

HOW A DIGITAL TWIN OF THE EARTH
CAN HELP TO SAVE THE REAL ONE

HOW DIGITAL TOURISM CAN
BECOME LIKE TIME TRAVEL

HOW DIGITAL BODY COPIES
CAN MAKE OUR LIVES HEALTHIER

DIGITAL TWIN

IMPACT

2022

AN FII INSTITUTE PUBLICATION



NICE TO MEET ME
DIGITAL TWIN TECH IS NOT
JUST A METAVERSE THING.
IT'S A BOON FOR HUMANITY

FII INSTITUTE
Future Investment Initiative Institute

Impact
on Humanity

HOW RELEVANT ARE DIGITAL TWINS FOR YOUR COMPANY?

Digital twins provide companies and organizations with a more realistic and holistic approach to unforeseen and unpredictable scenarios, and are a great tool to increase productivity, competitiveness, and efficiency.

● NOW ● IN FIVE YEARS

DIGITAL TWINS OF THE PRODUCT

23 %
43 %

DIGITAL TWINS OF THE FACTORY

19 %
44 %

DIGITAL TWINS OF THE PRODUCTION ASSET

18 %
39 %



ECONOMIC GROWTH INCOMING

Projected compound annual growth rate of the digital twins market, from **US\$3.8 billion in 2019 to US\$35.8 billion by 2025.**

FACTS & FIGURES

DIGITAL TWINS ARE GROWING UP FAST

A digital twin is the virtual version of something that happens or exists in physical space – whether a process, person, or object. The digital twin operates in the same way as their physical relative, and in real time, coded as a virtual model to carry out the same tasks or think in the same way. The concept of the digital twin has now moved out of industry and into everyday life with the rise of the Metaverse, as we start to see digital twins of ourselves likely to live, work, and play within it.

A WAKE-UP CALL



Cars: Tesla creates a digital twin in every car it sells and woke up the car industry with significant investment in the technology. Tesla updates the car's software based on the individual vehicle's sensor data and uploads updates for a better driving experience for the vehicle's owner.



Cities: A wake-up call for cities arrived when **Singapore** created the first digital twin of a city, or in this case an island-state. Its digital twin technology is helping the government in its rollout of renewable energy, urban planning, and coastal protection efforts.



Socials: Fifteen years since its launch and with some 2.8 billion users, **Facebook** announced in October 2021 that it was creating a parent company called Meta to refocus the company's virtual reality activities, waking tech companies up to the opportunities of diversifying revenue streams.



Icons: Swedish pop sensations **Abba** woke up the entertainment industry in 2022 when their "Abba-tars" took to the stage in London for the group's Abba Voyage show, featuring groundbreaking twin technology that recreated the quartet in their 1970s prime for fans all over the world.

THE BIGGEST CHALLENGES FOR DIGITAL TWIN TECHNOLOGY



Cybersecurity

AI analytics can be trained to search for "bad actors," tampering, theft, and intrusions. But sharing personal information online will always be a risk.



Limited skilled workforce

It's all about the data! But this new technology requires a new breed of engineer with greater knowledge and understanding for digital twin simulations to happen.



Lack of awareness of cost benefits

Organizations need to seize the aha moment and realize the savings that can be made in productivity and efficiency.

FEED YOUR TWIN

87% update digital twins when physical counterparts change.

54% of digital twin users are using one or more constituencies.

40% Some 40% of the organizations implementing digital twins report at least seven sources of data captured and monitored as part of their digital twin efforts.



TOP 15 INDUSTRIES USING DIGITAL TWINS

- 1 AUTOMOTIVE
- 2 AUTONOMOUS VEHICLES
- 3 QUALITY MANAGEMENT
- 4 SYSTEMS PLANNING
- 5 LOGISTICS
- 6 PRODUCT DEVELOPMENT
- 7 DISASTER MANAGEMENT
- 8 AVIATION
- 9 CONSUMER PRODUCTS
- 10 HEALTHCARE
- 11 INSURANCE
- 12 SMART CITIES
- 13 CAR RACING
- 14 SPACE OPTIMIZATION
- 15 WEARABLES

SOURCES: GARTNER, "SURVEY ANALYSIS: DIGITAL TWINS ARE POISED FOR PROLIFERATION," JANUARY 31, 2019, ID: G00366837; ANALYSTS: ALFONSO VELOSA, NATHAN NUTTALL, MARC HALPERN, BENOIT LHEUREUX; PWC, STATISTA 2022; GARTNER, "MARKET GUIDE FOR DATA PREPARATION TOOLS," 9 JULY 2020 - ID: G00719343; ANALYSTS: EHTISHAM ZAIDI, SHARAT MENON; MARKETRESEARCH, DIGITAL TWIN MARKET WORTH \$35.8 BILLION BY 2025; MARKETRESEARCH, DATA UNIVERSITY, NET, OMNISIGHTS.COM, BUSINESSINSIDER.IN, RESEARCH.AIMULTIPLE.COM, WWW.SAS.COM, WWW.THEGUARDIAN.COM, WWW.BBC.CO.UK

EDITORIAL

THE METAVERSE IS ABOUT YOU



WHENEVER I ATTEND AN INTERNATIONAL TECH EVENT these days, it's all about the Metaverse. This is the next big thing, Mark Zuckerberg has promised to deliver it, and while no one at these events seems to know what to do with it right now, the final outcome is crystal clear: money.

As the FII Institute is a non-profit foundation focused on Impact on Humanity, we are looking at this big thing to come from the perspective of the people. What will you see, feel, experience in the Metaverse?

I assume the key element of the experience will be the birth of your digital twin. It sees for you, it travels for you, it will be like you. Almost, at least. So we decided to make this Impact Report, our seventh, not about the Metaverse, but about digital twins.

We check how this technology can have a positive Impact on Humanity. We follow digital twins through healthcare and tourism, we explore how they improve investment decisions and help fight climate change. And we discuss what will happen to our identity as humans when there is always a second Me around.



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Future Investment Initiative

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A DEEPER DIVE

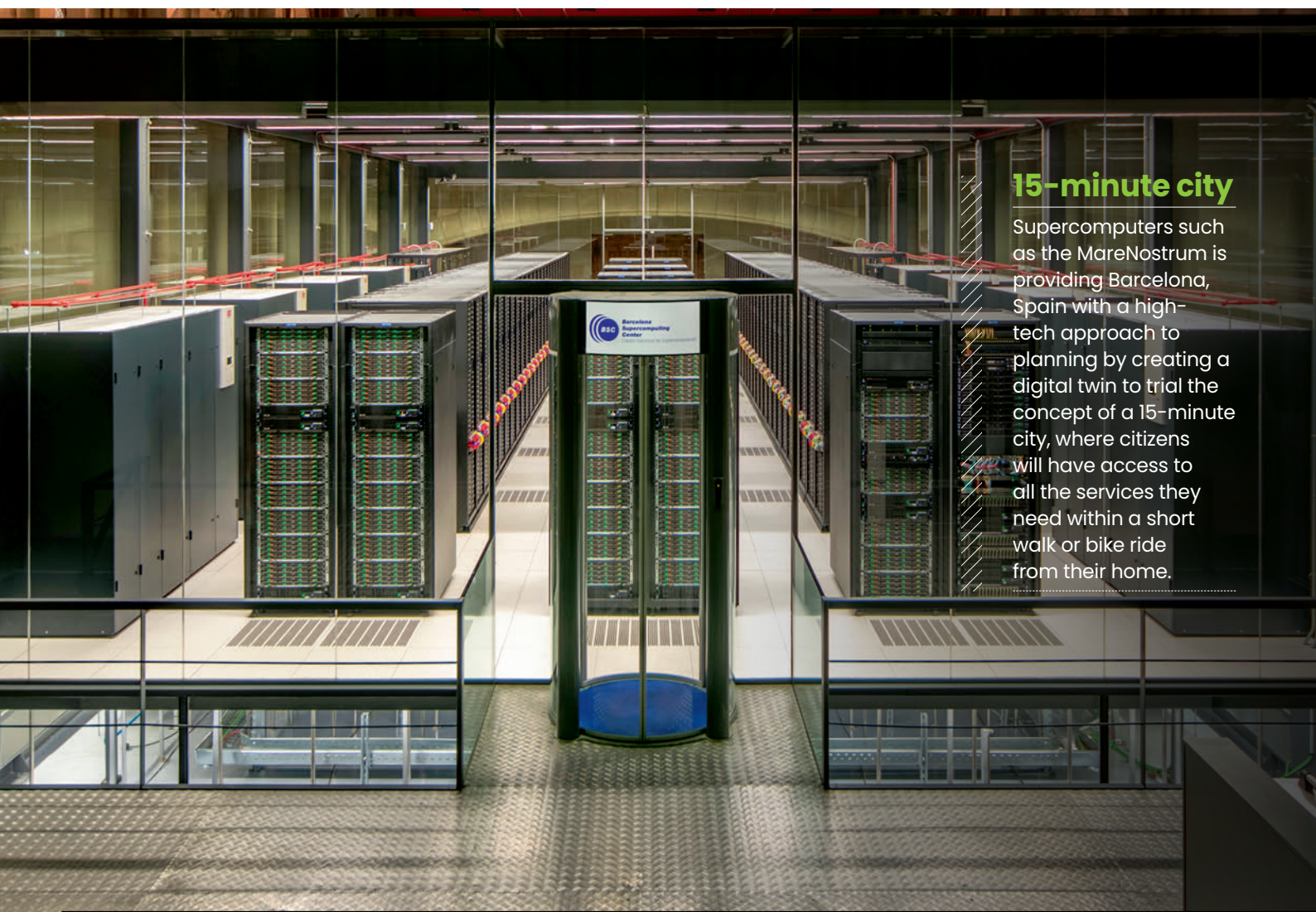
A COLLABORATION BETWEEN AKER SOLUTIONS AND SIEMENS FOCUSES ON A PLATFORM OF ENGINEERING AND DIGITAL TWINS TO DRIVE EFFICIENCIES IN THE OIL AND GAS SECTOR, REDUCING MANUFACTURING AND OPERATIONAL COSTS AND ENABLING IMPROVED DECISION-MAKING.

Data pipeline

Digital twin solutions are providing increased insight in projects like this, which in turn enables better performance, maintenance, and investment decisions. By working to develop and deploy advanced digital solutions, the project will allow energy customers to liberate data and solve important engineering challenges.



BARCELONA UPGRADE



15-minute city

Supercomputers such as the MareNostrum is providing Barcelona, Spain with a high-tech approach to planning by creating a digital twin to trial the concept of a 15-minute city, where citizens will have access to all the services they need within a short walk or bike ride from their home.

FILE: DIGITAL TWIN IMPACT REPORT 2022



Digital Tour de France

In 2021, IT infrastructure and services company NTT created a digital twin of the Tour de France - 3,400km of connected people, places, and things - using a broad range of IoT sensors integrated into a common platform and mapped against a geolocation model of each stage.

LET'S TALK ABOUT DIGITAL TWINS

A quick, all-you-need-to-know guide on realizing the potential for digital twin technology's impact on humanity – and other less important areas.

Forecasts that the digital twin market **will grow 58% a year to US\$48.2bn by 2026** (MarketsandMarkets) is an indication that digital twin-backed investment is soaring, but the true value of this technology is perhaps better viewed through its impact on humanity. Digital twins work in a wider orbit, or ecosystem, of technologies in the fourth industrial revolution, principally IoT, artificial intelligence (AI), and machine learning (ML). Healthcare, agriculture, education, environment, infrastructure, and travel can all benefit from this new wave that is exploring human behavior and testing hypothetical problems and solutions in a virtual environment.



DEFINE DIGITAL TWINS – I DARE YOU

Try this: "A digital twin is a virtual representation of an object or system that spans its life cycle, is updated from real-time data, and uses simulation, machine learning, and reasoning to help decision-making." Thanks, IBM.
In plain English, this means creating a highly complex virtual model that is the exact counterpart (or twin) of a physical thing.

So it's not all pie-in-the-sky sci-fi theories?

Au contraire. A digital twin is a technological leap through the looking glass into the very heart of physical assets. Digital twins give us a glimpse into what is happening, or what can happen, with physical assets now and far into the future.

But how does a digital twin work?

It is a virtual tool that helps engineers and scientists to understand how physical objects are performing – and how they will perform in the future after all the data is analyzed, kind of like a crystal ball for the tech world.

Where can I see digital twins?

That's the thing. You can't. But at the same time, they are everywhere.



1. The energy sector

Digital twin technology is being used to create digital wind farms, for example.



2. Hospitality

Digital twin technology can be used to simulate real-life events and situations, and this could play a major role in the hospitality industry in the future.



3. Retail environments

The digital twin is still a relatively new concept in retail, but it could prove valuable, particularly when it comes to modeling customer behavior in stores.



4. Healthcare

Digital twins of patients or their organs enable practitioners to simulate procedures and specific environments before trying them in real life.



5. City management

ABI Research expects more than 500 urban digital twins to be deployed by 2025, and forecasts that they will save city planners US\$280 billion by 2030.

ILLUSTRATIONS: FLATICON.COM

SO 'TWIN CITIES' NOW TAKES ON A WHOLE NEW MEANING?

Correct. Singapore and Shanghai both have complete digital twins while Las Vegas, Los Angeles, New York, and Phoenix are all building digital twins.

DO I NEED A DIGITAL TWIN?

You may already have one. You've heard of avatars, right? Our digital doubles could soon take over our lives, especially in the Metaverse.

WHAT ABOUT PRIVACY?

Good point. And there is a move to give digital twins the same human rights as, well, humans.



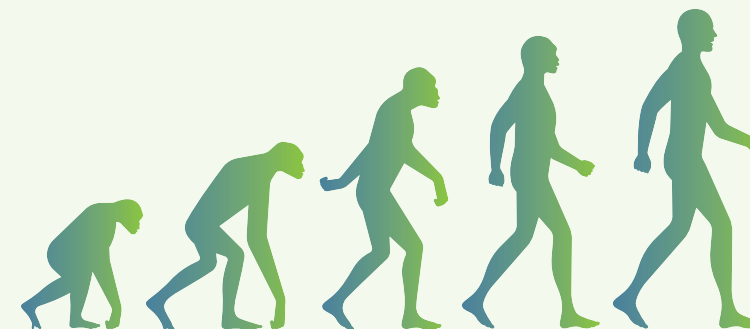
BUT AREN'T DIGITAL TWINS JUST FANCY VERSIONS OF THE AVATARS WE ALL HAD WAY BACK WHEN?

Avatars have also grown up and can be represented either in three-dimensional form (for example, in games or virtual worlds) or in two-dimensional form as icons in internet forums and virtual worlds. And digital avatars will soon be able to interact like digital twins do, but also in enhanced ways and with a much wider set of digital partners and circumstances. *You need to keep up.*



IT ALL SOUNDS LIKE A GAME TO ME

Well, avatars have been used in the gaming world from the get-go, and software companies like Unity Pro or Unreal Engine are leveraging their online experience of Non-Player Characters (NPCs) to turn digital twins into immersive 3D simulations where users can freely explore their surroundings, just as they would in a game such as Fortnite.



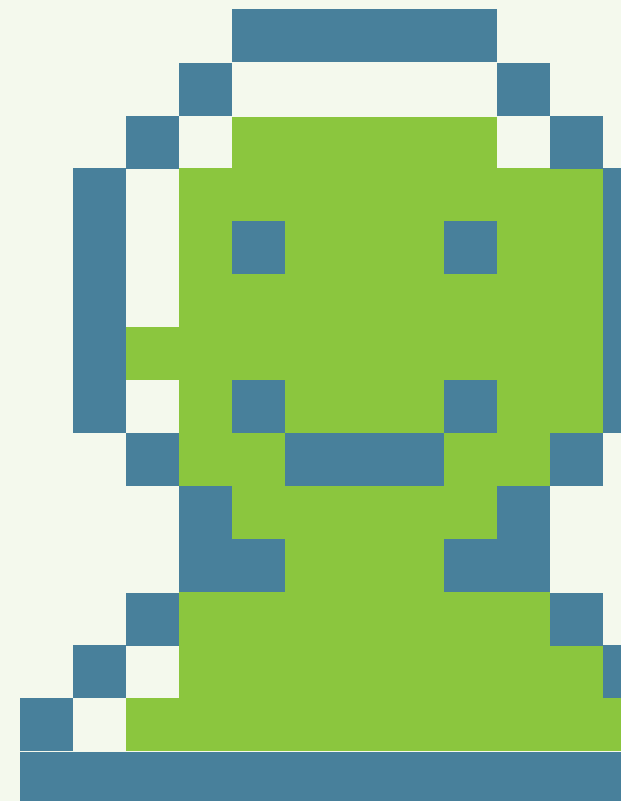
ARE ALL DIGITAL TWINS EQUAL? WHAT ABOUT COGNITIVE DIGITAL TWINS?

What about them? Once off the leash, digital twins promise to go still further. The use of cognitive computing increases the abilities and scientific disciplines of the digital twin.

ANYTHING ELSE I SHOULD KNOW ABOUT DIGITAL TWINS?

Plenty. The beauty of them is that they are constantly evolving.

See you in the Metaverse.





**ONE GIANT LEAP
FOR HUMANITY**
HOW DIGITAL
TWIN SAVED
APOLLO 13
AND BECAME
THE DEFINING
TECHNOLOGY
OF OUR AGE

A digital twin is a powerful
standalone technology.

PHOTO: GETTY IMAGES/E+/IMAGINIMA



“HOUSTON, WE HAVE A PROBLEM.”

These now-famous words were spoken by astronaut Jim Lovell on April 13, 1970, after the Apollo 13 crew had experienced an onboard explosion, prompting Commander Lovell to calmly call mission control in Houston.

At this point, neither the crew nor the team in Mission Control knew the cause of the problem. It soon became apparent that Oxygen Tank 2 had exploded, and the CSM (Command and Service Module) was losing the oxygen required for the crew to breathe and generate power in the fuel cells.

Mission Control estimated that at the rate the quantity was decreasing in Oxygen Tank 1 they had less than two hours of power generation remaining.

NASA used what we now know as digital twinning to repair the damaged Apollo 13 spacecraft, working with an exact digital replica to bring it and the crew safely back to earth.

Repairing a physical asset 200,000 miles away in space was no mean feat, particularly with the rather rudimentary technology available to the scientists back in 1970; and the exercise is seen as a masterclass in rapid responsiveness and re-engineering in a time-critical scenario, which helped save three lives.

By mirroring training simulators that included failure scenarios to match the perilous conditions on Apollo 13, NASA scientists could research and perfect different strategies and quickly reject ones that would not work, saving crucial minutes in bringing home the stranded astronauts. The techniques used by the team on the ground are seen as early and archetypal use of the technology we now know as digital twin.

A digital twin has three elements: a physical product, a digital/virtual product, and the data or connection flowing between the two components.

The concept of digital twins took off in early 2002, when Dr. Michael Grieves introduced a digital twin concept originating in a presentation on a product life cycle management center. Digital twins had also been anticipated in 1991 by David Gelernter’s book *Mirror Worlds*, and we



NASA scientists at Mission Control use an early “digital twin” to rescue the stricken Apollo 13 spacecraft.

can trace the evolution of digital twins from *Mirror Worlds* through Mirrored Spaces Model 2002 and Information Mirroring Model (2006) to 2010 when another NASA scientist, John Vickers, first used the term “digital twin.”

A STAND-ALONE TECHNOLOGY

Today, digital twin has grown up and is hailed as the defining technology of the next decade by *Forbes* magazine, estimated to be worth at least US\$48bn by 2026.

A digital twin is a powerful stand-alone technology that has become closely aligned with the IoT (Internet of Things), the fourth industrial revolution (Industry 4.0), and the Metaverse, but is not always necessary in these technologies.

While the term “Metaverse” has been making all the headlines recently, its introduction has been followed by a degree of marketing hype – but digital twins are one of the Metaverse’s core building blocks, because of their ability to connect real worlds with virtual worlds.

While the Metaverse can help us create virtual worlds and experiences beyond our dreams, digital twins can bring a little reality into the digital world.

The nonprofit Digital Twin Consortium (DTC) was launched in May 2020 as an open-source, collaborative platform, with representatives from government, academia, and industry, including companies such as Microsoft. It describes digital twin technology as a way to transform business by accelerating holistic understanding, optimal decision-making, and effective action. The DTC is motivated by outcomes that use real-time and historical data to represent the past and present and simulate predicted futures.

In a blog written for the DTC, Thomas Lacroix, Chief Technology Officer at Cosmo Tech, elaborates a more nuanced and holistic understanding of how digital twins can impact humanity: “To begin with, we need to press pause to consider ‘three levels of understanding’ – understanding ▾

what exists and what is happening, understanding the future, and understanding how to act and control performances,” he writes.

Lacroix says that digital twins offer the capacity to virtually test strategies and scenarios to discover their impact on an organization before choosing which to implement. Risk can be measured, safety levels optimized, and the impact of major transitions (such as decarbonization) or disruptions (pandemics, for example) assessed.

“This holistic understanding, and the resulting value creation, therefore, impacts the industry in a variety of ways,” he writes.

A digital twin is like a crystal ball for scientists and engineers, allowing them to predict future states of processes, ensuring full control and optimization, and transforming the decision-making in two major ways: the first is a reduction

in the decision cycle time to near-zero; the second is greater anticipation and less reactive decision-making, a shift from crisis management to opportunity management.

TWIN RIGHTS?

Protecting the human digital twin from a legal standpoint is becoming a hot issue, and there is a petition instigated by MindBank AI to the UN Human Rights Council calling for future digital twins to have the same rights as their human counterparts.

Sounds crazy? Not in terms of the ethical perspective of individual data security and privacy around a person’s digital footprint. A study by Gartner Research predicts that the Personal Digital Twin will become a transformation technology used by up to 5% of the world’s population within the next five years.

“**Digital twin technology is a legal minefield ... the regulatory environment is tougher now.**”



ASHLEY WINTON

Partner at law firm
Mishcon de Reya LLP

In the field of intralogistics (warehouse management), digital twins of humans are being used by large companies to create a virtual model of the warehouse employee. This throws up all sorts of privacy and surveillance issues. Companies stress that the human digital twin is not about checking up on individual employees. The focus is on improving process performance and ergonomics, as well as discovering areas for improvement. All data is therefore collected and processed anonymously, and displayed as an average value for all team members.

General Data Protection Regulations (GDPRs) have placed greater pressure on organizations to ensure data compliance. If a digital twin was to jeopardize this, it could lead to huge financial and reputational damage.

Ashley Winton, Partner at law firm Mishcon de Reya LLP, says: “Digital twin technology is a legal minefield. The

virtual representation of the real world can easily infringe the intellectual property of third parties – whether it is the architects of buildings, or the owners of brand signs or product designs. It can also infringe the data protection and privacy rights of individuals that are within sight of the environment. The problems that Google had with its Streetview rollout are well reported. However, if anything, the regulatory environment is tougher now.”

Winton says that hotspots for data protection regulators are the automatic live facial recognition of participants and the use of AI and automated decision-making. “Particular care must be taken if the digital twinned environment is going to identify non-participants who may be in the environment or undertake any processing which could have a real-world significant effect.”

In his view, digital twin technology is likely to be one of the more successful

Metaverse implications – but for this sector to thrive, it needs to develop a layer that identifies potential legal landmines. “Using this technology to minimize and mitigate its own legal risks would be a particularly satisfying outcome.”

THE FUTURE OF MEDICINE

Healthcare is one of the key areas in which digital twins can impact humanity. With medical researchers using digital twins of human organs to design safer, more effective treatments, data is the key to unlock the future of medicine. We are now all candidates for digital twinning. The more our biodata can be recorded and stored, the more a digital version of ourselves can be medically treated in the same way as in the real world.

According to the DTC, your digital twin would provide you and your doctor with a more holistic understanding of your health. It would initially integrate data from digital systems that are already used by your doctor and eventually might replace them.

The DTC is clear on how digital twins can have an impact: It doesn’t mean you won’t need a doctor anymore; it just means you’ll have a better doctor.

SMART AGRICULTURE

A similar holistic approach can be used for another vital industry: food.

There are many ongoing initiatives in the food and drink industry, and digital twin technology is beginning to play a significant role.

The benefits of improved product traceability via digital twins make it easier to track various compliance requirements in different countries or regions with their own food safety regulations. By creating a virtual model of a product or process, data collected by sensors in the supply chain or manufacturing process enable simulations or real-time analyses of the status of a product.

To ensure the safe supply of foods, production processes must allow high flexibility and adaptivity, without affecting product quality, especially in the case of seasonal fluctuations impacting the quality of commodities

Siemens has developed intelligent intralogistics by using a digital twin of warehouse operations and performance, so the entire value chain is simulated and validated to run more efficiently



and raw materials. With the correct flow of data between the production line and a digital twin, scientists can build a detailed digital simulation that takes into account the chemical, physical, or (micro)biological properties of the food to help maintain health and hygiene standards.

In a new Agrifood 4.0 era there is an obvious need for the data from smart agriculture to be collected and analyzed to provide improved insights, leading to better process control, supply chain management, traceability, and ultimately decision-making.

And there is a lot to improve in the food sector. The World Food Programme (WFP) in Germany estimates that globally there are more than 800 million people going to bed hungry every night, and the UN Food and Agriculture Organization (FAO) says that approximately one-third of all food produced in the world for human consumption every year – roughly 1.3 billion tonnes – is lost or wasted.

REDUCING CARBON EMISSIONS

Changes in climate and increases in extreme weather are having an impact on food security and disrupting the supply chain, threatening people's livelihoods and the ability to earn a stable income to purchase food.

Digital twin technology could prove a vital link to the urban Metaverse in tackling building emissions and the decarbonization of cities.

Research from Ernst & Young suggests that digital twins could reduce urban carbon emissions by more than 50%, while also reducing operating costs for asset owners by 35%.

Digital twins are already helping companies to make sweeping energy savings, something that has been given fresh financial impetus in the current energy crisis. From digging tunnels without using massive machinery to changing the type of glass fitted in office block windows, digital twins are already saving companies tens of millions of dollars in energy and helping them to decarbonize, while creating a healthier environment for human beings.

Homes, offices, supermarkets, roads, power plants, and many other pieces of physical infrastructure are being turned into digital twins so that scientists and engineers can experiment without making costly modifications to the physical property. Or costly mistakes.

A VIRTUAL WORLD

If digital twin technology is a crystal ball for scientists, it could act as a “what if...?” moment for the adventurer, whereby their digital twin could embark on expeditions to inaccessible lands in a time forgotten or to unknown planets yet to be discovered, all in a virtual and immersive world with the use of VR and artificial intelligence.

As a form of escapism, digital twin has no equal as a social tool, and now the technology has grown up with the arrival of the Metaverse, the need to make your digital self the best possible representation of you will become stronger than ever – and one day it may even save your life. ■

CALL TO IMPACT

1 Data compliance is key. It's not yet clear whether digital and analog twins share the same rights, but as we enter the Metaverse, data protection regulation will place more pressure on organizations to ensure data compliance.

2 Digital-human cooperation. No matter how incredible the technological advancement in patient care may become, it doesn't mean you won't need a doctor anymore – you'll just have a better doctor.

3 Basic needs first. Food security is crucial to feed the planet, which is where smart agriculture can play a role, particularly in supply chain management and more efficient farming methods.



By using digital twins to predict what type of glass is more efficient in office blocks, companies such as IES can save organizations millions in energy costs while reducing urban carbon levels

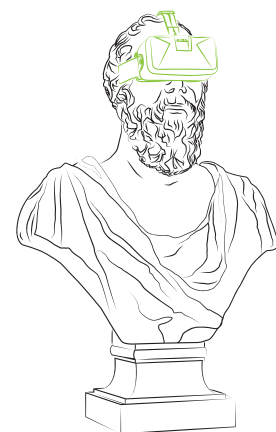
CONNECTED ACROSS THE UNIVERSE

Digital twins are now omnipresent, but where did they come from? And, more importantly, where are they going?

3D DIGITAL TWINS IN A VR WORLD

Corporate companies are rolling out VR technology across their global workforce to help with training new hires and staying in touch remotely with staff. To meet these new challenges emerging in a cyber-physically integrated world there is a fusion of physical twins, digital twins, and virtual twins signifying a pronounced move toward a future virtual world.

THREE STEPS TO USING DIGITAL TWIN WITH A VR HEADSET



Capture

Capture the reality with a laser scanner by creating a colored high-density point cloud.



Connect

Connect a digital twin to VR headset.



Immerse

Put on a pair VR goggles and, in seconds, immerse in the digital twin.

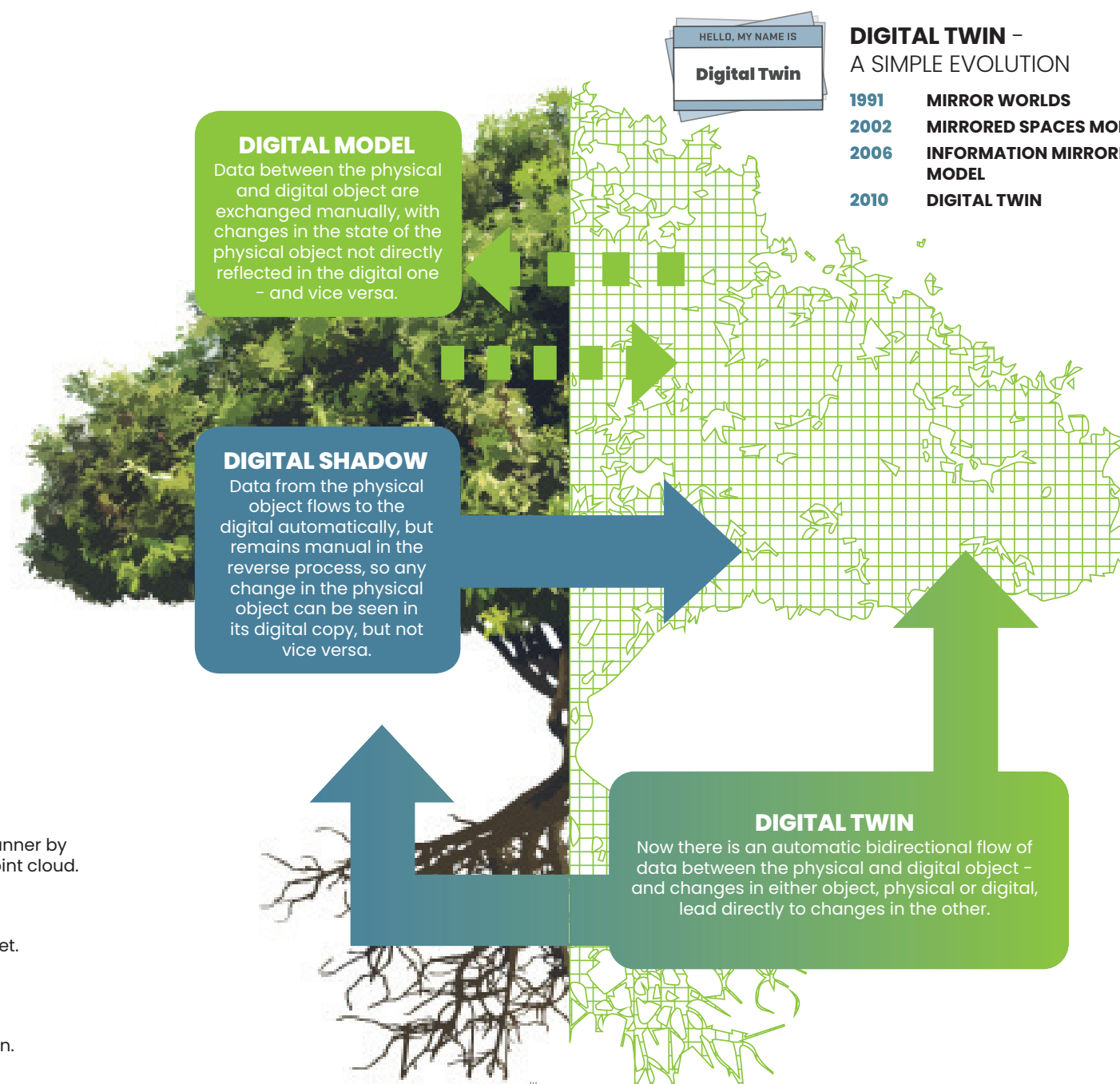
NOT TO BE CONFUSED WITH ...

→ **Certain digital concepts**, including "Product Avatar" or "Digital Thread", are sometimes confused with digital twin. The term Digital Thread, for example, originated in the aerospace industry, where it was used to describe an integrated system engineering process used for managing projects, incorporating 3D CAD models, model-based engineering, BoM, manufacturing processes, assembly logistics and delivery systems, etc.

Digital Thread is sometimes known as a communication framework that consolidates the asset's data and allows seamless data flow, but is simply a record of the information on the physical twin throughout its lifetime.

The **difference between a Product Avatar and digital twin** is that they have been derived from two different research lines and have different capabilities and purposes. A Product Avatar is a digital counterpart of a smart product that lets its user access the attributes and services of that smart product during its life cycle.

ILLUSTRATIONS: VIERU ADRIAN / GETTY IMAGES, SOPHIE NYNCKE (8), TIMANDTIM / GETTY IMAGES



THE FUTURE IS IMMERSIVE

→ By combining Digital Twin technology with Augmented Reality (AR) and Virtual Reality (VR) the digital transformation of various industries and sectors (as well as the impact on humanity) becomes even more impressive.

With AR and VR coming into play, engineers can show a digital twin on top of a physical machine and provide information a technician wouldn't otherwise see (AR), and scientists can immerse themselves in a VR of a digital twin to simulate various scenarios, – for example, in healthcare.

A BRIEF HISTORY OF DIGITAL TWIN



1960s

NASA use basic twinning ideas for space programming, particularly on **Apollo 13** when it developed an early version of digital twin to **assess and simulate conditions on board the spacecraft**.



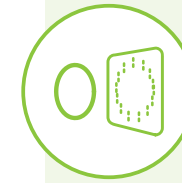
1991

Digital Twins are anticipated by **David Gelernter's 1991 book Mirror Worlds**.



1998

The term "digital twin" is first mentioned and referred to as a digital **copy of actor Alan Alda's voice** in **Alan Alda Meets Alan Alda 2.0**.



2002

A digital twin concept originates from a presentation on a product life cycle management (PLM) center by Dr. Michael Grieves, then of the **University of Michigan**.



His presentation slide was simply called "Conceptual Ideal for PLM," but contained all the elements of the digital twin, exploring ideas behind real space, virtual space, data flow link from real space to virtual space, and vice versa.



2005

Mirrored Spaces Model referenced in a 2005 journal article (Grieves 2005). In the seminal PLM book, **Product Lifecycle Management: Driving the Next Generation of Lean Thinking**, the conceptual model was referred to as the **Information Mirroring Model (Grieves 2006)**.



2010

NASA's John Vickers introduces a **new term** to describe the process: **digital twin**.



2010

Sensor prices start to **drop**.



2013

Cloud computing gains sufficient traction to support the **adoption** of digital twins.



2017

Huawei's digital platform for **smart cities** includes an idea for a city digital twin.



2017–2019

Digital twin recognised as a strategic technology trend for three consecutive years by Gartner, and as one of the defining technologies of the next decade by **Forbes**.

2020

The digital twin market is valued at US\$3.1bn. Some industry analysts speculate it could continue to rise sharply until at least 2026, climbing to an estimated US\$48.2bn.

2021

Estimates suggest that by 2021 half of all large industrial companies will use digital twins.

DIGITAL TWIN OF SOCIETIES

Although it's impossible to predict the future with 100% accuracy, users of the latest digital technology can stay ahead of the curve and create virtual scenarios with "agent-based" virtual simulations.

BILLIONS OF PEOPLE move through the office of Reza Abhari in Zurich's venerable technical university ETH. Or, more precisely, billions of digital reproductions of real-life people. The way these "agents" move and behave shows researchers at ETH's Laboratory for Energy Conversion what the outcome of upcoming shifts in energy production or distribution would be. It's a planning and operations tool, designed mainly for long-term infrastructure investments.

And it's more than that, as lab director Abhari found out. His agent-based simulation can act as a "digital twin of society." It can model any kind of event, investment, or policy – and this way can become a planning tool for the common good. We talked about the billion-twins technology with Prof. Abhari and Anna Gawlikowska, CEO of Swiss AI, the ETH spin-off based on this technology.

What is a digital representation of millions or billions of people good for?

Reza Abhari: For the future. Basically, Swiss AI creates a digital twin of a sector or country. We gather actual data – where people are and how they

behave, where the buildings are, the infrastructure, the transportation systems – and build it up layer by layer, the entire complexity of a society, but on a continental scale. And then the software accelerates the time by about a hundred million times. It looks at lives, movements, and behavior of everybody involved, and allows you to experiment with different conditions.

So we don't have your software walking besides us like our mirror image. It's more running ahead of us?

Anna Gawlikowska: Not in the crystal-ball way that it just predicts what could happen. It's more like an exploration: the digital twin is running ahead on multiple trajectories, and looks at the outcomes from multiple points of time and from multiple perspectives. Based on these explorations, you can choose your future. You can experiment.

Abhari: Let's say you want electromobility – a lot of people want that quickly right now. But what does a rapid shift to electromobility do to your city or your country? Or you suddenly have millions of refugees coming into your country – what does that mean for jobs?

What does it mean for services? Instead of just reacting somehow in real time and real life, you can accelerate and run tens of thousands of possible futures and then choose what you want.

But these futures remain uncertain. Let's take refugees: They flee from war or famine, but their behavior will change as soon as this cause is gone. And your digital twin will never be able to predict when a war or a famine will be over.

Gawlikowska: The future will stay partly uncertain. But that doesn't mean we can't prepare for it. In the case you just mentioned, we would build different scenarios: The migration outflow can go on, it can increase or decrease, it can stop or revert. Then we would

“

The future will stay partly uncertain. But that doesn't mean we can't prepare for it.”

REZA ABHARI

is professor of energy technologies and director of the Lab for Energy Conversion at ETH Zurich. Agent-based simulations are just one of his many research topics.

ANNA GAWLIKOWSKA

is co-founder and CEO of Swiss AI, a spin-off of ETH Zurich that enables optimization of investment decisions through AI algorithms.

add another set of assumptions, about politics: How will countries' regulatory policies be transformed? We feed these assumptions into the model and it will allocate the people to the cities, to the jobs, and we can see what services are required, be it electricity and heat demand, for hospitals or mobility. This means governments can be prepared, even for unprecedented events, and they can choose the optimal outcome.

They can be prepared, but are they? For the latest few refugee waves there has not been much preparation.

Abhari: Response to refugee crises is just an example, but we focus on broader societal transformations. For most of the decisions, people take what was yesterday and assume that

it will be more or less the same tomorrow. There is little room to argue that it might happen otherwise. Yes, sure, there may come a crisis that will require completely different actions – but for most governments it's enough to deal with this crisis when it is there. Of course there are exceptions. Some have foresight, but most react. Politics tends to be more reactive than proactive.

That's the same for the public and for the private sector?

Abhari: Companies typically think a bit more longer term than governments. Governments only talk long-term, they don't really plan. On the other hand, the most uncertainty comes from governments, so companies have to anticipate potential changes to be able

to react; they have to be more proactive.

Gawlikowska: In both sectors, public and private, you do have some leaders that think long-term. And in both sectors that is more unusual. But those strategic long-term leaders, who are able to think ahead two, three, or five years, tend to be more in the private sector. Those in the public sector have their hands more bound. So when it comes to sophistication of technology, it's not written into public tender procedures – making real innovation more difficult.

Last time we checked, corporations were harshly criticised for too much short-term thinking, being driven more by quarterly results ➤



A more efficient energy source will make decarbonizing the planet more economically feasible.

➤ **than by the future of the next generation.**

Gawlikowska: Private sector leaders recognize that the world is not as it was yesterday. We see our customers recognize that their strategy moving forward has to account for various unprecedented changes. They need to bring these perturbations into consideration.

Abhari: Resiliency is the driver. Since Covid, we see greater awareness from the private sector. Corporations realize how sensitive they are to the world around them. They need to understand the transformations that are going on and they

need to be able to react to them in their planning and budgeting. And they have learned for themselves how useful digitalization can be. In every sector, in every company, at least in the West, the Covid pandemic has led to some kind of digital innovation drive – and this time, they really mean it.

And digital twins increase resiliency?

Abhari: Yes, they do. It is bit like when you go to a dangerous cave. You send a robot first, because the robot allows you to explore where you're going and adapt your strategy according to the outcome of the

exploration. The digital twin is like that robot. It allows you to experiment without much harm and without much cost. Things you wouldn't dare to do otherwise now become doable. You can figure out more strategies and more approaches to make your company more resilient.

Gawlikowska: Resilience and risk is one aspect, but it's not the whole story. Sure, if you are in front of a dangerous cave, it's good to have an exploratory robot. But not all caves are dangerous, and not all the world is caves. I see the digital twin also as a design tool: You can design your future.

That's what we do anyway anytime, don't we?

Gawlikowska: Designing your future with real life experimentation can be much more risky – you can hit the opportunity, or you can miss it. The moment you can design different futures at rapid speed and low cost and compare them in the digital framework, you can choose your policy design, your business model design, your portfolio design, and so on. Basically you can not only de-risk, you can also create new opportunities.

We are starting to get used to digital twins in other aspects

“**Digital twin technology can de-risk the future and can make it more attractive.**”

of life. So having a digital twin for a whole society doesn't sound that weird anymore?

Abhari: This is a great vision that we completely share. The notion of using digital twin technology to de-risk the future makes future-minded thinking more attractive.

There is one huge risk looming: climate change. Can digital twins of societies also de-risk climate change?

Gawlikowska: Yes, it can and it will. The biggest challenge of decarbonization is economics. How can you balance the needs of decarbonizing a society in a way that is economically feasible? There is a financial gap right there. Digital twin technology can bridge part of this financial gap by de-risking transformative projects, and at the same time improving their profitability. So projects to reduce carbon can be realized without subsidies, or with lower subsidies.

Traditional investment budgeting isn't good enough?

Gawlikowska: It's not good enough for calculating changes during the project. And there will be dramatic changes. One part will be demand changes, and one part will be energy pricing changes. These fluctuations

will impact the decarbonization project. And we can model that into the project.

If you had a wish list, for what kind of solution would you like to have your digital twins used?

Abhari: For me, how can we improve the lives of people? We talk about decarbonization, about the climate change that is coming, about the lives of hundreds of millions of people who are affected. Yes, in the end the private sector plays an important role, but before that it's the role of the public sector to come up with solutions, with guidelines, with planning, with transformation of our cities, of our infrastructure, on a large scale – and then to allow the private sector to prosper within that. Currently this link between public and private is rather weak, but we are hopeful.

Gawlikowska: For me, the key word is transformation. And the key resource are leaders who are willing to transform. And this is not limited to a certain sector or region, but is limited by the number of people who are willing and able to take it up. ■

CALL TO IMPACT

1 De-risk investment. Digital twin simulation can show the probable outcome of specific strategies and reduce investment risk this way.

2 Prepare for the unknown. Simulating unprecedented events gives informational edge in case the unthinkable becomes reality.

3 Design the future. Exploratory simulations allow the testing of many business models or policies to choose the best fit.

WHOSE LIFE IS IT ANYWAY? NEXT-GENERATION DIGITAL AVATARS COULD RESULT IN AN IDENTITY CRISIS – IF WE AREN'T CAREFUL

→ **OVER DECADES, WE'VE BECOME** accustomed to living our lives in parallel, online and offline. From coming up with usernames for chat apps and forums in the late 1990s and early 2000s, to how we opted to present ourselves on early social networks like MySpace and Facebook, we've been compelled to choose what face to put forward on the internet. Today, our personal brands on Twitter, and the curation we put into our Instagram feeds, can have as much impact on how people see us as our personal interactions.

And with the imminent arrival of the Metaverse, the next generation of digital lifestyle that Mark Zuckerberg feels so sure is an inevitability that he's pivoted and renamed his entire company to accommodate it, that need to make your digital self the best possible representation of you will become stronger than ever. But the question is whether your digital self should be an accurate digital twin, or something more aspirational.

"One of the things that makes the Metaverse proposition quite different to what we're used to with the 2D internet is that there's an opportunity for you to be present and feel present in a space, as well as being observed by other people in that space," says Verity McIntosh,

senior lecturer in virtual and extended realities at the University of the West of England. "Having an avatar can make a lot of sense in the representation of you, your body, and your self – and the origin of where your voice is coming from."

The big question is what it means for those of us looking to develop our digital twin in the Metaverse. "It's fraught with so many unresolved questions that we're really just starting to poke at because these things haven't really existed in this context long," says McIntosh. One key question still to be established is what role realism and representation will play in Metaverse-based digital twins. Because of the intrinsic, all-compassing way in which we're expected to live, work and play in the Metaverse, do our digital representations there need to hew as closely as possible to the reality of who we are?

Can a furry – someone who dresses up as an animal in a giant fur suit – interact with others in their place of work in the Metaverse, or do they need to wear a shirt and tie?

In a world like Second Life or Fortnite (see box page 29), where most interactions are based around recreation rather than business, that may be possible. But in a Metaverse where you check into

There's an opportunity for you to be present and feel present in a space.



PHOTO: SHUTTERSTOCK/DERTER





By creating individual digital avatars, users can create different genders of themselves.

an office, things may need to be more rooted in reality. “A lot of people are really interested in the potential of your avatar to kind of transcend the physical restraints of your own body and to think about a transhuman approach,” says McIntosh. Digital twins may not need to be that closely twinned to the person who possesses them. You could play with different genders or age groups. But whether that would be permissible in a world where you’re expected to interact with colleagues and clients in the Metaverse, that could be tricky.

“It’s more of an idealized form of themselves as they once were, or still see themselves as.”



WAGNER JAMES AU

Author of *The Making of Second Life* and *Why the Metaverse Matters*

“It is going to be vital that we have digital avatars, or some kind of representation of ourselves,” says Charlie Harry Smith, who studies digital identities at the Oxford Internet Institute. Whether that needs to be a full-blown digital twin of the type we know from their use in manufacturing – where they literally copy the minutiae of the person or object they’re trying to represent – is uncertain, says Smith. That’s in part because of the current technological limitations of the Metaverse.

THE IDEA’S (NOT) GOT LEGS

One of the main criticisms of emerging technology in the Metaverse has been the challenge of representing legs. Characters interacting within Microsoft and Meta’s versions of the immersive virtual world so far simply hover with their upper bodies in the space. “Until you’ve got full-body motion tracking, I think it’s more important to have a representation of you, rather than a perfect copy of you,” says Smith.

There’s also the question of the “uncanny valley.” Around since the 1970s, when the term was invented by robotics professor Masahiro Mori, the uncanny valley is the space in which robots can provoke feelings of confusion or concern if they don’t quite capture someone’s physical likeness. A perennial fear for those developing movies and video games, it can trigger suspicion in viewers or players if a digital representation of an individual doesn’t look quite right. Some of the trickiest elements to capture in computer-generated graphics are accurate eye movements, which is perhaps why Metaverse graphics have more in common with early video games and their colorful, brash palette, than with the more complex shades of reality. Microsoft’s 3D avatar service launched in November 2021 as an integration into its Teams platform, and allows users to develop a personalized avatar that can replace their physical presence on a video call, granting them some relief from on-camera call fatigue. Yet even that likeness has more in common with Miis or Memoji than a physically accurate depiction of who we are.

Even if computer graphics were able to accurately portray a person’s likeness, there’s still the question of whether it can be multiplied by the millions and calculated in real-time. The Metaverse as a concept will sink or swim based on people being able to interact with each other without buffering or glitches. If you’re trying to hold a conversation with an individual while standing in a virtual representation of a bar, it’s important that information is transferred quickly and accurately. “As mass multiplayer

games have shown, it’s really difficult to have 500,000 people all interacting simultaneously without huge lag,” says Nick Kelly, who studies the Metaverse at Queensland University of Technology. The attempt to ward off the risk of that happening may go some way to explaining the childlike graphics that currently represent our digital selves in the Metaverse.

And it’s not clear that it’s necessary to have lifelike graphics for their digital twin in order to get people engaged with the Metaverse. “The kind of thing Facebook is going to design will represent the economic incentives they have,” says Smith. “They don’t necessarily have an incentive to make it physically accurate. They’d much rather people be happy with it, and that it’s good enough to be used for monetization purposes, I’m sure.”

CASHING IN

The idea of monetizing digital twins is what is likely to energize early movers trying to establish their own versions of the Metaverse as the gold standard for others to follow. “With an avatar digital twin, it’s very much on a theoretical level at present, but with smart devices getting better at telemetry, you can model a person’s health and represent it in the shape of an avatar, and make some educated assessments based on machine learning about what, based on the person’s behavior in real life, could happen to them in the future,” says Wagner James Au, a game development consultant, founder of New World Notes, and a journalist covering the Metaverse in all its guises for nearly 20 years.

That medical application has its promises – and concerns. “One of the things we know is different about the way personal data can be understood in the Metaverse is that what your avatar does is effectively a direct representation of what you do,” says McIntosh. Tracking your digital twin in the Metaverse may not seem like a big deal, but when it’s so closely intertwined with your physical existence and your personal life, it becomes a goldmine for data. “Behavioural information about the way you

WHAT IS THE METAVERSE?

Metaverse is a virtual universe of social connections where human interaction takes place in a 3D digital network using AR/VR devices to make the connections look more lifelike.

Since Facebook renamed its parent company Meta, the race to own the Metaverse has intensified, with technology companies such as Apple, Microsoft, Samsung, and Tencent clamoring to become part of users' virtual worlds.

Users can create a virtual avatar to interact in the Metaverse, make purchases with digital currencies such as bitcoin, connect with family and friends or search for information, just like they use the internet but in a more real, augmented way.

The Metaverse as a concept will sink or swim based on people being able to interact with each other without buffering or glitches.



move and the way you talk, if that's collected, could potentially be exploited in ways that I think I'd be a bit nervous about," says Smith.

Whether it's economic exploitation – a company discerning interests and attitudes from a far more granular, minute-by-minute analysis of your actions and words in the Metaverse, much more detailed than the snapshots we already share on social media – or a more malicious way, the risk of giving up too much of ourselves is something to be carefully considered when designing and implementing our digital twins.

Smith points out the risk of deepfakes being much more accurate when trained on a neverending corpus of data that follows us as we go from work to rest in the Metaverse. Behavioral and biometric data, both of which are being used now as an added layer of security in bank accounts and other key areas of our lives, become less infallible when we're sharing similar information every minute of the day in the Metaverse. "Biometrics are clues to who we are," he says. "This knowledge that you can glean through the way we interact with things, the way we move and speak

and things like that, is important, and anything that's going to make collecting that easier is going to come with a lot of legal and ethical challenges."

A PROTEAN IDEAL

Another key question for those designing the Metaverse – and those of us likely to be compelled to live our lives in it in the near future – is whether we can ever feel an umbilical connection to our digital twin. Early research into digital twins suggests this is possible. The Proteus effect has been identified by academics at Stanford University, who discovered

that if people are able to control an avatar in an immersive space, and able to see through its eyes, they create an association with it – and it shapes their real-life persona as a result. "Looking at their avatar has been shown to change a person's outlook about themselves," says Au. Those whose avatars are attractive take that positivity into their real life, where they feel more confident. "That would be the theoretical basis for why this could be powerful when we have the functionality to create a mirror image or digital twin that connects an avatar with a real person," he adds.

The Proteus effect, and using your digital twin to feel more confident in real life, comes with its own challenges, however. To date, digital representations of our physical selves have needed to be tied only loosely to who we are in reality. We've felt comfortable shifting genders, races, and sexualities, as well as dressing more outlandishly or differently. For some, their digital twin isn't a twin at all, but an escape. "It's an expression of personality, but for the most part it's kids trying to figure themselves out," says Au. "They're throwing out different roles and guises through their avatar." ➤

A BRIEF HISTORY OF DIGITAL AVATARS AND THE METAVERSE

- 1987** Habitat is released, In LucasArts' massive multiplayer online role-playing game (MMORPG), users can combine predesigned heads and bodies in their own avatar.
- 1992** Author Neal Stephenson writes the novel *Snow Crash*. The book tells the story of people exploring a digital world through avatars – and coins the term "the metaverse."
- 2003** Second Life is released by Linden Lab, a video game development company. In the game, players create a 3D avatar through which they explore immersive worlds.
- 2006** Nintendo introduces Miis, customizable avatars to be used on its Nintendo Wii console – and later the 3DS, Wii U, Switch and subsequent devices.
- 2006** Game design platform Roblox launches, encouraging children to interact with each other and build their own businesses and games within.
- 2017** Fortnite is released. The virtual world is popular with kids, who can buy and wear their own skins for their characters.
- 2018** Apple introduces Memoji, which creates animated avatars based on you that can be used in conversations in place of emoji.

➤ In Second Life, which Au studies intently, the demographics of the average user are slightly different and skew older, with the median age in the thirties or forties. “It’s more of an idealized form of themselves as they once were, or still see themselves as,” says Au. He spoke to one Second Life user, a professor at a college, who said that as he got older and looked at himself in the mirror, he didn’t feel connected to himself anymore. His avatar, stuck in amber, forever young,

was a better representation of how he saw himself.

GETTING METAPHYSICAL

In the Metaverse as designed by big tech businesses like Meta and Microsoft, the idea of the digital twin is more closely defined by your physical embodiment. “The position they seem to be taking is that you should have one avatar that is trackable across the whole of Web3, that is consistent and clearly associated with a

real person, identifiable and accountable for behavior,” says McIntosh. There are commercial advantages to this, too. Just as they can track cookies across the internet, linking them to one individual user, so they could trace an avatar across the Metaverse, wherever it pops up. “But this idea that you have a static identity that is tightly defined and associated with you seems very limiting and quite cynical,” says McIntosh. “A lot of what people enjoy about connecting through

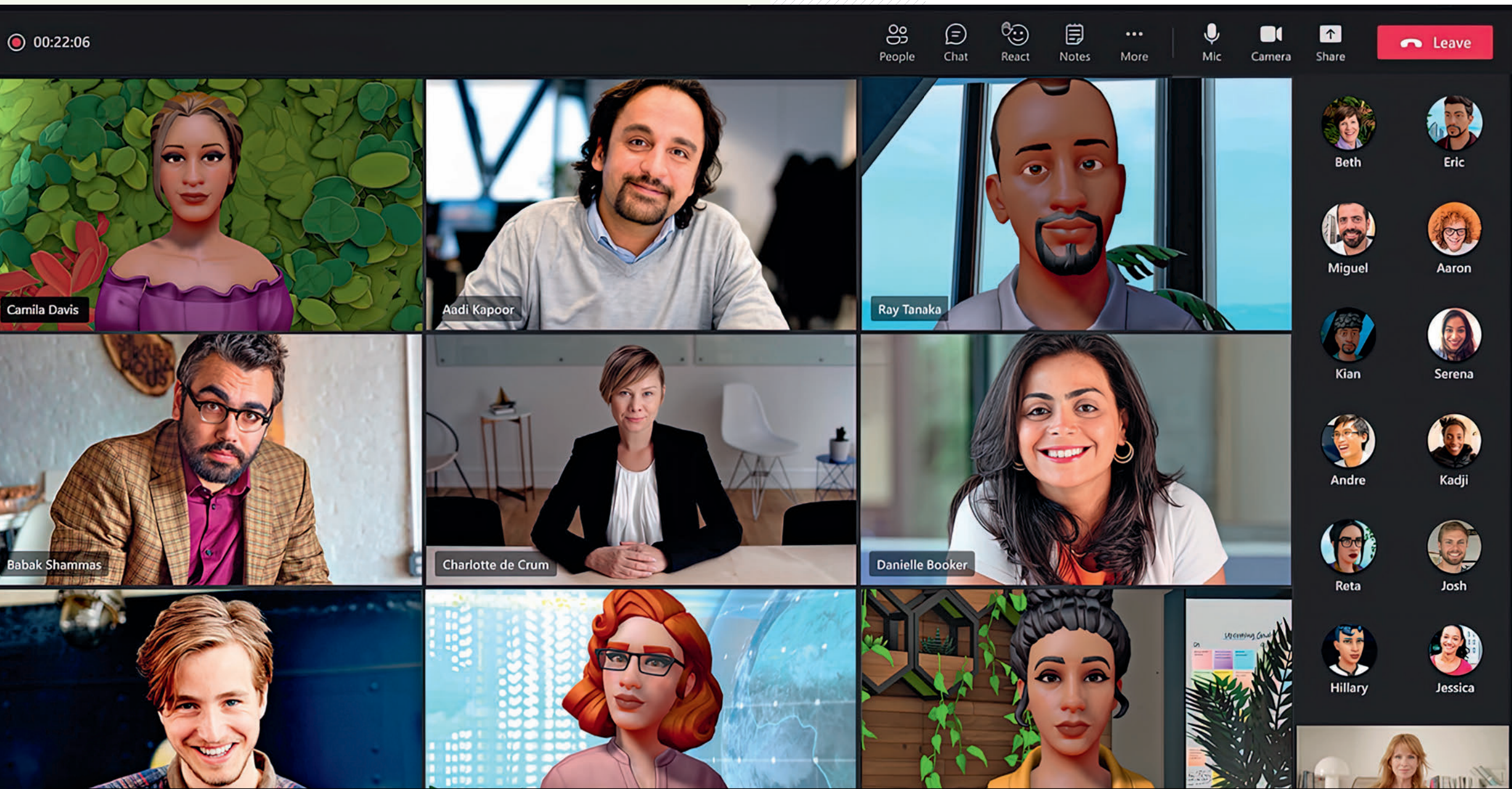
PHOTO: MICROSOFT

the Metaverse, even in the nascent stage it is at now, is the potential to have a certain amount of privacy and anonymity, and to switch skins according to the context.”

Whether you’re trying to recapture the old days, trying out an entirely new character or look, or feel it’s best to hew close to your physical presence, one thing is certain: designing and maintaining your digital twin is likely to be a big driver of economic growth in the

Metaverse. Already pegged as a US\$13trn market opportunity by Citi research, being able to customize your digital twin will be big business. It already is, with people designing skins (costumes) in the likes of Fortnite and Roblox that can net them a significant income. “It’s massive,” says Au, who estimates that avatar customization accounts for some 60–70 percent of the entire economy in Second Life, reckoned to be around half a billion dollars.

Figuring out how best to present your digital twin – and how twinned it should be with your real-life existence – is going to be imperative in the coming years. Mark Zuckerberg hopes a billion of us will inhabit his Metaverse by the end of the decade, with hundreds of millions more likely to join competing alternatives. Making sure you put your best face forward is vital: you don’t want your digital twin to be the black sheep of your family.



Microsoft’s 3D avatar service for its Teams video-calling platform allows users to develop a personalized avatar that can replace their physical presence.

CALL TO IMPACT

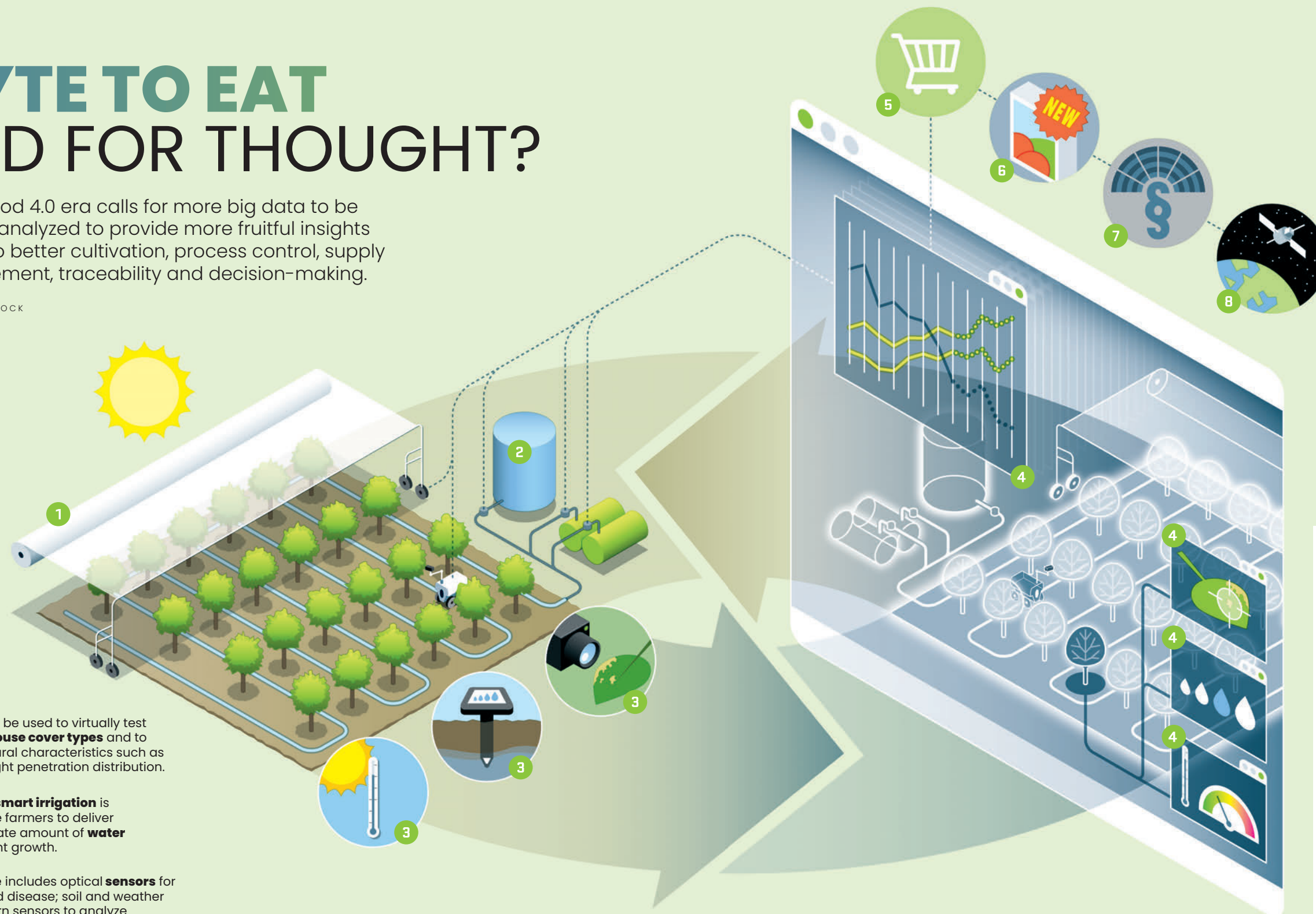
- 1 The mirror as influencer. So far, our digital representations have needed to be only loosely tied to who we are in reality. But chances are good that digital twins shape our real-life persona as well.
- 2 Be person, not product. Everywhere and always there will be money and marketing people looking at ways of monetizing digital. Assess your own benefit before you follow.
- 3 Beware of deepfakes. With all this behavioral and biometric data sloshing around, key areas of our lives become more vulnerable and need more protection when we’re sharing information every minute of the day in the Metaverse.
- 4 Customizing matters. Designing and maintaining your digital twin is likely to be a big driver of economic growth in the Metaverse. The customization of individual twins will be key for this market.

A BYTE TO EAT FOOD FOR THOUGHT?

The new Agrifood 4.0 era calls for more big data to be collected and analyzed to provide more fruitful insights that will lead to better cultivation, process control, supply chain management, traceability and decision-making.

ILLUSTRATION: JÖRG BLOCK

- 1 A digital twin can be used to virtually test different **greenhouse cover types** and to model canopy structural characteristics such as foliage density and light penetration distribution.
- 2 The adoption of **smart irrigation** is helping to enable farmers to deliver to crops the appropriate amount of **water and nutrients** for plant growth.
- 3 Smart agriculture includes optical **sensors** for plant canopy and disease; soil and weather **sensors** for crops; barn sensors to analyze temperature, humidity, and ammonia for animals.
- 4 Creating digital twins of orchards to run virtual experiments at a scale and speed never before possible helps **make food production more productive, resilient, and sustainable**. Computer simulations could be the conceptual design of an orchard that doesn't yet exist, a digital twin or detailed replica of an existing orchard, or a digital variant, where changes are made to a digital twin.



- 5 Making sure product quality (e.g. color, taste and texture) is consistent and meets **customer expectations**. During the Covid-19 pandemic, people's eating habits changed considerably. Digital twins can help manufacturers adapt to **new consumer demands**.

- 6 Digital twins allow food scientists to experiment with new ingredients, flavors, portions and even packaging to develop **new products**.

- 7 Countries and regions have varying **food safety and regulatory requirements**. By incorporating a digital twin into a product, batch or serial number, production data is available in a digital form for every item, providing full traceability insights.

- 8 **Global Positioning System (GPS)** and Real-Time Kinematic-Global Navigation Satellite for tracking agricultural robots, and traceability in the food supply chain are being used in smart agriculture.



WHAT A WASTE

The UN Food and Agriculture Organization (FAO) says that by 2050 humans will need to produce 60% more food to feed a world population of 9.3 billion.

Roughly one-third of all the food produced in the world for human consumption **every year – approximately 1.3 billion tonnes – is lost or wasted**.



CREATING A MIRROR WORLD HOW THE WHITE HEAT OF TECHNOLOGY IS HELPING TO COOL DOWN THE PLANET

→ **IS MAKING A COPY OF THE PLANET THE BEST way to save it?** Nvidia's Earth-2 Supercomputer will soon create a digital twin of the Earth at meter-scale resolution, many times more accurate than the 10-100km resolution that climate simulations are working at today.

Earth-2 will for the first time allow scientists to simulate how clouds reflect sunlight back into space. It will predict regional changes in weather, decades before they happen. It will model changes in the global water cycle, helping us to predict the intensity of storms or droughts.

But it's going to take more than modeling the globe at super-high resolution to help us avoid a climate catastrophe. In fact, creating digital twins of the planet's more mundane assets will likely have a much greater impact on climate change. Homes, offices, supermarkets, roads, power plants, and many other pieces of physical infrastructure are being turned

into digital twins so that scientists and engineers can experiment without making costly modifications to the physical property. Or costly mistakes.

Digital twins are already helping companies make sweeping energy savings, something that has been given fresh financial impetus in the current energy crisis. From digging tunnels without using massive machinery to changing the type of glass fitted in office block windows, digital twins are already saving companies tens of millions of dollars in energy and helping them to decarbonize.

However, the real power of digital twins is when they join together. The digital twin of a supermarket decides to charge the batteries of all its electric delivery vehicles, because the twin of the local power station has reported excess energy in the grid, for example. It's not twins of the entire planet that might save the Earth, but millions of much smaller twins all working in harmony, cleaning up resource-sapping industries.



TUNNEL-DIGGING ROBOTS

Digging tunnels is one of the most energy-intensive engineering tasks. It traditionally requires huge boring machines that are often overspecified to make sure they can plow through any unexpected obstacles that might block their path, and enormous amounts of concrete are used just to get the tunnel boring machine held in place. A company called hyperTunnel uses digital twin technology to make it far less energy-intensive.

Instead of using massive machinery, hyperTunnel uses a swarm of robots to create tunnels. It starts with a small, central index bore, down which a robot is sent to survey the terrain. Once that initial scan is complete, hyperTunnel then drills further bores around the outside of that initial bore, down which the robots are deployed. "We use hundreds or thousands of robots, all working at the same time," says Patrick Lane-Nott, hyperTunnel's director of engineering.

"They are putting just the right amount of material in the right place in the ground, using the ground as a support medium. So it's effectively a sort of 3D printing or additive manufacture. We create the tunnel in the ground before we've actually removed any soil."

The robots are constantly surveying as they build, feeding live data into a digital twin of the tunnel that allows the engineering team to have full visibility over what's going on underground without a person going into the tunnel until the final stages. "We know when there's an 'unexpected,' as it's not unexpected for us, because we've gathered all the data during that initial phase," says Lane-Nott.

PHOTOS: SHUTTERSTOCK/MIA STENDAL; HAJAJ & ASSOCIATES, NVIDIA

A DECARBONIZED, CLEAN ENERGY FUTURE

While countries are still grappling with Covid-19 uncertainties, digitalization, AI and robotics are being seen by many as an unheralded opportunity to create a decarbonized, clean energy future.

A recent white paper by accountancy firm Ernst & Young predicts that digital twins can cut a building's carbon emissions by at least 50%, improve its operational and maintenance efficiency by 35%, boost human productivity by 20%, and improve space utilization by 15%.

CityZenith, headquartered in Chicago, and a leading digital urban climate twin (DUCT) software provider, is building a ground-breaking carbon offset project to monitor and protect regions like the Amazon Rainforest – often called the "Lungs of the World," using digital twins to enable the forest's vital CO₂ cleansing capabilities to be used as a carbon asset maintained and harnessed by Brazil and other South American countries.

The Lamina Tower, under construction at the Jeddah Corniche resort on the Red Sea in Saudi Arabia, is one of the first of its type in the Middle East to use a digital twin to replicate a physical building and infrastructure to optimize design, construction, and ongoing operations and management functions.

Motasim Hajaj, CEO of Hajaj & Associates, the developer of Lamina Tower, says: "Lamina is an ultra-luxury residential skyscraper.... Together with our partner Cityzenith, we are implementing AI-driven digital twin technology customized to help us provide a unique, technology-enabled experience for residents, emphasizing convenience, safety, and discretion."





KEEPING SINGAPORE COOL

Decarbonization of the built environment is a key metric for digital twin technology, and researchers from the Singapore-ETH Centre and the Singapore- MIT Alliance for Research and Technology are using a digital urban climate twin (DUCT) to address the city’s urban climate challenges through climate-responsive design.

Working with the Singapore Government, DUCT allows planners to ask the “what if...?” questions, and provides the relevant information required for better-informed urban planning and design to enhance the city’s climate resilience.

Dr. Juan Angel Acero, climatologist and the lead investigator of Singapore’s Climate and Vegetation pillar, says: “Through modeling studies based on data shared by the agencies, our initial findings in an earlier phase of Cooling Singapore is that the major contributor to urban heat is the building mass in Singapore. Buildings alone, without taking into account any indoor activity or air-conditioning ... have a spatial mean impact of 1.8°C in air temperature on the urban area.”

Dr. Heiko Aydt, a computational scientist and Singapore’s lead investigator of the DUCT pillar, says: “The Digital Urban Climate Twin would provide a better understanding of the urban environment and its local climatic conditions, allowing planners to take an iterative approach in planning. Furthermore, the idea of the Digital Urban Climate Twin is not limited to Singapore. Many other cities in the region and around the globe would be able to benefit from such a technology.”



SUPERMARKET SAVINGS

Digital twins are also helping to save energy in another building many of us visit daily: supermarkets. Any energy savings made in these huge businesses could make a significant contribution to hitting climate targets.

Jason Kay, CEO of IMS-Evolve, which creates digital twins for big retailers, cites the example of a UK nation-wide supermarket with 5,000 stores that has a controller for all its external lighting.

“It portrays itself to the external world as an energy-sensitive organization, yet its car park lights are on during the day. Why is that? It’s because you’ve got an old controller there with a hard-coded schedule in it. It’s overridden by a lumen sensor which is outside, but has been there as long as the control systems – for 20 years – and it’s become dirty.”

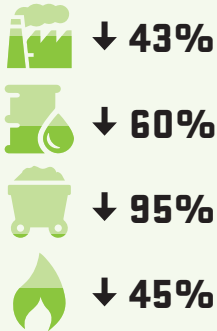
Kay claims that many would suggest the supermarket spends millions replacing the broken sensors and control system across its network. Instead, his company creates a digital twin using daylight and sunset times that are geographically sensitive down to 50 meters, and combines this with live weather data to decide when the lighting should be switched on and off. “We’ve done what would have cost tens of millions of pounds for next to nothing, because we’re using an existing platform.”

The digital twin even lets the supermarkets treat their stores like enormous batteries, retaining heat or cold for when it’s needed. And the saved energy can even be used to charge actual batteries, for electric vehicle charging stations for customers, for example.

PHOTOS: GETTY IMAGES/UNIVERSAL IMAGES GROUP/VIEW PICTURES/HUTTON+CROW; GETTY IMAGES/MOMENT/BUSSA PHOTOGRAPHY

PARIS CLIMATE AGREEMENT

The latest Intergovernmental Panel on Climate Change (IPCC) report says that to avoid more than 1.5°C of global warming, emissions must peak before 2025 and then fall by 43% before 2030, compared with 2019 levels. Achieving the 2°C Paris goal means that global use of coal must decline by 95% by 2050, relative to 2019. Oil use must drop by 60% and gas by 45% in that period.



CARBON INCREASE

The carbon footprint is currently **60% OF HUMANITY'S OVERALL ECOLOGICAL FOOTPRINT** and its most rapidly growing component. Humanity’s carbon footprint has increased elevenfold since 1961.



CARBON INTENSITY DECLINE

Carbon intensity declined by 0.3% per year in the 2010s, a fraction of the 3.5% per year that experts say is needed to stand a chance of limiting warming to 2°C. For a 1.5°C goal, the annual improvement would have to be 7.7%.

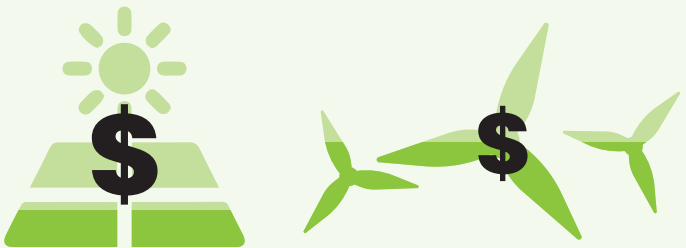
FACTS & FIGURES

CREATING A DIGITAL TWIN OF THE ENTIRE PLANET

Digital Twin technology is becoming an essential tool for engineers and scientists in addressing the climate crisis, because it presents new and exciting opportunities to obtain net zero carbon emissions by companies and organizations.



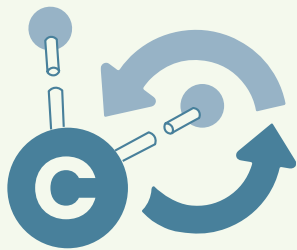
E2 E2 (Earth 2) supercomputers will be capable of creating a digital twin of the entire Earth. By modelling the planet at unprecedented resolution, E2 is meant to accurately predict the climate decades into the future, and guide efforts to mitigate global warming.



GREEN DEAL?

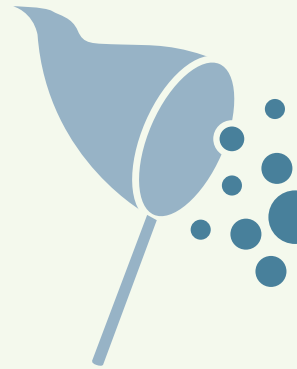
The cost of **solar energy dropped by 85%** during the 2010s, and **wind power by 55%**. During the same period, the market for electric vehicles grew one hundred times as much.

SOURCES:
WWW.WINDPOWERENGINEERING.COM/HOW-DIGITAL-TWINS-COULD-TRANSFORM-THE-WIND-ENERGY-INDUSTRY/
WWW.FOOTPRINTNETWORK.ORG/OUR-WORK/CLIMATE-CHANGE/
WWW.ECONOMIST.COM/SCIENCE-AND-TECHNOLOGY/2022/04/09/THE-LATEST-IPCC-REPORT-ARGUES-THAT-STABILISING-THE-CLIMATE-WILL-REQUIRE-FAST-ACTION
WWW.GE.COM/RENEWABLEENERGY/STORIES/IMPROVING-WIND-POWER-WITH-DIGITAL-TWIN-TURBINES



CARBON RECYCLING

BASF redesigned its methanol production process to **cut CO₂ emissions by recycling the carbon**-containing off-gases back into the process. AspenTech says a digital twin created with its software modeled planned changes to the production process, so adjustments could be made before they were put into production.



CARBON CAPTURE AND STORAGE

Keeping warming to less than 2°C will mean shortening the lifespans of existing fossil-fuel power stations and refineries. Digital twin technology could help retrofitted installations capture warming gases before they escape into the atmosphere in order to store them underground or beneath the oceans.



Baalbek Reborn lets the traveler fly over the UNESCO World Heritage Site of ancient Baalbek and go back in time

TRAVELING LIGHT

HOW VIRTUAL TOURISM REVEALS NEW DESTINATIONS FROM THE PAST – AND THE FUTURE

PHOTO: FLYOVER ZONE PRODUCTIONS AND GERMAN ARCHAEOLOGICAL INSTITUTE



IMAGINE WALKING INTO MONET'S famous Giverny garden and studio to experience his water lilies. How about stepping into a spaceship and traveling to explore other worlds? Maybe you want to go back in time to the year 215 AD and virtually fly over one of the world's most important cultural heritage sites – Baalbek, part of the ancient Roman Empire, and the Greek city of Heliopolis before that?

From Google Arts and Culture, Amazon, and Spielberg's Dreamscape to newcomer Flyover Zone, consumers have stepped into the era of virtual

tourism with technology. From smartphones to virtual reality headsets such as Oculus to 3D modeling, augmented reality, high-resolution imagery, and 3D mapping, the travel industry has been reimagined for adventurers who can now roam the world without ever stepping out of their homes.

Those pieces of technology consumers touch and connect with that allow them to have these new interactive experiences are only part of the larger story behind the new world order of consumer travel, which is increasingly driven by digital twin technology.

THE TRAVELING TWIN

A digital twin is a digital representation of the physical world that's updated continuously with information from the physical world. That information comes from Internet of Things (IoT) sensors, GPS location data, artificial intelligence (AI), and the Metaverse.

Ashiss Kumar Dash, Executive Vice President and Global Segment Head – Services, Utilities, Resources and Energy at Infosys, believes the role of the digital twin in the travel industry begins with redefining what a digital twin should do.

“Digital twins have become an indispensable tool that creates enriched customer experiences.”



BILL LINEHAN

Global Strategy lead for Travel and Hospitality at Matterport

“Traditionally, the digital twin concept across industries, including travel and hospitality, was used to create a virtual model of an asset or a process,” says Dash. “Think about building a digital twin for hotels, airports, cargo movement, and other assets.”

In this scenario, Dash says the primary benefits of building the digital twin were to improve operations by reducing asset downtime, improving asset efficiency, and improving asset safety. “The underlying technologies that powered these outcomes are data, machine learning, and artificial intelligence, edge



Five-star resort Atelier Playa Mujeres in Mexico uses 3D visual experiences to offer guests the ultimate preview of their stay.

devices powered by a strong network backbone.”

So in this case, the digital twin offered situational awareness and provided the management team with the ability to make business-critical and operational decisions.

CUSTOMER EXPERIENCE

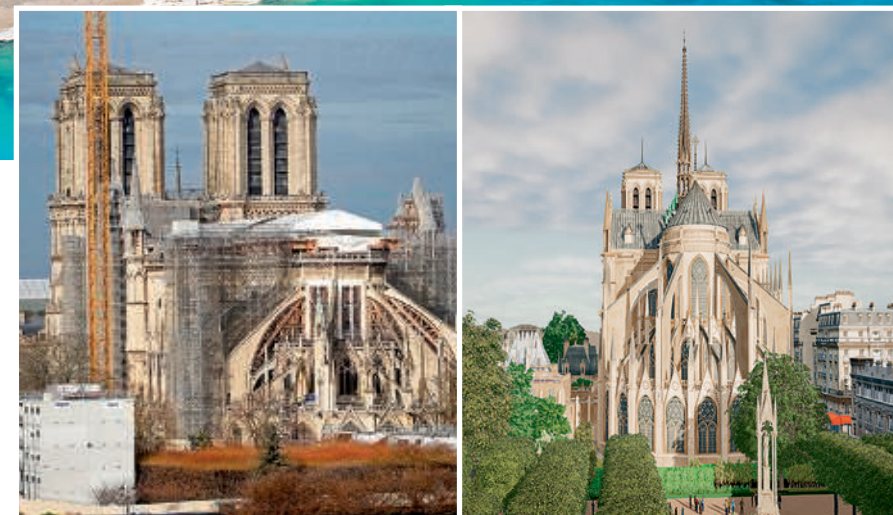
But Dash says this traditional view of a digital twin fails to address a fundamental aspect of the travel and hospitality industry – the customer experience (CX). “This brings a new dimension of the digital twin that revolves around the Metaverse, offering an immersive experience for customers and other users.

“Here, data and information will layer through mixed reality for customer experience, and this multi-sensory experience can be enhanced to embed care and inclusion for people,” says Dash. “In the Metaverse, the digital space can be customized for a personalized experience.”

Take the five-star resort Atelier Playa Mujeres in Mexico. The resort created an intelligent, enhanced guest experience with digital twin technology allowing users to experience the hotel from exploration to booking and check-in. For the hotel, this information became essential for estimating and reducing wait times for guests. With 3D visual experiences and real-time location information, guests can determine their location at the resort and have the ability to experience different resort amenities virtually to decide which they want to use before they go there physically.

In contrast to experiencing your hotel before you travel is the virtual history tour, Baalbek Reborn. Launched in 2021 by Flyover Zone and the German Archaeological Institute with the Lebanese General Department of Antiquities, Baalbek Reborn lets the traveler fly over the UNESCO World Heritage Site of ancient Baalbek. The travel experience

PHOTOS: AUTODESK; ATELIER DE HOTELES; GETTY IMAGES/CHESNOT; MATTERPORT



SAVING NOTRE DAME

Notre Dame Cathedral in Paris, France was one of the biggest tourist attractions in one of the world's biggest tourist destinations. Around 300,000 people visited Notre Dame every day, and nearly 13 million people a year. It was also an operational Catholic church. In 2019, Notre Dame was engulfed in flames. In 2022, a digital twin from Autodesk in conjunction with the French government allowed architects and engineers to construct a digital model that allowed them to begin restoration of one of the world's oldest cathedrals. The model was more detailed and interactive than a 2D blueprint, and the digital twin allowed them to retain the original structure of the cathedral and incorporate new innovations in design and materials.

features a collection of ancient Roman sites and monuments that date back almost 2,000 years. Baalbek Reborn shows the virtual tourist what the city looks like today, but also has digital recreations of the sites from 215 AD.

Dash says technology such as Live Enterprise from Infosys defines the critical design principles for creating digital twins that can achieve higher levels of efficiency and as a result deliver a better consumer experience.

AI ALGORITHMS

Dash points to Netflix's use of an AI algorithm that "knows" the user, suggests a match, and shows the user appropriate movies based on their viewing history. "Metaverse will take this experience to another level," says Dash.

Bill Linehan, Global Strategy lead for Travel and Hospitality at Matterport, echoes Dash's focus on CX. "Digital twins have become an indispensable tool that creates enriched consumer experiences," says Linehan. "Airlines have adopted digital twins that allow passengers to virtually experience a cabin, compare sections, and view their ideal seat before purchasing. Hotel and vacation property operators are leveraging this technology to provide a deeper visibility of any physical space, so travelers can make better-informed decisions on accommodations."

DIVING INTO THE RED SEA

The Red Sea Development company is building a digital twin to create real-time virtual versions of physical destinations. Their digital twin offers awareness and understanding of how buildings and infrastructure might look and feel within a virtual space. This in turn reduces the need to physically visit sites. The company believes the technology will help overcome the challenges of building in harsh and remote locations, and provide a higher level of agility, flexibility, and customization.

Their digital twin platform will be the backbone of their Smart Destination IoT platform, which includes 2,500 IoT sensors deployed around coral reefs,

“
The larger the
coverage or scope
of a digital twin,
the larger
is the
impact.”



ASHISS
KUMAR DASH

Executive Vice President and Global
Segment Head – Services, Utilities,
Resources and Energy at Infosys

lagoons, and turtle nesting sites to measure progress against achieving a 30% net conservation benefit by 2040.

And here is where Dash and others' predictions of digital twins begin to merge. Dash believes the travel industry's top two digital twin technology usage trends come down to customer experience and operational monitoring. Both of these could profoundly affect climate change commitments by the travel industry.

"For travelers, digital twin technology can be used to provide a virtual experience and to customize their travel plans and experiences," says Dash. "For providers, it is operational monitoring that gives them a real-time view of their assets, service status, potential failures, ad hoc service options, ancillaries, etc."

But with any technology adoption, there are hurdles. Dash believes that organizational change management, investment priorities, data availability, and legacy system fragmentation will be the biggest challenges for the industry.

"Organization change management is the biggest barrier to designing the future [...] because it involves significant reimagination of how the industry works," says Dash. "And since emerging from the pandemic induced revenue fall, most travel providers are managing expenses carefully, so the budget for

PHOTOS: PICTURE ALLIANCE/XINHUA NEWS AGENCY/THE RED SEA DEVELOPMENT COMPANY; INFOSYS



The Red Sea Development company is using a digital twin platform not only to create a real-time virtual experience, but also to monitor the fragile ecosystem.

innovation and transformation is likely to be tight.”

But Dash is hopeful; he believes that digital twin applications will be more mainstream in practice in the next three to five years, because of advances in 5G, the Metaverse, and sensor development. “The travel industry is beginning to build back as the number of Covid cases worldwide is subsiding, but it will be some time before they return to their healthy state.”

Roger Crellin, Executive General Manager NZ at Universal Communications Group agrees, noting that hotels stay within their ecosystem but that digital applications and services, particularly digital twin technology, need the enterprise to open up.

“In particular, as GenZ and Gen Alpha now are targeted customers for hotels or short-term rentals like Airbnb, they are happy for profiling to be used to provide better services. but they will not be able to do this across multiple capture one-dimensional apps,” says Crellin.

A GREENER TRAVEL EXPERIENCE

The tourism industry accounts for 8% of greenhouse gas emissions world-

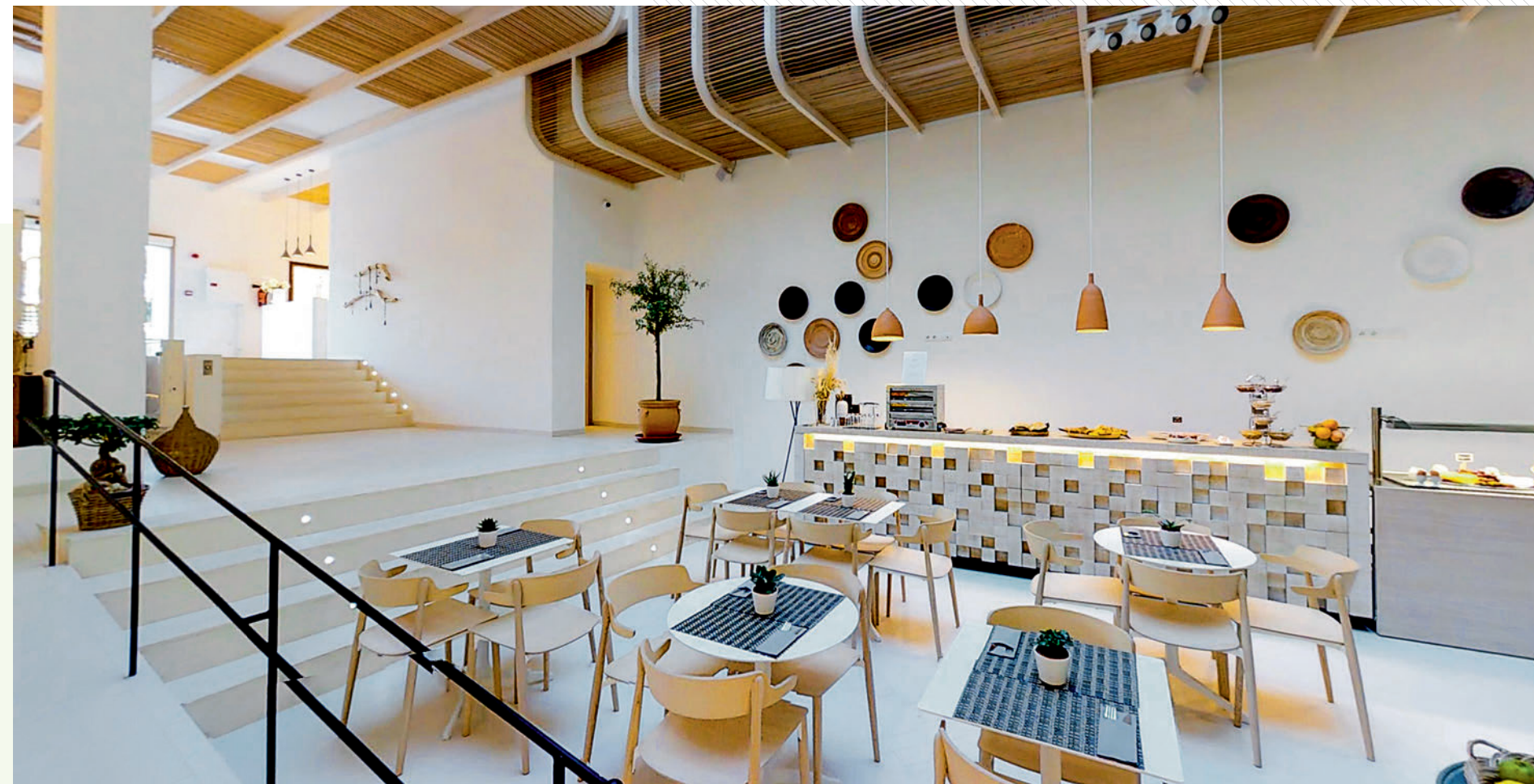
wide, and produces more than 319,339 tons of waste each year. According to a 2020 Booking.com report, 73 percent of global hotel visitors today would prefer an eco-sustainable hotel over a traditional one, 96 percent of global travelers admit that sustainable travel is important, and 76 percent want to make more sustainable travel choices in the future.

Bas Steunebrink, Co-Founder and Director of Artificial General Intelligence at NNAISENSE, says a clear benefit of digital twin technology for the hospitality industry from a climate change perspective stems from applying digital twins at hospitality facilities to improve operational efficiency.

“Travel itself, especially aviation, is a major contributor to global emissions,” says Steunebrink. “Making airplanes closer to climate-neutral – for example, by building electric or hydrogen-powered aircraft – is an effort undertaken by aircraft manufacturers that governments are stimulating.”

Steunebrink says that applying digital twin technology to construct a holistic virtual model of a hotel and its services and personnel has the potential to improve operational efficiency.

Digital twins can monitor hotel rooms like this one at the Matterport Boutique Hotel Gatzara in Ibiza, giving guests ultimate control of their environment via a smart device



“This is good, not only for the bottom line, but also for the environment, when improvement targets include the reduction of energy consumption, waste, and emissions,” says Steunebrink. “A digital twin can compute the changes required to reach those improvement targets.”

He also believes that digital twins can do a lot, from assisting guests carrying a smart device with onsite navigation to ordering services via a virtual concierge.

For example, they can control a hotel room filled with IoT devices – lights, air conditioning, entertainment, and amenities, allowing both guests and management to create their own climate control with lower energy consumption.

Because digital twins form a base to capture, organize and model the behavior of the physical world, they can be used as a predictive guide to “what if...?” scenarios to get to the optimal solutions that have sustainability as the goal.

“The larger the coverage or the scope of a digital twin, the larger is the impact,” says Dash.

Another important area is how the digital twin facilitates a transition towards a circular economy. “Think about the sustainability need for airlines to reduce food waste on board. The inflight catering services market was estimated at US\$15.5bn in 2017, and IATA has stated that up to US\$3.9 billion is landfilled or incinerated.”

“When the customer experience can be virtualized, the carbon footprint naturally reduces,” says Dash.

Dash believes that digital twins have immense potential. “They can positively impact the entire value chain. Both providers and customers are set to benefit – providers by improving their operations and offerings, reducing cost and increasing predictability, and customers will get better service and newer experiences.”

CALL TO IMPACT

1 Digital pays off. For smart destination management, the integrated and coordinated use of smart technology is a must.

2 Digital serves people and planet. Digital twins can benefit tourists with better service and newer experiences – and providers with higher efficiency, reducing energy consumption and waste. As a result, tourism’s carbon footprint will improve.

3 Public-private preparedness. The pandemic showed the need for enhanced preparedness and resilience in travel and tourism to external shocks (such as outbreaks) and stress factors like demographics and climate change. The method must be tighter private-public collaboration.

'IT'S A PERFECT, POSITIVE STORM'

How the executive director of the global Digital Twin Consortium sees the state of the technology and the development it is taking.

RON ZAHAVI IS A STANDARDS GUY.

The career of the freshly appointed executive director of the Digital Twin Consortium spans more than 30 years and includes working with the standardization of emerging technologies and industry consortia. We talked with him about the overarching and unique issues that digital twin technology is facing.

Mr. Zahavi, what is the Digital Twin Consortium? And what are you doing there?

Ron Zahavi: The Consortium was created to address needs in the marketplace, like security and interoperability – interoperability among the components of a digital twin, between different digital twins, and between digital twins and other legacy systems. A second focus area is helping to explain to the market what a digital twin is. There is a lot of confusion and hype out there, so it needs someone to stand up and come out with the right taxonomy. And the third area is helping to accelerate the market. We do that by creating the ecosystem, bringing together end-users, vendors, and research institutions to address gaps and challenges.

Let's do speed first. How fast is the development of digital twin technology right now?

Do you lose your breath, or can you still take it?

It's not just one speed. We see some early adopters and innovators. And we see that for some industries the tipping point is coming very soon. Digital twins have been used by NASA and others as a technology for more than 20 years. So that's not necessarily new. But right now, at big events of the industry such as the IoT solutions world congress, you can see a lot of movement on digital twins. But also from actors that would typically be laggards, like governments or the engineering and construction industries, we see a lot of demand. Anything that is large and expensive, where you don't get many chances to build it, we are seeing a lot of end-user interest and investment in that area.

Is this a herdlike behavior? Tesla's cars all have a digital twin, so shouldn't our products have one, too?

Some of that behavior happens with every new technology. What's unique with digital twins is that they're driven by digital transformation. That's a critical necessary component of digital transformation, and we're seeing it in a lot of industries – from retail to construction to automotive. Companies realize that the only

way they can achieve what they are trying to achieve is to build a digital twin into it. There are even end-users coming to the consortium in search of a technological solution to a problem they have – and that's something you don't see very often.

How do those cases look?

In classical manufacturing, this is about how to build better products, how to manage the supply chain, how to improve the efficiency of their assembly lines, and how to do carbon reporting. In aerospace and defence, it's about simulation

and maintenance of their big assets, like plane engines. In agriculture, it's about how to maximize crop yield, how to minimize energy and water use. So, a lot of sustainability and resilience topics. In healthcare, we see it in the machinery, maintenance and operation, and also with digital twins of people, detection, analysis and treatment. Natural resources: How do you do grid design? How do you predict disasters and emergencies? Renewable energy, wind farms. So each sector is focusing on what is important to them, and then there are topics that cut across all sectors, like asset maintenance.

And who is the driver of this development? Is it you, the consortium? Or customer demand, or technological breakthroughs?

There is not only one driver. There are not only tech companies trying to sell their solutions, and there's not a

push only from the demand side. There is movement and development on all sides: demand, supply, technology, regulation. And you need all of it: the innovators and the start-ups, the bigger companies, the marketing aspects.

You didn't name the usual suspects as drivers for the development of this technology: Covid-19, Wall Street, Mark Zuckerberg.

Obviously all are factors. Events like Covid can indeed shift investments. And there was a huge shift towards remote capabilities, and massive investments in some sectors of healthcare. I don't know if I would call it Wall Street, but the digital transformation of corporations is one main driver of the digital twin market. And the Metaverse – not just Zuckerberg, other players too – is bringing these pieces together, the real world, the virtual world and simulations. Obviously digital twin is

“The market for digital twins is driven by the digital transformation of corporations.”

RON ZAHAVI

has been Chief Strategist for IoT Standards, Microsoft Azure IoT, since 2015. In 2022 he was also appointed Executive Director of the Digital Twin Consortium.

a core component of it. So it's a kind of perfect storm – but a positive one.


The main tasks of the Digital Twin Consortium are interoperability and influencing standards. What is your approach? I'll give you three examples from history: agreeing on more or less one gauge for railways, developing a unified flag alphabet for maritime travel, and creating your own universe like Lego, where you can build whatever you want, as long as you use Lego bricks. Which direction are you heading in?

Something of all of the above. When we look at standards, digital twins are just one component of digital twin solutions. These solutions have been evolving as part of IoT technologies and are built on top of that. What you find are horizontal standards, for example about the communication between systems, or for architectures and guidances. These are more like your railway or alphabet examples – an underlying infrastructure that allows mobility and exchange. They need universally accepted protocols. And then there are vertical standards, mainly for specific regions in specific industries. This is where it gets complex, because there are a lot of them, they're not universally accepted, and sometimes they even compete. Try to build a factory anywhere in the world and you will find out how many standards exist just for this one industry in this one country.

And now you join in the competition and define even more standards?

Our main job is different. As all those standards are already





One world, one standard: With Lego, you can build almost anything – as long as you only use Lego bricks.

set, we work together with the organizations behind the standards to find out how they can come together. Do they fit? Is there an overlap? Is there a gap between them? We are doing a lot of work on ontologies – just collecting what kind of standards already exist. So when you are, for example, creating the digital twin of a building, we are working on aligning the standards of the traditional industry (construction) with the standards of the new technology.

But you are not just aligning what already exists?

If we find a gap in the existing standards, we work with the respective organization to close it. And the closer you get to our specific technology, the more we also define and set standards. Take artificial intelligence or machine learning. There are a lots of standards

already existing or evolving right now, and we are one of many players in that evolution. And then there are standards specific to digital twin technology, like what kind of modeling technique do you use, what kind of simulations?

Can we expect to get a unified set of rules for all digital twins, or will there be different sets for digital twins in, say, architecture and healthcare?

It depends on the layer you're talking about. The ontologies and syntax may be different for every industry, but you may have the same type of interfaces and rules for how you put a digital twin together, regardless of what industry you're in. You need both: the foundational pieces that allow you to construct all those products and make them interoperable. If we

“**As people interact with the Metaverse, smart cities will have to talk to other ecosystems, like factories or streets.**”

go into the Metaverse, you will need smart cities that can talk to factories, to the streets, to the buildings – the digital twins of each industry will have to interoperate with the ones from other industries. Those interfaces have to be the same. But on top of that, each industry will have its unique aspects.

Let's look at the actors. You come from the tech industry. Your steering committee consists mainly of other representatives from the tech industry. What about governments, or international institutions, or other stakeholders?

We work closely with governments, and we have also governments as members of the consortium – the government of New South Wales has even been a member from day one. The intention is not to have

standards solely driven by the industry. We publish opinions, we advise governments in the USA and in Europe. So it's really about the ecosystem, not just about a part of it versus the other parts. We collaborate very openly with everyone.

Well, not everyone wants to be open in the internet. Some countries have even more or less closed off their communications. How much of your approach is global, and how much is western?

We have members from 36 countries in the Americas, Europe, Asia, Australia and the Middle East. So geographically we are open. And when it comes to standards, we also believe very much in openness. But when governments create restrictions and specific regulations, obviously we have to follow them. ■

CALL TO IMPACT

1 Build bridges. Digital twin development will require cooperation in the value chain and with other sectors and industries. Trying to be exclusive may end up being lonely.

2 Don't invent everything. The new technology will not be completely new, but will integrate already existing building blocks. That's good news for investment budgets and for the reliability of earlybird products.

3 The change goes on. Covid-19 has massively accelerated the digital transformation in almost every sector and industry. Even if the speed of change decreases, there's no return to a previous normal – the transformation is here to stay.

THE HEALING TWIN

TRANSFORMING HEALTH WITH CUTTING-EDGE MEDICINE AND REPLICAS OF OUR BRAINS AND HEARTS

→ **A DIGITAL TWIN APPLIED** in medicine, where the promise for patients extends from improved accessibility and convenience at a hospital to groundbreaking, tailored medical interventions based on an individual's unique genetics, health, and condition, is another powerful example of how this technology is having an impact on humanity.

With the introduction of digital twins in healthcare, personalized and precision medicine will become the norm, with the ability to build biologically detailed digital reconstructions of a brain or heart creating particular models for specific conditions.

In one example, French start-up Sim&Cure has developed a patient-based digital twin for treating aneurysms. Sim&Cure uses simulations and digital twins to help neurosurgeons maximize patient safety as they undergo treatment. It's not just practiced on a simulated patient, it is practiced on precisely the right patient, the company explains.

In another case, pharmaceutical giant GSK is working with King's College, University of London on a project to adapt AI technology to tailor cancer treatment to a patient's individual genetic makeup.

A key driver for this is that, at present, cutting-edge treatments that mobilize the body's immune system against cancer either work extremely effectively

– in about 20% of patients – or seem to do very little at all. The hope is that, with a better understanding of these genetic interactions through increasingly sophisticated digital models, this effectiveness can be made much more widespread.

The idea behind the GSK/King's partnership is to explore AI research models – a longstanding and widespread existing practice – and also look at molecules in blood, tissue, and bodily fluids in real patients to track the course of the disease more accurately. This would enable medical professionals to diagnose patients more thoroughly and avoid extremely high-risk treatments, as these can be tested safely on the digital twin, rather than on an actual (very ill) patient.

"We are linking up the patient with the twin and can immediately feedback info to the clinical trial or clinical management algorithms," says King's College professor Tony Ng. "The biological twin will not only tell us this person has a high risk, but also what we as oncologists do about it."

A TECHNOLOGICAL COCKTAIL

By using the "–omics" – genomics, biomics, proteomics, or metabolomics – simulation models will allow more interventions for operations along with the prediction of other physical

PHOTO: SHUTTERSTOCK/GORODENKOFF



Personalized and precision medicine lie at the heart of how surgeons are now using this new technology to prevent disease and save lives.

markers, such as demographic and lifestyle data, over the life of an individual. The digital twin in the context of clinical trials is not just one technology, but a “technological cocktail.”

However, as a report by *lssjournal.biomedcentral.com* states, the use of digital twins in healthcare has not only prompted significant hope for the improvement of diagnostics and treatment, but has also sparked debates about its social and ethical consequences.

“To start with, digital twins inherit most of the socioethical issues concerning privacy and individuality (our conception of a human individual) that have been associated in the past with personalized medicine and health. It is unclear whether the digital twin will eventually exacerbate or alleviate such already-existing concerns. As a technological cocktail, however, it is fair to presume that a digital twin will trigger more, rather than fewer, areas of dialogue. The time is therefore ripe for a socioethical scan of the use of digital twins in healthcare,” the report states.

Unlearn.AI. is a start-up that has developed the first machine learning technology that creates digital twins of patients in clinical trials to enable smaller, faster studies. Unlearn.AI works with pharmaceutical and biotechnology companies, as well as with academic institutions, to optimize human clinical trials via its TwinRCT platform. A TwinRCT is a randomized trial that uses historical control data and machine learning to achieve a higher probability of success with a smaller number of patients.

“Our TwinRCT solution enables smaller, faster trials that ultimately reduce the time it takes to develop new medicines, while also limiting the number of patient volunteers. That translates to new therapies getting to patients who need them faster and at lower prices. We believe that every trial should use our approach to become more efficient and reliable,” says Charles K. Fisher, PhD, founder and CEO of Unlearn.AI.

Siemens is also working with several vaccine manufacturers to design and test various vaccine production line

“**The biological twin will not only tell us this person has a high risk, but also what we as oncologists do about it.**”

TONY NG

Professor at King's College, University of London.



Digital twins are helping pharmaceutical companies to design and validate lifesaving vaccines in record time.

configurations. In the case of new mRNA vaccines, which are fragile and must be precisely combined using microfluidic production lines, digital twins allowed it to design and validate the manufacturing devices, scale these processes, and accelerate their launch from one year to five months.

THE NEUROTWIN

But the ultimate challenge for digital twin technology and the human body is, of course, the brain. We each have some 86 billion neurones in our brains, and the unique structure of and connections between these form our personalities, memories, abilities, and more.

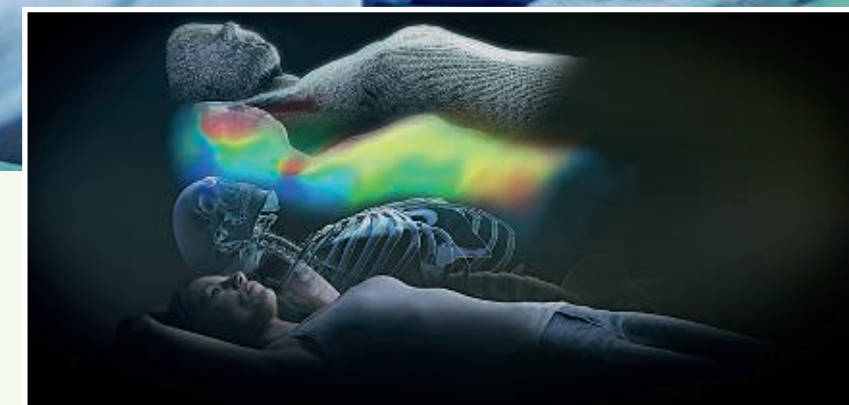
This is not a simple application to model, but the potential for successful projects is substantial. Early trials in an EU-funded project neatly dubbed “Neurotwin” is aimed at creating digital twins of the brains of patients with

Alzheimer’s disease, intended for the tailoring of customized treatment plans based on an immensely detailed picture of their individual brain health.

This could in time lead to more reliable and effective treatments for other neurological disorders, such as epilepsy. But in the more distant future it also has the potential to become the stuff of sci-fi. It is hard not to be drawn to the idea of a fully functional digital replication of your own brain, working in the online world.

A TWIN OF THE HUMAN HEART

There are other ambitious projects underway that are gaining considerable traction, such as the Living Heart Project (LHP), a simulated 3D heart model that aims to drive the creation and use of simulated 3D personalized hearts in the treatment, diagnosis, and prevention of heart diseases. The Living Heart Project has grown to involve more than



PRECISION MEDICINE

German company Brainlab is a pioneer of precision medicine, providing 3D image models of a patient’s anatomy using data streams that can be linked to form a digital twin. Together with AI, cloud computing, augmented reality, and robotics, it means that the medical industry can offer better healthcare through technology. Like a Google Maps of the human anatomy, Brainlab is able to build anatomical digital models of patients by aggregating data from different sources – computer tomography, MRI scans, and various examination results for the same patient over time, offering a much better visualization and a better understanding of the body. With sufficient data, surgeons are able to start personalizing treatment for every patient and come up with a specific risk profile that allows them to pick the best treatment for every person individually.

95 member organizations worldwide, including device manufacturers and regulatory agencies, medical researchers and practitioners, united in a mission of open innovation to address healthcare challenges.

At its core, the LHP involves stakeholders coming together to crowdsource a virtual twin of the human heart to serve as a common technology base for education and training, medical device design, testing, clinical diagnosis, and regulatory science.

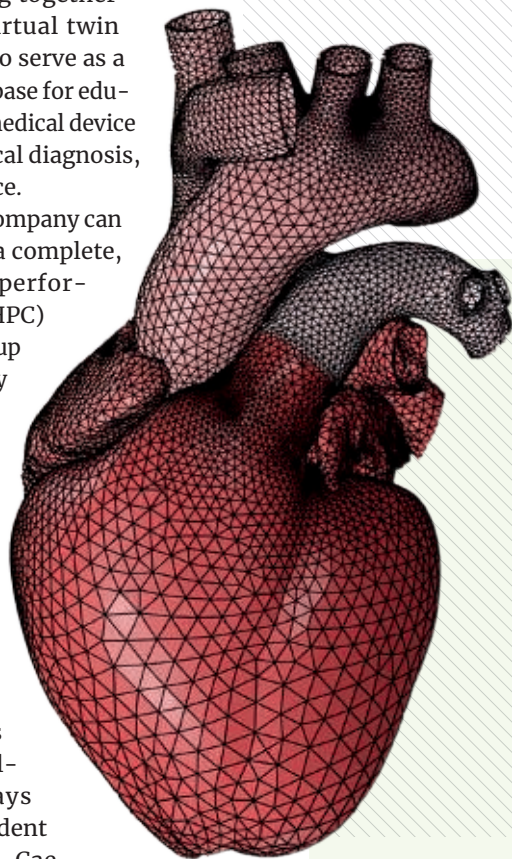
Any life sciences company can immediately access a complete, on-demand, high-performance computing (HPC) environment to scale up virtual testing securely and collaboratively, while managing infrastructure costs. This also crosses an important boundary toward the use of the Living Heart directly in a clinical setting.

“Medical devices require thousands of tests in the development stage,” says Joe Formicola, President and Chief Engineer, Caelinx, one of the LHP member organizations. “With the move of the Living Heart to the cloud, effectively an unlimited number of tests of a new design can be carried out simultaneously using the simulated heart, rather than one at a time, dramatically lowering the barrier to innovation, not to mention the time and cost.”

PRIVACY AND SAFETY CONCERNS

On a micro level, a digital twin of you would provide you and your doctor with a more holistic understanding of your health, and could revolutionize the treatment of some of the most challenging diseases faced by humanity.

Moreover, this is a technology that can be developed incrementally. Each



“**Our TwinRCT solution enables smaller, faster trials that ultimately reduce the time it takes to develop new medicines.”**



CHARLES FISHER

Founder and CEO of Unlearn.AI

new system, when it becomes ready, can be integrated with already operational ones; new features and more granular data can be built into systems powered by digital twins; and healthcare providers will have the ability to iterate as they go – seeing what works for patients, what seems to be unnecessary, and what might provoke regulatory or consumer backlash.

It will be necessary to manage privacy and safety concerns with extreme care, particularly because this technology would involve the integration of some personal healthcare data in the building or transporting of digital twins. This creates a risk of compromise, as well as of commercial misuse.

From the patient perspective, much of the potential for easy wins – a better journey through the hospital, fewer missed appointments, automated prescriptions, and so forth – relies on the creation of an ecosystem of digital twins that can communicate and interact with each other.

This means that interoperability is crucial. If vendors all create walled gardens that force everyone to use their software that doesn’t speak effectively to rival systems, many of the potential benefits will never be realized.

There can be a win for healthcare providers, suppliers, and patients if the course is handled judiciously, security is built in from the creation of these new

PHOTOS: GETTY IMAGES/THE BOSTON GLOBE/DINA RUDICK; LIVING HEART PROJECT; UNLEARN.AI



The Living Heart Project is one of the earliest examples of digital twin technology being used to solve a healthcare challenge.

systems, and the principle of interoperability is present from the start.

The early benefits will be less hassle for the patient and more convenience – excellent for winning early acceptance and even enthusiasm for the tech.

COMPLEX SYSTEMS

On a more macro level, hospitals are a complex ecosystem of clinicians, patients and equipment. In an article for Forbes Business Council, Sindhu Kutty, Partner & Co-Founder at Kuroshio Consulting Inc, says using a combination of digital twin and AI technology, medical facilities can simulate efficiency improvement areas and their impact on the interconnected system. “There are a host of significant challenges that hospital systems face with respect to operational efficiency that could be alleviated. These include the lack of interdisciplinary coordination, transcription errors, equipment and device downtime and long waiting lines. Digital twins combined with other emerging technology can be used to improve clinical outcomes, lower operating costs, and optimize resource allocation.”

BYTES OF BITES?

Incheon Metropolitan City, one of the largest cities in South Korea, is home to 3 million people – and a sizeable population of mosquitoes, which is causing concern for public health officials. As part of Incheon’s wider smart city initiative, it continues to monitor the threat of dengue fever and other mosquito-borne diseases. These include malaria, yellow fever, West Nile fever, and Japanese encephalitis.

Climate warming is making the situation worse and Incheon’s digital twin attempts to mirror many of the city’s functions in real time.

“The real-world system it duplicates is nothing less than Incheon itself. In this context, mosquitoes are not just pests and disease vectors; they represent one more dynamic system in a city that contains many, ranging from power grids to weather activity. To varying degrees, these systems all affect – and are affected by – the others. The digital



twin is an ongoing record of the processes and interactions of these systems,” says Greg Milner, a writer with strategic content group Esri, a mapping and spatial analytics software company.

PANDEMIC TRACKING

The Coronavirus pandemic has led many countries to dramatically step up their public health tracking – sometimes intrusively, but often with huge effectiveness in preventing or slowing the transmission of the virus.

Contact tracers in South Korea, for example, have been able to use real-time financial and mobile phone data to accurately track an individual’s close

“**Digital twins combined with other emerging technology can be used to improve clinical outcomes.**”

PHOTOS: GETTY IMAGES/MOMENT OPEN/LOVE KOREA...; LAIF/JUN MICHAEL PARK

contacts even if they were unknown to the infected person. This is an integration of existing digital data with newly reported testing in the interests of public health – a true digital twin project.

China, too, had been experimenting with requiring temperature and similar checks at airports even before Covid-19. This kind of tracking has been cited by some advocates as raising the possibility of virtual hospitals or a “hospital without walls” – potentially able to proactively track infectious diseases and make health interventions earlier and outside of the hospital environment.

Those benefits could be huge, even for modest opt-in systems. James Kinross, a

surgeon at St Mary’s Hospital, London, is one of the advocates of the “hospitals without walls” approach, believing integration with smart technology, vital signs tracking, and AI-assisted diagnosis and treatment could mean lots of people were able to access hospital care without ever accessing a hospital.

This would be of particular benefit in a pandemic. During the acute phase of the Covid-19 pandemic, all but the most essential treatment for other conditions stopped, leading to an uptick in deaths as an indirect result of the coronavirus, but also to a huge backlog in access to care for chronic pain, hip and joint replacements, mental health appointments, and

more. With appropriate use of digital twin technology, much of this care could continue in a future pandemic – an event that is probably inevitable, according to Kinross.

Many of the new technologies that are introduced are done so as solutions in need of a problem – a criticism leveled at virtual reality, blockchain, the Metaverse, and more, fairly or otherwise. Digital twin technology is something different – something most patients will likely never hear of, let alone hear hyped, but that could nonetheless make a genuinely substantial improvement to their lives. And that is surely the ultimate goal for any new technology? ■

Officials in Incheon in South Korea have stepped up their public health tracking capabilities as part of a wider city-smart initiative to combat Covid-19 and other mosquito-borne diseases.

CALL TO IMPACT

1 Simulation gets real. With digital twin technology, neurosurgeons can prepare for an operation with a simulation of the very patient that they have to treat.

2 Less hospital stress. By combining DT and AI technology, medical facilities can simulate efficiency improvement to make a patient’s visit less stressful.

3 Health gets whole. Digital twins will provide doctor and patient with a more holistic understanding of a person’s health.

THE FUTURE BELONGS TO C-SI COOPERATIONS

→ **NO, THE C-SI WE MEAN HERE** does not come from TV crime series, it is not the acronym for Center of Special Investigations. Our C-Si comes from chemistry. It is the acronym for the combination of the chemical elements Carbon (C) and Silicon (Si), and It stands for the collaboration of us carbon-based humans and silicon-based entities like computers, robots, AI.

And this is a very powerful combination. As experiences from chess tournaments have proven, C-SI teams perform better than C- or SI-teams alone. It's not us against them, it's us and them together, what brings the best results, the highest Impact on Humanity. For us, the FII Institute, it is the Impact on Humanity that counts (see below). So we are ardent promoters of new technologies that assist humans and digitals to make the world a better place.

The digital twin technology is an outstanding example for this. It will spread to every sector, every region, every generation, probably facilitated by the rise of Metaverse in the coming years. The proponents of this new technology may have different reasons for pushing it: be it power or profit, be it image or PR. And there is no 'invisible hand' that turns these particular interests into something good for society. That's what we are here for – a kind of visible hand for the public good.

ABOUT THE FII INSTITUTE

THE FUTURE INVESTMENT INITIATIVE (FII) INSTITUTE is a new global nonprofit foundation with an investment arm and one agenda: Impact on Humanity. Global, inclusive and committed to Environmental, Social and Governance (ESG) principles, we foster great minds from around

THE FII INSTITUTE

is guided in all it does by a strong purpose, vision and mission.

PURPOSE
"Enabling a brighter future for humanity"

VISION
"Empowering the world's brightest minds to shape a brighter future for ALL, and with ALL"

MISSION
"Curating and enabling ideas to impact humanity sustainably"

PHOTO: ADOBE STOCK, FII INSTITUTE

FII-I has three pillars to deliver its mission: THINK, ACT and XCHANGE

1 FII-I THINK
Identify societal challenges and current inhibitors. Curate the brightest ideas to address societal issues

2 FII-I ACT
Catalyze innovation and initiatives by mobilizing partners and resources

3 FII-I X CHANGE
Create platforms for live discussions on the future of humanity. Share knowledge, stories and publications with different stakeholders

the world and turn ideas into real-world solutions in five critical areas: Artificial Intelligence (AI) and Robotics, Education, Healthcare and Sustainability. We are in the right place at the right time: when decision-makers, investors and an engaged generation of youth come together in aspiration, energized and ready for change.

We harness that energy into three pillars: THINK, XCHANGE, ACT. Our THINK pillar empowers the world's brightest minds to identify technological solutions to the most pressing issues facing humanity. Our XCHANGE pillar builds inclusive platforms for international dialogue, knowledge sharing and partnership. Our ACT pillar curates and invests directly in the technologies of the future to secure sustainable real-world solutions.

Join us to own, co-create and actualize a brighter, more sustainable future for humanity. ■

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REALLY INTERESTED
IN THE POTENTIAL OF
YOUR AVATAR TO KIND
OF TRANSCEND THE
PHYSICAL RESTRAINTS
IN YOUR OWN BODY ...”

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