Generation After Next for Defence Simulation and Synthetic Environments

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ABSTRACT

The United Kingdom (UK) Ministry of Defence (MOD) Science and Technology Strategy has directed research to focus on Generation After Next (GAN) capabilities. GAN capabilities are those things that Defence cannot buy today, and that require basic science and technology before they become available. Dstl have recently led an activity to identify what GAN means for the research of Defence Simulation and Synthetic Environments applied to Defence Training, Education and Preparation. This has involved gathering input from Defence stakeholders (future front line military users), alongside a review of GAN technology from UK industry and academia (led by QinetiQ, Thales, Cordillera Applications Group, and Microsoft).

This presentation will provide an overview of the recommended GAN technologies that are important for Defence to mature over the next five years. This includes areas such as; Extended Reality (XR); Digital Twins; Metaverses; Learning Technology; Core Simulation Technology; AI and Automation; and those required to represent Future Complex Operating Environments. It will provide an overview of where Defence should focus research; what should be left to the consumer domain to mature; and what functionality and capability Defence might expect to be able to utilise in the five year time frame.

1.0 INTRODUCTION

1.1 UK MOD Science and Technology Strategy

Technology and its use are increasingly central to the UK MODs ability to deliver its strategy and how we operate. The MOD S&T Strategy[1] and recent Integrated Review for Defence and Security[2] both emphasise the need for the UK MOD to better understand the future, and find, nurture and fund **Generation After Next** technologies. UK MOD must also identify, evaluate and pull-through emerging technologies and innovation through demonstrators, experimentation, better exploit processes and structures and accelerate adoption of existing technologies at scale to enable UK advantage.

1.1.1 Generation After Next

The MOD Chief Scientific Advisor (CSA), Dame Angela McLean, provided a definition of GAN as follows:

[1] https://www.gov.uk/government/publications/mod-science-and-technology-strategy-2020

[2] https://www.gov.uk/government/publications/global-britain-in-a-competitive-age-the-integrated-review-of-security-defence-development-and-foreign-policy

"Things you cannot buy today – capabilities we know we need, but that require basic science and technology before they become available. This does not imply any particular timeline – Generation After Next could be this year" [3]

MOD's CSA referred to GAN as a separate area of interest to next generation technologies, which are available to purchase by Defence but require de-risking for use in a military context. GAN is not considered against a linear timeline as described in a traditional roadmap-based approach. Rather it has a non-linear horizon where the next generation of one technology may be only a matter of months away, another may be several years in the future. For examples, the GAN of a smartphone may be ready this year, the GAN of a nuclear power station (e.g. fusion) could be decades before it reaches maturity.

2.0 Generation After Next for Simulation and Synthetic Environments

Simulation and Synthetic Environments are broadly used across the UK MOD to provide improved capability for a range of areas, including: Acquisition; Test & Evaluation; Research; Capability Development; Operational Analysis; Wargaming; Experimentation; Force Preparation; and Decision Support.

Dstl is tasked by MOD to steward S&T capabilities – both inside Dstl and throughout the supply chain – so that the right capabilities are available now and in the future for the UK's defence and security. Stewardship involves taking responsibility for planning, management and oversight of S&T capabilities. The GAN objective in the MOD S&T strategy places a renewed emphasis on this activity to ensure that internal Dstl capabilities, and for those in industry, academia and other partners are fit for purpose to meet the emerging and future needs of defence. This remit includes stewardship of Simulation and Synthetic Environments.

To support this capability stewarding and inform future research activities that the UK MOD should undertake, Dstl have conducted a study alongside UK Industry and Academia to understand:

"What does GAN mean for the future development of Simulation and Synthetic Environments to support UK advantage?"

The report identified the following key areas that should be flagged for the research of GAN capabilities:

- Information and Communications Technology (ICT).
- Core Simulation Technology.
- Artificial Intelligence (AI) and Automation.
- Extended Reality (XR).
- Digital Twins and Data.
- Metaverses.
- Future Complex Operating Environments.

Within these areas the study aimed to identify:

- GAN capabilities and technologies that are not yet available to purchase – This means that the capability has not yet been developed into a purchasable product or service.
- S&T activity required to de-risk the capability – This means the fundamental science and technology research that will be needed for defence to exploit the capability. This may involve a

[3] https://www.youtube.com/watch?v=7SODEEclbr0

range of activities including fundamental scientific studies to more mature demonstration and experimentation de-risking activities with end users.

The study was scoped to only include the use of Simulation and Synthetic Environments relevant to support Defence Training, Education or Preparation. It is acknowledged that these areas are heavily influenced by adjacent markets and industries (such as the civilian learning market for military education) and the scope of the study included wider relevant markets where there are future 'spin in' opportunities. Previous examples of 'spin ins' include the use of Commercial off the Shelf (COTS) gaming technology for training.

2.1 Information and Communications Technology (ICT)

Forecast: Cloud computing has transformed how organisations process and store information. Processing and storage are now available 'on tap' and like a water utility, organisations pay for as little or as much as they need. While the current generation of cloud computing is increasingly available to defence and will almost certainly support the next generation of simulation capability, there is also an opportunity to exploit the GAN of computing technology.

Characteristics: Emerging computing technology such as quantum computing, neuromorphic and thermodynamic computing may offer the following opportunities:

- Thermodynamic computing seeks to run computing hardware to the limits of its thermodynamic potential[4]. This has the potential to reduce the Size, Weight and Power (SWAP) of computing devices. Potential exploitation opportunities include instrumented live training, where, allied to 5G or 6G communications it could allow edge devices to be widely deployed with far lower power requirements. The limiting factors are the R&D needed to prove the technology at scale and supply chain and industrial capacity requirements.
- Quantum computing is unlikely to be found in the pocket of defence users any time soon. Although cloud-based workloads are emerging, these have limited availability, security and latency could be an issue, and reliability could be improved. Quantum computing is likely to be used for defined workloads relating to running detailed models as part of scientific studies, even within the GAN timescale, with exploitation into general purpose training education and preparation uncertain. Investment from UK Government is currently substantial and the training, education and preparation community should continue to monitor its development.
- DNA memory may offer potential for the training, education and preparation community to store the increasingly large amounts of data it will generate in the future. This has the potential to improve the accessibility of data at rest.
- The capability of Graphics Processing Units (GPUs) will continue to offer support to large scale simulations. The trends in the GAN timescale are for increasingly capable GPUs to support ever larger M&S environments with the potential for scaling at the infrastructure level rather than through middleware software.

Benefits and Opportunities: In summary, the training, education and preparation community are likely to have at their disposal increasingly powerful and low SWAP compute within the GAN. This has the potential to revolutionise instrumented live training, but may also have an impact upon all M&S environments. This may in turn place a premium upon Verification and Validation (V&V) of the input data used to generate these environments.

2.2 Core Simulation Technology;

Forecast: Core simulation technologies include tactical environments, image generators, protocols and standards, monitoring and control tools and systems to represent the natural and physical environments. Core simulation technologies will leverage innovations from consumer information technology and gaming

[4] https://arxiv.org/ftp/arxiv/papers/1911/1911.01968.pdf

markets, increasingly using these to support previously bespoke applications such as image generation and current generation XR capabilities. A fully operational Modelling and Simulation as a Service (MSaaS) capability will be a feature of the next generation of simulation technology, and the Generation After Next is likely to fully exploit service-oriented architectures and cloud technology. MOD will define and own reusable building blocks and standards for core simulation functions. Simulations for platform and systems will be provided as Digital Twins by OEMs.

Characteristics: The GAN of core simulation technology is likely to include:

- Inherently scalable environments where previous limitations in terms of processing power and connectivity are removed.
- Service based approaches and on-demand capabilities which may move to an entirely cloud-hosted model.
- Blended Live, Virtual and Constructive (LVC) simulations where the barriers between these three domains are increasingly blurred or non-existent.
- Continued convergence with consumer gaming and information technology.
- Secure, high bandwidth, resilient networks.

Benefits and Opportunities: Core simulation technologies have a broad range of uses in support of training, education and preparation. They could be considered essential enablers for both the efficiency and effectiveness of these MOD outcomes. The move towards a service-based architecture for simulation technology is likely, in particular, to enhance the efficiency of simulation delivery through re-use of assets and a reduction in the need for on-premise hardware.

2.3 Artificial Intelligence (AI) and Automation;

Forecast: Investment into AI and Automation both within Defence and in wider markets is considerable and is expected to continue to drive rapid improvements in both Next Gen and GAN capability. Promising early stage technologies include foundation models, which provide general purpose, trainable AI able to tackle a wide range of tasks. Developments in computing, including ‘web 3.0’ or edge computing, quantum computing and processor development may improve the capability of AI and Automation. Process automation in the civil industrial sectors may also provide potential cross over opportunities for the management and delivery of training, education and preparation. However, despite significant investment, there is unlikely to be a single ‘silver bullet’ general purpose AI and automation tool that will completely transform training, education and preparation. Instead, interventions may be on a more limited basis but will still likely be impactful. In addition to its capability, AI and Automation tools are likely to become more usable and easy to operate by end users.

Characteristics: GAN AI and Automation may benefit training, education and preparation in the following areas:

- Through ‘human machine teaming’ to deliver more effective event planning, delivery and support.
- To provide insight and understanding into training, education and preparation data at rest, in order to improve efficiency and effectiveness.
- To provide an improved representation of entity or system behaviours.

Benefits and Opportunities: AI and automation has the potential to contribute to both efficiency and effectiveness improvements. If correctly harnessed, it could assist in reducing the overhead associated with delivering training, education and preparation events, by (for example) substituting for a human role player. In terms of effectiveness, it could be used to improve productivity of exercise personnel (e.g. monitoring the status of trainees and flagging to an instructor when there are anomalies), thus freeing them to focus on improving the training experience.

2.4 Extended Reality (XR)

Forecast: GAN XR Technologies (inclusive of Augmented Reality (AR), Virtual Reality (VR), augmented virtuality and multi-sensory simulation) are highly likely to be the chosen form factor for user facing capability against a broad range of training, education and preparation use cases in future. GAN Mixed Reality Technology has a high generational churn and is likely to be accessible to Defence users in the 2-5 year timeframe, largely as a result of funding by consumer technology markets. GAN XR Technology will likely displace conventional projected displays as the predominant form of user facing capability, with Next Generation applications already approved for elements of civil flight training, although legacy displays will remain in use for some time. Significant private investment from the consumer technology markets will ensure that the price point for this technology will remain competitive against traditional display technology. For high end applications such as flight simulation, XR may be considerably more cost-effective, subject to accreditation and policy requirements

Characteristics: GAN XR technology and capability is likely to be characterised by the merging of AR, VR, haptics (including body suits and other wearable technology) and multi-sensory stimulation to further increase immersion and extend stimulation beyond purely visual and audio senses. GAN XR technology development will benefit from wider investments in the metaverse, cloud and edge computing, mobile and computing device technologies, 5G/6G wireless networks, streaming and consumer entertainment and gaming technologies.

Benefits and Opportunities: GAN XR technology has the potential to improve the immersivity of elements of training, education and preparation through improved quality of shaders/realism e.g. touching holograms, pass through and greater fields of view, super realistic avatars and immersive rooms/experiences. If its effectiveness can be proven to compare favorably to live experiences, it may also support the transition of some live or legacy virtual delivery means into the virtual environment, providing efficiency opportunities. It may also support improved integration of the LVC domains, for example through more credible representation of virtual simulation entities in the live environment, driving improved training effectiveness. GAN XR usage may also drive user engagement, particular from 'Gen Z' members of Defence, over legacy user facing technologies. The use of XR to support operations may blur the lines between training, preparation and operations.

2.5 Digital Twins and Data

Forecast: A Digital Twin is defined as "A virtual representation that serves as the real-time digital counterpart of a physical object or process"[5]. Digital Twins are emerging in engineering, science and operational planning as a means to understand and optimise current and future performance. Digital Twins could therefore be particularly useful in preparation, but may also support both training and education capabilities. There is currently significant investment in Digital Twins across a wide range of industries, however both definitions and implementation approaches vary considerably, with the 'real time' and fidelity of the digital counterpart currently limited in many cases. GAN Digital Twins will broaden the range and complexity of entities that can be twinned, improve the quality of input data and thus the fidelity of the model, and improve the usability or interoperability of the Twins. In the GAN timeframe, Defence may deal with a single Digital Twin 'to rule them all' rather than multiple representations of a platform or system generated for different purposes. Although the term 'Digital Twin' may fall out of favour, the use of the capability provided will provide a general direction of travel in a broad range of industries and will be exploited in many ways. Digital Twins and the Internet of Things will set a direction of travel to enable more authoritative and live data sets to be used in simulations. The ability to capture, store, and analyse data from a plethora of sources will be enabled. They will form a core capability to manage and de-risk future defence acquisitions where the principles of Synthetic Environment Acquisition are likely to be resurrected.

[5] https://ieeexplore.ieee.org/document/8625931

Characteristics: GAN Digital Twins will potentially act as the authoritative single data source for a range of objects and entities, from individual platforms, to training areas, populations or even adversaries. They will be truly real time and based upon validated, re-usable data sources (including biometrics). They will be interoperable, and able to function within a wider range of use cases than is currently possible. Use of a Digital Twin has the potential to consolidate and cohere data management across Defence.

Benefits and Opportunities: Digital Twins have the potential to support a wide range of training, education and preparation use cases. Although currently unproven, they also have the potential to improve efficiency through the re-use of a single authoritative model for a platform or system, removing the need to procure multiple models fulfilling separate functions. Further, they have the potential to improve the effectiveness of training, education and preparation by generating higher fidelity, multi-purpose models of complex systems.

2.6 Metaverses

Forecast: Although no single definition exists, the Metaverse is considered to be the next generation of the Internet that will convey inclusive immersive digital experiences, which in the future will be inextricably linked with our physical reality[6]. The building blocks include most of the capability areas listed above, including: Cloud Infrastructure, data (historic and live), Real time game engines, including new rendering techniques like Lumens and Nanites.5G, Haptics, Computing, Volumetric Video and Immersive environments. The metaverse is currently subject to massive investment from consumer technology companies. There is also significant debate as to its potential ownership, governance, credibility as a standalone concept and a commercial proposition. A key debate is whether the metaverse will be monetised by large technology companies (e.g. social media platform providers) or will be developed in an open and democratised way. A military metaverse concept of operations has been developed by Dstl research to understand its potential future utility. Defence cannot afford to ignore the metaverse and it is highly likely that the investment from the consumer domain will be able to be leveraged in part or full by Defence training, education and preparation users, however its specific benefits to these areas needs to be better understood.

Characteristics: As noted above the metaverse is an emergent capability from a number of lower level innovations or technical capabilities. It is expected to leverage the ability to summon large amounts of processing and storage from the cloud, user facing capabilities such as XR, elements of consumer games frameworks and collaboration tools. Developments may include new input methods including accessible devices, new MR User Experience (UX) patterns based on learnings from consumer gaming, AI decision trees for non-player characters, avatar capture and generation from live data, holocapture, computer vision and wearables.

Benefits and Opportunities: Metaverses are an emerging capability and as a result, the benefits and opportunities are still subject to discussion. Metaverses offer the potential to serve use cases across defence and ensure M&S capabilities are up to date, consistent, verifiable, cost effective and reach all that could benefit. The ultimate vision could be in helping defence to fully utilise the potential of its M&S resources as an integrated and coherent M&S capability. This could provide user/creator communities; provision of on demand accessible M&S systems that can reach all users; and new on demand procurement and business models. Investment in the underlying technologies or functions needed to deliver the metaverse may also provide opportunities for the Defence community.

2.7 Future Complex Operating Environments

Forecast: Both the current and the next generation of simulation systems are improving the ability to represent complex environments such as megacities, and support systems and effects relevant to Multi Domain Integration (MDI) such as cyber and electromagnetic activity, space and highly complex terrain such as megacities. This is different to a Digital Twin in that it may not be updated in real time. This trend is

[6] https://en.wikipedia.org/wiki/Metaverse

likely to continue within the GAN of simulation systems, with larger amounts of processing power via cloud computing, improved data acquisition and environment generation tools. As the scale and complexity of simulations becomes less of a limiting factor, the focus may switch from the ability to provision or scale processing power to assuring that the data that makes up simulations can be verified and validated as being fit for purpose (noting this is a challenging concept to achieve both technically and culturally). The requirement to represent complex operating environments to provide benefit to defence use cases is understood where it can add value, and importantly where increasing such complexity is not required (e.g. where it may have a negative impact on training or other use cases).

Characteristics: The GAN ability to represent future and complex environments is likely to be driven by:

- Improved data acquisition, verification and validation and testing tools to build complex environments with validated information.
- Improved processing and storage through the use of cloud computing to serve simulation environments, removing historical constraints on environment size/complexity.
- Improved ability to understand, characterise and represent soft factors such as the human sub-environment using dynamic models linked to wider simulation components.

Benefits and Opportunities: Complex environments are a likely feature of future operations (as reflected in several MOD policy documents and publications – e.g. Global Strategic Trends) and thus their effective representation with simulation offers potential to effectively prepare Defence personnel for operations in an environment that may not be able to be represented in live training approaches. The provision of appropriately accurate and representative simulations of operating environments should improve the effectiveness of training, education and preparation, as such simulations are developed to be able to better support emerging training outcomes related to the future operating environment. Caution will need to be taken so that training solutions are not over-engineered and the return on the investment in such simulation capabilities is understood to support business cases.

3.0 Conclusions and Recommendations

3.1 Consumer technology

Defence simulation is ultimately a relatively small and specialised market, and far smaller than the consumer technology market. Within the GAN, the sheer size of the consumer technology sector and its R&D budgets will mean it will continue to have an influence over the defence simulation sector. The modular nature and relative low cost of these tools offer an opportunity for defence to improve its efficiency and their realism and immersivity provides a chance to deliver improved effectiveness.

The period 2005-2020 saw a steady increase in the influence of consumer games technology on the defence simulation market. Defence's people now include a keen and growing gaming community who expect the experience of their defence simulations to match that delivered from their games consoles. Defence users require COTS games engines to be modified for them to be usable training and preparation tools, with the addition of scenario planning and After Action Review (AAR) functionality. However, some games engines have successfully transitioned to defence use. Investment in a Defence Virtual Simulation (DVS) in the UK MOD has likely paid for itself several times over. Over time, technology with its roots in the consumer sector has gradually eroded the market for proprietary simulation tools used only in the defence sector. The announcement that games engine to power a flight simulator Image Generator (IG) by the world's largest defence simulation company, CAE, at I/ITSEC 2021 was an important moment for the industry. We may have seen the last generation of proprietary IGs and virtual and constructive simulation tools developed by specialist defence simulation companies. As well as the engines themselves, consumer gaming may offer tools or processes that can be used to generate simulation content or events more quickly, boosting efficiency. There are underlying risks with relying on markets outside of the defence domain though, where influence in the development decisions of certain products and services may quickly move their utility away

from being relevant to defence use cases, and hence defence investment in such products and services may become redundant (e.g. a new release breaks backward compatibility, or new ethical user rights restrict their use for defence). The risk reward ratio needs to be carefully considered in the decision to use such approaches.

It is highly likely that the larger market size of the consumer gaming sector, and interest in the metaverse will continue to throw off GAN innovations that are interesting and usable for defence simulation users. Historically consumer gaming companies have not all been interested in the defence simulation market due to its small side or potential damage to their Environmental Social and Governance (ESG) credentials However, there is evidence that large consumer gaming companies are interested in offering their tools into the defence sector. This has the potential to throw up some possible industrial challenges.

Ongoing investment in consumer XR will also provide an opportunity that defence could exploit. While some attendees at study workshops felt XR had peaked as a technology in the consumer sector, it is a realistic possibility that XR could ultimately replace traditional projectors and screens as IGs in the medium term, at least for some Defence training & education applications. The accreditation of civil XR based flight simulators highlights its potential.

The action on the defence simulation S&T community is to continue to monitor these developments through technology watch, horizon scanning and de-risking trials. Defence has its own specific functional and non-functional requirements (e.g. security) that may not always align to consumer focused capabilities and which must be assessed in order for Defence to understand the exploitation potential.

3.2 Risks and Challenges

There are several challenges in the delivery of the GAN of simulation.

- V&V of both input data and resulting simulations is likely to be an increasing constraint as simulations are less limited by processing and storage. This may be a particular challenge for simulation of the FOE. Appropriate V&V is a long running requirement for the defence simulation community. Increasing computing and networking capability means that future simulations have potential to be unconstrained by processing or storage and will have the capacity to run larger, more complex simulations. Ensuring that the accuracy of models and data that underpins simulation is appropriate to the need is likely, over time, to become a greater challenge than providing sufficient compute to run them. The limiting factor for exploiting simulation technology is verifying that it is operating correctly with no unforeseen consequences and validating that the resulting implementation is suitable for the task being undertaken (e.g. the level of implementation and the V&V is suitable to achieve a given training objective
- As simulations become more capable at representing complexity, the ability to control the level of complexity will be important to ensure that defence training, education or preparation activities are focussed on achieving their outcomes. There is a danger that simulation capabilities become too cumbersome and costly to manage and maintain, and provide a genuine risk of negative training.
- The ability to effectively insert new simulation technology in training, education and preparation capabilities will need appropriate means to assess the value they offer over or alongside current or alternative methods. While affordability of some GAN capabilities is likely to reduce, there may be trade-offs between increased effectiveness and cost.
- The use of non-Defence capabilities in the GAN will require a greater understanding of the origin of new capabilities and their funding sources for security reasons. This is particularly relevant for Venture Capital (VC) funded companies and consumer gaming technology.
- The increasing amount of industry funded IP generation, or the use of consumer or VC funded capabilities as part of the GAN, may mean suppliers are less enthusiastic to collaborate on research activity. This may also pose challenges in the policy and standards area.

- Defence lacks the infrastructure necessary to fully exploit the use of these technologies barriers such as Defence's security requirements could be an increasing constraint on the use of technologies such as streaming technology and wireless networks.
- Defence lacks the culture in setting requirements, acquiring and using M&S that makes it challenging to introduce and successfully adopt GAN M&S approaches. It is thought that improved education and SQEP will improve this, alongside things like new training methods, through life risk management approaches, novel commercial approaches etc.

3.3 The GAN Simulation Vision

Within the GAN timeframe, dynamic, scalable, reconfigurable highly immersive and data driven capabilities will be provided, delivering a step change in the effectiveness and efficiency of training education and preparation.

User facing systems will understand where and when to leverage (or where they should not) the ability of holographic projection, mixed reality technology and highly realistic graphics to provide immersive experiences that benefit the delivery of training, replacing current projection systems and monitor displays where appropriate. These will allow seamless transition and interplay between live, virtual and constructive domains, facilitated by edge computing and powerful wireless networks. User facing systems will stimulate not only visual and audio channels but provide multi-sensory stimulation. They will use real time feedback of the mental and physical status of the user, and an appropriate blend of learning methods, to provide personally optimised training and education and drive the trainees' experience

M&S systems will deliver appropriately accurate and dynamic representations of the operational environment including complex systems and information effects in all domains. Through the seamless integration of digital twins, environment data and stand-alone complex models using open data standards and a composable approach, training delivery professionals will be able to rapidly build environments to meet their requirements. Data will be able to be more quickly captured, processed and verified and validated for inclusion in simulation systems, opening up new preparation use cases.

Enabling systems will leverage improvements in data analytics, wired and wireless networks, AI and process automation, computing and software systems. These will enable GAN simulations to be more quickly and cost-effectively provided and delivered securely at range.

3.4 S&T Recommendations

In order to achieve the vision above, S&T activity is required to de-risk the development and delivery of simulation capability. The S&T activity proposed as part of this task is split into the following areas:

- Monitor and understand – This relates to areas where Defence needs to conduct horizon scanning activities to better understand the direction of a GAN capability or technology. Here there is likely to be benefit for Defence, but the use cases or potential fundamental capability need to be better understood before more directed de-risking activity is needed. This includes International Research Collaboration (IRC).
- Deep applied research – This relates to areas where fundamental research is required to de-risk a capability or technology.
- Practical de-risking – This relates to areas where Defence needs to de-risk the use of a GAN technology or capability by undertaking practical experimentation or hands-on trials activity. This may be where a new technology or capability emerges whose use in Defence has been as yet unproven or where integration issues associated with convergence need to be de-risked

3.4.1 Monitor and Understand

S&T de-risking to monitor and understand new capabilities should focus on developments in consumer and

business technology markets. Technology watch activities should include:

- User facing systems including mixed reality technology, holographic displays, haptics, multi-sensory stimulation, and brain computer interfaces.
- Consumer gaming technologies including the tools required to build gaming environments, frameworks used to deliver content and streaming and other networking technologies. Streaming is a potential key enabler for future M&S delivery, and also appears below.
- Novel compute and consumer IT. Simulation related S&T is unlikely to do the heavy lifting required to fund novel compute research, but the M&S community may see some significant opportunities in improvements in SWAP, from (for example) thermodynamic computing. In a similar vein, while cloud based simulations form the next generation of simulation, there is also the need to continue to understand and leverage improvements in consumer and business IT.
- Metaverse related capabilities including underlying individual technology and functionality, standards and use cases. Defence cannot afford to ignore the metaverse and the amount of funding associated with it, but its benefits to Defence are currently uncertain. We need to help defence to understand and de-mystify the opportunities the Metaverse presents.

3.4.2 Deep Applied Research

Fundamental applied research is needed around the following areas:

- Improved simulation composition, as a general enabler for the more dynamic generation and integration of simulation components. This will require fundamental applied research into simulation data structures.
- Representation of the FOE. In the GAN, more complex environments should be able to be represented routinely but there will remain significant V&V challenges.
- Integration of digital twins including how these can be routinely linked to other simulations.

3.4.3 Practical De-Risking

Defence has its own specific requirements in areas such as security, assurance, ruggedness and usability. As such, practical experimentation is required to de-risk Defence's use of new capabilities.

- Work to understand and benchmark the effectiveness of consumer technology, particularly user facing systems, versus legacy approaches. These could include comparative 'side by side' trials to understand training or education effectiveness.
- Work to de-risk the convergence of edge computing, displays and networks for LVC training or instrumented live training.
- Work to understand how improvements in AI and automation could be applied to training, education and preparation. AI has some promise for improving efficiency and effectiveness but defence's specific requirements need to be accommodated.
- Work to de-risk wireless and streaming technology for defence as a general enabler for M&S activity. The current generation of technology is insufficient in terms of latency and there remain security issues.
- Work to inform Defence policy and strategy for the implementation of the infrastructure required to fully exploit GAN technologies i.e. development of a simulation ecosystem; enterprise data management approach; secure wireless infrastructure.

3.5 The role of NATO and International Research Collaboration

The NATO Modelling and Simulation Group (MSG) will play a key role in the de-risking and the interoperability of GAN simulation and synthetic environment capabilities. Also, the NATO Human Factors and Medicine (HFM) will provide crucial insights into the human aspects of the development and delivery of future training.

The NATO MSG currently has the following groups that align well or offer the opportunity to be aligned to inform GAN simulation and synthetic environment capabilities:

- The **MSG-195 MSaaS Phase 3** group is supporting the development of simulation to adopt modern ICT infrastructure such as the Cloud, Containerisation and Metadata to provide automation and efficiency in the development and provision of service based simulation capabilities that can be accessed on demand. These technologies are already being used in the consumer sector, and are being considered for the next generation of defence simulation capabilities, but further research is required in GAN autonomy and efficiency to fully deliver the MSaaS ecosystem approach.
- **MSG-198** group looking at **Composable Human Behaviour Representation in Constructive Simulation Systems** will require GAN technologies to provide the ability to represent and re-use human behaviour representations of the Future Operating Environment.
- **MSG-203 The Role of Modelling and Simulation to Support Current and Future NATO Operations** lecture series will play an important role in highlighting to senior stakeholders the likely GAN technologies that are maturing for use by NATO and nations.
- **MSG-205 Allied Interoperability and Standardization Initiatives for Digital Twins** group will play an important role in understanding the role of Digital Twins to support NATO and the nations and how common approaches can be developed to enable their use.
- **MSG-206 group** will provide a **Common Framework for the assessment of XR technologies for use in Training and Education** within NATO and the nations. Common ways of assessing and communicating developments in the consumer domain will be key to tracking and exploiting these technology developments.

Some areas where there are potentially gaps in NATO MSG activity include:

- **The Metaverse:** Understanding and demystifying what the metaverse means for NATO and the nation will need to be undertaken. The opportunity to exploit the large investment in the Metaverse in the consumer domain will be plentiful. Tracking and maintaining these developments will require resource and shared understanding across the community. The military has key use cases that can also be used to help focus the metaverse development to ensure the military use of this technology is de-risked as early as possible in the development lifecycle.
- **General Technology Watch and Horizon Scanning of Consumer Technology:** Related to the metaverse is the need to provide quick insights and evaluations of emerging technology so that NATO and the nations can rapidly exploit such technology as it emerges. A whole of community effort through a common way of evaluating, understanding and communicating such relevance will be key.
- **Standards Groups:** The NATO MSG currently has excellent relationship and collaboration with the Simulation International Standards Organisation (SISO) through which it helps to provide a common NATO influence and voice to the formulation of SISO products and services. With the large investment and relevance of consumer technology, it is noted that the MSG and SISO will need to expand their relationship with other standards organisations such as the Khronos Group and Digital Twin Consortium (among others).

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