Evolution of Modelling and Simulation

In the Singapore Armed Forces

ABSTRACT

The Singapore Armed Forces (SAF) has been capitalising on Modelling and Simulation (M&S) technologies for its simulation and training systems since the early 1980s. The primary focus in the initial years was on the training of soldiers, operators, gunners, pilots and commanders as individuals, or as members of combat teams.

Over the years, the SAF has forged ahead, harnessing M&S for areas beyond training, including operational mission planning and rehearsals, decision support, as well as test and evaluation. In recent times, M&S has also become an essential technology and tool for military experimentation.

This paper traces the evolution of M&S in the SAF, and provides a view of the changing M&S landscape with each successive wave of technology advancement. It also provides an assessment and forecast of the nature of M&S systems in the future.

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INTRODUCTION

The impetus for using Modelling and Simulation (M&S) systems in many armies has traditionally been driven by the need to overcome various constraints, such as the lack of training areas, rising costs in conducting actual training and the fact that equipment for training are sometimes unavailable. For the Singapore Armed Forces (SAF), the situation is no different.

In fact, the SAF faces even more acute constraints in resource-scarce Singapore. After all, the 'little red dot' measures just 699 square kilometres[1], faces falling birth rates[2] and has to grapple with issues affecting the region. These have included the Asian financial crisis, the "dot-com" bust and the SARS epidemic.

So what better way to overcome these constraints than to employ M&S technologies to conduct training in virtual space? With M&S technologies advancing by leaps and bounds over the last decade, such a solution is not only increasingly viable as a key strategy for the SAF; it has also become strategically advantageous, enabling the SAF to turn constraints into strengths.

Besides simply increasing the opportunities for training and enhancing its quality and realism, the SAF has also harnessed the power of M&S for purposes beyond training. Specifically, the technology has been capitalised on for operations such as mission planning and rehearsals, and decision support, and for test and evaluation purposes.

More recently, arising from the need to transform the SAF to meet new challenges in the battlefield of the future, M&S has also become an essential driver and indispensable technology for military experimentation in the support of force transformation.

This paper traces the evolution of M&S in the SAF in three ways of development since the 1980s.

THE FIRST WAVE - The Embryonic Years (1980s to early 1990s)

Early Achievements

The SAF's first foray into M&S began in the early 1980s. This era of standalone simulations was fuelled by the emergence of graphics and Image Generator (IG) technologies, which developed in tandem with the advancement in computer and display technologies.

The maturity of two-dimensional (2D) graphics enabled the development of the shore-based Tactical Training Centre for the Republic of Singapore Navy (RSN). Tactical scenarios were simulated and presented in monochrome 2D graphical symbology to train ship commanders in various tactical decision-making situations.

Soon after, 3D IGs began to emerge. For the first time, the real world could be replicated graphically in a synthetic 3D environment to a degree of realism acceptable for training.

This quickly led to the development and delivery of various types of flight simulators for the Republic of Singapore Air Force (RSAF) to train pilots for its fleet of A4S and F5Es, as well as the AS332 and AS550 helicopters.

For the Army, the Artillery Fire Control Training System (AFCTS) was the first training system. Delivered in 1983[3], the AFCTS was used to train forward observers in call-for-fire and artillery ranging procedures. The system comprised a projection system made up of 11 slide projectors to simulate and display the delivery and impact of artillery fire.

The Army's first simulator to exploit 3D graphics in a significant way was the Armour Tactical Trainer (ATT). It was delivered in 1989 to train armour commanders and gunners of the AMX-13 tank in gunnery as well as crew co-ordination skills. Historically, the ATT marked the beginning of a new era in 3D simulators for the Army.

Technology Driver - Graphics and Image Generator Technologies

The principal technology driver of this first wave of M&S systems was the emergence of Graphics and IG technologies (Figure 1).

Figure 1. Typical 3D Image Generated by IG

IGs then were 'custom-made' and proprietary in nature. The run-time graphics software for scene management and displays were uniquely developed in-house by the few major simulation system vendors or by niche IG manufacturers.

One popular model used, for instance, was General Electric's (now Lockheed Martin) CompuScene IG. This IG, which was utilised in the ATT system, was huge, filling almost an entire room (Figure 2).

Figure 2. Proprietary IG used in the ATT

Characterising the First Wave

The first wave can be characterised by the deployment of simulators, which were generally standalone and single-purpose. Most were focused on honing the psychomotor skills of individual operators such as gunners and pilots prior to 'live' training.

THE SECOND WAVE - The Fledgling Years (Mid 1990s to 2000)

The M&S industry matured considerably in the 1990s - the second wave. Spurred by the advent of broadband networking, 'Distributed Networked Simulation' was the rallying call, and the focus shifted rapidly from standalone training to team training and joint or integrated warfare training.

The global simulation industry responded with great enthusiasm. New technologies and concepts soon emerged, enabling geographically-separated simulators to be networked for joint training in common synthetic environments, as if they were a single simulator. It was this era that gave birth to distributed simulation protocols. In addition, Computer-Generated Force (CGF) technology progressed, facilitating intelligent automated behaviour of simulated entities that reduced the need for large teams of exercise support personnel to 'move the pieces'.

Vision for SAF Simulation 2000

Recognising the immense potential of M&S, the SAF formulated and launched a major programme called the Vision for SAF Simulation 2000 (VSS2000) in 1995 to capitalise on the rapid M&S technology advancement.

VSS2000 envisaged the strategic use of SAF simulators in three dimensions, i.e. Joint Training, Operations, and Test and Evaluation (T&E) (Figure 3). The main emphasis was on joint training through integration at both the systems level, i.e. simulation-simulation and simulation-operational systems integration, and the Services level.

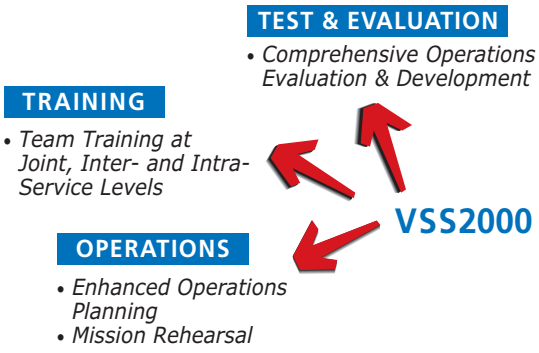

Figure 3. VSS2000 Thrusts

This ambitious programme resulted in a series of major M&S implementations in the SAF from the mid 1990s. In fact, the VSS2000 roadmap saw the realisation of some 'first-of-its-kind' training systems then, along with several innovative M&S concepts.

Notable Achievements

The Army operationalised a constructive wargaming system called SIMulation for LAnd Battle (SIMLAB) (Figure 4), which facilitated HQ command and staff training at different command levels, from Battalion to Division. Besides command-team training, the system also proved to be a useful tool for exploratory studies of different force structures, and for evaluation of new platforms and weapon systems.

Figure 4. SIMLAB

The other notable simulators that facilitated integrated team training in the Army are the Driver Training Simulation System (DTSS) and the Armour Gunnery Tactical Simulator (AGTS). Both were fielded in the late 1990s.

The DTSS (Figure 5) is a full motion-based driving simulator comprising eight Land Rover stations and eight Iveco Truck stations. It enables SAF drivers of these vehicles to learn and master driving skills on various road conditions, which include some of Singapore's local estates and terrain such as Ang Mo Kio, Bukit Batok and Pulau Tekong. In addition, all 16 stations are networked to provide capability for convoy training in a common virtual environment.

Figure 5. Driver Training Simulation System

The AGTS is another unique team-based simulation system. Besides training soldiers in individual gunnery skills, its six visual crewstations are integrated to enable joint tactical training at the combat team level. The system also pioneered several new concepts. For example, the simulator can be easily and speedily reconfigured to support up to four different armour platforms (including the SM1 and Bionix) through a unique 'roll-in/roll-out, plug-and-play' concept. Thus, depending on specific exercise requirements, the desired mix of armour platforms can be 'plugged' into the visual system cubicles (Figure 6) for integrated training.

Another technological achievement of the AGTS is its ability to simulate highly intelligent friendly and enemy forces, which act and react autonomously according to pre-defined tactics. Powered by state-of-the-art CGF technology, the system is able to simulate not only platforms such as tanks and helicopters, but also dismounted infantry soldiers. This greatly

Figure 6. AGTS Crewstation rolled into a Visual System Cubicle

reduces the need for additional manned stations and personnel to support training and exercises.

Technologically, the fielding of the AGTS was a watershed for Army simulations as it encapsulated many of the key M&S technologies of this era: intelligent CGF, networked training, common virtual environments, reconfigurable, plug-and-play concepts, and off-the-shelf IGs.

For the RSAF, several technological milestones were also realised during this period. From the A4SU Full Mission Simulator (FMS) with a full-dome display (Figure 7) to the Air Traffic Control Simulator with a 360-degree full field-of-view panoramic 3D display system (Figure 8), these simulators are a far cry from the days of 'cut-out' cockpits and toy aircraft on model runways.

Figure 7. A4SU FMS

In another major milestone, the RSAF also took delivery of a distributed Command and Control (C2) simulator - the first two-sided wargaming tool which enabled the RSAF to conduct vertically-integrated C2 training from headquarters and command centres down to

Figure 8. Air Traffic Control Simulator

the air bases. Notably, this was also the first simulator to be fully integrated with real C2 systems. This was significant, as one of the key thrusts of VSS2000 was to realise the 'train-as-you-fight' paradigm where training is conducted using actual operational equipment.

The advent of the Global Positioning System (GPS) in the 1990s allowed for live training at the force-on-force tactical level. This is known as 'instrumentation' in M&S parlance. The RSAF implemented the world's first 'rangeless' Air Combat Manoeuvring Instrumentation (ACMI) system. By capitalising on GPS and an indigenous datalink, the ACMI erased the boundaries imposed by a range-based system (Figure 9). ACMI also pioneered the 'embedded simulation' concept for the SAF, where weapon effects simulation was embedded on the actual aircraft. This allowed pilots in real flight to engage one another virtually, allowing the training of tactical engagements to be performed realistically yet safely.

With the success of ACMI, the technology was quickly adapted for naval platforms for the RSN. The system, called the Fleet Instrumented Training System (FISTS), provided 'embedded simulation' capability with onboard operational systems so that simulated training could be carried out even as the ships sailed out to sea.

Figure 9. ACMI Conceptual View

With 'Integration by Design' as the hallmark of VSS2000, FISTS was also integrated with ACMI to provide the first-of-its-kind integrated training between the RSAF and the RSN (Figure 10), taking embedded simulation and joint training to the next level.

Technology Driver - Networking Technologies

The second wave was fuelled by advances in Simulation Networking Technologies. This took the form of two main developments in Distributed Interactive Simulation (DIS) and High Level Architecture (HLA).

The origins of DIS can be traced back to 1983, when the US Defense Advanced Research Projects Agency (DARPA) sponsored the SIMulation NETworking (SIMNET) programme to create a new technology to expand single-task trainers into networked team trainers. DIS established a common data exchange environment by formalising protocols and standards to support the interoperability of heterogeneous, geographically-distributed simulations (Defense Modelling and Simulation Office, 1994).

DIS was the de facto networking standard in the M&S community until the mid 1990s, when a new standard called HLA emerged. Besides adopting an object-oriented methodology and publish-subscribe mechanism, HLA provided an overall framework to facilitate the architectures, as well as to further promote the reuse of existing simulation assets. In 1996, the US Department of Defense mandated HLA as the new simulation networking standard (Undersecretary of Defense for Acquisition and Technology Memorandum, 1996). Subsequently, HLA was also mandated under VSS2000 in order to exploit emerging commercial off-the-shelf (COTS) simulation technologies better.

Separately, the advances in Graphics Technologies from the first wave continued unabated, albeit with a shift in focus. Proprietary IGs, for all their processing power and might, soon became expensive for decreasing budgets. They lost favour, and their cause was not helped by the emergence of workstation-based IGs. In particular, Silicon Graphics soon became the darling of the simulation industry with its brand of COTS IG workstations (Figure 11). From the mid to late 1990s, SGI was the dominant IG supplier not only for defence simulation applications, but also the entertainment and scientific communities at large. The SAF was a keen user of SGI's IG technology during this period, with close to 10 simulators employing SGI solutions.

Characterising the Second Wave

The second wave saw the transition from standalone simulation to distributed, networked

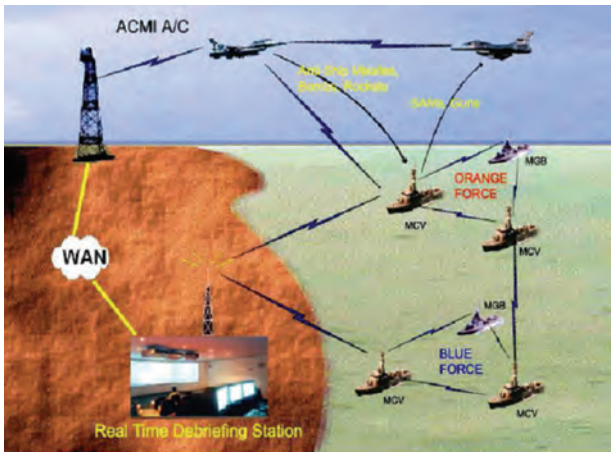

Figure 10. ACMI-FISTS Conceptual View

Figure 11. SGI Onyx(r) Visualisation Workstation (Image courtesy of Silicon Graphics)

simulation in common synthetic environments, aided by advances in networking technologies. During this period, the SAF also implemented many flagship simulation systems, and pioneered new M&S concepts such as 'plug-and-play', 'simulation-C2 interoperability', and 'embedded simulation'.

THE THIRD WAVE - Soaring to Greater Heights

In the new millennium, the SAF is now on the threshold of another wave of M&S evolution.

VSS21

The SAF and DSTA unveiled VSS21, a new M&S masterplan in January 2001.

VSS21 continues to be anchored on the three thrusts established in VSS2000 (Figure 12). However, the key objective of VSS21 is to exploit M&S for the purpose of force development and modernisation through experimentation under the Test and Evaluation (T&E) dimension.

M&S-based experimentation will serve as an objective platform to provide the digital probing ground for testing and experimentation of new warfighting concepts to meet the requirements of the 21st century.

New concepts and technologies can be appropriately 'modelled' and represented in simulation for experiments configured and conducted in a 'Synthetic Theatre of War'. Such capability also permits inexpensive evaluation of innovative concepts and technologies to determine their operational utility and payoffs prior to development, fielding and implementation.

Figure 12. VSS21 Thrusts

Notwithstanding the emphasis on the T&E dimension, VSS21 will also see the large-scale implementation of the concepts pioneered under VSS2000. In addition, technology envelopes will continue to be pushed with every M&S implementation, and several initiatives are already underway.

New Initiatives

Underlining the importance of M&S-based experimentation, the SAF set up the SAF Centre for Military Experimentation (SCME) in November 2003. Dubbed the 'key to the SAF of the future' by the Minister for Defence Teo Chee Hean (The Straits Times, 2003), the SCME will leverage M&S technologies and tools to conduct experiments on new warfighting concepts and innovative technological capabilities.

In the instrumentation domain, with the ACMI and FISTS already operational, efforts are now centred on fielding the Battlefield Instrumentation system for the Army as well as the possible instrumentation of the RSAF's Air Defence assets. The ultimate goal is to integrate all these systems to realise the objective of conducting tri-service and inter-service training. These instrumentation systems will allow the SAF to capture events and data in the battlefield and provide a good mechanism, in the form of after-action reviews, for improving doctrinal procedures and operational processes.

Another flagship of VSS21 will be the Air Mission Trainer (AMT). A network of low-cost pilot fly-boxes and mini-domes, the AMT will further elevate the RSAF's training realism. Not only will pilots be able to rehearse their combat missions to simulate the conditions they will face, they will also be able to fight while they train in simulated conditions. The AMT will also provide the mechanism supporting a fully-integrated environment which can accommodate the full spectrum of training - from the individual level up to campaign level mission rehearsal, through electronic links to the operational C2 systems.

Yet another flagship system belonging to the Army will also be implemented under VSS21. The Infantry Gunnery Tactical Simulator will be a new generation, immersive virtual simulation system which will train battalion commanders and their principal staff officers in battlefield planning, co-ordination and execution skills.

Technology Trends

Graphics Technology - Graphics technologies will continue to grow at a relentless pace. For example, SGI, for all its good work in the 1990s, has already been outpaced in recent years by the emergence of a new class of commodity PC-based graphics, commonly referred to as PC-IGs, and the accelerated advances in 3D graphics processor technology. Even then, new signs have already emerged and the IG technology is again on the brink of another change - from PC-IG 'boxes' to PC-graphics cards. Again, in line with the faster, cheaper, better, and COTS mantra, the SAF and DSTA have already begun moving towards PC-IGs, and where possible, PC graphics cards (see Figure 13).

One of the direct benefits of the move towards PC-based IGs is the attendant reduction in cost, size and weight of systems. For example, the visual capability provided by a compact PC-based IG today would have required a six-foot tall rack of equipment a few years back. The fall in price is equally dramatic. While a compact, state-of-the-art PC-based IG can be purchased for US$25,000 or less, the traditional IGs of yesteryears would have cost US$250,000 or more (The Straits Times, 2003).

Composable Simulations - In the new era, not only will there be greater proliferation of M&S, there will also be ready access to M&S as a service. This will be achieved primarily through composable M&S architecture and standards to promote the reuse of M&S models and components. The impetus is to allow M&S synthetic battlespaces to be configured rapidly in a Lego-like fashion for the purpose of experimentation and wargaming.

We have seen various initiatives in the US such as the Defense Modeling & Simulation Office's Composable Mission Space Environment (CMSE)[4], the Models Driven Architecture (MDA)[5] and

Figure 13. PC-based IG and PC Graphics Card (Images Courtesy of Quantum3D(r) and nVidia(r))

the Extensible M&S Framework (XMSF)[6]. DSTA also embarked on JEWEL (Joint M&S Environment for Wargaming and Experimentation Labs) as the framework and means to attain composable simulations for the SAF (Figure 14).

Convergence of Computer Game Technologies and Military Simulation - Although military simulation and computer games appear to have a lot in common, they have traditionally been developed very differently.

On one end of the spectrum is military simulation where the focus is on complex and realistic high fidelity simulation to attain maximum learning transfer.

On the other end are low-cost games with lower fidelity but highly compelling content (though with PC graphics cards becoming more powerful, PC games have demonstrated an ever-increasing degree of realism). The focus is on fun and entertainment through engaging creative content.

The new M&S era will see applications bridging the gap, together with the infusion of computer game technologies into military simulation, to attain the balance of training value and fun.

Not only will such hybrid solutions continue to provide realistic training as desired, they will also engage our soldiers in the emotive domain where interest, thrill and excitement are key elements. This is what we call Experiential Simulation. Studies have shown that such applications can enhance learning transfer (Wigforss, 2002).

Recognising this potential, DSTA has begun to harness innovative technologies from the entertainment industry as a supplement to conventional military training methods. For example, DSTA, together with the Army, has adapted a military-themed COTS game called Operation Flashpoint (OFP) for both training and experimentation (Figure 15). The 3D models depicting our soldiers, vehicles

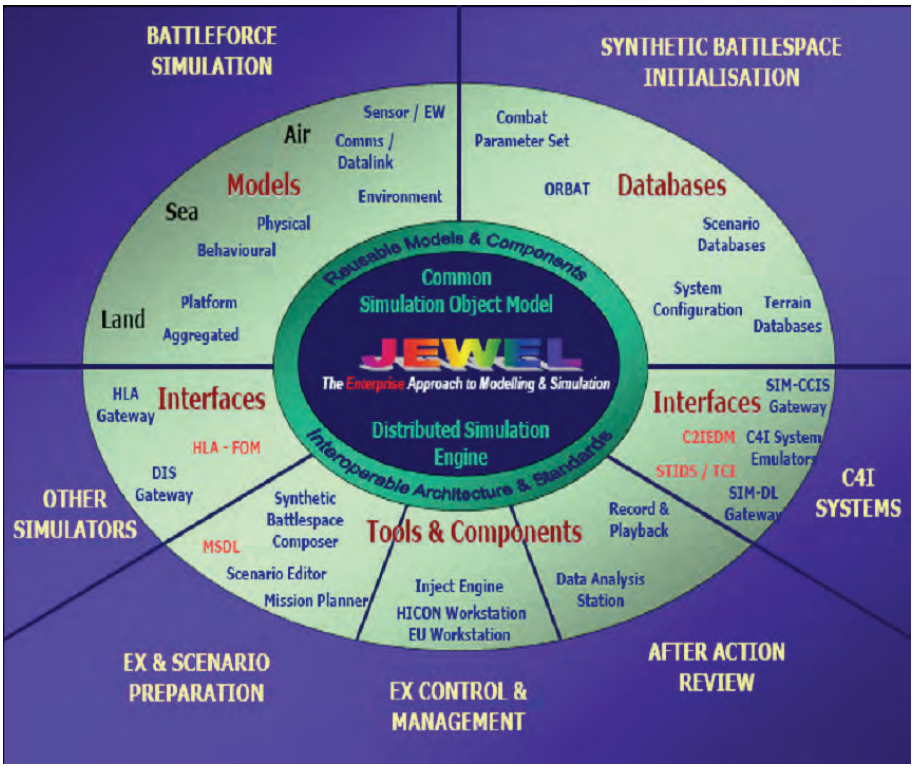

Figure 14. JEWEL Framework

Figure 15. Operation Flashpoint customised for SAF

as well as local terrain, were developed to customise OFP for the SAF. The results and feedback from the soldiers have been positive (Fong, 2005).

In another development, DSTA and the Army also collaborated with the Institute for Creative Technologies to custom build two new games, Full Spectrum Command and Full Spectrum Leader (Figure 16). Targeted at company commanders and platoon commanders respectively, these games aim to train cognitive skills, tactical decision making, resource management and adaptive thinking, through realistic yet fun and entertaining game-play. Both games are currently being evaluated for their training effectiveness.

Other technologies from the computer game industry such as creative storytelling techniques and multi-player online games will also be researched and adapted, if possible, for suitable military application.

Figure 16. Full Spectrum Leader

COMING OF AGE

M&S in the SAF has evolved tremendously over a short span of time. From pioneering implementation by pushing the edge through two decades of innovation, the SAF now stands on the brink of another evolution in the new millennium. In short, M&S in the SAF has matured and looks set to be the key enabling technology for the 3G SAF and its transformation efforts.

ENDNOTES

1 The area of Singapore is generated from the Lot Base System based on the Cadastral maps as at 8 January 2005. (www.singstat.gov.sg.)

2 In 2002, there were 40,864 births, down from 41,451 births in 2001. There were 31,171 births in the first nine months of 2003, versus 33,618 in the same period last year. (The Straits Times Interactive, Government Exploring 'Total Solution' to Baby Shortfall, 15 December 2003)

3 Artillery on the Web (www.mindef.gov.sg/army)

4 The goal of CMSE is to identify issues related to composability to target the related efforts and research that will lay the groundwork for increased reuse and improved ability to compose simulations more rapidly, flexibly, and efficiently. (www.sisostds.org)

5 MDA defines an approach for designing and building component-based systems that remain decoupled from the languages, platforms and middleware environments that are eventually used to implement the system. The resulting components would be compliant to interfacing standards and reusable across multiple execution platforms (for example, Simulation Engines). (www.sisostds.org)

6 The XMSF is the initiative in advanced distributed simulation to exploit emerging web standards and web services model. XMSF will comprise a composable set of standards, profiles and recommended practices for web-based modelling and simulation. XMSF, embracing commercial web technologies as a shared-communications platform, can fully leverage mainstream practices for enterprise-wide software development. (www.movesinstitute.org)

REFERENCES

Defense Modeling and Simulation Office (1994) DMSO M&S Master Plan. https://www.dmso.mil/public/dod/policy/

Fong, Gwenda (2005) Adapting commercial of-the-shelf games for military simulation. In DSTA Horizons 2005.

The Straits Times (2003a) Government exploring 'total solution' to baby shortfall. 15 December 2003.

The Straits Times (2003b) SAF virtual mission battleground ready. 6 November 2003.

Undersecretary of Defense for Acquisition and Technology Memorandum (1996) Department of Defense High Level Architecture (HLA) for Simulations.

Wigforss, Eva (2002) Learning through computer games: transfer of knowledge. Presented at the PROMETEUS Conference, 29-30 September 2002.

BIOGRAPHY

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