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Using simulations can ease the complex development process and provide insights into how products are performing in the real world.

Digital twins improve real-life manufacturing

Before reality, there's simulation.

A 2021 missile-inceptor test conducted by aerospace and US defense technology provider Raytheon Technologies held no surprises because the company had already tested almost every aspect of the launch in simulation. Siemens and space agency NASA's Jet Propulsion Laboratory worked together on a digital twin of the Mars Science Laboratory on the Curiosity rover to solve heat dissipation problems caused by the radioisotope power generator. And tire and rubber manufacturer Bridgestone uses digital twins to simulate the performance of its tires using data from actual vehicles to develop a price-per-kilometer service in Europe.

Real-world data paired with digital simulations of products – digital twins – are providing valuable insights that are helping companies identify and resolve problems before prototypes go into production and manage products in the field, says Alberto Ferrari, senior director of the Model-Based Digital Thread Process Capability Center at Raytheon.

"As they say, 'All the models are wrong, but some of them are useful,'" Ferrari says. "Digital twins, supported with data – as real facts – are a way to identify models that are really useful for decision-making."

Key takeaways

1. Digital twins speed up development, design, and manufacturing processes. Simulations focused on real-world performance help organizations break down the barriers between disciplines; provide necessary data, information, and tools when and where they're needed; and power a far more cost-effective and efficient pace of innovation.

2. Transitioning to virtual simulations to design real products boosts sustainability. In design, digital twins help companies run what-if scenarios to test vehicles more efficiently. In manufacturing, automated designs lead to cost-effective production, with less waste, less energy, and less scrapping of subpar vehicles.

3. Digital twins have moved from modeling to managing operations. Augmenting simulations with real-time operations data allows manufacturers to optimize efficiency and recognize improvements for follow-on new designs.

The concept has started to take off, with the market for digital-twin technology and tools growing by 58% annually to reach $48 billion by 2026, up from $3.1 billion in 2020. Using the technology to create digital prototypes saves resources, money, and time. Yet the technology is also being used to simulate far more, from urban populations to energy systems to the deployment of new services.

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Take manufacturers as varied as Raytheon and Swedish distillery Absolut Vodka, which are using the technology to design new products and streamline their manufacturing processes, from the supply chain through production and, eventually, to recycling and disposal. Singapore, London, and several Texas Gulf Coast cities have created digital twins of their communities to tackle facets of city management, including modeling traffic patterns on city streets, analyzing building trends, and predicting the impact of climate change. And companies such as Bridgestone and drone-service provider Zipline are using the technology paired with operational data to help launch new services.

Companies have adopted digital twins as part of their digital transformations, a way to simulate performance, identify weaknesses, and operate services more efficiently. Any company's digital initiative should explore whether some facet of its product, operations, or environment can be simulated to gain insight.

Simulating design and manufacturing

The digital-twin technologies of today have their foundations in the computer-aided design (CAD) and computer engineering tools developed more than three decades ago. Those software systems allowed engineers to create virtual simulations to test changes in product designs. Engineers designed a product component, such as an airfoil, on a computer and then tasked a modeler or sculptor to craft the item in clay, wood, or stock components for physical testing.

Today, the process has shifted the prototyping stage to much later in the process, as massive growth in computational power and storage allows not only the entire product to be prototyped but other information to be integrated as well, such as information on the supply of raw materials, the components needed for manufacturing, and the operation of the product in the field.

"If you look at those CAD and engineering tools from 30 years ago and squint your eyes a bit, you would see that those things were digital twins," says Scott Buchholz, government and public services chief technology officer and emerging technology research director at Deloitte Consulting. "As the power computation and storage went up, the ability to do useful simulations went up, and we went from low-fidelity renderings to high-fidelity simulations."

Design, realize, and optimize

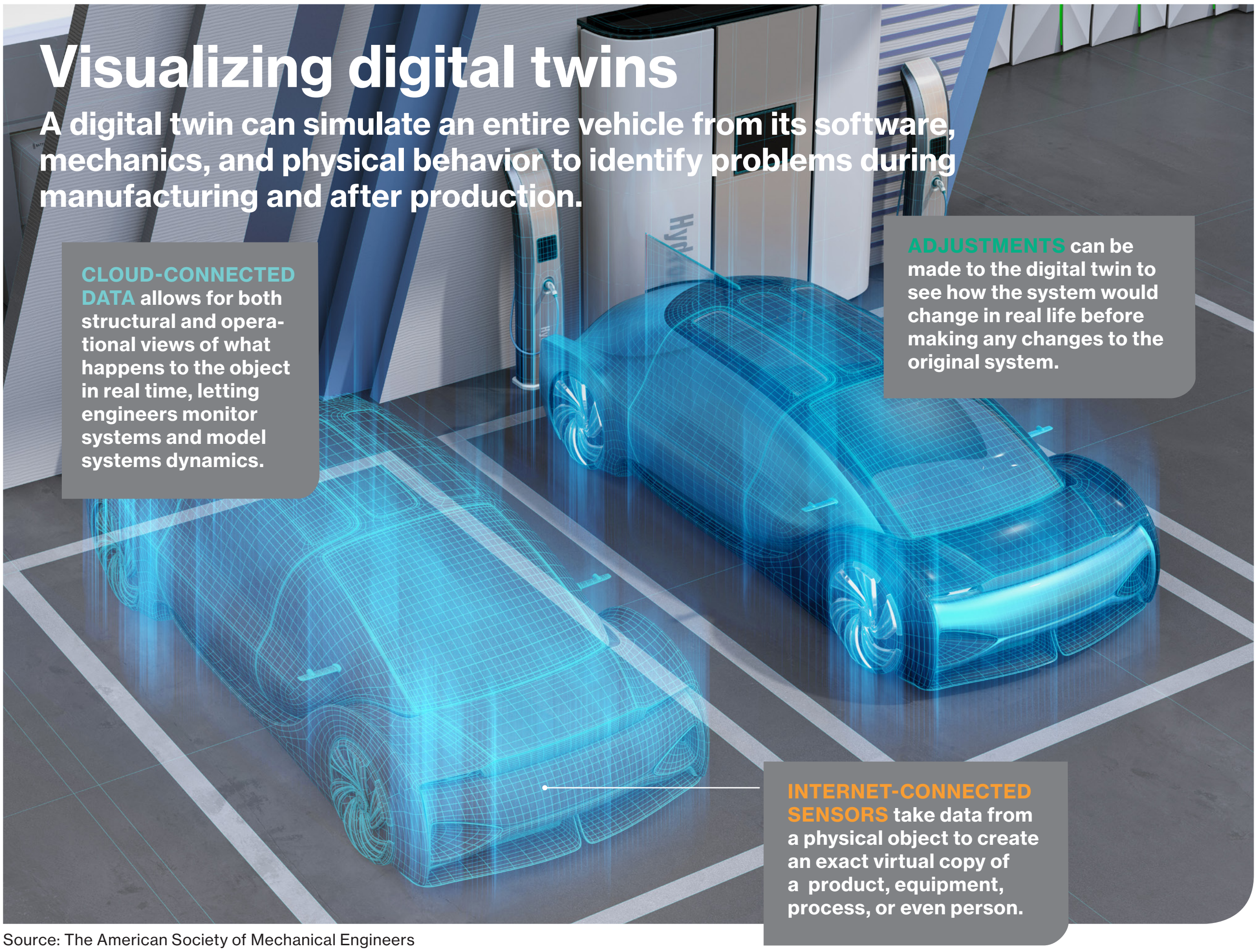
A digital twin is a virtual representation of a material, product, process, or service that focuses on three aspects:

1. Design The requirements, parameters, components, and materials that go into a product, as well as the concept and development for creating the product.

2. Realize The process of creating the product and delivering it to the consumer.

3. Optimize The operational component that includes life-cycle management and data from consumer use, which can then be fed back into the Design and Realize phases as part of a never-ending, closed-loop development process.

The result is that digital-twin technology has taken a variety of industries by storm. Makers of expensive vehicles and infrastructure products benefit from shortening the design and development cycle, making aerospace companies, car manufacturers, and city planning agencies all early adopters. Yet startups are also adopting the simulate-first mentality to quickly iterate on product improvements.



Source: The American Society of Mechanical Engineers

A major benefit: digital twins have pushed off the physical construction of prototypes much further down the design pipeline. Some companies pursuing zero-prototype initiatives aim to eliminate the prototyping steps altogether and enable direct-to-manufacturing efforts, says Nand Kochhar, vice president for the automotive and transportation industry at Siemens Digital Industries Software.

$48 billion

The projected value of global digital twin market in 2026, reflecting a compound annual growth rate of 58% from $3 billion in 2020

Source: Markets and Markets

That's a massive shift from times past. "A typical product development life cycle was anywhere from six to eight years," Kochhar says of automobile manufacturing. "The industry has been working on that, and now they have an 18-month or 24-month life cycle. Now, automaking is more reliant on software, which is becoming the determining factor in the life cycle."

Where digital twins fit

Using digital twins and simulating their performance with real-world data can help companies shorten development cycles, improve manufacturing, and adapt to changing operations in the field. Automaker Tesla creates a digital twin of every car it sells, both as a digital-twin prototype during development and as a digital-twin instance (DTI), a post-production way of simulating the state of any vehicle in the field. The prototype is about making the simulation relevant for Tesla's decision-making process in development, while the DTI is about integrating data into an operational

Minimizing manufacturing and development costs

In a case study by consultancy Challenge Advisory, profit margins increased and manufacturing time was reduced when digital-twin technology was implemented.

Automobile manufacturing profit margins increased by 41% to 54% per model.

The estimated average automobile manufacturing time was reduced to approximately 10 hours.

Source: "Digital Twin Genie Case Study," Challenge Advisory, March 2018

model. The key to digital twins is the connection between the real world and the simulated product, service, or process.

Airplane manufacturing is a prime example of the two approaches. Model-based engineering using digital twins allows Boeing to create more accurate designs, so suppliers provide the requested parts that fit right the first time. The company created two prototypes of its T-X trainer in one fifth of the normal time, with such accuracy that the first two aircraft were assembled with minimal tooling and a rework rate of 0.3%.

Boeing is also using the digital-twin framework to monitor and improve equipment in the field. Sensors have become less expensive, allowing companies to put more sensors and actuators into their products. Airplanes have gone from having no sensors on them to having tens of thousands of sensors. Once used to improve product design, digital twins are now improving operations as well.

Such operations platforms harken back to an early "digital twin" – the simulator for the Apollo 13 mission. When an explosion caused the spacecraft's oxygen to leak into space, NASA used the Apollo simulator to diagnose and solve the problem, using real-world data from the spacecraft to modify the simulator and its tests.

Chipmakers are adopting the technology as well. With the size of chips growing and heat management a critical problem, companies must simulate changes to chip layouts and designs before problems arise. This analysis is part of what's known as the "shift left" in development, in which testing is done earlier and in simulation, rather than on prototypes.

Here's how it works: a design analysis is performed on simulated chip, writes Siemens systems architect director Per Viklund in a Semiconductor Engineering report, "and the results are used to drive design decisions as well as make corrections to mitigate the risk of verification failures later in the design flow."

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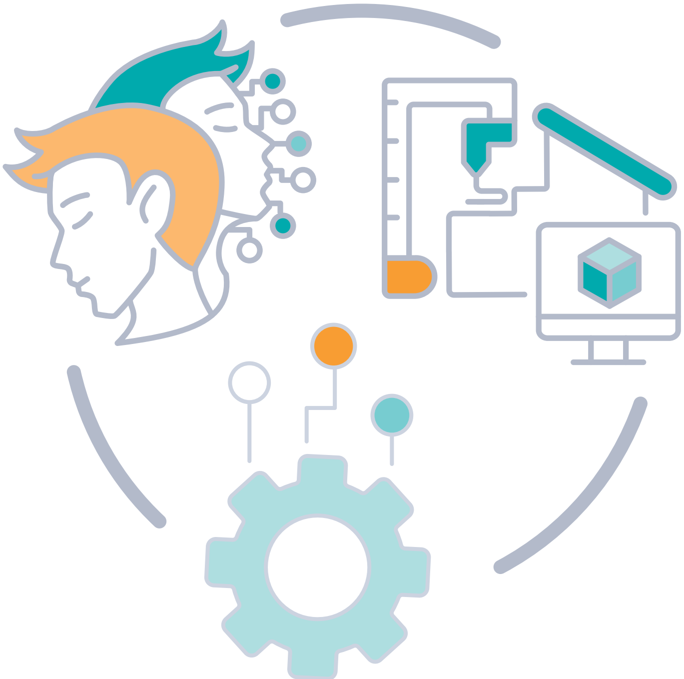

Thread of support

To create the foundations for digital-twin simulations, companies need to create digital threads, pipelines for data and information that feed the simulated reality, and machine-learning systems to analyze the data and model the digital twin. Companies must seamlessly pull together all the information that's needed from all the different parts of the life cycle to build a digital twin. Representing the pipeline of data from products back to development, digital threads have become foundational to digital transformation.

How far can simulations go?

The concept of digital twins has moved from a specific meaning in design and manufacturing and expanded to encompass all sorts of simulations based on real-world data. Virtual design models have replaced static physical prototypes, which would traditionally be made of clay, wood, or custom parts. Computer simulations based on real-world data are replacing functional-performance prototypes, which are used to test a product's operation in a variety of situations.

With the broadening definition of digital twin, other industries have picked up on the concept. City planners have started simulating their population centers to test out how certain policies could affect growth. Singapore, for example, is building a digital replica of the entire city and has created pilot projects aimed at improving the urban environment. Security-operations teams are starting to incorporate real-time threat data to simulate attacks on their networks and determine whether they're prepared to fend off attackers.

Digital-twin powers, activate

Using digital twins offers manufacturers a virtual replica that can boost production capacity and improve customer service.

PRODUCT TESTING
Simulating product performance – say, new tires in varying weather conditions – can allow for virtual experiments.

PRODUCT MANAGEMENT
By monitoring data from sensors, digital twins can predict when maintenance will be needed.

SUPPLY CHAIN MANAGEMENT
Digital twins can track and analyze performance measures such as route efficiency.

TARGETED RECALLS
Digital twins offer full product traceability, so businesses don't have to recall all products if there's a problem.

COLLABORATION
The sharing of data across engineering, production, and sales departments enables better communication and faster decision-making.

CUSTOMER SERVICE
A vehicle's a digital identity allows businesses to determine how often it was serviced and when parts were changed.

Sources: EY/The American Society of Mechanical Engineers

Living in the simulation

Digital twins are not just about devices and processes. Human behavior is being modeled as well. In its simplest form, humans can be incorporated into simulations as users of the product being analyzed. Advertisers have already created predictive models using behavioral profiles—essentially, digital twins. But creating actual digital twins of humans can give city planners insight into a city's population and how people might respond to urban changes. Manufacturers can gauge the efficiency of factory workers by modeling human fatigue. And economists could test potential policies using a simulated country.

A major challenge for organizations using digital twins is managing the data pipeline between the simulation and the real world, also known as the digital thread. Data is collected on the device, on local servers, in the cloud, and on development systems, such as workstations. Yet most companies can't use all that data. Only 34% have access to the data generated in another department, and only 9% can access data from products in the field, according to the State of Digital Thread survey.

"The fundamental concept of digital thread is about connecting digital twins to the right digital information and the right people at the right time," Siemens' Kochhar says. "For most companies who started their digital transformation journey, or who are just starting, it is not an easy thing."

Managing that data becomes even more important as digital-twin technology evolves. Rather than just collecting data from products in the field, companies are pushing new configurations and software to their products, making digital twins increasingly an operational technology. With the quick adoption of sensors and actuators in everything from cars to cell phones and from planes to tires, companies not only can collect real-time data on their products in the field but also can adjust operations of the devices and adapt to the consumer's use of a product.

Digital twins enable sustainablity

With sustainability and reduced energy consumption a priority for many companies and countries, digital twin technology has two major roles to play. First, companies can easily prioritize energy efficiency in simulations, using properly constructed digital twins to check device functionality and determine how much power a design will likely consume.

Using digital twin simulations to include sustainability goals at the beginning of the design and development life cycle, companies can dramatically reduce the environmental impact of consumer products, according to consultancy Accenture. Such efforts could save $131 billion in inefficient raw material usage, $6 billion in product development, and 281 million tons of carbon dioxide production.

Digital twins can also be used as a research and analysis tool, creating simulations of energy systems to determine ways to make use of power-consuming devices more efficient. In August, for example, Oak Ridge

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National Laboratory announced the research center had created a modeling program, Automatic Building Energy Modeling, to provide energy profiles on every one of the approximately 129 million buildings in the United States using publicly available data. The program, part of the laboratory's five-year Model America effort to create digital twins of all US buildings, used satellite imagery, street views, the number of windows, the number of floors, and other information to create a power-efficiency model of each building.

"Before this program, no one had the capability to perform that analysis with detailed, building-specific energy modeling at this scale," said Joshua New, leader of the Oak Ridge research team, in a press statement. "Individual utilities now have the capability to perform modeling to show the potential of reducing demand and greenhouse gas emissions."

In all these industries, digital twins are delivering faster development at a lower cost, accounting for manufacturing pipeline all the way to the end user and allowing companies to gain insight before ever investing in actual products. For any company looking for ways to further embrace digital transformation, digital twins are a necessity.

"Digital twins improve real-life manufacturing" is an executive briefing paper by MIT Technology Review Insights. It is based on research and interviews conducted in August and September 2021. We would like to thank all participants as well as the sponsor, Siemens Digital Industries Software. MIT Technology Review Insights has collected and reported on all findings contained in this paper independently, regardless of participation or sponsorship. Jason Sparapani, Sonia Rubeck, and Laurel Ruma were the editors of this report, and Nicola Crepaldi was the publisher.

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