend on cycling profile and contract terms. End-of-life is shown at 80% of original capacity, a common industry threshold.



The rotable pool: An out-of-industry servicing inspiration

Conventional BESS has three onsite systems to maintain

Most conventional BESS units fit the industrial electrical equipment design format. They are large, single-level metal enclosures placed side by side. Within each unit, multiple battery strings are managed by a shared control system. But because most must be held within a narrow temperature band and can go into thermal runaway, the BESS is dependent on two additional systems: the HVAC that cools and heats it and the fire suppression system that protects it. While fire suppression adds annual service requirements, the weak point is the HVAC. Liquid-cooled equipment leaks, compressors fail, and when it goes down, the energy storage system must shut down with it. For technicians who maintain these systems, HVAC is a well-known and persistent source of frustration.

Because of their size and weight, a fault in any of these three systems generally requires that they be serviced on site. That BESS unit's capacity becomes unusable from the moment of failure to the point when a certified technician completes the repair and can bring the system back online. Mean time to repair depends on multiple factors: the time it takes for a technician to get to the site, the speed of their problem-solving, the availability of replacement parts, and the duration of the actual work. As the scale of individual units has grown over the last decade, with each representing a larger fraction of the overall installation, the impact of repair downtime has grown substantially.

Eos Cube has fewer systems, but the same form factor

The nonflammable, water-based zinc-halide chemistry in the Eos Z3 modules eliminated the need for the two ancillary systems. There is no fire suppression, because there is no thermal runaway. And there is no HVAC. The Z3 operates across a wide temperature range, and thermal management is minimized to a set of fans moving ambient air. And the chemistry's inherent resilience enables modules to self-heal from imbalances, a process Eos DawnOS® manages automatically. Together, these capabilities help reduce the risk of downtime on Eos systems.

But the two generations of the Eos Cube largely followed the form factor of conventional BESS, with multiple battery strings inside a large enclosure. So in the event of a fault that required manual intervention, the Cube itself was still subject to the time challenges of onsite servicing and maintenance.

The aviation servicing precedent suggests a new approach

Minimizing downtime for repairs was a key priority as Eos developed Indensity, its next-generation storage system. Guided by the Spatial Intelligence design philosophy, the goal was not simply to create a high-performance, scalable architecture, but one that could be installed and serviced with ease and speed, using commonly available equipment and appropriately trained personnel.

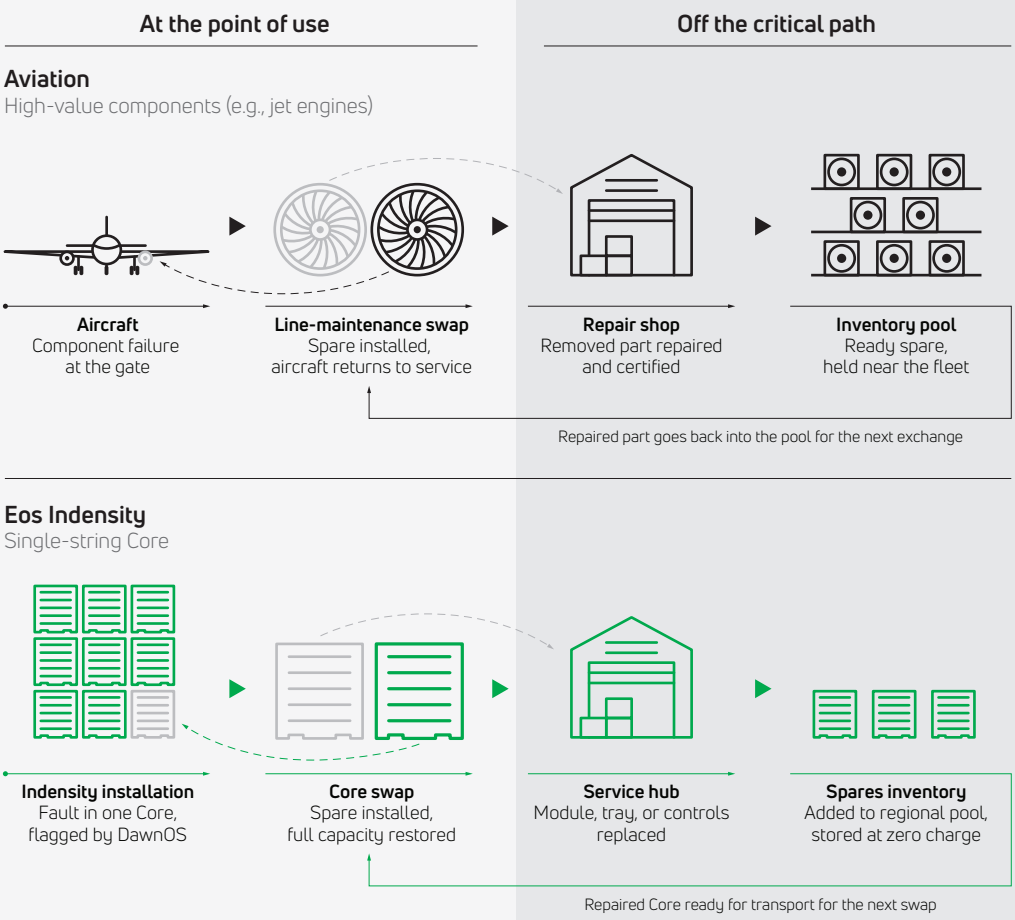
To achieve that, Eos employed a strategy that has delivered for the company since its early years: looking beyond the energy industry for proven ideas that could be applied in new ways. Industrial zinc plating inspired its zinc-halide chemistry. Aviation's rotable-pool model became the foundation for the Indensity servicing approach.

Complex, high-value aircraft components like jet engines, landing gear, and avionics aren't typically serviced on the aircraft. When a component needs attention, it is removed and immediately replaced with a ready-to-use spare, pulled from a local inventory pool. The quick exchange minimizes flight delays, while the removed part is sent to a central facility for maintenance or repair. Once restored and certified, it's returned to the inventory pool, ready for reuse.

Aviation introduced the rotable-pool model; it has since been adopted by the oil & gas, rail, and heavy manufacturing industries and, in the solar industry, for inverters. Eos saw an opportunity to apply the same principle to energy storage and significantly reduce downtime. But to make it work, a new form factor for the individual BESS unit would be required—one that could be handled with relative ease.

Figure 3
The rotable-pool model: How aviation does it, and how Indensity mirrors it.
A unit in need of repair is exchanged for a ready spare at the point of use; repair happens elsewhere, and the unit returns to the pool.

Aviation pioneered the rotable pool for high-value components; it has since been adopted by oil & gas, rail, and heavy manufacturing. Indensity applies the same approach to the battery unit itself: the Core is exchanged at the installation, repaired at a service hub, and returned to a regional inventory pool.



The Indensity Core: Serviceability starts with the form factor

Collapsing the failure domain to the replacement unit

With the Indensity architecture, Eos bucked the industry trend. Rather than build bigger and more complex, the company designed simpler and smaller. That shift is enabling the transformation of Eos' approach to servicing.

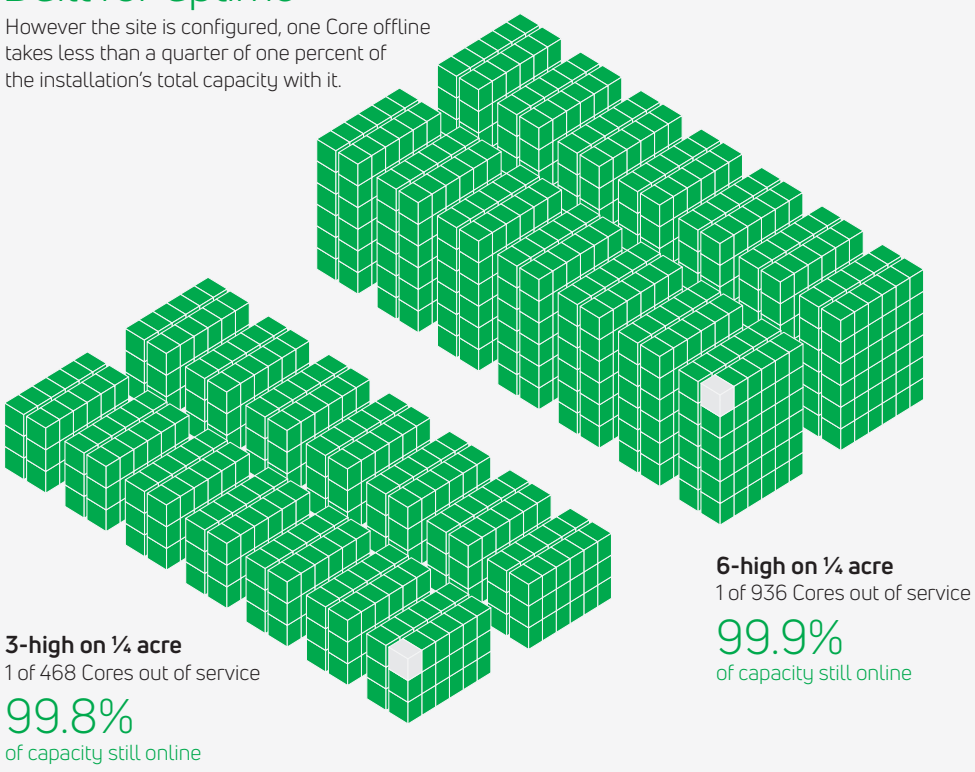
Indensity Cores are self-contained, outdoor-rated units, each housing just a single string of Z3 modules with its own controls, cooling, and communications. The inherent nonflammability of the zinc-halide Z3 chemistry allows Cores to be racked and stacked closely, both horizontally and vertically, and seamlessly aggregated into systems of virtually any size through a proprietary, prefabricated framing infrastructure. The assembly provides structural support, electrical distribution, and signal routing in a single integrated system.

With Indensity, Eos introduced a modular energy storage architecture that delivers greater density, configurability, constructability—and reliability and serviceability.

The Core's single-string format means that each unit represents a much smaller fraction of a system's total capacity. In a six-level Eos Indensity configuration on a quarter-acre lot—an installation large enough to power more than 4,000 homes for a full day—taking a single Core offline would reduce total capacity by just 0.11%; even on an installation half the size, the reduction would be just 0.21%. What was previously a significant capacity impact has become a contained, negligible event. And because of the Core's compact, modular form factor, that lost capacity can be quickly restored, simply by swapping it out for a replacement unit.

Figure 4
Share of installation capacity offline when a single Core is out of service: 3-high vs. 6-high*
Two Indensity installations on the same quarter-acre site, three high and six high. When a single Core is in need of service, about 99.8% of installed capacity stays online at either height.

* Assumes 156 Cores per level on a quarter acre, derived from Eos' published "Standard" density tier of up to 250 MWh per acre at three levels, and 133.34 kWh maximum discharge energy per Core (Eos Indensity Core datasheet). Layout and spacing allowances are illustrative.



The goal: restore capacity by the next cycle

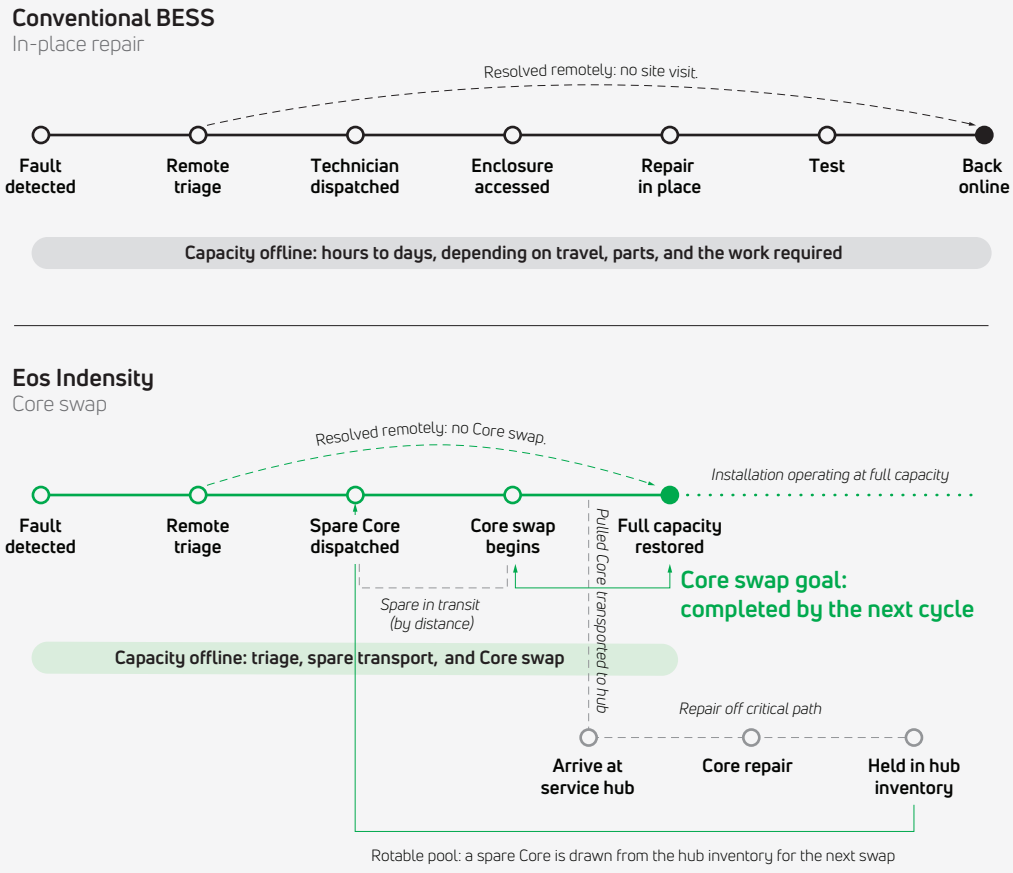
Cores are, by design, compact, plug-and-play units. They measure just 54 by 75 inches in footprint and 68 inches tall and weigh in at approximately 6,800 pounds. Each has a forklift-ready base and push-to-connect connectors. And they can be transported with all Z3 battery modules at zero charge, another benefit of Eos' zinc-halide chemistry. A Core is a serious piece of equipment, but a two-person crew with a telehandler and standard tools can unbolt, unplug, and remove an underperforming Core, then slide a fully functioning unit into its place and reconnect it. The specialized skills, tools, and controlled conditions that actual repair work requires are shifted to the service facility, where it can be performed without taking any part of the installation out of service.

The Core effectively transforms the stationary BESS into a rotable component. And that shift is enabling Eos to set a new serviceability standard for the energy storage industry: any appropriately trained site team should be able to swap out a Core and restore the installation to full capacity by the next cycle.

In this rotable-pool model, the MTTR metric takes on a different meaning. It's no longer mean time to *repair*; it's mean time to *restore*.

Figure 5
Mean time to *repair* vs. mean time to *restore*
Response to a single-unit fault: conventional in-place repair compared with an Indensity Core swap.

Note: Durations are schematic. Both systems support remote diagnosis; the tracks diverge when a site visit is required. Indensity downtime is dependent on spare and crew transport time.

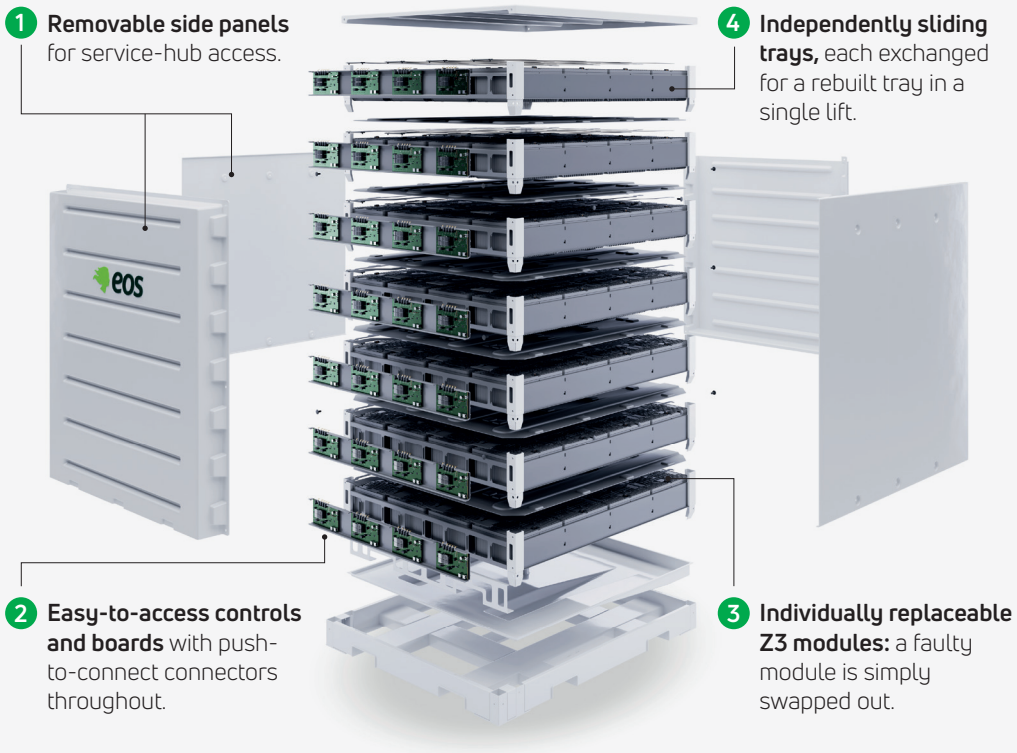


Modular inside as well as out

The Indensity Core's internal design also speeds the technical repair process. The modular approach that defines the overall Indensity architecture is mirrored inside the Core in layers. If a single Z3 module is at fault, it is replaced. If a full tray needs attention, that tray comes out in one lift and a rebuilt tray goes in, so the Core is ready to return to service while the original tray undergoes repair. Controls and boards are just as accessible, with push-to-connect connectors throughout. A Core that has been pulled from an installation is a Core that will be restored—at whatever level the fault requires—and returned to service at any installation.

That is a clear departure from the conventional model, in which cells removed during repair or augmentation are hazardous waste, to be packaged, transported, and disposed of accordingly. Every Core is built to be repaired and reused, again and again, over the life of a project and beyond.

Figure 6
Indensity Core: serviceable at every level.
The modular design of the Indensity installation is mirrored inside each Core. Once a Core is removed, its modular interior makes service straightforward at every level.



Swap the whole Core at the installation, then restore it at a service hub, ready for future use.

Building a data-driven, hub-and-spoke servicing infrastructure

The Indensity architecture provides the hardware foundation to support a rotable-pool service model. The Eos DawnOS controls and software platform, together with a growing Field Operations organization, complete the picture.

24/7 monitoring and remote-first response

DawnOS enables highly accurate State of Charge and State of Health monitoring not just at the Indensity installation or Indensity Core unit levels, but down to the individual Z3 module. Module-level imbalances can be isolated and routed around and, because of the inherent resilience of Eos' zinc-halide chemistry, will often recover on their own. Faults in a Z3 or other Core component that cannot self-heal are immediately identified by DawnOS and mapped to the specific Core that houses it.

Eos monitors its systems around the clock through a dedicated technical service center and DawnOS, and a project's own site team can do the same. When DawnOS flags a fault, the response starts remotely. Engineers investigate first. Most issues, whether they need a reset, a configuration change, or a module rebalancing, are resolved without anyone setting foot on site. When hands-on intervention is required, the team already knows what it is likely to find and what parts are needed. With a Cube, that means a technician on site, opening the enclosure and working on the strings in place. With Indensity, the response changes: the site team, or Eos, is alerted that a Core swap-out should be initiated, and the repair itself happens off the installation.

Who performs a Core swap depends on the owner. Utilities and independent power producers (IPPs) that operate fleets of storage assets typically have their own operations teams, and a Core swap is well within their capabilities. Commercial and industrial owners who have a facilities team but no high-voltage specialists can contract with Eos under a long-term service agreement, and Eos technicians handle it end to end.

Regional service and spares hubs

Meeting the next-cycle goal for removal and replacement depends on having a functioning Core ready to install—and a team ready to repair units so they can be returned to the spares pool. Initially, Core restoration activities and spares warehousing will be based in Pittsburgh, but Eos is building toward a regional network of service and spares hubs, close to concentrations of customer sites within the nation's major grid markets. The Field Operations team is already organized into East, Central, and West regions, with roughly two dozen technicians today and a plan to grow that number several-fold to support the hubs as Indensity deploys. Each hub will stock spare Cores, trays, and Z3 modules, and the fuses, boards, and other components the team will require for repairs.

Outdoor-rated, with nonflammable Z3 modules that can be stored at zero charge with no temperature control or trickle charging, for an indefinite amount of time, spare Cores can be stored efficiently, anywhere space allows at each hub, and still be ready for installation when needed. In fact, one Eos customer has proved the resilience required for the spares inventory model on their own site, maintaining an idle Cube in the field for more than 5 years, with no loss in performance capacity.

When a Core swap-out is initiated, Field Operations team members will simply bring a spare unit to the customer site from the closest regional hub. At the same time, the unit in need of repair will be collected and transported back to the service and spares hub. Cores will be restored there and, once certified for use, will be added back to the hub's inventory pool, ready for the next swap-out.

One principle has been fixed from the start: this new service infrastructure will run separately from manufacturing. Repair facilities and production lines have different jobs and different response times, and neither should slow the other. Field Operations will have its own parts supply and its own capacity to restore Cores, so that servicing the installed fleet never competes with building the next one.

5+ years

idle in the field and still fully operational, based on a customer's field experience

Zinc chemistry doesn't degrade while sitting idle, so Eos batteries can stay in reserve for years and still perform when called on.

A model of American ingenuity

Eos is introducing not just the first continuous rotable-pool servicing model in the energy storage industry, but one that, like Eos' R&D and manufacturing, is dependent on and driven by skilled U.S. team members and a domestic supply chain. Cores move from installation to regional hub and then back into service, across the fleet. The rotation continues throughout the life of all projects, minimizing downtime of installed capacity while shifting complex repair work away from the field. At each step, Eos' network of service and spares hubs, and the regional parts and logistics partners that support them, will add to economic activity and job growth across the nation.

And what's being built today is just the start: Eos is already imagining future enhancements to the approach. In the architecture of an Indensity Core, its single string is composed of a series of four Z3 modules, or parallel battery units (PBUs), each connected and controlled in tandem. Redefining the rotable replacement unit from the Core down to the PBU would collapse both the failure domain and the required restoration interventions even further.

This is what zinc makes possible.

Owners of conventional energy storage projects have had to accept costly workarounds to ensure their installations deliver on their primary purpose: reliably providing a promised amount of energy or power at every moment over the full life of an offtake contract. With its Indensity architecture and rotable-pool servicing model, Eos set out to render that status quo obsolete.

That goal is made possible by the proprietary zinc-halide chemistry of its Z3 battery modules. Their low degradation rate, deep depth of discharge, and self-healing capacity keep usable energy close to nameplate over the life of a project. Their inherent nonflammability enables the modular, plug-and-play architecture of Indensity and makes Core swap-out and repair simpler, safer, and faster.

The system delivers what was bought, without oversizing or augmentation. When something needs attention, the installation is back to full capacity by the next cycle, not the next week. And the cost of keeping it there is known from the start. Predictable output, predictable costs, and a repair that happens off site while a replacement Core keeps the system running. That's what serviceability means at Eos.

Forward-Looking Statements and Performance Expectations. Certain statements in this paper describe expected or anticipated future performance, development targets, design objectives, serviceability objectives, field-service processes, mean-time-to-restore expectations, next-cycle restoration goals, rotable-pool concepts, regional service and spares hub plans, spare Core availability, technician staffing and growth expectations, transport and logistics assumptions, customer-site response models, 25-year capacity-retention or degradation projections, expected warranty or service-contract performance, anticipated service-cost predictability, potential future replacement approaches at the parallel battery unit or other component level, and other anticipated capabilities of Eos Indensity and Eos Z3 systems. Such statements are based on current expectations, assumptions, engineering analyses, test data, representative configurations, service-model planning, customer and site assumptions, availability of trained personnel, availability and location of spare Cores and parts, hub proximity, site access, transport times, operating conditions, customer requirements, applicable warranty and long-term service agreement terms, financing and capital availability, and other currently available information, and are subject to risks, uncertainties, and change. Actual results, performance metrics, capacity retention, system availability, service response times, restoration timing, repair duration, hub deployment, technician availability, spare availability, service costs, warranty or service-contract outcomes, operating characteristics, customer use cases, project economics, and future product or component-level serviceability enhancements may differ materially based on engineering development, testing, customer requirements, project design, site conditions, permitting requirements, local code requirements, setbacks, access requirements, regulatory approvals, construction conditions, operating environments, supply-chain conditions, availability of capital, financing-document requirements, customer operating profiles, warranty claim experience, equipment performance, logistics constraints, availability of replacement components, labor availability, safety requirements, and the other risks and uncertainties described in Eos's filings with the Securities and Exchange Commission. Except as required by law, Eos undertakes no obligation to update these forward-looking statements or performance expectations after the date of this paper.

About the series

This paper is part of Principle to Proven, the Inside Eos Innovation Series exploring how Eos' zinc-halide chemistry reshapes every layer of energy storage. The next paper examines manufacturing: how Eos is building a high-performing production capability, right here in the U.S.

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