Modelling & Simulation-Based Acquisition Decision Support: Present & Future

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Abstract

The Ground Based Air Defence System (GBADS) Programme, of the South African Army has been applying modelling and simulation (M&S) to provide acquisition decision and doctrine development support. The purpose of this paper is to discuss these M&S activities that have contributed to the GBADS programme over the years and to look specifically at the future role of M&S within the Joint Air Defence (JAD) environment. Examples of simulation studies and field exercises in support of doctrine development during the acquisition process are presented. The paper highlights some lessons learnt and some insight into where M&S could contribute in future. The paper concludes by discussing the way forward for M&S within the GBADS programme with specific reference to Project FELLOWSHIP.

1 Introduction

Traditionally the main acquisition focus has been on procuring the 'tangible' product system, often neglecting the impact of the emergent behaviour that results from the interaction of one system on another or the interaction of the operator on the system performance. The change in focus implies a system of systems approach, requiring the early development and alignment of tactical doctrine, and the modelling of complex operator and system behaviour.

The GBADS acquisition program of the South African National Defence Force (SANDF) offered an opportunity to apply M&S as a decision support tool. This move is in line with international acquisition reform in its increased utilization of M&S to reduce program risk. The CSIR's systems M&S capability is being used to assist in concept evaluation and concurrent tactical doctrine development. The Virtual GBADS Demonstrator (VGD), developed for this purpose, provides a virtual environment for deploying GBADS entities in a defined scenario to observe the behaviour, as well as interactions between these various entities of a user system, comprising a products system and human operators. Using VGD as a decision-support tool, tactical doctrine is developed to improve the operational effectiveness of the future user system.

Whilst M&S was applied in various roles during GBADS acquisition, this paper focuses on the contribution M&S made specifically towards acquisition decision and doctrine development support. It forms part of a series of papers and presentations addressing the topic. Oosthuizen [1] has shown the importance of doctrine development during the acquisition phase, and how M&S can be used as a support tool. Baird and Nel [2] looked at the changing role of virtual environments through the acquisition life-cycle, Combrink and Nel [3] address the M&S based acquisition life-cycle from a systems engineering approach. Le Roux [5] addressed the virtual environment aspects in more detail. Naidoo and Nel [6] detailed the process followed and the incremental validation of the tactical doctrine within a virtual environment.

2 M&S Within the Acquisition Life Cycle

A simplified representation of the armaments acquisition system life cycle, used for South African defense procurement and management, is depicted in Figure 1.

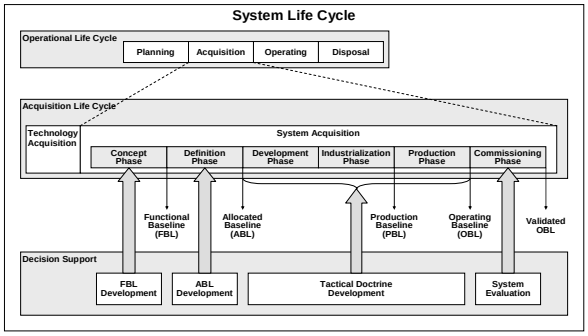

Figure 1: System Life Cycle [7]

Traditionally the main focus has been on procuring the "tangible" Products System, often neglecting the impact of the operator on system effectiveness. The change in focus toward acquiring User Systems implies a system of systems approach, requiring the "early" development and alignment of tactical doctrine.

Decision support is divided into classes of analysis as indicated in Table 1. Each of these classes is paired with a life cycle phase (refer to Figure 1).

Table 1: Classes of analysis during support phases

		Classes of Analysis				
		Performance Specification	Performance Trade-offs	Performance Development	Performance Prediction	Performance Optimization
Life Cycle Phases	Concept Phase	X				
	Definition Phase		X			
	Design, Industrialization, Production			X		
	Commissioning				X	
	Operating				X	X

2.1 Performance Specification

This type of analysis serves to determine the effectiveness of alternative system configurations against predefined threat scenarios. Effectiveness serves as input to Cost and Operational Effectiveness Investment Analysis (COEIA), which results in the "make" or "buy" decision of a specific system option. It also serves to establish a broad base of expected performance and the Functional Baseline (FBL) is set and forms the basis of the tendering process.

2.2 Performance Trade-offs

Trade-off analysis during the Definition Phase entails the evaluation of different technical solutions, with regard to effectiveness, in order to support the Acquisition Program Team (APT) in the tender evaluation process and establishing the Allocated Baseline (ABL) for contracting purposes.

2.3 User System Performance Development

Decision support during the design, industrialization and production phases focuses on User System optimization and preparations for Operational Test and Evaluation (OT&E). These activities have a strong doctrine bias, and may be regarded as User System development, concurrently with the Products System. In this manner it is ensured that operator documentation and training curricula are developed with due cognizance of the doctrinal impact on system employment.

2.4 User System Performance Prediction

The purpose of the OT&E activity is to verify that the User System meets the FBL. This performance assurance activity is conducted in an incremental manner, progressing through sub-system, product and system acceptance, and culminating in an in-field OT&E activity with end user participation, thus ensuring that the Products System is evaluated under representative operating conditions. M&S is applied to predict system performance and to evaluate tactical doctrine for OT&E purposes.

2.5 User System Performance Optimization

M&S is applied to optimize system performance through exploiting latent User System characteristics and tactical doctrine enhancement during the Operating Phase as part of a continuous improvement process. M&S is also applied to evaluate the impact of proposed sub-system or product upgrades on User System performance.

3 The M&S Virtual Environment

The VGD is an in-house suite of software that provides for the deployment, simulation and analysis of virtual entities within a defined scenario to observe the behavior and interaction between the various operators and their related subsystems within a GBADS deployment. The VGD architecture supports the distributed simulation of many-on-many engagements. The behavior of equipment and operators is modeled, as well as the interaction between these entities.

VGD can function as both a virtual and constructive simulator. For virtual simulations Operator in the Loop (OIL) consoles allow human operators, from battery-level to detachment-level, to interact with the real-time simulation in order to evaluate various doctrinal concepts from within the virtual environment. An example of the Battery Fire Controller Human Machine Interface (HMI) is shown in Figure 3. Constructive simulation is used for statistical analysis and evaluation of emergent behavior at battery level.

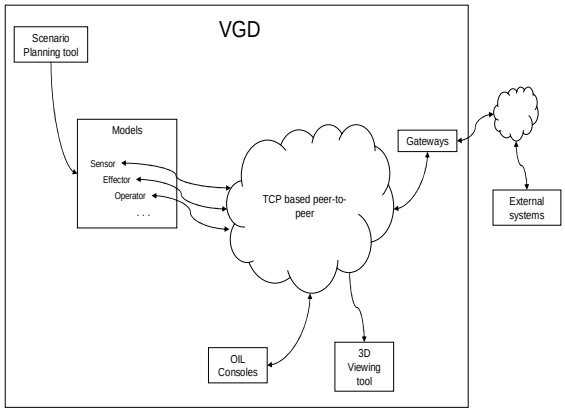

Figure 2: Architectural Overview of VGD

In real-time mode the architecture supports the integration of VGD with operational systems via gateways (shown in Figure 2) allowing a live air picture to be imported into the simulation. It thus allows tactical doctrine to be tested through the active participation in live exercises.

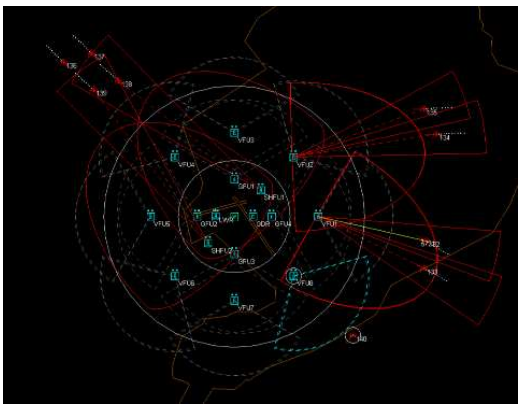

Figure 3: Screenshot of an OIL Console

A scenario-planning tool is used to create scenarios consisting of each of the GBAD entities to be simulated. An example deployment of a battery is shown in Figure 4.

3D visualization is used for real-time viewing of a scenario, as well as after action review. 3D visualization, specifically for complex scenarios allows for the detailed analysis of events and object interaction. A 3D view of a threat scenario is shown in Figure 5.

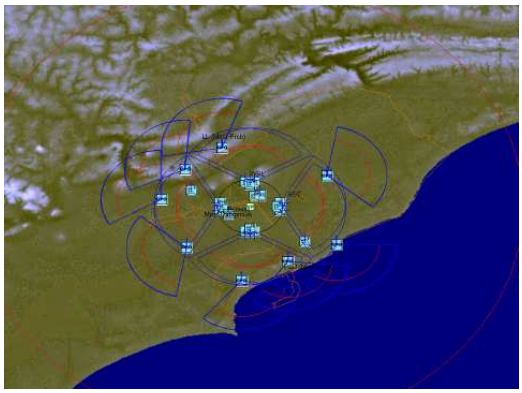

Figure 4: Screenshot of the scenario-planning tool

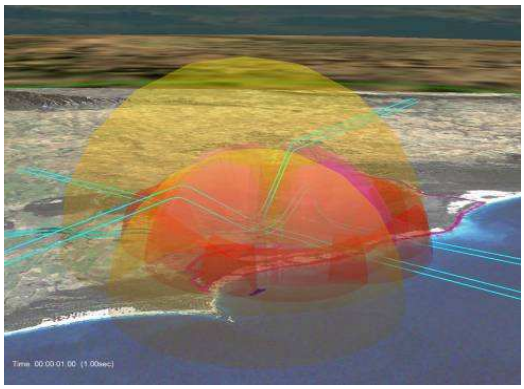

Figure 5: Screenshot of 3D visualization tool

4 M&S Applied to Support GBADS Doctrine Development

Doctrine development is an iterative process, proceeding through various phases resulting in promulgated doctrine as a final state. As the development proceeds through each phase, the draft doctrine is evaluated, tested and updated before proceeding through subsequent phases.

Drew [8] states that the structured steps of a research project provide a framework for the development of doctrine. These steps, according to Drew [8], are: devise a research question; devise a research plan; gather the required data; analyze the data; in light of the data formulate and evaluate potential answers to the research question; in light of the data, identify the best answer; and, finally, write and publish the research report.

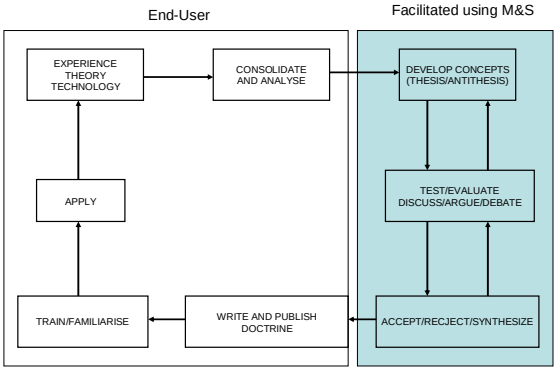

Figure 6: Procedure for doctrine development (adapted from [8])

The basic process for applying M&S to support doctrine development follows a similar approach to that discussed by Drew (shown in Figure 6) with some slight modifications. The activities to the left of the process diagram are end-user driven and typically occur after hand-over of the User System. The focus is on the highlighted area where iteration occurs between concept development, concept evaluation and testing, and concept acceptance/rejection. The basic process is repeated during three stages of the doctrine development process, resulting in a spiral process as depicted in Figure 8. The basic stages of the doctrine development process are:

- Initial drafting and validation of conceptual doctrine
- Validation through virtual simulations
- Validation through involvement in field exercises

4.1 Drafting and Validation of Conceptual Doctrine

This is a preparatory stage where current doctrine and system-specific technical information provide the embryo inputs to the doctrine development process. Doctrine is the formalization of "common sense". For doctrine to be developed an environment needs to be created for the soldier to develop this "common sense". During this important initial phase system characteristics and current doctrine are captured in VGD and through experimentation the "common sense" is developed.

Existing tactical doctrine, in conjunction with the system characteristics, is critically evaluated by the end user Doctrine Development Task Group (DDTG) and specific areas of focus identified. Areas for analysis are prioritized and sets of experiments are defined to evaluate the existing doctrine, and alternatives, within the VGD environment.

Examples of such areas are:

- Threat Evaluation and Weapon Assignment
- Fire Distribution
- Rules of Effective Engagement
- Deployment Considerations

Results are presented to the end user for analysis and if necessary, the doctrine may be updated. Once again the cycle continues with the implementation of the updated doctrine within VGD and further experimentation.

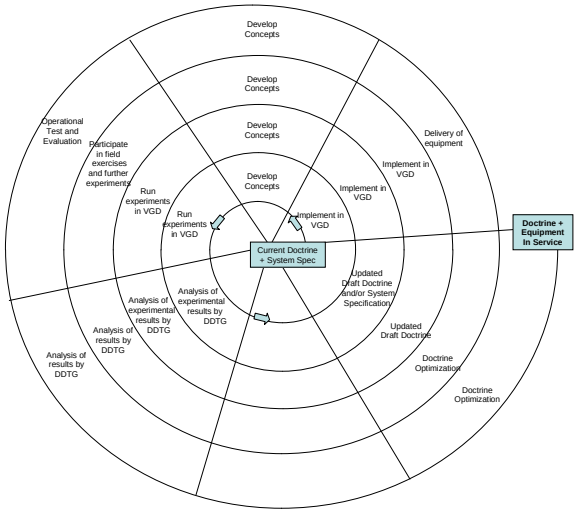

Figure 7: The Doctrine Development Spiral

4.2 Validation through Virtual Simulations

Using virtual simulations it is possible to immerse operators into scenarios to apply procedural doctrine and to optimize roles and responsibilities. The OIL terminals allow actors at different levels of the battery to procedurally control air defense activities. Other entities still function automatically, in predictable ways, allowing for the testing of concepts without requiring large numbers of people.

The OIL-based experiments also serve to highlight shortfalls in doctrine. Figure 8 shows an example of an experiment with a single actor interfacing at level of Batery Fire Control Post with the simulation of GBADS.

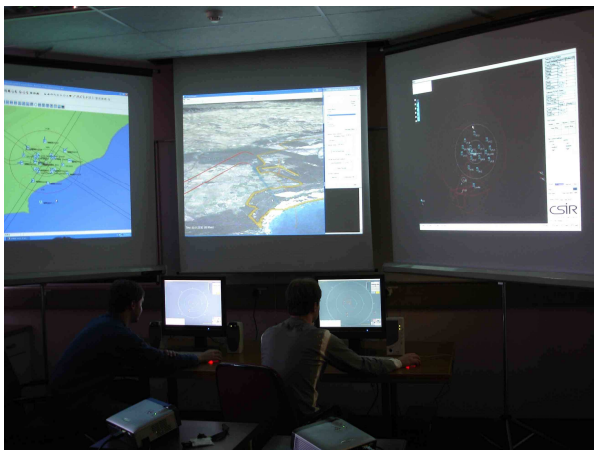

Figure 8: Operator in the Loop Experiment

4.3 Validation through Involvement in Field Exercises

While doctrine is initially formulated, developed and validated using M&S within the laboratory environment, the validation of doctrine during a live field exercise is a critical next step in the process. The non-availability of a Products System necessitates the use of M&S during such exercises.

Figure 9: Mobile Simulation Facility

By integrating VGD with the operational system, the yield of exercises carried out at this phase of the development cycle is optimized. VGD provides the facility to simulate the planned acquisition systems in real time during an exercise. By importing the real time air picture into the simulation, a trained Fire Control Officer (FCO) is able to perform fire control on a virtual GBADS battery against real aircraft, exercising the draft doctrine developed by the DDTG.

Exercises conducted by the SANDF offered such an opportunity to integrate VGD with the live operational system within a JAD environment and thereby test and evaluate various doctrinal concepts.

A mobile facility was fitted with the equipment necessary for VGD to run at such a field exercise and the Mobile VGD (MVGD), depicted in Figure 9, was integrated with the live command and control system.

The aim of participating in such a JAD exercise was primarily to demonstrate the integration of VGD with other operational systems and import the live air picture into the simulation so the virtual GBADS battery can engage live targets from within the simulation environment, thereby exercising draft doctrine.

Since doctrine is an essential component of deployment and planning, an appreciation was performed as part of an Air Defence Artillery (ADA) Battle Appreciation course held at the CSIR taking into account the local terrain, the defended asset and expected threat approach directions. Parameters such as effector lines were calculated as defined in the draft doctrine. This resulted in a GBADS battery layout that was deployed within VGD. Since deployment planning and battery layout has a significant effect on the performance of the system, experiments were run using simulated threats to evaluate the expected performance of the proposed layout before the actual live exercise was conducted. The simulated threat elements were then removed and the simulation integrated with the operational system. The air picture was imported into VGD in real time and fire control was exercised within the virtual environment, with a simulated FCO and then with a trained human FCO interacting with the simulation through the OIL terminal.

Although until recently the primary focus of VGD has been GBADS, such exercises also allowed for specific JAD doctrine and its impact on the GBADS domain to be tested and evaluated. In particular, the dynamic transfer of Weapon Control Orders (WCOs) within the JAD environment was evaluated during the most recent exercise conducted. During an exercise, WCOs are decided upon by the JAD executive and sent to each of the forces over a voice communications link. In the GBADS environment, the FCO must observe the WCO for engagement planning. VGD was configured to allow the FCO to set up WCOs received from JAD at GBADS level.

The data logging facility of VGD was used to record a complete exercise and the exercise was reviewed using the 3D viewing tool. This provided the various SANDF personnel an opportunity to review and visualize the interaction during an exercise thereby facilitating a discussion among the various subject matter experts.

Using M&S together with live exercises allowed the user to evaluate draft doctrine in a representative operational environment concurrently with system acquisition.

5 Future role of M&S for Acquisition Support

There is an increasing focus on the application of JAD to operations other than war (OOTW). This changing operational environment must by necessity incorporate the reality of the civilian presence in many forms, in addition to a large number of interconnected systems and variables that include several other safety and security agencies. Noncombatant entities typically outnumber combat entities, and more now needs to be learned about noncombatant activity than traditional direct force-on-force activities.

Today's joint exercises need to mix live activities (pilots flying, civilian air traffic, etc.) with simulated activities, often seamlessly and often with participants not even knowing or caring which targets are real and which are simulated. Detailed mission-rehearsal simulations are now becoming an essential of operations planning generally, as are simulations of mobilization, deployment, maneuver, and logistics. Today's defense-planning analysis need to draw on end-to-end simulations of how joint forces would actually be employed in hypothetical scenarios.

A new generation of M&S is therefore needed to support concept development linking together many types of simulations, from aggregate and detailed computer models to simulators and OIL hardware components. If we consider the complex nature of warfare, then we must exploit the use of field exercises as a part of the simulation.

This does not mean that all M&S activities should focus on complex, dynamic, adaptive systems or networks but means rather that it should be considered when developing and exploiting M&S for analysis and operations. GBADS Phase 3 acquisition is currently applying M&S based decision support during the Project Study phase. The objective of Phase 3 acquisition is to enhance GBADS capability effectiveness through optimisation of the BMC4I (Battle Management, Command, Control, Computers, Communications and Information) element of GBADS. Phase 3 acquisition requirements and the experience gained during the earlier phases of the GBADS project indicate that the current VGD architecture should be extended to cope with this added complexity [9]. As such, a simulation environment that is tailored to incorporate these various elements needs to be created. Of course, this environment must be an extension of the current architecture. This approach would result in a new simulation using the upgraded VGD architecture that interoperates with the existing environment and merely adds to it. Furthermore, the simulation environment must be capable of stimulating and evaluating real equipment, systems or systems-of-systems with simulation. This involves either replacing real equipment with simulated counterparts or injecting simulated data into the real systems. This will allow M&S to contribute to Command Post Exercises (CPXs) where operations centres (or crisis centres) can exercises with real or simulated events or information.

This upgraded VGD simulation environment is still under development. It has however already been used successfully during a recent JAD exercise held at Roodewal Test Range. The framework is also gaining momentum with several new SANDF projects planned to take advantage of the capabilities of the framework. The framework inherently benefits from this momentum, maturing in parallel at the pace set by the projects that make use of it. The upgraded VGD framework is a suitable framework to support all the M&S based decision support activities within DPSS

6 Conclusion

Whilst M&S has been successfully utilized for acquisition decision support, the changing operational environment has necessitated a revision of the architecture of the simulation environment.

This paper has presented the use of M&S as a means to support the acquisition process. In particular, it has focused on the contribution of M&S towards doctrine development concurrently with the acquisition process. New requirements for continued future application of M&S for acquisition decision support have been outlined.

M&S ensures that the end user is equipped to efficiently put into service the new acquisition as soon as it is available, as the doctrine is already in place. Clearly, final validation takes place through application, and the need for the M&S environment to include live systems with simulation has been highlighted.

The VGD/MVGD is available as a decision support tool for doctrine optimization during the operating phase of the system life cycle once GBADS has been handed over to the end user.

7 Acknowledgements

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