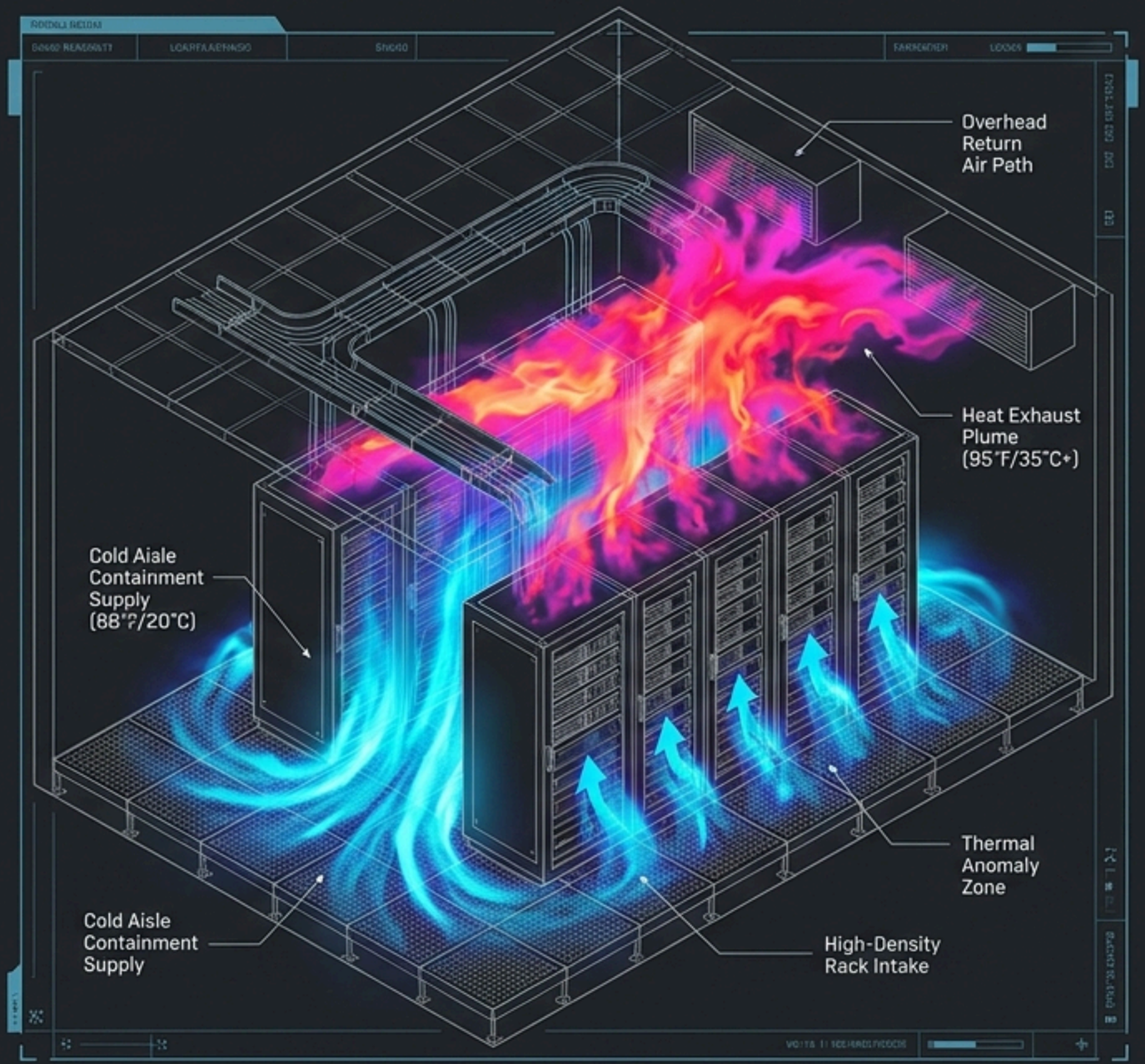
BIM-Driven Thermal Optimization for Hyperscale Data Centers

Transitioning from static MEP coordination to predictive operational platforms.



Roots BIM LLC Case Study

The Hyperscale Challenge: Mitigating High-Density Risk

Facility Scale

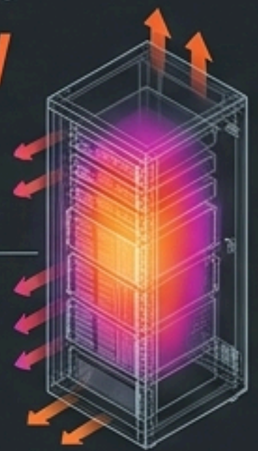
180,000 sq. ft.

White space across multiple server halls.

Thermal Load

>25 kW

Per high-density server rack.



Financial Stake

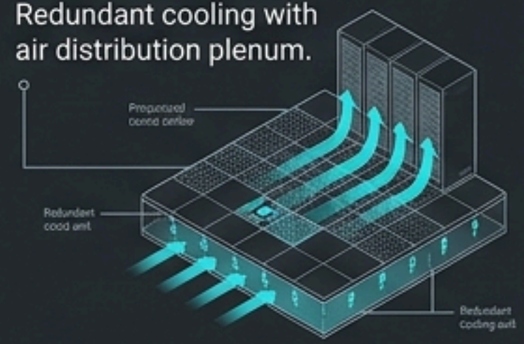
35-45%

Total energy consumption dedicated to cooling.

Infrastructure

Raised Floor

Redundant cooling with air distribution plenum.



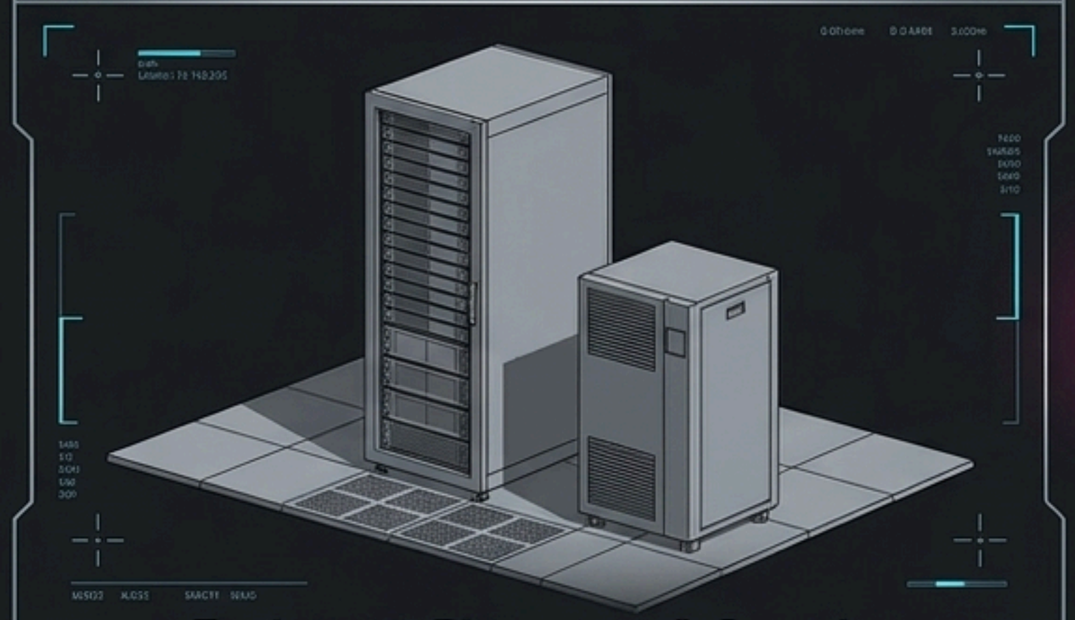
CRITICAL INQUIRY // THERMAL VIABILITY ASSESSMENT

Can the proposed infrastructure reliably support the load while eliminating hotspots and minimizing energy consumption?

SYSTEM DIAGNOSTIC: PENDING ANALYSIS

The Blind Spot in Traditional Design Reviews

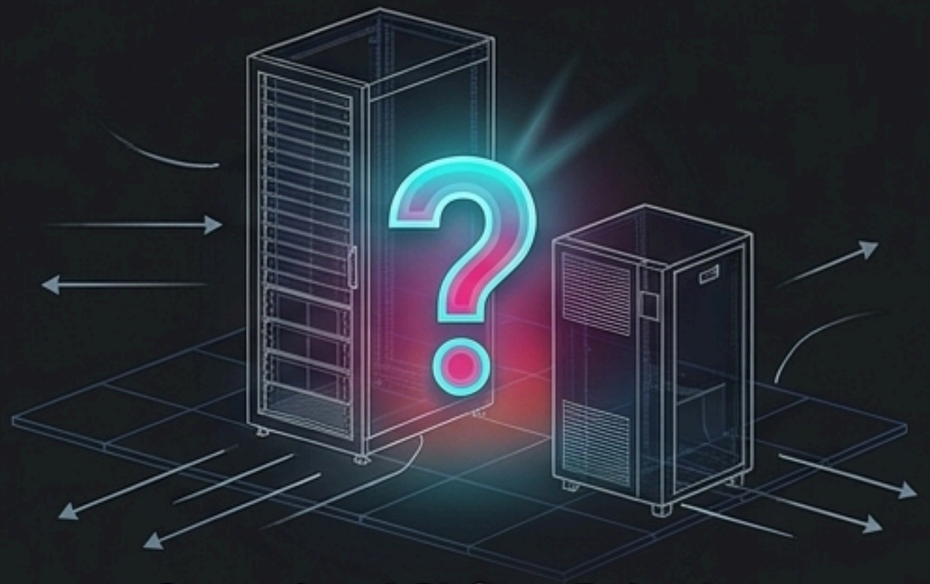
The Known



Equipment Placement & Capacity

Traditional reviews verify spatial fit and nameplate capacities.

The Blind Spot



Operational Airflow Behavior

Cannot accurately predict how air will move, mix, and behave under live thermal loads.

The Risks:

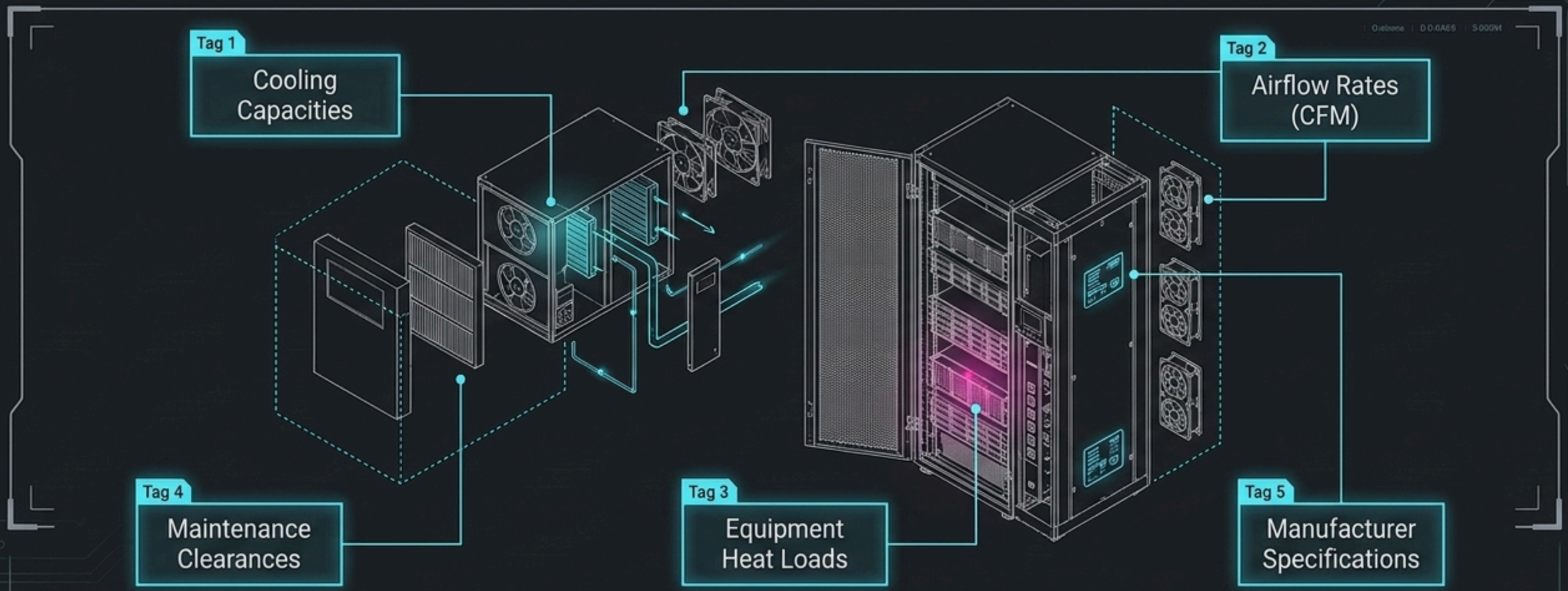
- Potential hot air recirculation
- Inconsistent underfloor distribution
- Unverified containment effectiveness
- Escalating energy costs

The BIM Paradigm Shift: Geometry vs. Performance

Geometric Representation (Standard Approach)	Performance-Based Engineering (Roots BIM Approach)
Focus: Spatial fit and clash detection.	**Focus:** Thermodynamics and operational behavior.
Data: Dimensions, shapes, and manufacturer names.	**Data:** Embedded operational metadata (airflow, heat loads, capacities).
Output: Static 3D coordination models.	**Output:** Intelligent BIM Environment paired with predictive simulation.
Limitation: Assumes optimal performance based strictly on layout.	**Advantage:** Validates real-world performance before construction.

ROOTS BIM

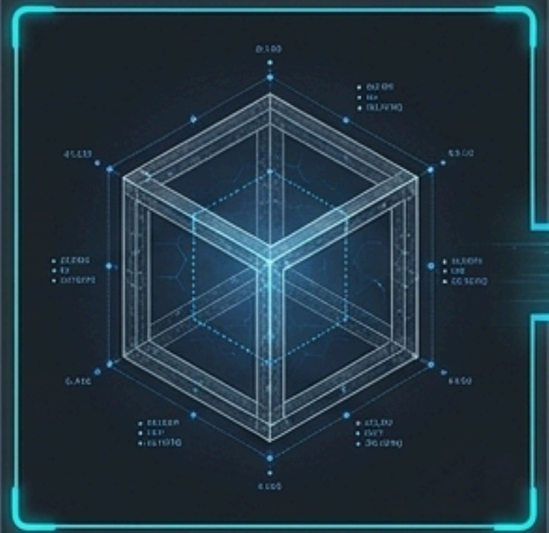
Phase 1: Injecting Operational Metadata



Core Concept: A federated BIM model integrating mechanical cooling, chilled water networks, power infrastructure, and raised floor assemblies into a single, data-rich ecosystem.

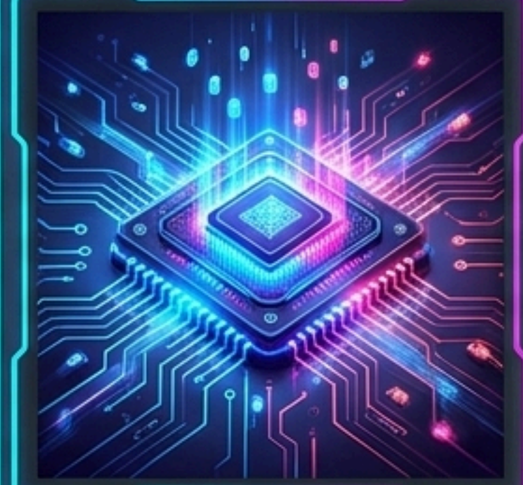
Phase 2: CFD Airflow Simulation Engine

Input



BIM Geometry +
Embedded Metadata

The Engine



Computational Fluid
Dynamics (CFD)

Key Parameters Analyzed

Supply air
velocity

Return air
temperature

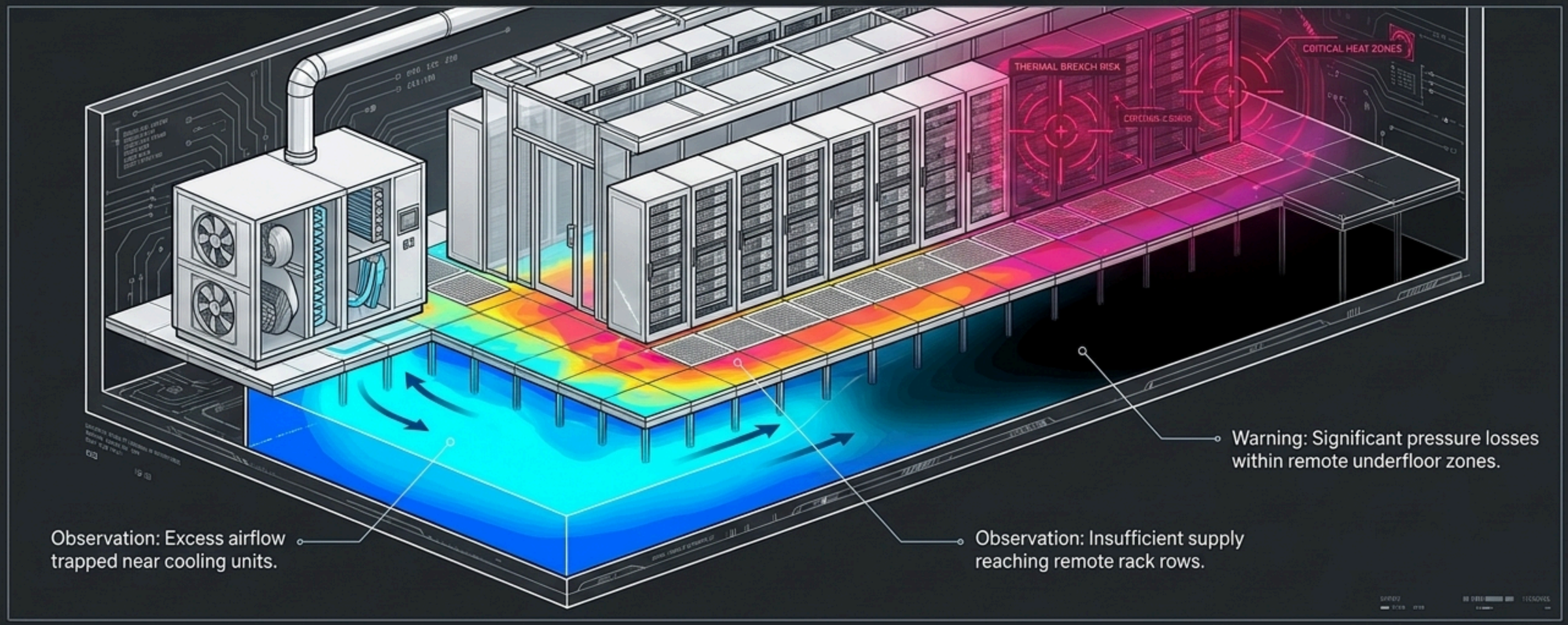
Pressure
differentials

Airflow distribution
patterns

Heat plume
behavior

Rack-level cooling
performance

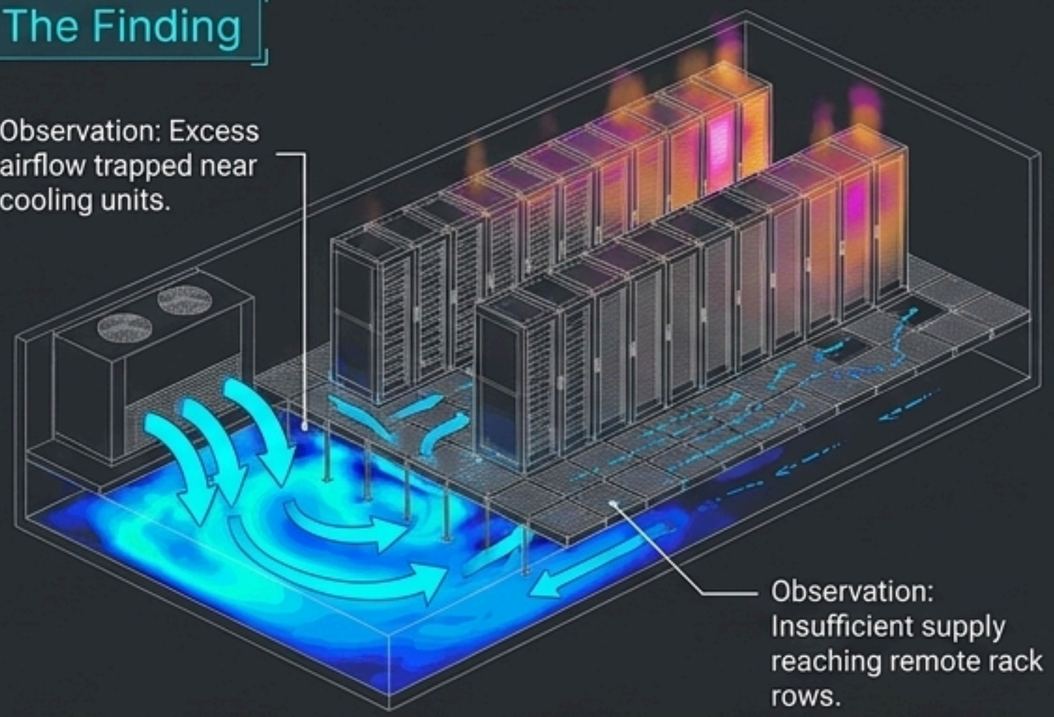
Diagnostic #1: The Underfloor Pressure Crisis



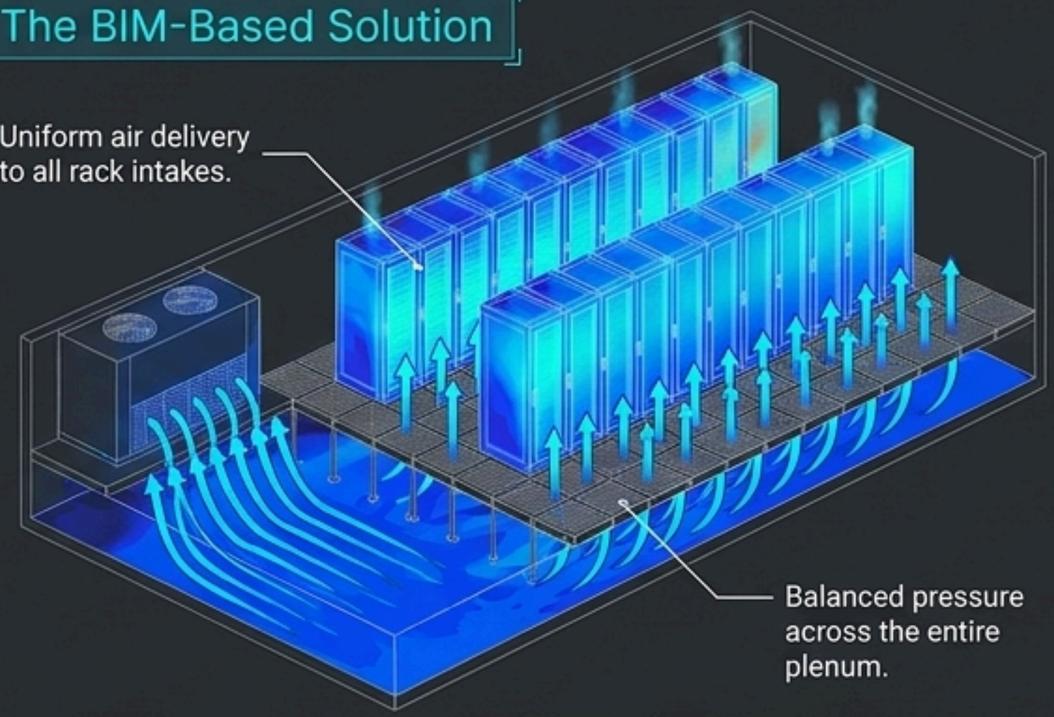
Impact: Without intervention, remote rack clusters were projected to operate above recommended thermal thresholds, threatening equipment reliability.

Intervention #1: Balancing the Plenum

The Finding



The BIM-Based Solution



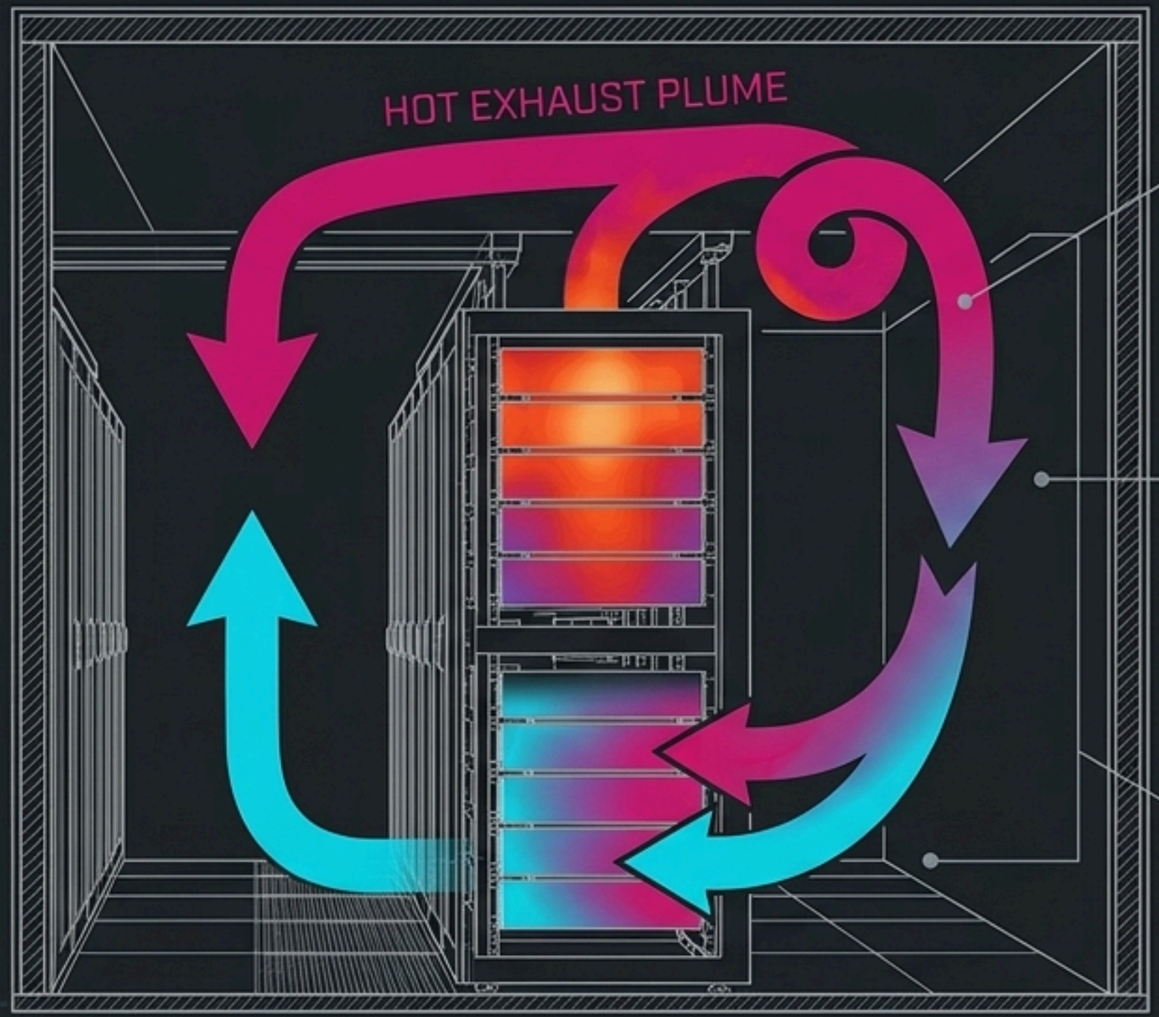
Optimization Actions Taken:

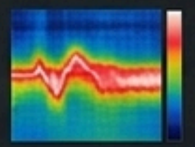
1. Repositioned perforated tile placement.
2. Reconfigured raised floor plenum zoning.
3. Executed targeted airflow balancing strategies.

Result:

Uniform air distribution achieved across all server rows, maximizing cooling effectiveness.

Diagnostic #2: Hot Air Recirculation





Anomaly Detected:

Unexpected hot air migration above rack rows.

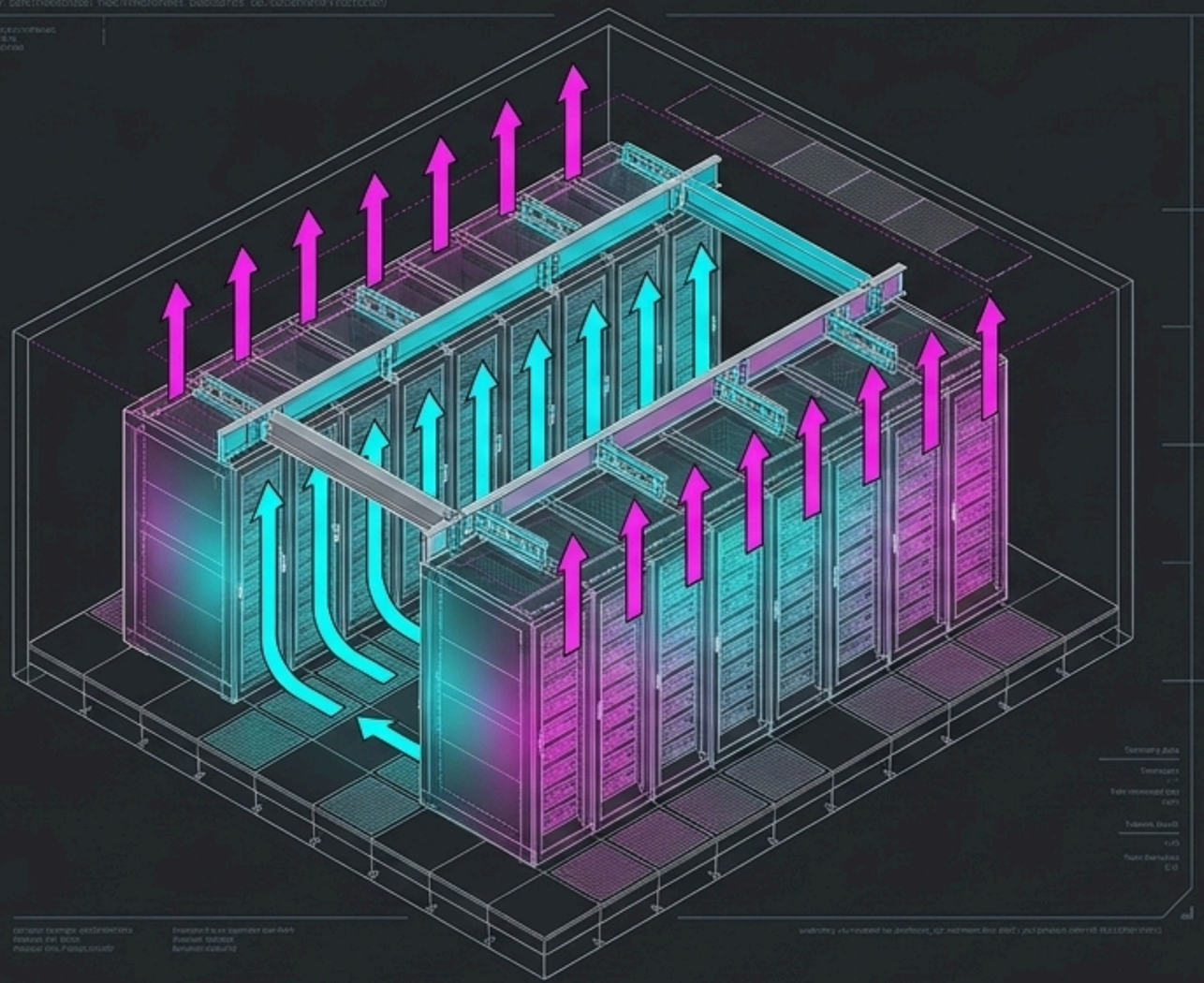
Mechanism:

Exhaust streams bypassing intended return pathways.

Consequence:

Mixing with conditioned supply air, drastically reducing cooling efficiency and spiking server inlet temperatures.

Intervention #2: Containment & Orientation Restructuring



Optimization Actions Taken:

1. Deployed enhanced cold aisle containment structures.
2. Engineered improved return air pathways.
3. Revised server rack orientations to eliminate bypass zones.

Result:

Simulation reruns confirmed substantial reductions in recirculation zones and total isolation of hot/cold streams.

OPERATIONAL STRESS-TESTING & VALIDATION

STABILITY: 99.9% ▶

FULL-LOAD OPERATIONS

Verified thermal stability at maximum design capacity

PRESSURE Δ: OK ▶

PRESSURE Δ: OK ▶

PARTIAL OCCUPANCY

Confirmed pressure balancing during initial phased facility rollout

REDUNDANCY: EPEIX ▶

EXTERNAL TEMP: MAX ▶

PEAK SEASONAL LOADS

Validated cooling delivery during maximum external ambient temperatures.

EXTERNAL TEMP: MAX ▶

REDUNDANCY: ACTIVE ▶

EQUIPMENT FAILURE SCENARIOS

Simulated CRAH downtime to ensure redundancy strategies maintained containment.

REDUNDANCY: ACTIVE ▶

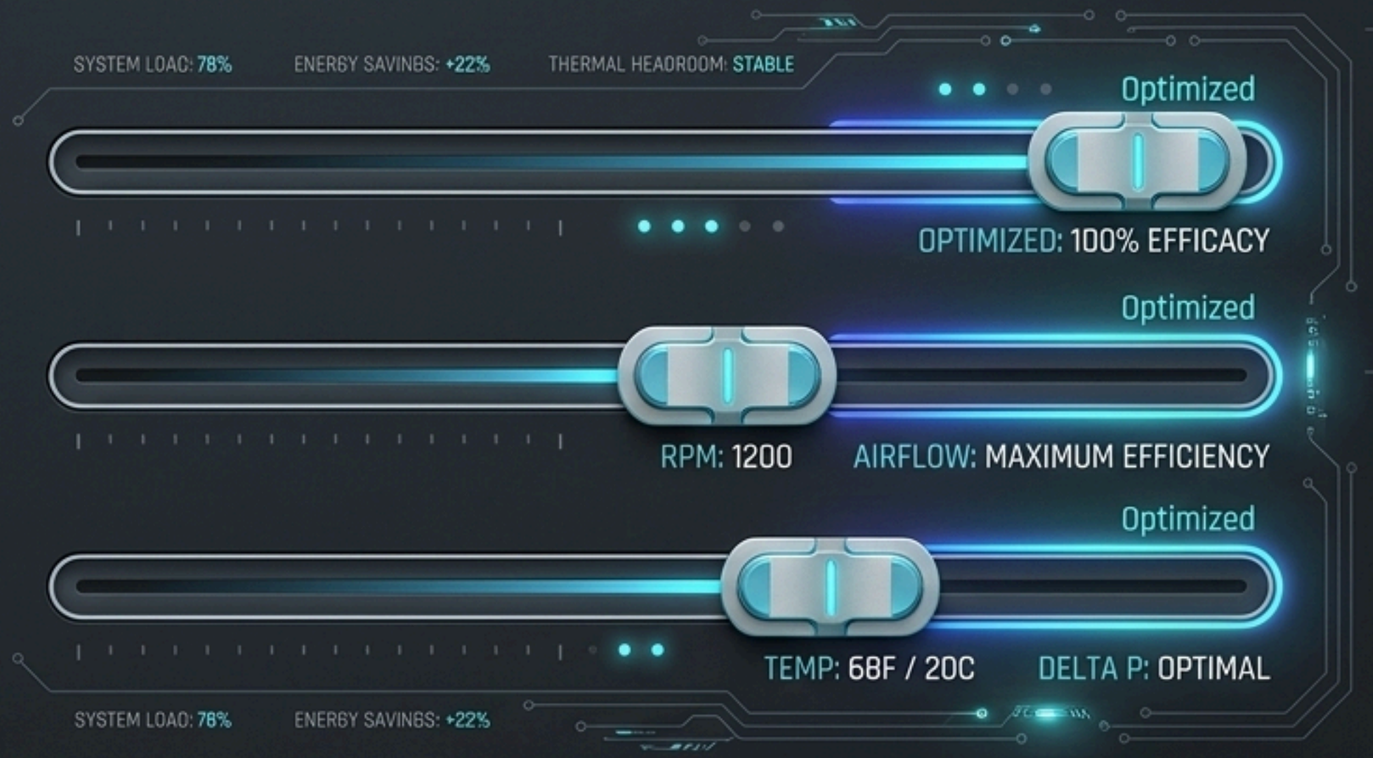
CORE FINDING: The BIM-integrated analysis confirmed stable cold aisle temperatures and highly effective hot aisle isolation under all operational extremes.

Beyond Cooling: Energy & PUE Optimization

1. **CRAH Operating Strategies**
   Eliminating unnecessary cooling workload and validating redundancy.

2. **Fan Speed Adjustments**
   Lowering fan energy consumption while maintaining required underfloor pressure.

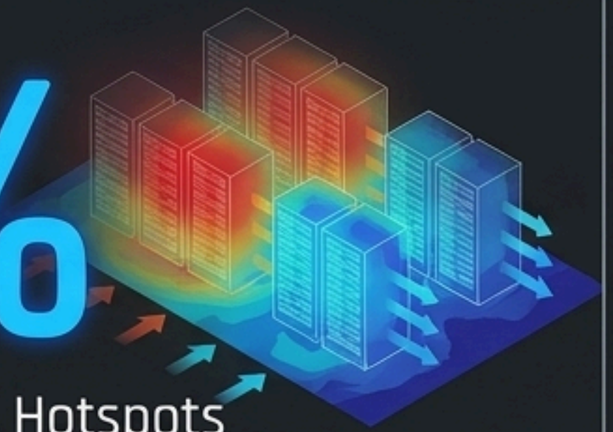
3. **Chilled Water Temperature**
   Optimizing supply temps to increase cooling capacity utilization.



Refining these variables in the simulation allowed the facility to achieve a significantly improved projected Power Usage Effectiveness (PUE) without compromising mission-critical reliability.

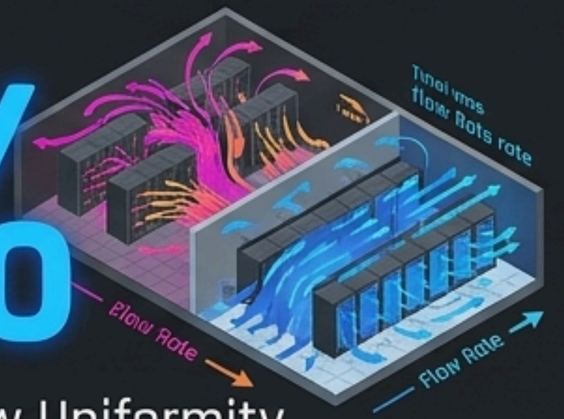
Measurable Project Outcomes

85%



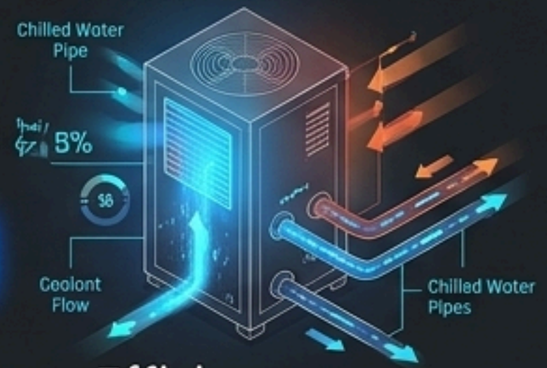
Reduction in Thermal Hotspots

30%



Improvement in Airflow Uniformity

18%



Increase in Cooling System Efficiency

12%

Reduction in Predicted Energy Consumption

Commissioning risk significantly reduced. Future Digital Twin readiness fully enabled.

Synthesis: The Digital Deliverables Ecosystem

Digital Twin Readiness Framework
Structured data primed for future integration with live sensor networks.

Operational Recommendations
Data-driven guidance for commissioning and facility management.

Thermal Risk Maps
Visual diagnostics of potential hotspots and recirculation areas.

Airflow Simulation Reports
Detailed CFD outputs mapping paths, pressures, and temperatures.

Federated BIM Model
The coordinated digital representation of all thermal management assets.

This five-stage ecosystem delivers a comprehensive, structured digital foundation for optimizing facility performance and enabling future real-time thermal management.

Engineering the Future of Hyperscale

In today’s mission-critical facilities, BIM is no longer just about coordinating systems. It is actively engineering operational performance, resilience, and long-term sustainability before a single server is installed.

Roots BIM LLC

Visualize your airflow. Validate your performance.

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