09 / 2022

REPORT

BLUE SHIFT

BY ARTHUR D. LITTLE

*Synthetic world, real economy

The Metaverse, beyond fantasy

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“We are not on our screens; we are playing hide-and-seek with our friends in Roblox.

— Maya and Iseline, 12 years old, March 2020, first lockdown

The Metaverse, beyond fantasy

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Preface

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1 Synthetic world, real economy

CONTENT

CONTENT
CONTENT
CONTENT

Executive summary

For many, the term “Metaverse” first entered their consciousness when Facebook changed its name to Meta in later 2021. At the time, many people assumed it was merely a passing trend, focused on gamers and younger audiences, with little or no relevance to them or their businesses. However, key players and consultancies have since been falling over themselves to declare its huge potential, outdoing each other with the scale of their market forecasts. In this report we have sought to provide a realistic picture for businesses, focusing in particular on the technologies that are necessary to realize the Metaverse.

It is important to recognize that the Metaverse is not a new concept. The reason it is high on the agenda today is that we are seeing a rapid acceleration of development activity and usage adoption. This acceleration is driven by the convergence of three industries: gaming; collaboration and productivity tools; and social media and networks. The acceleration is also fueled by the confluence of key trends in user behaviors, software, and hardware development.

Businesses should not underestimate the importance and potential of the Metaverse. Put simply, it promises to be the future version of the Internet, powered with new properties that will open up new usages and business models — in a similar way to how the smartphone transformed the Web.

Forecasting the size of the market is difficult. If key enabling technologies are included, such as artificial intelligence (AI), Internet of Things (IoT), and blockchain, as well as the required digital infrastructure development, then the market could easily reach several trillion euros by 2030. However, we advise caution, as some of this market represents substitution rather than genuinely new market space. Our more conservative view suggests an incremental market, excluding infrastructure, of perhaps €500 billion by 2030, with a 30%-40% growth. In any case, however you define it, the Metaverse market is enormous and very dynamic.

To help understand the Metaverse and its current development status, we developed a six-layer architectural framework. Using this analysis, we concluded that, in contrast to what many observers are saying, the underlying technology to enable the Metaverse as the complete "future version of the Internet" won't be fully available for around a decade. This is something that businesses need to be aware of.

Instead of a single, unified Metaverse, businesses face today a world of unconnected proto-metaverses.

Instead of a single, unified Metaverse, businesses face today a world of unconnected proto-metaverses. That said, there are still huge opportunities. Despite the remaining technological challenges, businesses need to take steps now to understand the current market and position themselves for the future.

In summary, we believe that among all the trends and factors currently shaping the Metaverse, three of them are especially critical because they combine high potential impact and high uncertainty. These three critical factors are:

1. **Immersivity.** The development of new augmented reality/mixed reality (AR/MR) technologies that effectively overcome current technical obstacles would be a strong accelerator of new usages in the coming years. In the same way that smartphones made the digital economy shift from computers to mobiles, we believe that user-acceptable AR/MR glasses would drive a similar shift from screen to Metaverse.
2. **Interoperability.** Interoperability is essential to provide a true seamless experience to users and to allow them to share resources, irrespective of their access platform. However, due to diverging interests between vendors, users, and other players in the value chain, there is no guarantee that this will be achieved.
3. **Abundance.** In the physical world, scarcity drives the value of assets in a market economy. In the traditional digital economy, since a digital file can be duplicated at no cost, scarcity was reintroduced artificially through systems such as digital rights management. In a virtual world with blockchain and non-fungible tokens (NFTs), a new economic paradigm of "abundance" may appear, implying a more fundamental value shift from physical assets to experience and, perhaps, status. The extent to which this will happen, and its implications for business, are uncertain.

Preface by Primavera De Filippi

Having discovered the Internet at a very young age, I spent most of my childhood exploring the new opportunities of this virtual environment — socializing with people all over the world, traveling through the blue trails of hyperlinks, and making software to do things not previously possible. Similarly, today I am fascinated by the potential of the Metaverse. This new virtual environment in which anything is possible — a place where you can be anyone you want to be, do anything you want to do, and go anywhere you want to go.

I am confident that the Metaverse will eventually become an ineluctable component of our everyday reality — whether that is through virtual reality (VR), augmented reality AR, or extended reality (XR) — and that it will change the way we live, work, and play in ways that we cannot even imagine. As an artist, I am excited about all the new opportunities of artistic production and creative expression that this new medium will engender. In a world where there is no sky, imagination is the only limit that can hold us back.

But what is the Metaverse, exactly? Very few people can give a precise answer to this question, and those who do might possibly change their minds after reading this Report. Indeed, as this Report shows, the Metaverse as we envision it does not exist (yet). All we have are walled gardens — siloed virtual worlds competing with one another in order to become "the" Metaverse. But if the Internet has taught us anything, it's that interoperability is crucial and that open permissionless innovation is key to any flourishing digital ecosystem.

All the commercial opportunities of the Metaverse have attracted the attention of many new businesses, eager to establish themselves in this new virtual landscape. Yet, the Metaverse can only be what we make of it. And as the short history of the Internet has shown, there will always be a battle between those who see the Metaverse as a new opportunity to build an open and participative society, and those who see it as a means to promote their own vested interests and economic profits.

As a legal scholar and digital activist, I am today committed to ensuring that the Metaverse — whatever direction it takes — will become a powerful tool for good that can help us build a better world, one where new communities can emerge and collaboration can strive. I hope this Report will inspire you to push toward the same direction.

Preamble

Over 20 years ago, without knowing it, I was contributing modestly to some of the technological bricks that underlie the Metaverse. I was finishing my studies as a telecom engineer and, in 2001, beginning my internship at the Australian National University (ANU), where I would explore the frontiers of VR, which already fascinated me at the time. A year later, I started my PhD in computational physics, still at the ANU. During a screening of the film *The Matrix*, I had the chance to meet the Australian philosopher David Chalmers, a specialist in the nature of reality and consciousness, who was giving a lecture entitled "*The Matrix* as Metaphysics." Exciting!

Since that time, digital and synthetic worlds have never ceased to fascinate me. They fascinate me as technologies, and also as sources of disruption in terms of uses and business models. They fascinate me also as vectors of societal and anthropological transformation. And finally, they fascinate me as sources of dizzying ethical and philosophical questions.

In fact, some, like the philosopher Nick Bostrom[2] or the entrepreneur Elon Musk,[3] think that the world we live in — what we call reality — is in fact a simulation. In a nutshell, the argument goes like this: (1) if humans don't become extinct and (2) if humans don't decide against running so-called "ancestor simulations" (i.e., simulations aiming at simulating the apparition and evolution of life), then (3) there is a point in time when humanity will reach enough technological maturity to be able to run such simulations. In which case, there will be a lot more simulated worlds than there are real worlds. It follows that the probability that we are not in a simulation today is actually very small.

But back to our "real world." During the first COVID-19 lockdown in March 2020, when my twin daughters were playing hide-and-seek with their friends on *Roblox* — which I thought was just a teen video game — I realized that the vast majority of young people stuck at home because of the pandemic were reproducing uses of the physical world in synthetic worlds, and that this shift from real to synthetic would be anchored for life.

2 Bostrom, Nick. "Are You Living in a Computer Simulation?" *Philosophical Quarterly*, Vol. 53, No. 211, 2003.

3 "Are We in a Simulation? — Elon Musk." YouTube, 17 February 2018.

This awareness, supported by an initial analysis, led me to write an article for *Harvard Business Review France* in early 2021:[4] I felt that the Metaverse was going to become "the place to be." In response to the article, we received many requests from our ecosystem to give conferences or consulting on the topic. So, we decided to investigate the matter even further to help you navigate through the technological fog and make the right strategic decisions today. This study aims to answer three questions:

1. What is the Metaverse?
2. How mature is the Metaverse?
3. What are the business opportunities of the Metaverse?

Before immersing ourselves in the Metaverse, however, I would like to share an anagram I discovered for "Metaverse Flippant" (Creepy Metaverse):

platement pervasif/
flatly pervasive

This may sound a little scary or pessimistic but, as always, anagrams move in mysterious ways. What do you think?

— Albert Meige, PhD

4 Meige, Albert. "Metaverse: A Virtual Universe for a New Real Economy." *Harvard Business Review France*, 5 October 2021.

CHAPTER 1

1. THE METAVERSE: THE FUTURE VERSION OF THE INTERNET

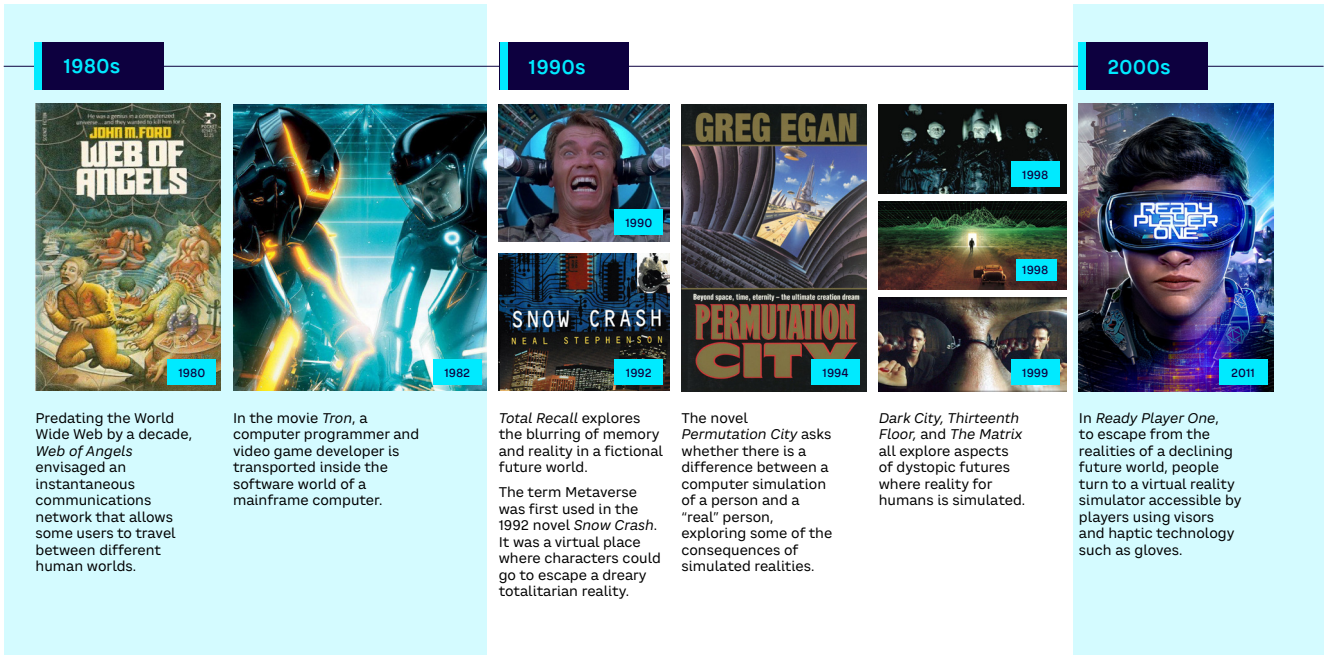
#1 The Metaverse: The future version of the Internet

Despite what some would have you believe, the Metaverse is nothing new. The concept of synthetic or virtual worlds in which people connect has been around for at least 40 years in science fiction and 20 years in real life (see Figure 1). However, what is important is that there has been a strong acceleration of development activity around the concept over the last two or three years. This acceleration is due to two main reasons: convergence between three industries fighting for the same market, and a confluence of trends in users, software, and hardware coming together for the first time. Rather than a new concept, the Metaverse can be best considered as the future version of the Web, powered with new properties that will open up new usages and business models — in a similar way to how the smartphone transformed the Web.

The concept of Metaverse has been around for 40 years

The Metaverse is not a new concept — it actually predates the Web itself. The idea of synthetic[5] or virtual worlds that people visit in order to interact with others dates back over 40 years in science fiction, becoming more mainstream thanks to films such as *Tron* and *Total Recall* in the 1980s and 1990s. The term itself was coined in Neal Stephenson's 1992 novel *Snow Crash*, defining a virtual space where users could go to escape a dreary, totalitarian reality.

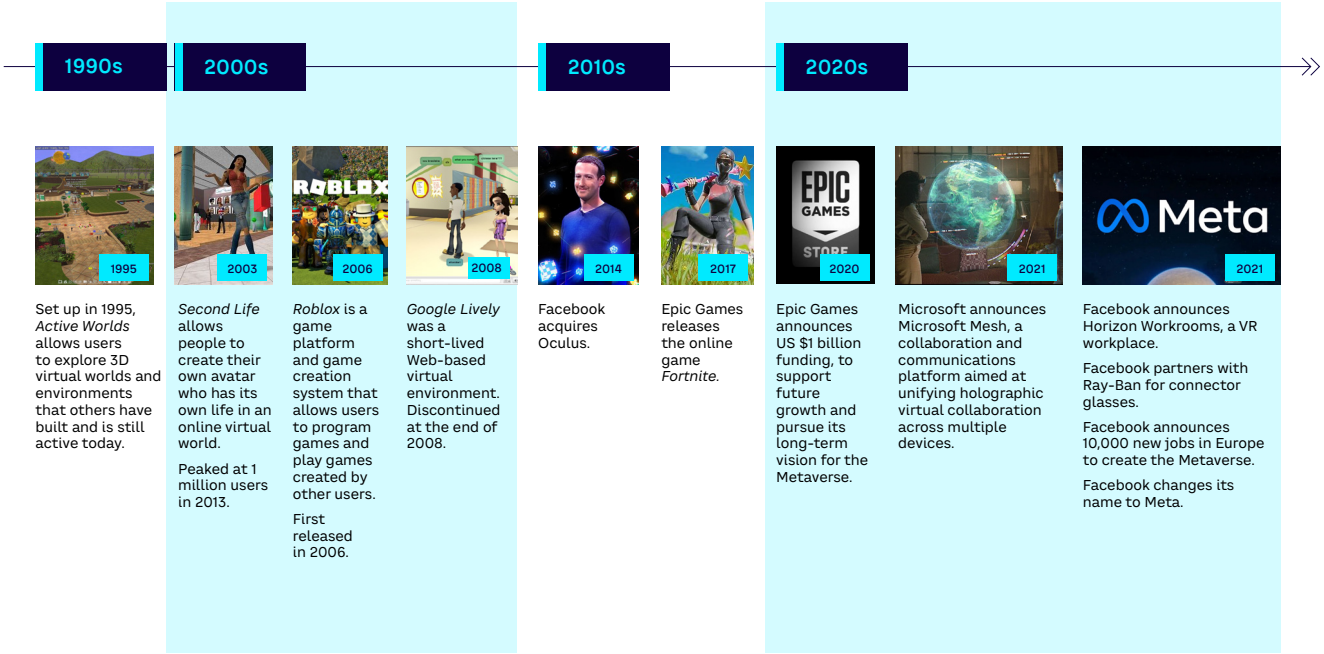
Fig 1 — The concept of Metaverse has been around for 40 years, both in science fiction ...



Source: Arthur D. Little

5 Since "virtual world" is often associated with VR, which is too narrow when it comes to Metaverse, we refer to the "synthetic world" rather than "virtual world," with a slightly broader concept.

Fig 2 — ... and in real life — the pace is accelerating



Source: Arthur D. Little

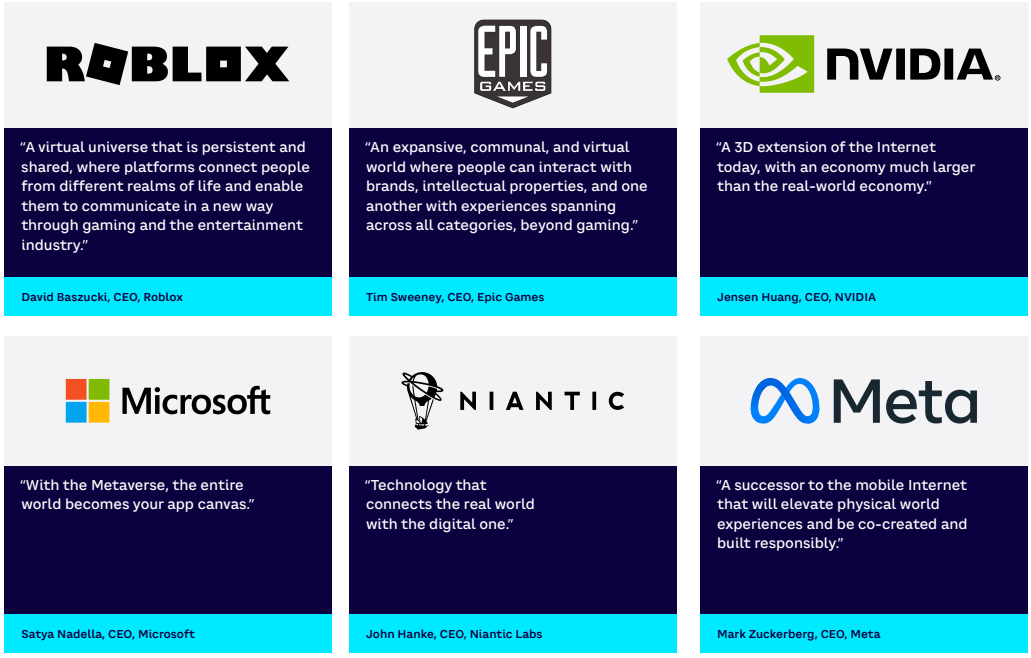
In real life, a Metaverse is not a new concept, either. As illustrated in the timeline in Figure 2, *Active Worlds* was created in 1995 and still exists today, allowing users to own worlds and universes, and develop custom three-dimensional (3D) content. *Second Life* followed in 2003, allowing players to create an avatar who lives another life using voice and text in a virtual world. The game generated substantial hype and high expectations, but usage peaked at less than one million in 2013, and declined gradually until the 2020 pandemic, when there was a large spike in new registrations. More generally, there has been a very strong acceleration of activity over the last two to three years. This acceleration is visible from various points of view, such as the frequency of announcements, investments by venture capitalists, startup creations, and number of users.

Today, the Metaverse is best considered as the future of the Internet at the convergence of three industries

So, what is different about the Metaverse today and what does it mean for businesses? Why are the major players such as Meta (formerly Facebook), Microsoft and NVIDIA, *Roblox*, Epic Games (the creator of *Fortnite*), and Niantic (*Pokémon Go*) all heavily pushing the concept? What we observe today is better viewed as the result of various usage and technological trends that the key players want to accelerate. The term "Metaverse" is a useful wrapper around these trends to facilitate the understanding of what will soon be enabled.

The Metaverse is generally described as a virtual world where people can interact, but as the words of various CEOs in the industry reveal (see Figure 3), leading players have their own slants and definitions of what it means. And while these definitions and visions converge to a large extent, there are a number of differences reflecting the players' backgrounds and objectives.

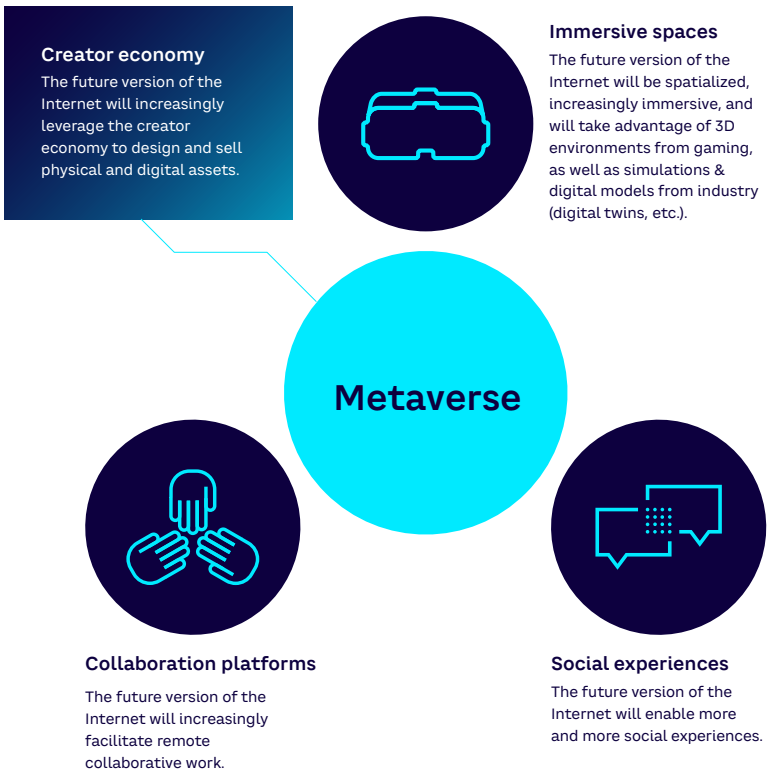
Fig 3 — Leading players all have their own slant on what the Metaverse means



Source: Arthur D. Little

It is therefore important to define precisely what we mean by the term before diving into our analysis. Taking a more holistic approach, we adopt the following definition (see Figure 4):

Fig 4 — Definition of the Metaverse as a future version of the Internet



Source: Arthur D. Little

The Metaverse is the future version of the Internet, blending the frontiers between reality and virtuality, at the convergence of immersive spaces, collaboration platforms, social experiences, and leveraging the creator economy.

- **"Future version of the Internet."** The Metaverse is not a collection of private platforms — it is a new evolution of the Internet, similar to what we saw with the advent of the smartphone.
- **"Blending the frontiers between reality and virtuality."** What we call reality is, and increasingly will be, augmented by one or several layers of data, information, or representations. The real world becomes the screen on top of which digital layers are superimposed — think "augmented reality" to get a sense of what we mean.
- **"At the convergence of immersive spaces, collaboration platforms, social experiences."** Three industries are converging and are fighting for the same market:
  - *The gaming industry* — ignored for decades by the rest of the world, it is now taking center stage due to the amazing technologies it has developed.
  - *Collaboration platforms & tools* — producing the technologies and applications that allow individuals and companies to collaborate, communicate, or work remotely.
  - *Social networks & media* — generating the technologies and applications that allow people to connect, socialize, and share experiences.
- **"Leveraging the creator economy."** We have seen over the last two decades the explosion of the digital creator economy (platforms allowing creators to create and users to consume). The creator economy will take on another dimension in the Metaverse as the same principles will apply to both virtual and physical products.

Now let's look in more detail at the convergence that is enabling the Metaverse:

Gaming industry: More and more nongaming experiences are moving toward the social network & media and collaboration spaces

Over its relatively short life, the gaming industry has undergone a series of transformations (see Figure 5). It has moved from its initial "pay to play" model (with famous games such as *Pac-Man*) to encompass "free to play" models (i.e., freemium/ad-supported games such as *Candy Crush*), and "play to earn" models to enable players to actually earn money through e-sports competition. The most recent transformation of the gaming industry, as it becomes increasingly immersive, finds a growing portion of its revenues coming from nongaming experiences. These experiences include social events, music concerts, and e-commerce.

"Most industries have ignored the game culture and industry. This is changing. It's an industry that's becoming mainstream and relevant to all the others."

Morgan Bouchet, VP/Global Head of XR, spatial computing & Metaverses, ORANGE

Fig 5 — Transformation of the gaming industry toward increasingly nongaming experiences

Source: Arthur D. Little

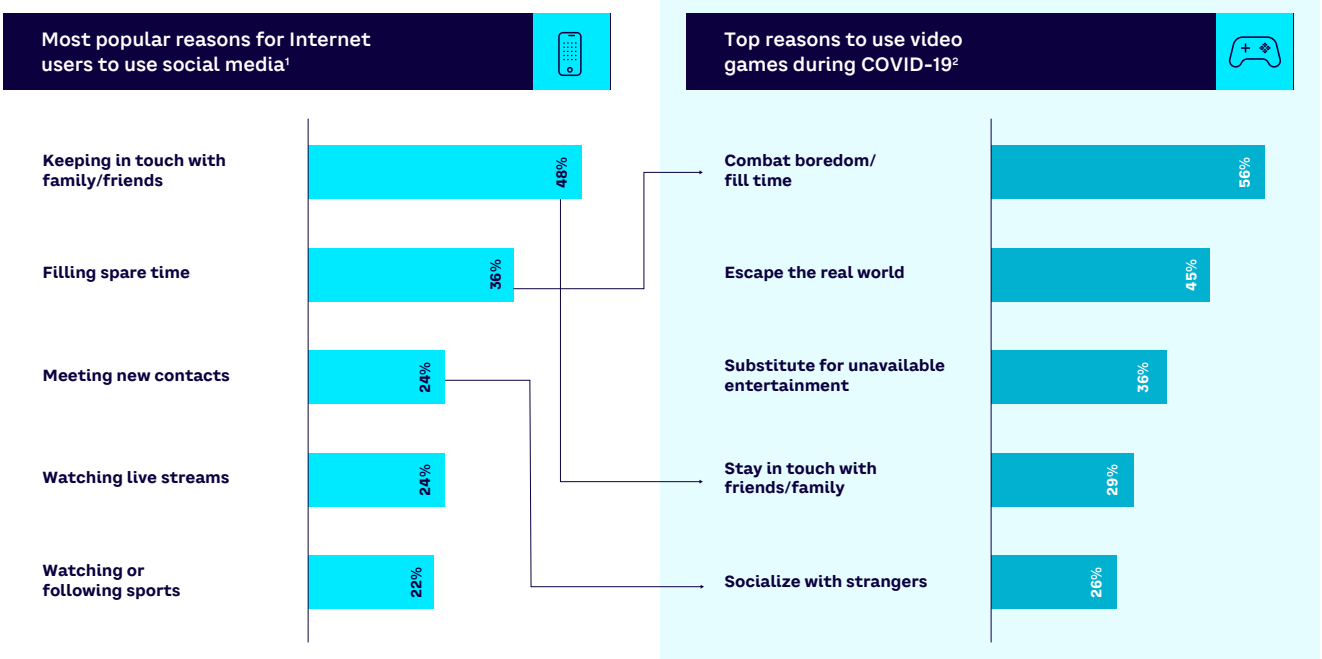
Games are becoming social platforms that players use to interact with their friends and share experiences. For example, 29% of gamers surveyed by Nielsen in April 2020 said they used games to stay in touch with friends and family, and 26% to socialize with strangers (Figure 6).[6] Showing the growing convergence between gaming and social platforms, 250 million people are registered players on *Fortnite* — around the same size as Snapchat's user base. Each of these steps has brought in new audiences and revenues.

Gaming platforms are also increasingly becoming collaborative platforms. Some companies are allowing third parties to develop their own games and virtual assets using their engines.

From the outset, *Roblox* has been a platform where developers and users can build and publish their own games or other virtual assets. Demonstrating the increasing interest in virtual assets, in May 2021 Gucci released a limited edition of in-game virtual bags that sold for US $4,115 on the platform (more than the physical equivalent!), as part of a wider partnership.[7]

Other games and video creation platforms have also opened up their technology. Epic Games' Unreal Engine, which powers *Fortnite*, can be used to create 3D environments, while Unity's real-time content development engine enables the development and creation of films, as well as games and high-quality, immersive architectural and automotive renders.

Fig 6 — Comparison of reasons why Internet users use social media versus video games



Source: Arthur D. Little, Statista, Nielsen, BBC News

Note: Answers do not sum up 100% because respondents could choose different options; (1) Worldwide as of Q3 of 2021. 7 other options between 22% and 35%; (2) Data collected from April 2020 of US residents 18 and older, only residents who played or watched video games; (3) December 2019

6 "The Future of Video Gaming Is Bright — Even as Real Experiences Return." Nielsen Entertainment, 6 January 2021.

7 Dey, Asmita. "Brands Go the Metaverse Way." *Fortune India*, 8 July 2022.

Social network & media industry: From social experience to collaboration platforms

The pandemic turbocharged the adoption of collaboration platforms such as Microsoft Teams or Mural (see 2019-2020 bump in Figure 7). Helped by the shift to hybrid working, these tools are now standard for most organizations. Returning to voice-only telephone conference calls feels as if it would be a step back in time.

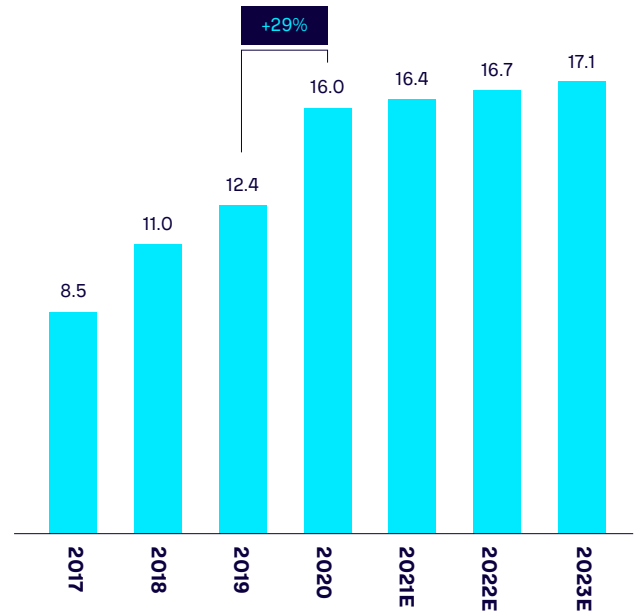
Collaboration platform features such as real-time chat and multi-person video calls enable social interactions. Social media platforms are aggressively moving into the collaboration space themselves to combat this potential threat to their usage (and revenues).

In August 2021, Meta (Facebook) released the open beta of Horizon Workrooms, a collaboration app targeted at teams managing remote work environments, designed to improve their ability to collaborate and connect remotely. The app offers virtual meeting rooms, whiteboards, and video call integration for up to 50 people. It works across both virtual reality and the Web, with users able to bring their desks, computers, and keyboards into VR. Avatars and spatial audio aim to deliver an immersive experience, with gesture-based control rather than a need for controllers or keyboards.

Horizon Workrooms aims to compete directly with players such as Microsoft. Coming from the collaboration platform space, Microsoft has already developed the Mesh collaboration toolset, which aims to provide more immersive virtual meetings by enabling presence and shared experiences from anywhere — on any device — through MR applications.

Fig 7 — The growth of collaboration software

The growth of collaboration software has accelerated rapidly during COVID-19 pandemic[1]



Source: Arthur D. Little, Statista

Note: (1) Collaboration software enables the sharing, processing, and management of files, documents, and other data types among several users or systems. Popular examples include Slack and Microsoft Teams

Three main properties of the Metaverse distinguish it from today's Internet

The Metaverse has three main properties that distinguish it from today's Internet: immersion, interaction, and persistence:

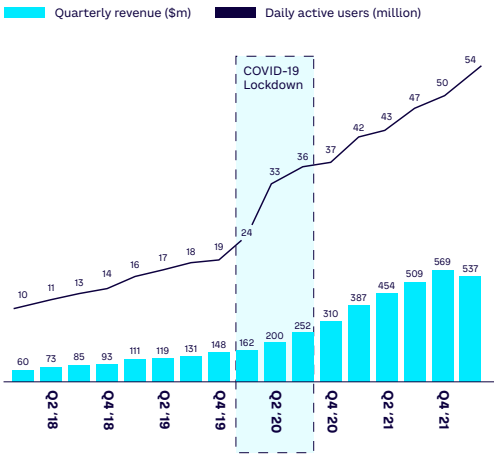
1. **Immersion.** The Internet is becoming spatialized and immersive — the real world is becoming the screen. Users can become totally engrossed and involved in the experience, effectively living in another universe or in an augmented universe, where one or several layers of data, information, or representations are superimposed on the real world. Today's Internet is cognitive, meaning it gives access to knowledge, whereas the Metaverse also provides perspective, and will increasingly involve all our five senses.
2. **Interaction.** Real-time interaction between users (or between users and machines) is becoming increasingly natural. For example, today, a video conference with more than three or four people provides a very degraded experience compared to a real-life meeting. In particular, the timing of how people speak does not occur exactly as it would naturally, which leads to significant cognitive fatigue. Close to real-life, real-time interactions will be at the heart of the Metaverse.
3. **Persistence.** The synthetic world, objects, and people will continue to exist and develop internally even when users don't interact with them. It may even extend to the real world, much like in today's pervasive games.

The confluence of recent trends in users, software, and hardware is making the revolution possible for the first time

As we have shown, the concept of the Metaverse has been around for many years. Previous attempts at creating virtual worlds, such as *Second Life*, have faltered. So, what has changed? Essentially, three ingredients are now coming together to provide the building blocks of the future Metaverse: software, hardware, and users. Just like with other digital technology domains in the past, this confluence provides a good indication that we could possibly be at the inflection point in an exponential growth curve.

Users: A very rapid growth of the user base and corresponding revenues

Fig 8 — Revenue generated by Roblox worldwide and daily active users



Source: Arthur D. Little

The user base for synthetic worlds is growing dramatically, and although it is no longer limited to younger people, more than a quarter (26%) of teens say they own a virtual reality headset, according to research from Piper Sandler.[8]

Taking the example of *Roblox*, which was established in 2006 as a video game mainly for teenagers and pre-teenagers, *Roblox* generated revenues of $2 billion in 2021 by selling virtual assets in the game. These numbers are significant, even if small compared to the $300 billion generated by the whole gaming industry. *Roblox's* growth is even more impressive: the number of daily users has increased from 10 million to more than 55 million in the past four years. This growth was accelerated by the COVID lockdown, as can be seen in Figure 8.

Another company that has seen significant growth is Epic Games. Epic released the online game *Fortnite* in 2017, which became something of a cultural phenomenon. The game generated over $5 billion in revenues in 2020, including proceeds from a live performance by Travis Scott that drew an audience of 12 million people.[9] Young people, the consumers of tomorrow, already spend considerable sums of money to dress up their *Fortnite* avatar in a fashionable skin. In April 2020, Epic Games announced that it had completed a $1 billion round of funding, which will allow the company to support future growth and pursue its long-term vision for the Metaverse. Epic announced another $1 billion round of funding in 2022, half of which comprises investments from Sony Group Corporation and KIRKBI, the holding and investment company behind The LEGO Group. Another live *Fortnite* performance in 2021 — the Rift Tour, headlined by Ariana Grande — attracted an audience of nearly 78 million.[10]

Familiarity with virtual worlds undoubtedly accelerated with the pandemic, as locked-down consumers of all ages were forced to switch from physical to virtual interactions and companies found ways to enable their homeworking employees to communicate and collaborate online. Even *Second Life* saw a spike in new registrations in 2020 after years of decline.

8 "Taking Stock with Teens." Piper Sandler, Spring 2022.

9 "Fortnite's Travis Scott Virtual Concert Watched by Millions." BBC News, 24 April 2020.

10 Oyinloye, Tunboson. "Pop Culture Moments That Predicted the Metaverse." Dailycoin, 10 July 2022.

Software: Major platforms are allowing third parties to form new value chains

Previously, we described *Roblox* as a video game for teenagers, although in reality, *Roblox* is a platform, not a video game. On one side of the platform, users (mostly preteens and teens) can access various experiences: play, meet, socialize, listen to music together (through a recent partnership with Deezer), and go to concerts, among other things. On the other side of the platform, third parties, individuals, or companies create and sell experiences such as virtual worlds or games, as well as various digital assets such as skins to customize avatars. *Roblox* is thus a platform similar to Apple's App Store, in that it allows developers to develop applications and users to purchase these applications. It is also like a YouTube of video games, bringing creators and consumers together.

With the infrastructure and the ecosystem that it has built, *Roblox* has become a major player in developing the Metaverse. It has also managed to attract the attention of many brands, including luxury players. For example, Gucci opened its Gucci Garden virtual space on *Roblox* for two weeks at the end of May 2021, and, as previously mentioned, released a limited edition of in-game virtual bags that sold for $4,115 each. Cosmetic brands have also started to offer their own virtual beauty products. At the end of April 2020, for example, L'Oréal allowed Snapchat users to virtually try the products of several of its brands, such as Garnier and Lancôme.

Epic Games is also a platform in the sense that its Unreal Engine technology is used by third parties to develop synthetic worlds, experiences, and games. For example, Epic has worked with NASA on VR simulation for Mars exploration and with LEGO to create a child-friendly Metaverse space. (Further details on these collaborations and use cases can be found in Appendix 1: Experience continuum use cases.)

The bottom line is that despite the fact that *Roblox* and Epic are known for their games, they are in fact infrastructure platforms. By making the development environment and data available, anyone can develop things on these platforms, such as worlds, games, virtual assets, or social experiences in fields as diverse as e-commerce, entertainment, social interaction, and enterprise services.

Hardware: The hardware required to power and access the Metaverse is developing rapidly

Up until now, the required hardware to power and access the Metaverse was not sufficient to enable the three main properties of immersion, interaction, and persistence that we described above.

However, there are signs that accelerating advances in hardware, at both an infrastructure and man-machine interface level, will reduce some of the barriers to wider adoption in the years to come. Major players are entering the market. Meta bought VR headset developer Oculus in 2014 and is now selling its Quest 2 headset from new, dedicated, physical stores.[11] Apple has filed multiple patents over the last 10 years related directly to VR headsets, as well as increasing hiring and acquisitions in this area. On the infrastructure side, faster fiber networks and 5G rollouts will reduce the impact of latency and increase available bandwidth.

Technologies that enable more convenient and effective high-quality AR and immersivity, such as lightweight glasses and headsets that provide easy transition between VR, AR, and the physical world without bulky equipment, will be transformative in terms of adoption.

Looking further into the future, rapid advances are being made in brain-computer interfaces (BCIs). Elon Musk's startup, Neuralink, has already successfully implanted AI microchips in the brains of a pig and monkey, and released a video of the monkey playing the classic video game Pong solely using its brain.[12] Another startup, NextMind, is already offering a noninvasive BCI device that can read brain waves from the visual cortex of the brain to enable direct control of functions in games.

11 Jockims, Trevor Laurence. "Meta Is Opening Its First Store as VR Headsets Inch Closer to Mainstream Reality." CNBC, 8 May 2022.

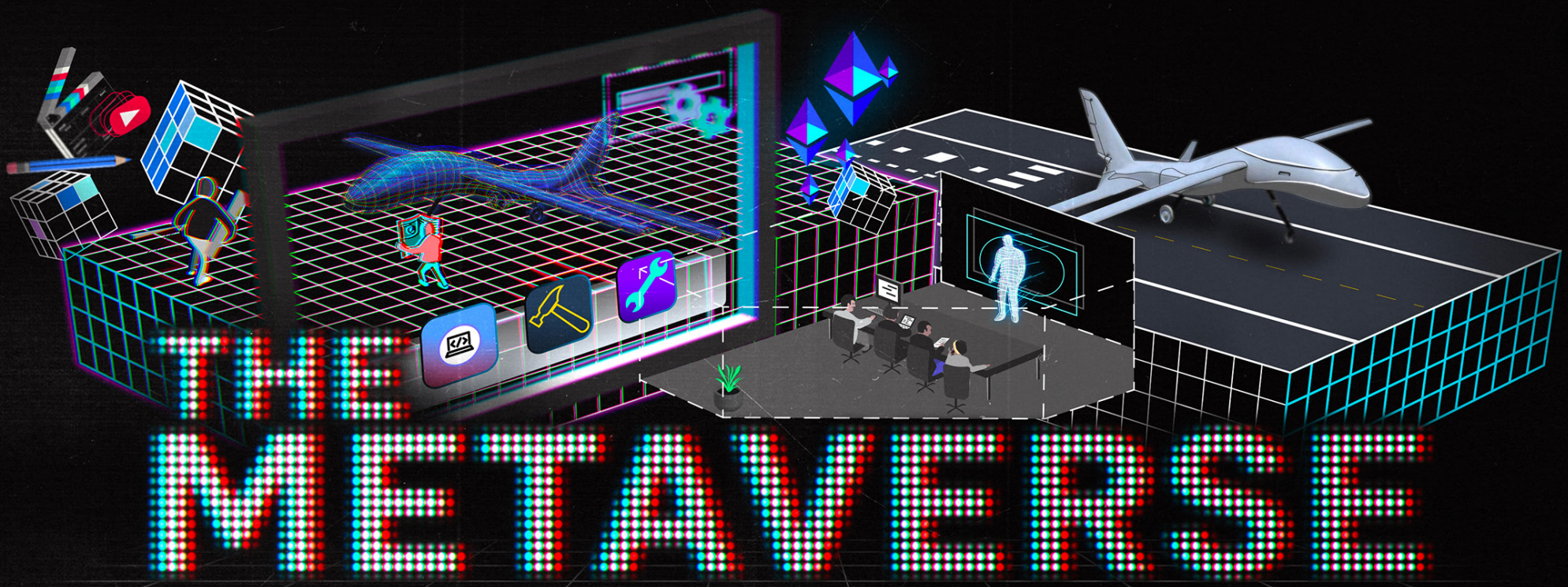
12 "Monkey MindPong." YouTube, 8 April 2021.

INTERLUDE#1 DEFINING THE METAVERSE

Although the Metaverse is still strongly associated with science fiction, it already raises new questions and solutions.

Even if it is difficult to visualize what it will be, we know that the Metaverse is about to play a decisive role for businesses, society, and humans. The mesh of the movie *Tron* inspired me for this illustration, which aims to define the Metaverse. In this isometric view, some people design an airplane (left), and individuals collaborate with avatars from this virtual universe (middle) to produce this airplane in reality (right).

— Samuel Babinet, artist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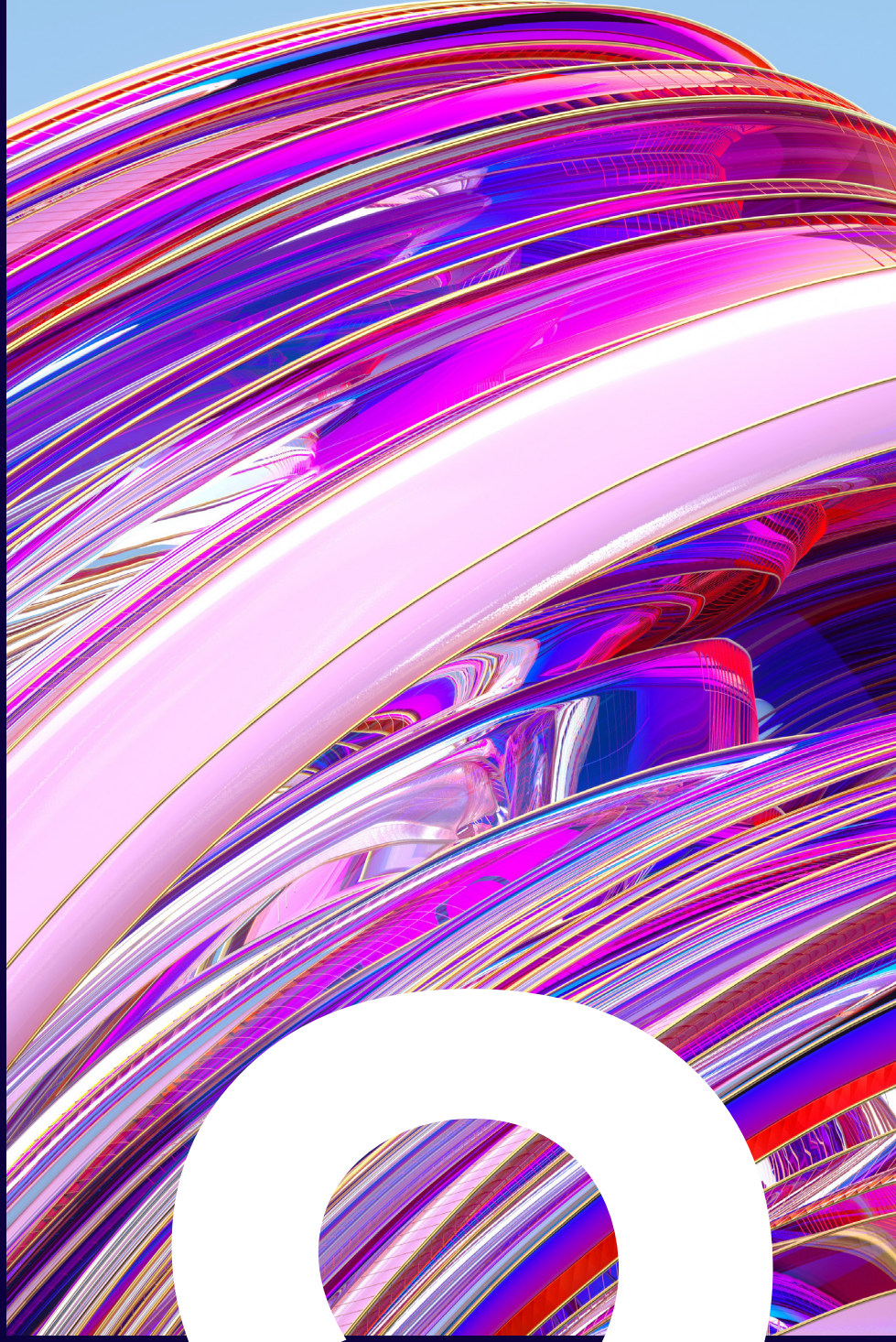
CHAPTER 2



II.THE METAVERSE: NOT FOR ANOTHER DECADE

While some analysts claim that the underlying technology for the Metaverse "already exists,"[13] a more detailed analysis of the technology shows that this is not true. The Metaverse, as envisioned by the main players and as we defined it in the previous chapter, does not yet exist — and we forecast that it won't be fully available for another decade. There are two main reasons for this: first, the various platforms that exist today are not interoperable, which means that it is not yet possible to share experiences, data, information, or other resources across these platforms; and second, even though both hardware and software are getting closer to maturity, closer analysis of the full architecture tells us we are not there yet. We are currently in an era of proto-metaverses.

#2 The Metaverse: Not for another decade

13 "Value Creation in the Metaverse." McKinsey & Company, June 2022.

There is no Metaverse until there is interoperability

Try to remember the Internet in the mid-1990s (see timeline in Figure 9). Many readers may remember the mythical sound of the 56k modem. Or AOL and its famous "You've got mail." Once connected to the Internet via AOL, it was possible to access all sorts of strange things. Unfortunately, this door to the Internet was in fact only a door to a proto-Internet surrounded by impassable walls. It was a walled garden without any walkways to other gardens; an Internet bubble not connected to other bubbles. Users were unable to share resources or communicate with other walled gardens such as CompuServe, Prodigy, and so forth.

Toward the end of the 1990s, it became clear that the Web browser had to allow communication and exchange of information with any other user, regardless of their Internet service provider. Users and usage defeated the walled garden model and the Internet became interoperable — at least to some extent.

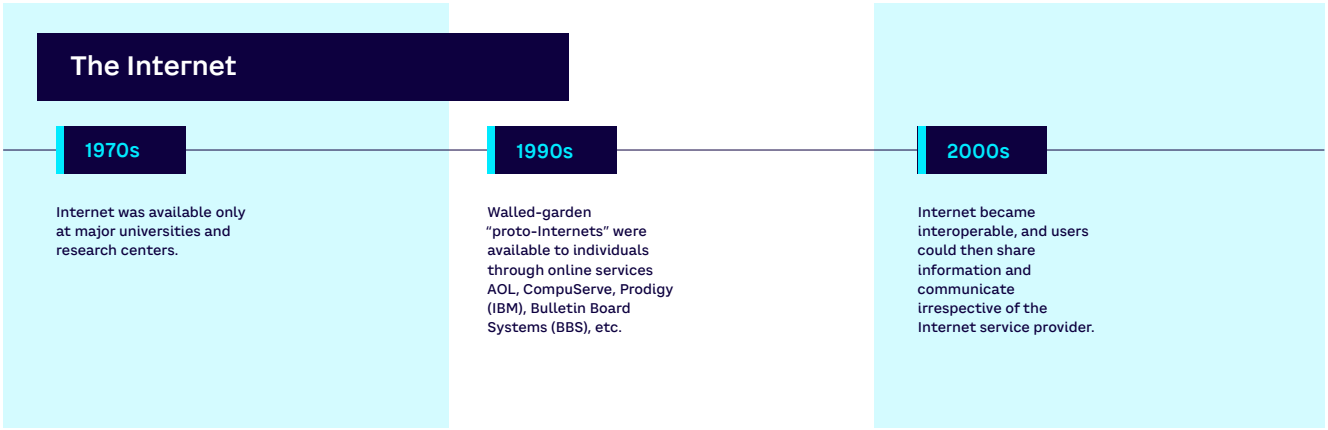
The Metaverse is in the same state as the Internet in the mid-1990s. Today, there is not a Metaverse, but a whole set of proto-metaverses — walled-garden Metaverses. The majority of companies aspiring to develop the Metaverse — such as *Roblox*, Epic Games, NVIDIA, Microsoft, Decentraland, or Meta — are actually developing noninteroperable proprietary platforms. This means that currently it is impossible to exchange virtual assets or even to communicate between one platform and another. Until there is interoperability, there will be no Metaverse.

Interoperability is one of the factors that may have a strong impact on the development of the Metaverse. At the same time, there is a tension between vendors and users. On one hand, vendors invest massively in the development of the Metaverse and want a return on investment. They will therefore tend to push for a noninteroperable Metaverse to keep users within their own environment. On the other hand, users and brands will maximize value by having an interoperable Metaverse. At this point, as no one knows yet whether or not interoperability will occur; interoperability is a key uncertainty.

"People frequently conflate one domain of interoperability with another, and that adds confusion to how people think about the challenges and opportunities."

Jon Radoff, CEO, Beamable

Fig 9 — Development of Internet operability



Source: Arthur D. Little

A detailed analysis of the full Metaverse architecture shows the path to maturity

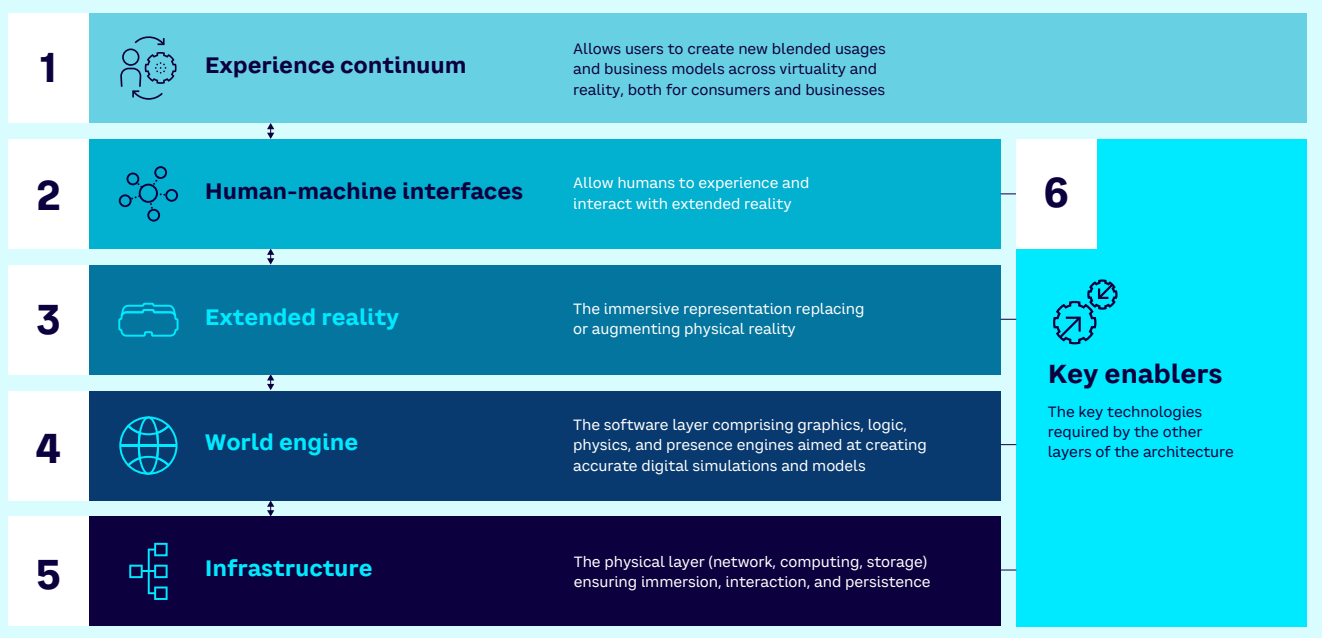
Some of the technologies behind the Metaverse, as defined in the previous section, are not particularly new. However, since the Facebook (Meta) announcement in September 2021, many people have had an uneasy feeling: either the Metaverse is indeed something completely new, or else it's simply a repackaging of a set of technologies that have been under development for several decades.

What is the situation, exactly? What are the building bricks that make up the Metaverse? What are the technologies in each of these building bricks? How mature are they and when will they become mature? When can we hope (or fear) to see the "real" advent of the Metaverse?

To begin answering these questions, we developed a framework, which aims to represent the architecture of the Metaverse in six layers (see Figure 10). These layers effectively cover the value chain of the Metaverse, in which the top level corresponds to new user experiences and business models, and the lowest level corresponds to the required hardware and software infrastructure.

This is, of course, a simplified view of reality (if we can talk about "reality" when we talk about the Metaverse!). This simplified view, however, helps us to analyze the complexity that underlies the Metaverse. Below, we dive into each of the layers to understand its nature and the maturity of each of the technological elements that compose it. This helps us to answer the questions: Should I be interested in the Metaverse as part of my business? And what are the opportunities today and in the future? As we will see in the final section of this report, even in this embryonic state, many business opportunities can be seized in all the layers.

Fig 10 — The six architectural layers of the Metaverse to help assess maturity and business opportunities



Source: Arthur D. Little

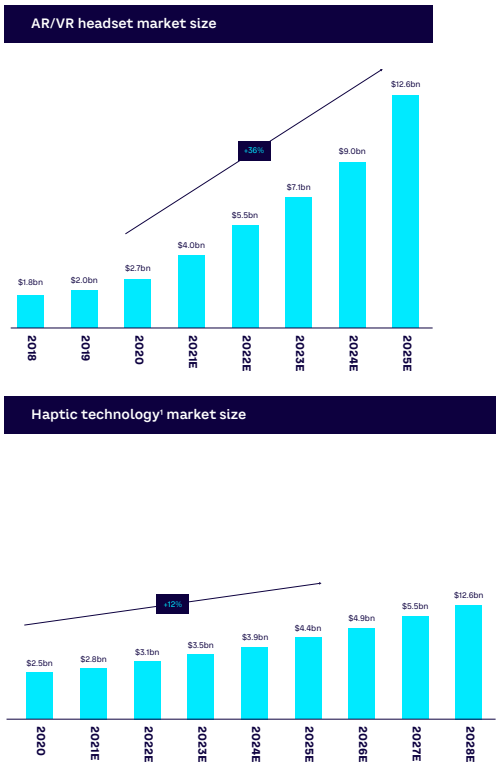
"The Metaverse is the tool to search, find, and capture value in complexity by immersing (space) oneself in it and projecting (time) oneself into it."

Michel Morvan, President and cofounder, Cosmo Tech

Layer 1: Experience continuum — Use cases and business models

Layer 1, which we call "experience continuum," is the layer that brings together all the new use cases, experiences, and business models, existing and future. These new use cases and business models blur the boundaries between reality and virtuality. Like the Internet today, use cases can be segmented into three categories: consumer (socializing, entertaining, playing, etc.), enterprise (meeting, exchanging, collaborating, etc.), and industrial (modeling a production line or distribution network, collaborating around a digital twin, etc.). We will describe Layer 1 in more detail in the next chapter when we consider the opportunities and use cases that exist today.

Fig 11 — Rapid growth in AV/VR headsets and other HMI technologies



Source: Arthur D. Little, Credit Suisse, IDC, Researchandmarkets.com

Layer 2: Human–machine interfaces — The gateway

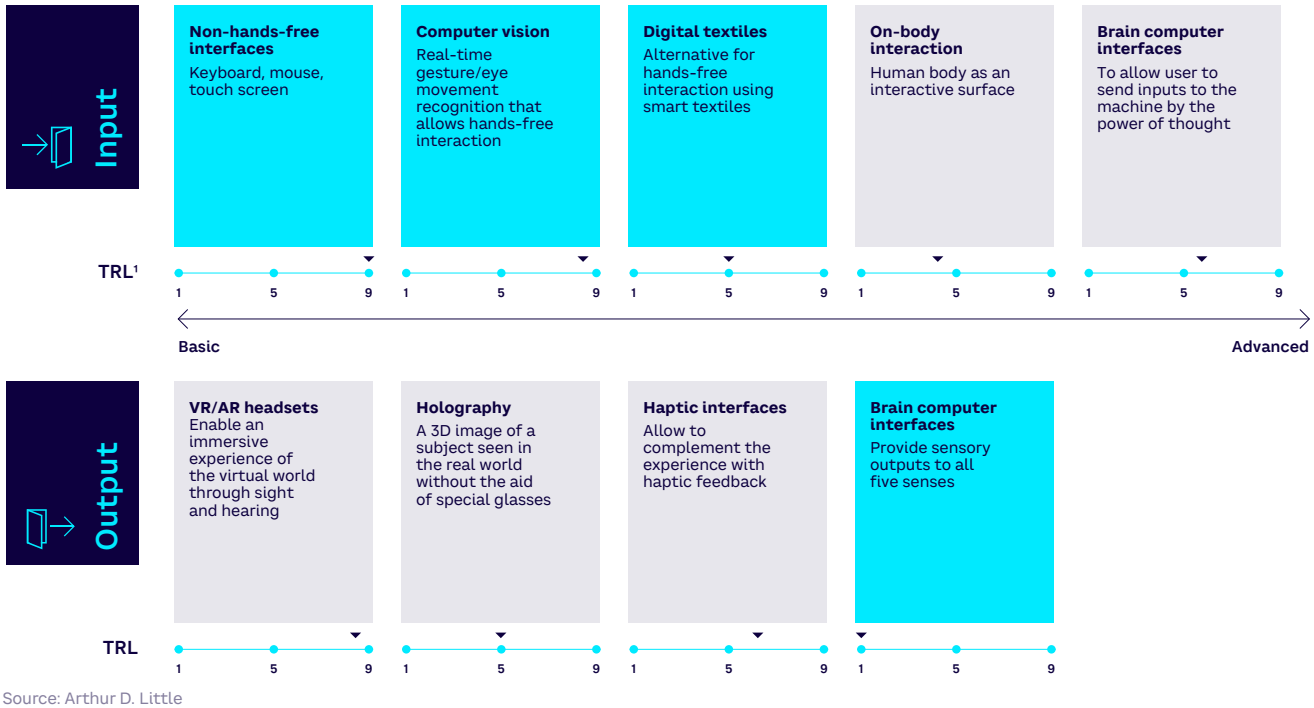
Layer 2, which we call "human-machine interfaces (HMIs)" is, as the name suggests, the layer that allows humans to perceive and interact with Layer 3's "extended reality" (described below). HMIs are the gateway to the Metaverse. They include a mix of hardware and software that allows users to send inputs to the machine and the machine to send outputs to users, thus forming a consistent interaction loop.

The HMI market is forecast to see rapid expansion over the coming years, with over 35% yearly growth in the AR/VR headset sector up to 2025 and a 12% increase in sales of haptic technologies up to 2028 (see Figure 11).

Some of the underlying technologies, such as the keyboard and mouse on the input side, or the screens on the output side, are very mature. In contrast, other technologies, such as brain-computer interfaces, are much less mature. Between the two, there is a whole range of more or less mature HMIs, such as VR and/or AR visors, holography, and haptic interfaces on both the input and output sides (see Figure 12, which shows HMI technologies mapped by technology readiness level [TRL] — see Appendix I for further description).

Overall, we can conclude that the way users will immerse themselves in the Metaverse is a critical uncertainty that will have a major impact on the rate of adoption. The more these technologies advance, the more immersion and interaction with the Metaverse will involve all our five senses. We predict that AR glasses, despite their current immaturity compared to VR headsets, is the interface likely to revolutionize usage and adoption in the coming five years. The real world is becoming the screen.

Fig 12 — Types of human-machine interface and their technology maturity



Source: Arthur D. Little

On-body interaction technology

On-body interaction technology uses the human body as an interactive surface, eliminating the need for a touchscreen or other hardware device. Users can either tap or swipe specific parts of their body to access specific applications or perform location-independent actions anywhere on their body.

It offers the advantage of always-available control, an expanded input space, and additional proprioceptive and tactile cues that support nonvisual use. Companies in this space include Makeability Lab, which has been exploring a suite of sensors mounted on the finger, Soli, and Ultraleap.

Current challenges include being able to demonstrate the accuracy of interactions and overcoming potential embarrassment at performing on-body interactions in public, which could hold back adoption.

Brain–computer interfaces (input type)

BCIs enable users to send inputs to the machine through the power of thought. A BCI system consists of four components: signal acquisition, feature extraction, feature translation, and device output. Two types of BCI exist: invasive and noninvasive.

Prototype input invasive BCIs have already been successfully developed. At Stanford University in May 2021, for example, a microchip implanted in his brain allowed a paralyzed man to communicate by text at speeds that approach the typical smartphone user.[14] Companies and startups developing invasive BCIs include Elon Musk's venture Neuralink.

BCIs may eventually be used routinely to replace or restore useful functions for people severely disabled by neuromuscular disorders or to improve rehabilitation for those with strokes or head trauma. They could also augment natural motor outputs for pilots, surgeons, and other highly skilled professionals.

And although it may sound like science fiction, some noninvasive BCIs are already available commercially, with companies such as NextMind, Emotiv, and Kernel involved in the space.

The future of BCIs depends on progress in three critical areas: development of comfortable, convenient, and stable signal-acquisition hardware; BCI validation and dissemination; and proven BCI reliability and value for many different user populations.

14 Goldman, Bruce. "Software Turns 'Mental Handwriting' into On-Screen Words, Sentences." Stanford Medicine News, 12 May 2021.

VR/AR headsets

The most well-established HMIs, VR/AR headsets are already widely used with video games as well as in other applications, including simulators and trainers. They comprise a stereoscopic head-mounted display (providing separate images for each eye), stereo sound, and head-motion-tracking sensors, which may include devices such as gyroscopes, accelerometers, magnetometers, or structured light systems. Some headsets also have eye-tracking sensors and gaming controllers.

Since they were first launched, VR/AR headsets have improved both technically (in terms of resolution and lightness) and cost. However, they are still not yet widely available to the general public due to key challenges related to comfort and affordability. Other challenges include resolution, field of view, movement tracking, and immersivity capabilities. Players in this space include Apple, HP, Oculus (owned by Meta), Valve Index, and HTC Vive.

The three main performance factors that are considered when evaluating VR headsets are resolution (pixels per degree), field of view (FOV), and refresh rate. Resolution has improved year-on-year to ~30 pixels per degree and is getting closer to the eye-limiting resolution of about ~60, or normal sight. These performance factors are key for future mass adoption. Even if AR headsets/glasses are currently at a lower maturity level, it is likely that AR glasses will be the main interface in the coming three to five years.

Manufacturers have reduced the cost of developing devices, although it seems there is room for improvement. In addition to the three performance factors above, the main challenges are related to comfort and affordability. Wired headsets usually have better graphical power, while wireless glasses currently have lower quality. The final challenge, to provide a "sense of embodiment," is a key research area that focuses on methods to allow the user to see themselves within the virtual scenario without the use of avatars.[15]

Holography

The holography process creates a 3D image of a subject seen in the real world without the aid of special glasses or other intermediate optics. The image can be viewed from any angle, so as the user walks around the display the object will appear to move and shift realistically. Holographic images can be static, such as a picture of a product, or be an animated sequence.

While best known as a method of generating 3D images, holography also has a wide range of other applications. For example, it is already used in data storage (by storing information at high density inside crystals or photopolymers) for applications including art, security, and logistics. And while increasing computing power may enable the creation of digital human models that will render faster and more realistically, this potentially leads to issues around voice cloning and fraudulent impersonation. Leading players include HYPERVSN, MDH Hologram, SeeReal Technologies, and VividQ.

The future of holography lies at the intersection of AI, digital human technology, and voice cloning. Increasing computing power should enable creation of digital human models that will render faster and more realistically. The evolution of holographic technologies is hoped to lead to their increasing availability and portability.

Haptic devices

Haptic devices allow users to touch, feel, and manipulate 3D objects in virtual environments. They are employed for tasks that are usually performed using hands in the real world, such as manual exploration and manipulation of objects. Computer keyboards, mice, and trackballs constitute relatively simple haptic interfaces. Other examples are gloves and exoskeletons that track hand postures and joysticks that can reflect forces back to the user. Companies involved in the area include CyberGlove Systems, Force Dimension, HaptX, and Ultrahaptics.

Key challenges for greater adoption are being able to scale up from laboratory to market readiness, along with overcoming technical challenges such as following or allowing the motion of the user with minimum resistance.

15 Kilteni, Konstantina, Raphaela Groten, and Mel Slater. "The Sense of Embodiment in Virtual Reality." *Presence: Teleoperators and Virtual Environments*, Vol. 21, No. 4, 2012.

Layer 3: Extended reality — The visible face

Layer 3, which we've named "extended reality" (XR), is the immersive representation that augments or replaces reality. It comprises a spectrum ranging from 100% real to 100% virtual. Extended reality combines the world and real objects with one or more layers of computer-generated virtual data, information, or presentation. Thus, XR may be thought of as the visible face of the Metaverse. XR includes AR, MR, augmented virtuality (AV), and VR, reflecting different mixes of real and virtual information along the spectrum (see Figure 13).

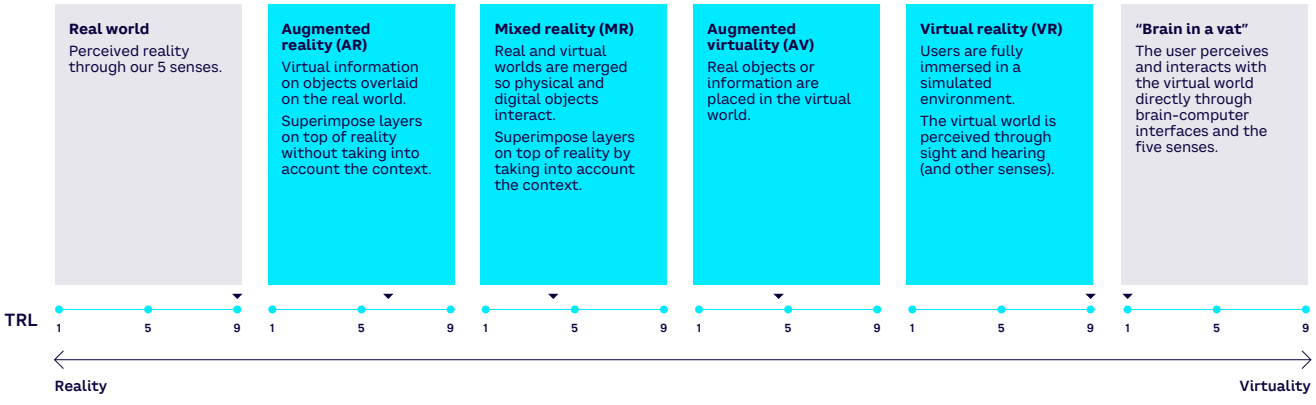
The technologies that comprise XR are at varying degrees of maturity. For example, VR today is much more mature than AR. As these technologies develop, the more they will converge and the more the Metaverse will be synonymous with continuity between the real and the virtual.

Augmented reality

Augmented reality enhances the real-world experience by superimposing on it computer-generated contextual data, information, and virtual experiences. AR software works in conjunction with devices such as tablets, phones, headsets, and more. These integrating devices contain sensors, digital projectors, and the appropriate software that enables these computer-generated objects to be projected into the real world. Once a model has been superimposed in the real world, users can interact with and manipulate it.

AR is commonly used for entertainment purposes (such as Niantic's *Pokémon Go* mobile game), but also increasingly in enterprise and industrial applications such as training, maintenance, construction, healthcare, and retail, where users can access contextual data superimposed on real-world objects. Although relatively mature, the technology faces challenges related to costs, accessibility, and education as well as potential privacy concerns since it depends on the ability of the device to record and analyze the environment in real time. Major players active in the AR space include Help Lightning, Niantic, Plattar, SightCall, and Streem.

Fig 13 — The spectrum of real and virtual mixes that constitutes XR



Source: Arthur D. Little

Mixed reality

Mixed reality refers to the intertwining of real and virtual worlds. In contrast to AR, in MR, digital objects are not just overlayed on but are anchored to the physical world, meaning they can be interacted with. Green screen and video chat backgrounds are nonimmersive 2D examples of MR. However, some definitions of MR include both AR and AV.

Organizations across many industries have already begun developing MR applications to make certain processes safer, more efficient, or more collaborative. It is already used in sectors such as manufacturing, healthcare, and architecture for training and development, remote collaboration, and turning concepts into pre-production models. MR headsets like the Microsoft HoloLens allow for efficient sharing of information between doctors. Other players include the US Air Force Research Laboratory and Skywell Software.

Augmented virtuality

Augmented virtuality refers to predominantly virtual spaces into which physical elements (such as objects or people) are dynamically integrated. The objects or people can then interact with the virtual world in real time with the use of techniques such as streaming video from physical spaces (such as webcams) or the 3D digitalization of physical objects.

The use of real-world sensor information, such as gyroscopes, to control a virtual environment is an additional form of AV, in which external inputs provide context for the virtual view. Current use cases include gaming and design applications. For example, using a touchscreen, people can design their own kitchen or bathroom by selecting and moving virtual appliances and fixtures around a digitally created room. Blacksburg Tactical Research Center is a leading player in the AV space.

Virtual reality

Virtual reality refers to an entirely simulated experience that can be similar to, or completely different from, the real world. It uses VR headsets or multi-projected environments to generate realistic images, sounds, and other sensations that simulate a user's physical presence in a virtual environment, allowing for movement and interaction.

VR headsets commonly comprise a head-mounted display with a small screen in front of the eyes, but can also be created through specially designed rooms with multiple large screens. While seeing increasing adoption, there are health and safety concerns around VR's prolonged use, especially by children. Leading companies active in the market include Autodesk, France Immersive Learning, Google, SteamVR, and Threekit.

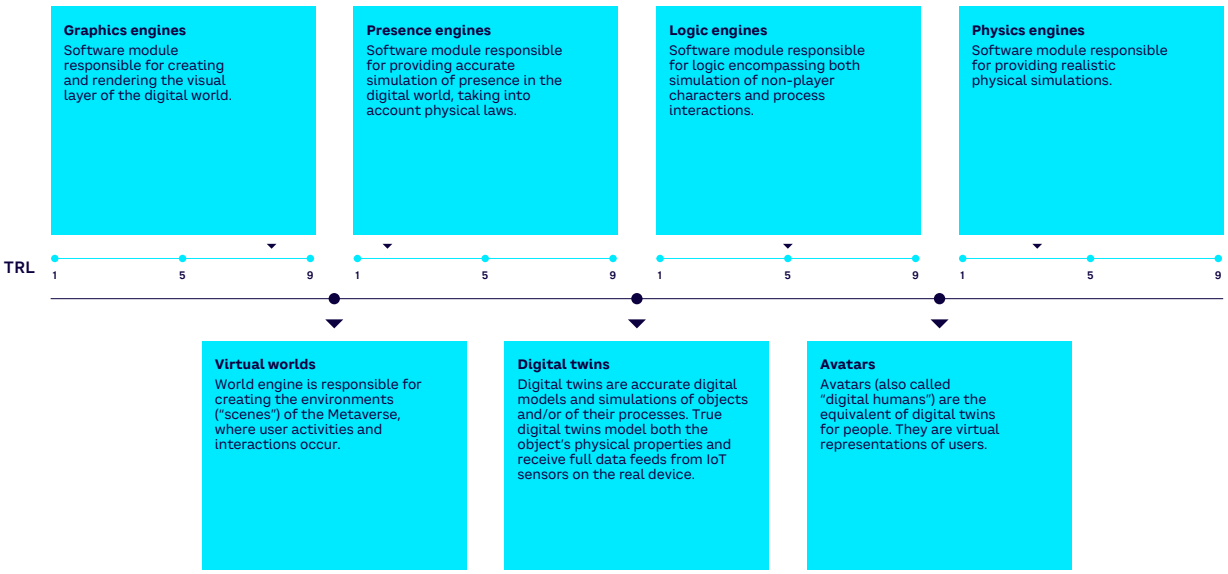
Overall, it is important to realize that the Metaverse is not all about interactions in a completely virtual world, which is typically the type of experience that many observers focus on and is often the source of skepticism about its likely level of adoption. As XR technologies mature, the Metaverse will offer seamless continuity between the real and virtual worlds.

Layer 4: World engine — The engine

Layer 4, which we call "world engine," corresponds to all the software allowing the development of virtual worlds, virtual objects, and their processes (digital twins) and virtual people (avatars or digital humans). The world engine (see Figure 14) will likely evolve from today's game engines, such as Unity or Unreal, combined with physics engines such as that of Dassault Systèmes. They will thus have similar core architectures. The world engine is composed of four essential building blocks: graphics engine, presence engine, logic engine, and physics engine.

World engine technology development is still at a relatively early stage. It will take several years before the different engines within it combine to enable more complete realism. While there are already solutions for these components, there is still much development necessary and more convergence is expected between gaming and digital twin engines. Players include Dassault Systèmes, Epic Games, Nuke, NVIDIA, and Unity.

Fig 14 — The main building blocks of the world engine



Source: Arthur D. Little

Graphics engine

The graphics engine is responsible for creating and rendering the visual layer of the virtual world. The key component of the Metaverse — the integrated world combining the physical and virtual world — will be based on graphical techniques, including the 3D construction of world scenes, digital items, non-player characters (NPCs), and player characters (avatars). Computer graphics engines are likely one of the most advanced and mature components currently available for Metaverse projects, as near-photorealistic 3D computer graphics can be generated in real time for games, albeit using state-of-the-art hardware that is not easily accessible to the average user and at a relatively high energy consumption (powerful desktop graphics processing units [GPUs] can consume over 500 watts of energy at peak load), limiting their mobility. Leaders in this space include Unity, Unreal Engine, CRYENGINE, 3ds Max, and Amazon Lumberyard.

Presence engine

The presence engine enables users to feel present in any location as though they were there physically. For example, a first state of presence technology can now be found in 4DX cinemas, which incorporate on-screen visuals with synchronized motion seats and environmental effects such as water, wind, fog, scent, snow, and more to enhance the on-screen action. Presence engines are currently in the early prototype phase, though significant work is happening in the field, especially in the areas of haptic feedback propelled by both gaming and training simulators.

Logic engine

The logic engine is responsible for managing interactions between various virtual entities. It encompasses both simulation of NPCs and process interactions. Logic engines currently are driven mainly by game development, as the most successful Metaverse-like environments currently in existence are computer games. In most cases, logic engines allow the attachment of additional "components" or "behaviors" to a 2D or 3D model. At this time, logic engine components are relatively simplistic and focus on highly specific behaviors such as the ability for a digital model to emit light, move, or play sounds. Today's logic engines are highly deterministic and control the bits and pieces that attempt to give the digital model verisimilitude. In future, logic engines will likely have more advanced and free-form components based on AI and machine learning (ML). For example, AI components will synthesize speech and responses rather than relying on pre-recorded text. Leaders are much the same as those in the graphics engine space, and include Unity, Unreal Engine, CRYENGINE, 3ds Max, and Amazon Lumberyard.

Physics engine

The physics engine allows the creation of realistic multi-physics modeling and simulations (e.g., concerning fluid dynamics or gravity). It describes the physical behavior of the materials supporting actions like heat, bending, or chemical reactions. The physics engine is responsible for providing an approximate simulation of physical systems to enable the verisimilitude of the virtual world to help with immersion, and will handle tasks such as collision detection and body dynamics.

Physics engines tend to be broadly categorized in high-precision and real time, although the distinction is already becoming somewhat blurred due to better algorithms and the increase of computational power. High-precision engines are typically used to calculate very precise physics, such as fluid dynamics. Real-time engines, on the other hand, tend to have simplified algorithms and reduced accuracy but allow for real-time computation. Real-time engines are a key requirement to maintain verisimilitude as, for example, too slow computation of collision detection will result in objects passing through each other and potentially being repelled with abnormal correction force when the computation catches up.

Players in the scientific space are developing numerous physics engines for a wide variety of purposes, with each tending to focus on a particular high-precision physics challenge. From a Metaverse perspective, where at least the initial versions will likely be collaborative spaces where physics will be an approximation of reality sufficient to maintain realism, the usual game creation engines are key players in the space, including Unity, Unreal, CRYENGINE, Amazon Lumberyard, 3ds Max, and Dassault Systèmes.

Virtual worlds

Looking now at the output side of the world engine, the user in a virtual world accesses a computer-simulated world that presents perceptual stimuli to them, allowing users to manipulate elements of the modeled world and thus experience a degree of presence. Communication between users can range from text, graphical icons, visual gesture, sound, and, rarely, forms using touch, voice command, and balance senses.

While virtual worlds have made impressive steps forward in terms of immersivity, they currently require robust hardware and fast connectivity to operate effectively. Notable players in the space include IMVU, Kaneva, and *Second Life*.

Digital twins

Digital twins create a virtual copy of a physical object, such as a machine. Sensors produce data about different aspects of the physical object's performance, such as energy output, temperature, weather conditions, and more. This data is then relayed to a processing system and applied to the digital copy.

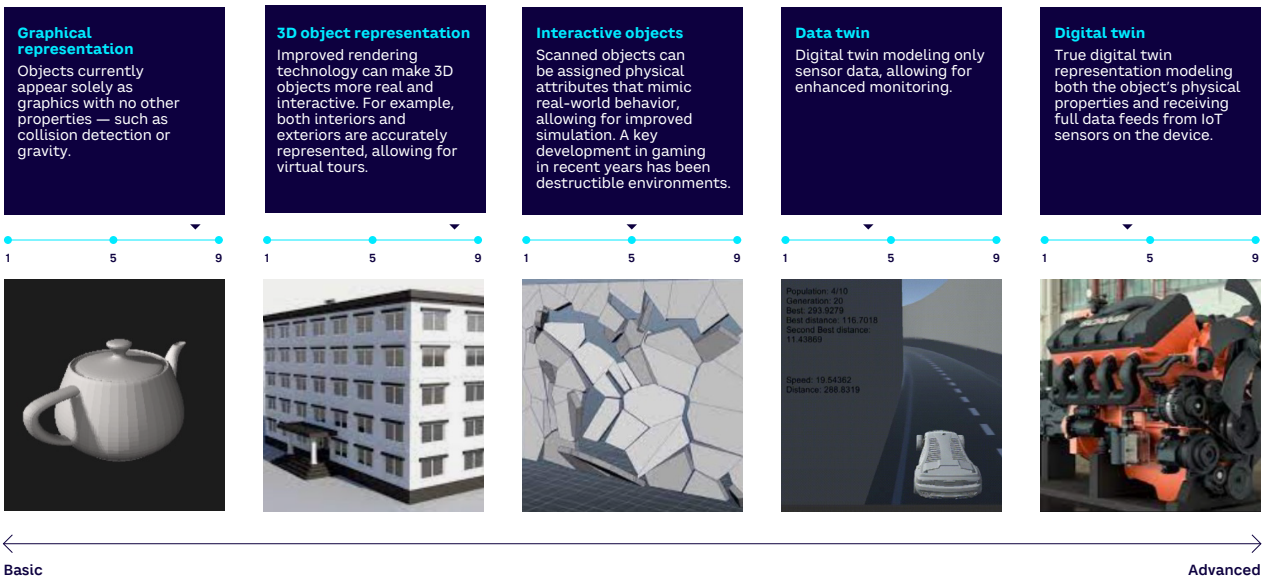
This virtual model can be used to run simulations, study performance issues, and generate possible improvements — all with the goal of generating valuable insights that can then be applied back to the original physical object.

While digital twins are increasingly being adopted, there is still significant development needed to fully model all properties of a complex object in the digital domain. Companies involved in the market include Ansys, Cosmo Tech, Dassault Systèmes, IBM, and Siemens.

"Virtual objects are more expensive than real ones because they give access to knowledge."

Pascal Daloz, COO, Dassault Systèmes

Fig 15 — Technological maturity of key digital twin developments, from basic to advanced



Source: Arthur D. Little

Avatars

Avatars are developing toward becoming photorealistic 3D renditions of human beings in the virtual world that are nearly indistinguishable from the real thing. They rely on a complex combination of technologies for their functionality. These include AI to process input and provide feedback, natural language processing to understand voice commands, advanced 3D modeling to replicate expressions of human emotion with precision, and natural language generation so that the digital human can respond via voice.

While they already have business applications, such as acting as the face of customer experience chatbots, the introduction of truly realistic physical and mental simulations is still a long way in the future. Current challenges include, for example, achieving real-time response without latency and enabling avatar autonomy. There are also ethical issues associated with an avatar, which both is and isn't the same thing as the real person it is representing. Companies active in the market include Banuba, Emova, Imverse, Soul Machines, Uneeq, and Unity.

Avatars can be projected into the Metaverse in one of two ways — either through real-time 3D video (which is bandwidth intensive) or through photorealistic models that only transfer changes (such as body movements) to the Metaverse, reducing the network capacity required. For example, Emova is working to deliver photorealistic 3D models that capture movement and also control lighting effects to enhance realism. The first target market is online fashion, enabling consumer avatars to digitally try on clothes or jewelry to get a realistic impression of how an item will look when worn. The aim is to reduce return rates (a third of clothes purchased online currently are returned), thus increasing efficiency and lowering environmental impacts.

While certain areas, such as photorealism and movement capture are now mature, techniques such as emotion capture and avatar autonomy are not. This limits the usefulness of avatars for applications such as online meetings in the Metaverse, which are also currently held back by a lack of sufficient bandwidth.

Layer 5: Infrastructure — The piping

Layer 5, which we have named "infrastructure," corresponds, as its name suggests, to the physical infrastructure — network, computing power, and storage — that enables the real-time collection and processing of data, communications, representations, and reactions (see Figure 16).

Infrastructure is in a sense the "piping" that enables achievement of the three essential properties of the Metaverse described earlier: immersion, interaction, and persistence.

Infrastructure is probably the least interesting layer for the nonexpert, so it is not often discussed in the media. However, infrastructure is critically important to the development of the Metaverse. The infrastructure we have defined does not yet exist, and probably won't be realized for around a decade due to the technical challenges involved.

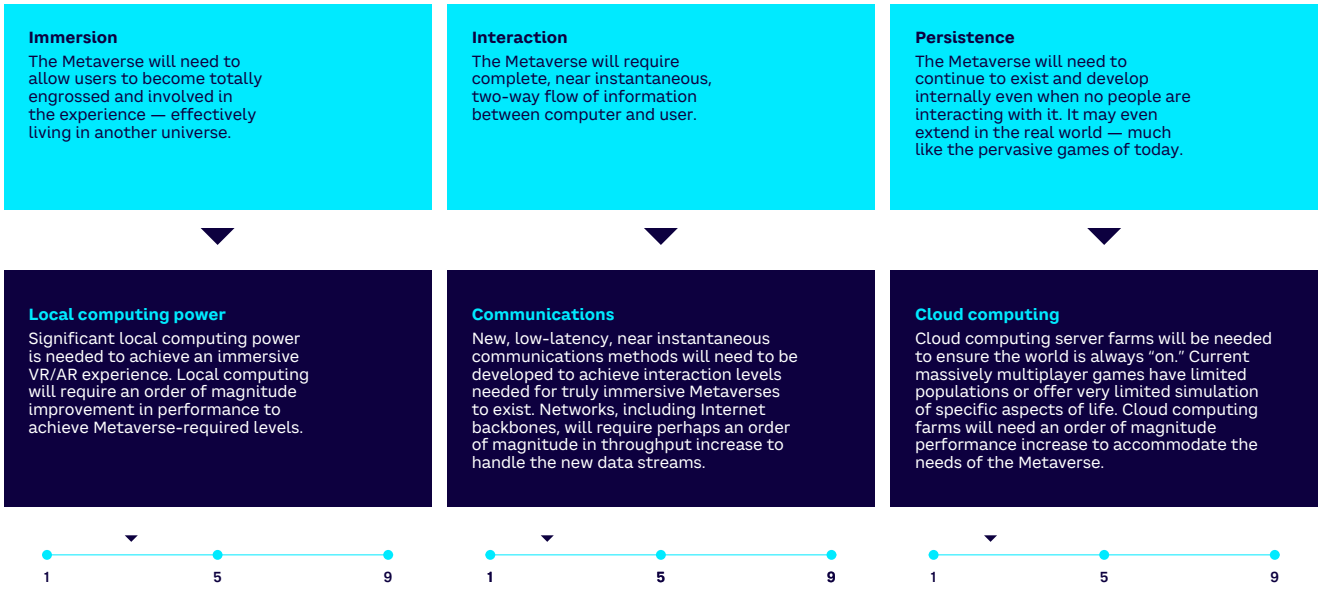
A localized high-bandwidth, low-latency infrastructure is needed, requiring development in gigabit speeds, millisecond latency, and local and cloud compute. To achieve anything close to what Metaverse advocates promise, most experts believe nearly every kind of chip will have to be more powerful by an order of magnitude than it is today.

This means there are huge opportunities for players at the infrastructure level. For example, some estimates suggest that the market will be worth more than $700 billion for telecom operators by 2030. Some relevant telcos and local infrastructure players have already entered the Metaverse by themselves or through different partnerships, including e&, MTN Group, SK Telecom, Telefónica, T-Mobile, Turkcell, Verizon, and Vodafone.

Areas where infrastructure will need to be expanded include:

- **Local computing power.** Significant local computing power is needed to achieve an immersive VR/AR experience and will require an immense improvement in performance to achieve levels required by the Metaverse.
- **Communications.** New, low-latency, near-instantaneous communications methods will need to be developed to achieve the interaction levels needed for truly immersive Metaverses to exist. Networks, including Internet backbones, will require perhaps an order of magnitude in throughput increase to handle the new data streams.
- **Cloud computing.** Current massively multiplayer games have limited populations or offer very limited simulation of specific aspects of life. Cloud computing farms will need an order of magnitude performance increase to accommodate the needs of the Metaverse and to ensure the world is always "on."

Fig 16 — The infrastructure needed to support the Metaverse

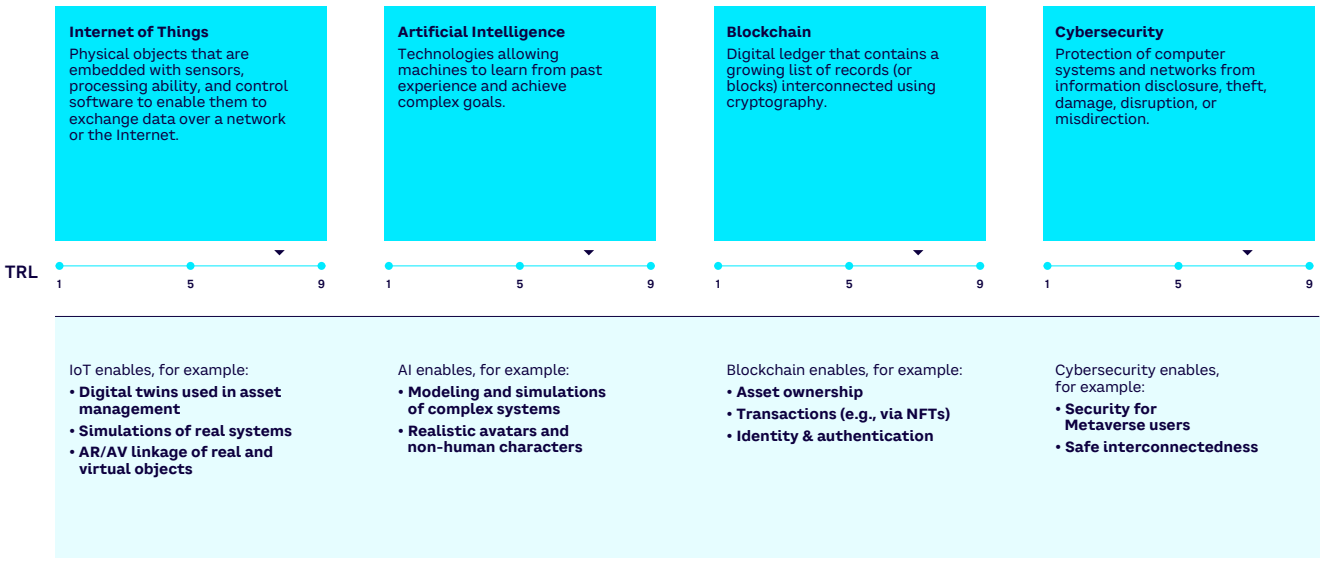


Source: Arthur D. Little

Layer 6: Key enablers — Oiling the wheels

Layer 6, which we call "key enablers," brings together a set of technologies, mostly software, that is essential to the proper functioning of the other layers. This sixth and final layer may be thought of as the oil that lubricates the wheels. It brings together IoT, blockchain, cybersecurity, and AI (see Figure 17). The latter, for example, is necessary for the automatic generation of digital twins or for the creation of realistic avatars with realistic attitudes. The technologies below are already mature in many existing applications but will require further development to enable new Metaverse applications. The TRL for each type of technology shown in Figure 17 is therefore a simplification.

Fig 17 — Key enabling technologies for a functioning Metaverse



Source: Arthur D. Little

Internet of Things

IoT refers to physical things that are embedded with sensors, processing ability, and control software to enable them to exchange data over a network or the Internet.

IoT enables, for example:

- **Digital twins.** Allows complete end-to-end asset management of interconnected devices.
- **Simulation.** Enables customers to create and simulate hundreds of virtual connected devices, without having to configure and manage physical devices.
- **AR/AV.** Allows real data to link virtual and real objects in different applications along the MR spectrum.

The global market size has been estimated at $750 billion in 2020 and $4,500 billion in 2030, with a CAGR of 20%.

Artificial intelligence

AI refers to technologies allowing machines to learn from past experience and achieve complex goals and enables, for example:

- **Simulation of digital twins.** Allows better modeling and simulation of complex systems such as industrial equipment or living entities, leveraging larger amounts of heterogenous data that could not be processed manually.
- **Realistic avatars.** Together with generative adversarial networks (GAN), improving the realism of avatars (in both representation and behavior).
- **Computer agents.** Mimicking the behavior of nonhuman characters.

The global AI market size has been estimated at $94 billion in 2021, and $1,000 billion in 2028 with a CAGR of 40%.

Blockchain

Blockchain is a digital ledger that contains a growing list of records (or blocks) interconnected using cryptography. Blockchain enables, for example:

- **Asset ownership.** Its immutability allows for a record of NFTs within Metaverse economies as proof of digital asset ownership, allowing quick, efficient, and cost-effective transactions.
- **Identity and authentication.** The technology can effectively keep track of digital identities, bringing trust to identity challenges.

The global blockchain market size has been estimated at $4.7 billion in 2021 and an estimated $165 billion in 2029, with a CAGR of 55%.

Cybersecurity

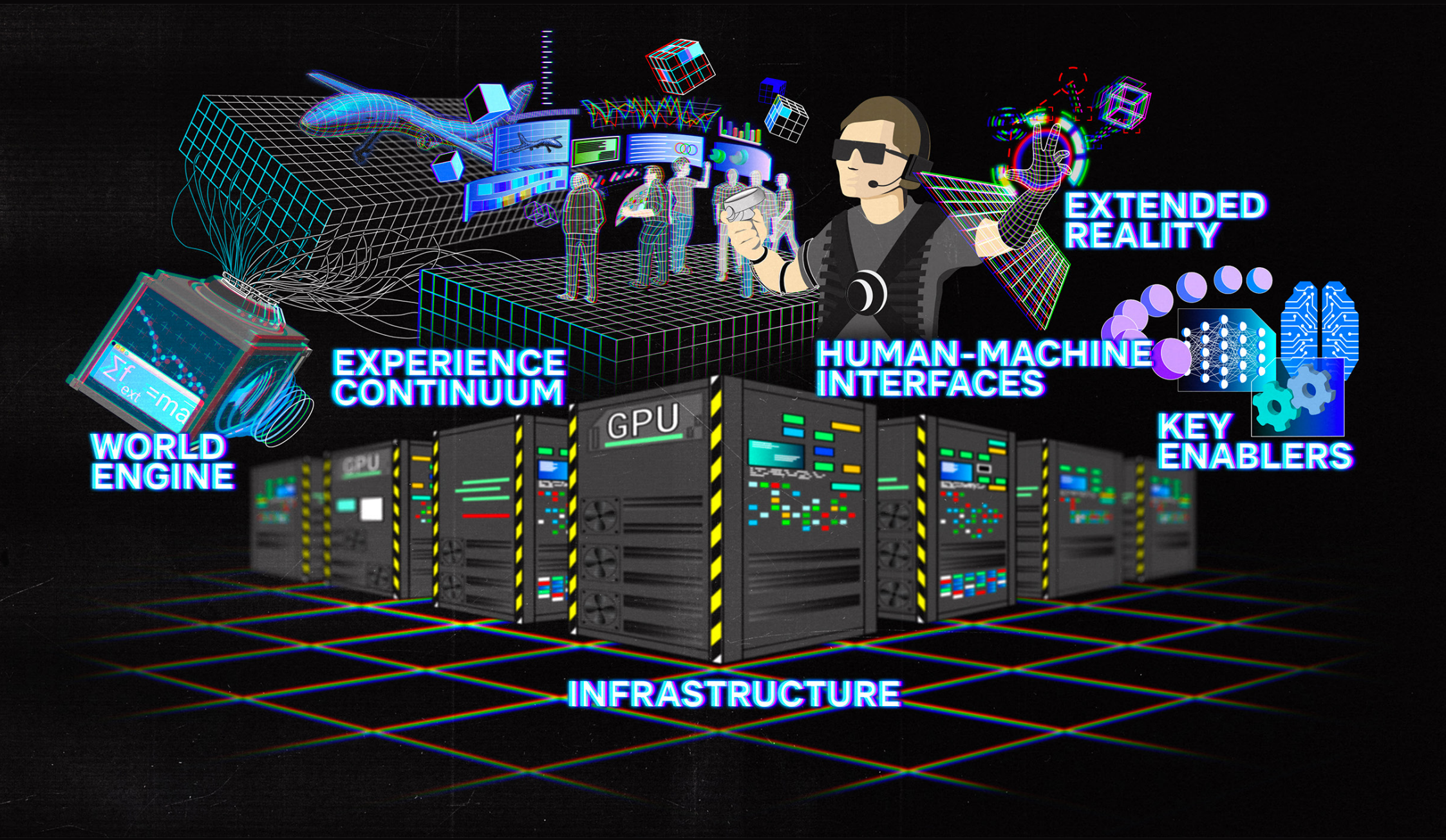
Cybersecurity refers to the protection of computer systems and networks from information disclosure and theft of or damage to hardware, software, or electronic data, as well as from the disruption or misdirection of the services they provide. Cybersecurity enables, for example:

- **Security.** Must be guaranteed before any platform can attract users.
- **Interconnectedness.** Essential to allow the Metaverse to offer new, secure paths for the connections between humans that may be required to enable new applications and capabilities.

INTERLUDE#2 BUILDING THE METAVERSE

With this work, I sought to represent the complexity of the Metaverse with various intricacies: the intricacy of both the physical and the real, the intricacy of both the hardware and the software, and finally the intricacy of the six layers of the architectural model of the Metaverse developed by Arthur D. Little.

— by artist
Samuel Babinet


EXTENDED REALITY
EXPERIENCE CONTINUUM
HUMAN-MACHINE INTERFACES
KEY ENABLERS
WORLD ENGINE
GPU
GPU
INFRASTRUCTURE

CHAPTER 3

III. PROTO-META-VERSE: VIRTUAL WORLDS FOR REAL ECONOMY, TODAY

#3 Proto-metaverses: Virtual worlds for real economy, today

Dimensioning and forecasting the Metaverse market is challenging because it depends on what is included in the calculations. Some analysts project a market as large as $5 trillion by 2030, based on assumptions around the proportion of the global digital economy that will shift toward the Metaverse. These headline-grabbing numbers are very speculative. Instead, we propose a more conservative approach that suggests new markets, excluding enabling technologies such as IoT, AI, and blockchain, in the hundreds of billions of dollars by 2030 with a 30%-40% annual growth rate. Even though the Metaverse, as envisioned and defined previously, is not yet a reality, a large number of business opportunities already exist and can be seized in today's proto-metaverses. Just like the Internet, in considering the opportunities it is useful to segment the Metaverse market into three types: consumer, enterprise, and industrial.

Market: Very significant, but consider multi-trillion-dollar forecasts with caution

Several analysts have already come up with numbers to quantify the Metaverse's market size and dynamics. Some, such as Citibank, estimate the market size in a top-down manner, producing very large figures.[16] For their predictions, they considered the overall global GDP, the percentage of this attributable to the digital economy, and the percentage of the digital economy attributable to the Metaverse. Working on the assumption that the digital economy makes up between 25%-30% of global GDP and that 10%-50% of this is attributable to the Metaverse puts forecasts in a range of market sizes between $2-$20 trillion. However, this does include supporting digital infrastructure and enabling technologies, which as we explained above, will not be driven or used solely by the Metaverse.

Others, such as McKinsey, get to a $5 trillion market in 2030 with a more bottom-up approach.[17] Their approach is based on assumptions about future use cases. In practice, a large proportion of these use cases represent a shift in the already rapidly growing digital economy from the classical Web to the Metaverse, rather than being genuinely new market space — much in the same way that a very significant part of the digital economy shifted from computers to smartphones.

The point is not to claim that one approach is better than the other, but to stress the fact that forecasting the future size of the Metaverse market accurately is difficult for three main reasons:

- **Scope.** Delivering the Metaverse will require extensive and expensive digital infrastructure (such as high-speed, high-capacity networks) to be in place. However, these enabling technologies will not be driven by the Metaverse alone. In other words, sizing the market depends on what we decide to include in its scope, which is somewhat arbitrary.
- **Lack of maturity.** As with any immature market, predicting when (or if) growth will occur is hard. When will the inflection point be reached when consumer demand grows exponentially, for example?
- **Substitution.** Some market activity in the Metaverse will be a substitute for activity that would have taken place anyway in the conventional digital economy, and is thus substitution rather than new growth.

16 "Metaverse and Money: Decrypting the Future." Citi GPS, 30 March 2022.

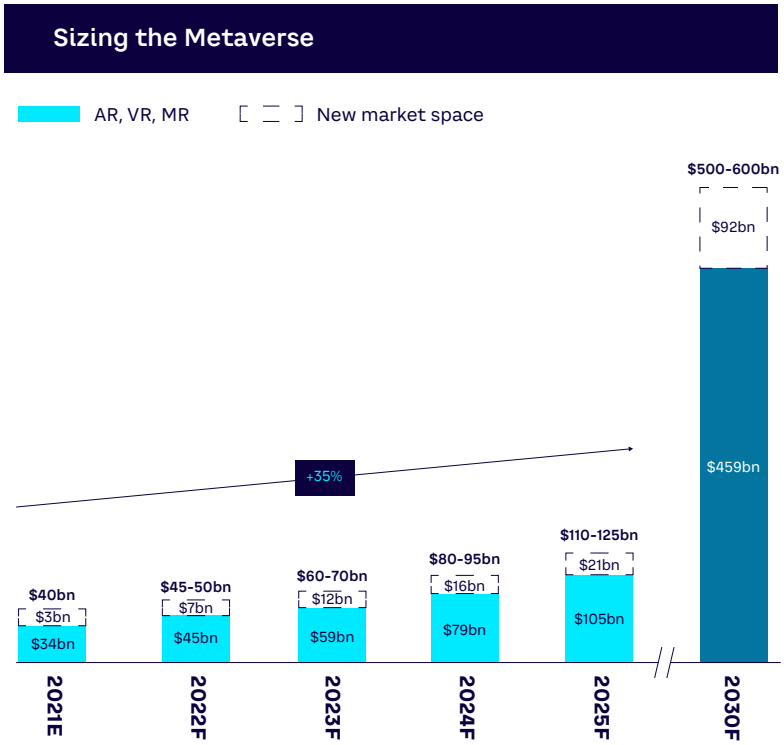
17 "Value Creation in the Metaverse." McKinsey & Company, June 2022.

A conservative forecast suggests that it will increase to around $110–$125 billion by 2025 (see Figure 18), and we expect it could reach around $500 billion by 2030, assuming linear growth.

Given these factors, our analysis provides a cautious, low-end forecast, which estimates that the current Metaverse market, excluding infrastructure and enabling technologies, is estimated to be worth $50 billion.

These numbers are from ADL analysis based on recent credible forecasts for AR, VR, and MR software and hardware markets across multiple consumer, enterprise, and industrial segments. Taking into account the current technological challenges that still need to be overcome, we have conservatively assumed 10%-30% new market space created by further progress in Metaverse adoption up to 2025, over and above recent forecasts. Importantly, these figures exclude revenues from the new digital infrastructure and enabling technologies such as blockchain, AI, and IoT required for Metaverse growth.

Fig 18 — Conservative forecast of Metaverse market growth to 2025



Source: Arthur D. Little, Markets and Markets, Fortune Business Insights, Grand View Research, The Insight Partners, Emergen Research, Adroit Market Research

Note: Estimates for the different applications exclude what it is already considered under other categories

Three types of Metaverse: Consumer, enterprise, & industrial

In this section we focus on the experience continuum — the layer that contains new usages and business models across virtuality and reality. As we mentioned before, these applications can broadly be split into three areas (see Figure 19):

- **Consumer Metaverse.** Referring to all applications and experiences designed for and accessed by accessed by individual consumers.
- **Enterprise Metaverse.** Referring to non-industry-specific applications used across businesses for interaction. These are driven mainly by the need for corporate collaboration among employees.
- **Industrial Metaverse.** (including concepts such as digital twins). Focused on technical collaboration among employees and machines. These applications are often industry- or business-specific.

Many real applications for the Metaverse already exist in most sectors for consumers, enterprises, and industry. However, these are currently implemented as proto-metaverses — the walled gardens we referred to earlier. Additionally, there are current infrastructure opportunities. We have shared a range of current use case examples in Appendix 1. Here, we share a topline summary with some illustrative examples from across different industries.

Fig 19 — Three applications of the Metaverse

Source: Arthur D. Little

Current opportunities: Proto-metaverses across all industries

Consumer Metaverse

The consumer Metaverse provides many of the opportunities that first come to mind, given the Metaverse's partial origins in the gaming industry. There are opportunities across virtually every consumer sector, for example:

Retail and consumer goods:

- Digital assets — including branded, virtual only, replicas of physical assets, or add-ons.
- Virtual try-ons/shops/auctions/retail experiences — aimed at enhancing consumer experience, engagement, loyalty, touch-points, and brand awareness.
- New payment models.
- Enhanced product customization and comparison through digital modeling.
- Improved customer tracking.

Entertainment:

- Virtual events/experiences/simulators — a vast range of applications that could be further enabled by new HMI technologies, which would allow for additional merging of gaming/entertainment and social/collaborative applications.
- Digital assets — building on the existing global digital entertainment market.
- Virtual worlds/virtual tourism — development of what are currently "gaming-only" opportunities into what could be an almost endless array of virtual experiences.
- E-sports/music — New opportunities for sports and music content creation, and new ways for consumers to virtually attend and participate in sports and music events.

Travel:

- In-journey entertainment — new immersive entertainment opportunities (see above).
- Customer interface enhancement — virtual interactions and facilities to revolutionize the customer experience along all stages of the journey from pre-travel to post-arrival.

Financial services:

- Virtual support for clients — enhancing customer engagement, personalization, and quality of interaction along the customer journey.

Healthcare:

- Virtual healthcare provision — enhanced "telecare" offerings for patient consultation, diagnosis, and treatment from a distance and from virtual hospitals.

Enterprise Metaverse

This category includes nonspecialist virtual training courses, virtual meeting and event tools, and remote collaboration and workshop tools. The category is of course already well established in the 2D environment, although technical shortcomings still prevent more widespread application in truly immersive environments. Improvements in the quality of the immersive experience could lead to a step change in the adoption of enterprise tools.

Industrial Metaverse

The industrial category has one of the longest histories and is already extensive in scale. Examples of typical applications include the following:

Manufacturing:

- Digital twins of factories, plants, and other operational facilities — used to enhance and optimize design, operations, and maintenance.
- Human behavior simulation — integrating realistic human behavior models into digitalized manufacturing process models.
- Simulations of complex supply chains — the ability to model entire supply chain networks, from suppliers to end customers, continually balancing supply and demand in real-time, virtual environments to collaborate between supply and demand.
- Asset management and maintenance — tools to enhance and optimize asset management and maintenance, enabled by Industry 4.0 technologies such as IoT, AI, ML, and AR.

Travel and transport:

- Digital twins of assets and infrastructures — as per asset management and maintenance, above.
- Asset design, manufacture, operation, and maintenance — tools to enable enhanced design of assets such as complex travel infrastructure, integrated mobility systems, etc.

Healthcare:

- Remote monitoring of patient health conditions.
- Digital human simulations to test therapies — reducing cost and improving safety.
- Digital twins of manufacturing facilities — as with manufacturing, above.
- Better diagnostics and solutions — leveraging "in silico" approaches for drug discovery and development in a digital environment.

Energy and utilities:

- Design, inspection, testing, and validation of equipment — using digital twins and models, using AR to provide real-time data on asset conditions, etc.
- Modeling and visualization of operating data — using virtual 3D simulations to enhance the ability to optimize and make decisions based on complex and changing data.
- Operator/engineer training — virtual training environments.

Aerospace and defense:

- Digital twins to optimize operations and maintenance — as above.
- Future combat air systems — combining manned and unmanned systems.

Financial services:

- Decentralized finance approaches.
- New financial products — new financial and payment models to suit the emerging Metaverse economy.
- New security approaches — suitable for the virtual world.

Education:

- Campus digital twins — extending the concept of virtual training environments.
- More realistic simulations — to enhance learning.
- New forms of collaboration — among students and teachers.

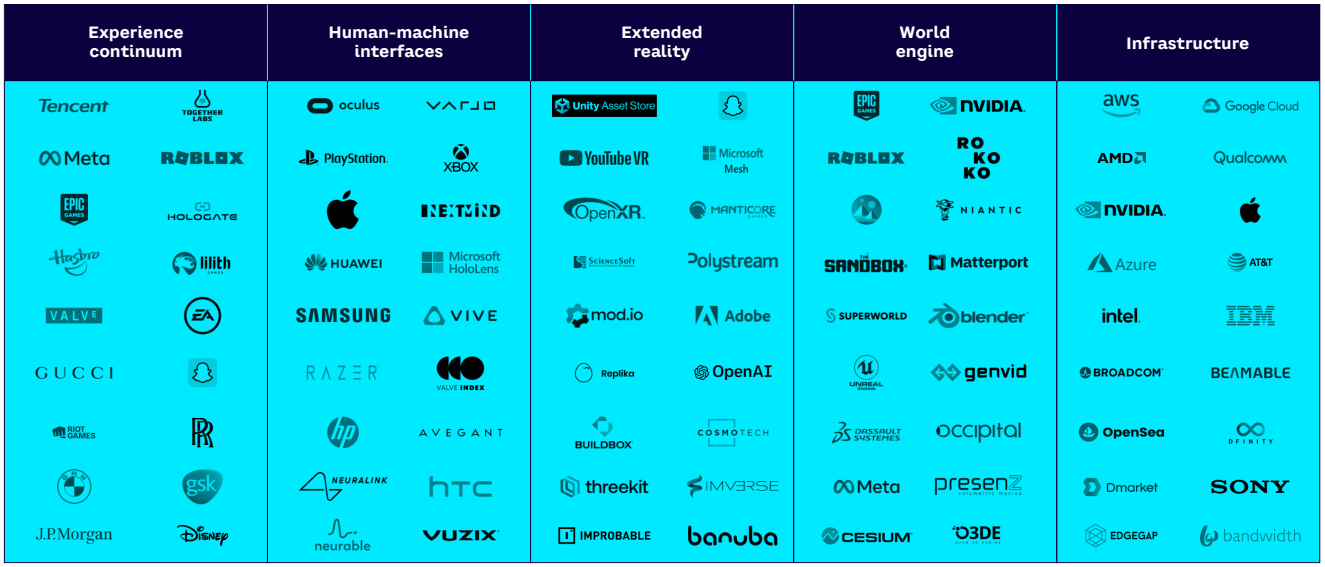
Key players in the Metaverse

There are perhaps 100 companies that are prominent today in shaping the future of the Metaverse, although the total number of companies involved is much greater. Figure 20 shows a selection across the top five layers of the Metaverse framework.

The large gaming companies such as *Roblox*, Epic Games, and Niantic have been leading the way in shaping the Metaverse, together with the tech giants such as Meta and Microsoft. At each layer of the Metaverse architecture, multiple large and well-funded players are active, as well as hundreds of smaller players. Companies investing in Metaverse activities are to be found in nearly every sector, from fast food to football.

By way of illustration, selected key players include the following:

Fig 20 — Selected key players in the Metaverse, organized by layer



Source: Arthur D. Little, Meta Annual Report, Blue Shift Institute

Meta

Fig 21 — Meta

Meta's business model

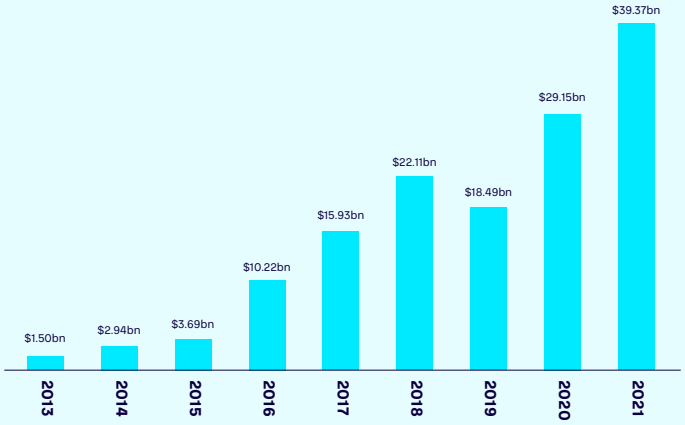
1 Ad sales on Meta's family of apps

- Primary source of Meta's revenue is from ad sales.
- Meta sells ads on social media websites and mobile apps.
- The family of apps segment posted $32.4 billion in revenue in Q4 FY 2021, comprising over 97% of the company's total revenue.

2 Reality Labs

- Comprised of Meta's AR/VR-related hardware, software, and content, including the Oculus VR headset.
- This segment is key to the company's plan of building out the Metaverse.
- This segment reported revenue of $877 million in Q4 FY 2021, accounting for 3% of the company's revenue.

Meta annual revenue, 2013-2021



- Oculus was acquired by Facebook for $2.3 billion in 2014.
- Since 2014, Meta has made numerous VR acquisitions (e.g., VR workout app Supernatural in October 2021).
- Quest 2 was unveiled in September 2020.

Source: Arthur D. Little

For many, the term Metaverse first came to prominence when Facebook changed its name to Meta in 2021. The company is investing heavily in the Metaverse, focused on three current initiatives (see Figure 21):

- **VR hardware.** Since acquiring Oculus in 2014 for $2 billion, Meta has focused on creating best-in-class hardware and complementary software & services to support VR experiences. Currently this allows users to play games, try fitness classes, play sports, and watch concerts in virtual environments. One of the biggest differentiators for Oculus is its large array of nongaming experiences designed for the headset. For instance, users can explore extreme terrain in National Geographic Explore VR, join virtual fitness classes, or simulate being a chef.
- **AR lenses.** Meta has built AR lenses within the Instagram chat and Messenger platforms. There is clearly interest in Meta's AR platform, with the company stating that there are currently 600,000 AR creators in 190 countries working with the technology, who have so far produced 2 million AR filters.
- **Horizon Workrooms.** Meta has launched a VR experience for the Oculus Quest 2 headset that allows users to join collaborative workspaces virtually. Horizon Workrooms creates a virtual office space that can be accessed by up to 16 people who can join as their avatar. While the experience is Metaverse-like, there are still many technical limitations, including the number of people in the space, the ability to dynamically alter the environment, and the cost and complexity of hardware required to access it.

Partnerships include:

- **Verizon (infrastructure layer) —** developing 5G ultrawideband networks with lower latency and higher upload and download speeds to deliver a high-quality Metaverse experience.
- **VNTANA (world engine) —** allowing brands to upload 3D models of their products to Facebook and Instagram and easily convert them into ads.
- **Microsoft (experience continuum) —** integrating between Meta's Workplace enterprise social network software and Microsoft Teams, allowing Meta customers to access Workplace content inside the Teams app, and vice versa.
- **Xiaomi (human-machine interfaces) —** producing a Chinese variant of the Oculus Go VR headset, and establishing the foundations of a VR ecosystem that straddles North American and Chinese markets.

Meta's revenues are still overwhelmingly based on ad sales on its social media networks. The Reality Labs division, which comprises AR- and VR-related hardware, software, and content, including the Oculus VR headset, provided just 3% of revenues ($877 million) in Q4 FY 2021 and is not currently profitable, losing $2.96 billion in Q1 2022 alone.[18]

18 Daniel, Will. "Meta's Metaverse Business Is Losing Billions, But Mark Zuckerberg Says It's All Part of the Plan." *Fortune*, 28 April 2022.

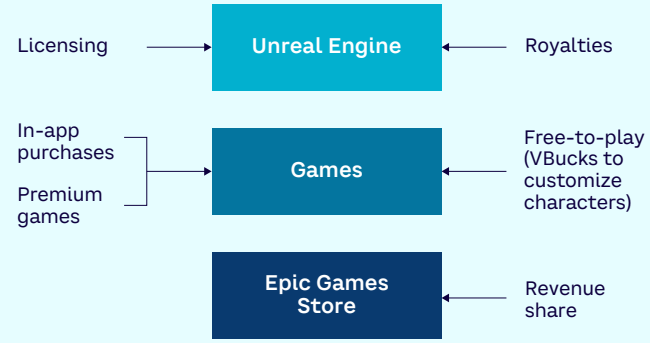
Epic Games

Fig 22 — Epic Games

Epic Games business model

Ad sales on Meta's family of apps

Unreal Engine (UE) works in a royalty-based model, where it succeeds only if the developers succeed. UE charges a 5% royalty fee once the developed game or platform has reached $1 million (accumulated).



Epic Games revenue, 2018-2022E

- Epic Games saw a decline in revenues in 2019, but has since recovered and is expected to generate ~$6.2 billion in income in 2022, a growth of ~14% CAGR since 2019.
- Unreal Engine (version 4) contributed to ~$1 billion (17%) over total Epic Games revenue.

Source: Arthur D. Little, News, GamesBeat, Blue Shift Institute

Epic Games is a US-based multinational technology company best known for developing the *Fortnite* game, which has emerged as a proto-Metaverse used for concerts and brand partnerships alongside gameplay features (see Figure 22).

To diversify revenues beyond its own games, Epic Games now provides its Unreal Engine world engine to third-party developers. Due to its availability and feature set, many industries have adopted the Unreal Engine, including film and television as well as noncreative fields. For example, it has been used as a basis for a virtual reality tool to explore pharmaceutical drug molecules in collaboration with other researchers, as a virtual environment to explore and design new buildings and automobiles, and by cable news networks to support real-time graphics.

Pricing for the Unreal Engine works through a royalty-based model, with Epic Games charging a 5% royalty fee once the developed game or platform has reached accumulated revenues of $1 million.

Partnerships include:

- **WPP (experience continuum) —** partnership to help WPP agencies deliver new digital experiences for brands in the Metaverse through a comprehensive training program.
- **LEGO (experience continuum) —** long-term partnership to shape the future of the Metaverse to make it safe and fun for children and families.
- **NVIDIA (infrastructure layer) —** the NVIDIA Edge Program provides high-end hardware to individuals and teams to create content with Unreal Engine.
- **Intel (world engine) —** collaboration to bring game developers low-power and mobil -optimized support for Windows and Android + in Unreal Engine.

Roblox

Fig 23 — Roblox

Roblox business model

1 Robux

Robux is the currency within Roblox that is used to buy new games, private servers, and other goods.

2 Advertising

Roblox partners with various brands, ranging from Marvel to LEGO, that in turn promote their products and services on the platform.

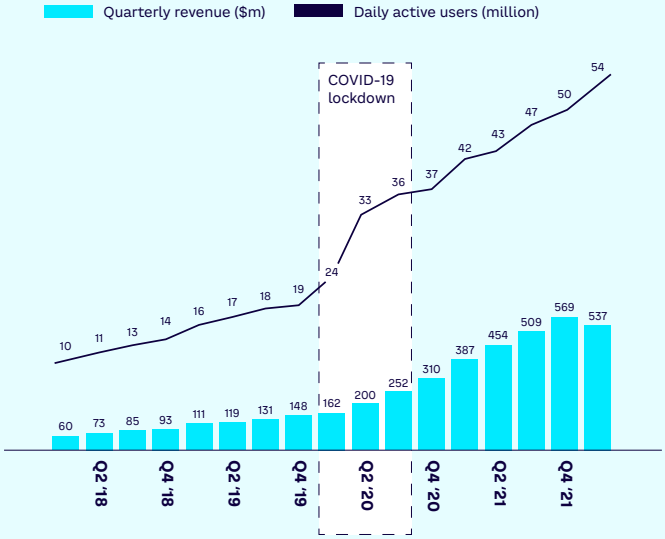
3 Licensing

Partners like Toys "R" Us or Walmart pay a licensing fee in exchange for being able to sell Roblox-branded items.

4 Royalty fees

When IP is used, a licensing fee must be paid; while developers retain all the copyrights, they agree to grant Roblox the right to license out that content.

Roblox quarterly revenue & daily active users



Source: Arthur D. Little, Roblox website, The Roblox Business Model – How Does Roblox Make Money? (productmint.com), Roblox Business Model: Monetizing The Metaverse – FourWeekMBA, Roblox Revenue and Usage Statistics (2022) - Business of Apps

Roblox is an online game platform and game creation system. It is free-to-play, with in-game purchases available through a virtual currency called "Robux." Revenues come from users buying Robux, advertising by brands, licensing of the *Roblox* name for products such as toys and clothes, and content royalty fees (see Figure 23).

The platform offers all the tools required for content creation and handles publication, language translations, billing, safety, and security of the environment. There are professional studios being built on the platform, and many consumer-facing brands/content are partnering with *Roblox* to ensure a virtual presence.

Roblox seems to be moving the platform beyond gaming/leisure experiences and into education and workplace offerings. In essence, the *Roblox* ecosystem includes creator economy features, a virtual platform, and some interoperability.

Partnerships include:

- **Alo (experience continuum) —** launched the Alo sanctuary, an immersive wellness space for yoga and meditation.
- **McLaren (experience continuum) —** unveiled its new car via the Metaverse and developed the McLaren F1 Racing experience, enabling fans to race virtually.
- **NFL (experience continuum) —** launched a US National Football League (NFL)–themed game and hosts virtual events that coincide with the NFL calendar.
- **Nike (experience continuum) —** created Nikeland, a virtual world modeled after Nike's headquarters. Users can dress their avatars in Nike gear, play mini-games, and eventually join in in-play moments from global sporting events.
- **Hasbro (experience continuum) —** developed a *Roblox* version of the Monopoly board game and released a range of *Roblox*-inspired Nerf Blasters.
- **Sony (experience continuum) —** collaboration includes a 2020 Lil Nas X concert inside *Roblox*, as well as a 2021 virtual dance party with Zara Larsson.
- **BMG (experience continuum) —** strategic agreement to empower talent with new ways to reach and engage fans, bringing new artists, labels, and publishers into the Metaverse.

NVIDIA

Fig 24 — NVIDIA

NVIDIA business model

1 Graphics processing units

Includes GeForce GPUs for gaming and PCs; this segment consists of GeForce NOW game-streaming service and related infrastructure; total revenue generated in 2021 = $9.834 billion.

2 Compute and networking

Second-highest earner for NVIDIA; this segment includes data center platforms and systems for AI, HPC, autonomous vehicle solutions, and accelerated computing; total revenue generated in 2021 = $6.841 billion.

NVIDIA annual revenue, 2017-2021

- NVIDIA launched Omniverse enterprise in November 2021 and FY revenue rose 53%.
- Omniverse is an open platform designed for virtual collaboration and physical-level accurate real-time simulation.
- Creators, designers, and engineers can connect major design tools, assets, and projects to collaborate and iterate in a shared virtual space.
- Omniverse is more of a Metaverse builder that allows worlds to link together and form a web of accessible spaces.

Source: Arthur D. Little, NVIDIA Annual Report, Blue Shift Institute

NVIDIA is a US-based multinational technology company well known for its GPUs. The company caters to gamers and professional markets, and in addition to its chips-powering Metaverse infrastructure, it has launched NVIDIA Omniverse, a scalable, real-time development platform for 3D simulation and design (see Figure 24).

In the Omniverse, creators, designers, and engineers can connect major design tools, assets, and projects to collaborate and iterate in a shared virtual space. Over 700 companies, including Lockheed Martin, Sony Pictures Animation, and BMW Group, are using these tools to advance innovation in their products.

Partnerships include:

- **Adobe (infrastructure layer) —** collaboration on a Substance 3D plugin (a dynamic texture generator) to enhance Omniverse capabilities.
- **Pixar (infrastructure layer) —** incorporating Pixar's open source universal scene description into Omniverse, enabling large teams to work simultaneously across multiple software applications on a shared 3D scene.
- **Blender (experience continuum) —** allowing materials to be exchanged between Blender's 3D design and animation tools and the Omniverse.
- **BMW (experience continuum) —** a virtual version of the BMW factory floor to allow collaborative simulation and planning (as described in the Industrial Metaverse use case section).
- **Ericsson (experience continuum) —** using the Omniverse to build virtual cities to accurately simulate 5G cells within the environment.

Decentraland

Fig 25 – Decentraland

Decentraland business model

1 MANA

Decentraland makes money by issuing and holding its MANA tokens — a native ERC-20 token with a limited supply

- During its ICO, Decentraland's team sold only a portion of MANA tokens, reserving and slowly distributed some to the platform's developers and employees.
- The higher the value of one token, the greater the incentive for developers to contribute to the platform (since they are compensated in MANA).
- Decentraland drives demand for MANA by issuing plots of land to other users, who build various attractions that fill its Metaverse with activities.
- Decentraland does not participate in any transactions (e.g., if an artist sells a piece of artwork, then all the proceeds go to him or her).

Decentraland funding

Decentraland, according to Pitchbook, has raised a total of $51 million in funding across four rounds (neither a valuation nor the firm's revenue was disclosed during the rounds).

Deal type	Date	Amount	Status	Stage
Seed round	08/18/2017	$25mn	Completed	Generating revenue
Accelerator/ incubator	11/01/2017	$50k	Completed	Generating revenue
Secondary transaction – private	—	—	Completed	Generating revenue
Later stage VC	04/30/2021	$25.5mn	Completed	Generating revenue

Notable investors

animoca BRANDS · GENESIS CAPITAL · FABRIC VENTURES · DIGITAL CURRENCY GROUP · boostVC

Source: Arthur D. Little, PitchBook, Productmint, Blue Shift Institute

Decentraland is one of the world's first virtual real estate companies, allowing users to purchase, build, develop, and sell digital land parcels in a 3D virtual world (see Figure 25). Users can log in to play games, earn MANA (the native token of Decentraland), and purchase or create NFTs, including land or collectibles. The use of NFTs gives players real-world interoperability for their time spent in-game.

While early in its development, Decentraland has experienced rapid user growth, with 500,000 monthly unique users in March 2022 versus just 30,000 in March 2021 (see Figure 25). Examples of some more popular business activities within Decentraland include art galleries (where owners can showcase and auction their digital NFT art), offices for business collaboration, games and casinos where players can win MANA, advertising via digital billboards, sponsored content, and music venues where DJs and musicians can hold concerts.

Partnerships include:

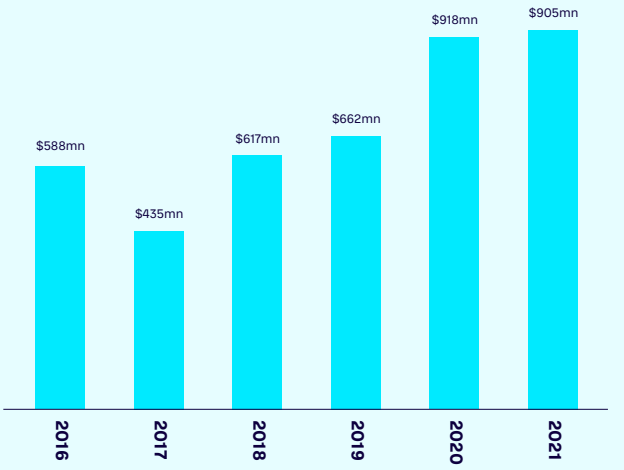
- **Metaverse Fashion Week (experience continuum) —** world's largest, entirely digital, Metaverse Fashion Week, featuring brands such as Selfridges and Dolce & Gabbana.
- **Samsung (experience continuum) —** Samsung's first Metaverse virtual store, an exact replica of a live store in New York City, was available for around one month.
- **Under Armour/Stephen Curry (experience continuum) —** NBA athlete Stephen Curry and his key sponsor, Under Armour, announced a partnership in December 2021. Further details have yet to be shared.
- **Metaverse Group (extended reality) —** Metaverse Group, a virtual real estate company, bought an "estate" for ~$2.4 million. It will use this to support its expansion into the digital fashion industry.

Niantic

Fig 26 — Niantic

Niantic freemium business model

Pokémon GO annual revenue, 2016-2021



- In November 2021, Niantic unveiled its Lightship AR Developer Kit (ARDK), which makes tools to develop AR games publicly available for free to anyone who has a basic knowledge of the Unity game engine.
- Companies like Coachella, Historic Royal Palaces, Universal Pictures, SoftBank, Warner Music Group, and the PGA of America have already used ARDK to create AR experiences.

Source: Arthur D. Little, Niantic Annual Report, Blue Shift Institute

Software developer Niantic aims to overlay virtual reality onto the physical world in what it calls the "real-world Metaverse." Niantic is doing this through smartphone-based AR games such as *Pokémon Go* and *Harry Potter: Wizards Unite*, whereby virtual objects, people, clues, and so on, appear in the real world as part of the story (see Figure 26).

In November 2021, Niantic unveiled its Lightship AR Developer Kit (ARDK), which makes tools to develop AR games publicly available for free to anyone who has a basic knowledge of the Unity game engine. Companies such as Coachella, Historic Royal Palaces, Universal Pictures, Softbank, Warner Music Group, and the Professional Golfers' Association of America have already used ARDK to create AR experiences.

Partnerships include:

- **Sony (human-machine interfaces) —** combining technologies to develop headphones that have an auditory AR experience.
- **Nintendo (experience continuum) —** developed the Pikmin app, which includes gameplay activities to encourage walking outside through points for steps and exploration.
- **Verizon (infrastructure) —** creating next-level real-world AR experiences that demonstrate the possibilities of 5G.
- **Qualcomm (human-machine interfaces) —** developing affordable AR glasses.
- **Starbucks (experience continuum) —** turning more than 7,800 US Starbucks locations into *Pokémon Go* locations to entice players in, as well as a *Pokémon Go*-themed Frappuccino.

“You take the blue pill — the story ends, you wake up in your bed and believe whatever you want to believe. You take the red pill — you stay in Wonderland, and I show you how deep the rabbit hole goes. Remember: all I'm offering is the truth. Nothing more.”

— Morpheus,
The Matrix, 1999

CHAPTER 4

IV. THE WAY FORWARD

#4 The way forward

The prospects for the Metaverse may be subject to a large degree of hype, but its current acceleration is driven by a real convergence of multiple factors around software, hardware, and user growth. In turn, this has driven a major acceleration of funding and commercial activity over the last two years.

Many observers remain skeptical about people's desire to spend large amounts of time in virtual worlds. However, the value of the Metaverse lies for a large part in its linkages with the physical world, and the creation of an extended reality across a spectrum of combinations of real and virtual experience.

Looking ahead, technological advances are likely to transform the quality and cost of the virtual experience and lower the barriers to adoption. However, as we have said, the technology required to realize the Metaverse as the "future of the Internet" is not likely to be available for a decade. In the meantime, the proto-metaverse of the present still offers considerable opportunities for many industries.

Finally, our study has shown that among all the trends and factors currently shaping the Metaverse, three of them are especially critical because they combine high potential impact and high uncertainty. These three critical factors are:

1. **Immersivity.** The development of new AR/MR technologies that effectively overcome current technical obstacles would be a strong accelerator of new usages in the coming years. In the same way that smartphones made the digital economy shift from computers to mobiles, we believe that user-acceptable AR/MR glasses would drive a similar shift from screen-based Metaverses to more immersive Metaverses. However, there is still a high degree of uncertainty about the device (or devices) that will be the main gateway to the Metaverse. Depending on what device emerges as dominant in the coming years, usages may be very different from one scenario to another.
2. **Interoperability.** Interoperability is the key to ensure seamless experiences and to maximize value for users and brands. As we explained previously, we currently are in a state of proto-metaverses. Each vendor (Microsoft, Meta, Apple, *Roblox*, etc.) is a gateway to a specific synthetic world not connected to the others: users of these proto-metaverses cannot share experiences or resources with users of other proto-metaverses. In the coming years, there will be a tension between vendors on one hand, and users and brands on the other. Vendors invest massively in the development of these proto-metaverses and will want a return on investment, and therefore will have a strong incentive to keep users captured within their private environment. Users and brands, on the other hand, will get more value out of the Metaverse if they can share experiences and resources irrespective of their access point. Due to these diverging interests there is no guarantee that interoperability will be achieved.
3. **Abundance.** In the physical world, scarcity drives the value of assets in a market economy. In the traditional digital economy, since a digital file can be duplicated at no cost, scarcity was reintroduced artificially through systems such as digital rights management (DRM). In a virtual world with blockchain and NFTs, a new economic paradigm of "abundance" may appear, implying a more fundamental value shift from physical assets to experience and, perhaps, status. The extent to which this will happen, and its implications for business, are uncertain.

The Metaverse offers a large potential market with great opportunities, but also with tremendous uncertainties. Businesses should therefore certainly not ignore the Metaverse and the possibilities it delivers for consumers, enterprises, and industrial uses. As with other emerging technology areas, strategies for responding to the Metaverse should comprise some basic elements:

- Envisioning the future.
- Assessing opportunities to create advantage.
- Building ecosystem capabilities.
- Testing and learning.

We describe these further below.

Envisioning the future

To access the full potential of the Metaverse, companies should adopt a creative mindset when defining their strategy, going beyond obvious opportunities such as using it for new marketing approaches, or increasing internal collaboration and training through virtual tools.

Organizations should therefore take time to envision the future in three to five years' time and beyond, and think creatively about their role in this future. This should not be defined solely in terms of current products and services, but rather by the values and sense of purpose of the company. This means understanding how new products, services, and business models are made possible through the existence of the Metaverse. Involving suppliers and customers in this process is valuable if feasible and appropriate.

Given the high degree of uncertainty about the speed and nature of development of the future Metaverse, it is important to use scenario thinking to establish a strategy that is resilient to change.

Assessing opportunities to create advantage

A key aspect of any Metaverse strategy is to identify and assess potential opportunities to create competitive advantage and ensure resilience. Based on the vision of the future, a good starting point is to think creatively about what business model innovations could be feasible with the Metaverse. Some examples to consider include new ways to create/capture value, new ways to change the boundaries of the business, or new ways to share roles with other parties. These opportunities span three key segments:

- **Consumer.** New ways to identify, attract, serve, communicate with, and engage with customers (including customers in the business-to-business sectors) and to market products and services in the Metaverse.
- **Enterprise.** New ways to work, collaborate, train, and educate internally.
- **Industrial.** New approaches for key operational processes that leverage the virtual/digital environment, including, for example, design, development, operational improvement, maintenance, and so on.

Companies should consider opportunities across new products, services, and business models as well as use cases for the existing business, including:

- **New products and services.** What are the potential areas where the company's products or services, or the underlying capabilities and know-how the company possesses to realize them, could translate into new virtual products or services? Are there ways that new virtual offerings could be developed to help sell physical products and services?
- **New business models.** Are there any opportunities for new or disrupted business models resulting from the emergence of the Metaverse as a place to do business? For example, could the company's position in the value chain change, could the company form new relationships with partners, use assets differently, or adopt a new pricing or cost model? What are the threats and opportunities for the current business?
- **New applications and use cases.** In current business operations, which aspects could benefit from the virtualization opportunities the Metaverse offers? For example, global collaboration, training, or problem solving?

Long lists of potential opportunities can then be screened and ranked in terms of factors such as impact and ease of execution.

Building ecosystem capabilities

Ensuring that you have access to the right skills and capabilities to respond to the opportunities and threats of the Metaverse is key. This is especially important as the endemic shortage of experienced digital and IT specialists continues, which is likely to become even more acute in the coming years.

For example, key skills that may not already be available in a typical nondigital native company include experience design, UX design, 3D artist/design, motion design, community growth/engagement, and software development. These can be accessed via suitable partners, based on a careful make/buy strategy if it is unfeasible to employ people directly.

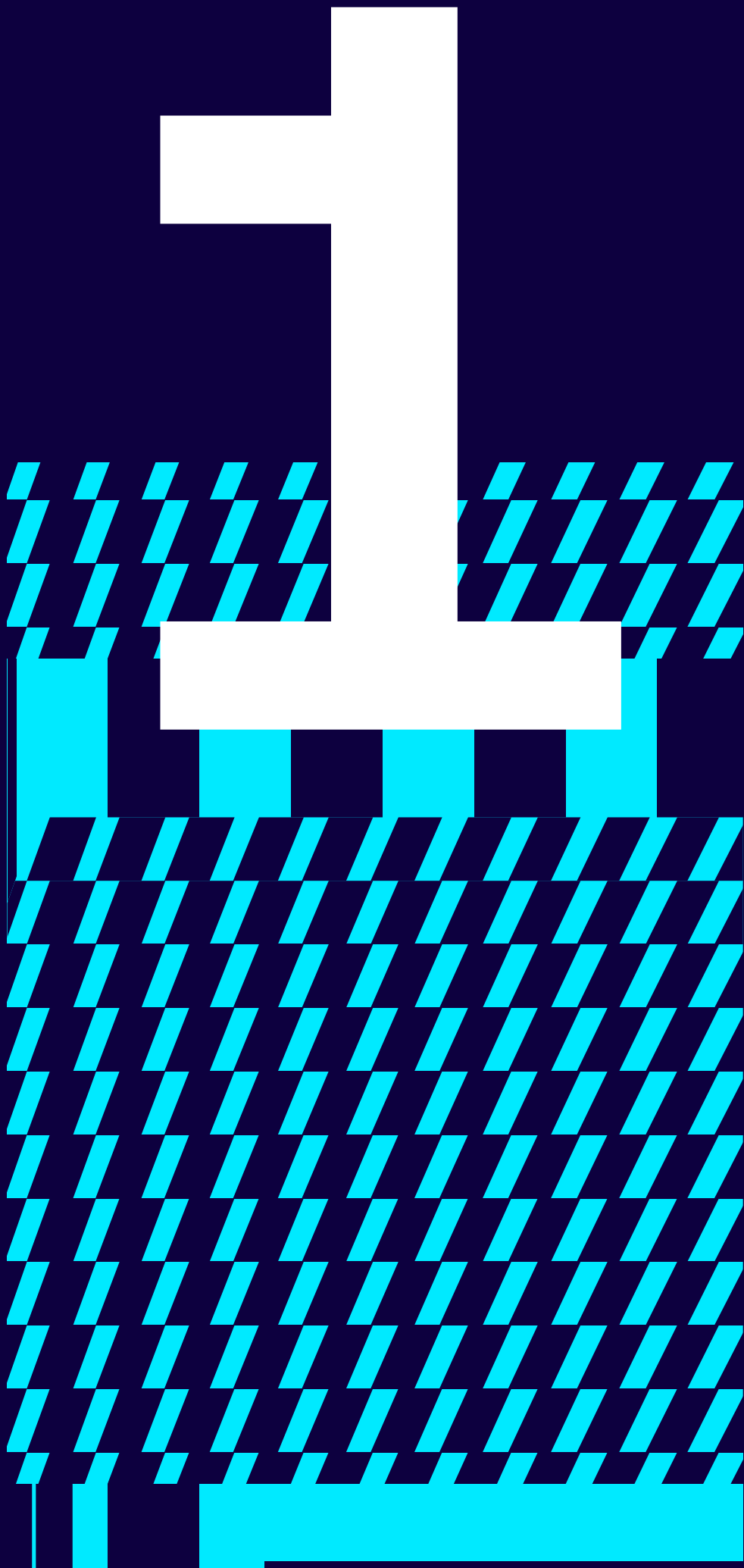
It is also advisable for businesses to start to become involved in the ecosystem of players currently engaged in Metaverse development, for example through direct contacts or via conferences and other networks.

Testing & learning

The future development path of the Metaverse cannot be predicted with any certainty. Experience suggests that a smooth growth curve is improbable, and there are likely to be sudden accelerations and slowdowns reflecting breakthroughs and setbacks. An agile "test and learn" approach is therefore essential, rather than a rigid plan.

There are already existing Metaverse opportunities and use cases for companies to consider in nearly all industry sectors. Companies that are not already engaged should consider the possibility of running pilots and trials, and engaging with other partners. By becoming actively engaged, companies are in a far better position both to develop skills and capabilities, and to monitor ongoing technological and commercial developments.

APPENDIX



I. EXPERI-
ENCE CON-
TINUUM
USE CASES

Here we outline a large number of case examples across industry sectors to illustrate the range of opportunities within the consumer, enterprise, and industrial Metaverses.

#1 Experience continuum use cases

Fig 27 — Current proto-metaverse applications within the consumer, enterprise, and industrial Metaverses

	Travel & transportation	Energy & utilities	Healthcare	Retail & consumer	Aerospace & defense	Financial services	Manufacturing & automotive	Entertainment	Education
Early adopters/ key players	ANA, Inflight VR, Matterport	groupe e, vedanta	Pfizer, Johnson & Johnson	Coca-Cola, Nike	Boeing, Rolls-Royce	J.P.Morgan, BNP Paribas, Citi, Bank of America	Hyundai, NVIDIA	Roblox, Meta, Unity, Disney	Strivr, Seoul National University
Typical focus of applications ***Consumer***	• In-journey entertainment • Customer interface		• Virtual care	• Digital assets • Virtual try-ons/ shops/ auctions • Virtual experiences		• Virtual lounges • Virtual support for clients • VR apps for account opening		• Virtual events/ experiences/ simulators • Virtual assets • Virtual worlds • E-sports/music	
Enterprise	• VR/AR training		• Virtual meetings and events		• Remote collaboration and workshop tools				
Industrial	• Digital twins for asset design, manufacture, operation, maintenance	• VR to design, inspect, test & validate equip. • Live operating data • Operator/ engineer training	• Remote monitoring • Digital human simulations to test therapies • Digital twins of facilities	• Product customization and comparison	• Digital twins to optimize operations/ maintenance • Future combat air system	• Decentralized finance	• Digital twins of factories • Human behavior simulation • Simulations of supply chains • Asset mgt. and maintenance		• Campus digital twins
Remarks	• Sector was early adopter of VR for training • Future potential for virtual tourism is a threat/ opportunity	• Digital twins already present in some facilities • Levels of energy consumption of the Metaverse could be an issue	• Better diagnostics and solutions • Personalized medicine • Show patients the surgery before performing it	• Boost brand awareness • Collaborations with platforms • New payments • NFT creation • User behavior tracking	• Reduce costs of training • Increase pilot safety • Enable predictive maintenance • Reduce emissions	• Enhance personalization, "human approach" for banking • New financial products arising from Metaverse	• Enable performance improvement across supply chain • Digital twinning already established • Industry 4.0 will help Metaverse adoption	• Convergence of social experiences and entertainment • Gaming companies among most active in shaping Metaverse	• Generate more realistic simulations for students • Enable new forms of collaboration among students/ teachers

Source: Arthur D. Little

1 Travel and transport

Leveraging VR to improve in-flight entertainment

In-flight VR offers over 200 hours of native VR content designed for the maximum immersive experience, covering cinema and TV, games, travel and relaxation, kids' corner, and culture and sports.

The company has different business models from which airlines can choose hardware, content, marketing, and various add-ons.

Benefits

In a saturated market such as the airline sector, VR and immersive experiences can be a differentiator.

In-flight VR promises simple setup and logistics, intuitive user onboarding and discovery phase, diverse content experience, and platform agnosticism.

Enabling virtual tours

Matterport provides a 3D space-capture platform to enable businesses to provide virtual tours of hospitality, event, and leisure facilities.

For example, it could deliver an immersive trip of a lifetime around specific historical or geographical landmarks — all without requiring tourists to leave their sofa.

Benefits

According to Matterport, these 3D tours drive 300% higher engagement compared to 2D imagery and a 14% increase in bookings.

Providing flight crew training

JAL is using VR to train flight crews on pre-take-off checks, in-flight preparation, and emergency evacuation drills.

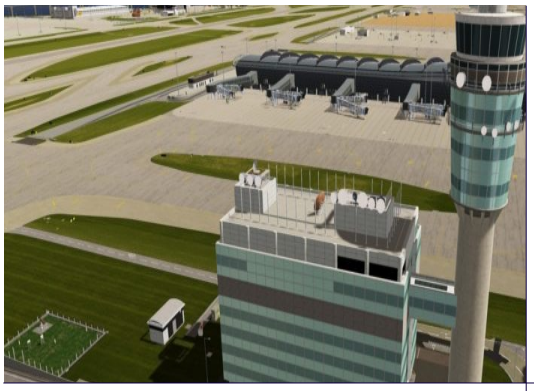
The system includes a head-mounted display, dedicated controller, and voice recognition software.

The system can learn work procedures and areas that need to be checked.

Benefits

Offers the ability to simulate the experience of daily operations as well as those that are difficult to perform. Accessible to the crew member, irrespective of time or location.

Digital twin to manage all airport assets



Using a digital twin helps Amsterdam Schiphol airport monitor and manage all the assets that make up its systems in real time from a single dashboard. The digital twin, known as the Common Data Environment (CDE), organizes data from multiple sources: building information model data, geographic information system data, and data collected in real time on project changes and incidents as well as financial information, documents, and project portfolios.

Benefits

The digital twin allows the airport's operators to track and maintain more than 80,000 assets, from networks, runways, and lighting systems to information booths and fire extinguishers. The airport can interact and simulate with different predefined scenarios, optimizing operations and saving money and time.

2 Energy/utilities

Using digital twins to manage assets and improve investment decisions

Switzerland's Federal Energy Act focuses on the reduction of energy consumption, increasing energy efficiency, and promoting renewable energy.

Network operator Groupe E has begun its transformation process. It must be able to justify investment plans while keeping safety and reliability at their current levels.

Through digital twins, Groupe E is able to simulate everyday actions performed on each asset. Simulations are performed for long periods of time.

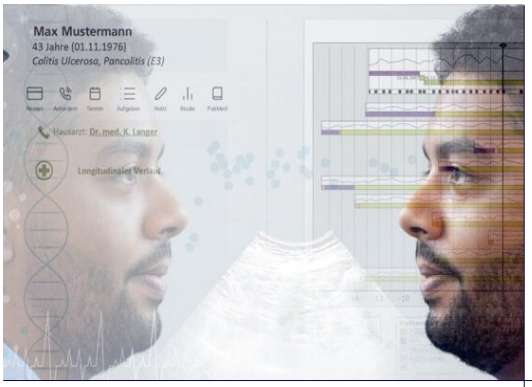
Benefits

Through simulation, users can experiment with variables to see exactly what impact different choices have in terms of OPEX, CAPEX, outage minutes, or any other metric.

"Getting results over such a long simulation period brings fresh insight into where we currently stand and where we're actually heading. It's only then that we can be sure to make the right decisions for the next 10 to 15 years," says Aurelien Lair, Lead Strategic Asset Management at Groupe E.[19]

3 Healthcare

Creating a digital patient for personalized healthcare



Fraunhofer has created a prototype digital patient model by merging unstructured, multidimensional health and disease data sets to form a digital patient image.

This can be used to test thousands of drugs on the digital twin to identify the best-performing drug for a particular disease.

Benefits

The US Food and Drug Administration estimates that current medication is ineffective for 38%-75% of patients with common diseases.

Delivering personalized, more targeted, and effective prevention and diagnosis will therefore not only provide better patient outcomes but will also improve the cost-effectiveness of treatment.

19 How the Swiss Power Grid Benefits from Digital Twins." Cosmo Tech, 23 August 2021.

Enabling more lifelike virtual ſurgical training

FundamentalVR is a startup leveraging VR and haptic feedback for more efficient surgery training.

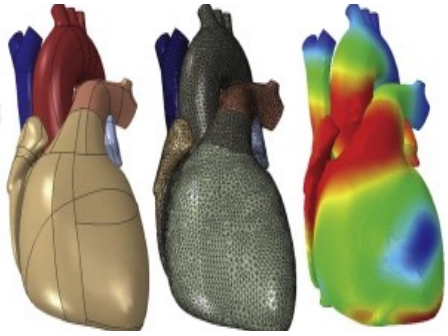
It provides a surgical simulation system for training composed of:

- Head-mounted display allowing users to visualize surgery from various angles.
- Haptic devices providing feedback, allowing operators to feel the skin and bones and to experience sensations while operating.

Benefitſ

Experience can be gained anywhere and at any time. Avoids the need to practice on actual patients.

Providing a digital twin of the human heart to develop, teſt, and validate medical ſolutionſ



By replicating in vivo conditions, Dassault Systèmes Living Heart can disrupt different industries:

- **Education and training.** Surgeons can train on a full model of the human heart.
- **Medical device design.** Companies can develop and refine ideas faster, leading to more effective, safer medical devices.
- **Device testing.** Improves testing, accelerates regulatory approval, and reduces the cost and need for clinical trials.

Benefitſ

Heart disease is the leading cause of death globally. Time required for the development, testing, and validation of drugs and medical devices for a wide range of pathologies is notoriously long.

Living Heart could improve the effectiveness and reduce the time and cost of developing, testing, and validating drug and medical devices for cardiovascular applications.

The market size for cardiovascular medical device market was $48 billion in 2021 globally.

Learning & practicing new surgical skills

In the healthcare sector, new devices and innovations are constantly introduced at an accelerating pace. Modern surgical procedures tend to be significantly more complex.

Osso VR's surgical simulation training gives healthcare professionals better ways to share, practice, and learn new skills and procedures using VR. Its analytics enable professionals to measure engagement and proficiency.

As a Preferred Partner of Oculus, Osso VR leverages off-the-shelf technology that is affordable and scalable.

Benefits

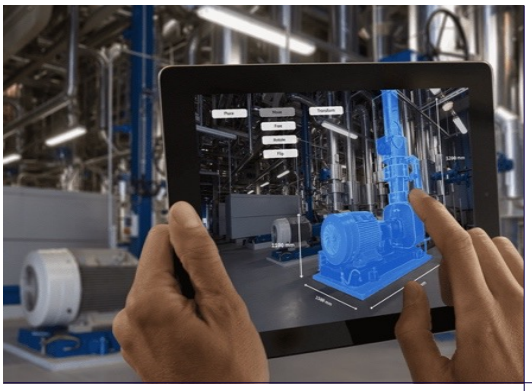
Enables cheaper training, without the need for real surgical theaters.

Trainers can track the progress of the user or larger cohorts through a customizable dashboard.

Analysis allows trainers to identify where procedures are most challenging to inform product education or training enhancements.

Surgeons can stay on top of the latest advancements and quickly learn any procedure.

Simulating vaccine manufacturing through digital twins



Partnering with Siemens and Atos, GSK has launched a digital twin initiative, creating a real-time simulation of the vaccine manufacturing process.

Each step in the vaccine manufacturing process is equipped with sensors. This data is combined with physical, chemical, and biological models to build a digital twin of the future vaccine, creating a live, in-silico replica of the physical production processes.

Benefits

The project, launched in 2020, has already shown promise in:

- Reducing manufacturing times.
- Optimizing product quality and other areas.

"With digital twins, you're able to do huge amounts of digital experiments and minimize the number of wet experiments that you do," says Matt Harrison, head of sciences, digital innovation and business strategy at GSK Vaccines.[20]

Digital twin–based experiments can also eliminate the need to build new test facilities, which can potentially take years.

20 Buntz, Brian. "An Inside Look at GSK's Digital Twin Initiative." Drug Discovery & Development, 24 June 2021.

4 Retail/consumer

Staging virtual fashion experiences

Gucci has entered the Metaverse through a partnership with *Roblox*. The virtual Gucci Garden exhibition space opened its doors to everyone on *Roblox* for two weeks.

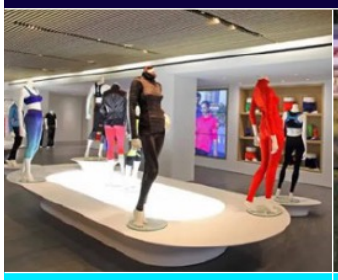
Similar to a physical space, the Gucci Garden experience on *Roblox* was divided into themed rooms, where visitors could immerse themselves into a creative vision with diverse inspirations and share the experience of the exhibition with their friends.

Benefits

A limited edition of virtual bags sold for $4,115 (more than their $3,400 retail value).

This shows that the Metaverse can be leveraged as an effective marketing and communication channel for virtual goods, and at the same time provide exposure in the real world.

Using virtuality to improve the customer experience

Virtual stores	Virtual experiences	Virtual auctions	Others
			
– Digital assets are being sold on the Metaverse (such as Gucci bags and Zara, Ralph Lauren, and Nike collaborations with Zepeto). – Virtual try-ons through apps (such as Forma). – Virtual shops (H&M is in talks with Ceek). – User behavior tracking. – Ability to shop from anywhere.	– Chipotle opened a virtual shop on *Roblox* in which virtual "Boorito" users can get a free main course after completing a maze on the platform. – In a collaboration between Louis Vuitton and Riot Games for the 2019 League of Legends World Championship Finals in Paris, Louis Vuitton designed prestige skins along with other digital assets. – Shopify envisions shopping enhanced by VR/AR.	– Coca-Cola NFT sold for $575,000 in an online auction. – A pair of Louis Vuitton x Nike sneakers being auctioned for $80,000 at a virtual auction. – Collectors who bought an "Epic level" Gap NFT will also receive an exclusive physical hoodie.	– Boosting brand awareness via virtual factory tours and interactive assemblies. – Virtual presentations of products and services. – Payments via blockchain technologies, cryptocurrencies, and NFTs. – Collaborative R&D for design, simulations, and testing of products and services. – Leveraging the voice of the digital customer to improve real-world customer experience. – Product customization and comparisons.

Creating new consumer experiences & boosting efficiency in fast-moving consumer goods

Nestlé	P&G	Unilever	Coca-Cola	Heineken
Nestle is using AR to speed up factory support. It is using tools such as remote desktop, smart glasses, 360-degree cameras, and 3D software so specialists can advise on complex tasks without needing to travel to the site.	In January 2022, P&G announced BeautySPHERE, an immersive virtual experience that allows visitors to virtually interact with P&G Beauty's portfolio of brands through live and simulated content.	Unilever is creating new worlds of branded communities in which products play a central role, populated by consumer advocacy.	Coca-Cola has unveiled a new innovation platform for limited-edition products (Coca-Cola Creations). The platform will introduce a series of limited-edition flavors, collaborations, and experiences spanning the physical and digital worlds.	Heineken launched an NFT collection called Lucky Tiger, linked to its Tiger Beer brand.

5 Aerospace & defense

Enabling a virtual trade show

For Asian Sky Group, Mytaverse partnered with PureWeb to deliver an immersive 3D virtual trade show, built on Epic Group's Unreal Engine.

Benefits

By offering customized, photorealistic 3D design packages, Asian Sky Group gave business aviation vendors the ability to display life-like models of their aircraft, have digital face-to-face chats with customers in real time, and deepen business relationships in an entirely virtual environment.

Delivering fully immersive flight training through VR

The Royal Danish Air Force (RDAF) has partnered with the VR aviation training provider VRpilot to introduce a fully immersive training experience on ground.

The virtual cockpit solution can be specifically tailored to RDAF needs and includes VR headsets as well as a haptic feedback loop in the seat and controls, and shared VR reality simulation for several students at the same time.

Mentors have the ability to follow student performance in real time and change simulation conditions as required.

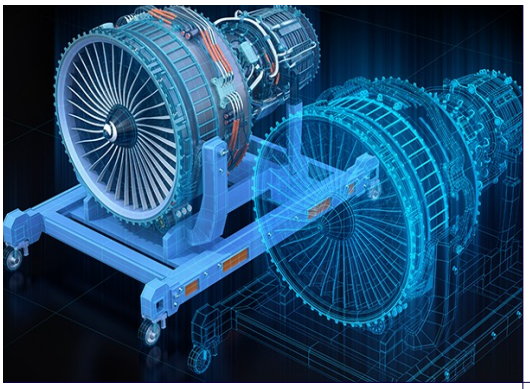
Benefits

Pilot training is very costly: basic training for a US Air Force fighter pilot costs ranges between $5-$10 million. Similarly, a fully FAA-approved flight simulator costs between $10-$20 million.[21] This solution could lead to a reduction of training costs.

It can be used for training on flight maneuvers on the ground as well as a supplement to flight training in the actual aircraft.

The global civil aviation training market was worth approximately $6 billion in 2021.[22]

Deploying digital twin technology to optimize aircraft maintenance



Rolls-Royce creates a digital twin of every engine in use, kept up to date through all the data and metadata around the engine.

This includes real-time data during flights, operations data after landing, data on original and replacement parts, as well as the entire maintenance history.

Benefits

The ability to carry out predictive maintenance extends the time between maintenance for some engines by up to 50%, thereby enabling Rolls-Royce to dramatically reduce its parts inventory.[23] The global aircraft maintenance market was $18.34 billion in 2021 and is expected to increase to $28.73 billion in 2029.[24]

The approach has also greatly improved the efficiency of engines and reduced carbon emissions per flight. The global aviation industry represents about 2% of all greenhouse gas emissions.[25]

21 McCarthy, Niall. "The Cost of Training US Air Force Pilots." *Forbes*, 9 April 2019.

22 Salas, Erick Burgueño. "Global Civil Aviation Training Market Size 2017-2021." Statista, 12 April 2021.

23 Olavsrud, Thor. "Rolls-Royce Turns to Digital Twins to Improve Jet Engine Efficiency." *CIO Magazine*, 10 June 2021.

24 "Aircraft Line Maintenance Market Is Projected to Hit USD 28.73 Billion in 2022-2029; Aircraft Line Maintenance Industry Exhibit a CAGR of 5.8%." Fortune Business Insights, 31 March 2022.

25 Ritchie, Hannah. "Climate Change and Flying: What Share of Global CO2 Emissions Come from Aviation?" Our World in Data, 22 October 2020.

6 Financial ſervices

Opening a virtual lounge for cuſtomerſ

JP Morgan has opened its Onyx virtual lounge. This provides a block-chain-based platform for the exchange of value, information, and digital assets.

JP Morgan aims to transform the way money, information, and assets move around the world.

The lounge provides the opportunity to experiment with decentral-ized finance collateral management.

Benefitſ

Every year, an estimated $50 billion is spent on virtual goods — almost double the amount spent buying music.

JP Morgan aims to use the virtual lounge to facilitate cross-border payments, foreign exchange, financial assets creation, trading, and safekeeping in the virtual world.

7 Manufacturing & automotive

Creating the factory of the future

NVIDIA and BMW are working to create the factory of the future, using digital twinning of both machines and humans.

Digital humans are trained with data from real employees and can be used in simulations to test new workflows for worker ergonomics and efficiency.

BMW's global teams can collaborate to design and plan factories in 3D, with all changes visible in real time.

Benefitſ

Facilitates factory reconfigurations for new lines; helps to improve workflows, ergonomics, and safety; and is envisaged to ultimately deliver 30% more efficient planning processes.

8 Entertainment

Holding high-profile music & entertainment events in the Metaverse

Epic Games has organized multiple nongaming experiences in its *Fortnite* platform, including music concerts by Travis Scott (audience of 12 million), and the Rift Tour (over 78 million).

Decentraland held a Metaverse music festival in October 2021, attracting 50,000 virtual attendees who claimed 11,204 unique digital NFTs.[26]

Roblox has hosted numerous events, including for example Lil Nas X,[27] who performed four shows that garnered 33 million views in total.

Spotify is launching a new virtual island on the *Roblox* platform that lets users meet their favorite musical artists, play different sounds, explore quests, collect virtual merchandise, and listen to music.

Benefits

The Metaverse offers new ways to engage with consumers and generate revenues beyond gaming.

There is a growing user community accustomed to using game platforms for a wider range of experiences.

Selling virtual & real items via the Metaverse

Luxury fashion house Balenciaga collaborated with Epic Games to design four virtual outfits and various accessories for avatars, available for players to purchase through *Fortnite*.

Limited edition physical Balenciaga x *Fortnite* merchandise was also available through the brand's shop and website.

Balenciaga has also created its own separate business division, solely dedicated to the Metaverse and its future opportunities.

"The usability of digital fashion is the point that's missing, but that's making gigantic steps every day," said Balenciaga Chief Executive Cédric Charbit.[28]

Benefits

As the physical and digital worlds continue to merge, consumer brands are becoming increasingly entrenched in the Metaverse.

Some fashion brands are creating digital garments solely for virtual avatars, generating another source of revenue.

Brands can also leverage the Metaverse as a marketing/communication channel for real goods, engaging with a younger generation.

26 Shumba, Camomile. "Decentraland's Four-Day Metaverse Festival." *Business Insider Africa*, 30 November 2021.

27 "Lil Nas X Performs His First Virtual Concert on Roblox." BBC News, 16 November 2020.

28 Adegeest, Don-Alvin. "Balenciaga to Launch Metaverse Business Unit." Fashion United, 2 December 2021.

Creating, sharing, and monetizing assets and games

The Sandbox is a decentralized, community-driven virtual world, one of several blockchain-based virtual worlds attempting to change the dynamics of the gaming market and reward creators for the value they produce. The Sandbox is made up of three products:

- VoxEdit allows users to create and animate 3D objects in the Metaverse.
- Sandbox Marketplace is a venue in which users can publish and sell their assets.
- Sandbox Game Maker allows users to create 3D games for free.

Benefits

Virtual worlds enable companies to take part in the new economy by helping creators monetize their assets.

As one of the pioneers, the Sandbox has positioned itself as one of the most relevant virtual worlds.

It represents the convergence of different technological trends, including gaming, social media, blockchain, cryptocurrencies, mobile, 5G, AI, and cloud.

9 Education & training

Delivering immersive, effective training

Developed from work in the Stanford University Virtual Human Interaction Lab, Strivr's Immersive Learning solution offers VR-based training solutions covering areas such as operational efficiency, health and safety, customer service, and soft skills.

It aims to combine the sense of presence of VR with advanced learning theory, data science, and 3D design.

Benefits

According to Strivr, users have already seen the following benefits:[29]

- 96% reduction in pickup tower training at Walmart.
- 10% increase in customer satisfaction in less than six months at Fidelity.
- 97% of professionals felt prepared when put in dangerous situations at Verizon.

Facilitating and optimizing the operation, maintenance, and energy efficiency of buildings in real time

Universidad de Málaga has started to create a digital twin of a university building.

The digital twin will be composed of a 3D digital model of the building generated by BIM modeling tools, 3D laser scanning technique (LIDAR), along with all relevant information associated with the building components (including brands and models, manuals, technical data sheets, and supplier contacts).

The digital twin also integrates real-time environmental conditions for the building, such as occupancy, temperature, and humidity.

Benefits

The digital twin enables predictive maintenance, reducing costs and time; provides more accurate, deeper information for decision making; and will collect performance data from its sensors for energy-efficiency improvement.

29 Strivr.

10 Collaboration — Across enterprise Metaverse

A VR space for teams to connect, collaborate, and develop ideas together

Through its Horizon Workrooms, Meta envisages "a new kind of remote teamwork."[30]

The space enables people to come together to work in the same virtual room for meetings and workshops. It also aims to provide a virtual space for work colleagues to socialize or have conversations.

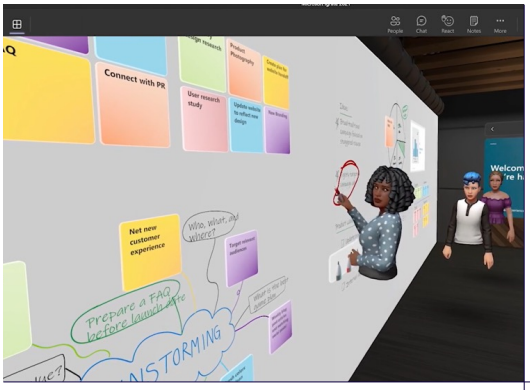
Users have the ability to bring their real keyboard and desk into VR, share the screen, access whiteboards, receive phone notifications, and see 2D apps in the screen.

Benefits

Advantages claimed include:

- Richer teamwork and collaboration with a better sense of presence than normal screen-based remote working.

Improving virtual meetings



Microsoft has developed the Mesh collaboration toolset with the aim of enabling its users to take virtual meetings one step further.

It claims to enable presence and shared experiences from anywhere — on any device — through MR applications.

Benefits

Mesh enables better, more natural virtual meetings and the ability to access the tool through a range of VR headsets, mobile phones, tablets, or PCs via any Mesh-enabled app.

30 Oculus.

APPENDIX 2

II. TECH-NOLOGY READINESS LEVELS

#2 Technology readiness levels

TRLs provide a commonly accepted means of describing technology maturity. They are referred to in Section II of the report with respect to the technology building blocks at each level of the Metaverse.

Pre-concept refinement	TRL 1	Basic principles are described or observed, at the theoretical or experimental stage.
	TRL 2	Technological concepts are formulated and not yet necessarily tested.
	TRL 3	Proof of concept is carried out in a laboratory, at the level of the technical process.
Concept refinement	TRL 4	Technology is validated in the laboratory as a whole.
Technology development	TRL 5	Technology model in a production-grade environment is created.
	TRL 6	Technology prototype is demonstrated in an environment representative of the intended use case.
System development and demo	TRL 7	Prototype is evaluated in an operational environment.
Production & deployment	TRL 8	Complete system has been evaluated and qualified.
	TRL 9	Complete system is operational and qualified in production.

Source: Arthur D. Little

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Blue Shift, by Arthur D. Little, explores the impact of technologies on business, society, and humans. The Blue Shift Report covers these topics in depth, inviting guest authors, academics, and artists to contribute to the conversation.

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