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The metaverse and the NSW Government

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Executive summary

This report aims to help the NSW Government prepare to meet the risks and opportunities created by 'the metaverse': a collection of immersive, computer-generated virtual worlds in which to 'work, play, relax, transact and socialise'.[1] Should the metaverse and its enabling technologies mature quickly and become widely adopted, the NSW Government aims to be ready to take advantage of the opportunities it provides and to mitigate the risks it creates.

What is the metaverse?

Exactly what systems and technologies are encompassed in the term 'metaverse' is not universally agreed upon. For this report, a metaverse application is a software application that possesses the following three properties:

1. a persistent virtual world (users join a world that continues to exist and change even when they're not present)
2. presence (users feel as though they're 'really there')
3. social connectivity (users can interact with each other).

The report generally considers technologies, services, platforms and applications that have or enable these properties to be part of 'the metaverse'.

Today, metaverse applications typically run on virtual reality (VR) or augmented reality (AR) headsets. These headsets give users the sensation that they are present in a virtual world by fooling the senses with imagery and sound that respond to the motion of a user's head and body.

- **VR headsets** fully replace the user's surroundings with a digital alternative, so are today used for activities like gaming, exploring virtual art galleries, or socialising in virtual chat rooms.
- **AR headsets** still allow a user to see their surroundings, but 'augment' those surroundings with digital objects or annotations. This makes AR headsets useful in applications that still require the user to be present with their surroundings: an AR headset might, for example, provide a schematic overlay of a machine for a maintenance worker assembling it.

Contrary to marketing hype, the metaverse is currently at an early stage of development. It is best thought of as a collection of separate VR and AR applications with social aspects, rather than a single, connected 'virtual internet' as originally depicted in science fiction.

Opportunities and risks created by the metaverse

The metaverse and its enabling technologies are general purpose. Metaverse applications may be useful in many domains including education, health and aged care, art and tourism, asset management, emergency services and community support. Across domains, metaverse applications may help in:

- **bringing people together** *(for example, a VR application supporting virtual family visits to aged care facilities during Covid-19 lockdown)*
- **assisting people with contextual information about their activities** *(for example, an AR 'hologram' of a remote expert collaborating with a field maintenance worker)*
- **providing people a model of the real world** *(for example, a VR re-creation of a damaged building that can be examined for emergency response planning)*
- **giving people experiences** *(for example, a virtual reality art gallery that users can explore together)*
- **transporting people out of their environment** *(for example, a virtual outdoor world for people confined indoors due to illness).*

Metaverse technologies also introduce risks, however. Some of these risks are apparent from similar technologies already in more widespread use, including:

- **exposing people to anti-social and abusive behaviour** *(for example, physical threats and intimidation, already common online, made more impactful by the sense of presence the metaverse provides)*
- **excluding people** *(for example, by providing a service that can only be used with a VR headset, which are expensive and can cause nausea and dizziness for some people)*
- **violating people's privacy** *(for example, by gathering and using personal data like body language, facial expressions, gaze direction and even heart rate, that can be used to predict people's identity, behaviour and preferences)*
- **influencing people's behaviour** *(for example, by amplifying the algorithmic influence techniques used in social media with the metaverse's richer sources of user data and greater control of user experience)*
- **denying people a livable environment** *(for example, by using the availability of virtual worlds as an excuse not to improve living conditions in a real world accommodation facility)*

- **increasing social anxieties and disconnection** *(for example, over-reliance on VR for escapism and communication affecting social competencies in the real world).*

How the metaverse may involve the NSW Government

The NSW Government is already undertaking projects involving virtual reality (See Section 3.6), and some of these projects satisfy the metaverse definition above.

In the future, the government may take some or all of the following roles:

- **application user** *(for example, developing or procuring metaverse applications for use by NSW public servants to assist them in carrying out their duties)*
- **application provider** *(for example, developing or procuring metaverse applications that provide services for the NSW public)*
- **service provider** *(for example, by hosting an application programming interface (API) that allows third parties to integrate NSW Government data into their metaverse applications)*
- **platform provider** *(for example, by creating a marketplace where developers can host applications vetted as suitable for use by NSW schoolchildren)*
- **regulator** *(for example, by ensuring commercial venues don't circumvent NSW gambling regulations through the use of augmented reality).*

Recommendations

We share the government's belief that it is not too early to start planning for a future where the metaverse is more sophisticated and more widely adopted. We recommend that, initially, the government focus on

- building understanding of, and expertise in, the metaverse and its supporting technologies
- augmenting existing systems and infrastructure to support future metaverse applications
- starting to develop governance for the use of metaverse technologies by the NSW Government.

In each of these work areas we have made a series of specific recommendations, summarised below and explored in more detail in the referenced sections of the report.

Recommendations to build understanding and expertise

1. **Examine the legal questions raised by metaverse applications (Section 5.1)**. Adoption of metaverse technologies both by the NSW Government and the wider public will raise new legal questions. Considering these questions now will help the government understand and prepare to take on its roles as a metaverse user, platform provider and regulator. Key questions include:
    - What existing activities and products (such as computer games, phone apps, websites and social networks) are legally relevant to the metaverse?
    - Are there any circumstances where objects or locations in metaverse applications could take on property-like elements?
    - When are augmented reality objects 'in' a real-life location?
    - Are the data collected by metaverse applications appropriately regulated, especially for children?
    - When would the NSW Government have obligations to ensure metaverse services are accessible to all members of the NSW public?
    - Are there circumstances in the metaverse where people have a right to their own likeness, as instantiated in the form of an avatar?
2. **Ensure NSW Police are equipped to address criminal activity in the metaverse (Section 5.2)**. Many online crimes that are already within the remit of NSW Police will occur in the metaverse. The sense of presence and immersion users feel in metaverse applications may also increase the potential harm caused by (virtual) physical intimidation or abuse. Additionally, given the foundational use of cryptocurrency and Non-Fungible Tokens (NFTs) in some metaverse applications, it would be reasonable to expect that the rampant fraud making use of those technologies will present significant risks relevant to NSW Police.

    Even if conduct falls short of the legal threshold of a crime, it may be important for NSW law enforcement to be involved in prevention activities in the metaverse. The NSW Police Force's cyberbullying activities, for example, could be expanded to encompass risks in metaverse applications.
3. **Begin training key staff (Section 5.3).** Deeper engagement with the metaverse in any role will likely require NSW Government staff to gain expertise in new skills. This will require training:

- **leaders**, who will need to understand when metaverse technology may be useful, its risks and benefits, and their own responsibilities for establishing effective governance of metaverse applications developed or used by the government
- **technical staff**, who will need to understand the new content and behaviour moderation challenges associated with VR, as well as the development challenges of building metaverse applications such as 3D modelling, network architecture and suitable API design.

4. **Run a pilot to develop and release a metaverse application (Section 5.4).** A pilot will help build skills and experience in government, and help inform the development of metaverse governance. Considerations for selecting a use-case for an initial pilot include
    - whether it provides an opportunity to build staff capability and enhance existing NSW Government data, infrastructure and services (such as the Spatial Digital Twin)
    - whether it provides the three metaverse properties of a persistent virtual world, presence, and social connectivity to achieve its purpose
    - whether it augments, rather than replaces, an existing service or functionality
    - whether the risks of unintended consequences can be predicted and controlled.

    Specific applications that may be suitable for an initial pilot include:
    - a virtual tour of the Sydney Opera House (Section 4.6)
    - a VR emergency services (police, firefighter and medical) training application (Section 4.5)
    - an AR rail corridor maintenance application (Section 4.4)
    - an emergency and disaster response planning visualisation (Section 4.5).
5. **Establish a cross-departmental metaverse community of practice (Section 5.5).** This group would aim to bring together existing work with metaverse technologies across government and to begin developing whole-of-government approaches and resources to engage with the metaverse. This community could be internal, but could

also be open to other public sector or private employees, at the NSW Government's discretion.

Discussions with NSW Government staff have revealed a number of prototype metaverse projects and research in the area, dispersed across different departments (see Section 3.6). By establishing a metaverse community of practice, branches of the NSW Government can share knowledge and insights from their research. This could lead to a more cohesive overall NSW Government metaverse strategy, and encourage collaboration between departments on new metaverse incentives.

6. **Create a 'metaverse experience lab' (Section 5.6).** Metaverse technologies, particularly VR and AR, are new enough that many people have not experienced them at all. Creating an 'experience lab' for NSW Government staff gives an opportunity for the staff to have such a first hand experience in a controlled environment, and may help develop staff's intuition and judgement about their various roles with the government's work in the metaverse.

7. **Cultivate broader collaborations for knowledge sharing (Section 5.7).** Events bringing together metaverse researchers and practitioners from governments, universities and private industry across Australia can expose NSW Government staff to developments and ideas in the field.

8. **Define the scope of the NSW Government's interest in the metaverse to differentiate it from cryptocurrencies and Non-Fungible Tokens (NFTs) (Section 2.4).** Contrary to the marketing material of some metaverse developers and platforms, cryptocurrency and NFT technologies are not required to define ownership or enable commerce in the metaverse.

   Cryptocurrency demonstrates no benefit when used to purchase virtual items when compared to fiat currencies. Similarly, the claim that NFTs enable ownership of virtual items to be recognised across different metaverse worlds is misleading. The record of ownership of an item and the effective rights that it grants a user is entirely at the whim of the operators of a virtual world. This is true whether or not the record is stored as an NFT on a blockchain or as an entry in some other type of database.

   The NSW Government will likely have to examine cryptocurrencies and NFTs in other contexts, for example as they relate to taxation, financial regulation and crime. If cryptocurrencies and NFTs continue to see use and adoption, then they may become common within metaverse applications. However, we believe they should still be considered a distinct area of concern.

Recommendations to augment existing systems and infrastructure

9. **Consider how the NSW Government's digital identity systems can accommodate metaverse use cases (Section 6.1).** Metaverse use cases could include applications and services delivered by NSW Government, as well as 3rd party metaverse applications that would benefit from being able to verify a NSW resident's identity through a digital identity API under appropriate circumstances.

   Given that metaverse adoption is still relatively low, there may be novel requirements for digital identity in the metaverse that have yet to emerge. We recommend that the NSW Government, as a digital identity provider, assume that digital identity will be an important service in the metaverse and consider what new technical, legal and regulatory issues may arise as a result.

10. **Consider augmenting NSW Spatial Digital Twin to better serve data to metaverse applications (Section 6.2).** The NSW Spatial Digital Twin (SDT) already provides API access for third parties to use NSW Government spatial data in their web applications and these APIs can be leveraged and further extended for many digital twin use-cases that naturally benefit from the use of VR and AR.

    For example, the existing SDT contains telecommunications and infrastructure data intended to assist emergency response teams with understanding the locations of valuable infrastructure during events such as bushfires. The use of an augmented reality display of this data could enable firefighters to make better use of it.

    Better AR/VR support in the SDT could also support a variety of useful, 3rd-party tools for NSW residents. This could include, for example, using live Transport NSW information to provide augmented reality overlays depicting the locations and routes of NSW buses, trains and ferries, or using spatial data from local councils to provide augmented reality overlays for building planning and approvals.

11. **Identify gaps in NSW network infrastructure that may impair access to metaverse applications (Section 6.3).** Many homes and businesses in NSW lack high bandwidth, low-latency internet access. This is particularly true in remote areas, some of which don't have internet access at all. Such lack of connectivity introduces problems for accessing metaverse applications, many of which will require high-quality connectivity to function. Many of the potential NSW Government use-cases described in Section 4 which would otherwise be useful for people in remote areas, such as remote learning, may be impossible to deploy due to poor connectivity. Upgrades to connectivity will therefore be critical to support wide access to metaverse applications for NSW residents and businesses.

As a starting point for identifying and addressing specific connectivity gaps, the NSW Government may wish to consider:

- conducting a state-wide analysis of connectivity, in order to provide a metaverse-ready view of the state to inform investment decisions
- predicting the locations that might see greater early take-up of metaverse applications and prioritise improving connectivity at these locations (for example, remote areas using VR for remote learning)
- running metaverse application trials in areas of good connectivity to better characterise performance requirements
- developing a connectivity investment plan that explicitly balances targeted investments based on the likelihood of widespread use with the need to deliver inclusive outcomes
- investigating what implications the limited 5G and fibre broadband access in remote areas has on metaverse connectivity
- ensuring that the NSW Connectivity Strategy's objective of bringing meaningful digital connectivity to all citizens and achieving metro-equivalent standards can be met in light of metaverse connectivity requirements.

Recommendations to start developing governance

12. **Consider using AI governance as a model for metaverse applications (Section 7.1)**. This could include developing instruments similar to the government's AI Assurance Framework, AI Strategy and Ethics Policy and AI Review Committee for metaverse application governance.

    AI and metaverse technologies are analogous in several respects:

    - both are complex, novel technologies with significant scope for benefit and harm
    - both have ill-defined boundaries, with no clear definition on exactly which systems should 'count' as AI or the metaverse
    - both require specialised, multi-disciplinary expertise to implement which may not be widely present in the government
    - both often require procurement of products from third parties

- both involve the collection and use of users' personal data.

The NSW Government's AI governance is already well-designed to address the above challenges, making its use as a template for metaverse governance compelling.

13. **Develop a set of responsible metaverse principles to inform detailed frameworks and guidelines (Section 7.2)**. Again, this work could draw from the similar work done by the government with AI governance. Principles developed for an AI setting such as fairness, accountability, transparency, positive impact, and privacy, apply equally well to metaverse applications as they do to AI systems.

    More specific principles, intended for organisations developing platforms for online communication (which would include metaverse applications), have been developed by the Australian eSafety Commissioner. These principles emphasise:

    - service provider responsibility
    - user empowerment and autonomy
    - transparency and accountability.

    Being general in nature, principles typically need to be augmented with more detailed guidelines or rules in order to inform specific design decisions.

14. **Incorporate documentation of key design trade-offs into governance processes (Section 7.3).** Whilst principles act as aspirational targets, examining how to balance competing objectives of such aspirations can help inform design decisions.

    Explicit requirements to document and balance competing objectives could form part of ensuring responsible use of metaverse technologies. The trade-offs could be framed through the competing interests of involved parties, such as a metaverse application developer, a NSW resident user, and the NSW Government regulator. More specific trade-offs common to metaverse applications could also be documented and used as a way to inform key design decisions.

15. **Define ethical requirements for NSW Government metaverse applications (Section 7.4).** Such standards serve to guide internal design decisions and procurement of 3rd-party technologies. The government could draw from existing rules, for example those developed by Dr Louis Rosenberg (Chief Scientist for the Responsible Metaverse Alliance). Rosenberg's rules intend to control some of the specific risks of the metaverse including:

- manipulation of user behaviour through collection of their biometric data and the use of AI to understand and control their emotional state
- fabrication of reality through undisclosed product placement and AI avatars that interact with users, similar to 'bots' in current social media
- collection of behavioural and physiological data and its associated privacy risks.

In addition to informing future regulation discussions, the NSW Government could draw from the ethical requirements it defines to create a set of red lines for metaverse applications it is involved in. Such red lines would inform the government's own development of metaverse applications as well as its engagement with other metaverse providers.

16. **Develop procurement guidelines and partnership strategies (Section 7.5).** The government's existing IT procurement process could be straightforwardly extended to incorporate considerations for metaverse technologies.

    As the government is fully accountable for systems it deploys to end users — even if the system involves third party elements — transparency of procured services is crucial. Transparency is necessary for the government to understand and exercise oversight on the metaverse applications it procures. Information such as how and when data is collected and stored, how the product works, how it is tested, and the potential negative impacts, are all as critical for metaverse applications as they are for AI systems or any other large IT system. The provision of such information to the government could be mandated as part of the procurement process.

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1. Introduction

This report aims to help the NSW Government prepare to meet the risks and opportunities created by 'the metaverse': a collection of immersive, computer-generated virtual worlds in which to 'work, play, relax, transact and socialise'.[1] Should the metaverse and its enabling technologies mature quickly and become widely adopted, the NSW Government aims to be ready to

- build, procure and deploy metaverse applications to improve services and outcomes for NSW residents while minimising the risks of unintended harms
- provide data and digital infrastructure to support NSW businesses in developing metaverse applications and services
- address legal and regulatory gaps to ensure safe and equitable outcomes from NSW residents' interactions with the metaverse
- otherwise adapt to residents' increasing interactions with metaverse applications created by third parties.

This report identifies some of the first steps in preparing for these responses. It outlines

- what the metaverse is and what technologies underpin it
- the properties of metaverse applications that differentiate them from other digital technologies
- potential use cases for metaverse technologies that are relevant to the NSW Government
- risks from misapplication of these technologies by the NSW Government and others along with potential approaches for minimising those risks
- recommendations for capability-building activities that the NSW Government can undertake.

1.1 Overview of the metaverse

Origins

The science fiction author Neal Stephenson introduced the original conception of the metaverse in his 1992 novel *Snow Crash*: a single, persistent virtual world rendered by computers and accessed with a virtual reality (VR) headset by millions of people

simultaneously. In the original conception, the metaverse was a kind of immersive internet, acting as the globally dominant location for commerce, recreation and socialising . A person in a VR headset could shop on a virtual high street, meet friends at a bar or visit a museum without leaving their living room. The virtual worlds in films such as *The Matrix* (1999) and books such as *Ready Player One* (2011) draw heavily from Stephenson's original vision.

A closely related concept, also originating from science-fiction, is the augmented reality (AR) metaverse. In the AR metaverse, the structure and geography of the metaverse is still informed by the real world. Wearing AR glasses augments the real world with layers of additional computer-generated content such as objects and scenery that are a near-permanent presence for users. Vernor Vinge's 2006 novel *Rainbows End* is a famous depiction of such an AR metaverse.

The metaverse today

The science fiction visions of the metaverse do not exist today, nor, we believe, are they likely to be built in the near future.

Today, 'the metaverse' has come to be used as an encompassing term for all the various multi-user virtual environments that currently exist. These are created by different companies and individuals with different technologies on different platforms. They are generally accessible by the internet but not connected to each other.[2]

The encompassing use of the term metaverse means that two different virtual worlds might both claim to be part of the metaverse but have very different properties. Not all virtual worlds that claim metaverse membership even use virtual reality for instance, instead being accessible from phones and desktop computers.

Defining the metaverse

The variety of applications claiming metaverse status and the many definitions proposed in the literature presents a problem for anyone wishing to discuss the metaverse in detail. This report uses a definition based on 3 key properties shared by many metaverse applications:

*A metaverse application is a software application incorporating a **persistent virtual world**, a sense of **presence**, and **social interaction**.*

We believe these properties are the most relevant to understanding the sources of the novel opportunities and risks for the NSW Government that the metaverse creates.

Key metaverse properties

- **A persistent virtual world:** Metaverse applications are typically built around a computer-generated 'world' with locations users can travel to and objects they can interact with. Changes made to the world are perceived by all users and are not reset when a user logs off. The world may pause when no user is logged in, or it may continue to run and evolve.
- **Presence:** Metaverse applications aim to give users the sensation that they are 'really there', typically through the use of virtual or augmented reality headsets.[3]
- **Social interaction:** Metaverse applications allow multiple users to join virtual worlds together and interact, for example by having virtual meetings, playing games or co-designing objects or buildings.

How different combinations of these properties may be found in different applications is depicted in Figure 1.1.

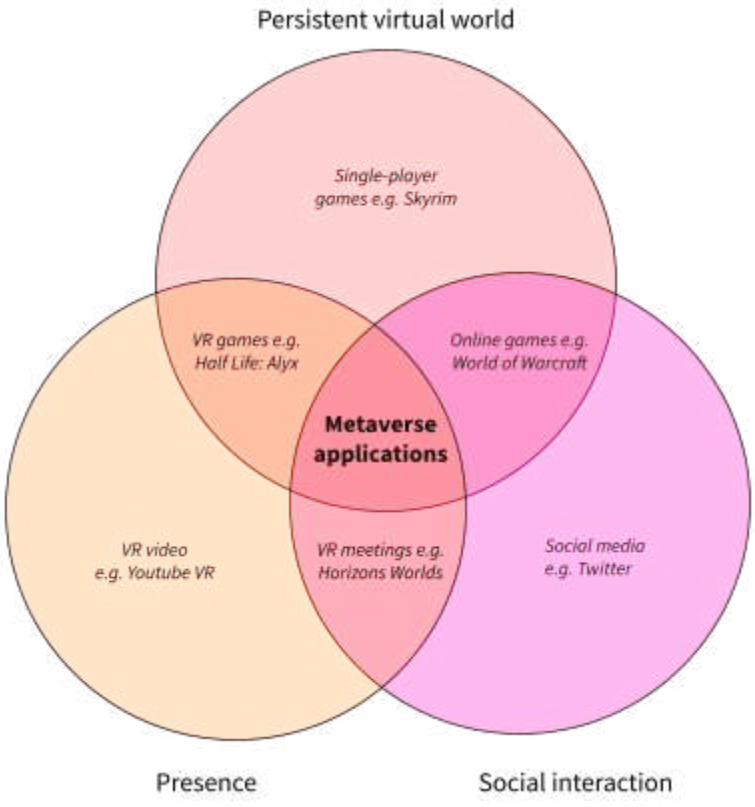


Figure 1.1: Depiction of the overlapping properties of the metaverse, and examples of applications that possess them in different combinations. (Source: Gradient Institute)

1.2 The metaverse's novel opportunities and risks

Metaverse technologies are powerful, even at their current stage of development. Today a metaverse developer can create a virtual world that is completely under their control, from the sights and sounds, to the laws governing people's behaviour and even to the laws of physics. This world can then be joined by users from all around the globe, each of whom increasingly feel 'present' in the world and with each other through virtual and augmented reality.

The capability to create a shared virtual world such as this presents new opportunities to improve work and life across many domains. However, it also creates risk of harm. Some of these risks are already well established in areas like social media and online gaming, but others will only emerge if and when metaverse adoption becomes more widespread.

The details of these opportunities and risks depend heavily on the specific use-case to which metaverse technologies are applied. Section 4 lays out these opportunities and risks for specific application areas relevant to the NSW Government. However, common themes from that section are summarised below.

Opportunities

The metaverse and its enabling technologies can be applied across diverse domains including education, health and aged care, art and tourism, asset management, emergency services and community support. The private sector is already engaging with these; Case Western Reserve University is using AR to teach students about anatomy[4], for example, and Harley Davidson is using AR to improve customers' retail experience in their showrooms.[5]

Many of the examples outlined in Section 4 of this report cross over multiple application areas. The metaverse's propensity for immersive remote social connectivity is applicable to both people in nursing homes and correctional facilities. Immersive VR training simulations could be useful for the emergency service, medical surgeries, and even for general workplace behaviour monitoring. New possibilities for VR and AR art could be beneficial for tourism, or even as a new medium for artists to showcase their work.

The following *application classes* capture opportunities this report has identified as relevant to the NSW Government.

Metaverse application classes

- **Bringing people together:** By recreating many of the visual cues present in real social interaction that are missing in phone or video conferencing, metaverse applications

have the potential to improve the social benefits of remote interactions compared with less-immersive alternatives like video conferencing.
Example: Virtual family visits to aged care facilities during Covid-19 lockdown

- **Assisting people with contextual information about their activities:** Mixing virtual elements into real-world environments presents opportunities to combine real- and virtual social interaction, or to provide information to users that they can process without diverting their attention.
Example: 'hologram' of remote expert collaborating with field maintenance worker

- **Providing people with a model of the real world:** Many circumstances such as emergency response require training or planning with high-fidelity models of the real world. The ability to have shared, immersive experiences in such models may increase their effectiveness compared to presenting them on flat screens, and also present an alternative to real-world simulacrums in some circumstances.
Example: VR emergency and disaster response planning tool

- **Giving people experiences:** Metaverse applications allow for shared interactions with virtual spaces and objects, and could be used to create virtual art galleries or performances, or to augment existing spaces with digital sights and sounds.
E.g. virtual art gallery

- **Transporting people out of their environment:** There are some circumstances where escaping an unpleasant but unavoidable environment may be desirable: the immersion metaverse technologies provide may be one mechanism to achieve this
E.g. virtual outdoor worlds for people stuck in confined spaces

Risks

Every particular metaverse use case will have its own unique risks. However, the properties of metaverse applications and the technologies on which they are built suggest some risks that may be common across many use cases.

Metaverse application risks

- **Exposing people to anti-social or abusive behaviour:** Intimidation, bullying and abuse have not been eliminated from social media and online gaming, and may prove similarly prevalent in an immersive metaverse world. The impact from these negative interactions may also be magnified by the immersive properties of the metaverse. A virtual 'physical' assault, for example, may feel real to the victim, or at least engender similar physical and emotional responses to an assault in the real world.[6]

- **Excluding people:** The hardware and software required to access metaverse applications is still expensive, and the quality of network infrastructure required to access it is not universally available (see Section 6.3). Many people also cannot wear headsets for an extended period without feeling dizzy, such as for example, recent mothers experiencing postpartum vertigo. This lack of universal accessibility to the metaverse creates a risk that important services or opportunities are denied to some parts of the population.

- **Violating people's privacy:** Metaverse applications are a rich source of personal information for developers. In addition to developers being able to track where a metaverse user goes and who and what they interact with, headsets used to access metaverse applications can gather detailed biometric information that may include body language, facial expressions and gaze direction.[7] Such highly detailed information about the behaviour, attention and physical or emotional responses of users creates novel and significant privacy risks.

- **Manipulating people:** Metaverse applications may give developers powerful levers with which to influence the behaviour of their users. Social media platforms already do this with attention-maximising algorithms that learn from users' clicks and reading behaviour[8], but metaverse applications have both richer sources of data about users and more direct control over their experience. The risk is that such increased information and control will lead to some of the same problems caused by algorithmic control of social media such as increased polarisation, promotion of extremist material, addiction and fragmentation of a shared worldview.[9,10]

- **Denying people a livable environment:** Creating a virtual world will be cheaper and faster than improving the real world in many cases. This creates a risk that metaverse applications are used to paper over poor-quality environments in facilities such as prisons or aged-care homes.

- **Increasing social anxieties and disconnection:** An over-reliance on VR as an interaction tool may impact peoples' ability to communicate in the real world. By engaging heavily in an immersive virtual 'life' that can be curated and superimposed onto a user's online personality, users risk creating an identity disconnection that may elevate social anxieties in the real world.[11,12]

1.3 The future of the metaverse

Longer-term visions of the metaverse imagine a single virtual world or a set of highly connected virtual worlds that users can move between at will.[13] They imagine large fractions of the population using augmented reality devices on a daily or near-constant basis, with

semi-permanent overlays providing contextual information about many aspects of their daily lives.[14,15] Some metaverse materials even predict brain-computer interfaces that will bypass sensory organs like ears and eyes and interact directly with the brain to achieve otherwise impossible degrees of immersion.[16]

This longer-term vision for the metaverse (closer to the one illustrated in science fiction) is highly speculative, and we believe is too far away and too uncertain for the NSW Government to begin preparing for in earnest. This report therefore focuses on current-term and near-term metaverse technologies.

In the near term, we believe that metaverse applications will remain unconnected or only loosely connected through means such as the ability to move an avatar or certain items between worlds. Current restrictions on the number of users that can be simultaneously present in metaverse virtual environments (currently in the 10-1000 range) will be relaxed gradually, probably involving compromises that constrain the visual fidelity of avatars further away, or limit the number of avatars that can be present in a given area.

1.4 This report

Audience of this report

This report is intended for the NSW Government policy makers, ministers and staff.

Navigating this report

Following this introduction, Section 2 examines the metaverse and metaverse applications in more detail. It describes some key properties of metaverse applications that differentiate them from various existing technologies and approaches.

Section 3 gives an overview of the metaverse as implemented today, with a particular focus on the investment in metaverse technologies around the world and uptake amongst governments, private industry and the public. It also provides a brief description of some applications of metaverse technologies already in use by the NSW Government.

Section 4 examines potential future metaverse applications that may involve the NSW Government in different ways. This may be as a creator, user or regulator of metaverse applications or enabling technologies. The section focuses specifically on the potential harms and benefits associated with applying metaverse technologies in different contexts.

Finally, Sections 5-7 present the report's recommendations. Section 5 presents approaches for the government to build knowledge and experience metaverse technologies. Section 6 recommends augmenting existing NSW Government infrastructure and systems to better

integrate with the metaverse, focusing on digital identity and the NSW Spatial Digital Twin. The report concludes with recommended elements of metaverse governance in Section 7.

2. Properties of metaverse applications

Three key properties define metaverse applications in this report: a persistent virtual world, presence, and social connectivity. This section examines each of these properties and the various technologies that enable them.

2.1 Property 1: A persistent virtual world

Metaverse applications are typically 3D persistent virtual worlds experienced in the first-person, similar to 'first-person' computer games. There are locations users can travel to and objects users can interact with. They are typically persistent, in that they do not reset to an initial configuration but change over time (possibly through interactions with users). Users are present in the virtual world through their 'avatar': a 3D representation of themselves that may or may not resemble how they look in reality.

Enabling technologies

3D modelling

Techniques and tools to construct, texture, and animate 3D objects and environments are well-established in computer-aided design (CAD) and computer game development, as well as TV and cinema. These tools support output that can be highly detailed, realistic or stylized. Through 3D scanning and photogrammetry, real objects or locations can be recreated digitally with high fidelity.

Game engines

Game engines are software tools used to create virtual worlds. Unlike the rendering tools used to generate TV or cinema effects, game engines render 3D sound and vision in real time: meaning it is possible for the world to be interactive, reacting to the inputs of users as they occur. Game engines are responsible for a number of tasks in a virtual world including

- rendering, which turns mathematical representations of digital objects into visual output for display in a headset or screen that accounts for lighting, shadows, colours and textures
- simulating physics and other processes, such as ensuring that a lamp falls to the ground and smashes if a user pushes it off a table
- simulating 'non-player-characters' (NPCs); avatars controlled by software rather than a human.

Examples of game engines commonly used for metaverse-style worlds include Epic Games' Unreal engine and Unity Technology's Unity engine.[17,18]

Typical elements

- **A well-defined geography:** The virtual world has locations users can travel to, perhaps corresponding to the real world's geography or a completely invented one. The world might have buildings and open spaces like a modern city, or be under water, in space or in some other fantastic setting.
- **3D representation:** The virtual world has length, depth and height just like the real world, and can be examined from different positions, angles and locations. This is contrasted with many 2D computer games that show a flat, drawing-like world or a pseudo-3D world rendered from a fixed perspective.
- **Interactivity:** The virtual world has interactive elements: objects can be picked up, manipulated and interacted with. Potentially, buildings or the landscape itself may be able to be altered by users.
- **Persistence:** Changes made to the world persist over time. This is in contrast to a world that resets every time a user logs in. Changes may be caused by users' interactions, developers' interventions, or simulated dynamics of the world itself. Time in the world is sometimes frozen when no user is present, or it may continue to pass. This means, for example, that a user may notice changes that have occurred while they have been disconnected from the metaverse application.

Current limitations

- **Rendering fidelity:** There are currently significant limitations on the complexity and visual fidelity of virtual worlds when using virtual or augmented reality technologies. The computing power available for rendering on headsets requires compromises between:
    - high frame rates required to combat cyber-sickness
    - high resolutions needed to render to screens very near the eye
    - high levels of geometric and lighting complexity to reproduce many natural scenes.

  These issues may be ameliorated by offloading some or all rendering to a dedicated desktop or server, however the network bandwidth and latency to that server then imposes its own limitations.

Figure 2.1: Mark Zuckerberg takes a selfie in Meta's VR Horizon Worlds. Low geometric and lighting complexity are a consequence of the limited computing power of the Meta Quest 2 headset for which Horizon Worlds is designed.[19]

- **Simulation complexity:** Many natural and human processes are too computationally expensive or too poorly understood to simulate in a virtual world. Phenomena such as object deformation, turbulent fluid flow, chemical and biological processes and many others are infeasible to simulate today in many cases, for example. Virtual worlds use simplifications and/or visual tricks to give the appearance of complex phenomena like these.

2.2 Property 2: Presence

Metaverse applications use virtual and/or augmented reality to immerse users in their virtual worlds, giving them a strong sense of presence. Rather than viewing the world from the outside, akin to watching a movie, users get the sense that they are 'really there'.

Enabling technologies

Virtual reality (VR)

Virtual reality replaces the real world around the user with an alternative. A user may be sitting in their living room, but in virtual reality they are taking a tour of (a computer recreation of) the Eiffel Tower. To an extent the user is perceiving the virtual world as if they are there: they can turn their head to view the scene from different angles, and stand up from their living room chair to help them gain a better view.

Today, virtual reality experiences are most commonly produced by headsets, devices somewhat akin to large ski goggles that users wear over their eyes. Each eye sees its own small video display to allow for stereoscopic 3D imagery to be presented, and hear spatial audio from headphones either built into the headset or worn separately.

Figure 2.2: Researchers in Germany using a VR headset and motion controllers to demonstrate how astronauts might use VR to train how to extinguish a fire inside a lunar habitat.[20]

Augmented reality (AR)

Another approach to completely replacing the real world with a virtual alternative, is to 'augment' the real world with additional (virtual) features. This is the approach taken by augmented reality (AR), which for example, can place virtual posters on real buildings, or display information about a person that appears to hover over their head.[21]

Like virtual reality, augmented reality can be delivered via a headset-like or glasses-like device, however at its current stage of development it is most commonly accessed via mobile or tablet camera overlays. Users wearing AR headsets can navigate without bumping into things, but their visual and audible experience is augmented with sights and sounds the headset is overlaying on the real world in such a way as to make them seem real. AR headsets may use semi-transparent displays that let light from the real world in, or may be more similar to VR headsets and use outward-facing cameras to recreate the augmented scene in its entirety on opaque displays.

One feature of augmented reality is that additional information can be provided to users in their current sensory context: for example, a user conducting a field repair of a generator can have the service manual in their field of vision, perhaps even with relevant parts visually highlighted as needed.

FIgure 2.3: A smartphone augmented reality application by artist Vishal Dar, that adds abstract light sculptures in response to the environment.[22]

Mixed reality (XR)

When speaking generally about virtual reality, augmented reality, or a mixed experience in which some participants are using either technology, it is common to use the term mixed reality (XR).

Typical elements

- **Experienced in the first person:** The virtual world is experienced in the first-person, similar to 'first-person' computer games. This means that the view into the world is rendered from the perspective of the user's eyes. First-person contrasts to a third-person view, common in 'role-playing' computer games in which the view into the world is rendered from the perspective of a floating camera tracking the user from above or behind.
- **Stereoscopic visuals:** A headset presents each eye with a different image, calculated so that the brain perceives depth correctly as it would in a real scene.

- **Head tracking:** In order to adjust the images displayed to each eye as the user moves their head, headsets must track the head's position in space. Head-tracking can be accomplished with the help of external sensors or markers placed about the user's room, or through sensors (cameras, gyroscopes and accelerometers) built into the headset.

- **Spatial audio:** Sounds appear to come from the direction they should, get softer as the source gets further away in the virtual world, and can even seem to be muffled when occluded by virtual objects.

- **Avatar:** Users typically inhabit a virtual body in the metaverse world called an avatar. This may resemble them physically or not, and may not even be human. Users look out the avatar's eyes' and control its motions through keyboard, hand controls or motion tracking.

- **Body tracking:** Tracking more aspects of the users body allows for a higher fidelity recreation of them in the virtual world. For example, modern headsets typically track the hands to allow users to see them to aid picking up virtual objects.[23] New headsets arriving on the market will track gaze direction, facial expressions and positions of more of the body (like legs) to improve the fidelity of avatars from the perspective of other people in the virtual world.[24,25]

Current limitations

- **Cyber sickness:** Human balance systems can be sensitive to inconsistencies between their visual inputs and those from their inner ear. Such inconsistencies cause not only sea-sickness, but 'headset-sickness', where users of XR headsets feel dizzy, nauseous and get headaches after prolonged use.[26] Improving headsets' head tracking capabilities and decreasing the latency in their displays will likely reduce the frequency and severity of this effect. However, many users today find the current generation of headsets impossible to wear for extended periods.[26]

- **Placing objects in a complex scene**: AR, despite making fewer changes to the user's perception, is more difficult to implement than fully replacing a user's perception as with VR. Not only does the headset have to account for the virtual elements in a scene, it also must be able to understand the geometry and lighting of the user's real-world environment to be able to integrate those new elements convincingly. Many of the current 'augmented reality' products are really 'heads-up displays (HUDS)' which are standard screens overlaying information onto the users' field of vision without attempting to integrate that information into the scene.

- **Senses beyond hearing and vision**: Other sensory phenomena are increasingly being added to the virtual reality experience but the work is at an early stage and is low fidelity. Haptic gloves or suits can mimic the physical sensation of interacting with objects and are expected to reach the mainstream market shortly[27], and some companies have experimented with smell-dispensers to further increase the sensation of immersion.[28]

2.3. Property 3: Social connectivity

Metaverse applications allow multiple users to join virtual worlds together and interact with each other. Current metaverse applications include the ability for people to have virtual meetings, play games, create art, and design objects or buildings.[29]

Enabling technologies

Social networks

Social media such as Facebook, Instagram, Twitter and TikTok rely on an underlying social network of connections and interactions between individuals. This network informs inferences about what content may be of interest to a particular individual, who they might interact with in the future, and what content may 'go viral'.

Given the interest in the metaverse from social media companies, it is reasonable to expect that these same approaches will find use in the metaverse. Explicit friendship links, similar to social media, exist in many metaverse applications. These may soon be augmented with 'implicit' links, inferred by the metaverse application from user behaviours. Implicit social relationships could be inferred, for example, by noticing people stopping to talk to each other, sharing a physical space, or even making eye contact.

Typical elements

- **Shared presence:** Users can simultaneously navigate and interact with one another in a virtual space as if they were physically in the same room.
- **Long-distance communication**: Users in the same world but not located nearby may be able to teleport to each other's locations or send text or audio messages.

Current limitations

- **Content moderation:** Content moderation is an unsolved problem in existing social networks and internet forums. The addition of more flexible means of expression (for example, through body language) opens up new difficulties for platforms trying to remove abusive or unacceptable behaviour and content.

- **Scalability of simultaneous users:** The technical challenges involved in creating metaverse worlds increase with the number of users present in an environment simultaneously. VR applications with higher fidelity avatars are currently limited to small numbers of participants (for example, 16 in the case of Meta's Horizons Workrooms application),[30] whilst those with larger numbers of users typically have simple, mostly static geometry and highly stylised avatars that do not attempt to reproduce accurate body pose.[31] Currently, network and computing power limitations make it difficult or impossible to support more than a few thousand concurrent users in a virtual space.[32]
- **Requirements on network infrastructure:** Metaverse applications are heavily dependent on high-bandwidth, low-latency network connections to achieve real-time interaction between users. For people in remote areas with lower-quality internet connections, this may represent a significant barrier to their access to the metaverse.

2.4 Other technologies associated with the metaverse

This section outlines some technologies that are commonly associated with metaverse applications. These are not enabling technologies in the sense that they contribute to the properties of metaverse applications. Rather, they are associated with the metaverse because some application developers choose to integrate them. From the perspective of the NSW Government, these technologies are mainly relevant to this report because of the risks they create for users.

Cryptocurrencies

Commerce is an important part of the metaverse. Many metaverse application developers create virtual property including clothing, items and 'land' in their worlds which is for sale to users.[14] Gambling, especially virtual poker and casino games, is also offered in several metaverse applications.[33] Brands also perceive the benefit that a virtual world can be used to showcase real items: users could, for example, examine a new car or accessory in VR before purchasing it for themselves in real life.[34]

The mechanisms on which transactions within the metaverse are based are being explored by application and platform developers, but some are building their efforts on cryptocurrencies and non-fungible tokens (NFTs).[35] Cryptocurrencies such as bitcoin or ethereum take the place of traditional national currencies in these worlds. For example, a user may purchase a piece of virtual land in a metaverse world by transferring a certain amount of bitcoin to the metaverse application developers.[36]

The utility of cryptocurrencies for digital transactions is contentious, and is also largely independent of the metaverse as a particular application: advocates claim that such currencies are inherently 'private, safe and untraceable',[37] however, the bulk of both technical and financial experts without direct stakes in the success of cryptocurrency believe it has limited utility as a payment method, and is largely a way to circumvent banking regulation for the purposes of money laundering and fraud.[38]

Technical details aside, the volume of documented instances of large-scale fraud and ransomware attacks enabled by cryptocurrency suggests that if these currencies do become an integral part of the metaverse, users will be exposed to significant novel risks.[39,40]

Non-fungible tokens (NFTs)

Some metaverse applications record the purchase of an item or land in a metaverse world with non-fungible tokens (NFTs). These are records on a decentralised public database (a 'blockchain') that record a particular user has purchased a particular item in the virtual world. In principle, this item can then be on-sold by the user to another party, independent of the metaverse developer. Advocates of using NFTs to record metaverse ownership also contend that the public nature of the blockchain facilitates owners moving their items between metaverse worlds.[41]

Technical experts argue about the degree to which NFT technology is required or even useful in enabling this notion of ownership, or the ability to transfer items between virtual worlds. One uncontested fact is that the relationship between the record of ownership of an item and the effective rights that grants a user in a particular virtual world is entirely at the whim of the developers of that world.[42] A user purchasing a virtual pair of sneakers for their avatar in one world, for example, cannot have their avatar in another world wear those sneakers unless that second world creates the in-game asset and chooses to acknowledge the user's ownership of it. Similar to cryptocurrencies, the world of NFTs is replete with fraud, and its use in metaverse applications is a source of significant risks for users.

3. The metaverse today

3.1 Familiarity with the term 'metaverse'

According to an April-May 2022 survey by Ipsos for the World Economic Forum, over half of the 21,000 adults surveyed across 29 countries are 'familiar with' the metaverse (though the poll did not make clear what familiarity entails). Of those, familiarity was highest in Turkey (86%), India (80%), and China (73%).[43] The lowest was in Poland (27%), France (28%), and 'Belgium/Germany' (30%).

Familiarity of the enabling metaverse technologies is even higher, with 61% of the total surveyed adults familiar with AR and 80% with VR.[43] Emerging countries had higher interest in XR than high-income ones, with approximately two-thirds of adults surveyed from China, India, Peru, Saudi Arabia and Colombia 'feeling positive about engaging with XR'.

For Australia, the study shows 46% of the 1000 total Australians surveyed are familiar with the metaverse, compared to the global average of 52%. [43] VR familiarity was at 80%, on-par with the rest of the world at 80%. AR familiarity was at 51%, which was below the global familiarity at 61%. A total of 36% of the surveyed Australians had 'positive feelings about engaging with extended reality in their daily life' , compared to the global average (50%).

Participants were asked: 'How much do you agree or disagree that, over the next 10 years, the development of the following metaverse applications using extended reality will significantly change the way people live?'. The options and the average of Australian participants' responses were as follows, ordered by percentage of 'strongly' and 'somewhat agree' responses.

Response option	% Strongly or somewhat agree
Virtual learning (e.g., learning, courses, attending school)	65%
Digital health resources (e.g., virtual consultations, remote surgery)	61%
Digital entertainment in virtual reality (e.g., movies, concerts)	60%
Virtual socialisation (e.g., chats with friends/family, dates, meetups)	59%
Virtual work settings (e.g., virtual collaboration, networking)	58%

Virtual/enhanced gaming (e.g., virtual reality games, multiplayer tools)	56%
Trading of digital assets (e.g., NFTs, collectibles, cryptocurrency)	48%
Virtual travel and tourism (e.g., replicating the real world in virtual reality)	44%

3.2 Market and corporate investment

Estimates of the current (2022) 'metaverse market' value range anywhere from $10B to $1T. According to research conducted by Bloomberg in 2021, the value of the metaverse market is projected to grow to $783.3B USD in 2024, compared to its $478.7B USD value in 2020.[44] Grand View Research estimated the 'global metaverse market size' to be $38.854B in 2021, with an annual growth rate (CAGR) of 39.4% from 2022 to 2030.[45] McKinsey & Co. estimated that the 'value of the metaverse could reach $5T by 2030'.[16]

Some large technology companies have rebranded or developed products to cement their role in this market. Facebook rebranded itself as Meta Platforms Inc. in October 2021, to 'transition from . . . being a social media company to being a metaverse company' and to 'help bring the metaverse to life'.[46] NVIDIA developed the *Omniverse*; a 'real-time, cooperative design platform for in-game art and virtual worlds' to support metaverse creators and digital-twin development.[47]

Other tech companies have undertaken acquisitions or partnerships to engage with the metaverse. Microsoft acquired the video game producer *Activision Blizzard* for $68.7B USD in January 2022 to 'provide building blocks for the metaverse' in game development.[48] Epic Games and WPP formed a partnership in May 2022 to 'deliver a new era of digital experiences for brands in the metaverse'.[49]

New companies are forming to capitalise on this emerging market. An example is Decentraland — the 'first decentralised metaverse that is built, governed, and owned by its users' — which opened to the public in February 2020 and it allows the public to purchase virtual land using ethereum as a currency.[50] Various companies have purchased 'real estate' in Decentraland, including Samsung, who created an 'immersive world' called *Samsung 837X.*[51]

Figure 3.1: Avatars interacting in Decentraland's 'Genesis Plaza'. [52]

Finally, the World Economic Forum, an international non-governmental lobbying organisation with 1000 member companies, also has a number of metaverse task groups underway. These groups aim to work towards an 'economically viable, accessible, and inclusive metaverse'.[53]

3.3 Government interest and adoption

A small number of governments and cities internationally are investing in metaverse strategies, however there are few details publicly available on exactly what these strategies contain.

In June 2022, the South Korean Ministry of ICT announced a 'pan-government strategy on metaverse' to 'become a leading global metaverse country', as part of their *Digital New Deal 2.0* initiative.[54] They have earmarked 223.7B won total (equivalent to $250M AUD) for the initiative.[55] Their support strategies include nurturing companies specialised in the metaverse, establishing a 'Metaverse Academy' to train young developers and creators for capability in the metaverse, and creating regional hubs to encourage domestic metaverse service and platform development.

Part of South Korea's metaverse strategy is a suite of ethical principles and proposed regulatory procedures. According to their press release, these ethical principles will be 'voluntarily complied with by participants in the metaverse ecosystem to foster trust and safety'.[55] They will be establishing a government-wide metaverse committee to discuss the protection of personal information and intellectual property, and to determine regulation

procedures for unethical and illegal activities in the metaverse. The specific principles and regulation procedures are not public as of June 2022.

In May 2022, Dubai's ruler Sheikh Hamdan bin Mohammed bin Rashid Al Maktoum launched a higher committee to prepare a 'Dubai Metaverse Strategy'. The goal is to 'transform Dubai into the world's best city in the world [sic] to live, work, and invest. The constant development of government services is vital to achieve this goal and ensure Dubai maintains high levels of global competitiveness'.[56] The aim of the strategy is to 'increase the contribution of the metaverse sector to the emirate's economy to $4 billion by 2030', and to '1% of the emirate's GDP'.[57] As part of the strategy, the committee aims to use 'metaverse technologies' to 'improve the performance of resident surgeons by 230%', 'increase the productivity of engineers by 30%', and 'support 42,000 jobs to become virtual'.

The Dubai Virtual Assets Regulatory Authority (VARA) is also developing a regulatory framework 'for financial entities to operate in the metaverse, including bank and state services'.[58] In early May 2022 it established a *MetaverseHQ* so that the 'Dubai government [can] extend its services and regulatory power to audiences in an open technological expanse, without constraints or borders' as part of its new 'prototype decentralised regulatory model' strategy.[59] The MetaverseHQ (also known as 'MetaHQ') will be based in The Sandbox virtual world. Although these regulations are unlikely to be delivered in 2022, the initial focus will be on 'younger licensees', development of an API to help integrate other state and regulatory structures into the metaverse and issuance of digital IDs.[58] The authorities are aware of the complexities, such as digital ID privacy concerns, the independent guidelines and security requirements of each state and the issue of enforcing regulation in a decentralised environment, however they are optimistic of the outcomes. As of July 2022 the details of the regulatory frameworks have not been made public.

In November 2021, the Government of Barbados signed an agreement with Decentraland to develop a Barbados Metaverse Embassy in the virtual world. The embassy 'will be an important forum . . . to deepen engagement in the diplomatic arena; the investment, business, tourism and cultural sectors; and people-to-people interaction'.[60] The details of the digital embassy's capabilities have not been made public, however the Barbados' Ambassador to the United Arab Emirates, H.E. Gabriel Abel, said that e-consular services and virtual teleporters will be core elements. The teleporters act as a 'common access point to all of the metaverses to foster meta-diplomacy'.

Some international cities have engaged in their own metaverse strategies too. The Shanghai Municipal Commission of Economy and Information Technology released a five-year plan in December 2021 that listed the metaverse as one of four avenues for developing the electronic information industry.[61] It recommended metaverse research for application in 'public

services, business offices, social entertainment, industrial manufacturing, and production safety and electronic games', however specific timelines and goals for the research were not released. The Provincial Government of Jakarta is another example, where in April 2022 it established a strategic partnership with WIR Group (an AR company in Southeast Asia) to enhance its Jakarta Smart City initiative with the metaverse in mind.[62]

3.4 Commercially available metaverse hardware

The AR and VR headset market grew 92.1% over 2021, shipping over 11.2 million units, according to the IDC's Worldwide Quarterly Augmented and Virtual Reality Headset Tracker.[63] According to their projections, by the end of 2026 there will be over 50 million units shipped worldwide per year for the commercial and consumer market combined.

VR systems

Access to VR content does not necessarily require a headset — many VR videos are available for free on websites such as YouTube under 'YouTube VR' — but headsets provide a heightened sense of immersion when viewing VR and 3D content compared to using a 2D screen.[64,65]

The first stereoscopes were introduced as early as the 1800s, allowing a person to view a pair of 2D image overlays as though they were in 3D and the first hand-held variety were the Brewster stereoscopes in 1849.[6667] The (widely-considered) first computer-connected head-mounted 3D display was created in 1968 by Ivan Sutherland and his students and the first interactive virtual reality experiences were released by video game companies in the 1990s by companies like Sega and Virtuality.[68,69] Their popularity waned in the 2000s before the first Oculus Rift headset was presented to the public in 2012.[70]

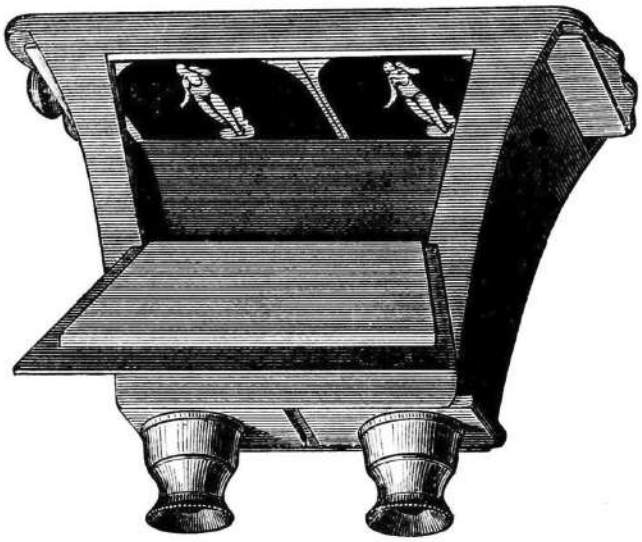


Figure 3.2: Brewster stereoscope[71]

The first modern head-mounted VR devices (HMDs) — such as Oculus Rift — were 'connected', i.e., they only functioned if they were attached by cables to an external computer. In other words, the bulk of the VR computation was done by the connected computer. Then in the mid-2010s emerged 'mobile' VR headsets such as Samsung Gear VR, Google Daydream View and Google Cardboard. These HMDs dispensed with external computer attachments in favour of housing smartphones to display VR-compatible content on their screens, converting the phone into a headset. This had the benefit of portability, as users could take their headsets with them, rather than be confined near a computer. These were succeeded by 'standalone' HMDs such as Oculus Go and Vive Focus, which required no external devices at all and had an embedded computer that could run VR applications.[72]

VR headsets are widely available to purchase today. Popularised headsets include the *Quest* series from Meta (who purchased Oculus in 2014),[73] HTC's *Vive*, Sony's *Playstation VR*, Samsung's *Gear VR*, and HP's *Reverb*. Some of these headsets come with accessories and configurations designed to improve the user's immersive experience, such as prescription lenses,[74] trackers to improve movement detection,[24] and controllers designed for specific games such as first-person shooters.[75]

Meta's *Oculus 'Meta' Quest 2* headsets dominated the 2021 VR headset market at 80% of the total worldwide sales that year.[76] The remainder of the market share was split between DPVR (a VR headset company with primarily commercial clients), Pico, Valve, Sony, and smaller firms. The prices of the baseline commercial headsets — excluding accessories and upgrades

— range anywhere from $15 AUD to $1000 AUD, however the self-functioning VR devices are usually $300+ AUD.[77]

Figure 3.3: Oculus Quest 2 (later rebranded as Meta Quest 2) on display in a Japanese electronics store.[78]

AR systems

True AR systems are not yet common, although optical head mounted displays that project 2D information onto the user's field of view have existed commercially for some time.

Perhaps the best known example of these optical head mounted displays is Google Glass, originally launched by Google in 2013. This device, resembling a pair of wire-frame spectacles, augmented the user's perception to support their everyday activities, or even thrill-seeking activities such as skydiving and wall-scaling.[79] However it was expensive (retailing at $1500 USD), buggy, and received backlash over its privacy issues such as recording people without their consent.[80] The device — in this original form — was removed from the commercial market in 2015.[81] Google has announced a second *Enterprise Edition* version of Google Glass to improve workplace efficiency.[82]

Meta has partnered with Ray-Ban to produce head mounted displays called *Ray-Ban Stories*, with colour filters, video recording, and sharing features for the new social media age.[83] Other companies have contributed to the venture, such as Qualcomm who created a reference design for hardware markers to build AR glasses.[84]

One of the first commercially available 'true AR' headsets that did integrate its content into the user's surroundings was the Microsoft *HoloLens,* launched in 2016. The HoloLens is marketed mainly to enterprises and professionals, with potential applications in surgery, architecture, and construction. NASA's Jet Propulsion Laboratory reportedly uses the HoloLens to help explore the surface of Mars.[85]

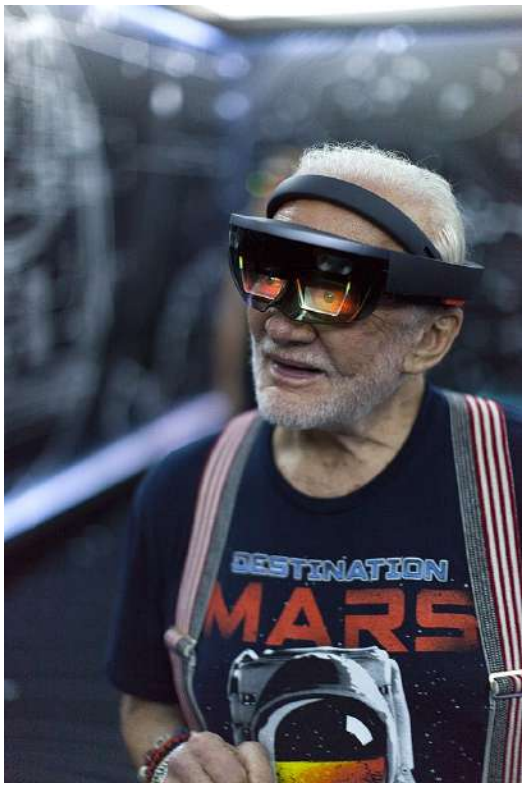


Figure 3.4: Apollo 11 astronaut Buzz Aldrin wearing Microsoft HoloLens during the 'Destination: Mars' experience at the Kennedy Space Centre Visitor Complex.[86]

Simpler augmented reality applications that rely on smartphones rather than headsets have had significant commercial success. Platforms such as Instagram, TikTok and Snapchat have integrated AR filters into their video creation tools to enhance the users' experiences and to encourage interconnectivity. According to Snapchat's CEO Evan Spiegel, '200 million people are using augmented reality every single day' via the Snapchat app.[87] Other platforms gamified AR, such as Niantic, who created *Pokemon GO*, an AR-based open-world roaming application for users to catch and grow Pokemon.[88]

3.5 Metaverse applications

Many applications marketed as 'metaverse' adopt similar play structures to massive multiplayer online (MMO) games. Some games have VR headset compatibility, others forgo the VR hardware and AR elements entirely and have users play on their desktops or smartphones. Some are designed for access by the public, others are designed for enterprise invitation-only meetings.

An example of a popular metaverse application is Horizon Worlds. Meta developed Horizon Worlds for their Meta Quest platform,[89] an open world 'social VR experience'.[90] Users create avatars of themselves to portray in this environment, and as avatars they can travel through these environments and interact with other players, chat and play games. The system uses spatial audio and tracks body movements to increase users' sense of immersion. It is not playable without use of a Quest VR headset, however Meta's chief technical officer Andrew Bosworth revealed on Twitter that a web version compatible with other hardware is in development.[91] This application was released to users aged 18 or older in the US and Canada in December 2021.[90] According to Meta's chief product officer Chris Cox, by 17 Feb 2022, Horizon Worlds had around 300,000 users, which was a 10x increase in three months.[92] As of June 2022 it contained more than 10,000 different worlds.[89]

Meta also developed Horizon Workrooms; invite-only VR rooms for work colleagues to have meetings and conferences.[93] It adopts similar immersion techniques to Horizon Worlds. Users are placed in a static meeting room environment whose layout and styling is configurable from a list of presets.

Microsoft released *Mesh* in November 2021, a mixed reality platform that 'allows people in different physical locations to join collaborative and shared holographic experiences'.[94] In combination with Microsoft's *AltspaceVR* social networking platform, users — in their personalised 3D avatar form, like in Horizon Worlds — can socialise with other members of the public. Microsoft trademarked an additional feature called 'Holoportation', which uses '3D capture technology to beam a lifelike image of a person into a virtual scene' without requiring an avatar substitute.

Microsoft also developed a meeting-specific version of Mesh called *Mesh for Microsoft Teams*, which behaves in a manner similar to Horizon Workrooms. It 'combines the mixed-reality capabilities of Microsoft Mesh . . . with the productivity tools of Microsoft Teams'.[95] Although Mesh for Microsoft Teams and Horizon Workrooms are not designed as open world social networking platforms that encourage societal interconnectivity (unlike Mesh and Horizon Worlds) they do aim to address the social and physical limitations of purely 2D virtual conferencing platforms such as Zoom. Additionally, even though Mesh for Microsoft Teams and Horizon Workrooms have been tailored for use with VR headsets, users can also dial into

the meetings through their mobile phones, tablets, or any PCs that have the relevant applications installed.[96,97]

The Sandbox is an example of an application claiming to be in the metaverse but that does not require XR headsets. Rather, users access this application through a traditional keyboard, mouse, and monitor setup. In this virtual world, 'players can build, own, and monetize their gaming experiences in the Ethereum blockchain'.[98] The goal of this platform is to 'provide creators with true ownership of their creations as non-fungible tokens (NFTs) and reward them for their participation in the ecosystem.' Like many online multiplayer games, The Sandbox has an in-world economy in which players can buy and sell in-game goods and services. There are several free 3D model and game development tools on offer that are compatible and endorsed by The Sandbox, such as VoxEdit and Game Maker. The Sandbox reportedly had 'over 30,000 monthly active users, about half of whom spend more than an hour per day in the metaverse' as of November 2021.[99]

3.6 Existing applications of the metaverse in the NSW Government

NSW Department of Education

The NSW Department of Education (DoE) Information Technology Directorate has been exploring VR technologies for use in education, both as a teaching and learning tool. As part of its STEM Technology 4 Learning (stem.T4L) program, DoE provides support materials for teachers, students and schools to adapt VR or other emerging technologies into the classroom.[100] NSW teachers can borrow Handheld Virtual Reality (HhVR) kits for their classroom through the stem.T4L Learning Library platform.[101,102] School engagements in the stem.T4L program have yielded positive outcomes for teachers and students over the three years since its inception,[103] however the quantified impacts of the HhVR kits and VR materials on this positive result are not publicly available.

Figure 3.5: Students of Blacktown Girls High School using stem.T4L's immersive VR kit in an after-school art masterclass[104]

The NSW Government has also encouraged use of VR for art and design. The NSW DoE and the NSW Education Standards Authority created a VR gallery for ARTEXPRESS, an annual exhibition showcasing exemplary artwork by NSW HSC visual arts students.[105] Users can wander through the exhibition and peruse the artworks on the walls as though they are in a physical space.[106] Several schools have also adopted the stem.T4L VR kits to teach art in the classroom. An example is Blacktown Girls High School who implemented an after-school art program using VR, which a case study revealed improved students' understanding and appreciation of the possibilities of technology.[104,107] Another example is the students at Merrylands High School who used the stem.T4L VR kit to build a virtual environment to showcase the 'site-specific artworks' that were created as part of the Kaldor Public Art Projects and DoE partnership program.[108] The app contains artworks from schools across NSW, and in 2020 was available to download through the Microsoft app store.

Figure 3.6: A screenshot of one of the 2022 ARTEXPRESS VR exhibit areas.[109]

TAFE NSW

TAFE NSW have also been exploring how VR can be used to deliver and develop course content. Use of VR is 'supplementary to practical training' and an opportunity for students to experience their industry worksites before graduating into the workforce, which is 'better than being taught laws and regulations on paper'.[110] By June 2020, the TAFE Digital Lab had developed eight virtual and augmented reality application prototypes. These support different TAFE disciplines such as childcare, stage lighting, construction, plumbing, welding, and even training work, health and safety processes such as putting on protective equipment. TAFE NSW's research indicated that students who completed training in virtual reality had a 'combined learning outcome improvement of 64% on completing their practical assessment tasks in comparison to a traditional learning cohort'.[111] TAFE NSW was awarded the Learning Impact Award from the IMS Global Learning Consortium for its work in this field, and Meta provided them with 1000 VR headsets to support this program.

Figure 3.7: TAFE NSW students interacting with VR training materials developed by the TAFE DIgital Lab.[112]

NSW Department of Health

VR has been integrated into some training for health professionals. The NSW Department of Health affiliated Agency for Clinical Innovation (ACI) created a VR training program for stroke treatment. Using VR allows 'staff to train in a realistic environment before they need to treat patients . . . in the real world. This is particularly valuable in high-risk scenarios, such as stroke'.[113] The training is 20 minutes long and has proven successful in rural and regional hospitals across NSW. TAFE NSW also partnered with NSW Health Pathology in 2020 to create a 'world-first' VR training simulation to 'expand and increase acute care point of care Testing capability'.[114] The training module is being piloted in a number of clinical sites across NSW and in December 2021 won the Australian Good Design Award.[115,116]

Transport for NSW

Transport for NSW has made several investments in XR. Sydney Trains have developed a Track Augmented Reality View app for iOS that 'improves the current ways of identifying assets on-site' to 'ensure the safety of workers in the field'.[117] The application uses satellite navigation to locate assets, and allows workers to search, view and upload information about assets relevant to their operations. Transport for NSW, in partnership with the University of NSW, is also using VR to research how to integrate cycling facilities into urban and suburban environments without causing rider safety concerns. The goal is to 'evaluate possible design elements (i.e. facilities) for their acceptance by potential cyclists' and use that to determine necessary design interventions.[118] Internally, Transport for NSW recently purchased 20 VR

headsets for its staff. The department has indicated that these headsets will be primarily used for video conferencing in Microsoft Teams.

4. Metaverse applications with government involvement

This section examines some current and predicted applications of metaverse technologies that may involve the NSW Government. Being general-purpose, metaverse technologies may be applied in many different domains relevant to the government, including health, education, justice and infrastructure. Different applications will also involve the government in different roles, including those of a user, developer and regulator.

4.1 Roles of the NSW Government

The NSW Government may adopt metaverse technology to provide services directly to the public or to facilitate peoples' day-to-day activities. It may wish to provide support for third-parties building metaverse applications, and it may be required to engage with third-party applications as a regulator. The following paragraphs enumerate key roles the government may have in different metaverse applications.

Application user: The Government has identified internal activities it conducts that may benefit from metaverse technologies in the near-term. This could be done through internal application development, the commissioning of an application from a third party, or by using an application that is commercially available. In some cases, the NSW Government already has VR applications deployed internally, which may become more 'metaverse-like' through augmentation with support for multi-user shared presence and persistent virtual worlds.

Application provider: Some NSW Government services may be provided to the public through metaverse applications created or commissioned by the NSW Government in the future. In some instances, such as primary and secondary education, the government is already providing virtual reality applications to students as learning tools.

Service provider: Some metaverse applications, whilst being developed and run by private entities, may benefit from NSW Government infrastructure or services like digital identity.

Platform provider: In circumstances where the NSW Government needs to retain a greater degree of control over user experience (such as in education), it could provide a platform that hosts approved metaverse applications.

Regulator: As the metaverse expands, private metaverse applications accessible to NSW residents may pose risks that require regulatory intervention from the NSW Government.

4.2 Application classes

For each application, we examine the

- potential benefits and harms of applying metaverse technologies
- alternatives to the use of metaverse technologies
- differing ways in which the NSW Government may be involved.

Though some of these considerations are unique to a particular application, we have identified clusters of similarity in application *classes*. Each of the five classes captures a reason for using metaverse technologies common across many applications. These classes are:

1. **Bringing people together**
   e.g. VR meetings
2. **Assisting people with contextual information about their activities**
   e.g. AR schematic overlay for maintenance worker
3. **Providing people a model of the real world**
   e.g. VR emergency and disaster response planning tool
4. **Giving people experiences**
   e.g. virtual art gallery
5. **Transporting people out of their environment**
   e.g. virtual outdoor worlds for people stuck in confined spaces

Of course, these classes are neither exclusive nor exhaustive: some applications may fit into multiple classes and others won't fit well into any class. However, we believe they capture and differentiate between the applications most relevant to the NSW Government.

Illustrative examples

A set of illustrative example applications accompany the analysis of each application class. We chose the examples that appear because they are relevant to NSW Government and

- have been proposed or implemented by the NSW Government
- have been proposed or implemented by third parties
- might reasonably be proposed or implemented.

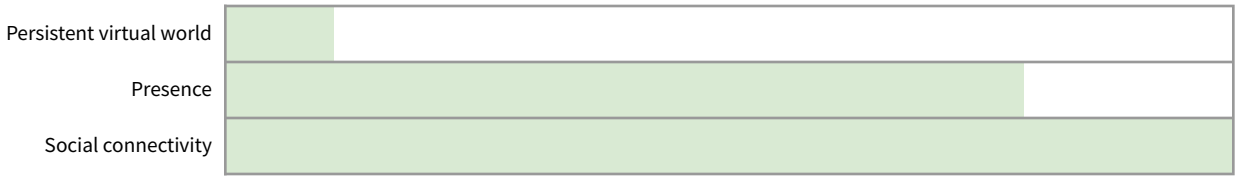
Note that an application appearing as an example should **not** be taken as a recommendation or suggestion for the NSW Government to implement it. Many applications have significant or unknown risks of harm, and can also be addressed with other approaches. As Sections 5 and 7 indicate, we believe the onus is on those advocating for metaverse technologies to demonstrate their effectiveness and safety compared to established alternatives.

The table below provides a summary of the application examples and their associated class:

Class	Application domain	Application example
bringing people together	socialising during covid-19 lockdown	virtual nursing home visitations
	remote enterprise collaborations	virtual tech precinct for NSW
	remote customer service	VR service NSW
	live expert guidance for high-complexity tasks	'over-the-shoulder' live collaboration during surgery
	legal obligations	VR courts
assisting people with contextual information about their activities	schematic overlays for asset management	rail corridor maintenance activities
	informational overlay for the public	NSW food safety certificate AR overlay
providing people a model of the real world	workplace training and upskilling	police and firefighter training in building entry and navigation
		VR medical training in hospitals
	logistics and planning	emergency and disaster response planning
giving people experiences	virtual tourism	AR Vivid Sydney
		virtual tour of the Sydney Opera House
	educational tours	high school student VR tour of manufacturing facility
	gambling	AR gambling bars
transporting people out of their	alleviating pain and emotional	VR as an augmentation /

environment	distress	alternative to anaesthetic in hospitals, e.g. for children or for mothers during birth
	alleviating confinement for people who are bed-ridden or location-constrained	VR experiences for residents of nursing homes who may be unable to travel physically

4.3 Application class: Bringing people together



relevant metaverse properties

This class encompasses metaverse applications that enable social activities: engaging in conversations, conducting meetings, or interacting with other people. Such applications typically allow participants to interact with digital avatars of other people in a shared environment. The environment could be entirely virtual if using VR, or a real environment with AR.

Building larger shared virtual environments provides the possibility of scaling levels of co-location: for example, whilst a virtual meeting room allows participants to directly converse, a virtual office building or city block gives the opportunity for different styles and frequencies of interaction.

Existing alternatives

Obvious alternatives that should form a baseline of comparison for this class of applications include

- co-locating in the real world, for example meeting in person or sharing an office space
- other digital communications tools like phone calls, email, video conferencing etc.

Potential benefits

- **Convenience:** In many circumstances bringing people together with metaverse technology will be cheaper, easier and faster than doing so in the real world, especially for people in remote or distant locations.
- **Prevention of disease transmission:** Virtual co-location removes the risk of disease transmission (which is particularly pertinent during the Covid-19 pandemic).
- **Better social immersion than 2D video conferencing:**
    - **VR:** The immersive property of VR environments may provide direct benefits in the quality of the social interaction compared to other forms of remote communication like video conferencing (see Section 2.3). Spatial audio, for example, allows small groups to huddle together and have separate conversations in the same virtual room as they might in a real gathering.
    - **AR:** Similarly, interactions enabled by AR are reported to be more similar to natural face-to-face interactions than screen-based alternatives. This may leave users feeling more attentive, focused and motivated.[119] AR can also help improve spatial reasoning and visualisation abilities, facilitate kinesthetic learning, and increase creativity by allowing users to explore and absorb new knowledge, and solve novel problems.[120]

Potential harms

- **Lack of access control:** Depending on the level of accessibility of the metaverse application, it may be difficult to control who is permitted to attend. This issue may arise particularly when using large, 'open world' platforms such as Meta's Horizon Worlds or The Sandbox to hold events.
- **Anonymity may encourage anti-social behaviour:** Like many online situations, physical remoteness and possible anonymity of participants may encourage anti-social behaviour which can be difficult or impossible to police in large settings.
- **Excludes users who cannot wear headsets:** Though users that can't afford headsets or are unable to wear them for extended periods may still be able to participate (using their phone, for example), this risks creating a two-tier experience that excludes or disadvantages those individuals.

- **Excludes remote users:** Lack of access to high quality network infrastructure is most common in remote areas, potentially excluding the very people that stand to benefit most from these applications.

Example applications

APPLICATION: VIRTUAL NURSING HOME VISITATIONS

Description: VR visitation rooms for residents of nursing homes where in-person visitations are infeasible.

Role of government: Application user

Rationale: During quarantine and lockdown, in-person family / friend visits to facilities such as hospitals, aged care homes and prisons were not permitted. NSW Government staff indicated that this was particularly problematic for people in nursing homes, as visits from family & friends could be a crucial social interaction. By bringing people together using VR, real-life in-person visitations can be replicated without requiring family and friends to travel to the physical location.

Assumptions: Nursing homes adopting this strategy are equipped with the VR hardware and network infrastructure required to run these virtual environments in a realistic, immersive manner.

Specific considerations: In-person visitations may be preferable to VR visitations. VR visitations should be seen as an opportunity to increase the number of interactions between residents and their families rather than replacing in-person meetups.

Existing implementations:

A similar AR-based nursing home visitations study yielded positive results.[121]

A number of companies have already begun to stake a claim in this space, offering VR experiences to aged-care residents.[122–125]

APPLICATION: VIRTUAL TECH PRECINCT FOR NSW

Description: A dedicated virtual space for tech startups, problem owners, domain experts and academics to come together and innovate within.

Role of government: Platform provider or application provider

Rationale: By creating a 'virtual tech precinct' in a virtual world, the NSW Government can encourage collaborations between departments involved in new technologies and private companies in the VR space.

Metaverse virtual spaces combine many of the benefits of Zoom or Teams spaces (global reach, inexpensive to run) with the social aspects and spontaneity of in-person encounters that are often crucial for innovative endeavours.

Assumptions:

A sufficient number of people with access to VR headsets would be interested in such a hub to attain a critical mass of participants.

Participants are willing to wear a headset for however long they intend to participate in the hub.

Specific considerations: The global reach of these spaces can be a double-edged sword. International talent can contribute to the space, but local talent would also have access to similar workspaces set up anywhere else in the world. Any virtual tech precinct will need to invest heavily in developing its community to make it an attractive location for potential collaborators to base themselves.

Existing implementations: Horizon Workrooms offers elements of what is required for a virtual workspace. The application provides virtual meeting rooms in which crowds of up to 16 people can interact. The application lacks any sense of physical connectivity between rooms which one might expect in a hub. Avatar movement is restricted to teleportation between preset locations within each space, preventing elements of socialising that arise through less structured mingling.

Application: VR Service NSW

Description: A 'virtual NSW Service Centre' which can be accessed through VR, allowing users to access the same services they would in a real service centre, but from any location.

Role of government: Application provider

Rationale: In this service, users enter a virtual room containing avatars of NSW employees, that they would be able to converse with to conduct their business with the NSW Government. This service could be accessed from the home and could be focussed towards groups with mobility issues such as the elderly or remote communities who may prefer a face-to-face interaction with a representative rather than through a website or over the phone.

Assumptions: The government would need to provide this service functionality as a stand-alone VR app, or as part of a widely-adopted metaverse application. It would need to be bespoke, and would need to have the endorsements of the NSW Government in terms of regulations, behaviour management etc.

Specific considerations: This strategy would only be effective if there is large-scale community take-up of VR, where the public are comfortable spending significant time periods in VR and conduct

activities there as part of their daily lives. The need for a digital verification method would be crucial in this application to prevent malicious actors from stealing the identities of others. Safeguards are currently in place for the online and phone services. These may be a suitable starting point for a VR centre too.

Existing implementations: None in the public service, and there are no other similar examples globally. However, as discussed in Section 3.3, some international governments are investigating ways to involve themselves in the metaverse.

Application: 'Over-the-shoulder' live collaboration during surgery

Description: The use of AR headsets as a 'telementoring' medium, for example engaging remote experts while undertaking unfamiliar medical procedures.

Role of government: Application user

Rationale: This approach could be life-saving if we consider high-complexity and time-crucial surgical procedures with experts on the other side of the world. A local surgeon could use their AR headsets to contact a specialist during an unfamiliar procedure. This call would be superimposed on the worker's headset and a camera feed showing their environment would be transmitted live to the expert. This allows both expert and worker to have a common line of sight, therefore a common frame of reference when offering advice, allowing for greater collaboration and a reduced chance of miscommunication.

Instead of the patient needing to travel for the right care, a local surgeon could put on an AR headset and communicate remotely to an expert who coaches them through the procedure.

Assumptions: The reception in the area of work is able to handle live video feed uploads and downloads, and audio or video conferencing is of an acceptable quality.

Specific considerations: For surgeries, low network latency would be a requirement.

Existing implementations: The University of California San Diego and Naval Medical Center San Diego (NMCSD) collaborated on an Augmented Reality Technology-Enabled Remote Integrative Surgery (ARTEMIS) project.[126] In this project, 'expert surgeons in remote sites use VR to access a 3D reconstruction of a patient's body, and instruct novice surgeons on complex procedures as if they were together in the operating room. Novice surgeons in the field can focus on saving a patient's life while being guided through an intuitive AR interface'. A separate study on the use of AR for 'telementoring' and remote assistance in spine surgeries also showed promising results.[127]

Figure 4.1: Matthew Vasquez, a neurosurgeon at NMCSD, conducting a craniotomy using the ARTEMIS system.[128]

APPLICATION: VR COURTS

Description: As an alternative to video conferencing, some court sessions could take place in a VR space.

Role of government: Application provider

Rationale: VR technology could offer a number of benefits in the courtroom setting.

- Jurors can visit a virtual reconstruction on the crime scene giving them a deeper understanding and additional context about key events.
- Defendants could be given the opportunity to be represented by a generic avatar of neutral appearance to conceal traits that are irrelevant to the trial such as gender or race but which may influence jurors.
- Virtual courtrooms could offer a safer setting for defendants or witnesses whereby they can choose who they see when giving their testimony.

Assumptions: The changes to the court and its operations still comply with all of the legal requirements that the trial must adhere to.

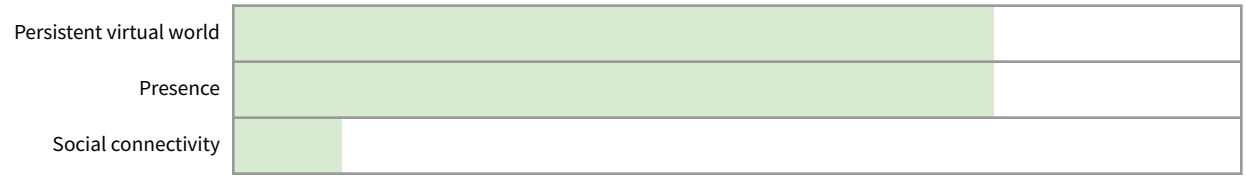
Specific considerations: There is precedent for Australian courts becoming early adopters of new technologies. The Australian High court was one of the first in the world to admit evidence via video link.[129]

Existing implementations:

- VR reconstruction for jurors [130]

- Fair administration of justice for groups affected by prejudice [131]

4.4 Application class: Assisting people with contextual information about their activities



relevant metaverse properties

This class is primarily relevant to AR applications, which are able to inject additional information, objects or features into a user's existing perception of their environment.

Users equip an AR-enabled headset that can scan a real-life environment and overlay the image with data-based contextual information in real-time.

Existing alternatives

The obvious alternative to AR applications is experiencing reality without information overlay, in other words, continuing to operate business-as-usual.

Potential benefits

In AR, users can see hidden information about their surroundings as they are experiencing them in real-time. This can be useful for

- **tourism:** for example, walking past points of interest and seeing information about the height of a building and its history
- **multi-tasking:** undertaking difficult or mentally taxing tasks without needing to switch contexts or use other devices
- **obtaining remote assistance:** drawing on expertise remotely or whilst in the field, which will improve work efficiency and upskill the workforce. The ability to channel expertise remotely reduces the costs and time pressure of bringing an expert onto the physical scene.

Potential harms

- We can identify few risks of using AR technology in this context, outside of the risks already occurring with business-as-usual. For example, errors in maintenance from using an outdated AR schematic map is akin to having used an outdated paper map, but AR schematic maps can be more easily updated and distributed, provided other workers use the same AR systems.
- **Unexplored technical limitations:** As AR tech is still in its infancy, the technical limitations are unclear. As a result, setup could be expensive, only purchase-able from certain vendors, and may require certain environments to work (e.g. good lighting conditions, good bandwidth).

Example applications

APPLICATION: RAIL CORRIDOR MAINTENANCE ACTIVITIES

Description: AR headsets with automatic digital schematic overlay to assist workers in rail corridors.

Role of government: Application user

Rationale: By generating a digital schematic (e.g. of a railway network or an electrical network) with corresponding geographical coordinates, this information can be superimposed on an AR device, such as headsets or smart glasses. A rail-corridor maintenance worker could use this digital overlay to obtain a 360° view of the underlying corridor infrastructure (e.g. wires, pipes) while standing in the corridors themselves. This would be comparable to the existing Sydney Trains smartphone-based AR maintenance approach, but the automated overlay on an AR headset would remove the degree of separation between the phone and the scene.

Assumptions: Maintenance areas — especially ones underground — may lack the lighting conditions and sufficient internet download speeds for live AR schematics overlay, unless the schematics have been stored in the AR device itself. In that case, a sufficient storage space on the device would be essential.

Specific considerations: The success of AR overlay maintenance procedures depends on the accuracy and completeness of the schematics used. If necessary information that impedes maintenance (e.g. electrical network routes used by private companies) is not included in the schematics, it could disrupt networks and the NSW Government could be liable for damages.

Existing implementations: None for AR headsets, however Sydney Trains has implemented AR rail corridor safety applications for mobile devices [132].

Application: NSW food safety certificate AR overlay

Description: A metaverse company or third party developer could provide a Restaurant Finder app. A user would walk through a restaurant area and see properties of restaurants displayed on the facade of the restaurant. This could include properties such as:

- restaurant review ratings (from a platform provider, third party user rating service or a critical specialist restaurant review site)
- restaurant hygiene and food safety scores ('Scores on Doors' provided by the NSW Food Authority[133])
- restaurant offences (from the 'Name and Shame' register provided by the NSW Food Authority[134])
- Business licences such as food handling licences from NSW Food Authority.[135]

Role of government: Service provider

Rationale: This AR certificate overlay could replace restaurant guide phone applications with no significant risks to the community. Having a wearable AR device that automatically overlays information about a restaurant would forgo needing to manually search and cross-reference restaurants using a phone, and would have few or no additional requirements on the data APIs. It could encourage the public to try different businesses, raise public awareness of the hygiene statuses of businesses, and thus generate further incentive for businesses to maintain good hygiene standards. However, as this AR overlay would be bespoke, it could be more expensive and complex to implement compared to using a phone, and have more significant hardware requirements.

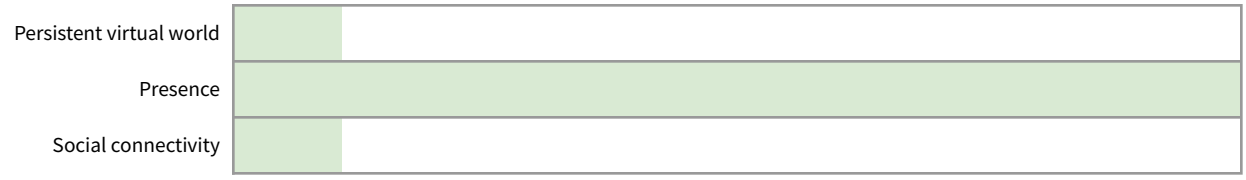
Assumptions: The wide adoption of AR interfaces commonly worn or used in public

Specific considerations: To achieve this, The NSW Government would need to

- Provide business data through an API
- Provide hygiene and food safety scores for each business through an API
- Provide business offence data through an API
- Provide building data from digital twin to assist visualisation of virtual facade

Existing implementations: There are no AR headset examples with similar use cases to Scores on Doors, however source code for automatic QR tracking has been created for AR headsets such as HoloLens 2.[136] Combining the two may be feasible to create the desired functionality.

4.5 Application class: Providing people a model of the real world



relevant metaverse properties

Virtual 3D models can be used to train people in the operation of complex systems in high risk applications such as medical or emergency services. VR can also be used as a low-cost and accessible supplement to the practical portions of many other education and training courses by simulating the lab environment and allowing students to experiment without needing to access expensive equipment.

Existing alternatives

Obvious alternatives that should form a baseline of comparison for use cases with this application class are

- field training, such as practising surgery on real people and conducting emergency service operations with experts supervising, or shadowing experts while they are on duty.
- training in a testing facility using real infrastructure, props, and body doubles to simulate a workplace scenario

Potential benefits

- **Low-risk alternative to field training**
    - **Medical:** For medical training, VR is a low-risk alternative to field training, such as asking trainees to conduct real surgical operations. This can also create more opportunities for hands-on training, so trainees can conduct no-consequence virtual surgical procedures that can be easily reset after mistakes.
    - **Emergency services:** For emergency service training or any other high-risk training, VR simulations offer a safe, repeatable, updatable and likely cheaper

alternative to a fully-equipped testing facility. Multiple participants in the same virtual environment could cooperate to rehearse complex tasks. .

- **Educational:** VR experiences that simulate car engines are an ideal interactive tool that enables students to understand the inner workings without having to leave their seat.

Potential harms

- **Over-reliance decreases sensitivity:** over-reliance on training simulations — especially incomplete or inaccurate ones — may increase the likelihood of mistakes in the field.
    - Additionally, a trainee who has exclusively trained in simulations with no field experience may be conditioned to undervalue the severity of their mistakes or actions in the real world.
    - VR-based training simulations should therefore be used as a supplement to all other forms of training, not in lieu of it.

Example applications

APPLICATION: POLICE AND FIREFIGHTER TRAINING IN BUILDING ENTRY AND NAVIGATION

Description: VR-based training programs for the emergency services that simulate real-life scenarios.

Role of government: Application provider

Rationale: The emergency services deal with high-risk, time-sensitive operations on a daily basis. Effective training for all staff is paramount, however it can be difficult to provide frequent and effective training for all necessary staff. This could be due to the resource and setup costs required for equipping the training facilities, the need for all staff to be on site for the training, as well as the potential dangers in these scenarios e.g. firefighting and simulated hostage situations.

Assumptions: These VR simulations are reflective of a realistic workplace scenario, with relevant interactive capability.

Specific considerations: VR simulations for emergency services may be more effective in large, open spaces, especially if all trainees are in the same physical area. As mentioned, these VR training experiences should be used as a supplement to real-life training, never as a substitute.

Existing implementations:

- Leicestershire Fire & Rescue Service (UK) have produced VR films for trainees to experience a real-life firefighting scenario [137]
- Zurich City Police have been undertaking tactical training using VR [138]
- New York Police Department (NYPD) are using VR to train unit response to active shooting scenarios [139]
- The Department of Homeland Security created a system called Enhanced Dynamic Geo-social Environment (EDGE) for first responders to practise coordinated responses and fine-tune strategies [140].

Figure 4.3: A first responder using VR as part of Ars Electronica's Impressions of Challenge: Emergency Error Battle in Austria[141]

Application: VR medical training in hospitals

Description: VR-based surgery training to upskill medical professionals

Role of government: Application provider

Rationale: Training medical staff could mean conducting procedures on a functioning 3D body simulated in VR rather than a real patient, where mistakes in the latter could result in life-long health complications. The easily duplicable, resettable VR simulations — in combination with VR's remote capabilities — means all training can be conducted remotely and with a low risk of physical injury.

Assumptions: The simulations must be reflective of a realistic workplace scenario, with appropriate interactive capability. Additionally, if the training is conducted remotely, all trainees have sufficient internet access and the low network latency required for them to immerse in the training.

Specific considerations: As mentioned, these VR training experiences should be used as a supplement to real-life training, never as a substitute.

Existing implementations:

- University College Hospital (London) has adopted a VR surgery simulator to train its medical staff [137]
- The University of Melbourne's Virtual Reality Surgical Simulation laboratory has developed a VR simulation for ear surgery [142]
- The University of Toronto's medical school is using made-in-Canada VR technology to train surgeons [143]

Application: Emergency response and disaster relief planning

Description: A VR or AR live tracking 'sandbox' map for strategic disaster and emergency response planning

Role of government: Application user

Rationale: Emergency responses can be high-risk. Strategic placement of team members can be crucial to the success of the operation, and knowledge of the live locations of these units can ensure action in the most efficient and safest manner. By generating a dynamic 3D replica of the target environment with a live feed of the location of all units deployed in the area, that is accessible through either VR or AR, the response team managers can determine the best strategy moving forwards. An example is during large-scale bushfires. It could be beneficial to see a live rendering of the bushfire front and its pattern of spread, along with the live locations of firefighter troops in the area, so that effective strategies can be developed.

Assumptions: There is a low-latency method for troops to broadcast their location to the application that runs the 3D rendering and tracking.

Specific considerations: The rendered sandbox map does not require high fidelity, as long as it portrays the pattern of spread and the location of each of the troops to the requirement of the strategists.

Existing implementations: There are no large-scale VR response procedures similar to the description above, however there are pilots for disaster response and mass-casualty VR response training in the US.[144]

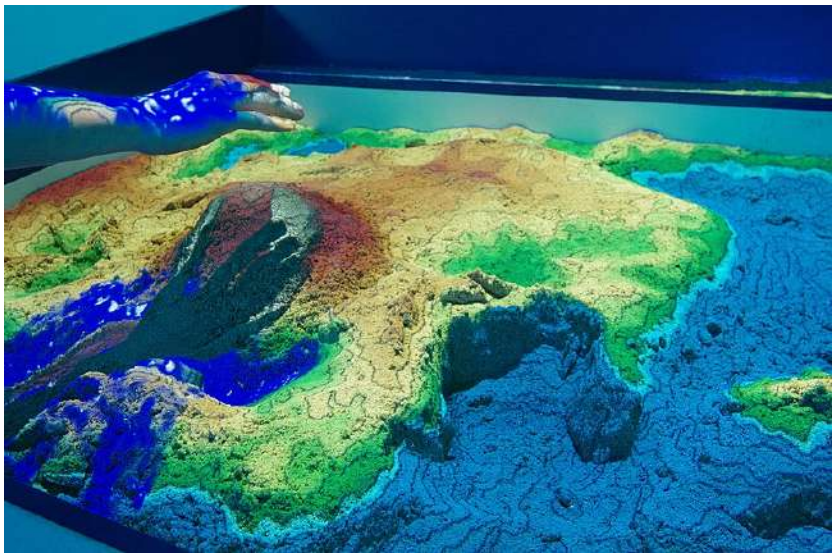
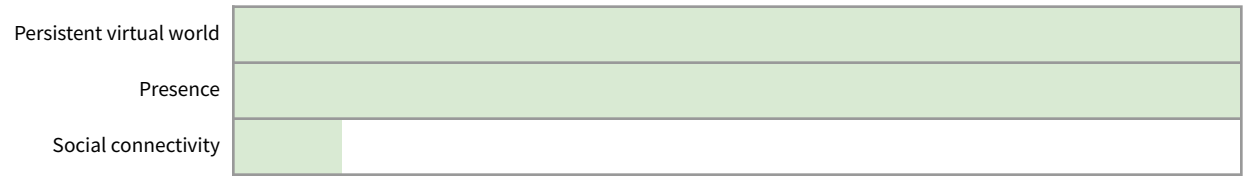


Figure 4.4: An example of an AR-based 'sandbox' map (from the Berlin Game Science Centre), that could be adapted for emergency response planning.[145]

4.6 Application class: Giving people experiences



relevant metaverse properties

This class of applications explores objects and experiences in the form of interactive persistent virtual worlds and 3D visual overlays.

Virtual worlds are 3D rendered environments that users can interact with while in VR. These worlds can be replicas of the real world to encourage tourism, provide a unique form of creative expression for artists, act as a form of general entertainment for users, amongst other applications.

In addition to contextual information overlay, AR can be used to add virtual 2D or 3D elements to a person's view of the real world. An example is adding a holographic rendering of a poker

machine to a person's environment while they are using AR, so they can play without needing to be in a physical casino, or superimposing live digital visuals onto a real installation without needing to build the physical infrastructure.

Existing alternatives

Obvious alternatives that should form a baseline of comparison for use cases with this application class are

- engaging with the real world, e.g. visiting the real tourist destination rather than a duplicate in a virtual world
- building the infrastructure for the 2D or 3D visuals in real life, e.g. projecting live digital visuals onto the physical scene using projectors

Potential benefits

- **Virtual worlds provide artistic freedom:** Virtual worlds do not need to be bound by realism, and can openly manipulate visual elements such as gravity, colour, and shape. This creates endless new possibilities for artists and developers.
- **Virtual worlds are cheaper to create:** Creating expansive virtual worlds can be significantly cheaper than developing these worlds in real life. In VR, the worlds can be built anywhere, by anyone. Individual buildings do not need purchase of real-estate or land (unless they are being built in a pre-established virtual world, such as Decentraland or The Sandbox) . Buildings and trees can be cloned efficiently, forgoing construction OH&S concerns due to their digital nature, making them quicker to complete and easier to modify upon completion.
- **AR provides unique tourism opportunities:** By augmenting a real environment with dynamic and novel visuals, one can establish an entertainment experience that is not bound by the restrictions of reality, and also without needing to duplicate the world in virtual reality (see the example applications below). This results in a cheaper and more flexible setup without also de-incentivising tourists from visiting the real location.
    - For example, an AR-based Vivid Sydney event would be better for incentivising tourists to visit Sydney — as the AR would only work while looking at the points-of-interest in person — compared to a VR-based Vivid Sydney that duplicates Sydney in a virtual world.
- **Novel opportunities for artists:** Digital art in VR and AR form also creates more opportunities for artists to showcase their work, as the art would only be available

digitally. These art installations may not need to meet locale restrictions such as awareness of the city skyline or neighbouring obstructions.

Potential harms

- **Discourages in-person tourism:** By providing virtual duplicates of tourist destinations and points of interest, in combination with the novel immersive opportunities presented by VR, it could discourage people from visiting the real-life location. Designers of the virtual world should be cautious to create a duplicate that intrigues, rather than de-incentivizes, tourism to the real-life destination.
- **Difficult to monitor for harmful behaviour:** Virtual worlds can be difficult to regulate and monitor, which means harmful behaviour could be difficult to control (see Sections 5.1 and 5.2).
- **Lack of regulation results in legal ambiguity:** The lack of regulation could create a previously-unexplored and possibly legally ambiguous relationship between a real life location (e.g. a bar) and the services used by patrons while in the location (e.g. a virtual pokies machine). Especially for illegal activities, would the location be held accountable for allowing patrons to use these activities in the establishment, or would it be separated as part of the user's own internet activity?
- **AR visuals could be distracting:** Supposing AR technology becomes widely-adopted, any augmentations to reality — artistic or informative — would need to have public safety in mind, so pedestrians would not be distracted or have their vision obscured in a dangerous way. An example is while they are crossing a busy street, or stopping in a busy walkway, to watch an AR light show.

Example applications

Application: An augmented reality (AR) enhanced Vivid Sydney

Description: Enhancing Vivid Sydney events and points of interest using AR

Role of government: Application provider / Platform provider

Rationale: NSW's annual Vivid Sydney event could be enhanced in AR. AR technology can add dynamic visual elements to points of interest in Vivid Sydney, with greater artistic freedoms compared to the real world. The NSW Government could develop a mobile application where users point their cameras at a Vivid POI and the AR feature renders superimposed visuals exclusive to people using the app. This approach could similarly be used for other points of interest across NSW to increase tourism, as these AR features would only be viewable when the user is in a direct line of sight from the venue, ensuring that the locals (e.g. nearby restaurants, bars) can benefit from this tourism as well.

Alternatively, the NSW Government could create a platform for AR Vivid, and local companies and artists could adopt the platform to create their own AR scenes with standards and regulations set by the NSW Government.

Assumptions: There is sufficient reception in the area to download and render these dynamic visuals on mobile devices. Additionally, the app is free to download and is provided or endorsed by the NSW Government. If the NSW Government chooses to become a platform provider for the AR Vivid service, it will need to ensure all of the external AR offerings have been approved before going live on the public-facing app.

Specific considerations: Vivid Sydney attracts a lot of people each year. Supposing the app requires an active internet connection and everyone is using their phones to view the AR graphics, there will need to be sufficient bandwidth to handle the large number of people in the same area. The graphics will need to be at an appropriate resolution without significantly draining battery life and internet data. The NSW Government will also need to be transparent if it is collecting any user data from these experiences. AR also may not work under low-light, so lighting in the surrounding areas should be considered.

Existing implementations: There are no existing implementations that align to the description above, however AR as a medium for enhancing public artworks has been explored.

- Ohio's Akron Art Museum's 'Interplay: Art Play for All' exhibit where scanning a QR code via a mobile phone renders an interactive piece of artwork using AR [146]
- The National Gallery of London placed QR codes all over the streets of London which renders an AR artwork when scanned by a mobile device [147]
- The National Museum of Singapore hosted a 'Story of the Forest' exhibit with 3D animations that visitors can interact with by downloading an app [148]

- The Museum National d'Histoire Naturelle in France hosts an experience called 'Revivre' that renders extinct animals in AR. Visitors use a Microsoft HoloLens to view the 3D AR animations [149]

Figure 4.5: National Museum of Singapore's 'Story of the Forest' exhibit, where audiences can use an app to interact with the illustrations in the exhibit[150]

APPLICATION: VIRTUAL TOUR OF THE SYDNEY OPERA HOUSE

Description: Generating a 3D interactive replica of the Sydney Opera House in a virtual world to encourage tourism.

Role of government: Application provider

Rationale: With the NSW Digital Twin already in development, there is potential to upload the 3D rendering of a NSW point of interest into a virtual world. An example landmark is the Sydney Opera House. Users could explore detailed and to-scale renderings of the Sydney Opera House in the virtual worlds through their VR headsets. Increased public interest in the area could encourage tourism, especially if the VR Sydney Opera House visit is also able to promote interest in surrounding areas.

Assumptions: The rendering would be available for free to the public.

Specific considerations: There may be important legal considerations that will have to be addressed regarding the digitisation and online display of the Opera House and its various art pieces.

Existing implementations: There are several 360 VR tourism videos already available for free on the public domain, however they are static videos and not interactive. Examples are guided tours of Venice [151] and aerial VR shots of Angel Falls in Venezuela [152]. Google Arts and Culture created VersaillesVR, a free interactive tour of the Palace of Versailles available through the gaming platform Steam [153,154], however this is a standalone game and is not part of a virtual world.

Application: High school student VR tour of a manufacturing facility

Description: Replicating industrial facilities in virtual worlds for use as a remote educational tool

Role of government: Application provider

Rationale: Providing replicas of industrial areas — such as manufacturing facilities, foundries, or refineries — in a virtual world could provide educational benefits. For high school students studying subjects like physics and engineering, visits to these facilities could prove useful for their studies and provide insights into their career pathways. However, where these facilities are not operated locally or they are not open to the public, having a VR alternative for students to interact with may be cheaper and more manageable than a school trip to a real facility, especially if it is interstate or international.

Assumptions: For virtual school trips, students would require access to a VR headset, with appropriate bandwidth to explore these virtual environments.

Specific considerations: These replicas should not be used in place of a trip to a real site, particularly if a school trip is feasible and the facility is safe to visit.

Existing implementations: Similar to the 'Virtual tour of the Sydney Opera House' application, there are VR videos with tours of manufacturing facilities available for free in the public domain, such as one created by the American Fuel & Petrochemical Manufacturers [155]. However, they are static films and cannot be interacted with.

Figure 4.6: Generating a 3D replica of a manufacturing facility in a virtual world could yield positive educational outcomes.[156]

Application: AR gambling bars

Description: A NSW pub or club could offer AR 'virtual gambling', where for example, patrons interact with virtual pokies placed in the bar by augmented reality headsets.

Role of government: Regulator

Rationale: The AR pokies machines could replace physical pokies machines. The cost to build an AR pokies machine would be negligible compared to a real-world version. Removing the physical pokies machines would also result in more available bar space to host other forms of entertainment.

Assumptions: Wide adoption of AR interfaces commonly worn in public

Specific considerations: Creation of an AR gambling bar creates a new and possibly legally ambiguous relationship between the real location and the virtual location. There is an unclear division of responsibilities between the bar and the metaverse pokies application provider, and it is difficult to police any relationships between a physical space and the AR content digested by users in the space. Additionally, lowering the barrier of access to gambling in public venues may increase opportunities for problem gambling.

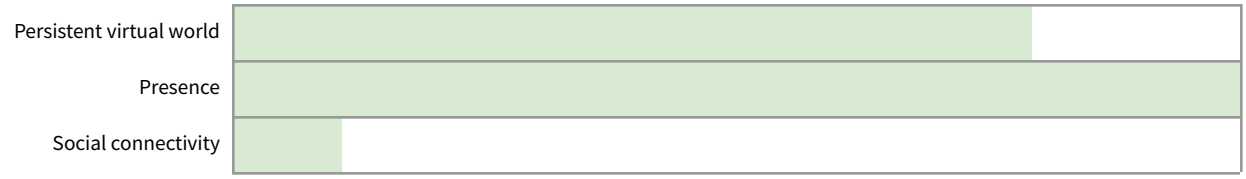
The regulatory role of the government would require resolving questions such as:

- Under what circumstances would the poker machines 'in' the bar for the purposes of licenced gambling venues?

- What if an augmented reality provider places the pokies in the bar without the bar's permission?
- Do limits on numbers of physical poker machines apply?
- How would safe gambling rules be applied?

Existing implementations: There are no existing examples of AR gambling bars in the nature described above, however there is a lot of public interest in this area.

4.7 Application class: Transporting people out of their environment



relevant metaverse properties

For people in an unpleasant or emotionally distressing situation, the sense of presence afforded by metaverse technology may be used to help people escape from their reality into an alternative reality that is more befitting to their needs.

Existing alternatives

Obvious alternatives that should form a baseline of comparison for this application class, especially as a form of escape or easement of emotional distress, are

- watching TV and movies
- reading books
- browsing the internet
- video conferencing and phone calls with friends and family

Potential benefits

- **Virtual escapism:** The immersiveness of VR means users can escape into another location without needing to leave their real environment, which could be infeasible given their personal circumstances. VR can provide an unlimited number of alternative

environments to escape to, which could also be cheaper than physically travelling to a location.

Potential harms

- **De-incentivises improvement to the real world:** By creating convincing, effective forms of escapism in a virtual world, it de-incentivizes improvement of the person's real environment. For example, it creates the notion that improvement of a derelict prison or nursing home environment can be forgone with a good VR setup. Unsupervised adoption of these systems could foster neglect and violate human rights.
- **Increased social anxiety:** Excessive use of virtual reality as a form of escapism could lead to increased social anxieties and feelings of isolation [11,12]

Example applications

APPLICATION: VR AS AN OPTIONAL ALTERNATIVE TO PAIN MANAGEMENT IN HOSPITALS

Description: Meditative VR environments could be used to ease emotional distress in hospital patients

Role of government: Application provider

Rationale: By putting on a VR headset, people can leave their current reality and escape into an alternative one. This can be particularly impactful during periods of emotional distress, anxiety or pain, if the alternative reality presented to them has a meditative or calming effect. There is potential for this type of VR to be used in hospitals, to help alleviate the distress of young children, or to assist mothers during birth.

Assumptions: The virtual reality gear is comfortable to use, and the patient is not prone to motion sickness, which could increase emotional distress.

Specific considerations: Different people require different forms of anxiety reduction (meditation, high energy distractions, a social component, etc.) so there needs to be a variety of virtual environments on offer.

Existing implementations: Multiple studies have been conducted on use of virtual reality for pain and anxiety relief when undergoing hospital treatments. Some studies found that VR helped to decrease pain and anxiety [157–161] whereas others found no significant decrease in patient pain and anxiety levels with VR treatment.[162,163] If this application is to be considered, further research should be conducted by the NSW Government to determine whether this approach will be effective.

Application: VR experiences for residents of nursing homes

Description: Providing VR to residents of nursing homes so they can explore virtual worlds when they are unable to travel physically.

Role of government: Application provider

Rationale: Travelling may be difficult for some residents of nursing homes. VR can provide a convincing alternative to physical travel, with limitless possibilities for the location of travel due to the artistic freedoms the platform provides. Providing these opportunities for nursing homes may assist in reducing residents' feelings of loneliness or isolation.

Assumptions: The VR experiences are operated by the elderly, which means the software and technology needs to be intuitive and comfortable for them to use.

Specific considerations: VR technologies should always be used as a supplement to improved living conditions, not as a primary solution. Additionally, care needs to be taken to ensure alternative VR environments are mental health positive and regulated.

Existing implementations:

- Australia-based NomadVR is a service that provides VR for aged care facilities [164]
- Researchers from QUT, Griffith University, University of Melbourne and La Trobe have integrated VR technologies into six Australian aged care facilities [165]
- Blue Cross and Build VR developed a VR application for aged care residents and those with dementia [166]

Figure 4.7: VR could be beneficial for residents of nursing homes, especially if they are unable to travel physically.[167]

5. Recommendations for building understanding and expertise

Part of NSW Government's preparation for deeper engagement with the metaverse will involve building understanding and expertise. Beginning to invest in staff and institutional knowledge skills and capabilities now will help ensure that the government is ready if and when metaverse technologies become more widely adopted (including within government). The following sections provide a series of recommendations for starting this process.

5.1 Examining open legal questions

Adoption of metaverse technologies both by the NSW Government and the wider public will raise new legal questions. Considering these questions now will help the government understand and prepare to take on its roles as a metaverse user, platform provider and regulator.

The authors of this report are not legal experts. This section raises questions of a general nature based on possible metaverse deployment scenarios. We implore the NSW Government to seek legal advice before undertaking any new activities whose legal status is not well-established.

Understanding the legal status of metaverse applications

What existing activities and products are legally relevant to the metaverse?

Metaverse applications combine elements of various existing technologies. Therefore, in seeking to understand their legal implications, it may be helpful to first establish where existing law can be applied directly. Relevant technologies may include:

- computer games, especially massively-multiplayer online games (MMOs)
- phone or desktop apps
- websites including e-commerce sites
- social networks.

In many of these cases a metaverse application will differ from these existing technologies only by virtue of being accessible through VR or AR, which may be irrelevant to many legal questions. This may apply particularly in areas such as:

- taxation

- data privacy
- fraud
- contracts
- intellectual property.

Status of property in metaverse applications

Are there any circumstances where objects or locations in metaverse applications could take on property-like elements?

Consider a virtual object or piece of land in a metaverse application whose ownership in that application is contested. Though Australian law does not recognise the data or information that represents the object in the computer as property,[168] it is an open legal question whether such virtual objects or land in metaverse worlds may have enough property-like elements that property law becomes relevant.[169]

Copyright law may also intersect with metaverse applications: reproduction of existing architectural works in virtual worlds or modification of existing works with augmented reality may, for instance, require obtaining a licence from the copyright holder of the work in question.

It may be important for the NSW Government to plan for the legal ambiguities around property when developing metaverse applications. Similarly, the government is responsible for the collection of property taxes in some circumstances: the status for metaverse land or objects may also be relevant for this role.

Localisation of metaverse elements

When are augmented reality objects 'in' a real-life location?

Augmented reality allows for the projection of virtual objects into real environments (see Section 2.2). This raises the question of when those objects should be legally considered as 'in' that environment. One example (described in Section 4.6) is the placement of virtual poker machines placed in bars through augmented reality. Different legal issues may arise depending on the bar's involvement or knowledge of this placement, which will also have implications for gaming regulations and gaming tax, both administered by the NSW Government.

Other examples where the question of locality may be legally important are the addition of illegal material such as child abuse imagery into a location through augmented reality, or the creation of augmented reality hazards that cause people to trip and fall.

The ambiguity of localisation also arises when considering the rights of individuals over their own real property: it may be important to understand whether a homeowner, for example, has any rights to control the kind of virtual objects placed on their land by third party metaverse application providers (including, potentially, the NSW Government). This issue has already arisen with the augmented-reality app 'Pokemon Go', which encouraged throngs of players to particular real-life locations as part of the game.[170]

Privacy

Are the data collected by metaverse applications appropriately regulated, especially for children?

As described in Section 1.2, metaverse applications may be in a position to collect high-fidelity data about users including heart rate, eye, head and body movement, gaze direction, and facial expressions. Data such as these are not necessarily identified as sensitive in Australian privacy law, but still present significant privacy risks: they are typically able to uniquely identify an individual, and also can be used to infer a variety of emotional responses and states.

Metaverse technology is already being rolled out to schools in NSW (Section 3.6). A NSW Department of Education staff member involved in the stem.T4L VR program explained the safety and privacy precautions taken by its coordinators. Examples include confirming the location of collected student data (i.e. student data must be stored in Australia, preferably NSW) with the application owners, and the use of 'non-immersive' VR hardware (such as Google Cardboard [171]) that permits only '3 degrees of freedom'. However, they noted that the emergence of internet-based metaverse applications has increased the risks, especially as there is no regulation protecting children's privacy rights or controlling the data collected about them in the metaverse.

Accessibility

When would the NSW Government have obligations to ensure metaverse services are accessible to all members of the NSW public?

Accessing metaverse applications typically requires a VR or AR headset and a high-speed, low-latency internet connection (see Section 6.3). Apart from the cost associated with obtaining these items, some people may be unable to wear a headset without feeling nauseous and so will be excluded from any services that require them. We recommend that

the NSW Government therefore investigate any legal requirements for accessibility when developing or regulating metaverse applications.

Identity

Are there circumstances in the metaverse where people have a right to their own likeness, as instantiated in the form of an avatar?

Current Australian law does not generally recognise 'personality rights' for the public: a person's likeness may be used, for example, in a painting, without obtaining their permission (though some limitations do exist on the use of likenesses in commercial contexts). As metaverse avatars become higher-fidelity and their use increases, this legal status may become less clear.

5.2 Preparing for crime in the metaverse

Crime is inevitable in metaverse applications. When that crime involves a NSW resident, the NSW Government may be the relevant jurisdiction in which that crime is investigated and prosecuted. As described above, the existing approaches to policing and prosecuting crimes conducted through the internet (for example, abuse and fraud) may serve as a starting point.

Given the use of cryptocurrency and NFTs in metaverse applications, it would be reasonable to expect that the rampant fraud in that world [172] will present significant risks for the people of NSW.

One question of law that may become relevant in the metaverse is whether certain kinds of traditionally physical crimes such as assault, can be perpetrated in virtual reality. This question may become especially relevant as the fidelity and level of immersion provided by VR and AR headsets increases.

Even if conduct falls short of the legal threshold of a crime, it may be important for NSW law enforcement to be involved in prevention activities in the metaverse. The NSW Police Force's cyberbullying activities, for example, could be expanded to encompass risks in metaverse applications.

5.3 Training key staff

Formal training in 'the metaverse' is currently nascent, but training resources in the underlying technologies are well-established. Should the government wish to develop or deploy metaverse applications, platforms or services, then training both leaders and technical staff will be important. Some of the key areas for these roles are described below.

Leaders

- the kind of application areas for which metaverse technologies may be suitable
- the risks of metaverse applications for NSW residents and the government
- the responsibilities of leaders to establish effective governance of metaverse applications developed by the NSW Government to ensure they are fit for purpose and do not cause unintentional harm.

Technical staff

- the new content and behaviour moderation challenges associated with virtual reality environments, such as identifying and preventing physical intimidation
- the construction of 3D interactive virtual worlds, which involves expertise in 3D modelling and the development or use of game engines
- network architectures that can provide latency and bandwidth requirements suitable for metaverse applications
- API design considerations for streaming data formats appropriate for metaverse applications
- user experience, especially harmonising the variety of devices users may use to access the metaverse, such as phones, desktop computers and XR headsets.

5.4 Initiating a metaverse application pilot

Developing a metaverse application as part of a pilot project may be an effective approach to upskilling NSW Government staff. Such a pilot could provide practical experience that complements formal training. Importantly, careful control of the pilot design can allow the government to identify currently unknown risks whilst preventing serious consequences for the government and the public.

The following questions and considerations may help inform selection of a metaverse application pilot project.

Questions and considerations when choosing pilot use case

1. Does it provide the opportunity for NSW staff to build capability with metaverse technologies?

    a. If yes, will experience from the pilot be useful across the government, beyond just the team that developed the application?

2. Does the application provide a service to which all NSW public are entitled?

    a. If yes, then does an equally capable mechanism to access that service already exist (such as a web application)?

        i. If not, is there a risk that people without the required hardware to access the application (such as headsets or good internet) would be unfairly disadvantaged?

3. Does the application provide an alternative to in-person interaction with NSW Government staff?

    a. If yes, is there a risk that the pilot would be perceived as a cost-cutting or automation exercise?

4. Does the application take advantage of existing NSW Government, data, infrastructure and services (for example, the Spatial Digital Twin and NSW Digital Identity services)?

    a. If yes, is there a potential to use the pilot to improve those services' utility for future 3rd party metaverse applications?

5. Does it depend on the three metaverse properties (Section 1.1) to achieve its purpose?

    a. If not, is there a risk that the pilot will be perceived as a waste of money, given non-metaverse alternatives like a web application may achieve the purpose just as well?

6. Does the use-case require the NSW Government to moderate the behaviour or language of users?

    a. If yes, consider that automated solutions for moderation are not yet well-developed for metaverse applications, opening NSW residents up to significant risk of harm.

7. Does the use-case require collection or use of detailed behavioural or physiological data?

    a. If yes, consider the heightened privacy risks from collecting this data.

8. Does the use-case involve algorithms or automation designed to influence the behaviour of users?

    a. If yes, consider the risk of unintended consequences of these features, as demonstrated in social media applications (See Section 1.2).

9. Does the use-case involve cryptocurrency or NFTs?

    a. If yes, consider the additional risk this exposes users to given the widespread cases of fraud, scams and cyberattacks surrounding these technologies.

10. Are there any other risks of unintentional harm to the NSW public?

    a. Given that metaverse applications are new to the NSW Government, it may be prudent to be especially conservative and avoid pilots that pose any foreseeable risk to people of NSW.

Pilot ideas suggested by NSW Government staff

During interviews informing this report, NSW Government staff proposed a number of specific use-cases that they thought would be worthwhile, including:

- **VR tour of Sydney Opera House (Section 4.6),** in which users (jointly) explore and learn about the venue in virtual reality, possibly even seeing performances on a virtual stage.
- **virtual Service NSW shopfront (Section 4.3),** in which users can interact with Service NSW staff through VR to pay bills, renew their driver's licence etc.
- **virtual tech precinct (Section 4.3),** in which organisations can obtain virtual offices for collaboration and co-location.

These ideas are examined in the sections listed.

Choice of first pilot application

Based on an evaluation of the questions and considerations above, the following applications (drawn from Section 4) may be suitable for an *initial* pilot project:

- **Virtual tour of the Sydney Opera House (Section 4.6):** This project would produce a 3D interactive replica of the Sydney Opera House in a virtual world to act as a tourist attraction. Utilising the NSW Digital Twin as infrastructure for this pilot would have the benefit of serving as a testing ground for metaverse support there. The application does not provide a critical service (which would imply requirements for high levels of accessibility and reliability), and does not depend on social interaction (which would require careful moderation to be in place).

- **VR emergency services (police, firefighter and medical) training (Section 4.5):** Replicating emergency service scenarios in VR could provide a safe and effective approach to training, especially for situations that are difficult to re-create practically. VR training programs of these types have already been deployed by international governments, so the NSW Government could investigate procuring existing tools. The application is also not public facing, nor is it involved in critical decision-making, reducing the risk of large-scale negative impacts.
- **Rail corridor maintenance activities (Section 4.4):** Transport NSW has suggested that a live AR headset overlay for rail corridor maintenance could improve upon the functionality of its existing mobile application pilot. The application is not public facing, which could reduce the risk of large-scale negative impacts. It also replicates and improves on an existing solution that could serve as a backup during development and testing.
- **Emergency and disaster response planning visualisation (Section 4.5):** With the recent floods devastation and upcoming bushfire season, improving emergency response is an urgent and relevant effort. A live geospatial visualisation for tracking incidents and responses in VR or AR could assist teams directing emergency and disaster response efforts. Developing such an application could also be an opportunity to improve existing data sources. The application is not public facing, reducing the risk of large-scale harm from errors in design. It is, however, performing a critical function and would need to be extensively tested before being relied upon.

5.5 Founding a community of practice

If the NSW Government wishes to upskill its staff and build metaverse capability, it may benefit from engaging with a metaverse community of practice. Globally, there are no active metaverse communities of practice, so NSW will need to create its own. This community could be internal, but could also be open to other public sector or private employees, to the NSW Government's discretion.

Discussions with NSW Government staff have revealed a number of prototype metaverse projects and research in the area, dispersed across different departments (see Section 3.6). By establishing a metaverse community of practice, branches of the NSW Government can share knowledge and insights from their research. This could lead to a more cohesive overall NSW Government metaverse strategy, and encourage collaboration between departments on new metaverse incentives.

A department should be chosen to lead the metaverse community of practice, an example being the Department of Customer Service, or any department who has conducted extensive

research into XR technologies, such as Transport for NSW, Department of Health, or Department of Education. The group in charge could organise an email chain for communications, as well as an online community forum for members to post interesting articles or upcoming events.

Community meetups should be organised on a recurring basis — i.e. quarterly — so that representatives from each department and other interested parties from the NSW Government can share ideas, showcase their work, and raise discussion items.

5.6 Creating a metaverse 'experience lab'

Metaverse technologies, particularly VR and AR, are new enough that many people have not experienced them at all. Creating an 'experience lab' for NSW Government staff gives an opportunity for the staff to have such a first hand experience in a controlled environment, and may help develop staff's intuition and judgement about their various roles with the government's work in the metaverse.

5.7 Cultivating collaborations and knowledge sharing

If the NSW Government plans to develop metaverse applications, there is value in networking with other entities who have either applied, or are conducting their own research into the metaverse. These networking events can be any of the following, or a combination of

- NSW Government cross-agency metaverse strategy events that invite members of different areas of the NSW Government to showcase their current efforts in the metaverse
- cross-government events with representatives of federal, state, and territory governments across Australia to share their metaverse research and help to establish a national strategy for the metaverse
- partnership and collaboration events involving both public and private sector, where the private sector participants are encouraged to showcase their metaverse capability at the event. Increasing networking opportunities with the private sector will also help to establish a chain of recognised metaverse suppliers to support future metaverse-related procurements.

6. Recommendations for augmenting existing systems and infrastructure

To prepare for wider adoption of metaverse technologies, the NSW Government needs to consider the systems, services and infrastructure that will enable its potential involvement. Regardless of the extent to which the NSW Government itself decides to build or deploy metaverse applications or platforms, the existing digital services it already provides (such as digital identity) may need to interact with metaverse environments. As a regulator, the government may also require new technology and infrastructure to perform its role in the metaverse.

The following sections outline some of the key enabling technologies and infrastructure that we believe the NSW Government should start considering now, to ensure that rapid metaverse adoption does not catch them by surprise.

6.1 Designing NSW Digital Identity for the metaverse

Digital identity is an important part of operating online today. This is true whether a user is interfacing with a phone app, a website or an avatar in a metaverse world. Given that metaverse adoption is still relatively low, there may be novel requirements for digital identity in the metaverse that have yet to emerge. We recommend that the NSW Government, as a digital identity provider, assume that digital identity will be an important service in the metaverse and consider what new technical, legal and regulatory issues arise as a result.

Anonymity and identity

In the diversity of virtual worlds and services, there will likely be a need for different levels of user identification. These levels range from anonymous, un-authenticated (and potentially automated) users through to fully authenticated legal individuals identified to the metaverse platform or service.

Anonymity and/or lack of authentication can create the potential for harmful behaviour. In the case of social media, the ability for users to be anonymous has been cited as a key causal factor driving societal problems such as amplified hate speech (including extreme racism), harassment, abuse and large-scale election manipulation.[10]

This has led to the calls for social media platforms, including metaverse developers, to require users to verify their identities with the platform provider, even if interacting anonymously on the social media platform.[173, 174]

There are situations where full anonymity is important, however. For example, Technology companies have shared sensitive information with governments in the past, including identity information.[175] Dissidents, human right activists and journalists pursuing the dissemination of truth about potentially inappropriate, self-serving or downright harmful government actions stand to lose unless they can be confident their work can be carried out under full anonymity. There is also public value in removing barriers to whistleblowing.

Similarly, the institutional status quo in different countries and jurisdictions is never politically neutral and full anonymity can be important for political minorities to voice their views. It is often difficult for individuals holding political views underrepresented among mainstream institutions to openly participate in the political process without being consistently censored, defamed or vilified. As an example, the Federalist Papers were written anonymously by three of the United States' Founding Fathers; given the controversial contents of the US constitution, their ratification could have been compromised or delayed had the papers not been written anonymously so as to prevent ad-hominem political backlashes.[176] Anonymity can be of critical importance to promote and maintain diversity in political discourse.

It is therefore important to acknowledge and recognise the legitimacy of this tension between potential benefits and harms of anonymity in the metaverse, and consider Digital Identity within the context of that tension.

Purposes of digital identity verification

Types of verification of users or of certain properties of users that are likely to be important in the metaverse include:

1. Human verification (that the given person is a human - which could use, for example, a CAPTCHA-like service or be tied to a full legal verification service)
   Example use case: NSW Food Safety Overlay (Section 4.4) to ensure that reviews are provided by people rather than bots.

2. Age verification (that the user is of, is more than, or is less than a certain age)
   Example use case: AR Gambling Bar (Section 4.6) to ensure participants are of a legal gambling age.

3. Nationality or residence status verification (that the user is of a certain nationality or is a resident in a certain physical jurisdiction - for example NSW - where virtual services are relevant to physical jurisdiction)
   Example use case: Region-restricted VR media streaming

4. Legal identity verification (that the user is the legal person who they claim to be)
   Example use case: Virtual nursing home visitations and VR courts (Section 4.3) to ensure participants are who they say they are.

There may be a role for governments to play in types 2-4.

Some other forms of verification that are also likely to be used in the metaverse and may include government involvement include:

5. Voucher verification (that a given voucher is valid - for example, vouchers for services like the NSW Government's Dine and Discover vouchers could be used to encourage people to use metaverse services run by NSW companies)

6. Credential verification (that the identified user has the stated credential - for example accredited to provide a specific service related to healthcare provision, education provision, gambling service, etc).

Mechanisms of digital identity verification

The NSW Government describes digital identity as "a form of transactional identity that allows customers to access services online. An 'identity provider' relies on existing legal and trusted transactional documents to confirm your identity and establish your digital identity. Digital accounts can allow the reuse of the identity information you have previously provided so that you don't need to keep providing evidence of your identity". [177]

According to a NSW Government Digital Identity Strategy,[177] the main five principles involved in the NSW Government's digital identity policy and legislative development are:

1. privacy, consent & control

2. transparency & security

3. user-centricity, inclusivity & accessibility

4. technology neutrality & data portability

5. simplicity, effectiveness & efficiency.

Although there are no explicit references to AR and VR compatibility — or the metaverse — in these principles, they are encompassed in the 'technology, neutrality & data portability' component. By creating a digital identity that is technology-agnostic and built with international standards in mind, users' identity will ideally be provable in any digital environment including VR and AR scenarios, such as in virtual courts and digital classrooms.

Existing mechanisms for digital identity verification for Internet services will likely be leveraged within the metaverse. For example, a metaverse platform provider may require that, for account creation, a user be associated with a legal identity as part of signing up. In such a case, the actions of this user over time could be associated with that legal identity (optionally with just-in-time authentication for specific actions). In other cases, association with a legal identity could be done on the use of a specific location (e.g. a virtual casino) or service.

Some examples of these existing mechanisms are:

- the ATO using voice authentication to verify a caller's identity[178]
- the NSW Government trialling comparing digital photos captured via a smartphone app against official images such as a driver's licence to confirm an individual's identity.[179]

For those metaverse platforms or worlds that use the blockchain, there are also some emerging proprietary approaches for 'Web3' decentralised identity verification products. This includes services such as Magic[180] (which supports email, WebAuthn, fido2 security keys), PhotoChromic[181] (an approach to a universal digital identity that is a single blockchain asset that maps to official physical ID) and Liquid Avatar[182] (for management, control and using verified digital identity and personal data). These may be utilised by some virtual worlds. These efforts are all at an early stage of development and are largely non-standardised (though in some cases make use of standards).

6.2 Augmenting NSW Spatial Digital Twin for metaverse support

The NSW Government's Spatial Digital Twin (SDT) project could become a useful resource for developers building metaverse applications, as well as for the government itself to use in development of its own metaverse applications.

The NSW SDT serves as a management, delivery and visualisation tool for various 3D and spatial and spatio-temporal data. The long-term vision of digital twins in general is to create a virtual replica of the real world in digital form that can be visualised, analysed and annotated.

There are some compelling reasons to explore augmenting SDT with support for metaverse technologies: Many of the existing digital twin use-cases naturally benefit from VR and AR. For example, the existing SDT contains telecommunications and infrastructure data intended to assist emergency response teams understand the locations of valuable infrastructure during e.g. a bushfire. The use of augmented reality display of this data could enable firefighters to make better use of it.

By extending the capabilities of the data access APIs already available in SDT to facilitate use by metaverse applications, the SDT could support a variety of useful, 3rd-party tools for NSW residents. Examples include:

- using live Transport NSW information to provide augmented reality overlays depicting the locations and routes of NSW buses, trains and ferries
- using spatial data from local councils to provide augment reality overlays for building planning and approvals
- using spatial data about telecommunications infrastructure to provide AR overlays for emergency response teams.

In considering building explicit support for metaverse applications, the government may need to examine:

- the feasibility of streaming raster, vector and mesh data to XR headsets, including formats for efficient ingestion by game engines commonly used to implement metaverse virtual worlds
- whether certain applications have constraints on latency or response time that impact the design and deployment of the APIs (See Section 6.3)
- whether support for XR visualisation is feasible in the federated model of data provision currently employed by the SDT.

6.3 Identifying gaps in network infrastructure

Many homes and businesses in NSW lack high quality internet access. This is particularly true in remote areas, some of which don't have internet access at all. Such lack of connectivity introduces problems for accessing metaverse applications, many of which will require high-bandwidth, low-latency connections to function. Many of the potential NSW Government use-cases described in Section 4 which would otherwise be useful for people in remote areas, such as remote telehealth consultations and remote learning, may be impossible to deploy due to poor connectivity. Upgrades to connectivity will therefore be critical to support wide access to metaverse applications for NSW residents and businesses.

Bandwidth and latency are the two key metrics that will determine an application's performance.

- Bandwidth is measured as the amount of data that can be transferred from one point to another within a network in a specific amount of time.
- Latency is an expression of how much time it takes for a data packet to travel from one designated point to another.

Bandwidth

Most current VR applications pre-install content on the headset to reduce the amount that needs to be streamed, and/or stream low resolution assets all to reduce the bandwidth requirement. This limits the size and detail of the virtual worlds due to hardware constraints within the headset.

Today, applications that stream immersive 360 degree videos do so at a reduced resolution and still require about 25 Mbps. HD resolution videos demand about 100Mbps. As network speeds in the target markets improve, more apps will seek to stream their content from data centres to provide a grander and more immersive experience. Users on slower networks risk getting left behind. However, streaming data that is rendered on the headset may require considerably less bandwidth.

NSW and Sydney are in the bottom half of the table when ranked against international comparators based on average speed and penetration of broadband connectivity. Sydney averages speeds of 16.2 Mbps (below the 2018 SIS targets of 25 Mbps), which compares unfavourably with Hong Kong (26.5 Mbps), Seattle (42.7 Mbps) and Singapore (43.6 Mbps). Only 17% of National Broadband Network (NBN) connections are at 100Mbps or above, whereas in New Zealand 17% of fibre broadband customers are already on plans of 1 Gbps or above.[183]

NSW also has 'numerous areas with poor or no connectivity', with '4,000 reported mobile black spots that impact around 10,000 premises.' As a result, 'more than 26% of children under the age of 15 in remote areas of NSW did not have the internet at home in 2021. Only 23% of people living in outer regional, remote or very remote areas accessed telehealth services compared to 30.4% of those living in inner regional areas and cities.' Furthermore, '38% of NSW's Aboriginal households did not have an internet connection in 2016.'[184]

The NSW's Connectivity Strategy (released in October 2022 by the NSW Telco Authority) aims to address this 'digital divide between metropolitan centres and regional NSW . . . to enable world-class, affordable and resilient connectivity'[185], with 'modern, high speed digital networks . . . available to all'. It will support the roll-out of NSW Government programs such as the Regional Digital Connectivity program, which will 'ensure families and businesses across regional NSW have better access to mobile, internet and digital services.'[184]

Latency

Applications that depend on reaction times such as elements of social interaction, gaming and streamed content need a low network latency to quickly relay data, user actions and audio between the relevant parties at a speed that doesn't frustrate or disorient the participants.

Network latency depends on a number of factors including the quality of the network and the physical distance between the source and destination. Typically, latency between Sydney and Melbourne is about 0.15 ms. Australia to the US is greater than 100 ms while Australia to the UK is usually greater than 250 ms.

Acceptable levels of latency are subjective and task dependent. Dan Rampton, director of engineering for Meta, has stated that a metaverse where content could be streamed seamlessly from the data centre to a user would require a network latency of between 10-20 ms. This should be seen as a vision for the future rather than what is needed to run today's less-ambitious applications which store most of the required data in the headset. For comparison, video calls typically require a latency of around 150 ms while online gaming typically requires latency of less than 70 ms.

These low latency requirements may have consequences for NSW public adoption of metaverse technologies.

- There may be growing demand for local data centres to reduce the distance travelled by the data from the hub to the VR or AR headsets.
- There may be regions with poor network connectivity or regions located a large distance from a data centre that miss out on many of the benefits offered by this technology.
- There may be some unavoidable fragmentation of the global user base into geographical regions for activities that demand low latency between users (as has been evident within gaming communities).

Starting to address connectivity gaps

As a starting point for identifying and addressing specific connectivity gaps, the NSW Government may wish to consider:

- conducting a state-wide analysis of connectivity, in order to provide a metaverse-ready view of the state to inform investment decisions

- predicting the locations that might see greater early take-up of metaverse applications and prioritise improving connectivity at these locations (for example, remote areas using VR for remote learning)
- running metaverse application trials in areas of good connectivity to better determine performance requirements
- developing a connectivity investment plan that explicitly balances targeted investments based on the likelihood of widespread use with the need to deliver inclusive outcomes
- investigating what implications the limited 5G and fibre broadband access in remote areas has on metaverse connectivity
- ensuring that the NSW Connectivity Strategy's objective of bringing meaningful digital connectivity to all citizens and achieving metro-equivalent standards can be met in light of metaverse connectivity requirements.

7. Recommendations for developing governance

Design choices made for metaverse applications, platforms and services control how these systems operate: whether they act lawfully, how they achieve their purpose, and how they distribute harms and benefits to those they impact. Governance processes help ensure these design decisions are made with appropriate authority, information, documentation and oversight.

Given the early stage of the NSW Government's engagement with the metaverse, and of metaverse development generally, it may be premature to implement immediately new governance for departments undertaking metaverse work. However, we do recommend the government begin developing elements that can later form part of an established metaverse governance process. This section presents recommendations for such elements.

7.1 Drawing from experience with AI governance

Because of the parallels between AI and metaverse technologies, the NSW Government's May 2022 NSW AI Assurance Framework [186] could serve as a helpful starting point from which to model future metaverse governance.

AI and metaverse technologies are analogous in several respects:

- both are complex, novel technologies with significant scope for benefit and harm
- both have ill-defined boundaries, with no clear definition on exactly which systems should 'count' as AI or the metaverse
- both require specialised, multi-disciplinary expertise to implement which is not widely present in the government
- both often require procurement of products from third parties
- both involve the collection and use of users' personal data.

The AI Assurance Framework is already well-designed to address the above challenges, making its use as a template for metaverse governance compelling.

Establishing a metaverse review committee

Again drawing on the government's experience with AI, the NSW Government's AI Review Committee could serve as a template for a metaverse review committee. This committee would consist of experts from government and industry across disciplines, and oversee the legal, ethical and technical design and impact of the government's metaverse applications.

Initially, such a committee could perform an advisory function. As the government's projects in the metaverse moved beyond pilot stages it could be required to examine and approve higher risk projects in a similar manner to the existing AI Review Committee.

Relevant fields of expertise that members of the committee could be selected to cover include:

- cybersecurity
- psychology and user experience
- ethics
- artificial intelligence
- law, regulation and human rights.

7.2 Developing responsible metaverse principles

Defining aspirational principles that capture what ethical or responsible metaverse applications look like is a potential first step towards preventing harm with concrete guidance and regulation. The NSW Government took this same approach with artificial intelligence: beginning with high-level statements about what ideal deployments of AI look like, before moving into more concrete governance measures to manage practical considerations.

Principles developed for an AI setting such as:

- fairness (ensuring the systems do not discriminate against certain individuals or groups)
- accountability (ensuring that the owner of a system is accountable for its impact)
- transparency (ensuring that information about the system's operation including how it works, its benefits and risks, is available to the right audiences)
- positive impact (ensuring that the system acts in the best interest of its users and does not cause unnecessary or unintended harm)

- privacy (ensuring that the system manages personal data safely and securely)

apply equally well to metaverse applications as they do to AI systems (or really to any system).

More specific principles, intended for organisations developing platforms for online communication (which would include metaverse applications), have been developed by the Australian eSafety Commissioner.[187] These principles emphasise:

- service provider responsibility
- user empowerment and autonomy
- transparency and accountability.

Being general in nature, principles typically need to be augmented with more detailed guidelines or rules in order to inform specific design decisions.

7.3 Documenting and recording key design trade-offs

One reason that principles are not generally useful for helping with practical design decisions is that they tend not to acknowledge the central fact of practical ethics: that most real decisions involve balancing trade-offs between different, competing harms and benefits.

Explicit requirements to document and balance potential trade-offs could form part of ensuring responsible use of metaverse technologies. The trade-offs could be framed through the competing interests of involved parties, such as a metaverse application developer, a NSW resident user, and the NSW Government regulator.

More specific trade-offs common to metaverse applications could also be documented and used as a way to inform key design decisions.

Example trade-offs in metaverse applications

- Anonymity can enable whistleblowing and political activism but also make it difficult to police threats, abuse and misinformation.
- Improving a user's sense of presence amplifies positive and negative experiences.
- More aggressive content moderation will create greater protection from inappropriate or abusive content and behaviour, but also wrongly stifle more legitimate expression.
- Interoperability empowers users to move more freely between service providers but may make commercialisation more difficult.

- Data collection about users enables personalisation but erodes privacy.
- Enforcing platform interoperability may increase user choice but make commercialisation more difficult in some circumstances.

7.4 Defining ethical requirements for NSW Government metaverse applications

The following rules developed by Dr Louis Rosenberg (Chief Scientist for the Responsible Metaverse Alliance) are intended for large providers of metaverse virtual worlds such as Meta. Rosenberg developed these requirements as a starting point for metaverse platform regulation.[188]

The rules intend to control some of the specific risks of the metaverse examined in Section 1.2 including:

- manipulation of user behaviour through collection of their biometric data and the use of AI to understand and control their emotional state
- fabrication of reality through undisclosed product placement and AI avatars that interact with users, similar to 'bots' in current social media
- privacy risks associated with the collection of behavioural and physiological data.

Transparency rules

Platforms must disclose:

- what user behaviour is tracked and when it's tracked
- if AI is being used for emotion or sentiment analysis
- what aspects of the world are being injected on behalf of a paying third party (product placement) and the identity of that third party
- when an avatar is being controlled by an AI agent or by a human being
- when a user is being targeted by a promotional conversation or interaction on behalf of a third party, and the identity of that third party.

Data collection and use rules

Platforms must limit:

- limit storage of tracking data

- prohibit storing user emotion or sentiment data
- prohibit tracking vital signs / physiological data for anything non-medical.

Manipulation-free interaction rules

Platforms must prohibit:

- behavioural profiling of users
- using promotional AI agents that react to your emotions in real time.

In addition to informing future regulation discussions, the NSW Government could draw from these rules to create a set of red lines for metaverse applications with which it is involved. Such red lines would inform the government's own development of metaverse applications as well as engagement with other metaverse providers.

7.5 Developing procurement guidelines and partnership strategies

The NSW Government will likely need to undertake procurement to develop metaverse applications due to specialised expertise and resources required. Developing clear procurement guidelines and strategies for partnership will help the government align the design of the application to its objectives and control risk.

Procurement guidelines can be integrated with existing processes

The NSW Government already has an active ICT procurement process. We recommend integrating the new metaverse procurement requirements with these existing processes. An example is adding a new 'Category S' in the ICT Services Scheme for 'metaverse services' that suppliers can register under. Subcategories could include

- AR and VR software-as-a-service
- AR and VR hardware and support services
- 3D modelling software and capability
- metaverse application testing services.

Requiring transparency from procured systems

As the government is fully accountable for systems it deploys to end users — even if the system involves third party elements — transparency of procured services is crucial. Transparency is necessary for the government to understand and exercise oversight on the metaverse applications it procures. Information such as how and when data is collected and

stored, how the product works, how it is tested, and the potential negative impacts, are all as critical for metaverse applications as they are for AI systems or any other large IT system. The provision of such information to the government could be mandated as part of the procurement process.

8. Conclusion

The metaverse represents a collection of powerful technologies that could significantly reshape the daily lives of the public, including how they interact with the NSW Government. The government also has an opportunity to utilise the metaverse to improve its service delivery and day-to-day operation.

Along with these opportunities come risks, particularly of large-scale unintended harm to users and the public. Preventing such harm will involve the NSW Government both as a user of the metaverse and as a regulator.

This report represents an early step by the NSW Government to prepare for the wider adoption of metaverse technology. It aims to help the government take advantage of the metaverse's benefits and to mitigate its risks. The report provides recommendations for building the government's capability through training and development, augmenting existing systems and infrastructure, and beginning to identify approaches to governance.

We believe that the information and recommendations contained in this report will assist the NSW Government in deepening its engagement with the metaverse in the future: from developing a metaverse strategy, to exploring the potential of the technology through pilot projects, and, ultimately, developing operational capability and governance.

Endnotes

1. Moy, C. & Gadgil, A. *Opportunities in the metaverse: How businesses can explore the metaverse and navigate the hype vs. reality*. 17 https://www.jpmorgan.com/content/dam/jpm/treasury-services/documents/opportunities-in-the-metaverse.pdf (2022).

2. Benford, S. Metaverse: five things to know – and what it could mean for you. *The Conversation* http://theconversation.com/metaverse-five-things-to-know-and-what-it-could-mean-for-you-171061 (2021).

3. Mestre, D., Fuchs, P., Berthoz, A. & Vercher, J. Immersion et présence. *Le traité de la réalité virtuelle. Paris: Ecole des Mines de Paris* 309–38 (2006).

4. Case Western Reserve University. HoloAnatomy® Software Suite | Case Western Reserve University. *HoloAnatomy® Software Suite* https://case.edu/holoanatomy/.

5. Pimentel, K. Theia Interactive's Harley Davidson AR Experience Showcases the Potential of Real-time. *Unreal Engine* https://www.unrealengine.com/en-US/spotlights/theia-interactive-s-harley-davidson-ar-experience-showcases-the-potential-of-real-time (2018).

6. Patel, N. J. Fiction Vs. Non-Fiction. *Kabuni* https://medium.com/kabuni/fiction-vs-non-fiction-98aa0098f3b0 (2021).

7. Klaris, E. & Bedat, A. M&E Journal: The Biometric Data Concerns Around Virtual and Augmented Reality Applications. *Media & Entertainment Services Alliance* https://hitsonline.org/2018/08/08/me-journal-the-biometric-data-concerns-around-virtual-and-augmented-reality-applications/ (2018).

8. Bhargava, V. R. & Velasquez, M. Ethics of the Attention Economy: The Problem of Social Media Addiction. *Business Ethics Quarterly* **31**, 321–359 (2020).

9. Boxell, L. The internet, social media, and political polarisation. *VoxEU.org* https://voxeu.org/article/internet-social-media-and-political-polarisation (2017).

10. Haidt, J. Why the Past 10 Years of American Life Have Been Uniquely Stupid. *The Atlantic* https://www.theatlantic.com/magazine/archive/2022/05/social-media-democracy-trust-babel/629369/ (2022).

11. Aboujaoude, E. *Virtually You: The Dangerous Powers of the E-Personality*. (W W Norton & Company, 2012).

12. Kim, M. The Good and the Bad of Escaping to Virtual Reality. *The Atlantic* https://www.theatlantic.com/health/archive/2015/02/the-good-and-the-bad-of-escapin

g-to-virtual-reality/385134/ (2015).

13. Shankland, S. The Metaverse Will Be a Multi-Platform Mess. *CNET* https://www.cnet.com/tech/computing/features/here-comes-the-multi-metaverse-mess/ (2022).

14. Marr, B. How To Buy Land & Real Estate In The Metaverse. *Forbes* https://www.forbes.com/sites/bernardmarr/2022/03/23/how-to-buy-land--real-estate-in-the-metaverse/ (2022).

15. *HYPER-REALITY*. (2016).

16. McKinsey & Co. Value creation in the metaverse. *McKinsey & Company* https://www.mckinsey.com/business-functions/growth-marketing-and-sales/our-insights/value-creation-in-the-metaverse (2022).

17. Epic Games. Unreal Engine | The most powerful real-time 3D creation tool. *Epic Games* https://www.unrealengine.com/en-US.

18. Unity. Unity Real-Time Development Platform | 3D, 2D VR & AR Engine. *Unity* https://unity.com/.

19. Zuckerberg, M. We're launching Horizon Worlds in France and Spain today! Looking forward to seeing people explore and build immersive worlds, and to bringing this to more countries soon. *Facebook* https://m.facebook.com/story.php?story_fbid=pfbid022pq5FB8QF3EivSeUjDGRRF4tseWLg5gkANHb7VGtAvyod7pgr8wK9XFH98Ptf6vBl&id=4 (2022).

20. Advanced Ground Software Applications Laboratory. Reality check. *The European Space Agency* https://www.esa.int/ESA_Multimedia/Images/2017/07/Reality_check (2017).

21. IEEE Computer Society. Personal AR for Data Visualization. https://www.computer.org/publications/tech-news/trends/augmented-reality-for-information-visualization/ (2021).

22. Florin, F. *Edge Of See: Twilight Engines*. (2019).

23. Donald, A. How To Use Hand Tracking With the Oculus. *Alphr* https://www.alphr.com/use-hand-tracking-oculus-quest-2/ (2022).

24. Vive. VIVE Tracker (3.0) | VIVE Australia. https://www.vive.com/au/accessory/tracker3/ (2022).

25. Pultarova, T. Emotion tracking sensors add feelings to virtual reality. https://eandt.theiet.org/content/articles/2016/09/emotion-tracking-sensors-add-feelings-to-virtual-reality/ (2016).

26. Biener, V. *et al.* Quantifying the Effects of Working in VR for One Week. Preprint at

https://doi.org/10.48550/arXiv.2206.03189 (2022).

27. Goode, L. Facebook Reaches for More Realistic VR With Haptic Gloves. *Wired* (2021).

28. Stone, Z. Inside the smell-o-verse: Meet the companies trying to bring smell to the metaverse. https://www.fastcompany.com/90744828/inside-the-smell-a-verse-meet-the-companies-trying-to-bring-smell-to-the-metaverse (2022).

29. Oculus VR. Introducing Studio Share: Sculpt with Friends in Oculus Medium. *Meta Quest* https://www.oculus.com/blog/introducing-studio-share-sculpt-with-friends-in-oculus-medium/ (2017).

30. Meta. Horizon Workrooms for VR Remote Collaboration. *Meta* https://about.fb.com/news/2021/08/introducing-horizon-workrooms-remote-collaboration-reimagined/ (2021).

31. VRChat. VRChat. *VRChat* https://hello.vrchat.com (2017).

32. Takahashi, D. Improbable is attacking the metaverse's networking problem. *The Machine: Making sense of AI* https://venturebeat.com/2022/01/27/improbable-is-attacking-the-metaverses-networking-problem/ (2022).

33. Lenihan, R. The Metaverse Has a Winner: Casinos, Gamblers. *TheStreet* https://www.thestreet.com/investing/cryptocurrency/the-metaverse-has-a-winner-casinos-gamblers (2022).

34. Wong, Q. Shopping in the Metaverse Could Be More Fun Than You Think. *CNET* https://www.cnet.com/tech/computing/features/shopping-in-the-metaverse-could-be-more-fun-than-you-think/ (2022).

35. Fonarov, O. What Is The Role Of NFTs In The Metaverse? *Forbes* https://www.forbes.com/sites/forbestechcouncil/2022/03/11/what-is-the-role-of-nfts-in-the-metaverse/ (2022).

36. Binance Academy. How to Buy Land in the Metaverse? *Binance Academy* https://academy.binance.com/en/articles/how-to-buy-land-in-the-metaverse (2022).

37. Edwards, D. How Cryptocurrency will be used in the Metaverse. *Robotics & Automation News* https://roboticsandautomationnews.com/2022/03/09/how-cryptocurrency-will-be-used-in-the-metaverse/49752/ (2022).

38. Zeitchik, S. The crypto-skeptics' voices are getting louder. *Washington Post* (2022).

39. Hanoch, Y. & Wood, S. Scams and cryptocurrency can go hand in hand – here's how they work and what to watch out for. *The Conversation*

http://theconversation.com/scams-and-cryptocurrency-can-go-hand-in-hand-heres-how-they-work-and-what-to-watch-out-for-182033 (2022).

40. Bainbridge, A. & Kent, L. Cryptocurrency scams targeting Australians as scammers bank more than $100 million. *ABC News* (2021).

41. Ratan, R. & Meshi, D. The metaverse is money and crypto is king – why you'll be on a blockchain when you're virtual-world hopping. *The Conversation* http://theconversation.com/the-metaverse-is-money-and-crypto-is-king-why-youll-be-on-a-blockchain-when-youre-virtual-world-hopping-171659 (2022).

42. Marinotti, J. Can you truly own anything in the metaverse? A law professor explains how blockchains and NFTs don't protect virtual property. *The Conversation* https://theconversation.com/can-you-truly-own-anything-in-the-metaverse-a-law-professor-explains-how-blockchains-and-nfts-dont-protect-virtual-property-179067 (2021).

43. Ipsos. Enthusiasm for the metaverse and extended reality is highest in emerging countries. *Ipsos* https://www.ipsos.com/en/global-advisor-metaverse-extended-reality-may-2022 (2022).

44. Bloomberg Intelligence. Metaverse may be $800 billion market, next tech platform. *Bloomberg Professional Services* (2021).

45. Grand View Research. Metaverse Market Size, Share & Trends Analysis Report By Product, By Platform, By Technology (Blockchain, Virtual Reality (VR) & Augmented Reality (AR), Mixed Reality (MR)), By Offering, By Application, By End Use, By Region, And Segment Forecasts, 2022 - 2030. https://www.grandviewresearch.com/industry-analysis/metaverse-market-report (2022).

46. Newton, C. MARK IN THE METAVERSE: Facebook's CEO on why the social network is becoming 'a metaverse company'. *The Verge* https://www.theverge.com/22588022/mark-zuckerberg-facebook-ceo-metaverse-interview (2021).

47. NVIDIA. NVIDIA Launches Omniverse for Developers: A Powerful and Collaborative Game Creation Environment. *NVIDIA Newsroom* http://nvidianews.nvidia.com/news/nvidia-launches-omniverse-for-developers-a-powerful-and-collaborative-game-creation-environment (2022).

48. Microsoft News Center. Microsoft to acquire Activision Blizzard to bring the joy and community of gaming to everyone, across every device. *Microsoft* https://news.microsoft.com/2022/01/18/microsoft-to-acquire-activision-blizzard-to-bring-the-joy-and-community-of-gaming-to-everyone-across-every-device/ (2022).

49. WPP. WPP and Epic Games partner to accelerate innovation for clients in the metaverse | WPP. https://www.wpp.com/news/2022/05/wpp-and-epic-games-partner-to-accelerate-innov

ation-for-clients-in-the-metaverse (2022).

50. Decentraland. The gates to Decentraland have opened! *Decentraland* https://decentraland.org/blog/announcements/decentraland-launch/ (2020).

51. Samsung Newsroom U.S. Samsung Debuts New Fan Experience in the Metaverse with Samsung 837X. Here's How to Get In! *Samsung US Newsroom* https://news.samsung.com/us/samsung-837x-new-metaverse-fan-experience/ (2022).

52. Eibriel. *English: This is a screenshot taken from the Decentraland web client, in the foreground two avatars are dancing, in the background part of the Genesis Plaza can be seen.* (2022).

53. World Economic Forum. The Metaverse. *World Economic Forum* https://www.weforum.org/topics/the-metaverse/.

54. Ministry of Science and ICT. MSIT to announce pan-government strategy on metaverse. *Ministry of Science and ICT* https://www.msit.go.kr/eng/bbs/view.do?sCode=eng&mId=4&mPid=2&pageIndex=1&bbsSeqNo=42&nttSeqNo=621&searchOpt=ALL&searchTxt=Emerging+Metaverse+Industry+Promotion+Strategy (2022).

55. Ministry of Science and ICT. The MSIT supports the creation of a metaverse ecosystem! *Ministry of Science and ICT* https://www.msit.go.kr/eng/bbs/view.do?sCode=eng&mId=4&mPid=2&pageIndex=&bbsSeqNo=42&nttSeqNo=657&searchOpt=ALL&searchTxt= (2022).

56. Oommen, A. Sheikh Mohammed launches higher committee to develop Dubai Metaverse Strategy in two months - Arabian Business. https://www.arabianbusiness.com/industries/technology/sheikh-mohammed-launches-higher-committee-to-develop-dubai-metaverse-strategy-in-two-months (2022).

57. Oommen, A. Dubai's metaverse sector to support 42,000 virtual jobs and add $4 billion to its economy by 2030 - Arabian Business. https://www.arabianbusiness.com/industries/technology/dubais-metaverse-sector-to-support-42000-virtual-jobs-and-add-4-billion-to-its-economy-by-2030 (2022).

58. Shazhaev, I. Dubai to put metaverse into a legal framework: Obstacles and forecasts - Arabian Business. *Araban Business* https://www.arabianbusiness.com/opinion/dubai-to-put-metaverse-into-a-legal-framework-obstacles-and-forecasts (2022).

59. Zimwara, T. Dubai Virtual Assets Regulator Establishes HQ in the Metaverse. *Bitcoin News* https://news.bitcoin.com/dubai-virtual-assets-regulator-establishes-hq-in-metaverse/ (2022).

60. Loop Business. Barbados to establish world's 1st Metaverse Embassy with Decentraland | Loop Barbados. *Barbados Loop News*

https://barbados.loopnews.com/content/barbados-establish-worlds-1st-metaverse-embassy-decentraland (2021).

61. Cheng, E. Shanghai doubles down on the metaverse by including it in a development plan. *CNBC* https://www.cnbc.com/2021/12/31/shanghai-releases-five-year-plans-for-metaverse-development.html (2021).

62. PT WIR Asia Tbk. Jakarta Provincial Government & WIR Group to Develop Jakarta Metaverse - PR Newswire APAC. *PR Newswire Asia* https://en.prnasia.com/story/359646-0.shtml (2022).

63. IDC. Worldwide Quarterly Augmented and Virtual Reality Headset Tracker. *IDC: The premier global market intelligence company* https://www.idc.com/getdoc.jsp?containerId=IDC_P35095 (2022).

64. YouTube VR. Home. *YouTube VR* https://vr.youtube.com/ (2022).

65. Tian, F., Hua, M., Zhang, W., Li, Y. & Yang, X. Emotional arousal in 2D versus 3D virtual reality environments. *PLoS One* **16**, e0256211 (2021).

66. Wheatstone, C. Contributions to the Physiology of Vision.—Part the First. On some remarkable, and hitherto unobserved, Phenomena of Binocular Vision. *Philosophical Transactions* **128**, 371–394 (1838).

67. Stafford, B. M., Teppak, F. & Poggi, I. *Devices of wonder: from the world in a box to images on a screen*. (Getty Research Institute, 2001).

68. Sutherland, I. E. A head-mounted three dimensional display. in *Proceedings of the December 9-11, 1968, fall joint computer conference, part I* 757–764 (Association for Computing Machinery, 1968). doi:10.1145/1476589.1476686.

69. Williams, K. The Virtual Arena – Blast from the Past: The VR-1. *GMW3* https://www.gmw3.com/2020/07/the-virtual-arena-blast-from-the-past-the-vr-1/ (2020).

70. Gilbert, B. Facebook just settled a $500 million lawsuit over virtual reality after a years-long battle — here's what's going on. *Business Insider* https://www.businessinsider.com/facebook-zenimax-oculus-vr-lawsuit-explained-2017-2 (2018).

71. Le Conte Stevens, W. The Stereoscope: Its History - Fig 7. - Brewster's Stereoscope, 1849. in *The Popular Science Monthly* vol. 21 47 (New York, D. Appleton and Company, 1882).

72. Paule, L. Standalone Virtual Reality headsets and their uses. *Laval Virtual* https://blog.laval-virtual.com/en/standalone-virtual-reality-headsets-and-their-uses/ (2020).

73. Facebook. Facebook to Acquire Oculus. *Meta*

https://about.fb.com/news/2014/03/facebook-to-acquire-oculus/ (2014).

74. Meta. VirtuClear lens inserts for Quest 2. https://store.facebook.com/gb/quest/accessories/quest-2/virtuclear-lens-inserts/ (2022).

75. Sony Playstation. PlayStation VR Aim Controller | Control PS VR shooter games with incredible precision. *Sony PlayStation* https://www.playstation.com/en-au/accessories/playstation-vr-aim-controller/ (2022).

76. Needham, M. AR/VR Headset Shipments Grew Dramatically in 2021, Thanks Largely to Meta's Strong Quest 2 Volumes, with Growth Forecast to Continue, According to IDC. *IDC: The premier global market intelligence company* https://www.idc.com/getdoc.jsp?containerId=prUS48969722 (2022).

77. Baker, T. How much is a VR headset? *gamesradar* https://www.gamesradar.com/au/how-much-is-a-vr-headset/ (2022).

78. KKPCW. 店頭展示中の「*Oculus Quest 2*」のサンプル。名古屋市の家電量販店で撮影。. (2020).

79. *Project Glass: Live Demo At Google I/O*. (2012).

80. Kelly, H. Google Glass users fight privacy fears. *CNN Business* https://www.cnn.com/2013/12/10/tech/mobile/negative-google-glass-reactions/index.html (2013).

81. Luckerson, V. Google Will Stop Selling Glass Next Week. *Time* https://time.com/3669927/google-glass-explorer-program-ends/ (2015).

82. Google. Glass. *Glass* https://www.google.com/glass/start/ (2022).

83. Meta. Introducing Ray-Ban Stories: First-Generation Smart Glasses. *Meta* https://about.fb.com/news/2021/09/introducing-ray-ban-stories-smart-glasses/ (2021).

84. Qualcomm. Qualcomm Cuts the Cord with the New Wireless AR Smart Viewer Reference Design Powered by the Snapdragon XR2 Platform. *Qualcomm* https://www.qualcomm.com/news/releases/2022/05/qualcomm-cuts-cord-new-wireless-ar-smart-viewer-reference-design-powered (2022).

85. Christian, B. Microsoft HoloLens in the real word: the companies using the headset. *Wired UK* https://www.wired.co.uk/article/industries-using-microsoft-hololens (2017).

86. Babir, C. & NASA. *KSC-20160918-PH_CAB01_0056*. (2016).

87. Spiegel, E. SNAP INC. Q1 2021 TRANSCRIPT. https://s25.q4cdn.com/442043304/files/doc_financials/2021/q1/Snap-Inc.-Q1-2021-Transcript.pdf (2021).

88. Niantic Inc. Pokémon GO. *Pokémon GO* https://pokemongolive.com/ (2022).

89. Meta Quest. Horizon Worlds | Virtual reality worlds and communities. https://www.oculus.com/horizon-worlds/ (2022).

90. Meta. Opening Horizon Worlds to Everyone 18+ in the US and Canada. *Meta* https://about.fb.com/news/2021/12/horizon-worlds-open-in-us-and-canada/ (2021).

91. Boz [@boztank]. We're making good on our goal to ensure that developers have a path to real financial success on our platform. It's early days, there is still a lot of work to be done and we continue to partner closely with our creators and developers to enable them to earn meaningful revenue. *Twitter* https://twitter.com/boztank/status/1514666496340885506 (2022).

92. Heath, A. Meta's social VR platform Horizon hits 300,000 users. *The Verge* https://www.theverge.com/2022/2/17/22939297/meta-social-vr-platform-horizon-300000-users (2022).

93. Meta Quest. Workrooms | VR for business meetings. https://www.oculus.com/workrooms/ (2022).

94. Langston, J. "You can actually feel like you're in the same place": Microsoft Mesh powers shared experiences in mixed reality. *Innovation Stories* https://news.microsoft.com/innovation-stories/microsoft-mesh/ (2021).

95. Roach, J. Mesh for Microsoft Teams aims to make collaboration in the 'metaverse' personal and fun. *Innovation Stories* https://news.microsoft.com/innovation-stories/mesh-for-microsoft-teams/ (2021).

96. Mesh. Introducing Microsoft Mesh | Here can be anywhere. *Microsoft* https://www.microsoft.com/en-us/mesh (2022).

97. Oculus blog. Introducing 'Horizon Workrooms': Remote Collaboration Reimagined. *Meta Quest* https://www.oculus.com/blog/workrooms/ (2021).

98. Sandbox, T. What is The Sandbox? *The Sandbox* https://medium.com/sandbox-game/what-is-the-sandbox-850de68d893e (2020).

99. Chevi, D. Softbank leads US$93m funding into NFT gaming firm The Sandbox. https://www.marketing-interactive.com/softbank-leads-us93m-funding-into-nft-gaming-firm-the-sandbox (2021).

100. NSW Department of Education. About us. *Technology 4 Learning* https://t4l.schools.nsw.gov.au/about-us.html (2022).

101. NSW Department of Education. stem.T4L. *Technology 4 Learning* https://t4l.schools.nsw.gov.au/stemt4l.html (2022).

102. SharePoint Gurus. stem.T4L Learning Library. *Sharepoint Gurus*

https://sharepointgurus.net/case-studies/stem-share/ (2022).

103. Izadinia, R. *An overview of the research on the stem.T4L project: A three year journey*. https://schoolsequella.det.nsw.edu.au/file/a1ec90d0-e0bd-4e6c-bf47-759740df8f0b/1/stem.T4L_ResearchOverview.pdf (2021).

104. Izadinia, R. *IVR as a tool to create digital art: The case study of Blacktown Girls High School's engagement with stem.T4L*. https://schoolsequella.det.nsw.edu.au/file/ba45fdfe-fc8c-4772-9748-762f7c6c18c9/1/IVRasATool_BlacktownGirlsReport.pdf (2021).

105. The Arts Unit. ARTEXPRESS Virtual Gallery. *NSW Government Arts Unit* https://www.artexpress.vr.artsunit.nsw.edu.au/ (2022).

106. The Arts Unit. About. *NSW Government - ARTEXPRESS* https://artexpress.artsunit.nsw.edu.au/about.php (2022).

107. Technology 4 Learning. Immersive Virtual Reality (IVR) for digital art. *Technology 4 Learning* https://t4l.schools.nsw.gov.au/news/2021/9/immersive-virtual-reality--ivr--for-digital-art-.html (2021).

108. *When art and technology intersect in the hands of students*. (2020).

109. Arts Unit of NSW. ARTEXPRESS VR 2022. *ARTEXPRESS* https://artexpress.vr.artsunit.nsw.edu.au/2022/viewer/?id=GALLERY&q=high (2022).

110. *TAFE NSW - Virtual Reality in Training: Evaluating Effectiveness & Efficacy*. (2020).

111. TAFE Digital. TAFE NSW recognised on global stage for proving effectiveness of VR training. https://www.tafensw.edu.au/media/-/blogs/tafe-nsw-recognised-on-global-stage-for-proving-effectiveness-of-vr-training (2020).

112. NSW Government TAFE NSW. TAFE NSW - VR Experimentation. *We Discover* https://wediscover.com.au/case-studies/tafe-nsw-vr-experimentation/ (2020).

113. ACI. Using virtual reality to improve stroke treatment. *Agency for Clinical Innovation* https://aci.health.nsw.gov.au/about/clinician-connect/feature/2021/virtual-reality-telestroke-training (2021).

114. Lee, G. & Hazzard, B. TAFE NSW develops virtual reality health training. (2020).

115. NSW Health Pathology. World First Healthcare Technology - Virtual Reality Training. *NSW Government Health Pathology* https://www.pathology.health.nsw.gov.au/clinical-services/point-of-care-testing/poct-latest-news/virtual-reality-training (2020).

116. NSW Health Pathology. NSW Health Pathology's FIRST Good Design Award. *NSW*

Government Health Pathology
https://www.pathology.health.nsw.gov.au/clinical-services/point-of-care-testing/poct-latest-news/nswhp-first-good-design-award (2021).

117. Varayudej, M. & Nyugen, M. Asset Management Systems & Princip[les and the Development of Track AR View Application.

118. Transport for NSW. Using Virtual-Reality Technology to Improve Cycleway Design. *NSW Govenrent Transport for NSW* https://www.transport.nsw.gov.au/node/12618 (2022).

119. Alzahrani, N. M. Augmented Reality: A Systematic Review of Its Benefits and Challenges in E-learning Contexts. *Applied Sciences* **10**, 5660 (2020).

120. Diegmann, P., Schmidt-Kraepelin, M., Eynden, S. & Basten, D. Benefits of Augmented Reality in Educational Environments - A Systematic Literature Review. 16 (2015).

121. Abels, E. A. M. *et al.* Augmented Reality-Based Remote Family Visits in Nursing Homes | ACM International Conference on Interactive Media Experiences. in *ACM International Conference on Interactive Media Experiences* 258–263 (2021). doi:10.1145/3452918.3465502.

122. NeuronsVR. Home. *NeuronsVR* https://neuronsvr.com/, https://neuronsvr.com/ (2022).

123. SilVR Adventures. Virtual Reality Experiences for Seniors. *Silvr Adventures* https://silvradventures.com.au/ (2022).

124. WyndVR. Virtual Reality for Seniors. *MyndVR* https://www.myndvr.com/.

125. Rendever. Virtual Reality for Seniors. *Rendever* https://www.rendever.com (2022).

126. Weibel, N. *et al.* ARTEMIS: Augmented Reality Technology-Enabled reMote Integrated Surgery. *HXI - Human-centered eXtended Intelligence* https://hxi.ucsd.edu/project/artemis/ (2022).

127. Cofano, F. *et al.* Augmented Reality in Medical Practice: From Spine Surgery to Remote Assistance. *Frontiers in Surgery* **8**, (2021).

128. Navy Medicine. *NMCSD ARTEMIS Project*. (2020).

129. Williams, D. R. Use of video recordings and video links by courts and tribunals. *Western Australian Law Review* **17**, 257–271 (1987).

130. Yeo, A. Jurors could use VR to visit crime scenes, and help them reach a verdict | Mashable. *Mashable* https://mashable.com/article/virtual-reality-jury-trial-courtroom (2021).

131. Meltzer, I., Zhang, K. & Lim, J. A New (Virtual) Reality for the Courtroom. *Sydney University Law Society*
https://www.suls.org.au/citations-blog/2020/9/25/a-new-virtual-reality-for-the-courtroo

m (2020).

132. Crozier, R. Sydney Trains progresses AR protection for rail workers. *iTnews* https://www.itnews.com.au/news/sydney-trains-progresses-ar-protection-for-rail-workers-582159 (2022).

133. NSW Food Authority. Scores on Doors. *NSW Food Authority* https://www.foodauthority.nsw.gov.au/retail/scoresondoors.

134. NSW Food Authority. Name and shame. *NSW Food Authority* https://www.foodauthority.nsw.gov.au/offences.

135. NSW Food Authority. Licensing and notifying. *NSW Food Authority* https://www.foodauthority.nsw.gov.au/help/licensing.

136. qianw211. QR code tracking overview - Mixed Reality. *Microsoft* https://docs.microsoft.com/en-us/windows/mixed-reality/develop/advanced-concepts/qr-code-tracking-overview (2022).

137. *Virtual Reality Training For The Emergency Services - BBC Click*. (2020).

138. *VR Tactical Training of the Zurich City Police with Refense*. (2021).

139. *NYPD using VR to train for active shootings and real-life scenarios*. (2019).

140. US Department of Homeland Security - Science and Technology. Enhanced Dynamic Geo-Social Environment. *US Department of Homeland Security - Science and Technology* https://www.dhs.gov/science-and-technology/EDGE (2022).

141. Ars Electronica. *Impressions of Challenge: Emergency Error Battle / Oö. Landes-Feuerwehrverband (AT), Rosenbauer International AG (AT), Ars Electronica (AT), g.tec medical engineering GmbH (AT)*. (2018).

142. O'Leary, S. Virtual Reality Surgery Simulation. *Melbourne Medical School* https://medicine.unimelb.edu.au/research-groups/surgery-research/virtual-reality-surgery-simulation.

143. *How virtual reality is improving surgical skills during the pandemic*. (2021).

144. Hsu, E. B. *et al.* State of Virtual Reality Based Disaster Preparedness and Response Training. *PLoS Curr* **5**, ecurrents.dis.1ea2b2e71237d5337fa53982a38b2aff (2013).

145. Etter, C. *Game Science Center exhibit: Augmented Reality Sandbox*. (2014).

146. Akron. Akron Art Museum Launches Interplay: Art Play for All Augmented Reality Experience. *Akron Art Museum* https://akronartmuseum.org/newsroom/akron-art-museum-launches-interplay-art-play-for-all-augmented-reality-experience/ (2020).

147. *AOL AUGMENTED ART GALLERY*. (2021).

148. *Story of the Forest*. (2016).

149. Museum Nal Hist Naturelle. Revivre, Extinct Animals in Augmented Reality. *Muséum national d'Histoire naturelle official website* https://www.mnhn.fr/en/experience/revivre-extinct-animals-in-augmented-reality.

150. Shing, C. Y. *Story of the Forest*. (2017).

151. *Venice, The Floating City: A Guided VR Tour - 8K 360 3D Video*. (2021).

152. *360°, Angel Falls, Venezuela. Aerial 8K video*. (2017).

153. Google Arts & Culture. Versailles: The Palace is Yours. *Google Arts & Culture* https://artsandculture.google.com/project/versailles.

154. Google Arts and Culture & makemepulse. VersaillesVR | the Palace is yours on Steam. (2019).

155. *Refining Virtual Reality Tour (VR)*. (2019).

156. Feruz110. *3D model*. (2018).

157. Bani Mohammad, E. & Ahmad, M. Virtual reality as a distraction technique for pain and anxiety among patients with breast cancer: A randomized control trial. *Palliat Support Care* **17**, 29–34 (2019).

158. McSherry, T. *et al.* Randomized, Crossover Study of Immersive Virtual Reality to Decrease Opioid Use During Painful Wound Care Procedures in Adults. *J Burn Care Res* **39**, 278–285 (2018).

159. Gold, J. I. & Mahrer, N. E. Is Virtual Reality Ready for Prime Time in the Medical Space? A Randomized Control Trial of Pediatric Virtual Reality for Acute Procedural Pain Management. *J Pediatr Psychol* **43**, 266–275 (2018).

160. Le May, S. *et al.* Immersive virtual reality vs. non-immersive distraction for pain management of children during bone pins and sutures removal: A randomized clinical trial protocol. *J Adv Nurs* **77**, 439–447 (2021).

161. Gold, J. I., SooHoo, M., Laikin, A. M., Lane, A. S. & Klein, M. J. Effect of an Immersive Virtual Reality Intervention on Pain and Anxiety Associated With Peripheral Intravenous Catheter Placement in the Pediatric Setting: A Randomized Clinical Trial. *JAMA Netw Open* **4**, e2122569 (2021).

162. Glennon, C. *et al.* Use of Virtual Reality to Distract From Pain and Anxiety. *Oncol Nurs Forum* **45**, 545–552 (2018).

163. Walker, M. R. *et al.* Treatment efficacy of virtual reality distraction in the reduction of pain

and anxiety during cystoscopy. *Mil Med* **179**, 891–896 (2014).

164. *NomadVR | VR For Aged Care*. (2018).

165. QUT Design Lab. Transforming Aged Care with Virtual Reality (VR). *QUT Design Lab* https://research.qut.edu.au/designlab/projects/transforming-aged-care-with-virtual-reality-vr/.

166. *Aged care residents use virtual reality for the first time*. (2016).

167. P, P. *Old man tries VR googles. This image has been originally created as the illustration for jego ojcem dziadek entry in szarada.net crosswords dictionary. It has been released under CC-BY-3.0 license.* (2015).

168. Norton Rose Fulbright. The Metaverse: The evolution of a universal digital platform. *Norton Rose Fulbright* https://www.nortonrosefulbright.com/en-us/knowledge/publications/5cd471a1/the-metaverse-the-evolution-of-a-universal-digital-platform (2021).

169. Moses, L. B. The applicability of property law in new contexts: from cells to cyberspace. *Sydney Law Review* **30**, 639–662 (2008).

170. Niantic is tweaking Pokémon Go to settle a lawsuit with angry homeowners - The Verge. https://www.theverge.com/2019/2/15/18226604/niantic-pokemon-go-lawsuit-changes-settlement-private-property-pokestop-gym.

171. Google Cardboard. Google Cardboard – Google VR. https://arvr.google.com/cardboard/.

172. White, M. Web3 Is Going Just Great. https://web3isgoinggreat.com/ (2022).

173. BCS - The Chartered Institute for IT. Social media should require verified ID to help stop racist abuse. https://www.bcs.org/articles-opinion-and-research/social-media-should-require-verified-id-to-help-stop-racist-abuse/ (2021).

174. Lucatch, D. Digital Identity In The Metaverse. *Forbes* https://www.forbes.com/sites/forbesbusinesscouncil/2021/12/28/digital-identity-in-the-metaverse/ (2021).

175. Nicas, J. What Data About You Can the Government Get From Big Tech? *The New York Times* (2021).

176. Hamilton, A., Jay, J. & Madison, J. Research Guides: Federalist Papers: Primary Documents in American History: Full Text of The Federalist Papers. *Library of Congress* https://guides.loc.gov/federalist-papers/full-text (1787).

177. NSW Government. *NSW Government Identity Strategy: For a better protected, safer 'you'*. 4 https://www.nsw.gov.au/sites/default/files/2021-05/NSW-Government-Identity-Strategy-

accessible.pdf (2021).

178. Australian Taxation Office. Voice authentication. *Voice authentication* https://www.ato.gov.au/general/online-services/voice-authentication/.

179. NSW to pilot digital identity verification for government services | ZDNET. https://www.zdnet.com/article/nsw-to-pilot-digital-identity-verification-for-government-services/.

180. Magic | Web3 Infrastructure Leader. *Magic* https://magic.link/home.

181. PhotoChromic - Your identity as an NFT. https://photochromic.io/index.html.

182. Liquid Avatar. https://liquidavatar.com.

183. Infrastructure NSW. State Infrastructure Strategy 2022-2042. 14.

184. Digital.NSW. NSW Connectivity Strategy | Digital.NSW. *NSW Government - digital.nsw* https://www.digital.nsw.gov.au/policy/nsw-connectivity-strategy (2022).

185. Telco Authority. New connectivity strategy delivers better digital services across NSW | NSW Government. (2022).

186. Digital.NSW. NSW AI Assurance Framework. *NSW Government - digital.nsw* https://www.digital.nsw.gov.au/policy/artificial-intelligence/nsw-ai-assurance-framework (2022).

187. eSafety Commissioner. Principles and background. *Australian Government - eSafety Commissioner* https://www.esafety.gov.au/industry/safety-by-design/principles-and-background.

188. Rosenberg, L. Regulation of the Metaverse: A Roadmap. in (2022).