Looking Back to Look Forward

Keith Ford Ph.D.
Thales UK
Crawley
UK
keith.ford@uk.thalesgroup.com
keith.ford130@gmail.com

ABSTRACT

Before starting the journey of implementing 'Emerging and Disruptive Modelling and Simulation Technologies to Transform Future Defence Capabilities', it is worth looking back to learn from history. George Santayana stated that 'Those who cannot remember the past are condemned to repeat it'1. This paper provides a personal reflection of lessons learnt from working in the simulation industry for over 40 years.

Virtual Reality and Artificial Intelligence are considered as disruptive but I remember working on projects using these technologies in the 1980s and 1990s. A disruptive multinational project called 'Realising the Potential of Networked Simulation in Europe' (Euclid RTP 11.13) was initiated in 2000 although it was not until the principle of providing 'Modelling & Simulation as a Service' took-off that many of the concepts were 'rediscovered'. It prompts questions such as why doesn't simulation related research get exploited and why did it take nearly 16 years for a key interoperability standard (HLA) to become 'useable'?p

This paper will provide my perspective of why transformations in the simulation industry move at a snail's pace compared to other industries. It will address issues such as timing, technology, standards, knowledge, adjacent markets and culture, and provide some words of caution about jumping on 'bandwagons'.

1.0 INTRODUCTION

This paper reflects on my 45 years in the simulation industry. It initially describes the state-of-the-art in the 1980s and goes on to describe some of the experiences I have had and things I have learnt through my career. One of the highlights of my career was being the technical lead on Euclid RTP 11.13, and there are several things I learnt from the programme, which I will share. The paper concludes by highlighting what I consider are the grand challenges that the simulation community has to resolve. The purpose of the paper is to challenge the status quo and to stimulate debate within the Modelling & Simulation Group (MSG) to ensure it continues to maximise the effective utilisation of Modelling & Simulation (M&S) within NATO.

Please note that the views expressed in this paper are my own and do not necessarily reflect those of my employer.

2.0 THE DARK AGES?

So what was the simulation world like in the 1980s? Excuse me while I have a quick trip down memory lane. I remember during my interview at Redifon in 1977 being shown around the main simulator construction hall where there was a large model board of an airport. I was told a camera was 'flown' across this as the simulated aircraft was taking-off/landing and the image was displayed on 2 beam penetration tube monitors; one for the captain and one for the first officer. A white image, to represent cloud, was displayed when the

[1] George Santayana (1905) *Reason in Common Sense*, p. 284, volume 1 of *The Life of Reason*

pilot 'flew' off the extent of the model board. Computer generated imagery was in its infancy and was initially limited to night scenes depicted by a horizon bar, light points and a few polygons to represent the runway and 'piano keys'. Cathode ray tube calligraphic projectors were being developed that displayed the polygons in an image using a raster scan, and bright smear-free light points were obtained by deflecting the electron beam to the desired location where it was momentarily paused. Wide angle, wrap-around collimated displays were introduced at this time using projectors, which facilitated cross-cockpit viewing.

Two types of motion system were prevalent; the A-Frame that provided 6 degrees of freedom (DOF) and 3 and 4 DOF motion bases. The 6 DOF 'Stewart' synergistic motion platform was just being introduced in the industry. A big debate at the time was the benefit of motion systems on fast jet simulators. I guess that this question will only go away when we can directly stimulate the brain.

Digital computers had been in use for a few years and these had to be initialised by setting a number of switches for booting-up the paper tape reader or 8" floppy disks. Fortran was the preferred language for modelling the aircraft dynamics, stimulating the avionic displays and for the Instructor Operating Station. This was seen to be a great improvement over Assembly language that had previously been used. It is amazing what could be squeezed into the limited resources at that time. I think the challenge analogue engineers had transitioning to the new digital world was like the one I had going from procedural to object oriented programming languages.

The motion system, control loading and cockpit dials in a simulator were all analogue. Bespoke digital-to-analogue interfaces were required to enable them to be driven from the nascent digital computers. A MOD funded research programme at that time was to develop a digital control loading system, which was programmed in assembler language. I remember the joys of performing 'fixed point arithmetic' in assembler where you had to keep track of the scaling factors used[2].

In spite of the challenges of the limited technology that was available at that time, it provided a good understanding of the low-level technologies that we now all take for granted. It also gave me a greater appreciation of the benefits of the technology as it advanced. I remember the excitement when we got the first IBM Personal Computer in the Company, which had two 5 ¼ inch floppy disk drives that could each store a massive 160kB of data and when we got a 10Mb hard drive we thought computing technology had peaked!

Two big differences compared to today was that most of the components for a simulator were developed in-house, compared to the use of COTS and outsourcing today, and that innovation in the simulation world was driven by the military. Research programmes had an eye-watering amount of money such as for investigating laser, helmet mounted and area of interest displays. I remember a government initiative to promote the use of AI and my colleagues working on a research project that was exploring the use of AI (using Prolog and Poplog) to reduce instructor workload – some things never change!

A must read for all simulation engineers at that time was the 'Flight Simulation' book by Rolfe & Staples [1].

3.0 OBSERVATIONS

3.1 The Emperor's Clothes

"I couldn't stand living in a society that admires the emperor's new clothes, when I see so clearly that he is naked" – Patricia McConnell

[2] https://en.wikipedia.org/wiki/Fixed-point_arithmetic

Euclid RTP 11.13 was a major initiative to promote the use of Synthetic Environments (SEs) in Europe by creating a process and set of prototype tools [2]. One of the lessons I learnt from being the Technical manager on Euclid RTP 11.13 was experiencing how things get a life of their own. One of the tasks was to develop a process for developing and executing synthetic environments. At that time (2000), as part of DOD's HLA initiative, it developed the 6 step FEDEP (Federation Development & Execution Process), which was the forerunner of SISO's Distributed Simulation Engineering & Execution Process (DSEEP) [3]. After analysing the FEDEP, the Euclid team realised that it did not provide the breadth and depth required and as a result produced the 8 step Synthetic Environment Development Exploitation Process (SEDEP) [4]. Although the SEDEP was described in Euclid RTP 11.13 conference papers, there was no great push to have it adopted outside of the 13 supporting nations. However, for reasons that I still do not understand, it got a life of its own. Before long it was being referenced in other papers and became a requirement for being used on MOD projects. I thought it was completely bizarre for a process to achieve such recognition. When Euclid RTP 11.13 finished in 2003, I realised it was not helpful having two rival processes. I therefore joined SISO's product development group for the FEDEP where the development team incorporated the best points in later versions of the IEEE 1516-3 standard. I then 'killed' the SEDEP off at the Euro SIW in 2007.

The main point of this story is how things get a life of their own and become self-fulfilling prophesies. There are many examples of good technologies not being taken forward whilst others do. We need to take care to objectively assess what is being promoted and not just follow the crowd. This is particularly important when 'shiny new technology' becomes available as a healthy dose of scepticism is required. I guess we are all guilty of promoting ephemeral initiatives by ensuring we get all the buzzwords in our proposals, as this is what the customer expects.

Over the years I have seen many initiatives 'wax and wane'. In the late 1990s synthetic environments were being promoted as the future. All the main organisations in the simulation industry had research programmes to develop the capability. However, because nobody 'owned' synthetic environments, there was a different understanding of what they were between the US and the UK. The US view was that it was a virtual environment that participants could interact in whereas in the UK it was viewed as more of a framework for using M&S across the lifecycle of a programme. Subsequently we have had Simulation/Synthetic Environment Based Acquisition (SBA/SeBA), Enterprise Architecture and Digital Transformation. During their heyday, everybody was claiming to be experts and promoting these initiatives but they quickly move on as soon as they go out of fashion. And now Modelling & Simulation as a Service (MSaaS), Digital Twins and the Metaverse are in vogue.

So how do we ensure that we reap the benefits that these latest initiatives promise and that they don't become yet another short-lived fad? The problem with any new initiative that grows organically is that nobody owns it and I believe this is the reason why many subsequently fall by the wayside. Although arguably there is merit for letting Darwinian principles prevail as new initiatives evolve, as it encourages innovation, at what point should an organisation take control of it and who should this be? The reason for doing this is that development of the initiative needs to be controlled, roadmaps defined and standards developed. I am very pleased to see that NMSG has instigated MSG-205 (Allied Interoperability and Standardization Initiatives for Digital Twins). NMSG has obviously realised the importance of Digital Twins and taking ownership of them. This will not only help ensure their development will align with NATO's operational needs but will greatly influence the wider use of digital twins.

Everyone has their view what a Digital Twin is but there is no universally agreed definition. Depending who you believe, a Digital Twin can be a simulation of a physical system (but surely we have been doing that for decades), the use of live data feeds to correct the output from a simulation (I did that for my Ph.D. many years ago) to collecting real-time data from a physical system that can be interrogated to determine the current state of the system (as control engineers have been doing since the start of the digital age). People also talk about Digital Threads and Digital Tapestries that similarly have an equally wide range of definitions and understandings. For the record, my view is that Digital Twins are a special case i.e. a sub-set, of

Modelling & Simulation (M&S).

Many organisations are jumping on the Digital Twin bandwagon and it is easy to spot those that have no previous M&S experience. It is clear that they don't understand the basics of simulation by knowing the limitations of how their simulations can be used and what can be inferred from them.

Similarly nobody has been able to provide me with a convincing explanation of what the Metaverse is. This is definitely a technology push as I don't currently see a user pull. However, I suspect it will become successful in some form due to the amount of money the big companies are pumping into developing the Metaverse. It will be interesting to see when ideas start to align whether the big players will want to go it alone or be happy to develop standards together.

3.2 Innovation

"Innovation distinguishes between a leader and a follower" - Steve Jobs

A disappointing observation over the years is the slow pace of development in the simulation industry compared to other industries. Progress is usually measured in decades compared to months for the telecommunication industry. Also, a lot of 'innovation' has involved repackaging/designing existing capability rather than providing new functionality. A good example of this is how the simulation has kept up with developments in computing which have evolved from main frames, to distributed computing and now to the cloud. Similarly we have transitioned from analogue to digital control loading and motion systems. The way we exchange data between our applications has changed from 'Datapool' to message passing and now to data centric architectures. However, as far as the pilots training on our simulators are concerned, they are not really aware of these innovations. Arguably the greatest impact to our simulators has been achieved in the simulation of out-of-the-window scenes, with significant innovation in the generation and displaying of the images. In future, innovations in the use of XR and haptic technology will greatly increase the ability to train when and where required.

Until recently, very few simulation related patents were generated compared to other industries. It is only since the Games industry started developing technology that the number of simulation related patents has greatly increased. This can be a blessing and a curse, as although the simulation industry can leverage on these innovations, the expectation of users who enjoy the latest games is not immediately met due to the time it takes to exploit the technology in a different domain.

One of the biggest innovations in the simulator industry is the acceptance of virtual controls on lower level flat panel trainers. I remember being told that pilots would never accept the use of virtual controls as the muscle memory related to interacting with physical interaction and was essential to their training. It is important that technology is not forced on users for technology sake and that evidence is provided about the benefits being provided. In the 1990s, I was technical lead on a collaborative European Esprit programme known as MATE (Multi-Aircraft Training Environment) [5]. This was one of the first demonstrations of virtual controls used in a prototype training device. Projectors were used to recreate the overhead and front panels in a generic aircraft cockpit and an innovative patented touch system developed to interact with them. The prototype device enabled the cockpit to be configured as a SAAB 340 and a Boeing 737. Equally important to producing a technology demonstrator was a parallel study to objectively measure and compare the transfer of training between the SAAB 340 configured simulator and real aircraft. A control group of pilots learnt the engine start procedure on the aircraft and another group on the simulator. The results showed that there was little difference in performance between the two groups when they performed the procedure on the aircraft. Although there was a lot of scepticism about pilots accepting virtual displays, a combination of the evidence provided and the ability to try it for real meant that the prototype device was well received at the 1998 Paris Air Show.

The main take-away from this is the importance of obtaining hard evidence when introducing innovations. Unfortunately performing experiments with a statistically significant number of participants to produce a meaningful set of results takes a lot of planning, time and budget. However, if conducted properly, they are invaluable for generating business cases and for getting the buy-in from senior decision makers. In my opinion, the simulation industry should be performing more experimentation as whenever a new technology or approach is developed, the first question asked is "provide quantitative evidence for how much it is saving"? The bean counters want to make decisions on hard facts not subjective assessments.

Although counter intuitive, I think when a project has too much budget, this can stifle innovation. I have seen various well-funded projects not live up to their expectations. I think this is because when people have limited resources they have to work that much harder to meet their objectives, which requires them to be more creative and innovative.

I believe one of the reasons for the lack of innovation in the simulation industry is that there hasn't been the push from operational personnel as they want to drive/fly/command real platforms rather than simulators. When I first started work, Government's provided the main source of funding innovation. Over the years, this has slowly been overtaken by the billions invested by the Games industry. The problem of this is Governments are losing control and there is a danger requirements are greatly influenced by what is available rather than what is really required. To combat this, it is important that Governments and NATO have roadmaps that define a path for innovation to meet future operational requirements. Production of these roadmaps should be by a combination of operational users and technology free thinkers. However, the problem I have found when talking to operational users about their future requirements is that they usually can only think about how to solve today's problems rather than what they will need to overcome the challenges in 5 years' time. In the UK, Dstl's Serapis SSE initiative has just produced a set of roadmaps for 'Generation After Next' simulation, which would be useful for the NMSG to review [6].

I particularly like the criteria used by the UK's Defence And Security Accelerator (DASA) for assessing and selecting innovative research projects[3]. These are the projects desirability, feasibility and viability;

- Desirable: strategic fit, end user support/pull
- Feasible: technical credibility, innovation, risk, expertise of team/capability
- Viable: costs and value for money, project delivery/plan

I recommend that the NMSG should adopt these criteria when evaluating Technical Activity Proposals.

3.3 R&D Projects

"If we knew what we were doing, it would not be called research would it" – Albert Einstein

The very nature of research means that the outcomes are not what was expected and it may be necessary to change the direction from what was originally envisaged. Although the government person managing the technical direction of the project may be very sympathetic and encouraging of changes, their commercial department may be less so. This is not so much a problem when industry is seeking funding from a customer for a novel concept, as they will have a good idea as to what they want to do to achieve their aims. The problem comes when the customer has a particular challenge where there are no COTS solutions and they want to initiate an innovative R&D project.

This was a massive problem when developing the proposal for Euclid RTP 11.13 as although the broad aim and objectives of the project were known and agreed with the customer, which was the Western European Armaments Group (WEAG), a large part of the initial research was determining how the programme

[3] https://www.gov.uk/government/publications/defence-and-security-accelerator-dasa-open-call-for-innovation

objectives were going to be achieved. It is a ‘chicken & egg’ situation as how do you produce a costed Work Breakdown Structure (WBS) when you haven’t performed the required research to understand the problem? There is a view that if you can define a WBS for a research programme or come up with a reasonable estimate of the effort required, you are not performing research. A fine balance is required between defining a meaningful programme of work with well-defined outputs that is acceptable to the customer’s commercial officer without restricting the flexibility required for a research programme.

I think more use should be made of feasibility studies where exploratory projects can investigate novel ideas. Although it is considered to be acceptable for research projects not to meet their objectives, the trick is to ‘fail fast’. Feasibility studies can be a few months long and if the research is promising, the output should be a costed programme of work. I particularly like the approach adopted by DASA where a pot of money is made available that organisations can compete for. A phased approach is used whereby the feasibility of an innovative solution can be investigated. Successful solutions are then funded by follow-on contracts.

People conducting research have a unique set of abilities that means they are able to come up with solutions from a very ‘woolly’ set of requirements. The downside of this is that they also tend to be perfectionists and want to explore every aspect of the problem. Although this approach may be valid for some low TRL research, it can delay the introduction of the innovation as the concept of a Minimum Viable Product (MVP) is something of an anathema to them. From my experience, successful projects have been those where there is a close relationship between the research team and the customer’s technical lead and they effectively operate as an Integrated Project Team. This provides a good balance between exploring a problem from all angles and having a useable outcome in a timely manner.

I think NMSG has got the right approach to the way it manages research projects as the participants tend to have different backgrounds and expertise. The use of shorter duration exploratory teams provide an ideal forum for determining the viability of a research topic and for developing plans for how future research should be conducted. The breadth of experience in the NMSG enables a good oversight and governance of the research it is responsible for. However, I believe for some working groups, more involvement of academia should be encouraged to provide fresh thinking. Maybe the NMSG should also consider lower TRL research and take more initiative in promoting novel innovation.

A negative feature of NMSG working groups is the time taken to progress outcomes. When the newly formed MSG-195 concludes in 2025, it will have taken 12 years to develop the concept of providing Modelling & Simulation as a Service (MSaaS). A much more agile approach is required to enable the benefits to be realised far quicker. If a working group takes more than 3 years to produce its output, there is a danger that the world and technology has moved on and is irrelevant. My experience is that most progress is actually made during working group meetings and little is done between meetings. If the outcome of a working group is important, its progress should not develop in an ‘ad hoc’ manner and that it is essential that all aspects of its production is planned and has sufficient funding from the nations. I also think there should be more control on the size of NMSG working groups and the commitment of the participants. Although I understand the need to allow ‘Observers’ to help disseminate knowledge amongst the smaller NATO nations, their attendance can slowdown the proceedings if they are not aware of the issues being discussed. Maybe it would make better use of everybody’s time if dedicated dissemination events were held once specific milestones have been achieved. These could efficiently be held as virtual briefings throughout the course of the working group.

History has shown that in times of war, significant military innovations have been developed and exploited in a very short time. Maybe we need to understand how this has been achieved and learn from our predecessors. Closer liaison with the war fighters is required to identify what challenges they have and when they need novel technical solutions.

3.4 Exploitation of R&D

"Exploitation needs to be considered at the start of an R&D programme" – Keith Ford

Over my career, the simulation industry has spent millions of dollars conducting research but how much actually has actually been exploited, and even if it is exploited, 'why does it take so long'? Compared to other industries such as IT, or mobile phones, significant developments in the simulation industry progress at a 'snail's pace'. I believe part of the problem is that exploitation of the research is only considered at the end of the project if at all. Arguably it is difficult to know how low Technology Readiness Level (TRL) research may be exploited but how much low TRL do we currently perform in the simulation industry?

I have been told that one of the reasons that the concepts developed by Euclid RTP 11.13 were not exploited was because it was ahead of its time. It is disappointing to note that a lot of the reports written 20 years ago are as valid now as they were then. The project was well received by the 13 nations funding it and there was a lot of interest in exploiting the novel approach for developing synthetic environments, but after the initial flurry of interest, the enthusiasm and significance of the programme faded. Because the concepts developed by Euclid RTP 11.13 laid the foundation for providing Modelling & Simulation as a Service (MSaaS), some observers say that it was not exploited because the technology was not sufficiently advanced. Yes, the advent of Service Oriented Architectures and cloud technologies facilitates MSaaS but I believe the reason it wasn't exploited was due to other factors. These include the unfortunate timing of the Western European Armaments Group (WEAG) morphing into the European Defence Agency (EDA), which meant that the 13 nations involved were focussed on higher priority matters. More importantly though in my opinion, it was also due to not 'selling' the concept and benefits to key operational stakeholders and influential budget holders in the different governments. The key lesson from this is that government research projects should not only have a budget to conduct the research but also a budget to conduct a 'sales' campaign to exploit the research. It should be noted that promoting the research will require a different set of skills compared to those technically directing or performing the research.

In these times of austerity, we don't have the luxury of conducting research without a well-defined reason for it. From a Government/NATO perspective, I think the situation has improved over the last few years with the research requirements being driven more by operational stakeholders. In my opinion, a Government/NATO stakeholder should be present at some progress meetings to ensure that the direction of research is aligned to their needs. Due to the rotation of operational posts, it may be a different person providing advice at the end of the project than at the start. This is fine if they have a similar mind set but could certainly cause tensions if the new person in post has different ideas.

I really liked the approach used on the European Esprit framework[4] which specified that each organisation had to provide an Exploitation Manager. This person, typically from the sales organisation, was responsible for ensuring the research was exploited. They had a light touch during the first half of the project but got more involved once the final outcome of the project became clearer. By considering how the research might be exploited at the proposal stage really helped to define the direction of the research.

I suggest that any research project that culminates in the production of a Capability Concept Demonstrator (CCD) really need to consider what happens to it at the end of the project. Typically a lot of time and budget is expended producing CCDs and once the demonstration(s) is over they are discarded. A longer-term view is required where the CCD is considered to be a Minimum Viable Product (MVP) and if it is successful, future phases turn it into a full product. This will require a more rigorous approach to software development rather than just producing prototype code but I think will provide better value for money in the long term. I suggest that NMSG consider production of CCDs as an output from its working groups, which with further development could be productionised for operational use, as this would speed-up exploitation of the

[4] https://en.wikipedia.org/wiki/European_Strategic_Programme_on_Research_in_Information_Technology_(ESPRIT)

technology. CCDs could also be used to develop CONOPS/CONUSE that would provide requirements for running a competition to productionise the capability.

3.5 Standards

“Standards are always out of date. That's what makes them standards” - Alan Bennett

I believe the use of standards has both a positive and negative influence in the simulation industry. Arguably it can stifle innovation as people stick with those standards that don’t completely support their needs but consider it easier to stick with them. On the other hand, new standards can help promote innovation. I have often been told that it is up to industry to define the standards they require. However, I don’t believe this is a practical approach as the standard has to be accepted by the whole simulation industry and that there will be a big push-back from those not involved with developing it.

History has shown that competing organisations are happy to work together to develop standards and Governments/NATO needs to make more of this prospective collaboration. A good example of this is the development of the SEDRIS (Synthetic Environment Data Representation and Interchange Specification) standard for enabling interoperability between synthetic environment databases e.g. for visual image generators, which was produced by an international working group. At that time (1994) there were several competing standards and the goal of SEDRIS was to provide a unified approach for database interoperability. It is interesting to note that although SEDRIS met its objectives and provided a lossless format for transferring data between different systems, the standard hasn’t been fully adopted in the way it had been hoped. Given that it was produced by an international consortium of experts, SEDRIS should have been a greater success. However, it highlights the challenges of trying to produce a unified standard from which we need to learn the lessons from. I have been told there were several reasons for this including, politics, it was perceived to be too complex, database interchange was usually a secondary requirement so traded out and it didn’t provide a runtime solution. However, a positive outcome is that components of SEDRIS are being used in different contexts e.g. the Spatial Reference Model (SRM) in TENA. Although not as encompassing, OpenFlight effectively became the defacto standard c.f. Betamax v VHS.

The development of the Common Database (CDB), which was initially developed by CAE is now often specified as the preferred format for synthetic environment data. However, its adoption has had an interesting and tortuous path as CAE initially developed CDB as a proprietary standard. When CAE made it available as an ‘open’ standard, there was a lot of push-back, probably because it was perceived that it gave CAE a competitive advantage. It was not until the standard was picked-up by the Open Geospatial Consortium (OGC) that it started being accepted by the wider simulation industry.

Mak took a different approach with developing the WebLVC standard as once they had a draft version of the standard, they worked with the Simulation Interoperability Standards Organization (SISO)[5] to form a Product Development Group (PDG). This enabled other organisations to influence the development of the WebLVC standard, which should have made it more acceptable to them. However, as far as I can see, it is only being developed by a small cohort of organisations. Is this because other organisations are not interested in the standard or that they don’t have the budget and resources to develop it? In my opinion, this leads to important simulation standards being developed in an ad hoc manner effectively by a few people and organisations. I think a good example of this is how long it took to develop the HLA standard to a usable state once the DoD stopped funding its development. The danger of this is that if the standards are only developed by a few organisations with a vested interest, they will not necessarily cover the full gamut of situations where they may be used. On the other hand, if there are too many views, this can significantly extend the time taken to develop the standard and it may become overly complex.

[5] https://www.sisostds.org/

This leads to a dilemma in that everyone thinks standards are important and are happy to use them but only a few number of organisations are willing or able to fund developing them. The other observation is generally organisations are willing to provide appropriate resources for developing standards if they were paid.

If Governments/NATO transitions to an MSaaS approach to delivering simulation capability, there is a need to decompose its current monolithic simulations into reusable 'building blocks' or services. Although there have been various initiatives over the years to define what this lower level of granularity should be e.g. SCORE [7], none have really been accepted or adopted by the industry. This is also an area that the various NATO MSaaS working groups e.g. MSG-136 and MSG-164, have put on-hold, although it is crucial to the success of MSaaS. There is an urgent need for the whole of the simulation industry to work together to not only identify what these services should be, but also their functionality and interfaces. I think defining the standards for these services is too important for them to evolve in an ad hoc way as there are significant functional and commercial implications. I believe MSG-195 provides the ideal forum for tackling this important and challenging topic as it comprises an international group of experts from a wide range of simulation backgrounds from governments and industry. However, it is essential that the participant's organisations are committed to support them for the duration of the working group. There is a danger that if participants come and go due to lack of funding, this will not only slow down the development but there is a danger of not producing a cohesive and coherent set of standards.

SISO provides a unique forum for the development of simulation standards. However, what it can achieve is constrained by relying on 'volunteers' for participating in the Development and Support Groups and I recognise names from when I first went to what was then called Simulation Interoperability Workshops (now known as a Simulation Innovation Workshops). I think the NMSG's relationship and Technical Agreement with SISO has had a very positive effect for both organisations. Given the importance of standards, I think there is a case for nations to fund more participation from their government organisations and industry.

3.6 Knowledge

"Real knowledge is to know the extent of one's ignorance" – Confucius

As an old 'greybeard' I have developed a lot of knowledge and useful skills that Generation X and Millennials have not had time to acquire. I remember the frustration in the early days of my career of feeling side-lined in discussions because I didn't understand the bigger picture. It is important that more senior people recognise this to ensure that prior knowledge is not assumed and to proactively involve less experienced people in discussions.

One advantage of going through the educational system when I did was that I was taught how to use a slide rule and log tables that meant I was also taught to perform reasonability checks when performing computations (younger readers should Google what slide rules[6] and log tables are[7]). This skill has been transferable to many situations and has saved me many times from problems arising from 'garbage in, garbage out'. Also, because it usually took 24 hours to return the output from a set of computer punch cards, it made you ensure that you tried to get it right first time, which is another good work ethic to have.

When I was in secondary and tertiary education, we were expected to remember all the important maths and physics formulas along with dates of important historical events. It is interesting from talking to graduates today that they no longer have the need to learn and remember a long list of facts as the information is immediately available from their smartphones. These days I no longer have to remember any events as I get reminders on my phone – although I don't trust the technology with my wife's birthday! A new skill I am having to learn is how to filter the amount of information I am bombarded with on a daily basis.

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

[7] https://en.wikipedia.org/wiki/Mathematical_table#Tables_of_logarithms

I think society is beginning to suffer from the latest generation of engineers not having the continuity of experience as their predecessors. I remember being at a Royal Aeronautical Society Conference a few years ago where the issues being presented and discussed were very similar to those from decades earlier. It was a real case of déjà vu. However, I do acknowledge that because the new generation does not have the baggage my generation has, that this may increase rather than stifle innovation. Because something failed before, it doesn't mean that it won't with the latest technology and insights.

I am discovering an increasing number of consumer products which don't perform as well as older versions did and I am sure that this is due to the loss of corporate knowledge. I appreciate that for some things it's because the younger generation think and do things differently than I do e.g. why do you have to go through two menus to change a filename in Windows 11?, but I have a kettle where you cannot easily see the water level, which is important for minimising energy consumption. In the past there would have been a coloured piece of plastic floating on the water to make the level of water easily visible. Was this really due to making a cost saving or has the importance of the user's need been lost?

The Internet is a great source of information but it doesn't contain corporate knowledge and certainly not experience. An organisation's Intranet and Wiki's are becoming increasingly used to capture corporate knowledge but they rely on having a good search capability, which is not always the case. Even when knowledge is captured it is not always acted upon. A case in point being the difference between lessons learnt and lessons identified.

As my peers start to retire, I am conscious how much knowledge and experience they take with them. Organisations have a problem with how to capture and transfer that knowledge and experience. I am also concerned that with the increase of home and hybrid working, that the ad hoc exchange of information between senior and junior engineers that naturally occurs by 'osmosis' when physically present will not happen as much. Working together in this way is also very important for promoting and reinforcing expectations of behaviour and work ethic.

Although many organisations have succession planning, due to the day-to-day challenges people have, the amount of time for exchanging knowledge is very limited. The ability to share experience is even more challenging and questionable whether it can even be really transferred. I find it interesting how some seminal experiences from long ago, both positive and negative, still affect what I think and do to this day. Although we can talk about them, I don't think it is possible for another person really to comprehend the meaning and impact of another person's experience.

So what has all this got to do with the NMSG? NATO's operational systems have evolved over many decades and in my own company I am aware of engineers who have worked on a particular system for all of their career. During that time they will have identified approaches that didn't work, learnt tricks to expedite progress, have an intimate knowledge of the customer's needs and know why key design decisions were made. If this knowledge disappears when these engineers retire, how does NATO ensure that previous mistakes are not made in future developments? The problem is exacerbated by the fact that not only do these systems evolve over decades, they can be in-service for many more decades (with the additional problem of managing obsolescence).

Traditionally NMSG Working Groups produce long reports to capture what they have learnt. The problem is do people have the time to read them these days. Does the NMSG need to look at alternative ways of retaining and disseminating information? Euclid RTP 11.13 produced a video to summarise the main outcomes from the programme and a DVD containing hyperlinked web pages to all the reports. I am sure in these multimedia days that there are more effective ways to satisfy the younger generation's expectations. However, because it is still not cheap to enable the information to be more accessible, it may be necessary to perform a cost benefit analysis to determine the real value of the information.

Given the increasing importance of simulation to NATO, there may also be a case for expanding the scope of the Modelling & Simulation Centre of Excellence in Rome by setting-up a similar capability to the UK's Defence Simulation Centre (DSC). When operating at its full capability, the DSC will provide a 'one-stop-shop' for anything to do with simulation, including maintaining a registry of simulation capability available across the MOD Enterprise. This will hopefully expedite the use of simulation and facilitate its use by operational people who have little simulation experience but are responsible for it.

3.7 Conferences

"Alone we can do so little; together we can do so much." – Helen Keller.

The way information is acquired and exchanged has drastically changed over the last 40 years. When I started in the simulation industry, conferences were the main way of obtaining knowledge and networking with peers. This was reflected by the number of attendees. I remember the Royal Aeronautical Society's simulation conference being a 4 day event with a room full of people. Likewise, it was not unusual for the Spring and Fall SIW events to have 800+ attendees and even a European SIW was introduced. In those days the conference proceedings were read diligently and particular note was made of the references as these would lead to further sources of information. In my organisation, a request would be made to the internal library for relevant papers referred to in the references and a few weeks later, a hard copy would be received through the post!

These days the Internet is the primary source of information, which has completely changed the way we acquire information. However, I don't think the role of conferences has changed with the times and this is reflected in the number of attendees. There are also, in my opinion, too many simulation related conferences; some which offer little value. One of the challenges commercial organisations have with presenting papers is that, not surprisingly, they wants to protect their Intellectual Property. It should also be noted that once a paper has been published, it is not possible to patent the technology. This leads to papers that only can hint at what they are developing, which reduces the value of the paper.

It is interesting to reflect why people present at conferences; is it to satisfy their ego, put on their CV, to subtly promote a product or actually to facilitate a technical discussion by peers in the industry (I realise you are now questioning my motives for why I am presenting a paper at this Symposium!)? My views on conference papers and presentations is greatly influenced by a paper I acquired for my Ph.D. The paper was titled 'A Platform with Six Degrees of Freedom' and was published in the Proceedings of the Institution of Mechanical Engineers [8]. The author describes the different arrangements of hydraulic pistons for moving a platform accompanied by all the geometry equations. The paper was reviewed by a number of peers and their comments were captured in the paper along with the author's response. In my opinion, this paper published in 1965 is still a really valuable document for anybody wanting to know about synergistic motion systems (aka Stewart platform). Can the same be said for some of the presentations and papers that are written today?

It is also worth considering why people attend conferences as they can take up a significant amount of their week, travel these days is not cheap and a large proportion of papers may only be of limited interest to them. Obviously an important aspect of attending a conference is the networking that goes on and most allow long coffee and lunch breaks to facilitate this. Given that not all papers are relevant to people and networking is important, is there a case for reinventing the format of future conferences? Should we be organising more workshop like events where a few selected important topics are discussed in detail? A number of short presentations could be made to introduce the topic and it is opened to the floor to obtain in-depth views from the wider simulation community. The kind of topics that might be appropriate are standards (see section 3.5) and future challenges (see section 4.0).

Having said all that, I still think there is a place for traditional conferences and over the years, the NMSG

Symposiums I have attended have been well run and stimulating. Although it is always tempting to cut-corners, it is essential that to maintain the high-standard of these Symposia. Both papers and presentations should be mandatory and papers should be peer reviewed before being accepted for presentation. I think conference organisers owe it to all participants to provide the best experience possible and I suggest the following for consideration. My understanding is that NMSG only reviews abstracts and I think it would be beneficial if accepted papers also undergo a review process in the same way as IITSEC does. This will ensure that the papers do actually address the points raised in the abstract and also ensures that the points are clearly made, particularly when English is not the author's native language. I appreciate that this will require more work but would help maintain the standard of the conference. To share the workload, NMSG could maintain a register of experts willing to review conference papers. Papers on a particular topic could then be reviewed by an expert in that field, which enables them to keep abreast of innovations and pass on their knowledge.

Well-defined criteria should be provided for reviewers so that there is a consistent approach to scoring the abstracts/papers. These should also be included in the calling notice so that potential authors now what is expected of them. Potential criteria could include:

- Relevance to conference theme
- Operational relevance
- Novelty of technology or approach
- Relevance to NMSG objectives
- Clarity of what is being proposed
- Purpose of paper
- What consequences are expected from presenting the paper?

If these criteria were applied to the last paper I presented at an NMSG Symposium there is a good argument that it shouldn't have been accepted. The paper reported on the development of a 6 layer model for simulating communications that Dstl funded in the UK [9]. I think the paper was well-received and I had some questions but that was the end of the story. So what did giving the paper achieve, what impact did it have, was that 30 minutes well spent by conference attendees? I think in future, it would be good for authors to highlight what they expect from presenting a paper. Appropriate reasons could include:

- Publicising a new NMSG working group
- Obtaining wider industry feedback on the outputs from an NMSG working group (this will require a longer Q&A session)
- Getting wider industry feedback on a proposed new standard
- Identifying an operational problem that simulation could help solve
- Tutorial on a new technology and how it is relevant to simulation e.g. Reinforcement Learning

Covid and the introduction of virtual conferences has been an interesting experience and learning curve for conference organisers and presenters. Fortunately when the Covid pandemic hit us, reasonably mature technology was available to support remote working and hybrid conferences. Arguably, the needs of Covid

just hastened its introduction. I am sure psychologists are already analysing the results from this enforced 'social experiment'. Initially conferences were all virtual but as travel restrictions were eased, hybrid conferences became the norm and now some conference organisers have gone back to only face-to-face. So what format should NMSG Symposia take? I think if the technology can be reliably delivered (and it shouldn't be underestimated how challenging this is), virtual attendance should be allowed/encouraged to enable people to select which papers they want to hear. This will provide efficient use of people's time (as well as reducing their carbon miles) along with a wider audience for disseminating the information provided by the papers. An idea worth considering is that as well as NMSG publishing papers and presentations, a collaborative working environment is set-up for obtaining feedback and promoting further discussion after the conference has finished. However, given my experience of Wiki's (see below), I am not necessarily convinced about the longevity of this approach.

3.8 Reuse

"Reuse is the original green collar job." - MaryEllen Etienne

Having been involved since the early days of MSaaS, I am a great believer of reusing existing assets rather than reinventing the wheel. There is an apocryphal story that the MOD has purchased over 30 databases of its training area on Salisbury Plain. Whilst I accept that the fidelity of the database for a land simulator will be different to that used by a fast jet simulator, wearing my tax payer's hat, I think over 30 version of a database is a bit excessive and doesn't represent good value for money.

It is almost a 'no-brainer' why you wouldn't keep a library of reusable simulation assets. Over the last 20 years, there have also been various other initiatives to capitalise on the benefits of reuse that have come and gone. The technology ranged from keeping a simple spreadsheet of the assets to more advanced distributed databases. I believe one of the reasons why they haven't been long-lasting is similar to why Wiki's often fail. When a Wiki is set-up there is usually a champion who drums-up support and is very enthusiastic about the initiative. It is when their day job catches up with them or they move on that the Wiki slowly dies a death. I believe for a simulation repository to be successful, it needs to be championed by at least a 1* and funding for a long-term commitment has to be made. I am greatly encouraged by the UK MOD funding a 1* post responsible for Modelling & Simulation and the Defence Simulation Centre at Shrivenham as I think this sends out an important message to the services and industry as to how the capability is to be provided.

Even when the infrastructure has been set-up for managing simulation assets, there is another problem. When Governments/NATO procures simulation assets should they just specify the functionality to satisfy the immediate requirement, try and pre-empt future additional requirements or even provide hooks for additional capability? There is a challenge with building a business cases for funding anticipated requirements that may not happen or worse still to only get them partially right. However, if only the immediate requirements are implemented, careful configuration management is required for the future updates, particularly if they go off in different directions.

A more subtle problem with reusing simulations rather than building them yourself is understanding what assumptions were made during the modelling process. There is a danger that the metadata doesn't adequately describe the limitations of the model, which can lead to erroneous results. Also, it is often the modelling process itself that can lead to greater insights and understanding into how a system works, which is lost when reusing other people's simulations.

4.0 SIMULATION GRAND CHALLENGES

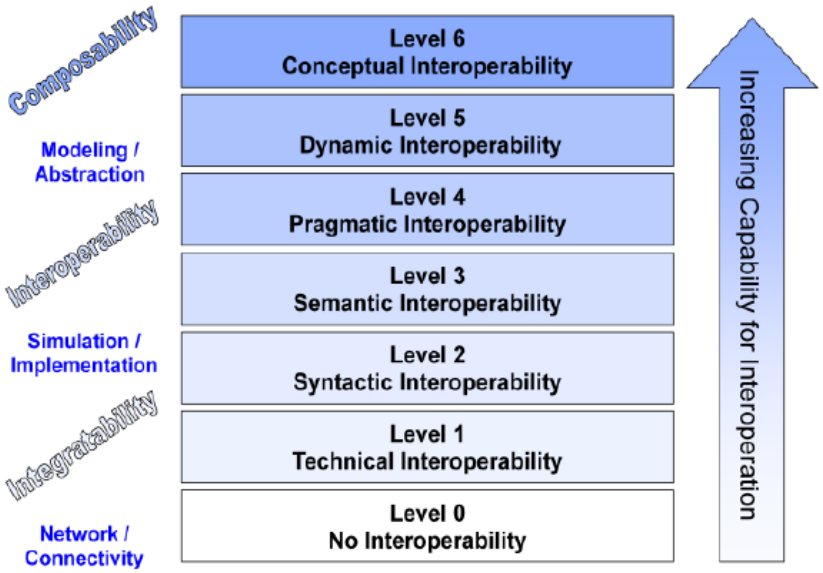
Having spent time looking back, it is now time to look forward. As previously mentioned, the pace of development has been very slow in the simulation industry and some of the challenges that were present

when I started my career are still there. I think one of the reasons for this is due to them being put in the 'too hard' pile. However, I think it is time for the research community to start focussing on these challenges. My top four challenges are Composition, Verification & Validation (V&V), simulation of non-kinetic effects and security.

4.1 Composition

A key activity required by MSaaS is the ability to 'compose' services; the ability to get disparate services, applications and simulators to interoperate. Although the simulation industry has been producing distributed simulations for several decades, the integration of simulation capability is still challenging, requiring specialist knowledge. This is because unlike the games industry, where distributed homogeneous systems are networked together, in the simulation domain heterogeneous simulators and simulations need to interoperate. The problem is exacerbated as simulation capability is decomposed into smaller services in order to promote reuse.

The magnitude of the composition problem is highlighted by Tolk's 'Level's of Conceptual Interoperability' Model (LCIM) [10], which describes 6 levels of interoperability.



Levels of Conceptual Interoperability Model

The main challenge for a Simulation Developer when composing simulation capability is to ensure that all the applications, services and simulators can interoperate at all levels of the LCIM. Although it is not usually a problem these days at the lowest levels of the LCIM days i.e. we have tools and protocols for exchanging data, significant research is required at the higher LCIM levels where it is necessary to understand the content and meaning of the data being exchanged.

MSG-205 (Allied Interoperability and Standardization Initiatives for Digital Twins) potentially has a greater problem as they will be having to also consider physical systems interoperating with our simulations. However, I believe in future, the introduction of data centric architectures will help facilitate the integration of systems using disparate interoperability protocols.

4.2 Verification & Validation

Performing verification and validation is essential when creating simulation environments. I remember being confronted with the problem of Verification (have you built the thing right) and Validation (have

you built the right thing) early on in my career. The ‘art’ of simulation is knowing what the minimum fidelity of the simulation should be to achieve the desired objective. A favourite saying of mine is ‘Good enough equals perfect’. The challenge is being able to adequately capture a simulation’s limitations and to know the implications for how it is to be used.

My first extra mural research programme was to develop a method of automatically identifying the parameters of a simulation’s control loading model i.e. the system for representing the forces felt on the aircraft controls. In those days, the control loading system was validated by pulling the control to its end stop, releasing it, and plotting the resulting position against time. I was easily able to demonstrate that the same response could be achieved for a wide range of model structures and parameters. I therefore developed a complex forcing function that required the pilot to move the control to each end stop in a particular manner. This led to an interesting experience when this manoeuvre was performed in flight to capture data on an ageing VC10!

By having a wider range of resources available, MSaaS potentially can alleviate some of the V&V problem as higher fidelity simulations may be available than would be the case if they had to be created from scratch. However, the reuse of simulation capability comes with its own V&V challenges as it is essential to capture the assumptions and limitations of the simulation capability being reused. Due diligence is required when reusing the capability in a different way than it was designed for. In addition, a simulation capability validated for one application will have to be revalidated when used in a different situation. As an example a sensor simulation developed for war gaming is unlikely to be of a high enough fidelity when used in a training simulator. Also, it is important to realise that the operation of an MSaaS composition will need to be re-verified each time it is redeployed, even if it is on the same infrastructure.

Although SISO has made great strides in tackling the V&V challenge much more needs to be done to provide a methodology to objectively V&V our simulation capability. I believe successful V&V currently relies on the experience of our simulation developers and we somehow need to extract this knowledge. I think automatic verification of heterogeneous simulations is an achievable goal but I suspect validation will always require an element of human involvement. This is because for example, how do you train a system to determine that a feature modelled in one simulator’s database and not in another, will not have an impact on a mission’s outcome?

A bigger problem is also on the horizon when we have to start V&Ving our AI systems.

4.3 Simulation of non-kinetic effects

The current generation of distributed simulations mainly focus on physical warfare effects and do not adequately represent the full gamut of activities in the operational space. In order to provide a more realistic environment, future simulations must include a better representation of other aspects of operations including;

- Human behaviour e.g. sentiment, relationships, interactions, morale
- Information warfare e.g. cyber and psychological operations using social media, television/radio
- Infrastructure e.g. electricity, gas, water, communication, food distribution, road and rail network
- Populace e.g. number of people/vehicles, individual and group behaviours

The war in Ukraine has highlighted the importance of training tactical and operational commanders about understanding and applying non-kinetic effects. This will require the representation of information flowing into their simulated headquarters being the same as would be experienced in an operational headquarters, which will require simulating;

- Intelligence, Surveillance Target acquisition & Reconnaissance (ISTAR) feeds with sufficient number of people and vehicles to provide realistic background 'clutter'
- Social media and news feeds that reflect the operational context and can react to simulated kinetic and other effects
- Impact of fake news, operational activities e.g. destruction of infrastructure, etc. on people's behaviour and morale
- Political and military decision makers to reduce the number of white force required

Due to the magnitude of the task of producing a high-fidelity simulation of the battlespace that includes people's behaviour and infrastructure, this activity should be driven by the operational user's requirements. It is very easy to fall into the trap of representing capability just because you can. The biggest challenge will be in validating these new simulations as there will not be a reference to compare with.

Although aspects of the above are becoming available, these are independent disjointed developments. NMSG needs to start identifying the requirements, building blocks and standards that will be required to ensure a coherent solution.

4.4 Security

Many would say that security is not the simulation industry's problem but in reality it is, as it is a major blocker for many things we want to do. We regularly trade-off using credible missions in our research programmes against having unclassified representative missions. Although with the security tools currently available to us, we regularly facilitate missions being performed in simulators networked across geographic locations at high classifications, setting-up ad hoc networks is still a time consuming activity. The problem is made more challenging with the introduction of cloud technology, which the security accreditors are still coming to terms with.

The simulation industry has a unique problem when networking simulators at different classifications in a multi-domain security solution. This is the concept of being able to conduct a 'fair-fight'. It can occur when any heterogeneous simulators are networked but is a particular problem when they are of different security classifications. In this case data is only usually allowed to flow from the low side to the high side and any data coming from high to low maybe sanitised. This means that some players don't have all the information available to them. Whether this is an issue or not needs to be determined by the V&V of the overall system.

Obtaining accreditation of our simulation networks within our nations is challenging but the problem increases when we are operating together as NATO. I hope that NMSG's Support to Distributed Synthetic Training (MSG-204) and Modelling and Simulation in Federated Mission Networking (MSG-205) will start coming-up with solutions to some of the security challenges we have.

5.0 CONCLUSIONS

I think NMSG provides a unique non-partisan organisation for overcoming simulation challenges and driving simulation technology forward. I firmly believe that NMSG are doing many things right. The use of exploratory teams and the topics of the working groups, in my opinion, seems to be focussed in the right areas. However, the organisation needs to be more agile and needs to speed-up the outputs from its working groups to get the benefits into the hands of our war fighters and peace keepers sooner. NMSG should utilise the skills from its large membership and be more proactive in influencing how it wants simulation technologies to develop and interoperate across the 5 operational domains. It needs to take more ownership in proposing and developing the standards required rather than letting them develop in an 'ad hoc' manner. I think this can only happen if nations adequately fund participation in working groups to ensure commitment and continuity.

The benefits of having a coherent plan for using M&S as proposed by SBA/SeBA needs to be re-evaluated and relearnt. I think NMSG should take the lead in promoting the use of M&S across the lifecycle of future military platform and system acquisition programmes.

Time will tell how long MSaaS and digital twins will be around for and whether they will be superseded by the next initiative. I would like to think that the industry will be more wary of 'jumping on the next bandwagon'. There is a danger that if we keep moving to new initiatives before the last has fully delivered, we never actually solve simulation challenges and move the industry forward. Hopefully NATO will be prepared to take a much longer term view.

I believe the Metaverse will need to overcome some of the simulation challenges I have identified, particularly with respect to 'Composition'. Therefore, the amount of money being pumped into the Metaverse may expedite developments, which NMSG can leverage.

So these are my reflections from 45 years in the simulation industry. Will they make any difference or as Georg Hegel quotes "We learn from history that we do not learn from history"?

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