Modelling Joint Air Defence Doctrinal Issues with a LinkZA-based Integration of two C^2 Simulators – A Case Study

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Abstract

This paper describes the integration between two command and control simulators in order to clarify doctrinal issues surrounding Joint Air Defence using as example the uncertainty of roles and responsibilities between the Air Defence Cell of the Sector Control Centre and the Fire Support Coordinating Centre of the Tactical Head Quarters. It illustrates the feasibility of clarifying this uncertainty by integrating the BattleTek Constructive War Simulation (from CyberSim) with the Virtual Ground Based System Demonstrator (from CSIR). It further discusses integration using an existing interface standard, LinkZA, and concludes with some recommendations for the standardisation of scenario definitions.

Introduction

Although different Command and Control (C^2) simulators have been developed and are being maintained independently within the South African Defence environment, they are operated at different systems levels and fidelity. These simulators tend to support either constructive or virtual simulations, and in some cases, both modes.

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[1] Defence, Peace, Safety and Security (DPSS) is an operating unit of the Council for Scientific and Industrial Research (CSIR) in South Africa.

[2] CyberSim (Pty) Ltd is an IT company, developing unique software solutions for clients in the domains of Constructive Simulation, C^2 Systems, Software Planning Tools and Disaster Management Simulations and Operational Software.

In order to determine the feasibility of using more than one simulation to assist in clarifying current doctrinal issues, a task was undertaken to integrate two simulators: the Virtual Ground-Based Air Defence System Demonstrator (VGD) developed within the Defence, Peace, Safety and Security (DPSS) Operating Unit of the CSIR and BattleTek developed by CyberSim. This paper reports on the approach followed, the results achieved and concludes with some recommendations around the standardisation of certain aspects pertaining to C^2 simulations. Standardisation would allow similar work to be performed in future making use of even more simulators or simulations and potentially operational systems.

Before addressing air defence doctrinal issues, the two simulators that are integrated are presented with condensed descriptions of the relevant air defence systems, structures and doctrine. Finally the paper is concluded with some recommendations.

Virtual GBADS Demonstrator

The VGD [3] is a suite of software that provides for the deployment, simulation and analysis of virtual entities within a defined scenario to observe the behaviour and interaction between the various operators and their related subsystems within a Ground-Based Air Defence System (GBADS) deployment. The VGD architecture supports the distributed simulation of many-on-many engagements. The behaviour of equipment and operators is modelled, as well as the interaction between these entities.

Figure 1 shows the primary run-time components of VGD. Models include all equipment and (modelled human-) operator software models whereas services include terrain, line of sight and logging services, amongst others. Consoles are dedicated to specific operator interfaces such as fire control operator interfaces. Each Gateway is dedicated to a specific protocol such as LinkZA or Asterix to interface to external systems such as the Air Picture Display System (APDS).

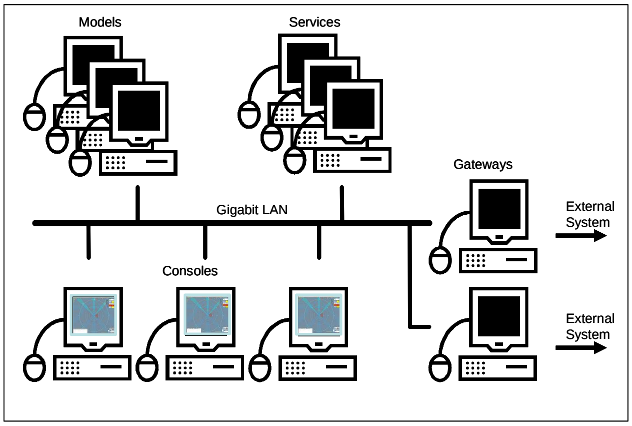

Figure 1: Virtual GBADS Demonstrator

VGD can function in both virtual and constructive simulation modes. For virtual simulations Operator in the Loop (OIL) consoles allow human operators, from battery-level to detachment-level, to interact with the soft real-time simulation in order to evaluate various doctrinal concepts from within the virtual environment.

VGD was developed in response to the need for acquisition decision support of the GBADS acquisition programme of the South African Army. It is currently being applied in both Phase 1 and Phase 2 of the acquisition programme.

BattleTek

BattleTek [1] is a Constructive War Simulation product from CyberSim (Pty) Ltd. The main application of the system is to support war simulation exercises on the higher and lower tactical levels of command.

The system provides comprehensive simulation support in terms of land, air and naval-based warfare activities. A key characteristic of the system is the flexibility in application, the ease of software maintenance and expansion, and the utilisation of standard hardware components. The System was developed in order to provide a user extensible Simulation System suitable for a wide range of training applications and exercise types.

The System has been designed to provide a user-friendly interface promoting ease of operation and maintenance and is based on commercial quality computer equipment (desktop or laptop) but ensures System availability by means of freely interchangeable stations. The System can be used in a standard office environment, as depicted in Figure 2.

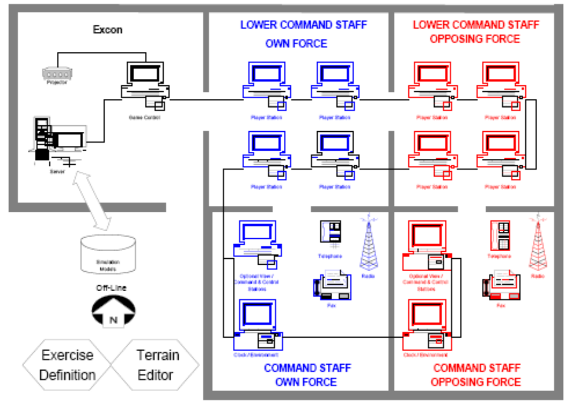

Figure 2: BattleTek System Layout [1]

BattleTek caters for exercises at division, brigade and battalion level for any number of forces and / or groupings. BattleTek caters for two simulation modes, namely, single entity (vehicle or weapon system) modelling and statistical modelling of aggregated entities.

Air Picture Display System

The APDS is a system that combines the input of various radar sensors, in order to display an integrated situational awareness picture of the airspace of interest. This air picture is aimed at satisfying civil and defence related needs. The APDS provides the situational awareness through the Joint Air Defence (JAD) structure. VGD is equipped with dedicated Gateways to accept aircraft tracks as either LinkZA or Asterix protocol messages from the APDS and to create virtual aircraft from the tracks that may be engaged by virtual sensors and effectors in VGD.

LinkZA

LinkZA has been established to support the exchange of tactical information for the C^2 of joint operations [9]. It is a tactical data link standard that allows:

- Awareness information communications
- Free text messaging
- Video frame message communications
- Link control
- Radio interfacing
- Networking

Joint Operations

Joint Operations (J OPS) is responsible to the SANDF to conduct missions as depicted by the Military Strategy and the Force Employment Strategy, in accordance with doctrine captured in Joint warfare Publications (JWP).

The Joint Operations Divisional Headquarters (J Ops Div HQ) plans, directs, monitors and co-ordinates the sustainment of all operations at the military strategic level. The Joint Operational Headquarters (J Op HQ) conducts operations at the operational level. A Joint Task Force Commander (JTFC) is appointed by Chief of Joint Operations (CJ Ops) and is assisted by the Joint Task Force Headquarters (JTF HQ). Within the J OPS organisation, the JAD Commander (Cdr) and associated staff are responsible for air defence.

For the purpose of this paper the focus is on a generic command affiliation where both the JAD structure in the form of a Sector Control Centre (SCC) and JTF in the form of a THQ is deployed. Where possible the generic make-up of these structures was used.

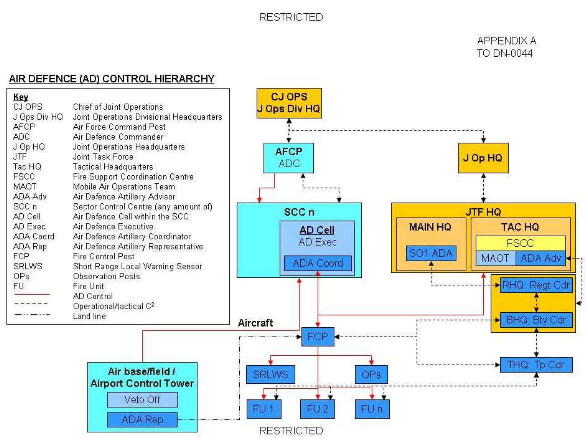

Figure 3: The Air Defence Control Hierarchy.

Figure 3 shows the complicated interaction between the SCC and JTF HQ. It will become evident that air defence resources are not under full operational command of the JTF HQ.

Ground Command & Control (GCC) Structure

A surface battle is under command of a Ground Command and Control (GCC) Structure, in the form of a JTF HQ, which consists primarily of a main head quarters which is the brain of the formation and is therefore primarily responsible for the planning and control of operations. Should a commander deem it necessary to have close direct control over a specific battle part of the operation, a tactical head-quarter is deployed as an element of the main headquarters. The rear and home HQs focus more on logistical and other support functions. These roles are depicted in Figure 4.

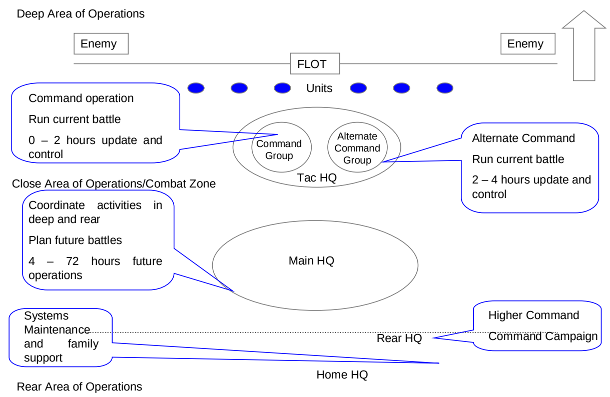

Figure 4: GCC Structure

Composition of the Tactical HQ

The Tactical HQ [6] is an element of the Main HQ, and is deployed when the GCC commander feels it is necessary to directly control a specific part of the battle. The Tactical HQ consists of a Command Group and Alternative Command Group. The Alternative Command Group takes control should the Command Group not be able to exert control due to some eventuality. The Fire Support Coordination Centre (FSCC) is situated at the Tactical HQ, if deployed.

The FSCC is where sources, equipment, communications and personnel are grouped to provide FSC (Fire Support Coordination) and is normally placed close to the commander of the ground forces. The FSCC Structure is shown in Figure 5.

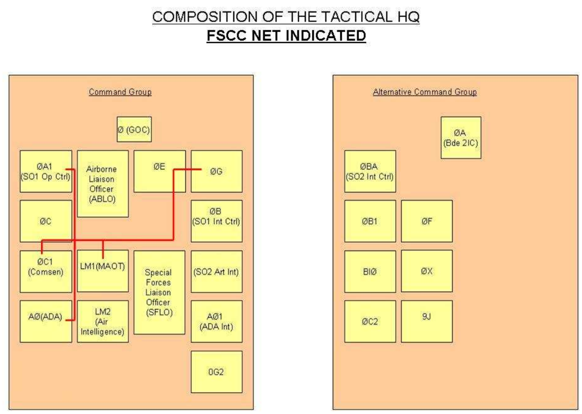

Figure 5: FSCC Structure

Figure 5 shows the interaction of entities of the Command grouping forming a virtual structure called the FSCC. When deployed statically, these entities will group close to the OG (Artillery Cdr). When moving tactically, the members will remain in communication with each other.

The coordination of fire is of utmost importance as part of the commander's execution of his plan. Sources of fire are:

- Direct fire sources.
- Indirect fire sources.
- Air delivered weapons.
- Naval gunfire support.

The primary function of the FSCC is the compilation of the complete fire plan and the subsequent exercising of centralised control over the available fire support resources. This entails both ground and air-borne weapons. Its functions as summarised from [8] are:

- The complete joint fire planning of ground and air weapons. This planning takes place from the initial planning stage.
- Exercising centralised control over the available fire support sources.
- Continuous evaluation of the battle situation and the commander's fire support requirements.
- To act as the commander's advisers iro the various elements.
- Allocation of suitable fire support resources.
- Co-ordination, utilisation and control of all fire support resources.
- Deployment and movement of both ground and air observers.
- Air space control.
- Safety of aircraft, therefore fulfilling the task of control and reporting post.
- Safety of ground forces,
- Anti-aircraft and all arms anti-aircraft control.

Members of the FSCC, representing the different sources of fire, typically include [6]:

- Army representative (SSO Artillery, acts as commander of the FSCC, and his staff).
- ADA Representative (ADA Regiment commander or most senior ADA officer).
- SO1 Air (Air Liaison Officer (ALO)).
- Air Force Representative (Mobile Air Operation Team (MAOT)).
- Navy Representation (Mobile Navy Operation Team (MNOS) if Naval vessels are required for Ordnance support).

The MAOT is mainly concerned with Intelligence and Own Forces Air Operations in the AOR (Area of Responsibility). It has a very limited involvement in coordination of JAD activities between the GCC AD resources and SCC (Sector Control Centre) although the commander of the MAOT is ultimately responsible for the safety of own aircraft.

The commander of the MAOT and ADA Representative participate in the JTF commander's planning cycle. Both of them will provide "air planning" requirements in the absence of other representatives of the Air Force. The role of the ALO is primarily during the planning phase to liaise and convey air support requirements from the THQ to the Air Force Command Post (AFCP).

Joint Air Defence Structure

In South Africa, air defence is controlled through a JAD structure (Figure 6). Operational control of JAD is dependent on the mission and task of CJ Ops. For the purpose of this paper, it is assumed that the SA Army AD resources is under full operational command of the GCC.

JAD doctrine recognises that as an element of a Task Force, deployed land based AD units are subject to FSC Measures (FSCMs) deriving from the FSCC, which is responsible for planning, coordination and control of fire support resources. FSCM management is a command function, handled via the command channel, which ***may*** influence AD Control.

JAD is centralised under a Sector Control Centre (SCC), directly subordinate to the Joint Air Command Post (JACP), established under the auspices of CJ Ops. SCCs could be static or mobile but functions identically in all aspects. The SCC is ultimately responsible for airspace control during a war situation for its specific sector. Although it controls air defence and offensive activities through controlling complexes (previously known as cells [7]), the air defence structure is of importance for the purposes of this paper.

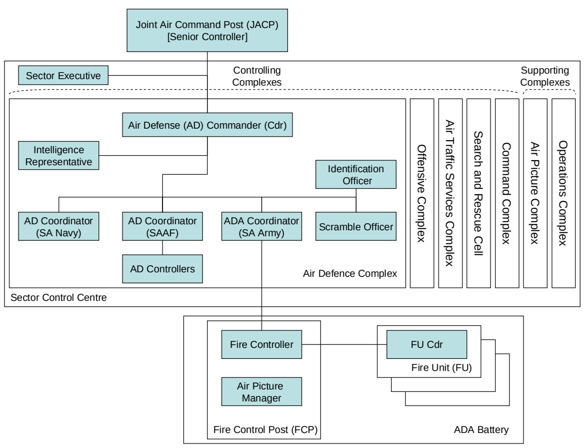

Figure 6: Joint Air Defence Structure

The functions of the SCC with regard to AD are as follows:

- Compilation and maintenance of the Recognised Air Picture (RAP).
- Dissemination of the relevant portion of the RAP to surface-based AD elements deployed in the AD sector.
- Issuing Early Warning Reports on targets approaching the AD element AOR and which have not been identified as friendly.
- AD Control of all AD weapons in the sector.
- Activation and control of airborne AD intercept missions.
- Directing in-flight fighter aircraft towards selected targets (mission control).

AD Complex

Within the Air Defence (AD) Complex is an AD Commander (AD Cdr) (previously referred to as the AD Exec [7]) who receives orders directly from the JACP and is responsible for all activities of the AD Complex. AD Coordinators forms the intermediate level between the AD Cdr and mission controllers while the ADA Coordinator serves this function between the AD Cdr and the ADA Battery (through the Fire Control Post). The other roles and complexes are of lesser interest for the purposes of this exercise.

The AD Complex in the SCC is responsible for the control and allocation of all airborne and surface-based (naval and ground-based) AD resources in order to ensure an optimised defence and safety of own forces.

The AD Cdr is an Air Force officer on the staff of the SCC and is responsible to the SCC Cdr for the control and allocation of AD resources. The Sector Cdr is in command of the AD Cell and has the following responsibilities:

- Issuing AD control measures, including Air Raid Warning States, Weapon Control Orders, Air Defence Zones, etc.
- Allocating the most appropriate (effective) AD resource to counter the threat.
- Disseminating the relevant portion of the RAP and other relevant early warning information.

The AD Coordinator supports the AD Cdr in the execution of intercept missions conducted by the mission controllers. The Navy Coordinator supports the AD Cdr in the execution of all Naval AD conducted in the sector while the ADA Coordinator is an ADA officer situated in the AD Cell at the SCC and assists the AD Cdr in the execution of all ADA conducted in the sector. This officer is the AD Control authority over FCPs deployed in the sector, subject to the AD Cdr's AD Control measures.

The ADA Coordinator (ADA Coord) is not a structured post in the deployed Regiment or Battery, but is an appointment done by the ADA Formation HQ. The functions of the ADA Coord are as follows:

- Serves as an AD Control coordination link between the SCC and the FCPs.
- Issues air intelligence to the FCPs.

- Issues AD Control measures and AD plans to the FCPs.
- Disseminates early warning to the FCPs.

Air Defence Doctrinal Issues

One of the challenges facing AD entities under full operational command of the JTF THQ, is the definitions of the roles and responsibilities, with regards to air defence, between the THQ structure and the JAD structure. For the purpose of the land battle the ADA Battery falls under full operational command of the GCC structure, specifically with regards to fire support coordination, i.e. safety.

The air picture is available in the SCC and the ADA Battery while air space control measures, which are driven by safety considerations, are determined by the Main or Tactical HQ.

From the previous sections it is evident that AD resources are not under full operational command of the THQ. It is rather a case of being under operational command of the THQ but under AD control of the SCC.

The challenges facing the AD commander in this situation are the following:

- Separate planning guidelines from two different organizations.
- Separate execution guidelines from two different organizations.
- Integration of information or execution orders from two different organizations is problematic.

In addition issues need to be investigated such as:

- The need of a control link to the MAOT at the FSCC from the SCC.
- A solution to the perceived “clash” between the planning principles of the SCC and FSCC.
- A clarification of the information flow both during the planning and operational phases.

Integration of the Simulators

In order to address the above concerns an integrated simulated environment was created.

The integrated simulation focussed on the tactical command and control interactions between the THQ and AD assets as well as between SCC and AD assets.

VGD and BattleTek needed to be integrated at a number of levels. The main integration requirements were:

- Exchange of scenario information
- Exchange of flying object information
- Exchange of simulation control

Each of these was addressed separately and will be briefly discussed below [10].

Exchange of Scenario information

To limit the development effort it was decided that scenarios would be created separately in the two simulation environments. This was feasible because fixed scenarios are used by BattleTek during exercises. This implies that some information needs to be exchanged beforehand (manually) in order to ensure that both simulations represent the same reality to the operators. These include:

- GIS Data,
- ORBATS,
- Locations or Features,
- Defended assets,
- Deployments or Force Structure Elements (FSE’s).

Although all of the scenario information is exchanged prior to integrated simulation executions, it is still a future task to exchange as much of the information via the integration protocol (non-manual).

Exchange of air vehicle information

An important simulation integration design consideration is what information is exchanged using which protocol. In order to demonstrate the feasibility of an integrated simulation execution but to minimise implementation effort, information that remains static or is only used at simulation initialisation, such as scenario information, is exchanged manually. Other information, such as air vehicle tracks, is exchanged via LinkZA for the reasons:

- Both the C^2 simulators already support LinkZA.
- To reduce future software implementation efforts when integrating with actual (user) systems.
- One of the primary reasons LinkZA was conceived was to support the exchange of air

vehicle track information between systems. The most important information exchange between VGD and BattleTek is air vehicle tracks.

Only a subset of the LinkZA messages are used to exchange applicable air vehicle tracks between VGD and BattleTek. BattleTek supports a wider set of LinkZA messages, whereas VGD only supports those that are necessary for relevant air track and control measures exchanges.

As BattleTek is a constructive war simulation, air vehicles are updated at a slower rate than in VGD. Battletek updates aircraft positions at 1Hz, whereas VGD update aircraft at 100Hz. This presents a problem when exchanging air vehicles from BattleTek to VGD as sensor and effector models expects 100Hz update rates for aircraft. It is thus necessary to extrapolate aircraft state between updates so that it can be re-sampled to 100Hz. When exchanging aircraft from VGD to BattleTek, the updates rate is merely sub-sampled.

Exchange of simulation control

Simulation control between BattleTek and VGD includes messages to be able to stop, start or pause the two simulations in unison. No time synchronisation is performed although the simulation control may be extended in future to include synchronisation. Time synchronisation is achieved by running each simulation soft, real-time by synchronising it with the PC clock on which the simulation runs. The actual simulation time of the two simulations might differ slightly, but all information exchanged between the simulations are stamped according to the LinkZA specification [9], and using world-time. The interface is based on the exchange of binary messages employing a Microsoft Distributed Communications Object Model (DCOM) client-server approach.

Should time synchronisation and other simulation logistic information be exchanged in future, another protocol than LinkZA should be used, such as the High Level Architecture (HLA), as LinkZA does not support such information exchange.

Resulting Simulation

The integrated simulation is shown in Figure 7. The integration is limited to the South African forces part of the simulation. Opposing forces are still completely simulated using BattleTek. As evident, the roles within the SCC are limited to a number of role-players in order to demonstrate the principle.

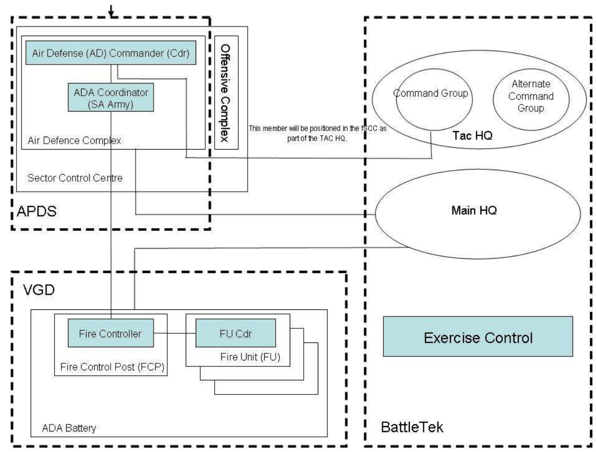

Figure 7:

Demonstration

A phased approach has been adopted for the integrated experiments to be able to manage test & debugging more efficiently. As air vehicle track information are the primary source of information exchange between VGD and BattleTek, the experiments mostly focused on that aspect. Air vehicle track information should be exchanged in both directions between the two simulators, including kinematic state and vehicle status (alive of killed). An air vehicle may also be created in one simulator but successfully engaged (killed) by a virtual effector in the other simulator. In such cases vehicle status should be correctly exchanged. In summary the integration tests are:

- Create, maintain and destroy an aircraft in VGD. The aircraft should be correctly displayed in BattleTek.
- Create, maintain and kill an aircraft in BattleTek. The aircraft should be correctly displayed in VGD.
- Create and maintain an aircraft in VGD, but kill it in BattleTek. The aircraft should be correctly displayed in Both BattleTek and VGD.
- Create and maintain an aircraft in BattleTek, but kill it in VGD. The aircraft should be correctly displayed in both BattleTek and VGD.
- Create, maintain and kill multiple aircraft in both VGD and BattleTek. Also kill aircraft created in one simulator in the other and *vice versa*.

To demonstrate the AD Doctrine issue outlined above, an experiment is defined: Air Defence operations are controlled by the ADA Coord in the AD Complex in the SCC. If an aircraft is tasked from the THQ for a Counter Air Strike (CAS) mission to attack enemy infantry at a given location, the SCC only controls the aircraft up to certain point, where the MAOT takes control of the aircraft. The MAOT is ultimately responsible for the safety of own aircraft. Air Defence Artillery is put on weapons tight (from the SCC AD Complex), to give an opportunity to the aircraft to conduct their mission (strike). However, the FSCC should also influence the weapon control order, but cannot since it does not have an SCC representative in the THQ. Another scenario is when Rotary Wing (RW) aircraft are ordered from the THQ, without the SCC notified to change weapon control orders to control GBADS firing. It is thus the primary purpose of the integration between VGD and BattleTek to demonstrate such clashes, and to provide a means for resolving it.

To implement the experiment described in the previous paragraph, the configuration of the integrated simulators is required:

- An APDS configured to receive aircraft tracks from VGD. At present this is not possible, thus air vehicle tracks modelled in the APDS (in simulator mode) will be exchanged to VGD.
- An ADA Coordinator that operates the APDS terminal and controls AD operations.
- A virtual GBADS battery, but with a human operator acting as Fire Controller using the OIL capability of VGD.
- A pilot flying a virtual aircraft (through a flight simulator connected to VGD) – This supports both Air-based AD, CAS missions and threat aircraft. Multiple flight simulators can be connected at the same time. Note that this is a future requirement of the integration.
- BattleTek configured with enemy ground forces and THQ (MAOT and ADA Adv).
- BattleTek configured with RW aircraft for support.
- The required simulation operators to configure and control simulation execution and logistics.

Recommendations

Although the integration proved to be successful, certain areas need further attention. The first is to standardise the scenario definition format to allow a single, shared scenario definitions instead of multiple, different formatted copies. For the purpose of this exercise the same scenario had to be recreated in proprietary formats in both the VGD and the BattleTek environments. It is proposed that the Military Simulation Definition Language (MSDL) [2] currently under development by the Simulation Interoperability Standards Organisation (SISO)[3] be considered as a viable option.

Secondly, it is recommended to support a proper simulation framework, such as HLA, to exchange simulation logistic information for improved time synchronisation and simulation control. This will definitely be required should a third simulator be integrated to reduce design and implementation complexity.

Thirdly, the link between VGD and the APDS should be updated to allow virtual aircraft to be exchanged from VGD to the APDS. At present aircraft can only be exchanged from the APDS to VGD. This will allow for more efficient control over virtual enemy aircraft, and the use of a flight simulator connected to VGD to provide more realistic and responsive (evasive manoeuvring etc) threat aircraft.

Lastly, it is recommended that a unified framework be adopted for C^2 modelling in the South African context. As C^2 modelling and simulation is not as widespread in South Africa yet, the opportunity still exists to standardise on a framework with not too much effort and cost.

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Biographical Notes

COBUS NEL is the Research Group Leader of the Mathematical and Computational Modelling Research Group within the Systems Modelling Competency Area of the Defence, Peace, Safety and Security Operating Unit of the CSIR in South Africa. Cobus leads a team of Modelling and Simulation experts developing virtual environments for acquisition decision support. The focus of the team's activities is air defence of which the GBADS Program plays an integral part. Cobus is a Professional Engineer (Engineering Council of South Africa) and has a Masters Degree in Electronic Engineering and a Masters Degree in Project Management.

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OCKERT VAN DER SCHYF van der Schyf has spent the largest part of his career involved in simulators and simulation systems. Most of this has been for the SANDF. He started out in software development, where he specialised in technical systems, with a high real-time component.

In his current capacity as marketing and program manager for CyberSim, he also bears the full responsibility for all technical aspects on all projects undertaken. This includes the responsibility for the preparation, facilitation and support of war simulation exercises at the SA Army and SANDF. He fulfils a major role in specification, design and marketing of all CyberSim software products.

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LT COL MARCHAND MOSTERT is an appointed SO1 Air Defence Artillery Project Officer from the SA Army ADA Fmn seconded to DAA (Director Army Acquisition). The largest part of his career was spent at various positions at ADA School and 10 AA Regt in Kimberley. He was transferred to DAA in 1999. His main focus as a Project Officer was the development of four Mobile Battery Fire Control Post Systems for the SA Army. His current focus is mainly on Command and Control in the GBADS programme, modelling and simulation, doctrine development and logistic engineering issues. Future involvement will be to assist in the acquisition of GBADS systems for the SA Army.