DEVELOPMENT OF A 2ND GENERATION SEMI AUTOMATED FORCES (SAF) WORKSTATION

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ABSTRACT

A redesigned SAF workstation will provide significant cost savings by lowering the operator hours required to create exercises and increase operator effectiveness in commanding units during an exercise. Current SAF workstations, such as Close Combat Tactical Trainer (CCTT) SAF and Modular Semi Automated Forces (ModSAF), date back to a SIMulation NETwork (SIMNET) design legacy of the late 1980 s and have had few improvements since then. STRICOM has funded an effort, CCTT PC Visualization , under the CCTT SAF Environments contract, which starts the process of redesign.

This paper reviews many of the problems with current SAF Workstation designs and past improvement efforts. The paper describes the trade studies performed and selection criteria used to select a low cost Image Generation (IG) system for the prototype that will provide the SAF Operator a 3D view. To take advantage of a 3D view, it is important the system allows the operator to move and place control measures in the 2D view while monitoring the accuracy of the position in the 3D view. The paper details the architecture of the system that will provide this link making a very powerful planning and monitoring workstation for the SAF operator. Other issues that affect the SAF operators are also discussed and possible solutions are provided.

ABOUT THE AUTHORS

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Figure 1. CCTT SAF Workstation

INTRODUCTION

Currently, the configuration of the CCTT SAF workstation consists of two 19-inch monitors, two SINCGARS radios, a keypad, and a mouse (see Figure 1). During execution, one monitor displays a 2D-map display, typically called a Plan View Display (PVD) of the terrain with a top down view of the visible units. The other monitor displays unit editors and execution matrices for the units assigned to that workstation. The operator coordinates inputs to the Combat Instruction Sets (CISs) that are the basic behaviors that can be assigned to units, by drawing control measures on the PVD such as routes, areas and points and assigning them to the CIS. The CISs are organized into an execution matrix that synchronizes the execution of the CISs based on various triggers that transition the execution from CIS to the next CIS. The SINCGARS radios are programmable to one of the radio nets used in the exercise. The radios allow the operator to coordinate and role-play SAF friendly units by communicating with the training unit and other exercise facilitators such as the After Action Review (AAR) operator.

The CCTT SAF workstation design was largely based on the workstation used by the SIMNET system dating back to a late 1980 s design. Other SAFs such as ModSAF are also based on a similar legacy. There have been few notable improvements to workstation designs since that time. Much of the SAF research emphasis has been in the area of behavioral automation. During the development of CCTT SAF many of the attempts to automate some of the decision-making processes had limited success and showed how complicated the tactical decision process can be. In most cases difficult decisions had to be referred to the SAF operator for input. Thus, the only reliable solution has been for a knowledgeable operator who is overseeing the execution of the exercise to adjust the unit s behaviors.

A redesigned workstation has the potential to greatly reduce exercise creation times and increase operator effectiveness controlling units during the exercise. In the future, CCTT will be used to support more battalion and brigade level exercises. In addition, much of the functionality of the Battalion Tactical Operations Center (TOC) is being moved from trainee workstations to the SAF Workstation. Both of these future changes will place more workload on the SAF operator demanding either higher workstation productivity or an increased number of operators. To meet this demand, STRICOM has funded an effort, CCTT PC Visualization , under the CCTT SAF Environments contract which will start the redesign process.

Legacy Improvement Efforts

One past effort that related to SAF Workstation improvement was a project referred to as Odin. Odin was sponsored by the Defense Advanced Research Projects Agency (DARPA). This project used SIMNET technology such as the AAR to develop a Commander s operational planning tool. The system used both 2D and 3D battlefield views to provide a digital version of the old sand tables used by commanders throughout history to provide a realistic 3D view of the battlefield terrain and force positioning. This system allowed commanders to view both units and their control measures in both the 2D and 3D views. Examples of control measures were routes, phase lines and zones representing the tactical intent of the unit. One difficulty the developers had was how to represent the control measures in the 3D view. If the control measures were made too large or tall they would mask out adjacent control measures. If they were made too small or close to the ground, trees or dips in the terrain would mask them out. Control measures that were easily visible in a desert database were quickly lost in a forested database. One of the conclusions of the effort was that a 3D view was useful at all echelons all the way up to the division level.

Other efforts include the Fort Knox SIMNET site, which used an innovative way to provided a 3D viewer to SAF operators. They routed the outputs of the Image Generators (IG) in the manned modules to a common switch so the outputs of unused modules could be used as a SAF 3D viewer. The SAF operator would specify the viewpoint to the unused module.

During the development of CCTT it was realized that a 3D viewer would greatly aid the operator, but with CCTT IG prices then around $250K, it was cost prohibitive.

Current System Issues

One of the major issues SAF site operators now face is the time it takes to implement scenarios to support training exercises. Estimates to implement scenarios are as follows: platoon exercises - 10 minutes to 3 hours; company exercise – 1 hour to 3 days; and battalion exercise – 1 to 2 weeks. At the Fort Hood site, typically ninety percent or more of the exercises have to be specialized to meet the training needs of the unit. To build an exercise, the SAF operator must coordinate unit placement with the AAR operator who monitors the unit s placement on a 3D view. The PVD used by the SAF workstation does not allow the operator to see many items such as rocks and individual trees that are tactically critical. Also it is difficult to determine how well the unit is positioned so it can best visualize approaching forces from just the 2D view. Determining effective secondary positions is also difficult. To perfect the exercise the operators must develop the exercise, execute the exercise, readjust the unit s positions and control measures based on feedback received from the AAR operator and repeat this whole cycle if necessary. Controlling units during an exercise also presents problems. For example, a platoon commander requests that the SAF operator position the SAF vehicles that are tethered to the command vehicle on an Intervisibility (IV) line such as a ridgeline. This is nearly impossible with just the 2D display.

Clearly a redesigned SAF workstation has the potential to greatly lower exercise creation times by as much as forty percent based on eliminating the times to adjust the exercises between the SAF operator and AAR. It also reduces the number of personnel required to develop the exercise. A redesigned workstation can also greatly increase the quality of the training experience that can be provided during exercise execution. The redesigned system should provide a robust Commander planning and control capability by allowing coordination of unit control between the 2D and 3D displays in a manner similar to that done in the Odin project. The price of image generators has fallen greatly since the development of CCTT. In fact several low-cost solutions that can meet the needs of this system are available. To select the best candidate system a trade study was performed.

IG SELECTION TRADE STUDY

A trade study was conducted under the CCTT SAF Environments contract for the PC Visualization task to determine the IG system that would be used for the prototype system. Given the fast moving progress of IG technology it was assumed that the system chosen for the prototype might not be the best choice by the time a production decision was to be made. Based on the possibility that a different system may be chosen for the production system, a high priority was given to systems that utilized industry standards rather than proprietary solutions. It was determined to be more cost effective to choose from the numerous existing products instead of developing a new system. The products were weighed against a list of criteria to determine which one would best fit with the defined task. The criteria were schedule constraints, visual rendering requirements, long term database development, support of control measures, and cost including support and maintenance. Eleven products were identified and assessed against the above criteria. Some of the requirements related to cost, schedule, and compliance were deemed absolute. Others were considered tradable and the deviations would be allowed but reflected in the score assigned to the visualization system. The system with the highest final score was the selected candidate as long as it met all of the absolute requirements.

Trade Study Critical Discriminators

Schedule Constraints - The schedule was the main driving factor for the system selection. The schedule that was defined for the PC Visualization task was short term and had already begun. The total period of performance for the PC Visualization task is from September 1999 to August 2000. Since there was little time for development, the selected PC IG would have to already be developed and meet or exceed the critical discriminators. This fact eliminated many products from consideration.

The schedule also dictated the architecture of the system. Two options were available. One was to integrate an IG Application Programmers Interface (API) into the SAF Workstation. The IG API would then communicate with the PC IG through the protocols defined by the PC IG (Figure 2). The other option consisted of a DIS-based Stealth application running on the PC IG. The application would use the DIS protocol to communicate with CCTT since CCTT is also DIS-based (Figure 3). The first option would require approximately four additional months of effort, which was not available under the current schedule.

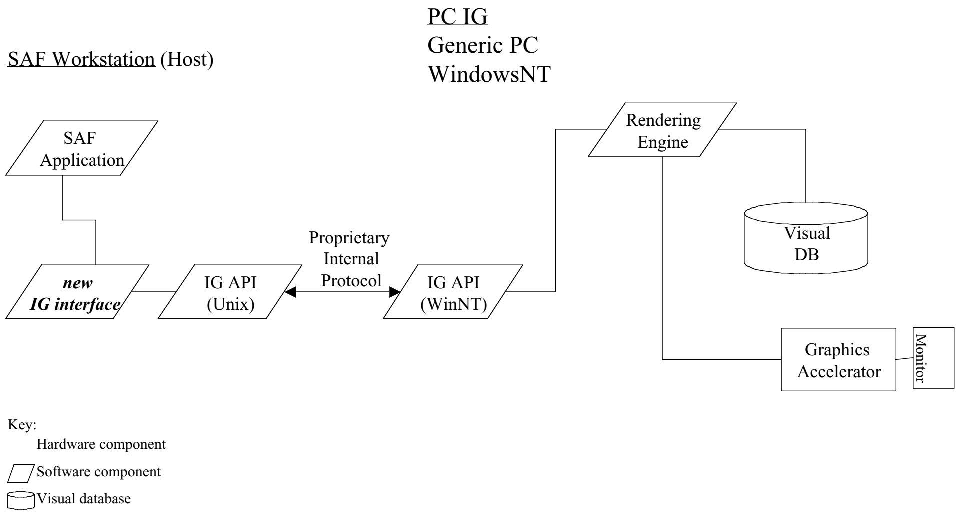

Figure 2. Architecture using IG Proprietary Interface.

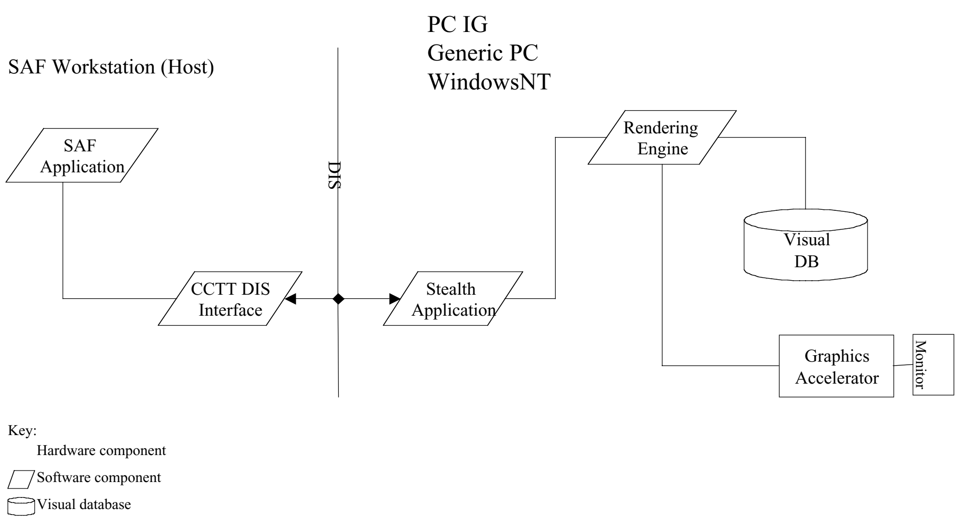

Figure 3. Architecture using DIS Interface.

Visual Rendering Requirements - Numerous requirements are necessary for the visualization system to be integrated into the CCTT system. The 3D features rendered must correlate to those found in CCTT. CCTT databases are high density and require the Visualization system to support database paging. Additional features that were considered were a high frame rate, pixel resolution, and anti-aliasing. The minimum acceptable frame rate was 15hz while the minimum pixel resolution was 1024x768. Existing CCTT requirements drove these numbers though improved rates and resolution were preferred. Lower frame rates and non anti-aliasing would be acceptable since a workstation operator doesn t have the resolution and high update rate a simulator would demand; though it would be reflected in the score.

Long Term Database Development- New databases are being generated for CCTT and are a major cost item. The visualization system must be able to support the conversion of future databases as well as existing databases. The forecasted rate is two new databases per year. It is important that the visualization tool will grow with the expansion of the CCTT synthetic environments. Other issues that affect long-term database support are interchange format or conversions supported, the visual rendering format, and the current support of SEDRIS. An optimized or smaller rendering format is preferred to OpenFlight since OpenFlight databases are extremely large. A direct conversion to the visual rendering format is considered the best option.

Support of Control Measures - Control measures are symbols required to execute orders and missions in CCTT. Routes, phase lines, and checkpoints are some of the control measures utilized in CCTT. To facilitate the creation of exercises and mission, it is necessary for the control measures to be visualized on the 3D display. To support this functionality, the visualization system must be able to render the control features created on the CCTT PVD in three dimensions. Two issues affecting the support of control measures are the communication between the CCTT SAF Workstation and the PC IG and the support of the control measures within the PC IG. The DIS-based stealth solution would support the communications between CCTT and the PC IG.

Cost including Support and Maintenance - The visual system will serve as the prototype for the design of the final product. The costs analyzed were to include current and future requirements. The current costs include the hardware as well as the design and maintenance of the system required to implement a successful prototype and to fulfil prior requirements. The recommended hardware solution would be a generic PC solution that supports the system requirements. This choice would balance the hardware cost issue for the visualization systems. The future costs were also analyzed to include post-production support and maintenance. This would be necessary to ensure that the visual system grows with CCTT and continues to be able to support CCTT s growth path.

Selection Decision

Eleven systems were investigated as possible solutions for the prototype. Of them, three candidates fulfilled all of the desired features for the prototype system and schedule considerations. The three systems candidates were CATI s X-IG, CG2 s DIScretion and MetaVR s VRSG. All of these systems are capable of satisfying visualization requirements for the prototype. A combination of the available capability to render part of CCTT Primary 2 terrain database, HLA/DIS interfaces, low database conversion costs resulting from leveraging off of other STRICOM efforts, and a strong leadership role in the PC-based 3D visualization technology led us to select the MetaVR s VRSG. It should be noted that this selection was for the prototype system and a similar trade study will likely occur for the production system since this fast moving technology creates more capable products continuously.

WORKSTATION PROTOTYPE ARCHITECURE

This section describes the software and hardware architecture of the prototype implementation of the SAF workstation. As described above, the schedule imposed the primary constraint in this effort. This led to the selection of an architecture that would allow implementation of the prototype within the scheduled time but would also provide flexibility for future enhancements.

Software Architecture

Integration of 3D visualization capability into the CCTT SAF workstation required modifications to various software components within CCTT. The modifications that were made are applicable to two configurations of the CCTT SAF capabilities. We will describe these modifications as applied to a particular CCTT SAF configuration, the CCTT Combined SAF Workstation.

The CCTT Combined SAF Workstation combines various CCTT components to support pre-exercise development efforts as well as control of computer-generated forces (CGF) during exercise execution. Extensions made to the Combined SAF Workstation provide the system with the ability to display exercise information in the 3D view of the terrain database that is displayed on the PC IG. (Figure 4) shows a functional block diagram of the system, including the PC IG. Underlined text represents additions to the CCTT components. Components with a heavy dashed border represent new additions to the system (this includes the PC IG and associated off-line tools).

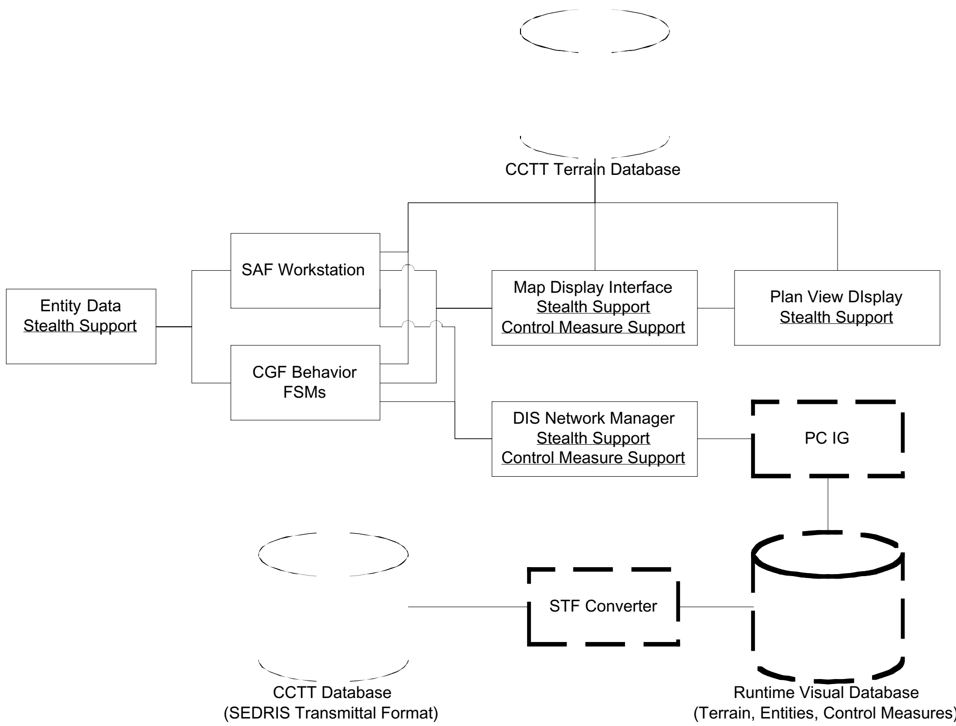

Figure 4. Prototype Architecture.

The CCTT Combined SAF Workstation combines CCTT SAF and CGF capabilities into a single application. The Combined SAF workstation comprises a SAF Operator Control Interface, a set of Entity/Unit/Behavior Editors, a Plan View Display (PVD), a Map Display Interface, an Overlay Database, an Entity Database, a Terrain Database, CGF Behavior FSMs, and a DIS Network Manager. The selection of a DIS capable PC IG minimizes requirements for modification to the CCTT SAF workstation. Modifications were limited to extending existing capabilities to include support for PC IG viewpoint control, and for transmission of control measure data to the PC IG.

PC IG Viewpoint Control - User control of the PC IG viewpoint is effected through the CCTT PVD. From the PVD, the user can initialize the PC IG control and set the location and orientation of the viewpoint displayed on the PC IG 3D display. In addition, the user can attach the PC IG viewpoint to entities active in the exercise. The system allows connection to entities in a variety of modes. These allow the operator to view the environment from the entity viewpoint, or from a viewpoint offset from the entity location. The location and azimuth of the PC IG viewpoint is displayed on the SAF workstation PVD as an arrow.

Control Measure Display -The SAF operator also uses the PVD to create control measures appropriate to the exercise. Control measures are associated with a force (BLUFOR or OPFOR) and an overlay layer (Maneuver, Engineering, Logistics, etc.). Control measure data is stored in an overlay database. This data is transmitted to the PC IG using DIS Set Data PDUs, and are displayed on the PC IG as 3D symbols.

The SAF operator can also control display of control measure symbology on the 3D display. The SAF operator controls display of control measure symbology on the PVD by enabling or disabling display of overlay layers.

Control measure symbols associated with an overlay layer are displayed on the PVD when the overlay layer is enabled. Similarly, control measures are displayed on PC IG when the overlay layer is enabled on the CCTT PVD.

In addition to on/off filtering, control measure symbology can be displayed using either a 3D representation or a 2D representation. Display representation is dependent on the class of control measure. Control measures can be broadly classified into three categories: point, linear, and areal control measures.

Point control measures are represented in 3D as a billboard showing the appropriate standard military symbology for the control measure. In the PC IG, a billboard is a vertical polygon that always presents the same face to the user viewpoint. In 2D, point control features are represented as decals that overlay the terrain, and that show the standard military symbology for the control measure.

Linear and areal control measures have similar 3D and 2D representations. The 2D representation of the control measures is a decal, overlaid on the terrain, matching the display of the symbology on the PVD. The 3D representation of the symbols adds a vertical component to the symbology, so that the symbol can be detected at a distance from a viewpoint close to the ground. Height of the vertical component of the control measure symbology is user-configurable.

Entity/Relocatable Object Display- The PC IG also displays entities and environment relocatable objects generated by the SAF workstation. No modifications were required for the CCTT SAF workstation to generate data for entities or relocatable objects. This data is already being generated by the combined SAF workstation.

PC IG Network Interface - Communication between the SAF workstation and the PC IG is implemented using the DIS protocol over an ethernet-based network. There are several advantages to this implementation. First, the use of an industry standard interface protocol allows alternative solutions to the PC IG. Also, the PC IG utilized in the prototype implementation already had a DIS 2.04 compliant interface. This allowed integration of the PC IG with the CCTT SAF workstation with a minimal amount of modification.

The required modifications to the CCTT SAF workstation included transmission of PC IG viewpoint control data and control measure data. Both types of data were implemented using the DIS Set Data PDU. Datum records for the PC IG view point control already existed, but had to be added to the CCTT SAF workstation Map Display Interface.

Datum records encapsulating control measure data had to be defined and added to both the CCTT SAF workstation and to the PC IG. The information transmitted includes the symbol class (point, linear, or areal), the symbol type, the action to be taken (creation, modification, or deletion), the force identification for the symbol, the overlay layer for the symbol, the symbol location, the symbol orientation, and additional identifying information for the symbol. In addition to location information, datum records for linear and areal symbols include vertex lists defining the control measures.

Visual Database - The PC IG displays a 3D view into the environment represented by the terrain database and displayed as a 2D map on the PVD. In order to display this 3D view, the CCTT database used in the exercise must be converted to the runtime representation used by the PC IG. The source format for this process is a SEDRIS Transmittal Format (STF) representation of the CCTT database. The STF database contains terrain data, entity models, relocatable objects, and texture maps used to display the synthetic environment.

In addition to the exercise run-time components to the prototype system, a STF converter was written to convert the source database to the run-time format utilized by the PC IG.

Hardware Architecture

The prototype SAF workstation can be utilized in two configurations. Both configurations utilized the same set of CCTT processes. The primary difference is the hardware utilized to host the CCTT processes.

In the first configuration, known as the Combined SAF workstation, all CCTT processes execute on a single PowerPC platform under the AIX operating system. In the second configuration, the process executing the CGF Behavior FSMs executes on one or more separate PowerPC platform, providing for scalability of CGF capabilities.

The PC IG utilized in the protoype SAF workstation is hosted on an Intel-based processor running Windows 98 or Windows 2000. The graphics subsystem is a COTS product that supports full-screen, four-subpixel anti-aliasing. No proprietary or special-purpose hardware is required. In this configuration, the system supports sustained visual update rates above 30 frames-per-second with high data densities in the visual scene. Because all hardware components are standard COTS products, the hardware can be upgraded without modification to the PC IG software. The upgrade cycle for the graphics subsystem has been approximately six months, with the most recent set of low-cost cards providing such features as full-screen anti-aliasing or hardware transform and lighting capability.

OTHER ISSUES WITH THE SAF WORKSTATION

Below are other areas to consider in improving the performance of the SAF Workstation.

Consolidate Communication Equipment – To coordinate and role-play with other training units, the current configuration has two SINCGARS radios at each workstation that allow the operator to monitor two radio nets. During the development of Force XXI Brigade and Below (FBCB2) into CCTT, the prototype design had two FBCB2 workstations at a SAF workstation. The operator could assign and role-play these stations as any of the SAF vehicles under that workstation s control. Many of the messages that are exchanged in FBCB2 have intent , such as they are attacking or defending, or Free Text Messages that are too complex for an easy SAF automated solution. This forces the SAF operator to evaluate and enter these types of messages. Other issues include the addition of Operations

Center (OC) functions to the SAF workstation. This will force the operators that role-play these units to monitor the communication nets they correspond on. To perform this adequately the operator may have to monitor more than the two radio nets provided. Estimates for complicated scenarios range as high as four nets. As the demands for higher echelon exercise grow the SAF operator will have to monitor more equipment making the task of monitoring communications and adjusting SAF controlled vehicles a human factors challenge. The SAF workstation communication equipment is another configuration challenge. The SINCGARS radio is based on the design used by the training modules and the FBCB2 is based on a PC emulator. The FBCB2 configuration is changing rapidly, so a design decision was made to use actual equipment. An area for future research is how to best consolidate all the role-playing communication equipment, perhaps by integrating it directly into the workstation, while minimizing the hardware footprint.

Add Second PVD – One suggestion from the Fort Hood operators was to add a second PVD. In battalion and larger exercises a SAF operator may have several areas of interest to monitor and control units. An example would be controlling artillery and other units that operate in the rear of the battle as well as front line units. If the operator sets the PVD to view all the units at once, it appears cluttered. However if the PVD is focused in on an area of interest it looses feedback from other areas. A second PVD would be helpful in larger exercises but may be of limited utility in the smaller (platoon/company) exercises that are typically run at most CCTT sites.

Improve Execution Matrices – Current execution matrices have difficulty with handling automatic subordinate level tasking and control of situational interrupts within the battalion/company level. To work around this problem, units are controlled at the level where they all have a common behavioral pattern (e.g. do the same things). Typically this is platoon level for BLUFOR (Friendly) and as high a company level for Opposing Force (OPFOR). Improved execution matrices that would support automatic or enhanced subordinate control at the battalion/company level would present a difficult challenge.

Lower Equipment Footprint – With additional PVDs and communication equipment the workstation has tended towards increasing its footprint. An increased footprint can make logistical support of the workstation more difficult and increases the space required for the equipment. An operator has a limited field of view which can make it difficult to monitor numerous pieces of equipment that could be physically far away. One possible solution is to use a panoramic style display like is currently used by many control operations that operators monitor large numbers of systems. One such system is Panoram Technologies PV 290 (Figure 5). This system is being evaluated as a constructive trainee station. The prices of these systems are around $27K but newer models and volume discount may put them under 10K making them an affordable solution.

CONCLUSION

Many of the enabling technologies for the development of 2nd Generation workstation, such as low cost graphics capabilities, are becoming increasingly available. They offer greatly improved performance at a reduced price. A redesigned workstation will clearly provide a tremendous reduction in operator exercise creation times and increase their performance during exercise. This will provide a large return on the development and latter production system investments. Other areas of application for a redesigned workstation are trainee workstations that will allow constructive training directly from a modified SAF workstation. This application is currently being considered by several training schools. Clearly, from both a cost and performance enhancement perspective a redesigned workstation has been long over due.

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Figure 5. Panoramic Display with CCTT SAF Windows.