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THE METAVERSE
COMING TO A DEVICE NEAR YOU.
SOON.

DECEMBER 2022

CONTENTS
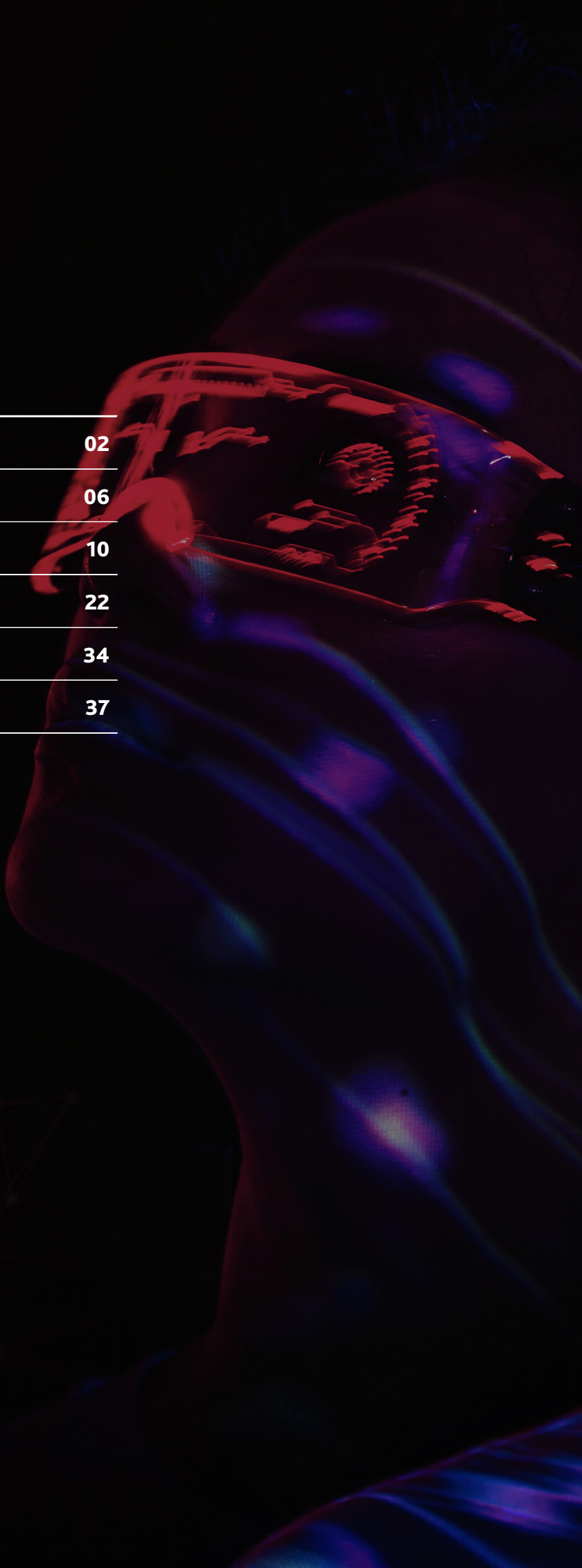
FOREWORD

We've all heard of the metaverse in some context or another, but few of us can articulate clearly what it is or what it has the potential to be. Although there is a growing body of papers and articles on the topic, much of it either assumes a pre-existing level of knowledge or takes a specific angle or point of view, such as a financial focus or a gaming focus. This paper has been written for the layperson to help disentangle the facts from the fiction, the present realities from the future potential. We have also taken a generalist approach and assumed little or no previous knowledge on the topic (other than assuming our readers are familiar with the internet and the use of smartphones to access the internet today).

We begin our paper with a general introduction to the metaverse and provide our definition of what the metaverse means in clear and simple language. We also provide a view of what the economic value of the metaverse will be to the economy in the not-too-distant future. To bring the somewhat, albeit necessarily, clinical definition to life, we then continue by telling a story – a Day in the Life of an imaginary character set in 2033 when we are confident the metaverse will have reached something much closer to its full potential than we see today.

Armed with a clearer understanding of what the metaverse is and what it has the potential to become, we then discuss the obstacles that exist in terms of the technology needed to make this vision a reality and consider how those obstacles are likely to be overcome over the next few years. To support this view,

we then look at case studies of entrepreneurial businesses that are delivering the next wave of innovation in the metaverse across a diverse range of technologies and capabilities and, where the data is available, we look at the valuations those businesses are achieving, in many cases within one or two years of being established.

Finally, we leave the reader with our ideas for future-proofing their business in the context of what the metaverse might mean to them (whether as an opportunity or a threat, although we believe it will be more of the former).

We hope you will find this paper both insightful and helpful in navigating this rapidly emerging brave new world, and that it will provide you with a level of understanding as well as a framework with which to explore further.

Jonathan Rowan
London, December 2022

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1. WHAT IS THE METAVERSE?

INTRODUCTION

It was October 2021 when Mark Zuckerberg announced the rebranding of Facebook's parent company (which also owns other apps including Instagram and WhatsApp) to Meta and outlined his plans to build a metaverse as the "successor of the mobile internet". Since then, the metaverse is being mentioned everywhere, albeit with varying definitions of what the metaverse actually is or will be. One of the most referenced depictions of the metaverse is from the novel (and Stephen Spielberg movie of the same name) Ready Player One, but in fact this presents only a narrow interpretation of the metaverse as a world that is engaged with exclusively using a virtual reality (VR) headset.

Despite the recent surge in references to the metaverse, the origins of the word date back to 1992, when the term "Metaverse" was coined by the author Neal Stephenson in his novel Snow Crash to describe a virtual world sitting alongside the real world. To some extent fictional accounts, presented in Snow Crash and various subsequent works, such as those have contributed to a degree of confusion as to the precise meaning of the term today. Ironically, this means the confusion that exists around the metaverse, which is in some senses a blurring of the boundaries between the physical and the virtual world, is at least in part due to the blurring of definitions of the metaverse between the worlds of fiction and fact.

🖓

*If you want to define the 'proto-metaverse',
we already have it, it's called the internet.*

DANIEL COLAIANNI

CHIEF EXECUTIVE
aixr.org

DEFINITION

To solve this confusion, and for the purposes of this paper at least, we define the Metaverse based on a set of criteria which need to be met, specifically that it:

▶ Has the ability to allow users to interact, work, play, create, and engage in commerce, simulations, or other activities

▶ Provides an immersive experience for users (and therefore may, but need not necessarily, be accessed through Virtual Reality (VR) headsets)

▶ Has the ability to integrate both the virtual and the physical world (for example through the use of Augmented Reality (AR) or Mixed Reality (MR))

▶ Has the ability to include connections between the physical and digital worlds (for example through digital twins being used to safely control smart buildings, crowds, traffic, and many other physical world situations)

However, it should be noted that as with all new and developing technologies, what the metaverse is today, and what it will be in a few years' time are quite different. Our definition above stands for now and for the foreseeable future, although in the context of the metaverse, the foreseeable future may be quite short.
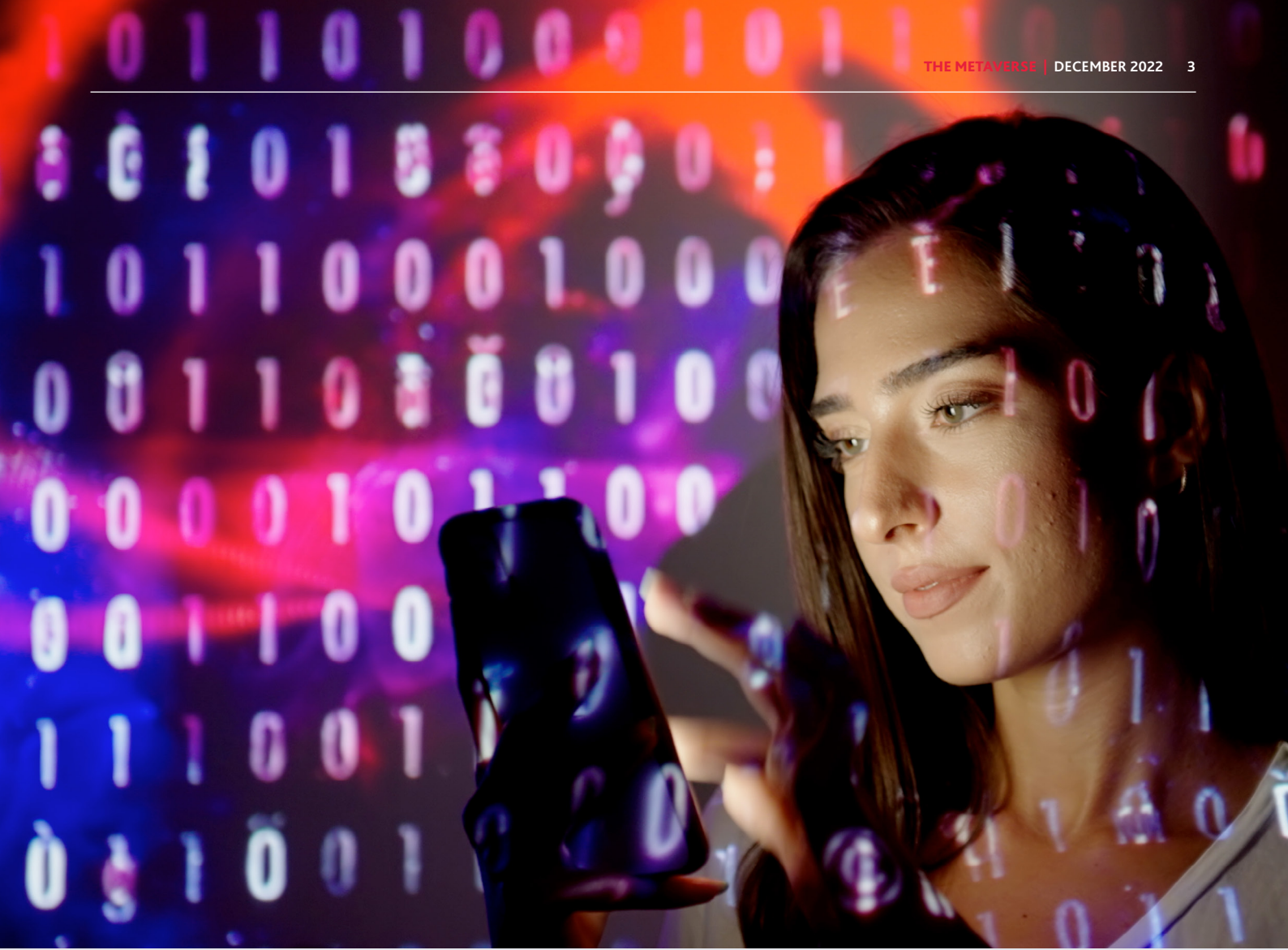
In addition to the above criteria, for 'a' metaverse (or as we refer to it a Metaverse World) to become part of 'the' Metaverse, we need interoperability between metaverse worlds. We have metaverse worlds, such as Decentraland or Second Life, which already, to some extent, meet many of the criteria listed above, but until those metaverse worlds are genuinely and seamlessly interoperable we will not have the Metaverse in its truest sense.

Accessing the Metaverse in future will not be exclusively through VR headsets as some of the narrower definitions suggest, but as an evolution of the internet (and particularly the mobile internet) as we know it today. The metaverse will, over time, be accessed through many different devices including laptops and desktop computers, smartphones, Smart Glasses or Lenses, ear buds, Smart Watches, VR Headsets and a plethora of smart devices and appliances in home, office, retail, leisure and entertainment environments. While we may consider the internet to be ubiquitous today, the Metaverse will surpass it in terms of ubiquity (while having the potential to be less intrusive) due to the wide variety of means to access and interact with it.

Coming back to today's Metaverse, we currently have as ituation that is far from a single interoperable metaverse but is made up of many diverse and disparate metaverse worlds. Users must either choose the metaverse would they prefer or complete multiple registrations and engage with multiple metaverse worlds, with no transfer of data or information between those relatively rudimentary worlds.

The concept of the metaverse has been around for decades, but why is it being talked about so much now? Basically, the building blocks of the metaverse, the physical enablers (the devices and bandwidth), the virtual enablers (blockchain, NFTs and cryptocurrencies) and the platforms themselves (metaverse worlds) have all developed to a point where (relatively simple) metaverse worlds are emerging.

A similar situation took place with the development of smart phones, a device that few of us can live without today. All the individual components to make a Smartphone such as the touch screen display, Lithium-ion battery, System-on-a-Chip, Storage, Camera, Modems, Sensors, and Speakers all existed to a good standard in separate devices prior to the advent of the smartphone. What Apple did in developing the iPhone which launched in January 2007 was to put these components together in a convenient form. A similar situation therefore needs to take place with the metaverse to create another 'revolutionary and magical product' as the iPhone was described by Steve Jobs when unveiled, although in this case, each of the components also needs to evolve as we discuss in Chapter 3.

VALUE

To a certain extent, we now understand what the metaverse is and what it is likely to become, but given the confusion over definitions, it is not surprising that there is also a very wide range of estimates of what the metaverse will be worth in terms of economic value in the future.

Many industry observers and analysts have attempted to estimate the potential future value of the metaverse, and depending on the definition the values range considerably, but all are of globally significant scale. Citi, in their report "Metaverse and Money: Decrypting the Future" published in March 2022, highlight the two extremes through two separate definitions and associated valuations. In their 'narrow' view, based on accessing the metaverse exclusively through VR headsets, they value the metaverse at USD 1-2 trillion in 2030. Taking the broader view (as espoused by Mark Zuckerberg, with the metaverse seen as the evolution of mobile internet) the value is estimated to be USD 8-13 trillion in 2030. Most other estimates fall somewhere between these two extremes, with various estimates at USD 5 trillion, USD 8 trillion and so on depending on definitions and scope[1]. Of course, at such levels the precise quantum is broadly irrelevant – the key message is that the metaverse will be huge and, even with a narrow definition, will have a material impact on global eCommerce, gaming and entertainment (at the very least).

Our view is that the Metaverse should be considered as a natural and inevitable evolution of the internet today, and that everything we currently do on the internet (and much more) will, over time, migrate to metaverse worlds for a more immersive, interactive and personalised experience. On this basis we expect the metaverse to replace existing sales channels for retail (from eCommerce websites, social media and even leading eCommerce storefronts) and so for our estimate of the value of the metaverse we have looked at eCommerce growth and market size as a proxy.

eCommerce growth, which was already impressive prior to the pandemic, saw an even more dramatic increase during the various lockdowns around the world since early 2020. In the US, just 4.2% of retail sales were online in Q1 2010 and by Q1 2019 that had grown to 10.5%. However, by Q2 2020 that figure had increased significantly to 16.1%, and there is no sign of the trend reversing post pandemic. In fact, the trend is expected to further continue, with eMarketer forecasting that by 2030 nearly 30% of US retail sales will be conducted online[2].

Extrapolating that figure to a global market (and we expect metaverse penetration to develop rapidly in currently underserved markets with a resulting rapid growth in eCommerce in those markets) we expect a USD 11.6 trillion global eCommerce market by 2030, with a material proportion of that figure being procured through metaverse (as opposed to conventional eCommerce) channels by that time.

While it may seem farfetched today to equate the value of the metaverse with general eCommerce, we believe the migration of eCommerce to metaverse worlds is already happening (as we will see later in this paper) and that by 2030 most eCommerce will be conducted in what we today consider to be the Metaverse. This view is supported by the evidence of a population level behavioural shift as highlighted by a few key statistics[3]:

► **67%** of Millennials (Gen Y) prefer eCommerce to traditional retail
► **56%** of Gen X prefer shopping online
► **41%** of Baby Boomers share that opinion
► **28%** of senior citizens have made the switch

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[1] mckinsey.com | Value Creation in the Metaverse | June 2022,
bitcoin.com | Goldman Sachs Sees the Metaverse as $8 Trillion Opportunity | January 2022,
morganstanley.com | Metaverse: More Evolutionary than Revolutionary? | February 2022
[2] xsellco.com | Retail vs Ecommerce: Can Traditional Retailers Compete in 2021?
[3] businesswire.com | BigCommerce Survey Shows Americans Consider Online Shopping Essential | June 2016

Considering that Gen Z, the most digitally native generation yet, have already begun reaching maturity and will see their spending power as a proportion of the total economy rise over the coming years, the view that 30% of retail sales will be through eCommerce by 2030 starts to seem more reasonable. Beyond 2030, some analysts[4] are even suggesting that up to 95% of the global retail market will be happening online by 2040, and given the anticipated seamlessness between online and real world environments, that might not be so farfetched either.

If, on top of retail eCommerce, we add other use cases of the Metaverse such as education and training, healthcare, virtual spaces/communities, concerts and gaming, smart manufacturing, virtual smart cities and so on, perhaps the more pertinent question becomes "what percentage of the global economy will not be addressable through the metaverse". Our view is that the broader Citi estimate of the metaverse referenced above, valuing the global market at USD 8 to 13 trillion in 2030 is realistic.

So, in summary, the metaverse is going to be big and it is going to be everywhere. While it may seem an ethereal concept to many people at present it will soon be influencing all our lives in a multitude of different ways, as we will find out.

To begin that journey of discovery, and to try and bring the Metaverse of the future to life, we attempt to describe a typical (metaverse enabled and empowered) day in the life of an ordinary person in 2033 in the next chapter.

Most companies ... understand that this is not going to be an instant gold mine. They are looking for much longer term.

DANIEL COLAIANNI
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67%
OF MILLENNIALS (GEN Y) PREFER ECOMMERCE TO TRADITIONAL RETAIL

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OF GEN X PREFER SHOPPING ONLINE

41%
OF BABY BOOMERS SHARE THAT OPINION

28%
OF SENIOR CITIZENS HAVE MADE THE SWITCH

[4] nasdaq.com | UK Online Shopping and E-Commerce Statistics for 2017 | March 2017

2. A (METAVERSE) DAY IN THE LIFE (IN 2033)

To help develop a better understanding of the metaverse, we have invented a fictional character, Bella Ashley and we will describe a typical day in Bella's life in 2033. Born in 2000, Bella is 32 on the (imaginary) day in question. A typical Gen Z, Bella is a true digital native and has never known a world without technology at her fingertips (the iPhone was launched when Bella was just 6 years old). Bella is a history teacher at a local High School and is married to George. Bella and George have two children, a daughter aged 7 and a son aged 4.

THURSDAY 28TH APRIL 2033

07:00 TO 09:00

Beep-beep-beep-beep, Bella opens one eye to see the alarm clock marking 07:10 and smiles, grateful for those extra 10 minutes that the planner AI has given her after assessing the lighter than normal traffic; her mood improves further with anticipation triggered by the smell of coffee that automatically started brewing a couple of minutes ago in the kitchen.

The activities of the previous evening ended a bit late, and Bella didn't think much about what to wear for the following day when she was going to bed. So she calls up her online mirror. The augmented reality mirror suggests this is already the time of the year for a woollen cardigan and her favourite boots, and even if it's too dark for Bella to see out the window, the weather forecast highlighted in the corner of the mirror seems to justify the turtleneck and recommends a bead necklace to accessorise.

The digital twin of the contents of Bella's jewellery box appears in the mirror but does not have quite the right necklace for this outfit, so Bella quickly visits an online jewellery store and finds the perfect accessory in moments. Her choice will not be delivered until later that morning, but she will have it for the evening and in any case her avatar will be able to wear it immediately as the NFT token is delivered with the purchase.

The rest of the family is already up and getting ready for their days, so Bella says goodbye to them. George will wait for the autonomous school bus to pick up the children for school before he gets in their self-driving car and attends a meeting while on his way to the office. Bella leaves the house to go to work at a school across town, while confirming through her watch directly to the family coffee machine that the new Indonesian coffee beans sample was great, and to please buy enough for the rest of the month.

As Bella is waiting for the driverless bus, scrolling thorough the headlines on her smart glasses; a pop-up message from the house pings up in her field of vision. It's just for information: George and the children have left some lights on at home, but the domestic AI system has turned them off and ensured the house is safely locked up. Sitting down on the bus, Bella takes the opportunity to drop into the digital twin of her home and check that everything is in order, that the robotic vacuum cleaners are cleaning the floors unobstructed, and the appliances are each doing what they are meant to do.

As she has a 40-minute bus ride to work, Bella decides that instead of looking outside, she is going to "go full in" and get a proper review of the news. She gets her VR headset out of her bag and pops it on. The Morning Show is a great program, Bella thinks, and it's so much better to sit here among the audience experiencing the debate directly.

A gentle buzz of increasing intensity prompts Bella to remove her VR headset. Her stop is next, and after a short walk in the still crisp morning air, the warmer air of the building and the teachers' room is welcome, as is the smell of the freshly brewed coffee, even if there is no smart barista at the school.

09:00 TO 11:00

There is a sense of anticipation and a little nervousness in today's senior teachers' meeting. The face on head teacher Mrs Thomson's avatar is quite composed but the body language that is conveyed from the motion capture sensors gives away her nervousness to those that know her.

Today can be particularly tricky, not because of the mixed classes with the French and German schools, Mrs Thomson is already used to those, but because of an impending inspection by the Department for Education. The team assure her there is no need to be nervous as the AI teaching assistants have been recently upgraded, the new edge datacentre located in an old telephone exchange near the school is now online and has a direct fibre optic connection with the school and everybody has the right data at their fingertips ready for their interview as part of the inspection.

Next up is a History lecture. One of the highlights of the syllabus this year is today's virtual tour of a First World War battlefield conducted jointly with students from French and German schools. Thankfully it was agreed in advance that the olfactory features would not be switched on in the trenches, as the smell, while realistic, would have been awful. The artillery shells exploding nearby are terrifyingly realistic and are right at the limit of system's safety settings, as the moving visuals and shaking of the VR headsets can be disorienting.

The shelling ends and the programmed sequence lifts the students over the field, now eerily silent, until the sound of trench whistles blowing send the class into action again. It's so important that we don't forget, and this experience really brings home the horrors and realities of war for these students. Later, the teachers' and students' avatars huddle in a bunker to discuss the lessons learnt from the experience, over some Red Cross-replica chocolate drinks distributed in the classrooms. After the graphic history lesson everyone is glad to leave the metaverse while realising how lucky they are to be in 2033 and not 1916.

It's now time for a 10:00 meeting with schoolteachers (from this school and other national schools) to discuss changes to next year's history syllabus. Bella is very happy to be engaging with fellow history teachers (both old friends and new faces) in the metaverse symposium.

11:00 TO 14:00

Break at 11:00 provides the perfect opportunity to ensure the reception of a package at home. Once more achieved through her home's digital twin, Bella is able to complete the remote acceptance of a drone-delivered parcel. As the parcel (containing the new necklace) enters her home, the associated NFT certificate is downloaded, and so it immediately becomes available in the digital twin of her jewellery box as well.

Now Bella can see the students walking back towards the class from the changing rooms, all wearing their Haptic Suits. Time for Bella to get changed as well as she is covering a biology class for a colleague next.

At 11:15, the biology class has just settled down. For today's special class, they are putting on their VR Headsets and switching on the receptors of their Haptic Suits, connecting them wirelessly to the headsets so that the settings on the suits match their virtual environment. Bella is at her desk and flips the switch that connects the headsets to her computer screen. From here, she connects the whole class to the metaverse learning environment (jointly hosted by the Department for Education and the NHS). She and her students are welcomed as guests in the virtual hall. The students can join a VR session taking place in the digestive and respiratory systems of a seagull. This is a relatively new method of learning about the impacts of both medicine and plastic pollution in a more immersive way, witnessing the causes of illnesses and the effects of their treatments first-hand. Students travel through the body of a seagull, very much like one would go through the halls of a museum, but in this case looking specifically at how immunity against avian flu was achieved not long ago and at the impact of plastic pollution on sea birds. The class travels inside the body and is taken deeper, "decreasing" in size to reach the blood vessels. Bella and her students can feel the palpitations of the coursing blood in the fibres of their suits, the rhythmic but faster thumping of the bird's heart clearly audible. Many students realise that birds do cough when they suddenly feel thrusts through their Haptic Suits, the blood pumping stronger in the veins as the seagull reacts to the virus. From here, they see now how the white blood cells go about engulfing the virus-infected cells and destroying them. After the session finishes, the class debrief highlights the value of such immersive sessions and Bella reflects on the incredible capability of the Metaverse to bring learning experiences to life.

Afterwards, Bella enjoys her lunch break and is comforted to learn, according to the augmented reality readings, that the meal she has is well balanced from a protein / carbohydrate / fat perspective. Bella gets a visual and audible reminder through her Smart Glasses to limit her lunchtime calorie intake since dinner in the evening is going to be a bit special. Her personal AI assistant suggests she synchs with the eating plans of other family members for the next few days and suggests a few options for balanced menus.

14:00 TO 17:00

The 14:00 class is probably the most creative class of the day. It is the time for the Digitalization project, where students will conduct research, then design and proceed to NFT minting of items, working on architecture, landscaping, and other metaverse creation activities. As one of the younger members of the faculty (and therefore a digital native) Bella has volunteered to take this class. She enjoys guiding the students in their choice of material and designs for clothing, armour, food recipes, architecture, and tapestry design for a medieval castle set in 12th Century England.

Some of the older students focus on a more complex and advanced topic. Running in the same metaverse as the school's castle, it's time to study the topic of sociology and politics in the Middle Ages. Bella thoroughly enjoys overseeing the older students' clever AI programming of the behaviour of mediaeval avatars. She encourages the students to consider a wide range of factors in their work such as the superstitions of the time, the effects of the feudal system, contemporaneous attitudes towards work and leisure and distrust of strangers: the level of sophistication in the resulting avatars is incredible and they certainly help develop a deeper understanding of historical themes, generating a positive and unforgettable learning experience.

At 16:00 it's time already for the commute home. As she is in a hurry, Bella has ordered an autonomous taxi with the passenger exercise bike option. It's definitely safer to cycle inside the vehicle without having to mind the traffic. If on top of everything she can burn a few calories and catch up on the TV series that everyone has been watching, well that's an efficient use of commuting time!

17:00 TO 22:00

17:00 and Bella is at home with the family. George is getting the children's dinner ready while Bella prepares for their friends to arrive for a games night which is due to start around 19:00. While dressing she uses her AR Smart Glasses to check up on her children. She sees that her son is enjoying engaging with a virtual reality White Rabbit from Alice in Wonderland who is reinforcing the lesson from school that morning on how to read a watch. Then she checks in on her daughter and finds herself in the old familiar halls of Hogwarts where Professor Snape is assessing the chemistry formulas of the science revision class. The metaverse simulation shows the test tubes bubbling satisfactorily and she's happy that her daughter is engaged in the class and having fun while learning.

The guests arrive soon after 19:00. There are two couples who are joining physically and one couple joining through the metaverse. The holographic projections of Jim and Stephanie, who are joining from their home hundreds of miles away using their Haptic Suits and VR Headsets appears in the room via everyone's Smart Glasses as an AR overlay. Having live and interactive conversations with a group that is a mix of physically present and virtual/remote has been taken for granted for some time now.

It's not just nice to be able to see and interact with Jim and Stephanie, but it's also quite amazing how the movement trackers in the living room can replay the three physical couples into the metaverse digital twin of the setting that Jim and Stephanie are sitting in. The household AIs have already synced up to ensure that the same cheeses and wines have reached Jim and Stephanie in advance of the evening. The focus for the evening is an online board game that all the friends enjoy playing together, and with glasses and nibbles in hand, the game can begin. The metaverse-based 3D board is perfectly synchronised for all the players, irrespective of location and appears on the tabletop in Bella's home in front of the physical guests at the same time it does in the digital twin version for Jim and Stephanie. The game goes well and is enjoyed by everyone – Jim and Stephanie are very happy that they have been able to be part of the evening despite the physical distance between them and the other players. It's so much easier to stay in touch with old friends these days.

Bella takes a break from the game to put her son to bed. Reading bedtime stories synched with holographic projections, music and sound effects is not just fun, but also wonderfully effective. Her daughter interrupts the story to ask for permission to buy content to play with her friends (a game pass for the season plus some game items and their associated NFTs). Bella checks the age appropriateness and authorises the transactions through her glasses.

With the children settled, Bella gets back to the game evening and is delighted when she and George win the final round. Before long the game is over and after both real and virtual hugs all round, the guests depart. Bella sees the time in the corner of her vision: it's just after 22:00 and with work the next day, it's time to call it a night. Once in bed, Bella picks up her book, reads a chapter, and senses more than notices how the home AI fades the lights as it starts that comforting humming to synch with her circadian rhythms and lure her into sleep.

All this may look very futuristic, but it has been imagined based on technology that is already commercially available or in reasonably advanced stages of R&D. If one thinks of the changes we have managed in the last fifteen to thirty years, and the effect of Moore's Law (processing power doubles every 18 months), it does not appear too farfetched. In fact, some of the enablers of the vision depicted above are already there or are maturing rapidly.

So: how do we build the metaverse?

3.BUILDING THE METAVERSE FROM FICTION TO FACT

Armed with a better understanding of what the metaverse will be in the future, and how it will inevitably be a pervasive feature in all our lives (just as the internet already is for most of us); we now turn our attention to how today's fiction will become tomorrow's fact. To facilitate this discussion, we have developed a simple model, separating the building blocks of the Metaverse into four main categories which we will consider in turn. Our model is presented below:
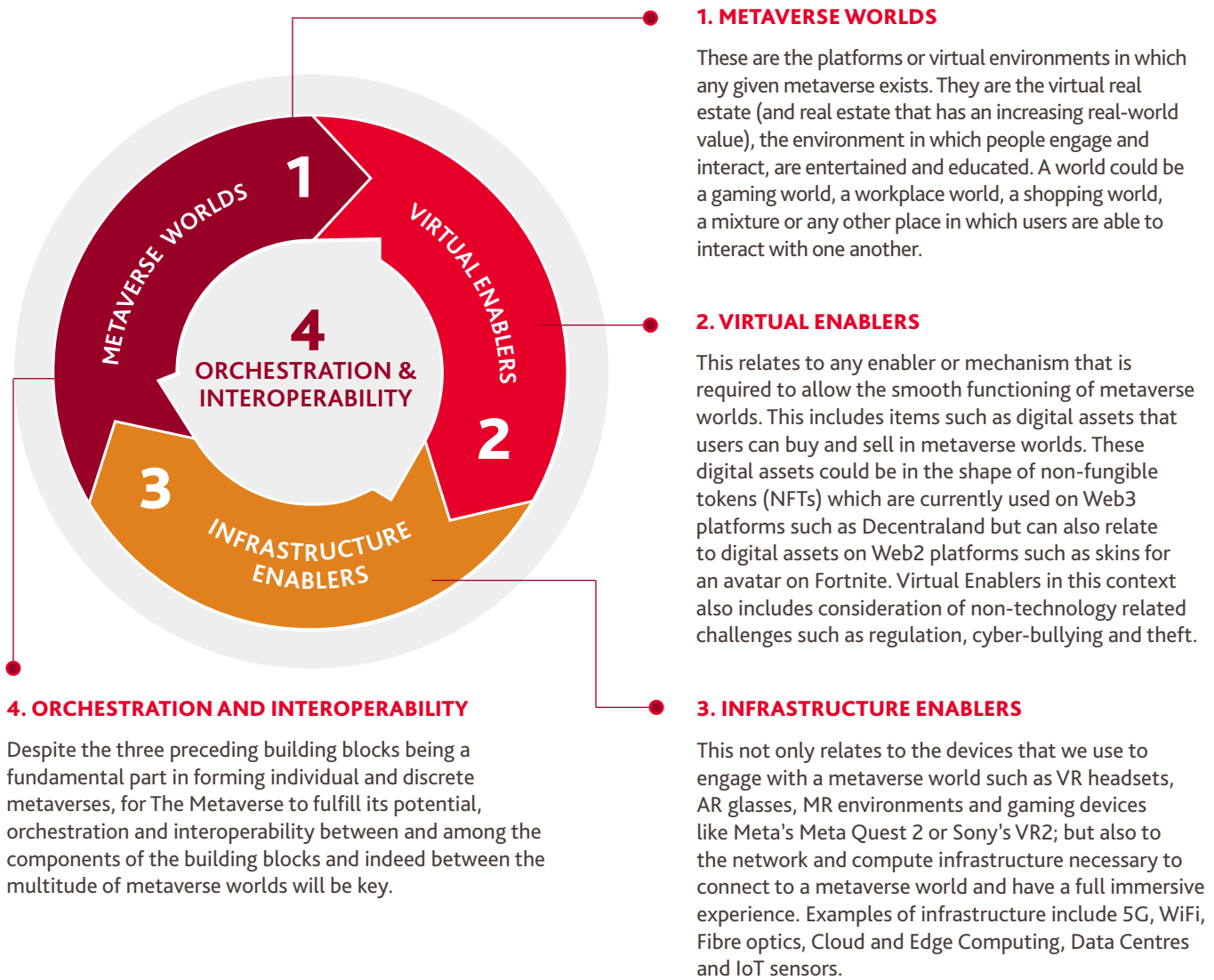
1. METAVERSE WORLDS

These are the platforms or virtual environments in which any given metaverse exists. They are the virtual real estate (and real estate that has an increasing real-world value), the environment in which people engage and interact, are entertained and educated. A world could be a gaming world, a workplace world, a shopping world, a mixture or any other place in which users are able to interact with one another.

2. VIRTUAL ENABLERS

This relates to any enabler or mechanism that is required to allow the smooth functioning of metaverse worlds. This includes items such as digital assets that users can buy and sell in metaverse worlds. These digital assets could be in the shape of non-fungible tokens (NFTs) which are currently used on Web3 platforms such as Decentraland but can also relate to digital assets on Web2 platforms such as skins for an avatar on Fortnite. Virtual Enablers in this context also includes consideration of non-technology related challenges such as regulation, cyber-bullying and theft.

4. ORCHESTRATION AND INTEROPERABILITY

Despite the three preceding building blocks being a fundamental part in forming individual and discrete metaverses, for The Metaverse to fulfill its potential, orchestration and interoperability between and among the components of the building blocks and indeed between the multitude of metaverse worlds will be key.

3. INFRASTRUCTURE ENABLERS

This not only relates to the devices that we use to engage with a metaverse world such as VR headsets, AR glasses, MR environments and gaming devices like Meta's Meta Quest 2 or Sony's VR2; but also to the network and compute infrastructure necessary to connect to a metaverse world and have a full immersive experience. Examples of infrastructure include 5G, WiFi, Fibre optics, Cloud and Edge Computing, Data Centres and IoT sensors.

Each of these four main building blocks of The Metaverse will now be considered in terms of maturity and development.

Metaverse worlds
maturity assessment

low   medium   high

1. METERVERSE WORLDS

Online worlds have been with us for some time. Going back to the telnet chat servers with purely text-based graphics or ASCII art, through MMORPGs such as World of Warcraft, to today's GPUs and Physics Engines-powered environments like Roblox, Fortnite and Decentraland. Given this rapid and ongoing evolution, the question is: when does a world cease to be an online world as we generally understand it today and become a metaverse world?

Expanding on our general Metaverse definition presented in Chapter 1, we suggest that to be defined as a metaverse world, an online environment should have the following six characteristics:

1 REAL WORLD FEATURES AND INSTANCES
Continuous; non-pausing and resetting; consistent with seamless interoperability (even if not yet interoperable); multiple individuals, business and objects running simultaneously in parallel. The possibility to run certain parts of the metaverse for simulation purposes.

2 IMMERSIVE
Highly involved and interactive experiences spanning both the physical and digital worlds

3 FUNCTIONING ECONOMY
Participants can create, own, buy and sell physical and digital assets and services

4 MULTIPLE CONTRIBUTORS
Independent, commercial and non-commercially focused

5 REALITY MAPPING
Possible connection to IoT sensors and actuators from real-life (e.g. one could open up a security gate in the real world from the metaverse/digital twin of the building)

6 ADEQUATE POLICING
Adequate policies in place for a secure and safe environment for all users
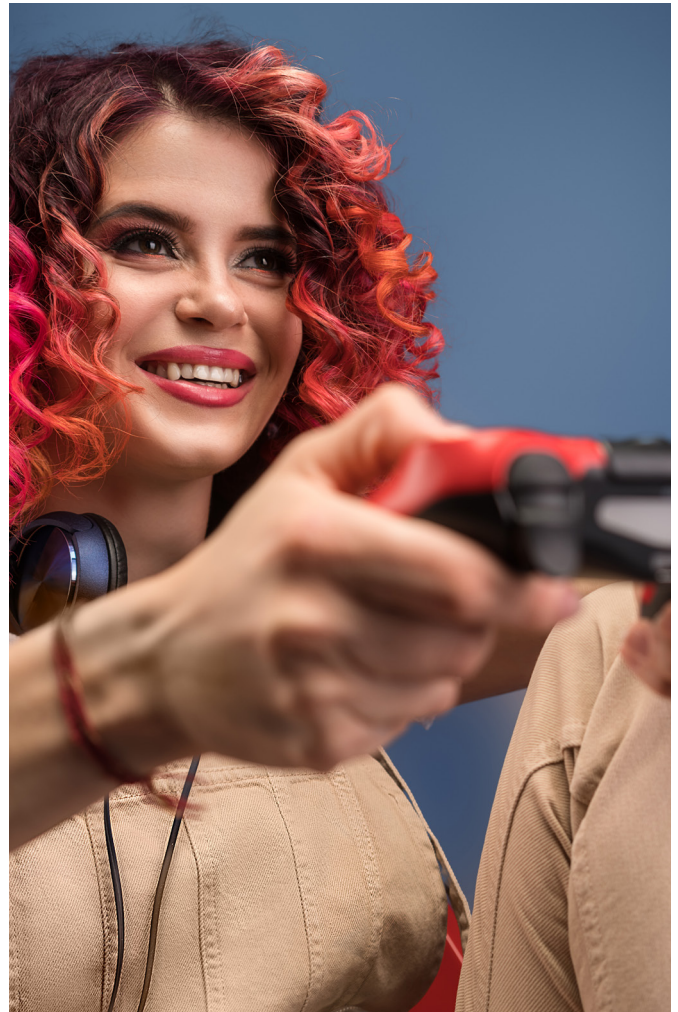
Recent advances in 3D creation tools and physics engines (such as Unreal Engine 5, formally launched earlier in 2022) have been significant. Gaming platforms such as Fortnite are now able to produce avatars and worlds of the highest quality thanks to these advances. What this means in practical terms is that the technology to develop photorealistic metaverse worlds already exists.

Such developments are part of the rationale for the proposed acquisition of Activision Blizzard for nearly USD 70bn by Microsoft in early 2022. This acquisition, if permitted, will allow Microsoft to leverage Activision's technology to create high quality metaverse worlds.

As the Metaverse will be so much more than 3D gaming, it is worth considering some examples of non-gaming applications for metaverse worlds:

▶ **HEALTHCARE**: In a metaverse healthcare world, platforms could allow doctors to train all around the world, improve their skills and accelerate training and familiarisation with new equipment. Companies like Osso VR have already developed a platform which enables surgeons to interact with medical devices in VR and practice surgery on virtual bodies, helping to increase familiarity with new devices and proficiency in implanting them.

▶ **TOURISM**: Through being in a metaverse world, users would be able to travel all around the world for a fraction of the cost and hence the ability to travel and explore would be more accessible for everyone. Current developments include RobotLAB Inc.'s VR Expeditions 2.0 that have found a new way to make tourism more accessible, with hundreds of virtual field trips available. From Rome's Colosseum to coral reefs, and the surface of Mars, users can travel the world (and beyond) from the comfort of their own home or classroom.

▶ **EDUCATION**, learning and development: Just like tourism, an educational metaverse world will allow students from all over the world to sit in a virtual classroom together learning the same things. Therefore, in theory, regardless of your background, everyone would be able to have access to high quality education. Companies such as Victory XR has partnered with Engage to provide digital twin campuses to enable students to learn in live, interactive classes from some of the brightest minds in the world.

▶ **MANUFACTURING**: Digital twins (effectively a small metaverse world replicating a specific real-world environment) can be applied to buildings such as factories or industrial plants. Examples of this already exist such as NVIDIA and BMW collaborating to create digital twins of 31 factories. These digital twins allow BMW to identify any points of failure, to maximise output through finding more efficient ways of production (such as improved automation) and to identify sophisticated cost saving options.

In general, the potential of metaverse worlds is almost limitless and they will facilitate a multitude of use cases which will create both tangible and intangible value to business and society as well as providing an engaging way to interact that is more personal and intimate than current online interactions.

MATURITY

Despite the fact that the worlds that currently exist are only really related to gaming and social activities, the fact that the technological capabilities exist to produce high-quality worlds leads us to believe that the maturity to build these platforms with varying use cases is quite advanced.

However, as mentioned previously, the technology being available is not enough. It is up to companies/organisations to ensure that the technologies are used optimally to produce use cases that generate real value. Only once we see the technology being leveraged to provide a wide variety of use-cases will metaverse worlds be able to achieve their potential.

Virtual Enablers
maturity assessment

low   medium   high
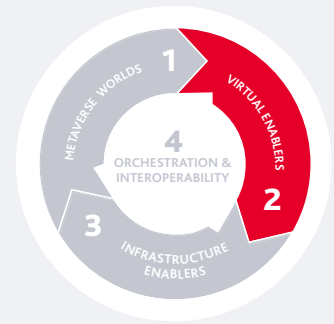
2. VIRTUAL ENABLERS

When we discuss virtual enablers as a building block, we refer to any mechanics, mechanisms or other virtual enablers that are required for metaverse worlds to operate in a way that closely resembles the real world. For example, for a metaverse world to feel like a 'world', a fully functioning digital economy will be required and therefore purchase mechanisms will be necessary.

Currently, any money spent in one digital world does not create a transferable asset. The average Fortnite player spends USD 84.67 in the game each year[5]. This is relatively small compared to their likely other outgoings, and the money is spent knowing it has no value outside the game.

When the metaverse world becomes a place to socialise and work then it is likely that a proportion of clothing outlay will go towards having a well-dressed avatar. Recent analysis shows adults between 25 and 45 spend in the region of USD 2,000 a year on clothing[6]. Some of that will inevitably migrate to digital wear. It will migrate more comprehensively depending on the level of interoperability between metaverse worlds, so that a physical new shirt can be worn to the office, even if originally purchased in a metaverse world as a digital version.

In this section we discuss what we consider to be the four key virtual enablers, specifically:

▶ Digital Asset Ownership and NFTs
▶ Smart Contracts
▶ Virtual Currencies
▶ Regulation and Policing

2.a. DIGITAL ASSET OWNERSHIP AND NFTS

Digital assets, for the purposes of this paper, refer to any assets that can be purchased in a metaverse world. Examples of such assets include anything from clothes or accessories for your avatar to virtual plots of land or interior decorations for your virtual house.

In mature metaverse worlds we expect to see the ownership of digital assets being managed using non-fungible tokens (NFTs). NFTs are basically the legally binding deed of ownership of an asset (which can be either a physical asset like a painting, or a digital asset such as a piece of digital art). To gain a better understanding of the use of NFTs it is first important to consider the meaning of 'non-fungible' and 'tokens' separately.

Non-fungible means something that is unique and is unable to be replaced with something else. For example, diamonds are not fungible as each diamond is unique with a different cut, colour, size, grade etc. On the other hand, cash is fungible as any given dollar bill can easily be replaced with another dollar bill of the same value.

The 'token' element in NFTs relates to the fact that a token, containing the data of the ownership of the asset, is placed in a blockchain where it cannot be changed or deleted and forms a permanent record of ownership (until such time as the asset in question is legally sold in which case the NFT is transferred). An NFT can only have one owner at a time and through blockchain technology and each token's unique data, ownership can easily be verified and traced.

Despite the robust characteristics of NFTs as a purchase and ownership mechanism for digital assets, they are not without critics. Currently, NFTs and their associated projects are in its early stages and hence the sector is not very liquid. There has also been a high level of volatility in 2022 with NFTs. For example, in July 2022, the average price of an NFT sale has decreased rapidly, by 92% since the beginning of May 2022, falling from USD 3,894 to USD 293[7]. Such volatility is the characteristic of an immature market, and far greater stability will be required before we can consider NFTs as a stable option. Another challenge for NFTs is that the problem of replica items exists just as in the real world. Although the original token can be traced on the blockchain network, there are no barriers to stop someone creating an electronic image of the digital asset (such as a digital image), attaching a token to it and selling it on a virtual marketplace. As a result, adequate regulations and policing will be required to mitigate this risk.

While NFTs are generally the preferred mechanism in a Web3 environment, Web2 platforms often use alternative approaches whereby digital assets are leased within the platform. An issue with these digital assets is that they remain on the platform and therefore you will no longer have access to these assets if the platform, for whatever reason, ceased to exist. Another issue is that there is an inability to trace ownership. However, there is less volatility in these assets compared to NFTs.

If metaverse worlds continue to be built on Web2 platforms, and no advancements are made in combining Web2 and Web3 technology, then the purchase of digital assets in this form may be the only viable option.

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[5] lendedu.com | The Finances of Fortnite: How Much Are People Spending on This Game? | April 2020

[6] creditdonkey.com | Average Cost of Clothing Per Month Will Surprise You | February 2021

[7] investmentmonitor.ai | The NFT market has collapsed (but that may not be a bad thing) | August 2022

The ideal scenario would be for Web2 based metaverse worlds to also incorporate Web3 based technologies such as NFTs but it remains to be seen if there will be NFT collaborations between Web2 and Web3 organisations to make this a reality.

In our view, the maturity of digital assets and tokens such as NFT's and other in-game assets is medium as despite the volatility, there are already many established projects with many big brands getting involved. For example, Nike has already generated USD 185m in NFT revenue[8]. Other in-game digital assets have also been around for a long time and are well-established.

2.b SMART AND DIGITAL CONTRACTS

When purchasing assets above a nominal value in the real world there is usually a contract in place to record the transfer of ownership. For example, contracts are made and signed when one is purchasing a house. The same principle applies when one is purchasing a digital asset.

In Web3, a mechanism called smart contracts is used. A smart contract is a self-executing contract with the terms of the agreement between buyer and seller being directly written into lines of code. The code and the agreements contained therein exist across a distributed, decentralised blockchain. The code controls the execution, and transactions are trackable and irreversible. Smart contracts permit trusted transactions and agreements to be carried out among disparate, anonymous parties without the need for a central authority, legal system, or external enforcement.

This, in theory, is a strong mechanism to use for the transfer in ownership of assets and eliminates the need for any third-party involvement leading to a secure and smooth transaction between parties. However, this is not currently the case. The need for traditional legal and financial institutions will still be necessary, as smart contracts are immutable and do not offer any form of flexibility which is required in the real world. Therefore, institutions are likely to step in when there is a level of complexity in the terms and conditions of a contract. For example, if plots of land are rented out by a metaverse user, the details of the smart contract may need to be discussed with a law firm to discuss and incorporate what tenants can and cannot do etc. An ordinary coder may be unable to write complex contracts as they are not, generally, legally trained.

For metaverse worlds built on Web2 platforms, instead of smart contracts, digital contracts or e-contracts tend to be used. These are amendable, unlike smart contracts, and therefore allow for a greater level of flexibility. However, there is a lack of automation in these contracts so that execution of the contracts still needs a degree of manual intervention which adds both cost and time to the process.

If the issues revolving around smart contracts can be fixed, an ideal solution, and one that has been a recurring theme so far in this paper, is the potential for integration of Web2 and Web3 technologies and the ability to use smart contracts on Web2 platforms.

From a maturity perspective, although Ethereum, the worlds' first smart contract platform went live in 2015 and companies have already started to adopt this technology (e.g. Blockchain start-up Propy using smart contracts to allow users to buy and sell real-estate[9]), there is currently limited legal regulation for enforcement of smart contracts. At the same time, there is a high dependence on programmers and there is therefore a risk of coding errors and vulnerabilities. For example, in April 2022, the highly anticipated non fungible token (NFT) project Akutars was marred by both an exploit and a bug, causing over 11,500 Ether (ETH), worth nearly USD 33 million at the time, to be locked forever within a smart contract, inaccessible even to the development team[10]. So while the concept is strong the issues in this area mean that we consider it to be relatively immature at this stage.

2.c. VIRTUAL CURRENCIES

To purchase digital assets, each user will need virtual currencies, just like using real money to buy physical assets.

Virtual currencies can be in the form of a cryptocurrency. This is a digital currency in which transactions are verified and records maintained by a decentralised system using cryptography, rather than by a centralised authority. All transactions are stored on the blockchain and therefore just like NFTs, ownership of these assets can be tracked and verified. To help distinguish the terms, cryptocurrencies are a type of virtual currency, but not all virtual currencies are cryptocurrencies.

Each metaverse world may develop its own cryptocurrency such as Decentraland having the currency MANA or The Sandbox having the currency SAND; or it may use one of the existing cryptocurrencies such as Ethereum.

In either case, cryptocurrencies, and the crypto-wallets in which they are stored, are extremely secure using private key technology and all Web3-based metaverse worlds are likely to have cryptocurrencies as their primary mechanism to facilitate their digital economy. However, just like NFTs there is still a high risk of volatility with cryptocurrencies. Greater stability is required for cryptocurrencies to be able to underpin a mature Metaverse.

An alternative to cryptocurrencies as a payment mechanism could be the concept of in-game currencies such as Robux for Roblox. This is currently the only viable option for any metaverse worlds built on Web2 platforms in the absence of greater integration of Web2 and Web3. Whilst there is less volatility in these in-platform currencies, it is currently more difficult to sell any excess currency that you may have, as opposed to cryptocurrencies which could be sold on any crypto exchange. Another fundamental issue of Web2 platforms and their associated currencies are the level of security risks in the form of hacking and theft. More than two in five (42%) UK gamers have experienced a cyber-attack targeting their gaming account or device according to a study from NortonLifeLock in 2021[11]. This issue would need to be resolved if users are to have confidence that their virtual currencies would be secure and hence be willing to store money in virtual wallets. This

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[8] binance.com | Despite crypto winter Nike NFT revenue exceeds $185 | August 2022

[9] medium.com | 5 Companies Already Brilliantly Using Smart Contracts | March 2018

[10] cointelegraph.com | AkuDreams dev team locks up $33M due to smart contract bug | April 2022

[11] infosecurity-magazine.com | 42% of UK Gamers Have Experienced a Cyber-Attack on Their Account or Device | November 2021

further illustrates the need for there to be increased integration between the Web2 and Web3.

Despite the volatility, maturity in this area is relatively high in our view, since there are already a lot of well-established cryptocurrencies and in-game currencies and therefore the relevant mechanisms are present to create robust virtual currencies for metaverse worlds. Significant challenges remain, however, including interoperability of virtual currencies in the form of an exchange rate mechanism or central marketplace.

2.d. REGULATION AND POLICING

Whilst payment and purchase mechanisms are fundamental in creating a strong and sustainable digital economy, these are not the only mechanisms that are relevant.

The fact that metaverse worlds will imitate the real world and be an extension of today's internet means that all the (anti) social issues that currently exist in both the real world and on current social media and gaming platforms are also likely to exist in these metaverse worlds. For example, users in the metaverse worlds could be bullied, defamed, defrauded or even assaulted. As a result, mechanisms revolving around rules, regulations and policing will also be critical to manage these challenges.

A key challenge in this area is the question of who will create these rules and who will police these metaverse worlds. Web3 based platforms are built around the core concept of decentralisation and some of these platforms have decentralised autonomous organisations (DAOs). This is an organisation that is constructed by rules encoded as a computer program that is often transparent, controlled by the organisation's members and not influenced by a central government. Therefore, rules can be written in a metaverse world to ensure users act in a certain way with punishments for those who do not adhere to the rules. However, the question that needs to be asked is can these organisations really be trusted with protecting all users and to create a safe and secure environment? Decisions in a DAO can take a large amount of time as all participants may need to be involved in the decision-making process. Furthermore, not all users will necessarily have adequate information to make well-informed decisions or may themselves have prejudices or bias which leads them to favour regulations which are not egalitarian.

An alternative is for one or more national Governments to step in and establish the rules for all participants in the Metaverse. This would allow experienced law makers and regulators who have access to various statistics and information to establish rules to protect all users. However, the question then emerges of which Government or Governments should take the lead in setting regulations and who should police these non-geographical metaverse worlds. If there are conflicting rules and regulations between Governments, then these could take time to be resolved and lead to delays in decision making. It may be that the ultimate outcome is that Governments come together, perhaps through wider orchestration activities to write universal laws for metaverse worlds, but the complexities of such an approach are certainly non-trivial.

In summary, for the rules, regulation and policing to be adequate for metaverse worlds, it is highly likely that orchestration will be needed, which we discuss later in this chapter.

This virtual enabler is where we see the lowest level of maturity at present. Issues such as cyber-bullying have not been dealt with in our current internet domains and the added complexity and sophistication of the Metaverse means there are real and significant concerns in relation to user safety and protection. That 41% of adult internet users in the US have experienced harassment online (as of January 2021[12]) highlights the scale of the issue.

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[12] statista.com | Share of adult internet users in the United States who have personally experienced online harassment as of January 2021 | November 2022 ust 202

Infrastructure Enablers
maturity assessment

low   medium   high

3. INFRASTRUCTURE ENABLERS

Advanced metaverse worlds supported by robust and mature virtual enablers are only a part of the puzzle. Infrastructure in the form of connectivity, hardware and devices is vital to provide access and to enable the Metaverse to be ubiquitous. In this section we consider these infrastructure enablers and assess their maturity today.

GATEWAYS TO THE METAVERSE: DEVICES AND THE USER INTERFACE

To date, the most common user interface to access virtual worlds has been gaming consoles such as Sony's PlayStation or Microsoft's Xbox, or through devices such as PCs and mobile phones. In the future we are likely to be accessing the Metaverse through a wide variety of VR, AR and/or MR devices. These devices will provide both high levels of immersion and seamless transitions from metaverse worlds to real world environments.

VR, AR and MR technology has evolved at a rapid pace in recent years but has not yet become mainstream even in gaming. However, in the past few years, as graphics and computing technologies have evolved, AR and VR have experienced a renaissance and the industry is only predicted to get bigger with projected AR/VR spending worldwide estimated to reach USD 72.8 billion in 2024 and for there to be 1.7 billion AR users by 2025[13].

To understand why these devices will be at the forefront of future metaverse user interfaces, it is important to discuss AR, VR and MR in turn.

Augmented reality is a technology that allows the superimposition of digital elements as an overlay onto the real-world environment. Businesses across many sectors are already exploring this technology. For example, furniture and homewares retailer Ikea allows users, through AR technology, to digitally visualise furniture in their home using the IKEA Place app on a mobile device[14]. This is an early example of how AR technology will allow metaverse users to combine the virtual with the physical.

Virtual reality is a technology that allows the creation of a fully immersive digital environment. VR headsets such as the Meta Quest 2 have proved to be successful and more recently Apple has announced it will be launching its first AR/VR headset in

2023. Users that enter metaverse worlds through VR headsets will likely be able to have a full-on immersive experience as the headsets are able to block the outside world.

Mixed reality is a technology that allows not only the superposition of digital elements into the real-world environment but also their interaction. In the MR experience, the user can see and interact with both the digital elements and the physical ones. This could be one possible way forward for user interfaces for metaverse worlds as it would allow users to get the best of both worlds with this technology. An example of devices of this nature (although without any metaverse integration at this stage) include the Samsung HMD Odyssey+.

Further developments and miniaturisation of technologies we have already seen, such as Google Glass, will also proliferate. AR glasses with built in cameras and speakers will play a major role in creating a seamless interface between the real world and the metaverse, with all the associated functionalities. Miniaturisation is likely to drive the technology towards contact lenses with AR overlays and implants to provide audio feedback. An example of this technology, although not yet commercially available, can be seen with Mojo Vision Inc.'s Mojo Lens[15].

Technologies such as holograms could also play a significant role in future user interfaces. In July 2022, researchers at the University of Western Ontario completed the world's first-ever real time international holographic teleportation[16]. It remains to be seen how this technology might be used in the metaverse, but the potential is clear. What is certain is that there will be technological advances that seem like science fiction today in the not-too-distant future.

At present, there are already a wide variety of user interfaces of high quality that are affordable to mass market consumers in developed markets, and as we have seen there are already plenty of announced launches expected in 2023 and 2024. So, although there is plenty more to come in terms of future developments, the current maturity is already quite advanced.

An immersive use interface is not just about sight and sound though, and for a user to feel fully immersed in a metaverse world interfaces will need to incorporate all the five senses of smell, touch and taste as well as sight and hearing which we

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13 businesswire.com | Worldwide Spending on Augmented and Virtual Reality Forecast to Deliver Strong Growth Through 2024, According to a New IDC Spending Guide | November 2020;
bcg.com | The Corporate Hitchhiker's Guide to the Metaverse | April 2022
14 ikea.com | IKEA launches IKEA Place, a new app that allows people to virtually place furniture in their home | September 2017
15 mojo.vision
16 cbc.ca | Western University researchers achieve international holographic teleportation | August 2022

have already discussed. Without the integration of supporting technologies, smell, touch and taste will remain elusive. However, this is not to say that these supporting technologies do not exist and that there are no developments that are currently taking place. For example, the AiRres Mask seeks to increase multi-sensory stimulation levels. By controlling the user's breathing capability, the device increases the perception of danger, thus enhancing the immersion of the virtual reality experience[17]. There have also been developments exploring ways to achieve the sense of touch. Companies such as Senseglove have developed gloves which allow users to feel the size, density and resistance of virtual objects[18]. Other innovations include Teslasuit's full-body suits[19] (which were used in the movie Ready Player One) that can provide physical feedback based on visual simulation on a flat screen or immersive reality devices.

In even more early-stage developments, researchers[20] have also found that you can use electrical or thermal stimulation to induce a sense of taste however such activities are still restricted to experimental laboratories and are some way from any commercial applications.

Beyond the five senses, there have also been developments to facilitate the free-flowing movement of users in a Metaverse. The Infinadeck Experience Platform (URL) is a patented omnidirectional treadmill designed for state-of-the-art simulation and training in VR.

However, it must be noted that presently the cost of many of these experimental technologies is prohibitive to the average user (for example the Teslasuit is available to purchase for USD 12,999) , but they provide us with a glimpse into the future where these technologies have matured and achieved mass market price points.

On this basis, we believe that interface maturity is semi-mature but in order to reach full maturity, the technologies would need to be available and affordable for the average user.

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[17] designboom.com | AiRres mask enhances VR experience by utilizing breathing resistance

[18] senseglove.com

[19] teslasuit.io

[20] ncbi.nlm.nih.gov | E-Taste: Taste Sensations and Flavors Based on Tongue's Electrical and Thermal Stimulation | June 2022

CONNECTIVITY, PROCESSING POWER AND NETWORKING

While an immersive metaverse experience is the result, there are many layers of complex technology needed to drive the Metaverse, including network infrastructure, data centres, cloud computing and edge computing.

Regardless of how advanced the user interface is, it becomes immediately unusable if the supporting network and compute infrastructure is not adequate to support it. For example, a user would be unable to have a high quality metaverse experience even with a high-quality interface if their internet connection is poor and the virtual environment they are engaged in keeps pausing like a poor quality internet video stream today.

To ensure that this does not become an issue, network and compute infrastructure will need to ensure that it meets significantly increased application demands. Mark Zuckerberg's

Meta have stated[21] that some essential requirements for the Metaverse will be required as follows:

▶ **Speed**: Super-fast symmetrical broadband speeds with a one-gigabit bandwidth to transmit the large quantities of data required to build real-time virtual reality

▶ **Latency**: Very low latency (sub 10 milliseconds). Dense fibre networks and short range 5G can deliver latency at these levels, but significant densification of both fibre and 5G (through small cells) is required. Meta is not just talking about the last mile network but also the backhaul networks that connects the edge of the network back into the cloud. Backhaul carriers will need to invest in many cases. Some networks already operate such low latency levels, but many others do not

▶ **Beyond UHD**: To be truly immersive higher resolution video than 4K is needed to express the pixels necessary for creating immersive environments

21 iceconnect.com | Network Requirements for the Metaverse, Are We Ready? | April 2022

- ▶ **Video Compression**: The next generation of video compression is needed to compress large data files in real-time and then decompress these huge files without delaying the signal

- ▶ **Collaboration**: Various parties will have to collaborate on the network to function in real-time. Today, network operators employ traffic optimisation techniques, while content providers optimise their material using a real-time integrated approach that includes all participants in the metaverse

- ▶ **Smarter software**: Metaverse software must have the capacity to shape and adapt to the user. The metaverse system must be able to adjust to local network conditions for it to work with predominantly fibre connected customers

The above highlights the critical role of telecoms and telecoms infrastructure players in driving the Metaverse. It is estimated that operators could earn up to USUSD 712bn in revenue by 2030 if they introduce 5G applications that support the creation of metaverse worlds[22].

In a repeat of the Net Neutrality debate of the early 2000s, the path from such incremental investments to a satisfactory Return on Investment is unclear for telcos and their investors, as a lot of value will accrue to third parties. To solve this, industry alliances are already forming, such as SK Telecom and Hyundai Motor Co, to build platforms required for metaverse worlds, sharing in both the investment and the returns.

With regards to compute and processing power the Metaverse will require orders of magnitude improvements in capabilities to reach its full potential. Intel has predicted that a 1,000-fold increase in processing power will be required to power the Metaverse[23]. Such increases in compute power will need to be housed in data centres (and in particular edge datacentres close to users) that have greater HPC capabilities than are needed today.

In terms of maturity, we are clearly a long way from the end state in terms of compute and network power, and as such this is an area that we consider to be immature.

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[22] telecomreview.com | Telecom in metaverse: A new space to connect and monetize | October 2021

[23] theverge.com | Intel thinks the metaverse will need a thousand-fold increase in computing capability | December 2021

Orchestration & Interoperability
maturity assessment

low   medium   high
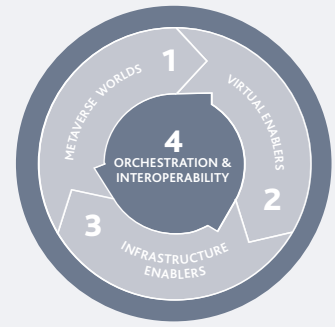
4. ORCHESTRATION & INTEROPERABILITY

The fact that the term 'internet' was originally a diminution of internetworking provides an idea of the importance of interoperability in the long-term development of the Metaverse. Just as the internet came about from various academic and other networks agreeing to connect using a common networking approach, for the Metaverse to achieve its full potential there will need to be layer upon layer of orchestration and interoperability. Precisely how this orchestration and interoperability will come about remains unclear as there are areas where there are competing technologies that will need to be rationalised into a single technology or standard.

For the Metaverse to be realised, high levels of orchestration and interoperability will be needed and here we explore what developments are likely to be required for metaverse worlds, virtual enablers and infrastructure enablers in turn.

ORCHESTRATION OF METAVERSE WORLDS

As we have already discussed, there will be many metaverse worlds. To create a real sense of a unified digital world, orchestration will be required between platforms in order to create a unified experience for users and for there to be general interoperability.

Whilst interoperability has not yet been achieved, there have been developments in communications between companies/organisations to introduce interoperability and we discuss this further when we talk about the interoperability of digital assets later in this paper.
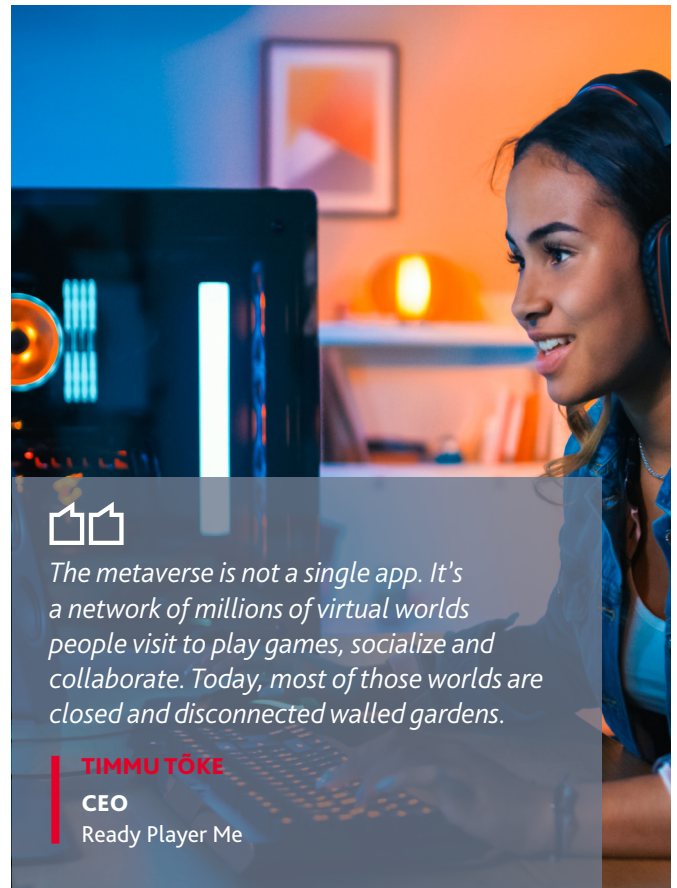
The metaverse is not a single app. It's a network of millions of virtual worlds people visit to play games, socialize and collaborate. Today, most of those worlds are closed and disconnected walled gardens.

TIMMU TÕKE
CEO
Ready Player Me

The watch word of the Metaverse is continuity. The feeling that when you go from one place to another place, there's some things [such as] identity [that] come with you. So avatars [are] important. Your digital goods come with you. Can your friends come with you? Can you travel together? Can you stay in communication while you move from place to place?

ANDREW BOSWORTH,
CTO
META

Full interoperability would facilitate movement or migration from one metaverse world to another seamlessly. It would allow communication between users in different metaverse worlds. Just as someone on one country's telephone network can connect with someone on a different network, metaverse worlds would be without barriers. In a virtual workspace, for example, people all over the world would be able to meet together or to meet with clients all accessing each other from different platforms without this causing any glitches.

Currently there is no interoperability between worlds. A user of Fortnite cannot communicate with someone playing Roblox. The only development in this area is the ability to connect with friends on gaming platforms, irrespective of what device they are using. General interoperability will be key to reaching full maturity.

> *Barriers to implantation of this technology include societal – people are not yet ready to adapt; skills – knowing how to utilise the space; and legal – although companies will override it, but it will come back to bite them.*

DANIEL COLAIANNI,

CHIEF EXECUTIVE
aixr.org

ORCHESTRATION OF VIRTUAL ENABLERS

DIGITAL ASSETS:

As mentioned earlier, the need for interoperability and cross-utility of digital assets is necessary for this category of building block to reach full maturity and the only way this can be achieved is through orchestration.

Purchase of digital assets

One way of achieving orchestration between metaverse worlds is through building such worlds on blockchain-based Web3 platforms. This will allow users to purchase NFTs.

Blockchain technology requires a public immutable ledger of transactions. Once an NFT is purchased, it is accessible in your digital wallet and can be used on other platforms built on the same network.

However, this functionality is limited, and restricted to certain platforms such as the RTFKT Studios and Atari digital shoe NFTs[24] that can be used in virtual worlds like The Sandbox and Decentraland. Most digital assets acquired on these platforms do not have interoperability, as such you cannot buy an avatar or accessory in one and use it in another.

There is currently an InterWork Alliance to mitigate this issue which has created the Token Taxonomy Framework so that multiple parties can work together to define a "common language, behaviours, and properties" for digital tokens[25]. The world's leading Web3 organisations have also come together to form the Open Metaverse Alliance for Web3 (OMA3). Animoca Brands and its subsidiary The Sandbox are joined by Alien Worlds, Dapper Labs, MetaMetaverse, Space, Superworld, Unstoppable Domains, Upland and Wivity. These organisations share a common goal of overcoming the challenges of interoperability in the Metaverse[26].

The same issues exist for Web2-based applications. It is more likely that the interchange of digital assets will be harder to implement where there is not a blockchain underpinning the platforms, and ownership transparency is more problematic.

However, there is currently a consortium known as the Khronos Group, which is comprised of more than 150 organizations including Apple, Google, and Amazon and is working to establish open industry standards for extended reality, 3D graphics, and more[27]. Companies will require deep collaboration to ensure interoperability is achieved.

Utility of digital assets

To solve the issue of cross-utility of digital assets, it may be a case that each asset purchased may have a range of utilities depending on which Metaverse you are in but again, this will require orchestration between companies/organisations forming metaverse worlds to come to an agreement in terms of how different assets in different metaverse worlds can be utilised.

Virtual currencies:
For a robust payments infrastructure to be developed, orchestration between potential payment and e-wallet companies will be required, and between companies/organisations running the metaverse worlds themselves, to ensure that payments can be made with a currency that is not native to a Metaverse and that no issues will arise. Other factors such as exchange rates would also need to be agreed.

Smart and digital contracts:
As mentioned previously, smart contracts may not be enforceable if they do not comply with contract law in a given jurisdiction. There is therefore no value in a smart contract if it is written by a coder with no regard to legality as it will not be regarded as a valid contract in the real world and hence will not be legally enforceable. To mitigate this, orchestration between organisations running metaverse worlds on Web3 platforms, creators and legal/financial institutions will be necessary to ensure smart contracts are written to comply with contract law and cater for the level of complexity required for the contract.

Orchestration will also be necessary when there is a complexity in the performance of the contract. It will be required not only between the parties involved in the contract, but also third parties such as regulatory authorities to verify proof of performance. These issues will be tested in real world courts.

Rules, regulations and policing:
Regulation and policing is a major issue to be resolved before interoperability can be established. A Code of Conduct will need to be agreed by all major stakeholders, including a process for preventing a rogue user, who has been blocked by one platform, moving to another to repeat unacceptable behaviour. Consistency across all platforms will be essential.

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[24] accesswire.com | Atari(R) Partners with RTFKT Studio on Limited-Edition NFT Fashion Series | March 2021

[25] interwork.org

[26] oma3.org

[27] khronos.org

4. INNOVATION IN THE METAVERSE

Having considered the various building blocks of the Metaverse, we now turn our attention to the inventors, engineers and entrepreneurs who are driving innovation in the Metaverse. To do this we have selected eleven case studies of businesses that have developed ground breaking technology or solutions that, each in their own way, are taking us a small step towards the Metaverse of the future. To make the connection with the building blocks described in the previous section we show below how each of the eleven case studies aligns to one or more building blocks in terms of their area of focus. All four of our building blocks are covered by the case studies and our aim is to highlight both the exciting and broad ranging developments in this space as well as the high valuations being placed on these businesses by investors keen to get involved in Metaverse developments.

To be successful in the metaverse – you have to [be prepared to] try and fail.

DANIEL COLAIANNI,
CHIEF EXECUTIVE
AIXR.ORG.

CASE STUDY		METAVERSE WORLDS	VIRTUAL ENABLERS	INFRASTRUCTURE ENABLERS	ORCHESTRATION & INTEROPERABILITY
1	LootMogul	✓			
2	STEMuli	✓			
3	Condense Reality	✓	✓		
4	Improbable	✓			✓
5	MetaStreet		✓		
6	METAV.RS		✓		✓
7	Ready Player Me		✓		✓
8	Hadean			✓	
9	HaptX			✓	
10	Swave			✓	
11	Oorbit				✓

CASE STUDY 1:
LOOTMOGUL[28]

METAVERSE BUILDING BLOCKS ADDRESSED:
METAVERSE WORLDS

CONTEXT:

Whilst brands have currently invested in metaverse worlds such as The Sandbox and Decentraland to interact with users, we have not yet seen much evidence of sports teams or professional sportspeople who have established connections in the real world with their fans, attempting to interact with their fanbase in a metaverse world. LootMogul have set out to change this.

Founded in 2020 by Raj Rajkotia and Kuntal Sampat, LootMogul, a US Sports Metaverse start-up, secured a USD 200m investment commitment from Global Emerging Markets ("GEM") in September 2022, providing the company a share subscription facility of up to USD 200 million for a 36-month term following an equity exchange listing. This leads to total funding of USD 204m and values the company at approximately USD 1.5bn.

LootMogul offers athletes, sports teams, and brands the ability to create virtual 'sport cities' to engage with fans, as well as offering real world perks. Users interact with these sport cites using digital avatars to participate in contests, training academies and games. Owners of the sport cities can also host special events and sell digital and real-life merchandise.

The funding is expected to help provide the financial flexibility for strategic development plans for LootMogul's metaverse which includes building meta (virtual) sports cities around the world with real world benefits, brands and professional athletes on a true cross-metaverse and blockchain (multi-chain) platform on multiple devices such as Oculus, HoloLens, Web, Mobile & Console.

"LootMogul is super excited about this investment commitment from GEM as it empowers athletes, fans and brands to provide an immersive engagement and tools to bridge experiences between Web3 metaverses and real world," said Raj Rajkotia, CEO, LootMogul.

> ❝
>
> *LootMogul is super excited about this investment commitment from GEM as it empowers athletes, fans and brands to provide an immersive engagement and tools to bridge experiences between Web3 metaverses and real world"*
>
> **SAID RAJ RAJKOTIA,**
> **CEO,**
> LOOTMOGUL.

[28] prnewswire.com | LootMogul receives $200M Investment Commitment from Global Emerging Markets Group ("GEM") | September 2022,

digitalmarketnews.com | LootMogul Confirms $200m Deal | September 2022, crunchbase.com

CASE STUDY 2:
STEMuli [29]

METAVERSE BUILDING
BLOCKS ADDRESSED:
METAVERSE WORLDS

CONTEXT:

The metaverse worlds that currently exist are mainly gaming-related platforms. However, for metaverse worlds to be adopted by the mass market, a variety of use-cases would be required. Start-ups have formed to bring a variety of use-cases to the user. An example of this is STEMuli.
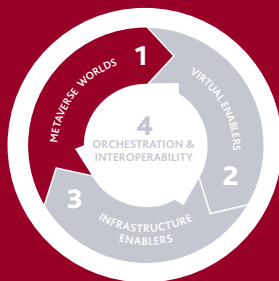
Founded in 2016 by Taylor Shead, US Based STEMuli, a Web3 education startup, received USD 3.25 million in seed funding in May 2022. The funding was co-led by Slauson & Co and Valor Ventures, with participation from Draper Associates.

STEMuli has created an Educational metaverse that brings a one-of-a-kind 3D game-based platform to the core classroom. Within the digital world, STEMuli connects companies to their future workforce of K-12 students and endeavours to reduce achievement and employment gaps for users. The seed funds will be used to expand the metaverse launched in the Dallas Independent School District across the US to New York, California, Illinois, Georgia, and Washington DC.

"We're bringing this technology to the country's largest urban school districts, in which the majority of students are economically disadvantaged. Our vision is to improve learning outcomes by providing ALL students with an experience that rivals playing their favourite video game. The metaverse consists of the STEMuli navigator, a GPS of learning that ensures every learner reaches their destination every time. Soon learning will be as reliable and ubiquitous as Google Maps. We are pioneering the learn-to-earn model to increase engagement and utilising AI to improve teacher productivity. The metaverse is a game-changer for teachers and learners," said Taylor Shead, founder and CEO of STEMuli.

"STEMuli is re-imagining teaching and learning at scale by integrating classrooms with the metaverse. We at Draper Associates are thrilled to be part of their journey to disrupt traditional learning. It's incredibly exciting!" said Tim Draper of Draper Associates.

> *Soon learning will be as reliable and ubiquitous as Google Maps. We are pioneering the learn-to-earn model to increase engagement and utilising AI to improve teacher productivity. The metaverse is a game-changer for teachers and learners…*
>
> **TAYLOR SHEAD,**
> **FOUNDER AND CEO ,**
> STEMULI.

[29] prnewswire.com | EdTech startup STEMuli raises $3.25M to transform traditional classroom learning with the Educational Metaverse | May 2022

CASE STUDY 3:
CONDENSE REALITY [30]

METAVERSE BUILDING
BLOCKS ADDRESSED:
**METAVERSE WORLDS
AND VIRTUAL ENABLERS**

CONTEXT:

As metaverse worlds have continued to develop over time, we have seen an increasing number of real-worlds events such as concerts being replicated in a virtual setting. For example, Ariana Grande performed a virtual concert on Fortnite in 2021. However, what is yet to be seen is a real-time event taking place that also takes place in a Metaverse simultaneously. Condense Reality is working to deliver this capability.

Founded in 2019 by Dan Fairs and Nick Fellingham, UK based Metaverse infrastructure start-up Condense Reality raised £3.7m in a funding round in July 2022 to develop its hybrid virtual and real-world event technology.

Condense previously raised £800,000 in October 2020 in a seed funding round from SFC Capital and RLC Ventures, which has now rebranded to Concept Ventures. Total funding for the company has reached £4.6m, valuing the start-up between USD 18m – 27m.

The funding round was led by LocalGlobe, 7percent Ventures and Deeptech Labs, with additional funding coming from angel investors including Monzo founder Tom Blomfield and Song Kick CEO Ian Hogarth.

Condense Reality captures real-world events such as music concerts in 3D using a portable multi-camera system. It then streams the event via its cloud platform and provides plugins for businesses to integrate the 3D video into their own applications (or metaverse worlds).

The aim is to bring real-time events including concerts, conferences, art installations and sport to be experienced through virtual reality.

In addition to live events, Condense Reality is marketing its technology to businesses, metaverse developers and digital venues. For example, the start-up has worked with BT in a DCMS-funded project to explore the potential of 5G for immersive live sport viewing experiences through augmented and virtual reality.

"With our technology, we are essentially reinventing video," said Condense Reality co-founder and CEO Nick Fellingham. "It can be used to capture and stream anybody or anything into the metaverse. We expect our clients to use this technology for many interesting use cases however we are first focusing on live events and in particular music events."

Investors have also commented. "Demand for live entertainment inside virtual worlds has never been greater," said LocalGlobe partner Ziv Reichert. "Condense has built the infrastructure to connect the two – now music artists, sports stars and creatives can perform and play live in the metaverse, to the largest stadium audience imaginable."

> ❝❝
>
> *It can be used to capture and stream anybody or anything into the metaverse. We expect our clients to use this technology for many interesting use cases however we are first focusing on live events and in particular music events.*
>
> **NICK FELLINGHAM,**
> **CO-FOUNDER AND CEO,**
> CONDENSE REALITY

[30] uktech.news | Metaverse live streaming startup Condense Reality raises £3.7m | July 2022, app.dealroom.co

CASE STUDY 4:
IMPROBABLE [31]

METAVERSE BUILDING BLOCKS ADDRESSED: METAVERSE WORLDS AND ORCHESTRATION & INTEROPERABILITY

CONTEXT:

As we have seen, there is an issue of interoperability between metaverse worlds. However, within a given metaverse world, there are also constraints with the number of users in that metaverse at one time and whether those users can interact with one another. Various start-ups have formed to address this issue. One notable example is Improbable.
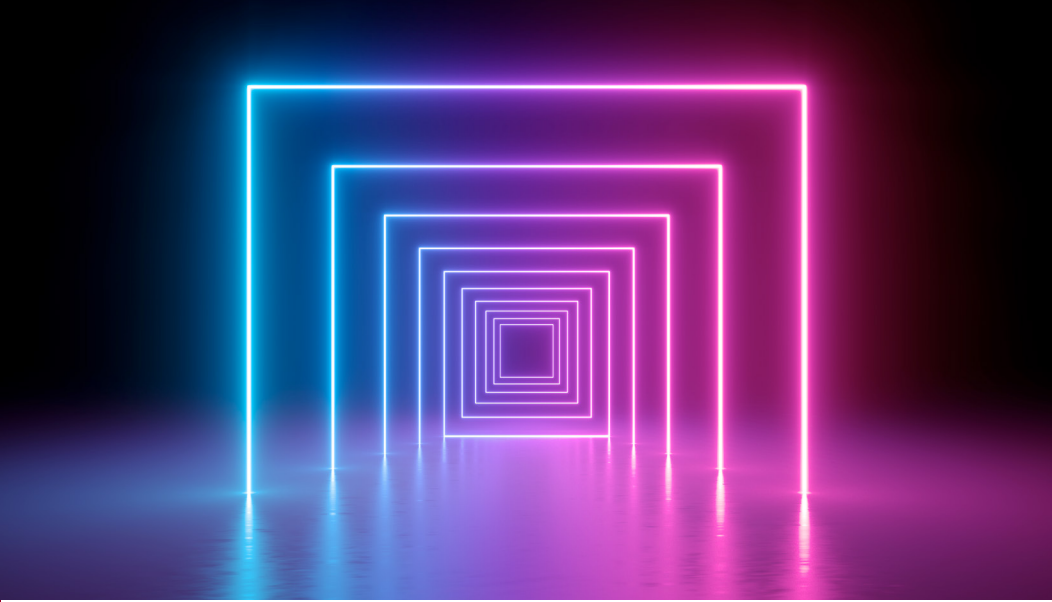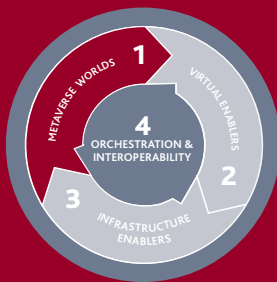
Founded in 2012 by Herman Narula and Rob Whitehead, Improbable, a UK gaming software developer that has recently pivoted to building metaverses, is closing in on USD 100m of new funding which will bring the company's valuation to over USD 3bn as of October 2022.

The upcoming funding round, which will be led by blockchain technology company Elrond, follows a USD 150m raise in April led by Softbank and US venture capital firm Andreessen Horowitz to establish "M2", a metaverse platform involving blockchain technology.

Additional funding comes after the company closed the 2021 financial year with a loss of GBP 152m (USD 170m), which at the time meant the company had so far burnt through almost all the money it had raised from investors since launching in 2012.

Improbable first raised USD 20m in Series A funding in 2015 from Andreessen Horowitz, Horizons Ventures, and Singaporean investor Temasek.

In 2017, the company raised USD 500m in Series B funding from Softbank, marking the biggest-ever funding round for a British start-up.

Based in London, Improbable's initial aim was to help smaller video game companies create massive simulations for open-world gaming, before refocusing all its business on the Metaverse.

Improbable's Morpheus technology enables enhanced social interaction and sense of presence inside virtual spaces, where over 10,000 real users can interact in high-fidelity, lag-free environments, at the same time and in the same place. Morpheus is also central to M² (MSquared), a network of metaverses initiated by Improbable to build interconnected virtual worlds and experiences that empower and amplify people's lives. The technology was demonstrated in a series of large-scale events, including a metaverse fan event with K-pop star AleXa, where fans freely explored the huge virtual arena, danced with the crowd and interacted with the performer.

Improbable's pivot to building metaverse worlds should see its revenues triple to over USD 100m in 2022, the company's co-founder and chief executive Herman Narula said.

> *Improbable's pivot to building metaverse worlds should see its revenues triple to over USD 100m in 2022.*
>
> **HERMAN NARULA,**
> **CO-FOUNDER AND CEO,**
> IMPROBABLE

CASE STUDY 5:
METASTREET[32]

METAVERSE BUILDING BLOCKS ADDRESSED: VIRTUAL ENABLERS

CONTEXT:

In the real world, we have financial institutions to help individuals make purchases through various financial vehicles. As metaverse worlds increasingly become part of our daily life, the stronger the economy in metaverse worlds will become and will start to replicate the real world. Therefore, financial institutions are likely to be necessary in metaverse worlds to help users fund digital transactions. MetaStreet is a pioneering example of such a business.

[32] blockworks.co | MetaStreet Secures $10M for NFT Loans in the Metaverse | October 2022

Founded in 2021 by Pip Watson and Russell Moffatt, MetaStreet, a US Metaverse-oriented decentralised interest rate protocol, raised USD 10m of venture funding in October 2022 as the start-up prepared to launch its latest product. The capital raise brings the company's one-year funding total to USD 24 million.

The round received participation from existing investors including Dragonfly Capital, Nascent and Ethereal Ventures. New investors include Fintech Collective, DCG, TheLAO, Focus Labs, Mirana Ventures, Metaversal, OpenSea Ventures, Ledgerprime, Meta4 and Flying Falcon.

MetaStreet operates as a capital provider and is the architect behind the infrastructure required to automate the underwriting and execution of fixed-rate, NFT-backed loans. Its latest product, PowerSweep, aims to increase the purchasing power of NFT traders by allowing them to buy and sell NFTs on margin via Reservoir, a Web3-native NFT order book protocol.

Conor Moore, co-founder of MetaStreet, said all the capital raised will be going toward product development, marketing and hiring. "Previously we were only focused on the capital deposit side of the equation, and now we're expanding our offering to help solve problems directly for borrowers," Moore said.

"The integration with MetaStreet basically allows users to make a transaction but do it with leverage instead of all their own capital," Moore said. "It's focused on borrowers and the origination side of the equation."

MetaStreet has facilitated around USD 40 million of lending volume to date, according to Moore. In fact, the protocol was the facilitator of two of the largest NFT-backed loans at 8.3 million DAI (a virtual currency pegged to the dollar for stability) and 8 million DAI respectively.

After launching its vault product, Moore says at any given time there are roughly a few million dollars in the vault from users. "We're fortunate to be deeply entrenched in NFT finance at such a formative period of time in the lifecycle of the metaverse," Moore said. "This is one of those unique moments in an industry's growth where everyone who's here today is simply focused on bringing new users into the space, an entire blue ocean of opportunity."

> *The integration with MetaStreet basically allows users to make a transaction but do it with leverage instead of all their own capital.*
>
> **CONOR MOORE,**
> **CO-FOUNDER,**
> METASTREET

CASE STUDY 6:
METAV.RS [33]

METAVERSE BUILDING BLOCKS ADDRESSED: VIRTUAL ENABLERS AND ORCHESTRATION & INTEROPERABILITY

CONTEXT:
eCommerce is expected to grow incrementally with the creation of metaverse worlds. One major consideration is: how can brands in a metaverse create a link between virtual and real-world sales to help generate revenues in both whilst ensuring full compliance with the rules and regulations that apply in the real world. One company that is working to bridge this gap is METAV.RS.
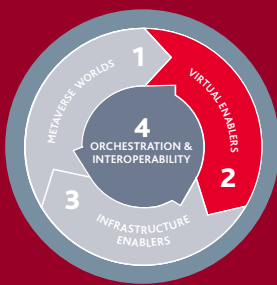
Founded in January 2022 by Simon Foucher, Clément Foucher, Jérémie Salvucci and Adrien De Lavenere Lussan, French start-up METAV.RS secured a EUR 3m seed round in October 2022, onboarding several French and international investment funds, experienced entrepreneurs, and a Web3 industry leader. This seed round was led by Jsquare, a specialized Web3 fund based in Singapore, which was joined by consulting firm, Sia Partners – via its investment arm, Studio – and 50 Partners.

METAV.RS' white label solution facilitates the creation of NFTs and their sale via dedicated websites, e-shops, or marketplaces, and the creation of enriched customer experiences.

The no-code platform provides brands and agencies with a series of integrated apps, which enable them to, among other things, manage their own virtual worlds. These are accessible from a web browser and allow users to discover a brand's universe in an immersive way, interact with numerous elements of this universe and purchase dematerialised goods (NFTs) through virtual dressing rooms.

The team has deployed a 3D reconstruction application (3D Builder), which allows users to easily scan physical objects and transpose them into the metaverse. The 3D models generated can be used to create digital twins, which can be integrated cross-metaverse and/or integrated into product pages on e-commerce sites to boost physical product sales. The team has also created a platform that interoperates with major metaverse and social networks, is compatible with major e-commerce platforms, and is accessible, secure and compliant.

Clément Foucher, co-founder of METAV.RS: "The emergence of Web3 is decentralizing the web and enabling the creation of many new virtual universes. The challenge for brands is to find a simple way to initiate and manage their presence in these virtual universes, so that they can benefit from greater reach and an enhanced customer experience, while maintaining control of their brand image. We are developing a tool that allows brands to easily manage their presence in the metaverse."

> *The emergence of Web3 is decentralizing the web and enabling the creation of many new virtual universes. The challenge for brands is to find a simple way to initiate and manage their presence in these virtual universes, so that they can benefit from greater reach and an enhanced customer experience, while maintaining control of their brand image. We are developing a tool that allows brands to easily manage their presence in the metaverse.*

CLÉMENT FOUCHER,
CO-FOUNDER,
METAV.RS

CASE STUDY 7:
READY PLAYER ME [34]

METAVERSE BUILDING BLOCKS ADDRESSED: VIRTUAL ENABLERS AND ORCHESTRATION & INTEROPERABILITY

CONTEXT:

Currently, there is an issue of interoperability of avatars. This means that an avatar and any digital assets you purchase for an avatar in one metaverse world is unable to be transferred to another. However, start-ups such as Ready Player Me have emerged that are working to address this issue.

[34] techxrunch.com | Ready Player Me, a platform to build dynamic cross-game avatars for virtual worlds, raises $56M led by a16z | August 2022,

app.dealroom.co,

mobidictum.biz | Ready Player Me secures $56 million in Series B funding | August 2022

Founded in 2014 by Timmu Toke, Haver Jarveoja, Rainer Selvet and Kaspar Tiri, Estonian metaverse avatar start-up Ready Player Me raised USD 13m through Series A funding in December 2021. Ready Player Me raised a further USD 56 million in a Series B round in August 2022, which, including seed rounds, led to USD 72 million in total funding. This results in an estimated valuation of USD 224m-336m. Investors include Roblox co-founder David Baszucki, Twitch and Fractal co-founder Justin Kan, and King co-founders Sebastian Knutsson and Riccardo Zacconi.

Ready Player Me offers developers a ready-made avatar system to allow users to have an online identity that is both persistent and consistent. It generates avatars based on a single user photo, something that runs across desktop, web, and mobile. The company is looking at bringing fashion brands into the fold so users can purchase digital accessories, including brands such as Adidas, New Balance, Dior, Pull&Bear, and Dune film outfits courtesy of Warner Brothers.

The funds will enable the company to continue scaling its avatar system to make it more flexible for developers, to create new tools to help developers monetise with avatar assets and build tools for individual creators to take part in the cross-game avatar marketplace.

"Our bigger vision is to connect the metaverse through avatars," said Timmu Toke, co-founder and CEO of Ready Player Me, in an interview. "There may be metaverse [experiences] owned by big companies, who will make all the rules, but there is a vision of an open one where people can travel, built by millions of developers, where no one controls the whole thing. Like the internet. We're trying to push the world towards that metaverse."

"Ready Player Me is loved by both developers and players as the largest platform for avatar-systems-as-a-service and is well on their way to building the interoperable identity protocol for the open metaverse," said Jonathan Lai, a general partner at Andreessen Horowitz, the firm that led the series B funding round.

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>
> *There may be metaverse [experiences] owned by big companies, who will make all the rules, but there is a vision of an open one where people can travel, built by millions of developers, where no one controls the whole thing. Like the internet. We're trying to push the world towards that metaverse.*
>
> **TIMMU TOKE,**
> **CO-FOUNDER AND CEO,**
> READY PLAYER ME

CASE STUDY 8:
HADEAN³⁵

METAVERSE BUILDING BLOCKS ADDRESSED: INFRASTRUCTURE ENABLERS

CONTEXT:

Whilst there have been developments made in the hardware used to enter metaverse worlds, the underlying infrastructure will be equally important for an immersive experience. Hadean is a UK business that provides a distributed cloud platform specifically designed to enhance the metaverse experience for users.

³⁵ techcrunch.com | Backed by Epic Games, distributed computing startup Hadean nabs $30M to build metaverse infrastructure | September 2022

finsmes.com | Hadean Raises $30M in Series A Funding | September 2022, mobidictum. biz | UK startup Hadean secures $30M

Series A funding to create a scalable metaverse | September 2022, crunchbase.com

Founded in 2015, Hadean, a UK distributed, spatial computing start-up committed to building the infrastructure for the Metaverse, closed a USD 30m Series A round of funding in September 2022. The full list of (known) backers include lead investor Molten Ventures (formerly Draper Esprit), Tencent, 2050 Capital, Alumni Ventures, Aster Capital, Entrepreneur First, InQtel and Epic Games (which is also a Hadean customer). Funding for Hadean has now reached a total of USD 65.7m.

Hadean provides a distributed cloud platform that enables scalability, security, and interoperability, driving the metaverse and digital immersive experiences for enterprise, commercial, gaming and government customers. The company has developed vital metaverse components and signed multi-year agreements in entertainment (including with Minecraft, Pixelynx, Sony and Gamescoin), as well as with education and enterprise digital twin providers. To date, Hadean has worked with organisations such as Microsoft, Minecraft, Epic Games, Sony, Gamescoin, Pilxelynx, Francis Crick, CAE, BAE and Thales.

The company intends to use the raised funds to build out its technology –

already supporting virtual worlds in immersive entertainment and enterprise digital twins and accelerate its ability to give creators the tools in new and emerging Metaverse markets.

"Today's virtual worlds are a limited experience – small scale, siloed, and insecure. Hence why these are the technical challenges we're tackling today," said Hadean co-founder and CEO, Craig Beddis. "But we believe the true success and mass adoption of the Metaverse will rely on the ease by which creators will be able to build their own experiences at scale, leveraging open and robust metaverse-as-a-service technologies."

Marc Petit, VP, of Epic's Unreal Engine also commented: "Hadean's computing power will provide the infrastructure that's needed as we work to create a scalable metaverse. The company's technology complements Epic's Unreal Engine by enabling massive amounts of concurrent users and unlocking new tools for creators and developers. We are pleased to contribute to Hadean's growth and look forward to continuing to work together to lay the foundation for the metaverse."

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>
> *But we believe the true success and mass adoption of the Metaverse will rely on the ease by which creators will be able to build their own experiences at scale, leveraging open and robust metaverse-as-a-service technologies.*
>
> **CRAIG BEDDIS,**
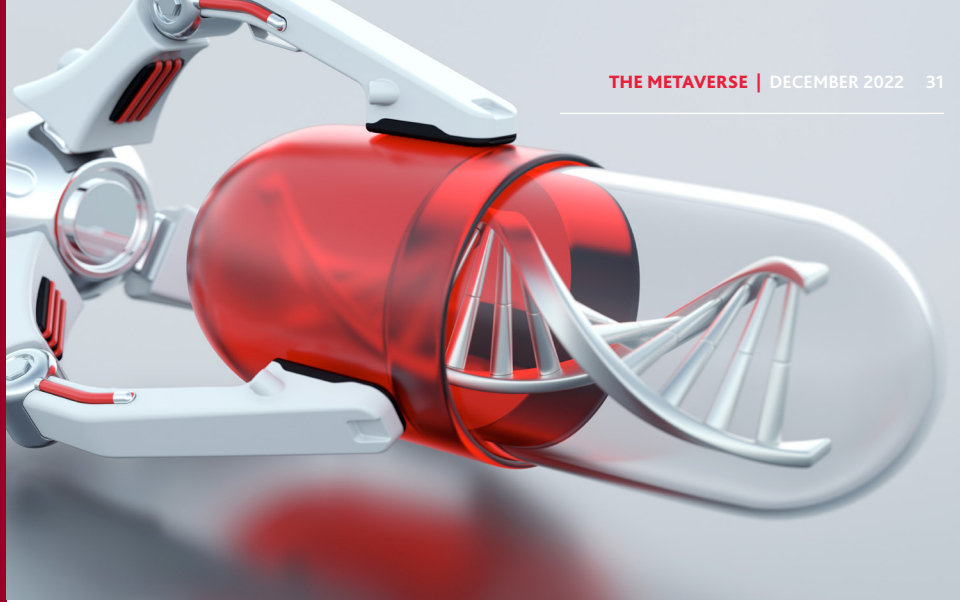> **CO-FOUNDER AND CEO,**
> HADEAN

CASE STUDY 9:
HAPTX [36]

METAVERSE BUILDING BLOCKS ADDRESSED: INFRASTRUCTURE ENABLERS

CONTEXT:

Whilst AR and VR devices have come a long way in building an immersive experience for a user, in order for users to truly feel immersed in these environments, all five senses will need to be captured by devices. Currently, the sense of touch and sight are ones that technology has been able to be somewhat capture. However, technologies are still required for the remaining senses and current technologies need to become cheaper so they can be adopted by the mass market. Companies who have already delved into providing users with an immersive experience such as HaptX are working on their successes to provide users with a deeper sense of immersion.

[36] prnewswire.com | HaptX Closes $23 Million Strategic Funding Round Led by AIS Global and Crescent Cove Advisors | September 2022

Founded in 2012 by Jake Rubin and Dr. Bob Crockett, US company HaptX, a provider of realistic haptic technology, announced a USD 23m strategic funding round in September 2022. The funding round was led by AIS Global and Crescent Cove Advisors, with participation from Verizon Ventures, Mason Avenue Investments, and Taylor Frigon Capital Partners. This investment brings HaptX's total funding to more than USD 58m.

The proceeds from this round will be used to fund commercialisation of next-generation products building on the success of HaptX's award-winning HaptX Gloves DK2. Unlike other haptic gloves which are limited to vibration and force feedback, HaptX Gloves physically displace the user's skin the way a real object would, delivering more than 130 points of tactile feedback per hand. Fortune 500 companies and governments around the world have adopted HaptX Gloves for the most demanding applications in training and simulation, industrial design, and robotics.

In conjunction with this transaction, HaptX has extended its partnership with AIS Global, a portfolio company of New York-based KPS Capital Partners.

"HaptX and AIS Global have built a deep, successful relationship dedicated to innovation at the cutting edge of the high-growth global haptics market," said Joe Baddeley, Chief Executive Officer of AIS Global. "AIS Global and KPS are thrilled to provide the resources, commitment, and expertise necessary to support aggressive scaling of HaptX's commercial footprint."

Crescent Cove Advisors, based in San Francisco, substantially increased its investment in HaptX in this funding round after providing a USD 4m credit facility to HaptX in 2021.

"HaptX has succeeded in generating tremendous customer demand across a wide array of use cases," said Jun Hong Heng, Founder and Chief Investment Officer of Crescent Cove Advisors. "We believe HaptX will play a foundational role in fulfilling the promise of the Metaverse as an immersive 3D successor to today's 2D internet."

> *We believe HaptX will play a foundational role in fulfilling the promise of the Metaverse as an immersive 3D successor to today's 2D internet.*

JUN HONG HENG,
FOUNDER AND CHIEF INVESTMENT OFFICER,
CRESCENT COVE ADVISORS

CASE STUDY 10:
SWAVE
PHONICS [37]

METAVERSE BUILDING BLOCKS ADDRESSED: INFRASTRUCTURE ENABLERS

CONTEXT:

Whilst AR and VR devices have become the leading technologies to use to enter into a metaverse, issues such as time lag could create problems such as nausea for the user. Furthermore, if users are planning to spend large amounts of their day in a metaverse, they are unlikely to want to spend most of their day wearing heavy glasses. Technologies are therefore needed to increase the ease in which users can access a metaverse whilst keeping the sense of immersion. One company that is exploring solutions to these challenges is Swave Photonics.

Founded in 2022 by Theodore Marescaux, Belgian Holographic eXtended Reality (HXR) technology platform Swave Photonics has raised EUR 7m in a seed round to bring the metaverse to life. The round was co-led by imec.xpand and Flanders Future Techfund (FFTF) and backed by QBIC.

The Belgian start-up is delivering lifelike, high-resolution 3D images that are viewable with the naked eye, with no compromises. HXR technology enables 1000x better pixel resolution with billions of tiny, densely packed pixels to enable true realistic 20/20 vision without requiring viewers to wear smart AR/VR headsets or prescription glasses.

The funding will go a long way in the realistic and immersive commercialisation of 3D HXR gigapixel technology for a wide range of emerging applications. Going forward, the start-up plans to partner with AR/VR/XR and metaverse platforms, so companies can have a shared, lifelike 3D experience of meeting around a conference table.

Theodore Marescaux, CEO and founder of Swave Photonics said: "Our aim is to help build the fundamental holographic technology to bring the metaverse to life and work. True, lifelike and immersive metaverse experiences powered by Swave technology are poised to replace every AR/VR display and headset to the point where virtual, augmented or eXtended reality is practically indistinguishable from the real world."

"We are convinced that Swave can bring to the market a fundamental technology we have been developing for more than five years through substantial R&D programs and imec investments," said Luc Van den Hove, president and CEO of imec.

Peter Vanbekbergen, partner at imec. xpand concluded: "We are convinced that Swave's transformative gigapixel holographic technology can fuel the USD 93bn AR/VR, metaverse market and will position Swave to enable an upgrade to today's challenging AR/VR immersive experiences."

> *We are convinced that Swave's transformative gigapixel holographic technology can fuel the USD 93bn AR/VR, metaverse market and will position Swave to enable an upgrade to today's challenging AR/VR immersive experiences.*

PETER VANBEKBERGEN,
PARTNER,
IMEC.XPAND

CASE STUDY 11:
OORBIT [38]

METAVERSE BUILDING BLOCKS ADDRESSED: ORCHESTRATION & INTEROPERABILITY

CONTEXT:

While various metaverse worlds are forming and even maturing, it is still the case that if you want to move from one Metaverse to another, you will need a different login, different website and will find no interconnectedness. For metaverse worlds to be adopted by the mass market, companies forming these metaverse worlds need to ensure that their platform is easily accessible. One way of doing this is for the metaverse to be on a platform from which one can access any metaverse with the same avatar all from one place. Oorbit is working to increase the ease of accessibility for users.

[38] uktech.news | Oorbit, a startup connecting the metaverse, raises £3.8m | March 2022

Founded in 2021 by Ash and Pooya Koosha, UK-based interactive entertainment Metaverse company Oorbit raised GBP 3.8m in a seed round of funding in March 2022. Oorbit's investors included Mark Cuban, Pixelynx (deadmau5) and HOF Capital.

Oorbit have used the funding to build its cloud OS software for connecting different virtual worlds which will launch in late 2022. Using Oorbit, users will have the ability to transform any devices they own including smart TV and instantly jump into a Metaverse and explore every single experience. Oorbit's software will aim to act as a bridge for all metaverse worlds. Users of Oorbit will have a unique digital identity with no downloads or extra hardware required, the company claims.

"Oorbit is demystifying the major technologies that will play the biggest role in the growth of Web3 and the metaverse; blockchain, cloud streaming, NFTs, fintech and more," said Ash Koosha, CEO and co-founder of Oorbit.

"We are combining the best parts of these complex technologies to enable episodic entertainment that is not just incredible but also approachable, for all audiences."

"As the metaverse moves from our imaginations into actual entertainment, experiences and products, Oorbit's founders have created an innovative platform where developers, publishers and brands can create and more easily deliver their most compelling work," said investor and entrepreneur Mark Cuban.

> *We are combining the best parts of these complex technologies to enable episodic entertainment that is not just incredible but also approachable, for all audiences.*

ASH KOOSHA,
CO-FOUNDER AND CEO,
OORBIT

5. EMBRACING THE METAVERSE

The pioneers driving the examples in the previous chapter are making an impact in the field of metaverse-development and are attracting significant investment, but these are not the only organisations that will be able to generate value in a metaverse world.

We have touched on how retail, finance, legislative and compliance organisations might be impacted. We have explored the business value available to medical, scientific and educational bodies, as well as manufacturing, tourism, sports and entertainment industries.

In this section we delve deeper into how various market sectors will be able to gain business value and competitive advantage from the metaverse, and conversely how those organisations that do not adapt and embrace the Metaverse might ultimately be disadvantaged.

Organisations with imagination and foresight should be considering the opportunities presented by the Metaverse now. Later in this chapter we present a potential framework with which to assess the potential of the Metaverse for any business.

VALUE CREATION

How can the Metaverse create value in different sectors?

Retail and Fashion: being able to test the popularity of an item, range, colour palette or collection in the virtual world would significantly cut production and promotion costs on less well received ideas. Customers who 'tried on' clothing virtually would be less likely to buy (and then return) unsatisfactory items. Virtual stores in virtual malls could experiment in many ways that would only enhance the real-world experience for shoppers. Non-clothing retail could showcase their products virtually, with easy links to on-line purchase and delivery options.

Advertising and Promotion: As well as using the Metaverse as a test site, similar to retail, promotional campaigns would be equally effective in the virtual world and could be very much more imaginative. Give-aways, loss-leaders, test-drives, almost all promotional tools would easily translate into the Metaverse. For example, in November 2021, Pepsi introduced the Pepsi Mic Drop genesis NFT collection. Although a give-away and thus generating no revenue, it was a smart move to increase brand awareness within the virtual world. The rise of the 'influencer' has been a recent and quickly dominant trend in advertising. The influencer marketing industry is estimated to be worth $15bn by the end of 2022, according to The Social Shepherd[39]. Influencers do not need to be real people, either. Prada already have an entirely digital influencer called Candy. Influencers who wanted to stay in the game would need to develop their virtual presence to exploit both real and virtual worlds.

Sports and other events: Imagine the full stadium experience with all your friends in the stands around you, the noise, the buzz, the atmosphere. This is not going to stay in the land of science fiction for long. There need be no limit on the number of seats that could be sold for a game, a concert, a performance; and a global audience to attract. Promotional events and fanzones would become virtual, a much safer environment for athletes and performers to interact with the public. Some of this is already happening: Tennis Australia partnered with Decentraland to promote the Australian Open. NBA fans can watch games through Meta's VR platform. In August 2022, Eminem and Snoop Dogg went 3D for the MTV Video Music Awards.

Financial services (banking): banks and fintechs would target virtual assets and experiences: mortgages for virtual real estate and loans for virtual business start-ups, virtual 'home' improvement or vehicle leasing. Web3 company TerraZero Technologies has already financed a property in Decentraland for which it conducts credit checks and requires a business plan from investors. Banks could open branches and conduct most of their personal business 'like the old days': in person, but virtually. Much better than endless calls waiting to speak to an agent.

Financial services (insurance): where there is property there will be insurance. There are strides needed to be made in this area, to stabilise digital assets sufficient to make them insurable, but the developments will be made. Nexus Mutual is an insurance company already offering some digital asset coverage.

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39 thesocialshepherd.com | 28 Essential Influencer Marketing Statistics You Need to Know in 2022 | October 2022

Highly fungible goods: one-off luxury purchases in the real world can be enhanced with a virtual token, an example would be Vineyard Robert Mondavi, who created the world's first NFT-sold wine label[40]. This enables tracking a limited edition of 1,966 bottles using blockchain technology. Customers gain a piece of digital memorabilia that will outlast the item itself (the wine if not the bottle) but proves that it was once owned.

Legal services: There is a wealth of opportunity available to law firms who invest in R&D on digital legislation and regulation. Current legislation is inadequate in a Metaverse world. New legislation and legal processes will be needed. Firms who innovate and lead the field are going to be in high demand.

Manufacturing: The use of digital twins and virtual factories in the metaverse could lead to significant efficiency savings and empower more people to design, invent and produce. A digital twin, for example, could help test and identify issues before construction of real-world production processes and continue to identify areas for improvement after construction. It could also allow employees to view the production process from anywhere in the world. BMW tested changes in a virtual factory without the need to stop production.

Workplaces: Horizon Workrooms by Meta and Mesh for Teams by Microsoft are recent releases that offer avatar-populated workspaces for enhanced team collaboration. Business value is added by enabling a wider geographic net for recruitment while maintaining a work community.

Telecommunications: this hardly needs saying, but telecoms are a key enabling sector for the Metaverse. The need for data connectivity is only going to increase if people are spending more time in the virtual world. Market advantage will go to those companies who leverage their existing infrastructure and prioritise research on ways to provide higher bandwidth and lower latency for their consumers.

There is clearly a metaverse of opportunity for organisations with courage and initiative to take advantage of. However, it has to be noted that any metaverse strategy will require significant initial investment, and longer-term commitment before seeing a return.

In most cases, it will be preferable for a non-tech company to buy into a pre-existing platform, rather than setting out to build their own metaverse world. Investment should rather be into researching the opportunities and innovations available for their particular market sector.

Every company that sees itself around for the long term will need to develop a Metaverse strategy that is an extension to and aligned with the company's existing business strategy and explores how the opportunities of the metaverse will generate business value in their own particular case.

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[40] bloomberg.com | Robert Mondavi Bids for Relevance With NFT, Art and a Porcelain Bottle | December 2021

To help we set out a simple stap by step approach that we use when evaluating any new technology.

HIGH LEVEL BDO APPROACH TO EVALUATING THE POTENTIAL OF THE METAVERSE

1 LEARN:
Study, explore, research: Look into all the material currently available that discusses what is and what might be coming. Explore some of the case studies and examples presented in this paper (and there will be many more such examples emerging every week and month).

2 IMAGINE:
Brainstorm, imagine, dream. Ask a teenager or Gen Z colleague. Think outside the box and generate as many ideas as possible, however weird and wonderful they may seem initially. Challenge yourself and your colleagues to consider how disruptive the Metaverse could be for your business. This is where you create your own big picture of the new world and your organisation's place in it. Be as big and bold and creative as you can. There are no barriers, anything is possible.

3 SCOPE:
Establish your big picture objectives. Your Metaverse vision, objectives and strategy. Build an outline of your organisation's future in the Metaverse. Outline the vision, share, discuss, debate and iterate. Agree primary objectives and draw up the high-level strategy.

4 DEFINE AND DESIGN:
Develop your strategy with quantitative analysis and benchmarking. This is the place for lists, for analyses, for graphs and charts. Turn your vision into a fleshed out strategic plan that is well defined and clearly articulated and understood by key stakeholders. Quantify (estimate) the risks of do nothing and the opportunities for growth.

5 VALIDATE AND ITERATE:
Test all your assumptions, review your vision. In the light of your strategy, does anything need to be reassessed? Set timescales for reviews (in such a fast-moving sector, maybe 6 monthly or even quarterly?) Consider alternative concepts and approaches which include consideration:

▶ Rapidly evolving metaverse technology

▶ Key players (Metaverse platforms, competitors with Metaverse ambitions etc.)

▶ Changes specific to your organisation and business model(s)

6 PRIORITISE:
Set your immediate focus (at least until the next review). Development on multiple fronts might be necessary. Communication between departments and stakeholders is essential. Get key players on board and keep them up to date.

7 EXECUTE:
Start the process of transformational change and embrace the metaverse in all its wonderful potential.

This framework will not be the right one for every business in every circumstance, but we hope it provides food for thought in terms of how to approach the nebulous and potentially confusing Metaverse opportunity.

6. CONCLUSIONS

We hope you have found our paper informative and insightful and that, if nothing else, it has provided food for thought around a complex and rapidly evolving topic. Our work is not exhaustive, and some of the references and examples we have presented are likely to be obsolete by the time you read this, such is the pace of change, and the appetite for 'fast failure' as a driver of such exciting innovation and development. There is much that we have missed, and there will be many who disagree with our points of view, but we have tried to be objective and to present a balanced view to inform the non-expert reader.

More than any single fact or datapoint, case study or example, what we hope you take away from reading this is the fact that the Metaverse is coming, and it is coming soon. It is coming to a home, place of work, social engagement or gaming experience near you. It is coming to all of those environments and more and it will change the areas it touches, mostly, we believe, for the better. The Metaverse will be a multi-trillion-dollar industry in less than a generation. Every business and most individuals will be affected.

The time to start thinking and planning is now.

It may be that for your industry sector there is no need to do anything yet (or at all) but we recommend some careful consideration before arriving at that decision. There are various cautionary tales of businesses or organisations that failed to take the advent of new technology seriously. One example is from the early days of aviation: in 1929 the UK Royal Air Force turned down designs for the jet engine as 'impractical', delaying development for nearly ten years and risking losing air superiority in World War II. Apparently, there was a feeling among some senior officers that the future was in airships[41].

Another famous failure to embrace new technology was Kodak's denial of digital photography as a serious alternative to film[42]. Considering Kodak invented digital photography as early as 1975 and then tried to keep the development quiet seems shocking today, and of course it led ultimately to Kodak's failure. The example highlights how easy it is for business leaders, particularly those of already successful businesses, to adopt an approach of 'if it ain't bust don't fix it'. Visionary leaders, in contrast, see the potential in disruptive technology and new business models, and the Metaverse is both a highly disruptive technology and one that will drive many new ways of doing business.

Bill Gates, arguably one of the great visionary leaders of recent times, and of course an avid technologist, sums it up in the quote below, which highlights the human tendency to think of the future as far away and not to be worried about, but of course the future is just around the corner.

The opportunities that the Metaverse will provide are going to become more apparent over the next few years, and those business that are prepared are going to enjoy the ride.

Reality will soon be optional. Are you ready?

"We always overestimate the change that will occur in the next two years and underestimate the change that will occur in the next ten.

Don't let yourself be lulled into inaction."

BILL GATES, 1996

[41] Frater | Alexander 'The Balloon Factory' | Picador 2008
[42] forbes.com | How Kodak Failed | January 2012

GLOSSARY

5G – Fifth-generation technology standard for broadband cellular networks

AR – Augmented reality (AR) is an enhanced version of the real physical world that is achieved through the use of digital visual elements, sound, or other sensory stimuli and delivered via technology

ASCII – American Standard Code for Information Interchange (ASCII) is the most common character encoding format for text data in computers and on the internet

Autonomous vehicle – A vehicle that is able to operate itself and perform necessary functions without any human intervention, through ability to sense its surroundings

Avatar – An icon or figure representing a particular person in a video game, internet forum, etc.

Baby Boomers – People born from 1946 to 1964

Bandwidth – A range of frequencies within a given band, in particular that used for transmitting a signal

Blockchain – A system in which a record of transactions, especially those made in a cryptocurrency, is maintained across computers that are linked in a peer-to-peer network

Cloud computing – The practice of using a network of remote servers hosted on the internet to store, manage, and process data, rather than a local server or a personal computer

CMS – A content management system (CMS) is a computer software used to manage the creation and modification of digital content

Contracts – Smart, digital and e-contracts

Smart Contract – Computer program or a transaction protocol that is intended to automatically execute, control or document events and actions according to the terms of a contract or an agreement

Digital/e-contracts – A contract, agreement, commitment, memorandum, contract addendum or other equivalent document that is expressed in the form of electronic data interchange and is signed, concluded and transferred via the Electronic trading system

Cryptocurrency – A digital currency in which transactions are verified and records maintained by a decentralised system using cryptography, rather than by a centralised authority

DAI – Crypto-backed stablecoin that seeks to maintain a soft peg with the U.S. dollar

DAOs – A decentralised autonomous organization (DAO) is an emerging form of legal structure that has no central governing body and whose members share a common goal to act in the best interest of the entity

Data centre – A large group of networked computer servers typically used by organisations for the remote storage, processing, or distribution of large amounts of data

Decentraland – 3D virtual world browser-based platform

Digital assets – Anything that is created and stored digitally, is identifiable and discoverable, and has or provides value

Digital twin – A small metaverse world replicating a specific real-world environment

Distributed cloud platform – The distribution of public cloud services to different physical locations, while the operation, governance, updates and evolution of the services are the responsibility of the originating public cloud provider

eCommerce – Commercial transactions conducted electronically on the internet

Edge computing – Distributed computing paradigm that brings computation and data storage closer to the sources of data

Edge/ edge datacentre – Smaller facilities located close to the populations they serve that deliver cloud computing resources and cached content to end users. They typically connect to a larger central data centre or multiple data centres

Ethereum – Decentralised, open-source blockchain with smart contract functionality

EUR – Euro (€)

Fortnite – Online video game

GBP – British pound sterling (£)

Gen Y – People born from 1981 to 1996, also known as Millennials

Gen Z – People born from 1997 to 2012

GPU – A graphics processing unit (GPU) is a specialised electronic circuit designed to manipulate and alter memory to accelerate the creation of images in a frame buffer intended for output to a display device

Haptic Gloves – Wearable device that allow users to experience realistic touch and interactions in their hands through advanced tactile feedback

Haptic Suit – Wearable device that allow users to experience realistic touch and interactions on their body through advanced tactile feedback

Hogwarts – Fictional Scottish boarding school of magic in the Harry Potter books/films

HPC – High performance computing (HPC) is the ability to process data and perform complex calculations at high speeds

IoT – Internet of Things (IoT) is the interconnection via the internet of computing devices embedded in everyday objects, enabling them to send and receive data

Latency – The delay before a transfer of data begins following an instruction for its transfer

Meta (facebook parent co) – American multinational technology conglomerate based in Menlo Park, California. The company owns Facebook, Instagram, and WhatsApp, among other products and services

Metaverse – A virtual-reality space in which users can interact with a computer-generated environment and other users

Millennials – People born from 1981 to 1996, also known as Gen Y

MMORG – Massively multiplayer online role-playing game (MMORPG) is a video game that combines aspects of a role-playing video game and a massively multiplayer online game

Moore's Law – The observation that the number of transistors in a dense integrated circuit doubles about every two years

MR – Mixed reality (MR) is a hybrid of augmented reality and augmented virtuality where virtual objects interact with real-life objects in your physical space

NFT – Non-fungible token (NFT) is a unique digital identifier that cannot be copied, substituted, or subdivided, that is recorded in a blockchain, and that is used to certify authenticity and ownership

Non-fungible – Not easy to exchange or mix with other similar goods or assets

NPC – A non-player character, or non-playable character (NPC), is any character in a game that is not controlled by a player

Platform – An environment in which a piece of software is executed

R&D – Research and Development (R&D) is a set of innovative activities undertaken by corporations or governments in developing new services or products, and improving existing ones

Reality-mapping – Use of technology for the interaction between the physical and digital world

Reservoir – Web3-native NFT order book protocol

Roblox – Online game platform and game creation system developed by Roblox Corporation that allows users to program games and play games created by other users

Second Life – Online multimedia platform that allows people to create an avatar for themselves and then interact with other users and user created content within a multi-player online virtual world

Smart Glasses – Eye or head-worn wearable computers that offer useful capabilities to the user such as Augmented Reality

Smart Watch – Mobile device with a touchscreen display, designed to be worn on the wrist

System-on-a-chip – An integrated circuit that takes a single platform and integrates an entire electronic or computer system onto it

Token – An object (in software or in hardware) which represents the right to perform some operation

UHD – Ultra High Definition (UHD), is a standard announced by the Consumer Electronics Association. It encompasses televisions with a 4K (3840 x 2160 pixels) or 8K (7680 x 4320 pixels) screen resolution, and a 16:9 aspect ratio

Unreal Engine 5 – The latest version of Epic Games' creation platform

USD – United States Dollar ($)

Virtual currency – a digital representation of value only available in electronic form. It is stored and transacted through designated software, mobile, or computer applications. Transactions involving virtual currencies occur through secure, dedicated networks or over the Internet. They are issued by private parties or groups of developers and are mostly unregulated.

VR – Virtual reality (VR) is a simulated experience that employs pose tracking and 3D near-eye displays to give the user an immersive feel of a virtual world

VR Headset – A head-mounted device that provides virtual reality for the wearer

Web2 – The current state of the internet, websites that emphasise user-generated content, ease of use, participatory culture and interoperability for end users

Web3 – The third generation of the evolution of web technologies which incorporates concepts such as decentralisation, blockchain technologies, and token-based economics

XR – Extended Reality (XR) is the umbrella term used for Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR)

FOR MORE INFORMATION:

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