Capgemini

ON THE PATH TO THE INDUSTRIAL METAVERSE

Using metaverse technologies to achieve operational excellence in the industrial workplace

FOREWORD

By Alexandre Embry

The metaverse is a potentially game-changing technology trend with incredible scope. Beyond the cacophonous hype, there is also a significant business dynamic that has crucial implications. Right now, companies in consumer-facing industries are the visible face of the metaverse, which we define as a blended space of virtual and physical interactions that can be used to improve the customer experience (CX), a unique opportunity for brands to get in touch with their audiences in fresh ways. But the metaverse will also lead to significant change within many other businesses, and will create more efficient engineering, manufacturing, and supply chain processes.

These changes will also help to boost employee experience (EX), without compromising on ecological ambitions. Thus the industrial metaverse is born.

How does this square with CX perspective? Look again at our definition of the metaverse: an open network of decentralized 3D virtual and hybrid spaces, a persistent place that is parallel to the physical world, with an aim of combining online digital and real-life experiences with a sense of presence, independent of place, time, or device. A single definition that is relevant for both consumer-centric use-cases, and engineering and manufacturing operations in the metaverse. Magic, right?

This paper focuses on the less glamorous but highly promising use cases of the metaverse: the industrial ones. This is core to Capgemini's Metaverse-Lab, a coordinating hub for technology research and development of customer solutions that have tangible business value and can be integrated and implemented at scale. Central is the next generation of digital twins, which will be interconnected, immersive, collaborative, persistent, and accessible from anywhere, and on many devices. The emergence of what we used to call, at Capgemini, "The Internet of Twins" will enable value -driven simulated experiences.

The technologies that will power the trend are progressing at an incredibly fast pace: advanced 3D rendering, immersive technologies (AR/VR), AI, IoT, and robotics. Virtual design and simulation will become more real. Ultimately, the next generation of digital twins will provide a unique experience: the feeling of being 'on site' from anywhere and everywhere, interacting with remote colleagues through realistic avatars. The result could be employees seamlessly monitoring or operating a physical asset in the metaverse from wherever they are.

So, what does the nascent industrial metaverse mean for manufacturing and what might its evolution and deployment at scale mean for businesses and their employees? Potential tangible outcomes include optimal resource utilization, reduced travel requirements, and advanced simulation models that cut the need to test products physically, while boosting desirability and sustainability.

This paper takes a strategic and operational view of the evolution of the Industrial Metaverse, assessing, its applications and current limitations, and exploring the undoubted opportunities to come.

01 INTRODUCTION: THE "MASTER OF THE GAME"

By Jacques Bacry

Digital experiences are cemented into our daily lives and routines. The gap between digital and real life is steadily reducing, and the boundaries between these two worlds are becoming porous; think of the way people now increasingly meet using online tools via social networks, or work using online collaborative tools.

As digital experiences become increasingly integral to our lives, we look ahead to the next evolution – the metaverse, where we see convergence between the real and the simulated.

The current promise of the metaverse is that the simulation of the "real" will be quick and complete. Is this a realistic approach and how can it contribute to achieving sustainability? Will the virtual environment become the "master of the game"? These are serious questions and lead us to a number of searching questions and propositions, which I cover in this paper.

02 CONVERGENCE AND EVOLUTION

Today, the metaverse is one of the hottest topics of conversation in technology departments, marketing organizations, and executive boardrooms. But if one digs deep beneath these discussions and considers the "reality" of the metaverse, several key questions quickly arise:

- **What makes the metaverse different from what's come before?**
- **What is the actual value or usefulness of the metaverse?**
- **What does the metaverse really change?**
- **What is the potential impact of the metaverse across different industries?**

These questions are just a starting point. The avalanche of technology involved in the creation of the metaverse does not immediately illuminate what the best environments for the different cases are. Further complexity arises given consumers and businesses have many different requirements.

Capgemini believes the industrial metaverse will assume a high priority because it will have significant impact on economic underpinnings. Many other industry observers are also starting to recognize the potential impact of this game-changing trend looming on the horizon.

To really understand the potential influence of the industrial metaverse, we need to keep in mind how a range of technological gaps have been filled by a convergence of systems, services, and data during the past 20 years or so, as illustrated in *Figure 1 overleaf*.

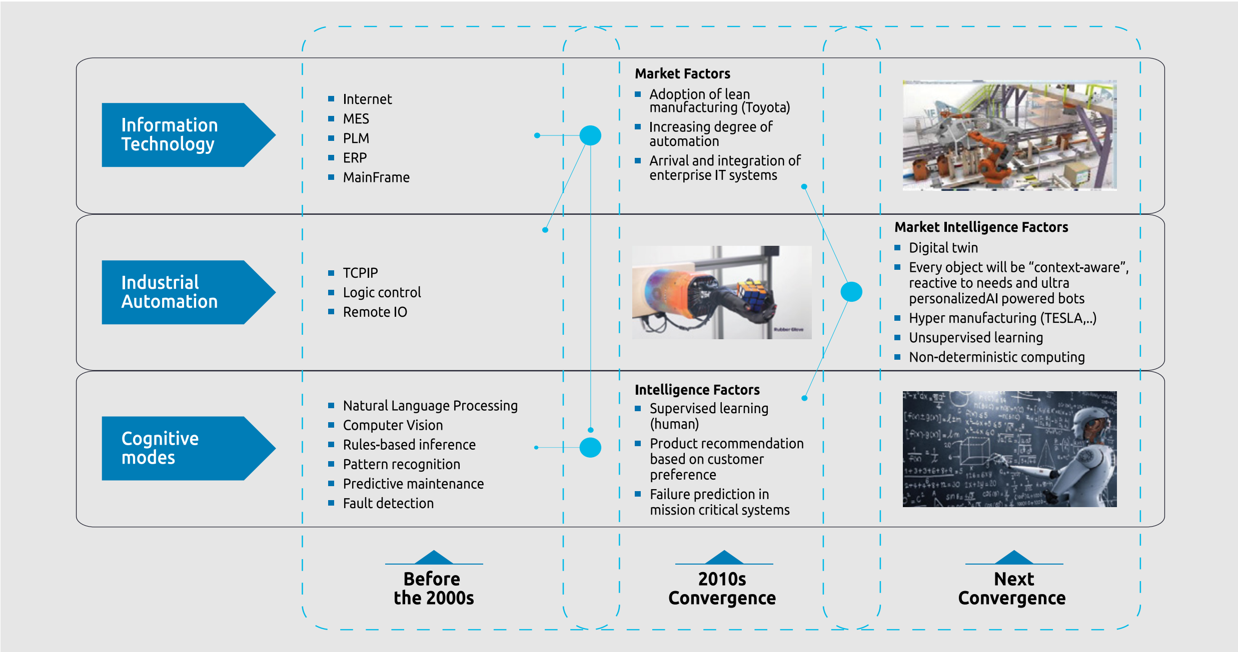


Figure 1: Convergence of IT, Automation and Cognitive modes over the last 20 years

The concept of the metaverse might have been popularized recently, but the term was first used in the 1992 science fiction novel Snow Crash[1]. Is the metaverse only a virtual reality setup? Just a new aggregation of technology? Today, the metaverse is best understood as a partial contributor to the next set of convergences. What's already clear is that we have come a long way from Snow Crash.

Just think, for example, of the release of Roblox, the introduction of blockchain, Decentraland, Pokémon GO, and the recent acquisitions and activities of Microsoft, Facebook, and latterly Disney in 2022.

If we take a step back and consider the evolution of the convergence so far, we can identify two main perspectives: differentiators and usefulness, both of which are very different depending on whether they are viewed from the standpoint of B2B or B2C.

Catalysts

If we are going to deliver on the potential of the metaverse and break the wall between the real and the virtual, then there are a number of technological and cognitive catalysts that will play a critical role in bringing these two worlds together.

Technological catalysts

We have grouped these catalysts as follows (For a full list of technology catalysts, see Appendix A):

- **Processing: microelectronics, software efficiency, and accessibility and commoditization**
- **Networking: lower latency/higher bandwidth, concurrency infrastructure, and decentralized infrastructure**
- **Devices: post-mobile platforms, crossplatform usage, sensory immersion, and ubiquitous endpoints**
- **Consumers: access to virtual worlds, identities and assets perceived as natural to integrate the real world, a new generation of "makers", and receptivity for crossover content.**

Cognitive catalysts

Let's turn now to the human dimension. A key challenge is to ensure the experience does not rely on too many cognitive functions from the user. The need to create a high-quality experience leads us to ask several questions:

- **To what extent is it necessary for a virtual world to be designed to mimic the basics for an effective experience?**
- **What level of realism should we aim for and how can we assess if this reality is effective?**
- **Given the desire for a 3D world and expectations of providing real-life experiences, how do we achieve high cognitive impact and a feeling of full immersion?**

Important research on digital transformation and virtual realities, notably by the Carnot Institute[2], addresses these three questions through the following concepts:

- ### Sociability/interactions
  As humans, we are a social species and need a certain level of interaction to function effectively. So what are the appropriate means of communication in virtual environments? Moreover, we all implicitly and instinctively use non-verbal communication, so how should we represent these signs in virtual environments?
- ### Incarnations and remote presence
  Self-identification in the virtual environment, such as extending the representation of the user through avatars, is key for psychological identification. Numerous academics are producing research that examines these issues, but many questions remain around key issues, such as the level of identity of self-virtual representation, action perception, and emotion capture.
- ### Learning in virtual environments
  A crucial research question relating to the digital transformation of companies concerns the learning process in an immersive environment, and how such processes should be improved.
- ### Human sensing
  Another key challenge is how to measure the incremental added value and benefits of using virtual environments, both in the shorter and longer term. Many sensors already exist for gauging quantitative bio-physiological and cognitive factors in the real world, but their application in the virtual world is still lacking.
- ### Decision-making processes
  In creating virtual environments, it is highly likely that the user will need to make decisions (such as requiring technical help or choosing between design options). We need to determine the influence of the different factors that will be involved in both real and virtual decision-making processes. We also need to consider the relationship between the real and virtual, and the impact of decisions made in the metaverse on peoples' reality.

In assessing the above questions, we suggest that the virtual reality we are moving towards is an integration environment of augmented life. The approach is to combine reality with some virtual extensions, and then integrated into the real world. The transition from the virtual metaverse to augmented life is illustrated in Figure 2.

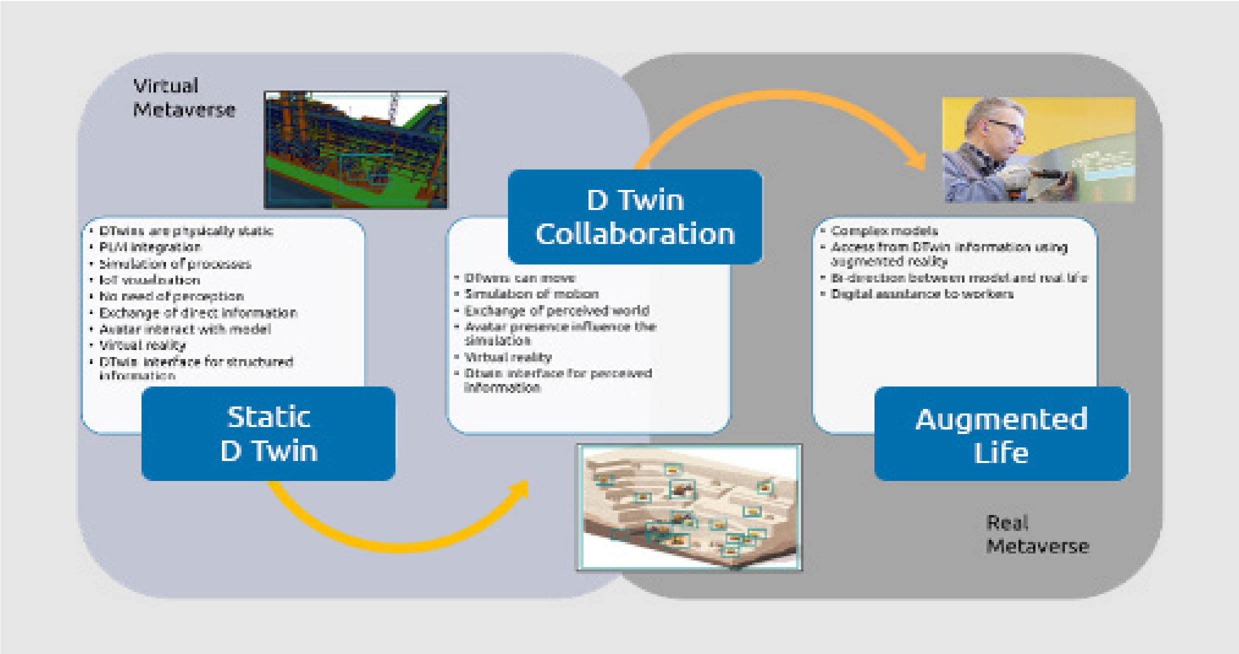


Figure 2: The transition from the virtual metaverse to the real metaverse

03 THE INDUSTRIAL METAVERSE

The current fascination with all things metaverse in the media might lead the reader to conclude that this nascent space is mainly an interactive environment for a B2C market. Here, metaverses are marketplaces, facilitating monetary transactions and exchanges in the broadest possible sense. It is in this context that an ever-growing interest in blockchains and NFTs (non-fungible tokens) has developed. However, as interesting as these developments might be, the metaverse is not just a space to socialize, play games, and shop. For businesses, something much richer and more impactful is emerging.

Using metaverse technologies to achieve operational excellence in the industrial workplace

The industrial metaverse is a significant opportunity to improve the operational, manufacturing, and supply chain processes throughout a product's lifecycle. It's a strategic economic shift that will generate new business potential in every sector.

Working in the industrial metaverse means we'll be able to recreate the feeling of being on site or in the workplace, and to facilitate next-level design, simulation, testing, training, or even remote operations. It is a space that will enable richer collaborations with colleagues in different locations, as well as capabilities to remotely interact with machinery, various assets, and environments.

Static versus dynamic metaverses: An evolving experience

You might think that creating different types of environments for different contexts simply involves taking a metaverse from a consumer environment and placing it in an industrial or workplace setting. However, there is more of a difference than first appears.

In the case of consumer -or shopping – metaverses, it's important to note that these spaces are in fact "static" metaverses, despite the use of clever graphics. Let us explain this situation in more detail. From an experience perspective, the staging or the environment represents a "frozen" situation. The user in this space simply needs to be able to navigate there, play there, make virtual visits, and maybe make transactions (such as buying goods, services, or NFTs for example). This is what we find in the virtual spaces of Meta (Facebook) or Roblox.

However, we might intuitively expect the metaverse to be more complex, more layered – an evolving reality, and an experience that is synchronized with reality, with interactions on a deeper, collaborative level.

This is what we refer to as "dynamic" metaverses, and it is this concept that underpins the industrial metaverse. It is this dynamism that makes the industrial metaverse a very different kind of space to that experienced in consumer settings.

The evolution of the concept of the digital twin is critical

The dynamic experience of the industrial metaverse is based on the concept of digital twins3, which are virtual representations of real-world physical objects, processes, or systems and their interconnections. Digital twins provide a virtual counterpart to real-life objects, processes, and systems.

Employees can use these twins to perform practical tasks, such as system simulation, integration, testing, and monitoring – and they can do so without having to interact with real- world objects.

In the industrial metaverse, the digital twin is taken to a whole new level. Here, there is a notable progression from the Internet of Things –which describes the interconnection of physical objects (using sensors), where data is exchanged over the internet or networks - to the “Internet of Twins,” with an additional dimension provided through the digital object(Figure 3).

This evolution makes it possible to scale up data exchanges and to interconnect with a vast range of information flows. The outcome of the Internet of Twins is that workplace users will be able to carry out co-design and co-simulation processes at scale.

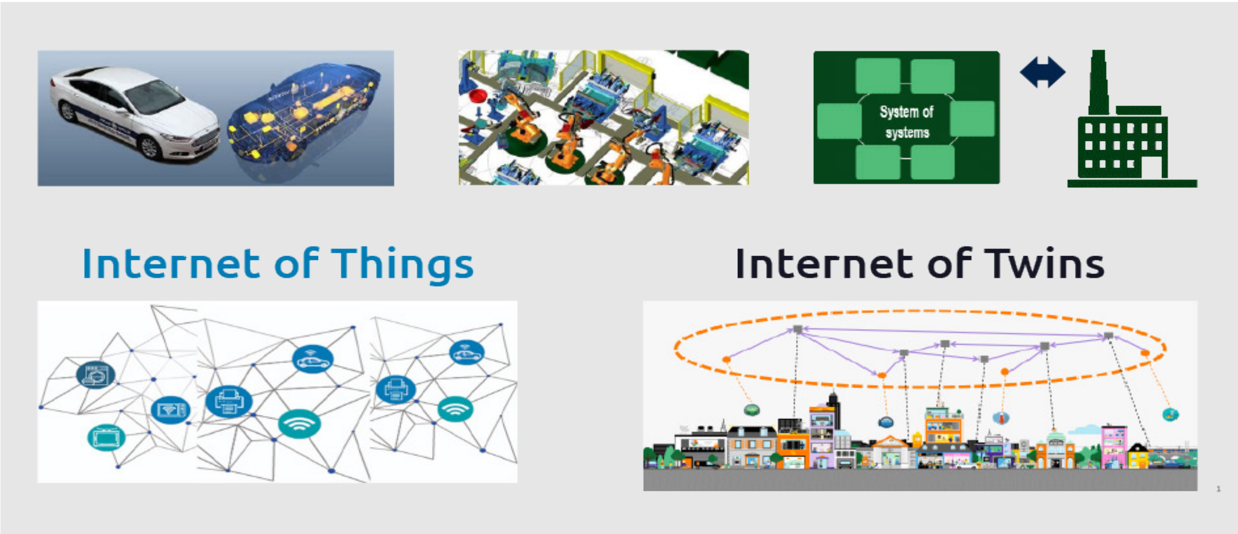


Figure 3: The evolution of the Internet of Things and Internet of Twins

In the not-too-distant future, it is likely that businesses will benefit from access to digital twins that are increasingly complex and interconnected. For example, in a factory, we could envisage a scenario in which equipment, products, and people are all connected. What’s more, the way in which these elements operate -and their associated behaviors - could all be simulated in the same dynamic experience.

So, how might this evolution be coordinated to generate meaningful decision-making data? We believe that control of this type of complexity will need to be applied through a model of the specific “universe” representing this environment, and most likely via a 3D representation that will allow users to better understand the dynamics.

Figure 4 shows a hybrid scene of a conversation on digital twin in MS Teams representing multiple objects.

Unlike the static metaverses of the consumer sphere outlined above, the dynamics of these industrial metaverses will be generated through the collaboration between different numerical twins and their associated simulations.

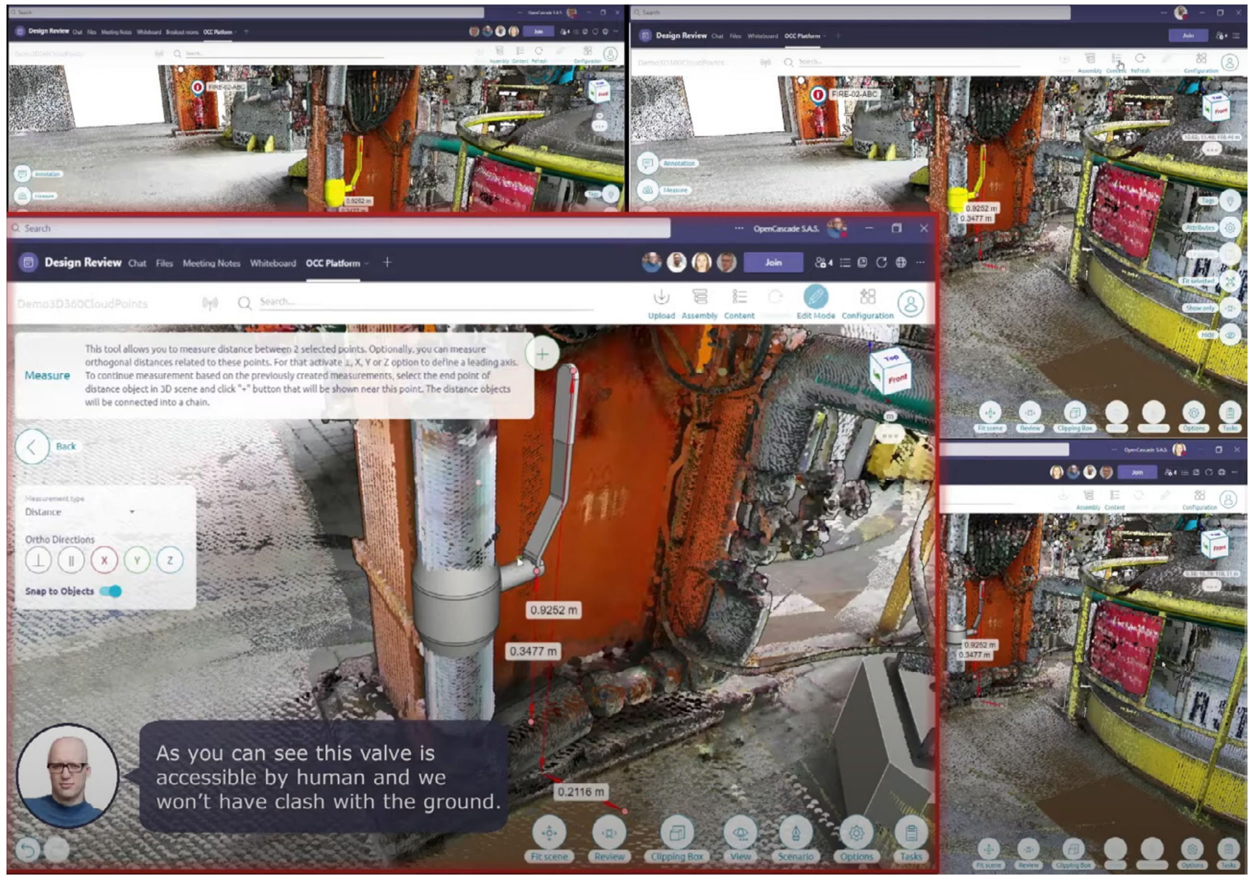


Figure 4: Digital twin team collaboration powered by Open Cascade, a Capgemini company

This high level of collaboration will make it possible to analyze an important combinatorial representation of the experience quickly, whether it’s from human to machine, machine to machine, or human to human, see Figure 5 overleaf.

DT collaboration though the internet

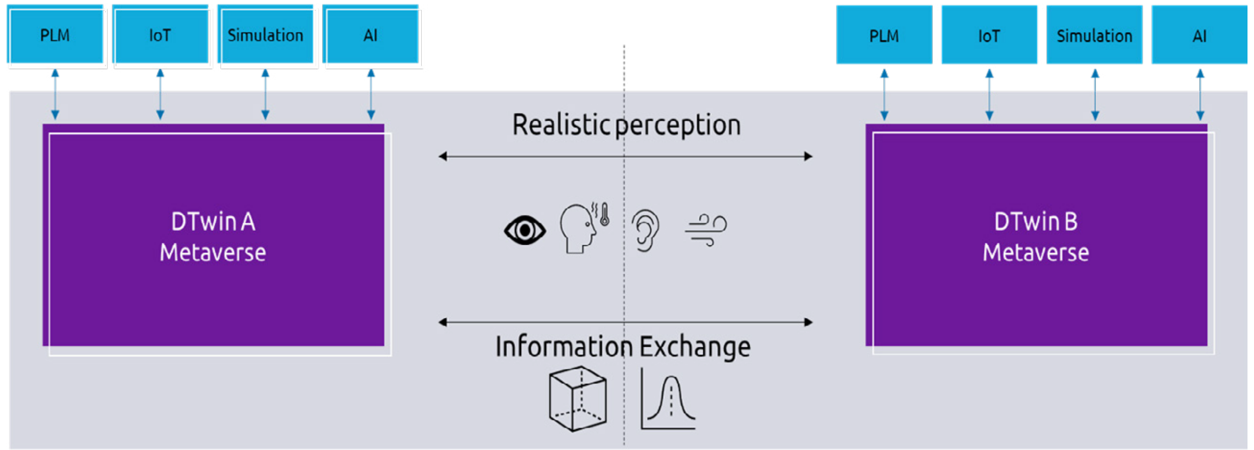


Figure 5: Digital twin collaboration, via the internet

I believe that if we accept the idea that this dynamic metaverse of interconnected machines and humans is the basis for staging evolutionary experiences, then we are about to enter a new era – the Internet of Experiences (IoX).

The three foundations of the industrial metaverse

As well as outlining limitations and challenges, we also need to identify the basic foundations on which we believe the industrial metaverse will be built.

First foundation: The augmented life

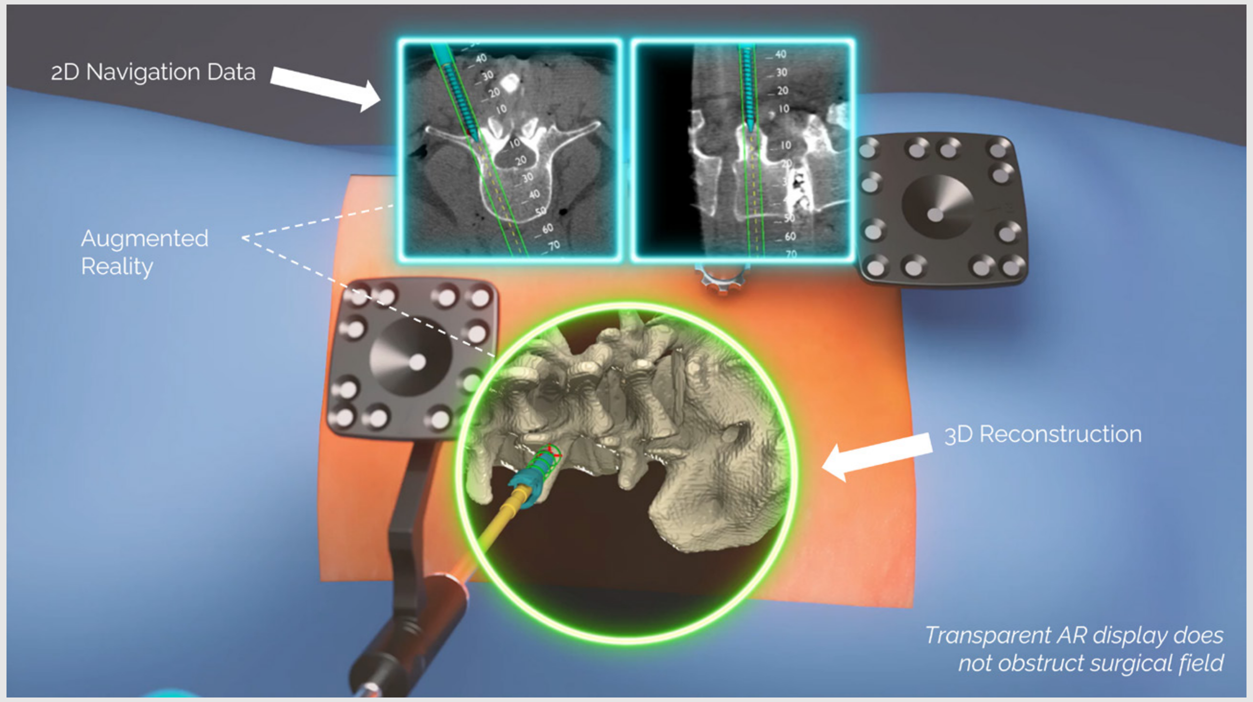
There is huge amount of data available in the real world, and an incredible level of detail that can be constructed in a virtual environment. For the industrial metaverse to be successfully implemented, the right balance must be achieved between effort to create, ease of use, and value of the experience.

It is therefore important that the industrial metaverse is driven by business value. At its core, this likely means that most experiences will be centered around real life, augmented by virtual.

For example, in the healthcare domain, the distance between patients and their medical teams could be reduced. Just as we have witnessed the increased use of Teams and other video-conferencing technologies, it’s possible to imagine how new technologies could allow patients to be immersed in a metaverse consultation, in their doctor’s office, and in 3D, without leaving their home.

Case Study

In June 2020, surgeons at Johns Hopkins Hospital in Baltimore, US, performedthe first spine surgery guided by an augmented reality navigation system, developed by the company Augmedics[3]. The tools used consist of an augmented reality headset with transparent near-eye display that can superimpose essential information and a detailed visual of the specific part of the body being operated on (see Figure 6). This can include stereotactic surgical navigation data that can give precise indications to practitioners, or projections onto the skin, providing an accurate, 3D reconstruction of the patient’s spinal anatomy. These technologies will make medical procedures faster and more reliable[4].



Source: Augmedics
Figure 6: Augmedics’ xvision Spine System® gives surgeons the power to see patients’ anatomy as if they have “x-ray vision.”

Second foundation: Real-time immersive collaboration

The creation of a unique and immersive experience, in which people feel they are interacting concurrently in real time, is an essential foundation for a successful metaverse. It's also important to recognize that these experiences will not be generic. There are at least three domains where effective collaboration has very different aspects and objectives – gaming and interactions in industrial settings.

Gaming – In 2016, the Pokémon Company launched a new smartphone-based game called Pokémon GO that mixed virtual and physical reality. Even though the game still relies on a device, the player starts to interact in real time between physical and virtual environments.

- **The virtual person is a decentralized representation of a real person – known as an avatar**
- **No real person exists behind the virtual person, who in many cases is referred to as a virtual assistant**

Whatever typology is used, the social and legal rules have to be formulated in detail, which is what we refer to as the Meta Alliance in Figure 7, on page 15.

Industry – One of the first goals of the "real metaverse" in industry is to solve the skilled labor gap that has been a persistent problem for manufacturing, logistics, and other sectors for decades.

The industrial metaverse offers a more human-centric approach to solving this problem. The real metaverse will provide mechanisms for humans to be part of the nexus of control.

One example is the 3D projective system powered by Diota that enables part positioning to be completed more accurately; similarly the projection of assembly instructions onto a satellite (see below).

Source: Capgemini

Third foundation: Device agnostic

Software independence is also essential to the creation of the metaverse, so that it will guarantee the portability of the different collaborations within which users participate. The integration that powers the metaverse must be device-agnostic, and the integration language of the virtual elements that constitute reality must be independent.

04 WHERE WILL INDUSTRIAL METAVERSE SOLUTIONS BE FOCUSED?

Before we dive into the technology underpinning this fast-emerging future, let us first look at the applications. Once we understand the concepts of interconnecting data and digital twins, the wealth of use cases opens up, and the depth and breadth of the scope is greater than one might imagine.

We, at Capgemini, along with several other observers, see a significant opportunity for using metaverse capabilities in a variety of sectors, including construction, engineering, manufacturing, and supply chains.

Several industries have already started to develop plans in which digital-real convergence will be a major asset. Let's start by taking a closer look at how manufacturing and the extended supply chain could benefit from a range of potential industrial-level metaverse applications, such as the use cases outlined below:

- Workplace visualization, design and layouts, including virtual factory walks and interactive assemblies
- Production-level simulations to test a vast range of manufacturing scenarios across machines, plants, and supply chains, and to explore different strategies across an ecosystem
- Collaborative R&D environments for design, simulations, testing, and virtual presentations of products and services
- Sustainability testing of solutions and processes, including materials, components, and maintenance
- Health and safety training, and work team collaboration
- Field sales and maintenance optimization.

These use cases are just the start of what could become a highly significant collection of industrial applications.

Using software, together with artificial intelligence and statistical-learning capabilities, to handle large and repetitive tasks previously performed by humans, these tasks include queries, calculations, maintenance tasks, records, and transactions.

Metaverse solutions and sustainability

Improvements to sustainability derived from the digital world are not a recent phenomenon. As soon as we started using digital simulations at scale, we started to improve sustainability. For example, the Boeing 777 was the world's first 100% digitally designed commercial aircraft.

Access to 3D CAD software provided designers and engineers with tools to create a virtual aircraft using accurate simulations; thousands of parts could be tested, replaced, amended, and tested again, without any of the cost and waste associated with producing these parts physically.

The scope of digitization is being extended to manage different kinds of simulations concurrently, which will avoid production issues, such as with managing the right equipment for the right function. The goal of this work is to anticipate the production process definition during the product-design phase, as well required resources.

We believe there is a strong synergy between the proposed metaverse stack and sustainability improvements – the more you improve simulation capabilities, the more you improve the potential for sustainability.

Take the example of the digital twin, which applies structure to the simulation framework and a series of "what if" scenarios throughout the lifecycle of the object, whether regarding an asset or system, or using real-time operational and behavioral data. By anticipating safety issues and future behaviors, the right choice can be made the first time.

Collaboration between digital twins will extend the impact of sustainability, as they will work as a network of heterogeneous synchronized simulations, further increasing the realism of the simulation.

The use of digital twins in factories or in smart cities – such as for vehicles negotiating traffic flows, signals, buildings, and pedestrians - highlights how several kinds of twins will be needed to represent the "real world" satisfactorily.

Another example: if we want to assess the carbon footprint of an entire city using real data, the collaboration between different digital twins and their data will be essential.

05 LOOKING AHEAD:
TECHNOLOGY ASSUMPTIONS FOR THE NEXT 10 YEARS AND CURRENT LIMITATIONS

All these exciting use cases will require the development and implementation of a range of metaverse technologies – some of which are ready to use, some of which are in various stages of development, and some of which are only now about to take shape. Let's find out more.

The limitations of the current metaverse approach

To assess these assumptions, let's look at an illustration showing the limitations of the current metaverse approach, based essentially on some type of virtual reality and interactive human-to-human collaboration, see Figure 7.

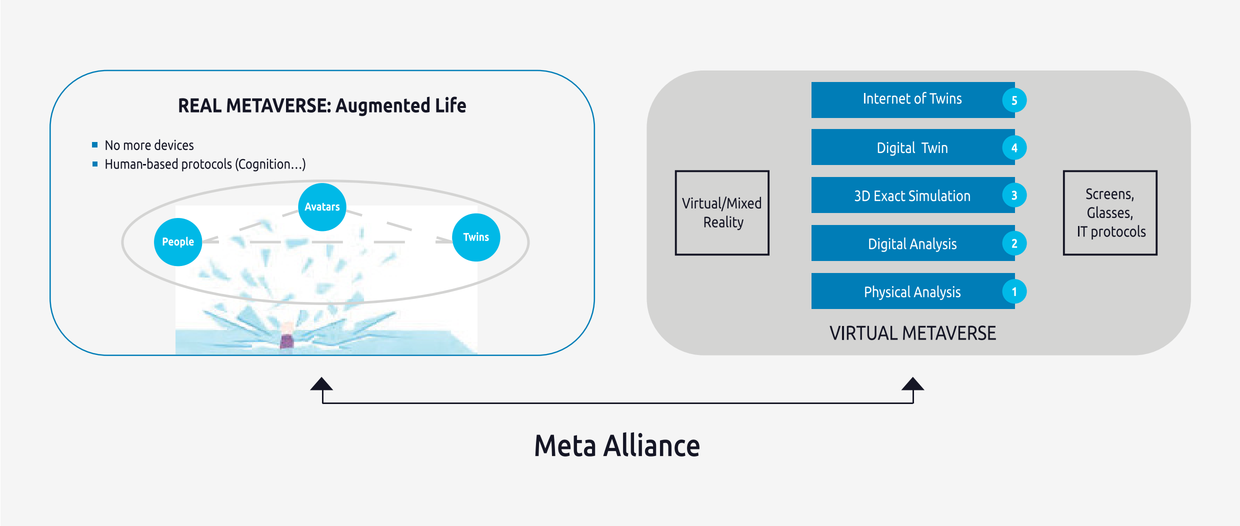


Figure 7: The interplay between the real metaverse and the virtual, creating a meta alliance between the two

The five levels of the virtual metaverse, in Figure 7, work together as follows:

1. **Physical Analysis -** carries out the real object analysis.

2. **Digital Analysis -** allows a huge increase in automation and productivity in the analysis of real objects (physical analysis), particularly relating to physical data measurements (such as temperature, stress, etc.), via virtual representation.

3. **3D Exact Simulation -** adds 3D representation and aggregation to visualize all the previous kinds of simulations (including 1D and 2D), combined with the appropriate physical results. Here, there is a clear difference between the requirements for B2B and B2C markets, such as the gaming industry, where different features are required.

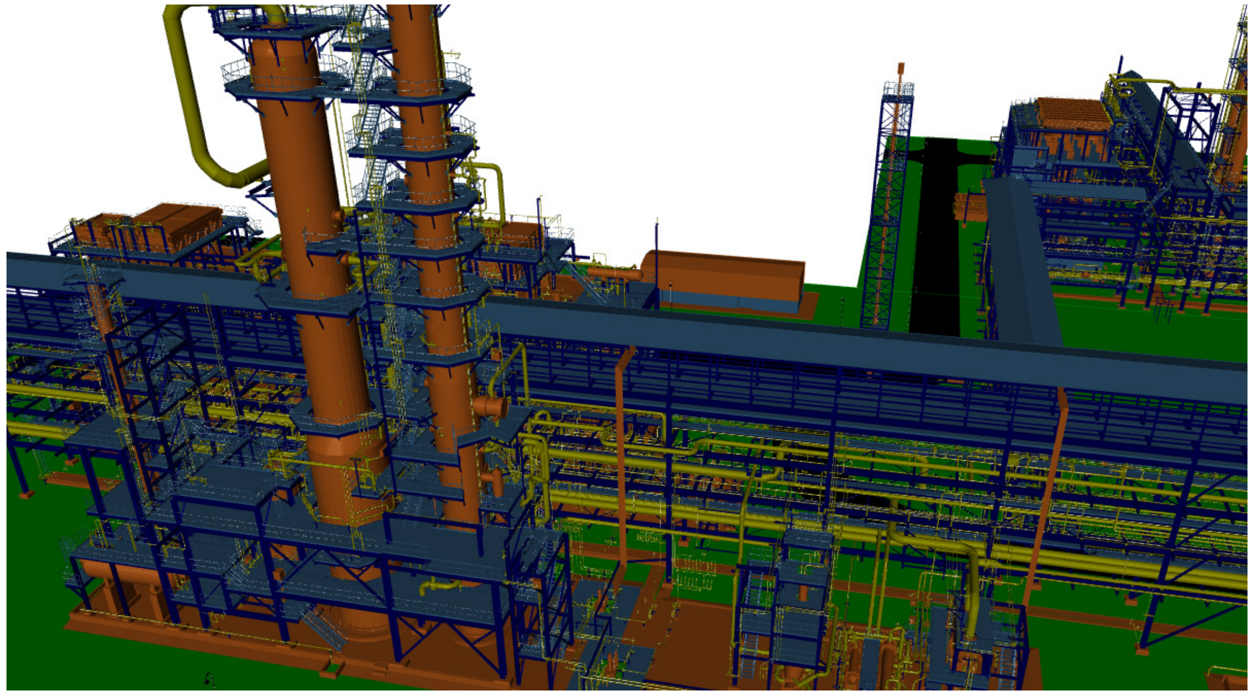
4. **Digital Twin –** expands the world of simulation to the behaviors of real objects throughout their entire life cycle; we are currently only at the beginning of this journey.

5. **Internet of Twins –** defines all the various elements of the virtual metaverse; this is where the B2B metaverse is currently trying to find a way to connect all these technologies. Indeed, the autonomous communication between digital twins, combining their simulations within a network, will in the future make it possible to model ever-more complex situations – but always in a virtual world.

To make these interconnections more concrete, let us look at an example. In a connected digital twin for energy, the global oil refinery's digital twin includes a third-party digital twin, which is delivered and controlled by external vendors.

The added value of the digital twin is delivered through:

- a multi-scale simulation and mutual improvement through the creation of a global installation and the equipment of each participant in this B2B metaverse;
- operational and emergency scenario testing, through the use of AI and human-controlled avatars with augmented reality.



Source: Open Cascade

Breaking through the wall

A key objective of an industrial metaverse is to anticipate and improve the desired reality. Therefore, it's important to try and capture as many parameters as possible, to simulate accurately an experience in a virtual world, before living it in reality.

So far, virtual and real experiences have been siloed in the nascent metaverse, although the digital twin is beginning to create interconnecting bridges. The reason we are still a long way from achieving a realistic collaborative model is because the increasing complexity of the developing metaverse makes it difficult to implement joined-up environments. We call this the "glass ceiling," represented in Figure 7, as the obstacle to achieving the benefits associated with the metaverse.

Technological complexity is not the only challenge. Other factors to consider include the specific nature of different sectors. For example, there is already a difference between process and discrete industries, due in part to the nature of the parameters captured (chemistry, fluid, etc.). The limitations of the devices being used are another challenge. It's certainly a bit strange to try and view a 3D reality through a 2D screen, particularly when representing big objects, such as the oil refinery in our previous example.

The role of Design for Excellence

Over the last few decades, industry has widely adopted the approach known as Design for Excellence (DfX), which is a series of guidelines applied to optimize a specific aspect or variable of a design in engineering and manufacturing. The design intent is captured by a deep analysis of the form, fit and function of the main characteristics of a part or assembly, requiring key assessments to be made regarding aesthetics, clarity, and impact (see Figure 8).

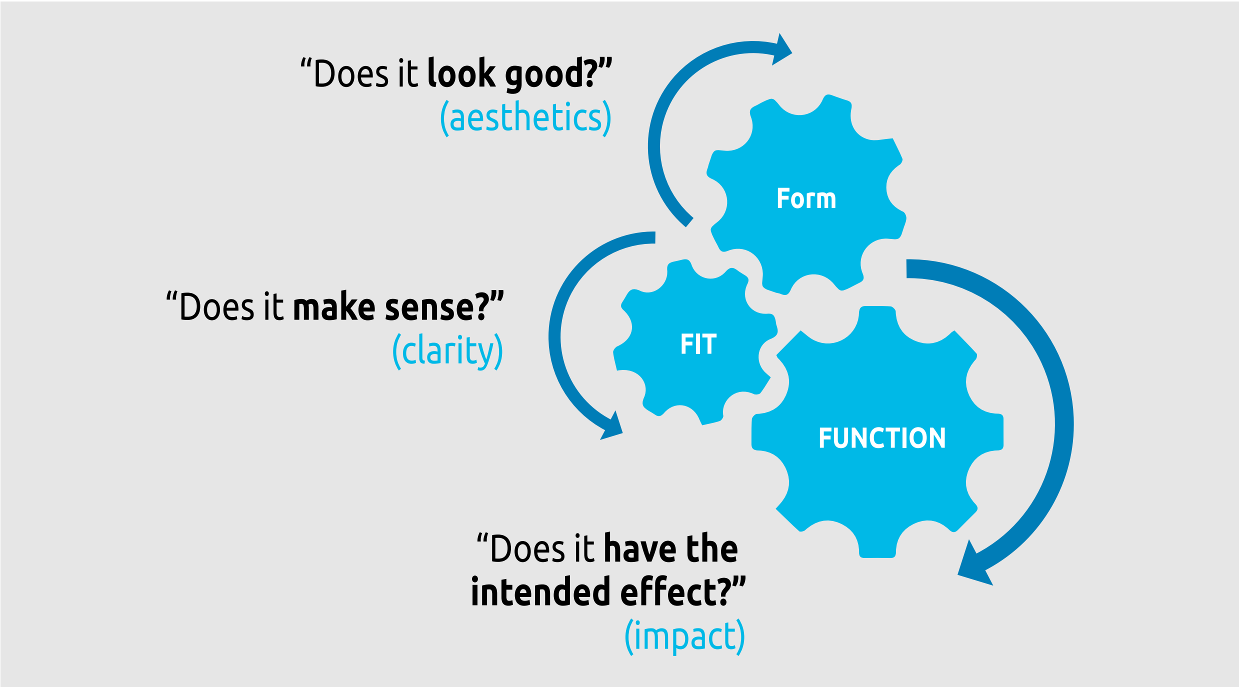


Figure 8: The interrelation of form, fit, and function in Design for Excellence

Each element defines a specific property of a part to help engineers match parts to needs. This identification allows better flexibility in the design-change process, by allowing modifications to parts with minimal documentation and design cost - so long as the fit, form, and function of the product are maintained.

We believe a DfX approach could help designers overcome some of the challenges associated with building the metaverse. We believe it is useful to take an augmented life approach that could be considered as augmented engineering and augmented manufacturing.

The approach focuses on the identification and description of the characteristics of the virtual, rather than the real object.

Just like a physical part, the virtual part must be created, tested, and validated to successfully extend the real experience, thus creating a realistic immersive collaboration.

This approach in turn leads to a VCR Framework, (Figure 9 overleaf) in which form, fit, and function become virtual, collaborate, and real. Analysis increases the design-change flexibility by allowing alterations and simulations in the virtual word, which can be used to prepare for and enrich the real experience.

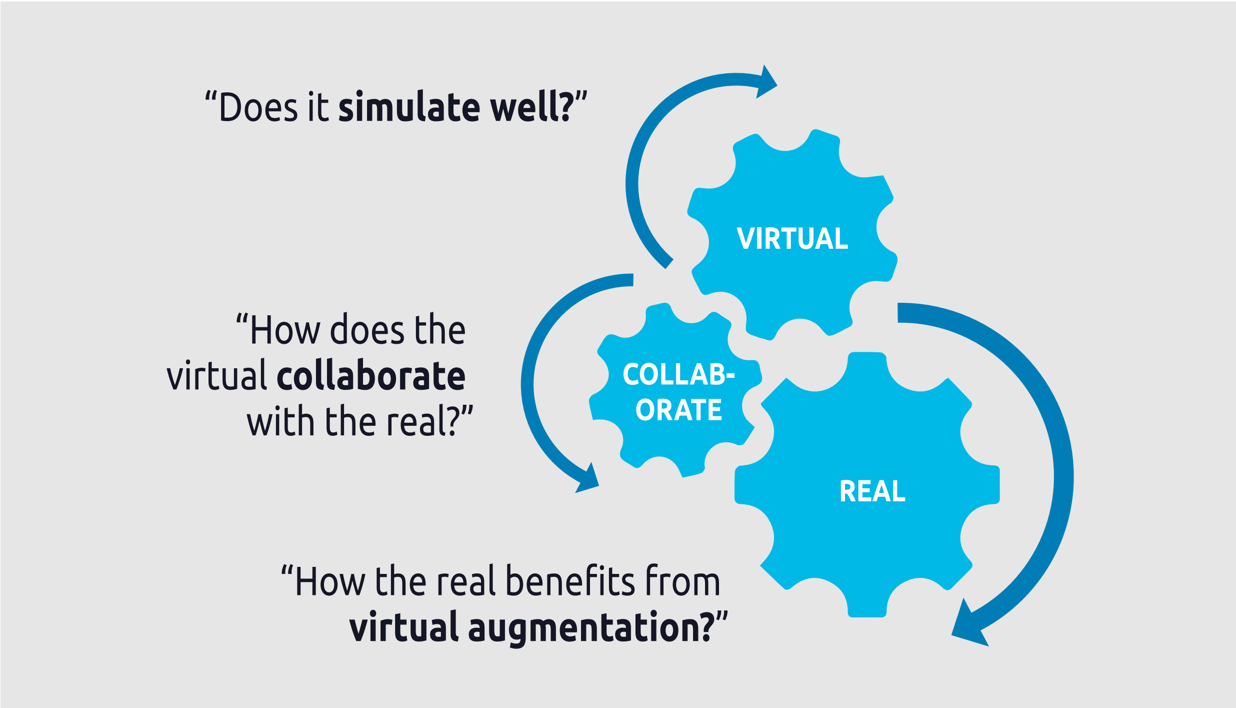


Figure 9: The elements of the VCR Framework

06 THE INDUSTRIAL METAVERSE WILL NOT BE WITHOUT ITS CHALLENGES

We are just at the dawn of the meeting of the digital and the physical, and changes that have the potential to transform society. In the future, we believe people will navigate seamlessly between real and digital environments, whether they are connected or not -without even knowing it. The very notion of "connection" will become obsolete. Restrictions of time, space, and capacity will be relaxed and, as a result, new value will be created.

Historically, there have always been gaps in our collective capacity to adapt to these types of changes. New social disparities might emerge because of these upheavals. Similarly, many ethical issues will have to be addressed. Today, nothing in the scientific literature indicates that it will be possible, within the near future, to manufacture electronic cerebral implants with the ability to increase our cognitive capacities. If it did become possible, we could acquire knowledge without appropriating it or interpreting it, and, therefore, without being able to question it.

When it comes to robots, concerns have already emerged regarding the replacement of humans in the workplace. This concern might also become manifest in the case of industrial robots, which will be specialized in carrying out tasks quickly and precisely.

However, this concern is less acute in the case of humanoid robots that are designed to interact with humans. Here, programmers need to be able to intervene regularly and a teacher or caregiver will have to remain present.

The penetration of digital into our real world will certainly generate high expectations. However, it is important to recognize that it might also accentuate social gaps within and between nations, and increase economic imbalances.

Before investing resources and diving into the digital version of a physical world, it's important that businesses and organizations explore and visualize the value-adding experiences that industrial metaverse solutions could deliver. Understanding the options and concentrating on appropriate use cases – such as in key stages in an operational supply chain – is essential, as is working with metaverse partners and consultants to ensure focus and pertinence.

07 CONCLUSION:
CONVERGENCE BETWEEN VIRTUAL AND REAL

New technologies are already creating incredible opportunities today. Robotics, automation, and computer vision are increasingly valuable. As computers become faster and vast amounts of behavioral data is collected, AI can tailor services relevant to the real world. This is a good example of the impact of the virtual on the real.

Digital–real continuity, we believe, is most likely the best path to follow. This cannot be done without first defining a holistic vision of the contributions that the virtual can make in the real world, including new types of collaboration, accepting the associated social and environmental impacts, and embracing the emerging technologies that form the backbone of the industrial metaverse. One of the keys to success will be to build a deep digital culture in the real world, and to address these aspects through all channels of education.

The metaverse in the future will present us all with new opportunities for human fulfillment, ability, and connection, allowing us not only to immerse ourselves in new forms of entertainment, but also to transcend the frontiers of human experience, collaboration, and performance.

1 https://en.wikipedia.org/wiki/Snow_Crash

2 Carnot Cognition Institute; www.instituts-carnot.eu/en/carnot-institute/cognition

3 Definition provided by the Digital Twin Consortium: A Digital Twin is a virtual representation of real-world entities and processes, synchronized at a specified frequency and fidelity.

4 Xvision – Surgery by Augmedics: https://augmedics.com

5 Mind Health Published on December 07, 2021 - Updated on May 13, 2022

APPENDIX A
TECHNOLOGICAL CATALYSTS TO ENABLE THE INDUSTRIAL METAVERSE

Processing

- Microelectronics: Advances in CPU/GPU performance, promising research in quantum- and nanocomputing
- Software efficiency: Algorithmic improvements (e.g., AI / TensorFlow), open-source libraries
- Accessibility and commoditization: Cloud computing services for affordable, scalable, and asset-lite development and deployment

Networking

- Lower latency / higher bandwidth: 5G, 6G, private network transit, satellites (e.g., Starlink)
- Concurrency infrastructure to allow billions in shared live environments
- Decentralized infrastructure: Edge computing, blockchain, …

Devices

- “Post-mobile” platforms: AR, VR, neural-lace, and biochemical innovation for direct human-machine connectivity
- Cross-platform use: Flexible, native software spanning devices and operating systems
- Sensory immersion: Haptics and audiovisual innovation
- Ubiquitous endpoints: Connected and smart devices, IoT

Consumers

- Exposure to virtual worlds, identities, and assets perceived as natural to integrate into the real world
- New generation of “makers”: Sophisticated no-code, user-generated content creation taps into creative energy of billions
- Receptivity for crossover content: Intellectual property no longer siloed inside media categories but permeating them.

Jacques Bacry

EVP, Digital Continuity Group Offer Leader

Jacques is Digital Continuity Group Offer Leader, with an objective to define and execute the strategy in this dynamic domain including PLM and Digital twin. His work is focused on unleashing the promise of end-to-end digital continuity across the entire product lifecycle, by seamlessly integrating ideation, engineering, manufacturing, and aftersales into one unified digital collaboration. He is a champion of PLM as an enabler for Industry 4.0 because it integrates the development of products, production, and services.

Prior to Capgemini, Jacques had a long career at Dassault Systèmes (DS). A graduate of computer science, specializing in AI, he started at DS in R&D, developing their infrastructure, and modelling for which he invented the features modeler of CATIA. Acting as chief Architect and VP R&D, he contributed to large PLM project implementations for a number of leading engineering / manufacturing companies in automotive and aerospace, across the world. He was subsequently responsible for Dassault Systèmes’ EMEA Aerospace & Defense services and consulting organization, and a key influencer of the PLM architecture for the Airbus A350 aircraft program. He was CEO of the Keonys spin off, developing a strategy of innovative solutions, using new technologies for manufacturing.

Alexandre Embry

Head of Capgemini’s Metaverse-Lab & CTIO Immersive Technologies

Alexandre is the founder and head of the Capgemini’s Metaverse-Lab, which helps clients shape and execute their metaverse strategies on various horizons, while contributing to build the future Metaverse and Web3 involving key partners.

A member of the Capgemini Technology, Innovation and Ventures Council, he leads the Immersive Technologies domain, looking at trends analysis and developing the deployment strategy at Group level. He specializes in exploring and advising organizations on emerging tech trends and their transformative powers.

He is passionate about enhancing the user experience and how Metaverse, Web3, NFT and blockchain technologies, and AR/VR/MR can advance brands and companies, with enhanced customer and employee experiences.

CAPGEMINI'S METAVERSE-LAB AND INTELLIGENT INDUSTRY

Capgemini's Metaverse-Lab and Intelligent Industry

Capgemini believes that the metaverse will offer opportunities for a more connected and emotional experience for consumers, for reinventing the employee experience,and collaboration, and for optimizing R&D, engineering, manufacturing, operations and supply chains, using the next generation of interconnected and immersive digital twins and other emerging critically-enabling technologies.

To help our clients explore the possibilities of these emerging technologies, Capgemini set up its Metaverse-Lab, a coordinating hub for research and solutions, designed to capture the business value of immersive experiences and the metaverse.

Together with our Intelligent Industry teams, we combine our CX, EX, engineering, technology and consulting talents to develop bespoke Industrial Metaverse solutions from research through to implementation and at-scale delivery.

Our Services

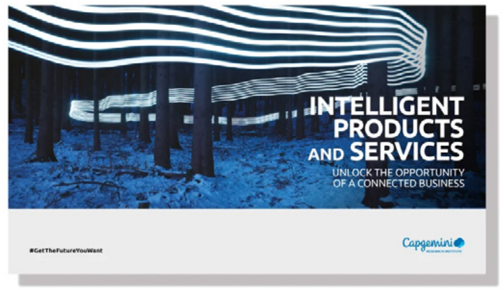
- Metaverse roadmap and strategy development
- Immersive Customer Experience and Immersive Employee Experience solutions
- Industrial Metaverse; combining virtual and real-world assets to create new ways of engineering, manufacturing and operations using metaverse capabilities, including next- gen digital twins
- Intelligent Industry; involving multi-physics simulation, remote operations, digitalization of products and processes, through to autonomous vehicles and connected products
- Technology infrastructure strategy and implementation.

For more information, please visit

www.capgemini.com/metaverse and
www.capgemini.com/services/intelligent-industry

FURTHER REPORTS FROM THE CAPGEMINI RESEARCH INSTITUTE

Total Immersion How immersive experiences and the metaverse benefit customer experience and operations



Intelligent products and services: Unlock the opportunity of a connected business

Digital twins: Adding intelligence to the real world

Conversations for Tomorrow #3: Intelligent industry

Accelerating the 5G Industrial Revolution: State of 5G and edge in industrial operations

Technovision: Being like Water – Trends for CIOs and Tech Practitioners

About Capgemini

Capgemini is a global leader in partnering with companies to transform and manage their business by harnessing the power of technology. The Group is guided everyday by its purpose of unleashing human energy through technology for an inclusive and sustainable future. It is a responsible and diverse organization of 350,000 team members in more than 50 countries. With its strong 55-year heritage and deep industry expertise, Capgemini is trusted by its clients to address the entire breadth of their business needs, from strategy and design to operations, fuelled by the fast evolving and innovative world of cloud, data, AI, connectivity, software, digital engineering and platforms. The Group reported in 2021 global revenues of €18 billion.

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