

+THE FUTURE OF THE WAC WINDOW

A 26 INCH CRT REPLACEMENT

David L. Peters
Diamond Visionics Co.
Vestal, NY

Angel Rodriguez
STRICOM
Orlando, FL

ABSTRACT

The CCTT (Close Combat Tactical Trainer) Team training program was awarded in late 1993 by the U.S. Army. This simulation program, the largest ever awarded, has undergone an extensive development and testing program, and is scheduled to go into full production in 1999. In the fall of 1995 after prototype development and deployment, the supplier of the 26-inch CRT, the key component in the commander's popped-hatch display, announced they would no longer manufacture the component, and no direct replacement was available. A Small Business Innovative Research (SBIR) contract was initiated through the Army SBIR program to recommend an alternative solution. The final recommendation is being developed in a prototype phase II contract, to be ready to fit within the final production contract to be let in early 1999.

This same 26-inch CRT is used extensively in the Wide-Angle Collimated (WAC) window, with many thousand in use worldwide. The demise of the 26-inch CRT left the future of spare parts in doubt, as evidenced by the great concern voiced by present users of the CRT. The same SBIR Phase II program that has developed the 26-inch CRT replacement unit for the CCTT program has also funded the development of a replacement for the 26-inch CRT used in the WAC window.

This new approach uses the fundamental building block of the micro-display devices just being introduced by display component vendors to produce a product that can be made to fit many display configurations, not being limited to available CRT bottle sizes. Scaling, improvement in optical characteristics, and other modifications are all made with relative ease, with no major NRE cost drivers as would be required if a new CRT is desired.

A unit will be available for viewing at the conference.

David L. Peters

Mr. David L. Peters has almost 40 years of experience in visual display systems engineering for flight and space vehicle simulators. He has a BSEE degree from the University of Dayton, and has taken numerous electrical engineering courses at the graduate level. Dave is a nationally recognized authority in the simulation of forward-looking infrared (FLIR) systems, and led the development team for the FLIR simulation on the Daedalian award winning AH-64 Combat Mission Simulator. He also led the exploratory team that conceived the ESPRIT, a unique eye-tracked display with very high-resolution capability over a 360° field of view. He has been involved in many successful research and development programs in the optical, video, and image generation arenas and holds 18 patents. He has written many papers, including two invited papers, one for the SID, and one for NAECON, and has taught courses for UCLA. He is a member of the ACM, IEEE, SID, SPIE, and the Image Society.

Angel Rodriguez

Angel Rodriguez is a Visual System Engineer with STRICOM and is currently assigned to the Close Combat Tactical Trainer (CCTT) and future aviation collective training systems. He has over 12 years experience as a visual systems engineer relating to Navy, Marine Corps and Army training devices. He holds a BEEE from City College of New York.

THE FUTURE OF THE WAC WINDOW

A 26" CRT REPLACEMENT

David L. Peters
Diamond Visionics
Vestal, NY

Angel Rodriguez
STRICOM
Orlando, FL

INTRODUCTION

The demise of specific cathode-ray tubes that are commonly used in the simulation industry raises havoc when these units need replacement or are in production. The commonly-used 26 inch CRT was manufactured by several vendors over the years, and has been used both as a direct view monitor and as a basic component in the Wide Angle Collimated (WAC) display that forms the vast majority of collimated displays in the simulation industry. Recently Mitsubishi, the last remaining vendor of a 26-inch tube, announced the impending demise of the production line. This has impacted several programs, notably the Close Combat Tactical Trainer (CCTT) program, where the 26 inch tube is used extensively, and the Synthetic Flight Training System (SFTS), which has several hundred WAC windows employing the 26 inch tubes in the field. Diamond Visionics (DVC) was awarded a Small Business Innovative Research (SBIR) contract to determine a work-around plan and a replacement for the displays that used the 26-inch monitors. This paper, a follow-on from the paper delivered at ITEC 98 on the initial trade-study and a paper delivered at IMAGE 98 on the CCTT digital form-fit-function unit, discusses the technology trade-off and the prototype development unit of the curved faceplate version designed for the WAC window.

BACKGROUND

The CATT program is developing a family of interoperable simulators for training a combined arms force in a real-time synthetic environment where the focus is sustainment training for collective tasks and skills in command, control, communication, and maneuver. A critical part of the CCTT program is the use of the popped-hatch for the Commander's cupola on the M1A1/A2, M2, and the M2/A3. The display used on the prototype CCTT modules consisted of ten 26-inch Mitsubishi monitors mounted in a ring around the central eyepoint. Five monitors are in a direct view mode, and five are mounted

vertically and reflected to the viewer. This method makes the gaps between images much smaller than if all ten were mounted in a ring, since most of the gap caused by the glass envelopes can be removed using this folding approach.

However, the folding approach causes the glass envelopes in the vertical mount to virtually touch one another. Further, many other component parts of the simulator are placed very close to the monitors, creating a tight fit for all visual components. Any modifications to the display would probably cause a major redesign of many components.

In November of 1995 the Army received a letter from Mitsubishi that they were planning to shut down the production line for the 26-inch CRT. The program office of the CCTT investigated several alternatives to solving the display problem. The alternative that the Program Manager (PM) CCTT ultimately chose to pursue was the Small Business Innovative Research (SBIR) grant program.

The fundamental premise of the Congressionally mandated SBIR program is to create jobs by soliciting and funding solutions from the community of innovative small businesses for tough, long standing problems. SBIR Phase I funding is intended to develop a notional or conceptual technical approach to solving the problem. Phase II is the prototype development phase, and the final commercial Phase III is intended to launch the small business into the commercial market place with a product developed under SBIR funds with data rights owned by the small business, and limited rights allowed to the government.

Diamond Visionics was awarded a Phase I SBIR in November 1996 to investigate a low cost alternative solution for the CCTT Commanders Popped Hatch (CPH) visual display system. Thirty approaches were investigated that ranged from the obvious, to the high risk and complex, to the trivial, to the elegant and simple. The Phase I study evaluated 30 different approaches. This study which was

discussed in the ITEC 98 paper, "COTS Usage - A case Study", gives the rationale and methodology of evaluation, and the recommendations leading out of the study. DVC recommended replacement of these monitors with a form-fit-function unit device DVC called the Digital Display Unit (DDU). These units are based on Digital Light Technology (DLT) using microdisplay rear projection techniques. This approach eliminates many of the fundamental causes for the high maintenance cost. The rigid physical geometry of the light-processing device along with a rigid optical relay system replaces the analog deflection processing circuitry. Geometry and image quality of DLT is not effected by electromagnetic interference. Geometric accuracy, design robustness, and alignment simplicity is determined by the physical mounting of the microdisplay and the optical relay system, and long term alignment is guaranteed by the physical structure of the unit.

DVC was invited by the Army, the SBIR sponsoring organization, to submit a Fast-Track Phase II proposal. The Fast-Track approach gives the highest priority for available funds to those asked by the sponsoring organizations to Fast-track, reduces the period from the end of Phase I to the start of Phase II from 9 months to 3 months, and supplies Interim funding for the period between the end of Phase I and the start of Phase II. But those asked to Fast Track must obtain outside funding (an "Angel investor") and support to validate the approach taken by the Phase I to assure adequate technical and marketing support for the concept developed during Phase I.

The Army's PM CATT became the "Angel investor", funding 20%, while the SBIR funded 80% of the Phase II effort. DVC was awarded the Phase II in August of 1997.

As part of the commercialization plan of the Phase II SBIR, DVC has developed a version of the DDU aimed at the WAC window, both new designs and the replacement market.

THE WAC WINDOW REQUIREMENT

Typical WAC window requirements are listed in Table 1.

Parameter	Specification
Total Field of View	48° x 36°
Resolution	7 – 8 arc min/OLP 5% MTF
Collimation(divergence/convergence)	-0.05; +0.10 Diopters (eye separation 2.5"
Viewing Volume	6" spherical radius
System Tran, (est)	18%
Luminance	7 – 8 Ft. Lambert's
Luminance Uniform.	35% beyond CRT height diameter
Contrast Ratio	30:1
Distortion	[2.5% of scene height
Mirror Radius	50.25 inches

Table 1 WAC window requirements

The parameters given in Table 1 are for a mirror radius of 50.25 inches, which has become one of the standards in the simulation industry. Other mirror sizes exist, such as 60 inch and 80 inch, which may require some slight modification to the WAC DDU.

MICRO-DISPLAY TECHNOLOGY

The approach selected was to replace the 26-inch monitor with a WAC Digital Display Unit (WDDU) that features one of the new micro-display units aimed at the projection market. The WDDU consists of a miniature rear-screen projection unit that uses the latest in miniature projection panels (microdisplay), with a wide-angle lens attached to the system that images the miniature panel on the screen, and a curved screen designed to match the optimal collimation of the mirror.

The WDDU approach is not technology-sensitive, and several present technologies and others still being developed are all candidates for inclusion in the display. This approach makes the WDDU able to migrate to different technologies as they become available and prove more cost-effective than the technology presently used. Thus the WDDU is not as liable to the modern phenomenon of technology withdrawal as a specific CRT would be.

Technology Choices

Three technologies had been identified during the Phase I study as presently applicable to the

WDDU. Critical among the parameters for choice are resolution and chip availability compatible with the SBIR schedule.

Texas Instruments Digital Mirror Display (DMD)

The DMD is based on a Complementary Metal Oxide Semiconductor (CMOS) Static Random Access Memory (SRAM) with a superstructure array of aluminum micromirrors functionally located over each memory cell. The DMD digital light switch moves between its two states ("on" and "off") to create and reflect digital gray scale images from its surface when light is applied. The digitally created images are transferred through the appropriate optics and filters to create the projected images. Each mirror is 16 microns square (about 16/100 the size of a human hair) with a one micron space between mirrors on all sides. The number of mirrors in use on a single chip can range to over 1.3 million. The mirrors are bistable, and the mirrors switch to digital 1 ("on" at +10 degrees) or digital 0 ("off" at -10 degrees), depending on the input signal. The switching time is constant at approximately 20 microseconds.

Strengths:

- a) Since the active portion of the DMD is a mirror surface, no polarization of the light is required, and a high luminous efficiency can be maintained throughout the optical system. This will result in a smaller illumination system and/or higher output luminance.
- b) The high speed of switching permits a single DMD chip to operate in a field-sequential mode and still maintain 256 levels of color in each primary. The input video will not be required to be field sequential, since a coupling circuit is part of the DDU that changes parallel inputs to field sequential outputs.
- c) The system has been tested over a 5 year expected lifetime without a single mirror failure. This assures a good MTBF rating for the DMD chip.

Weaknesses:

Since the operating method is to toggle a mirror +/-10 degrees, the optical system is more complicated. The incoming light is from 20 degrees off-axis, and the output light is emitted straight off the chip. This complicates the optical design, and makes the illumination design and the optical output design a single

package, based upon a tilted illumination system.

AMLCD Projector

The Active Matrix Liquid Crystal Display (AMLCD) projector display is an outgrowth of the standard tabletop projector used for graphic displays in many demonstrations. This is a three-chip display approach, which is available in our required resolution in larger formats. AMLCD systems are transmissive units that are simple to set-up and use in an optical system, and will result in the least complex of all optical systems.

Strengths:

- a) Since the AMLCD is a transmissive device, the optical configuration is a simple lens looking at the AMLCD chip in a straightforward design.
- b) The desired resolutions (1024 x 768) are available today.
- c) A three-chip device removes the need for field-sequential output, raising the optical efficiency by almost a factor of three.

Weaknesses:

- a) The transmission efficiency of the AMLCD is lower than the DLP, and this will offset some of the gain mentioned above.
- b) AMLCD materials have an inherent problem of being slow to reach peak and slow to decay, known as image lag, causing a loss of image content and resolution during motion. If this factor is not reduced to acceptable levels in the latest technology, the AMLCD will be less than desirable for our application.
- c) It has proven difficult to obtain the cooperation of television-capable projection AMLCD manufacturers for production units.

FELCD Projector

DisplayTech, Inc. of Boulder Co. has developed a ferroelectric effect in smectic-C liquid crystal display that was considered potentially suitable for the DDU. The FELCD display is based on a spatial light modulator, which consists of an array of square pixels. Each pixel is effectively a high-speed optical shutter on top of a mirror. The shutter can be toggled at high speed to produce a shade of gray. The chip is a VLSI chip that is a specialized version of a CMOS DRAM in which each memory cell corresponds to a pixel. Each pixel mirror is an aluminum pad, which is connected to one memory cell's capacitor. The

timing of the cell being "on" controls the brightness of the pixel, creating another digital approach, without any moving parts. It should be noted that during the device selection process the only DisplayTech device available was aimed at the helmet market. Since then (Spring 1998) DisplayTech has announced a 1280 x 1024 device for the projection market, and must be looked at further when production time is close.

Strengths:

- a) The inherent small size of 0.4 inches will assure a small optical package.
- b) The resolution will meet the CCTT application
- c) The high-speed mechanism of the device assures that lag will not be a problem.

Weaknesses:

- a) Since the chip is very small, the optical power on the surface is high. This is coupled with the absorbency of energy in the "off" state that may cause a heating problem. The original application of the FELCD device is aimed at the helmet display device market, which requires much lower levels of illumination than a projection device like the DDU. The extra heat will lower the contrast levels to unacceptable levels, and/or shorten the life of the device. Now that the projection device is available, the selection process must be re-examined.
- b) The FELCD is a front surface device, but unlike the TI DMD, it is an inline device. This means that the complexity of the optical system lies between the AMLCD approach and the DMD approach.

Interim Down-Select

The SBIR interim phase studied the three competing technologies that support the recommended DLT approach. The study resulted in the first step leading to a recommendation by down selecting to the two technologies to be carried into the breadboard phase of Phase II of the SBIR. The breadboard phase led to the final recommendation to meet the requirement that is driven by low cost and performance. This DLT technology was then developed and tailored to the specific CCTT CPH display requirements, and a full Commanders Popped Hatch display has been prototyped and integrated on a training module.

The Interim decision in 1997 concluded that the FELCD was not at a stage to be considered for the breadboard phase of the effort.

Texas Instrument DMD

The Texas Instrument Digital Micro-Mirror (DMD single chip) device continued to be the leading contender for the DDU. A technical interface was established between the technical office of TI and DVC. DVC purchased the evaluation unit, which consists of the display engine with an illumination system, optics, and the drive electronics and interfacing card with a PC. The engine is normally the unit supplied to all projector suppliers that sell a DMD based projector. For our purposes the unit would be purchased without optics. The display uses field-sequential sequencing as the basis of this cost-effective method.

Epson/Seiko AMLCD

The only AMLCD that was deemed applicable to the DDU was the unit supplied by Epson/Seiko. Other units are available, but deemed unusable in a real-time application like the DDU, because fast moving images leave trails, have blur, and have low contrast. Two versions of the unit are made by Epson/Seiko, one being a full color sandwich and one being a monochrome unit. DVC learned that the full color version is aimed only at the helmet mounted display (HMD) display, and will not withstand the temperature rise incurred by the high illumination needed for a projection display. While our display will have a lower illumination level with less heat than a normal large-screen projection system, it will still be many times the level used in a HMD unit. Epson/Seiko recommended the use of the monochrome unit, which requires a three-chip device with a combining cube, since the LCD may not be used in a field sequential mode due to image lag. Epson/Seiko is reluctant to sell DVC any units or sign DVC as an OEM user, and will not supply technical data. They recommended that DVC use a purchased commercial unit for a data source. A COTS projector was purchased for use as a breadboard evaluation unit for the first portion of the Phase II effort. The units are furnished as an engine configuration to their OEMs, similar to TI, and would require modification and adjustments for use in the DDU for CCTT.

Breadboard Evaluation

The breadboard evaluation between the Texas Instrument DLP approach and the Epson/Seiko approach was made during October-November 1997. Two off-the-shelf projectors were used in a side-by-side configuration with 800 x 600 resolution, one featuring the Texas Instrument DMD chip using their standard engine with the TI-designed zoom lens, and the other using the Epson/Seiko chip and drive circuits and zoom lens. Identical screens were used for the tests, and the image size and brightness was maintained at the expected system size, viewing distance, and brightness on both units. A series of 10 tests were run and rated in comparison with a CRT monitor. A detailed report on the breadboard evaluation was presented at the 98 Image Conference in the paper titled Digital Display Unit for CCTT: Compact DLP Projection System for Monitor Replacement by the present authors.

Recommended Approach

The final choice came to be the Texas Instrument DLP as the best choice at this time.

DESIGN CHALLENGES AND ADVANTAGES

The design of a projection system using a rigid source presents several challenges, but the result of the display gives many advantages. The design challenges have been:

- a) The design of the optical system to accommodate the high radius rear projection screen was difficult. The radius of the screen is just over 25 inches. The design has resulted in a system Modulation Transfer Function (MTF) for the display of over 50% at the limiting resolution of 1024.
- b) A micro-display projection system has no means of correcting the distortion of the display except for the optical design, since all components are rigidly coupled by the inherent mechanical design of the system. The design of the optics to accommodate the optical distortion of the WAC window resulted in an optical match of better than 1% with the eyepoint located 3.5 inches inside the optical center of the mirror.
- c) Keeping the design compact, light, and cost-effective is always a challenge. The resultant design, in its simplest approach, is a display, which weighs about 40 lbs., fits

within the confines of a monitor case, and is very cost competitive.

- d) Holding consistent color temperature, keeping color balance from display to display, and being able to adjust multiple channels for consistency over time is another challenge. The design uses filters and signal conditioning approaches not usually available on projectors to achieve repeatable results, and the luminance output is monitored and adjusted at startup to assure long-term consistency.
- e) Nighttime simulation is always difficult with a light-valve type projector since a low residue (darkfield) is always left on the display. The WDDU uses a neutral density wheel to adjust the light out depending on the time of day. The same wheel is adjusted to keep the luminance output constant over time, as discussed in d). The system can be configured to be compatible with NVG.

The advantage of the design is the simplicity, with minimum maintenance (other than changing a lamp every 1000 hours, the system remains at a constant brightness and has no drift in any area).

PROTOTYPE DEVELOPMENT

Following the technology selection, DVC proceeded to initiate the development of the flat-faced prototype system for the CCTT replacement monitor, the principle goal of the SBIR. The main task was to meet the field-of-view requirements, stay within the housing for the original 26 inch CRT monitor, and not impinge in any other equipment in that area of the simulator. Our choice for the prototype was to use the original equipment monitor case to assure fit in the simulation arrangement. Ten units have been constructed and were placed on a CCTT module undergoing evaluation during this past summer (98).

The technical performance goals that were set for the 10-unit prototype system were as follows:

Technical performance goals:

System Resolution: MTF of 70% or more at chip limiting resolution of 800 x 600.

Brightness: >30 FI

Contrast Ratio: >10:1

Gap between images: 0.5°

Power: 125 watts

Distortion: <5% center circle, 7% elsewhere

Supportability goals:

MTF: 2270 hours

MTTR: 35 to 60 minutes

First Prototype DDU design:

The flat-faced prototype unit has been designed to fit within the original CCTT Monitor case, with a slight modification in an area that does not impinge on any other object in the simulator. Figure 1 illustrates the flat-faced prototype unit developed for the CCTT, showing the placement of the component parts: the lamp, the illumination optics, the color wheel, the DLP drive board, the projection lens, and the fold mirrors to wrap the system inside the box, and the flat screen. The entire structure is a self-contained, stand-alone device that is capable of being completely adjusted out of the case, then inserted in the case for mounting and protection. Chip delivery dictated that the flat-faced prototype units use the 800 x 600 chip, with the production unit using the 1024 x 768 chip.

The field sequential approach has given rise to a concern that the well-documented color-breakup effects would prove to be so detrimental to the acceptance of the approach that it could not be accepted. The approach of TI that uses a 5-section wheel, including 2 small white areas, has resulted in much less apparent color-breakup than had been expected. The result has been deemed acceptable in the atmosphere of the CCTT, and the color breakup to be unobservable except under unusual conditions.

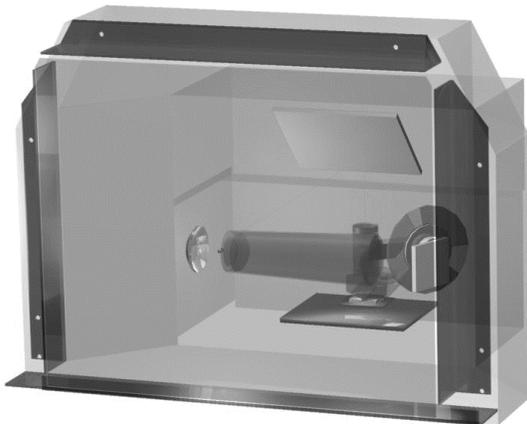


Figure 1 DDU unit

One of the primary challenges of the design was to keep any object out of the light pathway to avoid shadowing of the screen. The following section briefly describes each of the major components.

Support Structure

The unit is mounted on a supporting plate, which attaches to the case. The supporting plate carries the screen and the interface electronics. A secondary optics plate carries all the projection optics (including the lamp) and is adjustable for optical size and centering.

Interface Electronics

The interface electronic board interfaces with the image generator output and provides electronic color balance, size, and centering controls, adjustable from an external laptop control via an RS-232 interface. The unit has multi-sync capability.

Illumination Optics

The illuminator optics forms the basic illuminator path for the DLP chip. This path includes the lamp, lamp cooling, condensing optics, masks, color wheel, and means to adjust brightness, which controls the unit brightness and automatically keeps constant brightness as the lamp ages. The brightness control extends the dynamic range of the system for time-of-day purposes if needed, under software control. The illuminator path has two fold mirrors to move the path clear of the output light path.

DLP Chip and Driver Board

This unit is obtained from Texas Instrument and holds the chip and driver electronics, and is used as obtained from TI. This board is carried on the optics plate. Note that the only critical item is the chip location, and a form factor change in the board can be accommodated.

Projection Lens

The projection lens is above the TI chip, and projects the image via a fold mirror onto the screen. This lens is adjustable for focus and size adjustment in the factory.

Screen

The screen is a flat rear-projection screen.

System performance

After the prototype system development, further effort has been made to improve some of the performance areas and to reduce costs. The expected performance for the production version is as follows:

Resolution: MTF of 70% or more at the limiting resolution of 1024 x 768.
Brightness: (Final lamp still being investigated) 47 Fl.
Contrast Ratio: 40:1
Potential Gap between scenes: 0.2°
Power: 150 watts
Distortion: 1% anywhere

WDDU Development

Once the flat-panel DDU was completed, plans were made to develop the WAC version (WDDU) of the display. Two versions had a preliminary design completed, one using the high resolution (1024 x 768) single chip with field-sequential input, and a second using the 3 chip approach with all inputs (RGB) in parallel. The 3 chip approach is not field sequential, and would result in a higher illumination from a given source, and no potential for color breakup on fast moving objects or conditions.

The choice between using the single chip approach with lower cost, size, complexity, and weight, against the 3-chip device is one of performance and application. The single chip approach is aimed at lower velocity applications and/or where cost is critical. The 3-chip approach is for high performance applications, where any chance of color-breakup and reduced user acceptance may reduce training effectiveness. The customer needs to evaluate the application to determine if the increased user acceptance is worth the increase in complexity, weight, and cost.

It was determined to tackle one problem at a time, and the first product aimed at the WAC market is the single chip device operating using field sequential operation. This product solved the mapping problem, assuring us that we could grow the system to the 3-chip version and still meet our performance criteria. The remaining portion of the display is very similar to the DDU described previously, with the flat screen replaced by a screen with a radius of 25.125 inches. This screen matches the half radius of the 50.25" radius mirror, one of the most common elements in the installed database. Figure 2 illustrates the WDDU. The similarity with the original DDU is clear.

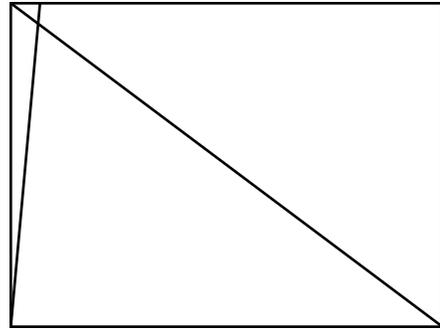


Figure 2 WDDU unit

Wide Angle Collimated (WAC) Mirror, Monitor, and Distortion Characteristics

CRTs have become more flat over the years, to help the average user. But the flat CRTs that are the pride of the industry create terrible problems for the collimated systems that depend on the face curvature for good acceptance. There has been great concern in the industry about this growing trend, even before the demise of the 26-inch tube.

The acceptance of the WAC window has depended upon the degree of match between the mirror and image surface, and the placement of the eye. If all would be perfect, the image surface would have a radius of exactly half that of the spherical mirror. The most common mirror used in the WAC window has had a 50.25-inch radius surface, which should have an image surface with a 25.125-inch radius. The result would be an image with little or no collimation errors. The 26-inch CRT used in these windows has an average radius of about 41 inches, which created many collimation errors. Anybody who has sat far off the viewing volume knows the discomfort that these errors can cause.

If the perfect match can be maintained in curvature, very little collimation errors would be found at any viewing point, particularly divergence errors. Since we have control over the image surface in a projection system, the use of a perfect match to the mirror is an option that will be maintained.

The distortion required on the image surface when the eye is at the mirror center is $\sin \theta$, and moves towards $F-\theta$ as the eyepoint moves in. Most WAC systems have designed the eyepoint inside the mirror center to increase the instantaneous FOV, and the design eyepoint on the WAC prototype is placed 3.5 inches in from the mirror center.

WDDU PERFORMANCE

The performance, based upon the design of the system, is shown in Table 2. (The measured performance of the WDDU will be given at the paper delivery, as the unit will be built and on display.) The performance met all of our goals.

Parameter	Result
Resolution	>60% MTF @ 1024 x 768
Distortion	<1%
Field of View	48° x 36°
Collimation	0 error (not measurable)
Viewing volume	> 6 inch rad.
Luminance	>50 ft. L
Lum. Uniformity	25%
Contrast Ratio	40:1
weight	<45 lbs.

Table 2 WDDU Performance

PRODUCT VARIANTS

Several variants of the prototype can be built, depending on the system being designed or replaced.

- a) The 3-chip version described earlier, where top performance is desired. This product is a natural extension of the single chip prototype.
- b) Higher brightness versions where high luminance is desired. This change requires a new lamp and cooling.
- c) Multiple joined versions, where the perfect collimation allows a wide viewing volume that could accommodate more than one viewer.
- d) Variations of mirror radius and other needs that require optical variations. These changes need to be discussed to determine the extent of modifications needed.
- e) Higher resolution versions of any of these systems as the technology develops. 1280 x 1024 DMD from Texas Instrument is expected to be available in 1999.
- f) Different technologies, such as the Display Tech 1280 x 1024 projection display set that is available now, if the overall results indicate improvement in performance and/or costs.

CONCLUSIONS

A replacement for the 26-inch CRT monitor used in the WAC window has been built using new micro-technology display devices. The new display has many performance advantages over the CRT monitor, and may be used in major program production or replacement units where this monitor has been designed into the device.

A step-by-step study was made in a Phase I SBIR to determine the most cost-effective way to replace the 26 inch CRT monitor in the CCTT simulator that had gone obsolete. The resultant recommendation was funded for prototype development in a phase II SBIR, and the technology trade-off resulted in the recommendation of a compact rear-projection system using the TI DLP chip. The original development has been extended to be a replacement for the 26-inch CRT used in the WAC window. The replacement effort has resulted in removing many of the optical shortcomings of the WAC window, giving a much more pleasing result to the viewer.

REFERENCES

Chase, W.W., Baron P.C., Lin B., Smith R. - A comparison of blue-yellow and red-green-blue field-sequential color displays and their effect on color break-up. AOA Council on Research Database, Current AOA Website

Gdovin, D.P., Rodriguez, A., (1998). Cots Usage - A Case Study (What happens when a manufacturer decides to cease production on a key component?). Proceedings of the 1998 ITEC Conference: 1998 ITEC Ltd.

Gove, R.J., (1994). DMD Display Systems: The impact of an All-Digital Display. Sid 94 Digest (pp. 673 - 676) Society of Information Display.

Hornbeck, L.J. (1996). Digital Light Processing and MEMS: Reflecting the Digital Display Needs of the Networked Society. SPIE/EOS European Symposium on Lasers, Optics, and Vision for Productivity in Manufacturing 1, Conference on Micro-Optical Technologies for Measurement, Sensors & Microsystems, Texas Instruments

Website

Peters, D.L., Rodriguez, A., (1998). Digital Display Unit for CCTT: Compact DLP Projection System for Monitor Replacement. Proceedings of Image 98, 1998 Image Conference

Yoder, L.A., (1997). The State of the Art in Projection Display: An Introduction to the Digital Light Processing (DLP™) Technology. Texas Instruments White Paper, Texas Instruments Website