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BRAINSHORING SERVICES

The digital twin revolution:

Simulate, predict, optimize

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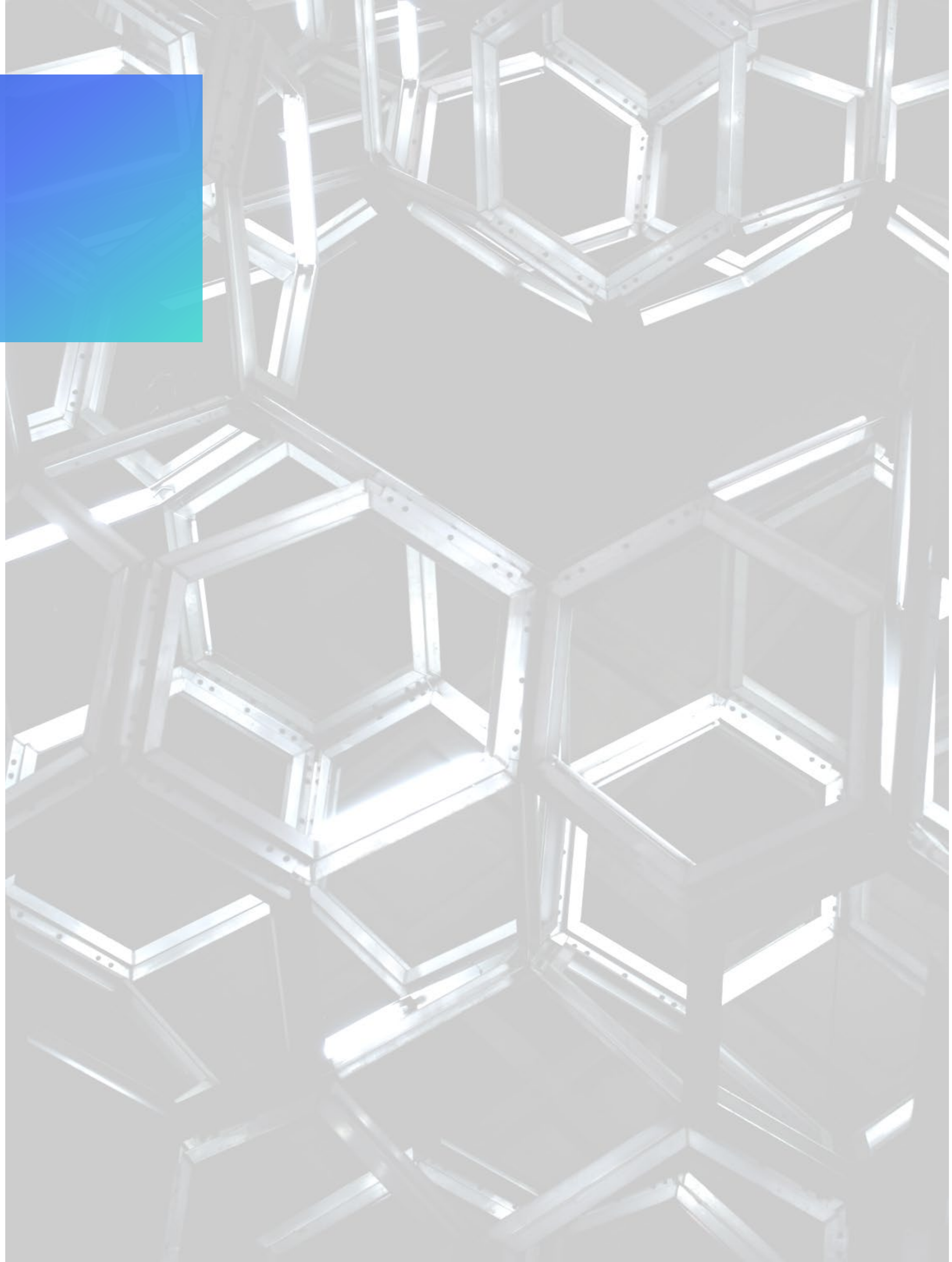

Introduction

Digital twins represent a revolutionary concept in the realm of technology and innovation. These **virtual replicas of physical objects, systems, or processes** have garnered significant attention and adoption across various industries. By **creating a digital counterpart that mirrors real-world entities and their behaviors**, digital twins enable organizations to **gain unprecedented insights, optimize operations, and drive decision-making with data-driven precision**.

Initially conceived as digital replicas of physical systems, digital twins have advanced significantly, enabling **precise simulations, predictive maintenance, and continuous real-time monitoring of assets and processes**. Digital twins play a pivotal role in optimizing various phases of a system's lifecycle, from design to operation and service delivery. **Facilitating collaboration throughout the lifecycle and across ecosystems**, digital twins enhance operational efficiency and empower organizations to reimagine their business models.

In this report, we delve **into the latest trends in digital twins**, exploring how innovative technologies, such as AI/ML, edge computing, 5G, and XR, are converging to enhance the capabilities of digital twins. Additionally, the rise of Digital Twin as a Service (DTaaS) and the emergence of cognitive digital twins are driving new possibilities for real-time monitoring, simulation, and decision-making. Thanks to these developments, digital twins are starting to expand and revolutionize industries, enabling organizations, countries, and regions to unlock new levels of efficiency, productivity, and sustainability.

Source: IBM “What is a digital twin?” (2022), Press Search

Digital Twin Overview

A digital twin is a virtual replica of a physical entity that leverages real-time data to reduce costs, enhance efficiency, and optimize maintenance

A digital twin is a virtual representation or digital counterpart of a physical object, system, or process. Created using real-time data and modeling techniques, it mirrors the behavior, characteristics, and performance of its physical counterpart. Unlike simulations that exist solely in virtual realms, digital twins model real-world assets with precision. Equipped with sensors, these digital models continuously update in real-time with detailed, high-quality data.

	Component Twins	Asset Twins	System Twins	Process Twins
	Component twins represent **individual components or parts of a larger system** or product, **storing properties and behavior data**.	Asset twins replicate **entire physical assets**, using data from component twins to provide **an overall view of an asset's status**.	System twins are digital replicas of **entire systems with multiple assets and components**, allowing for monitoring of complex systems.	Process twins replicate **business processes or operations**, offering insights into process efficiency and bottlenecks.
Benefits	• Deeper **understanding of components** • **Precise control** over parts for maintenance and optimization • **Preventive maintenance** by identifying a part's wear and tear	• **Optimization of asset operations** under varying conditions • **Predictive maintenance** to reduce downtime and improve efficiency	• **Identification of bottlenecks** and optimization of system performance • **Planning for changes or expansions** with insights into system interactions	• **Real-time monitoring** for quick issue identification and response • **Simulation of process changes** or improvements for optimization without real-world risks
Example	In automotive, component twins could be digital replicas of engine parts like pistons, cylinders, or sensors.	An asset twin could represent a **wind turbine**, including all its components and subsystems.	A system twin could represent a **city's transportation network**, including roads, vehicles, and traffic management systems.	A process twin could represent a **supply chain operation**, including order processing and inventory management.

Source: Mckinsey "What is digital-twin technology?" (2023), Siemens "Digital twins" (2024), Press Search

Digital twins started in the 1970s as simulations and have evolved into sophisticated tools, integrating advanced technologies and expanding to various industries

Pre-2000s

- In the 70s, NASA used **simulators post-Apollo 13 to study its failure**, leading to the first digital twin's creation
- In the 90s, NASA **experimented with digital twins** for spacecraft and Mars rovers

2000s

- **The initial proposal** for digital twins was formally introduced under **"conceptual ideal for product life management."**
- In Mid-2000s, the **advancement of sensors** and data methods **eased integrating physical data** into digital twins
- By the late 2000s, **real-time data integration improved**, enabling **dynamic reflections** of physical entities in digital twins

2010s

- **Advancement in simulation tools** were integrated, enhancing digital twins' scenario simulation and process optimization
- **Interdisciplinary experts' collaboration** expanded, leveraging diverse skills for digital twin advancement
- The **rise of predictive analytics implementation** allowed digital twins to anticipate future states and issues
- Efforts to **improve the user interface** made digital twins more accessible for professionals
- **Gartner** named digital twins among **the top 10 trends in 2017**

2020s

- **Digital Twin Consortium was formed** to develop digital twin's best practices
- **AI, ML, edge computing and XR** are being integrated with digital twins to improve their features
- Digital twins are **expanding to more industries** such as healthcare
- **Gartner** recognized **Digital twins in its top 12 strategic technology trends** for 2022, as part of autonomic systems

Source: Press Search

Emerging Trends

Emerging Trends

Digital twins are evolving, integrating advanced technologies, enhancing their capabilities, expanding their applications, and enabling the creation of new models. The technology is increasingly being adopted by new industries to drive innovation and sustainability efforts. This has prompted organizations to establish frameworks and standards while advocating open communication between DT systems.

Integration with advanced technologies

5G, edge computing, AI/ML and XR are key enablers in advancing digital twins. These technologies **facilitate the rapid processing of data**, enabling **smart analysis,** and **enhance the simulation and prediction capabilities** of digital twins.

Development of innovative new models

The development of digital twins has led to the **emergence of new models**, including **Digital Twins as a Service**, which offer greater accessibility and **cognitive digital twins** that leverage the power of AI for enhanced capabilities.

Expansion to new industries

Digital twins are **expanding beyond their original domains** like manufacturing and aerospace to various sectors like **healthcare, transportation, retail, and energy.**

Promoting sustainability

In addition to boosting production efficiency, companies are increasingly **using digital twins for sustainability,** helping them **cut costs, minimize waste, and achieve environmental targets.**

Rise of public-sector applications

Governments are utilizing digital twins to **monitor infrastructure, identify public safety hazards, and streamline urban planning processes.**

Call for interoperability

Organizations are **integrating standards** and **pushing for interoperability**, effectively ensuring that different digital twin systems, software, and technologies can **seamlessly communicate, exchange data, and work together effectively.**

The integration of cutting-edge technologies with digital twins enables enhanced data processing, smart analysis, and insightful predictions

Integration with advanced technologies

The evolution of digital twin applications has paralleled advances in 5G, edge computing, AI/ML, and XR. These technologies have enabled the processing, analysis, and intelligent interpretation of data, thereby enhancing the dynamism and capabilities of digital twins to perform complex simulations, predictions, and improvements across various domains.

AI/ML

- Optimizes **virtual representations**
- Spots **abnormal behaviors**
- Creates **extra data for training** when real data is lacking
- **Keeps** digital twins **updated**
- Simplifies **human collaboration**
- Enhances **resource optimization**

In manufacturing, AI can be used with digital twins across production lines to enable real-time product quality checks and predictive equipment maintenance.

Edge Computing

- Limits the risk of compromising sensitive data, **enhancing security**
- **Reduces data transmission and processing time**
- Offers **scalable resources** without investing in centralized infrastructure

Integrating edge computing in urban planning digital twin allows it to be deployed in different locations, analyzing local data without relying on a central server.

5G

- **Processes data** from multiple sensors
- Enables real-time **data collection for** instant responses
- Handles **massive volumes of data**
- Ensures **seamless device communication**

5G-enabled digital twins are particularly valuable in optimizing smart city applications, including traffic management, public safety, and environmental monitoring.

Extended Reality (XR)

- Allows **immersive visualization** of digital twins, aiding their inspection and exploration
- Supports **remote operations**, team collaboration, and maintenance
- **Enhances training** by facilitating realistic simulations based on digital twins

Using XR with digital twins helps companies with massive units overcome challenges in showcasing their equipment due to size and logistics. It enables users to explore the equipment from every angle.

Source: Dell “Your Digital Twin Needs Edge Computing” (2023), Verizon “5G-Powered Digital Twin”, Press Search

Digital twins are rapidly evolving, incorporating new technologies to create innovative concepts like cognitive digital twins and DTaaS

Development of innovative new models

Developments in key technologies have led to the emergence of new trends and innovative models in digital twins, such as cognitive entities and Digital Twins as a service. These developments are not only opening new possibilities for improving operational efficiency, but also making digital twins more accessible across various industries.

Cognitive Digital Twins

Cognitive Digital Twins (CDTs) are advanced digital replicas of physical objects or systems, **powered by AI to exhibit cognitive abilities like enhanced memory and reasoning, self-improve through data-driven learning, and autonomously make decisions**. Cognitive digital twins leverage AI and IoT to collect data, use ML/DL model generation to perform data analytics, and then present insights through various user-friendly interfaces (e.g., 3D, XR).

How is it different from digital twins?

Digital twins replicate physical assets digitally, enabling monitoring, simulation, and visualization through IoT sensors and real-time dashboards. **Cognitive twins go further, enhancing communication, analytics, and decision-making across three layers: access, analytics, and cognition**. They are smarter and more capable of independent decision-making, reducing human workload significantly.

Digital-twin-as-a-Service (DTaaS)

DTaaS refers to a **cloud service that provides a digital representation of a physical object or system**, allowing for data-driven decision-making and the elimination of business-process inefficiencies. To ensure successful implementation, the digital twin model, its infrastructure and pricing must be tailored to each organization and its deployment requirements.

How is it different from digital twins?

DTaaS is a cloud-based software solution that differs from traditional digital twins in that it offers significant cost savings **through economies of scale, faster implementation, quicker innovation cycles, and higher resilience**. It allows businesses to focus on operating physical assets efficiently without the burden of developing or hosting digital twin solutions.

Source: Medium “Digital Twins as a Service (DTaaS): What the SaaS is All About?” (2023), Digital Twin Consortium, Press Search

Digital twins, initially prevalent in manufacturing and aerospace, are expanding into other industries, including healthcare, transportation, retail, and energy (1/2)

Expansion to new industries

While initially prominent in manufacturing and aerospace, digital twins are now poised to revolutionize additional industries. Post-Covid-19, sectors like healthcare quickly adopted digital twins, while others, such as agriculture are gradually realizing their benefits and incorporating them.

Healthcare

- Aids in **simulation-based disease diagnosis and treatment planning**, including cardiac surgery and epilepsy surgery evaluation
- **Streamlines virtual clinical trials** by predicting responses, identifying unsafe treatments, and reducing development cycles and costs for biopharma products
- Uses personalized health data from live wearable sensors to **provide disease prevention guides** and **predict treatment responses** in cancer patients

Example - MSKCC

Memorial Sloan Kettering Cancer Center's (MSKCC) "Virtual Tumor Board" employs **digital twin technology**, representing each patient's cancer through a **personalized virtual model that mimics tumor characteristics**, genetics, and treatment response. It helps clinicians make informed decisions that are tailored to each case, ensuring maximum efficacy and minimal side effects.

Agriculture

- Creates a virtual field replica, factoring in size, topography, sunlight, and cultivation history for **accurate analysis and results**
- **Enables real-time monitoring** of crops, soil, and weather to simulate growth patterns and determine resource needs
- Helps in **detecting issues in advance**, conducting preventive maintenance, and forecasting weather patterns

Example - Syngenta

Syngenta utilizes a digital twin solution across nursery operations, trial planning, and crop/seed qualification. This approach **streamlines processes, optimizing seed timing and farm plot selection**. As a result, Syngenta has achieved a **15% reduction in costs** and improved **asset utilization by 25%**

Source: Press Search

Digital twins, initially prevalent in manufacturing and aerospace, are expanding into other industries, including healthcare, transportation, retail, and energy (2/2)

Expansion to new industries

In retail, digital twins boost engagement and cut costs through immersive shopping experiences and optimized store layouts. In energy, they analyze demand, simulate cost-cutting measures, and prevent errors in low-carbon energy technologies.

Energy

- Helps in **analyzing energy demand in microgrids**, enabling simulations of cost-cutting measures, and evaluating different capital expenditure strategies
- **Quantifies risks in adopting low-carbon energy technologies**, preventing errors, and certifying safety levels for new services and features
- Simulates the variability of renewable generation and forecasts energy output to **integrate renewable energy into the grid while ensuring its stability**

Example - MottMacdonald

MottMacdonald developed a digital twin for Watercare that has led to a **400% ROI** within two years. It achieved it by **improving the accuracy of water supply and wastewater network capacity assessments**. It is also reducing business risks by allowing development to proceed without upgrade requirements.

Retail

- Creates immersive simulations that **improve customer engagement and confidence,** resulting in higher conversion rates and lower product return rates
- **Optimizes store layouts**, shelving arrangements, and staffing scenarios virtually, reducing guesswork and capital expenses
- Integrating AI with digital twins **helps in informed decisions** on inventory management, shipping, and overall business strategies

Example - IKEA

IKEA uses **Digital Twins of Customers (DToCs) to design stores and create personalized shopping experiences**. By analyzing customer data and store performance, IKEA optimizes layouts and product placements virtually before implementing changes in the physical world.

Source: TechUK "Digital Twins for energy" (2021), Press Search

Global companies are increasingly turning to digital twins to minimize waste and optimize energy utilization, enabling them to achieve their sustainability objectives

Promoting sustainability

Digital twins help organizations understand and quantify decision impacts, reduce waste, increase efficiencies, and automate change. They merge profitability and sustainability by leveraging data and optimizing resource use across the value chain through virtualization, remote capabilities, and closed feedback loops. Examples include:

Procter & Gamble

In Procter & Gamble's Guangzhou, China, factory, a digital twin was utilized to enhance warehouse operations. Over three years, it not only achieved a 99.9% on-time delivery rate and lowered logistic costs by 15%, but also **managed to reduce inventory by 30%, limiting product waste.**

LG Electronics

LG Electronics' Changwon, Korea, factory converted its assembly line visual simulation tool into a digital twin by integrating real-time production data every 30 seconds. This led to a 70% increase in product quality and **a 30% reduction in energy consumption.**

Schneider Electric

Schneider Electric's LeVaudreuil site utilizes digital twins for its plant installations. Under the "No-Excuse" Framework, they leveraged data collected to **reduce energy management by 25%, cut material waste by 17%, and lower CO2 emissions by 25%.**

Western Digital

In Malaysia, **Western Digital** employs digital twins to establish a "lights-out automation" system. This approach integrates sustainability and efficiency, resulting in significant growth with a CAGR of 43% over four years and **cutting energy consumption by 41%.**

Source: Weforum "Why manufacturers should use digital twins for sustainability not just productivity" (2023), Press Search

Governments around the world are recognizing the potential of digital twins to enhance decision-making, improve efficiency, and promote sustainability

Rise of public-sector applications

Governments are increasingly adopting digital twins to monitor infrastructure, streamline urban planning, and enhance public safety. This approach enables data-driven decision-making and minimizes service disruptions, benefiting both governments and cities worldwide

Regional level	In **Europe,** the **TwinAIR project** uses digital twins and introduces technological solutions to enhance indoor air quality in various living environments	The **Smart Rural 21 project** promotes and implements smart village approaches across Europe, informing future policy interventions on smart villages	The **Digital Urban European Twins (DUET) project** develops virtual city replicas, facilitating the understanding of complex urban interactions like traffic, air quality, and noise

Country level	**Singapore** Virtual Singapore, launched in 2011, utilizes digital twins for flight safety, 5G deployment, infrastructure planning, and surveillance services	**India** In 2023, India unveiled its “DT Strategy for Indian Infrastructure” to enhance infrastructure planning and reduce construction costs	**UK** The 2018-launched National Digital Twin program aims to enhance infrastructure through stakeholder coordination and data sharing	**The UAE** In 2024, the Ministry of Energy launched a Digital Twin Platform to create accurate digital models of assets and operational facilities
City level	**Athens** Athens aims to improve citizen services with a Digital Twin, merging city data for easier access and raising stakeholder engagement	**NEOM** NEOM plans "The Line," a 170km car-free community with a metaverse and digital twins for a dynamic mixed-reality experience	**Seoul** Seoul's "Digital Twin S-Map" is South Korea's first 3D urban simulation, enhancing objectivity in urban planning	**Los Angeles** Los Angeles partnered with Cityzenith for a digital twin project, aiming to decarbonize buildings and reduce emissions

Source: Europa “Mapping EU-based LDT providers and users” (2023), Press Search

Recognizing the role of interoperability, digital twin organizations are collaborating to develop integration standards

Call for interoperability

Agreement on integration standards among digital twin technology providers is essential for digital twins to effectively interact and communicate across multiple systems. These standards allow manufacturers to ensure compatibility and scalability across diverse environments.

	Plattform Industrie 4.0 and CESMII	DTC interoperability framework	DTC and IDTA collaboration	DTC and OPC Foundation
	In 2020, Plattform Industrie 4.0 and CESMII* partnered to establish standards for manufacturers in Germany and the United States to better enable smart, sustainable competition.	**The Digital Twin System Interoperability Framework** developed by DTC in 2021 is a set of standards to **promote interoperability and collaboration in digital twins.**	In 2021, **DTC and the Industrial Digital Twin Association (IDTA) partnered** to develop standardization requirements, foster interoperability, and collaborate on open-source projects.	In 2023, **DTC and the OPC Foundation** announced a liaison agreement to accelerate the development and adoption of digital, promoting interoperability standards and processes.
Main Goal	Enhance **manufacturing workforce skills and competencies** while promoting **environmental sustainability** through digital transformation.	Create a **secure, collaborative, and scalable digital twin ecosystem** that addresses privacy, facilitates communication, fosters innovation, and delivers value across industries.	**Drive collaboration and digital twin innovation** by coordinating efforts across horizontal and vertical domains, establishing Value Innovation Platforms (VIP) programs, and developing open-source reference implementations.	

Source: OPC Foundation, Digital Twin Consortium, *Clean Energy Smart Manufacturing Innovation Institute (CESMII), Press Search

Outlook

Digital twins are providing greater opportunities for optimization, personalization, and innovation. In fact, looking ahead, digital twin technology is poised for **significant advancements** driven by trends such **as the integration with cutting-edge technologies like AI, XR, edge computing, and 5G**. This integration enhances visualization, collaboration, decision-making, and connectivity, particularly for smart city and healthcare applications. Moreover, the **rise of new models like digital twins as services (DTaaS) and cognitive digital twins is set to democratize access to the technology**. This shift offers scalable solutions without extensive infrastructure investments and leverages AI to simulate real-world elements, predict outcomes, and make data-driven decisions.

Simultaneously, digital twins are **expanding into new industries beyond manufacturing and aerospace**, revolutionizing **healthcare, transportation, retail, and energy, among others**. This evolution showcases their versatility in solving complex challenges, optimizing supply chains, managing energy grids, and enhancing customer experiences across diverse sectors. **Integration standards among digital twin providers** are also essential for **building cross-system digital twins**, enabling manufacturers to **offer universally applicable services and fostering interoperability and streamlined implementation** across various digital twin technologies and software.

As digital twins continue to develop, a **stepwise transformation is crucial, focusing on value and integration**. Companies must organize themselves around **capabilities, roadmaps, governance, and end-to-end integration for successful deployments**. Key areas include long-term roadmaps integrating safety and sustainability, necessary capabilities for designing, building, and operating digital twins, and robust architectures for scalability and data security.

Source: Capgemini “Digital Twins: Adding intelligence to the real world” (2022)

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