Looking to the Future: Representing Higher Level Planning in a Wargaming or Synthetic Environment

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Abstract

Planning by a higher level commander is, in most cases, regarded as such a difficult process to emulate, that it is performed by a real commander during wargaming or during an experimental session based on a Synthetic Environment. Such an approach gives a rich representation of a small number of data points. However, a more complete analysis should allow search in the vicinity of these data points, in order to allow a more complete analysis. In this paper we discuss an alternative approach to this problem, based on attempting to emulate the higher command process by a set of mathematical algorithms. This approach have been implemented, in an exploratory research initiative, in the UK Wargame Infrastructure and Simulation Environment (WISE).

Introduction

Since the Cold War period, the scenario context has widened considerably, reflecting the uncertainties of the future. Moreover, decision cycles for our customer community in the UK Ministry of Defence (MoD) have significantly shortened. The focus of war has also shifted from the Industrial Age of grinding attrition to the Information Age, as encapsulated in the term Network Enabled Capability (NEC). NEC is a key goal for the MoD, with the emphasis on command, the sharing of awareness among commanders, and the creation of agile effects. These influences together have led to the need for simulation models which are focussed on command rather than equipment, which can consider a large number of future contexts, and which can robustly examine a number of ‘what if’ alternatives (Taylor and Lane, 2004).

In response to these demands, we have built a new generation of simulation models, with command (and commander decision making in particular) at their core (Moffat, 2000). These span the range from the single environment (e.g. a land only conflict at the tactical level) to the whole joint campaign, and across a number of coalition partners (Moffat, Campbell and Glover, 2004). They also encompass both warfighting and peacekeeping operations. These models have been deliberately built as a hierarchy, feeding up from the tactical to the strategic level, to give enhanced analytical insight, a shown in Figure 1.

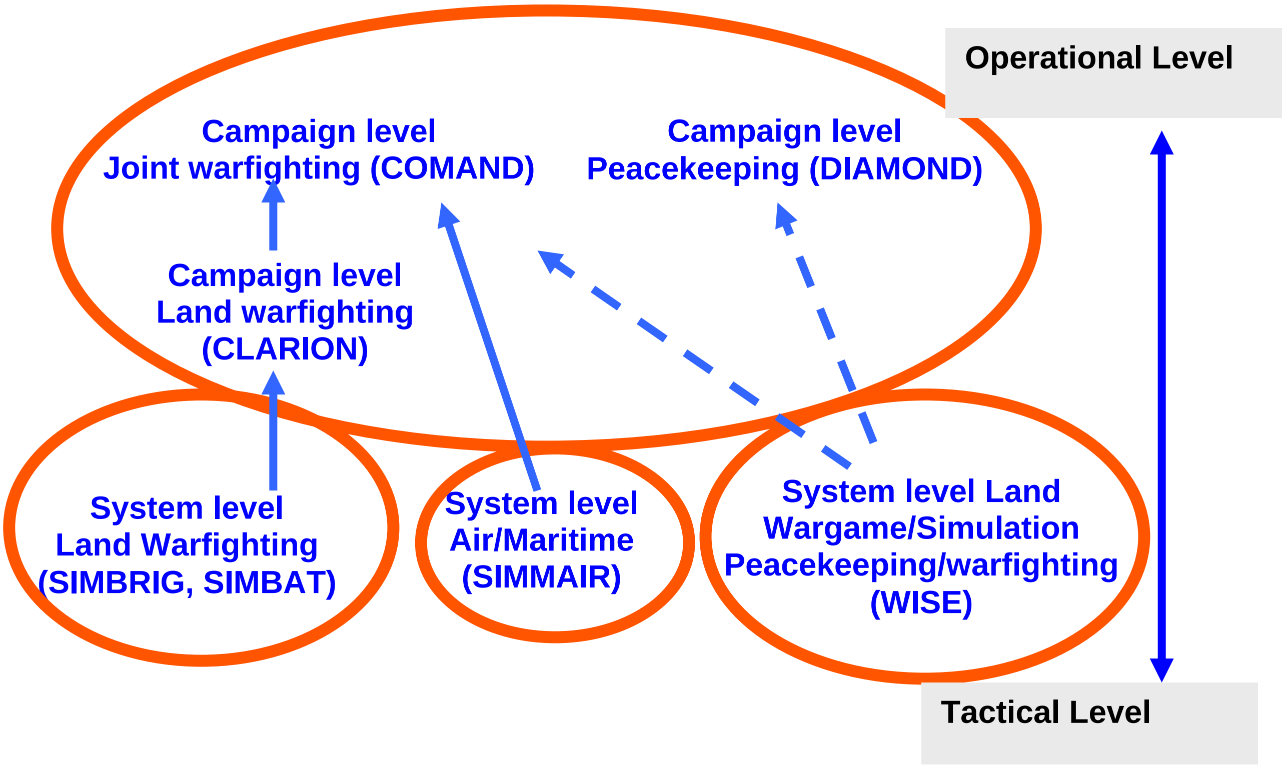

Figure 1: The hierarchy of key simulation models

WISE

As part of these development activities, we have constructed a stochastic wargame called ‘WISE’ (Wargame Infrastructure and Simulation Environment’. As the name suggests, this is more that just a single model, and in fact provides a modelling infrastructure from which a number of tailored models can be created. The key development thus far has been the wargame itself (Robinson and Wright 2002, Pearce et al 2003). However, a logistics simulation has also been developed and is being used to examine vehicle reliability and consequent repair.

The model addresses a previous gap in modelling capability relating to the representation of Command and Control (C2). It has utilised where possible novel techniques to represent the command decision making.

The wargame represents operations up to Army Division level. Army commanders play the roles of Division and Brigade commanders in the game, on both sides, and they are supported by an underlying simulation environment which represents the evolution of events. The Synthetic Environment (SE) representation exploits the Rapid Planning process (Moffat, 2002) to determine the decisions made by the lower level commanders that are not explicitly represented by players.

Wargaming and Experimentation are particularly good at exploring new situations and future contexts, as indicated in Figure 2.

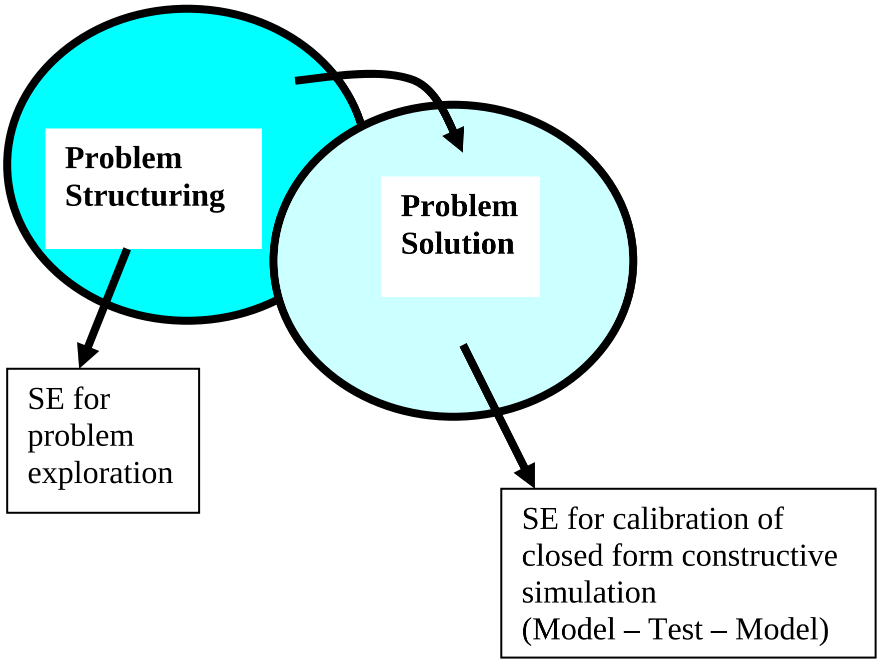

Figure 2; Synthetic Environments in problem exploration and problem solution.

They give a rich understanding (i.e. qualitative information) of a small set of possible options. In order to allow us to explore around these options, and thus develop a wider understanding of their robustness (a key aspect of understanding force 'agility') we needed to develop a closed form discrete event simulation equivalent of the WISE wargame – in essence replacing the human players by some form of artificial intelligence representation, to allow the running of the scenario without human intervention. This was done by exploiting the Deliberate Planning Process, an algorithmic representation of higher level command based on a combination of Game Theory and genetic algorithms.

Deliberate Planning Process

The Deliberate Planner emulates the 'formal estimate process' whereby a high level commander develops an overall plan for the campaign. At this level of the command process, a commander considers a number of potential courses of action, taking into account his intent (i.e. his primary goal or objective), and the intent of the enemy force. The algorithm which represents this process firstly develops a 'picture' of the layout and intent of the enemy force, based on sensor inputs and a

Bayesian approach to information updating. On the basis of this ‘picture’, the planner then decides on a layout of the friendly force which best achieves the commanders goals. It does this by ‘breeding’ plans in an innovative way, using a genetic algorithm (GA), and then selecting a plan with a high ‘fitness’ level from the GA.

The fitness of the plan is calculated using a number of historical analysis equations which relate force layout to campaign outcome (Rowland, 2006, Moffat, 2002). These allow the model to calculate aspects of the plan such as the likely level of casualties (own and opposing forces), the likely rate of advance towards the objective, the probability of breakthrough, and the probability of overall success. These are weighted to accord with different styles of command (for example a risk averse commander might put a high priority on keeping casualties to a minimum, while another commander might put more priority on getting to the objective). The fitness value also reflects the style of the commander through a Game Theory approach which seeks to either maximise his minimum payoff (cautious command), attempt an even spread of risk (median command) or attempts to maximise his maximum payoff (bold command) The latter appears to be a high risk strategy. However, when played through the modelling environment, it can give rise to very ‘manoeuverist’ plans which can catch the opponent out. Full details of the algorithmic approach adopted by the Deliberate Planner are given in (Moffat, 2002). Figure 3 presents a diagrammatic view of the operation of the deliberate planner.

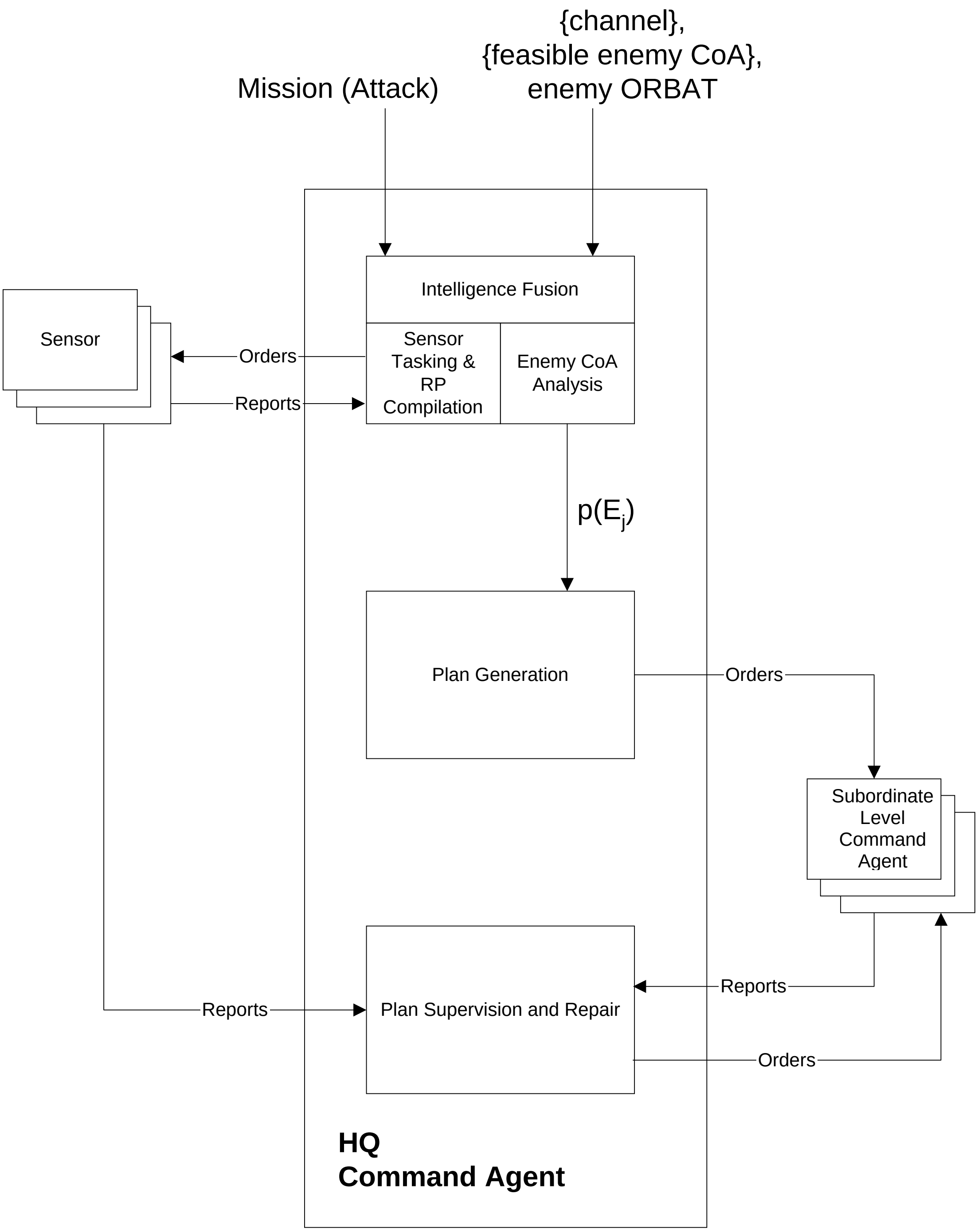

Figure 3; Implementation of the Deliberate Planner within a command agent.

Implementation of the algorithm in WISE

The Deliberate Planner algorithm has been implemented as a series of standalone C++ classes in WISE to improve the potential for re-use in other models. A WISE specific interface has been developed to allow it to be run as part of the decision making representation. The interface has been defined such that the data stored within WISE can be packaged generically and passed in to the algorithm in a standard format.

Figure 4 shows a high level process diagram of the implementation within WISE. The details in the remainder of this section relate to how the algorithm has been applied.

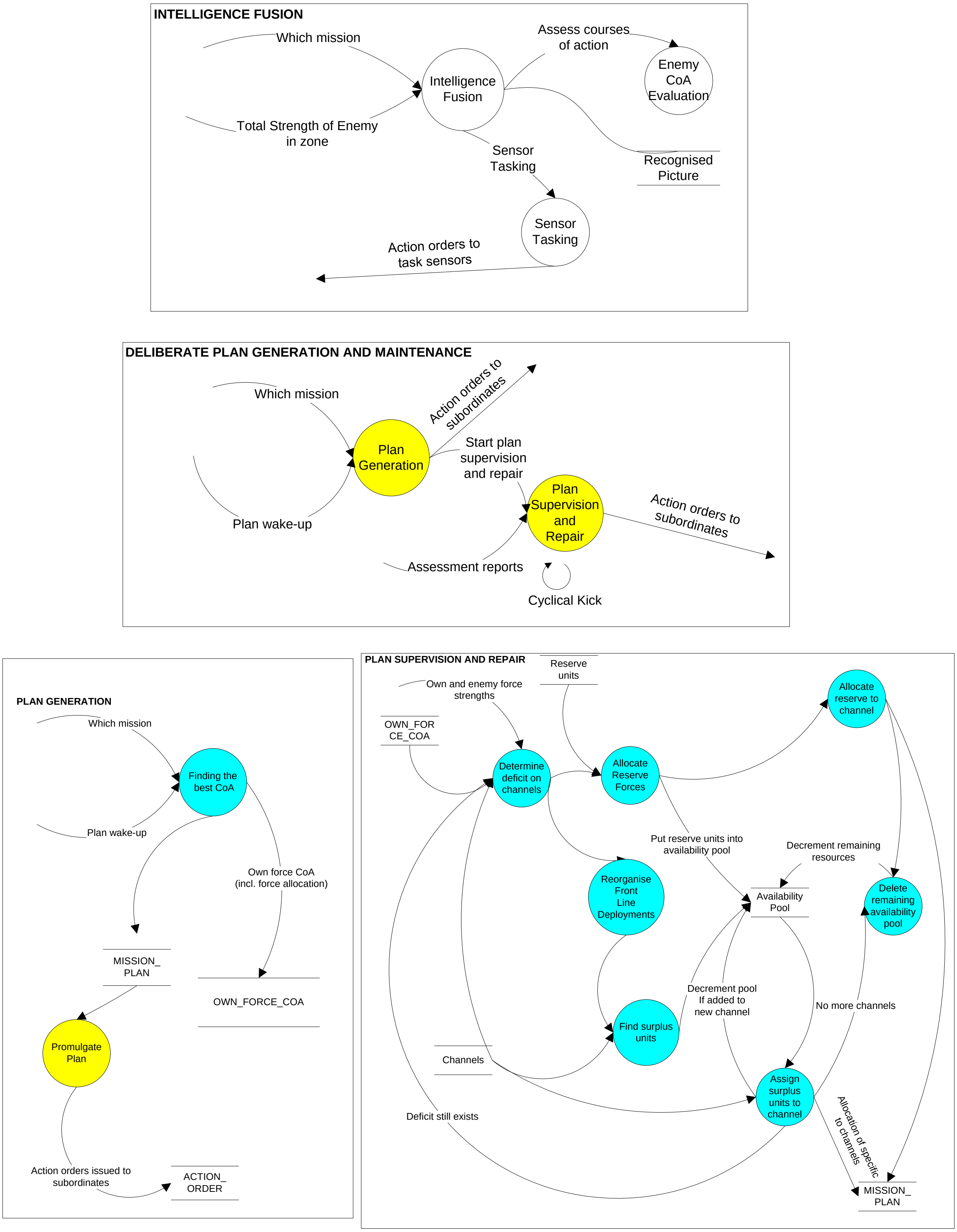

Figure 4; Deliberate Planning process model

In order for a plan to be generated there is an implicit assumption that the unit undertaking Deliberate Planning has an understanding (or ‘picture’) of what is happening around it in the model. This is shown in the top part of Figure 3, where a number of sensor platforms or units are feeding information in to allow the Recognised Picture (RP) to be compiled. At the beginning of a run an “Assess Current Situation” task is called which sends out the initial sensor tasking orders. The intelligence fusion process and re-tasking of sensor units is then carried out to allow enemy Course of Action (CoA) analysis to be completed. All of the sensor acquisitions are made using the Surveillance and Target Acquisition (STA) model in WISE which are passed up the Command and Control (C2) chain. When a sensor asset completes a search of its tasked zone a ‘fused’ set of acquisitions is passed into the Intelligence Fusion process, and a new order is generated for that sensor asset.

A number of cycles of intelligence fusion are required in order to build up a suitable picture against which to create a plan. Two criteria are specified in the data that determine when intelligence fusion is deemed to be complete enough for planning: (a) the number of times that specified zones must be searched, or (b) a time period. The first of these criteria to be realised is used to initiate the plan generation task.

Once started the plan generation process undertakes an assessment to determine the CoA to adopt and hence the orders that need to be issued. Based on a number of pre-input potential CoA’s different force allocations are evaluated against a set of standard equations that relate a series of available parameters to the likely outcome of the missions. The force allocation is then ‘bred’ using a GA to determine the best CoA to adopt. Once this is complete, a set of orders are generated and picked up by the interface classes to be translated into the orders required to task units within WISE.

As the plan is executed in the simulation, sensor assets continue to report and the Deliberate Planner’s recognised picture continues to be updated. Each time that this process is called, an assessment is carried out to determine whether the plan is performing within defined bounds. If it is not then a Plan Supervision and Repair process takes place. The planning algorithm determines which areas of operation are failing to meet the plan. It also identifies which units are surplus or in reserve and places these in an availability pool. The areas of operation that are in deficit are then supplemented as required and a new set of orders are issued.

Testing the Deliberate Planner

In order to test the resulting closed form simulation, we played through a future scenario using the wargame version of WISE, and then represented the same scenario within the closed form discrete event simulation version of WISE. The players were then asked a number of structured questions in order to test if the plan produced by the closed form version had the same characteristics as that of the plan developed by a human player.

In the Deliberate Planner, the broad movement of the forces on the ground is task organised into ‘channels’ or areas of operation, which head towards objectives (such as an area of ground to be attacked, or a capital city to be defended). These are options which the Deliberate Planner can use (or not) in its consideration of how to deploy the force, and forces can be moved between channels as the scenario progresses. In an example wargame of a future scenario there are two Blue channels (Figure 5) and two Red channels (Figure 6). Red are initially static with Blue moving towards their objective. In order to make a fair comparison, both the players in the wargame, and the closed form simulation, started with the same information from sensors and intelligence reports, and had the same initial appreciation of the battlespace in terms of movement and key areas of ground. Of course this could diverge as the scenario unfolded. It was also assumed in each case that the Unmanned Air Vehicles (UAV) deployed as sensors could not be shot down, in order that a reasonable level of situation awareness could be maintained and that this factor (i.e. loss of sensor input) would not greatly influence the plan created. For our comparison, the planner was run with a cautious command style.

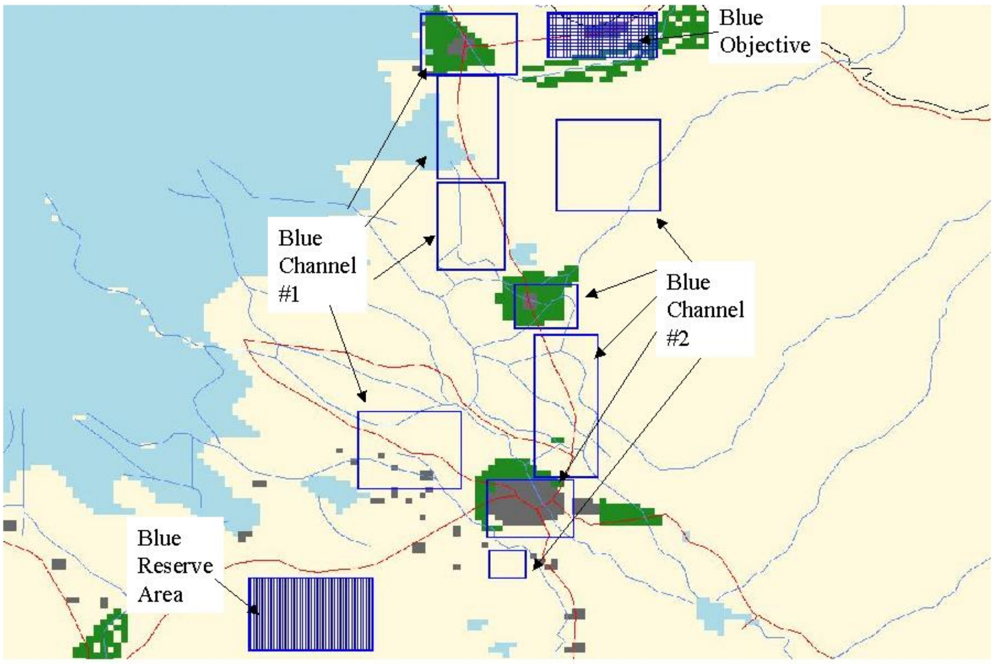

Figure 5; Blue areas of operation ('channels') within the context of Blue intent.

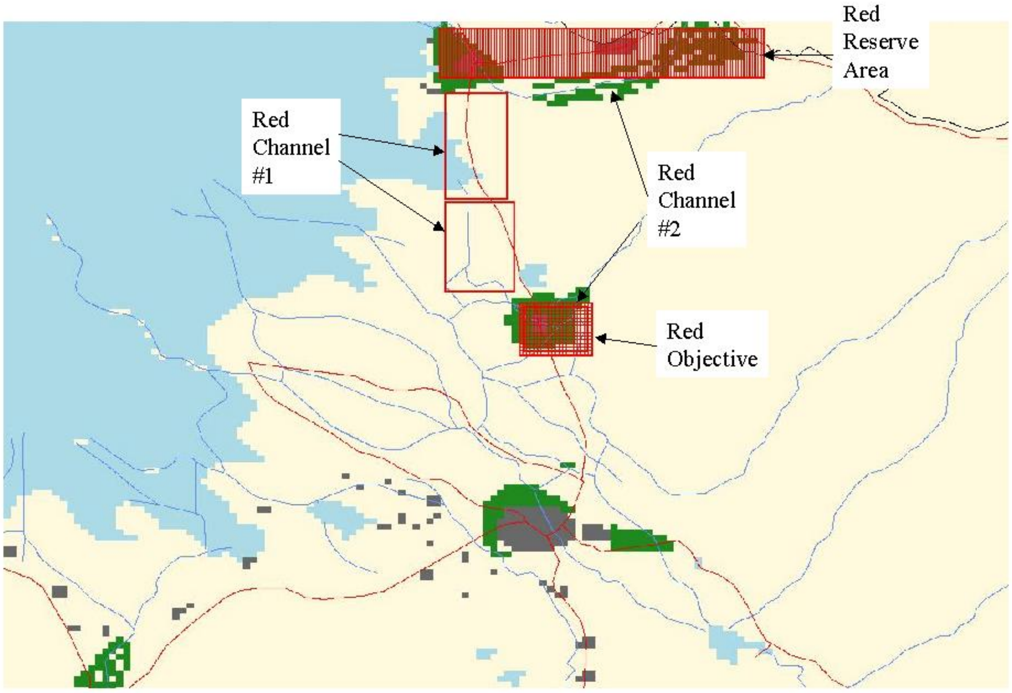

Figure 6; Red areas of operation ('channels') within the context of Red intent.

Figure 7 shows the initial deployment of the forces (the same for both the wargame and the closed form simulation, again to ensure fairness of comparison).

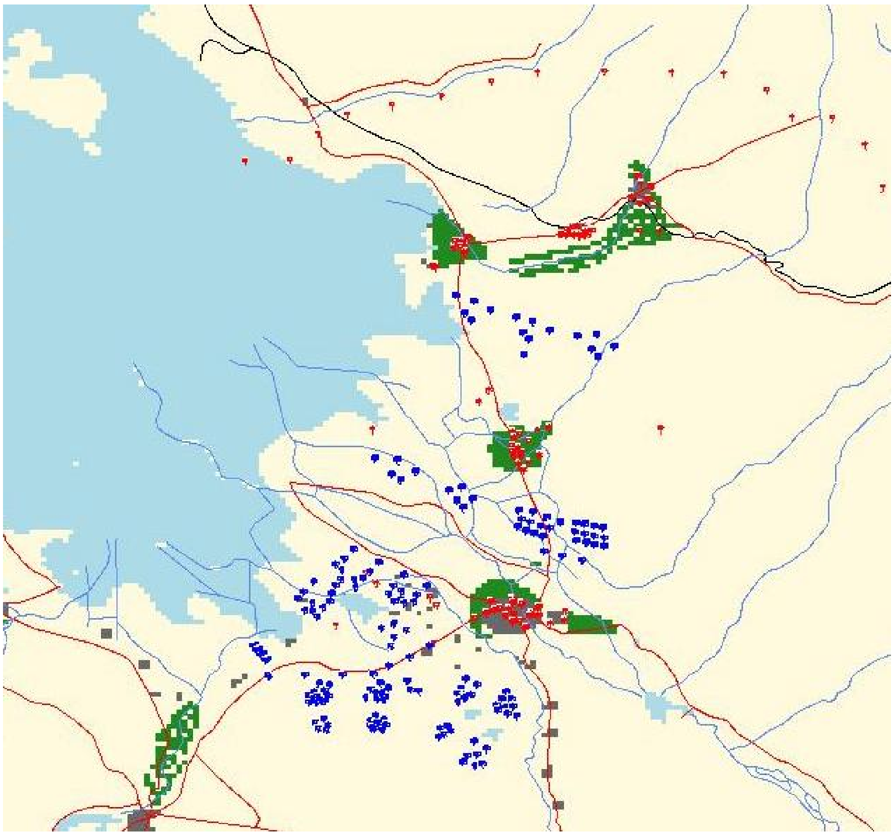

Figure 7; Blue and Red initial deployment locations.

Comparison of the simulation model algorithm with the wargame.

Military players played through a ‘vignette’ (a short scenario). We then ran the closed form simulation including the Deliberate Planning process, and asked the players, as military experts, to scrutinise the realism and credibility of the plan devised by the model.

Sensor Tasking

When the Deliberate Planner algorithm is initialised it allocates airborne unmanned air vehicle sensors (UAVs) to the first zones on the channels. Data is used to define the list of sensors allocated to each channel, as well as how many should be used on that channel at any one time.
The output log shows that both the initial sensor tasking and the subsequent sensor tasking took place in the model, with information from these sensors influencing the Deliberate Planner.

The initial sensor tasking can be seen visually in Figure 8.

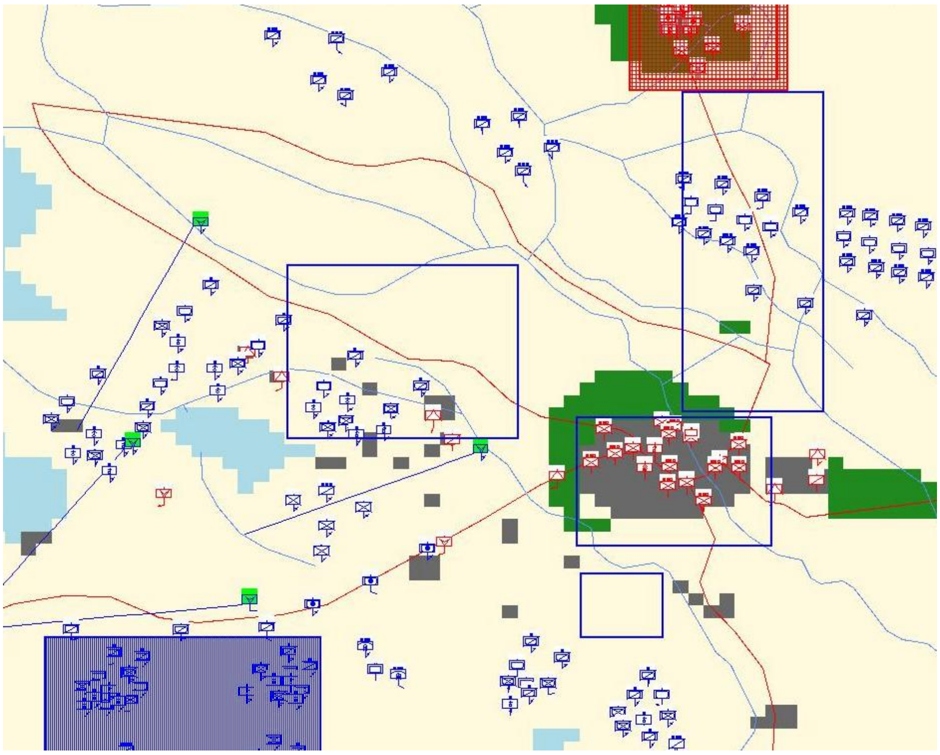

Figure 8 Initial sensor tasking and deployment.

Unit Tasking

A plan is generated either when the sensors have searched all of the zones three times or when a user defined trigger time has been reached. In terms of the simulation run, the plan generated was triggered by the user defined time.

Prior to the generation of the plan, information is supplied to the Deliberate Planner to allow it to build up its recognised picture. An idea of the type of information available in completing the situation assessment can be seen in the two Brigade perception screenshots at Figure 9 showing the initial assessment made by the planner, and then a more refined assessment as further sensor information is taken into account by the algorithms.

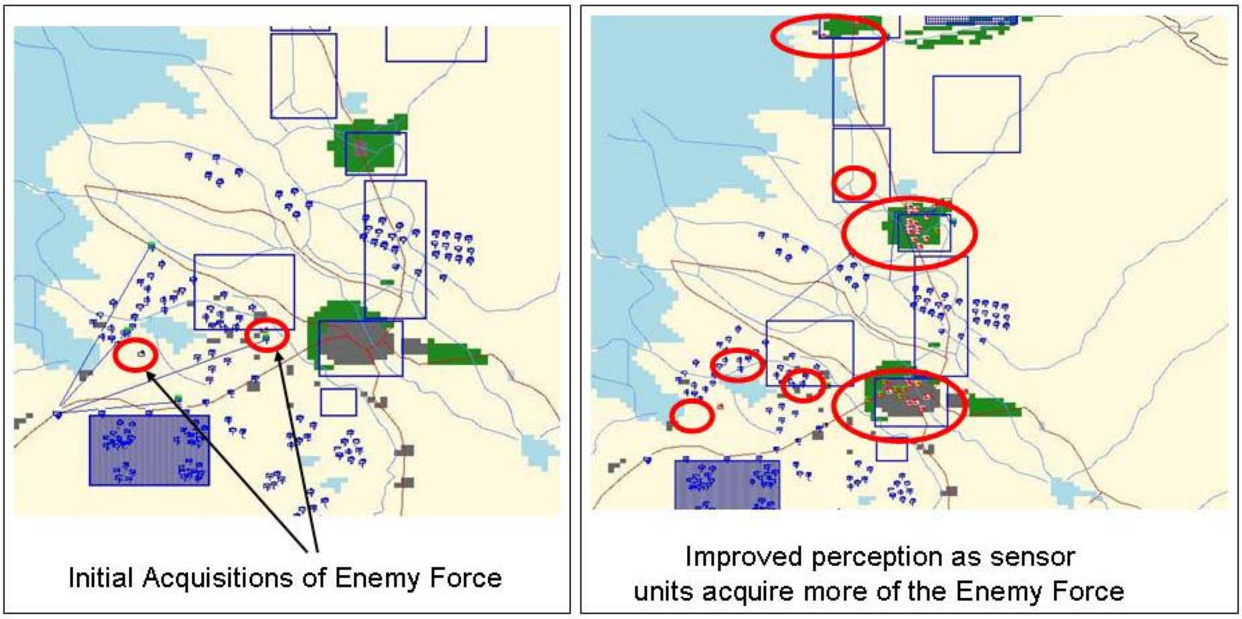

Figure 9; Brigade perception improvement following tasking of sensors.

The acquired locations of the enemy force as well as the location of own force units are used to generate the plan. It should be noted that acquisitions made outside of the defined zones are not passed into the Deliberate Planner. The algorithm only considers those acquisitions within the zones when it maintains its recognised picture, thus the plan is defined on the basis of the planner's perception rather than the total organisation perception that would be used by a player.

Figure 10 shows the execution of the plan within the simulation following the dissemination of orders to the forces. This higher level plan is a 'left hook' by Blue forces, bypassing concentrations of Red force in order to achieve Blue's objectives and intent in a timely way. A small allocation of Blue force is also directed towards the Red perceived objective in order to 'fix' Red forces in place.

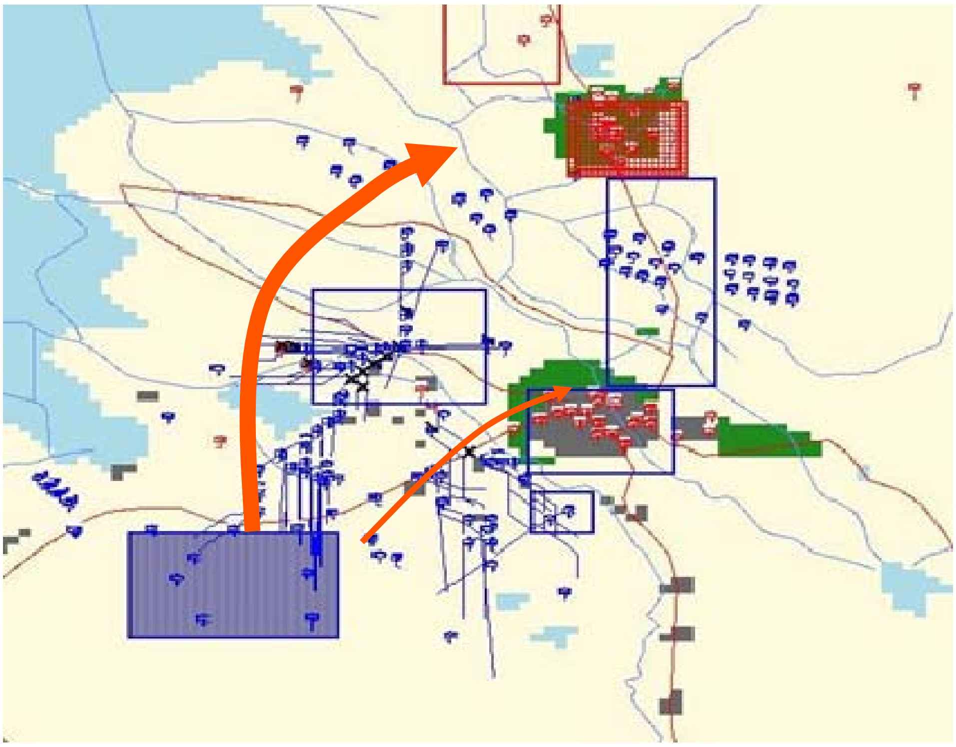

Figure 10; The higher level plan generated and implemented by the simulation.

Discussion

It was clearly recognised that the algorithm was attempting to replicate a complex area of decision making. It was thought that the current algorithm was a significant step towards a representation of the planning process. The discussion below covers areas of the plan that the players thought could usefully be improved to enhance the overall operation of the algorithm.

a). The plan that was generated sent the majority of units along the ‘left hook’, with only two company sized units being tasked down the second channel to ‘fix’ the Red forces. At first glance this appears to be counter-intuitive. However, since the planner is trying to reach the objective as quickly and with as few casualties on its side as possible (features set as part of the style of planning required), the plan is militarily credible. By choosing the left hook, the main enemy dispositions in the two urban areas are bypassed so that the objective can be reached through the least cost path. Bypassing urban areas rather than clearing them is an accepted tactic in order to maintain tempo, but the enemy left behind must be fixed or at the very least screened to provide intelligence on enemy movement. In the orders generated by the planner in the simulation, the allocation of Blue units to these areas would be insufficient to conduct this without support from other assets, e.g. UAVs, Attack Helicopters, Indirect Fire, etc.

b). The players were briefed on the Historical Analysis (HA) metrics being used in the genetic algorithm (GA) to generate the plan. They expressed concern that the weightings used for the Deliberate Planner were not fully representative of what they as commanders would use to plan. It was suggested that a higher weighting be given to the factors that consider the impact of the plan on own forces than those considering the impact on the enemy. There is the capability in the model to tune the weightings of the different HA metrics in this way.

Conclusions

We have demonstrated that Higher Level Planning can be carried out using genetic algorithms, and produces militarily credible plans. This approach is being exploited within the UK in current model developments.

References

J Moffat (2000) 'Representing the Command and Control Process in Simulation Models of Combat', J Opl Res Soc 51, 431-439.

J Moffat (2002) 'Command and Control in the Information Age: Representing its Impact', The Stationery Office, London, UK.

J Moffat, I Campbell and P Glover (2004) 'Validation of the Mission Based Approach to Representing Command and Control in Simulation Models of Conflict', J Opl Res Soc 55, 340-349.

A Robinson and S Wright (2002) ' The Wargame Infrastructure and Simulation Environment (WISE)', Operational Research Society Simulation Workshop, Birmingham University.

D Rowland (2006) 'The Stress of Battle: Quantifying Human Performance in Combat', The Stationery Office, London, UK.

B Taylor and A Lane (2004) ‘Development of a Novel Family of Military Campaign Simulation Models’, J Opl Res Soc 55, 333-339.

P Pearce, A Robinson and S Wright (2003) ‘The Wargame Infrastructure and Simulation Environment (WISE)’, Knowledge-Based Intelligent Information and Engineering Systems, 7th International Conference, KES 2003, Oxford UK, September 2003 Proceedings Part II, ISBN 3-540-40804-5