A COMPLEX SYNTHETIC ENVIRONMENT FOR AIRCREW TRAINING RESEARCH

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Abstract

During February 2000, DERA, a research and technology agency of the UK MoD, conducted the first in a series of simulation trials to investigate the potential of a collective environment for aircrew training. The trial involved simulating a mixed package of air-to-air and air-to-ground manned simulators, with additional friendly forces provided by computer generated forces (CGF) and human role-players. Hostile forces were also provided using air-to-air manned simulators, CGF and human role-players.

The simulated operational environment was designed to be as realistic as possible. Front-line crews manned the simulators, while other military personnel took the roles of the command chain for both friendly and hostile forces. This allowed the simulated missions to be run as they would be in a real operational environment, with full pre-sortie briefings, crew planning, sortie execution and debriefing.

The implementation of the trial infrastructure involved significant development and integration effort, covering aspects such as:

- Credible Computer Generated Forces
- Long-haul secure data and voice communications
- Terrain database generation
- Scenario development and management
- Exercise and technical management systems, including data recording and analysis tools
- Planning, briefing and debriefing systems
- Role-player systems

This paper covers the development of the trial infrastructure, and lessons learnt during development and use.

Biographic Sketches:

Ian Greig is a Research Leader within the Future Systems Technology Division of the Defence Evaluation and Research Agency, an agency of the UK Ministry of Defence. He has over 10 years of experience in simulation technology research, including as technical manager for the UK air component of the STOW-97 advanced concept technology demonstrator. Current research interests include advanced CGF and exercise management systems.

Edward Mayo is a technical leader within Future Systems Technology Division at DERA. He has worked for DERA for eight years, prior to joining DERA he worked for British Aerospace (Military Aircraft Division) as an Aerodynamicist after leaving Queen Mary and Westfield college with a degree in Aeronautical engineering. His first five years within DERA had been spent in the Centre for Defence Analysis (CDA) and its forerunners analysing future military airborne concepts. Having left CDA he now works for Air Systems sector in Flight Management and Control (FMC) department where some of his duties include the trials integrator for research relating to air training.

Daran Crush is a technical leader within Future Systems Technology Division at DERA, the research agency of the UK's MOD. Daran has 10 years experience in simulation technology in fields ranging from the design, integration and delivery of a fixed wing tactics trainer to processes for Secure Wide Area Network Accreditation. Current interests are formal measurement of simulator interoperability and desktop combat team training.

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INTRODUCTION

Through the year 2000 and continuing into 2001 DERA, the research and development arm of the UK Ministry Of Defence, is performing a number of simulation trials to confirm the potential of a collective environment for aircrew training. These trials place a number of different teams, drawn from front line aircrew, in a representative operational scenario, and provide them with all the facilities that would be available to them when performing a real operation, from appropriate briefings, to a representative fully populated simulation environment.

A vast amount of technology and civilian and military personnel have been brought together to provide the simulation environment. This paper describes some of the reasoning that has taken the research down this path, the scenario used within the trials and the underlying technologies that have been employed to provide the crews with this collective training environment.

This paper is one of a set of three papers submitted to the I/ITSEC 2000 conference. The others discuss the high-level objectives of the UK's Air Systems Training research programme ("UK Aircrew Training Employing Distributed Simulation" by Stephen Gale and Steven Kay), and the training theory behind the research programme ("Training in a Synthetic Environment for Improved Operational Effectiveness in Collective Air Operations" by Heather McIntyre and Ebb Smith).

BACKGROUND OF THE RESEARCH PROGRAMME

The research trial described in this paper is part of a larger on-going UK MoD funded research package to investigate the use of simulation technology and training methods to enable aircrew to achieve maximum readiness.

In the past the research programme has investigated diverse areas, including (amongst many other areas) motion cueing systems, the simulation of complex air wakes from tanker aircraft, and the infrastructure required to enable simulators to interoperate. Over the past few years the focus of the research has shifted from underlying technology to its application, and understanding the effectiveness of the training it provides. This shift has lead to the development of the current trials programme which acts as the focus and proving ground for the technologies, and the postulated training theories.

The trials programme takes a pair of offensive fixed wing teams (bomber/recce and escort) in a ground attack mission pitted against a force of ground and airborne threats to perform a number of missions of increasing intensity. The offensive teams were co-located and were able to perform their planning and briefing together. It is planned that for future trials the offensive teams will be located at two different sites and will need to perform their tasks using tele-working facilities.

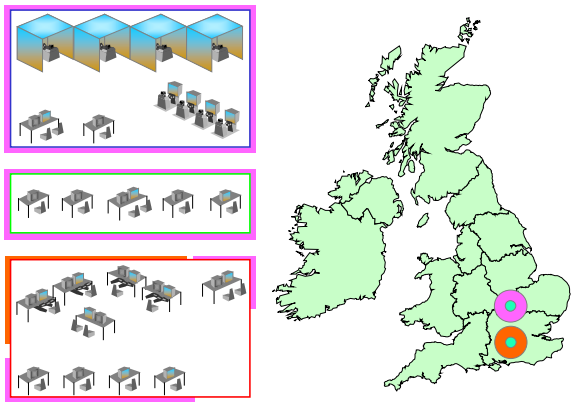

Figure 1 Trials configuration and location

The manned 'blue' aircraft were based at DERA Bedford and the manned threat aircraft were based at DERA Farnborough.

THE SCENARIO

One of the main objectives of the trials programme has been to represent, as accurately as possible within the constraints, a real operational theatre. To that end a scenario based on recent real-world operations was chosen. The specifics of the

scenario were based on recent operational experience of one of DERA's military advisors, who had just returned from a five-month deployment to that theatre.

The scenario was designed to cover three days of an escalating combat situation – day one was a simple reconnaissance mission (where friendly forces are engaged by ground-based air defence (GBAD) systems), day 2 was a retaliatory ground attack mission against the GBAD systems (with further GBAD engagements), and day 3 a higher intensity retaliatory mission (again against GBAD sites).

More specifically the missions were designed to exercise the aircrews' team interactions with the addition of 'trigger events', which were not expected by the aircrew. These included events such as intelligence updates during mission planning, radio communications jamming, munitions unavailability, system malfunctions, and engagements by previously unknown GBAD sites.

The coalition operation included the following air assets:

4 x Jaguar GR.1 (UK)
4 x Tornado F.3 (UK)
8 x F16 CJ (US)
6 x A10 (US)
4 x F15E (US)
2 x EA6B (US)
8 x F15C (US)
1 x E3D (UK)
1 x KC 135 (US)
1 x Nimrod R (UK)

For each of the primary missions, the main package of aircraft included the four Jaguars (as the recce or bombers), the four Tornado F3s (as fighter escort), four of the F-16 CJs (in the suppression of enemy air defences (SEAD) role) and an EA6B as an escort jammer.

The airborne threat included in the scenario comprised of the following assets:

4 x MIG 25
12 x MIG 23
4 x Mirage F1

The following threat ground-based air defence assets were also included:

4 x Early Warning (EW) radar
4 x SA-2
3 x SA-3
2 x SA-6
2 x ROLAND
2 x KS-12
2 x KS-19
1 x KS-30
4 x S-60

INTRA-SIMULATION SYSTEMS

Briefing, Planning and Debriefing

The actual time spent flying was a relatively small part of any one trial day. For every hour spent flying in the simulation environment, five hours were spent in briefing, planning and debriefing sessions. For the purposes of realism the aircrew brought their own mission planning equipment, the output of which was downloaded into simulators. In short, each day comprised of the issue of an Air Tasking Order (ATO), followed by a Met brief, an intelligence brief, planning session by the aircrews, a Mass brief and finally a formation brief before climbing into the cockpits. Debrief sessions were conducted for the individual squadrons and for the package as a whole. The planning session was aided and abetted by an adjoining Combined Air Operations Centre (CAOC) that injected information into the aircrew planning sessions, information such as latest met reports, intelligence reports and last minute reports that required the aircrew to re plan e.g. non-availability of support assets. The layout of the briefing, planning and debriefing sessions was as close as possible to reality.

Crewed simulators

Ground attack:

Aircrew from RAF 6-Sqn flew the ground attack missions in an immersive four ship environment using DERA's RTAVS (Real-Time All Vehicle Simulator) simulators. The simulators provide a 270^{o} field of view, a generic cockpit with three representative head down displays and the necessary controls to operate the aircraft and weapon systems including the Thermal Imaging and Laser Designation (TIALD) system. A Jaguar aircraft armed with sidewinders for self-protection and either carrying a reconnaissance pod, solely Paveway II (Laser Guided Bombs (LGBs)) or a combination of TIALD and Paveway II (depending

on the exact mission type and the role of the aircraft) was simulated. The Jaguar pilots flew the bombing mission whereby one aircraft designated the target and the other dropped the LGB.

Escort:

Aircrew from RAF 11-Sqn flew the four Tornado F3 fighters whose role was to escort the bombers to the target area and protect them from airborne threats. The Tornado F3's were armed with Sidewinders and Skyflash missiles. The aircrew flew the escort mission using the DERA/TT&SL developed ACES (Air Combat Evaluation System) mission simulators. These simulators provide a single outside world-view with three representative head down displays. For the initial trial single seat ACES mission simulators were employed; for latter trials two seat ACES mission simulators are planned.

Air Defence:

The threat air defence was provided by the DERA developed JOUST® system. JOUST® comprises a single outside world display and a simulated head down display presenting all the necessary information for air-to-air combat. Four JOUST® systems was configured to represent MiG-23's armed with AA-8 and AA-6 missiles. This system was manned by serving RAF personnel who employed tactics becoming to this particular platform type.

Role-Players

AWACS:

The role of the AWACS was to provide a Recognised Air Picture (RAP) that was then fed to the Tornado F3's (via the Joint Tactical Information Distribution System (JTIDS) and voice comms) and to the Jaguar's (via voice comms). The initial AWACS-only emulation was augmented by a system that also allowed the AWACS role player to see the simulation ground truth. This enabled the AWACS role player (a serving RAF officer) to fulfil his dual role as an AWACS weapon controller and White Force evaluator. As he wasn't being trained there was no requirement for an accurate AWACS operator station simulation; his main role was to provide stimulus into the scenario and provide the aircrew with the correct cues.

CAOC:

A prototype CAOC simulation was implemented for the initial trial, the purpose of which was to provide the exercise management ('White Force') cell with the necessary information so as to insert trigger events into the scenario. Again a CAOC emulation was used that although workable in the first instance became superseded by a system that comprised CAOC functionality and ground truth. This enabled the CAOC role player (a serving RAF officer) to fulfil his role as a CAOC operative. The CAOC was positioned in the white team cell so he had a lot of information at his disposal from which to provide stimulus into the scenario.

SOC:

The red Sector Operations Centre (SOC) was manned by a serving RAF intelligence officer who had a detailed knowledge of the scenario and the equipment deployed by the threat. His role was to provide a stimulus into the scenario by co-ordinating the threat systems both air and ground based. A SOC emulation was used that although workable in the first instance became superseded by a system that comprised SOC functionality and ground truth. The red SOC operator was physically located in a separate room to the white cell and Computer Generated Forces (CGF) operators and was geographically located in another county from his manned airborne assets. The four EW radars passed their RAP to the SOC from which the SOC operator gave voice instructions to his Anti-Aircraft-Artillery (AAA) and Surface-to-Air Missile (SAM) operators and to his manned airborne assets.

AAA, SAM & EW Radar:

The GBAD threat environment consisted of nine AAA units (KS-12, KS-19, KS-30, S-60), eleven SAM units (SA-6, SA-3, SA-2, Roland) and four EW units (Spoonrest). The AAA, SAMs and EW, were all operated from three separate PC's and all had the option to be operated man-in-the-loop. The AAA units could be fully automatic i.e. radar laid firings, man-in-the-loop firing or an emulation of man-in-the-loop firing. The SAM units could be operated automatically i.e. radar laid firings or an emulation of blind firing could be opted for. The EW radar could all be switched on and off by command. The AAA, SAM and EW were all operated by a single person, under strict control from the SOC operator. Each individual AAA, SAM and EW unit was manipulated as the scenario and evolution of the combat dictated employing strict emission control (EMCON) procedures.

'Voice Actors' – SEAD, ATC, etc.:

The missions were planned from take-off to landing. It was not necessary or cost effective to

simulate all the support roles, although where they were required to add realism to the exercise these functions were role-played by the White Forces cell. For example, the Air Traffic Control (ATC) function was performed by the white cell, as was the role of the SEAD voices communications with the package. The SEAD voice communications were used as a trigger event for the EA6B ('Prowler') to signal an equipment failure and so delay the manned package for 5 minutes before entering threat airspace. The 'Actor' at this point played the role of the EA6B operator, although the actual platform was being simulated by a CGF entity.

CGF

The CGF fulfilled all those roles that were not manned, role played or who had any direct manned decision making involvement e.g. EMCON measures by the threat GBAD forces. This amounted to about 60 (depending on mission type) airborne assets requiring simulation for both hostile and friendly platforms. The CGF was primarily supplied by ModSAF and typically consisted of 8 F-16CJ, 6 A-10, 4 F15E, 2 EA6B, 8 F15C, an E3D, a KC135, a Nimrod R, 12 MiG-23, 4 MiG-25 and 4 Mirage F1. The CGF mission planning was carried out prior to the missions being flown due to the number and complexity of the mission types. For the mission to succeed as planned, it was important that the CGF members of the scenario met their time on targets and fulfilled the role that they had been tasked with. To this end it was important that the aircrew took–off when they were tasked as those CGF flying from other airbases further from the combat arena were already airborne and had been flying for anything up to an hour prior to aircrew take-off times. It was very important that the CGF and manned players flew in relatively close formation and with as close timings as possible.

Blue Air Package:

The main thrust of the blue air package consisted of the four manned Jaguars, four manned Tornado F3, four F-16CJ and an EA6B. The Jaguars were to either reconnoitre the target area or bomb it, depending on mission type. The first mission flown was that of a reconnaissance mission; the second mission was to then bomb the target that had been reconnoitred. The Tornado F3's were there to provide fighter escort to the Jaguars and protect them from threat fighters. The F-16CJ's and EA6B were there to suppress the threat GBAD by hard and soft means. The F-16CJs were fitted with HARMs and were there to hard kill the threat, while the EA6B flew in an escort jammer role to deny the threat a good air picture from which to organise his defences. Close co-operation good planning and timing was required to make this package work as a unit.

Blue Air Support:

The rest of the blue assets were used in the scenario to provide support to the main package. This consisted of a number of assets airborne in the combat arena who provided on-call fire support, those assets that were aiding situational awareness, and those assets that were enablers to the combat. Additional F-16CJs to that of the main package provided on call hard kill SEAD. An additional EA6B provided stand-off jamming (SOJ) to the scenario and F-15E provided additional ground attack capabilities. The Tornado F3s were further backed up by F-15Cs to counter any additional airborne threats. Blue situational awareness was provided by an E3D, and electronic intelligence (ELINT) was provided by a Nimrod-R. Combat enablers were provided by a KC-135 that provided tanker cover for the US air assets, and up to half a dozen A-10's were present to suppress ground threats and provide air cover for and search and rescue (SAR) activities. Helicopters were also on standby to bring any downed aircrew back to base.

Red Air:

The red air was mainly stationed on Quick reaction Alert (QRA), with a limited number on Combat Air Patrol (CAP) to the north of the no fly zone. Their role was to prevent the bombers from achieving their mission objectives under guidance from the red SOC operator. They also used hypothesised tactics of trying to lure the blue air defenders into a Missile Engagement Zone (MEZ). The mainstay of the red air was the MiG-23 which employed these tactics. The MiG-25s were fewer in number, and were used more selectively, employing their great acceleration capabilities to trouble the blue air defenders.

UNDERLYING TECHNOLOGIES

Simulators

Three different simulators were employed for the trial, RTAVS-immersive (DERA developed), RTAVS-ACES (DERA/TT&SL) and JOUST® (DERA). The RTAVS simulators are based upon PC technology and use a high-performance graphics subsystem for outside world scene generation. JOUST® is based upon Silicon Graphics hardware, with the outside world view being generated using a high performance runtime system. Both systems used a common sourced database. Both systems have been developed in-house by DERA to meet research requirements.

All of the systems were DIS, compliant and this was the prime means of interconnection.

JOUST® has been used by DERA over a number of years for studies into Beyond Visual Range (BVR) air combat. RTAVS is a more recent development making use of PC technology as it has matured and has been used by DERA for studies in the Synthetic Environment (SE) field.

Computer generated forces

The CGF were provided using a combination of JointSAF (the STOW development of ModSAF) and an in-house system (based on the RTAVS modelling framework). Six PC-technology Linux workstations running JointSAF version 4.8 were used to provide all of the air-based CGF entities, which were split into three functional groups to ease management – 'package', 'support' and 'hostile'. The integrated GBAD systems were provided by RTAVS-based systems running relatively high fidelity models of the SAM sites, AAA sites and early warning radar systems. These were operated in a semi-autonomous mode, with a human role-player tasking them and monitoring their behaviour.

An initial intention to run some of the GBAD systems in EADSIM and some of the air entities in ITEMS was postponed to a later trial.

Figure 2: RTAVS-immersive

Figure 3: RTAVS-ACES

Figure 4: JOUST®

Secure infrastructure

To form the collective training environment the simulators and personnel at the two sites require connection, and due to the nature of the exercises nd the simulations included, this connection carries classified data.

A number of different options for the communications infrastructure were considered, ranging from existing dial-up connections to a fully managed secure infrastructure.

In the end, due to timescale and cost considerations, a new point-to-point service was installed, an E1 or MegaStream, very similar to a T1, but providing a bandwidth of 2Mbit/s. This option was selected as it was known to be compatible with some existing encryption devices.

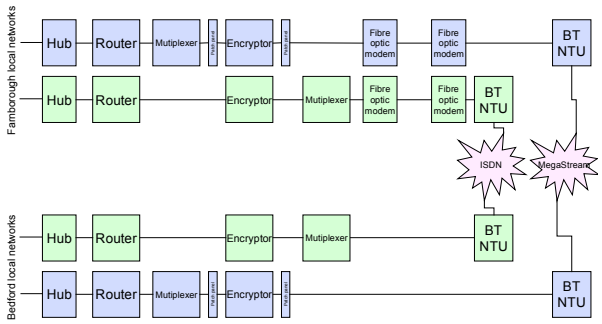

Figure 5 Communications components

Due to timescales and as a risk reduction option for the first trial, another means of connection was also sought. Because of DERA's close links with various US Research Laboratories, help was requested from the Air Force Laboratories in Mesa. This request was enthusiastically supported, and two Mesa staff were seconded to DERA for the duration of the first trial. These staff brought with them a pair of encryption devices that could be used with an existing dial-up connection, an ISDN-30 that provides a bandwidth of 2Mbit/s. Specific authorisation was required from the UK accreditation authority to use these US NSA accredited devices. This was significantly eased by the existing close working relationship between the government research departments. Unfortunately, due to a number of technical difficulties only the ISDN connection was available on the last day that aircrews were present during the trial.

The communications infrastructure was used to carry all of the simulation data, encoded using DIS, and the digitised voice traffic between the crews and other trial personnel.

The components of both the point-to-point and dial-up connections are shown below.

Terrain databases

The selection of an operational scenario for the trial dictated the use of a specific geographic area within the simulation. Fidelity requirements forced the development of a new database from DTED level 1 data and satellite imagery. The bulk of the terrain skin was created with 30m resolution texture, with mission routes at 10m resolution texture and target areas at higher resolution.

Figure 6 shows the extent of the database, which covers approximately 560nm x 770nm - 88 geocells.
There were a large number of different uses of the terrain database within the simulation environment. The types of databases and their relationships are shown below (figure 7).

These databases were used on a number of different hardware platforms, depending on the application's, ranging from desktops PCs to high end PC and SGI image generators.

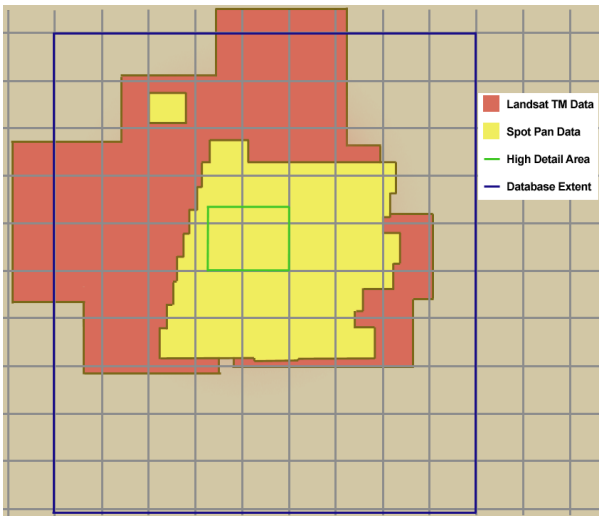

Figure 6 Terrain database areas

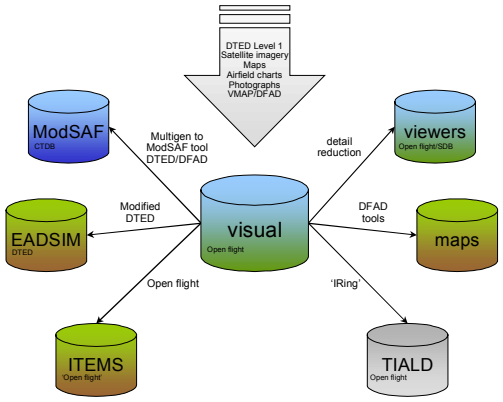

Figure 7 Uses of the terrain databases

EXTRA-SIMULATION SYSTEMS

A number of systems were provided to aid in the running of the trial. These can broadly be split into exercise management systems (ExMan), and technical management systems (TechMan). The ExMan systems were defined as those that were required to facilitate the control of the simulated environment and aid the exercise management team ('White Force') in their assessment of team performance; the TechMan systems are those that monitor the systems that provide the simulated environment.

ExMan Systems

The ExMan systems deployed for the trial can be split into two distinct, although related, groupings – those to aid the White Force in their understanding of the scenario as it unfolded, and those that enabled the role-players to interact with the simulation. For the trial, the former consisted primarily of a prototype system called "The ROC", the Real-time Observers Console.

Physically, the ROC, as shown below in figure 8, consisted of two high mounted 42" plasma displays, two 19" 'head down' displays, and a supplementary 21" 'head down' display. The two large displays were used to show a 3-dimensional tactical situation display (Tac Map, generated by a high-performance PC graphics card) and a 3-dimensional stealth view (generated by a high-specification Silicon Graphics workstation), with the viewpoints for each controllable by the operator sitting at the ROC. The larger of the head down monitors was driven from a PC running JointSAF in it's GUI-only mode, and was used to provide

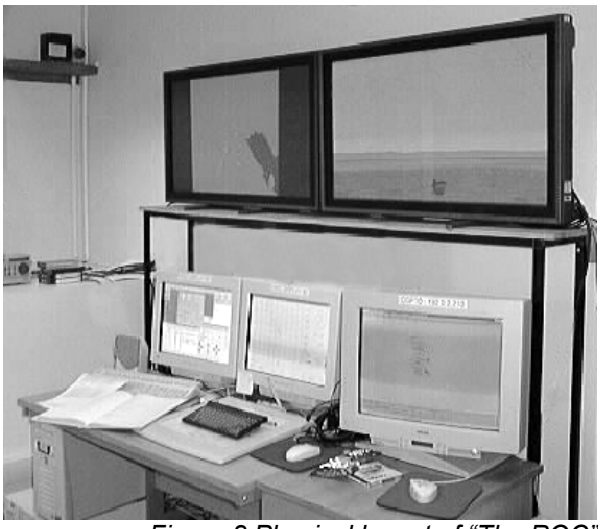

Figure 8 Physical layout of "The ROC"

supplementary information to allow the White Force to perform on-the-fly scenario re-planning. The other two head down displays were used to display experimental team-based status displays (i.e. displays to aid understanding of how cohesive the team were, how closely they were following the team plan, indicators to explain deviation from plan, etc.). This is illustrated in figure 9.

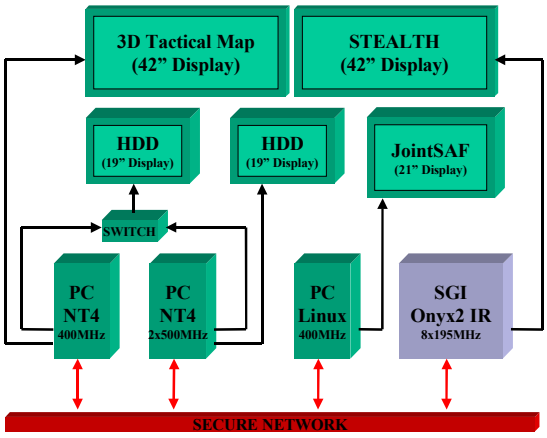

Figure 9 Hardware layout of "The ROC

The philosophy behind the design of the ROC was to concentrate on providing the information that the White Forces felt they required to assess the collective (rather than individual) performance of the teams. An important element of the trial was the use of 'injects', which were events that had been pre-planned by the exercise management team to trigger specific types of team-based responses, and it was important that the ROC and other ExMan systems allow the White Force team to judge the appropriate time in the scenario to

perform the inject, and then allow them to monitor the outcome.

The concept was to have a single operator (initially one of the development team) acting as a manager of the displayed information, but with the White Force team clustered around them asking for 'nuggets' of information. It was hoped that during the trial the original operator would be able to retire from the role, and allow the White Force team to take direct control of the ROC. This did not occur, as the White Force team were generally too busy to learn the system. Additionally, it became apparent during the trial that it would not be possible to satisfy all of the White Forces requirements simultaneously, due to differing data requirements. It is now planned to produce multiple copies of a cut-down version of the ROC which will allow each member of the White Force team to have their own specialised display.

The ROC included a system to generate event-markers in the network simulation log to aid subsequent replay and analysis. These could either be automatic (i.e. generated without human intervention when certain conditions are met) or manual, with the operator being able to select from a list of pre-defined event types or manually enter a new descriptor.

A number of 'Role-Player Stations' were produced to allow those members of the White Force team required to interact directly or indirectly with the experimental subjects. These included a synthetic AWACS display, a SOC RAP display, and a CAOC RAP display. These were variations of the same system, and basically provided the role-player with a view of the synthetic battle-space as perceived by the forces (both human and CGF) under their control.

Additionally, the ExMan system included datalogging and replay facilities to allow post-sortie and post-trial analysis of the exercise. This included voice and video recording of the briefing and debriefing sessions, as well as in-mission recording.

Future enhancements to the ROC systems will include the ability to directly influence the unfolding scenario by allowing direct control of the simulation (e.g. direct control of CGF tasking & status, control of systems failures, automated injects, automated role-playing, etc.)

TechMan Systems

The TechMan systems employed for the trial were relatively rudimentary, and relied heavily on manual monitoring and intervention. Experienced simulation staff were positioned at each of the simulator or simulation systems and were tasked with monitoring the performance of those systems. In addition they were required to monitor cockpit voice communications for problem indicators.

The overall trial Technical Manager was to act as the central point for all reports or requests to do with the health and performance of the simulation systems. One channel of the intercom system was dedicated to the technical management team, which consisted of two technical managers (one for each site), a network health monitor (also responsible for the network datalogging systems), four simulator monitors and two 'gophers' or 'runners' to act as rapid-response problem solvers. Additionally the three members of the CGF team and the ROC operator had secondary responsibilities to the overall Technical Manager.

The experimental aircrew had been briefed that they were to stay 'in role' unless told otherwise – to this end it was important that a system problem in one simulator did not detract from the realism in the others. The air crew were briefed to use the codeword, 'cyclops', followed by a brief description, to indicate a suspected simulation failure. They were briefed to then treat it as an aircraft failure (unless unduly intrusive, such as a display system failure) until a technician arrived. If a technician did not arrive to solve the problem, then they were to treat it as an integral part of the simulation.

CONCLUSIONS

Through this trial it has been shown that it is possible to create a complex synthetic simulation environment suitable for aircrew training. Creating this environment is not without its costs, from the considerable effort in establishing the components of the environment to the large number of personnel required to operate and support the exercises when they are running.

From this trial a number of key issues have become clear:

- Do not underestimate the length of time it takes to install and accredit a secure wide area network;

- Start performing integration work as soon as components become available to integrate;
- The process of taking a training requirement and converting it into a working synthetic training environment takes a great deal of effort. Relatively simple training needs can have a huge impact on the way equipment is developed and employed;
- Without a training requirement and the transformation process of generating a synthetic environment, all you have is a group of connected simulation components;
- Important to understand the training process when assembling the synthetic training environment;
- Need to take into account the requirements of those personnel (white forces) supporting the aircrew in their training environment.

From these lessons the task of creating a synthetic training environment should not be taken lightly. It is not sufficient to bring together a number of comparably capable simulators and CGF and expect them to provide training. A great deal of planning and work needs to be performed to establish the training need, translate this into the capabilities of the equipment, both simulation components and supplementary, create the synthetic training environment, verify that it provides the appropriate capabilities and validate that the original training requirement is met.