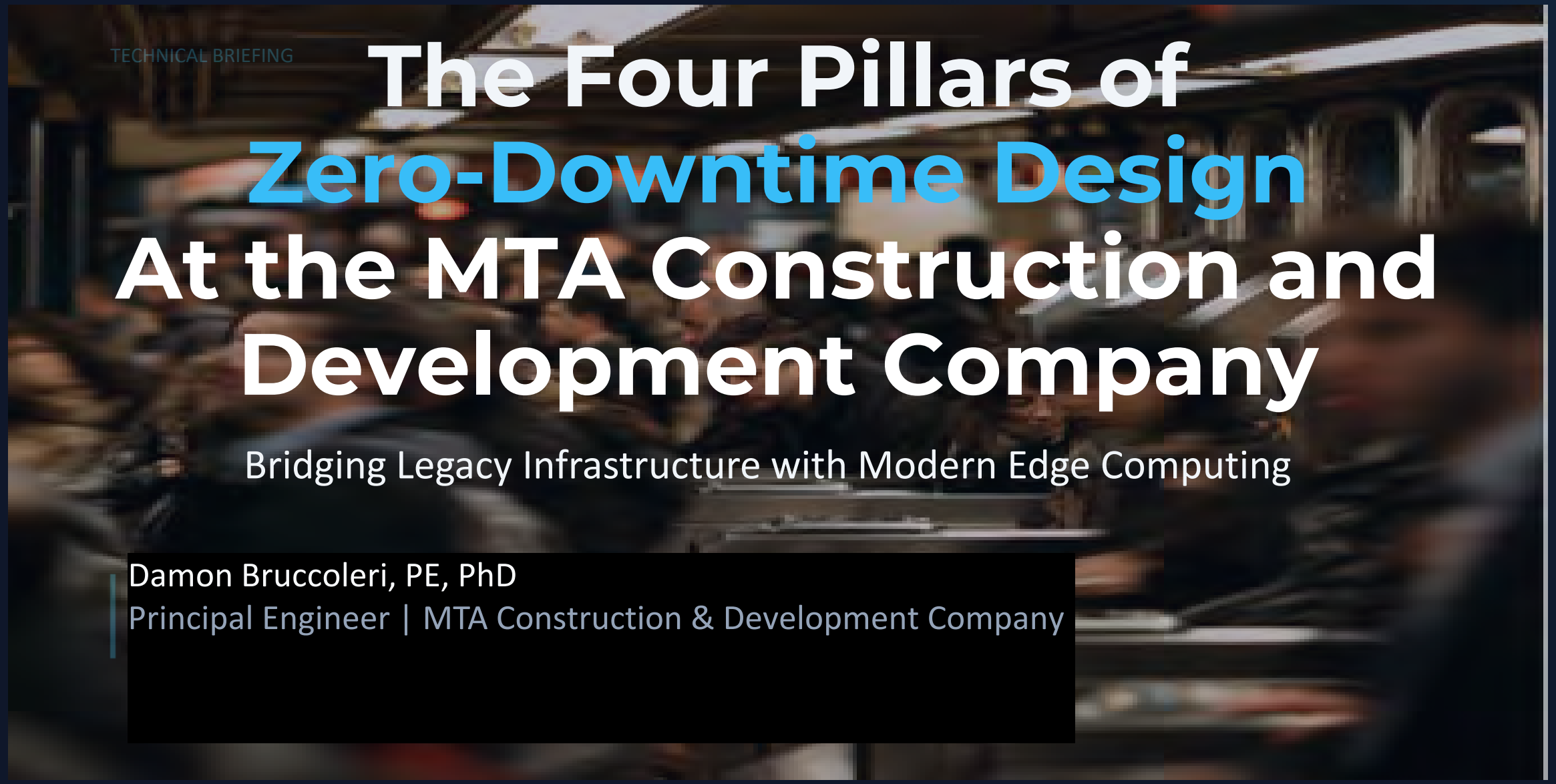


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The Physical Footprint

Establishing Scale

Managing the largest subterranean transit network demands keeping a massive, decentralized physical envelope operational 24/7/365.

472 Active Stations

665 Miles of Mainline Track

225 Traction Power Substations

280 Active Pump Rooms | 209 Fan Plants

24 Rail Yards

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NYC Subway Life
NYC View From Above
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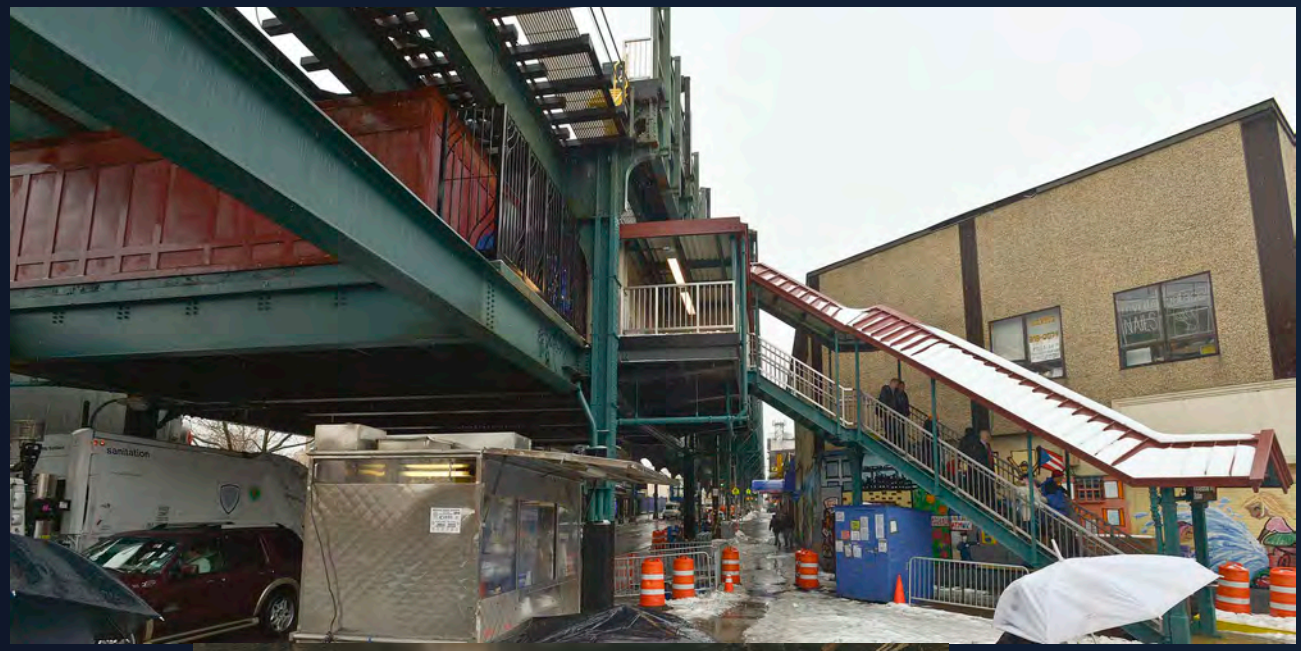
The Hostile Envelope

Physical Constraints

This is the engineering reality: routing pristine, high-speed networks through century-old concrete.

Expanding traditional conduit sizes or boring new pathways is often structurally impossible or prohibitively dangerous while trains are active.

You cannot simply pull new lines on demand. The architecture must work within the concrete skeleton that exists.





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The Nerve Center: Stakes & Monitoring

- **Centralized Oversight:** The Rail Control Center (RCC) and Power Control Center (PCC) govern this massive footprint via centralized SCADA.
- **The Core Vulnerability:** While monitoring is centralized, relying purely on central-to-edge "pinging" for operations creates critical latency risks.
- **Architectural Shift:** If the central brain loses connection to a station, that station must possess the localized intelligence to continue functioning.

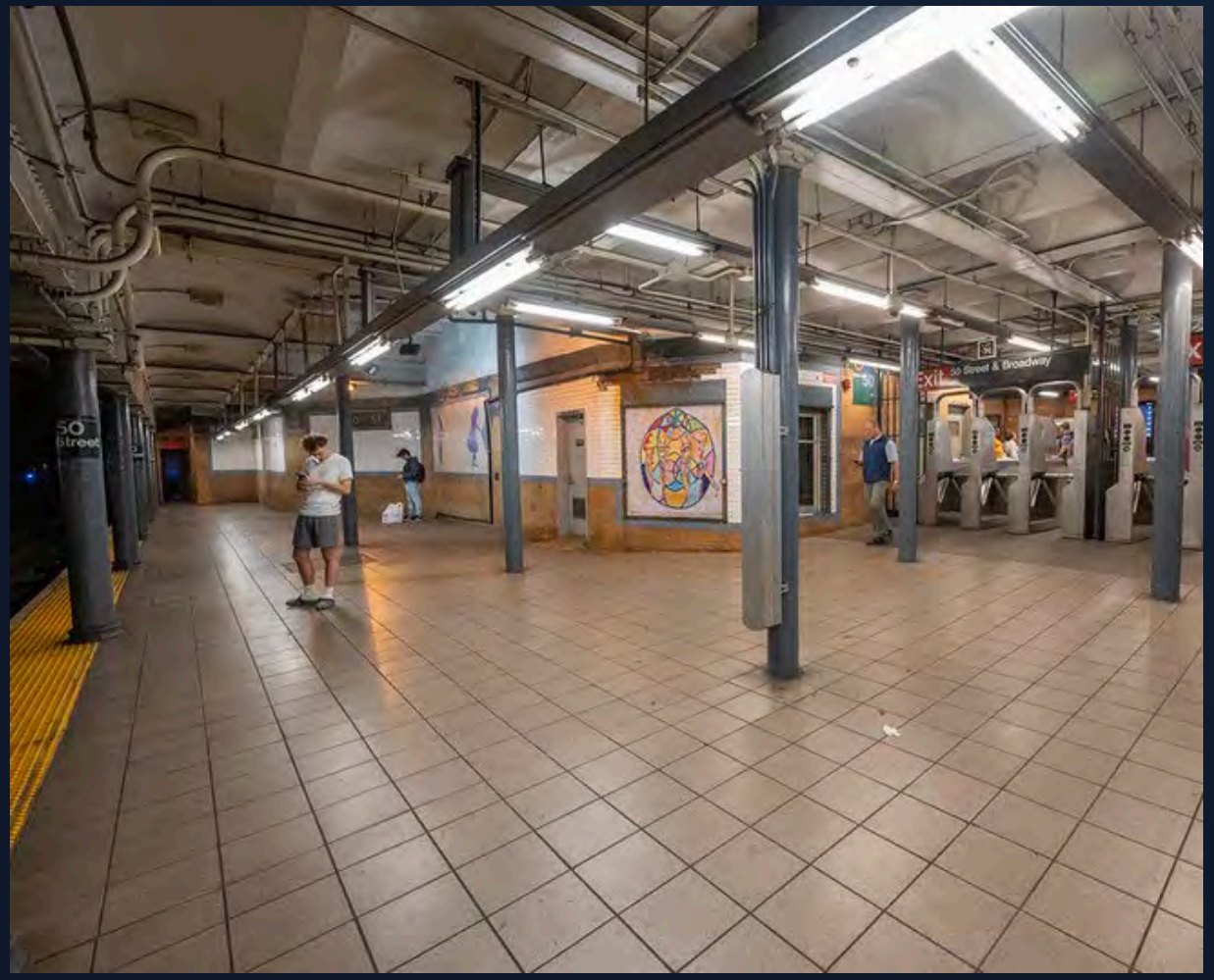




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The Edge Node Topology

- **Not a Centralized Cloud:** The network functions as a heavily distributed web of isolated environments.
- **Per-Station Requirements:** Minimum 1 Main Communications Room + 2 "B" Communications Rooms per station.
- **Massive Edge Deployment:** Anchored by core PBX and transport sites, we manage over **3,000 distinct edge environments** deep underground.
- **The Threat Vector:** Each node must survive extreme environmental conditions and constant physical vibration.



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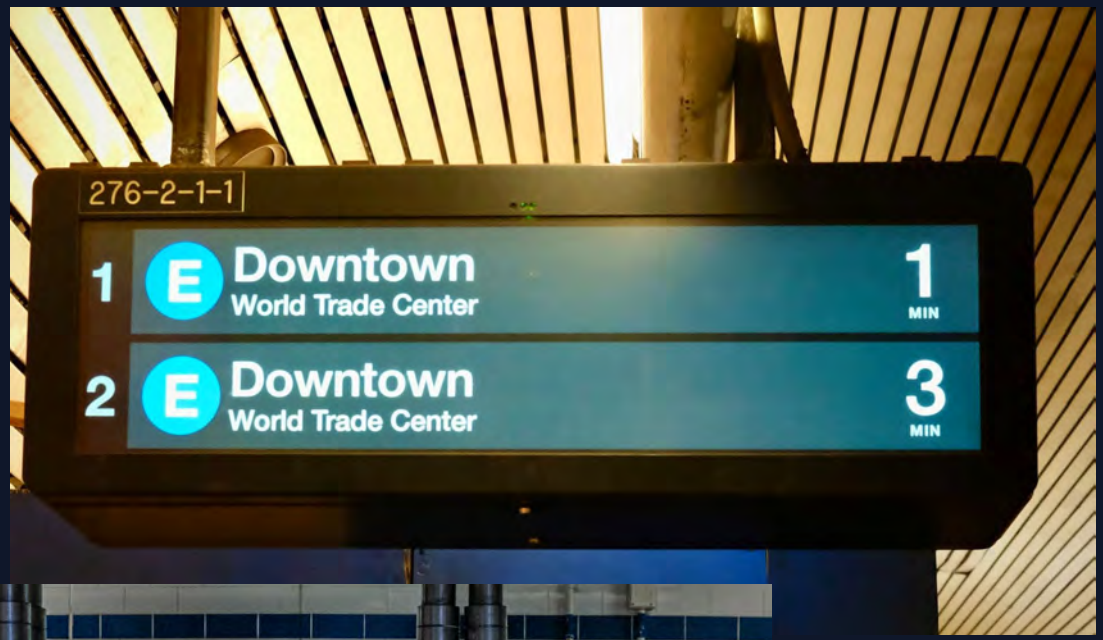




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Pushing Compute to the Edge

- **Decoupling from the Cloud:** High-availability environments cannot afford the latency of querying a central server for every graphical refresh.
- **Localized Processing:** Deploying ruggedized, compact nodes directly on the platform.
- **Data Sharding:** Pushing specific, relevant data chunks locally ensures arrival boards and critical displays remain live even during backbone interruptions.

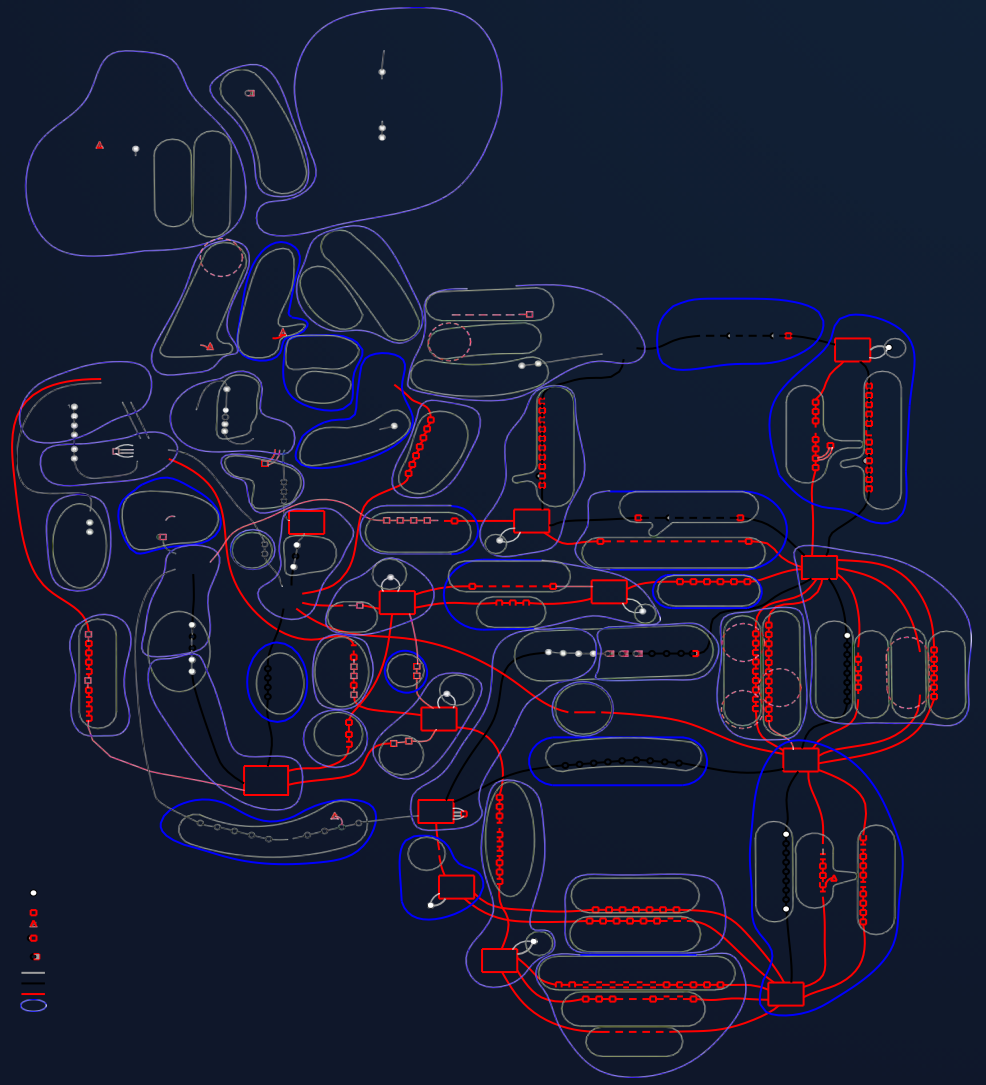




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The Communications Glue: Fiber Rings

- **Physical Path Redundancy:** SONET and packet optical fiber rings act as the lifeblood connecting thousands of edge closets back to the core.
- **Mitigating Cable Cuts:** In heavy industrial environments, track work and construction create a constant threat of severed lines.
- **High-Availability Loop:** Self-healing ring architecture guarantees that a single physical break does not drop an entire sector of stations offline.



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The Zero-Downtime Cutover



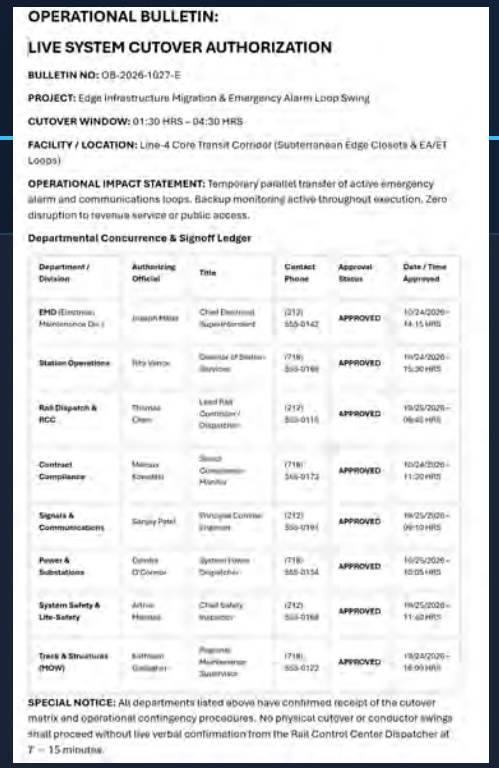
1. Staging

Pre-assembling and configuring hardware enclosures off-site. Establishing parallel power and network feeds adjacent to legacy systems to prepare for the switch.



2. Phasing

Operating legacy and modern edge systems concurrently. Sharding localized data selectively to verify logic and latency metrics without impacting public-facing operations.



OPERATIONAL BULLETIN:

LIVE SYSTEM CUTOVER AUTHORIZATION

BULLETIN NO: OB-2026-1027-E

PROJECT: Edge Infrastructure Migration & Emergency Alarm Loop Swing

CUTOVER WINDOW: 01:30 HRS – 04:30 HRS

FACILITY / LOCATION: Line-4 Core Transit Corridor (Subterranean Edge Closets & EA/ET Loops)

OPERATIONAL IMPACT STATEMENT: Temporary parallel transfer of active emergency alarm and communications loops. Backup monitoring active throughout execution. Zero disruption to revenue service or public access.

Departmental Concurrence & Signoff Ledger

Department / Division	Authorizing Official	Title	Contact Phone	Approval Status	Date / Time Approved
EMD (Electronic Maintenance Div.)	Jason Miller	Chief Electrical Superintendent	(212) 555-0142	APPROVED	10/24/2026 – 14:15 HRS
Station Operations	Rita Vance	Director of Station Services	(718) 555-0199	APPROVED	10/24/2026 – 15:30 HRS
Rail Dispatch & RCC	Thomas Chen	Lead Rail Operations / Dispatcher	(212) 555-0110	APPROVED	10/25/2026 – 06:45 HRS
Contract Compliance	Melissa Kowalski	Senior Compliance Monitor	(718) 346-9172	APPROVED	10/24/2026 – 11:20 HRS
Signals & Communications	Sanjay Patel	Principal Comms Engineer	(212) 555-0191	APPROVED	10/25/2026 – 09:10 HRS
Power & Substations	Deirdre O'Connor	System Power Dispatcher	(718) 555-0134	APPROVED	10/25/2026 – 10:05 HRS
System Safety & Life-Safety	Arthur Hansen	Chief Safety Inspector	(212) 555-0168	APPROVED	10/25/2026 – 11:40 HRS
Track & Structures (MOW)	Kathleen Gallagher	Regional Maintenance Supervisor	(718) 555-0122	APPROVED	10/24/2026 – 16:00 HRS

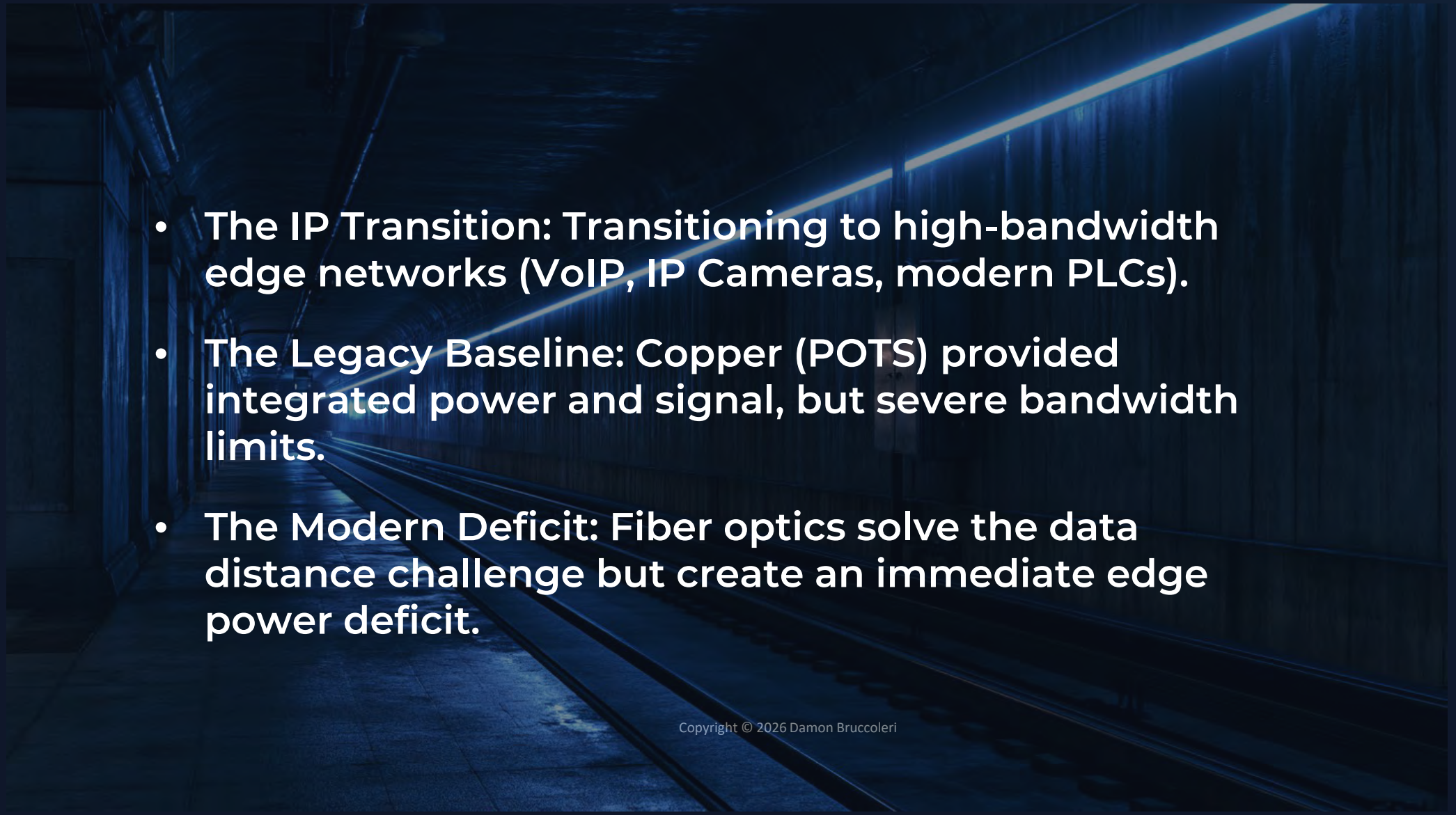
SPECIAL NOTICE: All departments listed above have confirmed receipt of the cutover matrix and operational contingency procedures. No physical cutover or conductor swings shall proceed without live verbal confirmation from the Rail Control Center Dispatcher at 7 – 15 minutes.

3. Execution

Coordinating live physical cutovers during optimal operational windows. Seamlessly transferring active load to the edge nodes with zero disruption to the end-user.

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The Distance Dilemma – Data vs. Power

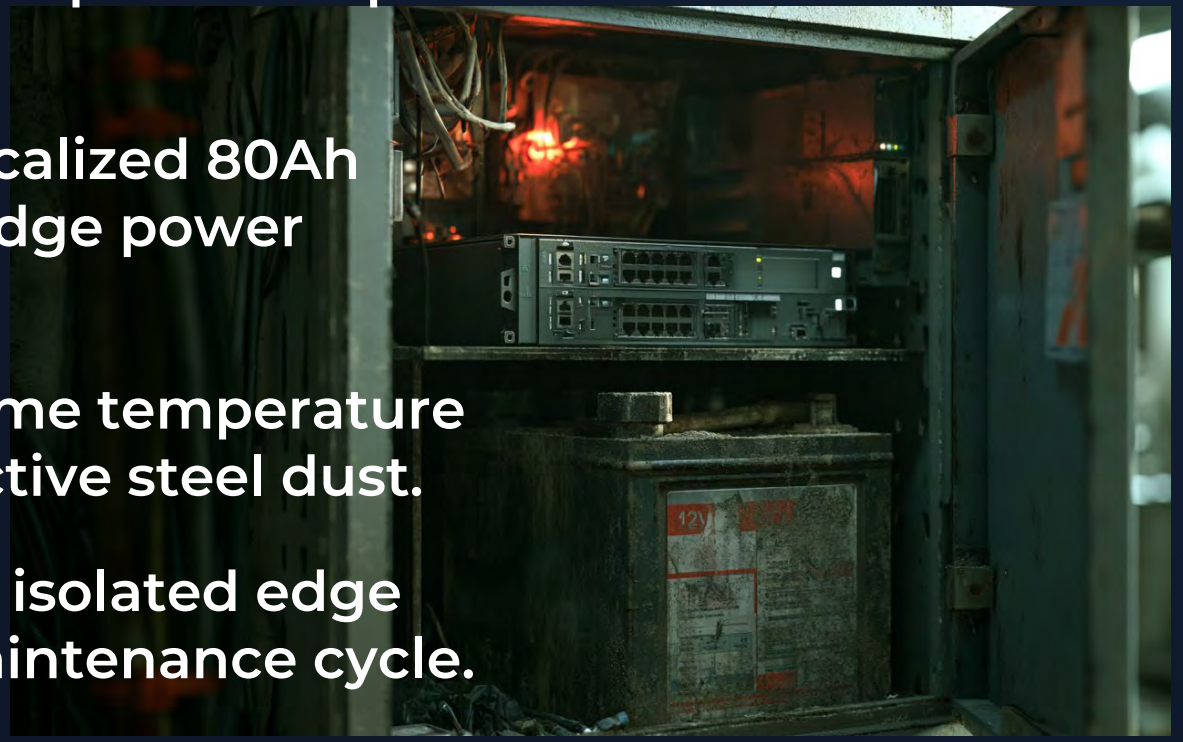


- The IP Transition: Transitioning to high-bandwidth edge networks (VoIP, IP Cameras, modern PLCs).
- The Legacy Baseline: Copper (POTS) provided integrated power and signal, but severe bandwidth limits.
- The Modern Deficit: Fiber optics solve the data distance challenge but create an immediate edge power deficit.

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The Distance Dilemma – Data vs. Power

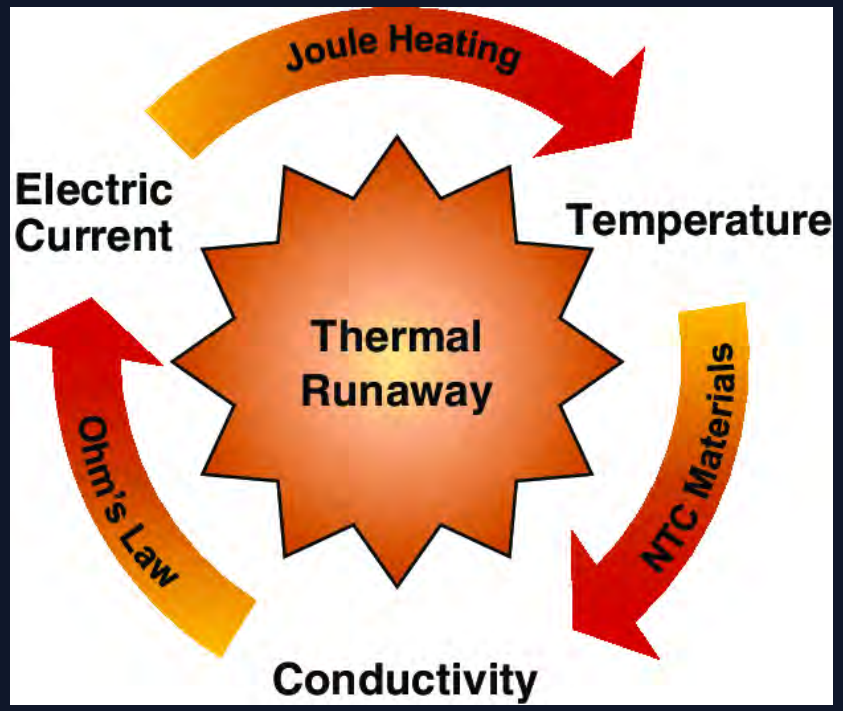
- The Edge Workaround: Localized AC power drops pulled to remote cabinets.
- Distributed UPS Requirements: Localized 80Ah lead-acid batteries deployed to bridge power bumps.
- Environmental Degradation: Extreme temperature fluctuations, vibration, and conductive steel dust.
- The Tracking Deficit: Thousands of isolated edge batteries resulting in a reactive maintenance cycle.



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Energy Storage Evolution – Thermal Resilience

- VRLA Thermal Sensitivity: Service calendar life halves for every 8°C rise above a 25°C baseline; unconditioned spaces cause rapid plate sulfation and dry-out.
- Subterranean Ambient Spikes: Platform and vault temperatures routinely exceed 40°C (104°F) during peak summer traction loading, accelerating lead-acid breakdown.
- Sodium-Nickel Internal Core: Zebra batteries operates an internal chemical core at roughly 270°C encased inside a double-walled, high-vacuum insulated steel container.
- Ambient Decoupling: Chemistry remains completely isolated from external environment; delivers consistent capacity across external ambient ranges from -20°C to +60°C.



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Energy Storage Evolution – Gravimetric Density & Structural Limits

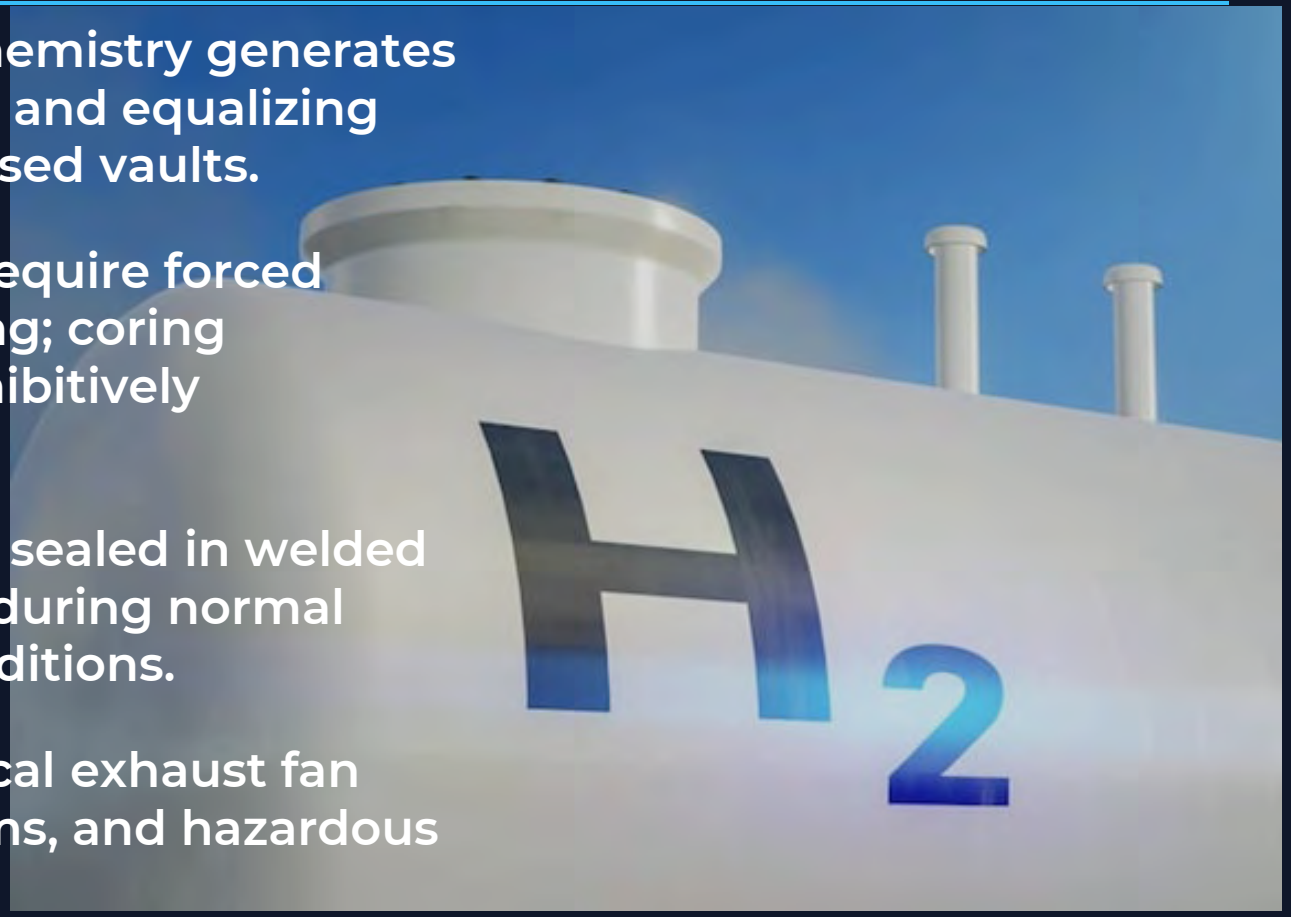
- Century-Old Structural Limits: Subway mezzanines and signal facilities built between 1904 and 1930 possess strict dead-load floor limits.
- VRLA Mass Penalty: Lead-acid (SBS190F) achieves only 30–40 Wh/kg; multi-hour backup strings require massive physical footprints and structural floor reinforcement.
- High Gravimetric Density: Zebra (48TL200) achieves approximately 96 Wh/kg, delivering up to a 70% reduction in
- Civil Infrastructure Relief: Enables installation of centralized 8-hour life-safety backup systems on existing concrete slabs without structural steel modifications.



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Energy Storage Evolution – Subterranean Life-Safety & Ventilation

- Hydrogen Deflagration Risk: Lead-acid chemistry generates volatile hydrogen gas during float charge and equalizing cycles, creating an explosion risk in enclosed vaults.
- Civil Ventilation Bottlenecks: Fire codes require forced mechanical exhaust and hydrogen sensing; coring ventilation ducts up to street level is prohibitively expensive.
- Hermetic Metallic Sealing: Zebra cells are sealed in welded metal containers with zero gas emission during normal float, deep discharge, or short-circuit conditions.
- Code & Space Relief: Eliminates mechanical exhaust fan requirements, hydrogen detection systems, and hazardous battery-room electrical classifications.



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Energy Storage Evolution – Endurance & Lifecycle Economics

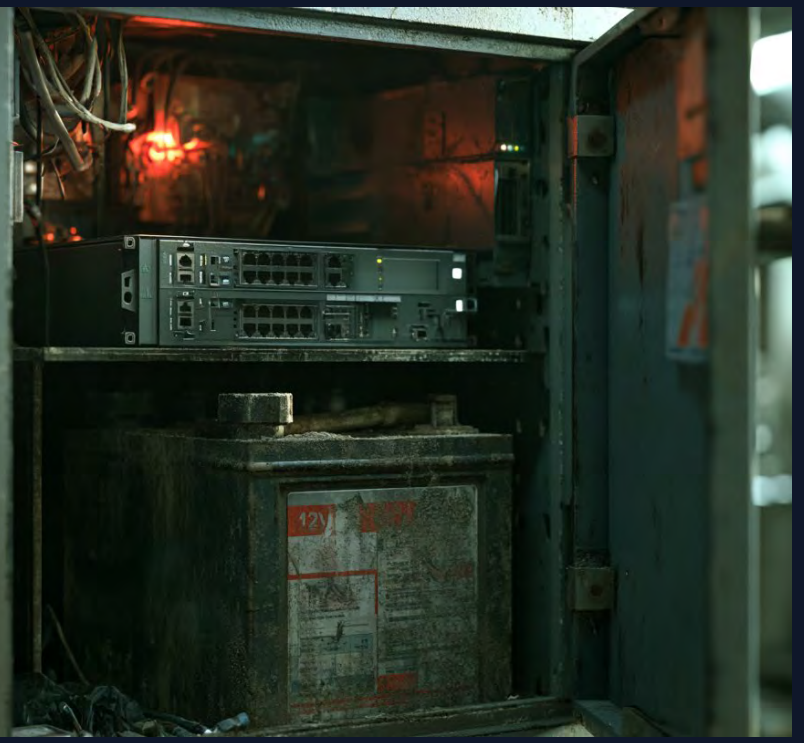
- The 3-Year Replacement Grind: Operating VRLA in harsh subterranean environments forces complete string replacements every 3 to 5 years.
- Logistical Burden: Technicians spend continuous maintenance hours transporting heavy lead batteries across active tracks and down narrow passenger stairs.
- Sodium-Nickel Service Life: Zebra provides a 15- to 20-year operational calendar life, matching the design lifespan of the communications hardware it feeds.
- Deep-Discharge Cycling: Exceeds 4,500 full cycles at 80% Depth of Discharge (DoD) with zero cell degradation from incomplete recharging or micro-cycles



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Energy Storage Evolution – Autonomous Diagnostics & Telemetry

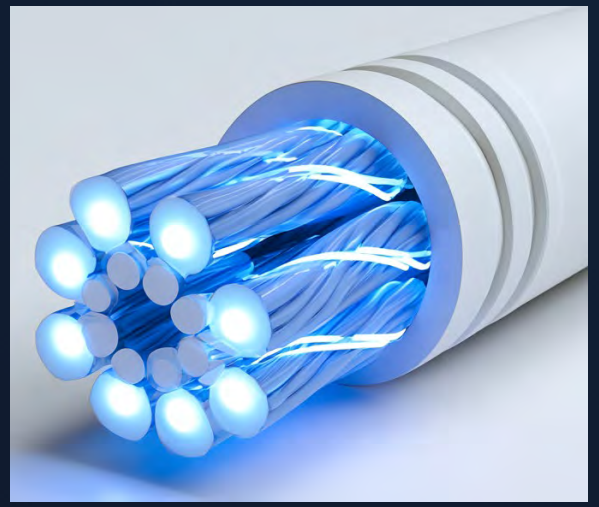
- The Latent Fault Dilemma: VRLA fails silently; normal float voltages frequently mask severe internal plate degradation until an active power outage drops the bus.
- Manual Testing Elimination: Eliminates the need for technicians to manually probe individual cell terminals or connect temporary resistive load banks in active corridors.
- Integrated Intelligent BMS: Every Zebra battery module features an autonomous internal Battery Management System (BMS) executing continuous real-time impedance and cell tracking.
- Native Supervisory Streaming: Diagnostic metrics—State of Charge (SOC), State of Health (SOH), and thermal status—stream directly over Modbus/SNMP into central SCADA.



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Deploying Class 4 Power Introduction

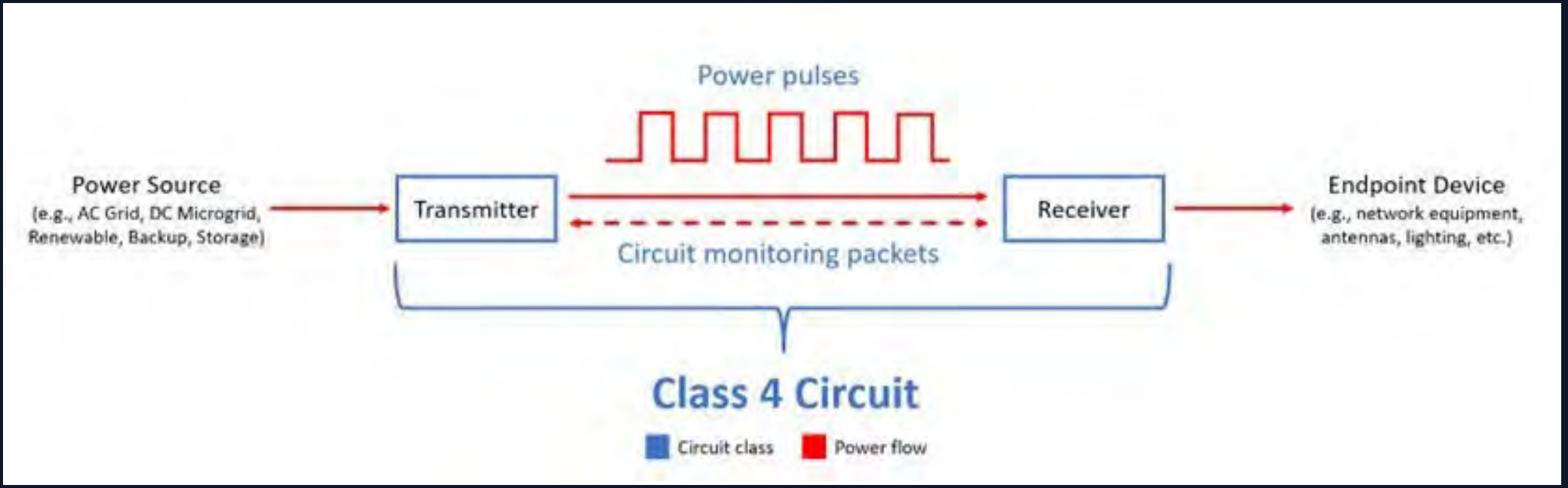
- Navigating Legacy Constraints: Safely transmits up to 450V (per Code) DC without the need for heavy, rigid AC conduit, easily routing through tight, century-old terracotta.
- Converged Infrastructure: Allows power and fiber optic data lines to be pulled simultaneously within the same cable trays and raceways.
- Inherent Life-Safety: Immediate fault arrest (milliseconds) protects transit workers and first responders in wet, highly conductive subterranean environments.
- Enabling the Centralized Edge: Overcomes the extreme voltage-drop limitations of low-voltage DC, finally bridging the physical gap between secure UPS rooms and remote IP equipment.



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Deploying Class 4 Power Introduction

- Long-Distance DC Distribution: Class 4 enables reliable transmission of DC power over hundreds of feet through legacy terracotta ducts without voltage-drop failures.
- High-Voltage Advantage: 450V DC transmission drastically reduces I^2R losses, replacing unreliable low-voltage distributed UPS drops.



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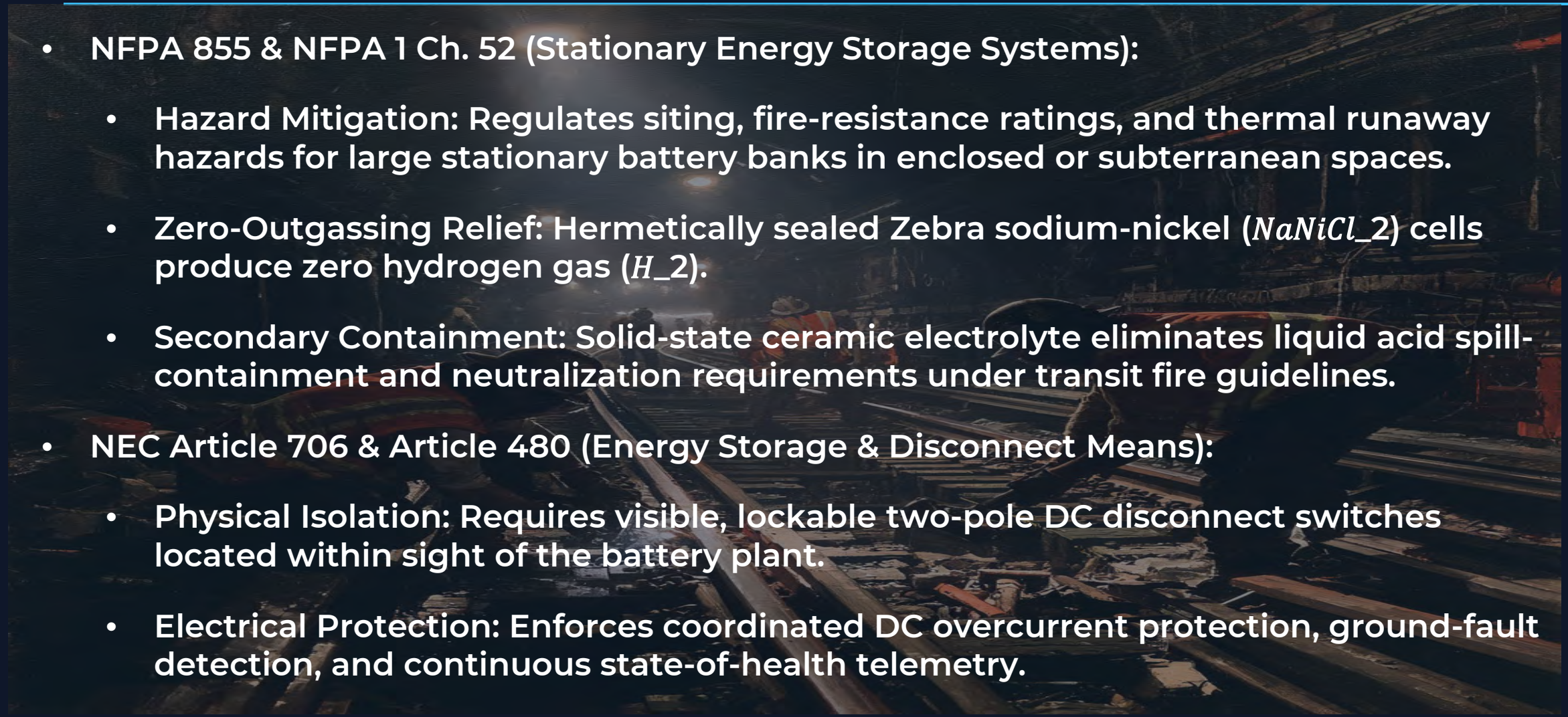
Deploying Class 4 Power Introduction

- Shared Pathways: Class 4 allows power conductors to be pulled in the same trays as optical fiber.
- Subway Practice: In MTA environments, we route Class 4 CT4 LSZH conductors in RMC due to legacy code requirement.
- True Backbone Power Delivery: For the first time, MTA can deliver clean, centralized UPS power to remote platform cabinets without installing new AC feeds or distributed batteries.



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Codes & Standards – Stationary Energy Storage Safety



- NFPA 855 & NFPA 1 Ch. 52 (Stationary Energy Storage Systems):
  - Hazard Mitigation: Regulates siting, fire-resistance ratings, and thermal runaway hazards for large stationary battery banks in enclosed or subterranean spaces.
  - Zero-Outgassing Relief: Hermetically sealed Zebra sodium-nickel ($NaNiCl_2$) cells produce zero hydrogen gas (H_2).
  - Secondary Containment: Solid-state ceramic electrolyte eliminates liquid acid spill-containment and neutralization requirements under transit fire guidelines.
- NEC Article 706 & Article 480 (Energy Storage & Disconnect Means):
  - Physical Isolation: Requires visible, lockable two-pole DC disconnect switches located within sight of the battery plant.
  - Electrical Protection: Enforces coordinated DC overcurrent protection, ground-fault detection, and continuous state-of-health telemetry.

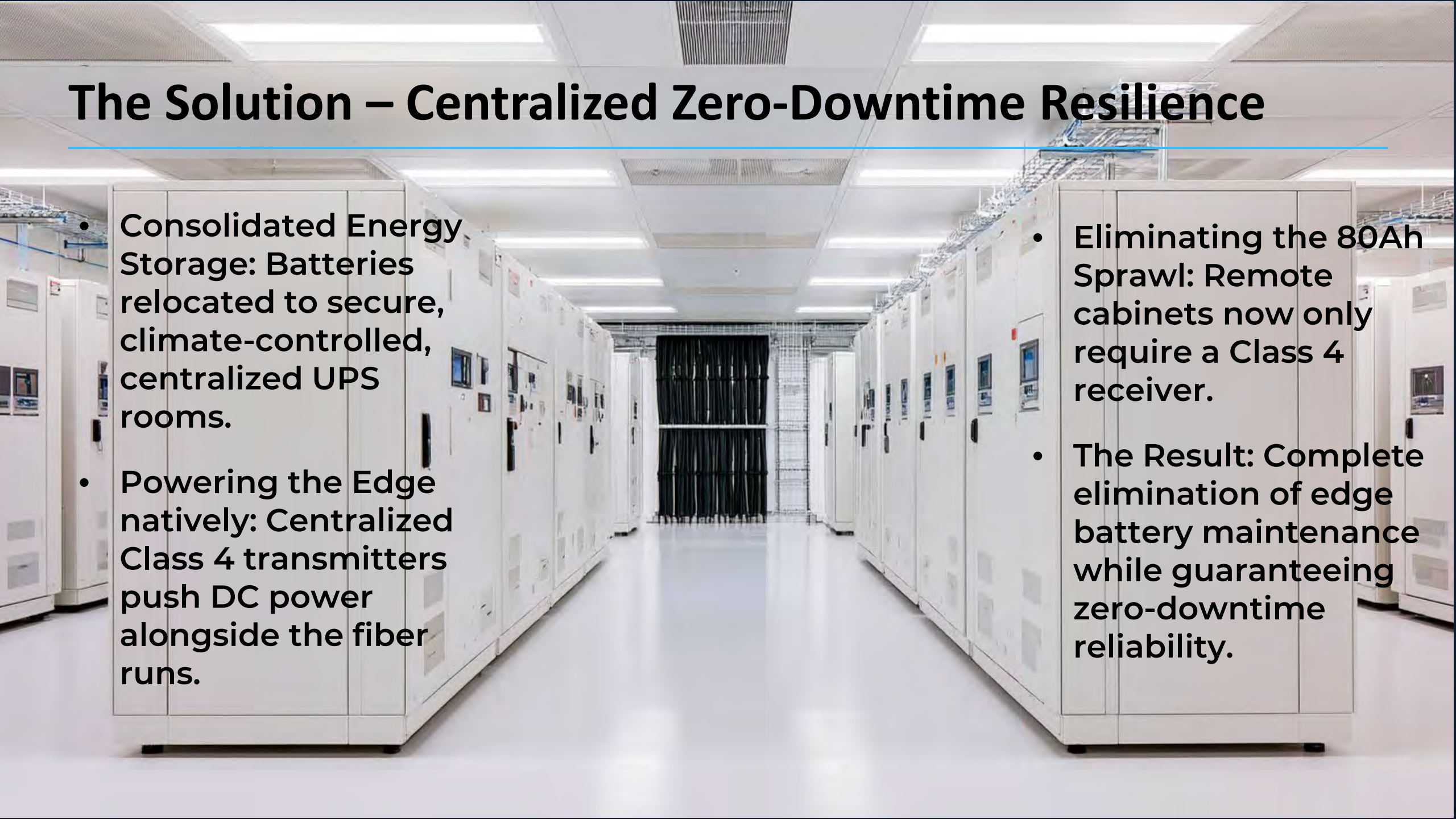
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Codes & Standards – Fault-Managed Power & Life-Safety

- NEC Article 726 (Class 4 Fault-Managed Power Systems):
  - Regulatory Distinction: Code-defines fault-managed power as distinct from traditional Class 1, 2, or 3 circuits, permitting safe transmission up to 450V DC.
  - Pathway Sharing: Legally permits Class 4 power cables to share cable trays, raceways, and historic terracotta ducts directly alongside single-mode optical fiber.
  - Inherent Touch Safety: Mandates hardware-level fault arrest within milliseconds upon detecting line faults or human contact, ensuring safety in damp railway environments.
- NFPA 130 & NFPA 111 (Transit Life Safety & Stored Emergency Power):
  - Level 1 Reliability: Classifies passenger emergency communications (Help Points, PA, CIS) as Level 1 life-safety loads requiring continuous, zero-break power transfer and an MTA NYCT agency specific standard.
  - Subterranean Survivability: Mandates low-smoke, zero-halogen (LSZH) materials and non-combustible construction to prevent toxic smoke generation in enclosed rail tunnels.

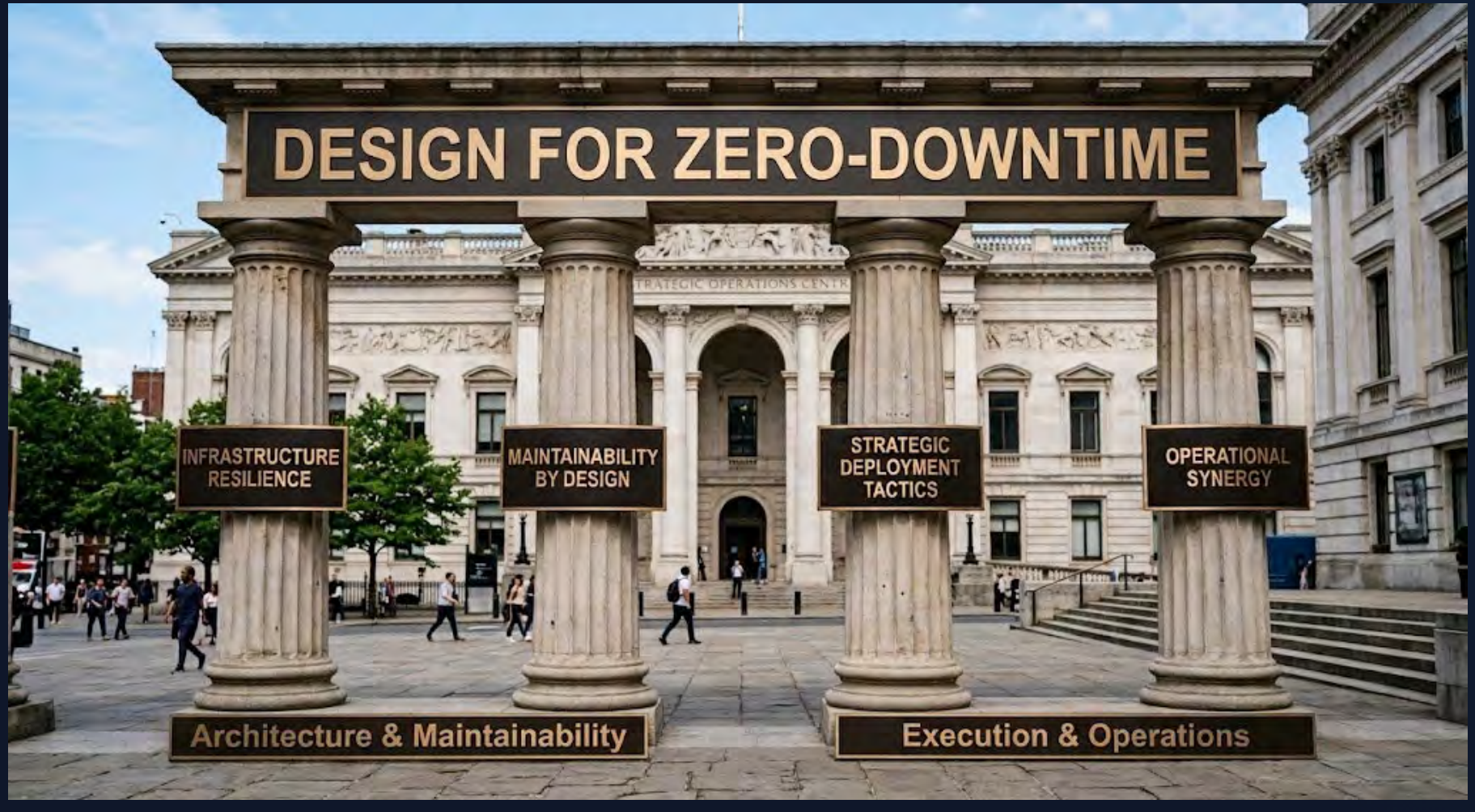
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The Solution – Centralized Zero-Downtime Resilience



- Consolidated Energy Storage: Batteries relocated to secure, climate-controlled, centralized UPS rooms.
- Powering the Edge natively: Centralized Class 4 transmitters push DC power alongside the fiber runs.
- Eliminating the 80Ah Sprawl: Remote cabinets now only require a Class 4 receiver.
- The Result: Complete elimination of edge battery maintenance while guaranteeing zero-downtime reliability.

Four Pillars of Zero-Downtime



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Architecture & Maintainability



- **Dual Power & Bus Redundancy:**
  Utilizing 2N power inputs and Automatic Transfer Systems (ATS) to ensure continuous feed.
- **A/B Network Path Redundancy:**
  Designing self-healing fiber rings so a single cable break doesn't drop a sector.
- **Redundant Field Equipment:**
  Implementing automatic failover at the localized edge nodes.

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Architecture & Maintainability



- **Superior Maintenance Access:**
  Spacing racks, utilizing rear access, and clearing load paths to prevent technicians from accidentally bumping live connections.
- **Temporary Bypass Circuits:**
  Utilizing UPS Maintenance Bypass Switches (MBS) to isolate power safely.
- **Alternate Pathways:**
  Utilizing abandoned ducts and ceiling voids to pull new cable without entering dangerous, active track areas.
- **Elimination of Latent Faults:**
  Proactively identifying hidden hardware/software defects (like VRLA batteries) before they compound into system failures

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Execution & Operations



- **Parallel Infrastructure & Live Cutovers:**

  Building new infrastructure directly beside the legacy system and running them concurrently before the swing.

- **Pre-Fabricated Assemblies:**

  Building and configuring enclosures off-site for rapid deployment.

- **Rolling Upgrades (N+1):**

  Methodically upgrading nodes sequentially to preserve overall network uptime

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Execution & Operations



- **Designing to avoid General Orders (GO):**

  Engineering solutions that don’t require shutting down train service to implement.

- **Operational Coordination:**

  Working directly with Rail Control, Power Control, and Station Ops to execute within optimal maintenance windows.

- **Predictive Maintenance:**

  Utilizing central monitoring and alarming to catch degradation before it becomes an outage.

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Questions?

Opening the floor to discuss parallel challenges in infrastructure.

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LinkedIn Connect

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