COST-EFFECTIVE SIMULATION of ENEMY FORCES
THROUGH 'EFFECTS-BASED' WARGAMING

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ABSTRACT

One of the biggest costs in setting up and running exercises is the provision of staff to run the 'White / Red Forces' response cells. This paper will look at a novel, but already proven, approach called 'Effects-based' Wargaming. When exercises (such as BLUE FLAG or UNION FLASH) are set up, the first task is to identify the 'training audience'. Once this has been done, the size of the white and red response cells and the amount of computer support required can be estimated. The assumption made is that for the exercise to be valid the white and red response cells and the computer simulation must simulate everything which leads to large expensive response cells and to simulations which can be cumbersome and inflexible to operate.

The paper questions this assumption and maintains that for many exercises an 'Effects-based' wargame would be more than adequate. 'Effects-based' wargaming starts by understanding and documenting the Warfighter Process (examples given in the paper). This indicates what thinking, knowledge acquisition and decision-making processes are required to be *stimulated* (especially those inside the heads of the warfighters) so that the exercise is successful. Once this has been decided upon, all that is then required is to provide an environment around the training audience which causes the required thinking to take place.
This environment is created by using *STIMULATION* systems which simulate the effects of the external entities with which the warfighter would interact. The stimulation systems can be much simpler and cheaper than 'normal' wargames as they only have to simulate *enough of the real world* to provide the warfighter with the effects and inputs / outputs which they would expect. This stimulation environment makes heavy use of real world message formats to simplify the C4I to simulation interface.

A key feature of Effects-Based Wargaming is the White Team Suite which provides a specialist White / Red Team interface to control the generation of the effects required in a non-deterministic way. Overall, the paper will explain what 'Effects-based' Wargaming is and how to use it effectively. Examples of exercises using this approach will be detailed.

Key Words: EFFECT-BASED WARGAME CONFLICT SIMULATION OPERATIONAL TRAINING LEVERS

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Patrick Beautement was at the Defence Evaluation and Research Agency (DERA) at Malvern, UK to assist with research into the Joint Air C2 process and with the development of wargame / exercise support facilities for the Joint Air Command Laboratory (JACL). He was previously a Squadron Leader in the Royal Air Force and was the Wargame Systems Specialist at the Operational Doctrine and Training (OD&T) Element of the AIR WARFARE CENTRE, where he was awarded the "Digital Trophy" for his contribution to Air Warfare and Aerosystems studies. At OD&T he was responsible for running the wargame "Thunder" (used as an "exercise driver" on the Air Battle Staff Course), and for advising RAF staff on synthetic environments. He has also been involved in producing avionics training systems for the Tornado, Buccaneer and Tucano as well as managing training design for ground electronics equipment. He has been working with computer simulations since he took his Masters Degree in Intelligent Systems (Artificial Life and Neural Networks) before joining the Royal Air Force.

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The former members of the JACL would like to acknowledge the inspiring and supportive leadership of the late Anthony J Alston.

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INTRODUCTION

The Joint Air Command Laboratory (JACL) at the Defence Evaluation and Research Agency (DERA), Malvern, UK started a research programme in 1994 whose aim was "To provide commanders with wargaming and training tools which will help them prepare better for future conflicts without the need for a large wargaming infrastructure". This paper will describe how the research has moved from experimentation to semi-operational use in just 4 years.

In trying to meet the aim it became apparent that there were several key issues. Firstly, it was clear that "scaleable wargames for scaleable conflicts" were needed and it was apparent that such wargames did not exist. In fact, C4I systems with designed-in scaleability do not exist either ... but that's an issue outside the scope of this paper. However, as a result of reviewing current synthetic environment approaches, the concept of "Effects-based Wargaming" was formulated to give the following advantages:

- rapid definition of simulation boundaries,
- warfighter-compatible White Team interface,
- easy interaction with C4I systems,
- improved control of exercise events,
- simplified generation of Red effects,
- reduced simulation overhead,
- and reduced White Team sizes.

A second issue was the need to have a process analysis technique and notation which would allow the definition of player / simulation interface to occur more quickly. It also became apparent that it was important that real-world information / data formats were used to reduce interfacing complexity. The final key issue was the development of a "White Team Suite" of tools specially designed to simplify the control of the exercise and reduce the size of the White Team. This Suite was designed after analysing the White Team's processes.

Please note that the scope of this paper doesn't include analysis or any other form of 'embedded simulation' for decision support. However, this work is very much about the development of a concept suited to wargaming for: command centre layout investigations, process assessment, training (individual and small-group), campaign rehearsal, C4I system testing and technology demonstrator evaluation. Also, in the paper the White Team means all the staff, (such as the Exercise Director, red response cells etc) who are not the 'training audience'. In addition, the term 'wargaming' is used in its all-encompassing meaning, but the phrase 'synthetic environment' would do just as well. Note that the term "C4I systems" is used in this paper to mean any Information Technology (IT) system designed to assist the warfighter (such as NATO's Interim CAOC Capability (ICC), or the USAF's Theatre Battle Management Core Systems (TBMCS)).

CURRENT SITUATION IN WARGAMING AND EXERCISE SUPPORT:

Over the years there has been a great deal written about wargames, their form and utility of which [1, 2] are just a small example. In many respects the basic tenets for the successful use of wargames [3] have not changed. However, with the increasing use of computer-aided exercises (CAX) there seems to be a growing assumption that everything must be simulated for the exercise to be valid. Certainly, in the case of an all-encompassing virtual battlespace (ie synthetic environment) it is difficult to see how this could be achieved without providing simulated, virtual or real entities at every level with the appropriate Red and White response cells to drive them. Despite all the hype, is this *really* how all warfighters are going to train in the future? Will military personnel 'log-in', determine which role they wish to fulfil and join in a war (which is always being fought 24 hours a day). This may be a reality soon,

but there will always be a requirement to configure wargames in different ways to achieve certain aims (see [3] for a detailed discussion of this) which cannot be met by having a single virtual battlespace.

Conventional CAX (eg Blue Flag, Warrior Preparation Centre (WPC)) are expensive to run and require many staff. As well as this problem of cost, such CAX are complex and this complexity can be the driver of technical as well as human failings. These, and other limitations are well covered in [4, 5, 6, 7]. One of the recurring themes is the large size, expense and sometimes cumbersome nature of the response cells which results in the White Team always being on the critical path. Often, much of the White Team interaction is with itself indicating nugatory effort. In the recent EXERCISE PURPLE LINK the Synthetic Theatre of War (STOW) was really a White Team Tool and was almost superfluous to the main Exercise play, yet it involved hundreds of people and a large IT infrastructure. Was this really the best way to exercise the processes used by the Joint Force Commander and the Component Commanders and their staffs?

Modularity has been a success story in wargaming with the ALSP (Aggregate-Level Simulation Protocol) confederation at the WPC being a prime example and the use of the DIS (Distributed Interactive Simulation) protocol to connect simulators providing a strong technology driver. As the scope of synthetic environments has broadened the problems of defining suitable simulation interface protocols has grown. Attempts to deal with this through the definition of the High-Level Architecture (HLA), see [8], and the use of CCSIL (Command and Control Simulation Interface Language) have provided a simulation-community centred solution. The main limitation of this approach is the extra translation overhead necessary to connect the HLA to C4I systems and so a more warfighter-centred approach is required based on existing operational message sets.

EFFECTS-BASED WARGAMING

The Effects-based Wargaming concept was developed out of the need to provide a cost-effective facility to exercise the staff of an Air Operations Centre and a research programme to achieve this was put in place by the Operational Research Branch (Air) of the UK's Ministry of Defence.

'Effects-based' Wargaming starts by understanding and documenting the Warfighter Process and the Boardman Soft System methodology (explained below) is used. Examination of the process model indicates what thinking, knowledge acquisition and decision-making processes are required to be *stimulated* (especially those inside the heads of the warfighters) so that the exercise will be successful. Once this has been decided upon then an environment is provided around the warfighter which causes the required thinking to take place. The process model assists in determining this warfighter / simulation environment boundary and in listing which effects have to be generated.

This environment is created by using *stimulation* systems which provide the effects of the external entities with which the warfighter would normally interact. The stimulation systems can be much simpler (and hence cheaper) than 'normal' wargames as they only have to simulate *enough of the real world* to provide the warfighter with the effects and inputs / outputs which they would expect. This stimulation environment makes heavy use of real world message formats to simplify the C4I to simulation interface.

A key feature of Effects-Based Wargaming is the White Team Suite (WHITS) which provides an interface, specially designed for the warfighters in the White Team, which allows them to control the generation (in a non-deterministic way) of the effects required and to manage all other elements of the Exercise. This enables the White Team to concentrate on the high-level issues, rather than getting embroiled in detail.

Understanding and Documenting the Warfighter Process.   For the Effects-based Wargaming concept to be really successful it is necessary to understand and document the warfighter processes which are to be used in an exercise. The JACL Team reviewed many of the existing process modelling techniques (eg IDEF, Checkland / Wilson) but were unhappy with one particular aspect - the inaccessibility of the diagrams produced. As a result, the team selected the Boardman Soft System Methodology (BSSM) [9] developed by Professor John Boardman of DeMontfort University, Leicester, UK.

There is not space in this paper to describe the BSSM in detail, but the essential points are as follows. For a particular system under review (eg a Combined Air Operations Centre (CAOC)) the processes in that system are listed along with the 'actors' (personnel / organisations) and what the actors do. In addition, the inputs and outputs of the process are recorded. Next the processes are broken down into activities showing in detail the necessary stages to achieving the overall process. In addition, related information about the C4I system used, the number of personnel involved, message formats used etc can be recorded and annotated to the various activities. All this information is kept in a data structure which underlies the diagrams (See Figure 1) which are then created.

Plan Air Tasking - Scene 1

Objective is:
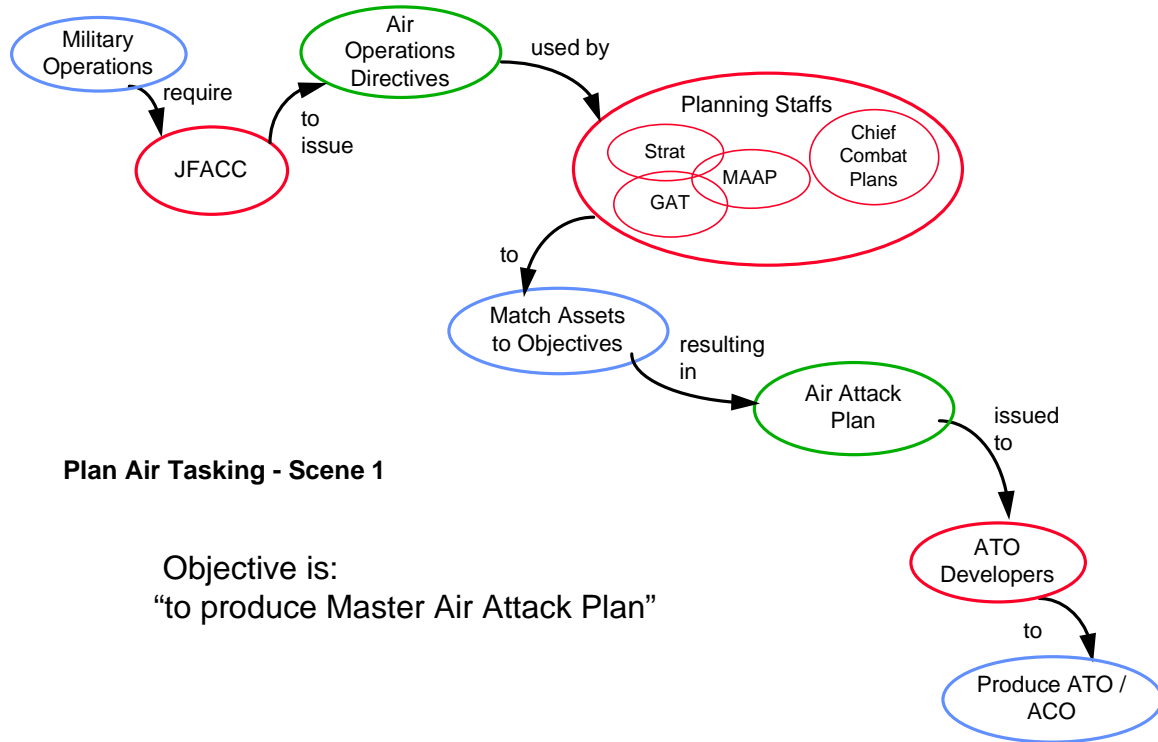"to produce Master Air Attack Plan"

Figure 1 - Example Boardman Process Diagram

So far, the JACL Team has completed a number of studies [10, 11, 12] of parts of the joint air process. These studies have been well received by the military community who find the diagrams both easy to understand and very useful. Indeed, the NATO IDCAOC, the UK CAOC and 32 AOS at Ramstein AFB have used the diagrams for reviewing the efficiency of their concepts of operation and for training new staff. The diagrams allow users to drill-down though the processes and activities and expose the related information. Eventually, it will be possible to interrogate the diagrams to answer such questions as "Which processes are affected if system 'x' stops working?", or "How long does it take (on average) to carry out these two processes?". The JACL Modelling Toolkit is being produced to support this functionality. The JACL Team plan to have a complete UK 'end-to-end' joint air study finished by March 1999.

Once a process model has been produced it can be used to identify the external entities with which the warfighter interacts. This is done by drawing a boundary around the process(es) which are to be investigated in an exercise. All processes inside the boundary will be carried out by real staff using their normal C4I systems. Everything outside the boundary is in the domain of the 'encompassing simulation' (see Figure 2 below) but *will not necessarily be simulated*. In this way it is easy to see which processes (and capabilities) will be exercised, and which will not, and so accountability is added to the exercise. Redrawing the boundary allows a rapid reconfiguration of the player / simulation interface.

This leads to the **Key Point of Effects-based Wargaming** which is that each of the interfaces between the real and simulated environment (the Enemy is ALWAYS part of the simulated environment) is examined on the process diagram and the nature of the knowledge / information transfer determined. The question then to be asked is "What needs to be simulated *to create the effects of external action* which then *stimulate* the warfighter's decision making?". For example, in a UK exercise it would be acceptable to simulate the effect of a 'scud' attack by giving the JFACC a message stating that "Airbase 'X' was hit at 1235 and that minimal damage was caused". It would not be necessary to simulate a full

suite of friendly and enemy theatre missile operations. However, the Defensive Operations officer in Combat Operations would need a more detailed representation. The JACL Team's experience is that this 'selective simulation' approach does work.

Figure 2 - The Encompassing Simulation

Providing The Warfighter's Environment. In common with most approaches to wargaming, Effects-based Wargaming also requires the provision of a realistic copy of the warfighter's normal working environment (room layout, systems etc). During the exercise the players must think and work as they would normally. It is vital that the usual operational processes are not distorted or corrupted as a result of the exercise. Sadly some C4I systems and exercise configurations are badly designed and do cause this type of corruption. However, the process analysis work and simplicity of Effects-based Wargaming helps to highlight this kind of problem so that C4I system designs can be improved to harmonise better with the warfighter's 'natural' way of working. Of course, experimenting with the warfighter's environment may be part of the exercise and investigating the effects of, for example, a changed room layout on the processes may be revealing.

The *Stimulation* Systems.   As was mentioned above, the key issue in Effects-based Wargaming is: "What needs to be simulated (*to create the effects of external action*) to *stimulate* the warfighter's decision making?". There are two important words here: *effects* and *stimulate*. The JACL Team has designed and built a *Stimulator* (no laughing please) which only simulates the activities which are operationally necessary to produce the effects needed to drive the exercise. These are the effects that would normally be seen as a result of interactions with the external entities described above (eg notification of a Red 'attack' on an airbase, which 'destroyed' escort aircraft, would *stimulate* the CAOC into considering whether it needed to cancel a composite air operation as a result). A discussion of the features of the Stimulator follows.

One primary feature of the Stimulator is that its inputs and outputs are real-world messages and that it can directly *stimulate* real-world C4I systems. In this way there is no input / output overhead for the C4I systems, nor is there any artificiality for either the warfighter or for the members of the White Team. This issue is discussed in more detail below.

The Stimulator (in its current Phase 5 version) essentially simulates the effects of the external entities and execution level (ie sub-CAOC functionality, including airbase operations) of Blue and aspects of the Red war. During the design phase there was no problem in determining which effects needed to be simulated as the method described above was followed. However, at first, the JACL Team

had problems deciding how the triggering of the Red effects was to be controlled and what the White Team interface would look like (how this was solved is discussed later). Version one of the interface proved too simplistic and the JACL Team is now working on a more sophisticated version with an interface designed to be used by the warfighter in the White Team. This interface forms just one element of the special functionality called the White Team Suite (WHITS) which is described in more detail below.
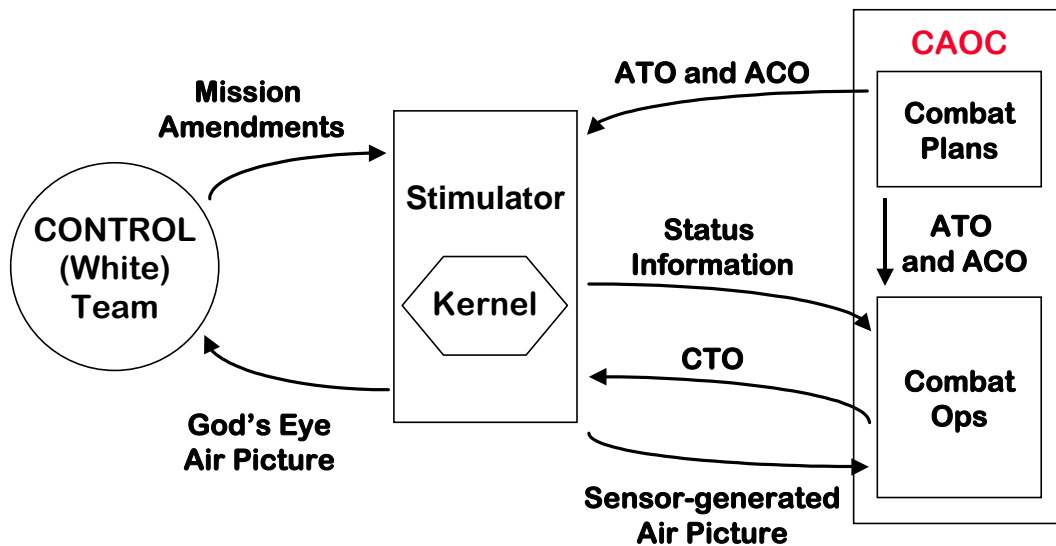

Figure 3 - Stimulator Schematic

The Stimulator produces a sensor-generated air picture for Blue and a God's-eye view for the White Team (see Figure 3). Blue's view of Red changes depending on which friendly ground or air sensors are operational, where they are and on factors such as terrain and sensor performance. This means that as Blue assets are attacked, or go unserviceable, Blue's control of the air is affected and the White Team could alter 'The Levers' (described below) to reflect this change.

C4I System / Simulation Interfaces.   As mentioned above, an important feature of the Stimulator's design was the use of real-world interfaces with the warfighter, the C4I systems and the White Team. The advantages of this approach are that, in theory, the Stimulator can be exchanged for real players and systems without the interfaces having to be modified as no extra interface layer is required. The issues raised by this approach are discussed below:

The military already have working C4I environment where information is exchanged between warfighters (including the enemy) and their systems. Effects-based Wargaming exploits and builds on this network, rather than duplicating it with a separate simulation environment. By making the real environment the default, the simulation environment becomes secondary and takes advantage of existing messages and protocols and so does not *always* have to invent its own. This results in considerable savings in time, effort and complexity. In this way, Effects-based Wargaming exploits the fact that people are already communicating successfully through the systems and so adding simulation does not corrupt these people-to-people interactions.

The JACL Team had already been involved in producing a prototype of a CTAPS / ICC Transfer (CIT) interface layer (including remote-access functionality). This work had provided considerable experience in solving the problem of real-time data transfer from CAFMS/X to the ICC MTOTE. A technology demonstrator to show that information could be transferred between TBMCS FLEX to the Stimulator soon followed and prototype Stimulator / ICC MTOTE connectivity has also been achieved.

In terms of interfaces, as stovepipe C4I systems go away, many of the currently 'external' interfaces become internal ones. For example, the CTAPS (via USMTF) to WCSS interface becomes, in TBMCS, an internal data replication. Consequently, stimulation of these systems becomes easier to manage as there are less 'external' entities and interactions to simulate. In addition, rapid reconfiguration of the interfaces (as training audience changes) becomes easier too.

Current C4I to wargame interfaces (such as CTAPS Wargame Interface controller (CWIC), Project Real Warrior (PRW)) and architectures and protocols such as the High-Level Architecture (HLA) and Distributed Interactive Simulation (DIS) are conversions into a simulation-centred world. The successes so far with Effects-based Wargaming suggest that these other approaches may be inherently over-complicated.

There may be merit in considering a Joint Battle API (ie a meta-language) which could it be used for ALL communications. This would be a superset which would include the information required for the C4I / warfighter interface as well as that required for simulations. It could take advantage of approaches such as the Compiled Message Protocol (CMP) approach (which allows messages to be negotiated on the fly, so that they don't all have to be defined in advance) and would include tools for aggregation and disaggregation [13]. This is an area which requires further study.

White Team Suite (WHITS).   It has already been mentioned that the WHITS is an essential part of the Stimulator and is being designed to reduce the size of the White Team and simplify its task. Previous experience and recent exercises (described in more detail below) have allowed the JACL Team to examine the processes which occur in a White Team. This has enabled the Team to design a user interface *specifically optimised* for the White Team. To deal with generating and managing the effects required to stimulate the warfighters' thinking the WHITS consists of 5 main elements (Campaign Planning Levers, Execution Control Panel, Dynamic Simulation Event List Manager, Air Picture Management System and the Simulation Technician Totes) which are described in more detail below:
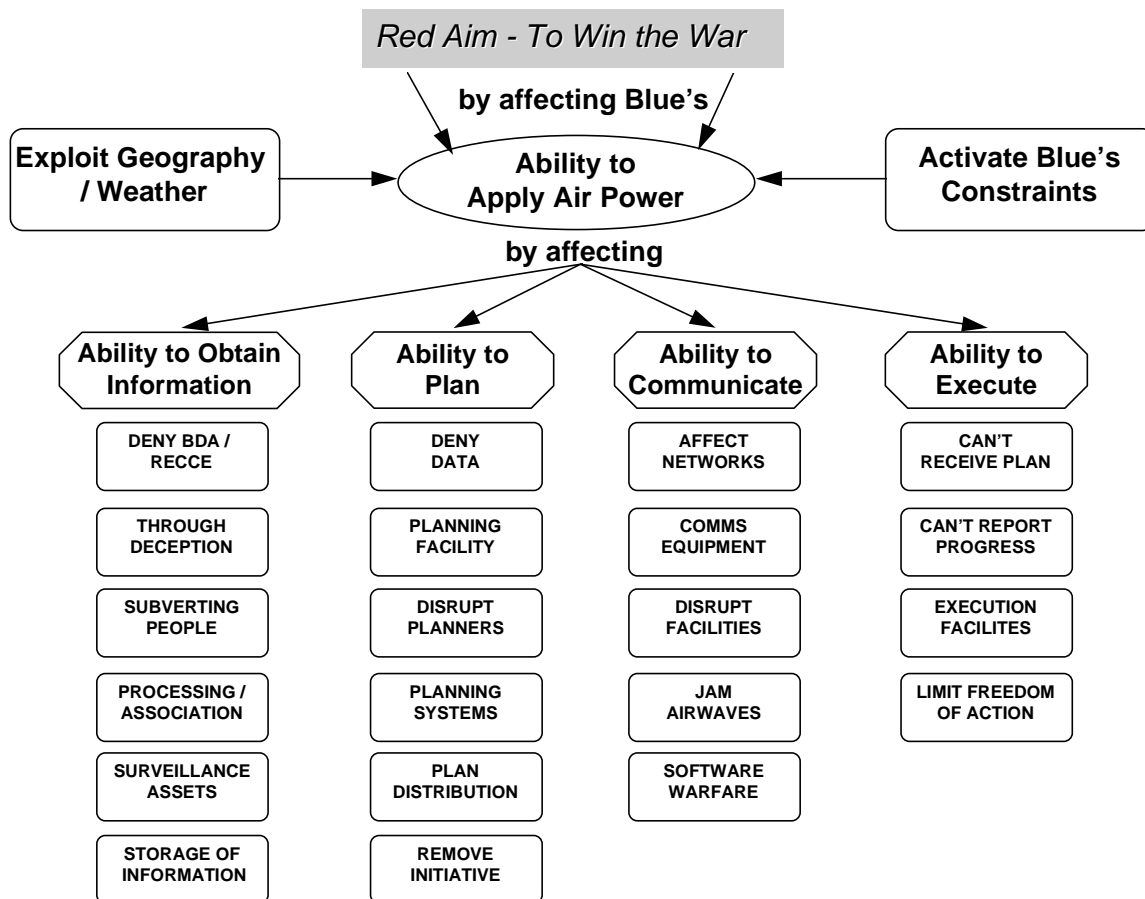

Figure 4 - Red Aims

Campaign Planning Levers and Execution Control Panel.   The WHITS philosophy builds on the Effects-based Wargaming ideas described above. The basic idea is to give the White Team 'buttons' to press which generate the effects of Red actions or the implications of Blue actions. It was essential that the Stimulator provided the effects of the external entities' own actions as well as reflecting the effects, implications and results of the warfighter's. It was also clear that the Stimulator should implement a "ruthless enemy" [14] (albeit a controllable one) as too many exercises use 'pussy-cat' enemies from which players learn nothing.

The mapping between the buttons and the effects was explored in an initial discussion document [15] which suggested two possible approaches: firstly, a series of 'buttons' related to the Red campaign aims (see Figure 4) and, secondly, a 'Red Levers approach (see Figure 5). The first approach was discarded because it was not discriminating enough (eg, selecting the "Can't Report Progress" or "Deny Data" buttons might result in the same type of Red air activity). The Levers approach is much more promising, but the specific Levers initially selected were too simplistic. It became apparent that Campaign Planning Levers were required to aid the generation of a suitable set of Red missions. In addition, the White Team needed an Execution Control Panel which could be used to manage the execution events. The Campaign Planning levers and the Execution Control Panel are being researched and the concept will be evaluated further at the September 98 STIMEX.
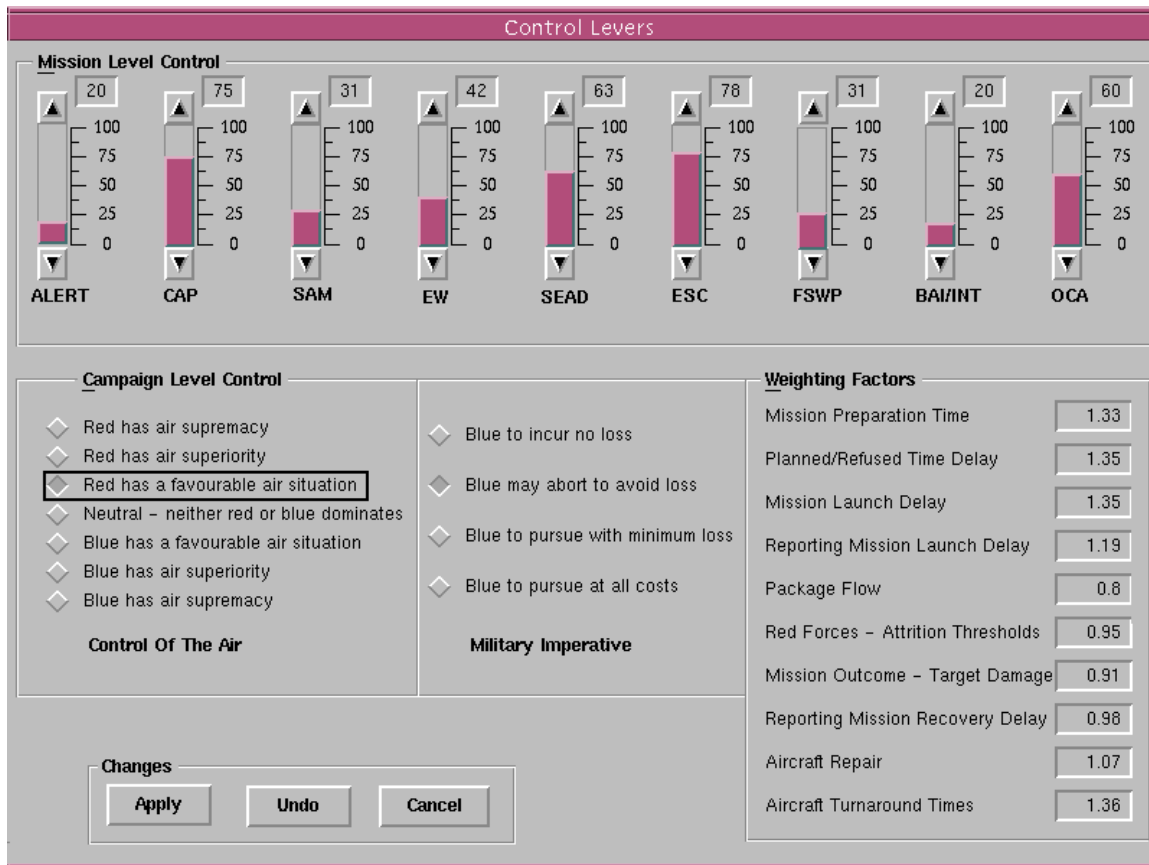

Figure 5 - Example Levers

Dynamic Simulation Event List Manager.   In most wargames the White Team generates events which are used to drive the players' decision making processes. Often, these events are pre-defined in a simulation event list which includes the timing of the event and the nature of the activities to be carried out. Unfortunately, as the wargame proceeds, the events become less and less relevant as the scenario develops. The JACL Team developed the idea of a Dynamic Simulation Events List (DSEL) [16] which would evolve as the wargame proceeded. The DSEL would be used as follows. Before a wargame, the White Team would have created an Event Option List (EOL) consisting of activities which could be injected into the play to achieve certain objectives.

During the play, the White Team would either activate items from the EOL (moving them into the DSEL) or they would add new items to the DSEL 'on-the-fly'. The DSEL would manage the events (and all the implications) creating a schedule of reminders. The schedule would prompt the White Team when they needed to carry out tasks to progress Events. In addition, the White Team could interrogate the EOL to find out what the effects would be of activating a particular Event. In this way, the White Team could choose the Events which would create the effects most relevant to the current situation. The DSEL Management System is still being researched, but it will be an important part of the White Team Suite which will reduce the load on the Team and so allow a smaller White Team to be used.

Air Picture Management System.   The next part of the WHITS is the interface which allows the White Team to interact directly with the simulation while it is running. The interface is called the Air Picture Management System (APMS) and it is being adapted to take advantage of the lessons learned from

DERA's work on the internationally-acclaimed 'Master Battle Planner' (see Figure 6). The APMS allows a warfighter, working as part of the White Team, to manipulate the simulation through an interface which is entirely consistent with an operator's view of the world. For example, to scramble aircraft to an intercept, all that is required is to 'drag' the aircraft on alert and 'drop' them on the threat. To return an aircraft to base, 'drag' it's icon to the base selected and so on. The Stimulator then generates the appropriate effects (issuing orders, making the appropriate reports back to Combat Operations and changing the sensor-generated air picture) based on the action selected. The air picture can easily be reconfigured to show different track notations. The APMS has already been used in previous exercises and is still undergoing further development.
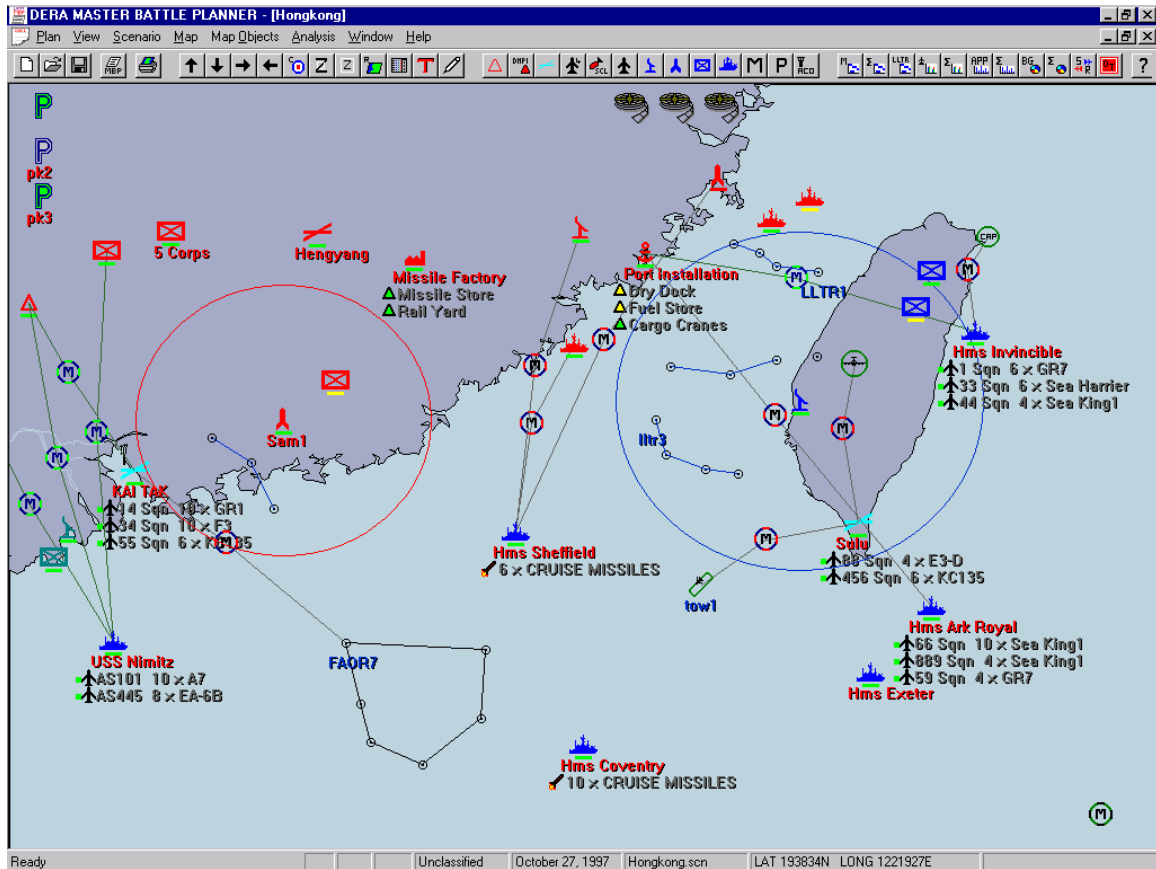

Figure 6 - Master Battle Planner

Simulation Technician Totes.   Finally, the Stimulator provides a number of Simulation Technician Totes which allows access to the Stimulator's 'internal state' on the rare occasions that this would be required. These totes would normally be used by a simulation technician.

EXAMPLES OF EFFECTS-BASED WARGAMES

Effects-based Wargaming has been in use for some time and it's usefulness as an approach has been proven. Two examples are given below:

The Air Battle Staff Course.   The UK's Air Warfare Centre has run an Air Battle Staff Course (ABSC) for many years. The course focuses on the Theatre / Operational level of war and is suited to personnel who will work for the Joint Force Commanders' air staff or for the Joint Force Air Component Commander (JFACC) or in any other air headquarters. Staff at this level of war are always planning one to three days ahead which suits the ABSC's wargames which have always been driven by the USAF's "Thunder" simulation.

Thunder is a cyclic game normally set to run for a 24-hour cycle. To create the *effect* of real-time the game is always run one day ahead with the results produced being 'leaked' to the players a bit at a time throughout the day. Thunder produces a great deal of detailed information (as it can also be used for campaign analysis) but the only information released is that which is required to *stimulate* the air staffs decision making. This arrangement has worked well, but Thunder provides no special tools for the White Team nor does it produce a credible air picture. Nevertheless, the ABSC's White Team had

considered the functionality which would need to be provided for a White Team Suite and this proved to be a useful starting point for the JACL. In addition, the experience with the ABSC had shown that Effects-based Wargaming was a valid approach which should be taken further.

Combat Operations Stimulator Exercise (STIMEX 98 / 1).   The Combat Operations staff at the UK CAOC approached the JACL about the possibility of running an exercise using the Stimulator and the Experimental CAOC (ECAOC) at DERA Malvern. The UK CAOC wished to evaluate both a new Concept of Operations (CONOPS) and a new room layout (see Figure 7). The UK CAOC could not use their operational facility as the room layout was literally bolted to the floor. The Malvern ECAOC could be quickly reconfigured as lessons were learned during the Exercise. In addition, the Stimulator (and the Effects-based Wargaming approach) was seen as the best way to drive the Exercise. STIMEX 98 / 1 was so successful that a repeat was run in September '98 and another is planned for January '99.
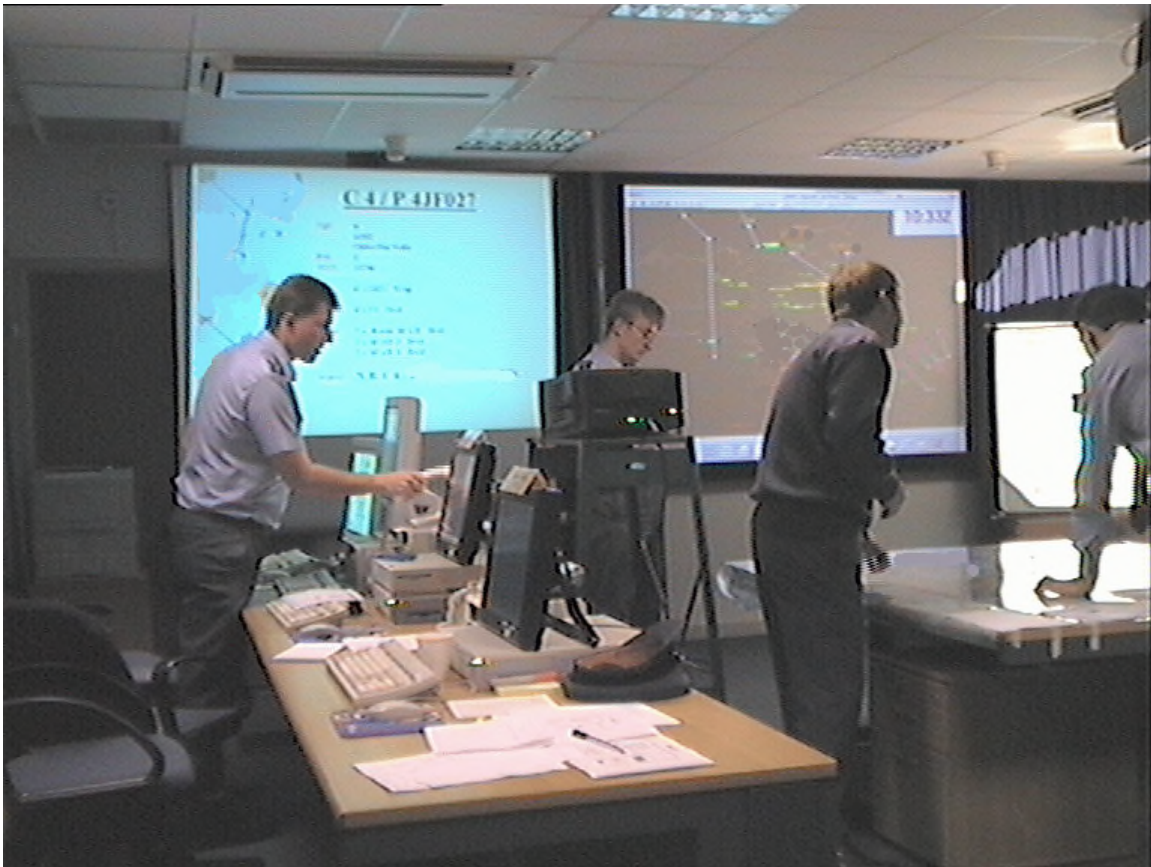

Figure 7 - STIMEX 98/1 - Combat Operations

SUMMARY

The Effects-based Wargaming concept was developed out of the need to research how a cost-effective facility to exercise air headquarters staff could be provided. 'Effects-based' Wargaming requires that there is a well understood and documented Warfighter Process and the JACL Team recommend that the Boardman Soft System methodology is used. Examination of the process models indicates what thinking, knowledge acquisition and decision-making processes are required to be *stimulated* (especially those inside the heads of the warfighters) so that an exercise will be successful. Once this has been decided upon an environment is created around the warfighter which causes the required thinking to take place. The process model assists in determining this warfighter / simulation environment boundary and in listing which effects have to be generated.

The JACL creates this environment by using *stimulation* systems which simulate the effects of the external entities with which the warfighter would normally interact. The stimulation systems can be much simpler and cheaper than 'normal' wargames as they only have to simulate *enough of the real world* to provide the warfighter with the effects and inputs / outputs which they would expect. This stimulation environment makes heavy use of real world message formats to simplify the C4I to simulation interface. In addition, Effects-Based Wargaming uses a White Team Suite which provides a

specialist White Team interface to control the generation (in a non-deterministic way) of the effects required and to manage all other elements of the Exercise.

The advantages of Effects-based Wargaming are its relative simplicity, its low cost, the small size of the White Team required and the ease with which Exercises can be reconfigured. In addition, warfighers in the White Team use an interface designed to be compatible with their operational thinking. Also, the Stimulator's inputs and outputs are mostly real-world messages and so it can interact directly with the actual C4I systems which the players would use in a war.

RECOMMENDATIONS

The experience which the JACL Team has had with Effects-based Wargaming has led it to make the following recommendations for further research:

- That the Effects-based Wargaming concept be further developed to provide a pragmatic alternative to the 'monolithic' modular simulation systems being proposed.
- That Effects-based Wargaming be used to evaluate alternative CONOPS (such as ATO-less planning, tasking and execution) and the validity of Self-organising C2 Structures [16, 17] currently being researched.

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