Next Generation Manufacturing Systems Architecture

Flexibility. Scalability. Intelligence.

How manufacturing systems need to evolve to support manufacturer's transformation toward data-driven adaptive operations.

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Accenture Industry X

Introduction

After nearly a decade since they were first introduced, the concepts of Industry 4.0 are now clear to most manufacturing leaders.

Based on Accenture research,[1] most have launched pilots to validate the potential of harnessing data and advanced analytics to improve their operations, and the most advanced have charted roadmaps to adaptive operations (see figure 1 on the next page).

However, there is still uncertainty around existing manufacturing systems architecture, emerging technology and their ability to support these roadmaps and the deployment at scale of the related use cases.

1. https://www.accenture.com/_acnmedia/PDF-139/Accenture-The-Race-for-Digital-Operations-Transformation.pdf
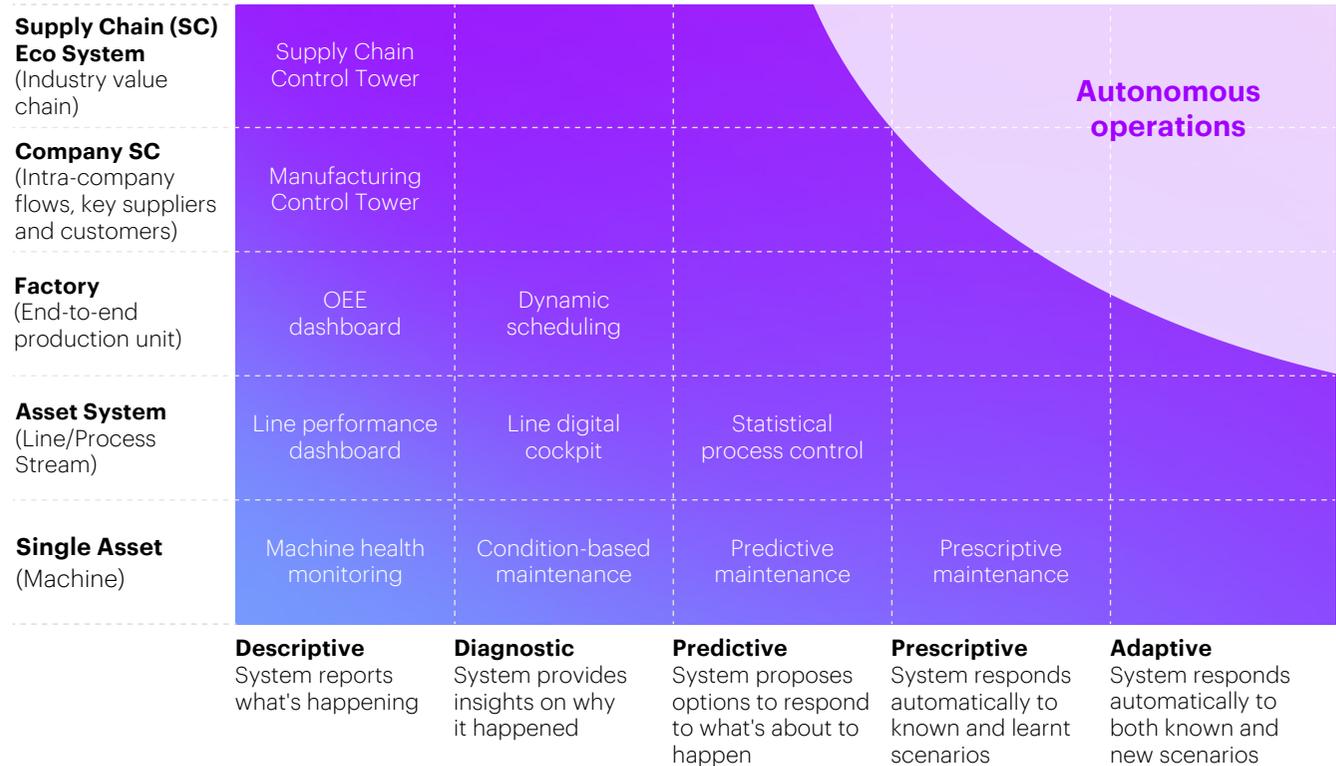
Use cases such as predictive maintenance or vision-based in-line inspection are relatively well understood. Software providers ranging from specialized start-ups to large, established software vendors sell specific niche solutions for such use cases.

However, as manufacturers strive to progress further and faster toward end-to-end adaptive operations, they face common challenges:

1. **The siloed nature of traditional manufacturing architectures doesn't support the tackling of the highest value use cases, which often require reaching beyond individual assets or lines and beyond one single function, like maintenance or quality.**

2. **The related solutions require the handling of vast amounts of data, which often exceeds the specs for existing architectures.**

As they try to tackle these high-value and high-complexity use cases, manufacturers are reaching the limits of traditional manufacturing IT architectures that are often built around functional silos: operations/Manufacturing Execution Systems (MES), quality/Laboratory Information Systems (LIMS) and maintenance/Enterprise Asset Management (EAM), etc.

Figure 1: Proper use of data and artificial intelligence (AI) helps manufacturers achieve end-to-end adaptive operations

	Descriptive System reports what's happening	Diagnostic System provides insights on why it happened	Predictive System proposes options to respond to what's about to happen	Prescriptive System responds automatically to known and learnt scenarios	Adaptive System responds automatically to both known and new scenarios
Supply Chain (SC) Eco System (Industry value chain)	Supply Chain Control Tower				
Company SC (Intra-company flows, key suppliers and customers)	Manufacturing Control Tower			**Autonomous operations**	
Factory (End-to-end production unit)	OEE dashboard	Dynamic scheduling			
Asset System (Line/Process Stream)	Line performance dashboard	Line digital cockpit	Statistical process control		
Single Asset (Machine)	Machine health monitoring	Condition-based maintenance	Predictive maintenance	Prescriptive maintenance	

■ Current capabilities*　　■ Aspirational capabilities*

* Illustrative, based on typical maturity level of a large number of consumer goods sites in North America

To overcome these limitations, manufacturing CIOs have started investing in data lakes to gather all manufacturing data into a single repository. Having all data in one place represents real progress when compared with the still common approach of managing data in separate silos or even spreadsheets. However, it falls short of providing engineers and operators with the structured information and tools they need to improve end-to-end operations.

And that shortcoming explains why the concept of digital twins is receiving more and more attention from manufacturing leaders. At the core of the digital twin is its ability to bring data together from multiple sources, unify and contextualize it. This provides a 'one-stop-shop' for applications that can utilize this contextualized data repository for a variety of use cases.

As a result, digital twins enable users to go beyond generating reports based on historical data in predefined silos and instead bring all data together, in context, to enable use cases such as simulation and predictive/adaptive intelligence at scale.

As manufacturers explore the possibilities enabled by digital twins, we're often hearing three main questions:

1 Why is a digital twin a game changer, and what additional value will it provide beyond what's possible with MES-centric manufacturing operations architectures?

2 Can we leverage digital twins without having to replace all underlying solutions, driving faster time to value at a much lower cost?

3 How are MES vendors positioning themselves vs. the major cloud platforms and Internet of Things (IoT) players?

This paper aims to answer these questions. We'll explore how and why current manufacturing systems both can and should remain in place to continue delivering the value they bring today. And we'll show how digital twins will complement those systems, first to deliver the full value of manufacturing data, and ultimately to accelerate manufacturers' evolution toward adaptive operations.

1. Why are digital twins a game changer?

# The difference between data and knowledge is context.

A temperature sensor reporting 75 degrees Fahrenheit is meaningless unless its context is understood: The sensor is on the extrusion line; it produces this type or variant of product according to this recipe, which has this historical efficiency, quality track record and so on.

A well-implemented control system, e.g., Supervisory Control and Data Acquisition (SCADA)/MES solution, has all this information and can be configured to raise an alarm or alert if the sensor data deviates from the defined thresholds. In fact, given the data in these systems, a SCADA or MES solution could be considered an isolated digital twin. But to improve their response to a production event on the line, engineers (or tomorrow algorithms) will need to understand additional context, such as the line's maintenance history and what product version is being made. It's also possible that the most important information about maintenance might be contained in unstructured reports or pictures.

It's this context of highly heterogeneous information that is the challenge for traditional siloed manufacturing systems architectures and their point-to-point integration. In contrast, a digital twin — based on a flexible and scalable structure — allows information to be captured and relationships mapped.
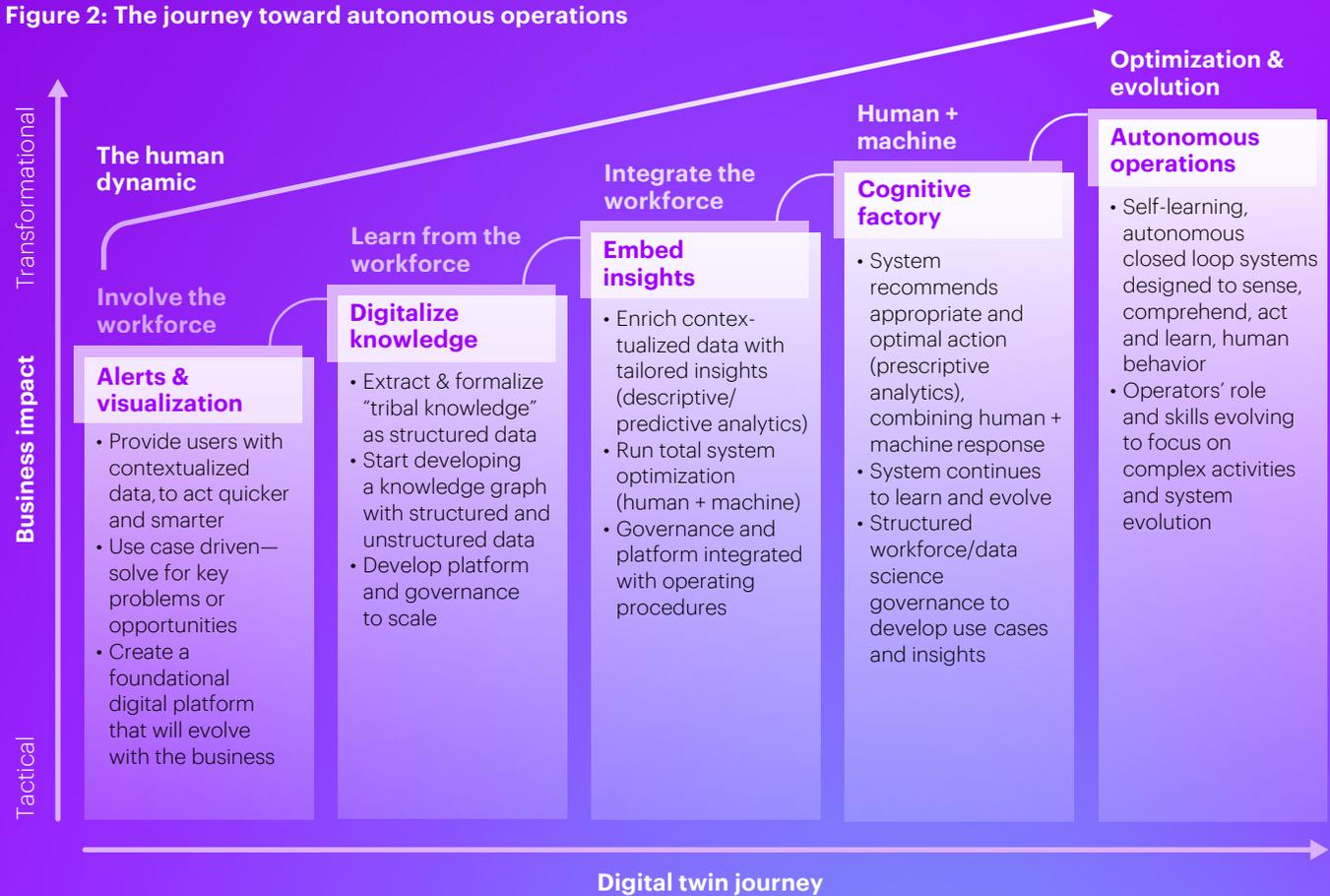
A digital twin's ability to enable progressive learning and capture tacit knowledge provides a key, differentiating benefit: **It stores and structures information in a way engineers and operators can understand.** That means that they don't have to rely on a data analyst each time they need to analyze data and develop the often very simple applications that address day-to-day issues like the temperature sensor previously illustrated. By combining the power of the digital twin and modern Low Code/No Code (LCNC) tools, manufacturing leaders can provide process and data engineers a safe domain in which they can collaborate to develop new ways of optimizing operations.
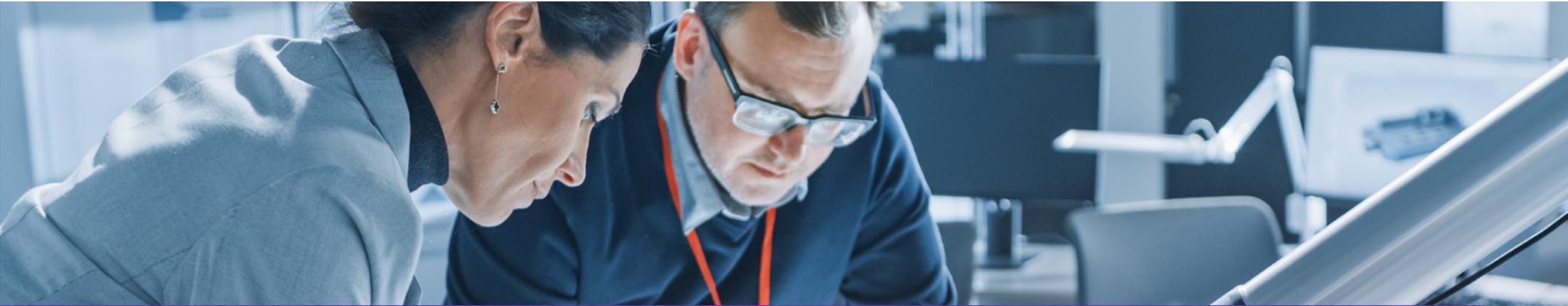
More importantly, the twin doesn't stop at capturing the configuration and behavior of the asset, line or plant. It also embeds optimization logic for all levels of the hierarchy.
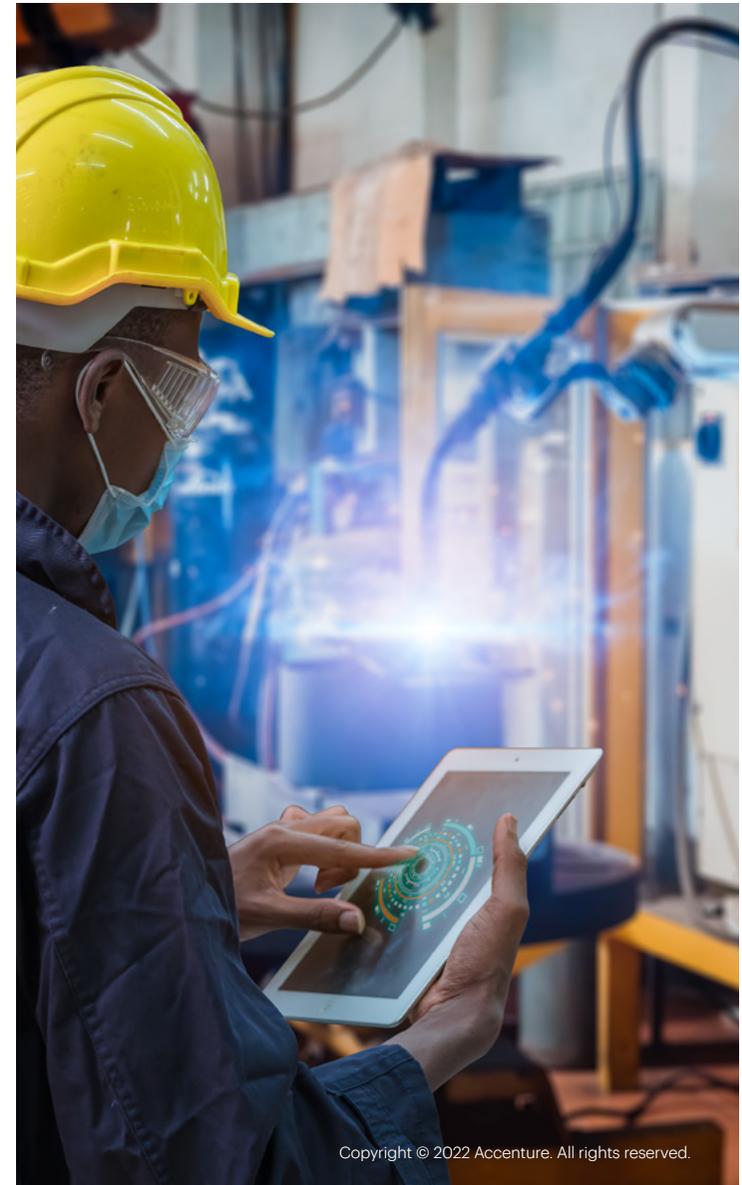
By allowing the progressive formalization of tacit knowledge and real time event based performance management, the digital twin supports the evolution towards autonomous operations.

Figure 2: The journey toward autonomous operations

Business impact (Transformational → Tactical)

Digital twin journey →

The human dynamic

Involve the workforce

Alerts & visualization
- Provide users with contextualized data, to act quicker and smarter
- Use case driven—solve for key problems or opportunities
- Create a foundational digital platform that will evolve with the business

Learn from the workforce

Digitalize knowledge
- Extract & formalize "tribal knowledge" as structured data
- Start developing a knowledge graph with structured and unstructured data
- Develop platform and governance to scale

Integrate the workforce

Embed insights
- Enrich contextualized data with tailored insights (descriptive/ predictive analytics)
- Run total system optimization (human + machine)
- Governance and platform integrated with operating procedures

Human + machine

Cognitive factory
- System recommends appropriate and optimal action (prescriptive analytics), combining human + machine response
- System continues to learn and evolve
- Structured workforce/data science governance to develop use cases and insights

Optimization & evolution

Autonomous operations
- Self-learning, autonomous closed loop systems designed to sense, comprehend, act and learn, human behavior
- Operators' role and skills evolving to focus on complex activities and system evolution

2. Can existing solutions integrate with digital twins to maximize investment?

The short answer is yes. A comprehensive and integrated manufacturing architecture remains the foundation of manufacturing operations across industries.

For example, the MES should remain the orchestrator and critical link between enterprise and shop floor systems. The rich, structured data that a comprehensive and integrated manufacturing architecture provides allows manufacturers to jumpstart their journey to autonomous operations.

By implementing a digital twin in parallel with existing systems (as illustrated in figure 3 on the next page) and feeding appropriate data from these systems to the twin, manufacturers can extract more value from years of investment, without the need to "rip and replace."

Unencumbered by the existing domain boundaries of traditional manufacturing systems and harnessing the power and flexibility of cloud platforms and technologies, digital twins allow manufacturers to capture data from all existing systems — from Enterprise Resource Planning (ERP) to Programmable Logic Controllers (PLCs) to supply chain, to distribution — and contextualize it quickly and effectively.

Most importantly, as this can be done on a use-case basis, benefits can be delivered within three to six months, depending on the use-case complexity. The fundamental difference here compared with the traditional pilot approach is that all use cases make use of the same data model and infrastructure rather than creating a new data silo. Instead of creating additional integration challenges, every use case adds to the digital twin's potential and can scale exponentially.
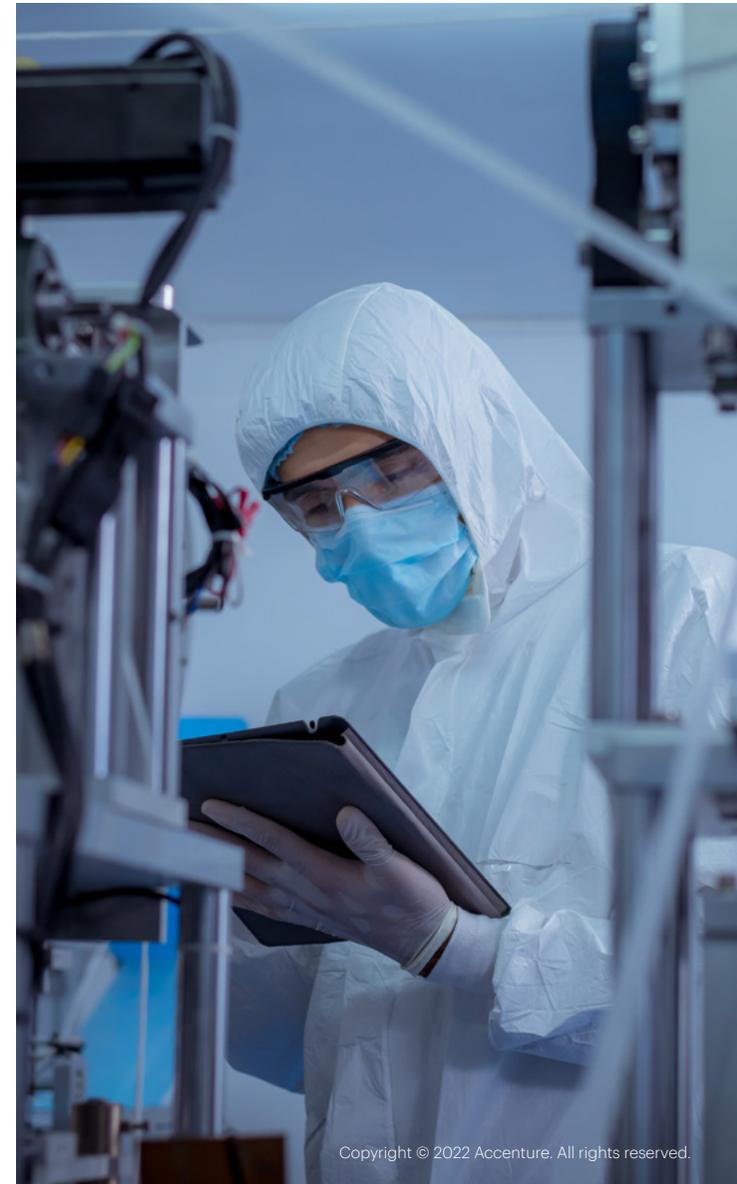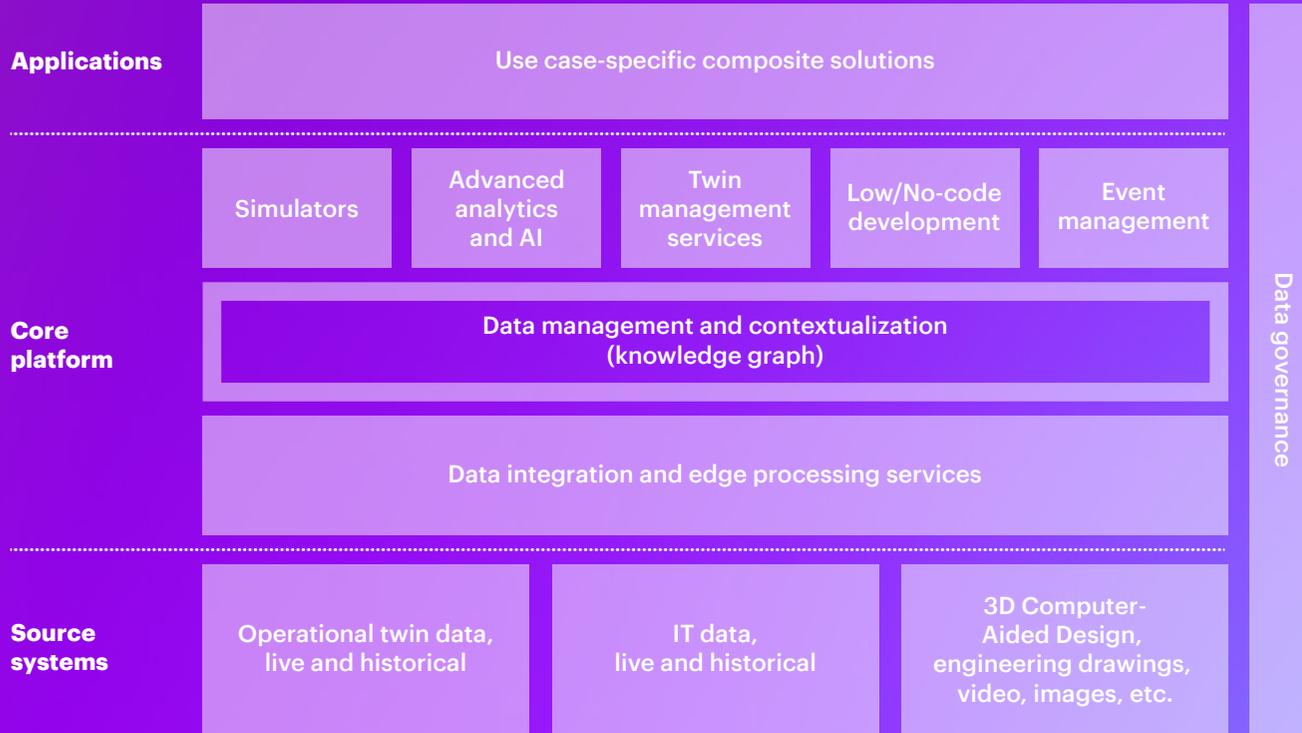
Figure 3: The digital twin is designed as an open integrated platform

Applications	Use case-specific composite solutions					

Applications — Use case-specific composite solutions

Core platform

Simulators	Advanced analytics and AI	Twin management services	Low/No-code development	Event management

Data management and contextualization
(knowledge graph)

Data integration and edge processing services

Data governance

Source systems

Operational twin data, live and historical	IT data, live and historical	3D Computer-Aided Design, engineering drawings, video, images, etc.

The diagram shows the simplified digital twin architecture including the three "layers" within the core platform.

- Data from the different source systems is acquired and pre-processed at the edge before being sent to the cloud for integration and storage.
- Data is contextualized, i.e., the relationships between engineering, IT and OT data are described as a flexible and scalable graph, presenting the full complexity of manufacturing operations.
- The digital twin platform usually offers base simulation and analytics capabilities and exposes the contextualized data to a variety of applications, from simple dashboards to complex machine learning logics.

Re-Examine Current Systems

While it's true that manufacturers can take advantage of digital twins without having to replace all underlying systems, those systems should not remain completely untouched. Manufacturers that do not have a streamlined manufacturing architecture as a result of uncoordinated investments and proprietary extensions may find them hard to evolve. In parallel with implementing and rolling out the digital twin, manufacturing leaders should streamline their existing manufacturing architecture to:

1 Create a data-driven templated approach and abstraction layer which allows simplification and standardization without having to replace expensive equipment at the site.

2 Move high-value specific developments, (e.g., what conditions upstream may be causing failures downstream), most of which are about data and AI, to the twin environment.

3 Reinforce the "vertical" integration between ERP and shop floor systems to establish a robust and efficient execution engine.

4 Integrate the execution and optimization (the twin) domains, progressively over time based on the shared data/information model, respecting the execution vs. optimization paradigm.

There are many versions of this roadmap, as manufacturers, requirements, ambitions and starting points vary greatly. But the overall approach remains valid for all.

3. How are MES vendors positioning themselves vs. the major cloud platforms and Internet of Things players?

Manufacturing Execution Systems are the backbone of the current manufacturing IT/OT stack, and will continue to be relevant as manufacturers transition toward next-generation MOM architectures.

In response to increased competition from IT players — specialized start-ups to cloud majors — MES vendors are evolving their solutions to increase their footprint, leveraging the flexibility of the cloud, while facilitating their integration into future-ready manufacturing architectures.

1. Major vendors are broadening their offerings and evolving their portfolios (often via acquisitions) into well-integrated platforms that include data historians, quality management systems, asset performance management and warehouse management solutions. Leaders today offer a much-improved range of core capabilities, packed with industry-specific best practices. These enable faster rollouts with limited customization.

2. Another major trend is toward cloud deployment. This not only enables easier rollout across sites, but also significantly eases integration into the overall MOM architecture, while substantially reducing the cost of MES deployments.

3. Finally, vendors' more flexible commercial models now enable manufacturing leaders to pivot from large, capex investments to incremental subscriptions. Combined with accelerated deployment, this makes MES deployments easier to justify financially.

Is the cloud just about lower costs?

No. Manufacturers have started leveraging cloud technologies to complement or extend their MES:

- Industrial Internet of Things (IIoT): to collect additional data from both retrofitted equipment and new smart sensors
- Analytic platforms: to analyze the resulting wealth of data
- LCNC: to address plant-specific and unique requirements
- Machine Learning: to support and potentially automate day-to-day decisions

MES vendors are flexing their architectures to also leverage these technologies to provide more value to their clients. To that end, some vendors are buying or developing their own IIoT, LCNC, Machine Learning and analytics products, while others prefer to collaborate with the cloud majors to offer clients seamless integration with open and powerful cloud-based tools.

In summary

Manufacturing leaders who succeed in moving toward this next generation manufacturing systems architecture are poised to improve efficiency, improve customer satisfaction, reduce costs and fundamentally outperform their peers.

Flexibility

allows a twin to adapt itself to very different requirements and starting points. By beginning with simple use cases that generate immediate payback, a digital twin can quickly become self-funding.

Scalability

will enable the extension of original use cases in scope, in extending to multiple sites across the enterprise and the enhanced sophistication of data analytics.
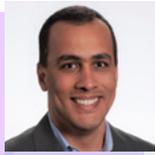
Intelligence

gleaned from the digital twin's optimization logic for all levels of the hierarchy gives engineers and operators control and accountability for the manufacturing data and related solutions.
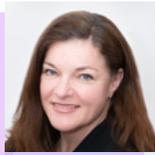
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