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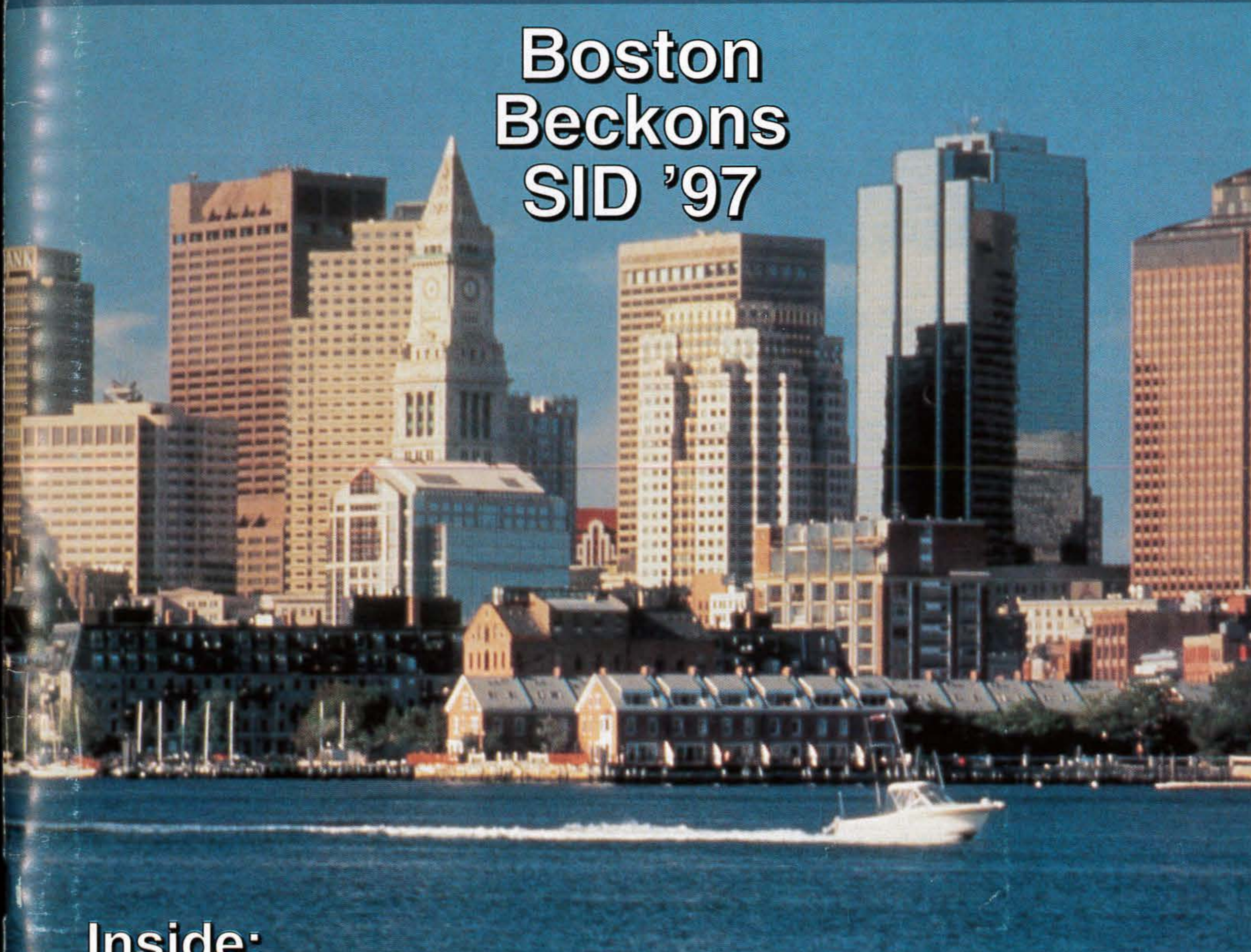
SID '97 PREVIEW ISSUE



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COVER: Boston welcomes SID '97. This view of downtown Boston from Boston Harbor is similar to the one that greets visitors who take the Water Taxi downtown from Logan Airport.

Credit: Greater Boston Convention & Visitors Bureau

For more on what's coming in *Information Display,* and for other news on information-display technology, check the SID site on the World Wide Web: http://www.sid.org.

Next Month in
Information Display

SID '97 Show Issue
- Products on Display
- Lithography for FED Production
- Interfacing Hi-Res LCDs
- Big Screens at Display Works 97
- Display Works 97 Review
- Display Phosphors Conference Review

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guest editorial

The Emperor and His Flat-Panel Displays

by Tom Holzel

We all smile with amusement when reading to children the story of "The Emperor's New Clothes." This, you will recall, is the tale of the high falutin' Emperor so entranced with his self-importance that he believed the two sly, swindling "tailors" who claimed that the nonexistent vestments he was being dressed in – at extraordinary cost – were so fine that boors and those unfit for the office they held could not see them. It took the innocence of a child along the route of the Emperor's naked march to cry out that the Emperor was wearing no clothes. Is there an analogy here for the kingdom of flat-panel displays?

AMLCD manufacturers are spending hundreds of millions of dollars building ever-larger displays. To what use? All they ever show on these $20,000 devices are Swiss calendar images every bit as gorgeous as can be shown with a $300 Kodak slide projector. Aha, the manufacturers reply, but this is going to be the replacement for CRTs and the technology for wall-hanging TVs. Really? If that is true, why don't the makers of large flat panels ever show full-motion video on their displays?

The reason they hardly ever show full motion is because they can't. Of the hundreds of AMLCDs seen at the last SID show (and in November at Electronica 96 in Munich) *three* AMLCDs were seen showing videotape/CD information. Not one looked gorgeous. The problem with the absolutely latest AMLCDs showing video is they do not have more than about six shades of gray showable – not "addressable" – when in motion. This is true to such an extent that a display showing a tiger stopping and starting *caused the tiger to lose its stripes* when it moved! (They dutifully returned when the tiger stopped.) Thus, just when you want to see more detail – during a motion sequence – you get less.

Look at all the AMLCDs used as seat-back TVs on the airlines. Everyone agrees they are terrible, and on a recent trip I saw, for the first time, people turning to books rather than watching a feature movie (that they had paid for) to completion.

To get around this inability to show full-motion video, AMLCD manufacturers either see their displays as slide projectors showing grand scenic vistas or, if motion is required, show very torpid fish somnambulantly cruising around in their bowls. (Admittedly, for more-or-less static computer displays viewed by a single user, AMLCDs are very good.) The plasma people also have problems showing video, but they are different problems.

If AMLCDs are too slow, plasma and digital mirrors are too fast. Watch plasma video displays and you will see an inability to show smooth transitions from black to white (a fade-out to black dims in staircase jerks). Vertical transitions are particularly awkward so that a smoothly descending object moves downward in jerks. To hide these intrinsic anomalies, special subject matter is selected for viewing: slow-motion sports activities is one favorite, as is MTV-type hyper-cuts – 1 second each of a frenetic series of activities, each presented so rapidly that the eye can barely keep up. Otherwise, we are back to glorious vistas.

Why haven't any papers been written on these fundamental display flaws? Very simple. Who could write them and keep his job? After all, building dis-

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the display continuum

An Encounter in the Audio Twilight Zone ...

by Aris Silzars

As Mike and his date Mary exited symphony hall, the bright lights and warmth of the lobby were abruptly transformed into a dark, cold, and damp late evening. A dense wet fog had settled in while they were enjoying the concert, and the cold wetness made them shiver. The performance this evening had more than met Mike's expectations. With its guest conductor, the orchestra had provided an outstanding interpretation of the Sibelius Second Symphony. With the sonorous tones of the final movement still in his ears, Mike wondered if Sibelius had ever been out on a similar cold, damp night in his native Finland.

In the gently swirling mist, the sodium-yellow street lights were casting irregularly shaped cones of light. Mike had watched the 6 o'clock news and there had been no mention of a foggy night ahead. Obviously, something had changed. An unexpected lump of cold ocean air must have rolled in. Earlier that evening, Mike had been quite proud of himself when he found a parking spot right in front of the restaurant where he wanted to get things started off in just the right way with his date Mary. That meant a few blocks' walk to symphony hall, but after a meal that had started with an appetizer and ended with splitting a tiramasu over coffee, they were both glad to have the opportunity to get some extended fresh air before taking their seats.

Now the walk back to the car didn't seem nearly so inviting. They both noticed how quickly the crowd dissipated. The few cars on the street were soon occupied, motors were started, and the headlights disappeared into the foggy night. Other concert-goers scurried off to the various parking garages, and in a few minutes Mike and Mary were very much alone. The fog was disconcertingly thick - the kind of thickness that makes one look at every street sign to make sure it's the right one. They commented on this strange phenomenon: how a thick fog makes one feel lost even in familiar surroundings. Mike, in his analytical engineer's way, suggested that it might be because we take visual cues from both near and far objects, and when the more remote visual aids are removed, we get more easily confused. Not only that, Mike was hoping that he could remember exactly where they had left the car. His male ego would definitely get in the way if he needed to ask Mary for help with directions.

At this late hour, all the stores and restaurants were closed. A few bars were still open but appeared to be mostly deserted. The empty darkness made Mike just a bit uneasy. Maybe it was this or maybe just the damp coldness, but they instinctively picked up their pace. Then, up ahead, they saw the sign.

At first it was just bright colors in the fog. Then, as they got closer, they could make out the words - THE STORE FOR THE AUDIO ENTHUSIAST. Not only that, the place was, for some reason, still open. Mike was intrigued. He always enjoyed seeing the latest in

continued on page 40

> In the Display Continuum column appearing in the January issue, there were several instances in which Aris Silzar's carefully chosen gender-inclusive pronouns were replaced with male singular pronouns. We regret any embarassment this may have caused Aris, the Society, or our readers.

Society for Information Display
1526 Brookhollow Drive
Suite 82
Santa Ana, CA 92705-5421
e-mail: socforinfodisplay@mcimail.com
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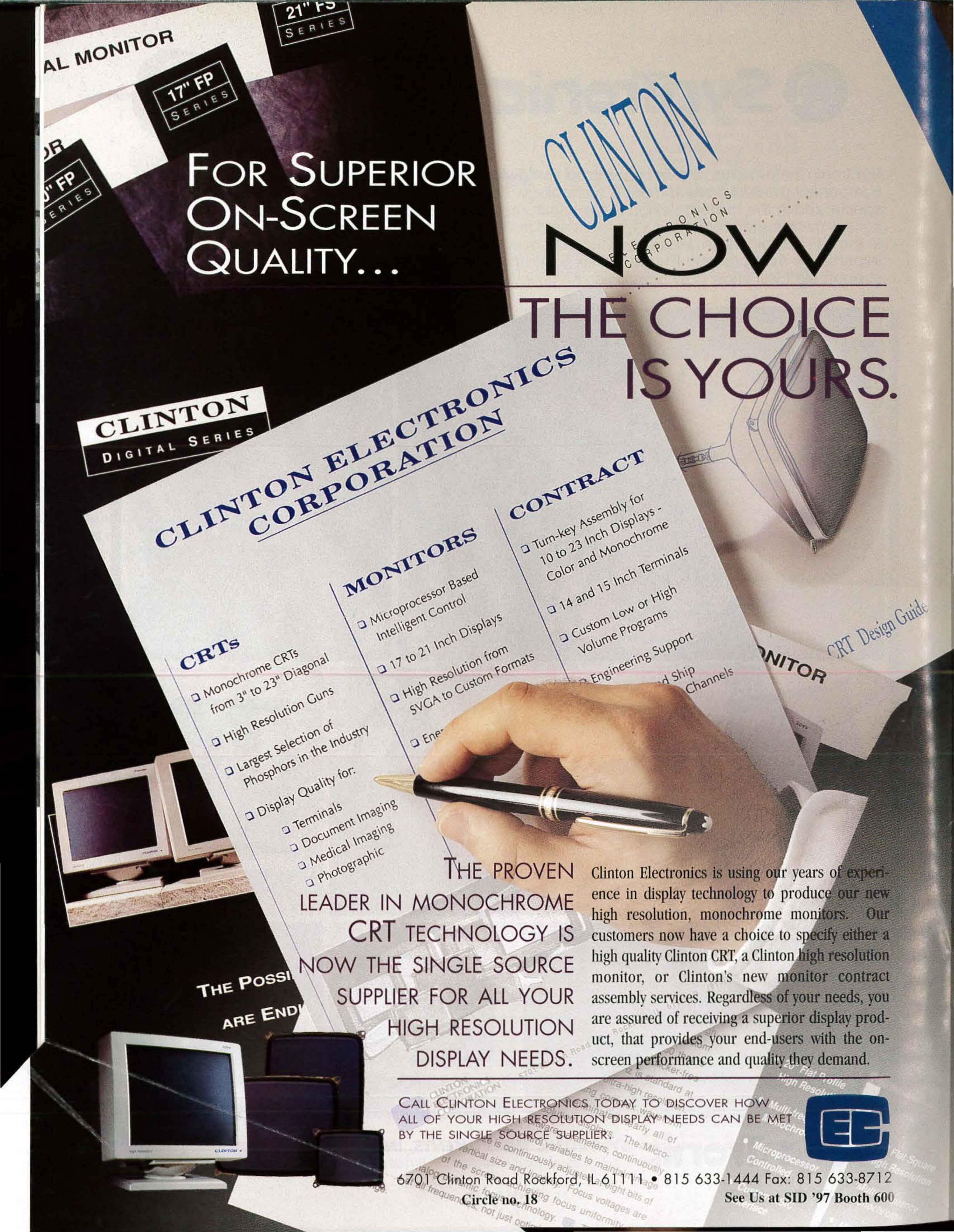

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Advanced Information Displays for the 21st-Century Warrior

Most display integrators don't have to worry about how their systems will perform while someone is trying to destroy them, or how users can quickly obtain information from a display while under extreme psychological stress. The U.S. Army does.

by Henry J. Girolamo, Clarence E. Rash, and Thomas D. Gilroy

THE U.S. ARMY is no stranger to high-tech devices. From the use of hot-air balloons for observation of troop movements during the Civil War to advanced war-training simulators, the Army has always been on the leading edge of technology. This has never been more apparent than in the recent rapid advancements in electronic miniaturization. In the area of displays, the U.S. Army is moving aggressively to take advantage of new miniaturization technologies.

"Information is power" is a well-known adage, and there is no place where it is more important than on the battlefield. The more information available to generals and individual soldiers, the greater the likelihood of a successful mission. The problem is delivering the necessary information in a coherent and timely way.

The sources and types of information have proliferated on the modern battlefield. Satellites, airborne radar planes, ground and air

***Henry J. Girolamo** is an operations research analyst at the U.S. Army Soldier Systems Command, Natick Research, Development and Engineering Center, Advanced Concepts Division, Natick, MA; telephone 508/233-5071; fax 508/233-4197; e-mail: hgirolam@natick-amed02.army.mil. **Clarence E. Rash** is a research physicist at the U.S. Army Aeromedical Research Laboratory, Electro-Optics/Visual Sciences Branch, Fort Rucker, AL 36362-0577; telephone 334/255-6814; fax 334/255-6977; e-mail: rash@rucker-emh2.army.mil. **Thomas D. Gilroy** is an operations research analyst at the U.S. Army Soldier Systems Command in Natick, MA; telephone 508/233-5855; fax 508/233-4197; e-mail: tgilroy@natick-amed02.army.mil.*

Avionics Division, Honeywell, Inc.

***Fig. 1:** Prototype of HMD for Miniature Flat Panel for Aviation program.*

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Table 1: Comparison of Flat-Panel Technologies

Technology	Advantages	Disadvantages
Active-matrix LCD	Full color Superior image quality Video speed	Limits on viewing angles Requires backlighting
Passive-matrix LCD	Low cost Simple design	Reduced resolution Slow response
Electroluminescent	Very rugged High resolution Wide viewing angle Long life	Full color questionable Inefficient drive schemes
Plasma	Large sizes High luminance	Affected by electromagnetic fields
Field emission	High luminance High energy efficiency	Questionable reliability Higher voltages required
Light-emitting diode	Low cost	Lack of full color High power requirement
Vacuum fluorescent	High luminance Wide viewing angle	Limited resolution
Electrochromic	High contrast	Problems with addressing techniques Low pixel addressing speed

reconnaissance vehicles, laser rangefinders, and automatic target-recognition systems are only a few of these sources. In fact, information saturation is a real danger. Expert systems capable of sorting, integrating, and prioritizing this information may help solve this overload problem. But, regardless of how much or how little information is available, the information must be presented to the soldier. In other words, some type of display device is needed. Until recently, the display of choice has been the cathode-ray tube (CRT).

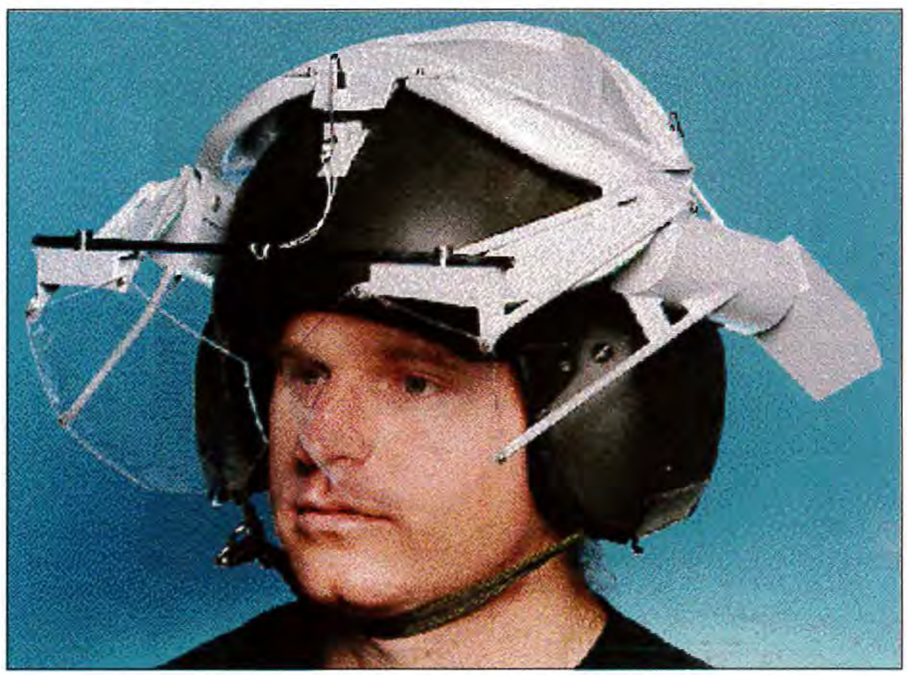
CRT displays offer dependability, low cost, and excellent image quality. But the CRT's inherent drawbacks of weight, size (primarily depth), heat generation, resolution capability, and power consumption are motivating the development of displays based on newer technologies.

FPD Technologies

CRT displays are based on a single technology: scanning electron beam. But flat-panel displays (FPDs) are based on a cornucopia of technologies, including liquid-crystal displays (LCDs), electroluminescent (EL) displays, plasma display panels (PDPs), field-emission displays (FEDs), and light-emitting diodes (LEDs) – all of which have distinct advantages and disadvantages (Table 1).

All display technologies can be classified as emissive (generating their own light) or non-emissive (requiring an auxiliary light source). EL, LED, and plasma displays are leading examples of emitters. LCDs, which act as shutters modulating the light passing through them, are the most common non-emissive type of display.

Despite their apparently recent emergence as competing display choices, these technologies are not new. The principle of electroluminescence was discovered in 1936, with the first patent for its application in a matrix display being filed in 1953. The first commercially viable LED display was introduced in 1968. The first designs for an active-matrix thin-film-transistor (TFT) LCD were proposed as early as 1968 at RCA Laboratories (now the David Sarnoff Research Center), Princeton, New Jersey, and Westinghouse Research Laboratories, Pittsburgh, Pennsylvania. But, as slow as the transition of these technologies into useful applications has been, one cannot look anywhere today and not see examples of



Aviation Applied Technology Directorate, Fort Eustis, Virginia.

Fig. 2: Advanced Visionics System HMD for CONDOR program.

Avionics Division, Honeywell, Inc.

Fig. 3: Combat Vehicle Crew (CVC) HMD.

FPDs. They are found in laptop computers, watches, hand-held televisions, electronic test instruments, calculators, and ovens - and the list goes on.

The most recent FPD applications area to emerge is the military. Weight, size, and power consumption are major concerns in the design of any device intended for military use, and displays using FP technologies are tailor-made for these three concerns. FPDs have been manufactured in sizes as small as three-quarters of an inch, measured diagonally.

Display subsystems using FPDs weigh much less than those using CRTs. This is especially significant for helmet-mounted displays (HMDs), in which miniature CRTs - with 1-in.-diameter screens - weigh 20 times as much as functionally equivalent miniature LCDs. While CRTs use operating voltages of 7000-35,000 V, FPDs use voltages of only 20-200 V. All of these advantages make FPDs perfect for integration into the 21st-century battlefield.

U.S. Army Programs

The integration of FPD technologies into U.S. Army programs has been rapid and widespread. Most of these programs can be classified by U.S. Army component, such as rotorcraft aviation, combat vehicles, medical, dismounted soldier, and maintenance. Other programs support multiple applications and are best classified as basic research and development (R&D) programs. Many of these programs are in support of integrated head-mounted display systems and are funded by the Defense Advanced Research Projects Agency (DARPA).

In 1991, DARPA established an HMD program with the goal of developing new display technologies that would overcome the technical challenges of CRTs and satisfy the strict operational requirements for HMDs. Two technologies - active-matrix electroluminescent (AMEL) and active-matrix liquid crystal (AMLCD) - were identified as the most promising display technologies. The DARPA HMD programs are directed by Dick Urban, Program Manager, DARPA, and Henry Girolamo of the U.S. Army Soldier Systems Command (SSCOM), Natick Research, Development, and Engineering Center in Natick, Massachusetts. Additional programs are funded fully or jointly by the Department of the Army (Table 2).

Rotorcraft Aviation Programs

Aviation is where the advantages of FPDs are most energetically sought. In the cockpit and, especially, on the aviator's head, space and weight are critical. Consequently, there are several aviation programs that are capitalizing on FPD technologies.

A major goal of the Miniature Flat Panel (MFP) HMD for Aviation program is investigating the use of miniature FPDs in an HMD for use in rotary-wing aircraft (Fig. 1). The program's goal is to build a prototype monochrome baseline HMD system utilizing a 1280 × 1024 AMEL image source. The MFP HMD is being developed by the Military Avionics Division of Honeywell, Inc., Minneapolis, Minnesota. The HMD will provide a 52° horizontal (H) × 30° vertical (V) field of view (FOV). The optical design is biocular with a 30° binocular overlap. The final system will consist of flight-worthy hardware and will be compatible with the U.S. Army's HGU-56/P aviator's helmet.

The program was launched in March 1994 and had a scheduled completion date of March 1997. In May 1995, a pre-baseline concept design using a 640 × 480-pixel LCD image source was completed and delivered to the U.S. Army for preliminary evaluation. A final prototype design based on a 1280 × 1024 AMEL image source has been developed, with testing scheduled for early 1997.

Another aviation application is the Aircrew Integrated Helmet System (AIHS) Comanche Compatibility program, which is an adjunct

Table 2: Overview of U.S. Army FPD Programs

Program	Application	Objective	Start date	End date
Miniature Flat Panel HMD for Aviation	Aviation	To investigate the concept of using FP technology in the development of an HMD for use in rotary-wing aircraft.	Mar 1994	Mar 1997
Aircrew Integrated Helmet System (AIHS) Comanche Compatibility	Aviation	To develop an HMD design using the HGU-56/P helmet shell that gives the Comanche developer an alternate system which capitalizes on recent display advancements.	Aug 1995	Dec 1999
Advanced Visionics System (AVS) for Covert Night/Day Operations for Rotorcraft (CONDOR)	Aviation	To develop a research HMD tool to use in investigating the impact of various display parameters on performance.	Jan 1994	Mar 1997
Combat Vehicle Crew (CVC) Head Mounted Display	Combat vehicle	To develop an HMD for providing battlefield information to tank commanders in a heads-out scenario.	Jul 1992	Jul 1995
Enhanced User Demonstration of CVC HMD	Combat vehicle	To integrate HMDs into combat vehicles and investigate human-factors issues.	Mar 1994	Aug 1997
Advanced Flat Panel HMD	Medical	To develop high-resolution (640 × 480 and 1280 × 1024) color and ultra-high-resolution (2560 × 2048) monochrome orthostereoscopic HMDs.	Jun 1994	Jul 1997
Hand-Held/Body-Worn Graphical Display System	Dismounted infantry	To develop a high-resolution portable display and computing platform for use in individual applications such as personal navigation.	Jun 1996	Jun 1998
Integrated Helmet Assembly Subsystem for the Generation 2 (GEN II) Soldier System and Force XXI Land Warrior	Dismounted infantry	To develop a helmet which provides an HMD, ballistic protection, integrated radio antenna, and integrated night-vision sensor.	Dec 1994 Evolved into LW & Force XXI LW	
Maintenance and Repair Support System (MARSS)	Maintenance	To develop an advanced lightweight body-mounted suite of electronics-integrated personal maintenance systems.	May 1995	May 1997
Advanced Microdisplays for Portable Systems	R&D/Multiple	To develop a series of color display systems with integrated drivers, control and interface logic, and novel low-power circuit techniques.	Jun 1996	Jun 1998
Micro-Opto Electro-Mechanical Systems (MOEMS) for Soldier-Based Systems	R&D/Multiple	To develop micro-opto electro-mechanical systems for head-mounted and hand-held display systems.	Jun 1996	Jun 1998
Advanced Technology for 2000 DPI HMDs	R&D/Multiple	To investigate extending resolution of AMEL and AMLCD displays to 2560 × 2048 in a 1-in. format using a 12-μm pixel pitch.	May 1994	Jul 1997
Combat Cueing (CBT-Q)	R&D/Multiple	To develop a portable tactical-information system that assists warfighters involved in small-unit operations.	Jun 1996	Dec 1998

program to the RAH-66 Comanche Helmet Integrated Display Sighting System (HIDSS). Managed by the Program Manager, Aircrew Integrated Systems, St. Louis, Missouri, the program's purpose is to develop an alternative HMD that capitalizes on the most recent advancements in displays and associated electronics. This parallel design must be compatible with the Army's AIHS, designated the HGU-56/P. This helmet meets the Army's long-term goal of fielding a single helmet usable in most, if not all, U.S. Army rotary-wing aircraft.

While not specifically requiring the use of FP technologies, the two contractors – Honeywell, Inc., and Kaiser Electronics, San Jose, California – are investigating alternative image sources and are expected to pursue designs incorporating miniature FPDs. The program's design criteria include wide FOV, head-tracking capability, biocular/monocular modes, and compatibility with Army image-intensification devices.

The first phase, which was initiated in August 1995, consisted of design-feasibility studies to analyze optimal image sources and optical-design approaches. The second phase,

U.S. Army Soldier Systems Command

Fig. 4: Demonstration of Advanced Flat Panel HMD during stereomicrosurgery at the U.S. Army Madigan Medical Center, Tacoma, Washington.

currently in progress, involves the construction and validation of a prototype design. A flight test of the final design is scheduled for late 1999.

A third aviation program is the Advanced Visionics System (AVS) program, which is the HMD subsystem being developed for the Covert Night/Day Operations for Rotorcraft (CONDOR) program. CONDOR, managed by the Aviation Applied Technology Directorate (AATD), Fort Eustis, Virginia, is a collaborative effort between the governments of the U.S. and the United Kingdom. CONDOR's goal is to couple an advanced avionics concept with an advanced flight-control system to improve rotorcraft mission effectiveness under adverse weather conditions during nap-of-the-earth flight, day or night. The AVS program is investigating the application of color displays, wide FOVs, stereo imagery, and other advanced imaging concepts to HMDs. The AVS HMD is intended for use in helicopters and ground-based simulators.

Just as important, the AVS HMD is a research tool that will enable researchers to investigate the impact of display parameters such as FOV, resolution, color, and percent overlap (Fig. 2). The AVS uses a subtractive-color AMLCD image source. Current design specifications are 120-fL peak luminance, 12:1 contrast ratio, 50° (V) × 60° (H) FOV per channel with selectable 20, 30, or 40° overlap, 1280 × 1024-pixel screen resolution, 15-mm-diameter exit pupil, and greater than 25-mm eye relief.[1] This program began in January 1994. Prototype testing and evaluation currently is in progress.

Combat-Vehicle Programs

Helicopters are not the only Army vehicles in which space and weight are limited. The Combat Vehicle Crew (CVC) Head Mounted Display program, which was completed in July 1995, developed a heads-out HMD (Fig. 3) that provides tank commanders with the vast amount of electronic battlefield information which previously was available only from the Commander's Independent Display located inside the turret. In addition, the CVC HMD allows tank commanders to track near-range threats, survey the proximal terrain, and avoid collisions with friendly vehicles and personnel.[2] The CVC HMD, developed by Honeywell, Inc., provides a 40° image and uses a 640 × 480 monochrome AMLCD developed by Kopin Corp., Taunton, Massachusetts. The HMD is a see-through binocular design with an approximate mass of 700 grams.

The Enhanced User Demonstration of the CVC HMD program has as a goal the integration of the CVC HMD into combat vehicles and the investigation of the associated human-factors issues. Specifically, the CVC HMD will be incorporated into the Army's M1A2 tank. If successful, tank commanders will have heads-up, eyes-out capability that will significantly increase situational awareness and mission effectiveness. Initiated in March 1994, the hands-on integration effort is being conducted at the U.S. Army Armor School, Fort Knox, Kentucky. The program has a scheduled ending date of August 1997.

Medical Program

With the recent increase in endoscopic surgical procedures for performing diagnostic and corrective surgery, there is a growing need to address the presentation of endoscopic medical imagery. Currently, this imagery is presented to the surgeon on CRT displays. The

Table 3: A Summary of Tests Conducted under USAARL's Display Program

Display Tests	Optical Tests	Visual-Performance Tests
Resolution	Field-of-view (FOV)	Visual field
Static MTF	Luminance transmittance	Static contrast sensitivity
Dynamic MTF	Spectral transmittance	Dynamic contrast sensitivity
Luminance range	Binocular overlap	Legibility
Luminance contrast	Exit-pupil size, shape, and location	Spatial acuity
Luminance uniformity	Focus range	Temporal battery
Chromaticity	Chromatic aberration	Vernier acuity
Gray levels	Spherical aberration	Dynamic target detection
Viewing angle	Astigmatic aberration	Peripheral target detection
Color contrast	Biocular/binocular disparities	Flicker detection
Spatiotemporal bandpass	Physical and optical eye relief	
Polarization	Refractive power	
Pixel geometry	Prismatic deviation	

Fig. 5: The GEN II/Land Warrior Integrated Helmet Assembly Subsystem (IHAS) HMD for the dismounted soldier.

Advanced Flat Panel (AFP) HMD program attempts to integrate FPD and HMD technologies as a possible way of improving imagery presentation. This approach provides a number of ergometric and functional advantages over that of a CRT.[3] The AFP HMD will present high-quality color imagery comparable to that presently available on 21-in. CRTs, provide enhanced user comfort, provide improved eye-hand coordination, and be compatible with all individual and operating-room equipment and procedures. Under the AFP HMD program, two prototype systems are being fabricated, one using an AMEL image source and one an AMLCD. System specifications include 20° (H) × 16° (V) FOV, 1280 × 1024 (24-μm) pixel pitch, 15-mm exit pupil, less than 5% distortion, 32-mm eye relief, and a head-supported weight of less than 10 oz. Because surgeons rely heavily on color and color discrimination, a major goal of the AFP will be to provide as wide a color gamut as possible. Progress, to date, includes the design and fabrication of a stereoscopic surgical borescope HMD prototype (April 1996), design validation during several arthroscopic knee-surgery procedures at the U.S. Army Madigan Medical Center, Tacoma, Washington (August 1996) (Fig. 4), and the redesign and fabrication of an advanced prototype based on feedback from the validation surgical trials. Begun in June 1994 and originally intended to last for 30 months, the AFP program has been extended to June 1997 to accommodate the development of newer image sources. The system developer is Honeywell, Inc.

Dismounted-Soldier Program

In December 1994, the U.S. Army began a major program called the Generation 2 (GEN II) Soldier System. This program has evolved into the Force XXI Land Warrior (LW) program. The goal of this program is to enable dismounted infantry to operate more effectively and efficiently on the digital battlefield. LW's intent is to enhance soldier mobility, sustainability, survivability, and command/control capability. An LW subsystem, Honeywell's Integrated Helmet Assembly Subsystem (IHAS) will provide ballistic protection; advanced communications capability; an integrated night-vision sensor; an HMD for viewing computer data, sensor data, and imagery; and may integrate a head-orientation sensor.[4]

The IHAS HMD (Fig. 5) will use a 640 × 480 miniature FPD, with potential growth to a 1280 × 1024 display as part of the Force XXI technology insertion. An added feature is the incorporation of an automatic brightness function to adjust for background-illumination levels. The IHAS is expected to be a monocular, see-around optical design that can be positioned over either eye. System parameters include a 40° (H) × 32.5° (V) FOV, a 14-mm exit pupil (12 mm off axis), and a 26-mm eye-relief distance. Initial deliveries of the LW system have been completed and field testing is currently under way. Program developers for GEN II and Force XXI LW are Hughes Defense Systems, El Segundo, California; Motorola, Scottsdale, Arizona; and Honeywell, Inc.

Maintenance Programs

As advanced-technology systems increase their presence on the front lines, the technical

McDonnell Douglas

Fig. 6: Artist's conception of the Maintenance and Repair Support System (MARSS).

data and the knowledge required to maintain them will also increase. The Maintenance and Repair Support System (MARSS) program's goal is to develop an advanced, lightweight, body-mounted suite of electronics-integrated personal maintenance systems. The planned result is an open-architecture system consisting of a wearable personal computer with object-oriented software that controls and integrates plug-in measurement instrumentation, diagnostic processes, interactive electronic technical manuals, and logistical databases for the soldier.

System input/output are achieved via a head-mounted microphone and an AMEL FPD. MARSS will have wireless local-area-network (LAN) interaction with the weapons-system data bus and with other members of the maintenance team, which will allow transmission of fault and diagnostic data. The system will also incorporate data storage of multimedia repair-and-replace instructions on removable data-storage cards. All electronics are packaged into a vest garment (Fig. 6) having a total weight of less than 12 lbs. The display uses a 640 × 480 AMEL image source. The MARSS program began in May 1995, with a scheduled completion date of May 1997. McDonnell Douglas, Huntsville, Alabama, is the prime contractor on this program. Honeywell, Inc., is the HMD developer.

R&D and Multiple-Application Programs

There are a number of programs that have as goals the development of display-related subsystems or the investigation of improvements such as pixel resolution or microelectro-optics. These goals can be considered basic or applied R&D and be leveraged against current and future programs.

The Advanced Micro Display for Portable Systems program is an effort to develop advanced micro - less than 1 in. - displays for use in portable hand-held display systems. This is a continuation of past developmental programs to explore miniaturization of electronic displays. The program plans to capitalize on the ability to integrate high-performance digital and analog circuity on a single CMOS substrate together with the highest spatial-resolution color-triad reflected-mode AMLCDs ever fabricated.

This program will attempt to extend the frontier of display technology by developing and demonstrating:

- An unprecedented level of portable micro-display systems-integration technology with an emphasis on application-specific single-chip devices that incorporate communications, computing, and display circuitry.
- A new generation of ultra-low-power active-matrix and LC drive electronics based on newly developed adiabatic charge-recovery logic techniques, new low-power bistable LC materials, new integrated illumination and drive techniques, and reflected-mode operation.
- A new generation of AMLCD manufacturing technology to rapidly fabricate application-specific low-cost micro-displays.

This 2-year program began in June 1996. The system developer is MicroDisplay Corporation, Richmond, California.

The Micro-Opto Electro-Mechanical Systems (MOEMS) for Soldier-Based Systems program is a research effort to develop micro-miniature photon-beam-scanning devices that can be used in head-mounted and hand-held display systems. MOEMS will greatly reduce the weight and size of displays, optical devices, and sensors. The display systems will have high resolution, light weight, low power requirements, and a revolutionary smaller image source. MOEMS have the capacity to be integrated into current soldier-worn eyeglasses and wristwatches. The 2-year program was awarded in June 1996. The system developer is MicroOptical Corporation, Boston, Massachusetts.

The goal of the Advanced Technology for 2000-dpi HMDs program is to extend high-resolution AMLCD and AMEL displays to 2560 × 2048 pixels in a 1-in. format using a 12-μm pitch. In this program, DARPA is funding a research effort to continue the development of these high-resolution displays based on single-crystal silicon (x-Si). The displays utilize x-Si monolithic scanner circuitry and are fabricated using standard foundry processing to attain high speed, high yield, and wafer-based integrated processing.[5]

The approach being taken is to design, build, and test a variety of pixel configurations in 256 × 256 arrays, evaluate process options, design the scanner and control circuits, and then insert the optimized 12-μm pixel into the full 2560 × 2048 AMEL and AMLC display arrays with 2000-dpi resolution. These displays will then be integrated into the various DARPA and U.S. Army HMD programs for demonstration. Additionally, color filters will be added to both the AMELs and AMLCDs to produce 1280 × 1024 color displays.

The 2560 × 2048 displays will be demonstrated first in the AFP HMD program. The 2000-dpi display development program began in May 1994. The technical efforts were planned to last for 36 months, with a final program completion date of July 1997. This program is a collaboration among Kopin Corporation, Planar Systems, AlliedSignal Aerospace, Massachusetts Institute of Technology, and the University of Colorado.

A final DARPA-funded program that has broad application is the Combat Cueing (CBT-Q) program. Its goal is to develop a portable tactical-information system that assists warfighters involved in small-unit operations. The CBT-Q system will detect an enemy transmitter and instantly provide the warfighter with the emitter's position. CBT-Q technology can support land, sea, and air operations. The CBT-Q concept consists of three portable sites – two scout sites and one base site. Geolocation using the three sites, combined with global-positioning-satellite data, can pinpoint an enemy position. HMD and FPD systems and technologies developed under other DARPA programs will be leveraged to serve as the primary mode for presenting this information. Initiated in June 1996, this program is expected to demonstrate a prototype system by December 1998. The system developer is Raytheon E-Systems, Falls Church, Virginia.

Test and Evaluation

The numerous programs described here show great promise and will greatly enhance the effectiveness of the 21st-century warrior. However, the advantages of FP technologies and their myriad applications, both commercial and military, must be placed in perspective. There is no such thing as a free lunch. Just as the excellent image quality of CRTs is balanced by the problems of weight, size, and power, FPDs have their own disadvantages.

One serious concern of the U.S. Army engineers and scientists responsible for characterizing display performance in military applications involves the interaction of the time constants associated with the various sensors and displays. The issue of image smearing, present in some CRT display environments, is believed to be an even bigger issue with several types of FPDs. Dynamic effects are only one of several areas of concern with these new displays. A list of the disadvantages of the various FPD technologies is presented in Table 1, but it must be noted that the flat-panel industry is extremely active in addressing these disadvantages. Indeed, while it is unlikely that all the disadvantages will be overcome, tremendous improvements in brightness and producibility have been made within the past year, and there is every reason to expect continued improvements.

However, with or without solutions to the remaining problems, it is necessary to evaluate display performance – especially as it pertains to user visual performance. So, in addition to the testing done by system developers, all displays built under the auspices of the various programs are subjected to a formal U.S. Army test-and-evaluation (T&E) program.

Historically, this T&E has been conducted at the U.S. Army Aeromedical Research Laboratory (USAARL), Fort Rucker, Alabama, which has over 25 years' experience in display research and evaluation. USAARL researchers have contributed to all major U.S. Army display programs, including the Integrated Helmet and Display Sighting System (IHADSS) used on the AH-64 Apache helicopter, the Aviator's Night Vision Imaging System (ANVIS), and the Helmet Integrated Display Sighting System (HIDSS) under development for the RAH-66 Comanche helicopter.

The USAARL display research and T&E program, under the direction of Clarence E. Rash, provides a solid foundation for both T&E and problem-solving for electro-optical display systems. It consists of an experienced team of physicists, engineers, and vision scientists. The program provides a comprehensive testing of display parameters, optical-system parameters (for HMD systems), and visual performance (Table 3).

In Conclusion

This review of major FPD programs most recently pursued by the U.S. Army provides strong evidence for the aggressiveness with which the Army is capitalizing on new and rapidly expanding display technologies. These displays provide the capability to place compact and lightweight display systems in the hands and on the heads of the modern soldier, whether he or she is on the ground, on the road, or in the air.

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Optical Engineering for Display Systems

Adding an optical engineer to the design team can reduce the cost and improve the performance of a display-dependent product – and differentiate the product from its competitors.

by Kevin Garcia

EVERY INFORMATION-DISPLAY SYSTEM contains some kind of optical system. To make informed decisions regarding optical performance and components in display systems, managers, design engineers, systems engineers, and manufacturing engineers need to understand the key aspects of optical-components engineering for information-display systems.

Display systems contain two kinds of optical subsystems: those intended for imaging and those intended for illumination (Fig. 1). Imaging components produce an image of an object, typically on a viewing screen. Illumination components supply light to the object. A liquid-crystal-display (LCD) projector system, for example, consists of an illumination system that supplies light to the LCD (the object) and a lens system that images the LCD onto a viewing screen. Even backlit laptop-computer screens and cathode-ray-tube (CRT) screens have illumination systems. In these cases, the human eye provides the imaging function.

Optical engineers compute the first-order properties, aberrations, and photometric characteristics of the imaging and illumination components, both individually and as a system. ***First-order properties*** refers to the image properties of the optical system. ***Aberrations*** are deviations from the image quality that would be produced by an ideal optical system. ***Photometric parameters*** describe the amount and physical characteristics of the light in the image transmitted by the optical system.

The mathematical models used by optical engineers stem from the traditional optical subdivisions known as geometrical optics and physical optics.

Geometrical optics simulates light as a series of lines, or "rays," propagating through space. ***Physical optics*** models light as a wave phenomenon, which accounts for diffraction. The rays of geometrical optics are generally the normals of the wavefronts of physical optics.

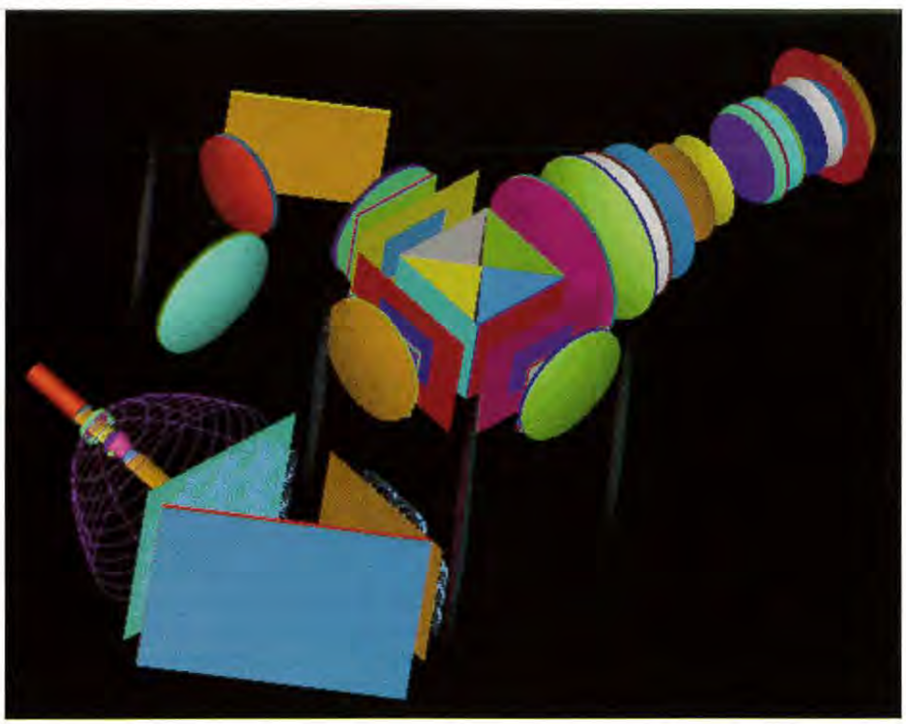

Fig. 1: A complex projection system with imaging and illumination subsystems. (Courtesy of In Focus Systems)

***Kevin Garcia** is the former Director of Optical Engineering Services at the Breault Research Organization (BRO), 6400 E. Grant Rd., Suite 350, Tucson, AZ 85715; telephone 520/721-0500; fax 520/721-9630; e-mail: kgarcia@breault.com. He now serves as a technical and business consultant to BRO.*

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Designing Imaging Components

Optical engineers determine the first-order properties of an imaging system by computing quantities such as projector-system magnifications, depths of field and focus, estimated resolution, and the geometrical location and size of the LCD image on a screen. The first-order design of the optical system is laid out as a thin-lens model - a model that simplifies calculations by assuming ideal thin lenses.

The basic theories and equations used in the thin-lens model - such as the imaging equation - are quickly presented to most physics and engineering college students in the 2 weeks devoted to optics in their electrodynamics course. These parameters are treated in a strictly geometrical manner; in fact, they can be derived from purely geometrical arguments. They can also be derived from the first-order terms of the power series expansion of a ray-tracing equation.

Computing the aberrations of the imaging subsystem is usually done by ray tracing. Optical aberrations are departures of the optical system's performance from ideal behavior. The computation of these aberrations is generally based upon the concept of a point source.

Light travels as rays from an idealized source of light that is located at a single mathematical point: the ***point source***. Real objects can be thought of as extended sources made up of individual point sources. These point sources on the object are called ***field points*** or (for objects that can be considered to be infinitely far away, such as stars) ***field angles.***

If all the rays from a field point in the object space (an LCD, for example) travel the same distance as they propagate through the optical system and then cross at a single conjugate point in image space (the screen, for example), then ideal behavior results: a point images to a point. If the point source is not brought to a point in the image plane, then the system suffers from aberrations. The most common aberrations are spherical aberration, coma, astigmatism, field curvature, and distortion. There are also chromatic aberrations due to dispersion of the light by the glasses in the projector optics: light at different wavelengths encounters different indices of refraction in the glass, so all the colors do not focus at the same point.

Ray tracing is simple enough to be done even in high-school mathematics classes. A ***ray trace*** involves intersecting a line (the ray) with a mathematical surface, which is equivalent to finding the roots of two equations simultaneously. The laws of refraction (Snell's law) and reflection are applied to optically transform the ray.

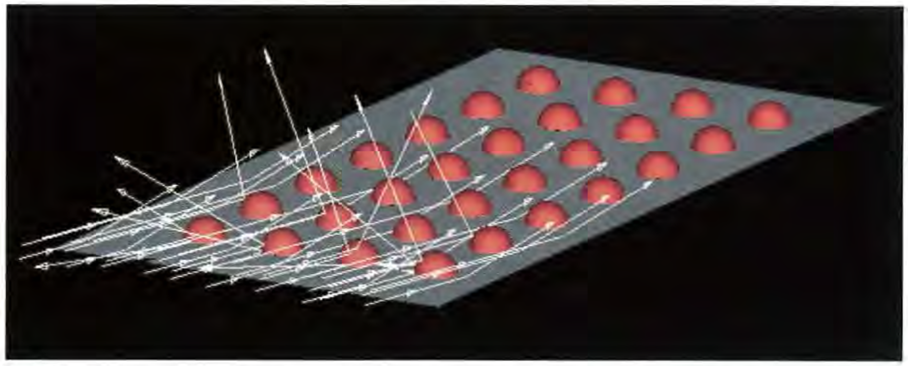

Fig. 2: A backlight system using a cavity and fluorescent tubes.

Calculations for ray tracing and computing aberrations are typically done by specialists who use lens-design programs. Today, a prescription for an actual thick-lens optical design is not produced immediately after the creation of the first-order design. Instead, the optical designer uses the first-order design or an existing patent as a starting point for a lens-design software package.

Lens-design codes ray-trace optical systems and give optical designers a powerful tool for optimizing the elements of the optical system. By minimizing a merit function, these programs automatically change the lens radii, refractive indices, and thickness of lenses (*i.e.,* the optical prescription) in projector systems to improve the image quality. A common figure of merit in such systems is the size of the spot to which a point source is imaged. The lens-design code changes the optical prescription to produce the smallest geometrical spot size. Many lens-design codes are available commercially. The optical-design engineers here at the Breault Research Organization (BRO), for example, use a lens-design code called Synopsys™ (Synthesis of Optical Systems).

Most optical-engineering problems, especially imaging problems, can be simulated by geometrical optics. If all of the aberrations of an optical system are corrected, then the system is ***diffraction-limited.*** The minimum possible spot size in the imaging component is determined entirely by diffraction, and, therefore, so is the imaging resolution.

A diffraction-limited optical system can be achieved by spending enough money, but how good is that? How does one know if the projector lens can resolve and image the pixels of the LCD onto the viewing screen without significant degradation?

A common rule of thumb is that the minimum on-axis spot size that a lens can produce is the f-number of the lens in microns. The ***f-number*** is the effective focal length of the projection lens divided by its clear aperture. This f-number definition is the same as that used in photography and is an indication of the "speed" of the optical system. For example, an f/2 system is considered "fast" and will produce a minimum spot size of approximately 2 μm at the viewing screen.

Lens-design software also computes image resolution for projection systems using a geometric or diffraction model. The software can also determine resolution as a function of field position or angle. Yes, unfortunately, the resolution of a display system changes with field position because most of the aberrations in an optical system, which affect resolution, also change as a function of field position or angle.

A more comprehensive measure of resolution is the ***modulation transfer function (MTF),*** which is well known to CRT designers. The MTF is a plot, at many field positions, of the resolution of an imaging system in terms of a normalized contrast ratio as a function of spatial frequency. This definition may be too compressed for readers who aren't already familiar with MTF. For more information, see Warren Smith's book [*Modern Optical Engineering*, 2nd ed. (McGraw-Hill, New York, 1990)], which is an excellent resource for optical-engineering information.

Resolution issues are not limited to the projector optics. The eye is the final optical system for all display systems. Most optics texts give the eye's minimum resolution as 1 arc minute.

Determining the photometric behavior of the display system involves computing how much light gets through the optical system onto the screen – the total screen lumens. Optical engineers also compute screen uniformity and color rendition.

Transmission losses in the imaging subsystem reduce the total screen lumens, and optical coatings can minimize these losses. Therefore, although the imaging component affects screen uniformity, it does not produce the drastic effects that the illumination component can sometimes produce. The ***illumination uniformity*** – measured in lumens/unit area – across the screen is generally a function of the fourth power of the cosine of the angle from the optical axis. The illumination uniformity in systems without projection lenses must often be computed differently, as a function of system geometry and optical properties.

The imaging component affects color rendition primarily through LCD and coating performance. Colors are usually described in terms of CIE color coordinates.

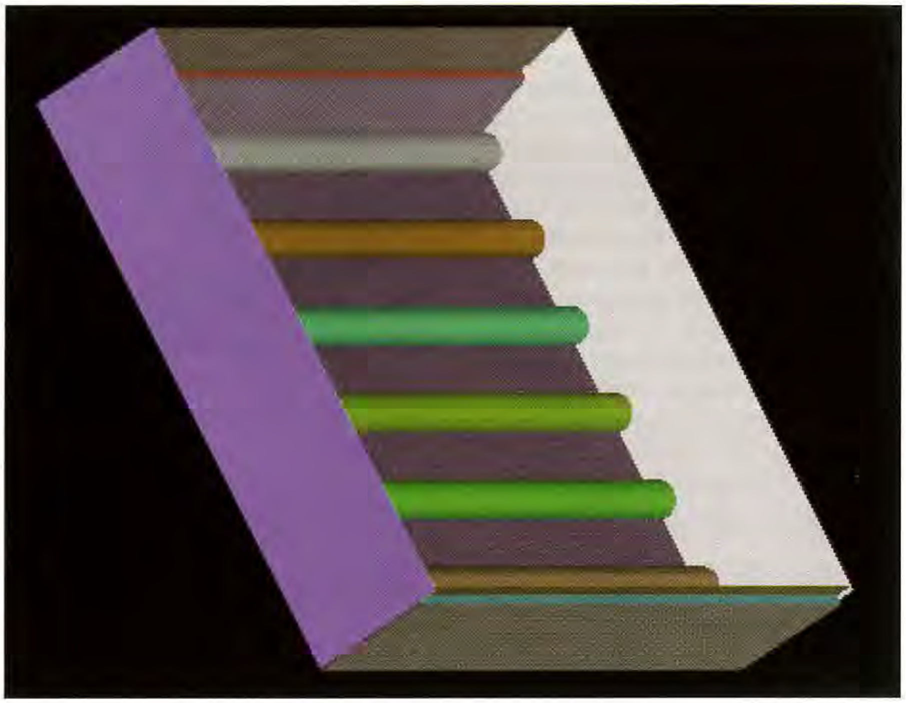

Fig. 3: A peened surface – one that has small bumps or dimples – is used on light pipes to spread light without scattering losses.

Designing Illumination Components

The illumination subsystem supplies light to the object to be imaged: an LCD, for example. *Rule one:* There is never enough light. The brightness of the image is limited by the brightness of the light source and the geometry of the system because throughput is conserved.

Many optical engineers refer to the throughput as the ***A-omega product*** because it is the product of the cross-sectional area of a beam at a location in the optical path (A) and its projected solid angle (omega). The ***luminance*** – lumens/projected area/solid angle – of the image at the screen is the luminance of the LCD (or source) less the transmission losses from the optical system. A calculation of the throughput at the beginning of the design process can help determine if the illumination component will meet brightness requirements.

The displayed object, such as an LCD, can introduce a significant light loss into the system. The extended sources used in the illumination systems emit randomly polarized light, but the crossed linear polarizers used as light-conditioning components in the LCD will transmit only about 50% of this light.

The most common types of illumination systems for displays are critical and Köhler systems. In a ***critical illumination system***, the object is illuminated by a diffusing screen or diffusing cavity. If a diffusing screen is not used, fluorescent tubes are commonly used as sources, with a redirecting light pipe (Fig. 2). Lambertian diffusing screens and sources, such as white paints and fluorescent tubes, have a uniform brightness and a luminous intensity (lumens/solid angle) that falls off with the cosine of the angle from the surface normal.

In a practical sense – though not in principle – diffusers destroy the conservation of throughput. These devices drastically increase the solid angle into which a given amount of power is redirected. Subsequent optical elements cannot capture all the light and "see" a reduced luminance. Consequently, many backlit systems use peened surfaces in light pipes (Fig. 3). (***Peened surfaces*** have small bumps or dimples. Peening the surface of a light pipe causes light to spread without scattering losses.)

Critical illumination systems are most commonly found in backlit display systems, such as laptop computers and consumer electronics. They are not sufficiently light-efficient to be used with projection display systems.

Projection display systems often use some variant of the ***Köhler illumination system***, in which the object is placed close to the source while the source is imaged to the entrance pupil of the projector lens. (The ***entrance pupil*** is the image of the aperture stop formed by all of the optical elements located before the aperture stop. The ***aperture stop*** is the physical aperture in the projector lens assembly that limits the amount of light through the optical system.) By imaging the source to the entrance pupil of the projector lens, optical engineers maximize the amount of light getting through the aperture stop. These types of projection systems can be quite complex, with arrays or mosaics of lenses imaging the source to the object (Fig. 1).

Optical engineers also use ray-tracing tools to simulate and design illumination components. However, they typically do not use automated optimization in the design because hundreds of thousands, if not millions, of rays would be needed to achieve a realistic picture of the photometric behavior of the display system. Because such ray traces are very time-consuming, they cannot be efficiently coupled with automated design.

Another limitation on the use of traditional optical-design codes is that they are rarely able to simulate the unusual nature of illumination surfaces, such as a light pipe with its peened structure. Moreover, they typically lack the algorithms needed to simulate complicated phenomena such as simultaneous reflection and refraction (or scattering) at optical interfaces.

Fortunately, powerful optical-engineering simulation programs exist for these problems. At BRO, for example, optical engineers use a package called the Advanced Systems Analysis Program (ASAP) that can perform these types of computations. But just as electronic-design software assists circuit designers without replacing them, optical-design software still requires the insight and experience of optical engineers, along with their knowledge of state-of-the-art design of the illumination component.

Display-System Design

Companies making display systems have several choices. They can buy an existing design, contract out the optical design, or develop the design in-house. A company that decides to do the design work itself must be prepared to develop the internal resources necessary to accomplish the task. Simply acquiring commercially available software and turning a convenient person loose on the problem will almost certainly prove to be penny wise and pound foolish.

The interaction of an optical engineer with display engineers, electrical engineers, and mechanical engineers in the development of a display-dependent system is likely to produce significant insights that can reduce costs, improve performance, and/or differentiate a product from its competitors. For example, using a smaller polysilicon TFT-LCD with finer pixel pitch (compared with an amorphous TFT-LCD) may allow substantial savings in the size, weight, and cost of optical components that more than compensate for the cost of the premium display. ■

FED Phosphors: Low or High Voltage?

Viewability depends on display brightness, and low-voltage phosphors simply don't have the luminous efficiency to be bright enough.

by Ronald O. Petersen

SEVERAL DISPLAY DEVELOPERS have attempted to use field-emission cathode technology to manufacture flat-panel emissive displays. Target applications include portable displays with low power consumption, large viewing angle, and large operating-temperature range. But viewability is the critical factor in attracting users to color field-emission-display (FED) technology, and the single most important factor influencing viewability is the brightness of the display.

Today there are two near-viewable, commercially available FEDs operating at an anode voltage near 200 V. Each uses a monochrome ZnO:Zn phosphor, and each has a specified brightness of approximately 300 cd/m^2. Because these displays have no internal mechanism – such as black surround or pigmented phosphors – for contrast improvement, their contrast ratios (CRs) are relatively poor (from 20:1 to 40:1 in a dark room). Operating these monochrome displays at approximately 800 V can produce a luminance close to 2000 cd/m^2.

Even without contrast improvement, the 800-V blue-green emissive display is very viewable in office conditions. The luminous efficiency for ZnO:Zn powder in a back-reflection mode can be as high as 13 lm/W at 500 V. But color displays are a different story. To date, there is no low-voltage ZnO:Zn phosphor equivalent with good RGB color coordinates. The standard P43 green phosphor, for example, has a back-reflection powder-compact luminous efficiency of only 8 lm/W at 500 V. Question: How efficient must RGB phosphor emission be, and can sufficiently efficient emission be achieved at low voltages?

Ronald O. Petersen is principal staff engineer at Motorola's Flat Panel Display Division, 2100 E. Elliott Rd., Tempe, AZ 85284; telephone 602/413-5930; fax 602/413-5934; e-mail: a338aa@email.sps.mot.com. This article was adapted from the author's paper presented at the 1996 International Display Workshops (IDW '96), Nov. 27–29, 1996, Kobe, Japan.

Viewability Modeling

Viewability is influenced by the ambient illumination reflected from internal and external surfaces, the pixel size and spacing, and the

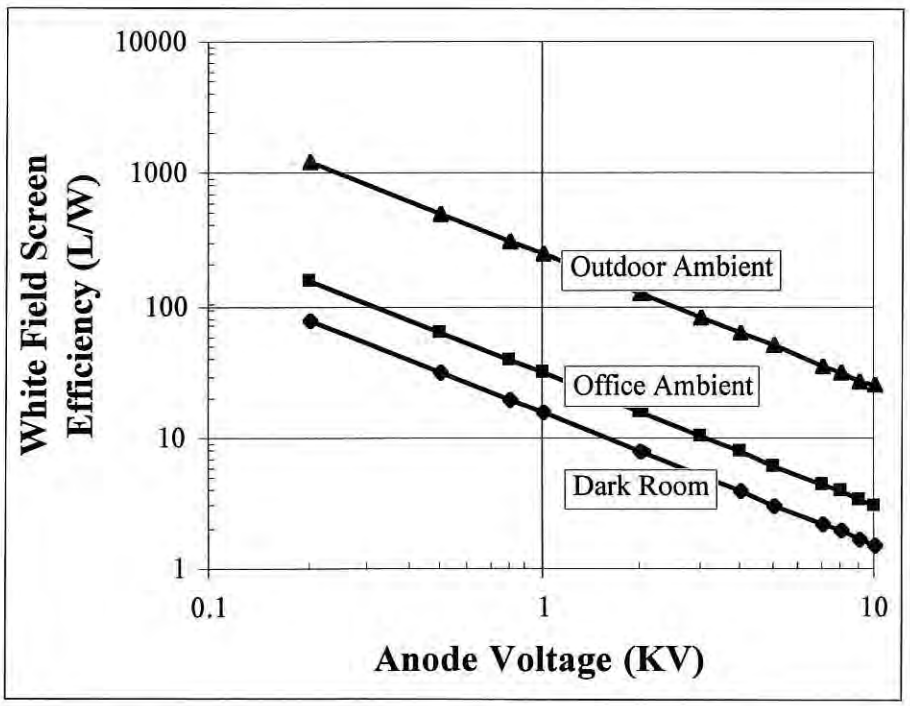

Fig. 1: The required white-field screen luminous efficiency for an FED under three important ambient-illumination conditions. The time to visibility was kept constant at 2 s, and the current density is 1 μA/cm^2.

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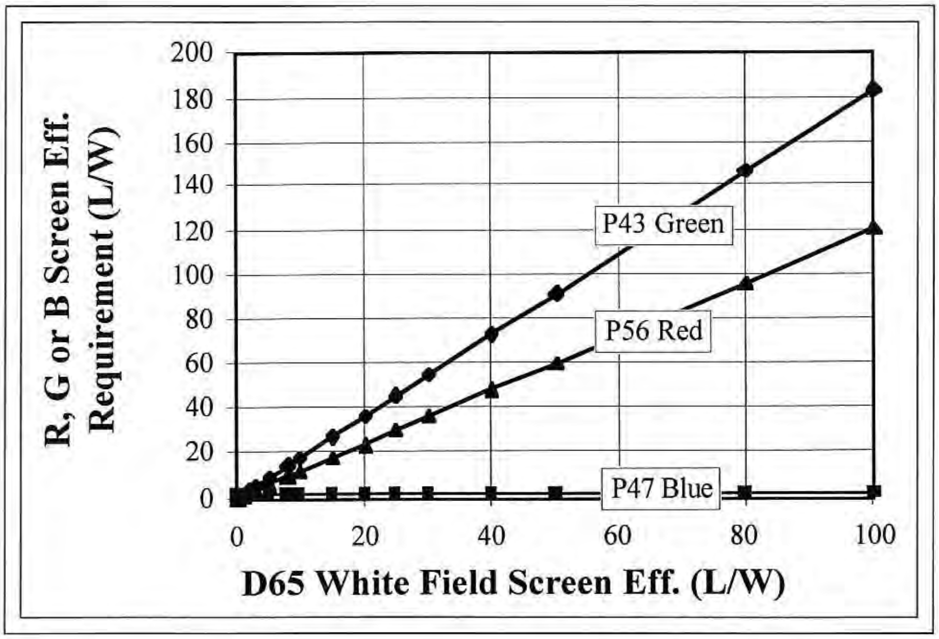

Fig. 2: *Any desired D65 white-field luminous efficiency requires specific luminous efficiencies from the red, green, and blue phosphors used in the display.*

contrast ratio of the display. Just how bright must the display be before it can be considered viewable?

The final test of a display is the viewer's approval. This is an easy judgment, not requiring information about display characteristics. However, because display characteristics generally do not incorporate an understanding of the vision processes of the eye and brain, early display engineers did not have a quantitative measure of overall display quality.

In the 1950s, Otto Schade made a major contribution to display science by deriving the contrast-sensitivity function (CSF). Other measures include the modulation transfer function (MTF) of the display and the modulation threshold function of the eye. [Measures of subjective image quality were reviewed by Peter Barten, "Evaluation of subjective image quality with the square-root integral method," *Journal of the Optical Society of America A*, **7**, No. 10, 2024 (1990).]

Display engineers now know that the human visual system's contrast sensitivity can be represented as the outer envelope of a bank of spatial-frequency filters having different center frequencies. [See Curt Carlson's "Economic Display Design," in *Information Display* **4**, 16 (May 1988).] Changes in the MTF result in perceivable changes that can be quantified by asking viewers when a change produces a just-noticeable difference (JND) in picture quality. One JND is the amount of change in image sharpness that can be perceived by viewers 75% of the time. A 3-JND change can be seen 99% of the time, and 10 JNDs constitute a significant change.

Another factor influencing viewability is the speed at which the human eye can detect changes. Through manipulation of ambient lighting conditions and the forward-field-of-view (FFOV) adaptation illumination, one can determine the time to visibility (TTV) of the display. Knowledge of the TTV, ambient lighting, and contrast ratio allows one to predict the desired white-field brightness for a display.

Brightness Requirements

It is useful to consider three ambient environments, each with a spectral distribution equivalent to the D65 standard illuminant:

- A semi-dark room with 50 lux of illumination
- A typical office with 1000 lux of illumination
- Typical outdoor daylight conditions with 50,000 lux of illumination.

Under these ambient conditions, and assuming a TTV of 2 s, the required space-average white luminance intensity and CR for a non-pixelated display are 50 cd/m^2 with a CR of 20:1 for the dark room; 100 cd/m^2 with a CR of 8:1 for the typical office; and 800 cd/m^2 with a CR of 2:1 for the outdoors in daylight.

With this background, we can calculate the white-field luminous efficiency in lumens per watt (lm/W) at a current density of 1 μA/cm^2 required for acceptable RGB screen efficiencies in an FED (Fig. 1). The figure indicates that the required luminous efficiency is too high by far for any existing phosphors excited at 200 V. At 5 kV, the white-field luminous efficiency at 1 μA/cm^2 would be within reason for dark-room and office ambients, and questionable for outdoor ambients. Higher current densities at the low excitation voltage could resolve this problem, but aging and saturation effects are of concern at higher current densities.

One soon-to-be-commercial color FED color uses P56, P43, and P47 phosphors for red, green, and blue, respectively. Using the model and white-field brightness just described, we can calculate the required RGB luminous efficiencies for displays with anode voltages of 500 and 5000 V. At 500 V, the required luminous efficiencies are 60 (red), 3 (blue), and 90 (green) lm/W (Fig. 2). Since actual back-reflection powder luminous efficiencies are 2.2 (red), 0.2 (blue), and 7.9 (green) lm/W [as reported by S. Yang and his colleagues in "Characterization of potential low-voltage phosphors for field-emission devices," *Proceedings of the IS&T/SPIE* **2408,** 194 (1995)], they are far too low to meet the objectives of D65 white-field emission with a luminance of 100 cd/m^2 and CR of 8:1. To make things even worse, the cited back-reflection screen luminous efficiencies are generally larger than the transmission values. When, in addition, you take into account the contrast-enhancement filters required to achieve the desired CR and light absorption resulting from phosphor-screen thickness, even more light is lost to the viewer.

At 5000 V, the screen luminous efficiencies would need to be 3.6 (red), 3.0 (blue), and 5.5 (green) lm/W. Yang and his colleagues reported values of actual phosphors as 9 (red), 3 (blue), and 21 (green) lm/W at 5000 V, so the situation here looks much better. Even taking into account phosphor-screen absorption and 30% losses in a neutral-density filter,

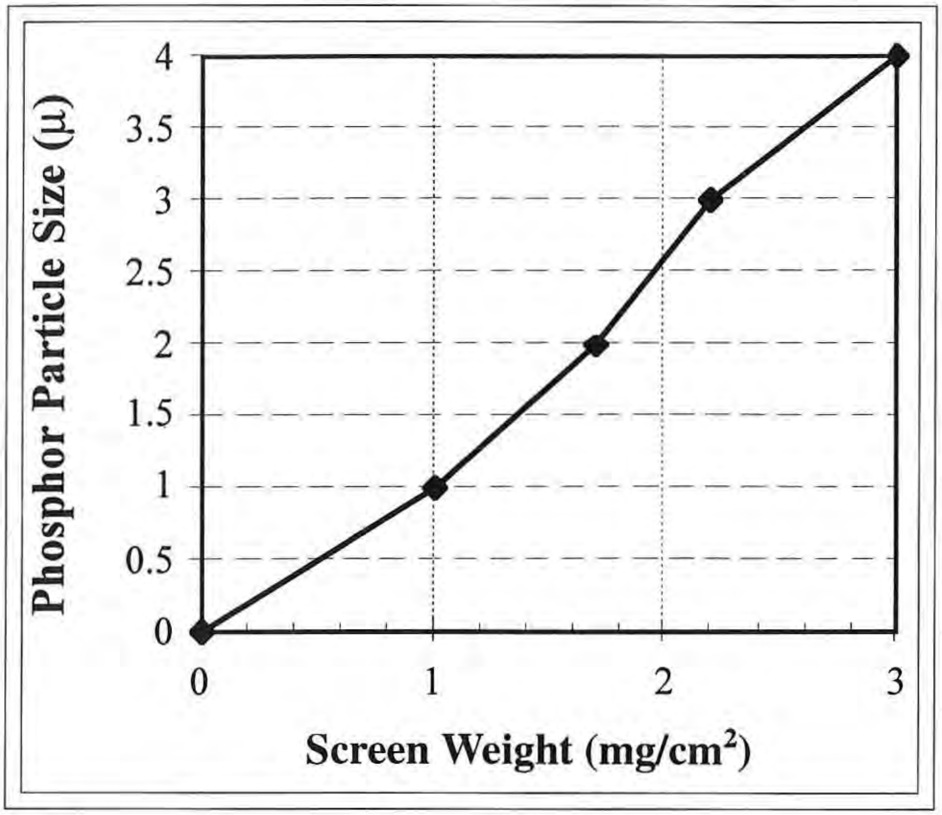

Fig. 3: Phosphor-screen weight is a function of particle size for 100% coverage. [From Z. Bodo and I. Hangos, Acta Physica Acad. Sci. Hung. *5, 295 (1955); J. Weiszburg and I. Hangos,* ibid. *10, 359 (1959).]*

the red and green luminous efficiency would be acceptable, although the blue emission is still marginal.

Choosing Phosphors

It is clear from the foregoing discussion that low-voltage color FEDs are not practical. While the ZnO phosphor for monochrome displays is very efficient at 500 V, it still yields insufficient light for outdoor viewing unless the screen current density is increased. High-voltage efficiency, on the other hand, is adequate with the P43 green phosphor and the P56 red phosphor.

The P47 blue phosphor does not have adequate luminous efficiency even at high voltage, but Yang and his colleagues report that the P55 blue phosphor has a luminous efficiency of 4 lm/W. Unfortunately, P55 is a ZnS phosphor, and sulfur-containing phosphors evolve sulfur during electron excitation, which results in reduced cathode performance.

In addition, the optimum "screen weight" of 5000-V phosphor screens is near 1 mg/cm^2. Under these conditions, for 100% screen coverage the particle size would have to be about 1 μm in diameter (Fig. 3). Unfortunately, 1-μm RGB phosphors with good luminous efficiency are not available: commercial materials run between 2 and 3 μm. The increased screen weight from such particle sizes would reduce even P43's screen brightness to an unacceptable level for FED use.

The situation is a bit complicated. Generally, optimum screen brightness is proportional to particle size and screen weight; *i.e.,* at lower excitation voltages, smaller particle size and lower screen weight are required to yield optimum luminescence (electron-to-light conversion) and light transmission through the phosphor-powder screen to the viewer. For 5 kV, the particle diameter would need to be near 1 μm and the screen weight would need to be near 1 mg/cm^2. In addition, the phosphor with 1-μm particles would need to have an intrinsic efficiency similar to that of today's phosphor particles that measure 3–6 μm in diameter.

Spherical phosphor particles pack more densely than polyhedral particles, resulting in a thinner phosphor screen. This can increase light transmission by 50% and improve spot resolution by 10%. However, conventional commercial phosphors have polyhedral particles.

Proper selection of particle size and shape determines the maximum screen brightness for a given phosphor type. But one also needs to deal with the saturation effect of traditional CRT phosphors when they are used in an FED. Because the e-beam dwell time of a matrix-addressed FED is about 1000 times greater than that for a CRT, saturation of FED phosphors is a real issue. This is particularly true for FEDs operating at the lower anode voltages, where the current density is higher and the electron penetration depth is very shallow. The P43 green phosphor saturates with particular readiness, the degree of saturation increasing with decreasing excitation voltage.

Conclusions

(1) High-voltage color FEDs will be the most practical in the near term. But more-efficient blue phosphors are required, and this may require us to deal with sulfur containment.

(2) Optimum performance at 5000 V requires a very small particle size, which is not currently available. If the particles were spherical instead of polyhedral, screen performance would be enhanced.

(3) Low-voltage color FEDs will not be daylight-viewable unless there are improvements in phosphor efficiency, saturation, and aging performance.

(4) RGB FEDs for viewing in office and daylight environments will operate at higher than 300 V for the foreseeable future. ■

Participants at CIC 4 Share Achievements and Disappointments

Halfway into their journey of a thousand miles, color engineers find that they have succeeded brilliantly ... but that the ultimate goal keeps receding.

by Ken Werner

THE FOURTH convocation of the Color Imaging Conference (CIC), held from November 19–22, 1996, drew 280 color scientists and engineers to the Radisson Resort in Scottsdale, Arizona. This attendance is a record for the conference, jointly sponsored by the Society for Information Display (SID) and The Society for Imaging Science and Technology (IS&T), up from 232 in 1995.

Color science had its roots in the photographic and printing industries, and has participated in the analog electronic arena for years. But with digital and computational electronics, color science found not only new areas of application but a market for a color-science-based engineering discipline. This was the origin of "color engineering," a term coined by Jim King of Adobe Systems at CIC 2, and now routinely used to describe many of the activities covered at CIC.

Indeed, "the technology is now pushing the science," said Mark Fairchild, Associate Professor of Color Science and Imaging Science at the Rochester Institute of Technology's (RIT's) Munsell Color Science Laboratory in Rochester, New York. This is a far cry from CIC 1 in 1993, Fairchild told *ID*, when people were asking what it was we needed to do. "There is now general agreement on what is needed, and people are focusing on how to do it. The pieces are coming together in a reasonable way, but progress has been slower than anticipated.

"The reason for that is that each time we solve a piece of the color puzzle, we find there are more pieces than we originally thought. First, we thought that most of the puzzle resided in the 'color matching problem.' But when we learned how to match colors accurately, we found that even when colors *are* physically the same they often don't *look* the same.

"So we had to go ahead and solve the 'color-appearance problem.' That one is actually harder than the color-matching problem, but we're making good progress. However, we now realize that even if you get the color-appearance piece down perfectly, there is still the issue of what colors people *prefer*.

"The very common problem of gamut mapping – finding substitutes, for example, for the CRT colors a printer cannot reproduce – comes down to selecting the color you *prefer* when you can't get the color that *appears* the same. To put it another way, once you know that the sky should be blue, how blue do you prefer it to be?"

The issue of approximate appearance matches and implementable standards that are practical for particular applications – such as digital photography or Web-based publishing – was to come up repeatedly during the conference. Two recent standards that will affect makers of displays or display-based systems were described during the standards session.

Christopher R. Hauf and J. Scott Houchin of Eastman Kodak, Rochester, New York, described the recent FlashPix™ image file format. FlashPix features multiple resolutions, tiled sub-images, structured storage, optional JPEG compression, multiple color-space options, and the incorporation of descriptive and non-image information. As a result, a low-resolution rendition of an image can quickly be loaded from a hard drive or over the Web and rapidly edited, with the high-resolution version receiving the changes only when needed. The tiled sub-images allow a user to go directly to an area of an image that is to be selected without having to load the entire image.

The storage structure allows many images to be used on-screen at once, with memory requirements never exceeding the amount of data needed to fill the screen – usually between 1 and 3 Mbytes, rather than the tens of megabytes required by many current applications.

FlashPix is consistent with OLE, uses defined color spaces and the International Color Consortium's (ICC's) embedded color profiles for accurate display and printing, and uses Kodak's Photo YCC color interchange space – the one that's used by PhotoCD. The format's definitions are shared with the Advanced Photo System (APS) and digital cameras. FlashPix differs from PhotoCD in that each resolution is independently stored in FlashPix, while PhotoCD has one file with keys for different resolutions.

FlashPix was developed by Kodak, in collaboration with Microsoft, Hewlett-Packard, and Live Picture, Inc. Apple, Canon, IBM, and Intel provided technical feedback during development. Products that meet the FlashPix format specification and pass the interoperability test suite will be able to use the FlashPix file format name. The FlashPix format specification will be open and available to all developers, with tools to help them incorporate its features to meet the needs of their customers.

Ken Werner *is the Editor of* Information Display Magazine.

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RIT Research Corp.

Fig. 1: *Combined with its accompanying* Profile/80 *software, a digital target similar to this one can generate input and output device profiles for "soft proofing."*

The developers are working to make FlashPix the new standard image file format. They believe it makes images so much easier to work with on typical computers – whether they stand alone, are connected by LANs or intranets, or have dial-up connections to the Web – that the format could spark a new consumer buying spree for computers (and displays).

In a paper that imaging consultant Jack Holm called highly significant, Ricardo Motta and Michael Stokes of Hewlett-Packard and Matthew Anderson and Srinivasan Chandrasekar of Microsoft presented a "Proposal for a Standard Default Color Space for the Internet - sRGB." The paper was given by Ricardo Motta. The proposed color space "is a more tightly defined derivative of Rec. ITU-R BT.709," which was unanimously accepted "as the calibrated nonlinear RGB space for HDTV production and program interchange" in April 1990. The authors are proposing that sRGB, which is consistent with Rec. ITU-R BT.709, be the standard color space for operating systems and the Internet. The new space, which uses typical CRT characteristics in a natural way, is not intended to replace embedded ICC profiles for high-end use, but is intended to "bring the benefits and availability of color management to a broader range of users" without the file overhead and processing-speed degradation inherent in the use of ICC.

"For computer software and hardware designers, the most significant aspect of the proposed space is the 2.2 gamma," said the authors. The phosphor chromaticities are those specified in ITU-R BT.709. The reference viewing environment includes a luminance level of 80 cd/m^2, an image surround with 20% reflectance, a typical viewing flare of 5%, a typical ambient illuminance level of 200 lux, and a D65 white illuminant.

Color Spaces and Color Management

In their paper, the authors provide clear, concise explanations of two basic concepts in color science and engineering, explanations that are well suited for display professionals:

A ***color space*** is a model for representing color numerically in terms of three or more coordinates; *e.g.,* the RGB color space presents colors in terms of the red, green, and blue coordinates. For color to be reproduced in a predictable manner across different devices and materials, it has to be described in a way that is independent of the specific behavior of the mechanisms and materials used to produce it. For instance, color CRTs and color printers use very different mechanisms for producing color.

To address this issue, current methods require that color be described using device-independent color coordinates, which are translated into device-dependent color coordinates for each device.

Color management is a term that describes a technology that translates the colors of an object (images, graphics, or text) from their current color space to the color space of output devices such as monitors and printers. Traditionally, operating systems have supported color by declaring support for a particular color space, RGB in most cases. Since RGB varies between devices, color was not reliably reproduced across different devices.

The high-end publishing market could not meet its needs with the traditional means of color support, so the various OS's added support for using ICC profiles to characterize device-dependent colors in a device-independent way. They use the profiles of the input device that created an image and the output device that displayed the image and create a transform that moves the image from the input device's color space to the output device's color space. This resulted in very accurate color. It also involved the overhead of transporting the input device's profile with the image and running the image through the transform.

For more details on sRGB, see page 238 of the *Final Program and Proceedings of IS&T/SID Fourth Color Imaging Conference* (November 19–22, 1996). The volume is available from either SID or IS&T.

A Color Sampler

Here is a sampling of the many technical papers presented at CIC 4.

X-Rite, Inc.

Fig. 2: X-Rite's Digital Swatchbook *is a colorimeter/software combination that makes the importing, management, and use of custom colors easy.*

In "Analysis of Multispectral Image Capture," Peter D. Burns and Roy S. Berns of RIT's Munsell Color Science Laboratory discussed the "dramatically improved colorimetric accuracy" that can be obtained with a camera using seven color channels instead of the usual three channels.

In "Scanning Color Negatives," Chris Tuijin of Agfa-Gevaert, Mortsel, Belgium, noted that most electronic input devices capture positive originals. Newspapers, however, are interested in scanning film negatives, and Agfa believes that the new APS - in which the photographer need never touch the film and the camera or other device can automatically position the film strip to any desired location - will also generate increased demand for negative scanning in the home-office market. However, scanning negatives is difficult because negatives vary so widely. Tuijin described Agfa's approach to negative scanning, which it calls Total Film Scanning (TFS). TFS automates the adaptive approach to working with negatives used today by photo finishers, which often requires a quick scan of the entire film roll to statistically establish reliable reference points.

In "Color Management Issues in the United States Imagery System (USIS)," Scott Foshee of Booz-Allen & Hamilton discussed the transition of the U.S. military to a Compuserve-style information-pull network. To illustrate the need for such a network, Foshee spoke of what happened when troops were sent from Schofield Barracks, Hawaii, to Bosnia. In addition to transporting the troops, the Army had to send their complete personnel and medical records, including x-rays, which was a "logistical nightmare." Had an information-pull network been in place, the records could have sat in one place and been accessed by any authorized person who needed them.

Among the many situations that must be considered in relation to the USIS are the following:

- In tactical-mapping applications, a company commander downloads maps to his laptop in the field, draws lines, prints the maps, and uploads the marked maps to his superiors. Maps and markings must be visible on laptop computers. (The U.S. Marines use only green, blue, black, and red for the computerized marking because, when the computers go down, they have to go back to their green, blue, black, and red grease pencils.)
- Night-combat planning is often done under red light, and displays must be visible.
- Everything must operate simply, with a quick learning curve. Many soldiers are high-school graduates, and command rotates every 2 or 3 years.

Foshee concluded by saying, "The military is increasingly reliant on commercial industry to solve its problems."

In "Ethical Issues in Digital Image Manipulation," Lindsay MacDonald, Professor of Multimedia Systems at Cheltenham and Gloucester College of Higher Education, stated that the ethical issues presented by digital techniques are no different in principle from the ones we have faced for decades in photography and for centuries in the traditional pictorial arts. But digital techniques do provide us with a much larger number of modified images that are harder (or impossible) to detect.

The central ethical question, said MacDonald, is whether the image manipulation is being deliberately used to misrepresent the truth. MacDonald showed how this might be done in the political arena with a photograph of George Bush (when he was President) walking with Margaret Thatcher (when she was Prime Minister). The two leaders are walking through a garden and their bodies are slightly turned toward each other. The photo was widely regarded as an indication of the "special relationship" between the two conservative leaders, as well as between their countries.

With a fairly simple manipulation, MacDonald exchanged the images of the two leaders and touched up the backgrounds to make the switch virtually undetectable. Now, the bodies of Bush and Thatcher are turned slightly away from each other, giving a sense of coolness or even mild hostility.

MacDonald also discussed *Playboy* magazine's well-known touching up of its cheesecake photos (which is done on a Macintosh with Adobe *Photoshop*) and the obviously manipulated photos used in the last British elections that, rather crudely, depicted the ultimately victorious Tony Blair with devil's eyes. MacDonald concluded by saying that the application of ethics to imaging is a challenge for educators.

In his keynote for the image-processing session, "The Symbiotic Relationship between Computer Graphics and Color Imaging," Donald Greenberg, Program of Computer Graphics, Cornell University, made an interesting suggestion. Computer Graphics, he said, never developed the experimental test-the-accuracy-of-the-image approach typical of color science. "We have very good simulations today but not much testing of how realistic they are," said Greenberg. Today's ray-tracing algorithms are very good for specular reflections, and radiosity algorithms are very good for diffuse and overall lighting.

If we knew our artificial images were really correct - *i.e.*, if they would be accurate representations of the scenes they depicted if those environments actually existed - we could use the artificial images as test images for printing and other purposes and have total control over the input parameters. In fact, said Greenberg, we're getting close to obtaining this "correctness."

How Good Is Good Enough?

In his keynote presentation for the applications session entitled, "The History of Photographic Image Fading with a Suggested Strategy for the New Hard Copy Media," James M. Reilly concluded that it is impossible to build a successful business on a foundation of extremely unstable images, but that moderate stability can be good enough. On the other hand, excellent stability can result in an unsuccessful business if the medium simply costs too much.

Reilly's first historical example was William Henry Fox Talbot, who established a widely publicized business for the mass publication and production of photographs in the 1840s. The business died because the images faded, often before customers received them!

Between 1855 and 1900, a successful business was based on albumen prints, even though their lack of long-term stability was well-known. However, the prints were good enough, and no unreasonable expectations were raised for them. At about the same time, carbon and platinum prints, despite being totally permanent, were too expensive to find a mass market.

Today, the expectations for ink-jet and other image-making technologies are set by photography, and Kodak's experiences with color photography are informative. Kodak had a honeymoon with its customers in the 1950s and 1960s, a time when there was fascination with color photography and runaway growth, even though stability was poor. In the 1970s, though, "a public outcry, suits by professional photographers, an FTC complaint, and claims of deceptive advertising by vocal critics added up to a major problem. Kodak built a formidable testing operation to inform management and the public of the facts on stability and invested heavily in improved dye technology.

"Some of today's hardcopy prints have quite poor light stability (much poorer than current color photos) and largely untested dark stability, and the industry has not had 25 years' experience in managing the stability issue."

To manage the situation, we should attend to the lessons of history, which are:

- Moderate light and dark stability is essential.
- Management must know the product's behavior.
- Management must invest in improved stability when necessary.
- Management must carefully inform consumers of just how much stability they can reasonably expect, and must include appropriate disclaimers with products and advertising.

The Brilliance of NTSC

In his typically fascinating session keynote paper, "Why Is Black-and-White So Important in Color," consultant Robert W. G. Hunt observed that the people responsible for the NTSC compatible-color television system knew they had created something special in the luminance/chrominance method. What they didn't know was that the human visual system works in much the same way.

In the human visual system, the retina communicates with the brain by means of a black-white signal and two color-difference signals (red-green and yellow-blue). The reliance on the black-white signal has important implications. Among them is the fact that if areas intended to be black, gray, or white have even a tinge of color, it is very noticeable. A second consequence is that the achromatic signal largely determines apparent contrast. Third, the sharpness of images depends much more on their luminance content than on their chrominance content, which can lead to substantial economies in the necessary information content of transmitted and displayed signals.

Posters and Demos

At the combined poster and product demo session, the RIT Research Corp. was showing its *Profile/80* system, which generates input and output device profiles for soft proofing. A CMYK output profile can be generated with only 80 color patches (Fig. 1). The software - which runs on a Macintosh with floating-point processor - and a digital target cost $500.

X-Rite showed its *Digital Swatchbook*, a Colortron™ colorimeter and software for easily importing the colors of any real-world objects, and storing, organizing, modifying, and using those colors (Fig. 2). The software is designed for Macintosh computers; Intel platforms do not yet support ICC profiles. X-Rite is a wholly owned subsidiary of RIT, so information for both the swatchbook and the *Profile/80* system can be obtained from Bill Erickson, RIT Research Corp., 716/239-6000.

Sony Corp.

Fig. 3: Sony's Cyber-shot™ digital still camera comes in a very compact package and can communicate without wires to a computer, a picture printer, or even another Cyber-shot.

Also shown was Sony's tiny DSC-F1 Cyber-shot™ digital still camera with VGA resolution; rotating lens/flash module; LCD viewfinder/monitor; IrDA interface for wireless image transmission to PC, picture printer, or other DSC-F1; and a very attractive four-color information brochure written entirely in Japanese (Fig. 3).

Tutorials

A day of tutorials was held prior to CIC's technical sessions. Two of the ten tutorials were of particular interest to display and imaging hardware professionals.

In *Color in Electronic Displays,* Louis D. Silverstein, VCD Sciences, Scottsdale, Arizona, carefully compared the attributes of the various display technologies. He concluded that, at present, only CRTs and LCDs offer color performance that is good enough for high-quality color-imaging applications.

In *Photographic Scanning, Digital Cameras, and Reproduction Goals,* imaging consultant Jack Holm, Rush, New York, commented that the goal of photography is to produce aesthetically pleasing reproductions. The images must look good but they often don't have to be accurate. A number of techniques are used to capture scene information in current digital cameras. Unfortunately, film-type standards - which evolved over decades - do not yet exist.

Holm discussed the many advantages and limitations of film-capture and electronic-capture photographic systems. Among his conclusions were the following:

- The performance of both systems can be improved dramatically.
- For ultimate quality, film-capture systems currently have the edge, particularly if the quality must be obtained on a budget.
- Electronic-capture systems have the edge in speed of operation; most newspaper photos are now electronic.
- Electronic-capture systems have advantages when color matching or exact repeatability are required.
- Eventually, electronic capture will become superior to film capture in all respects except cost.

In discussing color management, Holm said the idea of obtaining device-independent color by using monitor color as the reference seems to be "a reasonably new idea," and spoke highly of the sRGB concept.

In 1997

The Color Imaging Conference will once again be held in Scottsdale in November 1997. The organizing committee has identified the Internet, digital photography, computer graphics, motion imaging, and virtual reality as under-explored application areas for color science and color engineering. In addition, the committee believes that people involved in digital photography, television and motion pictures, and computer graphics don't have a place in their home organizations where they can investigate color issues.

The committee hopes to attract these people to CIC 5 with increased content in their fields of interest. As a result, the organizers anticipate continued growth for the Color Imaging Conference in 1997 and in years to follow. ■

SID Symposium Returns to Boston for '97

The 1997 edition of the world's leading display conference and show celebrates the 100th anniversary of the CRT, the 25th anniversary of the AMLCD, and the latest innovations in display technology.

by Ken Werner

THE SOCIETY FOR INFORMATION DISPLAY will hold its 28th annual Symposium, Seminar & Exhibition at the Hynes Convention Center in Boston, May 11–16, 1997. The headquarters hotel is the Sheraton Boston Hotel and Towers, which is adjacent to the Convention Center. (See map and hotel reservations form in this issue.) The annual SID event has become the leading international forum for advances in electronic-display products, technology, systems, applications, manufacturing, testing, and human factors.

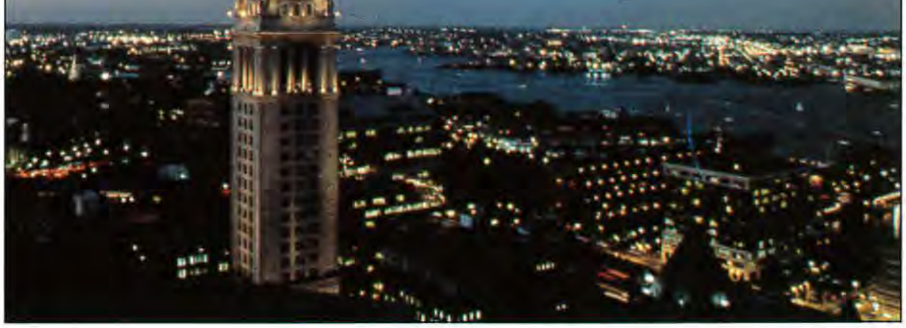
This year's edition, SID '97, will celebrate two of the display industry's most significant anniversaries. The first is the 100th anniversary of the Braun tube, the first modern cathode-ray tube (CRT), which was invented at the University of Strasbourg by Karl Ferdinand Braun in 1896-97 and first fabricated by Franz Müller of Bonn in 1897. The second is the 25th anniversary of the active-matrix liquid-crystal display (AMLCD). Peter Brody and his team at Westinghouse in Pittsburgh, Pennsylvania, built the first operating AMLCD in 1972. Special invited papers on May 13, 1997, will review the history and significance of these two crucial display inventions, which can reasonably be said to have changed the world.

In addition, there will be a unique exhibit of historical CRTs and products in the lobby of the exhibition hall. The curator of the exhibit will be Peter Keller, author of *The Cathode Ray Tube: Technology, History, and Applications* (1991), a long-time manager at Tektronix, and a private collector of significant CRTs. The organizers are anticipating the cooperation of the Smithsonian Institution, Philips Display Components, the David Sarnoff Research Center, and private collectors in mounting this exhibit. Once past this intriguing look at CRT history, visitors to the SID show will be treated to a record number of exhibits showing the state of the art in display technology, products, manufacturing equipment, components, materials, software, test equipment, services, and publications.

Display Week will kick off with half-day tutorial short courses on Sunday, May 11th, and 90-minute seminars on Monday, May 12th. There will also be seminars on Friday, May 16th. A rich multi-track menu of technical symposium papers, vendor exhibits, applications sessions, and applications seminars will all be held from Tuesday, May 13th through Thursday, May 15th.

Invited Papers

Approximately 20 invited papers will enliven the technical sessions. Low-temperature



Greater Boston Convention & Visitors Bureau

The U.S. Customs House Tower near the Faneuil Hall Marketplace overlooks parts of old Boston.

Ken Werner *is the editor of* Information Display Magazine.

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Boston Hosts SID '97

Boston is one of America's most agreeable cities, a city remarkably rich in history, science, technology, medicine, art, music, food, and architecture - and shopping, for those who are so inclined.

It is a compact city, seemingly made for walking. Thousands of people follow the painted "Freedom Trail" through the streets of Boston each year, stopping at the well-marked buildings, burying grounds, and monuments associated with America's battle for independence from Britain. Stopping for refreshments at one of Boston's many charming pubs and restaurants - some of which, including the Union Oyster House, are historical sites in their own right - is distinctly encouraged.

The American Revolution began in and around Boston. Early on the morning of April 19, 1775, there was a small battle in the village of Concord between 200 farmer/militiamen quickly called to arms - the Minutemen - and 700 British regulars under the command of Lieutenant Colonel Francis Smith. The Minutemen, strategically positioned on the far side of the Old North Bridge over the Concord River, resisted the British, who ultimately withdrew and were mercilessly harried by other Minutemen as they retreated to the village of Lexington, site of a skirmish earlier that morning. The Old North Bridge is enshrined in American history and literature. Ralph Waldo Emerson wrote, "Here once the embattl'd farmers stood / And fired the shot heard round the world."

The night before the battle, the silversmith Paul Revere and his associates implemented a plan to warn the Minutemen of the British advance and its direction. One of them was to observe the British troops and then climb the bell tower of the Old North Church, now a popular tourist site. Depending on whether the British advanced by land or crossed the Charles River by boat, Revere's friend was to raise either one or two lanterns. As Longfellow had Revere say, in words that were once familiar to every American schoolchild:

One if by land, and two if by sea;
And I on the opposite shore will be,
Ready to ride and spread the alarm
Through every Middlesex village and farm,
For the country folk to be up and to arm.

As one of the most skilled craftsmen of his day, Paul Revere clearly understood the value of rapid information delivery, and he would have appreciated what the members of SID are bringing to his city. Two hundred and twenty-two years after Revere's successful experiment in optical communications, SID members are bringing to Boston the latest fruits of display technology, an essential tool of the information age.

Greater Boston Convention & Visitors Bureau

The famous steeple of the Old North Church in Boston rises behind a mounted statue of Paul Revere.

polysilicon processing is something of a holy grail at the moment because it is required for the economical implementation of polysilicon's benefits. (Among these are the promise of AMLCD desktop monitors at prices comparable to those of CRT monitors.) It is therefore no surprise to find an invited paper on polysilicon devices: P. Migliorato's "Device Physics and Modelling of Poly-Si TFTs."

Now that the AMLCD's battle for the desktop has begun in earnest, more papers are taking this epic display conflict as their jumping-off point. Hsing-Yao Chen does exactly that in "The Importance of Electron-Gun Design in the Survival of the Color CRT."

The latest display technology to approach commercial status is the field-emission display (FED), and one of the most interesting developers of FED technology is Japan's Futaba. As a result, the invited paper "A New Structure and Driving System for Full-Color FEDs" by Futaba's Mitsuru Tanaka is likely to attract substantial attention.

Recently, Shigeo Mikoshiba's group at the University of Electro-Communications in Tokyo has directed attention to the artifacts that arise when moving images are displayed on plasma display panels (PDPs) and other matrix-addressed displays. With PDPs on the verge of moderately high volume production, the time is ripe for a paper entitled "Moving Picture Quality of a 40-in.-Diagonal PDP." That is just the title of the invited paper that will be delivered by Toshihiro Yamamoto of the Japan Broadcasting Company, NHK. Henri Doyeux of Thomson will provide a general overview in "Plasma Display Panel Technology and Applications." Sharp, one of the two manufacturers of thin-film electroluminescent (EL) displays in the world, has resisted even talking about color EL - in marked contrast to its competitor, Planar. It will therefore be very interesting to hear what Sharp's Akiyoshi Mikami has to say in "White and Color EL Displays with Stacked Phosphor Structure."

One of the critical steps in LCD manufacturing, the preparation of the layer that aligns the LCD molecules properly, is done by mechanical rubbing - a process that would not have looked horribly out of place in a 19th-century factory during the Industrial Revolution. Optical processing of the alignment layer would be more appropriate for a key technology of the 21st century. Martin Schadt of ROLIC Ltd. and H. Iimura of Tokyo University will describe optical approaches and their benefits in separate invited papers.

Greater Boston Convention & Visitors Bureau

Riding the Swan Boats in the Boston Public Garden has been a popular summer pastime for a hundred years. The Public Garden is near the Boston Park Plaza Hotel, one of SID '97's official convention hotels.

Other invited papers will cover organic EL and LEDs, optical components for high-throughput projection displays, novel CRTs (including flat ones), color CRT deflection yokes, the design of user interfaces for autostereoscopic displays, and global CRT markets. Then, of course, there are the hundreds of carefully peer-reviewed papers contributed by leading display professionals from around the world.

Special Events

The President's reception and the Awards Banquet will be held Monday evening, May 12th. (Tickets for the Awards Banquet must be purchased in advance.) The formal opening of SID '97 will be on Tuesday morning, with welcoming remarks from Boston and Massachusetts dignitaries, as well as from officers of the Society. We anticipate that these remarks will be of unusually broad interest. The exhibitor-sponsored reception will be held in the exhibit hall in the Hynes Convention Center on Tuesday evening, followed by the evening panel discussions.

At the gala Wednesday luncheon, the Second Annual SID/*Information Display* Display of the Year and Display Product of the Year Awards will be presented. The winners this year are Hitachi's "Super-TFT" in-plane-switching LCD and Sharp's Color Zaurus personal information tool; honorable mentions go to PixTech's FED and Virtual i-O's Virtual i-glasses VTV consumer 3-D head-mounted display. Awards for the best papers from SID '96 will also be presented. Following SID's tradition, the luncheon speaker will be stimulating and entertaining.

The special event will be held on Wednesday evening, May 14th. The Top of the Hub Restaurant & Skywalk, located on the 50th floor of the Prudential Tower, will play host to SID '97. ■

Getting to Boston

Boston's Logan International airport is served by many major U.S. and international carriers, including Aer Lingus, America West, British Airways, Delta, El Al, Korean Air Lines, KLM, Lufthansa, Northwest, Olympic, Qantas, Sabena, Swissair, TAP, TWA, United, USAir, and Virgin Atlantic. As we write this article, Japan Airlines Flight 8 is scheduled to leave from Narita for JFK in New York at about 1:30 pm each day in May, with arrival at about 12:50 pm on the same day. Exact times change with the day of the week, and JAL will recommend connecting flights from JFK to Logan when specific travel arrangements are made.

Logan Airport is about 4½ miles from the Hynes Convention Center. Shuttle buses that stop outside each terminal go to the major downtown hotels. Look for the bus stops outside each terminal building with the blue-and-white signs. The shuttle buses are operated by City Transportation, as well as other companies. City Transportation charges $7.50 per person one way, $13.00 round trip. Their buses run every 30 minutes between 7:00 am and 7:30 pm, and every hour on the hour after that until 11:00 pm, seven days a week. City Transportation also has a dispatch number: 561-9000.

Taxicabs are also available, with the typical fare from Logan to the Hynes Convention Center being about $15.00, plus tip and tunnel toll of $1.00. There have been stories of Boston cabbies charging tourists inflated rates, but Boston Taxi, 536-5000, will guarantee the $15.00 rate. And the $15.00 is for the cab, not per person. Up to four people can travel for the same amount. Boston cabs are metered, so make sure the meter is running.

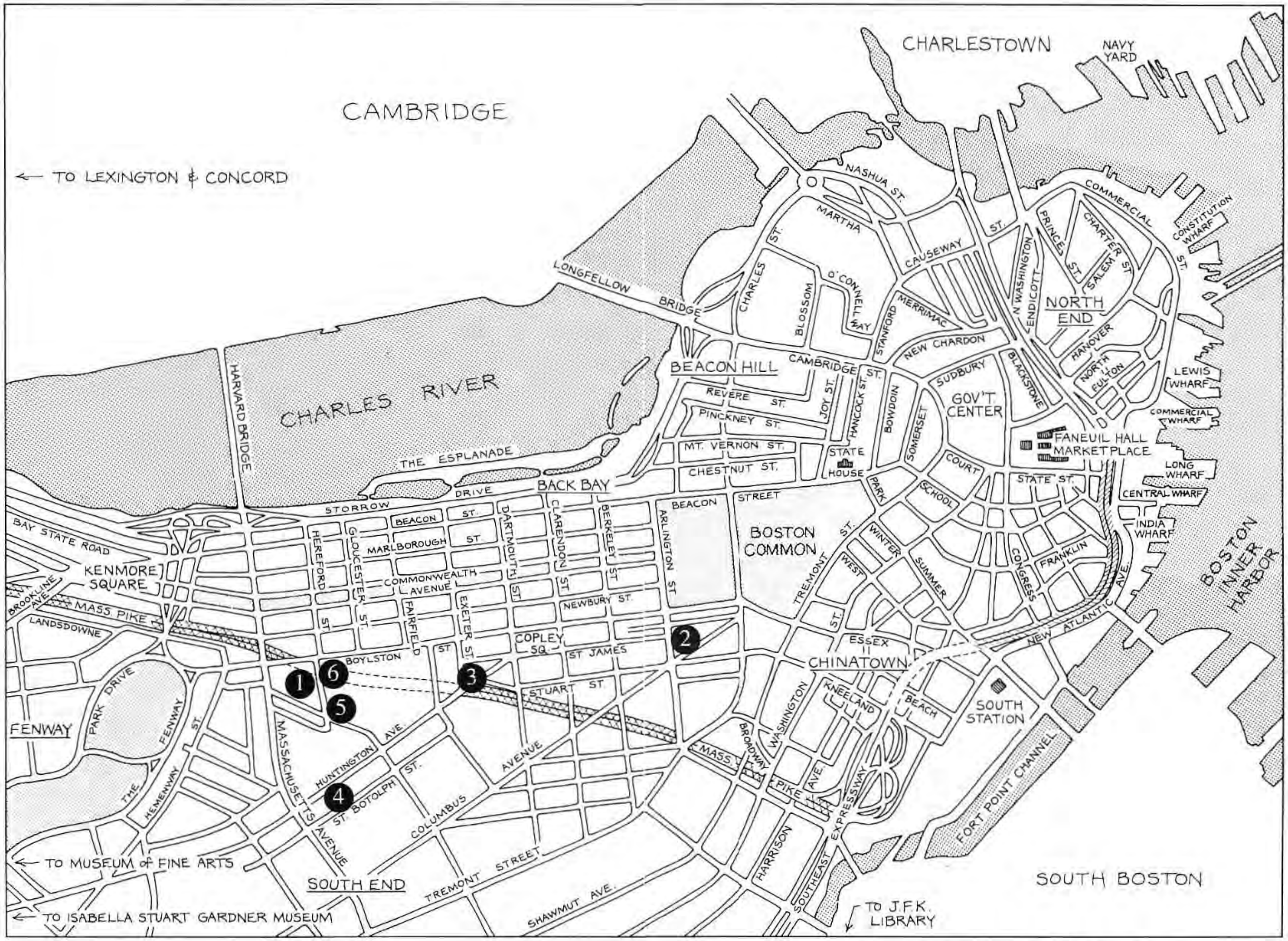
Alternatively, one can board the MassPort Shuttle Bus (free) outside any of the terminals at Logan and go to the Airport stop of the Blue Line of the "T," Boston's subway. Transfer to the Green Line at Government Center. Get off at the Arlington stop for the Park Plaza Hotel; at Copley for the Copley Square Hotel; or at Hynes Convention Center for the Convention Center, the Sheraton Hotel, and the Back Bay Hilton. The fare to all of these locations is 85 cents. It will be necessary to purchase a token at the booth when you enter.

Service on the "T" is available from 5:15 am to 12:30 am Monday through Saturday, and from 6:00 am to 12:30 am on Sundays. The last subway leaves the Airport station at 12:25 am. Tourist passes allow unlimited use of the "T" and Boston buses, and include discounts for tourist sites. The price of a tourist pass is $5.00 for one day, $9.00 for three days, $18 for seven days.

Instead of the "T," one can take the MassPort Water Taxi Shuttle Bus (free) to the Water Taxi, a boat that will take you across Boston Harbor to Rowes Wharf at the luxurious Boston Harbor Hotel (approximately $10.00 and 7 minutes). The Water Taxi runs every 15 minutes on weekdays between 6:00 am and 8:00 pm, with less-frequent runs later in the evenings and on weekends. From Rowes Wharf it is a 10-minute taxi ride to the Convention Center (about $8.00). Although more expensive and somewhat less direct than the other methods, the Water Taxi can be attractive at rush hours when the "T" and the tunnels connecting the airport with downtown are often crowded. It's also an interesting way to approach downtown Boston.

Convention Center and Convention Hotel Map List

1. Back Bay Hilton
2. Boston Park Plaza Hotel & Towers
3. Copley Square Hotel
4. MidTown Hotel
5. Sheraton Boston Hotel & Towers
6. **John B. Hynes Convention Center**



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SID '97 Exhibitors

Exhibit Hall A/B
Tues: 9:00 am - 6:00 pm
Reception: 6:00 pm - 7:30 pm
Wed.: 9:00 am - 5:00 pm
Thurs.: 9:00 am - 2:00 pm
Admission is free with your Symposium, Seminar, or Applications Seminar badge.
Exhibits-Only admission: $10.00

Ad-Vance Magnetics
Advance Reproductions Corp.
Advanced Display Systems
AGI
Amuneal Manufacturing Corp.
Applied Films Corp.
Applied Simulation Technology
Arconium
AST Products
Astra Products
autronic-Melchers GmbH
AVED Display Technologies
Aydin Controls
Balzers Process Systems
Balzers Thin Films, Inc.
BOC Coating Technology
Breault Research Organization
Brewer Science
Brimar Inc.
BriteView Technologies
Brooks Automation
bvm maskshop
CELCO
CFM Technologies
Chips & Technology
Clinton Electronics Corp.
ColorLink
CRT Scientific Corp.
Dark Field Technologies
Datalux
DCI Inc.
Dempa Publications
Display Inspection Systems
Display Laboratories
Displaytech
Dolch Computer Systems
dpiX, A Xerox Company
Earth Computer Technologies
Eaton Corp.
EDN
Edwards High Vacuum International
EG&G Electro-Optics
ELDIM
Electro Plasma
Electronic Designs
Elsevier Science
Endicott Research Group
Epson America
Ergotron
Exxene Corp.
Eyesaver International
FAS Technologies
Flat Candle Co.
Fujitsu Microelectronics, Inc.
Futaba Corp. of America
Gamma Scientific
General Vacuum
Genesis Microchip
Gerber Systems Corp.
Gerome Manufacturing Co.
Graseby Optronics
Hitachi America Ltd.
Hoffman Engineering
Holographic Lithography Systems, Inc.
Holtronic Technologies Ltd.
Hornell Engineering
Hp Reid
Hughes Lexington
Hyundai Electronics America
ICIA
ILC Technology
Image Processing Systems
Image Quest Technologies
Imaging & Sensing Technology Corp.
IMT Masken & Teilungen AG
Incline
Incom
Instrument Systems
Interface Products
InterLingua
International Polarizer
Interserv Corp.
Intevac
Ion Systems
Ito America
Jaco Electronics
James Grunder & Associates
Kenix Industries
Kent Displays
Klein Instruments
Kopin Corp.
Korry Electronics
Kurdex
Kurt J. Lesker Co.
Kyocera Industrial Ceramics Corp.
Lam Research
Landmark Technology
LCD Lighting
LG Electronics
Linfinity Microelectronics Inc.
LMT
Lumitex Inc.
Luxell Technologies
Man & Machine/Jump U.S.
Marshall Industries
Marubeni Specialty Chemicals
Matrix Components
Mecc
Melles Griot
Micromanipulator Co.
Microvision
Milgray Electronics
Millipore
Minolta Corp.
Mitsubishi Electronics
MKS Instruments
MRS Technology
Multichip Assembly
Nagase California Corp.
Nanometrics
National Semiconductor
NEC
Nikon Precision
Nippon Electric Glass America
Nitto Denko America
Noritake
OAI
OCLI
OIS Optical Imaging Systems
Olympus America
Optis Inc.
Opto Sigma
Optrex America
Orbotech
PC Video Conversion
Photo Research
Photon Dynamics
Photronics Spectra
Photonics Systems
Photran Corp.
Photronics
Physical Optics Corp.
Pilkington Micronics Ltd.
PixTech
Planar Systems
Plasmaco
Polaroid Corp.
Precision Imaging
Progressive System Technologies
Quantum Data
Rantec Microwave & Electronics
Raytheon Co.
Reflection Technology Inc.
Rexam Custom
SAGE Inc.
SAI Technology
Samsung Semiconductor
Sanritz Corp.
Schott Corp.
Seiko Instruments
Sekisui Chemical
Semiconductor Systems
Semitool
Sencore
Sharp Electronics Corp.
Shintech
Shipley Company
SI Diamond/Diamond Tech One
Siliscape
S-MOS Systems
Solid State Equipment Corp.
Solid State Technology
Solomon Technology Corp.
Sony Electronics
Southwall Technologies
Stanford Resources
Supertex
Syntronic Instruments
Tamarack Scientific Co.
Target Materials
Tartan Technical
TDK Corporation of America
TEAM Systems
Techneglas
Tekra Advanced Technologies Group
Teledyne Electronic Technologies
TELETRAC, Inc.
Telic Co.
Thin Film Devices
Thin Film Technology
Thomas Electronics
Thomson Components & Tubes Corp.
Three Bond U.S.A.
Three-Five Systems
3M
TNP Instruments
Toddco General, Inc.
Tosoh SMD
ULVAC Technologies
Uniax Corp.
University of Michigan
Ushio America
VESA
Video Display Corp.
Video Instruments
ViewTek
Viratec Thin Films
VisPro Corp.
VISUS Ltd.
Vivid Semiconductor
Vivitec Co., Ltd.
Wande
Westaim Corp.
Wintron
WPI Electronics
Wyle Electronics
Xentek
XMR

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audio equipment, and it would give them a chance to warm up a bit. Mary thought the warming up part was especially great when she saw the sign that this place also offered lattes and espresso.

As they entered, the door made a tinkling sound from the little bell hung there as a low-tech customer alert. The only person in the store was an older bespectacled gentleman who looked like the stereotypical old Swiss watchmaker. He gave them a pleasant welcoming smile and quickly met their request for two cups of liquid warmth. As they wandered about the store and sipped their lattes, Mike quickly established that this was indeed a high-end audio-equipment store. Most of the components were in the several-thousand-dollar range, and one set of speakers was actually priced above fifty thousand dollars. Mike prided himself as an audio perfectionist and classical-music connoisseur, but most of this stuff was clearly beyond his reach.

One part of the store that they found especially intriguing turned out also to be the warmest. This was where the various vacuum-tube amps were displayed. The storekeeper explained to them how there was a major revival in vacuum-tube components because of their more pleasing sound - apparently caused by just the right kind of harmonic distortion. Mike found this puzzling because he had always thought that the ultimate objective was an amplifier that added ***nothing*** to the program material, and yet here he was being told that certain kinds of distortion are a wonderful benefit. Most of these amps and preamps were in the several-thousand-dollar category. Many had gold-plated chassis and sculptured metal enclosures. The vacuum tubes in these amps were mostly manufactured in Russia and mainland China. Mike wondered if the buyers of these incredibly expensive products had any clue regarding the outdated equipment on which most of these tubes were being manufactured, or that most of these factories had done little to implement anything in the way of world-class quality standards. It seemed incongruous to him to see the precision-machined and gold-plated chassis holding these technologically prehistoric devices as if they were precious jewels. Indeed they sparkled and glowed as if they were, in spite of their humble and imprecise origins.

Then something strange and confusing began to happen. Later, Mike would not be able to explain exactly what had transpired. Maybe it was the specially brewed coffee or the sorcerer-like powers of the shop owner, but as the conversation progressed Mike became more and more intrigued and had an increasingly difficult time analyzing what he was being told.

Since Mike had earlier let it be known that much of this equipment was beyond his financial means, the older gentleman began to sug-

Circle no. 27

gest some ways that he thought Mike would be able to dramatically improve the performance of his existing audio system. He told Mike that a problem he should address was the way his system was wired together. He explained that by using conventional wiring between his components, he was in effect strangling his music. He suggested that the least Mike should do would be to completely replace his component interconnections. In fact, the gentleman suggested, with a wink at Mary, that such a move might improve the performance of his system so much that even his social life might take a turn for the better.

Mike's confused frown was quite apparent. What was this guy saying? How would stringing new wire between his components and to his speakers improve his system's performance? He searched for some logical and scientific explanation but could only come up with Ohm's law and his prior experience as a microwave engineer. He did a quick calculation. The wavelength of an electrical signal at 20,000 Hz is on the order of 15 km. A tenth of a wavelength, the point below which travelling-wave or antenna effects are negligible, is at least 1.5 km. So, unless he strung his speaker wires over to Mary's house (an intriguing thought in itself), what else could he have to worry about except resistance and maybe picking up some hum from a badly shielded phono or microphone cable - and wouldn't he be able to hear if that happened?

But unbeknownst to Mike, he was about to enter an entirely new world: the Audio Twilight Zone. The shopkeeper gently explained that only those truly skilled in the audio art are able to make out the dramatic differences offered by some of the newer interconnect cables. He told Mike that the most authoritative publication on this subject was *Stereophile* magazine, and that some of the quotes by its well-known reviewers, as well as those from other publications, would readily convince him - even before he did a personal listening test - of the merits of these new high-tech products.

The shopkeeper suggested that they start by looking at speaker cables. A type that was highly recommended, he said, was the "Discovery" cable Signature Series. This cable, he told Mike, was made of "stranded copper with all terminations performed by hand, using lead-free four-percent silver solder." Jonathan Scull of *Stereophile* magazine had written that with this cable "... the entire bass range was as close to perfect as I've ever heard from a cable. ... The upper midrange and treble ... were completely grainless and free of brightness or other artifacts," and Jonathan Valin of *Absolute Sound* magazine had written, "If you know the sound of live music, you will love Discovery Signature interconnects. At the price, it is a steal." The shopkeeper next asked Mike about how many feet of speaker cable he would need. Mike wasn't sure but he guessed about 10 ft. Maybe ten on the left side and twelve on the right; Mike wasn't sure and the price wouldn't be significantly different anyway, he figured.

Mike was convinced he hadn't heard anything resembling reality when the shopkeeper matter-of-factly mumbled as he wrote on the order sheet $750 for the 10-ft. length and $900 for the 12-ft. length. When Mike suggested that there must be some mistake, the older gentleman pointed to the advertisement in *Stereophile* magazine and told Mike that the reason he was getting such a ***low*** price was because his shop had the policy of matching the prices of the various mail-order houses.

Before Mike could regain any semblance of composure or say anything more, the shopkeeper was already looking up the next item – the component interconnect cables. For these he said he would recommend the Kimber Kable award-winning AG Silver Series. In the 1-m length, the XLR series would be only $720 per pair and would provide an "amazingly transparent" sound. Another excellent choice might be the XLO Type 1.1 interconnect about which Jonathan Scull says, "... neutral, detailed, very fast, alive, exciting, with a really big soundstage, plenty of well-controlled deep bass, and humpless midbass, and a somewhat leaner midrange than some cables, and open highs." Of course, he would need these between all of his components and the preamp. Mike couldn't even speak; his mind was racing so fast. What was going on here? How could anyone pay more for cables than he had paid for all of his electronics? And what was all this talk about a "leaner midrange" from a cable? How did this match up with the reality that the circuit boards inside most of today's audio components are typically made with low-cost substrates using conventional tinned copper runs? And even inside his speakers, the crossover network was wired with the cheapest 18-gauge wire – although it ***was*** stranded. He felt like he was losing touch with reality real fast. Mary just stood there and only frowned a little when she heard the dollar numbers being quoted.

The shopkeeper continued his work. His voice sounded most reassuring and authoritative. He continued to show Mike all the technical reviews and glowing quotes about these products. Then he went on to say that to complete his system interconnect upgrade, Mike should make one final but very important addition. For this he showed Mike three authoritative quotes. The first one, again from Jonathan Scull of *Stereophile* magazine stated, "These made a *significant* improvement to the sound of the amp, and as I moved them into the rest of the system, I noted how well they performed." The second quote came from Michael Gindi, of *Fi* magazine, "... the ESP's make your system sound as if you doubled your amplifier output, particularly during loud dynamic swings. … you'll hear the entire quality of a performer's movement about the stage change … in a goosebump raising way." And the final, and most convincing, one from Makoto Akikawa, *Audio Accessory* magazine, Japan, "As soon as I replaced my reference power cord with Aurora I knew this was no ordinary cable; the lower bass became lower, and at the same time, the resolution improved." The shopkeeper could see that Mike was anxious to learn where and how the ESPs and the Aurora should be used in his system. He told Mike that these special replacement ***power cords*** were made from "a patent-pending multi-conductor geometry, had proprietary connector components and termination process, had shielding to prevent RFI and EMI emissions for the quietest backgrounds, and had precise soundstaging and resolution." The special price on the ESP ac power cords was only $499 each in the 6-ft. length. Of course, he would suggest one for each of Mike's components.

Mike really hated being impolite. But he didn't know how to bring this conversation to an intelligent close. Besides, he suddenly noticed that both of their lattes were now empty and in his unplanned anxiety he had managed to crush his cup into a rather sorry-looking wad. This discussion was beginning to frighten him. Such a disconnect from his version of reality made it difficult to know how to behave. In a reflex motion, he grabbed Mary's hand and bolted for the door. The shopkeeper had only a second or two to realize what was happening. Before he could say anything meaningful, they were back out into the cold night air.

The fog and the dampness had lifted. The street was still dark and empty. But now about a block away they could see their car looking very lonely but apparently unharmed. They took just one quick glance back over their shoulders to see the lights in the store go dark. They were glad. Tonight they would say a little extra prayer that they had made it home safe and sound and financially intact.

But for days after, Mike would wonder about the shopkeeper and his high-tech wares. He would even go to the nearest Barnes & Noble and buy the latest copy of *Stereophile* magazine to make sure all of this hadn't been just a strange dream. It hadn't. He would wonder about how he used to think it was so funny to see movies about the elixir and snake-oil salesmen of the nineteenth century, when people were presumably less educated and thus more gullible. And finally, he would wonder about those who design, manufacture, and market these products. How do they feel about what they are doing? Do they actually live in this self-created twilight zone or do they count their profits and chuckle? And the

display continuum

reviewers? Do they get a portion of these profits or do they really believe the stories they write? Mike decided that if it was the latter, then he was even more sad for them.

We haven't seen too much of it yet in the display industry, but is there any reason why display products shouldn't be susceptible to these same kinds of "improvements" and "enhancements"? If any of you find anything along these lines being promoted for displays and would like to share them with me or your colleagues, let me know and I will pass them on. You can reach me by phone at 206/557-8850 and by fax at 206/557-8983 or you can send stuff to me at 22513 S.E. 47th Place, Issaquah, WA 98029. ■

Please send new product releases or news items to Joan Gorman, Departments Editor, Information Display, c/o Palisades Institute for Research Services, Inc., 201 Varick Street, New York, NY 10014.

editorial

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plays is a *team* effort, right? Mention flaws and you will be viewed as a low-life boor who doesn't know enough to recognize the exquisite finery of the AMLCD image. But there is an eventual cure - if having whole industries fail can be considered a cure - and that is the A-B comparison. In front of free-to-move subjects, place a large AMLCD and a plasma screen next to a CRT-based display (direct view or projection), all the same size, all showing the same program.

Watch which screen the viewers settle on after about 30 minutes of being able to watch any one of them. My bet is that the longer viewers have to decide (and in real life they will have months to decide - not a few minutes at a trade show), the more they will unconsciously select the venerable CRT. My contention is that 85–95% of all viewers will gravitate to the CRT-produced image. Why? This is a subject for many years of human-factors analysis, which will not be made available until it is too late, but here are my guesses:

1. A low ***"dynamic" contrast ratio*** (contrast while images are moving) will prevent the AMLCD from being used as a video display, unless its response time, *i.e.*, its full rise-time plus full fall-time, can be gotten down to the neighborhood of 20 ms.

2. ***Artifacts smaller than "the resolution of the eye."*** All image elements that are supposedly invisible because they fall below the classical, or textbook, measure of human resolution (about one minute of arc) are actually hard on the eyes because they offend the eye's actual dynamic sensitivity, which is as low as a few seconds of arc.

We are faced with a situation in which electrical engineers are often required to make these sorts of ergonomic engineering decisions (which is as reliable as accountants making marketing decisions). Screens that exhibit repeating artifacts - such as chicken-wire effects - supposedly smaller than the eye's resolution will be sensed as exhibiting visual noise or a crawling layer riding above the image. This is not acceptable for long-term viewing. Phosphor images cover up many of these small artifacts by controlled blooming that just overlaps scan lines.

3. ***Smooth luminance decay.*** Although not much studied, I believe it will come out that the smooth yet rapid decay time of a phosphor pixel will prove to be a major reason the human eye can watch 8 hours a day of TV

year after year - and not feel the slightest bit strained. Has there been a single article describing the viewing of television-program material for several hours on an AMLCD, a digital mirror, or a plasma display compared to that of a CRT? If not, why not? Are the Emperor's clothes too fine to criticize?

4. ***Luminance-level stability.*** Just as two-speaker stereo systems provide negative reinforcement of the stereo image when the listener moves his or her head, so do many AMLCDs irk the eye by not being able to produce an image that is exactly the same brightness from one eye to the other, particularly as the viewer moves naturally about. It is this "ranging" of the eye that builds up in the mind the sense that the image is stable and real. Images that show anomalies in brightness from one eye position to the next, or from one moment to the next, set off alarms in the brain that shriek out "fake." (This is one reason LCD shutters are so prone to "strobing" effects that cause color break-up for some viewers. A blue pixel is sensed, the eye moves saccadically, and the brain recalculates where the blue pixel should be - but it has turned off and is thus "missing." The eye flicks back, and what should have been an OFF pixel is suddenly red. This unnatural change of state causes a lock-up of the visual computing apparatus.)

5. ***Stable white-level brightness.*** As with the early video projectors that dimmed noticeably when high duty-cycle scenes - such as a polar bear looking for its white gloves in a snowstorm - were shown, so should any display maintain brightness regardless of subject matter. AMLCDs have no problem here (although they can never show the lively glint of sparkling light), but plasma displays do.

Until these many visual taboos are admitted, investigated, and cured, none of the new-fangled flat-panel displays will capture a significant portion of the wall-hanging TV market. What we will see is a bunch of techno-junkies ("early adopters") taking it in the eye once again (just as they did with LED watches, the displays of which looked great in the board room but became invisible outdoors) but whose purchases will fuel predictions of a new video revolution. Just as wall-hanging TV factories gear up for volume production, sales will inexplicably plummet, to much wailing and gnashing of very expensive teeth.

"Why didn't our engineers tell us?" will be the biggest lament, probably coming from the very president who fired the few engineers who once dared to suggest that maybe all is not well in Denmark. Those presidents and the Emperor have much in common. It is unfortunate that the children/engineers among us practically need an independent income to cry out that, in spite of the extraordinary cost and in spite of being able to show glorious calendar art, the president still has no flat-panel *video* display. ■

***Tom Holzel** is VP, Marketing and Sales, for PixTech, Inc., 3350 Scott Blvd., Bldg. 37, Santa Clara, CA 95054. Responses to this editorial should be addressed to The Editor,* Information Display; *telephone 203/853-7069; fax 203/855-9769; e-mail kwerner@netaxis.com.*

SID Conference Calendar

Next Show!

International Symposium, Seminar, & Exhibition (SID '97)

JOIN US IN BOSTON TO SEE AND HEAR WHAT'S NEW IN DISPLAY TECHNOLOGY.

· The Technical Program will consist of 180 original and invited papers with 50 more in a Poster Session, all organized in five parallel tracks:
- AMLCDs and Display Manufacturing
- Applications and LC Technology
- CRTs and Emissive Displays
- Applied Vision, Human Factors, Display Measurement, and Hardcopy/Imaging Systems
- Large-Area Displays and Display Systems

· The Seminar Program will once again draw on industry leaders for three days dedicated to short courses, technology overviews, and display applications.

· Over 200 vendors will demonstrate the latest in displays, components, and equipment.

· Evening Panel Discussions, an Exhibitor Reception, a Conference Luncheon, and an evening Social Event will complement the technical program.

11 MAY 97

SID '97

BOSTON, MASSACHUSETTS
MAY 11 – 16, 1997

• SID's MAJOR ANNUAL EVENT
• An International Symposium, Seminar, and Exhibition – Featuring:
– Technical Sessions – Poster Session
– Author Interviews – Evening Panels
– Short Courses – Applications Seminars
– Technical Seminars – Applications Sessions
– Product Exhibits.

15 SEPTEMBER 97

17th International Display Research Conference

TORONTO, CANADA
SEPTEMBER 15 – 19, 1997

• An international conference on display research and development aspects of:
– Display Fundamentals, Display Devices
– Hard Copy & Storage, Input Systems
– Integrated Devices and Applications
– Image and Signal Processing
– Color Perception, Human Factors

3 NOVEMBER 97

Third International Conference on the Science and Technology of Display Phosphors

HUNTINGTON BEACH, CALIFORNIA
NOVEMBER 3 – 5, 1997

• An international conference on the future prospects of phosphors for:
– ELDs – FEDs
– CRTs – Plasma Displays
– PL Devices – LC Backlights

16 NOVEMBER 97

Fifth Color Imaging Conference: Color Science, Systems & Applications

SCOTTSDALE, ARIZONA
NOVEMBER 17 – 20, 1997

• An international multidisciplinary forum for dialogue on:
– Creation and capture of Color Images
– Color Image reproduction and interchange
– Co-sponsored with IS&T.

For additional information:
Lauren Kinsey
Society for Information Display
1526 Brookhollow Drive
Santa Ana, CA 92705-5421
714/545-1526, fax - 1547
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Circle no. 34

new products

Edited by JOAN GORMAN

Open-frame flat-panel monitors

Kent Modular Electronics, Ltd., Rochester, U.K., has introduced four (10.4, 12.1, 13.3, and 13.8 in.) new open-frame TFT-LCD monitors constructed in a flexible sandwich arrangement that provides enough space for an additional tier of PC boards and HD drives, enabling OEMs to create integrated industrial computers or control systems for use in racks, panels, production lines, as well as other space-critical areas. The monitors are fully VGA, SVGA, or XGA (1024 × 768) compatible, and can be fitted with touch screens suitable for a chosen industrial environment and sealed to IP54 or IP65 standards. The models come as monitors, intelligent man-machine interfaces, or as OEM monitor kits with vacant housing ready for the addition of PC boards/power supply by the customer. The advantage of starting with a TFT monitor instead of just the TFT panel itself is that the integration process of adding PC boards and driving the panel is demystified, saving substantial development time. OEMs can benefit from the open-frame construction, which provides an option to mount the monitor in a panel of their own design, using any of the bushed holes machined into the metal chassis. Alternatively, a finished customized display with keypad or touch-screen inputs can be provided to meet specific requirements, with 486 or Pentium processors inside.

Information: Kent Modular Electronics, Ltd., 611 Maidstone Road, Rochester, ME1 3QL, U.K. +44(0)-1634-830-123, fax +44(0)-1634-830-619.

Circle no. 1

Sunlight-legible TFEL display

Luxell Technologies, Inc., Mississauga, Ontario, Canada, has introduced the model S-II-ETL3, an amber-over-black low-profile sunlight-readable thin-film electroluminescent (TFEL) display designed for critical applications in avionics, test equipment, medical instrumentation, and special vehicles. The new TFEL display is easily readable in ambient-light conditions ranging from total darkness to full sunshine (10,000 fC). To achieve this, a patented black-layer structure is placed between the phosphor and counter-electrode layers. The black layer causes optical interference of ambient light and reduces specular and diffuse reflection from a test condition of 75% reflectance (without the black layer) to 2% (with the black layer). By reducing glare and reflection and improving contrast, the black layer significantly increases legibility in high ambient illumination. The display saves appreciable space and weight, and offers wider-angle viewing (more than 160°) and longer life (an estimated 30,000 hours MTBF) than CRTs commonly used in these applications. The active viewing area of the S-II-ETL3 is 2.4 (W) × 2.4 (H) in. and is made up of 23,104 individually addressable pixels in 152 rows and 152 columns at 64 lpi. The high-resolution display is suitable for both graphics and text applications. Its typical contrast ratio is 100:1, with 2:1 in full sunlight. Both military and commercial versions are available, as are custom models with user-specified viewing areas.

Information: Luxell Technologies, Inc., 5170A Timberlea Blvd., Mississauga, Ontario, Canada L4W 2S5. 905/206-1708, fax 905/206-9174.

Circle no. 2

Landscape color FPD

Image Systems Corp., Hopkins, Minnesota, has announced the FP1610HBMAX, a flicker-free 1280 × 1024-resolution landscape color FPD with a brightness of 100 fL. The FP1610HBMAX comes with a 16.1-in.-diagonal AMLCD that provides a 12.5 × 10.0-in. viewing area, and is ideal for cath labs and surgical suites. The display measures 13.75 (H) × 16 (W) × 4 (D) in. and weighs 15 lbs. without the tilt-swivel base. The unit operates with existing software and standard analog video controller cards and is compatible with most PCs and workstations operating at 1280 × 1024 at 60 Hz. On-screen user controls include power on/off, brightness, contrast, RGB amplitudes, and vertical and horizontal size and position controls. The list price for the FP1610HBMAX is $12,000, with system-integration and OEM discounts available.

Information: Diana Scheff, Image Systems Corp., 6103 Blue Circle Drive, Hopkins, MN 55343. 612/935-1171, fax 612/935-1386.

Circle no. 3

Combined rubbing/dry-cleaning module

Hornell Engineering, Inc., Twinsburg, Ohio, has announced an innovation in LCD manufacturing. By integrating two processes, the combined rubbing/dry-cleaning module reduces substrate handling, increases LCD throughput, and reduces equipment costs and cleanroom space while improving overall efficiency. The non-contact dry-cleaning process eliminates 95% of particles greater than 1 μm. High-frequency pressure waves from an ultrasonic head cause particles to vibrate, which are then removed by an exhaust airflow. The rubbing process features both a rotating table and roller to achieve highly uniform rubbing action, which prolongs the life of the rub fabric and is excellent for high-volume production.

Information: Hornell Engineering, Inc., 9337 Ravenna Rd., Suite B-14, Twinsburg, OH 44087. 216/405-1419, fax 216/405-1420.

Circle no. 4

Automated LCD-inspection system

Integral Vision, Farmington Hills, Michigan, has introduced the LCI, an automated liquid-crystal inspection system specifically configured to meet the most demanding LCD/LED performance-verification requirements. The LCI system inspects displays for shorted or missing rows or columns, failed elements or pixels in a character, missing icons, and scratches or imperfections on the lens of the display. Keypads can be inspected for failure to illuminate on power-up, membrane verification, and proper positioning of decals, special markings, or features. The LCI automated vision system is an effective alternative to manual inspection of cellular phones, pagers, radios, watches, calculators, and medical instrumentation. For part set-up, the revolutionary "show-n-go" technique requires merely to be shown good examples. Built-in tools and analysis techniques for LCD/LED inspection are automatically configured. Even production batches of one are easily handled by communicating with the LCI through its serial port. Once the host tells it which product is in the inspection zone, the LCI takes a picture and starts the corresponding part-number analysis. After running a pre-configured sequence, measurements are extracted and compared to preset tolerances. Results are automatically interfaced with other factory equipment for pass/fail, trending, and data management. LCI pricing in quantity is available for under $15,000 per system.

Information: Integral Vision, 38700 Grand River Ave., Farmington Hills, MI 48335-1563. 810/471-2660, fax 810/615-2971.

Circle no. 5

Integrated touch screens

Dynapro Thin Film Products, Milwaukee, Wisconsin, has introduced a new line that combines touch-screen technology and membrane switches in a single product. Incorporating subassemblies from two separate suppliers, the new touch screens virtually eliminate the compatibility problems that often plague OEM designers. The combination provides ease of integration, design flexibility, and the convenience of working with one supplier instead of two. The new design offers tactile feedback with embossing and dome switches in a one-piece construction for a smooth look and feel which is also easier to keep clean. The parts can be front or rear mounted for easy product packaging.

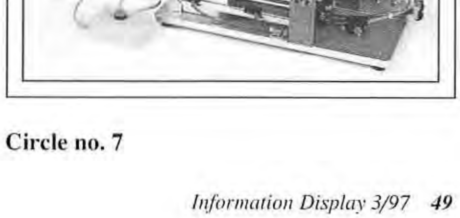
Information: Kevin Brown, Dynapro Thin Film Products, Inc., 7025 W. Marcia Rd., Milwaukee, WI 53223. 414/365-6210, fax 414/365-1133.

Circle no. 6

Polarizer lamination system

KISCO, Inc., Santa Clara, California, has introduced the MPA series of table-top polarizer-lamination systems, designed to provide excellent speed, accuracy, and repeatability in laminating various sizes of cells, resulting in substantial savings in polarizer material and manpower requirements. Semi-automatic operation, dual-vacuumed stages, and XY alignment nests for both the glass and film enable lamination rates of approximately 7 s per side with 0.3-mm repeatability. Four standard equipment sizes are available to laminate minimum cell sizes of 7 × 10 mm up to 10.4 in. on the diagonal. Modification options allow the system to process TFT displays. The approximate dimensions of the standard unit are 450 × 230 × 180 mm, with a weight of 9 kg.

Information: Thomas Climer, KISCO, Inc., 4655 Old Ironsides Dr., Santa Clara, CA 95054. 408/748-1888, fax 408/748-1064.



Circle no. 7

Hi-addressing STN-LCDs

Hitachi America, Norcross, Georgia, has introduced the SX39X001, a 15.5-in.-diagonal XGA color supertwisted-nematic (CSTN) liquid-crystal display incorporating Hitachi's new enhanced "hi-addressing" technology. Ghosting, shadowing, and crosstalk, which are major problems associated with current CSTN technology, are virtually eliminated. The SX39X001 features a resolution of 1024 × 3(RGB) × 768, a dot pitch of 0.3075 × 0.3075 mm, a typical response time of 150 ms, a brightness of 150 cd/m^2, and a contrast ratio of 50:1, making these displays appropriate for use in graphical applications. The CSTN LCDs are priced at one-third to one-half the cost of color TFT displays. Sample and demonstration models are available now.

Information: Tim Patton, Hitachi America, Ltd., Flat-Panel Display Division, 3850 Holcomb Bridge Road, Suite 300, Norcross, GA 30092. 770/409-3000, fax 770/409-3028.

Circle no. 8

Lightweight SVGA LCD projector

CTX Opto, Sunnyvale, California, has announced the EzPro 550, the first LCD projector under 10 lbs. to deliver true 800 × 600 SVGA resolution, matching that of the latest notebook computers. Weighing only 9.8 lbs. and projecting a brightness of 270 ANSI lumens (typical), the EzPro 550 is plug-and-play-compatible, connects to PCs, Macs, and video sources, offers on-screen display adjustment, features built-in stereo speakers and wireless remote, and sets up in under 1 min. The completely portable EzPro 550 measures 12.5 × 10.2 × 6.4 in., and its collapsible four-element lens folds into the unit for in-transit protection. The EzPro 550 is equipped with a full complement of standard accessories, including a padded carrying case, and lists for $6495.

Information: Mark Levitt, CTX Opto, Inc., 1257 Tasman Dr., Suite B, Sunnyvale, CA 94089. 408/541-6060, fax 408/541-6068.

Circle no. 9

Largest notebook TFT display

Mitsubishi Electronics America, Sunnyvale, California, has announced the AA142XB01, a 14.2-in. XGA display targeted at high-end "Mega-Note" and multimedia notebook PCs, as well as "all-in-one" desktop PCs. The AA142XB01, the industry's largest TFT-LCD for notebook PCs, features a 1024 × 768-pixel resolution, 0.28-mm dot pitch, and 18-bit color depth for defining 262,144 colors. At 130 nits, the display has 30% greater luminance than a conventional desktop monitor. The display also features Mitsubishi's integrated low-voltage differential signaling interface, which yields high-speed digital-signal transmissions at a low voltage with reduced electromagnetic interference (EMI). The viewing area of the 14.2-in. TFT display is equivalent to a traditional 15-in. CRT. Samples of the 14.2-in. AA142XB01, priced at $2500, are now available, with volume production scheduled for Q2 97.

Information: Mitsubishi Electronics America, Inc., 1050 East Arques Ave., Sunnyvale, CA 94086. 408/774-3189.

Circle no. 10

Display color and contrast measurement

Minolta Corp., Ramsey, New Jersey, has announced the CS-1000, a spectroradiometer that measures the spectral power distribution, luminance, color, and correlated color temperature of CRTs, LCDs, and LEDs with high accuracy and short-term repeatability. Weighing only 10.4 lbs., the CS-1000 can be operated as a stand-alone or connected to a PC through a standard RS-232C interface. Manufactured in Minolta's ISO 9001-certified facility, the unit features both a standard and macro lens, a measuring range of 0.01–80,000 cd/m^2, a wavelength accuracy of ±0.3 (center of gravity) over a range of 380–780 nm with a measuring angle of 1°. The wavelength resolution is 0.9 nm/pixel, and the spectral bandwidth is 5 nm.

Information: Minolta Corp., Instrument Systems Div., 101 Williams Dr., Ramsey, NJ 07446. 201/818-3517, fax 201/825-4374.

Circle no. 11

Sunlight-readable backlights

InSync Peripherals, Laguna Hills, California, has announced a new family of collimated high-brightness sunlight-readable backlights, in sizes ranging from 4 to 13.8 in. on the diagonal, designed to fit Sharp AMLCD modules. The backlights consume very little power, delivering the same brightness with one-third the power of a conventional light pipe, and have a wide dimming ratio range of 5000:1. Each backlight is packaged with driver electronics (inverters), a dimming control circuit, CCFL heaters, a heater control circuit, and a light sensor. The light sources for these new backlights are long-life CCFL fluorescent lamps. Custom backlight designs for avionics and harsh environmental applications are available.

Information: Jim Lee, InSync Peripherals Corp., 23362 Peralta, Suite 7, Laguna Hills, CA 92653-1711. 714/588-2675, fax 714/588-2679.

Circle no. 12 ■

15 **97**

SEPTEMBER

17th International Display Research Conference

TORONTO, CANADA
SEPTEMBER 15 – 19, 1997

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– Hard Copy & Storage, Input Systems
– Integrated Devices and Applications
– Image and Signal Processing
– Color Perception, Human Factors

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The SID Board of Directors Communicates across Cultures

by Shunsuke Kobayashi

The SID Board of Directors is, in my experience, a unique institution. At a typical Board meeting, 30 or 40 SID International officers, chapter directors and officers, SID staff members, and contractors conduct the business of the Society. Reports are delivered and discussed; motions are made, seconded, discussed, revised, and voted upon; proposals are made and discussed, and funds are allocated (or not). None of this may seem remarkable … until you realize that the people engaged in this intense communication and sensitive decision-making are typically from, going roughly from East to West, Belarus, the Ukraine, Germany, France, the United Kingdom, the United States, Canada, Japan, Taiwan, mainland China, and Korea.

The official language of communication is English, but rapidly spoken English is difficult for many of the Board members, even though they may read technical English readily. The Society has gone to great lengths to ease these difficulties.

First, the meetings are conducted according to Robert's Rules of Order. Although "Robert's" is commonplace in the West, many Asian Board members had never made its acquaintance before attending SID Board meetings. Most of us have found it very efficient, clear, and democratic, at least as practiced by SID President Webster E. Howard and his immediate predecessor Andy Lakatos.

But an orderly meeting would not be enough by itself. How are non-native speakers of English to follow the making and amending of motions that is so much a part of Robert's-run meetings, not to mention contributing their own motions? At SID, motions are captured "live" on a laptop computer attached to an LCD projection panel, making it easy for all Board members to understand, question, modify the motions, and to make sure they are transcribed accurately. This process is very successful. In conjunction with a carefully prepared agenda, written minutes of the previous meetings, and written reports and proposals whenever possible, all Board members are able to participate fully regardless of their national origin or degree of English-language proficiency.

SID honors and awards nominations

Nominations are now being solicited from SID members for candidates who qualify for SID Honors and Awards.

- FELLOW. Conferred annually upon a SID member of outstanding qualifications and experience as a scientist or engineer in the field of information display, and who has made a widely recognized and significant contribution to the advancement of the display field.
- JAN RAJCHMAN PRIZE. Awarded for an outstanding *scientific* or *technical* achievement in, or contribution to, research on flat-panel displays.
- KARL FERDINAND BRAUN PRIZE. Awarded for an outstanding *technical* achievement in, or contribution to, display technology.
- JOHANN GUTENBERG PRIZE. Awarded for an outstanding *technical* achievement in, or contribution to, printer technology.
- LEWIS & BEATRICE WINNER AWARD. Awarded to a SID member for exceptional and sustained service to SID.
- SPECIAL RECOGNITION AWARDS. Granted to members of the technical, scientific, and business community (not necessarily SID members) for distinguished and valued contributions to the information-display field. These awards may be made for contributions in one or more of the following categories: (a) outstanding technical accomplishments; (b) outstanding contributions to the literature; (c) outstanding service to the Society; and (d) outstanding entrepreneurial accomplishments.

Nominations for SID Honors and Awards must include the following information, preferably in the order given below.

1. Name, Present Occupation, Business and Home Address, Phone and Fax Numbers, and SID Grade (Member or Fellow) of Nominee.

2. Award being recommended:
   Fellow*
   Jan Rajchman Prize
   Karl Ferdinand Braun Prize
   Johann Gutenberg Prize
   Beatrice Winner Award
   Special Recognition Award

*Fellow nominations must be supported and signed by at least five SID members.

3. Proposed Citation. This should not exceed 30 words.

4. Name, Address, Telephone Number, and SID Membership Grade of Nominator.

5. Education and Professional History of Candidate. Include college and/or university degrees, positions and responsibilities of each professional employment.

6. Professional Awards and Other Professional Society Affiliations and Grades of Membership.

7. Specific statement by the nominator concerning the most significant achievement or achievements or outstanding technical leadership which qualifies the candidate for the award. This is the most important consideration for the awards committee, and it should be specific (citing references when necessary) and concise.

8. Supportive material. Cite evidence of technical achievements and creativity, such as patents and publications, or other evidence of success and peer recognition. Cite material that specifically supports the citation and statement in (7) above. (Note: the nominee may be asked by the nominator to supply information for his candidacy where this may be useful to establish or complete the list of qualifications).

9. References. Fellow nominations must be supported by the references indicated in (2) above. Supportive letters of reference will strengthen the nominations for any award.

Send the complete nomination - including all the above material - to the Honors and Awards Chairman, Dr. John A. van Raalte, Thomson Tubes and Displays, Av. du General De Gaulle, Genlis, France 21110 by **October 1, 1997.**

By such techniques, and the true international spirit that lies behind them, SID is ensuring that the needs of all its members are understood and honored.

Q & A

by Phil Heyman

In the controlled environment of a Board Meeting (see above), SID has implemented creative ways of communicating across cultures. But we need to do more in our technical conferences, particularly in the question-and-answer periods.

As readers of *Information Display* know very well, the Society for Information Display sponsors display science and technology conferences around the world. Wherever the international conferences are held, though, the official language is English. This makes a great deal of sense in terms of maximizing technical communication among people from many different countries and cultural backgrounds. But the use of English sometimes creates problems, and this is particularly true in the question-and-answer periods that follow the presentation of technical papers. Indeed, the problem of not hearing or understanding questions from the floor can be a significant one even for authors and attendees who are native speakers of English.

Professor Shunsuke Kobayashi has suggested that the Conferences Committee give this issue a higher priority. We are doing so, and we would like to ask the readers of *Information Display* to suggest possible solutions. To get you started, Prof. Kobayashi has made three suggestions of his own:

- Have a technically educated volunteer at each session type the questions on a laptop computer that is connected to a data projector or overhead projection panel.
- We already have floor microphones at most technical sessions. Arrange for the speaker to wear headphones attached to the audio system for the Q & A, since this should make the questions more easily understandable by cutting down the background noise.
- Obtain questions in writing.

We ask for your comments on these suggestions and for additional ideas. Please contact Phil Heyman, SID Conferences Chairman: fax 609/734-3261; e-mail: pheyman@sarnoff.com.■

calendar

Display Technology

SID International Symposium, Seminar & Exhibition (SID '97). Contact: Mark Goldfarb, Palisades Institute for Research Services, Inc., 1745 Jefferson Davis Highway, Suite 500, Arlington, VA 22202; 703/413-3891, fax -1315.
May 11-16, 1997 Boston, MA

The 17th International Display Research Conference and Workshops (IDRC '97). Co-sponsored by SID and the Advisory Group on Electron Devices (AGED) in co-operation with the IEEE Electron Devices Society. Contact: Ralph Nadell, Palisades Institute for Research Services, Inc., 201 Varick Street, Suite 1006, New York, NY 10014; 212/620-3341, fax -3379, e-mail: rnadell@newyork.palisades.org.
Sept. 15-19, 1997 Toronto, Canada

1997 Flat-Panel Display Strategic Forum and Technical Symposium. Co-sponsored by the University of Michigan, Center for Display Technology and Manufacturing. Contact: R. Donofrio, Display Device Consultants, 6170 Plymouth Rd., Ann Arbor, MI 48105; 313/665-4266, fax -4211.
Sept. 22-23, 1997 Ypsilanti, MI

The Third International Conference on the Science and Technology of Display Phosphors. Co-sponsored by the Phosphor Technology Center of Excellence, Defense Research Projects Agency, and Society for Information Display. Contact: Bill Klein, Palisades Institute for Research Services, Inc., 201 Varick Street, Suite 1006, New York, NY 10014; 212/620-3377, fax -3379, e-mail: bklein@newyork.palisades.org.
Nov. 3-5, 1997 Huntington Beach, CA

Fifth Color Imaging Conference: Color Science, Systems & Applications. Co-sponsored by IS&T and SID. Contact: IS&T, 7003 Kilworth Lane, Springfield, VA 22151; 703/642-9090, fax -9094.
Nov. 17-20, 1997 Scottsdale, AZ

The Fourth International Displays Workshop (IDW '97). Co-sponsored by the Institute of Television Engineers of Japan and the Japan Chapter of SID. Contact: IDW '97 Secretariat, c/o The Convention; +81-3-3423-4180, fax +81-3-3423-4108.
Nov. 19-21, 1997 Nagoya, Japan ■

letters

Another Reason for Paper

I appreciated your column in the August 1996 *Information Display;* I agree with it all. But there's one more reason to use paper. That is, let's say, "history."

A. I don't believe there's a good way to keep legally binding documents in any form of cyberspace; they must be multiply printed, "signed," and filed away for all parties to be bound. I'd be afraid to buy a car or a house or a refrigerator without paper records.

B. Great care must be taken to keep write/change access limited only to people who have that authority for a particular document. A mistaken technician (or a mistaken engineer or vice-president) might change a spec sheet for a semiconductor and cause no end of trouble. Worse, a hacker intent on destruction might do something similar or, say, mess up price quotations, security or not. I'm a Computer Engineer, and I am familiar enough with computer systems to be afraid of trusting important data to easily changed media. I'll do my best, for example, to avoid carrying my checking account balance around with me on a card that can be erroneously written on by someone else's by cash register. The printed word – multiple copies of it stored at different locations – is unimpeachable data, and has been for centuries. There is no real alternative in sight. Anyway, thanks for your column; as usual, it keeps us all thinking.

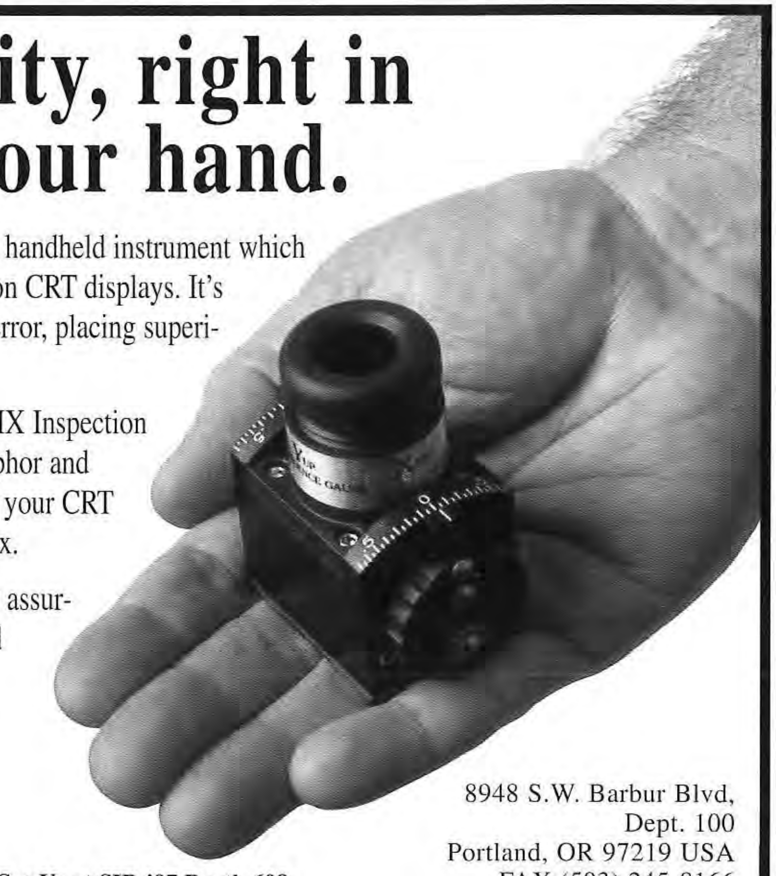
– Bob Peck
bpeck@prairienet.org

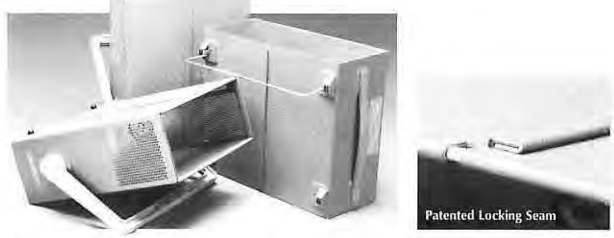
Please send new product releases or news items to Joan Gorman, Departments Editor, Information Display, c/o Palisades Institute for Research Services, Inc., 201 Varick Street, New York, NY 10014.

Circle no. 37

Circle no. 38

Circle no. 39





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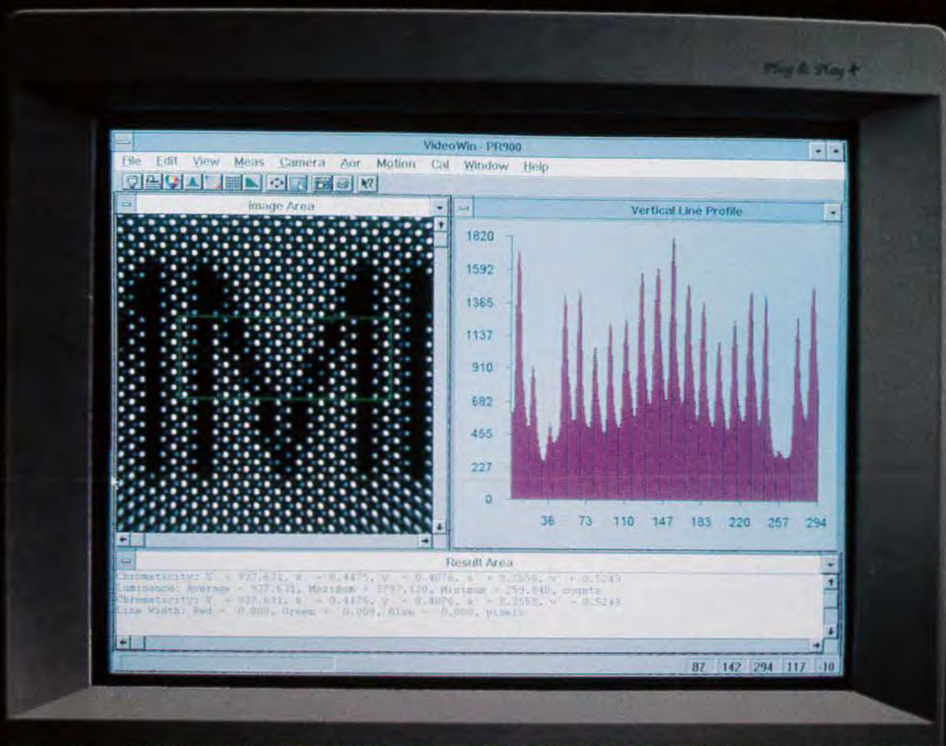

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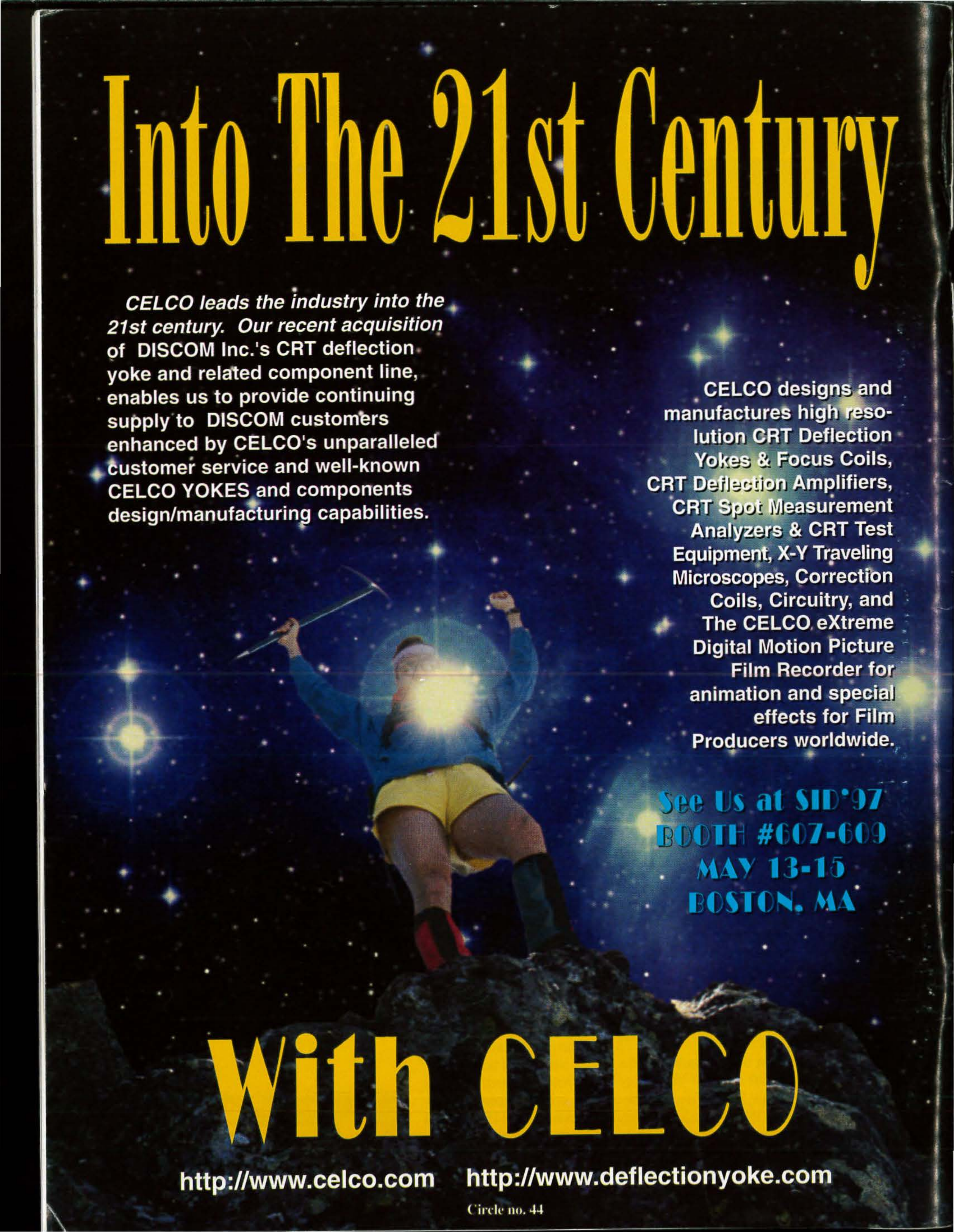
Into The 21st Century
CELCO leads the industry into the 21st century. Our recent acquisition of DISCOM Inc.'s CRT deflection yoke and related component line, enables us to provide continuing supply to DISCOM customers enhanced by CELCO's unparalleled customer service and well-known CELCO YOKES and components design/manufacturing capabilities.
CELCO designs and manufactures high resolution CRT Deflection Yokes & Focus Coils, CRT Deflection Amplifiers, CRT Spot Measurement Analyzers & CRT Test Equipment, X-Y Traveling Microscopes, Correction Coils, Circuitry, and The CELCO eXtreme Digital Motion Picture Film Recorder for animation and special effects for Film Producers worldwide.
See Us at SID'97
BOOTH #607-609
MAY 13-15
BOSTON, MA
With CELCO
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Circle no. 44