# The Digital Twin and the Smart Enterprise

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Across the globe, leading organizations are already embracing and implementing advanced digital technologies. Now the exciting questions are: how far can we extend these possibilities, and do these enterprises have the vision and organizational excellence to take advantage of the new economic opportunities?

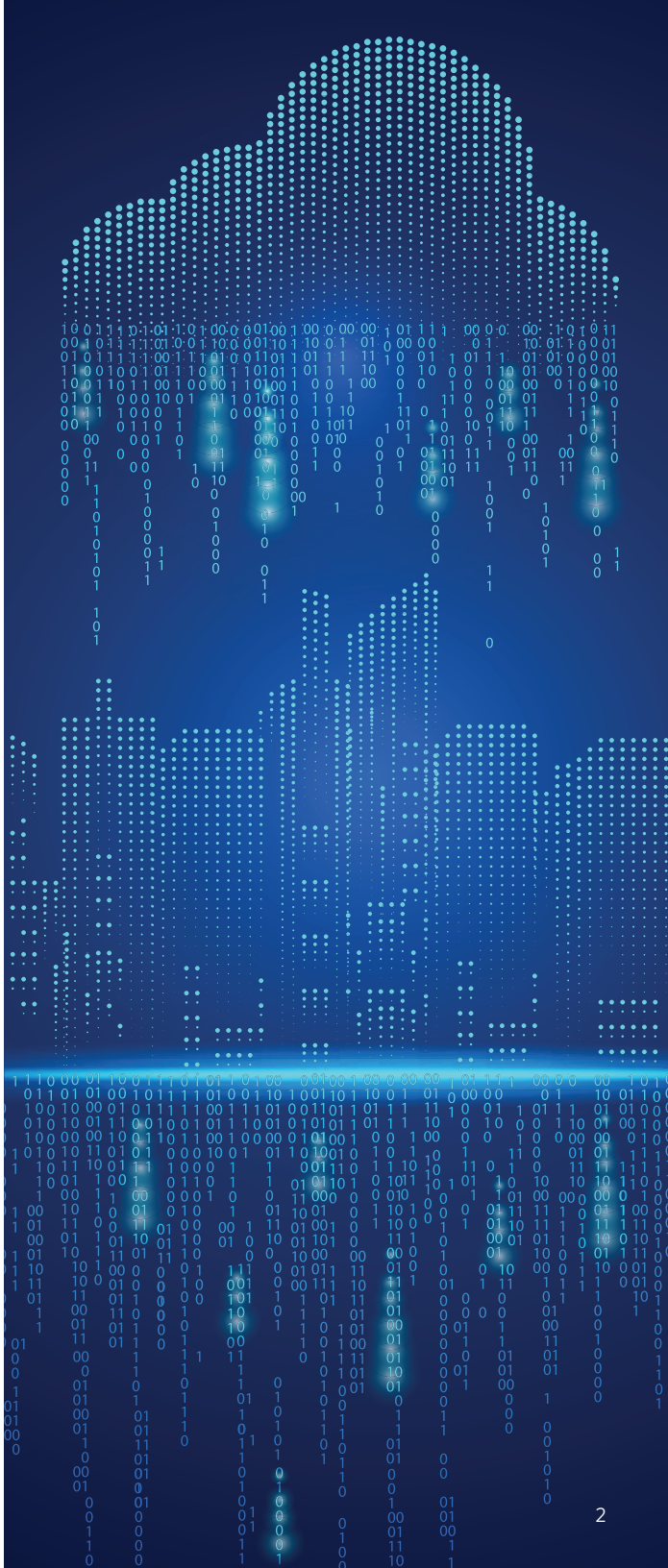
To transition from business-as-usual to digital-enabled, capital-intensive businesses need to transform their industrial facilities and value chains into a system of smart, self-optimizing, interconnected semi-autonomous assets — thereby unlocking higher levels of operational performance, agility and profitable growth while also enabling creation of critical new business models.

The digital transformation journey will change the nature of asset intensive industries, particularly the energy and chemicals businesses. In that context, **digital twins** — virtualized copies of physical assets and their operating behaviors — will play key roles. They will also fundamentally change how humans work, interacting with intelligent systems, and virtual models ("twins"); to examine alterative actions, predict future consequences, and making strategic decisions faster to achieve business objectives amidst complexity.

## *But what exactly is a digital twin and how will it evolve?*

AspenTech believes your enterprise should define "digital twins" broadly. The business impacts of any digital twins will be much bigger and broader than analysts and consultants forecast today.  Today, the digital twin is the essential tool to optimize business performance, to be agile, to maximize sustainability while retaining profit, and to optimize all capital-intensive assets. The importance and impact of digital twins will increase in the future.

Digital twins are a valuable **model of the physical asset, its behavior and performance**, so technicians can safely explore what-if scenarios without putting people or the asset at risk. It provides a valuable **model of asset health**, forecasting and recommending action to avoid degradation and asset failure events. Perhaps most important, digital twins



incorporate **business models** representing scenarios for product creation, operations, supply chain, trading, effective asset utilization, risk, customer satisfaction, and profit.

The possibilities of a broad virtual environment, driven by data and powered by AI, were first envisioned in fiction — notably, William Gibson's landmark treatise, ***Neuromancer.*** Where yesterday, technologies could not support those visions, today the technological solutions exist. Leading companies are succeeding with virtual environments. The broader industry seeks to understand where to invest and how to transform their businesses to provide their workforces with the intelligent advice that digital twins offers.

In today's VUCA (volatile, uncertain, complex and ambiguous) business world, the complexity of tradeoffs between profit, sustainability, quality and the like, sheer quantities of information, and need for agility and scenario development make a digital twin strategy and implementation plan crucial for the asset intensive business. The future connected worker and executive will take operational agility and effectiveness to new levels.

## Definition

The digital twin is an evolving digital profile of the historical, current and future behavior of a physical object or process that helps optimize business performance.

It is based on models and real-time data across multiple dimensions, including business performance, asset planning, the physical asset, equipment condition and reliability, chemical process performance, safety and risk, energy and sustainability, project timespans and more.

The digital twin creates an evolving profile of the object or process that provides insights on system performance, guiding actions in the physical world such as changes in process design, operation, safety and maintenance. The digital twin may be updated in real time or periodically, taking advantage of asset data to stay up to date, and increasingly made intelligent by AI agents.

# Scope

In an asset-intensive business, the digital twin needs to encompass the entire asset lifecycle and value chain from design and operations through maintenance and strategic business planning. AspenTech solutions for digital twins span 13 different modeling and analytics domains across the "whole plant digital twin," the "operational excellence digital twin," and the "operational integrity digital twin."

AspenTech is uniquely positioned to provide solutions comprising technologies that span the entire asset lifecycle, vertically integrated production and the end-to-end value chain, both through these digital twin domains and through integration across them.

**The plant digital twin:** The process plant, modeled rigorously using engineering models and enhanced by AI techniques with embedded cost and risk models. They are deployed offline and online, calibrated to plant operating conditions through autonomous model tuning. Used for equipment monitoring, operator "open-loop" advice or autonomous optimization, the scope may range from a single piece


**Figure 1:** Breadth of the digital twin

of equipment to unit operations (such as catalytic cracking), plant-wide (such as energy and utility systems), or enterprise wide (such as risk models encompassing multiple plants and sites). They can be simulated dynamically to provide operator training.

**The operational excellence digital twin:**
Plant operations, from a business level to a control level, modeled and virtually viewed as planning, scheduling, control and utility models. Such digital twins inform business decisions such as crude selections and products trading; as well as technical decision making, like optimizing quality, throughput, energy use, emissions compliance and safety.

**The operational integrity digital twin:**
This digital twin can provide guidance on both tactical and strategic decisions around prescriptive maintenance, offering real-time recommendations to maximize uptime, adjust production to deal with failing equipment, minimize environmental impacts, mitigate production losses and prioritize safety. In addition, quality and risk assessment provide a future view of equipment and asset health, risk profiles and root cause of failures to improve uptime and operational integrity. Here too, the scope ranges from a single piece of equipment, a single process unit, plant-wide or enterprise wide.

# Architecture

AspenTech's digital reference architecture helps companies to structure, organize and prioritize their digital twin implementations in a manner that supports collaboration and integration across business functions, supporting production optimization, value chain optimization, performance engineering and asset performance management.


**Figure 2:** Asset Optimization Digital Reference Architecture from AspenTech. This is a blueprint both for customers and for AspenTech innovation R&D. This digital reference architecture aligns with the breadth of AspenTech's digital twin solution (pictured on page 4). The left-hand boxes in the image above represent the plant digital twin, the center boxes represent the operational excellence digital twin and the right-hand boxes correspond to the operational integrity digital twin.

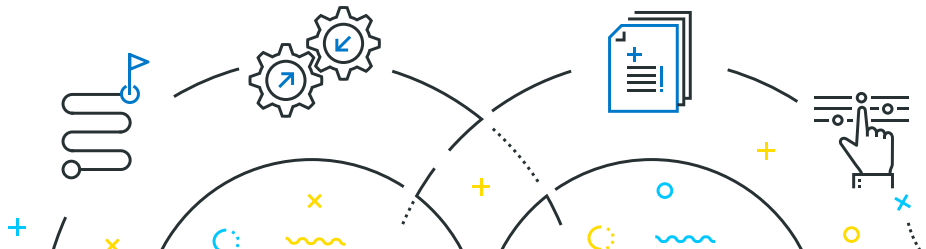
# Types of Digital Twin Models

There are several optimization paradigms relating to a process manufacturing environment. Each organization must define a scope for developing digital twins based on its business processes, their interactions and the enterprise's value drivers. Businesses must also establish creation and maintenance plans for each digital twin. An organization will prioritize where to first make digital copies of the enterprise based on their value. From a practical viewpoint, then, there will be multiple digital twin implementations. They will eventually connect and combine and become more intelligent. We see AI as a key enabler to make sense of the information in the multiple digital models for decision-making tasks and to present the information to people in a digestible way.

### *Plant Digital Twin*

**Process models:** rigorous process simulation models provide an accurate representation of chemical processes. Rigorous first principles models are always more accurate when the chemistry and physics are known and the model calibrated against the plant operation. Machine learning and deep AI have key roles to play for complex processes as operations change unit behavior. Emerging AspenTech hybrid models employ the best of both methods, applying both (first principles and AI), further improving fidelity. Dynamic what-if models are crucial operational tools to ensure both process safety and effective operator training to minimize human error. Additionally, advanced data analytics form the basis of empirical process unit models, using multivariate analysis that can simulate and optimize chemical process quality.

**Asset:** Asset models represent the functional elements of an asset, the physical instances, and the connectivity in terms of process flows, physical connections and associated infrastructure. In addition to 3D physical models (provided through integration with Hexagon PPM), asset data includes operating procedures such as data sheets and recipes; logical connectivity, such as process flow diagrams (PFD) and piping and instrumentation diagrams (P&IDs).



**Project:** Time and cost can be considered the digital twin's fourth and fifth dimensions. Digital twin models that effectively represent and simulate the design, resources, timing and costs of project execution are crucial to achieving minimum CAPEX and maximum lifetime value. Visualization and autonomous ad hoc workflows provide a ground-breaking approach to applying machine learning to project digital twins in ways that give project workers insight into their complexity.

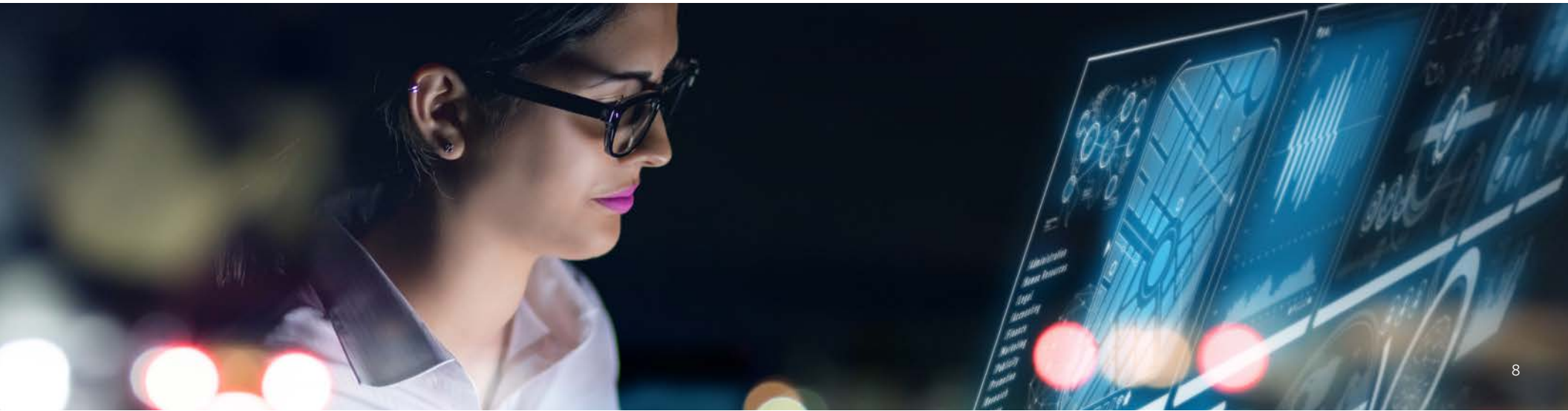
**Risk, Cost and Economics:** Risk and cost models together examine the asset and enterprise as a connected, constrained system to identify the biggest process, safety and economic risks, predict costs, and identify the optimal way to invest available capital.

**Safety:** Safety models look to minimize process safety incidents across an asset by modeling all aspects of a system, both process and physical, enabling analysis of worst-case scenarios and development of emergency response strategies, both accessible, and updatable in the most agile manner.

### *Operational Digital Twin*

**Planning and Scheduling:** Planning and scheduling models are extremely powerful drivers of value in refining, bulk chemicals, specialty chemicals, metals and mining and related businesses. Going far beyond spreadsheets, planning digital twins can evaluate many scenarios rapidly and optimize across the supply chain network of assets and/or for specific sites. They further improve upon spreadsheets and manual approaches by providing the automated workflow to tie together the process and planning models, optimizing plans across multiple objectives and increasing planning accuracy, operational fidelity, and consequently margin capture.

**Demand:** Demand models are used in collaborative demand planning and management business processes and are key inputs to digital twin planning, scheduling and distribution models in refining, bulk chemicals, specialty chemicals and related businesses. This provides a robust process which helps manufacturers better anticipate customers and their markets' future demand. Advanced demand models use demand segmentation capabilities to identify patterns that can be forecast based on data and higher-level human input.



Optimal forecast method selection capabilities allow the tool to determine the best forecasting method.

**Distribution:** Distribution models schedule movement of products from a source location to an intermediate plant or warehouse for further processing and/or storage, as well as to customers to ensure that materials are in the right place at the right time. Distribution models can use optimization to determine where to ship inventory when supply is constrained based on demand prioritization criteria such as confirmed/unconfirmed customer orders, company internal requirements, forecasts and safety stocks.

**Energy Demand and Supply:** Energy models are used to optimize supply and demand for energy intensive assets, such as those in refining, bulk chemicals, fertilizers and metals refining. These models can identify opportunities to reduce carbon footprint; visualization dashboards depict the impact of every operating decision on an asset's energy intensity.

**Control/Optimization:** Control and dynamic asset optimization models employ state-of-the-art self-learning and self-healing (including conventional and AI methods) advanced process control (APC) technology and dynamic optimization, providing closed loop optimization and operating advice to run assets closer to their economic and technical limits autonomously. Integrated digital twins combine process models for what-if and APC models to achieve maximum value.

### *Operational Integrity Digital Twin*

**Asset Condition:** Data streams from physical and process data feed, with associated machine-learning prescriptive maintenance tools, provide an asset condition digital twin, forecasting process, equipment, and environmental anomalies and diagnosing the reasons and preventative measures available. AI is employed to process the massive streams of data required to make these models feasible. Some integrate with planning and scheduling to identify operating adjustments to minimize impacts of equipment repair and/or failure.


**Sustainability:** Water and utility models of the asset implemented online show the minute-to-minute and long-term sustainability metrics of the enterprise and individual assets, incorporating water use, utility choices, energy use and cost, and emissions such as flaring and SOX and NOX capture. Combined with process models they provide a fuller picture of sustainability performance.

## How Many Digital Twins?

LNS Research has interviewed many companies and analyzed the digital twins required to model the operations of a typical refinery completely. LNS conservatively estimates over 1,000 digital twin models could exist for a single such asset. A company can build digital twins to match its market, operational strategy, and return-on-capital requirements — an evolving subset of the universe of possibilities. Clearly, companies would not construct all of these, though the best digital twins will emphasize ease of creation and maintenance.

The most fruitful implementation strategy will determine the scope and domain of digital twin solutions that will address crucial business needs to attain early wins. The focus may be a quality or customer supply challenge, a reliability and uptime challenge or a water or energy use sustainability imperative, for example. The areas to focus on first must be low-hanging fruit, proving effectiveness with short-term achievable value in areas like equipment uptime, yield optimization, energy minimization and planning.

### Toward an Integrated Digital Twin

Today, practical digital twins for an asset or enterprise begin by defining a scope that solves a meaningful and measurable business problem, such as a safety or sustainability concern or a source of margin leakage. Tomorrow, the pace of technological innovation may enable a larger scope, combined digital twin.

AspenTech has already integrated several key digital twin areas and made progress with a concept we call model alliance to bring together models along the road to autonomous systems that learn about asset behavior

and improve the increasingly sophisticated virtual copies. A visualization and automated execution layer combines the information from the digital twins into actionable insights for operations, safety and capital decision-making.

**Sharing Across Enterprises**

Most leaders consider digital twins within the scope of one enterprise. Beyond that, digital twins offer strategic bridges linking organizations to achieve new levels of business collaboration and agility. Across the asset lifecycle, crossing the boundaries between designers, technology suppliers, contractors, fabricators and asset owners delivers huge productivity and CAPEX benefits.

Tools such as Aspen Enterprise Insights, which introduced visualization and actionable work flows, provide crucial ways to achieve this cross-enterprise efficiency and agility without violating the security of an individual enterprise's data and intellectual property. Data, machine learning agents, and AI all can be shared across enterprises, subject to business and commercial boundary protections.

## Scale of the Digital Twin

When an organization considers the future smart enterprise, smart asset and the underlying digital twins, leaders should consider the scale of digital twins that will provide the best value. Starting from detailed and small to large and enterprise-wide, there are several levels to evaluate. Digital twins of larger scale and higher precision cost more to create today.

**Equipment level:** These reveal equipment's current, future and historical performance. Examples where the equipment level becomes a first priority include hyper-compressors (high economic cost of failure), large pumps and compressors (high cost of spare parts and maintenance), heat exchangers (impact on yield) and so forth.

**Unit level:** A process asset's economic value is typically created at the unit level. Unit level models such as cracking, olefins reactors and chemical distillation are often extremely high-value high return areas for digital twins involving process, asset condition, control and optimization.

**Plant level:** Plant level digital twins provide a digital representation of a plant, several plants or entire site; they may cover a subset of the systems involved. Energy, refinery and bulk chemical planning and specialty chemical scheduling are optimized to improve economics at this level.

**Enterprise level:** Enterprise level digital twins are an important emerging area. Such models enable rapid analysis of enterprise profit opportunities and effectively present actionable information to the executive level. Examples include enterprise risk models, combined scheduling and supply chain models, or multi-asset planning models to optimize utilization of a network of plants, transportation and storage facilities for maximum profit and customer satisfaction.

## Value of the Digital Twin to Successful Business

Digital twins are essential for creating future business value. Success occurs when razor-sharp focus matches digitalization technology adoption to where value can be created. Here are some real-world examples:

**Upstream Yield:** YPFB Andina, the Bolivian upstream company, constructed an asset-wide digital twin model of its gas wells, gas gathering, and gas production and transportation network (based on Aspen HYSYS and Aspen MES) achieving increases in production and revenues of $208 million US dollars per year over 3 years.

**Uptime:** A major U.S.-based international refiner adopted machine learning digital twins to improve refinery and petrochemical uptime and margins. The company embarked on a one-year test of prescriptive maintenance tools for improved uptime and margins. They saved tens of million dollars during an initial test year through avoided pump failures and are now expanding the solution globally.

**Energy and Water Sustainability:** Abu Dhabi National Oil Company (ADNOC), using the digital twin consulting company, Equinox, constructed an asset-wide digital twin, comprising several hundred wells, Abu Dhabi's largest gas plant (GOSP) and multiple models covering energy, utility, and production, with a visualization dashboard. The dashboard provided all operation personnel visibility into asset metrics around water use, energy use and hydrocarbon loss. The result: Better decisions and attained sustainability milestones.

**Order Fulfilment and Working Capital:** Specialty chemical producer Momentive optimizes their supply chain daily by using AspenTech's high-fidelity production and stock transfer scheduling solution as a digital twin. This technology allows Momentive to prioritize demands across key constraints and costs. Inventory at multiple sites dropped 25% while simultaneously improving on-time in-full (OTIF) order fulfilment metrics by 20 points, together with a 40% decrease in supply lead time.[i]

**Quality:** A polymer producer faced with routine out-of-spec batches implemented multivariate data analytics to monitor and analyze over 80 process variables, identifying the variables and associated process operating strategies that replicate good batches and minimize wasted products. The multivariate analysis-based digital twin approach is strategic for a wide range of specialty chemical applications where product quality is key and often problematic.

## Where Does the Digital Twin Reside?

Whether digital twins are hosted locally in an asset production stack, behind a firewall, or in the cloud is an individual asset and enterprise decision. Each aspect of the digital twin for the asset intensive enterprise we've described can be local, cloud deployed (and there are multiple cloud permutations) or some hybrid approach. The decision process for an organization is not about digital twin functionality, but about considerations such as infrastructure and deployment cost and resources, business model agility, information and advisory latency, and other key factors such as cyber security.

# The Future

### *Why a Digital Twin? Fact and Fiction*

A few years ago, a digital twin was a nice to have future idea. Today it is an essential part of any enterprise digital transformation strategy.

Sci-fi author William Gibson was prescient in forecasting and envisioning the massive value and power that the digital twin enables. That vision is instructive, because it shows the virtual copy of real enterprises as far more than a 3D visualization or view; Gibson presents the copy as an insightful way to harness the value of data. In his work, AI plays a crucial role in helping humans gain insight into massive amounts of confusing multi-dimensional data.

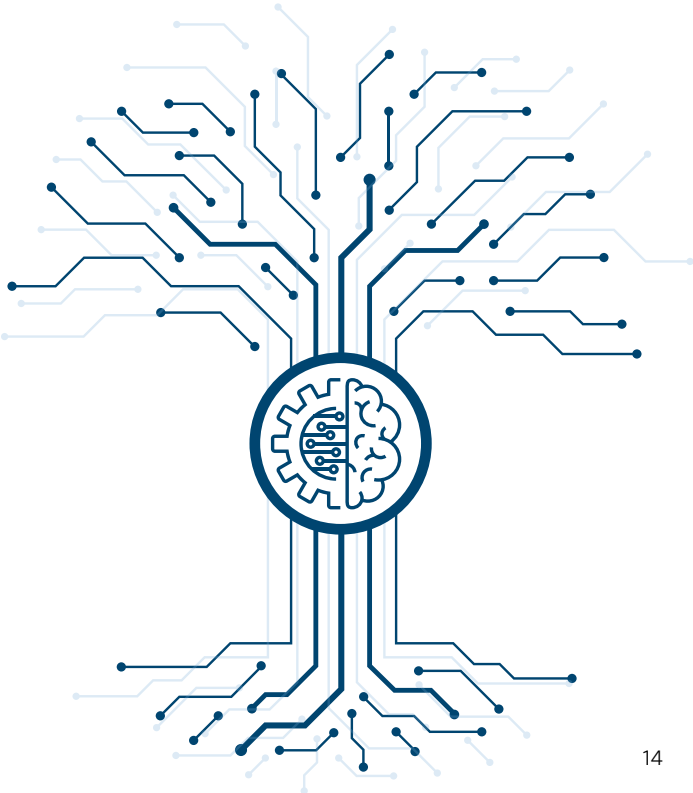
For the digital twins we can create today for enterprises, a key concept is the power of AI in providing insight and advice against the virtual data. Hanson Robotics' high profile and controversial "Sophia" AI robot has put further spotlight on the opportunities for AI. The progress of that AI platform in the past few years highlights the opportunities.

One may take away two important learnings from that seminal fictional preview and the thought-provoking Sophia robot/AI platform. First, the future value of the digital twin to your enterprise may be broader than you can envision when you commission the first applications. Expect a fast rate of change.

Second, the nature of work and how people interact with enterprise data will change. Consequently, focus on how to visualize that data, and how to help the organization to adapt are extremely important.

As you invest in digital twins, it is crucial to envision how this will help your business out-flank your competition. Also, it will be crucial to understand that the digital twin concept, as a key part of digital transformation, is as much about organizational change and evolution as about implementation of technology. Organizational adaption, enthusiasm and readiness must be supported daily. Finally, recognize that business value creation drives the technology and not the opposite way around.

AspenTech's broad scope, depth and scale of digital twin models are creating strong business value in asset intensive industries. We plan to continue along an aggressive path of merging data, analytics, rigorous models, AI, and deep domain expertise to innovate rapidly and maintain a leadership position in enabling industry to achieve the smart enterprise. AspenTech is positioned to be the technology partner who will best help you navigate an accelerating rate of uncertainty and change, evolving from the today's reliable systems to the future's even more capable, powerful, adaptive and smart technology.



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## About Aspen Technology

Aspen Technology (AspenTech) is a leading software supplier for optimizing asset performance. Our products thrive in complex, industrial environments where it is critical to optimize the asset design, operation and maintenance lifecycle. AspenTech uniquely combines decades of process modeling expertise with machine learning. Our purpose-built software platform automates knowledge work and builds sustainable competitive advantage by delivering high returns over the entire asset lifecycle. As a result, companies in capital-intensive industries can maximize uptime and push the limits of performance, running their assets safer, greener, longer and faster. Visit AspenTech.com to find out more.

**www.aspentech.com**

**Work Cited:** "Momentive Boosts Customer Service and Profitability with Detailed Scheduling and Finite Capacity Optimization." Michael Reifer (SIOP Center of Excellence Leader) and Aaron Hunt (SCM Senior Technical Manager), on-demand webinar, 2018.