

**The Battle Control Center, a Report From
The Joint Expeditionary Force Experiment (JEFX) '99**

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Abstract

The United States Air Force (USAF) is evaluating the next generation ground-based Command and Control (C2) equipment. As part of that effort the 133d Air Control Squadron (ACS) Iowa Air National Guard (ANG) has been an active participant in the Joint Expeditionary Force Experiment (JEFX) '99. The efforts of the ANG have included the development and testing of a prototype next generation C2 configuration, the Battle Control Center (BCC) and Remote Communications Cell (RCC) at JEFX. This paper will discuss the transition of the existing Modular Control Equipment (MCE) to the BCC, the JEFX experiment, lessons learned and further development of state-of-the-art C2 visualization systems. This paper will focus on the traditional MCE tasks that were performed in the BCC. Additional topics such as time critical targeting (TCT) and real-time imagery were also demonstrated at JEFX '99, but will not be addressed in this paper due to the time and space constraints.

INTRODUCTION

The ACS is comprised of a Control and Reporting Center (CRC)/Control and Reporting Element (CRE). The BCC and RCC are JEFX process initiatives attempting to improve the Joint Forces Air Component Commander's (JFACC's) ability to execute theater air operations by overcoming existing ACS deficiencies. These deficiencies include: use of non-Defense Information Infrastructure Common Operating Environment (DII COE) compliant, closed proprietary software, excessive footprint, inability to rapidly deploy, non-open systems etc. The RCC is comprised of sensor and communications equipment to forward and receive data. The RCCs are forward deployed near the Forward Line of Own Troops (FLOT)

and are self-sustained with their own security forces. The RCC contains the remote sensors and communications to support the BCC. The initiative seeks to make the BCC/RCC more interoperable while becoming more Expeditionary Aerospace Force (EAF) responsive. It also experiments with the migration of a traditional Air Operations Center (AOC) function, time critical targeting, to the BCC. The BCC/RCC concept and experiment will provide many lessons learned that will be invaluable in the design direction of next generation C2 systems. These new systems will be expected to allow operators to handle larger amounts of complex data using the latest in commercial display technologies. With these lessons learned and experience from JEFX, a parallel effort is being initiated by the Iowa ANG in the application of a virtual

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reality system, the CAVE, for full immersive visualization of the battlespace to aid C2 operators in dealing with immense amounts of data. The Iowa ANG is also investigating the use of technology such as the SMART Board in the BCC. This device is an interactive whiteboard that has the potential to enhance meetings, training, and briefings.

Description of JEFX '99

JEFX is a Chief of Staff of the Air Force (CSAF) sponsored experiment that combines live fly forces, live-play ground forces, simulations, and technology insertion into a seamless warfighting environment to test and evaluate new and promising technologies and processes.

JEFX provides the Air Force with a vehicle for experimentation with operational concepts and technologies, enhancing capabilities of the 21st century aerospace force. It is a broader effort to implement Joint Vision 2010, exploit the Revolution in Military Affairs and demonstrate emerging Air Force capabilities to deploy and employ decisive aerospace power for the joint force commander.

The concept of JEFX experiments is supported by the USAF Scientific Advisory Board (SAB)(1997). The 1997 SAB report specifically addresses JEFX '98. However, it's application is intended for all general large scale experiments such as JEFX '99.

The SAB report explicitly addressed exercises and experiments. A sampling of the recommendations in this report indicates a strong endorsement for JEFX to accomplish several things. First, validate battlespace awareness, directing the collection of intelligence and information in support of forward operations to the maximum extent possible. And secondly, validate distributed JFACC concepts through "reach back". Additionally, the report recommends validating the use of precision navigation, position, and timing as well as conducting lean sustainment and force protection experiments.

JEFX '99 was an opportunity to discover ways to accomplish Air Force missions in a joint/combined environment. The goal of JEFX '99 was to provide a seamless environment of simulations and live-fly forces into which advanced technology was introduced. Evaluations were conducted to determine the contributions to enhancing Air Force Core Competencies (AFCC). Specifically, JEFX 99 experimented on 24 new technology initiatives, 18 carryover initiatives from JEFX '98 and 18 process initiatives to develop 10 mission threads, that supported the overall hypotheses. These initiatives included: Combined Operational Picture (COP) as a forcing function, integrated space capabilities, two Air Expeditionary Forces (AEFs), increased Air Material Command (AMC) participation, Agile Combat Support (ACS) force protection realism, AOC Forward (AOC-F) co-located with Joint Task Force Headquarters (JTF/HDQ) coalition structure, Combined Air Operations Center (CAOC) versus Joint Air Operations Center (JAOC), dominant maneuver from above and beyond, BCC – a new air control concept, increased Air Force Forces (AFFOR) with combat support center at the rear, full crisis action Total Package Force Delivery Day (TPFDD) and real-time communications deployment.

Figure 1 illustrates the overall communications architecture of the JEFX '99 experiment.

Current C2 Equipment

The AN/TYQ-23 provides the Air Force with a transportable automated air C2 system for controlling and coordinating the employment of aircraft and air defense weapons as shown in Figure 2. (Janes, 1993-1994). The Air Force version of the MCE uses the AN/TPS-75, 3-dimensional, long-range, high-power, air defense radar.

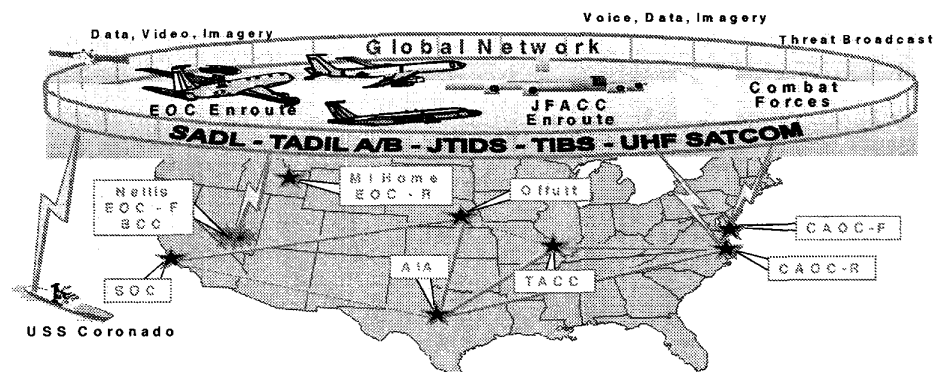


Figure 1. JEFX '99 Architecture

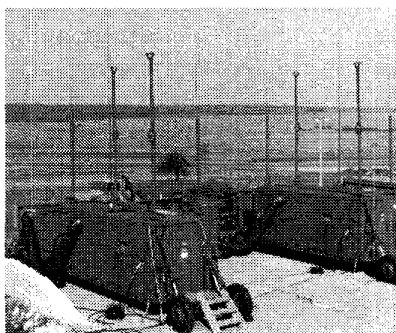


Figure 2. Current MCE C2 System

The basic system element of the MCE is the Operations Module (OM). A single OM is comprised of a standard six meter shelter containing all the C2 equipment including a full range of tactical digital data-links to perform the air defense function. System sensors and all power supplies are external to the shelter.

Up to five OM's can be connected through the use of fiber optic cables. Lengths of up to 500 meters allow a variable OM configuration at various locations for tactical or terrain reasons. The local radars can have locations up to 2 km from the OM and are connected using fiber optic cable. The distance for remote radars is only limited by the capability

of the communications medium being used to transmit data to the OM.

Within the OM, the weapons control function provides the capability to exercise positive control of aircraft employed in tactical operations: air defense, counter-air, interdiction, close air support, reconnaissance, refueling, search and rescue, and missions other than war. Four multicolor operator monitors for four C2 operators are located inside each OM as shown in Figure 3. These displays provide real-time information about the various tracks on the planned position indicator displays in regard to range and azimuth as well as Identification, Friend or Foe (IFF) and jamming status. The display shows superimposed track symbols, map or overlay lines, and alphanumeric data. There is a monochrome auxiliary display presenting stored alphanumeric data to supplement the situational display. Touch sensitive screens allow the operator system control.

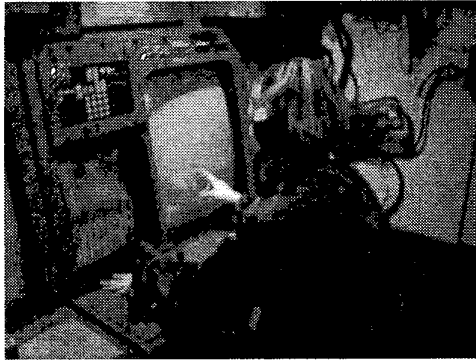


Figure 3. MCE Operations Module

The BCC at JEFX

The BCC was operated from Nellis Air Force Base, Nevada USA for JEFX '99 and housed in temper tents on the base. The RCC was located at a remote location from Nellis. The various workstations were positioned on tables in the tents. Figures 4 and 5 show the configuration of the BCC. The traditional core capabilities of the MCE are located on the right side as shown in Figure 4. These capabilities include: Air Battle Management, Air Surveillance, Combat Identification, Data Link Management, and Weapons Control. This includes the Mission Crew Commander (MCC), Battle Commander (BC), Senior Director (SD) and Weapons Directors (WD). On the left side tables are new functions of Time Critical Targeting (TCT) and Intelligence.



Figure 4. View of the BCC from Tent Entrance

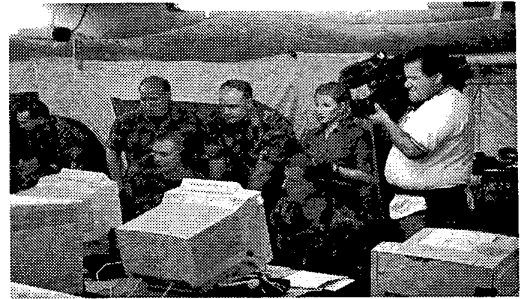


Figure 5. Weapons Directors at Work in the BCC

The main objectives for the BCC process initiative in JEFX '99 were to improve the MCE deficiencies and provide expanded functionality: 1) Reduce the footprint 2) Minimize forward vulnerability 3) Capitalize on BCC and Host Nation sensor feeds 4) Make the BCC tailorable for EAF operations, 5) Have growth capability 6) Utilize open system architecture 7) Utilize Commercial Off the Shelf (COTS) and Personal Computers (PC) based equipment 8) Utilize familiar and common tools such as Netscape and Windows 9) Reduce the number of personnel that are required for deployment 10) Provide a more effective capability to interface to synthetic battlespaces for training and research 11) Demonstrate global grid connectivity.

The objectives for the RCC were: 1) Maintain "gap-filler" role with reduced footprint 2) Extend Line-of-Sight (LOS) communications.

To accomplish these objectives, JEFX 99' had to demonstrate that the BCC could fulfill the traditional core competencies of the MCE and accomplish additional functions that migrate to the BCC.

Traditional Core Competencies: 1) Air Battle Management, 2) Aerial Surveillance, 3) Combat Identification, 4) Data Link Management, 5) Weapons Control.

Migrated Functions: 1) Time Critical Targeting, 2) Intelligence.

The BCC is a new concept and is significantly different and more flexible than the rigid MCE. The overall intent is to move information rather than people and equipment. The BCC brings all the radar and sensor data to one location and allows for dynamic fighting. Instead of waiting for intelligence reports and assessments to come in, the C2 operators can see the information on screen in real-time and re-task aircraft to higher priority targets. Those units that deploy to forward locations will present a much smaller and more effective footprint than the current.

JEFX: The Experiment

The primary focus of JEFX '99 was the use of experimentation, testing, and technology evaluation to aid EAF capabilities with particular emphasis on C2. JEFX creates a venue for potentially revolutionary technology for the EAF concept by creating the C2 system which will enable the EAF to function effectively.

The conceptualization and development of the BCC/RCC system was performed for over a year before the actual experiment. Incremental development was done using spiral development (Spirals I-III) with the actual experiment executing in August and September of 1999. The preparation and execution of the exercise was done in three parts: Training and preparation, Simulation phase, and Live fly.

Training and Preparation

Unlike most of the other JEFX initiatives, the core of personnel responsible for conducting the BCC and RCC initiative remained constant. This had a tremendous positive impact on making excellent progress from Spiral III to the execution phase. This constant allowed new personnel to become familiar with the concept of operations and quickly trained on the equipment. Personnel at the BCC had little trouble adapting to the new PC-based, user-friendly BCC systems. This was particularly important for our controllers who are already very familiar with

PCs in their everyday lives. The contractors from both Solipsys (control system) and AccessNet (comm system) were exceptional in the amount of time they spent in providing well-structured training sessions. The personnel at the RCC were virtually the same as those deployed to Spiral III for set up and testing. Therefore, new personnel were provided focused training from the cadre of personnel already familiar with the operation. It is important to point out that during execution, the RCC conducted business in nearly a flawless manner, providing the BCC with non-stop service.

One of the biggest problems encountered with the training was providing operators with the proper training and not interfering with the established schedule. While the established training schedule did add value toward familiarizing personnel with the various initiatives, it resulted in too much dead time. This time could have been spent conducting hands-on training. However, the assessment training turned out to be valuable. The assessment tool for experiment evaluation was initially thought to be a distraction, but found to be easy to use for feedback purposes. There were a couple of negatives to the assessment/job problem reporting system. First, the RCC should have been providing access to the assessment tools to provide feedback. Second, it was not feasible for operators in the BCC to stop what they were doing to fill out a Job Problem Report (JPR). A controller or surveillance operator needs to stay focused on the task at hand and is not able to switch between screens to fill out a form. This situation was remedied by having maintenance personnel available to verbally report the problem to the help desk.

Overall, the training and preparation portion of the execution phase was positive although the operators were not provided time to thoroughly test out the BCC systems. This lack of testing time became evident as the operators transitioned into the simulation phase. A better use of time would have been to conduct internal and external fidelity drills to ensure the architecture was solid and the

networks stable. All players would have been provided indirectly with valuable training and ensured that the systems had been properly debugged. This would also demonstrate that the communications lines could handle the transfer of data within the BCC and between sites.

Simulation Phase

This phase of the experiment was intended to build on the previous training period to prepare the operators for live fly. Many important lessons were learned from this part of the experiment. Although the latest in technology and software tools for conducting battle management were used, the simulation program and communications architecture did not support the experimental concept for simulation. The irony of this was that the problem was identified during Spiral II, yet the feedback was ignored and the situation eventually resulted in the operators being unable to properly prepare for live fly. The technology and software tools did not allow the sites to fully develop the procedures for communicating both up and down the chain to maintain situational awareness.

During the first simulation scenario, the communication lines dedicated for voice coordination to the simulation pilots (at the Command and Control Test and Innovation Group (C2TIG) at Hurlburt Field) did not function. Therefore, Collaborative Virtual Workstation (CVW) was used to communicate with higher headquarters. There was no prior coordination with the CAOC regarding communication checks. The number of tracks being displayed in the BCC did not match with the numbers of tracks being pushed through the system from the simulation generators at Hurlburt Field and the Theater Air Control Simulation System Facility (TACSSF) at Kirtland Air Force Base (AFB) in New Mexico. The simulators at both of those sites experienced multiple problems during the entire week of simulation. The identification of tracks in the BCC was not done according to correct procedures for C2 at the tactical level. The tracks came into the

BCC already identified, which negated the requirement for a surveillance section, and was very unrealistic. This situation was symptomatic of the overall problem and is a clear example of the overall ineffective simulation phase of JEFX '99. Simulation needs to be as realistic as possible in order to provide the players with a scenario representative of an actual combat situation. The simulation should have been generated and built at the tactical level and sent to the CAOC. Instead, a top-down picture was generated from multiple locations using a strategic scenario that is utilized during "Blue Flag" exercises and sent to the BCC. This type of scenario does not meet tactical level requirements.

Due the lack of success in getting the simulation to function properly, it was decided to allow the BCC to focus on their processes. The systems in the BCC had a lot of bugs to be worked out in order to be able to participate in live fly, and the simulation phase flushed those out. The Solipsys software had numerous anomalies and AccessNet was extremely unreliable. The MCCs and their crews took the time to develop a plan of attack to methodically test all of the systems in the BCC. Also, the maintenance personnel were merged into the crews to provide technical assistance in the configuration management of the PCs and Sunsparscs. The crews worked with the contractors and network administrators to ensure that each position had the proper suite of software tools to accomplish the mission. Software from various positions was eliminated in order to clean up the network to prepare for the final week of execution. The MCCs coordinated with the flying squadrons on the Nellis AFB range to obtain dedicated sorties to properly check out the communications and control systems. The support provided by the Range Control Center and 422 Test and Evaluation Squadron (TES) allowed us to complete the testing.

Dropping out of simulation play also afforded the link managers the opportunity to conduct some fidelity drills on the Tactical Digital

Information Links (TADIL) J network. The Interface Control Officers (ICOs) and Technicians (ICTs) worked long hours to get the network up and running. They conducted testing with the other sites and airborne assets to validate the architecture and Optasklink. As a result of this testing, the network was definitely one of the highlights of the entire experiment. The link was stable and new players were able to enter the network with little or no problem. The only real negative to the link structure was the location of the interface control cell outside of the BCC, due to the availability of an Air Defense Systems Integrator (ADSI) in the Red Flag Facility. This made the coordination game between the MCC and the ICO very difficult and led to confusion in the air picture.

By the end of the simulation phase, the systems were ready to operate and personnel were extremely familiar with both the hardware and software involved in the battle management process. A primary concern was the procedure for conducting an actual full-up scenario. The BCC had not yet been challenged with integrating all the BCC components to see if the new technology tools were up to the task of battle management. The lack of crew training, along with the upcoming pace of events had significant impacts on the BCC initiative.

Live Fly

Prior to Spiral II, it was decided that the BCC did not require a second crew to conduct the experiment. The plan for 24-hour operations was dropped, and the focus was on the processes of the BCC. The decision to eliminate the second crew distracted from the ability of personnel to get totally involved in the tests. The demands of the schedule put everyone into the "exercise" mode. There were two mission periods each of the four days for full-up live fly experimentation. Those mission periods required BCC battle managers/controllers to attend the mass brief, brief the crews, perform the mission, then debrief the crew, and eventually attend the mass debrief. This was repeated twice

daily, with the day finally ending up around 0100 to 0200. The intent of the experiment was to have two crews to handle this schedule.

The first hour of each mission period was dedicated to the Intelligence, Surveillance, Reconnaissance (ISR) assets and Category III initiatives using the Nellis range. Inside the BCC we had a Waterfall plus workstation that accepted feeds from the Global Hawk and the Predator. The Global Hawk only flew one day, but the Predator was up each day for each mission period. To allow the BC to get a better view of the Predator picture, large screen monitors were installed in the center of the BCC. This ended up assisting the BC when it came time to making a decision regarding the prosecution of TCTs. The first hour also provided time to get the Tadii J network operating smoothly. This was done with the Air Warning and Control Systems (AWACS) , Rivet Joint, Joint Stars, etc. Additionally, the first hour was utilized by the Joint Stars and F-18s to conduct Dynamic Battle Control (DBC) on the Fort Irwin range complex. The BCC had a Joint Stars Workstation (JSWS) in the Attack Ops cell to view the Moving Indicator/Synthetic Aperture Radar (MTI/SAR) data.

The second and third hours of each go concentrated on conducting C2 of the assets in the Nellis range complex.

Battle Control. To maintain centralized command and decentralized control of the air war, the battle managers utilized CVW. The BC, MCC, and SD were directed to go to a certain room in the collaborative center to coordinate with their CAOC counterparts. While the concept sounds good, the CVW system was not up to the task. The BCC operators had to switch between headsets to monitor the air war using AccessNet, and then back to the CVW headset to communicate with HHQ's. It also prevented the BC, MCC, and SD from maintaining contact with each other and the crewmembers involved in controlling aircraft or performing surveillance functions. A

solution to this problem would be to integrate the communication functions into one system to allow the leadership to maintain overall situational awareness. The BC and MCC spent a majority of their time transitioning from room to room in CVW to find and relay information. This is an example of technology driving operations and having an overall negative impact. There was a lack of discipline and planning for properly using the collaborative. A better communications plan would have helped this situation.

Weapons Section. The Java based Solipsys system was used by WDs to control aircraft and maintain situational awareness. At times the system provided an excellent display and was extremely user friendly. The Solipsys system had several different radars coming into the correlator for use in the BCC. The system did a good job of correlation, but at times the picture did not match what other sources were sending. Due to the ability of the system to handle the remote tracks being sent via link 16, the controllers were able to effectively conduct airspace management. The WDs used AccessNet to communicate with the pilots, and internally to the battle managers. The system used a Graphic User Interface (GUI) on the PC to allow operators to select frequencies and intercom sites. The problem was that operators had to tab between programs to make changes. This meant loss of situational awareness to change communications settings. Overall, the Solipsys system performed well considering it was the first time it was utilized for control of live aircraft. Further development will be done for JEFX '00.

Surveillance Section. This section also used the Solipsys system. The pull down menus and point and click options allowed operators to obtain information required to identify aircraft and change symbology. The surveillance section did have some of the same problems with the communications system as the other sections. In addition, they had a problem associated with obtaining information essential to the tracking and identification process. To get information on

aircraft from the Air Tasking Order (ATO), the operators had to go to a different terminal that was Unix-based and then pull up the ATO off the Theater Battle Management Core System (TBMCS). While this may have been an acceptable method for identification in the past, it is far from acceptable with the tools available today. A solution to this problem is to have the Solipsys system incorporate an automatic ATO association feature to speed up the identification process.

Further BCC/RCC Lessons Learned

The opportunity to be involved in an event such as JEFX '99 provided the vision of next generation C2 development.. Everyone learned first hand the amount of work and dedication required to conduct an experiment. They also learned that there is a fundamental difference between experimental and exercise mindsets. Flexibility and having an open-mind were key ingredients in the BCC/RCC development concept.

As far as meeting the objectives outlined in a previous section, progress was made toward breaking paradigms associated with Ground Theater air Control Systems (GTACS). The BCC footprint was drastically reduced through the use of COTS equipment and software. The configuration of the BCC was not optimal, but that was driven by other initiatives and allowable space at Nellis AFB. With emerging technology the BCC can be tailored to meet the need, which will allow the BCC to fit into AEF operations. Our connectivity to the Global Grid (GG) was satisfactory, but it could have been much better if planners would have understood the requirements. The BCC was able to utilize numerous radar feeds from both Federal Aviation Administration (FAA) and organic radar sets. This was the first time that a mosaic capability was demonstrated to this extent at the tactical level. The use of the BCC/RCC concept provides the ability to minimize forward vulnerability. The RCC performed in an outstanding manner and provided both radar and communications feeds to the BCC over Satcom. The Joint

Tactical Information Distribution System (JTIDS) terminal was located at the RCC and that capability along with the radar allows the BCC to extend the battlefield. The RCC, as an extension of the BCC is one of the cornerstones of the next Concept of Operations for GTACS. The core competencies were met and the value of having an intelligence section in the BCC was demonstrated. The TCT function shows promise, but needs to be reconsidered for process refinement.

During the experiment the positives far outweighed the negatives, yet there are several recommendations that can make future experiments such as JEFX '00 even more successful. These include:

1) During the planning process, ensure that the communications architecture does not determine how operations will be conducted. Our communications lines/networks limited our ability to effectively operate within and between sites.

2) Slow down the pace of events and let the experimental process have a chance to determine the success or failure of the initiative being tested. The emphasis needs to shift from quantity to quality. If this results in a delay so be it. That is better than completing an event for the sake of staying on schedule.

3) In the past, the training system was not considered part of the operational development. It was more of an after thought. For the BCC, standardized Modeling and Simulation (M&S) interfaces such as Distributed Interactive Simulation (DIS) are a part of the operational equipment. Perhaps more important today is the immediate ability to use operational COTS computers to quickly build stand-alone training systems. This concept should be further encouraged.

4) Simulation needs to be the heart and soul of the experimental process, with live assets reserved for final testing. It is necessary to radically improve how we do simulation in

order to bring realism to the program. One of the initiatives for the future that needs to be evaluated is a new simulation scenario that includes computer-generated forces (CGF) using advanced behavioral modeling techniques. The use of true Distributed Mission Training (DMT) with realistic CGF should be used for a vast portion of the experiment.

5) We need to keep simulation and live events separate. During the live fly phase, we had both events taking place which caused confusion among the operators in the BCC and airborne platforms. While there was a plan to keep the two separated in time and space we had to constantly check each track. This distracted from the process at hand.

6) We need to leverage the expertise found in the Air Force Research Laboratories (AFRL) to assist in the experimental process. The AFRL scientists are the experts when it comes to experimentation, simulation, and leading edge technology. While the warfighters need to be in the seats, we could use their advice as to how to proceed throughout spiral development and execution.

7) The planning process needs to involve all players. There was an obvious lack of communication between the players during JEFX '99. While high level guidance is required, it may be better to let the units work out the specifics to tie the sites together.

SMART Board Lessons

The SMART Board is an interactive whiteboard with the potential to improve meetings, training, and briefings. Combining the look and feel of a regular whiteboard with the power of a computer, it provides the capability to save and print notes, collaborate on electronic documents, share information and run multimedia materials. It also allows access of computer-based material using a finger as a mouse and capture of handwritten notes to a computer file. Developed by SMART Technologies, the SMART Board is available in several different formats. In order

to examine the potential of the device to be a useful tool in the BCC, a Rear Projection SMART Board was placed in the BCC. The Rear Projection device was selected because it allowed the operators to work naturally without casting a shadow. It was hypothesized that the SMART Board would provide a useful tool for pre-mission briefings, debriefings, and situational awareness during the mission. The device measured approximately 57 inches wide x 43 inches high x 36 inches deep. The BCC Solipsys display was easily interfaced with the SMART Board.

The device proved to be a very useful tool for the BCC operators. Lessons learned include the following:

1) The rear projection model was too large for the BCC; a smaller (thinner) model is needed.

2) Preparation and training on the use of the SMART Board is required in order to optimize use of the device in the BCC. Final approval for use of the device in JEFX '99 came only days prior to the exercise. Therefore, time did not permit careful preparation of the operators on use of the device.

3) The BC had a difficult time monitoring all of the various personnel in the BCC. In order to better meet the needs of the battle manager and other BCC operators, a new device built by SMART Technologies is under consideration for JEFX '00. It is only 14 inches deep, and has a 50 inch diagonal display. More importantly, these devices can be strung together to form a "wall" of displays. Each 50 inch diagonal device can display eight different windows of information, so that the BC could see a large amount of information in a quick glance at the "wall."

4) The BCC interfaces with other key external organizations, such as the AOC, which are located in various geographical locations during JEFX. There were many communications problems between the BCC and these external in JEFX '99. Therefore,

consideration is currently being given to placing a SMART Board in several key external organizations in JEFX '00. They would then be interfaced with Solipsys and with the BCC. By having one common "picture" to refer to, it is believed that use of the SMART Board could reduce the communication problems. This will also provide the capability to conduct distributed briefings and debriefings from various geographical locations, which should also help to eliminate communications problems.

A Brief Look to Full Visualization and the Future

The BCC/RCC concept will be further extended in JEFX 2000. In particular the time critical targeting functionality will be improved. Looking further into the future new information display technology will be considered.

Further generation C2 systems should provide a multi-dimensional representation of the battlespace. This will include Virtual Reality (VR) techniques that immerse the operator in a visualization of the battlespace. The controller will have a three-dimensional view of the airspace including weather and natural environment visualization. Target information can be depicted by numerous color, graphics and symbology representations. Such data is called high-dimensional or multivariate. Many approaches have been used to visualize this type of data.

Virtual reality (VR) approaches have proven effective in visualizing data using a helmet-mounted display (HMD) and full immersion in the virtual environment. At the 50th Anniversary of the Air Force, AFRL/Human Effectiveness Directorate (HE) demonstrated a VR helmet and virtual gloves that displayed the DMT environment and allowed the user to interact with the environment. The scenario consisted of four F-16 cockpits, two A-10 cockpits, a C-130, an AWACS, and CGFs. All entities were displayed real time in the VR helmet. The user could literally reach out and touch one to get bearing, range, and altitude.

The terrain (Alaska database) was depicted, and the user could "fly" around the database by using the gloves (up, down, etc.). Rings appeared in the database at intervals to represent altitude. CGFs indicating Red Air appeared in the scenario.

As an extension of JEFX experience the 133d ACS is exploring the use of the virtual reality system known as the CAVE for C2 applications. This system is being developed at Iowa State University. The CAVE is a surround-screen, surround-sound, projection-based VR system. The illusion of immersion is created by projecting 3D computer graphics into a 10'x10'x9' cube composed of display screens that completely surround the viewer. It is coupled with head and hand tracking systems to produce the correct stereo perspective and to isolate the position and orientation of a 3D input device. A sound system provides audio feedback. The viewer explores the virtual world by moving around inside the cube and grabbing objects with a three-button, wand-like device. Unlike users of the video-arcade type of VR system, CAVE dwellers do not wear helmets to experience VR. Instead, they put on lightweight stereo glasses and walk around inside the CAVE as they interact with virtual objects.

Multiple viewers often share virtual experiences and easily carry on discussions inside the CAVE, enabling C2 operators to exchange data and work as a combined team. One user is the active viewer, controlling the stereo projection reference point, while the rest of the users are passive viewers. The CAVE was designed from the beginning to be a useful tool for scientific visualization. The goal was to help scientists achieve discoveries faster, while matching the resolution, color and flicker-free qualities of high-end workstations. Most importantly, the CAVE can be coupled to remote data sources, synthetic battlespaces and remote sensors via high-speed networks. These characteristics allow C2 operators to visualize very complex battlespaces in a natural manner. By reaching out and touching the

entities various data can be displayed in several formats: histograms, barcharts, boxplots, audio, color coded and scatterplots.

CONCLUSIONS

The BCC/RCC will continue to evolve to meet the traditional core capabilities of Air Force C2 as well as new functionalities such as time critical targeting. JEFX overall proved an excellent environment to continue and validate this evolution. A major improvement over legacy systems is the use of standardized interfaces and COTS equipment. Not only does this reduce costs but it also provides more effective training system development and allows quick reconfiguration of the overall C2 system. A further use of standardized tools (Windows, Netscape etc) was very beneficial in that C2 operators are familiar with these tools from general computer use daily. This reduces the overall training effort. The use of state-of-the-art interactive display technology shows promise in further supplementing the BCC/RCC functionality. As we look beyond the BCC/RCC, full visualization will become useful in C2 operations in the 21st century.

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