Exercise Pacific Link 2: Distributed Training for Air Battle Managers

Craig Eidman, Dr Peter Crane, 1Lt Clinton Kam
Air Force Research Laboratory, Warfighter Readiness Research Division, Mesa, AZ
craig.eidman, peter.crane, or clinton.kam @meas.afmc.af.mil

Dr Michael Skinner, Christopher Best, Sam Hasenbosch, Eleanore Burchat, , Melanie Finch, Christopher Shanahan
Air Operations Division, Defence Science and Technology Organisation, Melbourne, Victoria
michael.skinner, christopher.best, Melanie.finch samuel.hasenbosch, eleanore.burchat or christopher.shanahan@dsto.defence.gov.au

Dr Sara Elizabeth Gehr
The Boeing Company
(Air Force Research Laboratory) Mesa, AZ
sara.gehr@mesa.afmc.af.mil

Mitch Zamba
Karta Technologies, Inc
(Air Force Research Laboratory) Mesa, AZ
mitchell.zamba@mesa.afmc.af.mil

Abstract

Distributed simulation provides warfighters with training to enhance their team and inter-team skills with greater frequency and at lower cost than range training exercises. Distributed simulation training for small groups of warfighters such as a formation of four fighters working with an Air Battle Manager can be focused on specific skills such as beyond-visual range, dissimilar air combat tactics using constructive simulations as adversary forces. Training for command and control teams, however, requires interactions among blue force entities, particularly voice communication, that cannot be supported using only constructive simulations. One solution is to conduct large scale virtual training events such as VIRTUAL FLAG exercises. Another solution is to combine human-in-the-loop virtual simulators with white-force role-players who provide responsive verbal communications for constructive entities. Both of these approaches require participation from a significant number of warfighters or subject matter experts which increases training cost and decreases ability to focus training on command and control teams such as Air Battle Managers. To overcome these difficulties, Australian and US researchers conducted Exercise Pacific Link 2 in which an Air Battle Manager team in Melbourne, Australia was networked with a four-ship of F-16 simulators and a constructive forces simulator in Mesa, Arizona. Using a novel approach to scenario design combined with an improved constructive entity generator, a small team of pilots and engineers provided five, fully interactive four-aircraft formations of F-16s which engaged multiple waves of adversary aircraft over a one-hour vulnerability period. Evaluations from the Air Battle Management team demonstrate significant training benefits from this approach. Data will be presented on constructive forces improvements and results, system and scenario design together with feedback from exercise participants regarding skills that were enhanced and opportunities for further developments.

ABOUT THE AUTHORS

Craig Eidman is an Electrical Engineer with the Air Force Research Laboratory, Warfighter Readiness Research Division, Mesa Research Site. He is the Lead Engineer for all laboratory synthetic environments, Electronic Warfare Training, and advanced targeting pod S&T efforts. Mr. Eidman attended the United States Air Force Academy where he earned a Bachelor of Science in Electrical Engineering in 1983. He served in the Air Force as a Command Pilot flying F-16, A-10, and OA-37 aircraft in multiple theaters. Additionally, he has a Masters of Aeronautical Science, Embry-Riddle Aeronautical University, With Distinction and is an Outstanding Graduate of the Air War College.

Dr Peter Crane is a Research Psychologist at the Air Force Research Laboratory, Warfighter Training Readiness Division in Mesa, AZ. His major research interest is enhancing effectiveness in distributed simulation systems. Dr. Crane earned a PhD in Experimental Psychology from Miami University in Ohio.

Lt Clinton Kam is currently assigned to the Warfighter Readiness Research Division in Mesa, Arizona working as the Threat Systems Engineer for the Warfighter Training Simulation Branch. Lt Kam holds a B.S. in Aerospace Engineering from the University of Texas. He has worked on several projects spanning the modeling and simulation and training spectrum including simulation performance testing and optimization, HLA networking, and high-fidelity piloted and unpiloted threat models.

Dr Michael Skinner is a Senior Research Scientist in the Air Operations Division of the Defence Science and Technology Organisation, Australia, specializing in the human factors of aviation systems. He has a PhD in cognitive psychology. His research interests include team training and assessment, collaboration interfaces, automation issues, and aircrew workload and situation awareness assessment.

Dr Christopher Best is a Research Scientis in the Air Operations Division of the Defence Science and Technology Organisation, Melbourne, Australia. His research interests include human perception, cognition, teamwork, team performance measurement, and training. Dr. Best earned his PhD in Experimental Psychology from Deakin University in Melbourne in 2001.

Sam Hasenbosch is a Researcher at the Defence Science Technology Organisation, Air Operations Division in Melbourne, VIC. His major research interest is simulated training systems for Air Battle Management. Mr Hasenbosch is a former RAAF Air Combat Officer and earned a Bachelor of Science in Computer Science and Management from the University of New South Wales

Eleanore Burchat is a human factors specialist in the Air Operations Division of the Defence Science and Technology Organisation (DSTO) in Melbourne, Australia. She joined DSTO after completing an honours degree in psychology at Deakin University. During her time at DSTO she has worked on a range of issues relating to team training and human-machine interface design. This research has involved small scale lab-based experimentation, high fidelity simulation and the observation of military exercises.

Melanie Finch works in Crew Environments and Training within the Air Operations Division at DSTO. Melanie has a B.Sc. (Hons) in psychology awarded in 2005 and commenced working at DSTO in 2006. Melanie's interests include modeling helicopter systems and crewing, human perception and cognition, team training and measurement, and data analysis

Dr Sara Elizabeth Gehr is a Human Factors Design Specialist with the Boeing Company. She works at the Air Force Research Laboratory, Warfighter Readiness Research Division, in Mesa, AZ, where she is the task order lead for coalition and international mission training research. She received her Ph.D. in Experimental Psychology from Washington University in St. Louis in 2001.

Mitchell Zamba is the Senior Telecommunications Network Engineer at the Air Force Research Laboratory, Human Effectiveness Directorate, Warfighter Readiness Research Division in Mesa, Arizona USA. He has over 10 years of modeling and simulation experience with the Air Force and industry and is currently working on network and encryption issues for multiple international projects for interconnection to the Mesa Research Site. Previously, he was with the Joint Advanced Distributed Simulation Joint Test Force (JADS JTF) in Albuquerque, NM where he engineered and installed secure wide-area networks used in the early research of distributed simulations.

Exercise Pacific Link 2: Distributed Training for Air Battle Managers

Craig Eidman, Dr Peter Crane, 1Lt Clinton Kam
Air Force Research Laboratory, Warfighter Readiness Research Division, Mesa, AZ
craig.eidman, peter.crane, or clinton.kam @meas.afmc.af.mil

Dr Michael Skinner, Christopher Best, Sam Hasenbosch, Eleanore Burchat, , Melanie Finch, Christopher Shanahan
Air Operations Division, Defence Science and Technology Organisation, Melbourne, Victoria
michael.skinner, christopher.best, melanie.finch samuel.hasenbosch, eleanore.burchat, or christopher.shanahan@dsto.defence.gov.au

Dr Sara Elizabeth Gehr
The Boeing Company
(Air Force Research Laboratory) Mesa, AZ
sara.gehr@mesa.afmc.af.mil

Mitch Zamba
Karta Technologies, Inc
(Air Force Research Laboratory) Mesa, AZ
mitchell.zamba@mesa.afmc.af.mil

Air Battle Managers (ABMs), ground-based or airborne, work as a team to coordinate and manage forces engaged in air operations. Simulator training for ABMs requires interaction with a complex, responsive, composite force and an unpredictable adversary. Researchers in Australia have gained considerable experience in developing training systems for ABMs while US researchers have focused their efforts on training for fighter pilots. The Air Operations Division of Australia's Defence Science and Technology Organisation (DSTO/AOD), Melbourne, Victoria and the US Air Force Research Laboratory's Warfighter Readiness Research Division (AFRL/HEA), Mesa, Arizona are conducting research efforts to enhance the scope and capabilities of warfighter training using distributed simulation. In 2005, DSTO/AOD and AFRL/HEA conducted Exercise Pacific Link, a coalition mission training event designed to assess the ability of an Internet Protocol (IP)-based distributed simulation network to support Distributed Mission Training (DMT) for air combat (Crane et al, 2006). During Exercise Pacific Link (PL1), a series of training scenarios of increasing complexity was carried out over three days, linking fighter pilots and ABMs at both sites with distributed mission briefings and debriefs. In 2006, DSTO/AOD and AFRL/HEA conducted Exercise Pacific Link 2 (PL2) with the aim of using lessons learned from the first Pacific Link exercise to develop new systems for training ABMs using distributed simulation.

PACIFIC LINK 2 OBJECTIVES

Based on lessons learned from the scenario limitations of PL1, a primary objective of PL2 was to develop and evaluate systems which would allow a small White force to inject multiple entities into the battlespace including radio communications, weapons engagements, and interactions with ABMs. The value of DMT for enhancing the skills of ABMs as well as pilots has been described since the earliest research on distributed simulation (Bell & Crane, 1993). One constraint on the quality of ABM training is that with a small number of virtual fighter events, training is limited to close-control of the fighters tactically employing against enemy fighters. While this is valuable training that effectively complements range training, other aspects of battle management are not trained. These tasks include force management with multiple flights of fighters, management of aerial refueling assets, and contingency operations. More friendly and adversary forces than can typically be provided via virtual simulation at a single mission training center will be required to support these aspects of ABM training. Coalition force DMT could be an effective system for providing this training. In live training, one group of warfighters will frequently provide training support for another group by serving as adversaries. These Red Air forces represent a significant use of resources with little benefit for the participants. An advantage of DMT is that these dedicated training forces can often be replaced with constructive (computer-generated) entities which reduces training costs but also reduces interactivity, scenario flexibility and responsiveness of simulated entities. One solution is to integrate constructive entities with voice actors who role play the part of friendly force elements (Crane, Tomlinson, & Bell, 2002). While this is a useful approach, it requires that each voice actor be a subject matter expert who can communicate correctly in accordance with standards and execute tactical commands as required. It also requires "user-friendly" instructor-operator interfaces easily controlling responsive and realistic constructive players. To provide training for a team of ABMs, several knowledgeable voice actors would be required.

An alternative approach was employed in PL2 combining novel scenario design with a new approach to scenario implementation using constructive forces which could fly autonomously or be controlled by a human operator.

Other key objectives of PL2 included: continuing the development of simulation infrastructure for conducting Australia-US DMT exercises, continuing the development of team performance measurement and feedback techniques DMT, and developing and assessing a structured method for designing ABM team training scenarios. This was done by drawing on guidance from previous research into DMT applications and team training including the USAF Mission Essential Competencies (MECs; e.g., Colegrove & Alliger, 2002), the Event-Based Approach to Training (EBAT; Fowlkes, Dwyer, Oser, and Salas, 1998), and Team Dimensional Training (TDT; e.g., Smith-Jentsch, Zeisig, Acton, & McPherson, 1998) as well as by linking into an Australian task framework, the Australian Joint Essential Task list (ASJETS; McCarthy, Kingston, Johns, Gori, Main, & Kruzins, 2003). Measurement of training effectiveness allowed evaluations of the scenario tools and constructive forces role-play supporting these mission areas, tasks, and skills and ensured that all participants in the exercise would receive useful training.

PACIFIC LINK 2 SYSTEMS

AFRL Mesa Systems

Constructive friendly and adversary forces were populated into the scenario via computer generated entities created from a specially developed, unclassified load of AFRL's Experimental Common Immersive Theater Environment (XCITE) software. XCITE is a research and development continuation of the Next Generation Threat System (NGTS), the software used during PL1. Similar to NGTS, XCITE uses physics-based models to generate aircraft, weapons, radar, and electronic warfare models from parametric data, but unlike NGTS, XCITE has undergone extensive development for increases in capability and user functionality.

Since XCITE is US Government owned source code, required modifications to the constructive environment were easily implemented for PL2. One major improvement to XCITE was the development of new Threat Instructor Operator Station (IOS) software. The Threat IOS gives the operator far more control in directing the constructive forces while adhering to Windows standards for intuitive use. Operators can easily drop single-, 2-, 3-, or 4-ship formations of aircraft at specified speeds, altitudes and headings. These aircraft formations can also be saved into Favorites for later quick retrieval at any time. The new entities are automatically configured for very realistic formation flying and leader / wing command and control structure. Operators can direct constructive aircraft to change headings, fly routes, form up with both XCITE and non-XCITE players, and perform a variety of tactically-based combat maneuvers. For example, the operator can command aircraft orbiting over a holding point to fly a route through a hostile environment. The lead aircraft, after scanning a hostile entity, can autonomously direct its wingman to attack the target or engage the aircraft itself. The autonomous aircraft will turn to maintain RADAR lock and fire the most appropriate munitions when they are within range. If they are targeted themselves, the aircraft will automatically begin jamming the enemy's transmissions. The XCITE models driving the weapons engagements, jamming, and emitter modes are validated and based on actual avionics simulations. At any point during the scenario, the operator can take total control of the entities to attack other targets or perform a variety of defensive or navigational maneuvers.

Due to network and security constraints, an unclassified database was used to drive the XCITE emitter, aero, and weapons models. During scenario development, it was noted that certain threat models were unavailable in the unclassified XCITE database. AFRL engineers were able to rapidly integrate, on the order of days, over 20 weapons including air-to-air and surface-to-air missiles and multiple aircraft platforms. This vastly increased scenario fidelity, depth, and interactivity for both the manned F-16 simulators and the C2 players. Two multi-screen XCITE consoles were constructed to manage scenario development, White force control, and act as manned Blue force players. These stations were integrated with ASTi compatible DISVOX software driven radios for voice communications.

Warfighter-in-the-Loop (virtual) simulators in Mesa consisted of two F-16 Deployable Tactics Trainers (DTTs) plus two desktop LiteFlite F-16 simulators (SDS International). DTTs are high-fidelity F-16 simulators developed at AFRL based on full-fidelity Multi-Task Trainers (Carr & Hernandez, 2005). The DTTs operate using software converted from the F-16 Block Operational Flight Program and were equipped with three Apple 30-inch High Definition Cinima Displays with AAcuity Image Generators (SDS International) providing 90° x 12° out-the-window display together with a Head-Up Display.

Figure 1. An AFRL Mesa DTT Cockpit Engages and Enemy Fighter

The desktop F-16 simulators consisted of PCs running SDS International LiteFlite software and AAcuity image generators. This flight code and image generator runs on standard personal computers. One 19 inch computer screen was used

Figure 2. An AFRL Mesa F-16 Pilot Operating a Desktop Simulator in PL2

for the visual display although pilots could control the viewpoint from forward view with superimposed head-up display to left, right, rear, or stealth view. Virtual and constructive simulators in PL2 used the DIS protocol (IEEE 1278.1a) external interface.

Exercise recording was conducted with AFRL's Distributed Control Station (DCS) software. DCS was also used to initialize and control the manned DTT and desktop simulators as well as providing DIS log files for mission debrief assessment, and engineering analysis. Communications between exercise control, SIMOPs, and participants at the two sites were provided via a DIS voice network composed of software-based devices.

DSTO Melbourne and Common Systems

Several key components of the Air Defence Ground Environment Simulator (ADGESIM), a suite of simulation applications developed by DSTO for ABM training and commercially supported by Ytek Pty Ltd (Melbourne, Australia), were utilised during PL2. The ADGESIM Pilot Simulation Interface (PSI) provides scalable, real-time control for a variety of entity models via a customised version of the COTS product 'VR-Forces' (MÄK Technologies, Cambridge, MA). The PSI was used by a RAAF

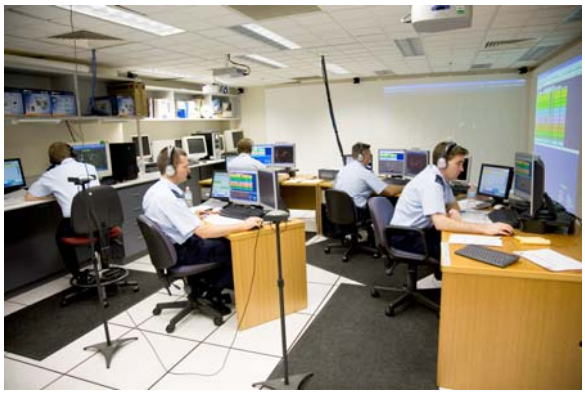

Figure 3. DSTO's Simulated C3 Environment

Simulation Operator (SIMOP) to provide minor Red force elements, Blue force High Value Assets (HVAs), and neutral entities. The sensor modeling and gateway application, known as SensorLink, was used to model ground-based, airborne, fixed and mobile sensor platforms. Sensors attached to any given entity within the simulation and detection volumes could be culled by Digital Terrain Elevation Data for a specific region or limited by radar horizon. SensorLink translates detections of DIS entities and outputs a real-world message format of choice for input to a C2 system.

The RAAF ABM team required relatively little training for PL2 because the operator systems utilised were identical or very similar to those available in the operational environment. A Solipsys Tactical Display Framework (TDF) prviding customisable HMI was the primary operator interface for track and sensor data. The TDF is connected to the Solipsys Multiple Source Correlation and Tracker (MSCT) server which receives a range of sensor inputs.

The TDF does not adequately support the shared situational awareness requirements of RAAF ABM teams so an ad hoc tool known as the 'toteboard' was developed to support real-time asset management. This macro intensive, shared Excel spreadsheet lists all

the air assets, and corresponding IFF codes, assigned to a C2 agency. For each asset the current alert state, fuel status and weapon status may be entered either directly or via macro. Each team member displays the toteboard adjacent to the TDF and enters information on aircraft within their area of responsibility. Updates to an individual view of the spreadsheet occur on a push-pull basis, and is stored centrally.

A further component of ADGESIM is the Tactical After Action Review for DIS (TAARDIS) application, a tool is capable of capturing DIS ground truth and operator 'perceived' truth (via console screen capture) and replaying both in a synchronous manner to any DIS viewer and Windows Media Player respectively. Performance data were collected via the Mentor software system (Calytrix Technologies, Perth, Western Australia). Mentor is a performance assessment package that provides for exercise definition, measurement and the review of outcomes. Data collection is facilitated by the Data Entry Tool (DET) which is loaded with an assessment form dynamically generated by the main Mentor application.

Polycom teleconferencing systems (Pleasanton, California, USA) were used at both sites for video conferencing and to capture video of the ABM team. Smartboards (Smart Technologies Inc., Calgary, Canada) were utilised for displaying and enhancing (via electronic pens) session briefings and AARs. UltraVNC, an open source remote desktop viewer, was used to share briefings data recordings between distributed participants. Due to the bandwidth and latency constraints of the WAN several combinations of quality and compression settings were trialed before an acceptable level of performance was achieved. Wireshark, an open source application, was used to conduct network traffic analysis.

Network

Connectivity was established between DSTO Melbourne and AFRL Mesa through an unclassified network of three separately administered segments: the DSTO internal network between Melbourne and Adelaide; the Australian Academic Research Net (AARNet) network, between Adelaide and Seattle; and the US Defense Research and Engineering Net (DREN), connecting Seattle with Mesa.

PARTICIPANTS

Exercise participants consisted of an ABM team (a weapons director (WD) plus three fighter controllers) and an ABM assessor/instructor at DSTO Melbourne, with four F-16 pilots at AFRL Mesa. The F-16 pilot training audience was represented by Subject Matter Experts, all current or former experienced F-16 pilots familiar with distributed mission training exercises. AFRL Mesa SIMOPs controlled constructive Red Threat and Blue interactive forces from the dual XCITE consoles. Senior Exercise Controllers (EXCON) were placed in Melbourne and Mesa. Both sides had engineering staffs, exercise managers/observers, and data collectors.

The RAAF ABM team had a mix of experience: the WD was very experienced (10+ years, 500+ controlling hours; B CAT Fighter Controller and Weapons Director); one of the controllers had medium experience (2 years, 200+ controlling hours; C CAT Fighter Controller); and the remaining team members had limited experience (1 year, 50 controlling hours; D CAT Fighter Controller). This represented a fairly average team. The team had not worked together previously as a team, although individual controllers had had some experience of working together. The senior members of the team had previous experience working live, large force coalition training exercises (e.g., Pitch Black, Talisman Saber), but none of the team had participated in virtual forms of such exercises.

SCENARIO DEVELOPMENT

PL2 provided an opportunity to develop and trial a structured method for designing training scenarios for RAAF ABM teams which drew on ideas from the USAF AWACS MECs which describe the knowledge, skills and experiences required for successful mission completion (Colegrove & Alliger, 2002). In addition, research on DMT and team training were linked into an Australian task framework: the Australian Joint Essential Task list (ASJETS; McCarthy et al, 2003).

An event-based approach to training design (e.g., Fowlkes, Dwyer, Oser, and Salas, 1998), which focuses on the deliberate presentation to trainees of opportunities to demonstrate and learn specific classes of competencies through the introduction of specific types of scenario events, was developed to guide the PL2 scenario definition. Each event is designed to create the requirement to act in a way which places demands on an identified set of competencies. Observations of behaviours related to these competencies are made and the successful (or otherwise) demonstration of these behaviours contributes to training outcomes. The scenario design effort focused on the definition of actual events to be included in the PL2 scenarios which were built in

XCITE and validated to ensure accurate implementation meeting scenario objectives.

SCENARIO IMPLEMENTATION

The exercise was conducted over four days, with the background being protection of a UN humanitarian relief operation by coalition air assets. The focus was on Defensive Counter Air (DCA) with escalating tensions and engagements leading to an Offensive Counter Air (OCA) mission on Day 3. Day 4 returned to a predominantly DCA focus. Each session followed a general exercise scenario of escalating hostility and increasing task complexity.

AFRL Mesa

XCITE provided as many as five 4-ships of Blue F-16 aircraft, multiple formations of MiG fighter aircraft, early warning radars, surface-to-air missiles, and ground targets. Scenarios included ATO holding CAP points, air refueling tracks, and routes were built and saved with the XCITE Threat IOS prior to the start of the exercise. A subject matter expert operated the radios during runtime for the constructive forces and controlled them via the Threat IOS. During periods of high activity, another operator would help control the entities with a second Threat IOS connected to the same XCITE server. Since as many as 20 constructive forces were operating within the scenario at the same time, a key factor in keeping them all flying properly with only two operators was XCITE's ability for autonomous control. Rather than micromanage the flight of all constructive forces, the IOS operators were able to issue simple commands to the aircraft such as "Form Up" to the tanker, "Follow Route" along a designated route, or "Attack" a specific target with a specific munition. The XCITE entities would then handle all necessary flight controls until their tasks were completed or the operator commanded them differently. If no changes were made to a group of constructive aircraft's tasks, then there was little-to-no additional burden on the operators to continue flying those aircraft.

To keep the pilots of the virtual simulators engaged as much as possible without disrupting the scenario play, the cockpits were periodically hot-swapped with the constructive forces. For example, one constructive formation of F-16s may have been formed up with the refueling tanker, a second formation may have been waiting at the base for launch, and a third formation may have been following a route to a holding point just

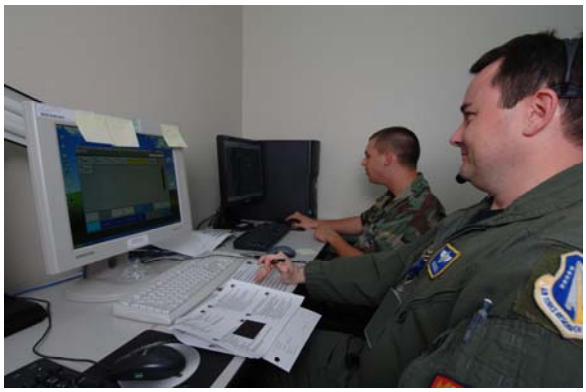

Figure 4. An AFRL Mesa SME Operating the XCITE Constructive Forces in PL2

outside the hostile environment. As the pilots in the virtual cockpits left the hostile area, constructive entities were dropped in their place. Next, the virtual cockpits were repositioned onto the route to take the place of the constructive entities there. These interactions, requiring substantial amounts of coordination between the pilots, cockpit operators, and XCITE operators, were performed several times throughout the exercise and ultimately presented a better, more active training environment for the pilots. Experiences from the PL2 Exercise identified 25 Threat IOS and XCITE improvements for increased functionality, stability, and ease of use.

Very detailed scenario events were implemented by the XCITE software and IOS. Throughout the exercise the F-16 pilots conducted interactive composite force tactical operations with constructive players including lane and target handoffs, combined flight targeting, and integrated strike packages. Controllers actively managed lane and CAP tasking, tanker flow, and CAP re-set procedures, as well as specific tactical engagements. In one unique event, one of the constructive F-16 players was damaged and flew a realistic battle damage route to include lost communications supporting a controller learning objective.

DSTO Melbourne

Tanker, UAV, and neutral aircraft were constructed in PSI/VR-Forces at runtime. A single SIMOP manipulated these entities by directing them manually or by assigning them to a pre-determined or quickly constructed route. SIMOP also provided voice acting for the tanker aircrew, UAV operator, UN pilots, and civilian aircraft captains. Some entities took a legitimate path from a known base of operations (even though this was beyond sensor coverage) and others

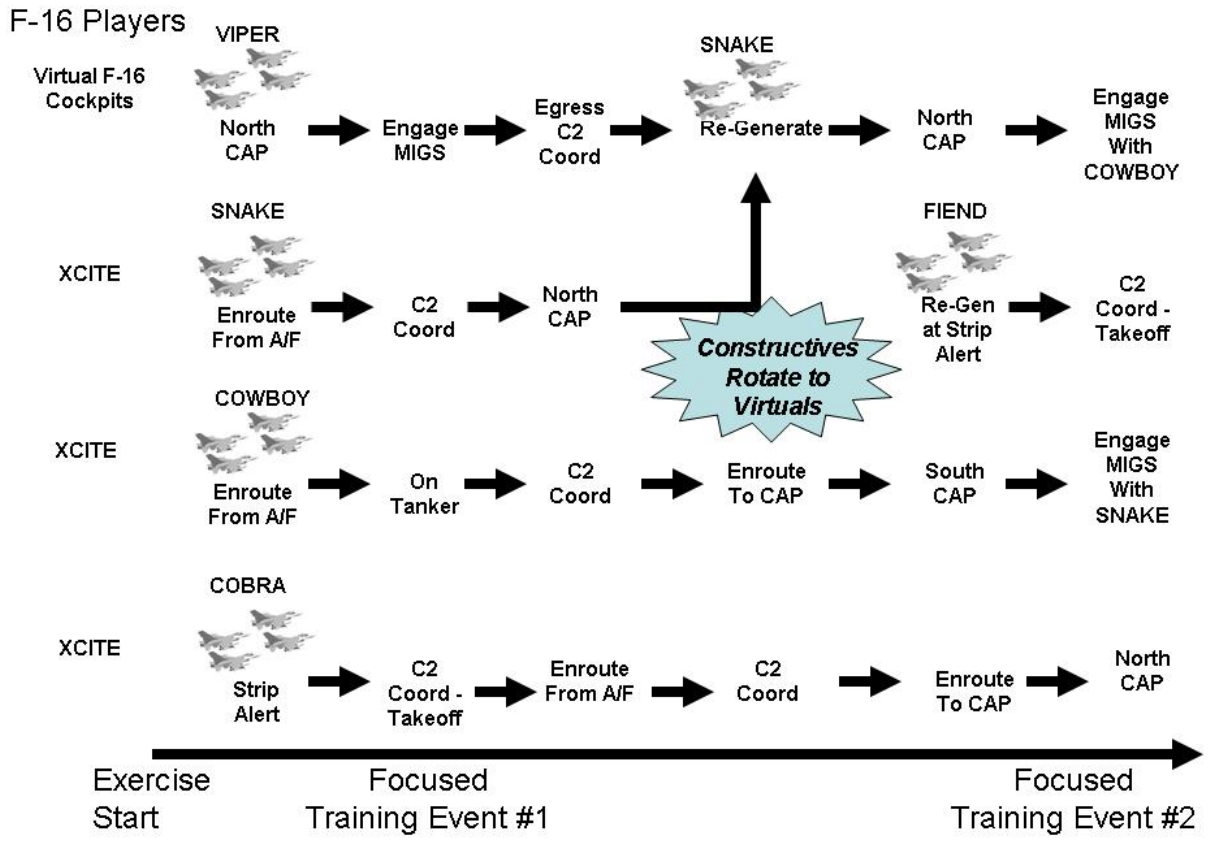

Figure 5. Exercise Pacific Link 2 Rotational Virtual-Constructive Team Concept

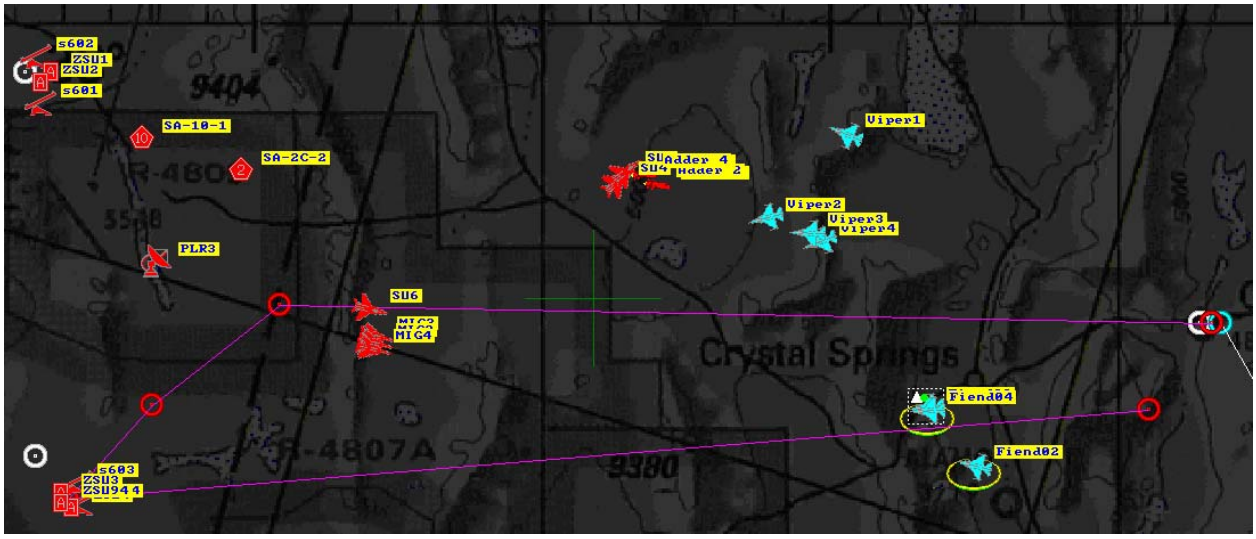

Figure 6. XCITE IOS Screen Capture Showing Virtual Fighters (North) Operating in Combined Tactics with White Force Constructive Fighters (South) Against Integrated Threat Array

were inserted directly into the area of operations to test the team's reactions to pop-up threats. During periods of high workload a member of Exercise Control would accept responsibility for a subset of the entities in terms of their manoeuvre, targetting and weapons employment. As a result of PL2, several suggestions were made to improve the manipulation of grouped entities within the PSI.

Exercise Control also manipulated the state of the sensor feeds during the scenario. Within the Sensor-Link package radars were degraded when not expected, depending on the desired training outcome. On occasion the parameters of one sensor were modified to reduce low level coverage around an exclusion zone.

EXERCISE OUTCOMES

Exercise Evaluation

Team performance, training outcomes, and the conduct of the exercise were assessed using a range of self-report measures (by members of the ABM team and pilots), measures of Team Objectives (by a qualified instructor/assessor using the MENTOR tool), and exercise evaluation measures (by all participants). Pre-exercise the ABM team members recorded their expectations of the effectiveness of DMT for ABM training and their training objectives. `During each day the ABM team members rated their own and teammates' workload. The US pilots also completed measures of coalition team efficacy, cohesion, and team processes each day. Teamwork measures (commitment, efficacy, cohesion, team process, and workload) would provide a snapshot of the team at each stage of the exercise, and an indication of the extent to which teamwork (both within the ABM team and across the coalition team) was improving over the course of the exercise. This would highlight the value of DMT for ABM training and the enhancement of coalition interoperability.

The measures of Team Objectives were collected during each mission by the instructor/assessor, and a stoplight report was generated using the MENTOR tool at the end of each mission as a guide for the debrief of the ABM team. Team behaviours were assessed across Mission Planning and Review; Manage Information Systems; Control Airspace; Conduct Defensive Counter Air; Military Liaison; Protect Key Points and Vital Assets; and Supporting Competencies. The trend with these measures across the exercise would highlight the training value. The exercise evaluation measures focused on the way the exercise was conducted and were filled out at the end of each day by all participants to capture what went right/wrong. These measures were especially useful to highlight particular procedural and technical issues that enhanced/constrained performance.

ABM Training Reactions

Overall, the ABM team found the exercise scenario met their expectations and provided significant combat mission training value, especially for team coordination skills. These kinds of missions are infrequent due to cost and availability issues, and the simulation facilities required to support such training are not currently available at their home unit. They found the scenarios were well structured, paced, and sequenced in a way that facilitated their learning. They also reported that they would be motivated to seek similar training opportunities in the future, and would recommend the training to other controllers. They rated it a valuable experience in coalition training, providing exposure to US forces and doctrine, and recommended that these kinds of exercises should be part of all future coalition spin-ups/preparations. The ABM team indicated that the exercise provided good training experiences for the basic mechanics of tactical air battle management (e.g., detecting, identifying, and tracking entities; force marshalling; tanker management; maintaining tracking and safe control of a number of groups; high value asset protection; return to force procedures/lame duck procedures/safe passage; working with multiple radio control frequencies). In addition, the scenarios presented effective training experiences of non-standard formations, detection and tracking of high fast flyers, and leaker scenarios. Pre-exercise, the ABM team did not expect complex scenarios (e.g., tracking large Red force groups, controlling large Blue force groups, working with combat search and rescue assets, working with complex ROE [rules of engagement]) to be effectively trained in a distributed simulation environment. However, following the exercise the team indicated that the training for these complex mission elements was effective.

Scenario Fidelity

The scenarios allowed team members to effectively measure team objectives in critical events. Events like enforcement of ADIZ procedures, identifying an emergency (an aircraft flying a triangle pattern), adhering to the ROE, and monitoring fighter fuel states of the fighters were effectively represented using the combination of virtual and constructive players.

Coalition Training Outcomes

At the end of the exercise the Australian ABM team and US pilots rated coalition interoperability training.

In general, the coalition team agreed that there was a high level of trust between coalition partners, that this increased over the course of the exercise, and the military doctrine, experience, and training enabled the coalition partners to work effectively together. Overall, there was evidence that the exercise provided training that enhanced key interoperability factors. The ABM team highlighted several coalition challenges as a result of their exercise experience, including: (i) while language and terminology were only slightly different, this had an impact during engagements, (ii) there were differences in doctrine and interpretations of ROE that were not easily overcome through briefing sessions, (iii) differences in standard operating procedures were not a problem in themselves, but knowledge of these differences meant that more explicit communication was required, and (iv) allocation of roles and resources at a tactical level differed due to the different capabilities of the participants in the coalition environment.

EXERCISE EVALUATION

Network Infrastructure

The network that was used for PL2 performed satisfactorily in supporting distributed briefing, debriefing, and mission execution. While this network route was longer than optimal due to the availability of peering points, long term measurement of the network using ping revealed a steady round trip time of 238ms, which proved acceptable for this kind of training exercise. The DREN and AARNet components of the network could easily support bandwidth of 100Mbit/s, but a limitation of 1Mbit/s incurred in the internal DSTO network constrained the resolution of electronic materials that could be shared during mission debriefs. Furthermore, the video conference system and remote desktop software demonstrated different effective latencies. This restricted the rate at which briefs could progress, as the appearance of complex images or replays at the remote end was delayed and, therefore, poorly synchronised with narrative of the speaker. This was overcome by confirming that the desired data had been received at the remote end before commencing a related discussion.

Increasing the bandwidth available for exercises would allow greater flexibility in the use of collaboration technologies and content. This would also have an effect on latency, as insufficient bandwidth can result in queuing. Future activities should seek to determine the level at which there is no significant network degradation. While latency may remain an issue for some systems, this could be countered procedurally or, by utilising systems that exhibit the least latency. For example, the distribution of replay data may be more robust than the sharing of display data.

Sub-system reliability

Several of the applications that were used exhibited some instability; however, as most were recoverable, this did not significantly degrade the exercise. In one instance a SROCCS device crashed and impacted the check-in of fighter aircraft, and in another, XCITE crashed to abruptly end the OCA scenario. The reliability of simulation systems has improved since PL1, yet software problems remain. This is likely to continue as systems are developed and may only be mitigated by regular, structured distributed simulation testing.

Performance Measurement

Performance measurement and feedback in PL2 centred on the use of the Mentor training management system. The Mentor system provided the facility to manage objectives, to undertake performance assessment during missions, and to provide feedback during after action review. Mentor received positive reviews from the ABM team. In particular, they found the ability to view performance on similar objectives over time valuable, as it was informative about the etiology of any marginal or poor performance that was observed. The Supporting Competencies section of the Mentor assessment form was not used effectively by the team assessor and due to assessor workload and was often completed at the end of a session. If assessing teamwork is a high priority, a separate assessor should focus on this dimension.

Scenario Design

The process event-based proved relatively straightforward to implement and was found to be quite useful in guiding researchers and SMEs during the development of the exercise by linking relevant team tasks to scenario design. The approach was grounded in previous research on team training, AWACS MECs, and the event based approach to training and had the advantages of a relatively rapid development cycle and relatively low resource requirements.

In general the participants reported that the scenarios were well structured and engaging. However, they identified some aspects of the scenarios that could have been improved. For example, a greater appreciation of Red Force activities could have been afforded through the provision of intelligence reports, realistic indicators and warnings. This could have allowed the ABM team

to manage the application of resources over the duration of the operation more appropriately.

Exercise management

The coordination of exercise control between distributed sites was problematic. It required detailed scenario guides to be shared and interpreted in advance, as well as runtime co-ordination to ensure good situation awareness of the implementation of events. This was complicated by the dynamic nature of some scenarios which, despite the planning of trigger events, did not eventuate as expected. This required ad hoc re-planning and significant communication between the sites to ensure effective coordination. Scenario preparation also required input from the ABM team to adjust their plan prior to the next session. Sometimes this process was abbreviated due to the late arrival of the planning materials. This occurred for the OCA scenario, and as the ABM team was also less familiar with this kind of mission, there was a perceived negative impact upon participant performance.

The roles and procedures for exercise management need to be documented and agreed well in advance of the exercise. These should include commitments to supply specific sets of information within a specific timeframe. If the overall scenario is to be fixed, rather than modified over time due to participant behaviour, then the participants should be permitted to perform their planning processes in advance. If a dynamic scenario is desired then adequate participant planning time should be allocated between sessions. If the participants are to encounter new kinds of missions additional preparation may be required to ensure valid outcomes.

Mission execution

There were several distributed team co-ordination issues that degraded collective mission effectiveness. These typically involved misunderstandings between the various Blue force participants and White force role players regarding the procedures to be implemented. These problems resulted in outcomes such as delays to time critical actions, breaches of ROE, fratricide and reduced trust in other participants. In almost all cases these were overcome by providing greater detail and clarification in briefings. There were also some differences in communication terminology (RAAF variations on the US 3-1 standard) that caused minor confusion, but did not appear to significantly affect the outcome.

Communication bottlenecks were encountered on a number of occasions with respect to those Blue force members controlling multiple constructive 4-ship formations. At times only one SME/SIMOP was available to provide communication interaction and tactical decision making for up to three formations. The level of automation provided by the XCITE entity generator did not alleviate the requirement for timely and effective responses to ABM requests. There were many instances of missed calls and significantly slow responses during high tempo/workload events. The OCA scenario differed to other sessions in that it required SIMOPs otherwise responsible for Blue forces to also provide Red forces. As this type of mission required concentrated and coordinated actions, communication delays degraded the ability of the ABM team to counter threats, which diminished fidelity and therefore training value.

Several of the above co-ordination issues are typical outcomes of team training events, and the rectification of these issues correlates with improved performance. However, where technical or procedural constraints reduce task fidelity below an acceptable level, negative learning can result. Whilst addressing these issues may be straight-forward, the resource implications may affect the feasibility of conducting these activities. Simulation operator and other White force manning must be comensurate with the desired scenario intensity and complexity. If the rate of effort is unsustainable, technologies to reduce manning requirements should be integrated with simulation tools. These may include voice recognition, machine speech, and intelligent teamed agents.

Simulation Fidelity

While the simulation environment was generally sufficient to achieve the desired training objectives, a lack of fidelity in some aspects and/or components had a negative impact on training effectiveness. Some of the Blue force simulators did not have the ability to readily set the IFF modes and codes required by the ABM team to monitor friendly aircraft, which created confusion. For example, when two such aircraft left the airspace and returned they were mis-identified as hostile. The Melbourne SIMOP was not advised to avoid constructing specific entity types in PSI/VR-Forces, the enumerations of which had not been verified against Mesa systems. Unfortunately this occurred and a UN Medivac Learjet was portrayed as F-15 within the virtual cockpits. Similarly, terrain was not represented consistently between simulation systems. The Mesa virtual cockpits modeled and displayed terrain whilst the DSTO constructive simulator did honour terrain. In one instance a Red aircraft was able to fly within the terrain and elude the Blue fighters. The fidelity limitations mentioned above

were largely procedural; however, there were others attributable to the nature of the systems.

Th restriction of operating within an unclassified environment prevented the use of the most realistic weapon and sensor models. The DSTO constructive simulators did not support an external electronic warfare (EW) environment interface. Therefore the Red entities created within did not stimulate the radar warning receiver (RWR) on any of the F-16 simulators. This made aspects of identifying hostile intent in accordance with ROE and threat avoidance difficult or impossible to perform, and resulted in negative learning. Additionally, the limited number of Blue force SIMOPs meant that there were times "when you knew that your sim pilot was busy talking with another controller, so key calls on the radio were not made". This may be an unintended example of team workload balancing behaviour; however, it degraded the ability to achieve the core training objectives.

CONCLUSIONS

The key objectives of Exercise PL2 were to: (i) develop systems which allow small White force to support ABM training (ii) continue development of AUS-US distributed simulation infrastructure, (iii) continue development of performance measurement and feedback techniques for coalition DMT, (iv) develop a structured method for designing ABM team training scenarios, and (v) investigate interoperability issues associated with air battle management and air combat missions for coalition operations.

The scenario network that was used for PL2 performed well in supporting distributed briefing, debriefing, and mission execution. This demonstrates that coalition mission training of this kind is feasible as an adjunct to regular training for ABM teams and fighter aircrew. Importantly, expert assessment of the ABM team revealed a performance increase over the course of the exercise. This demonstrates that there is indeed a benefit to undertaking such training. With the exception of a small number of systems and procedural issues, participant reactions to the exercise were overwhelmingly positive. This indicates that training of this kind is viewed as beneficial and is likely to garner a great deal of acceptance as it gains exposure within the Australian operational community, as it has in the US. These evaluations provide a solid foundation for advancing the development of tools and techniques for conducting coalition DMT between Australia and the US in the air combat domain. Future plans for the Pacific Link series of exercises involve building upon the infrastructure and expertise gained through the conduct of Exercises 1 and 2. In particular, it is anticipated that the development of the Aerospace Battlelab at the DSTO Melbourne site will enable future exercises to incorporate classified platforms, weapons, and sensor modeling for enhanced realism.

REFERENCES

Bell, H., & Crane, P. (1993). Training Utility of Multiship Air Combat Simulation. In, 1993 Winter Simulation Conference Proceedings, G. W. Evans and M. Mollaghasemi, (Eds.), Los Angeles: Winter Simulation Conference.

Carr, J., and Hernandez, J. (2005). Deployable Distributed Mission Operations ... in the Eye of the Beholder. MS&T Magazine, 2005(5), 24 – 27.

Colegrove, C.M., & Alliger, G.M. (2002). Mission essential competencies: Defining combat readiness in a novel way. Paper presented at: NATO Research & Technology Organization, Studies, Analysis, and Simulation Panel, Conference on Mission Training via Distributed Simulation (SAS-38), Brussels, Belgium.

Crane, P., Skinner, M., Best, C., Burchat, E., Gehr, S. E., Grabovac, M, Pongracic, H., Robbie, A., and Zamba. M. (2006). Exercise Pacific Link: Coalition distributed mission training using low-cost communications. Paper presented at: SimTecT 2006, Melbourne, Australia.

Crane, P., Tomlinson, B., & Bell, J. (2002). Similarities and Differences in the Implementation of Distributed Mission Training. In, Proceedings of 2002 Industry/Interservice Training Systems Conference, Orlando, FL: National Security Industrial Association.

Fowlkes, J., Dwyer, D.J., Oser, R., & Salas, E. (1998). Event-based approach to training (EBAT). The International Journal of Aviation Psychology, 8(3), 209-221.

McCarthy, A., Kingston, G., Johns, K., Gori, R., Main, P. & Kruzins, E. (2003). Joint Warfare Capability Assessment - Final Report: Australian Joint Essential Tasks Volume 1. DSTO Client Report. DSTO-CR-0293.

Smith-Jentsch, K.A., Zeisig, R.L., Acton, B., & McPherson, J.A. (1998). Team dimensional training: A strategy for guided self-correction. In J. Cannon-Bowers & E. Salas (Eds.), Making Decisions Under Stress: Implications for individual and team training (pp. 271-298). Washington, DC: APA Press.