C2-led Simulation and Synthetic Environments for Air Operations

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Abstract

The Australian Defence Science and Technology Organisation's Information Technology Division (ITD) has a research and development (R&D) program that aims to deliver integrated modelling and simulation capabilities which aid Joint operational planning and command decision. Synthetic Environments for C3I Experimentation (SENCE) is a scientific thrust that concerns the development and application of command and control (C2) led simulations and synthetic environments. The term C2-led signifies an emphasis on modelling of, and support to, military command and control. A key area of research for the SENCE thrust is focused on the utility of simulation and synthetic environment capabilities to the planning of air operations and training in air asset and battlespace management. Intelligent software agents representing C2 and physical behaviour are important components of such capabilities. The purpose of this paper is to convey ITD's current and projected simulation and synthetic environment R&D program and capabilities.

1. Introduction

The Australian Defence Science and Technology Organisation's (DSTO) Information Technology Division (ITD) has a research and development (R&D) program that aims to deliver integrated modelling and simulation (M&S) capabilities which aid Joint operational planning and command decision. Synthetic Environments for C3I Experimentation (SENCE) is a scientific thrust that concerns the development and application of command and control (C2) led simulations and synthetic environments. The term C2-led signifies an emphasis on modelling of, and support to, military command and control. A key area of research for the SENCE thrust is focused on the utility of simulation and synthetic environment capabilities to the planning of air operations and training in air asset and battlespace management. Intelligent software agents representing C2 and physical behaviour are important components of such capabilities. The purpose of this paper is to convey ITD's current and projected simulation and synthetic environment R&D program and capabilities.

DSTO's Joint Synthetic Environment Facility (JOSEF) provides the tools and technologies that enable development of C2-led simulations and synthetic environments. A vital component of the JOSEF is the DSTO developed Distributed Interactive C3I Effectiveness (DICE) simulation software suite. DICE provides a flexible GUI-driven architecture to facilitate communication between components in a simulation. These components include intelligent software agents, human participants (optional) and interfaces to physical domain models and command support systems.

An overview of the outlook on and objectives of Simulation and Synthetic Environments for Command and Control of Air Operations is given. This is followed by an account of the general strategy being adopted towards developing a capability to employ simulation and synthetic environments in operational planning, command decision, and training in the Air domain. The strategy includes defining objectives for the simulations and synthetic environments, specifying appropriate military scenarios, and developing models and simulations. Examples of the application of these capabilities are given.

2. Simulation and Synthetic Environments

A synthetic environment is an artificial (ie *synthetic*) representation of behaviour external to some real system of interest (ie it forms the system's *environment*). A synthetic environment is able to appropriately stimulate the system of interest. In addition, a synthetic environment must have *immersive* qualities that enable it to appropriately react to the behaviour of that system. A range of models and simulations (execution of a model over time) may be configured to form a synthetic environment and can include representations of real or hypothetical C2, physical entities and natural environment. The system of interest may be a mix of humans (the participants) that are being exercised as they undertake real or hypothetical roles, plus associated technologies and infrastructure. In order to achieve the required behaviour needed to stimulate or immerse a system, the synthetic environment itself may have human response cells and operators. Models and simulations that are closed, ie do not require or accommodate external interactions during their execution (eg linear programming software that optimises target selection; a Monte Carlo simulation that computes mean response time of a strike squadron), are not synthetic environments. Interactive models and simulations where the user is not playing some real or hypothetical role (eg an intelligence analyst using an animated interactive queuing model to support influence analysis) are not synthetic environments. An illustration of an interactive model or simulation is shown in Figure 1a. An illustration of a system of interest immersed within a synthetic environment is shown in Figure 1b.

(a) (b)

Figure 1: (a) User of models and simulations as support tools within command support systems; (b) System of interest immersed within a scenario-based synthetic environment

Simulations and synthetic environments (SE) are used extensively in today's research and have a range of applications. They may be used to conduct computational experiments where the real world is represented by a range of models implemented in a computer and executed over time. Simulations can represent activities such as communications network traffic, military conflict and organisational processes and behaviour. Simulations and SE can be used to experiment with the various issues that affect these activities such as inclusion of a higher bandwidth link between aircraft and command centres, different air defence and strike strategies, or changes in organisational structure and function (eg due to injection of technology).

There are many ways of listing the military application domains that a spectrum of models, simulations and SE can be used to support. Reference [1] offers:

a) *"Capability and force structure analysis - including preparedness and resourcing;*
b) *Acquisition - including systems design, development, … and procurement;*
c) *Individual training and collective single service, joint and combined training;*
d) *The conduct of operations - including courses of action analysis, [decision support], linking strategic, operational and tactical levels of command, mission planning and rehearsal;*
e) *Support to the force-in-being including development and testing of doctrine and tactics, systems evaluation and improvement;*
f) *Research and development of ways to enhance the force-in-being and of candidate future systems for the Australian Defence Force (ADF).*"

This paper will concentrate on applications of type (c), training, and (d), conduct of operations, but it is important to stress that the capabilities described here have utility outside of these particular application domains.

The primary requirement for training is that it must be focused, realistic, effective and challenging. Military exercises are constrained by factors such as cost and area-of-operations which limit the scenarios used and minimise the element of free play and hence can result in scripted, predictable, and unrealistic behaviour. Simulations for individual training through to SE for broader collective training give valuable alternatives to real world exercises. A controllable, composable, repeatable, and reusable environment can be provided that is both realistic and challenging. The system of interest in this case will be the trainees and any support technology available to them in the real world. The SE will be an artificial representation of behaviour external to the trainees and their systems.

Simulations and SE could be used in operational planning to support course of action (COA) development, analysis, wargaming, selection and rehearsal. Planners (red and blue) may be immersed within a SE in order to explore issues and conduct a wargame. A single planner may use a simulation to undertake scenario-based modelling or COA rehearsal. Products of operational planning could include models and simulations that are configured to form a distributed SE able to support rehearsal by a range of participants.

Whilst each simulation and SE application would have differing requirements, pursuing them should involve drawing upon common tools and methodologies and possibly reusing models developed for different purposes. The concept of a synthetic environment that exercises some participants (eg force structure analysts, trainees or wargaming planners) could apply to each application area. The participants could also employ a mix of prototype and operational technologies and systems. This would allow development, demonstration, assessment, trialing, and evaluation of the prototype C2 technologies alongside existing operational systems. Example operational systems in the ADF air defence system (AADS) include the Theater Battle Management Core Systems (TBMCS). Example prototype technologies include the Air Asset Visualisation Tool (AVT) [2].

The primary objective of this research is to develop a capability for the use of simulations and SE in training, operations planning and command decision for Air operations. The general strategy for accomplishing this goal will be amplified in the next section.

3. General Strategy

In order to explore the utility of simulations and synthetic environments to air operations training, planning and decision, there is a need to be aware of:

- Real-world **issues** faced by trainers, planners and decision makers within the air environment and associated **requirements** of M&S support;
- The context within which plans and decisions are made ie credible military **scenarios**;
- The **M&S** capabilities available, their limitations and **development** program.

M&S requirements broadly specify the "what, why, where, when, how, and who" for the simulation. They include what will be modelled and why, timeframes, customer, how it should be modelled, the required level of fidelity and resolution, how the results will be analysed, and what metrics will be used in the analysis. These requirements may change as scenarios are described and models, simulations and associated tools developed. Credible military scenarios are used to highlight the issues and provide context for development of models and simulations. The M&S development process responds to the identified requirements in the context, and within the constraints, of the defined scenarios. Important steps in the M&S development process include: knowledge elicitation for input to the computational models; designing and building models; and finally analysing results from the simulations using a range of metrics.

The goal tool-set for this research activity consists of a collection of models and simulations that can be used as planning and decision aids through to synthetic environment capabilities that can train or exercise air operations staff and be used for war gaming and rehearsal.

3.1 C2-led modelling and simulation

The term *C2-led* signifies an emphasis on modelling of and support to military C2. We adopt the following definition cited in reference [3]:

"C2 is everything an executive uses in making decisions and seeing that they are carried out; it includes … authority … and involves people, procedures, equipment, and the executive's own mind. A C2 process is a series of functions, which includes gathering information, making decisions, and monitoring results. A C2 system is a collection of people, procedures, and equipment which support a C2 process."

Coakley, 1991

The aim of this research is to explore capabilities that enable development of models and simulations that support or represent C2 of air operations. In the case of tactical air defence, for example, such products may support Aerospace Battle Management Staff (ABMS) in the management of aircraft alert states and scrambling. Models that automate or semi-automate aspects of these functions could be used as decision support tools by the ABMS. The ABMS and these support tools could be immersed within a synthetic environment for training or rehearsal purposes. The same models could contribute to a rich simulation with a high degree of intelligence and automation that permits operational planners to experiment with higher level issues. The same models may become components of an ABMS behavioural model used within a synthetic environment for exercising higher command level participants. The same models could be used to help represent an intelligent opponent for training or planning purposes. C2 models and simulations need to be supported by appropriate physical domain models of equipment, platforms etc.

3.2 Composition of a C2-led Synthetic Environment

A C2-led synthetic environment has at its core some explicit emulation of the processes and behaviour of the subject C2 system. The C2 system consists of key and supporting agencies (higher authority, flank and lower agencies) which are linked to reflect communication channels. Artificial agents are developed for each simulated agency in the C2 system using techniques such as Petri nets and intelligent agents. These artificial agents represent the behaviour or functionality of individuals or groups in the C2 system/organisation. The agents work within a framework that represents C2 processes and supporting systems. Human interaction with the synthetic environment can occur from participants within the military system being exercised and from any response cells and operators within the synthetic environment itself. Real world military messages should be employed where possible in order to maintain semantic and syntactic equivalence with real world C2 systems.

The C2 system has an associated environment that is represented by physical domain models that contain representations of the geospatial environment, platforms, sensors, weapon systems, and other assets. It is these physical domain models which provide the stimulus for the simulated C2 system and can be tasked through orders from that system.

Interfaces between the physical domain models, or any C2 technologies (eg command support systems (CSS) or decision support systems (DSS)) relevant to the study, and the C2 system are also required.

ITD's JOSEF enables the development of such C2-led synthetic environments. As requirements for SE evolve, further development of, and extensions to, the JOSEF will also be required.

3.3 The Joint Synthetic Environment Facility (JOSEF)

Development of C2-led synthetic environments is achieved within ITD's JOSEF. The DICE simulation software suite [4,5] is a key component of the JOSEF. One of the primary functions of DICE is to enable representation of the C2 system by explicitly modelling messages such as orders, reports and requests. In addition to C2 the JOSEF provides physical domain, visualisation & geographical representation for a range of environments (land, sea and air) with resolutions ranging from detailed 3D virtual geo-spatial navigation (fly-throughs) to broad picture (2D) map displays. Exploration and experimentation of concepts and capabilities is achieved in the JOSEF through the execution of closed models through to composable interactive and non-interactive experimental environments.

DICE provides a flexible GUI driven architecture to facilitate communication between components of the simulation. These components include intelligent software agents, human participants (optional) and interfaces to physical domain models and command support systems. The human interaction facility allows a real commander, for example, to interact with other agencies (real or artificial) present in the C2 system.

The intelligent software agents may be developed using a range of modelling tools and techniques, including Petri net tools for stochastic modelling (provided by the ALPHA/Sim software [6]) and intelligent agent capabilities for enhanced behavioural representation. Intelligent agent tools currently in use in the JOSEF include the JACK [7] and ATTITUDE [8] software. Simple scripts or C/C++ software may also be used.

Communication between the components, or nodes, is through a formatted textual message language. This allows for the exchange of information (orders, reports and requests) between humans and artificial agents. In aiming for semantic and syntactic equivalence with real-world C2 systems, military formatted messages such as those of the Australian Defence FORmatted Message (ADFORM) System and the Australian Air Defence Ground Environment Software Information Transmission Standard (ADGE SITS) can be employed in the simulation. Communication delay is represented explicitly within the DICE simulation.

The DICE simulation employs interfaces to physical domain models. The physical domain models contain representations of contesting force assets such as sensors (for example ground based radar (GBR), and airborne early warning and control (AEW&C) aircraft), weapons, aircraft, ships, and troops. Models of the physical environment influence the C2 system by providing stimuli such as sensor detections and other reporting. The physical domain models can in turn be influenced by the C2 system model through orders such as the altering of aircraft alert states and the tasking of intercept missions. The Scenario Toolkit And Generation Environment (STAGE) [9] (which represents the physical environment of air, maritime and land entities) is one of the physical domain models available for use with DICE.

Other interfaces employed by the DICE simulation are to CSS that are used by human participants. Operational and prototype CSS available in the JOSEF include the Phoenix Display System (PDS) [10] that provides air defence officers with a recognised air picture, the AVT that provides air defence officers with temporal information regarding air assets, the Battlefield Command Support System (BCSS) [11] which aids an Army officer’s land situation awareness, and a messaging capability.

4. Issues and Requirements for support to Air C2

Some example issues that shape the R&D program follow.

4.1 Operations planning

What immediate and future capabilities are required for the planning of exercise and real-world air operations?

Detailed simulations and SE have a key role in tactical-level planning. Detailed preparedness, platform performance, logistics and attrition models may be needed to explore particular COA issues. SE for interactive experimentation and analysis would need to be able to support in a timely manner COA execution, wargaming and visualisation in time and space. This would typically require a high degree of automation and intelligence.

4.2 Management of air assets

Issues of significance to tactical air operations may include:
How to best manage aircraft alert states and scrambling?
How to optimally position CAP based on current and projected threat?
How to best assign and control interceptors?
What are optimal refuelling practices?
How to best train officers in these management practices?

It is feasible that intelligent agents and supportive models could help address these issues by automating aspects of the associated functions. They could provide advice or suggestions, a ready reckoner, or a means of rapid trialing by the decision maker. The appropriate level of fidelity and intelligence of each agent/model would need to be determined on a case-by-case basis.

Part-task or other training capabilities would need to be supported by models that exhibit certain intelligence in asset behaviour, eg synthetic aircraft that permit the necessary degree of automation.

The issue of *"How to best train officers in these management practices?"* or *"How to train the Aerospace Battle Management Trainee (ABMT)"* will be addressed in this paper. ABMT is a term with an emphasis on <u>function</u> and is used to convey an individual or group of trainees with an aerospace battle management role.

4.3 Trialling and assessing new technologies and practices

How to best trial and assess new air operations support technologies?
How to best experiment with new operational concepts and practices?
How to best explore doctrine development for air operations?

The above issues can be achieved to some extent through participation in real-world military exercises, but such exercises are usually limited and unrealistic and can have much broader and different objectives than those that concern the new technologies and practices. Prototype technologies often have to be initially 'air gapped' to operational systems.

Immersing technology products into a synthetic environment offers the benefit of evaluation with multiple scenarios, including those without the products, some of which may not be possible with military exercises. A SE provides a controllable, composable and configurable environment within which support products can be introduced to users, allowing new products to be demonstrated and trialed, and enabling experimentation and assessment. The JOSEF capabilities were shaped by experiences in this area with the AVT [2].

An appropriately structured interactive synthetic environment can also aid further development of the C2 technologies (by placing the technology into the hands of potential users earlier than is normally possible), the transitioning of new products to operational systems (including training), and the evolution of organisational culture (including doctrine).

5. Scenarios

Having identified a range of issues faced by trainers, planners and decision makers in the air domain it is important to consider the context within which the training, planning and decision making associated with the identified issues are made. This is accomplished through the use of credible military scenarios. The scenarios described in this Section highlight some of the issues raised in Section 4 and provide context for development of the models and simulations (see Section 6).

The issue being addressed in this paper is that of training the ABMT. The associated scenario deals with a Redland air offensive and Blueland's defensive response. This scenario focuses on defining an Order of Battle (ORBAT) and setting an initial posture from which free play will occur.

Redland (a fictitious island to the north of Blueland/Australia) has two available airfields at KAM and MAK. Redland has four F15 and four F16 at KAM, and eight F15 and one AEW at MAK. There are air traffic control radars at KAM and MAK and two air defence radars at other locations on the main Redland island.

Darwin and Tindal are the available airfields for Blueland. The Blueland air ORBAT has six FA18 at Darwin, and six FA18 and one AEW at Tindal. There are air traffic control radars at Darwin and Tindal and three air defence radars at other locations in the north of Blueland.

Figure 2 shows the air scenario unfolding from a Red perspective. A Redland AEW&C and fighter escorts are positioned just south of the main Redland island. The Redland air strike plan involves four fighters that are sent to the east of Darwin as a feint. The real air strike package takes a western route to Tindal. This package comprises four F15 escorts and four F16 in the ground attack role. The Blueland scenario is entirely interactive, so no more information will be provided at this point.

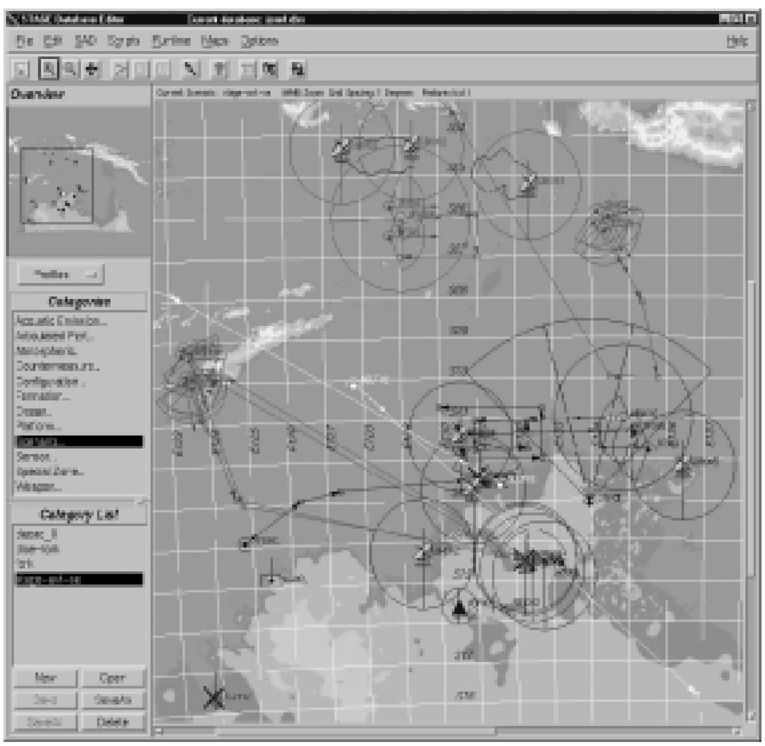


Figure 2: A graphic of the air component of the interactive ABMT scenario.

The interactive ABMT scenario also has a land element in the vicinity of Tindal. Blueland ground defence consists of machine gunners, armoured vehicles, and ground-based air defence (GBAD) surrounding the high value areas.

6. M&S Development and Experimentation for the ABMT Synthetic Environment

6.1 Objectives

One of the key roles of the interactive ABMT synthetic environment is to provide an immersive environment for the ABMT to undertake training in aerospace battle management. This immersive environment contains a combination of real, virtual and constructive elements interacting in a seamless fashion.

An immersive synthetic environment for the ABMT could also be used to demonstrate, trial, and evaluate prototype C2 technologies alongside operational CSS. The ABMT participant would interact with the SE via the C2 technologies (CSS, DSS and communications capabilities) available in the operational environment in addition to the prototype CSS [2]. The AVT is an example prototype CSS for the ABMT. In the operational environment the ABMT uses the PDS to provide the recognised air picture (RAP).

6.2 Models and Agents

With the above objective in mind a focus is to develop artificial agents for organisations and staff that interact with the ABMT. The level of fidelity of each of these artificial agents depends on the significance of the influence on and interaction with the ABMT and is assessed on a case-by-case basis. In designing this environment it is useful to firstly consider the roles of the ABMT and subordinate staff.

The ABMT has a prime responsibility for optimal management of the assets and resources available for conducting air defence operations under guidance of a higher authority (such as the Director of Operations (DO), for example). In summary the ABMT roles and responsibilities include maintaining situation awareness, managing alert states, scrambling of aircraft, deployment of CAP, and allocation of intercepts. In addition to these overarching functions the ABMT needs to be aware of fuel and weapon loads, aircraft utilisation rates, and aircrew duty limits as part of the overall scheduling of assets and resources.

Key C2 system agencies (organisations and staff) that interact with the ABMT are the DO, control element (CE), and the squadrons (SQN) – as shown in Figure 3. The ABMT also receives an updated RAP from the Regional Correlation Centre (RCC) via the PDS. Therefore, in the ABMT SE the key C2 agencies required are ABMT, DO, CE, SQN, and RCC, key C2 technologies required are AVT and PDS, and there must be a communications/messaging facility for the ABMT participant.

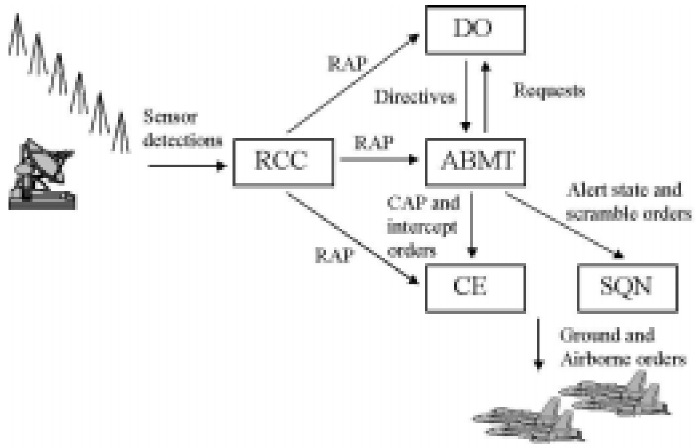


Figure 3: A graphic displaying key agencies that interact with the ABMT and information flows.

The ABMT SE was implemented in the JOSEF using the DICE software. The physical environment surrounding the C2 system was represented using the STAGE software [9]. Petri Nets (PN) were used to develop the RCC, DO, and SQN artificial agents. A CE artificial agent was developed using the JACK intelligent agent software and a Petri net tool. A collective CE/Pilot agent was developed using the ATTITUDE software.

The following simple sequence of events is used to describe the functions/behaviour of the various ABMT SE artificial agents and physical domain models:

- The RCC agent collates detections which it receives from many sensors (eg the GBR sensors in the STAGE physical domain model) and maintains the RAP. It forwards the updated RAP to the PDS and to the CE.
- In response to a new enemy track appearing in the PDS the ABMT participant may undertake an action to intercept the enemy aircraft track. Firstly the ABMT may need to request and receive approval from higher command (the DO agent in this case). Having obtained approval, the ABMT tasks an intercept mission. This is achieved by the ABMT tasking the relevant SQN to place a fighter aircraft on an intercept mission. The ABMT then tasks the CE to control a specified fighter aircraft on intercept. The ABMT may also need to readjust the posture of the other air assets, for example if the fighter aircraft selected for the intercept mission were re-tasked from an existing CAP mission then the ABMT may choose to replenish the CAP by scrambling new aircraft from the SQN.
- Currently, the DO agent accepts requests for intercept from the ABMT, then approves them after a prescribed short delay. Extensions to the ability to accommodate interaction with higher command are planned.
- There is a SQN agent for each aircraft type at each airbase. A SQN agent keeps track of the status (fuel, weapons, mission etc) of each aircraft as it is reported by STAGE, and reports this status to the AVT. Such statuses may be requested or actual. The SQN agent is also responsible for scrambling aircraft, CAP, and adjusting the alert states as tasked by the ABMT.
- It is the responsibility of the CE agent to direct allocated fighter aircraft to the intercept location/aircraft. The CE agent maintains a database of current intercepts and forwards the most recent target position (as observed in the PDS/RAP) to the relevant aircraft. The JACK version of the CE handles multiple intercepts on a single target, and initiates intercepts earlier than the PN version of the CE (which waits for the next update from RCC). Currently, neither the PN nor

JACK CE agent receives feedback if/when an own force aircraft intercepts and kills an OPposing FORce (OPFOR) aircraft or if an own force aircraft is shot down.

- The Pilot agent handles the behaviour for all pilots and extends the CE functionality. The Pilot agent includes organic sensor detections of the fighter aircraft in addition to the RAP during an intercept mission. The Pilot agent receives feedback if/when an own force aircraft intercepts and kills an OPFOR aircraft or if an own force aircraft is shot down. After the engagement the Pilot agent instructs any remaining aircraft under its control to return to base (note that the engagement occurs according to the weapon specifications as described in the STAGE physical domain model).

In addition to the air C2 system there is also a land C2 system and environment. This has been accomplished to date by inclusion of a simple GBAD capability at the Tindal air base. GBAD sites automatically fire at opposite side aircraft and may influence the number of aircraft available as the SE is executed. The ABMT SE has been developed to support a land commander human player who would use the BCSS as a Land picture and to influence the land battle as required. Currently the land battle is automated within STAGE but a human player could actively influence the land component during the simulation.

6.3 The ABMT SE

The artificial agents, models and C2 technologies that constitute the ABMT SE can be seen in Figure 4 which shows a snapshot of the DICE simulation scenario development screen for this SE.

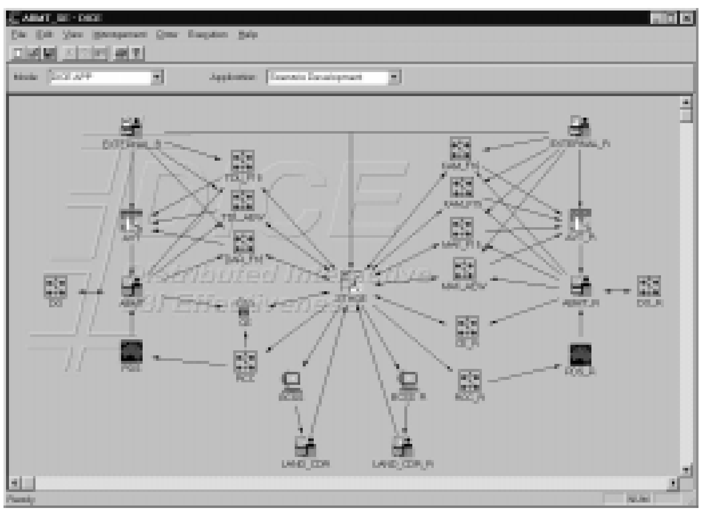


Figure 4: A snapshot of the DICE simulation screen for the interactive ABMT SE.

Blueland agents/nodes are shown on the left half of the screen while Redland agents/nodes are on the right part of the screen and are typically denoted by "_R". Currently Redland agent functionality is identical to the corresponding Blueland agent. Only air defence C2 has been considered to date, exercised by a scripted Redland air strike mission.

In the ABMT SE there is a potential for up to four participants (in addition to the simulation controller / External human player), namely a Blue and Red ABMT (indicated as ABMT and ABMT_R) and a Blue and Red land commander (indicated as LAND_CDR and LAND_CDR_R).

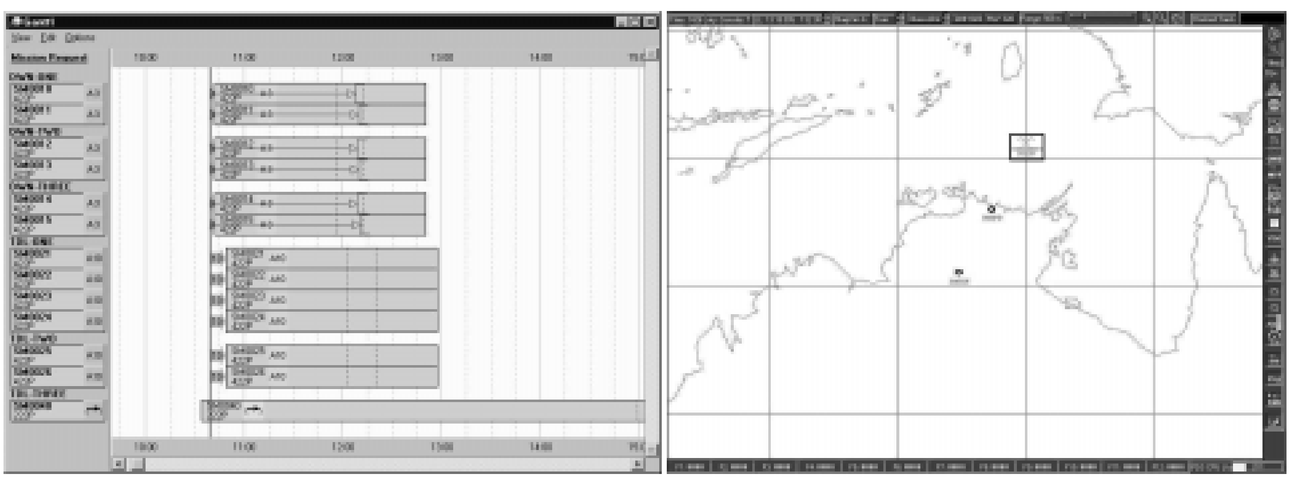
Each side's (red and blue) ABMT is provided with PDS, the AVT, and a messaging capability. Each side's (red and blue) land commander is provided with BCSS and a messaging capability.

6.4 Using the ABMT SE

Let's first consider execution of the SE with a Blueland ABMT participant and scripting or automation for Redland air strike and Blueland and Redland ground forces. In order to describe how the ABMT SE may be used an example sequence of actions undertaken by a Blueland ABMT, as seen through the eyes of the authors, will be presented.

The AVT displays air assets available and under control of the Blueland ABMT and the current asset status. In the case of the ABMT scenario the initial posture for Blueland is six FA18 aircraft available at both Darwin and Tindal, one AEW&C aircraft available at Tindal, and a range of GBR.

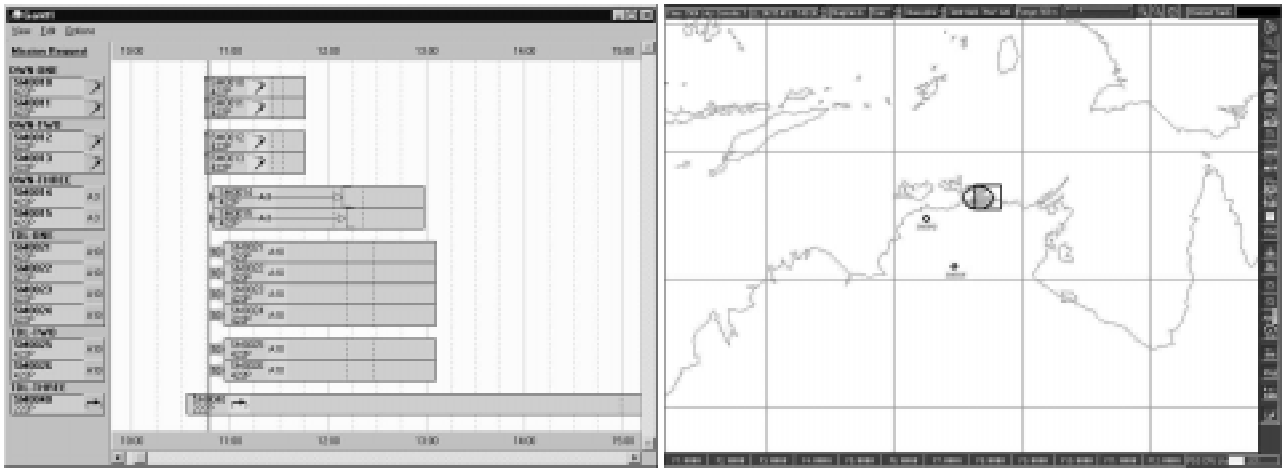
The Blueland ABMT must manage the assigned air defence resources depending on the estimated threat of any detected Redland aircraft (which would be displayed on the PDS) and any intelligence reports available. According to the ABMT scenario a previous intelligence report indicated that a large number of strike and fighter aircraft were forming up at an airbase in Redland. A recent report indicates that some aircraft have just taken off and appear to be heading south toward Blueland, with Darwin and Tindal both being potential targets. With this in mind the Blueland ABMT postures his assets by assigning CAP and alert states. Based on these intelligence reports the ABMT assigns all aircraft at Darwin an alert state of 3min and those at Tindal an alert state of 10min. No CAPs are assigned because firstly surveillance and intelligence information is considered to be adequate and secondly, due to fuel limitations, aircraft are best left on the ground as long as possible. This initial posture as displayed by the AVT is shown in Figure 5a.



(a) (b)

Figure 5: (a) An AVT snapshot displaying the initial status of assets available to the Blueland ABMT; (b) A Blueland PDS snapshot when Redland aircraft are first detected to the north-east of Darwin (highlighted by a square).

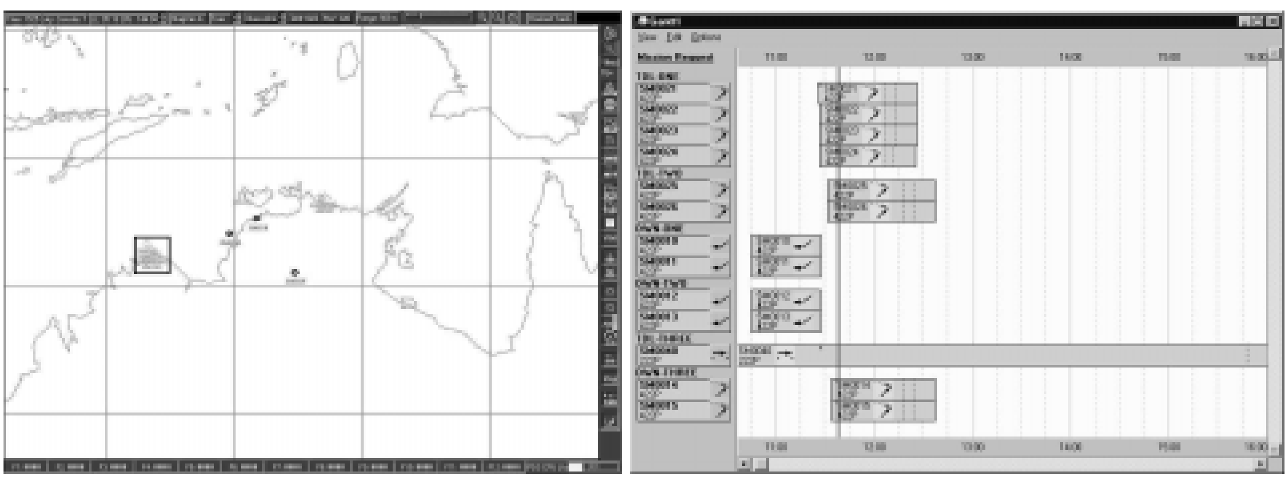
Figure 5b shows the Blueland PDS, as seen by the Blueland ABMT, when the first wave of Redland aircraft are detected by Blueland radars. At this point in time the ABMT scrambles a 4-ship of fighters (as there appear to be four Redland aircraft) from Darwin to intercept these aircraft. As seen in Figure 6a the AVT is automatically updated to reflect this tasking. Figure 6b shows the subsequent engagement between the Redland and Blueland aircraft.



(a) (b)

Figure 6: (a) A Blueland AVT snapshot after the ABMT has scrambled fighters to intercept a possible Redland strike package; (b) A Blueland PDS snapshot during the first engagement (Redland aircraft are highlighted by a square, Blueland aircraft are highlighted by a circle).

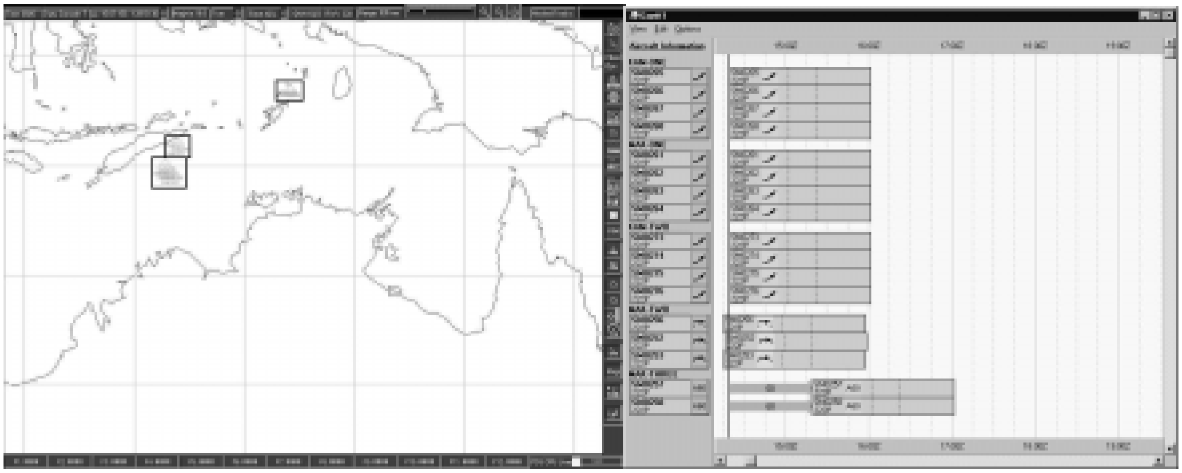
Figure 7a shows the PDS, as seen by the Blueland ABMT, when another wave of Redland aircraft are detected by Blueland radars – this time to the west of Tindal. The Blueland ABMT scrambles the eight remaining fighters (from Darwin and Tindal) to intercept these aircraft. As seen in Figure 7b the AVT is updated to reflect this tasking.



(a) (b)

Figure 7: (a) A Blueland PDS snapshot when a second wave of Redland aircraft are detected to the west of Tindal; (b) A Blueland AVT snapshot after the ABMT has scrambled fighters to intercept a second possible Redland strike package.

From a Redland perspective Figure 8a shows the PDS, based on detections by Redland surveillance assets, during the first stage of the Redland mission and Figure 8b shows the Redland AVT at this point in time.



(a) (b)

Figure 8: (a) A Redland PDS snapshot of the first stage of the Redland mission; (b) An AVT snapshot displaying the status of Redland assets available during the first stage of the Redland mission.

The ABMT SE also supports having a human player driving the Redland air strike mission during the simulation. Human players may also actively influence the red and blue land forces. Each additional human player adds another level of complexity to how the "game" unfolds but means that the participants can experiment in a realistic, dynamic and challenging way.

7. Conclusions

The term *C2-led* signifies an emphasis on modelling of and support to military C2. The aim of this research is to explore capabilities that enable development of models and simulations that support or represent C2 of air operations. The research needs to be driven by real-world issues. Models may automate aspects of C2 functions and be used as decision support tools. The user and these tools could be immersed within a synthetic environment for training or rehearsal purposes. The same models could contribute to a rich simulation with a high degree of intelligence and automation that permits operational planners to experiment with higher level issues. The models could become components of a behavioural model used within a synthetic environment for exercising higher command level participants. The models could also be used to help represent an intelligent opponent for training or planning purposes.

The R&D builds upon experiences to date in tactical air defence. A number of artificial and intelligent agents have been developed that allow for autonomous behaviour of certain functions in the AADS C2 system and a fictitious OPFOR. These models and simulations have been composed in an interactive synthetic environment for the purpose of training the ABMT in aerospace battle management. The same SE will be used for demonstrating, trialing and assessing prototype C2 technologies for use by the ABMT.

In the interactive ABMT SE an ABMT participant controls the air defence response to a scripted OPFOR air strike mission. An interface to the PDS operational CSS allows the ABMT to participate in the SE in a realistic fashion. Facilities to include a human player to "play-out" the offensive air plan are also included, thereby turning the simulation into a two-sided wargame (human player facilities for the Red and Blue land components are also available).

The artificial and intelligent agents could potentially be used by the ABMT as a decision making tool because of their autonomous nature. Therefore, an outcome of this research is a capability to employ simulation in the tactical air defence decision making process.

The next phase of this research activity has two threads. Firstly, the interactive ABMT SE will be extended to meet additional requirements of the ADF (Australian Defence Force) aerospace battle management course. This will be undertaken in consultation with ADF staff. Secondly, the ABMT SE will be extended to include the broader and higher C2 of the air environment. This will involve inclusion of air strike and other air operations for both Red and Blue forces. It will also necessitate interactions with the operational level of command. An outcome of this phase will be a capability to employ simulation and synthetic environments in training, operational planning and command decision in the broader air domain.

A future phase of this research activity is to develop a Joint synthetic environment that would represent air, land, and maritime functions and behaviour (along with a real and fictitious OPFOR) for the tactical through to operational levels of command. Such a SE has a range of potential applications ranging from training and exercises, to capability development and capability options studies, through to an operational role in planning where SE could be used for scenario based modelling for COA assessment and rehearsal.

8. References

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