

UNDERSTANDING METAVERSE'S CORE TECHNOLOGIES

IN-DEPTH GUIDE

Table of Contents

INTRODUCTION	3
WHAT IS THE METAVERSE?	4
THIS E-ARTICLE	6
CASE STUDIES	7
METAVERSE ANNOUNCES MARKET SIZING REPORT	8
METAVERSE TECHNOLOGY SECTORS	10
Infrastructure	10
Creator Tools	10
Decentralization	10
User Interface and Experience	10
METAVERSE INFRASTRUCTURE	11
Connectivity and Networking	11
B and width	12
Latency	13
Connectivity Solutions	14
Computational Resources	15
Graphic Processing Units	15
Microelectronic Systems	16
METAVERSE CREATOR TOOLS	17
Game Engines	17
Live Services Suites	17
Virtual Worlds' Developments	18
Spatial Computing	18
SDKs and Developer Support	18
DECENTRALIZATION & INTEROPERABILITY	20
Decentralization	20
Artificial Intelligence	21

Interoperability	21
USER INTERFACE AND EXPERIENCE	22
Virtual Reality Headsets	23
Augmented Reality Headsets	23
Supporting Devices	24
Consoles	24
Smartwatches/ Trackers	24
Haptics	24
Neurotechnology	25
Virtual Worlds	25
1) Centralized Virtual Worlds	26
2) Decentralized Virtual Worlds	26
Addressable Markets within Virtual Worlds	26
Advertisement	26
Gaming	27
ECommerce & Exchange	27
Live Entertainment	27
INVESTMENT OPPORTUNITIES	28
Metaverse Tech Stocks	28
Private Metaverse Tech Companies	29
Direct Metaverse Investments	29
CONCLUSION	30
ABOUT METAVERSE INSIDER	30
DISCLAIMER	30
END NOTES	31

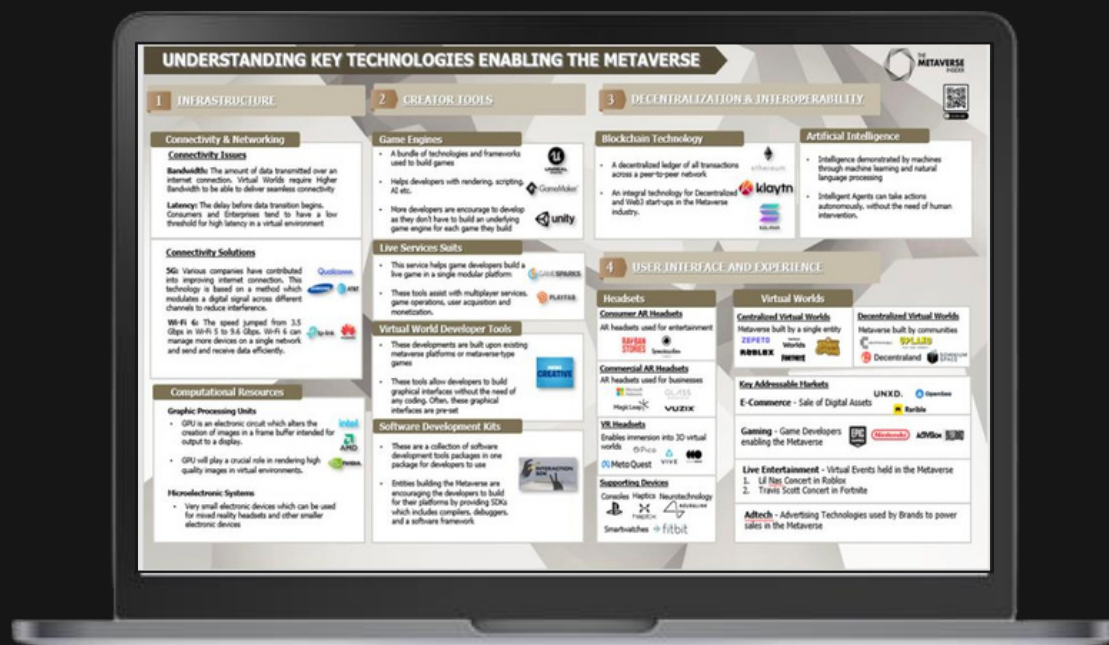
Author: Wazarat Ali Hussain, Market Intelligence Analyst
waz@metaverseinsider.tech

INTRODUCTION

The Metaverse is an abstract, hard-to-define concept. Is it the future online environments where humans will exist? Is it the crypto transactions that could underpin it or a combination of web3.0 and augmented reality? Or is it just multiplayer gaming with some additional features?

Rather than try and answer these questions, which we expect will naturally emerge over time, we at Metaverse Insider decided to focus on the emergent core Metaverse technologies that will likely make up a future Metaverse, irrespective of emergent business models and approaches.

This report was previously published as an article by the Metaverse Insider team. We have refined the information published in this paper and added data we have used to base our claims about the technologies being built to enable the Metaverse. The following infographic is Metaverse Insider's take on the set of technologies being developed for the Metaverse. These technologies are interdependent, and all must be developed for the Metaverse vision to be fulfilled.



WHAT IS THE METAVERSE?



To understand the technologies behind the Metaverse, we first need to understand what the Metaverse is. We will use Matthew Ball's definition from his book titled *The Metaverse: And How It Will Revolutionize Everything*, "A *massively scaled and interoperable network of real-time rendered 3D virtual worlds that can be experienced synchronously and persistently by an effectively unlimited number of users with an individual sense of presence, and with continuity of data, such as identity, history, entitlements, objects, communications, and payments.*"

Let's break down the main characteristics of the Metaverse as defined by Ball:

Massively scaled: The metaverse will become a huge part of the way most people experience their day to day lives.

Interoperable network: Different virtual worlds should be able to use and exchange information. For example, if a creator uses Ready Player Me to create a digital avatar, they should be able to use it in all virtual worlds and should not be confined to specific virtual worlds. An example from today would be a JPEG and PNG image. Users of both Mac OS and Windows can use these images.

Real time: The events in the metaverse should be processed consistently and without any lag. Seamless connectivity is the key to mass adoption.

3D worlds: A three-dimensional world can be measured in height, length, and width. While virtual worlds in the metaverse are not exclusive to 3D, it is a more immersive experience. With the rise of VR headsets, the popularity of more immersive 3D worlds will increase.

Experienced synchronously and persistently: All people in the same virtual environment should have the same experience continuously.

Unlimited number of users: A massively scaled metaverse should be accessible to everyone. There should be no limitations of how many people can be in a virtual world without any connectivity or networking issues.

Individual sense of presence: Everyone in the metaverse should have their unique identity. This can be through their digital avatars and decentralized identifiers.

Continuity of data: The data in the metaverse should have a complete path of flow. The data should be consistent between different devices and users.

THIS E-ARTICLE

This e-article will study the emergence of technologies which confirm this Metaverse description. In the following graphic, we attempt to signal the most important technologies powering the Metaverse and where they fit Ball's definition.

TECHNOLOGIES THAT FIT THE METAVERSE DEFINITION



	5G	Wi-Fi	GPUs	MEMs	Game Engines	Virtual Devs	Spatial Computing	SDKs	Blockchain	Artificial Intelligence	AR Technology	VR Technology	Virtual Worlds
Massively Scaled	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Interoperable network	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Real time	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
3D Worlds	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Experienced Synchronously and Persistently	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Unlimited number of users	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Individual sense of presence	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Continuity of data	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

yes
in-process
no

This report provides a guideline for understanding the critical technologies and their challenges in building the Metaverse and is based on Metaverse Insider's unique position to meet with the builders and changemakers as part of its study of a rapidly growing and adapting ecosystem.

CASE STUDIES

Before delving into each Metaverse technology section, it may be beneficial to do a quick overview of some news stories which have inspired us to explain the technologies behind the Metaverse being built. As the Metaverse continues to be built, even the most established tech giants seem to encounter challenges in realizing their vision for the Metaverse. Often, these enterprises face hurdles when attempting to develop their futuristic projects. Here are three prominent recent cases which should serve as informative examples:

1) Meta's Graphics: Meta (formerly Facebook) has made its intentions clear: be the market leader in the Metaverse. The social media company has invested substantially in building its vision for the Metaverse. With such a substantial investment by one of the world's biggest tech companies, many onlookers wondered why the graphics were subpar.i

2) OpenSea Hack: Blockchain Technology, Digital Assets, and Interoperability are undoubtedly Metaverse industry markets. OpenSea, a Y-Combinator startup, had established itself as a Digital Asset Exchange market leader. With many NFTs being hacked and ownerships illegally transferred, concerns about cybersecurity using blockchain technology have grown significantly.ii

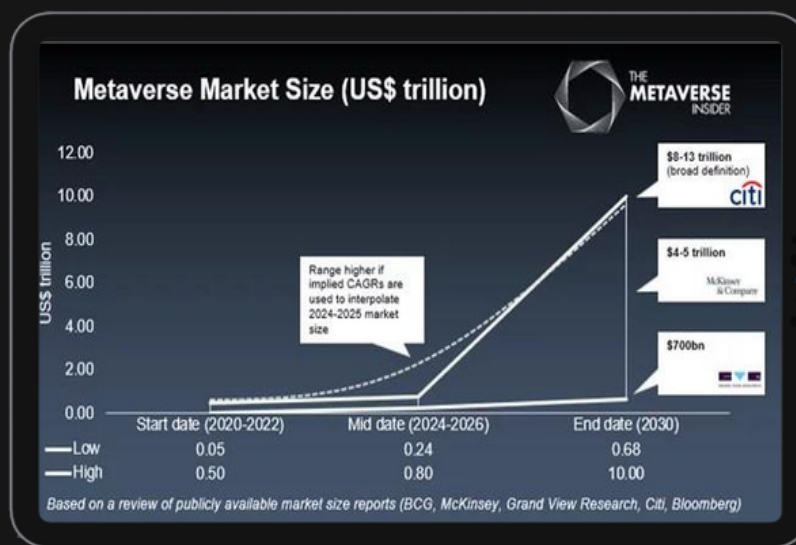
3) Epic Games vs. Apple lawsuit: In August 2020, Epic Games sued Apple for Apple's restrictions on the App store and charging a 30% revenue cut for every in-game purchase in the game Fortnite. Apple blocked the Fortnite game as Epic Games changed to bypass Apple, taking the 30% cut. Epic's CEO is one of the leading tech executives trying to position their companies towards the Metaverse and stresses making the Metaverse an open platform and not letting traditional tech companies have the control they've enjoyed in the Web 2.0 era. Sweeney famously said, "If one central company gains control of this, they will become more powerful than any government and be a god on Earth. What we want is not a company but a protocol that anyone can implement."iii

These hurdles faced by some of the biggest companies within the Metaverse industry have garnered media attention. Problems like these are caused because we are very early in the Metaverse development process. Blockchain and VR technologies are still underdeveloped which have caused companies like OpenSea and Meta certain negative media coverage. Meanwhile, tech giants like Apple and Epic Games have clashed as their vision on how business should be done in the metaverse is different. Here is Metaverse Insider's attempt in explaining which technologies effect the Metaverse the most. In doing so, we hope to help the reader gauge how the Metaverse will look like in the future.

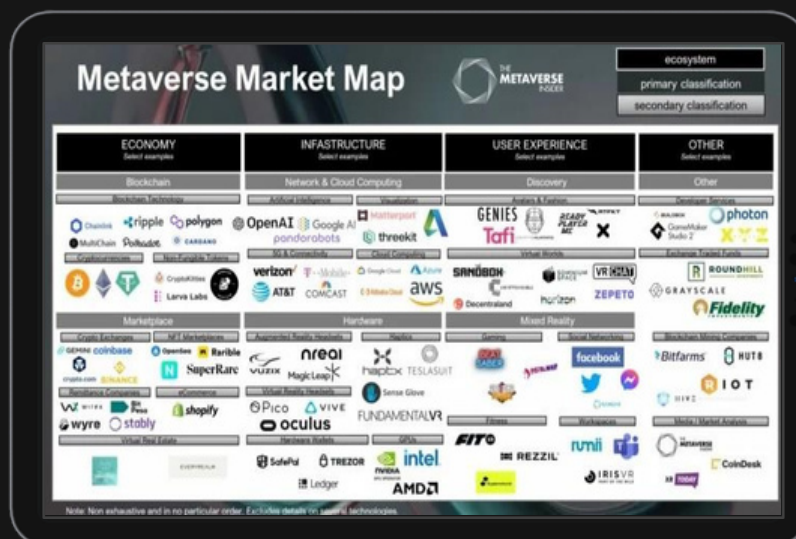
METaverse ANNOUNCES MARKET SIZING REPORT

Metaverse Insider released a report of Market Size of around \$6 Trillion by 2030. This Market Sizing Report is based on 1 year of extensive research by the Metaverse Insider team. The Metaverse Insider team studied the technologies which make up the Metaverse and their penetration rates in the industry.

We've studied and analyzed precedent Market Reports



We've Dissected the Metaverse Market Map





- The full Metaverse Market report is available for purchase and sponsorship**

Please reach out to us at waz@metaverseinsider.tech

or go to www.metaverseinsider.tech/reports

METaverse TECHNOLOGY SECTORS

If Tim Sweeney and many other Metaverse leaders are to be believed, the Metaverse industry should be interoperable without one definitive market leader. Here is the Metaverse Insider's take on the technologies which enable the Metaverse.

The Metaverse technologies are divided into the following four different sections:

Infrastructure: This section involves all the products and services on which the Metaverse is built.

Creator Tools: Utilizing the infrastructure, creator tools are created to help developers make the Metaverse.

Decentralization: Decentralization will prevent the Metaverse from being monopolized by one single entity.

User Interface and Experience: This is the Metaverse as a user experience it – all the products and services end users use to immerse themselves in the Metaverse.

This report will take a macro look into each section and learn about what each of these sections entails. Each section has different technologies and complications. This in-depth look will help expand upon the current limitations, provide possible future solutions, and mention which companies are providing these solutions.



METaverse INFRASTRUCTURE

Infrastructure is the first layer of Metaverse technology. These are the critical components that are the foundation of the Metaverse. We will investigate the hardware and network technology components essential for the Metaverse to become a reality.

Connectivity and Networking

Connectivity has become essential for education, business and even gaming. Popular games like Fortnite and Minecraft use about 100MB of data per hour. Moreover, virtual games require have larger virtual spaces and more features, which means more space and bandwidth for downloads. A newer game like Red Dead Redemption is a 105GB download. This is much higher than older multiple games like Dota2, which is a 15GB download. As virtual worlds become more complex, the need for bandwidth and space will significantly increase.

Virtual Worlds require high-speed networking for a seamless experience. 5G, the fifth generation of wireless technology, is often. It can provide higher speed, lower latency, and greater capacity than 4G LTE Networks. That means quicker downloads, much lower lag, and a significant impact on the Metaverse functions.



So why are features like higher speed, greater capacity, and lower latency crucial to powering the Metaverse?

To understand this, we need to understand Bandwidth and Latency. Bandwidth and Latency are the primary performance metrics for high-speed networking. For seamless networking, the higher the Bandwidth and lower the Latency, the better.

Bandwidth Bandwidth is the amount of data transferred over a defined period. In other words, it determines the amount of information that can be transmitted over a defined unit of time. It is referred to the capacity of a digital communications line, e.g., a gigabyte Ethernet connection delivers a bandwidth of 1000 Mbps. The higher the Bandwidth better the link for seamless connectivity.

For a virtual game like Fortnite to function, a live online game where players require data to be transferred fast from one point to another, significant Bandwidth is critical. In games like Fortnite, Call of Duty, and Halo Infinite, players tend to engage with each other online in maps which are often pre-downloaded. They are limited to specific actions which are often already downloaded in their systems, so they don't have to engage too much Bandwidth the number of preloaded actions increases, and the amount of Bandwidth that needs to be engaged increases as well. Thus, gamers must download game files before playing the game. The larger the game size, the larger the download that is needed. This prevents gamers from downloading data per hour (engaging Bandwidth while the gaming studios can control bandwidth usage for now). What happens when the virtual worlds become more extensive and more bandwidth usage is required?

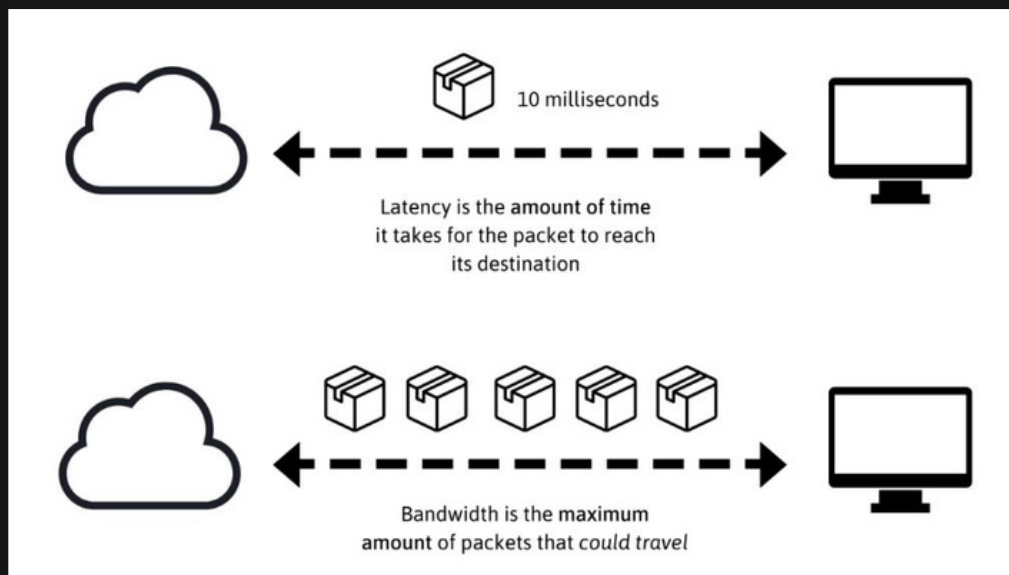
We can see these challenges already in live concerts in virtual worlds. Two such concerts are by Travis Scott in Fortnite and Lil Nas X on Roblox. Travis' concert had 27.7 million unique in-game participants. Moreover, an immersive XR platform, Wave experimented with a live concert with Justin Bieber. This concert was during the Covid-19 pandemic and thus, created a lot of news as people could not attend live events. These live concerts are a challenge as Bandwidth has to be managed. These live events require a stable internet connection which can manage live events. Despite its shortcomings, live virtual concerts were a significant achievement toward virtual events in the Metaverse. These events were only the beginning of how we can attend live concerts. Last year, during Connect 2021, Meta showed how live events could be in the future. In this demonstration, Meta showed how people will have a real-life event feel through the use of Mixed Reality. While live events held in the metaverse are mostly just digital avatars of artists singing in virtual reality, the potential of live events is so much more. However, fast bandwidth where data is transferred at a rapid rate is a prerequisite to holding these events. Connectivity issues remain at these events. While there are abundant live

events ideas by companies like Wave, Roblox, and Epic Games, these companies require innovations to help improve bandwidth as well. So far, these issues are still being tackled by traditional tech giants like AT&T and Samsung.

Latency

Latency is the delay before data transfer begins following an instruction for its transfer. The human threshold for Latency is incredibly low. An obvious example of this would be observing any gamer experiencing lag in an online multiplayer game. For virtual worlds, this problem would become colossal as businesses and governments will start to rely on this technology in a virtual environment. Many individuals interacting with their peers in a virtual environment would expect a seamless conversation. However, if an individual is conversing online and there is a constant lag, the experience will quickly become extremely unpleasant. Imagine having a conversation with someone in real life and there is a lag every time one talks or their voice is slightly delayed from their movement of their face. We often experience lag during online meetings. This lag would increase when there are more complications in a virtual environment (i.e. there will be more data to process when two digital avatars are talking in a 3D virtual world). The more interactive social networking becomes, the longer it will take for data to process; increasing latency.

This graphic by Networks Hardware explains the difference between Bandwidth and Latency.



Connectivity Solutions

As more and more experiences shift to the Metaverse, it will be critical to have seamless experiences with very high bandwidth and low latency. This is where technologies like 5G are crucial. 5G networks are said to have ultra-low Latency with around 20 ms. Starlink also offers ultra-low Latency through satellite internet as the problems of underground wires are eradicated. Satellite Internet solves the problem of Latency in many rural countries where the internet wiring is not present. This can be likened to mobile phones being present in many rural areas that never had telephones as they did not have the infrastructure for them.

Despite technologies such as Starlink and 5G being an important step toward achieving better connectivity, the issue has not been entirely fixed. For example, as augmented experiences become mainstream, even the smallest lags will be detrimental to adopting these technologies. If an individual is wearing an augmented glass, the reaction of any update in the eyeglass has to be as flawless as one's eye is for the experience to be natural. Thus, despite there being clear opportunities to fix Latency, there's still significant work to be done.

Networking is improving rapidly, but so is the need for higher Bandwidth and lower latency. For users to experience live entertainment and interact with each other in virtual and augmented environments, networks should be able to receive information at a rapid rate and without any delay.

The introductions of tech such as 5G and Wi-Fi 6 are essential to the growth of the Metaverse. These technologies assist with lower latency and higher Bandwidth. 5G is the fifth-generation technology standard for broadband cellular networks. In 5G, the ideal "air latency" is 8-12 milliseconds. The emergence of 5G has been spearheaded by many tech companies. For infrastructure, AT&T has been a clear leader in this space. The networking company was one of the first to test out 5G technology when they applied for an experimental license for 5G in Austin, TX. However, mobile companies like Samsung and Huawei have also contributed to the success of 5G as they allotted resources to R&D for 5G as early as 2011.

On the other hand, Wi-Fi 6 is a High-Efficiency Wi-Fi network that allows for seamless internet when one connects. Internet connectivity at home and offices increased significantly with the introduction of fibre-optics being used for internet connections. These cables become more resistance to interference, decreasing lag. Fibre has also been able to provide higher bandwidth than alternatives such as ADSL. However, Wi-Fi 6 is able to process the fibre connection by providing the internet connection. Like 5G technology, Huawei is also a leader in Wi-Fi 6 devices. These Wi-Fi 6 devices offered by the likes of Huawei and TP-Link support up to four times higher network bandwidth than previous WiFi

devices. This is critical for the Metaverse as the bigger the virtual worlds are, the more the bandwidth requirements will be.

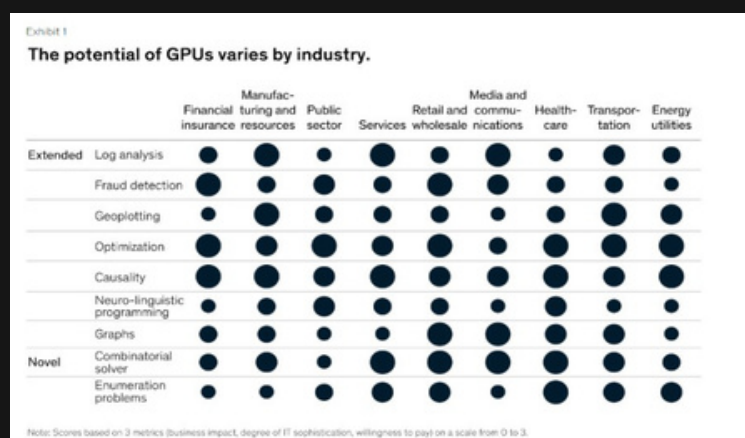
Computational Resources

The Metaverse faces challenges as technologies become more complex and the virtual worlds become larger. Developers require the Metaverse include large areas with a lot of moving parts. To achieve this feat, developers and users need great computational resources.

Graphic Processing Units

The graphic processing unit (GPU) is one of the most critical computer technologies that will power the Metaverse. Both developers and end users require a graphical processing unit for enhancing the graphics and video rendering. CPUs have a few cores while GPUs have many. Also, while CPUs do computations in serial form, GPUs do them in parallel. In simple terms, GPUs provide that extra bit of muscle that can help a program do more complex computations. This video by IBM explains GPUs and how they differ from CPUs.

Initially, the gaming industry was the most important customer of graphic processing units, but now they are becoming increasingly used in other computationally intensive areas such as Artificial Intelligence. McKinsey & Company researched some of the use cases of GPUs. Many different industries have use cases for GPUs.



A GPU should be able to compliment the Central Processing Unit (CPU) to deliver a performance which increases with the addition of cores.

Computational limits have evolved in the past few decades. A great way to observe this progression is by following the progression of PlayStation over the years. The original PlayStation, released in 1994, had no online multiplayer games, a system that in today's day could fit in a pocket, and 256×224 – 640×480 resolution. This system had a CD component so players could play games. Today, PlayStation 5 has a much faster GPU, with multiplayer games the norm, and the CD is optional as the system has enough storage to download games. However, currently, there is a requirement for better GPUs to power the Metaverse. With time, computational requirements have increased and devices have gotten smaller.

These GPUs are not just a requirement in the video gaming industry. In the Metaverse, GPUs will be required in finance, health care, machine learning, data science etc. Crypto mining has become popular too and is sped up by using GPUs. An alternative to having a physical silicon-based microprocessor is to have Cloud GPU providers. Almost all cloud services companies now provide this service, including Google Cloud and AWS.

Microelectronic Systems are a hardware which is used to increase computational power of Mobile Devices, Augmented Reality Headsets, and other smaller tech devices. These devices are made from semiconductor materials. As the functionality of headsets grows, MEMs will be essential for these products MEMs are electronic devices which utilize tiny, or micro, components to manufacture electronics. Explaining the challenges of building AR glasses on Meta's earnings call, CEO Mark Zuckerberg stressed that one of the hardest challenges will come down to fitting a supercomputer insider of a frame of glasses. MEMs will play a critical role in accomplishing the plans of Zuckerberg and other Mixed Reality headsets developers. The companies working for MEMs are XR headset developers and semiconductor companies such as Qualcomm and AMD. Qualcomm's Snapdragon XR2+ has been used the in the new Meta Quest Pro headset. As VR headsets advance, the semiconductor manufacturers will be asked to design harder MEMs and chips to power the metaverse.

METAVVERSE CREATOR TOOLS

Once, the Metaverse infrastructure is established, it is important to provide developers and investors with the tools which they can use to leverage that infrastructure. This layer of the Metaverse technology will include those tools which are being used by developers today.

Game Engines

All virtual environments that have any graphics require code. A tree, a gun, and a skin we purchase on Fortnite are all defined by lines of code. For all actions, movements, and features developers write code. The more complex the game gets, the more code must be registered. As virtual worlds become more complex, more regulation will be required and the bigger the development team will become. As we look at virtual worlds like Horizon Worlds from Meta, Roblox, and Decentraland become more complex and add more features, the more complicated it will become to create these experiences. An integral part of making these virtual worlds are Game Engines.

Game Engines are a bundle of technologies and frameworks that build a game, render it, process its logic, and manage its memory. Some features that a game engine allows a game creator (or a virtual world developer) to add include physics, input, rendering, scripting, collision detection, AI, etc. Previously, every game developed its rendering engines for one game only. However, with time games have gotten more complex and thus, rather than spending resources on a game engine, many developers tend to use commercially available game engines. It is helpful for game developers as they can work on multiple projects knowing only one or two game engines and their programs.

Two significant game engines today are Unreal Engine by Epic Games or Unity's Game Engine. However, there are other growing competitors in the market like The Godot Engine, AppGameKit, CryEngine etc. Each Game Engine has unique features which help developers decide which game engine they would like to build on. Examples of developers who use Unity Games Engine includes NASCAR Heat 5, PGA Tour 2K21, and Iron Man VR. Examples of games which use Unreal Engine include WWE 2K Battlegrounds, Time Machine VR, and The Walking Dead: Saints & Sinners. Factors that game developers use to decide which game engine they should pick includes which systems the game engines work on, the ease of programming, the cost etc.

Live Services Suites

The gaming engines developed, and another type of gaming solution for creators has also emerged called Live Services Suites. These services help game developers and creators make live games in a singular modular platform. These live services suites include PlayFab (Microsoft Azure), Gamesparks (Amazon), Live Game Development Platform (Unity), Steam, and Epic Online Services (Epic Games). Live Services Suites are a cheap option for game developers looking to build in the Metaverse.

Today, with the help of game engines, live services suites, and modern GPUs, many Web3 Games and Virtual Worlds are taking shape. These include Catheon Gaming and Gala Games. These gaming studios can leverage Live Services and Gaming Engines to develop Web3 games.

Virtual Worlds' Developments are also a part of the general purpose/cross-platform game engines enabling game creation. These virtual world developments require no actual coding. They allow developers to build experiences through graphical interfaces which are pre-set. Thus, these experiences require less investment of time and money. Some of the largest developments include Roblox, Minecraft, and Fornite Creative. These are already metaverse-type games which allow developers to create in their virtual environments and enhance user experiences. These virtual world developments have also enabled many existing companies to invest in the metaverse. Metaverse Insider's list of Fashion Brands investing in the Metaverse include many examples of fashion brands investing in these virtual worlds. For example, apparel giants like Nike, Forever 21, and Tommy Hilfiger have also invested in building their own personal space inside Roblox.

Spatial Computing is an emerging technology which digitizes activities of machines, people, objects etc. This technology has several use cases including enabling seamless interactions virtually and helping headsets understand surrounding environments. Businesses can use spatial computing to optimize design and operations. This is a great tool for augmented reality as it is an interface that can enable seamless transactions between processes. AR headsets' developers like Microsoft HoloLens and Magic Leap can benefit from Spatial computing advances. Thus, companies investing in VR and AR headsets are invested in Spatial computing including Meta, Snap, and Microsoft. As the industrial use cases of augmented reality grows, there will be more importance of a computational technology that can optimize complex workings within an environment by gaining a complete picture of movements. Spatial Computing is an important tool in enabling safety and efficiency in a virtual environment.

SDKs and Developer Support by organizations are an important aspect of creating services for the Metaverse too. For example, Meta has launched software development kits to help build Virtual Reality applications. Software development kits (SDKs) are a collection of development tools which facilitate the creation of applications. Organizations realize that many of these virtual worlds will need development support. SDKs used by developers to build applications will help bring traction to their platforms. There are also inhouse development in major tech companies to enable growth in the Metaverse. Google Labs has had a strong focus on WebVR, AR, and Artificial Intelligence. Google previously launched a AR eyeglasses, which are still on sale as an enterprise/commercial AR headset.

Creator Tools are vital to utilize the available infrastructure to expedite the growth of the Metaverse. Tools such as gaming engines, virtual reality developments, and Spatial Computing will help in the development and mass adoption.

A LIST OF COMPANIES CREATING THE METAVERSE

Company	Sector	Description
Unreal Engine	Game Engine	Unreal Engine is a 3D computer graphics game engine developed by Epic Games.
Unity	Game Engine	Unity is a cross-platform game engine developed by Unity Technologies.
Cry Engine	Game Engine	CryEngine is a game engine designed by the German game developer Crytek.
PlayFab	Live Services Suites	PlayFab enables developers to use the intelligent cloud to build and operate games, analyze gaming data and improve overall gaming experiences.
Gamesparks	Live Services Suites	GameSparks is a fully managed game backend service that makes it easier for you to build, optimize, and scale game backend features.
Minecraft	Virtual Worlds' Developments	Minecraft is a sandbox video game owned by Microsoft. It allows players to build experiences.
Roblox	Virtual Worlds' Developments	Roblox is an online game platform and game creation system used by many leading fashion brands to create digital experiences.

DECENTRALIZATION & INTEROPERABILITY

Decentralization may become an important aspect of the internet as the concepts of the Metaverse and Web3 get intertwined. Moreover, decentralization has seen more interest as the focus on cryptocurrencies grows, and governments begin to embrace / work with these emerging technologies. The most important technology behind the concept of decentralization is currently the blockchain.

The core of Blockchain Technology is the concept of a decentralized ledger. This technology can be used to keep records transparent in a decentralized environment. Transactional records (also known as blocks) are connected to each other and validated by peer-to-peer transactions. Transactions in a public blockchain can be seen by all users. Initially blockchain was used for a cryptocurrency called bitcoin. However, in 2013, Vitalik Buterin, co-founder of Ethereum realized that the technology could be built for much more. He and his peers created the Ethereum blockchain. Today, Ethereum blockchain is the most used blockchain among metaverse projects. The most popular virtual worlds today called Decentraland and The Sandbox are built upon the Ethereum blockchain.

Ideas such as Web3 were born to ensure that the tech industry is not confined to one big tech company. In Web 2.0 Facebook has monopolized the social media industry and Apple has become a clear leader in phones in North America. These companies not only have the largest sales in the market, today they have an unprecedented amount of data of all their users. There is a growing sentiment that decentralization can help prevent monopoly in the metaverse. In our case study of Apple vs Epic Games lawsuit, we have seen such a conflict that has risen. Epic Games clashed with Apple and Google as they did not agree with the thirty percent cut in all sales made on their phones. As the business model of Epic Games' Fortnite was based entirely on in-game purchases, the game developer did not appreciate giving away such a large part of their revenue. As we progress, issues such as these could arise in the metaverse too. Many fashion brands such as Adidas, Nike, and Gucci are have virtual spaces inside different metaverses. As these virtual spaces inside the metaverse begin to sell an increasing amount of digital assets (NFTs), conflicts can arise on the amount of revenue that will go to centralized metaverses such as Roblox.

However, this does not mean that the entire metaverse will need to be decentralized without any central authority. Certain central authorities will still be a part of these virtual worlds. Firstly, governments will still be able to regulate these virtual worlds and ensure that the metaverse does not become a hub for illegal activities. Moreover, centralized tech companies will still be needed to power the metaverse. For example, blockchain maybe fully decentralized, but the information will need to be stored. Cloud computing platforms such as AWS and Alibaba Cloud have already begun providing blockchain services on their servers.

Artificial Intelligence can be used to assist decentralization in the Metaverse as well. The concept of automating processes through machine learning can be helpful as it will eliminate the need for human intervention for many of the processes. It is a model that allows for isolation of processing without the aggregate of knowledge within one entity. Artificial Intelligence which should allow the computers to have the ability to control certain processes without human intervention will accelerate the growth of decentralization in the Metaverse. Natural Language Processing, Speech Recognition software and machine learning are all leading to a decentralized AI that can help power the Metaverse.

Interoperability is an important aspect in enabling the Metaverse as users acquire digital assets. This is the most complex part of the Metaverse as companies like Nike acquire RTFKT. As Nike and other similar clothing brands release NFTs, buyers would want them to be used in various virtual worlds. If Nike sells a digital sneaker, users may be able to wear those sneakers in select virtual worlds like Roblox (since Nikeland is a part of Roblox). But what about the virtual worlds where Nike is not a part of. Similarly, Adidas has land in the Sandbox and launch their own Metaverse projected called Into the Metaverse. Thus, user may be able to use Adidas digital products in these metaverses but may be unable to wear them in Roblox. Also, the user would not want to purchase the same product twice. A player would not want to purchase an Adidas product in The Sandbox and the same digital asset in Adidas' own metaverse. Thus, these digital assets must be interoperable. In the Internet Era, there are certain generally accepted formats used by all operating systems e.g JPEG and PPT. These are interoperable files. The challenge that the Metaverse Industry faces is to have generally accepted virtual products. this is a challenge that can be tackled by the current metaverse developers like Juego Studios and Crucible. These organizations can help build virtual items which can be used in multiple virtual worlds.

USER INTERFACE AND EXPERIENCE

Headsets are considered essential to enter the Metaverse. Currently, there are two types of hardware technologies that are being built to enable the Metaverse, including

- 1) Virtual Reality Technology
- 2) Augmented Reality Technology



The Metaverse Insider team testing the newly released Meta Quest Pro

Virtual Reality Headsets caught the attention of the mainstream tech world when companies like Meta and Google started releasing their versions of VR headsets in 2014. Google released its Cardboard project in 2014 and even released a Cardboard SDK to start developing their VR headsets. The device that Google released was Viewer, a \$15 foldout cardboard that users could insert their phones into to view VR applications. The same year, Meta acquired Oculus, A VR headset company which was released two years prior with a Kickstarter campaign. Oculus has been a significant success for Meta as it takes a substantial lead in the VR headset space. Due to Meta's Quest 2, sales of VR headsets have grown significantly. The sales have been mainly to consumers.

Augmented Reality Headsets allow users to view images superimposed into the natural environment. They differ from VR headsets, which immerse the user entirely in a virtual environment. AR headsets have a lot of commercial use as well as users, companies, and governments leverage headsets like Microsoft's HoloLens for construction, healthcare, manufacturing and education.

However, there are also AR headsets used by consumers like Snap's Spectacles. Meta also partnered with Ray-Ban to produce its eyeglasses, which take pictures and videos. While these are glasses which cost between USD 350 to USD 500, the potential of AR headsets is still unrealized as many of these headsets' potential has not been realized. With time, we will continue to see where the AR consumer headset market progresses. The potential for AR remains limitless with Meta investing in Project Nazare to build the next generation of Augmented Reality technology. As things stand, the realization of AR headsets is much farther than Virtual reality headsets.



However, to make Metaverse a genuinely immersive experience, we see other hardware technologies that are affecting the Metaverse. Here are some other devices that will support the Metaverse.

Supporting Devices: The following are the supporting equipment – considered to enhance the Metaverse experience.

Consoles: Zuckerberg said that our most complex technology. Currently, AR/VR headsets face a significant challenge of fitting cameras, GPUs and other hardware into a VR headset. One way to combat this issue is with the use of consoles. PlayStation uses virtual reality headsets to power VR games but also requires the use of the PlayStation console. This eliminates the need to fit a lot of computational power into a small device like a VR headset. Using a console which powers the VR headset will make it easier to fit in the computational power required by a 3D virtual world that can house an unlimited number of users. However, a downside to using a console's computational power will be the location restriction. Users will only be able to use the VR headsets when they are near the console.

Smartwatches/Trackers: Smartwatches and Fitness trackers have already gained popularity with products like Apple Watch and Fitbit. These devices are considered a supporting part of the Metaverse as they assist in helping keep track of the user even when they may not have a headset on. Trackers and Smartwatches are a significant part of the Health and Fitness applications as users like to keep track of their fitness throughout the day and not just when they are working out.

Haptics: Haptic Technology or “3D touch” applies vibration, forces, or motions for users to feel like they are in the virtual environment. This technology may be essential for total immersion in the gaming environment. This level of technology is currently a part of the gaming industry. While full haptic suits or even haptic gloves are not widely used, video game players will experience vibrations on their controllers. Companies such as HaptX are working on ensuring that haptics is the future of the Metaverse.



Testing HaptX haptics gloves at Economist Impact's Metaverse Summit in San Jose

Neurotechnology: Neurotechnology is perhaps the most futuristic supporting device of the VR headset. Neurotechnology refers to the electronic devices that interface with the nervous system to monitor or moderate neural activity. Neuralink is a famous example – developing ultra-high bandwidth brain-machine interfaces to connect humans and computers with a diverse team of engineers. Like Neuralink, all neurotechnology startups seem to be in the R&D stage and have not become commercially available.

Virtual Worlds: Having understood all layers of the Metaverse, The last layer of the value chain is the Virtual World itself. These virtual worlds result from great computational power, seamless networks and developers. They can be built independently by different creators. These virtual worlds include Roblox, Second Life, Horizon, Decentraland and The Sandbox.

Let's look at how virtual worlds seem to differ from one another:

- 1) **Centralized Virtual Worlds:** These are virtual worlds owned by one organization. These virtual worlds seem more user-friendly and have better graphics and experiences because they are built by traditional Web 2.0 companies with more capital and resources. Examples include Roblox and Horizon by Meta.



- 2) **Decentralized Virtual Worlds:** With the rapid growth of blockchain technology and Web3, the concept of a Decentralized virtual world has gained popularity as the tide against traditional virtual worlds grows. These virtual worlds allow users to build out their own experiences and can own land in these virtual worlds. Since decentralization is a newer concept, the graphics may not be as advanced, and experiences may not be well built. Example of Decentralized virtual worlds is Decentraland and The Sandbox.

Addressable Markets within Virtual Worlds:

What are these virtual worlds there are specific addressable markets within the value chain:

Advertisement: As virtual worlds develop rapidly, traditional brands and institutions seem to be rushing to make their mark in the Metaverse. This has resulted in many financial institutions and retail brands in making a mark in the Metaverse by purchasing virtual land and setting up their businesses on the Web3. For now, these virtual experiences in the Metaverse are considered an advertisement tool rather than a place for conducting business.

Gaming: With Integrated Virtual World Platforms, we can see that many Metaverse-type games allow creators to build their own gaming experiences. Minecraft and Roblox are examples of Metaverse type games where the game allows users to create their own experiences. These games also have their own in-game currencies too.

ECommerce & Exchange: ECommerce is a vast industry with a massive rise during the Covid-19 pandemic. Moreover, digital exchanges have become an enormous part of the Metaverse too as buyers purchased NFTs and crypto. These payment rails and financial transactions are also part of the metaverse virtual worlds.

Live Entertainment: Live Entertainment is a new concept in the Metaverse. Live Events are complex as computational complexities described earlier prevent many people from being in the same virtual space simultaneously. However, as these virtual worlds grow, there will be more live events held in the Metaverse.

INVESTMENT OPPORTUNITIES

There are apparent investment opportunities in the Metaverse technologies. According to the Metaverse Insider, this industry will be more than a 5.5 trillion-dollar market in 2030. Early in this investment means one has to bet which companies will solve the most significant technological challenges in the Metaverse. Metaverse infrastructure company, Improbable recently raised \$100M at a \$3B+ Valuation. Similarly, Ready Player Me, a digital avatar company that promises to integrate interoperability, raised \$56 million. Despite a bear crypto market, investment in the Metaverse has continued, and we believe certain investment opportunities can be attractive to those looking to invest in the Metaverse. However, with the recent collapse of crypto giants, FTX, we expect less VC investments in this sector in the near future. But we will talk about which enabling technologies could be great sectors to look into investors instead of Blockchain and Crypto. This is not financial advice; it is just our observation of the opportunities we believe are appealing.

Here are some of the top Metaverse tech investment opportunities:

Metaverse Tech Stocks

While there are a lot of new startups driving the Metaverse, certain Web 2.0 giants are ensuring they are not left behind. Facebook has made its intentions clear by changing its company name to Meta. Sales have proven that they are the clear leaders in VR headsets sales. Microsoft is also keen on extending their services to the Metaverse. Their Minecraft and Activision Blizzard acquisitions clearly indicate that the company wants to serve the multiplayer gaming community. Recently Microsoft CEO Satya Nadella also made an appearance at Meta's Connect 2022 event to announce the collaboration of Microsoft Teams with Meta. Unsurprisingly, public companies are dominating the technologies requiring a lot of investment. Thus, the infrastructure sector is heavily dominated by public companies. 5G and Wi-Fi 6 required an intensive amount of R&D. Huawei and AT&T have established themselves as market leaders in this space. Metaverse ETFs are also becoming increasingly popular. Many of these ETFs have covered the metaverse markets well. Check out this article to learn about Metaverse ETFs

Private Metaverse Tech Companies

Private Capital in the form of Private Equity and VC funds has been flowing very well in the Metaverse. In 2021, many significant startups received funding to build out the Metaverse. Technologies where we have noticed a lot of private Capital are blockchain and virtual worlds. Startups powering these virtual worlds are attracting private Capital. Digital Avatars, an integral part of the Metaverse, attract many investors. Genies and Ready Player Me are digital avatar startups which have raised funds to power the Metaverse. These avatar startups are working towards a decentralized interoperable virtual world – a theme popular amongst metaverse investors. Newer technologies continue to get the bulk of private capital as they create new markets within the Metaverse.

Direct Metaverse Investments

A unique feature of the Metaverse is that there seems to be a new investment class emerging. Rather than investing in tech companies that power the Metaverse, companies can invest in the Metaverse. One popular way is to purchase virtual land within a decentralized Metaverse, such as The Sandbox and Decentraland. Many established companies, such as Adidas and celebrities like Snoop Dogg, have purchased virtual land. The idea is that as more people begin to spend time in the Metaverse and the land value will increase.

Moreover, investors can hire developers to develop their virtual space. These virtual developments can be experiences that can help generate revenue.

If you're interested in keeping up with the capital markets news, follow our press releases page, which covers all significant investments flowing to the Metaverse

CONCLUSION

According to our study, the four layers and their sublayers of the Metaverse make up the technologies required to build the metaverse. Did we miss any significant technology that should be included? If you have any feedback, please reach out to the author at waz@metaverseinsider.tech.

ABOUT METAVERSE INSIDER

Founded in 2021, Metaverse Insider is the leading provider of news and information on the Metaverse industry. It was developed by our team who acted to address the gap in the market for quality media and market analysis in the emerging metaverse and web 3.0 space. Metaverse Insider also helps organizations in this space to promote their business. For more information, please visit www.metaverseinsider.tech

To contact the author, please email: waz@metaverseinsider.tech

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END NOTES

ⁱ <https://decrypt.co/108201/after-177-billion-in-investment-why-do-metaverse-graphics-still-suck>

ⁱⁱ <https://www.theverge.com/2022/2/20/22943228/opensea-phishing-hack-smart-contract-bug-stolen-nft>

ⁱⁱⁱ <https://appleinsider.com/articles/20/08/23/apple-versus-epic-games-fortnite-app-store-saga----the-story-so-far>
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