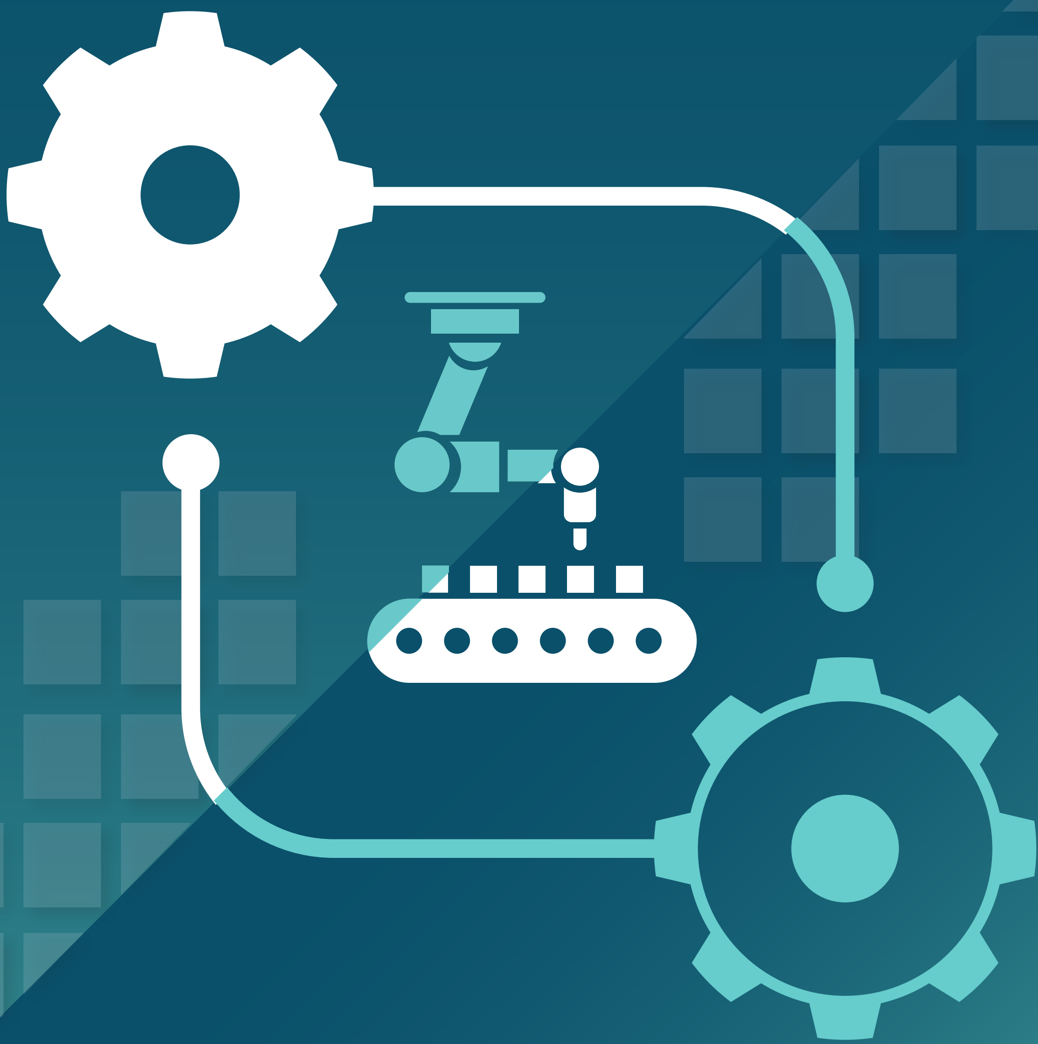
Hitachi Solutions

How Digital Twins are Revolutionizing Manufacturing

Winning with Twinning



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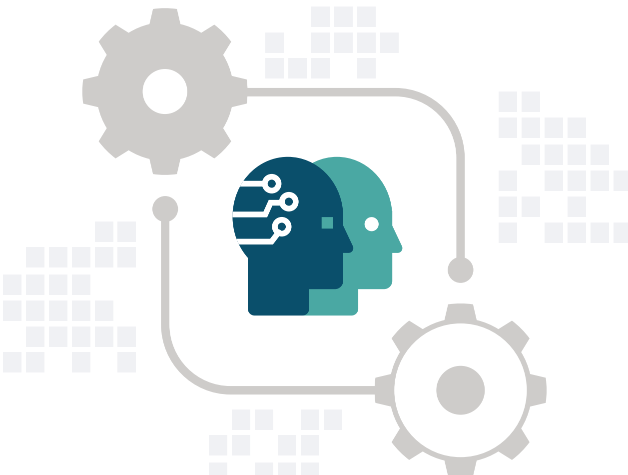
Introduction

With the speed of innovation, simulations have become an important tool in manufacturing today. Being able to create a replica and see how it performs provides valuable insights that help companies make smarter business decisions — which leads to better, faster, safer, and cheaper production.

However, physical prototypes are both costly and time-consuming to build, which is why the digital twin is such a hot commodity right now. A digital twin is a virtual representation of a physical object, system, or process. It integrates data from various sources, including sensors and historical data, to create a dynamic, real-time model.

From predicting equipment failures to optimizing production lines to developing new products, the digital twin has become a key enabler of Industry 4.0. Being able to quickly and cost-effectively understand the implications of any decision or concept before actual execution is game changing, revolutionize how companies model and understand their assets, products, and operations.

Want to hear more about digital twins? Twin-tastic! In this eBook, we take a deep dive into what digital twins are, how they work, why you need them, and how they impact the manufacturing industry.

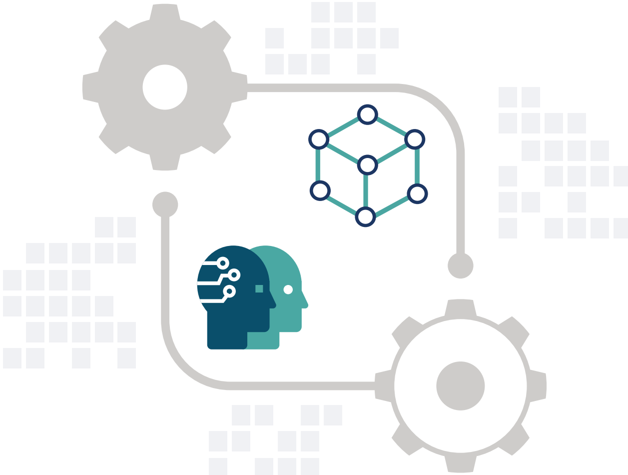


The Birth of Digital Twins

While simulations have been used since the 1970s, the term “digital twin” is thought to have first been used and defined by **Dr. Michael Grieves** at the University of Michigan in 2002. He used it in the context of **product lifecycle management (PLM)**, a process that can track a product’s life from conception to disposal. Even though the concept of the digital twin has its roots in PLM, it has evolved significantly with the advent of technology such as IoT, machine learning, and advanced data analytics.

Today, digital twins are used in a wide variety of industries, including manufacturing, automotive, healthcare, and even urban planning. They serve as a bridge between the physical and digital world, offering a powerful platform to simulate, analyze, and optimize systems and processes — which leads to improved efficiency, reduced costs, and better products and services.

To address the growing complexity and need for consistency, standards such as ISO 23247 have been developed to provide protocols and frameworks for creating and maintaining digital twins. Also, consortiums, like the [Digital Twin Consortium](), have been formed to drive awareness, adoption, interoperability, and development of digital twin technology.



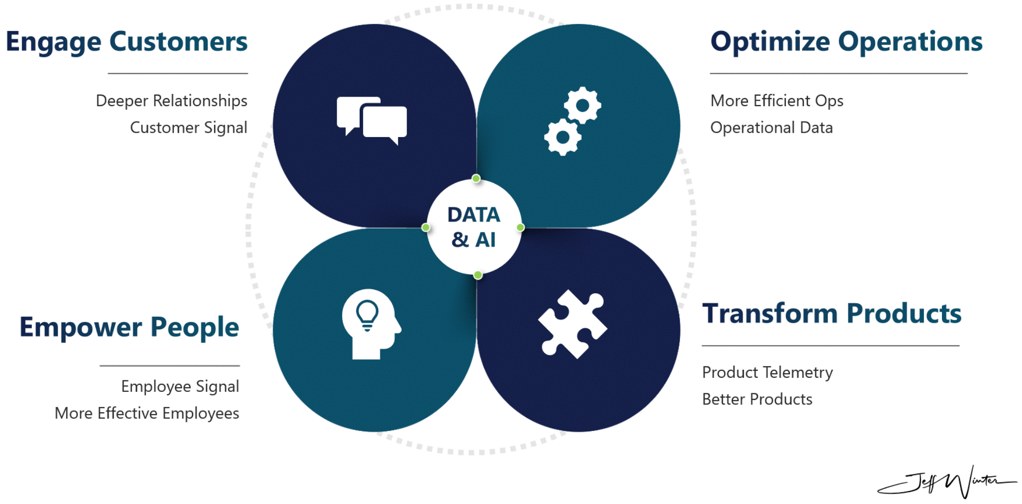
Difference Between a Digital Twin, Modeling, and a Simulation

A digital twin takes a real-life object and creates an exact copy of that same object in the digital world. It becomes the representation of a system to generate data and help determine decisions or make predictions about the system. This is used to optimize operations, validate design ideas, and provide predictive feedback.

Modeling and simulation in the context of engineering has been around since at least the mid-20th century, with significant advancements occurring during and after World War II as part of efforts to solve complex military and aerospace challenges.

Modeling involves creating abstract representations of systems to understand or predict their behavior, while simulation uses these models to study how a system behaves under different conditions. Both modeling and simulation are foundational to creating digital twins, as they provide the theoretical and computational frameworks necessary for replicating and analyzing real-world objects or systems in the digital realm. The main difference is the fact that a digital twin is fed real-time data from the real-world object to accurately and precisely imitate its actions and responses.

Digital Twins Enable Digital Feedback Loops



Digital feedback loops are transformative mechanisms that leverage data and artificial intelligence (AI) to continuously refine and enhance processes, products, and services. Central to enabling these loops are digital twins, which provide a dynamic, real-time bridge between physical entities and their digital counterparts. Here's how digital twins provide improvements across four key areas:

Engaging Customers

Digital twins enhance customer engagement by simulating real-world product interactions, enabling companies to analyze behaviors and tailor their offerings effectively.

Optimizing Operations

Digital twins optimize operations by providing a virtual environment to simulate, analyze, and improve real-world processes, leading to enhanced efficiency and reduced operational costs.

Empowering People

Digital twins provide employees with insights and tools, which are important for fostering a more informed, efficient, and innovative workforce

Transforming Products

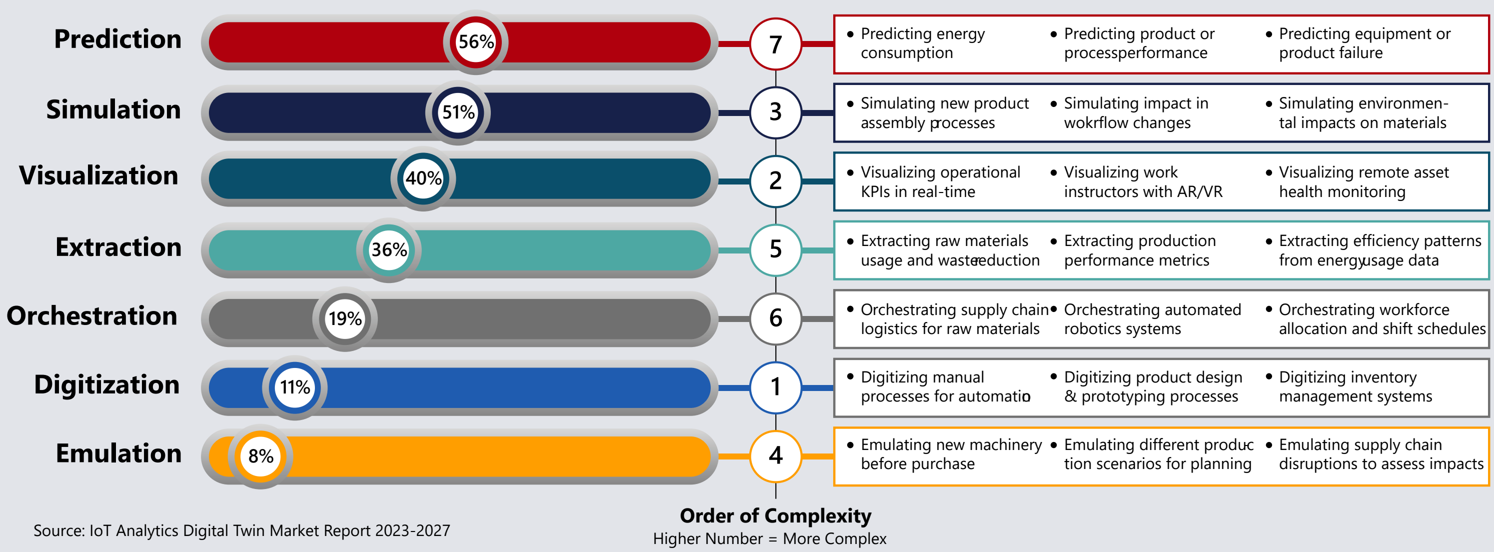
Digital twins drive product transformation by enabling the virtual testing and refinement of designs, fostering innovation and improving the functionality and sustainability of products.

Three Levels of Digital Twins

There are many different ways of looking at a digital twin. One way is by the complexity and capabilities, another is by what is being "twinned," and a third is by use case, which means examining the various practical applications and scenarios where digital twin technology is employed to solve real-world problems. Here's a summarized list (in order of complexity):

- **Digitization** — The transformation of physical data into a structured digital format, streamlining access and archiving.
- **Visualization** — The creation of digital models for interactive exploration and detailed understanding of physical counterparts.
- **Simulation** — The enactment of real-world scenarios within a virtual environment to predict outcomes and optimize designs.
- **Emulation** — The replication of physical systems with their operational software in a virtual space for accurate testing.
- **Extraction** — The continuous harvesting of real-time data from physical entities to enrich and update their digital twins.
- **Orchestration** — The strategic manipulation of digital models to guide and implement changes in their physical versions.
- **Prediction** — The analytical forecasting of future states or behaviors of physical systems based on virtual model data.

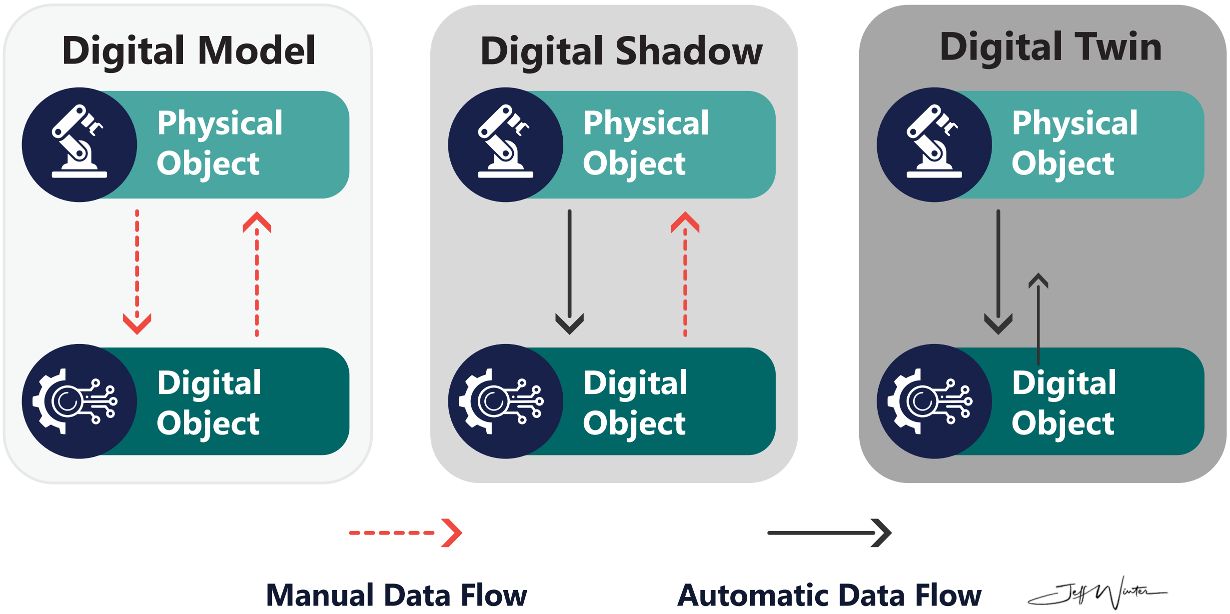
Top Digital Twin Use Cases



Source: IoT Analytics Digital Twin Market Report 2023-2027

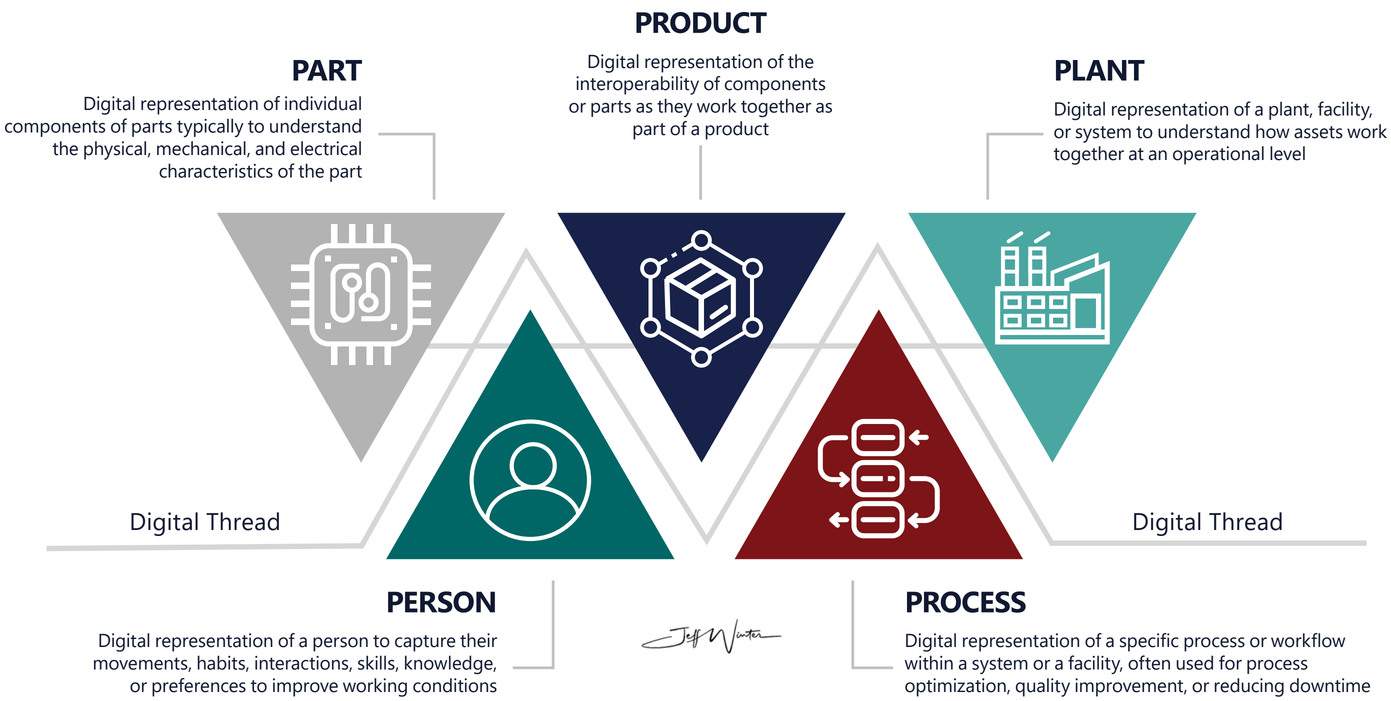
Relationship Between the Physical World and the Digital World

Digital Twin is not "one size fits all." Although not standardized, there are three terms we like to use when talking about digital twins – digital model, digital shadow, and digital twins.



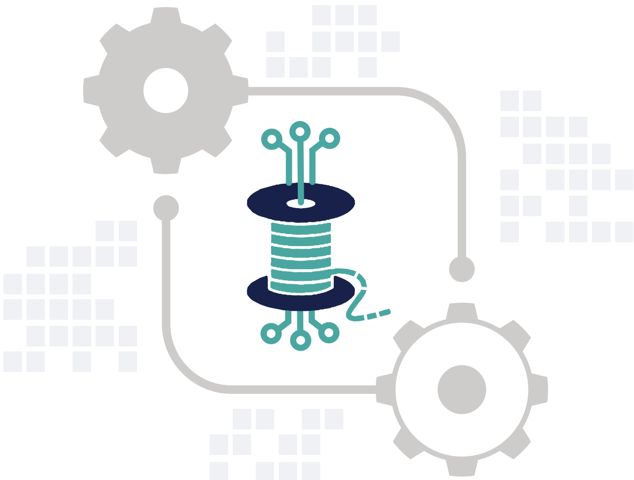
- **Digital Model** — This is a digital version of a pre-existing or planned physical object. The important defining feature of a digital model is that there is no form of automatic data exchange between the physical model and the digital model. This means once the digital model is created, a change made to the physical object has no impact on the digital model either way.
- **Digital Shadow** — This is a digital representation of an object that has a one-way flow between the physical and digital object. A change in the state of the physical object leads to a change in the digital object and not vice versa.
- **Digital Twin** — If the data flows between an existing physical object and a digital object, and they are fully integrated in both directions, this constitutes a digital twin. A change made to the physical object automatically leads to a change in the digital object and vice versa.

The 5 Types of Digital Twins



People slice and dice this terminology all different ways. While you can distinguish based on the twin source, in an industrial setting we break this up into the "5Ps" — part, product, plant, process, people.

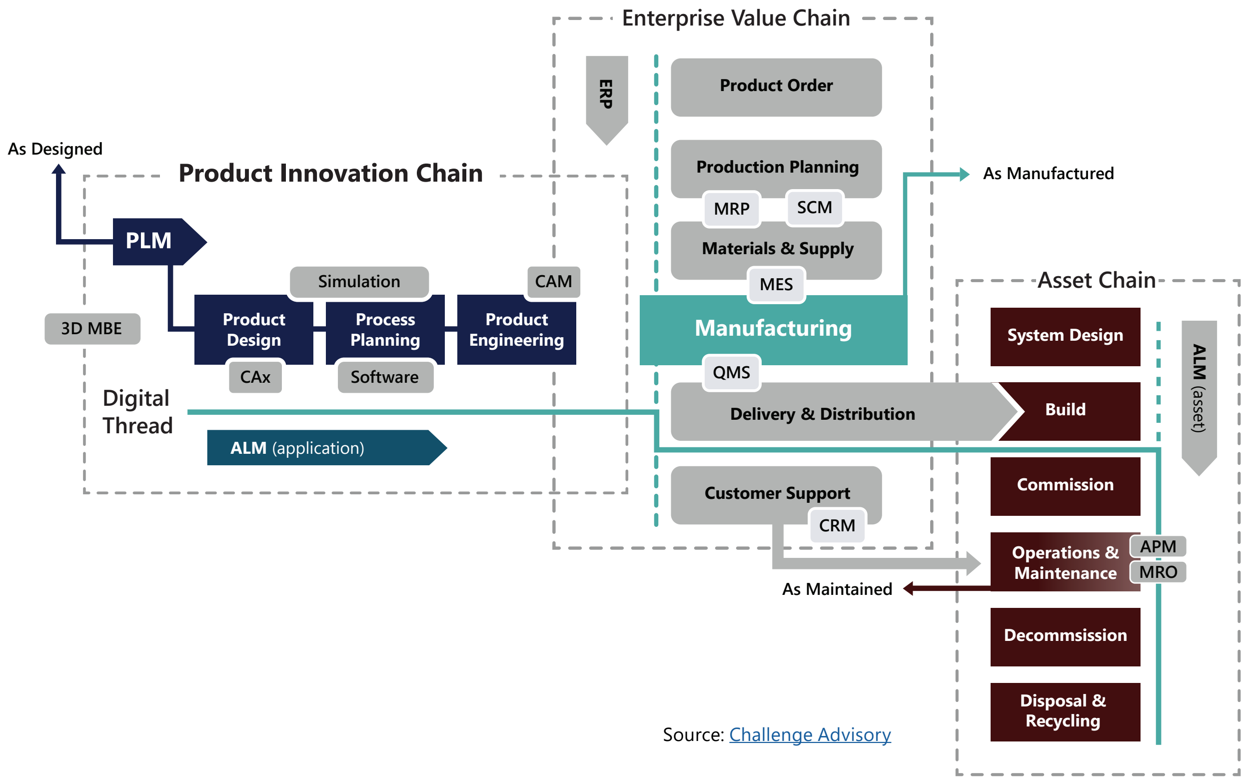
- **Part** — This refers to a digital twin of a specific component or part in a system. It's a digital replica that reflects the exact state, design, and properties of the physical part.
- **Product** — This is a digital twin that represents an entire product, which can be a composite of several "part" twins. The digital twin encapsulates the entire product's design, performance, and operational data. For instance, a digital twin of an entire car, an airplane, or a wind turbine would be considered a "product" twin.
- **Plant** — Also referred to as a "system" twin, this digital twin represents a complete system or a facility such as a manufacturing plant, a power plant, or a warehouse. It can be used for optimizing the plant layout, simulating and improving workflows, managing energy consumption, or planning facility expansions or modifications.
- **Process** — A "process" twin represents a specific process or workflow within a system or a facility. It's often used for process optimization, quality improvement, and reducing downtime.
- **People** — This is one of the more recent and less common types of digital twins. It involves creating a digital representation of a person, capturing their skills, knowledge, preferences, or behaviors. But it doesn't have to be a person as there are agribusiness companies doing digital twins of cows and chickens to evaluate and predict health.



Weaving Everything Together With a Digital Thread

So, what is a digital thread? A digital thread is an integrated framework that captures, connects, and communicates data across the lifecycle of a product, process, or system. It serves as a digital backbone, enabling seamless information flow and accessibility for stakeholders, thereby enhancing decision-making, efficiency, and innovation.

The digital thread supports the creation and management of digital twins, which are virtual replicas of physical entities, by providing the necessary data and insights to simulate, analyze, and optimize real-world performance and operations. In an industrial setting, this digital thread may include design specifications, materials data, manufacturing process data, performance data, and more.



Source: Challenge Advisory

Examples of digital threads include:

Product Lifecycle Thread

Tracks a product from concept through design, manufacturing, operation, and disposal, ensuring data continuity and integrity.

Production Process Digital Thread

Integrates and manages data across the manufacturing process, from initial design to final product — optimizing production efficiency and quality.

Supply Chain Digital Thread

Connects data across the entire supply chain, enhancing visibility, coordination, and responsiveness to changes and disruptions.

Software Development Digital Thread

Manages the flow of information throughout the software development lifecycle — from planning and coding to testing and deployment, facilitating collaboration and agility.

When there are multiple digital twins, the digital thread plays a crucial role in ensuring that each twin is updated with the latest, accurate data, enabling a coherent and synchronized representation of the physical entities. This interconnectedness allows for comprehensive analysis and optimization of complex systems, where changes in one part can be accurately reflected and analyzed across all related digital twins.

Trending Use Cases for Smart Manufacturing

	Average planned investments in the next 3 years (2023-2026) per smart manufacturing use case (compared to today)
Industrial automation based process control	+29%
Condition-based maintenance of equipment	+28%
IoT-based plant/worker safety	+27%
IoT-based energy management	+27%
IoT-based production planning and scheduling	+27%
Quality control using AI-based, modern machine-vision	+26%
Sustainability footprint optimization	+26%
Factory digital twin	+26%
AI-based predictive maintenance of equipment	+26%
AI-based plant network optimization	+25%
Digitally assisted shopfloor dashboards	+24%
Quality control using traditional machine-vision	+24%
Remote asset monitoring	+24%
AR-assisted operations	+23%
AR-assisted maintenance/service	+22%

Source: **Source: IoT Signals, 2023**

State of Digital Twin Industry

According to IoT Analytics, the market for standalone digital twin software grew 71 percent between 2020 and 2022 — outside of generative AI there aren't many technologies growing at this rate. In 2023, 29 percent of global manufacturing companies reported having fully or partially implemented their digital twin strategies, up from 20 percent in 2020. Most people would agree that digital twins have become a major ingredient to successful Industry 4.0 initiatives.

Consideration for Adoptors

Integration Capability: Prioritize digital twins that offer robust API support and compatibility with your current and future systems to ensure seamless data integration and functionality.

Scalability and Flexibility: Choose a digital twin platform that allows modular implementation and is technology-agnostic to accommodate growth and technological changes without significant overhauls.

Data Management and Analysis: Implement a comprehensive data strategy that includes storage, security, and advanced analytics capabilities to maximize the digital twin's potential for predictive insights and decision-making.

Top Challenges for Digital Twins

As you can see, digital twins offer many advantages for manufacturers. However, the technology also presents some challenges. The main issues include:

Data integration and interoperability — Creating an industrial digital twin involves integrating data from various sources such as IoT devices, sensors, and enterprise systems. According to Gartner's estimation, **75 percent of the digital twins for IoT-connected OEM products will utilize at least five different kinds of integration endpoints by 2023.** This number is probably a lot higher today!

They are only high cost if you don't have those things — Digital twins require a sophisticated technological foundation, which depending on your level of digital maturity, may require investment in integrated data systems, industrial networks, Internet of Things (IoT) infrastructure, simulation tools, data quality control, and security.

Data security and privacy — Industrial digital twins process large amounts of sensitive data, raising security and privacy concerns. Digital twins can create an expanded attack surface. Safeguarding data from cyber threats while complying with privacy regulations is a major challenge.

Scalability — As the scope of digital twins expands, managing and processing an increasing amount of data becomes difficult. It can be hard to maintain the system's performance, responsiveness, accuracy, and stability while scaling up.

Digital Twins in Action

There are many ways manufacturers can leverage digital twins to elevate their business. Here are a few examples:

Google Maps

Google Maps serves as a good example of a digital twin because it provides a detailed and dynamic virtual representation of the real-world environment, integrating live data such as GPS data, traffic conditions, business information, and street views to simulate your journey. And if you take a wrong turn, it will update itself automatically on the fly to get you where you need to go. Now, some argue this isn't a full-fledged digital twin, but it gets you to think about the concept differently.

Ford

Ford uses a digital twin to enhance efficiency and performance of its Central Energy Plant (CEP). Gathering real-time data via IoT devices, the digital twin enables informed decision-making and helps in quick fault identification. This technology guided the accurate assembly of 9.5 miles of pre-fabricated piping and manages the plant's 50 MW annual electric peak.

The digital twin is pivotal in Ford's vision for its Factory of Tomorrow, interconnecting various digital twins through a digital thread. This has supported Ford in achieving a projected 50 percent reduction in campus office space energy and water usage compared to older systems.

Rolls-Royce

[The second-largest maker of aircraft engines is using digital twin technology], along with analytics and machine learning, to significantly reduce the carbon emissions of its aircraft engines and optimize maintenance schedules. The company's Intelligent Engine platform monitors each engine's operation and customizes maintenance based on actual usage rather than standard manuals. This has enabled Rolls-Royce to extend maintenance periods for some engines by up to 50 percent, which significantly reduces parts inventory.

The platform has also increased engine efficiency, saving 22 million tons of carbon to date. Rolls-Royce is also using AI to manage waste from expired parts and has helped one airline save 85 million kilograms of fuel and avoid over 200 million kilograms of CO_2 since 2014. Real-time and post-flight data are used for predictive maintenance, engine performance monitoring, and customer-specific optimization.

The Future of Digital Twins

According to IoT Analytics in their Digital Twin Market Report 2023-2027, the global digital twin market is expected to grow from $418 M in 2022 to $1.5 B in 2027, which constitutes 29% Compounded Annual Growth Rate. Manufacturing consumes nearly 75 percent of the market.

Partnerships to Create Ecosystems

Big cloud providers and tech companies are collaborating with traditional OT companies like Siemens and GE for industrial data management, as well as with simulation companies that make AI models like AnyLogic or MathWorks. Together it makes for a pretty powerful ecosystem.

The Fusion of AR, VR, and Digital Twins

We are starting to see companies like ABInBev using a style of metaverse to have their breweries and supply chain interact with digital twins. This mixed reality can be used for remote assistance and deep reinforcement learning to predict and counter production line issues.

Generative AI is Expanding Possibilities

Generative AI (such as ChatGPT or **Hitachi Solutions Enterprise Chat)** can support digital twins by using their data to automatically create improved designs based on certain objectives or constraints. This partnership between the technologies not only enhances the functionality of digital twins but could also transform how we design and optimize large-scale systems in various sectors. Future advancements are expected to deepen this integration, enabling more comprehensive and functional digital representations.

> *Factories are seeing an average of **17-20% productivity gain** from embracing digital twin technologies.*
>
> **Microsoft**

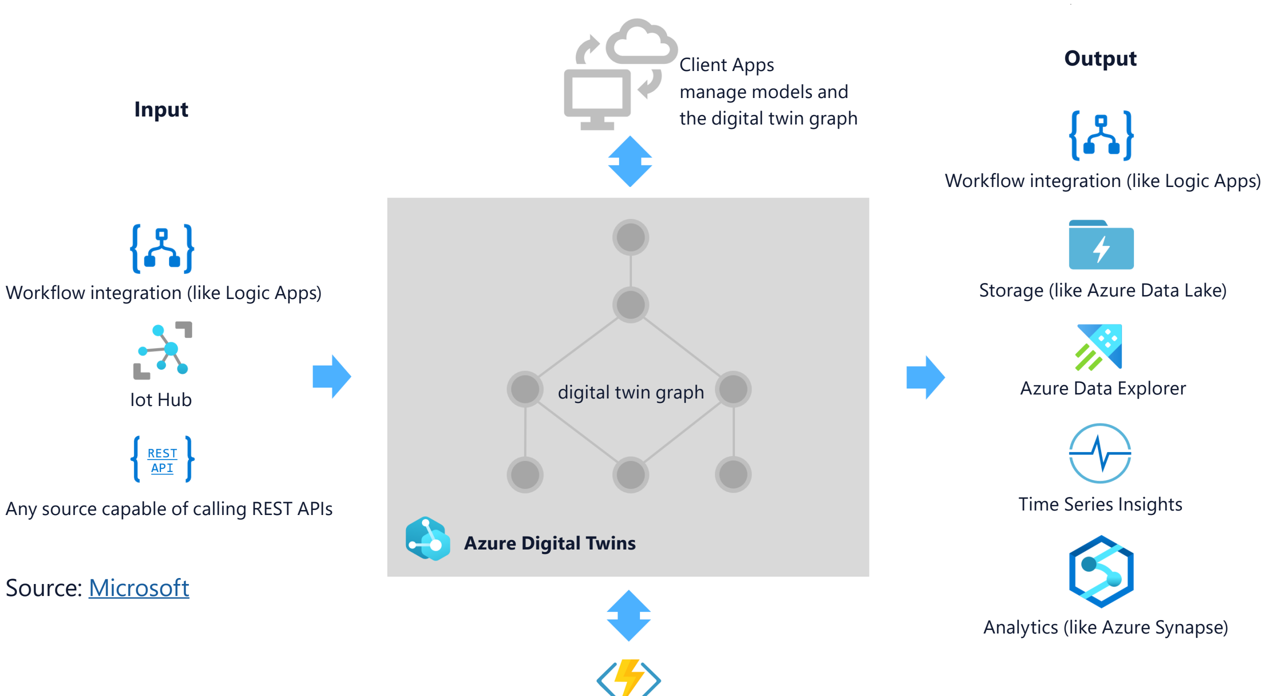
Microsoft Azure Digital Twins

[Azure Digital Twins](#) is a cutting-edge Platform as a Service (PaaS) offering from Microsoft that revolutionizes how we understand and interact with real-world environments through digital replication. At its core, it allows the creation of highly detailed and interconnected digital models of physical environments of any scale, ranging from individual buildings to entire cities.

What sets Azure Digital Twins apart is its comprehensive integration with the broader Azure IoT ecosystem, thus ensuring that digital twins remain dynamically updated with live operational data.

Uniquely, Azure Digital Twins supports the modeling of virtually any scenario through its use of the Digital Twins Definition Language (DTDL). This flexibility is enhanced by Azure's robust event system and powerful querying capabilities, allowing users to derive real-time insights, optimize operations, and even predict future trends by integrating with Azure's AI and analytics services.

Furthermore, Azure Digital Twins pushes the boundaries of digital representation through its 3D Scenes Studio, offering immersive 3D visualizations that bring digital twins to life in unprecedented ways. By providing a scalable, secure, and customizable platform, Azure Digital Twins empowers businesses across various industries to innovate, improve efficiency, and create more sustainable solutions by bridging the gap between the physical and digital worlds.



Source: [Microsoft](#)

Tips for Getting Started

Just like the adoption of any new technology, you need to have a clearly defined business case that articulates the objectives, scope, and expected outcome. Understanding why you need a digital twin and what you want to achieve with it is key. You also need to identify the necessary data — Can you model what you are creating a digital twin of? Can you monitor the physical asset?

We would also advise you to check out the **Digital Twin Consortium** as there is a wealth of free information there if you want to learn about frameworks, best practices, and collaborative initiatives. You can also get involved with associations to network and bounce ideas off other professionals with similar interests. **ISA's Smart Manufacturing** division has a digital twin committee that meets every month for this very purpose!

And unless you have the necessary know-how and resources in-house, you will need to partner with a provider to plan and implement digital twins. The provider should not only have the required technology expertise but also understand your industry and its unique needs and challenges.

Hitachi Solutions

— The Right Partner

For 20 years, Hitachi Solutions has been a market leader in helping manufacturers modernize operations and create more profitable outcomes. With industry-proven expertise, innovative solutions powered by Microsoft cloud technology, and deep technical knowledge, our team is uniquely equipped to help you with your data-driven digital twin initiatives.

If you'd like to talk to one of our experts about leveraging digital twins to enhance your decision-making, optimize operations, reduce costs, and promote innovation, please reach out.

Contact Us Today!