Nick Clark · Published June 30, 2026 · PDF

Supply-Chain-Resilient Field Power: An Abundant-Material Energy Cell for Defense and Expeditionary Operations

Expeditionary and defense power depends on battery chemistries whose critical inputs (lithium, cobalt, nickel, graphite) sit on contested, single-source supply chains, and whose stored cells slowly lose charge in depot and fail violently when punctured in the field. This application describes how those problems are addressed by a cell built on the Hydrogen-Aluminum Energy Cell, disclosed in U.S. Provisional Application No. 64/055,649, whose disclosed architecture stores energy in surface hydrogen-aluminum bonds within a biomass-derived boron-doped carbon gel using abundant, broadly sourceable materials. It draws on the provisional's bulk-equipotential charge retention, hot/cold proton asymmetry, mechanochemical self-healing, and intrinsic thermal-stall and mechanical-breach safety behaviors.

What This Application Specifies

This application describes how the energy cell disclosed in U.S. Provisional Application No. 64/055,649 (the Hydrogen-Aluminum Energy Cell) would serve defense and expeditionary field power, where supply-chain resilience and abundant-material sourcing govern whether a power source can be fielded at scale. The home invention is, as disclosed, a sealed electrochemical cell that stores energy as electron-stabilized hydrogen-metal surface bonds on metal nanoflakes dispersed through a dual-domain proton-conducting carbon gel, with no internal separator and no internal anode/cathode pair in the conventional sense.

The materials science underlying the cell is established and pre-existing: hydrogen chemisorption on aluminum and other metal surfaces, proton conduction in sulfonated carbon gels, electrochemical exfoliation of metal nanoflakes, and mechanochemical deposition at strained sites are all characterized in the prior literature. What the provisional discloses, and what this application maps onto the defense domain, is the combination and architecture: bulk-equipotential charge retention, electron-mediated bond stability, hot-proton charging versus cold-proton discharge through structurally distinct paths, hydrophobic gating, hydrogen-gated flake expansion and locking, mechanochemical self-healing of fatigue damage, and boron-doping precision multiplication, composed into what is effectively a new energy-cell category.

For the field-power domain, three architectural properties carry the application. First, sourcing: the disclosed active materials are aluminum nanoflakes (with magnesium, zinc, and iron recited as alternative active metals), a boron-doped turbostratic graphene gel derived from low-cost biomass feedstock (cotton waste, wood pulp, agricultural residues), and hydrogen. As disclosed, the architecture does not depend on cobalt, on nickel-rich layered oxide cathodes, or on graphite intercalation anodes. Second, at-rest stability: bulk-equipotential charge retention removes the internal driving force for self-discharge, so a stored cell holds charge without the calendar fade that depots plan around. Third, abuse behavior: the disclosed cell has an intrinsic, reversible thermal-stall interlock and a non-flammable mechanical-breach response, both distinct from conventional lithium-ion thermal runaway.

Why It Matters

Defense logistics treat the battery as a consumable that must be sourced, stockpiled, transported forward, and disposed of, often across a contested supply chain. The dominant rechargeable chemistries concentrate their critical inputs (battery-grade lithium, cobalt, natural and synthetic graphite, class-1 nickel) in a small number of mining and refining jurisdictions. A power source whose performance is acceptable but whose inputs cannot be sourced under wartime or sanctions conditions is, from a force-planning standpoint, fragile. Abundant-material sourcing is therefore not a cost footnote; it is a readiness question.

The at-rest problem compounds it. Conventional rechargeable chemistries lose roughly one to five percent of capacity per year in storage from spontaneous internal degradation, independent of whether they are ever used. For a stockpile of batteries held against future contingency, that calendar fade is a standing tax: cells must be rotated, recharged, and eventually discarded before they are ever fielded. The provisional discloses, at the architecture level, a charge-retention principle in which a cell at rest generates no new strain, the gel does not internally degrade in the absence of bias, and there is no internal potential gradient to drive self-discharge. Section 7.5 of the provisional recites calendar stability at rest as decoupled from the use-driven processes that limit cycle life, and the cell's longest-timescale degradation mode (aluminum cation migration into the boron-doped framework) is estimated in the disclosure as a half-life on the order of decades, not years. Treat those as disclosed mechanism and order-of-magnitude estimates, not measured shelf-life figures.

Finally, the field is an abuse environment. A dismounted radio battery, a vehicle pack, or a forward power module will be dropped, crushed, shot, and exposed to heat. The disclosed cell's safety behavior is structural rather than bolted-on, which matters where a single flammable failure can compromise a position.

How It Composes With the Domain

The mapping from the disclosed architecture to expeditionary power runs through four of the provisional's mechanisms.

Abundant-material sourcing composes directly with the bill of materials. The gel is produced, as disclosed in Chapter 1A, from biomass feedstock that is geographically unconstrained, doped with boron precursors such as boric acid or borax, and reduced to turbostratic graphene. The active metal is aluminum in the preferred embodiment, selected in the disclosure for low cost, low atomic mass, and abundance, with magnesium, zinc, iron, and titanium recited as alternatives. For a defense supply chain, this enumerates a range of substitution options: the same cell architecture admits multiple active metals and multiple biomass carbon sources, so a manufacturer is not locked to a single contested input.

Depot and pre-position storage compose with bulk-equipotential charge retention (Chapter 2). Because the charged cell holds every nanoflake at the same electrochemical potential with no internal terminus for electron flow, the cell retains charge by internal saturation rather than by an insulating separator. The practical reading for stockpiling is that a cell can be sealed at a known state of charge and held without the rotation cadence that calendar-fading chemistries force, subject to empirical confirmation of the disclosed mechanism.

Cold-environment and high-tempo operation compose with the hot/cold proton asymmetry (Chapters 3 and 4). Charging proceeds by hot protons under applied bias crossing a hydrophobic gate to bond at the flake surface; discharge releases protons directly into the hydrophilic channel network without recrossing that gate. The asymmetric dual paths mean the storage state is kinetically protected against thermalized self-charge and self-discharge, the property the disclosure ties to idle stability. For field use this implies a cell whose stored state is governed by applied bias and load, not by ambient drift.

Field survivability composes with the disclosed safety behaviors. The reversible thermal-stall interlock (Section 9.9) raises internal resistance as temperature climbs into the roughly 60 to 90 degree Celsius range and above, stalling discharge and then restoring capacity on cooling, in deliberate contrast to irreversible runaway. The mechanical-breach response (Section 9.12) drives a punctured cell's stored energy into non-flammable products (water vapor, aluminum oxide, carbon dioxide) rather than venting flammable organic-solvent vapor. Both are enabling implementations of mechanisms the provisional recites, not new safety claims invented for this domain.

What This Enables

As an enabling implementation of the disclosed architecture, this application supports a range of defense and expeditionary embodiments:

- **Dismounted soldier power.** Small-format cells (the disclosure admits thinner aluminum equipotential layers, 50 micrometers up, for portable formats) for radios, optics, counter-UAS handhelds, and wearable power, sourced from materials that do not depend on a single critical-mineral chain.
- **Pre-positioned and war-reserve stockpiles.** Modules sealed at a known state of charge and held against contingency, where the disclosed at-rest charge retention reduces the rotation and recharge burden of a calendar-fading stockpile.
- **Forward operating base and microgrid storage.** Larger stationary cells (thicker enclosure layers, up to several millimeters, are recited for stationary formats) stacked in series to reach the required bus voltage, since the provisional caps single-cell voltage near 2.5 to 3.0 volts and accommodates higher system voltages through series stacking with per-cell monitoring.
- **Vehicle and platform packs.** Multi-cell packs where the intrinsic thermal-stall and non-flammable breach behavior reduce the cascading-fire risk that drives armored-vehicle battery-bay design.

- **Cold-region and high-altitude operation.** Embodiments exploiting the disclosed bias-governed kinetics, with the recognition that hot/cold proton kinetics and the photo-assisted and isotope variants in the provisional are temperature- and condition-dependent and would require characterization.
- **Specialized and sensor power.** The disclosure recites operation with deuterium and tritium isotopologues; the tritium variant's low-level emission limits it to niche applications and is noted here only as a disclosed variant, not a recommended field configuration.

Across these embodiments, the substitutable active metals and biomass carbon sources let a program tailor sourcing to whatever inputs are securable, which is the supply-chain-resilience property the domain demands.

Boundary Conditions

This application describes an architecture disclosed in a provisional filing. The cell has not, on the record of the disclosure, been built, validated, benchmarked, or qualified to any defense standard. No energy-density, cycle-life, calendar-life, efficiency, or cost figure should be read from this application as a measured result; the provisional's own numerical ranges are presented as disclosed estimates and projections to be determined empirically, and several mechanisms (use-positive aging, the decades-scale degradation half-life, the photo-assisted variant) are expressly recited as projected or to be confirmed by prototype testing.

The underlying materials science is prior art. Hydrogen chemisorption on metals, proton-conducting carbon gels, boron doping of graphene, nanoflake exfoliation, and mechanochemical healing are established; the novelty asserted in the provisional lies in their combination, configuration, and the resulting cell category, not in any newly discovered material, bond, or physical effect. Nothing here should be read as claiming a basic-science breakthrough.

Domain qualification is external and unmet. Military power sources are governed by safety, environmental, electromagnetic, transport, and interface standards, and by formal qualification testing. None of that has been performed here. The abundant-material and safety properties described are enabling consequences of the disclosed architecture; whether a fielded cell meets a given program's qualification thresholds is an empirical and regulatory question outside this disclosure. End-of-life handling, per the provisional, is by centralized remanufacturing rather than in-field gel service, which has its own logistics implications a program would need to plan for.

Disclosure Scope

The technology described in this application is disclosed in U.S. Provisional Application No. 64/055,649 (the Hydrogen-Aluminum Energy Cell). This application addresses how that disclosed architecture would serve defense and expeditionary field power; the defense logistics framing, supply-chain and critical-mineral context, qualification and regulatory references, and deployment scenarios are external domain context provided for illustration and are not part of the patent disclosure or its claims. Statements about what the cell does (bulk-equipotential charge retention, hot/cold proton asymmetry, mechanochemical self-healing, intrinsic thermal-stall and mechanical-breach behavior, abundant-material sourcing) trace to the provisional's disclosure of mechanism and architecture; performance, qualification status, and fielded readiness are undisclosed and are not represented here. The underlying materials science is pre-existing prior art, and the novelty rests in the disclosed combination, configuration, and resulting cell category.

Hydrogen-Aluminum Energy Cell (/h-al-battery) All 40 steps → (/inventive-steps)

Sealed electrochemical cell storing energy as reversible covalent hydrogen bonds on carbon electrodes.

Provisional application

PRIMARY TECHNICAL DISCLOSURE

- A Hydrogen-Aluminum Surface-Bond Storage Cell with Bulk-Equipotential Charge Retention (/articles/a-hydrogen-aluminum-surface-bond-storage-cell-with-bulk-equipotential-charge-retention)

SECONDARY TECHNICAL

- Charge Retention by Bulk-Equipotential Saturation Without an Internal Separator (/articles/h-al-battery/bulk-equipotential-charge-retention)
- Storing Energy as Electron-Stabilized Metal-Hydrogen Surface Bonds Formed by Proton-Coupled Electron Transfer (/articles/h-al-battery/hydrogen-metal-surface-bond-storage)
- Electron-Mediated Bond Stability: The Kinetically Trapped Idle State Behind Indefinite Calendar Life (/articles/h-al-battery/electron-mediated-bond-stability)
- Hot-Proton Charging Versus Cold-Proton Discharge: The Bias-Gated Asymmetry That Blocks Self-Charge and Self-Discharge (/articles/h-al-battery/hot-cold-proton-asymmetry)
- Asymmetric Dual-Domain Proton Paths: Separate Ingress and Egress Routes in a Hydrogen-Aluminum Storage Gel (/articles/h-al-battery/asymmetric-dual-domain-paths)
- Hydrophobic Gating: Rejecting Neutral and Molecular Hydrogen While Admitting Only Biased Protons (/articles/h-al-battery/hydrophobic-gating)
- The Storage Gel as a Polarized Electrochemical Switch: Coherent Alignment, Equipotential Locking, and Load-Proportional Discharge (/articles/h-al-battery/gel-polarized-switch)
- Flake-Flake Electrostatic Isolation: DLVO Repulsion as a Self-Discharge Barrier in a Separator-Free Hydrogen-Aluminum Cell (/articles/h-al-battery/flake-electrostatic-isolation)
- Dynamic Flake Expansion: Carbon-Intercalation Wedging to Expose Buried Metal Surface Under Bias (/articles/h-al-battery/dynamic-flake-expansion)
- Hydrogen-Locked Expanded State: Surface-Energy Inversion as a Positive-Feedback Capacity Mechanism (/articles/h-al-battery/hydrogen-locked-expanded-state)
- Secondary Carbon-Hydrogen Storage on Transmuted Intercalated Carbon (/articles/h-al-battery/secondary-carbon-hydrogen-storage)
- Mechanochemical Strain Self-Healing and Use-Positive Aging in a Bulk-Equipotential Hydrogen-Aluminum Cell (/articles/h-al-battery/mechanochemical-self-healing)
- Boron Doping of the Carbon Framework as a Multi-Function Precision Multiplier (/articles/h-al-battery/boron-doping-precision-multiplier)
- The Floating Aluminum Equipotential Extension Layer: A Multifunctional Inner Case for the Bulk-Equipotential Cell (/articles/h-al-battery/aluminum-equipotential-extension-layer)

APPLICATIONS · GENERAL

- Grid-Scale and Renewable-Firming Storage with the Hydrogen-Aluminum Energy Cell (/articles/h-al-battery/grid-scale-storage)
- Building-Integrated and Behind-the-Meter Storage: Putting Energy Cells Inside the Structure With the Hydrogen-Aluminum Energy Cell (/articles/h-al-battery/building-integrated-storage)
- Stationary Backup and UPS Reserve Power for Data Centers, Hospitals, and Telecom (/articles/h-al-battery/backup-and-ups)
- Storage for Microgrids, Islands, and Off-Grid Sites: A Stationary Cell Built From Abundant Materials (/articles/h-al-battery/microgrid-and-off-grid)
- Electric Mobility and Transport: How a Hydrogen-Aluminum Cell Architecture Maps to Vehicle Constraints, and Where It Does Not (/articles/h-al-battery/ev-and-mobility)
- Marine and Rail Energy Storage: A Bulk-Equipotential Hydrogen-Aluminum Cell for Mass-Tolerant Heavy Transport (/articles/h-al-battery/marine-and-rail)
- **Supply-Chain-Resilient Field Power: An Abundant-Material Energy Cell for Defense and Expeditionary Operations (/articles/h-al-battery/defense-and-field-power)**
- Fast-Response Frequency Regulation and Power Quality Without a Separate Power Bank (/articles/h-al-battery/frequency-regulation-power-quality)

APPLICATIONS · SPECIFIC

- CATL (Contemporary Amperex Technology Co. Limited) alternative: a hydrogen-aluminum cell architecture vs LFP, NMC, and sodium-ion at the chemistry-category and materials-sourcing level (/articles/h-al-battery/catl)
- LG Energy Solution NCM/NCMA lithium-ion cells vs the Hydrogen-Aluminum Energy Cell: an architectural comparison (/articles/h-al-battery/lg-energy-solution)
- Form Energy iron-air multi-day grid storage vs a sealed bulk-equipotential hydrogen-aluminum cell: an architectural comparison (/articles/h-al-battery/form-energy)
- ESS Inc, maker of long-duration iron flow batteries vs a sealed solid-state cell: comparing the flow architecture to the Hydrogen-Aluminum Energy Cell (/articles/h-al-battery/ess-inc)
- Ambri liquid-metal battery vs a solid-state hydrogen-aluminum energy cell: architectural comparison for stationary storage (/articles/h-al-battery/ambri)
- QuantumScape solid-state lithium-metal battery vs a bulk-equipotential hydrogen-aluminum surface-bond cell: an architecture comparison (/articles/h-al-battery/quantumscape)
- Natron Energy sodium-ion (Prussian-blue-electrode) batteries vs a hydrogen-aluminum surface-bond cell: an abundant-materials architecture comparison (/articles/h-al-battery/natron-energy)
- Eos Energy Enterprises Znyth zinc long-duration storage vs a hydrogen-aluminum equipotential cell: an abundant-materials architecture comparison (/articles/h-al-battery/eos-energy)

- EnerVenue nickel-hydrogen stationary cells vs a hydrogen-aluminum equipotential cell: two ways to store hydrogen in a battery (/articles/h-al-battery/enervenue)
- Skeleton Technologies supercapacitors vs the Hydrogen-Aluminum Energy Cell: pairing high power with bulk energy storage (/articles/h-al-battery/skeleton-technologies)

Hydrogen-Aluminum Energy Cell overview → (/h-al-battery)