From SIMNET to the Metaverse – Why is it taking so long?

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Abstract - In 1978, US Air Force Captain Jack Thorpe proposed a network of simulators for combat planning and execution, and this concept was later developed by DARPA in the 1980s as SIMNET (SIMulator NETworking). SIMNET eventually included 260 simulators at 11 sites in the USA and Europe including tank and aircraft simulators, and connected to a real warship and command centres in the early 1990s. Today, there is renewed interest in creating multi-domain simulation capabilities, but it is unclear if any nation has succeeded in building a persistent system similar to SIMNET that integrates live, virtual, and constructive simulations across the whole defence enterprise. The trend towards the "metaverse" may offer an opportunity for the defence sector to establish an enterprise-wide simulation infrastructure that exploits the wider trends in the metaverse and computing. This paper will examine past initiatives to build multi-domain simulation capabilities and consider the issues that may have hindered progress, and then offer a vision for the defence sector to fully realize Thorpe's 45-year-old idea through an integrated enterprise approach to networked simulation in support of all defence activities.

1 Introduction and Approach

Exploiting networked distributed simulation in support of multi-domain training has been an aspiration since the 1970s, but although it has been demonstrated many times it remains an aspiration as a truly multi-domain persistent capability. This paper aims to provide an historical perspective on this challenge drawing on open-source research, research carried out for the UK Dstl, and the author's 25 years' experience in simulation technology and application. As a complex topic, no definitive solution has been proposed, rather it is a think piece for the military simulation and training community.

2 Why multi-domain networked training?

2.1 Why networked training?

Networked simulation-based training allows multiple people, sometimes in multiple locations, to interact with each other and a simulated environment in real-time. As a capability, NATO describes it as "a persistent, distributed and joint training capability able to support training from operational to tactical level across the full spectrum of operations" [1]. This type of training enables teams and teams of teams to be immersed in a variety of scenarios in a safe and controlled environment and experience situations that they may not be able to experience in the real world. If distributed, the training requires less travel time and opens up new training opportunities with less environmental impact and with more flexibility. Further, for urgent joint or coalition training, units can practice on a networked training system before actual missions, rather than for the first time facing the enemy.

2.2 Why multi-domain?

Beyond joint and coalition training, the concept of Multi-Domain Operations [2] (MDO) or Multi-Domain Integration [3] (MDI) point to every part of defence working as one to deliver a desired outcome. The multi-domain is important to defence for several reasons [4]: New grey zone threats that are complex, fast moving and occur frequently; the battlespace is broader and more complex than ever before with space and cyber domains increasingly prevalent; there has been an exponential explosion of data; and conflict is increasingly a competition for what people think. Ultimately, the multi-domain concept extends the range of capabilities available to decision makers, ensuring that any combination works together, and selecting the most appropriate ones to create and exploit vulnerabilities in adversaries. Supporting the training for such operations can be ideally suited to networked distributed simulation with its flexibility and cost effectiveness, but only if it is available on a timely persistent basis.

3 SIMNET and its accomplishments

3.1 SIMNET origins and convergence

Although SIMNET was a 1980s programme, its origins arose from a convergence of training challenges, people, technology, and organisational priorities in the late 1970s. In 1978, the then-Captain Jack A. Thorpe was at the Air Force Office of Scientific Research, where he authored "Future Views: Aircrew Training 1980-2000", a white paper that proposed a network of simulators for combat mission planning, rehearsal, and execution [5]. Thorpe considered affordability as a core requirement for such a system as a single simulator then would cost over $35 million, roughly the price of two fighter aircraft [6]. He had the view that flight simulators should not be substitutes for aircraft, rather they should augment them and be used to train air-combat skills that pilots could not learn in peacetime flying and trained with simulators in large-scale battle-engagement interactions. Meanwhile, DARPA employee J. Dextor Fletcher had come to similar conclusions, but for tank gunnery training, where both live training and traditional simulators ($18m) were high cost. His objectives for the DARPA tank gunnery trainer project were strikingly similar to what we might see today: "(a) procured in quantity for $10,000 or less each, (b) accessible, for example as a stand-alone "game" in military barracks or dayrooms, (c) motivating, for example in supporting competitive score keeping, (d) of sufficient fidelity to satisfy the training objectives, within the cost constraints, and (e) suitable for documenting training effectiveness in terms of transfer-of-training data" [7].

In parallel to these developments, digital technology was advancing rapidly with microcomputers, networking and early CGI. DARPA was also under pressure to move away from studies and analyses and towards the development of technology that led to "things" that could be used by the military and a shift towards adaptations of the rapidly developing new computer technologies [8]. Exploiting these trends Fletcher proposed a Tank Team Gunnery Trainer (TTGT) concept based on networked trainers viewing a single videodisc-generated scene, with the trainees competing to the first to sight and fire at an "enemy" tank. Fletcher left DARPA in 1980 but given their similar outlook he was replaced by Thorpe. Thorpe came to the view that TTGT could be extended to a low-cost, large-scale, battle-engagement network of simulators to provide warfighters opportunities to train for battles in the benign environment of a simulation. This concept led to the "SIMNET" project which was approved by DARPA management late 1982 and initiated early Spring 1983.

3.2 The SIMNET project

Cost was a driving factor of the SIMNET programme and hence the degree of fidelity that could be provided. Instead of aiming for high-fidelity simulators, the SIMNET simulators were designed to use lower cost workstation computers as hosts, and to provide only the controls and displays necessary to train for the task and to allow tactical team training involving many soldiers. As a result, the SIMNET contractors were able to provide a medium-fidelity simulator that was inexpensive enough to be purchased in large quantities suitable for team training [9]. Part of the design process was the so-called "60% Solution" whereby rather than taking a great deal of time studying every design issue, it was considerably more efficient to be about 60% complete and rapidly fabricate a prototype that soldiers could see and touch and provide feedback. This led to rapid iterations of design, many that were manifested as cheap foam core and plywood mockups [10]. As such, SIMNET marked a shift in simulator design from an engineering or physical reproduction approach in the tradition of the Link Trainers and flight simulators to manipulating "brain state" and relying more on human factors analysis [11].

To support simulation interaction, a SIMNET protocol was established which to reduce network traffic, was based on a single basic unified world model was shared across all the simulators, each of which would calculate their own status and broadcast corrections to the world model as necessary. Numerous other advances were made such as the incorporation of semi-autonomous forces to reduce exercise role-players. Incrementally developed over the 1983-1990 period, SIMNET became a network of 260 simulators at 11 sites in the USA and Europe including tank and aircraft simulators [12] and was made operational by the US Army in January 1990.

3.3 SIMNET and live training

By the late 1980s, the concept of integrating live training into the virtual exercises was investigated by the US Navy, which in today's terms would be termed Live-Virtual-Constructive-based training (LVC). The first so-called Battle Force In-Port Trainer (BFIT) exercises incorporating a naval simulation took place in December 1989 and April 1990 when long-haul links were established between the Fleet Combat Training Center Atlantic, Dam Neck, VA, Ft. Knox, and Ft. Rucker. Army and Marine Corps crews operated the SIMNET tank simulators and helicopters, and fixed-wing aircraft simulators were flown by Marine Corps and Army pilots at Ft. Rucker. The AEGIS Training Center and the USS Wasp were also connected to the network. That meant that a helicopter simulator at Ft. Rucker, flying over the simulated terrain at Ft. Hunter Liggett, could be viewed on the radar screens of the Wasp from its simulated position 50 miles off the California shore, while it was physically at the pier in Norfolk, VA. In a first for distributed simulation, armoured units came under naval gunfire, and rotary-wing aircraft took off from the deck of an aircraft carrier and flew inland to support armoured units [13].

The BFIT-SIMNET exercises were a culmination of less than 10 year's effort and proved that networked simulators from multiple vendors could be integrated and deliver single service and joint training exercises, at scale, and at distance. Thorpe himself sketched the figure below (Fig. 1) to illustrate what had been accomplished and provide a vision for the future. A significant component, the "Defense Simulation Internet", was subsequently promoted by Thorpe [14] but never became a persistent capability in the manner he envisaged. A more successful legacy of SIMNET is the Distributed Interactive Simulation (DIS) protocol/standard which is being used to this day.

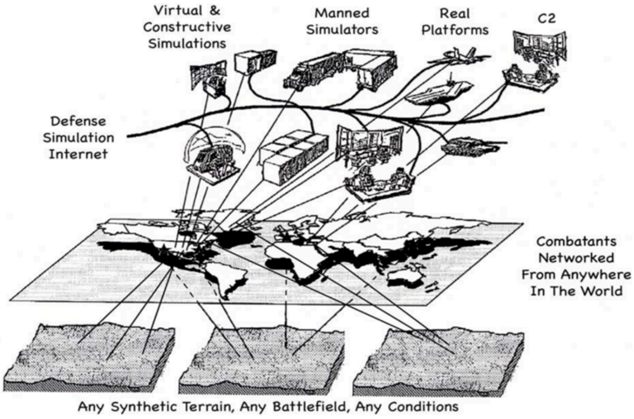

Fig. 1. SIMNET's 1980s Vision [15] - Jack Thorpe PhD

4 Beyond SIMNET

SIMNET undoubtedly caught the imagination of militaries across the world and inspired several initiatives through the 1990s and beyond, some of which are highlighted below.

4.1 Synthetic Theater of War (STOW)

STOW [16] was a significant program managed by the Advanced Research Projects Agency (ARPA) aiming to demonstrate a capability for large-scale LVC simulation based (ultimately theatre-level) battlefield simulation. Running from 1992 to the late 90s, the STOW exercises help to develop further the SIMNET concept and technologies and also introduced allies such as the UK, but no permanent capability was left behind.

4.2 Distributed Mission Operations (DMO)

The Distributed Mission Operations (DMO) concept was initially developed by the United States Air Force (USAF) in the early 2000s [17]. The concept was based on a distributed network of geographically separated systems to simulate a distributed air combat training environment and reduce the cost of conducting large-scale, distributed training exercises by using a distributed network of interconnected computer systems. The USAF has since developed several programs to support the DMO concept, such as the Global Air Combat Training System (GACTS), Air Force Integrated Training Environment (AFITE), and the Distributed Mission Training (DMT) program. These programs are designed to provide a secure, cloud-based distributed environment in which different elements of the Air Force can conduct distributed training exercises. Although it has joint capabilities it is not clear to what extent they are used by other services.

4.3 U.S. Joint National Training Capability (JNTC)

JNTC was a joint capability of the U.S. Department of Defense and the U.S. Intelligence Community. It was designed to provide an integrated, cross-agency training and education platform that would enable the U.S. government to respond to national security challenges. The JNTC consisted of a suite of online tools, virtual classrooms, and educational resources that allowed users from the military, intelligence, and civilian sectors to plan, prepare, and execute realistic and complex training events [18]. The JNTC was in operation from 2009 to 2016 and at the time of writing appears to be an approval body rather than a training capability.

4.4 US Army Synthetic Training Environment

The US Army Synthetic Training Environment (STE) is a virtual training environment that provides soldiers with realistic training and simulations to help prepare them for real-world operations [19]. The STE is designed to simulate a variety of battlefield environments, including urban, rural, and complex terrain. It also provides a platform for commanders to design and conduct joint exercises, as well as evaluate individual and collective performance. It also enables soldiers to access and use the same virtual environment to rehearse tactics, techniques, and procedures, as well as apply their knowledge in a simulated environment.

4.5 Exercise Viking

This Swedish-led exercise has run every few years from the 2000s and is designed to prepare civilians, military and police together for deployment to a peace or crisis response mission area. In 2022 more than 50 nations and 70 civilian organisations are trained in military and civilian cooperation in Viking 22 [20]. The Swedish Armed Forces retain a capability to run the exercises which are typically run over the Internet.

4.6 NATO Education and Training Network

Instigated in 2006, the NATO Education and Training Network (NETN) aims to deliver to NATO and Partners a persistent, distributed and joint training capability able to support training from operational to tactical level across the full spectrum of operations, whilst leveraging existing national expertise and capabilities [21]. Standards to support the concept have been established but the author is not aware of persistent capabilities being deployed.

5 The Military Metaverse

5.1 What is the Military Metaverse?

At the time of writing, there is no single definition of the metaverse, rather a set of broadly similar descriptions with 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. Whether the current interest in the metaverse accelerates or declines, the underlying technologies such as virtual worlds, eXtended Reality (XR), computing, networking and AI are in any case developing at pace. This digitisation of the physical world, the interoperability of the virtual world and the physical worlds, and the increasing use of AI as envisaged by metaverse visionaries has many similarities with the integration of LVC simulation first deployed in the late 1980s. In recognition of this, the author previously proposed a description of a "Military Metaverse" as follows [22]:

"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."

5.2 A Military Metaverse Vision

To help the UK's Defence Science and Technology Laboratory (Dstl) understand how metaverse technologies might be exploited to improve defence M&S, the author co-authored a "Military Metaverse CONOPS" [23]. The CONOPS (Concept of Operations) described 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 provided a unifying vision (Figure 2) 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. It can be envisaged that in future all M&S might be ubiquitous and networked, not only for training but across all defence activities, and that are always up to date, consistent, verifiable, cost effective and can reach all that can benefit.

Fig. 2. Integrated M&S built on Metaverse technologies and approaches.

6 Why is it taking so long?

6.1 Demand and supply

We have seen that there is a need for persistent multi-domain distributed networking training and that it has been successfully demonstrated technically since the 1980s. However, despite the very rapid digital technology advances over this period and sustained effort applied to simulation standards, militaries across the world have struggled to put in place persistent multi-domain distributed simulation infrastructure. With the demand there and the supply also there, why is this the case? Much can be put down to the sheer variety of training systems that have been procured and the contractual challenges of keeping them refreshed and interoperable. However, are there alternate explanations to the slow progress in deploying persistent multi-domain distributed networked simulation?

6.2 A "Wicked Problem"?

In 2007, Charles G. Sanders of the Alion Science and Technology Corp. proposed [24] that the US Joint National Training Capability (JNTC) was a "wicked problem" and "that the traditional linear approach to development could dramatically increase the risk of failure for JNTC". A wicked problem is a problem that is difficult or impossible to solve because of incomplete, contradictory, and changing requirements that are often difficult to recognize [25]. Such problems came into prominence in 1973 [26] when Rittel and Webber's proposed that wicked problems had up to ten characteristics (Table 1). Sanders identified that JNTC met all ten of the characteristics and that success for any project dealing with such a wicked problem "depends on participation of and open collaboration between all stakeholders, as well as exploration of all applicable perspectives of the problem". He also suggested that project stakeholders "need to take iterative steps to explore and better understand the problem".

Table 1. Rittel and Webber's "Wicked Problem" characteristics.

1	There is no definitive formulation of a wicked problem.
2	Wicked problems have no stopping rule.
3	Solutions to wicked problems are not true-or-false, but better or worse.
4	There is no immediate and no ultimate test of a solution to a wicked problem.
5	Every solution to a wicked problem is a "one-shot operation"; because there is no opportunity to learn by trial and error, every attempt counts significantly.
6	Wicked problems do not have an enumerable set of potential solutions, nor is there a well-described set of permissible operations that may be in the plan.
7	Every wicked problem is essentially unique.
8	Every wicked problem can be considered to be a symptom of another problem.
9	The existence of a discrepancy representing a wicked problem can be explained in numerous ways. The choice of explanation determines the nature of the problem's resolution.
10	The social planner has no right to be wrong (i.e., planners are liable for the consequences of the actions they generate).

Reviewing Sanders' work, the challenges of JNTC unsurprisingly echo those of any persistent distributed multi-domain simulation network. If we accept that such networked simulation is a "wicked problem" then how might it be addressed? In her 2000 paper [27], Nancy Roberts of the US Naval Postgraduate School, identified 3 different strategy themes to cope with wicked problems (Table 2).

Table 2. Nancy Roberts' Wicked Problem Strategies.

Strategy Theme	Explanation
Authoritative	These seek to tame wicked problems by vesting the responsibility for solving the problems in the hands of a few people.
Competitive	Wicked problems are solved by pitting opposing points of view against each other, requiring parties that hold these views to come up with their preferred solutions.
Collaborative	These aim to engage all stakeholders in order to find the best possible solution for all stakeholders.

Roberts described the advantages and disadvantages of such strategies but a combination of authoritative and collaborative approaches might set a clear vision for persistent distributed networked training and yet the issues and ideas can be discussed and a common, agreed approach formulated. The competitive approach seems to be the least effective when ultimately all parties need to operate together.

6.3 "Pace Layering" as an Explanation?

Stewart Brand is a long-standing American writer, ex US Army soldier, and worked with Douglas Engelbart on "The Mother of All Demos" in 1968, a famous presentation of many revolutionary computer technologies including hypertext, email, and the mouse [28]. In his 1999 "The Clock of the Long Now: Time and Responsibility" [29] he introduced the concept of "pace layering" as applied to civilisations. He proposed that the ability of a system or civilisation to manage change and absorb shocks lies in the relationship between its components, which have different rates of change and different scales of size. These systems can "yield" under stress rather than breaking, with some parts responding quickly to shocks and allowing other parts to maintain their steady duties, maintaining continuity in the system [30]. Brand proposed that "fast and small instructs slow and big by accrued innovation and by occasional revolution. Slow and big controls small and fast by constraint and constancy … fast gets all our attention, slow has all the power". His illustration for the layers is shown in Figure 3.

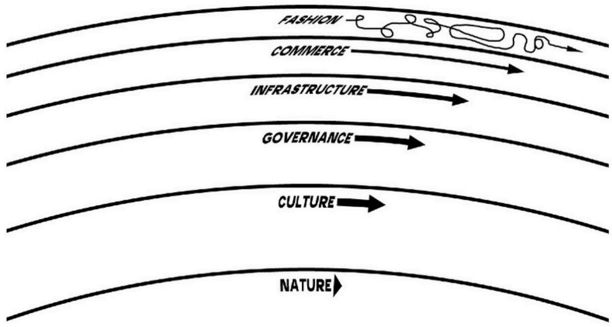

Fig. 3. Brand's Concept of "Pace Layering" as applied to Civilisations

Brand's concept is a powerful, widely cited, way to think about change and stability in a system. Could this be extended to networked simulation? The author proposes six layers in Table 3.

Table 3. Author's Proposed Distributed Networked Simulation Layers

Layer	Description
Technology	Digital technologies are constantly evolving and often combining and converging in unpredictable ways.
Requirements	Training requirements evolve as capabilities and operations change.
Process	The management of training capabilities are governed by processes to ensure cost effectiveness and these processes evolve over time.
Infrastructure	The training estate, buildings, systems and supporting personnel.
Culture	The overall defence culture is influenced by several factors such as external influences, technology, and legacy and helps to dictate the overall collective pace of change.
Procurement	Training capabilities are procured by teams typically aligned to the single services together with incentives to put in place long term contracts with large companies.

This ordering (Figure 4) is based on the author's experience, but of course could be discussed and rearranged. The purpose is to inspire thinking as to why progress can appear slow even though the enabling technology is advancing ever more quickly.

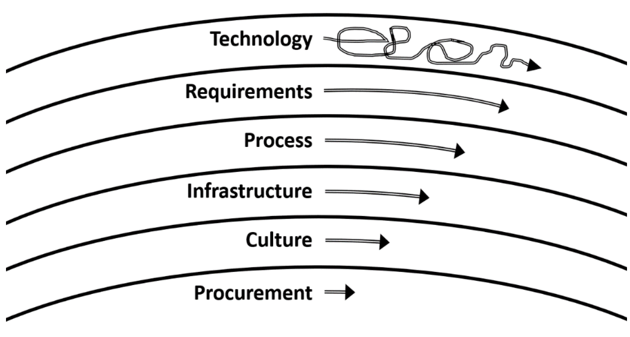

Fig. 4. Author's Concept of "Pace Layering" as applied to Distributed Networked Simulation

7 Conclusions and way ahead

The military-led vision of an affordable persistent distributed networked training capability has been in existence for over 40 years. The training requirement merges into mission preparation and is based on the need to bring teams and teams of teams together where travel is not practicable and to train and collaborate in complex battlespace operations, prior to doing so in the face of an enemy. Many of the technological challenges were overcome by the SIMNET programme in the 1980s including LVC-based training. Since then, there have been many programmes of research and experimentation and some persistent networked capabilities established, but not on a true persistent multi-domain basis. The current drive towards multi-domain integration yet again justifies the requirement, and military metaverse technologies indicate that wider technology convergence will only reinforce the supply side.

However, although the author is aware of initiatives to support multi-domain distributed networked training, they are piecemeal with little obvious wider progress being made, and do not build on and learn from past initiatives. To help assist discussion on this issue within the military simulation and training community, two concepts have been proposed: Treating the issue as a “Wicked Problem” that requires top-down intent driving a collaborative approach; and that a “Pace Layering” approach helps to explain why technology moves fast whilst the ability to procure it does not.

Learning from SIMNET and beyond, a number of recommendations are suggested:

a) The military S&T community could be a learning community and build on the past, not repeat it.
b) The requirements for an affordable enterprise-based persistent multi-domain networked distributed LVC-based training system could be revisited and captured, based on the necessary training fidelity, and flow down/across to all individual training projects.
c) Metaverse technologies and approaches are developing at pace and could be considered as an opportunity to consider M&S on an enterprise-wide basis, including in support of training.
d) Multi-domain networked distributed training is a “wicked problem” and could be addressed as such through both an authoritative requirement supported by a collaborative effort.
e) The tensions across an organisation and its relationship to technology and requirements could be recognised and accommodated.

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