

## The Interactive DataWall

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### **Abstract**

The increasingly complex battlefield environment drives the requirement for the presentation and interactive control of the endless stream of information arriving from a diverse collection of sensors deployed on a variety of platforms. At best, the situational awareness picture is fragmented without the benefit of data fusion and correlation to present a true picture of the battlespace from all information sources. Collaboration and interaction is also needed for operators within a control center and among remote geographic locations. The need to display and manipulate real-time multimedia data in a battlefield operations control center is critical to the Joint Commander directing air, land, naval and space assets. The Interactive DataWall being developed by the Advanced Displays and Intelligent Interfaces (ADII) technology team of the Information Directorate of the Air Force Research Laboratory (AFRL/IF) in Rome, New York is a strong contender for solving the information management problems facing the 21<sup>st</sup> century military commander. It provides an ultra high-resolution large screen display with wireless interaction. Commercial off-the-shelf technology has been combined with specialized hardware and software developed in-house to provide a unique capability for multimedia data display and control.

### **1. Introduction**

The problem is the inability to effectively display and manipulate large amounts of real-time, multimedia data in a Command and Control (C2) environment. Migration to electronic media for mission planning is progressing. However, conventional media such as large paper maps with acetate overlays and Plexiglas boards for grease pencil annotation are still the norm. The transition has been delayed since new methods of operation are often slow to be accepted, the use of individual workstations diminishes the *big picture* in a C2 environment, and an intuitive, unencumbered means of Human Computer Interaction (HCI) is limited.

The approach is to utilize commercial of the shelf (COTS) products to the greatest extent to create a very high-resolution, tiled wall display. It is usable by both operators who are in close proximity to the screen, and by commanders who typically work at a distance. Multiple users can directly manipulate the wall display using speech recognition and wireless pointing devices for unencumbered interaction.

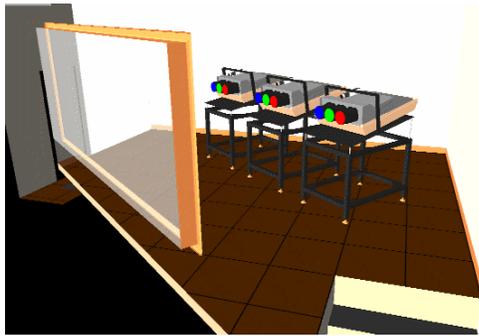
The uniqueness of the AFRL/IF Interactive DataWall is twofold. Its *enhanced computer display* capability tiles the output of multiple computer displays into a single workspace. The current configuration has a total display resolution of approximately 5.8 million pixels over a 12' x 3' screen area. Its *enhanced HCI* capability allows for wireless interaction with the display. Speaker independent speech recognition via wireless microphones and conventional mouse functionality via camera-tracked laser pointers have been incorporated. Further, the laser pointer's function has been enhanced to provide an electronic grease pencil capability.

## 2. High Resolution Tiled Display

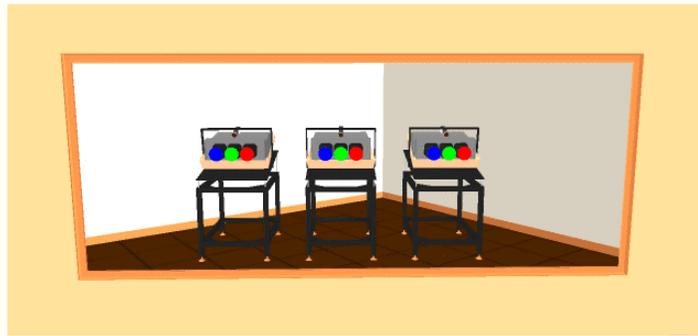
A *tiled* display consists of NxM distinct display devices, such as video projectors, each displaying a portion of an entire screen area. The Interactive DataWall's display consists of three horizontally tiled video projectors producing a very high-resolution, near seamless, large screen display (Fig. 1). Properly balanced color and brightness, and proper alignment of the display devices is critical to minimize any distractions caused by the seams between image tiles. Variations in chromaticity and luminosity among tiles can cause inconsistency in color and brightness across the screen. Vertical or horizontal disparity of the tiled images can cause segmentation of objects at the seams. Gaps between image tiles can cause discontinuity of the imagery.



Figure 1a. AFRL/IF's Interactive DataWall



3/4 View



Front View

Figure 1b. 1x3 Video Projectors Configuration

The rationale for this type of display is fourfold. First, a *large screen display* provides a global view of the information space, and allows the users to make comparisons and find relationships between items. It also makes collaboration within a localized working environment much more effective. It provides multiple users with a common display medium, coordinating data from multiple workstations and monitors. It provides a large canvas to present multiple windows with a variety of information. Windows can be spread out instead of continuously bringing the active window to the foreground. Windows can be maximized to the total 12' x 3' screen area.

Second, *high-resolution* is desired because AFRL/IF is researching the Interactive DataWall for military Command and Control, which requires the display of various kinds of data. This data can include terrain models overlaid with computer-generated imagery, digital maps, textual information, as well as live and recorded video. Although a conventional projection system allows a wide range of image sizes, and could provide the necessary large screen display capability, the display quality will inevitably decrease as the display area increases and pixels become larger. The DataWall is intended to be used both at a distance and at close range. A large screen display's utility is significantly reduced if imagery loses important detail or text becomes difficult to read at close proximity. Even today, large paper maps with acetate overlays are used for mission planning in the command centers. Therefore, near paper map quality is required to effectively replace conventional data sources with electronic media.

Third, *tiling* several images either horizontally and/or vertically provides a wider field of view, and allows displays of unlimited aspect ratios (i.e. the height to width ratio) to be created. Simply increasing a projector's display area will introduce pixelation problems, and will decrease the brightness of the image. In a tiled configuration each projector is displaying a small portion of the entire display area. The combined image is much brighter than a single projector displaying an image across the same screen area. By limiting each projector's display area, the projected light is more concentrated. Direct view displays are much brighter and less susceptible to ambient light problems than projection systems. However, implementing a single element direct view display creates a myriad of new problems. Scaling already bulky CRTs or flat panels is neither practical

nor economical. Scaling up CRTs beyond a 40-in diagonal would require glass envelopes that are heavy and high voltages that are radiation hazards. Fabrication of very large-scale flat panels would require the development of very expensive equipment [Alphonse and Lubin, 1992]. Larger flat panel displays are becoming available, but are far from the resolution capacity of the CRT systems. In addition, the state-of-the-art in display technology is limited to devices that are only capable of resolutions on the order of 2500 x 2000 pixels. Tiling the highest resolution display devices in an NxM configuration increases the display resolution NxM-fold.

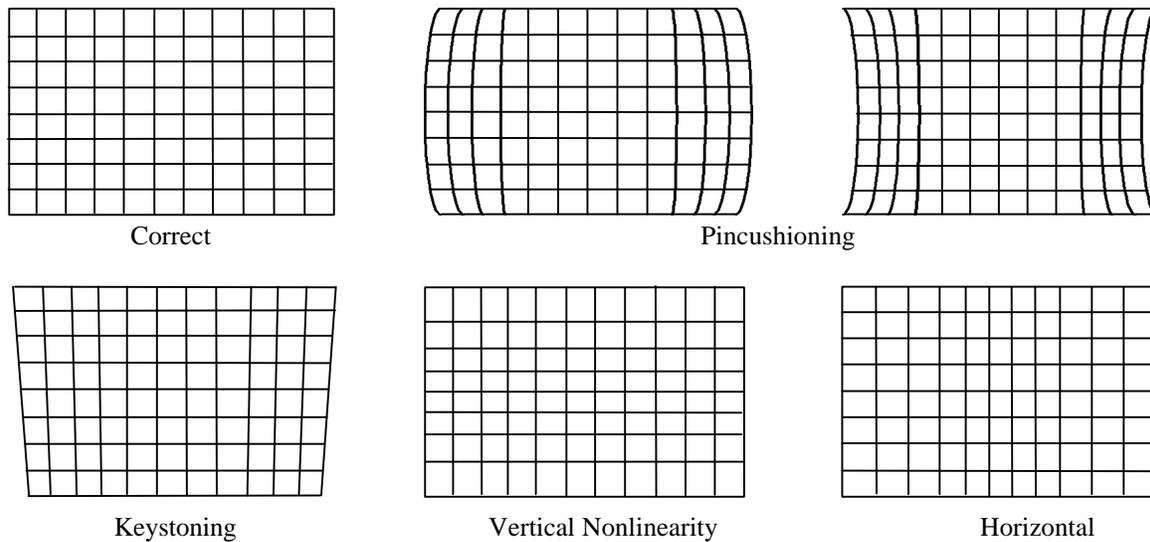
Last, *projectors* were utilized to minimize the seams between the image tiles. A common implementation for tiled displays is to use direct view monitors. All currently available direct view monitors have frames that enclose a certain amount of necessary electronics surrounding the display screen. Therefore, there is no way to effectively abut direct view display elements without having a gap between them.

## 2.1 *Optimizing a Tiled Image*

A significant challenge of producing a seamlessly tiled display is ensuring the projectors are properly aligned, with correctly balanced color and brightness across the individual projector images. The image should resemble a monolithic display. Varying colors and brightness caused by chromaticity and luminosity variations will give the impression of a mosaic rather than a single continuous image. There should be no segmented lines or gaps between the tiles caused by inaccurate alignment and geometric display distortions.

The ADII team developed an X windows-based application that generates several interactive test patterns [Jedrysik, *et al.*, 1998]. It provides a comprehensive testing environment for a seamlessly tiled NxM display. This application greatly improves composite display image quality by providing a more accurate and less time consuming method for registration, color balance and alignment of the video projectors. The patterns were designed to accomplish the following:

- Ensure each projector is displaying all pixels around its border
- Allow horizontal alignment of side by side tiled displays and include a capability for vertical alignment in future tiled displays greater than 1xN
- Ensure accurate color balance among all projectors for continuous color balance across the display
- Minimize geometric display distortions such as pincushioning, keystoneing, and vertical/horizontal nonlinearity (Fig. 2)
- Test the capacity of the display system to resolve very high-resolution images



Nonlinearity

Figure 2. Geometric Display Distortions

All the video projectors used in the DataWall implementations at the ADII Visualization Laboratory are either Cathode Ray Tube (CRT) based systems composed of separate red, green, and blue CRTs, or Liquid Crystal Display (LCD) based systems. A key advantage of the CRT based display systems is the ability to correct display image geometry. Display distortions can be isolated to specific components and adjusted in a number of ways both mechanically and electronically. Individual CRTs and isolated portions of the display image can be adjusted independently. However, a significant amount of effort is required to optimize the display image. Most LCD projectors have the distinct advantages of being much brighter, smaller, lighter, and easier to set-up. Their shortfalls, however, include lower resolution and the inability to correct display distortions through geometry adjustments. The latter necessitates precision optics to minimize these distortions in a tiled configuration.

All CRT video projectors have some type of internal test pattern generator to aid in focusing and converging the CRTs. Each provides a step-by-step process that includes manual focus and electronic adjustment of the CRTs to correct geometric display distortions. Although quite helpful, the patterns available are limited. None of the LCD projectors in the ADII Lab provide any kind of internal test pattern generation. Although the CRT projectors' built-in patterns can be used for some of the preliminary tuning, they were never intended to address the many issues associated with the DataWall's very unique multiple projector display configuration. Tiled displays have very specific needs with regard to alignment and color balance. A conventional large screen display would typically only consist of a single projector, where exact image positioning on the projection screen and color balance with other projectors aren't required. Alignment and color balance are critical for tiled configurations to reduce the distraction of the seams and to provide a continuous display image. Three examples of the patterns developed by the ADII team are depicted below in 1x3 configurations. They are used for aiding alignment, color balance and focus, respectively (Fig. 3).

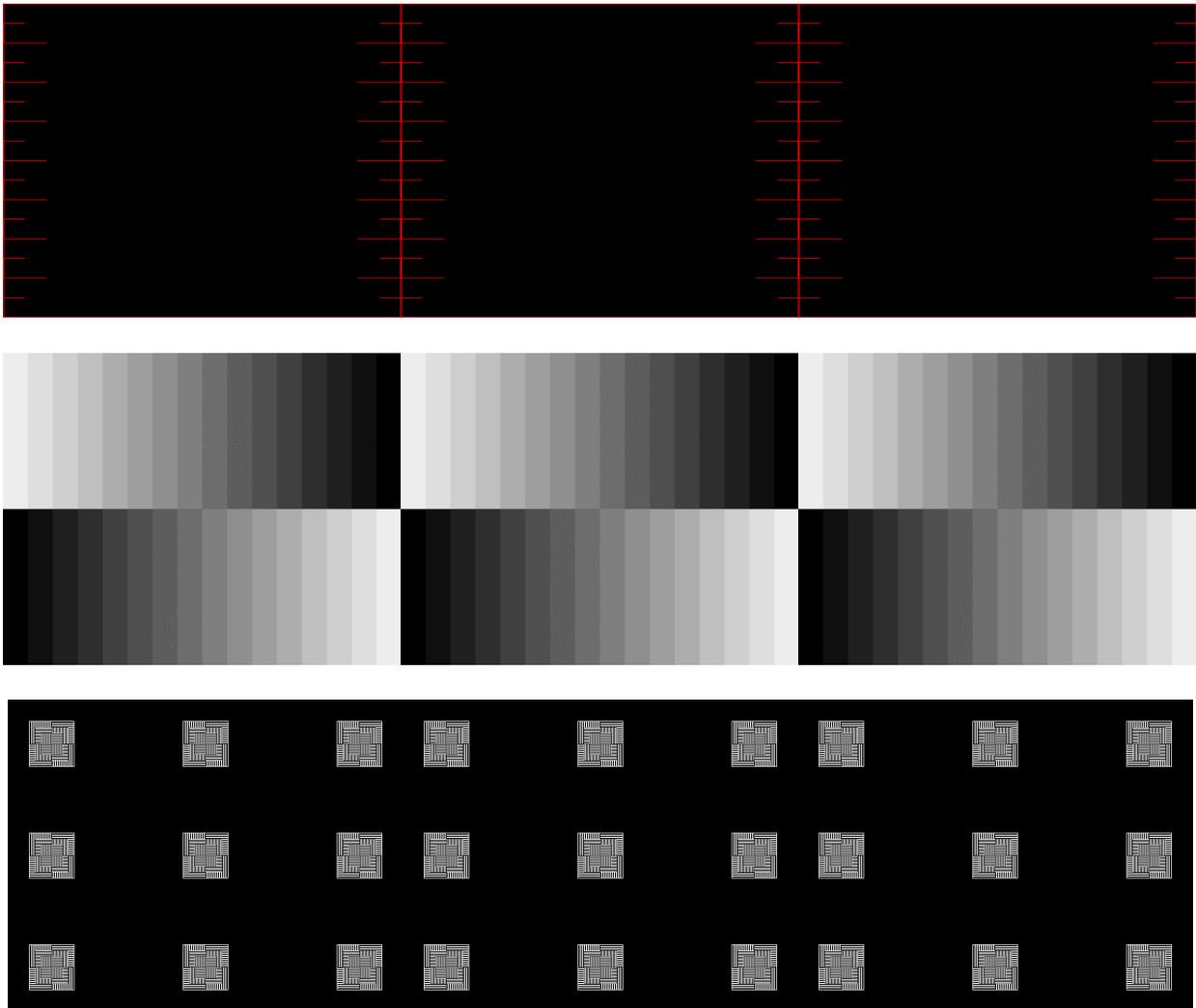


Figure 3. Three sets of test pattern examples represented in 1x3 tiled configurations

An important aspect of the ADII test pattern environment is that rather than using any internal test pattern capability, the projectors are being driven by the computer system. This system also generates the display imagery in the working environments. This provides a more accurate representation of a working environment display, and allows for a more accurate test of the entire display system. All external and internal distortions are taken into account. These include problems introduced by the computer, communication cabling, distribution hardware, and the projectors. This ensures more accurate tuning of the displays to produce better and more consistent images than would otherwise be provided using internally generated patterns.

## 2.2 Window Management

The Interactive DataWall uses X-META-X, a COTS software package from X-Software. X-META-X provides a meta window manager functionality, merging the separate X Window managers of the individual display drivers. A conventional X Windows-based tiled display can run

on either a single Unix workstation, with multiple graphics cards (multi-headed), or multiple networked Unix workstations. Each graphics card in a multi-headed workstation runs a separate X Window manager. Cursor movement across the individual display tiles is permitted, but windows can neither be repositioned nor resized beyond the boundaries of each display tile. The same windowing limitations apply to tiled displays running on multiple workstations.

X-META-X provides two significant features. It allows windows to be repositioned anywhere on the tiled display and lets them be resized to the maximum size of the total display area. X-META-X is neither a stand-alone X Window server nor a specialized window manager. The X-META-X proxy is stacked between the X Window server of the workstation and the X Window clients via inter-process communication. It is executed instead of the X Window server, which in turn calls the server itself. Managing the communication between servers and clients, X-META-X breaks the fixed relation between display area and communication port of one X server or multiple X servers simultaneously.

The total composite display resolution is not limited by X-META-X, but by the X Windows protocol which codes coordinates as 16 bit signed integers. Thus, the maximum meta display resolution allowed is 32,767 x 32,767 pixels.

### 3. Wireless Interaction

The purpose of the Interactive DataWall is much more than providing a high-resolution summary device. It embraces the notion of a truly interactive environment that avoids the tethers of conventional human-computer interfaces such as keyboards and mice. The Interactive DataWall is an environment that allows unencumbered user interaction from various locations near and far. Speech recognition via wireless microphones and conventional mouse functionality via camera-tracked laser pointers provide wireless interaction.

#### 3.1 Camera Tracked Laser Pointer

To provide a wireless mouse-like mode of input, a camera-tracked red laser pointer is used. Three video cameras equipped with red filters are positioned behind the screen atop each video projector (Fig. 4). The cameras' views of the screen are dark fields until the laser dot comes into a camera's field of view. The live video from the three cameras is processed and the data is subsequently sent to the display driver for proper positioning of the cursor. It allows all the functionality of a conventional mouse including: dragging/dropping windows, resizing windows, and interacting with graphical user interface (GUI) widgets such as buttons and scroll bars. An important aspect of the laser pointer

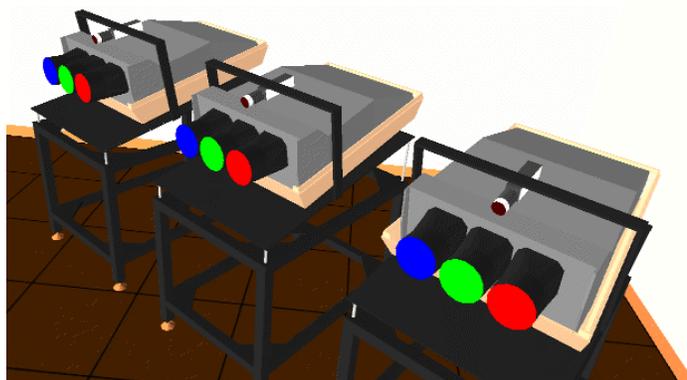


Figure 4. Video Cameras Mounted Atop Video Projectors

input device is that it is essentially application independent. Since the Interactive DataWall runs on a Unix platform under X Windows, the application must be X Windows compliant however. The only other requirement is it must have a GUI.

### **3.1.1 *PC/Video Capture Card Implementation***

The original laser pointer tracking implementation consists of three Personal Computers (PCs) equipped with video capture cards. These computers provide a frame by frame screen capture for each video camera positioned behind the screen. The frames are analyzed via ADII developed software on the PCs and subsequently transmitted to the display driver for cursor positioning.

Although quite effective, the process suffers several limitations. First, the system cannot operate in real time. The approach requires that the camera and computer complete a frame before analysis can begin. The delay penalty, therefore, is never less than the time required to complete a given frame.

Second, both resolution and update rate are constrained by the processing power available. A minimally acceptable 320 x 240 pixel image at 15 frames/second fully consumes the resources of a current high end PC.

Lastly, the cost/benefit ratio may be difficult to justify as even a minimal system can cost several thousand dollars, and multiple PCs are required in these multi-camera implementations (i.e. one PC per video camera/display tile).

### **3.1.2 *Custom Laser Pointer Tracking Hardware***

To address the limitations of the PC/Video Capture Card implementation, the ADII team invented specialized hardware to track the laser pointer. It functions in near real time, with readily expandable resolution, and at a small fraction of the cost.

The device combines a microcontroller, video processing logic, a pair of counters, and real time control logic, which together track the pointer image. The process involves synchronizing the counters to follow the camera video. At the point in time when the camera “sees” the pointer, the counters will contain values representative of the pointer’s position on the display surface. These values are then passed on to the display driver in near real time via serial cable to position the cursor.

In order to evaluate the effectiveness of the device, a side by side comparison between it and a 200MHz Pentium PC implementation was conducted. The exercise confirmed several significant advantages of the new system.

First, *speed*: The device can easily produce a detection each time the video scans the pointer while the PC system can only consistently maintain a detection rate of 20-25% of the scan.

Second, *timeliness*: The device begins to report a detection almost immediately after the video signal “sees” the pointer while the PC system must always complete a full frame before its analysis can even begin.

Third, *resolution*: In order to sustain a 10-15Hz-update rate, the PC version is limited to a resolution of 320 x 240 pixels. The device, is capable of 512 x 480 pixels, and can readily be increased to any practical video resolution without penalty.

Fourth, and finally *cost*: The original device was assembled at a cost of less than \$150 while the cost of the PC system was in excess of \$2500.

Although the prototype device was initially used to track the position of a laser pointer on a rear projection video display, it can be easily adapted to scan a pointer image on any projection (rear or front) or non-projection direct view display, including printed material such as a paper map. The technique also lends itself well to multiple panel displays as both the cost and complexity of the device scale linearly.

### 3.1.3 *Laser Pointer Tracking Software*

There are three phases involved in using a laser pointer with the Interactive DataWall. The first phase is the detection of the laser dot on the display surface, the second is the registration of the dot in reference to the displayed image, and the third is the manipulation of the systems resources to support interactivity.

#### 3.1.3.1 *Detection*

The first version of the detection system relies on a PC with a video capture card. The video capture card captures a single frame of video from a camera behind the screen. An algorithm then parses the information, based on the brightness and color, determines whether an instance of a laser dot is present. Upon a successful detection, the program sends the location of the laser dot over the Local Area Network (LAN). While the software was a necessary progression by providing quick prototyping, it does present some limitations. The video card was only able to capture each frame at 320 by 240 pixels with a 24-bit color depth at about 10-15 Hz.

The second version of the detection system uses the in-house developed custom tracking hardware. This device is capable of detecting a spike in the NTSC signal from the camera. It informs the display computer of the laser dot’s location through a serial port when the signal surpasses a customizable threshold. The hardware solution provides an increased resolution and speed by being able to analyze 512 by 480 pixels at 60 Hz.

#### 3.1.3.2 *Initialization*

It is difficult to correctly register the laser dot’s location in reference to the display image. Both detection methods have a lower resolution than the display with which they interface. Two

algorithms were developed to handle the interpolation and extrapolation. Each requires the operator to use the initialization software prior to executing the runtime system.

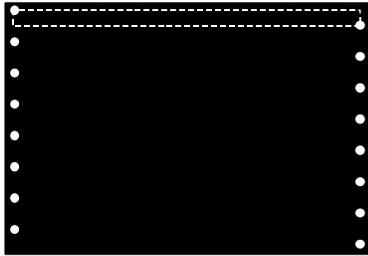


Figure 5. 16-Point

The first algorithm relies on a simple algebraic equation. The user is presented with a black screen and a series of white dots. Each dot must then be illuminated with the laser pointer. The dots appear one at a time and create the stepped pattern as seen in Figure 5. The dashed line represents the active field that the each initialization point is addressing. Each pair of dot locations are responsible for correcting the location of a laser instance within its bounds. The initialization software stores the sixteen locations per screen into a file and exits. This algorithm does a good job of correcting within the zones, but can cause incorrect interpolation

when traversing between the edges of two zones. This method also requires the runtime support to calculate the interpolation and extrapolation at runtime.

The second algorithm alleviates the problem of moving between seams and reduces the number of initialization points. The user is presented with the same black background, but illuminates only four initialization points (Fig. 6). The drastic reduction in points does not reduce the accuracy because the interpolated and extrapolated values use a more robust rhomboidal algorithm. A file is saved that contains a one-to-one mapping of every laser instance location to its corresponding screen image location. This produces a much larger file but reduces the number and type of runtime calculations.



Figure 6. 4-Point Initialization

### 3.1.3.3 *Runtime*

There are two runtime methods. Each initialization method is paired with its appropriate runtime application and can only read one type of initialization output file. However, both runtime applications perform the same task and will not be differentiated.

A mouse resource window that models a three-button mouse appears after executing the runtime program. This window allows the user to select the way in which the laser pointer should be used. If there are no buttons selected, the system mouse cursor only follows the operator's laser dot. If the first button is selected (Fig. 7), the runtime software will generate a left mouse button down event the first time the laser dot is seen. A mouse button up event will be generated when the laser is turned off. The same holds true for the other two buttons and their respective operations. This allows operators to wirelessly manipulate a GUI.

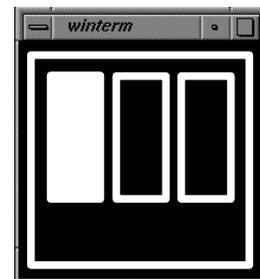


Figure 7.  
Mouse Resource Window

### 3.2 Continuous Speech Recognition

An essential component to keyboardless interaction is the use of speech recognition. Using a COTS continuous speech recognition system called HARK from BBN Systems and Technologies, operators are able to interact with applications using a wireless microphone. In order to voice enable an application, a grammar set is defined to trigger the actions desired. A very important capability of the HARK system is that it is speaker independent. Any user can immediately interact via voice without having to train the system for his/her voice.

Users are able to manipulate windows, the background and alter the mode of the laser pointer. By saying the command, "Minimize Window" the window manager will cause the active window to be minimized just as if it had been performed through the system keyboard. If the user utters, "Enter Freehand Mode", the application will cause the system mouse to emulate a grease pencil. When the user selects the leftmost button of the mouse resource window, he can make freehand annotations to the display. Simple geometric shapes can be drawn including circles, boxes, and lines using speech commands and defining point locations with the laser pointer. Annotation colors and line characteristics can also be changed through speech commands (Fig. 8).



Figure 8. Electronic Grease Pencil

The speech recognition program is a distributed application. The recognition occurs on a lower end machine and through multicast, broadcasts a code representing the understood phrases. There are two primary reasons for using multicast packets. First, connected sockets need to be started in

order, while multicast sockets do not. Second, multicast packets are broadcast and all applications that want to support speech recognition can listen to the understood phrase codes.

#### **4. DataWall Implementations**

AFRL/IF has successfully implemented a number of Interactive DataWalls each consisting of three horizontally tiled video projectors. The first implementation, which serves as a development system, uses CRT projectors each displaying 1600 x 1200 pixels for a total display resolution of 4800 x 1200 pixels across a screen area 12' x 3' (Fig. 1b). This far exceeds the state-of-the-art in single element display systems. A Silicon Graphics, Inc. (SGI) Onyx workstation with three Reality Engines drives the display. In addition, each projector has a video bandwidth capacity approaching 2500 x 2000 pixels, which could yield a future DataWall resolution of 15 million pixels.

In the interest of developing a less costly alternative to the SGI-based DataWall, a Sun workstation based version was successfully implemented to support the Joint Force Air Component Commander (JFACC) program. Again three CRT projectors were utilized but at a slightly reduced resolution. Each projector displays 1280 x 1024 pixels for a total display resolution of 3840 x 1024 pixels across a screen area 12' x 3'. One dual processor Sun Ultra SPARC 60 workstation and two Ultra SPARC 30 workstations drive the display. It also has the same wireless interaction capabilities as the SGI-based DataWall.

To provide a deployable version of the Interactive DataWall to support the testbed for the forward deployable element of the Configurable Aerospace Command and Control (CACC) Integrated Technology Thrust Program (ITTP), a Sun workstation based Deployable Interactive DataWall (DID) was implemented. One dual processor Sun Ultra SPARC 60 and two Ultra SPARC 10s drive this display. It is housed in an extensively modified Air Force S-530 A/G Standard Rigid Walled shelter, with its own Tactical Generator Set and Environmental Control Unit. Due to the unique, short-throw, rear-projection requirements, three LCD projectors with special short-throw lenses are used. In this configuration, each projector displays 1024 x 768 pixels for a total display resolution of 3072 x 768 across a screen area 110" x 27" (Fig. 9). It should be noted that even in this most reduced resolution configuration, the total display resolution still exceeds the state-of-the-art in single element display systems. A new feature implemented in the DID is window encapsulated live NTSC video feeds. This allows the commander and staff to view and manipulate information from such sources as real-time surveillance video, satellite broadcasts, and VCR mission playbacks.



Figure 9a. The Deployable Interactive DataWall (DID)



Figure 9b. The DID Interior Components

## 5. Technology Transition

A joint effort of AFRL/IF's ADII, CACC, and Logistics Support In-house groups, resulted in the first field evaluation and trial of the DID, with the *US Army's 10<sup>th</sup> Mountain Division* at Ft. Drum, New York in its Mountain Peak 98-01 field training exercise. The S-530 A/G expandable rigid wall shelter containing the DID, along with the supporting generators and air handling systems, were transported to Ft. Drum on 20 August 1998 to begin the field trial. The DID was set up at the Division Main headquarters in the field and provided the Division Commander and

his battle staff with the capability to display, interact with, and manipulate real-time multi-source information essential to the successful control of the battle. During this field exercise, personnel from AFRL/IFS's Division along with the Commander and soldiers from the 10th Mountain Division operated the interactive DataWall. It provided the following capabilities:

- Near real time sensor surveillance display/manipulation
- A unified interface with Army Command and Control software (All Source Analysis System (ASAS) and Remote Work Station (RWS))
- Ability to display large high-resolution still and motion Intelligence, Surveillance and Reconnaissance (ISR) photography (Navy P3 Orion live fly video surveillance and high resolution digital camera)
- A new medium for fusion of satellite information broadcasts and Command, Control, Communications, Computers, Intelligence, Surveillance & Reconnaissance (C4ISR) systems (Digital Satellite System (DSS) broadcast television for weather reports and CNN updates in conjunction with Air Force weather radar data)
- Ability to create and interactively deliver web based Microsoft PowerPoint briefings

The exercise was conducted from 24 August 1998 to 2 September 1998. The Army 10<sup>th</sup> Mountain Division commanders and staff users heartily endorsed the DID, giving it an A++ grade. Since this exercise, multiple service representatives have requested prototype variations for support of C4ISR operations both CONUS and abroad.

AFRL/IF is also providing expertise to the *C2 Battle Lab* at Hurlburt Field, and to *AFRL/HE* at Wright-Patterson Air Force Base to install DataWalls at their sites. The installation at AFRL/HE is part of a Memorandum of Agreement (MOA) that defines a cooperative relationship between the IF and HE directorates to provide their respective scientific and engineering expertise to further the development and application of technology in areas of mutual interest.

## **6. Conclusions and Future Work**

The custom laser pointer tracking hardware has proven extremely effective and reliable. Several copies of the device are planned for production, to replace the PC/capture card systems still being used in Sun DataWall configurations. In addition to the advantages discussed earlier, the devices also reduce space and power requirements, which is particularly beneficial in the DID configuration.

Also in development is a PC-based Interactive DataWall. Microsoft's Windows 98 and Windows NT 5.0 will support multiple displays. Therefore, a single PC with multiple graphics cards (one graphics card per display tile) could drive a tiled display system. The obvious advantage is further reduced hardware and software costs compared to Unix-based workstations. Preliminary testing is being conducted using Microsoft Windows NT 4.0 with special drivers for the multiple graphics cards in lieu of Windows NT 5.0, which is yet to be released.

Also planned is the development of a Transportable Interactive DataWall that can be disassembled, transported, and reassembled in a short period of time. Unlike the Deployable

Interactive DataWall, this version is intended for indoor use. It will most likely be PC-based and will be designed to fit through a conventional 3' doorway.

Other novel HCI devices are also being researched. One in particular is using a COTS magnetic position tracking system. Although these systems are designed for 3D interaction, and the Interactive DataWall is a 2D environment, the appeal of attempting to integrate this type of input device is the potential to further simplify the configuration. It will eliminate the video cameras, but more importantly is able to track multiple receivers. This in turn may allow the capability of multiple simultaneous pointers.

The ability to support multiple *simultaneous* users is the Interactive DataWall's greatest limitation. Although multiple users can interact with the display through speech and laser pointer, they cannot simultaneously. The problem with the current laser pointer-tracking paradigm is the inability to differentiate multiple red laser pointers on the screen. Research has been conducted by the ADII team using a recently COTS available green laser pointer. While preliminary results revealed the ability to differentiate the red and green lasers, it would add significant complexity to the configuration, requiring separate video cameras and pointer tracking hardware per display tile, to make it a two person system. Each additional simultaneous user increases the complexity linearly. Green laser technology is much more expensive to scale it down to the size of a pen, compared to the widely available red laser pens. Also, there are no other colors currently available in this size laser. Yet another reason the magnetic position tracking may be a more viable option.

If the multiple pointer-tracking problem is solved, there is still the issue of the window manager supporting multiple cursors. Currently only one cursor is supported under the X-META-X window management method. To assure all legacy applications can be supported on the Interactive DataWall without modification, has quelled our desire to develop a custom solution to the window manager. Hopefully the increasing popularity of tiled displays will motivate the commercial sector to develop an off-the-shelf solution.

Multiple speaker recognition is also desired. Currently, a copy of the speech recognition application has to be running for each user in a multi-user environment. Ideally a single speech recognition suite should accommodate multiple users. Also, once the multiple pointer issue is solved, the problem of associating a user's voice with a particular pointer must still be resolved.

The Interactive DataWall has been demonstrated to a number of visitors at AFRL/IF at Rome Research Site. It has been extremely well received, so the ADII team is confident that our research efforts are headed in the right direction for next generation Command and Control systems. Although a considerable amount of research and development remains, an extremely capable system has been created, integrating a significant amount of commercially available hardware and software.

## 7. References

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