Military Metaverse CONOPS

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ABSTRACT

Commissioned by the UK's Dstl, this study set out to investigate the origins and latest thinking on the metaverse, leading to the creation of a "Military Metaverse CONOPS". The CONOPS (Concept of Operations) describes a future defence modelling and simulation (M&S) ecosystem built on metaverse technologies, standards, and approaches, together with benefits, use cases and actions to take. It provides a unifying vision for defence to realise the full potential of M&S through an integrated enterprise approach in support of all defence activities including training and operations. The study found that although descriptions of the metaverse vary, it can be considered an umbrella term for many technologies of interest to defence and it is their integration and convergence that are driving metaverse developments, reflecting the evolution of computing itself, from predominately 2D, to 3D interaction and presence. Metaverse technology developments will be predominantly driven outside of defence, but key elements of a military metaverse include ubiquitous networking and computing, pan-enterprise access to verifiable M&S data, and the exploitation of open metaverse standards. The CONOPS approach provided a useful vehicle for communicating why and how technologies might be brought together for defence benefit, informing both M&S policy and the future direction of the M&S research programme.

1.0 INTRODUCTION

1.1 Research Background and Approach

This study was commissioned to support Dstl's Transforming Training, Education and Preparation (TTEP) research activities and is aimed at informing Dstl to gain competitive advantage in support of science and technology (S&T) activities relating to training, education, and preparation. It was suggested by Vedette as part of a simulation and synthetic environment innovation call in August 2021 in order to address two questions. What does the metaverse mean for defence and, by building on metaverse technologies and approaches, could a CONOPS be developed to provide a unifying vision for UK defence's approach to M&S? The study was principally aimed as a think piece and guide for why and how defence might actively explore and discuss metaverse developments and seek out opportunities to exploit externally driven innovation. It was conducted from mid-December 2021 through to mid-February 2022 with outputs of a "Military Metaverse CONOPS 2035" and a supporting report and presentation. This paper has built on the study incorporating key metaverse developments since the study end.

In terms of study structure, the first phase investigated the origins of the word "metaverse", captured the latest thinking on the metaverse, and formed and understanding of its relationship with defence M&S. From this work military metaverse technology summaries and a metaverse features versus defence M&S mapping were developed aimed at explaining the relevance of the technologies to defence. Building on this work, the next phase was to review latest UK Ministry of Defence (MoD) and international policy and thinking on future operations in order to set the scene and inform the military metaverse CONOPS. Finally, the "Military Metaverse CONOPS 2035" was written based on the ISO/IEC/IEEE 29148:2018 standard format for a CONOPS[i].

2.0 THE METAVERSE

2.1 Origins and History

2.1.1 Metaverse Origins

The word metaverse first came into existence in Neal Stephenson's 1992 science fiction novel Snow Crash, being a "computer-generated universe that their computers draw on their goggles and pump into their earphones … an imaginary place known as the Metaverse". It was a portmanteau of the prefix "meta" (meaning beyond) and "universe" and it was a science fiction vision of a future digital simulated world that humans inhabited, and one that also impacted on the real world. The attributes of the digital avatars controlled by the humans were based on their social economic status and wealth, an extension of the physical world in digital format. It was an influential book and the term metaverse has been used ever since, although its usage grew very significantly in 2021.

Snow Crash was not unique. Many science fiction writers and filmmakers of the time, no doubt influenced by the contemporary developments in computer technology, envisaged a future where the real and virtual worlds would come together and sometimes be indistinguishable. For example, William Gibson's Neuromancer novel (1984) popularised the word "Cyberspace" and introduced the concept of a "matrix" as a "mass consensual hallucination" in computer networks. In Ender's Game (1985) the protagonist thought they were in a simulation whilst they were actually in combat, and in The Matrix (1999) the majority of humans were unaware they were living in a simulation.

2.1.2 Metaverse Developments

Metaverse-inspired concepts slowly turned from fiction to reality. In 2003, the online multimedia platform Second Life launched allowing humans to create their own avatars and interact with others in a persistent user generated world with a working economy. Although its early rapid growth was not maintained, it provided a (still) working vision of what a metaverse might look like. Indeed, it is still in existence with a $650 million in-game economy[ii] from the buying and selling of digital content such as avatar clothing. In 2007 a cross industry/academia group including Sony and Harvard University published its Metaverse Roadmap[iii] which recognised that the metaverse was not only a virtual space but a "junction or nexus of our physical and virtual worlds". The EU ITEA project Metaverse1 (2008-11) project inspired the ISO/IEC 23005 standards[iv], providing a standard interface between the real physical and the virtual worlds.

In the 2010s, against a backdrop of advances in online gaming and XR (eXtended Reality[v]), the metaverse continued to provide a vision of how technology (and society) might advance with proponents such as Epic Games' CEO Tim Sweeney "be patient … The metaverse will come … and it will be open"[vi]. Virtual world gaming platforms Minecraft and Roblox grew steadily through the 2010s as they focused on ease of use and the younger generation. Minecraft grew 6-fold to 150 million monthly users from 2014 to 2021 and Roblox grew 45-fold in the same period to 225 million monthly users[vii]. However, it is arguably the COVID-19 pandemic that has helped to ignite mainstream interest in the metaverse concept, with current day technology supporting a step change in digital remote working and socialising. This can be illustrated by Facebook changing its name to "Meta" in 2021[viii] becoming a "Social Technology Company" and Microsoft and NVIDIA launching metaverse-related products for engineers and designers. As of 2022, recognising the need to build the metaverse with open standards, the Metaverse Standards Forum was formed[ix] with members including Meta, Microsoft, and NVIDIA, with a mission to bring together the multiple standards organizations the metaverse impacts on.

2.2 Contemporary Metaverse Descriptions

At the time of writing, there is no single definition of the metaverse, rather a set of broadly similar descriptions. Although this can be problematic in terms of describing the metaverse, this is similar to "cyberspace" which similarly started out as a science fiction term and has varied definitions as well, and the Internet was once popularly called the "Information Superhighway", so definitions can be vague and come and go as technology and culture evolve. Nevertheless, although the original concepts of virtual reality and avatars remain, the metaverse is generally considered now to also embrace a wider convergence of technologies of varying maturities that are bringing the physical and digital worlds together and is seen as the next iteration of the Internet, a trend from 2D to 3D interaction and immersion between humans, machines, and the digital world. Table 1 below has a range of contemporary metaverse descriptions.

Table 1: A Range of Contemporary Metaverse Descriptions

Source	Metaverse Description	Reference
Wikipedia	"In futurism and science fiction, the metaverse is a hypothetical iteration of the Internet as a single, universal and immersive virtual world that is facilitated by the use of virtual reality (VR) and augmented reality (AR) headsets."	Retrieved August 2022
Microsoft CEO - Satya Nadella	"The metaverse enables us to embed computing into the real world and to embed the real world into computing."	Microsoft Ignite November 2021
NVIDIA CEO - Jensen Huang	"The metaverse is the next evolution of the internet … the internet in 3D, a network of connected, persistent virtual worlds … where humans will portal into a virtual world with XR devices while AIs will portal out to our world as physical robots."	NVIDIA Special Address - SIGGRAPH 2022
Matthew Ball (Author)	"A massively scaled and interoperable network of real-time rendered 3D virtual worlds that can be experienced synchronously and persistently by an effectively unlimited number of users with an individual sense of presence, and with continuity of data, such as identity, history, entitlements, objects, communications, and payments."	The Metaverse: And How It Will Revolutionize Everything - 2022
JP Morgan (Company)	"The metaverse is a seamless convergence of our physical and digital lives, creating a unified, virtual community where we can work, play, relax, transact and socialize."	"Opportunities in the Metaverse" 2022

From these metaverse descriptions and others it can be seen that there are broadly two schools of thought, albeit closely aligned. One that considers the metaverse as principally consisting of persistent virtual worlds and one that sees it as also reaching into the real world.

2.3 One Metaverse?

Current thinking around the metaverse is that it will impact on a very wide range of human activity, hence the massive investments that are being made now by technology companies. For example, Meta expected to spend $10 billion on metaverse related technologies in 2021/22[x]. Already proto-metaverse or metaverse-like experiences are supported in gaming, but this will also migrate into the wider entertainment and leisure and the world of work, commerce and engineering. The ability to create, sell and buy virtual assets such as 3D models that can be used across different virtual worlds will drive further growth and investment in the metaverse. We are also seeing examples of where digital twins exist in the virtual world helping to design and optimise their equivalents in the real world. However, there remain many challenges to bring these technologies together at scale and to interoperate, and so it is unlikely that any one company can solve all the

complex and diverse technological, legal, and sociological issues of the metaverse. It is thus unlikely that there will be only one persistent virtual world, more likely a number of connected interoperable virtual worlds.

2.4 Proto-Metaverses

There are already platforms and technologies that have metaverse-like characteristics which contemporary commentators call "Proto-Metaverses", signifying an early form of the metaverse. They also signify that many humans already are experiencing metaverse-like experiences and that metaverse technologies are finding professional uses. Examples of proto-metaverses are listed below in Table 2.

Table 2: A Range of Contemporary Proto-Metaverses

Source	Proto-Metaverse
Microsoft	Mesh - a collaboration and communications platform supporting virtual collaboration across multiple devices and the Microsoft Metaverse Apps Stack
NVIDIA	Omniverse™ a scalable, real-time reference development platform for 3D simulation and design collaboration and CloudXR™ delivers XR across 5G and Wi-Fi networks
Varjo	Reality Cloud – "Teleport VR"
Epic Games	Unreal Engine – supports mobile, XR, through to flight sim domes
Roblox	225m monthly active users, creating and playing 3D games, played by >50% US children (<16) in 2022
Second Life	Launched 2003, a persistent 3D virtual world (GDP $650m (2022))
Decentraland	Open-source 3D virtual world platform with NFT-based land ownership (Launched 2020)

2.5 Metaverse Technologies

The study analysed a number of metaverse descriptions (see 2.7) and identified and categorised those technologies that underpinned the metaverse. They are of varying technology and commercial maturities and bridge both the digital and physical worlds. From this analysis, the following technologies and approaches are directly or indirectly helping to build and support the development of the metaverse (Table 3).

Table 3: Metaverse-Related Technologies

Computing	Software	Networking & Security	Human-Computing Interfaces	Data & Digital Twins	AI, Data & Analytics	Automation & Robotics	Sensors	Standards
Quantum	Collaborative 3D Software	6G	eXtended Reality XR	Digital Twins	Personal tutors and guides	Everyday Robotics	Computer Vision	Open
Cloud	Games Engines	Free-space optical comms & LiFi	Holographic Imaging	Personal Digital Twin	Natural Language Understanding	Telexistence	Volumetric Video	Industry/ Proprietary
Edge	Web 3.0	Zero Trust Security	Haptics	Block-chain/ Non-fungible Tokens	Auto/Machine Translation	Metamobility & Mobility of Things	IoT (Internet of Things)	
Spatial Computing			Wearables	Synthetic Data	Predictive Decision Support			
DNA Digital Data Storage			Human Augmentation		Video & audio optimisation			

2.6 Metaverse Standards

The current thinking of influential metaverse protagonists is that there will not be a single virtual world and that standards will be required to permit avatars and digital assets to move between worlds. For example, Mark Zuckerberg has said[xi] "you have your avatar and your digital goods, and you want to be able to teleport anywhere … and you don't want to just be stuck within one company's stuff", and the influential author Matthew Ball claims "there will be hundreds of metaverses, spread across a multiverse of genres and types for people to interact, live and conduct business and pleasure in"[xii].

Some of the key metaverse interoperability challenges will be to facilitate the:

- Creation and movement of 3D assets between 3D worlds/simulations
- Movement and transfer of personal data between 3D worlds/simulation

Interestingly for the military community there does not seem to be a big drive at present to dynamically link virtual worlds (as facilitated already by HLA/DIS) rather it is the transfer of assets and identity. Nevertheless, as the creation and distribution of 3D assets across multiple virtual worlds becomes more commonplace, together with advances in how the real and digital worlds interact (eg. XR, sensors), then standards forged outside of defence are likely to dominate. Defence will therefore need to actively monitor metaverse related standards developments and exploit as appropriate. Some of the current main standard initiatives are as follows (Table 4).

Table 4: Metaverse-Related Standard Groups/Organisations

Standards Initiative	Description/Comment
Khronos Group[xiii]	An open, non-profit, member-driven consortium of over 150 industry-leading companies (eg. Apple, Intel) creating royalty-free interoperability standards for 3D graphics, augmented and virtual reality, parallel programming, vision acceleration and machine learning. A good example of a Khronos standard relevant to both the metaverse and defence is OpenXR which provides cross-platform access to diverse XR device runtimes across multiple platforms.
Academy Software Foundation[xiv] (ASWF)	Focused on the open-source ecosystem for the animation and visual effects industry with a mission to lower the barrier to entry for developing and using open source software. One of the standards overseen is the Universal Scene Description (USD) which is open-source 3D scene description and file format developed by Pixar for content creation and interchange among different tools. It is being widely adopted, in the visual effects community, but also in design, robotics, manufacturing, and other disciplines.
Metaverse Interoperability Community Group[xv]	Part of the World Wide Web Consortium (W3C), its mission is "to bridge virtual worlds by designing and promoting protocols for identity, social graphs, inventory, and more". Newly formed, it has 103 participants.
ISO MPEG-V[xvi] (2020)	Provides "an architecture … to enable the interoperability between virtual worlds with the real world, e.g., sensors, vision, providing a lower entry level to multiple virtual worlds both for the provider of goods and services as well as the user". Although this standard is visionary and builds on interoperability research of the 2000s it does not seem to have gained widespread traction.
Metaverse Standards Forum[xvii]	Launched June 2022, and with similar membership to the Khonos Group, it is not aimed at developing open standards but coordinating, fostering and accelerating their development.

2.7 Metaverse Relevance to Defence

The digitisation of the physical world, interoperability of the virtual world and the physical worlds, and increasing use of AI as envisaged by metaverse visionaries has many similarities with the Live-Virtual-

Constructive (LVC) initiatives driven over a number of years by the defence M&S community. Indeed, the study authors have previously proposed[xviii] a description of a "Military Metaverse" as follows:

"Persistent secure networked interoperable live, virtual and constructive simulations, synchronized with multi-domain operational systems and enterprise-wide digital twins of equipments, platforms, infrastructure and personnel and the wider human and natural world."

It was also clear from the early research that a military metaverse has implications for defence that go beyond M&S. The metaverse will impact on the wider manner in which humans and machines interact with networked computing and there is significant crossover with defence's cyberspace initiatives in terms of data, networks, digital twins and AI for example. It was suggested that this work was made known across wider defence digital stakeholders, not least to show that defence M&S should be considered in UK MoD's digital and data strategies, including setting the requirements for the UK Defence Digital Backbone[xix].

To assist with describing a military metaverse, a mapping was generated which extracted key attributes of the wider metaverse from a number of references and these were brought together to generate attributes of a military metaverse. The results of this work can be seen in Table 5 below.

Table 5: Metaverse Attributes Abstracted for a Military Metaverse

Matthew Ball[xx]	**Jon Radoff[xxi]**	**Lik-Hang Lee et al[xxii]**	**Newzoo[xxiii]**	**Roblox[xxiv]**	**Microsoft[xxv]**	**Nvidia[xxvi]**		**Military Metaverse**
Hardware		Network	Gateways - Centralised	Identity	Mesh & HoloLens	Omniverse Apps		Discovery
Networking	Experience	Edge/Cloud	Gateways - Decentralised	Friends	Azure AI & Autonomous Systems	Omniverse Platform		User Interfaces & Immersion
Compute	Discovery	Artificial Intelligence	Avatar & Identity	Immersive	Power Platform	Artificial Intelligence		Robotics/Sensors/IoT
Virtual Platforms	Creator Economy	Computer Vision	User Interfaces & Immersion	Low Friction	Azure Analytics	Graphics		Data & Digital Twins
Interchange Tools and Standards	Spatial Computing	Blockchain	Economy	Variety	Azure Maps	Compute		Virtual Economy
Payments	De-centralization	Robotics/IoT	Social	Anywhere	Azure Digital Twins	RTX GPU		Content, Services, & Assets
Metaverse Content, Services, & Assets	Human Interface	User Interactivity	Cloud, Scalability & Hosting	Economy	Azure IoT			AI & Computer Vision
User Behaviours	Infrastructure	Extended Reality	Play-to-Earn/Collect	Civility	Physical World			Interchange Tools & Standards
		Avatar	Visualisation & Digital Twin					Network
		Content Creation	Artificial Intelligence					Edge/Cloud
		Virtual Economy	Decentralised Infrastructure					Security, Privacy & Culture
		Social Acceptability	Adtech					Procurement, Culture
		Security & Privacy	Connectivity					
		Trust & Acceptability						

The study determined that due to security concerns a military metaverse will most likely need to be hosted on its own defence network and have some connections as necessary with the wider metaverse. This is similar to many current day intranet/Internet defence network architectures.

3.0 MILITARY METAVERSE CONOPS

3.1 Why a CONOPS and CONOPS Format

In order to view the metaverse from a military and defence user perspective, the study team focused on writing a military metaverse CONOPS for the pan defence exploitation of M&S. As metaverse technologies potentially impact across the whole defence enterprise it was decided to widen the use of M&S beyond

training to all uses/users of M&S. There is no single definition of a CONOPS, but for this research it was taken to be a document describing the characteristics of a proposed system from a user viewpoint[xxvii] including the operational needs, desires, visions, and expectations of the user, without being overly technical or formal[xxviii]. The CONOPS document structure was based on ISO/IEC/IEEE 29148:2018:

- Purpose
- Scope
- Strategic plan
- Effectiveness
- Overall operation
- Governance

3.2 Military Metaverse CONOPS Purpose

The purpose of the CONOPS was to provide a unifying vision and propose actions to take now for defence to cost effectively exploit metaverse technologies and approaches, building towards a Military Metaverse 2035 (MM2035). It was aimed at the M&S community but also wider defence digital stakeholders. The intent was that by exploiting metaverse advances by 2035, defence could realise the full potential of M&S across all its activities through enhanced integration, coordination and sharing together with data being treated as an enduring strategic asset. The benefits were to include enhancing defence's ability to prepare, from concept studies through to operations, improved support to multi-domain integration, and the ability to work together more cost effectively and independent of distance with less of an environmental impact.

3.3 MM2035 Scope

Because current day M&S capabilities include many legacy systems, the CONOPS end state was set for 2035 envisaging that necessary course corrections could be made now for current and planned programmes and that the wider metaverse technologies were sufficiently mature across the board. As described earlier, with the potential to impact across all defence activities the CONOPS was med at all M&S customers and users and wider digital stakeholders within the whole capability cycle as in Figure 1 (derived from the NATO C3[xxix] and the M&S Taxonomy provided by the Dstl customer).

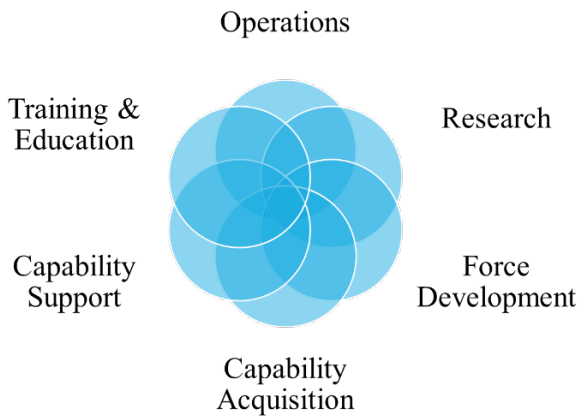

Figure:- 1 – A Military Metaverse Supporting all Defence Activities across the Capability Cycle

3.4 MM2035 Strategic Plan

M&S is inextricably linked to wider defence information strategies and technologies and key related strategies and policies are listed below. Although the documents are UK-centric, similar trends might be seen in other nations.

Table 4: Key UK MoD Digital and M&S Related Documents

Document	Key Directives	Military Metaverse Implications
UK Defence Digital Strategy[xxx] May 2021	(By 2030) A secure, singular, modern Digital Backbone is connecting sensors, effectors and deciders across military and business domains and with partners, driving integration and interoperability across domains and platforms.	All M&S will sit on, and be connected by, defence's Digital Backbone, likely with hybrid cloud computing platform(s).
UK Defence Data Strategy[xxxi] Sep 2021	Data is curated, ensuring it is assured, discoverable and interoperable. Data is to endure as an asset beyond individual projects.	M&S data too will be curated, interoperable and discoverable and treated as a strategic asset with value beyond individual projects.
UK Integrated Operating Concept[xxxii] Aug 2021	Multi-Domain Integration (MDI) ensures that every part of defence can work seamlessly together, and with other government departments and the UK's allies, to deliver a desired outcome.	The need for M&S to interoperate with bodies external to defence and across five domains (air, land, sea, space, cyber) is likely to drive a federated approach, much like the wider metaverse.
UK Defence Policy for M&S[xxxiii] (JSP 939) Apr 2021	DMaSC provides a defence wide coherent approach to provide better Modelling & Simulation (M&S) capability and reduce costs with less of an environmental impact.	The Military Metaverse will build on existing policies and standards but metaverse-driven standards will need to be monitored and embraced as appropriate.

Defence therefore has a number of recent strategies and policies in place to guide future M&S investment. However, as described previously, transition is only practicable over a period of time (to 2035). What defence could do now is to research and make any necessary funding and technology decisions that can be made in the present. The sheer weight of commercial funding behind the metaverse means that defence only might need to fund very few areas that require technological development, ideally none. Defence research might instead focus on technology application; informing defence policies; help generate requirements for M&S; and justify any central investment in M&S to realise MM2035. Such topics include:

Table 5: Proposed MM2035 Research Topics

Research Topic Area	Example Research Question(s)
M&S Data	Establish common M&S metadata standards and evaluate and recommend sharing tools
Connectivity	Identify MM2035 bandwidth and latency requirements and balance between fixed and mobile infrastructure (eg. 6G)
Cloud/Edge Infrastructure	Set requirements for M&S computing requirements and balance between cloud and edge
Discovery	Evaluate and recommend tools for data and tools/applications discovery
Communities	Evaluate sharing and communication tools and foster an M&S sharing community culture(s)
Security and Privacy	Establish policy for capture, storage, and access to personnel data
Standards	Engage with wider metaverse standards groups (eg. Khronos Group)
People & Process	What SQEP[xxxiv] does MM2035 require and what culture and processes will maximise M&S exploitation and sharing?
Experimentation	*Technology(s) to be evaluated with users prior to wider fielding*

3.5 MM2035 Effectiveness

MM2035 was designed to support all defence activities. Measures of MM2035 cost effectiveness would need to be established with stakeholders against a broad range of its use cases. Examples of such use cases are provided below in Table 6.

Table 6: MM2035 Use Cases

Defence Activity	Defence Use Case	MM2035 Support	MM2035 Benefits
Operations	Preparing for a Multi-Domain Mission	Links warfighters across a single distributed multi-domain simulation that represents the latest operational status	Warfighters can prepare with others across the multi-domain spectrum in timely and representative simulation
Training & Education	Training simulators represent the latest systems/platforms	Simulators automatically update as new system/ platform models are verified	Warfighters train in updated simulators avoiding negative training
Capability Support	Integration of new systems into existing platform	Stakeholders access legacy digital M&S together with digital representation of new system	Project stakeholders can assess and decide how new capabilities can cost effectively be integrated
Capability Acquisition	Distributed collaborative design by stakeholders	Geographically distributed project stakeholders can instantly interact with latest and legacy digital models in a virtual space	Decision making is timely, consistent, traceable, collaborative and travel is reduced
Force Development	Exploring and optimising human-machine teaming	Humans/warfighters can operate with autonomous systems in simulated environment	Human-machine balance is optimised across Lines of Development
Research	Programming autonomous systems across a spectrum of use cases and environments	Autonomous systems are trained in a broad range of simulated environment	Autonomous systems programming is robust and verifiable while operating in a broad range of scenarios

The value of MM2035 would be greater than the sum of its parts as sharing, commonality and interoperability benefits the whole M&S and wider digital ecosystem. As well as serving use cases across defence, a MM2035 would ensure M&S capabilities are always up to date, consistent, verifiable, cost effective and reach all that can benefit.

3.6 MM2035 Overall Operation

MM2035 would operate as a secure M&S ecosystem that supports users and providers and be built on the Defence Digital Backbone facilitating connection and sharing within and external to MoD. It would develop and operate following the design principles derived from the strategies and policies of Table 4 and are listed below in Table 7.

Table 7: MM2035 Design Principles

MM2035 Design Principle	Comment
Built on Defence's Digital Backbone	M&S is intrinsic to, and integrated with, wider operational and business Information Systems
Ubiquitous Computing & Sensors	Digital Backbone supports secure cloud through to edge computing technologies across the M&S ecosystem
Intranet of Simulations	Defence simulations are federated over a persistent network to support multi-domain integration and sharing, both for the UK and with international partners
Support Widest Range of Human Interfaces	Users can interact with M&S using the most appropriate hardware (eg. mobile device, or XR, through to full immersion)
"Create Once, Reach All" Data[xxxv]	Projects create/procure and manage their M&S data through life as a strategic asset, and ensure it is discoverable, interoperable with, and accessible to, projects and users and creators across the M&S Ecosystem
"Acquire Once, Reach All" M&S Applications	M&S Applications are acquired once and then made available across M&S Ecosystem
M&S Applications and Data are Discoverable	M&S Application and Data usage is optimised, consistent and cost effective
M&S is Verified and Cost Effectiveness Benchmarked	Defence understands the quality and cost effectiveness of its M&S systems and optimises its balance of investment
User/Creator Communities Supported	Technology, processes, and culture support vibrant supportive user/creator communities that optimise the use of M&S
Common M&S Standards	Commercial and military standards are exploited to enhance interoperability and maximise cost effectiveness
Federated Defence M&S Catalogues and Libraries	Sharing, reuse and coherence of tools and data will be everyone's responsibility and achieved through network-wide access to verified tools and data

Figure 2 below brings together key MM2035 design principles and the defence capability cycle.

Figure:- 2 – A Military Metaverse Supporting all Defence Activities across the Capability Cycle with MM2035 Design Principles

3.7 MM2035 Governance

It is envisaged that MM2035 would be governed with a minimum level of central governance, encouraging innovative and agile use of M&S and an overall vibrant M&S ecosystem. Overall enterprise level cost effectiveness and interoperability would be achieved through: One network; policies and tools to support the creation and sharing of data and content; and military and commercial standards.

A central coordinating authority would oversee the development and evolution of MM2035, setting "Ready for MM2035" rules and guidance, with the authority to raise any shortfalls at a higher level for resolution. It would also have a budget for central investments in tools, data and networks to support the MM2035 "common good" and ownership of MM2035 standards. MM2035 coordinating authority performance would be assessed against the aforementioned MM2035 Measures of Effectiveness. The MM2035 coordinating authority near-term tasks (0-3 years) are listed below in Table 8.

Table 8: MM2035 Co-ordinating Authority Near-Term Tasks

Serial	Task (0-3 years)
a	Develop a Metaverse Strategy for Defence
b	Develop MM2035 Measures of Effectiveness
c	Develop "Ready for MM2035" rules and guidance
d	Become the co-ordinating authority for UK Defence M&S
e	Establish common M&S-based research themes and lead their exploitation
f	Customer for central investments in M&S tools, data and networks
g	Lead a federated approach to creation & access to defence M&S tools & data
h	Build on the Defence Modelling & Simulation Coherence (DMaSC) M&S Standards Profile (DMSP) with wider metaverse-related standards (eg. Khronos Group)

4.0 CONCLUSIONS

4.1 Study Objectives

This study set out to investigate the origins and latest thinking on the metaverse viewed from a defence M&S perspective. Building on this work a "Military Metaverse CONOPS 2035" was written which articulates how defence's M&S ecosystem might look like if it exploited metaverse technologies and approaches, with benefits, use cases and actions to take articulated. Based on the latest MoD policy documents the CONOPS provided a unifying vision for all UK defence activities to realise the full potential of M&S by taking an enterprise approach.

4.2 The Metaverse and Defence

The study has identified that there is not single view of the metaverse rather it signifies the convergence of many technologies, and further that the metaverse is not a separate entity but it will be part of and reflect the evolution of the Internet itself, from predominately 2D to 3D interaction. The metaverse is also an umbrella term for very many technologies of interest to defence that go beyond M&S, and it is the integration and convergence of these technologies more than the maturity of each one that is driving metaverse developments. A source of confusion may be the overlap with defence cyberspace, but defence as a whole should in our view take the metaverse as seriously as cyber or at least consider and include it in its cyber/digital initiatives.

4.3 M&S Research Priorities

In terms of guiding research in this area we have proposed perhaps new areas of interest to the research programme, which are as much about people, process, and standards than technology, especially as technology developments will be driven outside of defence. Priority areas for research are in our view M&S data (eg. establishing common M&S metadata standards and evaluate and recommend sharing tools) and discovery (eg, evaluating and recommending tools for data and tools/apps discovery). Networking (on the Defence Digital Backbone) and establishing the tools and culture to support increased creativity and sharing are also critical. We have suggested terminology such as "Create M&S Data Once, Reach All" and "Acquire M&S Apps Once, Reach All" as part of this culture change.

4.4 M&S Standards

Agreed standards are essential to the successful development of the metaverse, and the evidence would suggest that the key players such as Epic Games and Meta recognise that there will not be a single virtual world rather a number depending on their use and the communities they support. This will require open standards and our research has encouragingly found a number of groups who are developing open metaverse standards, many of which are the key tech and gaming companies. Defence has a good heritage of exploiting standards such as DIS and HLA and we would recommend that it now broadens its review of M&S standards outside of SISO and NATO.

4.5 CONOPS Benefits and Way Forward

The Military Metaverse CONOPS has proven in our view to be a good vehicle for evaluating technologies and communicating how and why they can come together for defence benefit. Accordingly, we suggested it was given wide distribution in the MoD across both M&S and wider defence digital stakeholders. We also hoped that it could contribute to defence's strategic vision for M&S and make the case for a more co-ordinated approach to M&S. We suggested a "Military Metaverse Summit" be held to further explore what the metaverse means for defence and establish a consensus across defence on next steps. Multi-domain integration is a top priority for defence and would seems a very relevant theme to such an event.

5.0 REFERENCES

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