Digital Twins for Critical Infrastructure: Transforming Buildings and Beyond

A Trusted Edge-to-Core Foundation for Scalable Digital Twins

Introduction

Critical infrastructure, including airports, stadiums, and smart building portfolios, is becoming more instrumented, data-rich, and operationally complex. Dell Technologies and Intel are collaborating to bridge the gap between physical assets and intelligent digital operations by delivering a trusted, edge-to-core foundation for digital twins—combining infrastructure, compute, and AI at scale.

Intelligent Infrastructure Turns Complexity into Opportunity

Realizing digital twins at scale for critical infrastructure requires end-to-end capabilities: 3D modeling, sensor data, edge processing, secure data platforms, rendering and visualization, simulation engines, AI/ML workloads running efficiently from edge to core, closed-loop control, and a robust partner ecosystem spanning ISVs, system integrators, and domain experts. This is not a single-product challenge; it represents a platform, ecosystem, and architectural challenge that demands holistic solutions.

Dell Technologies and Intel, together with our partner ecosystem, provide a joint foundation for enabling a layered digital twin architecture:

- Dell Technologies provides edge-to-core infrastructure and platforms to host and manage digital twins.
- Intel provides the compute, acceleration, and open software toolkits needed for demanding simulation, media processing and rendering, 3D modeling and spatial computing, and AI components of digital twins.
- A partner ecosystem layer brings specialized applications, integration services, and domain expertise to connect industry-specific use cases, data sources, and operational systems into complete digital twins solutions.

Dell and Intel create the technology and operational foundation that enables partners to build their domain-specific solutions.

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The Challenge: The Operational Visibility Gap

Most operators struggle with a widening visibility gap between operational realities and the telemetry their systems can capture, analyze, and control.

Critical infrastructure operators face a set of compounding challenges that hinder safe, efficient, and resilient operations.

Siloed Operational Technology (OT) and Information Technology (IT) Data and Tools Different systems can't easily share information, so operators lack a unified view.	**Limited Real-time 360⁰ Situational Awareness** Operators see fragments of the state, making it hard to know what's happening now.
Reactive, Alarm-driven Operations Action is taken only after alarms or failures, instead of anticipating issues.	**Difficult Root-Cause Analysis Across Systems** Interactions between systems are opaque, so finding "why" is slow and manual.
Inability to Optimize Asset and Energy Usage at Scale Assets are over- or under-used, and energy spend is higher than it needs to be, because "what-if" configuration changes are hard to determine safely at scale.	**Risky Changes and Growing Design-to-Reality Gaps** Operational changes are hard to determine safely, causing deployed systems to drift over time from design models and documentation.
Complex, Unvalidated, and Hard-to-Scale IT Infrastructure Complex infrastructures are not validated at scale, leading to rework, downtime, inconsistent performance, and higher risk during expansion.	**Weak Security and Data Privacy Across IT/OT Systems** Legacy and mixed systems struggle to enforce consistent security and protect sensitive data across the architecture.

Bridging the gap between real-world operations and system visibility to enable safer, more efficient, and resilient infrastructure.

The Solution: Digital Twin Built on a Scalable IT Infrastructure

A digital twin is a real-time digital replica of a physical system that integrates real-time data using AI to assess operational efficiency and inform future optimization. It relies on a consistent edge-to-core infrastructure that provides reliable compute, storage, security, and AI services with data analytics, delivering insight, prediction, and operational control at scale.

Monitor	Predict	Simulate	Control
Real-time visibility into physical assets temperature, load, pressure, flow, and performance metrics.	AI-driven analytics anticipate failures before they occur, enabling proactive maintenance and zero unplanned downtime.	Test "what-if" scenarios virtually to optimize performance, validate changes, and reduce real-world risk.	Issue commands back to physical systems, adjust cooling, reroute power, throttle load from a single pane of glass.

It helps critical infrastructure operators:

- Gain holistic visibility into complex infrastructure systems
- Simulate "what if" scenarios and anticipate outcomes
- Optimize performance and resource utilization
- Reduce downtime, risk, and operational costs
- Bridge insights across IT and OT environments

The Anatomy of a Digital Twin

Digital twins are often mistakenly treated as standardized solutions. In reality, digital twins are complex constructions composed of an interconnected ecosystem of services and components designed to function cohesively. To structure this complexity, the Digital Twin Consortium defines the Capabilities Periodic Table (CPT).

1 Data Acquisition & Ingestion	9 Synthetic Data Generation	17 Enterprise System Integration	23 Edge AI & Intelligence	29 Prediction		39 Basic Visualization	45 Dashboards
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6 Real-time Processing	14 Data Storage & Archive Services	22 API Services	28 Data Analysis & Analytics	34 Mathematical Analytics	38 Composition	44 Virtual Reality VR	50 3D Rendering
7 Data PubSub Push	15 Simulation Model Repository	52 Device Management	54 Event Logging	56 Data Encryption	58 Security	60 Safety	51 Gamification
8 Data Aggregation	16 AI Model Repository	53 System Monitoring	54 Data Governance	57 Device Security	59 Privacy	61 Reliability	62 Resilience

Data Services · Integration · Intelligence · UX · Management · Trustworthiness

Table 1: Digital Twin Consortium, Capabilities Periodic Table (CPT)[1]

The CPT is a technology-agnostic framework for digital twin projects. It is aimed at organizations that want to design, develop, deploy, and operate digital twins based on use-case capability requirements relative to the features of technology solutions.

Using the CPT framework helps identify common capabilities:

Common Digital Twin Capabilities	Contextual Use Cases
Artificial Intelligence	• Analytics (reporting and predictive) • Synthetic Data Generation • Generative Physical AI • Federated Learning
3D Modeling and Simulations	• Computer Vision • Visualization • Real-time Monitoring
Data-integrated Services	• Data Ingestion • Data Processing • Data Streaming • Data Integration

Table 2: Common Digital Twin Capabilities and Representative Use Cases

Infrastructure as a Foundational Element of the Digital Twin

Digital twins move from concept to impact only when supported by a robust and cohesive technology foundation. As digital twins become more data-intensive, AI-driven, and distributed, they place increasing demands on infrastructure to support real-time data ingestion, AI inference, simulation, visualization, and human interaction at scale. Without this foundation, digital twin capabilities often remain fragmented or confined to isolated pilots, limiting their ability to scale, adapt, and deliver sustained value.

Key Adoption Considerations

Successful digital twin adoption requires careful planning across several areas:

- **Security and data privacy** – Digital twins consume large volumes of operational and potentially sensitive data while controlling physical systems.
- **Cost and complexity** – Adoption spans infrastructure, software, and multidisciplinary expertise.
- **Organizational alignment** – Engineering, IT, data science, and business teams must collaborate.
- **System integration** – Seamless integration with existing IT/OT systems is critical.
- **Flexibility and scalability** – Requirements evolve as data volumes grow and AI becomes more embedded in multi-tier infrastructure components.

Starting Your Digital Twin Journey

This step-by-step approach outlines how organizations can define clear objectives and progressively build a scalable digital twin foundation from pilot to production.

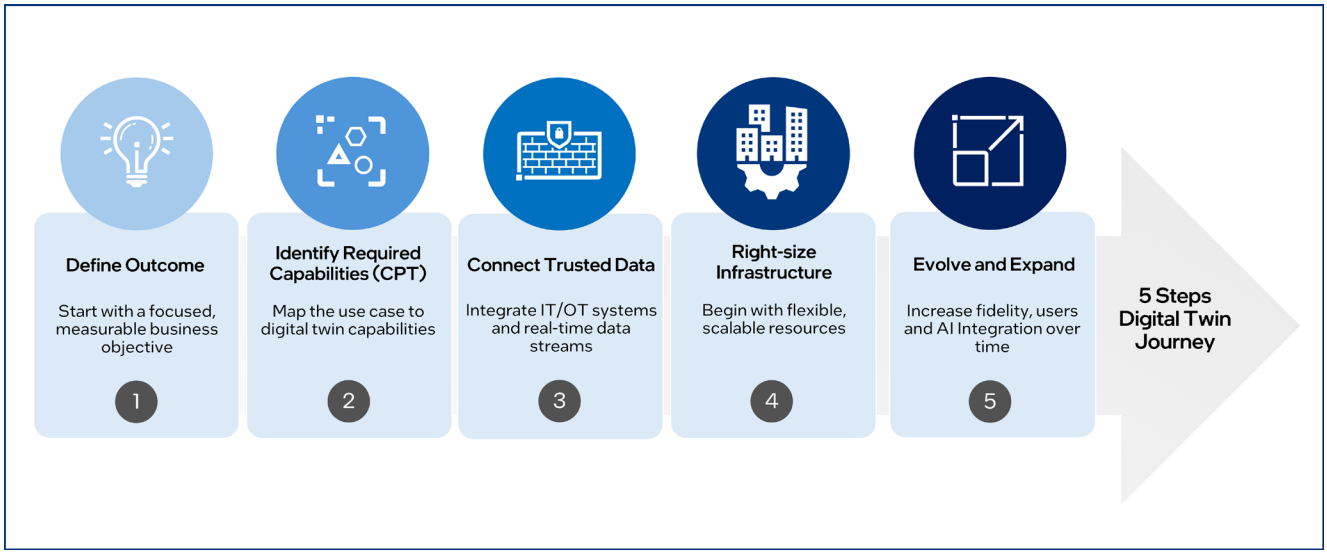


Figure 1: A Five-Step Digital Twin Journey

Establishing the right foundation is critical to ensuring digital twins remain reliable, responsive, and adaptable as operational complexity grows and new use cases emerge.

The Technology Foundation

Digital twins for critical infrastructure require a cohesive infrastructure foundation that supports real-time data ingestion, AI inference, simulation, visualization, and operator interaction across distributed environments.

Dell Technologies and Intel deliver this foundation by combining Dell infrastructure and platforms with Intel® technologies (CPU, AI accelerator, and GPU), together with a partner ecosystem of ISVs, integrators, and domain specialists. This joint technology foundation and ecosystem support digital twin deployments from edge-to-core, while scaling as operational requirements evolve and new use cases are introduced.

An Integrated Dell–Intel–Partner Ecosystem Architecture for Digital Twins

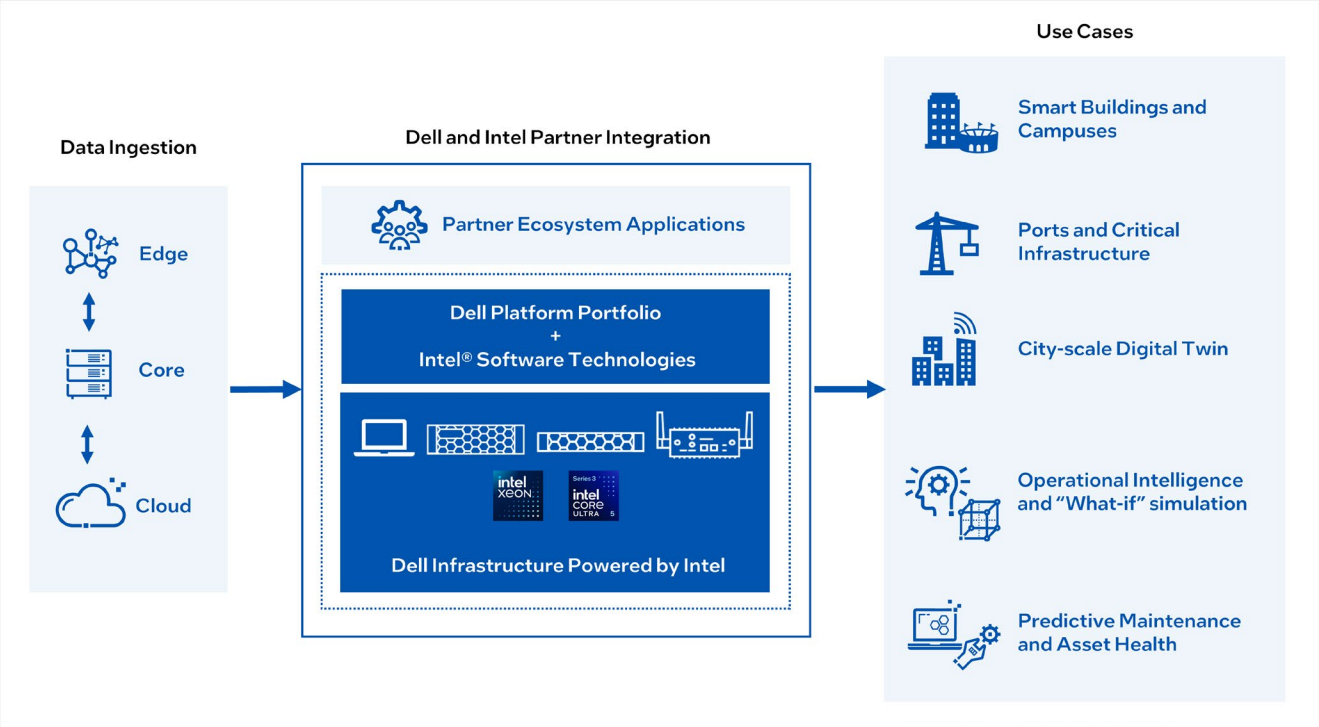


Figure 2: Digital Twin Ecosystem Architecture (Edge-to-Core)

Dell Infrastructure Powered by Intel

Compute – Dell PowerEdge with Intel® Xeon® Processor

At the core of the architecture are Dell PowerEdge servers powered by Intel® Xeon® processor:

- PowerEdge R-Series with Intel Xeon® processor delivers versatile, high-density compute for core and data-center–hosted twin services.
- PowerEdge XR-Series with Intel® Xeon® processor brings ruggedized, short-depth compute to the edge, placing digital-twin logic and analytics close to physical assets in the field.
- PowerEdge XE-Series with Intel® Xeon® processor provides accelerated, GPU-rich platforms for large-scale simulation and AI training/inference.

Intel® Xeon® processor servers provide the compute foundation for systems orchestration, enabling data ingestion, simulation coordination, security enforcement, and workload management, while supporting real-time analytics, 3D rendering, and AI workloads.

Together, these Intel® Xeon® processor–based PowerEdge platforms deliver consistent performance, enterprise-grade reliability, and long-lifecycle support from edge to core—allowing digital twins to operate near the assets they represent while remaining centrally managed.

AI Acceleration – Intel® Gaudi® Processor and Intel® GPUs

Digital twins rely on AI to analyze environmental status for event detection and situational awareness, predict conditions, optimize operations, and support real-time decision-making. The Dell–Intel foundation integrates purpose-built AI acceleration to efficiently support these workloads.

- Intel® Gaudi® processor AI accelerators support high-throughput AI training and large-scale inference for predictive maintenance and operational efficiency.
- Intel® GPUs accelerate AI inference, media analytics, and visualization, supporting video-driven and spatial workloads.

Integrated within PowerEdge platforms, Intel® Xeon® CPUs, Intel® Gaudi® accelerators, and Intel® GPUs form a heterogeneous compute architecture that applies to the right level of acceleration without fragmenting the infrastructure stack.

Data Storage — Dell PowerScale and ObjectScale

Digital twins generate continuous streams of real-time telemetry alongside growing volumes of historical data, simulation outputs, and AI models.

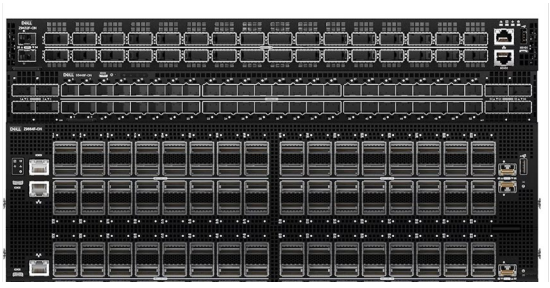
- Dell PowerScale delivers high-performance, scalable storage for analytics and AI models.
- Dell ObjectScale provides scalable, durable object storage for models and data.

By integrating tightly with compute and AI systems, Dell storage enables high-throughput data access for analytics and inference, persistent and governed model storage, and seamless scaling of capacity and performance as digital-twin deployments expand in scope, fidelity, and number of sites.

Cyber Resilience — Dell PowerProtect

Dell PowerProtect safeguards digital-twin and AI data with modern backup, recovery, and cyber-resilient protection across the edge, core, and cloud. It combines policy-based protection, space-efficient Intel-powered backup storage, and isolated cyber-recovery capabilities to keep critical operational and analytics data available, compliant, and rapidly recoverable as deployments scale.

Network Fabric — Dell Networking



Real-time digital twins depend on predictable, low-latency connectivity. Dell networking solutions deliver the bandwidth, security, and determinism required to connect endpoints, edge systems, and data centers.

This network fabric ensures consistent performance for time-sensitive workloads and secure data movement across operational and IT domains.

Endpoint Intelligence — Dell Pro 5 Micro

Digital twins are ultimately used and operated by people. Dell Pro 5 Micro Desktop, powered by Intel® processors, extends digital-twin intelligence to the endpoint.

The ultra-compact Dell Pro 5 Micro Desktop is well-suited for control-room consoles, operator dashboards, and kiosks, providing responsive client-side visualization and light local processing in space-constrained, always-on environments.

Dell Pro 5 Micro Desktop serves as the operator interface, securely connecting to back-end Dell infrastructure for real-time monitoring, status visualization, and interaction with digital-twin applications.

The Platform Layer

Dell Platform Portfolio

Infrastructure Orchestration A unified infrastructure orchestration layer that automates deployment and lifecycle operations across edge, core, and cloud to simplify, secure, and scale IT services.	
Dell Automation Platform	• Edge-to-core solution that simplifies infrastructure management and application orchestration. • Automates Day 0 and beyond operations to reduce manual effort. • Orchestrates applications and services across the full stack. • Helps maintain secure, agile city services with consistent policy control. • Dell Distributed Private Cloud enables zero-touch edge deployment and lifecycle management. • Dell Private Cloud delivers automated, secure private cloud operations.
AI and Data Platform An integrated AI and data layer that unifies compute, data pipelines, and AI software into a full-stack operations foundation for building, governing, and scaling digital-twin and AI solutions.	
Dell AI Factory	• Provides an end-to-end, full-stack foundation for building and operating digital twins. • Integrates hardware and software to support AI, analytics, and simulation workloads. • Enables on-premises execution close to operational and sensor data for lower latency. • Enhances data security, governance, and compliance by keeping data at the source. • Supports OT/IT use cases through validated architectures and reference designs. • Accelerates the design, deployment, and scaling of digital-twin and AI solutions.
Dell AI Data Platform	• Unifies compute, storage, data management, and AI-optimized software to turn data into actionable intelligence. • Simplifies and automates data pipelines for AI and analytics. • Delivers consistent operations across on-premises, hybrid, and multi-cloud environment. • Provides built-in security, scalability, and automation to operationalize AI faster, and reduce complexity. • Improves data accessibility and readiness for AI model development and inferencing. • Supports enterprise-grade data governance and trusted data sharing across domains.

Intel® Software Technologies

Open Edge Platform Provide foundational capabilities for digital twin creation, such as ingesting, processing, and analyzing video and sensor data; video analytics; video summarization; super-resolution; and bit rate optimization, to enhance visual fidelity and streaming efficiency.	
Spatial Intelligence and Situational Awareness	• Intel® SceneScape. • Enable data collection from diverse sources (e.g., IoT devices, sensors, cameras) to create real-time digital twins of facilities with spatial awareness. • Integrate AI to detect anomalies and track activity in real time. • SceneScape currently enables Intellias Digital Twin solution.
AI and Data Analytics Toolkits	• Open Edge Platform – Anomalib: Automates detection of unusual patterns, failures, or inefficiencies—enabling predictive maintenance and real-time malfunction alerts based on live data mirrored in the digital twin. • OpenVINO™ toolkit: Optimizes AI-driven video and sensor data processing, delivering real-time, scalable, and high-accuracy insights. • oneAPI: Optimizes AI workloads, provides a rendering toolkit for interactive virtualization, and includes the Math Kernel Library for accelerated simulation, numerical modeling, and environment analysis.
Metro AI Suite	• Metro AI Suite is an open AI software platform that provides industry-specific software development kits (SDKs), microservices, and sample applications for independent software vendors (ISVs), system integrators and solution builders to accelerate scalable smart city and critical infrastructure AI solutions. • Includes blueprint for digital twin for smart buildings. • Includes blueprint for agentic AI pipeline for critical infrastructure predictive maintenance. • Provide enablers secure deployment for platform security and application security.
Geti™	• Train AI Models Leveraging publicly available data with annotation for critical infrastructure data (e.g., bridges and water utilities). • Train AI Models using the provided data sample from the field and annotation.
Digital Twin Solution	
Intel® Factory Recon	• Support dynamic, real-time digital twins of factory production equipment and automated material handling systems. • Offer immersive 3D visualization, live monitoring, historical playback, troubleshooting, and scenario simulation. • Enable Sony Digital Twin Solution for factory automation. • Core capabilities—real-time visualization, asset tracking, event playback, and "what-if" scenario simulation—could conceptually be adapted for smart building digital twins.

Partner Ecosystem Applications

Partner platforms form the intelligence and application layer that turns the Dell-Intel technology foundation into a living, operational digital twin. They integrate OT, IT, and IoT data into a live contextual model of the environment and then run simulation and forecasting on that model to test scenarios (such as demand spikes, weather events, or asset failures) before changes touch the real world. Using agentic AI, they translate these insights into explainable, closed-loop actions that operators can supervise or automate, completing the Monitor, Predict, Simulate, and Control cycle and enabling faster decisions and rehearsed responses.

Within this layer, partner ecosystem applications add domain-specific capabilities (such as building management, crowd analytics, energy optimization, and safety and security) on top of the shared Dell-Intel foundation. ISVs, SIs, and OT partners use common data, AI, and simulation services to deliver industry-specific workflows, "what-if" scenarios, and closed-loop playbooks for airports, stadiums, smart buildings, and other critical infrastructure, driving measurable gains in efficiency, sustainability, and occupant experience.

In real-world deployments, these partner-led solutions have already created measurable impact in domains such as airport operations and smart buildings, improving operational efficiency, sustainability, and occupant experience.

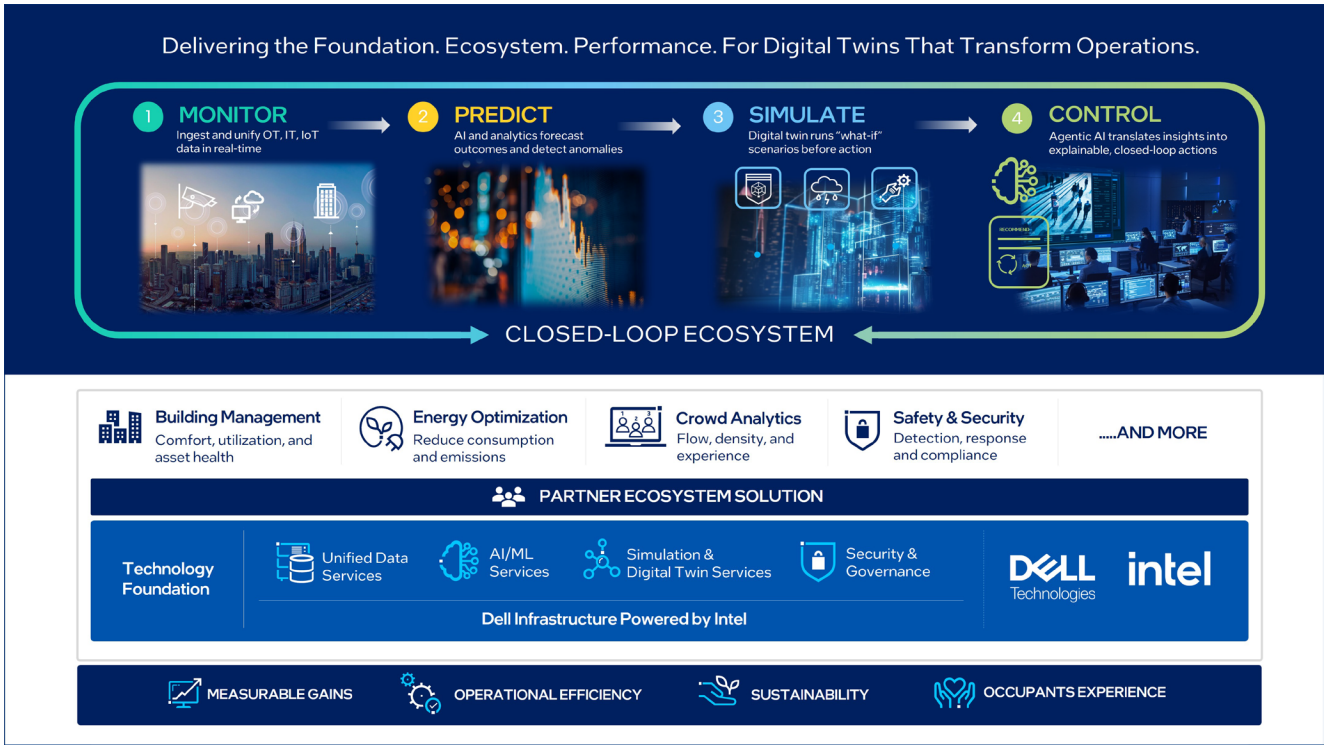


Figure 3: Partner Ecosystem Applications Enabling AI-Driven Digital Twin Operations

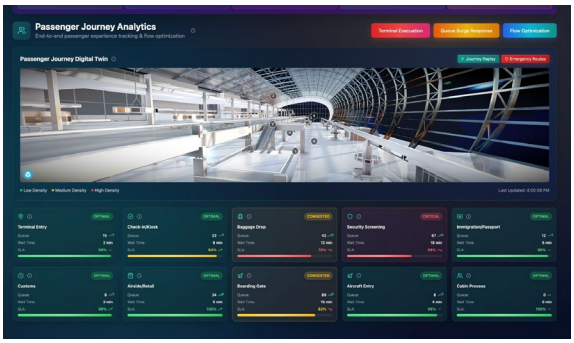
Real-World Impact: Airport Digital Twin for Critical Infrastructure

The Challenges

- **Unpredictable passenger flow and congestion**
  Across check-in, security, immigration, retail, and boarding, leading to long queues, missed connections, and stressed passengers, with no way to anticipate tomorrow's peaks.
- **Inability to pre-test operational changes**
  New security-lane layouts, gate-assignment rules, check-in configs, HVAC setpoints, must be trialed directly on the live terminal, creating rollback risk and passenger disruption.
- **Reactive disruption management**
  Diversions, severe weather, evacuations, and VIP movements are neither forecast in advance nor rehearsed in a virtual environment.
- **Inability to proactively optimize experience and revenue**
  Dwell times, wayfinding, and retail engagement remain suboptimal because passenger demand and behavior are not continuously predicted and fed back into closed-loop actions.

The Solutions

Astrikos addresses these challenges with S!aP (Smart Interop Analytical Platform) and its Astriverse digital twin—a live replica of the airport unifying CCTV, FIDS, BMS, and airside data to forecast demand, rehearse disruptions, pre-test changes, and deliver closed-loop actions through its agentic AI, S!aP. Running on Dell PowerEdge servers with Intel® Xeon® processors and Intel® AI acceleration, it shifts airport operations from reactive to adaptive at scale.



The Impact

- Shorter queues and smoother flows from curb to gate.
- Higher passenger satisfaction and retail spending through better dwell-time management.
- Fewer missed connections and delays through real-time alerts and predictions.
- Proactive disruption management (for example, lane closures, late arrivals, weather events).

An AI-powered digital twin gives airport operators an end-to-end view of passengers, assets, and operations so they can continuously optimize the journey from curb to gate.

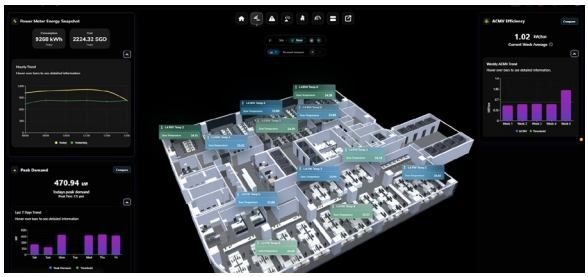
Real-World Impact: Smart Buildings Digital Twins for Critical Infrastructure

The Challenges

- **Fragmented systems and data silos**
  Systems are not connected, so there is no single source of truth, leading to conflicting data, inefficiency, higher costs, and risk.
- **High and opaque energy use**
  Limited visibility makes it difficult to understand where energy and resources are wasted, resulting in higher costs and inefficient building performance.
- **Manual, reactive operations with high truck rolls**
  Operations rely on manual processes, leading to slow, reactive responses and requiring on-site work for changes, fixes, and maintenance activities.
- **Inconsistent security and compliance at the edge**
  Devices are distributed and lack consistent control, making it hard to secure, manage, and maintain compliance across the environment.

The Solutions

SSI addresses these challenges by transforming buildings into high-performance, low-risk assets with outcomes that are continuously verified, optimized, and monetized. At the core is IVIVA, the AI-powered Smart Building & Precinct Platform, integrating Command & Control and Digital Twin capabilities to deliver real-time, lifecycle management.



Deployed on enterprise-grade Dell infrastructure powered by Intel® technologies, the IVIVA platform enables:

- Real-time operational intelligence across all building systems.
- End-to-end lifecycle management from design and commissioning through to operations.
- Continuous, AI-driven optimization of energy, performance, and occupant experience.

The Impact

- From **Visibility** → **Insights**. Enables faster, better decisions.
- From **Waste** → **Optimization**. Reduces energy consumption, emissions, and resource utilization, supporting Net Zero goals.
- From **Manual** → **Autonomous**. Centralized, zero-touch operations reduce truck rolls, accelerate fixes, and improve service efficiency.
- From **Risk** → **Control**. Standardized control of edge devices, systems and processes ensures stronger security, governance, and compliance.

An AI-powered digital twin gives city and building operators an end-to-end view of infrastructure, assets, and services so they can continuously optimize performance, resilience, and sustainability at scale.

Looking Ahead

Digital twins for critical infrastructure are not new, but their role is rapidly evolving. What began as static models and visualization tools is now being transformed by advances in AI, GenAI, Agentic AI, LLMs and VLMs, enabling digital twins to ingest live telemetry, understand operational context, and continuously learn how systems behave. This shift marks a move from descriptive insight to proactive, decision-driven operations that can improve how critical assets are managed.

Dell Technologies and Intel are laying the groundwork for that shift. A consistent edge-to-core fabric—anchored by Dell servers and storage, and high-performance Intel® platforms with GPU acceleration—paired with open AI toolkits creates the conditions for richer models, faster simulations, and more precise recommendations, with distributed deployment where they are needed, from substation to control room to cloud. Validated designs and reference architectures built on this infrastructure help organizations move with confidence from single-site pilots to portfolio-wide and city-scale rollouts.

For operators, this means evolving from "seeing what happened" to predicting what will happen, testing what could happen, and deciding what should happen before issues escalate. For the communities that depend on these systems, it means infrastructure that quietly becomes more efficient, more secure, and more sustainable over time.

Together, Dell Technologies and Intel are engineering the digital-twin foundation for how critical infrastructure is planned, operated, and evolved in the years ahead.

Learn More
Video & AI Cities Communities

Next Step
Contact: cities@intel.com

Sources:

[1] Digital Twin Consortium, "Digital Twin Capabilities Periodic Table," *Digital Twin Consortium*. [Online]. Available: https://www.digitaltwinconsortium.org/initiatives/capabilities-periodic-table/. Accessed: Jul. 9, 2026.

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