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UNITED STATES AIR FORCE RESEARCH LABORATORY

TRAINING FOR DYNAMIC AEROSPACE CONTROL: AN EXPERIMENT IN INTERNATIONAL DISTRIBUTED MISSION TRAINING

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PREFACE

This research was conducted at the Air Force Research Laboratory, Human Effectiveness Directorate, Warfighter Training Research Division (AFRL/HEA) under USAF Contract No. F41624-97-D-5000, Task Order No. 4, and Work Unit 2313-HA-04, Simulation and Distributed Mission Training. The Laboratory Contract Monitor was Maj Justine Good, AFRL/HEA, and upon her departure, Dr Herbert H. Bell, AFRL/HEA.

TRAINING FOR DYNAMIC AEROSPACE CONTROL: AN EXPERIMENT IN INTERNATIONAL DISTRIBUTED MISSION TRAINING

INTRODUCTION

Current training resources and methods limit our ability to train and practice combined air operations involving coalition forces. Distributed Mission Training (DMT) offers new opportunities to provide our air forces with the knowledge, skills, and experiences needed to successfully train and practice such missions. In response to these opportunities, the Air Force Research Laboratory, Human Effectiveness Directorate, Warfighter Training Research Division (AFRL/HEA) and Thales Training and Simulation (TTS) established a Cooperative Research and Development Program to investigate the potential of DMT and other advanced distributed simulation technologies as an additional media for training coalition air operations. This program, known as Project Allied CRAFT, seeks to establish a technical base that will assist the United Kingdom and the United States, as well as their allies, in developing a multi-national simulation network to enhance mission training.

Project Allied CRAFT is designed to use the distributed simulation capabilities and supporting infrastructures in the United Kingdom, United States, and the North Atlantic Treaty Organization (NATO) and to grow as these capabilities evolve. It is planned as a three-phase effort. Budget realities, resource availability, and classification issues will ultimately determine if all three phases are successfully completed. The phases are:

- Phase I, *Training for Dynamic Aerospace Control*, was intended to provide confirmation of the international DMT concept in the form of a training demonstration to show current technology has the potential to solve many of the operational training problems. Phase I was completed 11-13 September 2000 as part of Air Force Association's 2000 Aerospace Technology Exposition and is described in this report.
- Phase II will consist of a research and development (R&D) program to increase capability and conduct training research experiments to define the technical and training requirements needed to support and justify DMT procurement action.
- Phase III will establish an International DMT Program, possibly on a Joint Integrated Product Team (IPT) basis. It would no doubt include North Atlantic Treaty Organization (NATO) ground-based training assets as they are developed and fielded.

The primary purpose of this paper is to document the results of the Phase I training technology concept demonstration. This demonstration, *Training for Dynamic Aerospace Control*, linked multiple sites using the Internet and commercial data lines. We begin with a brief discussion of the background for the project. This discussion is followed by identification of our goals and objectives and a brief synopsis of our earlier unsuccessful attempt to link with TTS in 1999. Following the background material, we describe the successful demonstration conducted in September 2000 and some of the technical performance data collected during that demonstration. Finally, we conclude with a discussion of the lessons learned from the Phase I demonstration and the potential for distributed simulation to revolutionize the way we prepare for coalition operations.

BACKGROUND

Recent military conflicts have been predominately "asymmetric." This asymmetry stems from the use of high technology systems against relatively simple and widely dispersed enemy forces that often lack well-established, military-industrial infrastructures. Because of the lack of well-defined enemy lines and military-industrial infrastructure, the control of aerospace operations is becoming increasingly dynamic. Small, highly mobile enemy targets must be quickly pinpointed and aerospace assets rapidly deployed to successfully attack such targets with minimal collateral damage.

Training aerospace forces to successfully Find, Fix, Track, Target, Engage, and Assess damage in this time-compressed, highly dynamic mission environment presents a major training challenge. Because these missions involve a complex system of systems, there are numerous individuals and teams that must interact with one another to successfully plan and execute each mission. Unfortunately, these teams have limited opportunities to train together in realistic, collective training environments. These limited training opportunities mean that, while these teams may have developed high levels of expertise for the individual and team tasks within their particular specialties, they may not have similar levels of expertise involving the inter-team tasks needed to effectively operate as a part of a larger dynamic aerospace force. This training problem is further exacerbated by the increasing reliance on multi-national, coalition forces who have even fewer opportunities to conduct multi-team collective training prior to a real conflict.

One potential solution to this training challenge is to use DMT to create a distributed virtual training environment in which the various teams and nations can collectively train together in a common virtual environment from home station. Such a virtual environment could supply realistic mission training for national and multi-national teams. However, development and use of such virtual environments is still in its infancy. As a result, there is limited data available to operational warfighters, engineers, and training developers that describe the current readiness of both simulation technologies and training methods to provide such training. Consequently, it is difficult to determine the capability of these technologies and methods to meet warfighter training needs and to identify the enabling technologies that must be further developed to provide a robust team training environment. This paper describes a demonstration that linked simulators located in the United States and the United Kingdom to conduct a virtual training exercise and the data collected during that demonstration.

Goals and Objectives

There were two goals for the Phase 1 demonstration. The first goal was to demonstrate an international DMT capability between the United States and the United Kingdom using currently available products and technology. The second goal was to determine the potential utility of including command, control, intelligence, surveillance, and reconnaissance (C2ISR) assets. Effective integration of C2ISR assets into a real-time, international distributed simulation network could significantly enhance its training value by providing the capability to train the entire sensor-to-shooter mission. Such missions involve a number of the different teams that need to work together to successfully plan and execute coalition air operations.

Based on these goals, the following objectives were established for Phase I of Allied CRAFT.

- Showcase existing technology for Distributed Mission Training
- Establish a wide-area, international DMT connection to the United Kingdom
- Successfully execute a number of complex mission scenarios using that wide-area, international network
- Determine the utility of using real-time distributed networks to augment coalition training
- Document the latencies involved with transoceanic networks
- Identify the bandwidth requirements of a composite force mission scenario executed in real-time
- Demonstrate the use of the Internet as a possible low-cost method for providing DMT training
- Document what worked and what didn't work during the international DMT demonstration.

1999 Air Force Association Technology Exposition

The first attempt to complete Phase I of Allied CRAFT was in conjunction with the 1999 Air Force Association (AFA) Technology Exposition in Washington DC. Our original plan called for the establishment of a wide-area-network (WAN) that linked a number of sites in the US and TTS in the UK. These sites and the various virtual and constructive simulations from each of those sites are shown in Table 1.

Table 1. Simulation Participants Planned for the 1999 AFA Technology Exposition.

Location	Virtual Simulators	Constructive Simulations
Brooks AFB, TX	E-3 Mission Crew	
Hurlburt Field, FL	AC-130U	
Tucson, AZ	1 x A-10	
Crawley, UK	2 x Tornado	
Washington, DC	2 x F-16	ZSU-23* (Army TSMO)
Mesa, AZ	2 x F-16	Friendly Aircraft
	1 x A-10	Enemy Aircraft
		Enemy Ground Forces
Kelly AFB, TX		Surface to Air Threats

* ZSU-23 was located in a separate booth at the exposition and was treated as a separate site

Figure 1 shows the planned WAN design for the 1999 demonstration. This network plan assumed installation of a dedicated T-1 data line between AFRL Mesa and the Washington DC show site, existing, dedicated T-1 data lines between Mesa and the other sites, and a primary rate Integrated Services Digital Network (ISDN) between Mesa and Crawley, UK.

Unfortunately, we were unable to execute the 1999 technology demonstration as planned. While preparing to deploy to Washington, DC the week before the AFA Technology Exposition was due to begin, the telephone companies had not yet installed either the T-1 or ISDN data lines. Based upon a series of verbal discussions with the telephone companies, we speculated that the lines would be installed in time for the exposition and deployed our simulators to Washington. Unfortunately, such was not the case. Upon arriving in Washington, we discovered that the communications infrastructure was being upgraded throughout the Washington area and that there would be no available T-1 lines until the latter part of 2000. The only option left was to attempt to use the Internet. Therefore, we leased an Internet connection from the Marriott Hotel and attempted to use it as the major communications pipeline for the 1999 technology demonstration.

The use of the Internet presented two immediate and major problems:

- All the data between sites had to be encrypted
- The leased Internet pipe had a capacity of only 128 kilobytes per second.

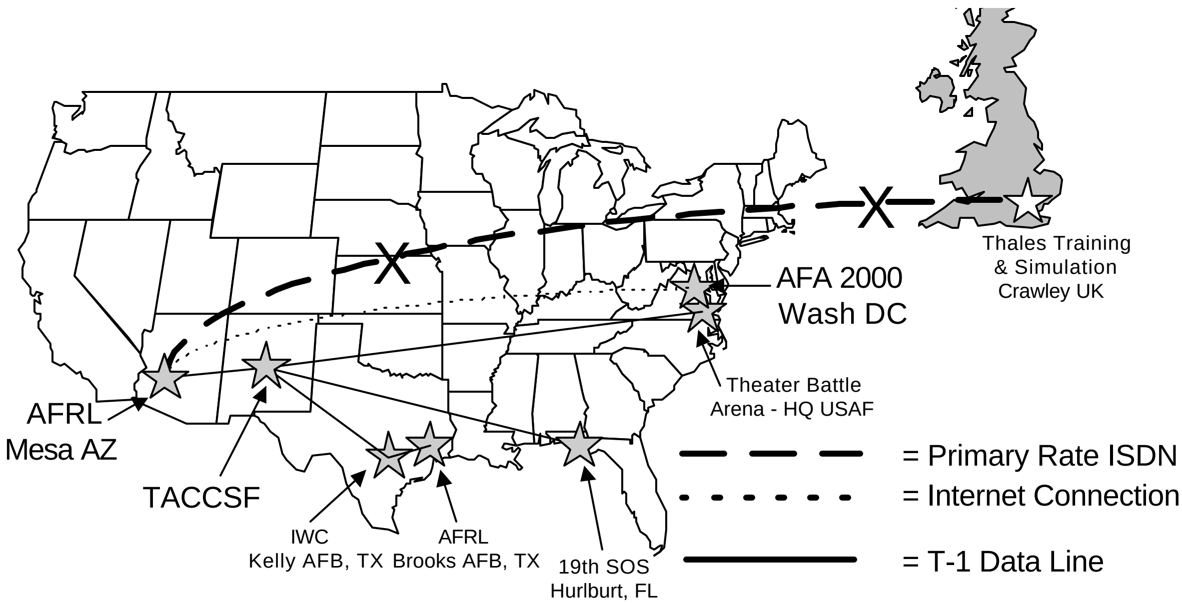

Figure 1. AFRL's 1999 AFA Technology Exposition DMT Demonstration

Based on these limitations, the plan to connect with TTS as part of the demonstration was cancelled. The two-ship demonstration that was planned to be virtual RAF Tornados was replaced with a two-ship of constructive RAF Tornados generated locally on the network. This two-ship was given the same airfield target as their objective. The other effects generated by the lack of a T-1 line and the narrow bandwidth pipe from the hotel to the Internet Service Provider (ISP) for the Marriott are discussed in more detail in the Results section.

Although we were unable to establish a bi-lateral connection between AFRL/HEA and TTS for the 1999 demonstration, we did learn three valuable lessons from this effort:

- First we discovered that we could successfully execute real-time mission simulations involving a number of geographically dispersed sites in the US using the Internet as one of the major trunks.
- Second, we showed that it is possible to use both a point-to-point encryption device and the Internet with DIS multicast protocols.
- Third, we learned that the commercial communications infrastructure in the US is undergoing such continuous growth that may not be possible to obtain new dedicated data lines in a timely manner in every case.

2000 AFA Technology Exposition

Overview

The 1999 AFA Technology Exposition provided us with invaluable information regarding the difficulties of obtaining data lines in a large metropolitan area and on the use of the Internet as a means of exchanging real-time simulation data. Based on knowledge that we not obtain a T-1 line in time for the AFA 2000 Technology Exposition, just as in 1999, we began planning for the 2000 show in October of 1999, one month after the we returned from the Washington DC show. As part of this plan, we made the early decision to use the Internet between the Marriott Wardman Park Hotel and the Air Force Research

Laboratory (AFRL) in Mesa, AZ, for the 2000 technology demonstration. Because of the performance limitations observed in 1999 due to the 128 kilobit per second wide connection from the hotel to their ISP, we negotiated with the Marriott to lease a private, dedicated 1-megabit/second connection from the Marriott to its ISP for use during the September 2000 AFA show. In January 2000, we finally obtained a dedicated primary rate ISDN line (T-1 equivalent of 1.5 megabit/sec bandwidth) between AFRL Mesa and TTS in Crawley, England. Several quick engineering tests were conducted using Distributed Interactive Simulation (DIS) protocols to verify interoperability, determine a common method of time-stamping, and determine the average latency between Mesa and Crawley

Once we had established our primary communication lines, we began refining our mission scenarios and finalizing the actual simulations that would be part of our 2000 technical experiment. The scenarios focused on distributed mission training for dynamic aerospace control with the emphasis on time-critical targeting. The objective was to demonstrate the utility of using DMT and for inter-team training involving C2ISR assets, decision makers, and shooters. The goal of this inter-team training was to successfully accomplish the six stages of the "kill chain" – Find, Fix, Track, Target, Engage, and Assess.

We decided that there would be three primary WAN nodes for the AFA 2000 Technology Exposition. These nodes were the Marriott Wardman Park Hotel, Washington, DC; TTS, Crawley, England; and AFRL/HEA, Mesa, AZ. Table 2 shows the simulators and simulations associated with each of these sites..

Table 2. Simulation Participants for the 2000 AFA Technology Exposition.

Location	Virtual Simulators	Constructive Simulations
Marriott Wardman Park, Washington, DC	Combined Aerospace Operations Center (CAOC)	AirSF intelligent agent constructive force generator,
	1 x F-16	
	1 x A-10	
	Joint Stars Mission Simulator	
	(called VSTARS)	
	AWACS E-3B Weapons Director	
	Space Maneuver Vehicle	
	Predator Uninhabited Air Vehicle	
AFRL/HEA, Mesa, AZ	3 x F-16	Friendly and enemy air and ground forces
	1 x A-10	
TTS, Crawley, England	1 x Tornado	1 x Tornado

Scenario

The scenario used in the 2000 AFA Technology Exposition was a modified version of the 1999 demonstration still conducted on the Nellis Range Complex. Figure 2 illustrates the WAN configuration for the 2000 demonstration, and Figure 3 shows the initial conditions for this scenario at "time zero." From a mission perspective, the scenario included offensive counterair, interdiction (conventional strike), high-value asset cap, suppression of enemy air defense (SEAD), time-critical targeting, battle management from airborne warning and control system (AWACS) and Joint Surveillance Target Attack Radar System (JSTARS), and reconnaissance from the Space Maneuvering Vehicle concept demonstrator and the UAV Predator. The theme of the demonstration was *Training for Dynamic Aerospace Control*, which focused on (and demonstrated) the three major categories of execution in an Air Operations Center:

- Fixed Target - Planned Event (Aircraft on an Air Tasking Order (ATO) tasked sortie)
- Planned Dynamic – Known in advance, but unable to fix location in advance (e.g., Moving Tanks)
- Unplanned Dynamic – Not known in advance (e.g., SCUD TEL or Launch)

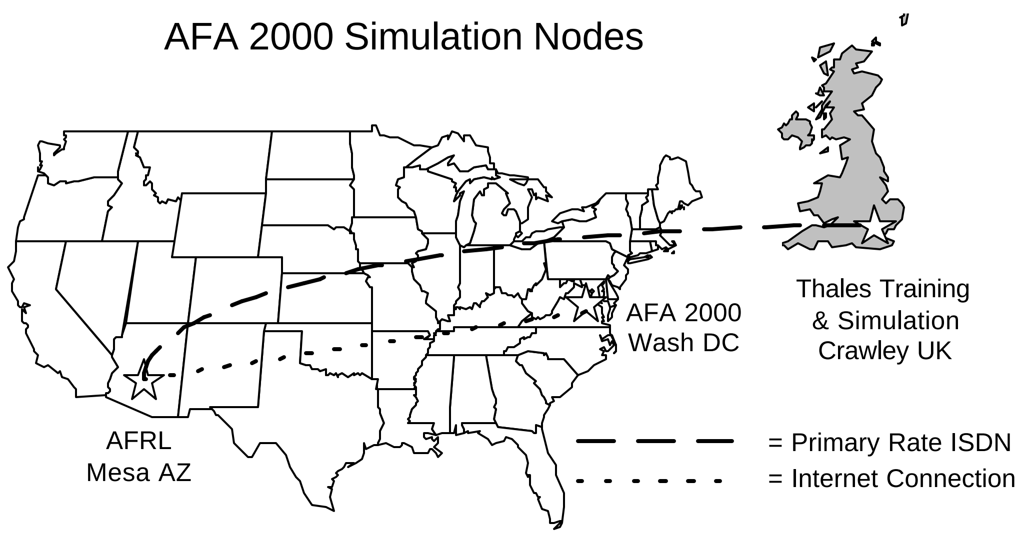

Figure 2. AFRL's 2000 AFA Technology Exposition DMT Demonstration

Because it is difficult to hold the attention of an audience very long in a technology demonstration, the scenario was designed to be as short as possible and have as much tactical action as practical without sacrificing the demonstration of training utility or becoming unrealistic to the warfighters executing the mission. Each live demonstration began with the players at a point just prior to the Forward Edge of Battle Area (FEBA), except for the UAV, which was flying behind the enemy lines. The following describes a typical scenario evolved from the initial conditions shown in Figure 3.

The mission began with the F-16 four-ship on a medium altitude ingress followed by the two Royal Air Force (RAF) Tornados in 2-minute trail. These six strike aircraft were executing a planned ATO-tasked mission to strike an enemy airfield and fuel tanks located on that airfield. One set of constructive or computer-controlled F-15Cs maintained a high value asset barrier cap between the FEBA and the AWACS aircraft. A second set of constructive F-15Cs proceeded out ahead of the strike package on a sweep mission to engage any enemy aircraft considered to be a threat to the friendly assets. Constructive F-16CJs also began just east of the FEBA in a SEAD role. After all active emitters were suppressed, the F-16CJs returned to a predetermined cap to re-engage any new threats. The two virtual A-10s (one in Washington DC, one in Mesa) proceeded to the FEBA to await tasking on any new moving targets detected by airborne sensors. Finally, several groups of friendly tanks (constructive) crossed the FEBA and proceeded west to engage enemy ground forces.

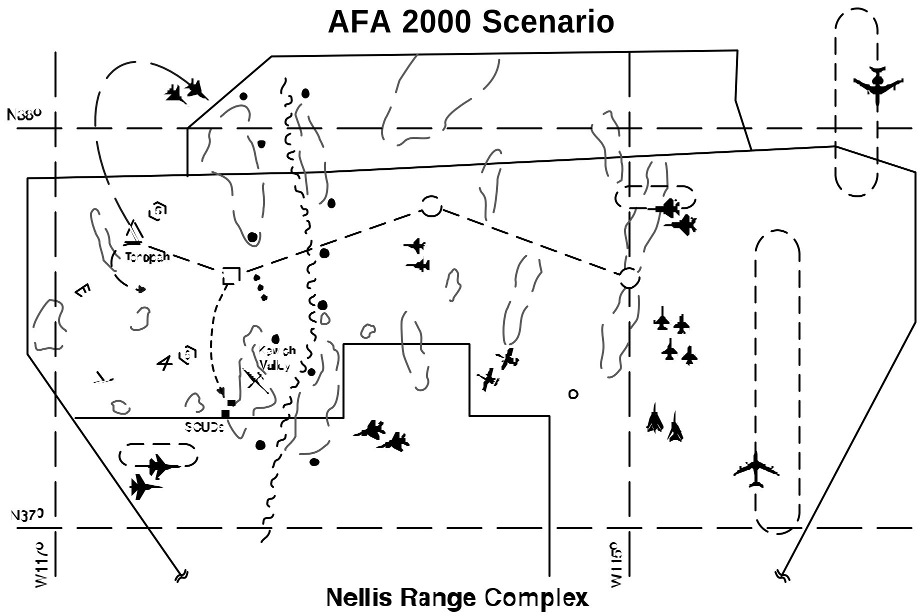

Figure 3. AFRL's 2000 AFA Technology Exposition DMT Demonstration Scenario

The enemy order of battle west of the FEBA included several columns of tanks up and down the FEBA, anti-aircraft artillery (AAA), surface-to-air missile sites, SCUD Tels being transported to new locations, MiG-29s, and Su-27s. As the mission came off freeze, the Su-27s came out of orbit in the south and proceeded east where the F-15C sweep aircraft engaged them. Several minutes later, once the enemy determined that strikers were inbound, MiG-29s took off from the enemy airfield in the north. These aircraft were engaged by two of the F-16Cs inbound on a strike mission to that airfield being controlled by AWACS. Several minutes into the mission, the VSTARS simulator detected a column of moving entities heading east and several suspicious movers heading south along the FEBA. VSTARS tasked the UAV ground station to redirect the UAV to the area of the suspicious movers to confirm that they were SCUD missile launchers. AWACS coordinated with the VSTARS aircraft, and the A-10s were told by AWACS to proceed towards what is likely a column of moving tanks. The A-10s identified the tanks and proceeded to engage them with Maverick missiles. The UAV confirmed SCUD launchers and passed that information back to VSTARS. AWACS directed Viper 1 and 2 to stand by for a divert mission and were sent to VSTARS frequency. Viper 3/4 and Lancer 31/32 (the RAF Tornados) were told to continue inbound to the airfield target. The VSTARS authenticated with Viper 1 and 2 and delivered the 9-line divert message. Viper 1 and 2 then proceeded to the area of the UAV, identified the missile launchers and proceeded to destroy the SCUDs. Meanwhile, AWACS detected the launch of the MiG-29s from the target airfield. Vipers 3 and 4 were paired against the MiGs. They engaged and destroyed the enemy aircraft and proceeded back towards the target airfield. The Tornados continued inbound to the target airfield. The Tornados struck the oil tanks, followed by Vipers 3 and 4, who returned to the airfield from the air-to-air engagement and delivered their conventional ordnance on the airfield. The airfield was protected by heavy AAA fire but the mission was successful. At this point, the demonstration was terminated by exercise control.

Marriott Wardman Park Layout

Figures 4 and 5 depict the floor layout of the two booths constructed at the AFA 2000 show site. Booth 3605 (the main hub of the demonstration) contained all of the C2ISR simulations. The centerpiece of Booth 3605 was AFRL's modular, deployable video wall. It consisted of six 67-inch diagonal screens arranged in a 2-high by 3-wide configuration. Each cube contained a Barco 808S, color, CRT-based projector.

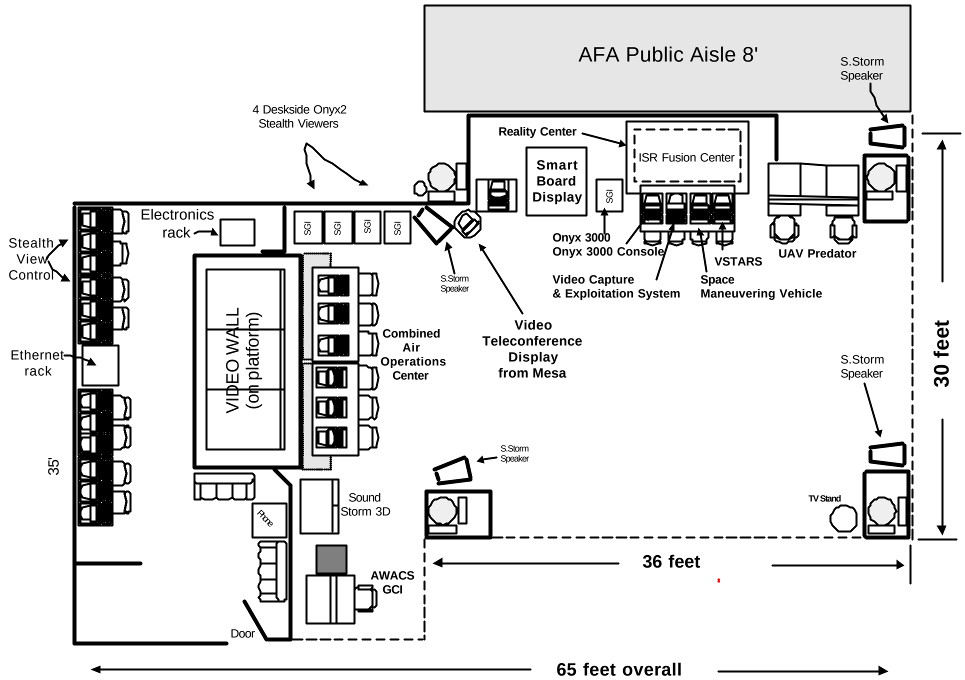

Figure 4. AFRL's Booth 3605 at AFA 2000 Technology Exposition

The video wall served as a mini-section of a Combined Air Operations Center (CAOC). The Sound Storm 3D four-channel sound system with speakers located at all four corners of the booth complemented the visual presentation. The public was able to see the demonstration visually from various viewpoints provided by front-channel video from the F-16 and A-10 at the show site and three stealth viewers used to move about the battlespace. The audience could also hear all of the C2 and pilot UHF/VHF radio transmissions throughout the demonstration through the four-channel sound system. AFRL also deployed a distributed briefing/debriefing system that linked the AFA show site to the testbed in Mesa. The flight lead for the DMT mission briefed from Mesa using an interactive SmartBoard and Microsoft's Net Meeting networked over a separate Internet line. Video teleconference (VTC) equipment was integrated to the briefing system and linked over three additional ISDN lines leased from the Marriott. The VTC and SmartBoard systems were left active throughout the show following each live DMT demonstration so that people in Washinton DC and Mesa could observe and use the distributed briefing system between shows.

SGI demonstrated a pre-production system called the Video Capture and Exploitation System (VCES). This system was hosted on the new Onyx 3000 on loan to AFRL. The VCES is capable of accepting almost any input signal format, capturing one frame or a motion sequence of frames and allowing the user to totally manipulate, enhance, or annotate the captured information and then re-transmit the information as desired in an number of output formats. The video capture system was displayed on a two-channel visual Reality Center system. Also connected to the Reality Center and the CAOC video wall were the VSTARS virtual simulator, the UAV Predator Multi-Task Trainer (MTT) and the Space Maneuvering Vehicle. Mission-ready aircrew associated with these platforms operated the VSTARS and UAV. The SMV was operated by one of the developers of the systems. In addition to the above training devices in Booth 3605, an E-3 AWACS Weapons Director (WD) simulator was also on the network operated by a WD from Tinker AFB, OK.

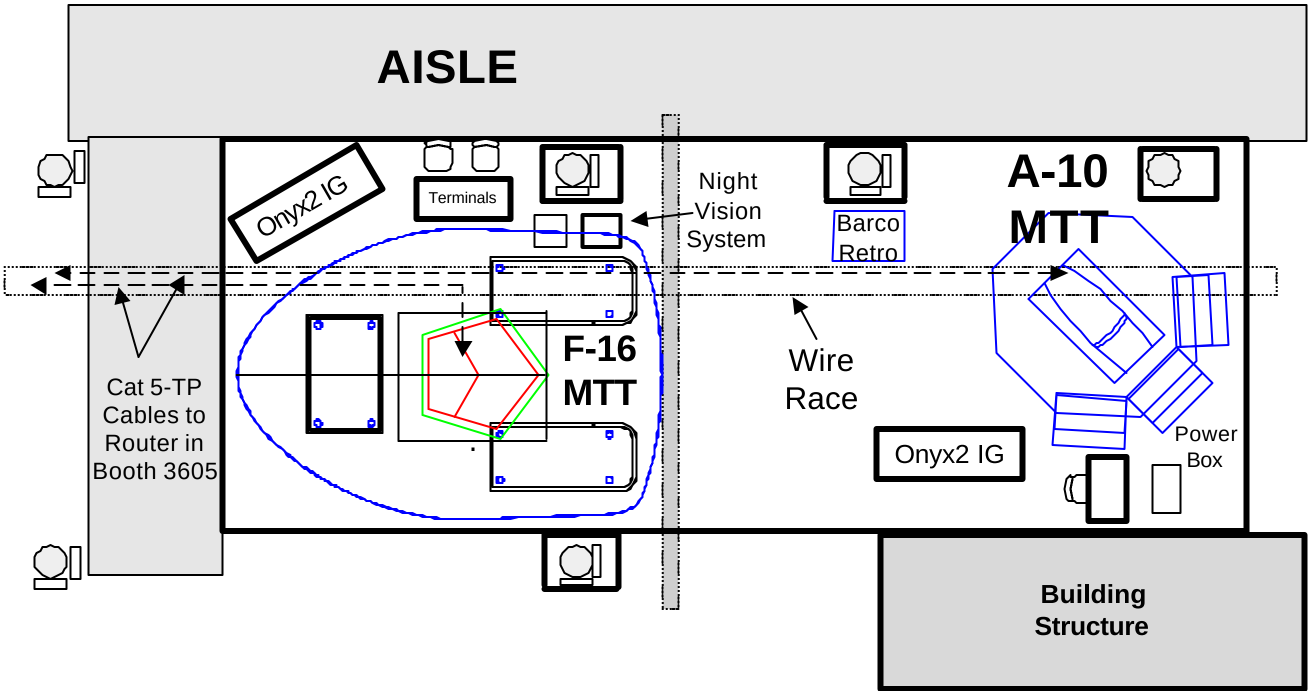

Figure 5. AFRL's Booth 3629 at AFA 2000 Technology Exposition

Booth 3605 was located about 75 feet from a second AFRL display, Booth 3629, and connected to it by a number of Category 5 Twisted Pair Ethernet cables and 5-wire RGB coaxial cables strung along wire braces suspended from the ceiling of the Marriott convention hall. Figure 5 shows the layout of Booth 3629. This booth contained the F-16C MTT equipped with a full field-of-view Mobile Modular Display for Research and Training (M2DART) color display system developed by AFRL Mesa. This F-16 was Viper 2, wingman of the flight lead located in Mesa. An A-10A MTT with a three-screen, 120-degree field-of-view display was also located at the opposite end of Booth 3629. This A-10 was Hawg 1, the flight lead whose wingman was located in the DMT Testbed at Mesa. Both cockpits were linked via individual network interface units (NIUs) to the Mission Control Center (CAOC) and network hub in Booth 3605 shown in Figure 4. SGI Onyx2 Reality Monsters, using the high-fidelity, photo-realistic development database from AFRL's night vision training system, powered both cockpit visual systems.

Network Topology

The AFA 2000 demonstration was generated from three primary sites with multiple simulations running at each site. Mission Control was located at the AFA site. As described in detail earlier, the three nodes were AFRL in Mesa, AZ, the Marriott Wardman Park Hotel in Washington DC, and Thales Simulation & Training in Crawley, England. Figure 6, the Mesa AZ site; Figure 7, the Washington DC site; and Figure 8, the Crawley England site, illustrate the hardware configuration at each of the three locations.

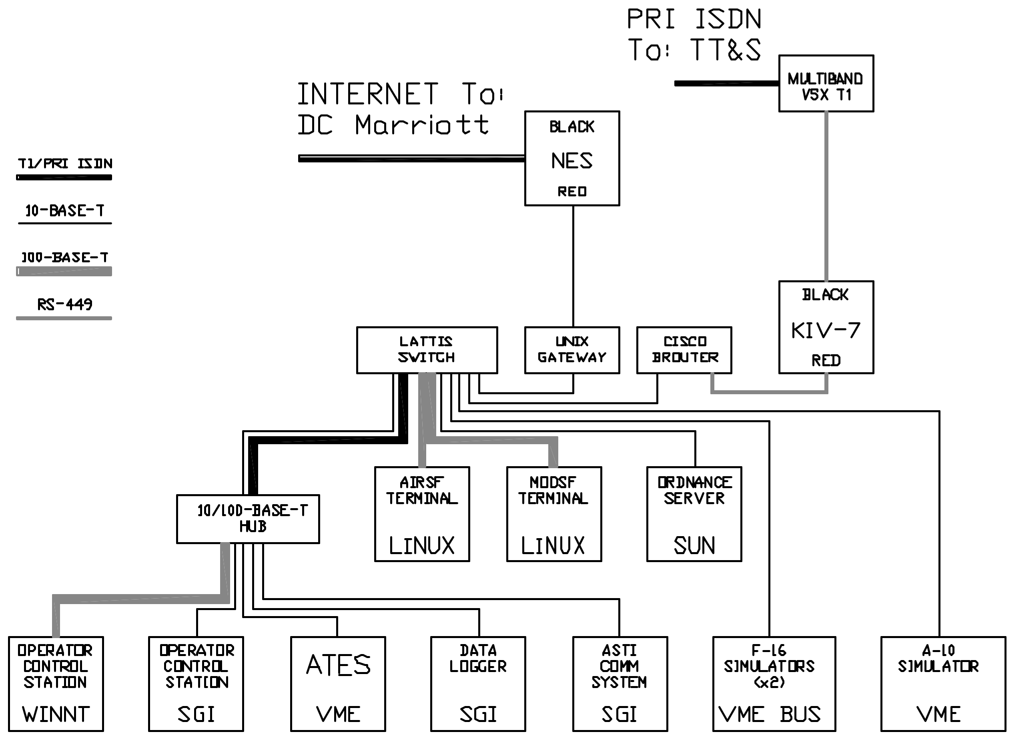

Figure 6. Mesa, AZ Site Local Area Network Topology

In preparation for the AFA 1999 and 2000 shows, all original hard disk storage media were removed from the testbed and replaced with new hard drives and configured with unclassified software. While the “clean disk” requirement causes initial upfront costs associated with these types of demonstrations to be higher than normal, having the spare unclassified removable storage hardware saves significant man-hour costs on any subsequent deployment, demonstration, or operation in an unclassified environment. Stripping and rebuilding operating systems is very labor intensive and introduces risk to the software integrity after rebuilding. The ordnance server shown in Figure 6 was there to provide missile flyout for the intelligent agents being generated by AirSF. As can be seen, two gateways to the outside world were used in the Mesa DMT Testbed. One was based on the Motorola NES (Network Encryption System) box used to connect to Washington DC via the Internet, and the other was a Mykotronix KIV-7HS used to connect via the ISDN lines to Thales Training & Simulation site in England (Figure 8). Figure 7 illustrates the local area network topology for the show site in Washington DC. All of the components at the show site were equipped with a network interface unit (NIU) that connected to the 10/100 Base-T Switch. AFRL also deploys a development system and a laptop workstation for technology demonstrations conducted outside of Mesa, AZ. The development system is used to write new code or modify any existing source code and then recompile, if necessary. The laptop workstation is used to boot all simulators over Ethernet from one location. This standardizes the software load and streamlines the boot procedures which all reduces the risk of failure when time and resources are critical. The use of a deployed development system also enables the engineers to have access to debug code. This improves their capability to troubleshoot whenever complex systems are deployed and reconstructed in less than perfect conditions.

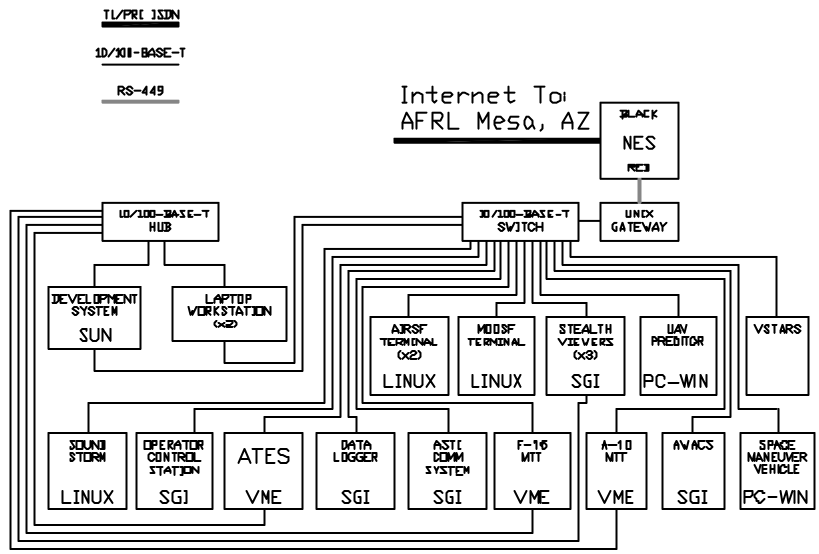

Figure 7. AFA 2000 Show site, Washington DC, Local Area Network Topology

Figure 8 illustrates the gateway configuration and local area network at the Thales facility in England. Mesa and Crawley were connected by the 1.5-megabit per second (ISDN) lines. An ISDN primary-rate line with thirty 64 kilobits per second channels was established to provide data and voice communications between the two locations. Both locations used Lucent ISDN multi-plexers and Cisco 2601 routers employing forwarding protocols over a V.35 electrical interface, because the demonstration was unclassified but connected to a classified facility in Mesa, to provide a firewall. Each end of the ISDN connection was attached to a Mykotronix KIV-7HS encryption system installed to operate in an unclassified secure mode over the public ISDN network. The KIV-7HS was installed between the Lucent multiplexer and the Cisco router. Due to lessons learned from the engineering test conducted in February 2000, which used an X.21 interface, the AFRL and TT&S engineers were able to configure a non-standard V.35 interface within less then an hour after resolving a few minor problems.

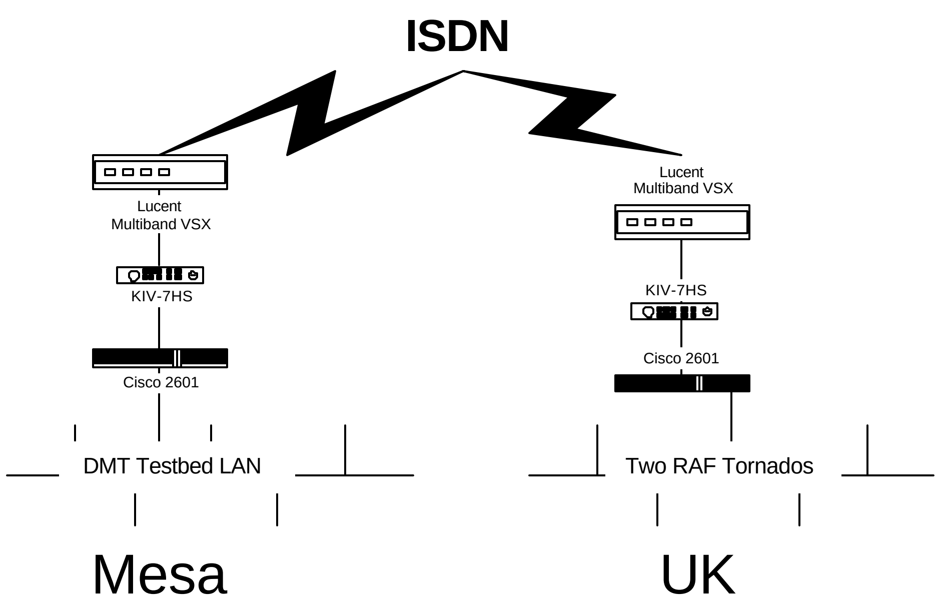

Figure 8. Crawley, England Site Local Area Network Topology

RESULTS

As was mentioned in the introduction, AFRL was notified on the Friday before the 1999 Exposition opened that there would not be a T-1 line available and that the west coast phone company involved would be unable to install the ISDN needed to connect the United Kingdom. Friday, Saturday, and Sunday before the show in 1999 were filled with engineering challenges and high levels of stress, but creativity prevailed. AFRL engineers were able to design and develop a software solution hosted on an SGI O2 that enabled DIS protocols which are a multicast to be processed prior to encryption into a unicast format that satisfied both the encryption operational requirements and the transmission protocol requirements of the Internet. The same software solution then reprocessed the packets upon receipt after de-encryption and put the data back into a useable DIS PDU multicast format for each local area network.

As stated earlier, the bandwidth available between the hotel and the Internet connection for the 1999 AFA show was 128 kilobits per second. As a group, we assumed that the narrow bandwidth Internet connection would not allow a very high level of activity once the scenario was executed. However, we had no choice but to use the narrow connection since the show equipment was already deployed to the AFA site. The software solution was finished and tested late Saturday night and into early Sunday by setting up two NES boxes at the hotel and verifying the solution appeared stable. Once tested, an NES box and the new software were flown back to AFRL in Mesa for installation and at 4:30 p.m. on Sunday afternoon (before the Monday opening) the DMT Testbed was heard on the UHF radio from one of the F-16s in Mesa over the Internet!

The use of the narrow pipe to the ISP in the 1999 show did have a significant impact on the DMT show. Routine network analyzer equipment confirmed that there were oftentimes 50% to 100% data collisions occurring depending not only on the show traffic but on the hotel traffic as well. While everyone was pleased and surprised to learn that, despite the narrow data path, AFRL was able to conduct the live demonstrations as planned, without significant degradation in the visual systems or weapons employment, there was significant impact to voice communications. Entities from different sites could fly formation with each other; however, if they attempted to fly close formation then the result of the numerous data packet collisions was apparent. There was an unacceptable level of jitter in the out-the-window scene. Any time spent outside close formation was acceptable. The major impact was to the DIS voice communications. Whereas a missed packet of positional data results in a visual frame jump, which may or may not be noticed, a missing (or several missing) voice packet resulted in the messages being chopped up and most of the time unreadable or unusable. Since this problem could not be overcome due to the narrow bandwidth, the voice channels were disconnected from the public address side of the booth and AFRL personnel reverted to narrating the demonstrations as they were flown each time. In general, most people who understood the challenge AFRL faced in 1999 and how the engineering side had to be put together appreciated the fact that we had demonstrated that the Internet could be used at all for such a training event.

For the AFA 2000 Exposition, AFRL took the lessons learned from the 1999 show and negotiated with the Marriott Communications Center to obtain a dedicated 1-megabit per second trunk to the hotel ISP. Given the level of complexity of the scenario, this solved almost 100% of AFRL's problems. Other than latencies no doubt introduced by the use of extended routing algorithms in the Internet cloud, there was no perceptible impact to the execution of the DMT demonstrations including voice traffic. The AFA 2000 DMT demonstration was a big success story and highlighted the fact that, aside from some security issues, the Internet may offer a lower cost alternative to distributed training using ground-based systems.

In general, the data packet flow rate between sites varied, as expected, based on the complexity of the local area network. The total number of entities on the network during each demonstration varied between 95 and 120. The number of data packets per second (pps) averaged 400 pps with peaks around 600 pps. The sustained (over a 5-min period) in-coming bit rate to Washington DC and Crawley UK was recorded as 800 Kbps. This would occur near the end of the scenario each time when most entities were engaging and firing at each other or against ground targets. There were occasional peak values of 950 Kbps when numerous simultaneous voice transmissions were made. The ISDN connection between the US and the UK systematic round-trip ping-time was variable and seemed to be dependent on the time of day the phone calls were placed. The average latency between Mesa and Crawley England ranged from 148 ms during the early morning calls to 198 ms during the calls later in the day. It should be mentioned that there was a 6-hr time difference between Crawley and the AFA show site. The average latency between Mesa and Washington DC over the Internet was 80 ms.

As discussed earlier the telecommunications link between Mesa and Crawley England was a primary rate ISDN line. Of the total available lines, we used 20 channels for each session. This equates to 1.28 Mbps. The bit stream was encrypted using the KIV-7HS interposed between the ISDN "modem" and router. No noticeable signal delay was seen through the encryptors. Voice traffic between Mesa and Crawley was crystal clear. The earlier test in February 2000 highlighted that using fewer channels than 20 resulted in noticeable voice break-up. The sustained (over a 5-min period) out-going bit rates from Crawley averaged approximately 20 Kbps (1 virtual Tornado + 1 CGF Tornado) with occasional peaks of about 100 Kbps (including voice). The ISDN link-up was very reliable, easy to synchronize, and deemed to be extremely successful.

CONCLUSION

Despite the challenges of deploying numerous complex systems and systems of systems, both the 1999 and 2000 AFA demonstrations clearly pointed out the utility of networked distributed ground-based training. If the concept of operations is to conduct coalition operations, then the challenges involved multi-national distributed training need to be clearly identified and solutions to known problems tackled head on. The AFA demonstrations have shown that the technology will support a reasonable number of entities and a level of complexity sufficient to augment peacetime unit level training. Phase I of Allied CRAFT also opened the technology door to the Internet infrastructure and proved that it may be useful in ways not previously assumed to be possible.

In terms of long haul experimentation, the AFA 2000 proved that we are not far from being ready to conduct coalition training on a new level. Given the level of complexity of the DMT demonstrations, bandwidth provided by T-1 equivalent data lines is sufficient to begin now. No doubt, as the size of the synthetic battlespace grows and the fidelity of the players increases, more bandwidth will be needed. But the infrastructure available now and necessary agreements that have to be initiated now can be pursued now in order to be ready when the time comes.

It is the opinion of the authors that Phase I of Project Allied CRAFT proved that existing technology is a good place to start, that long haul network environments appear to be feasible, that there is a training utility when using real-time virtual networks for coalition training, and that the bandwidth required and latencies involved with transoceanic lines are not as bad as might have been predicted. To be sure, there is more work to be done in studying the impact latencies have on training events. However, the International DMT long haul connections used in the AFA 2000 Technology Exposition demonstrated that it is feasible to expand the DMT concepts to NATO and our coalition partners. The significant achievement of this collaborative experiment is that it will serve as a first step in establishing a NATO/coalition DMT research environment. AFRL/HEA will continue to work closely with the Defence Science and Technology Laboratory (DSTL), NATO countries and agencies, and our industry partners to ensure that the path to International DMT is adequately defined and the technologies needed are identified and developed.

8 List of Acronyms

AFA	Air Force Association
AFRL/HEA	Air Force Research Laboratory, Human Effectiveness Directorate, Warfighter Training Research Division
ATO	Air Tasking Order
AWACS	Airborne Warning and Control System
C2ISR	Command, Control, Intelligence, Surveillance And Reconnaissance
CRAFT	Coalition Research for Asymmetric Force Training
DIS	Distributed Interactive Simulation
DSTL	Defence Science and Technology Laboratory (formerly DERA)
DMT	Distributed Mission Training
FEBA	Forward Edge of the Battle Area
ISDN	Integrated Services Digital Network
JSTARS	Joint Surveillance, Targeting, Attack Radar System
Kbps	Kilobits per second
MTT	Multitask Trainer
NATO	North Atlantic Treaty Organization
NES	Network Encryption System (an actual Motorola product in this paper)
PDU	Protocol Data Unit
R&D	Research and Development
RAF	Royal Air Force
SEAD	Suppression of Enemy Air Defenses
SMV	Space Maneuvering Vehicle
TTS	Thales Training & Simulation (formally Thomson Training & Simulation)
UAV	Uninhabited Aerial Vehicle
UTD	Unit Training Device
VSTARS	Virtual Surveillance, Targeting, Attack Radar System (the JSTARS simulation)
WAN	Wide Area Network