Official Monthly Publication of the Society for Information Display

INFORMATION DISPLAY

June 1995
Vol. 11, No. 6

CRT ISSUE

CRTs for medical imaging
Miniature CRTs
Projection-display shootout
London conference review

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COVER: The cockpit of a modern jet fighter is one of the most demanding environments for an information system whose components include both pilots and displays. Helmet-mounted displays (HMDs) using miniature CRTs are currently being used in helicopters. Now, the VCATS program is developing the first HMD CRTs suitable for daylight operation in fighter cockpits. Shown are T-38s on a training mission over the Sierra Nevada Mountains.

Next Month in Information Display

Industry Directory Issue
- Projecting with LCDs
- Touch technology
- CeBIT '95 review
- Directory of display industry

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editorial

That Stupid Super Info-Freeway Data Highway Thingamajig*

It's as seductive as Sharon Stone and it wastes more time than some of her recent movies. But as an e-mail and newsgroup utility, the Internet is an essential resource for many people.

Although it may change the way many of us work, e-mail quickly becomes ... well, a utility. The excitement today is in the World Wide Web – or WWW or W^3 or the Web – a bunch of protocols that enables the publication of graphical, interactive, hypertext documents on the Net. One type of document is the "home page," the introductory page published by an organization (or company or individual) to guide users through that organization's Web site and connect them to related sites and documents. By the time you read this, the Society for Information Display's home page will be fully functional. You can access it at http://www.display.org/sid.

Two of the Web's most seductive features are its search engines and hypertext links. The searchable directory called Yahoo, which is supported at Stanford University on a volunteer basis, contains over 32,000 sites. Search for MITI and, in addition to an interesting site devoted to native and priMITIve art, you will be directed to extensive information on the Program for Advanced Information Infrastructure of Japan's Ministry of International Trade and Industry. All you have to do is click on the highlighted listing and the hypertext link automatically links you to the computer that contains the MITI document. What is dazzling about this is that you have just switched from being connected to a computer in Palo Alto to one in Tokyo without having to know anything about addresses or routings.

Explore a bit, and you can quickly be in a directory of Japanese Government information and documents, including the Electrotechnical Laboratory, Embassies and Consulates, the Japan Information Center of Science and Technology, Research Labs, Japanese Govt. Organizations, The Constitution of Japan, Ministry of Posts and Telecommunications (MPT), and Members of the Cabinet. Click on any one, and the hypertext link takes you to the item that interests you.

From a walking map of Kyoto or a Playboy pin-up to the article on brightness and luminance from the March 1993 issue of this magazine, "surfing the Web" can become a global information adventure. A couple of times, I have even been able to find a particular piece of information when I actually needed it, but the Web is not yet an efficient place to do serious research. When it comes to displays, however, SID is trying to change that with a serious home-page development effort managed by Richard Bruce of Xerox PARC.

The SID home page is intended to be a convenient gateway to display technology and the display community. There will be information for sophisticated display professionals and for inexperienced display users. Whether information is intended for experts or neophytes, it will be posted only if it complies with SID quality standards. Richard's first major project is a *Digital Digest of Technical Papers* for SID '95. In addition, the SID home page will contain hypertext links to the home pages of display research organizations and recognized display and display-related companies.

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the display continuum

Overheating on the Information Superhighway ...

by Aris Silzars

What's happened to us? Is it THE MEDIA, or are too many people chasing too few good opportunities? Lately, it seems that whenever something new comes along we get so breathlessly overexcited, so carried away with it all. We succumb to some primordial need to leap about with chest-thumping proclamations and wildly bold predictions. Remember cold fusion and superconductivity? The cold-fusion hype cost quite a few people and the State of Utah real money, and it left enough egg on enough faces to feed most of the world's hungry. Superconductivity is still out there somewhere. It just lost its glamour after a few years of predictably modest progress.

I don't know what drives it all. Maybe it's greed or maybe it's the assumption that our society is so dependent on technology that there is no way to absorb any new development without causing some gigantic disruption to the existing order – like major indigestion with the accompanying gas bubble. Maybe, it's some of both. But if we listen to THE MEDIA, everything must happen to us as a revolution; we aren't allowed to even consider the possibility of reasonable and orderly evolution.

The latest popular theme is the Information Age, the Information Society, the Information Superhighway – I'm sure you've heard it described by these and a half-dozen other catchy names. No denying it; we are in a period of accelerated change. And we do feel the effects of these changes almost daily, both at work and at home. Several of these columns have been devoted to an analysis of what these changes might mean to the display community. And as we have noted, they are significant and they bode well. But let's keep things in some reasonable perspective.

Consider, for example, this quote from the lead article of the February 27, 1995 special technology issue of *Newsweek* magazine.

> "The revolution has only just begun, but already it's starting to overwhelm us. It's outstripping our capacity to cope, antiquating our laws, transforming our mores, reshuffling our economy, reordering our priorities, redefining our workplaces, putting our Constitution to the fire, shifting our concept of reality and making us sit for long periods in front of computer screens while CD-ROM drives grind out another video clip."
>
> "It's time to take a deep breath and examine where the revolution might be headed and what we might do to ease the transitions and ensure that its benefits will be broad and benign."

Well, I don't know about you, but I'm not feeling all that overwhelmed, redefined, or unable to cope. Up until now, I thought my e-mail, laptop computer, and CD-ROM were really quite easy to accept into my rather ordinary lifestyle. And by the way, who would *you* put in charge to make sure that you are only exposed to *benign* benefits?

Then there was the article in the February 10, 1995 issue of *USA Today*. Kevin Maney interviewed Nicholas Negroponte, who seems to have become a

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Helmet-Mounted Tubes for Displays

The VCATS requires the development of miniature CRTs that are bright, light, durable, and have small spot size – all at the same time.

by Jack Sauerborn

In *The Acceleration of History*, Gerard Peil discusses the relationship of natural forces and inanimate energy to time. The Age of Fire began 50,000 years ago; the Age of Water, 5000 years ago; and the Ages of Wind, Steam, and Combustion far more recently (Fig. 1). Each age has been successively shorter, but each has presented exponential increases in knowledge. The human mind can handle complex situations through the use of abstraction and combination, and can reach logical conclusions that may result in decisive action or creative ideas. If knowledge can be made available to people more readily, the resulting decisions and conclusions can be faster and more expansive. There is no specific point at which conceptual ideas began to influence mankind's accumulative experience and knowledge, but once the printing press was invented, new concepts became the yeast that caused an explosion of new knowledge.

Today, we are on the threshold of yet another plethora of disseminated knowledge – knowledge delivered along the Information Superhighway that will be available to anyone in the world who has access to the sky. This transfer of information demands the most efficient relay systems available, and dictates the use of real-time visual displays to efficiently utilize mankind's abilities.

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The need to transfer real-time information in a hostile environment is nowhere more urgent than for a fighter pilot in a modern aircraft cockpit (see cover). For him – and, increasingly, her – the proliferation of information from the many sensing and situational-awareness devices is nearing overload. To alleviate this problem, engineers are developing helmet-visor displays capable of superimposing the necessary tactical and logistical information over the pilot's panoramic view of the cockpit and outside world.

The great success of the Integrated Helmet and Display Sight System (IHADSS) in the Apache helicopter during Desert Storm legitimized miniature projection CRTs as an image source for such displays. Fixed-wing-aircraft cockpits are even more challenging than those in helicopters. New helmet-mounted displays (HMDs) promise to give the pilot vital information on speed, heading, and targeting overlaid upon views of the outside world.

The image-source requirements for such displays are severe, and must incorporate our constant and utmost concern for the safety of the pilot. Minimum mass and volume are two absolutely necessary criteria for the image source and optics that contribute to a viable system. In addition, the luminance for daylight operation will have to be in excess of 5000 fL (17,130 cd/m^2). Discernible pixel sizes on the order of 15-30 μm at 50% peak line brightness are required. The usable image-source diameter is a major item in determining the resolution and the field of view (FOV), so system designers will generally demand the largest useful diameter that is consistent with low volume and weight. With a useful screen diameter of 19 mm, the total number of discernible pixels can be between 580,000 and 1,600,000, depending on the actual spot size.

Competing image sources pale when exposed to these requirements. Addressing the potential number of pixels with any matrixing device – such as an active-matrix liquid-crystal display (AMLCD), active-matrix electroluminescent (AMEL) display, or plasma display panel (PDP) – becomes a monumental job. Even with multiplexing, the number of necessary connections would be extremely high. When this difficulty is coupled with the requirements for high light output, a large number of gray levels, and high contrast ratio, it is no wonder that the CRT is currently the image source of choice for emerging HMD systems in the cockpit arena.

Other applications for HMDs, such as virtual reality, make less restrictive demands on light output, weight, pixel size, and positioning accuracy. Such displays may use AMLC, AMEL, or other competing devices as the image source, but even here the CRT is a major contender at low-ambient-light levels. The combination of a full-color liquid-crystal (LC) shutter and a miniature CRT incorporating a red-enhanced white-emitting phosphor can form a full-color display. However, such an LC shutter is not very efficient: only 6–7% of the image source's light penetrates the shutter and filter assembly. Such a display also requires high-frequency operation because alternating red, blue, and green frames must be shown in the time normally required for a single frame in a traditional display. But even with these drawbacks, the

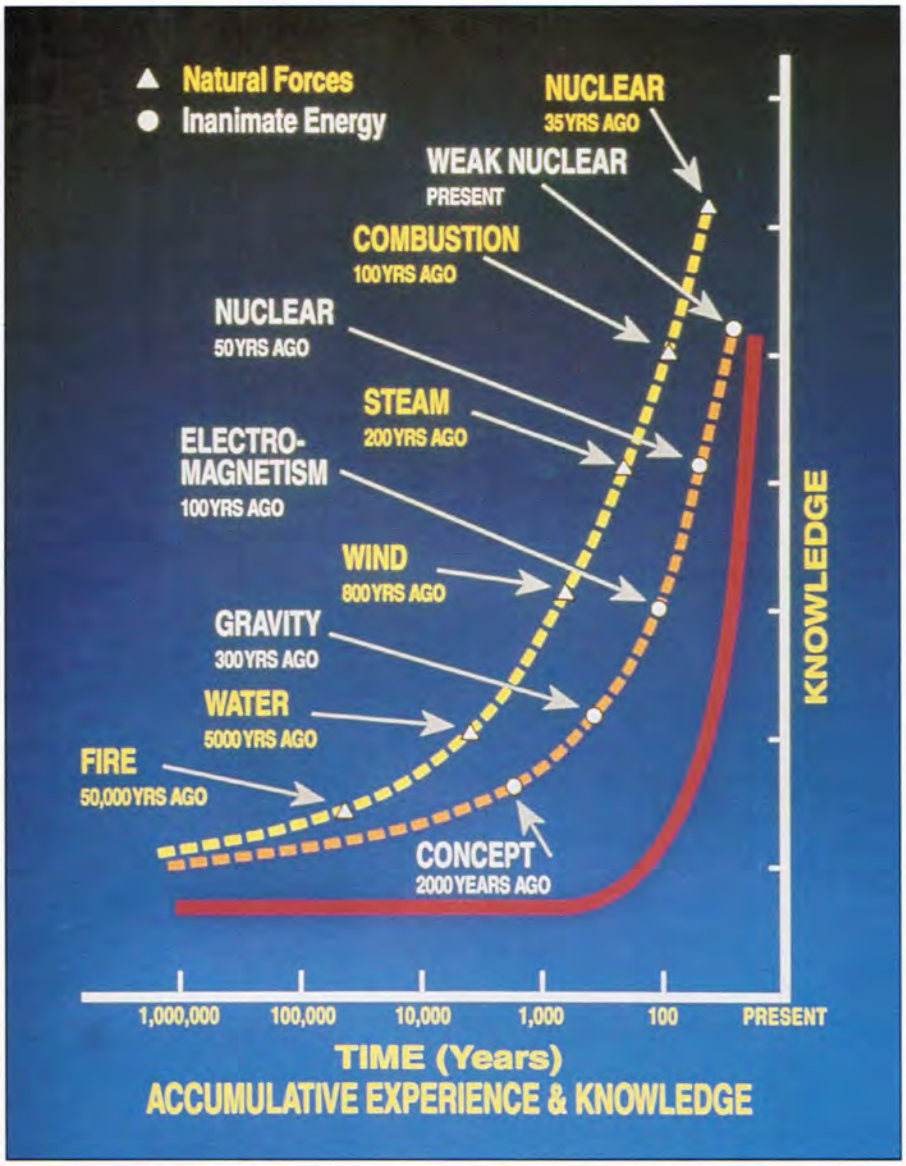

Fig. 1: Throughout history, each technological age has been successively shorter, but each has presented exponential increases in knowledge. The Information Age is not likely to be any different.

miniature CRT with an LC shutter can present a very adequate, full-color display at low-ambient-light levels.

It's Not a Light Bulb

An accountant friend of mine asks, "How are those light bulbs you are working on coming?" Clearly, he does not have a good understanding of the challenges associated with designing image sources for an HMD.

Making miniature projection CRTs involves many design minimums and maximums:

- minimum outside diameter and length,
- minimum weight,
- minimum pixel size,
- maximum light output,
- maximum reliability,
- maximum contrast and MTF.

The Honeywell IHADSS used in the Apache helicopter was a major program that moved the use of miniature projection CRTs in HMDs from experimental to operational status.

Additional improvements came slowly, but a developmental program initiated by the Armstrong Laboratory at Wright-Patterson Air Force Base (AAMRL-WPAFB) in 1986 produced a tube with significantly improved performance over the tube used in the IHADSS and provided the first hope that it was possible to use a CRT for daylight operation in the cockpit of a modern fighter aircraft.

This development incorporated major design and construction changes that allowed the light output to be essentially doubled while cutting the pixel size in half – all at the same drive levels (Fig. 2). In addition to the new design and construction, the new H1426 employed a YAG phosphor (P53) with the same 545-nm peak wavelength excitation as the P43 used in the H1380 but with superior phosphor-saturation characteristics.

Today, the challenge is to exceed this performance while reducing the weight and volume and increasing the reliability and life of the miniature image source. A new program to accomplish this is incorporated in the Visually Coupled Acquisitioning Target System (VCATS) program. Initially, the overall AAMRL-WPAFB program is aimed at incorporating an HMD in the F-15 aircraft. This will be the first full HMD in a fixed-wing aircraft in the United States.

Electron Optics

CRTs can be classified by type of deflection and method of focus – either electromagnetic or electrostatic. Modern deflection coils are superior to electrostatic deflection plates in their ability to precisely position the electron beam. The deflection circuit allows the linearity, pattern correction, and sensitivity to be tailored so that each pixel in the display can be located precisely. Even with its added cost and weight, magnetic deflection is the preferred choice for the miniature CRTs in new HMDs.

The focusing of the electron beam at the image plane can be accomplished electrostatically or magnetically. Although the magnetic focus lens can give superior spot size and density, it does have drawbacks, especially in regard to volume and weight. The potentially superior performance of magnetic focus stems from the size of the focus coil and the strong pre-focus lens that is formed. A lens with a diameter larger than the neck of the tube can reduce spherical aberration. Although it can easily incorporate dynamic focusing, the deflection coil is very sensitive to heat and slight current changes, and would require compensation for them.

Electrostatic focus lenses are divided into two major categories: bipotential and Einzel (or unit-potential). The Einzel lens can be manufactured very accurately. Since the mechanical formation of the lens is independent of the accuracy with which the gun is inserted, the lens can be inspected easily prior to sealing. The focus element can be designed to operate at near zero potential, which offers circuit design advantages. Although the Einzel lens generally offers a larger center spot size, it has less deflection defocusing because of its relatively longer image distance.

A major disadvantage is that the physical diameter of the lens is severely limited by the glass rods that support the lens. This in turn limits the current that the lens can accept before the spherical-aberration disk is exceeded and the spot size becomes unacceptable. The construction of the Einzel lens produces a magnification that is directly proportional to image distance divided by object distance, that is:

$$M \approx I/O,$$

where M is magnification, I is image distance, and O is object distance. Because the potential on both sides of the focus element is the same, the design does not provide an index-of-refraction advantage – a change in the effective index of refraction that would produce additional demagnification.

The bipotential lens has a very different structure. It is usually formed by the inside of the glass neck and the metal bell cup of the gun. This allows for a maximum bell-cup diameter in the neck, thus creating a larger spherical-aberration disk for a neck of the same diameter. Centering the metal cup in the neck is relatively difficult, but good centering is possible with tubular cylinders that are welded to the main focus-lens support – a design patented by Hughes.

The main advantages of the bipotential lens are the reduced spherical aberration for a given neck size, the ability to increase the object distance because of the mechanical

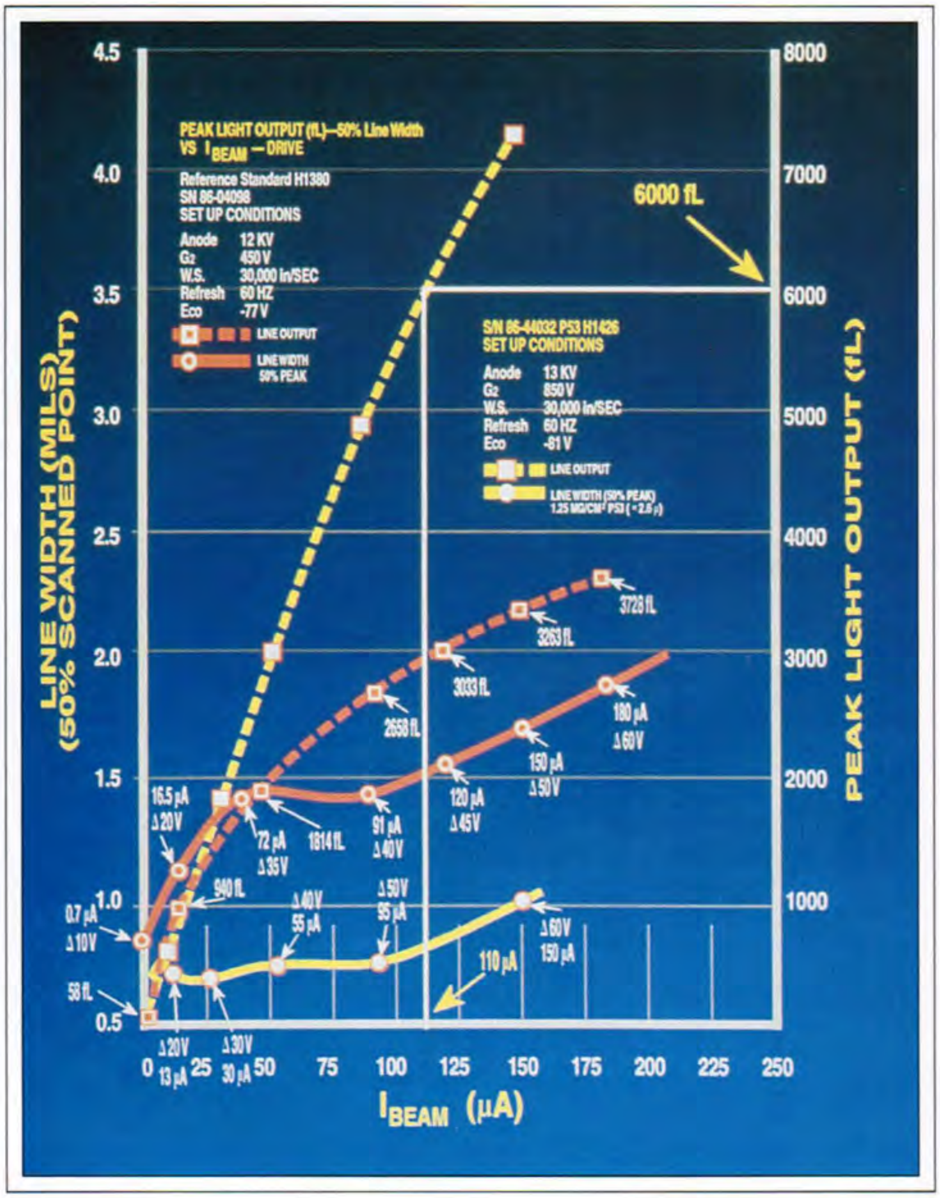

Fig. 2: When the H1426 CRT was developed in 1986, it doubled light output while cutting the pixel size in half compared with the H1380 tube used in the Apache helicopter's IHADSS.

construction, and the increased demagnification of the lens due to a favorable index-of-refraction advantage. The magnification is reduced beyond any image-to-object-distance advantage by a constant K that in this case has a value of approximately 0.7, so $M \approx KI/O$. Designers usually take full advantage of this lens by decreasing the image distance as much as possible, which produces more deflection defocusing. But we can partially compensate for the deflection defocusing by using a plano-spherical fiber-optic faceplate. We have found that the best overall performance characteristics are embodied in the miniature bipotential lens, while paying special attention to weight and volume requirements.

Under the VCATS image-source development program, line widths of less than 25 µm with a peak line luminance of more than 10,000 fL (32,400 cd/m^2) were achieved with an approximately 50-V drive. The line width was measured at 50% peak luminance with a scanning speed of 15,000 in./s at 60-Hz refresh. Better line widths and luminance can be obtained by increasing the refresh rate while maintaining the scan speed. With the present design, the increase in light output is nearly proportional to the increase in refresh rate over the range tested, which was up to 240 Hz. Using refresh rates greater than 60 Hz can offer a great advantage for stroke writing because luminance can be increased without any apparent loss in line width.

Reliability and Life

As CRT assemblies get smaller, it becomes more difficult to maintain electrical integrity and the final level of vacuum. Holding off 12 or 13 kV in a small area requires the utmost care during encapsulation. Under the VCATS program, a new high-voltage contact and miniature HV boot are being developed. We believe this combination will insulate and isolate the anode voltage from the shield and other low-voltage components in the CRT assembly – and with a minimum of weight.

When we design smaller and smaller tube envelopes to house the electron gun, the ratio of the gun's mass and surface area to that of the side walls becomes larger. In a standard TV tube, this ratio is very low, which allows for a greater gettering area per area of gun parts. (Gettering is the adsorption of gases on surfaces inside the tube, which is enhanced by installing a "getter." If there is insufficient gettering, it is difficult to reach and maintain an adequate vacuum.)

To a first approximation, gettering capability is directly related to the surface area where the barium from the getter is deposited. The larger this area – especially in relation to the area of other parts of the tube, such as the metal parts of the gun – the easier it is to reach a low vacuum level and sustain it. Therefore, as the ratio of side-wall area to gun-parts area becomes smaller, it becomes more difficult to control the normal outgassing in a tube. Minimizing size and volume puts additional pressure on this aspect of the design. A newly re-designed electron gun for the VCATS program has allowed us to triple the gettering capacity and area coverage in a 9.5-mm-neck tube, thus assuring longer life. Previous designs did not allow the installation of more than one 5-mm-diameter barium getter. The increase in the object distance of the new gun has the dual advantage of providing more room for the installation of two additional getters and improving the magnification factor.

We have also explored a new method of gettering, which uses a wire of tantalum-titanium alloy to evaporate pure titanium on the neck's side wall using a direct electric current. Potentially, such a process could allow the reflashing of a getter after encapsulation because a predetermined current could be applied to a coil of Ta-Ti wire for a specified period of time. The technique is interesting, but further development is still required.

We have also been developing a new plastic Mu-metal shield to improve operation at high temperatures and high voltages while reducing weight. The shield was developed in concert with Reynolds Industries, which is developing a new AVCON adapter for use on the VCATS CRT assembly. Provision has been made to incorporate an EEPROM chip that will characterize the individual CRT for optimum performance. These new adapters will facilitate quick interchanging of CRTs because the individual characterization from the EEPROM will automatically set the conditions for optimum performance.

A separate study was undertaken as part of the VCATS program to match the yoke to the tube and the deflection circuit. Two compatible miniature yoke designs were developed by Syntronic Instruments to optimize the complete system. One was a new stator design and the other was an interleaved-hank version. Both designs gave excellent performance. The stator yoke is 15–20% more sensitive and is slightly heavier.

The VCATS program has done far more than advance the performance of the VCATS CRT. The principles learned here will go a long way toward providing a good, reliable image source for many future HMDs.

As mankind enters more deeply into the information era, no one can fully predict what his achievements will be, but the attainment of knowledge and skill will surely be facilitated by viable high-performance helmet-mounted displays. ■

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Presenting Medical Images on Monochrome Displays

A display-function standard can provide tonal consistency between different displays, as well as between hardcopy and softcopy.

by Hartwig Blume and Edward Muka

SINCE THE BEGINNING of digital medical imaging, the radiological community has been plagued by inconsistencies in gray-scale – or tone-scale – presentations between different softcopy systems, as well as between hardcopies and softcopies. These inconsistencies have contributed to the reservations many radiologists have about working with softcopies. The problem exists because softcopy display systems and many digital image printers do not render gray scale predictably and according to a standard. A display-function standard is crucial for the proper telecommunication of images in medicine.

Most recently, an American College of Radiology/National Electrical Manufacturers Association (ACR/NEMA) ad hoc Working Group has begun to develop a display-function standard for monochrome display systems based on a previous proposal.[1-5] In this article, we will outline the concept behind the standard and its potential implementation.

A mathematical definition of the gray-scale response of a display – such as the logarithm of the luminance being a linear function of the digital input – provides predictable behavior. But because contrast sensitivity depends on luminance, a mathematical definition does not necessarily guarantee that a user will perceive a similar tone scale. To achieve also similarity, the proposed standard is based on perceptual linearization.

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Perceptual Linearization

Perceptual linearization produces a tone scale in which equal changes in driving levels – or command levels or digital input values – produce changes in luminance that are perceptually equivalent throughout the entire luminance range.

The concept of perceptually linearizing CRT displays to maximize information transfer has been employed by many investigators.[6-13] Briggs[6,7] used Rogers and Carel's formula for human threshold contrast to linearize CRT displays. When he did so, Briggs observed that the fine-contrast checkerboard patterns of his test image were equally visible at all gray levels over the entire wide luminance range. Johnston, Zimmerman, and Pizer,[8-10] who used the term perceptual linearization for the first time, linearized CRT displays based on their own measurements of contrast thresholds of two 1-cm^2 patches. The patches were close to each other and surrounded by a uniform background. The researchers observed that many more luminance differences were discernible in clinical images on a perceptually linearized CRT monitor than on an "as delivered" version of the same monitor.

Johnston, Zimmerman, and Pizer were also thinking of perceptual linearization as a standard when they said the technique facilitated "that the same image information when presented on different displays be seen as the same image" and "that displayed image luminance [values] are independent of the display device". Perceptual linearization is directly or indirectly assumed by various investigators when choosing perceptually defined quantization coefficients in lossy data compression, as well as when determining the minimum digitization resolution.

Human Contrast Sensitivity

Contrast thresholds of human vision – and their reciprocal, the contrast sensitivity function – have been measured only for simple test patterns. Typically, these patterns are uniform squares of variable size and contrast or sinusoidal gratings of variable frequency, number of periods, grating height, and modulation with respect to a uniform background covering the rest of the display screen. Barten[14,15] and Daly[16] have modeled the human visual response and have fitted model constants to different measured data sets. The models consistently describe human contrast sensitivity.

For a display standard, we propose a perceptually linearized function based on Barten's model[14,15] of human contrast sensitivity for sinusoidal gratings. Specifically, the standard refers to:

- Perceptual linearization of 4 cycles per degree (c/deg), which equals 0.5 line pairs per millimeter (lp/mm) at a 0.5-m viewing distance); and
- Square targets of 2 × 2 deg, which is about 17 × 17 mm at a 0.5-m viewing distance.

At the frequency range around 4 c/deg, the contrast sensitivity is maximal in the upper luminance range of current CRT monitors and in a large portion of the display range of radiographic film on a light box.[4] In the first stages of vision, perceived spatial information is decomposed by frequency channels. Contrast of complex objects may be, at least in part, determined by the combined effect of its Fourier components. If this is so, using a sinusoidal modulation as the basis for the standard may not be too primitive. The chosen target dimension – although not quite large enough to enable the eye/brain to fully utilize its integration capability – corresponds to target sizes having uniform texture in conventional radiographs.

The Display-Function Standard

The perceptually linearized display function (Fig. 1) is obtained by computing the threshold modulation S_J – or just-noticeable differences (JNDs) – as a function of mean grating luminance, and stacking these values on top of each other. The mean luminance of the next higher level is calculated by adding the peak-to-peak modulation to the mean luminance L_J of the previous level:

$$L_{J+1} = L_J \cdot \frac{S_J+1}{S_J-1} \, .$$

Functions like the one in Fig. 1 have been used to linearize CRT displays for presentation of gray-scale images having a broad spectrum of spatial frequencies, detail structures, and luminance ranges within the scene. And many researchers and engineers have found that observers are better able to discriminate gray scale in complex images when perceptual linearization is used. In fact, even if a uniformly incrementing luminous target – or step-tablet – with high super-threshold contrast intervals is displayed with the perceptually linearized display function on display devices having different absolute luminances and different luminance ranges, viewers find that the tone scales still look similar.

For the standard conditions – 4 c/deg and 2 × 2 deg targets – we find 1023 JNDs over the luminance range from 0.05 cd/m^2 (the minimum luminance within an image on a very-low-luminance CRT) to 4000 cd/m^2 (the unattenuated level of a very bright light box for mammography interpretation), which is the range shown in Fig. 1. It is possible to represent the standard display function either by 1023 luminance levels over this range or by an interpolated continuous function (see "An Interpolated Function").

Perceptual Linearization of a Display

To reach the perceptually linearized state of a display system, one must calculate a look-up table (LUT) for the digital driver of the display system that maps a digital input D_s to a digital output level D_m so that the standard luminance L_s is produced for D_s (Fig. 2). The LUT can be calculated by following these steps:

1. Display the yet-to-be-defined standard digital gray-scale test pattern with, for example, 17 different levels, including

A Function for Luminance Levels

The standard display function can be represented by an interpolated continuous function such as:

$$Log\, L_I = \frac{a + c\cdot Log\, I + e\cdot(Log\, I)^2 + g\cdot(Log\, I)^3 + j\cdot(Log\, I)^4}{1 + b\cdot Log\, I + d\cdot(Log\, I)^2 + f\cdot(Log\, I)^3 + h\cdot(Log\, I)^4 + k\cdot(Log\, I)^5} \, ,$$

where *Log* is the logarithm to the base 10 and $a = -1.3011877$, $b = -0.011222248$, $c = 0.034848933$, $d = -0.019465161$, $e = 0.025739271$, $f = 2.35464069\text{x}10^{-3}$, $g = -2.08619354\text{x}10^{-3}$, $h = -1.13763214\text{x}10^{-4}$, $j = 4.85068305\text{x}10^{-5}$, $k = 2.00733086\text{x}10^{-6}$. The logarithms of the luminance L_I are very well interpolated by this function over the entire luminance range. The relative deviation of any log(luminance) value from the function is at most 0.3%, and the root-mean-square error is 0.0003.

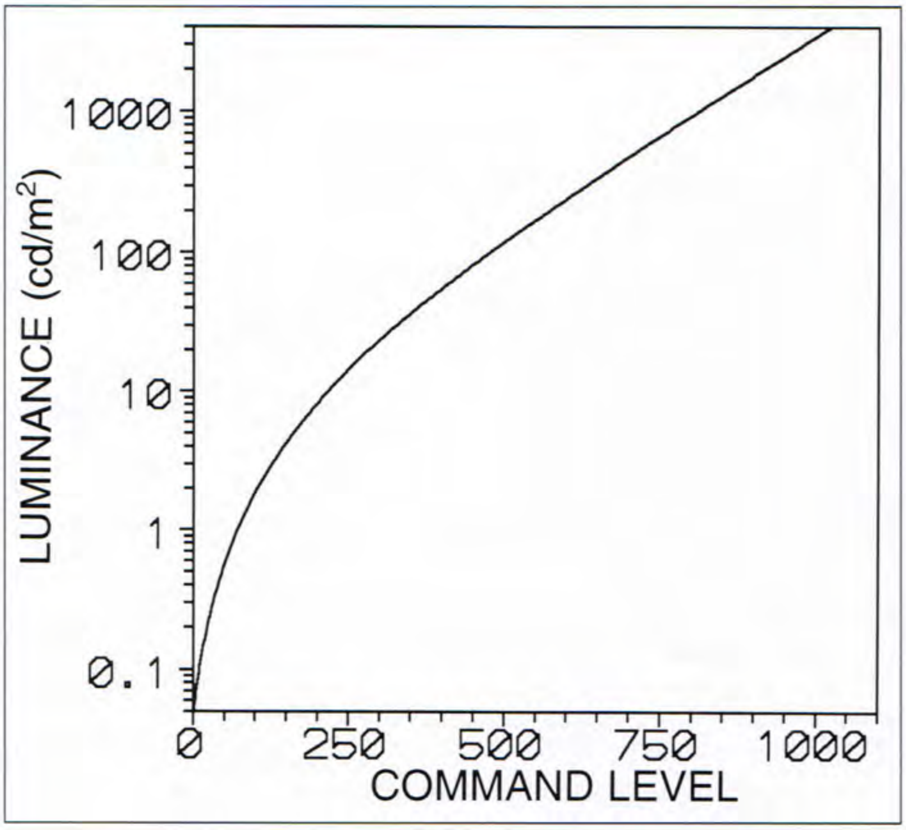

Fig. 1: *A standard display function based on perceptual linearization for sinusoidal gratings of 2 × 2 deg and 4 c/deg, derived from Barten's model of human contrast sensitivity.*

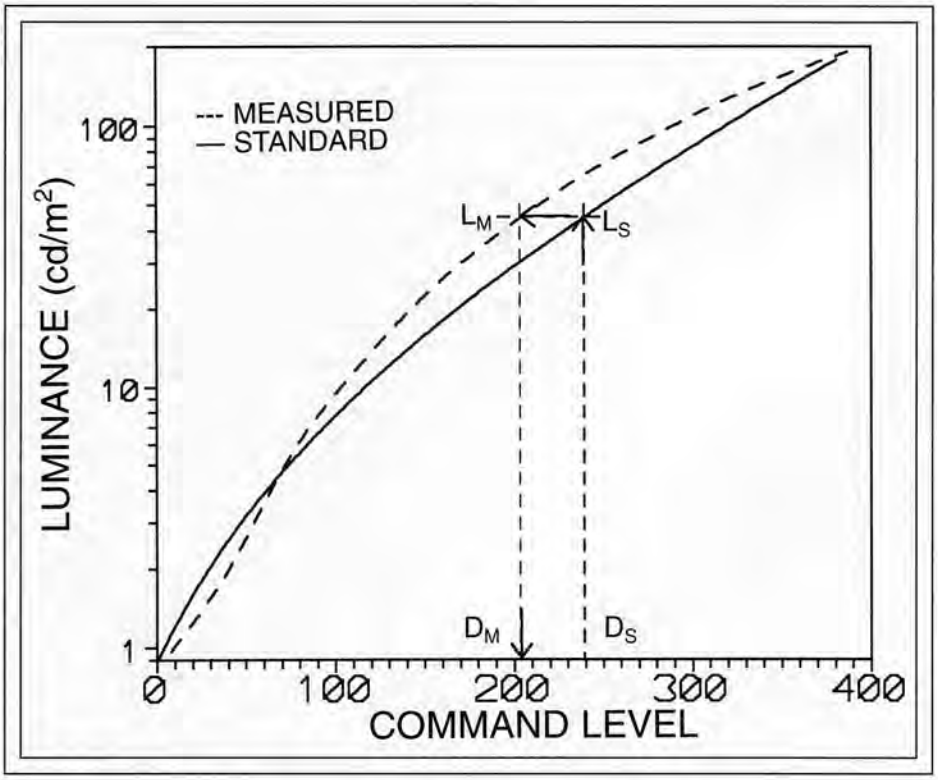

***Fig. 2:** An appropriate display-driver LUT puts a display system with a given measured gray-scale function into the perceptually linearized state.*

the levels corresponding to zero and maximum digital input. Ambient light illumination should be low, uniform, and diffuse. Measure the luminance values L_m at D_m with a photometer in such a way that ambient light is included. The measured values represent the characteristic curve of the display system for the respective test pattern and ambient light level.

2. Interpolate the inverted characteristic curve to obtain its mathematical representation, $D_m = F^{-1}(L_m)$.
3. Using the tabulated or interpolated standard display function $L_s = G(D_s)$ between the measured minimum and maximum luminance levels, compute the LUT according to the equation:

$$D_m = F^{-1}[G(D_s)].$$

The internal and output digitization resolution of the digital driver should be higher than the number N_{JND} over the luminance range of the display system to achieve good reproduction of the standard display function and to utilize human perceptual capabilities to the fullest. The input D_{input} to the driver with digitization resolution DR is scaled to D_s in the following way:

$$D_S = I_0 + \frac{N_{JND}}{DR} \cdot D_{input}, \quad D_{output} = D_m .$$

I_0 is the entry of the standard display-function table closest to the minimum luminance of the display system.

Standard Display-Function Features

The proposed standard display function has seven important features.

1. The proposed standard defines a mathematical function for the relation between luminance and digital input of a monochrome display system and thereby provides predictable and reproducible gray-scale rendition in images. We believe it is essential that the radiological and display communities accept the proposed function as represented by the table. The visual model and the fitting function are a matter of choice and are not critical for the standard.

2. The standard automatically facilitates similarity in tone scale between softcopies and hardcopies of a monochrome image over a wide range of display conditions.

3. The standard display function perceptually linearizes a display, especially for the peak contrast sensitivity near 4 c/deg. A standard display function can be produced for black-and-white (b/w) display systems independent of their maximum luminance and luminance range. And the standard accommodates differences in emission spectra of b/w displays.[4] Perceptual linearization is largely maintained independent of object size, external noise, observer performance variations, target orientation, low supra-threshold contrast, and ambient light.

4. The shape of the standard display function is close to the intrinsic CRT behavior of luminance *vs.* video voltage. But the luminance-*vs.*-voltage function is not adequate in itself, even apart from the fact that it is not mathematically defined.

5. The implementation of the standard display function requires a fine digitization resolution in the display driver. For a uniform distribution of digitization levels and a display system with negligible intrinsic noise, a minimum of 10 bits is required. For any image displayed with perceptual linearization, this is the minimum number of bits needed to avoid significant loss of information and/or contouring artifacts. (The characteristic curve of a commercial CRT monitor is shown in Fig. 2.) Three-hundred eighty-seven (387) JNDs of the standard display function fall within this monitor's luminance range. With 10-bit driver digitization resolution, *only* 262 of all potential gray-scale steps come within 95% of the 387 JND that exist for the perfectly and continuously reproduced perceptually linearized display function. Anything less might not be acceptable.

6. Even when the perceptually linearized display function is used for every image display, information transfer with softcopies and hardcopies cannot be the same unless the luminance of the displays is identical or the observer operates completely in the Weber region. A hardcopy of an image displayed at higher luminance always exhibits more JNDs than the softcopy.

7. The standard display function typically produces a satisfactory impression of an image, and it may yield optimal observer per-

formance when information is uniformly spread over the entire luminance range of the image. The perceptually linearized display function is not necessarily the best display function for a specific image, which would depend on the distribution of needed information over the input data range and the luminance range of the display when presenting the image.

The proposed standard is not a visualization standard. But since it gives a mathematical definition for the standard gray-scale response of a display system, one can modify the appearance of any particular image through additional LUT operations.

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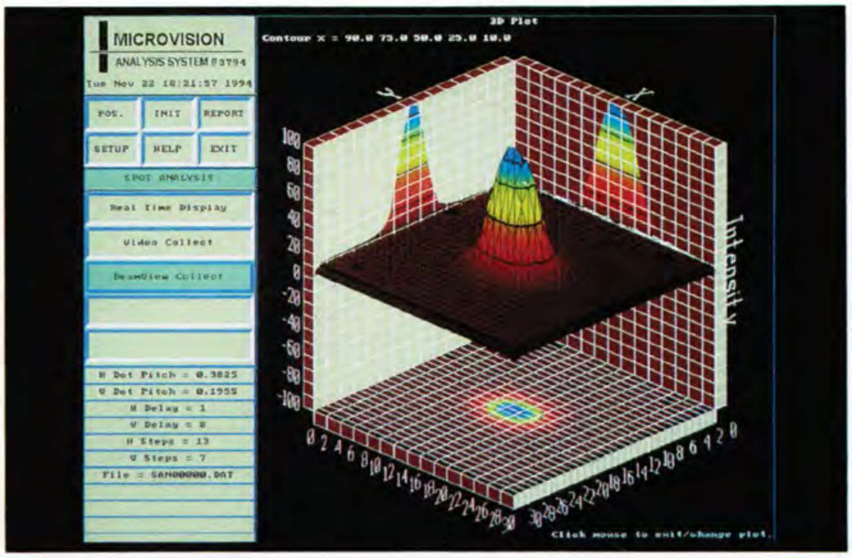

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INFOCOMM's Projection-Display Shootout

With dozens of vendors insisting on a scrupulously fair playing field, the Shootout's tech staff treads carefully – very carefully.

by Joe Hallett

SIDE-BY-SIDE demonstrations of professional-level display products are as hard to find as horseshoe nails in Manhattan. That's why the Projection-Display Shootout at the INFOCOMM show – to be held this year in Dallas, June 12–17 – has in a mere 5 years become a classic event for users and manufacturers of display equipment. INFOCOMM, sponsored by the International Communications Industries Association (ICIA), has as its highlight a "shootout" among video, data, and graphics projectors, but it also features side-by-side comparisons of monitors and videowalls.

Only products that are in production and available for purchase can be displayed, but that has not kept the Shootout from showcasing major advances in projection-display technology. The changes have been dramatic. All manufacturers have moved to a higher and more uniform performance level, and new technologies – mainly LCD-based – have gained a significant presence in categories that used to be dominated by CRTs. In recent Shootouts, it was often difficult to tell from a distance which technology was being used in a particular product.

The "high end" has also seen major changes. By 1994, the venerable Eidophor was shown separately, and did not participate in side-by-side comparisons. Perhaps this resulted from the discontinuation of the other stalwart oil-film light valve: General Electric's Talaria. But the void at the high end is quickly being filled with new products based on large LCD light valves from companies such as Hughes-JVC, Barco, and Ampro.

Creating a Classic

Imre Czsar set up the first Shootout while he was with Covid Electronics, a firm that specialized in interfaces among computers and audio-video equipment. According to Czsar, the Shootout was originally conceived as a vehicle for showing differences in projectors "regardless of claimed specifications." It was seen as a "sidebar" to the INFOCOMM show, and efforts were made to prevent it from becoming a distraction to attendees. Fewer than 25 products were shown at the first Shootout held in Dallas in 1990. Competitors quickly discovered their strengths and weaknesses. There were big differences among

Chuck Giorno Photography/ICIA

Fig. 1: Starting as a sideshow 5 years ago, INFOCOMM's Projection-Display Shootout is now the major attraction for many INFOCOMM attendees.

Joe Hallett is a consultant and can be reached at 22370 S.W. Grahams Ferry Rd., Tualatin, OR 97062-8022; telephone 503/692-5554, fax -5649. For more information on the Shootout, contact the ICIA at 703/273-7200.

displays, particularly in color temperature, brightness/uniformity, and focus.

Much of the equipment was donated, and test images were taken from a handmade laser disk. Czsar was the Shootout's first emcee. Wearing a cowboy hat, badge, gun, and borrowed boots, he added a show-biz touch that helped soften the charged atmosphere – despite the natural wariness of competitors showing their products in the same room for the first time. The manufacturers survived and the ICIA had a major new attraction on its hands.

The Shootout began at a time when display-equipment manufacturers were involved in a "horsepower race" over "brightness." The time was right for a cooperative effort among manufacturers and users to standardize methods for measuring and specifying the performance of projection displays. Side-by-side comparisons quickly demonstrated the need for standardized specifications. That need helped drive the creation of ANSI standard IT7.215, which now must be used by all Shootout participants.

From Sideshow to Main Event

By the time it was presented for the second time – in Orlando in 1991 – the Shootout was quickly taking on a life of its own and becoming the primary draw at INFOCOMM for many attendees. Customers and competitors, some equipped with portable measuring equipment, packed the specially prepared hall.

Following the 1992 show, the job of providing technical support for the Shootout was taken on by Gary Kayye and his associates at Extron Electronics of Tempe, Arizona. Among their other responsibilities, Extron sets up and operates the signal-generation and switching systems.

"The entrant's overriding concern is quality," says Steve Sommers, Extron's engineering vice president and architect of the signal system. According to Sommers, the setup is being adjusted right up to the last minute, and the necessary flexibility must be designed into the signal-distribution system.

Planning starts months before the actual event with identifying the categories – typically six or seven – and arranging the floor plan to minimize cable runs. "Satisfying the exhibitors' concerns that everyone receive identical high-quality signals means that all entrants in a category run from the same run of cable, typically 100 ft. from the last distribution amplifier," says Sommers. Different cables – ranging from miniature coax to fiber – are used, as appropriate to the length of the run and the nature of the signals being carried. Test patterns and images are chosen to highlight the parameters that are important in the applications for each group of projectors. For example, the factors critical in presenting business graphics are different from those that apply to motion video. The projection screens – critical elements in the side-by-side comparisons – are chosen for uniformity and acceptability to the exhibitors.

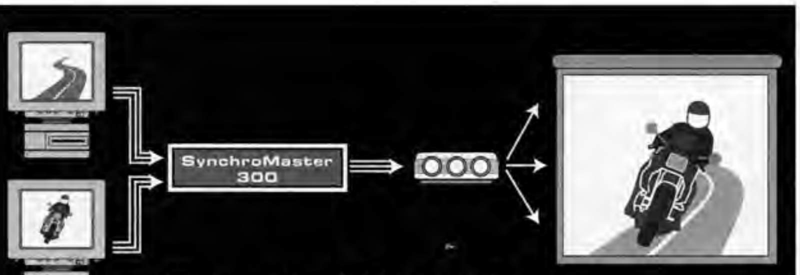
On site, it takes up to 12 people a day and a half to set up the signal system – including cleaning up the inevitable power and ground problems – and another half day to adjust signal levels. "We run with four to six people," Sommers said, with two on duty at all times when the Shootout is open.

Going International

INFOCOMM Shootouts held in the U.S. have made a big impact on manufacturers, dealers, and users of projection-display products. Now the event is going international. The ICIA will sponsor the first INFOCOMM Asia show in Singapore, November 24–26, 1995. The show will feature the display Shootout, including side-by-side demonstrations in light-valve, LCD, CRT retro, and monitor categories. The first Shootout to be held outside the U.S. was at the 1994 Photokina exposition in Koln, Germany, where more than 50 projectors were shown in side-by-side demonstrations.

Last year's U.S.-based Shootout was held conveniently in Anaheim the week before the SID conference, and attracted many SID attendees. INFOCOMM '95 will be held June 12–17 in Dallas, Texas – two weeks after SID '95. ■

OVERLAY GRAPHICS FROM MULTIPLE SOURCES



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SID-Sponsored Meetings

Symposium on vehicle displays

The Detroit Chapter of SID will be holding a symposium on Vehicle Displays at the Radisson Hotel in Ypsilanti, Michigan, on November 2, 1995, in conjunction with the University of Michigan's Second Annual Flat-Panel Display Strategic Forum. The field of vehicle displays has the potential of becoming a rapidly growing sector of the electronic display market. The one-day symposium will address the requirements vis-a-vis the technical issues concerning vehicle displays present and future. The concerns related to the choice and availability of displays suited to vehicle applications will be analyzed, focusing on technical and market requirements. There will be an evening panel discussion on vehicle displays after dinner on November 2. Abstracts on the following related topics are being solicited: displays for vehicles, special requirements for display glass components, standardization and environment display characterization, packaging issues, and human factors. The abstract deadline is July 14, 1995.

Information: Zvi Yaniv, Symposium Chair, or Sue Cutler, 810/476-4555, fax -4550. Bob Donofrio, Program Chair, or Ann Dalton, 313/996-9400, fax 313/662-9090.

Conference on display phosphors

The First International Conference on the Science and Technology of Display Phosphors will be held November 14–16, 1995 at the Mission Valley Hilton in San Diego, California. The conference is co-sponsored by the Phosphor Technology Center of Excellence, ARPA, and SID. The purpose of this conference is to discuss the present and future prospects of phosphors for electroluminescent (EL), field-emission, CRT, and plasma displays; photoluminescent (PL) devices; and liquid-crystal backlights. The development of phosphors for advanced display systems is a multidisciplinary field requiring input from system designers, materials scientists, chemists, and physicists. The goal of this meeting is to bring these disciplines together to present and discuss the latest results and directions, and to define the issues and challenges in future phosphor research and development.

Information: Christopher J. Summers, Chair, PTCOE/Georgia Institute of Technology, or Sarah Andrews, 404/894-1260, fax -1258. Jay Morreale, Conference Coordinator, Palisades Institute for Research Services, Inc., 212/620-3371, fax -3379. ■

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.
- BEATRICE WINNER AWARD. Awarded periodically (but not more than once a year) 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 should be concise, but they must include the following information, preferably in the order given below.

1. Name, Present Occupation, Business and Home Address, and SID Membership 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 specific evidence such as patents, publications, SID activities, other technical and/or professional society activities, evidence of outstanding leadership, etc. Please be specific and concise. Cite material that directly supports the citation and statement in (7) above. Limit the evidence to the most important patents, publications, or service – do not generalize. (The nominee may be asked by the nominator to supply information for his candidacy).
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, 1995.**

conference report

Getting the Best from State-of-the-Art Display Systems

This London conference pleased its attendees by focusing on systems, applications, and users.

by Bob Raikes

IN THE SPLENDID SETTING of the National Gallery in London, the Society for Information Display (SID) sponsored an international conference called "Getting the Best from State-of-the-Art Display Systems," February 21–23, 1995. It was refreshing to be able to walk through the gallery and marvel at the use of color and, at times, very limited gamuts and resolutions by artists who were masters of communication.

The first day of the conference – which was organized by Lindsay Macdonald of Crosfield Electronics and Tony Lowe of IBM – was billed as a tutorial. It was followed by 2 days of presentations aimed at the professional engineer engaged in the development of applications that depend on displays.

The tutorial session was opened by Carl Machover, who emphasized the enormous range of applications that now depend on computer graphics and displays. He showed videos of some state-of-the-art applications, including simulations of new products that were difficult to distinguish from reality. Nonetheless, he emphasized that there is still a long way to go to develop displays of sufficient quality for every application. For example, a current head-mounted display (HMD) is of such low resolution that users would be classified as legally blind if they saw with the same image quality. Virtual reality (VR) is unlikely to move much further until this changes.

Machover was followed by the sole software specialist at the conference, Ben Shneiderman, Professor of Computer Science at the University of Maryland and head of the Human–Computer Interaction Laboratory. Shneiderman made a passionate plea for care and thought in designing user interfaces, going beyond the idea of "user friendly." He stressed the importance of consistency in interface design, which would help the user by making it unnecessary to continually re-learn applications. Most of the tutorial was a description and demonstration of innovative visual approaches to database querying that are built on the principles that Shneiderman described as the visual-information-seeking mantra: overview, zoom and filter, and details-on-demand. The mantra, said Shneiderman, is to be chanted every morning before designing applications!

Louis Silverstein of VCD Sciences, Inc. reviewed the color performance of different display technologies. He explained the basic colorimetrics based on CIE chromaticity and discussed the appropriate occasions for using the different CIE color-matching functions. He went on to discuss the differences between the CIE Lab and CIE Luv color models, and explained his preference for the CIE Lab model for displays, although it has usually been favored for hardcopy applications.

Jean Glasser of the CNET/LAB of Telecom, France, concentrated on the question of measurement, differentiating between parameters important for legibility and those critical for fidelity. He also made a strong case for the importance of standards. But developing standards for displays is difficult because the task of a display is to interface with a human. That makes complete objectivity difficult.

Glasser highlighted the importance of controlled environments when making measurements. LCDs in particular are very sensitive to small temperature differences, so CNET circulates an optically neutral dielectric coolant round a display under test to control the temperature.

Technical Sessions: The First Day

In the first session of the conference proper, Carl Machover went through some of the ways that applications drive the technology of computer graphics and how this technology is taken up by different groups in the classic marketing model of innovation adoption. While innovators may be happy to accept technology with significant limitations and imperfections, the consumer further down the hierarchy will demand much more of the technology and its ease of use. For this reason, Machover is unconvinced that immersive and helmet-mounted displays will be successful without dramatic improvements.

Philip Robertson of the CSIRO Division of Information Technology, Canberra, Australia, discussed approaches for using perceptual color space in scientific modeling, particularly geoscience. He pointed out that a 1% improvement in ore extraction meant $750 million per

Bob Raikes is the Editor of Display Monitor Newsletter. *This article is a summary of a much longer paper that appeared in* Display Monitor Newsletter, *Vol. 2, No. 9 (March 3, 1995). For more information, contact Mr. Raikes at Meko, Ltd., 134 Upper Chobham Rd., Camberley, Surrey, GU15 1EJ, England; telephone 44-1276-22677, fax: -64004, e-mail: braikes@cix.compulink.co.uk*

year to the Australian economy, so helping geoscientists improve their data interpretation and analysis has a big payoff. This area of research is also crucial in fields such as medicine.

While color has been used for over 15 years in advanced applications, up to now color-management systems have not been effectively integrated into computer systems. Robertson would like to see displays that automatically compensate for different conditions. He would also like to see an indication to the user if adjustment to the monitor means a change in the gamut.

Earlier, we had heard some doubts about immersive VR applications, but Richard Holmes, Design Director of Virtuality, a leader in commercial exploitation of VR, is a committed supporter. He gave an overview of the technologies currently being used for HMDs in VR applications. Although CRTs have the edge in terms of visual quality, the problems of very high voltages and the mass of a CRT are major disadvantages. Active-matrix LCDs (AMLCDs), especially those based on polysilicon, are increasingly the display of choice. None of the competing flat-panel technologies can match the range of advantages of AMLCD at present. Holmes highlighted difficulties that are related to separate displays being used for each eye, among which is maintaining color balance between the two displays. A final point was that while traditional displays have been trying hard to develop flat screens, for HMDs a concave shape may be best!

Following on from his talk at the tutorial, Prof. Shneiderman gave an intriguing talk on consistency in the designs of graphical user interfaces (GUIs). Taking the highly regarded interface for the Apple Macintosh operating system as an example, he showed how inconsistent it was in its dialogue boxes and menuing despite the formal style guide. He then went on to describe how the University of Maryland is trying to develop a tool for analyzing applications to reveal inconsistencies. An example of the techniques used is the building of a concordance table for strings in dialogue boxes. This helps to highlight different spellings and abbreviations for similar words. A study of the range of words used may also reveal confusion in terminology. Analysis can also be performed on the size and position of common buttons – such as "OK" and "Cancel" – and the range of fonts and sizes used in an application.

David Travis of the British Telecom (BT) Centre for Human Communications at Martlesham Heath described how BT is working on the human aspects of visual communications. One of the major barriers to the adoption of video-conferencing and related technologies has been the discomfort that users have with current systems. Travis drew sympathetic applause when he spoke of the need to ensure that technological systems are usable. He explained how video-mediated communication disrupts normal patterns by failing to take advantage of the huge set of conversational and body-language clues that normally form a major element of interpersonal communication. Therefore, BT has been experimenting with ways of improving group work using video based on two fundamental principles:

1. Remote workers should have the same flexibility and tools as participants who are physically present.
2. Workers who are physically present should not have to change their style of working.

Lou Silverstein described the ViDEOS model for display performance, which has been developed with support from the U.S. Advanced Research Projects Agency (ARPA). The model has been used in developing Xerox PARC's 13-in. 1536 × 1024 full-color display, which has been widely exhibited.

Dick Bosman of the University of Twente discussed the change in visual acuity with age, and the effects of stroke width and character height in situations of normal and negative contrast (black-on-white display). He explained how anti-aliasing can lead to a reduction in the brightness level required to identify and see clearly small characters with thin stroke widths.

David Parker of Philips Research Labs explored the performance of different types of display devices; in particular, their ability to accurately display motion. Up to now, most computer graphics have displayed relatively static images, but with the increasing use of multimedia and video techniques, the question of motion portrayal is becoming a real issue.

Parker commented that the short impulse response of CRTs is ideal for dynamic displays. With an AMLCD, each pixel is held on for the entire frame period, so dynamic resolution is considerably worse than with a CRT. The capacitance of the LC pixel can introduce a delay in the pixel voltage reaching the required level. This can be corrected by pre-correction, but the pre-correction requires the use of a frame store and an increase in the column drive voltage.

What Current Technology Can Deliver

Tony Lowe of IBM started the second morning, which had as its theme, "What Current Technology Can Deliver." He first classified existing display technologies – including HMDs, paper and print, and projection systems – in terms of their size and resolution. He showed that direct-view systems are starting to overlap areas that have been the province of paper until now.

Ernst Lueder of Stuttgart University, Germany, looked in detail at some of the problems and opportunities involved in building TFT and metal-insulator-metal (MIM) based displays. He did not consider diode switching because the performance is lower than that of TFTs, while the cost is higher than that of MIMs. Lueder described details of the fabrication techniques of both devices. The cost advantages of the MIM come from low mask count, the robustness of the process steps, and the application of sputtering only. MIMs also have a high aperture ratio. a-Si TFTs typically have an aperture ratio of 40%, while MIMs achieve at least 80%, so MIM displays have roughly twice as much luminance as TFTs. Lueder sees MIM-based displays being used where low cost and high brightness are needed, but where low pixel density and fewer gray shades are acceptable – in automotive applications, for example.

Alan Mosely of the Hirst Research Centre presented a fascinating paper comparing the development of AMLCDs and ferroelectric LCDs (FLCDs). Although FLCDs were developed around 1983 at about the same time as supertwist LCDs, the total sales of FLCDs worldwide is probably less than $1 million, compared to several billion dollars for STN and AMLCDs. Mosely attributed much of the difference in development of the two technologies to the fact that the infrastructure to manufacture STN-LCDs was already in place because of the manufacture of TN-LCDs. There is still time for the FLCD technology to make an impact, and work is being carried on by Canon and GEC Hirst. The most likely area for success is in portable systems, where the power-saving of FLCD's bistable effect is most useful.

Jean-Pierre Budin of the Institut d'Electronique Fondamental, Université Paris Sud, France, next looked in detail at the technologies behind two current panel types, ac thin-film electroluminescent (ACTFEL) displays and plasma display panels (PDPs). He explained the different approaches used to create color: by using patterned phosphors that emit different colored light and by using a white phosphor with patterned color filters. Because of the problems in achieving full-color displays, applications are likely to remain in areas where a wide viewing angle is critical – as in medical monitoring.

Next, the principles of PDPs were looked at, as were some of the techniques used to achieve good gray-scale performance. As with other emissive systems, viewing angle is good. There is a lot of support over three continents for the development of PDPs, especially in the size range from 20 to 40 in.

Senyo Sluyterman of Philips in Eindhoven, The Netherlands, is a champion of CRTs. He stressed the great advantages of the CRT, including the ability to work easily in multi-standard monitors. The CRT will continue to be the dominant technology for some time because of the low cost, wide color range, gray-scale performance, large viewing angle, and excellent representation of moving images.

Measurement, Calibration, and Standards

The final session of the conference was devoted to measurement, calibration, and standards. The session was started by Jean Glasser, who discussed the effects of diffuse and specular reflections. He expressed his view, with examples of measurements of commercial STN displays, that the effects of reflection are such that speaking of display contrast in absolute terms has no meaning. While it would seem obvious that illumination can reduce contrast, it is also possible for contrast to increase because of reflection. This is currently the subject of work being done for the ISO9241/7 draft standard.

Andrew Hanson of the U.K. National Physical Laboratory presented a paper on measurement and standardization in the colorimetry of CRT displays. He commented that color variations in the individual phosphor dots in a CRT make it important to take the mean measurement of a number of triads. The color also varies with time because each of the different phosphor colors has a different persistence, and it will also change during the warm-up period.

Wrap-up

Three points came up many times during the 3 days of this excellent conference. The first was Robert Spence's concept of information, not data, being of paramount importance. Displays are arguably the most important component of many future systems, but if they are to be really useful, they must provide information as well as data – or at least make the process of extraction easier for users.

The second point was the need for interaction with the users of computer systems. This may be a fruitful area for display technologists, who have concentrated up to now on system outputs rather than inputs.

Finally, there was the question of characterizing displays, which are affected so much by ambient illumination, according to their contrast. Perhaps there is an opportunity to develop new ways of measuring performance. ■

SID '96

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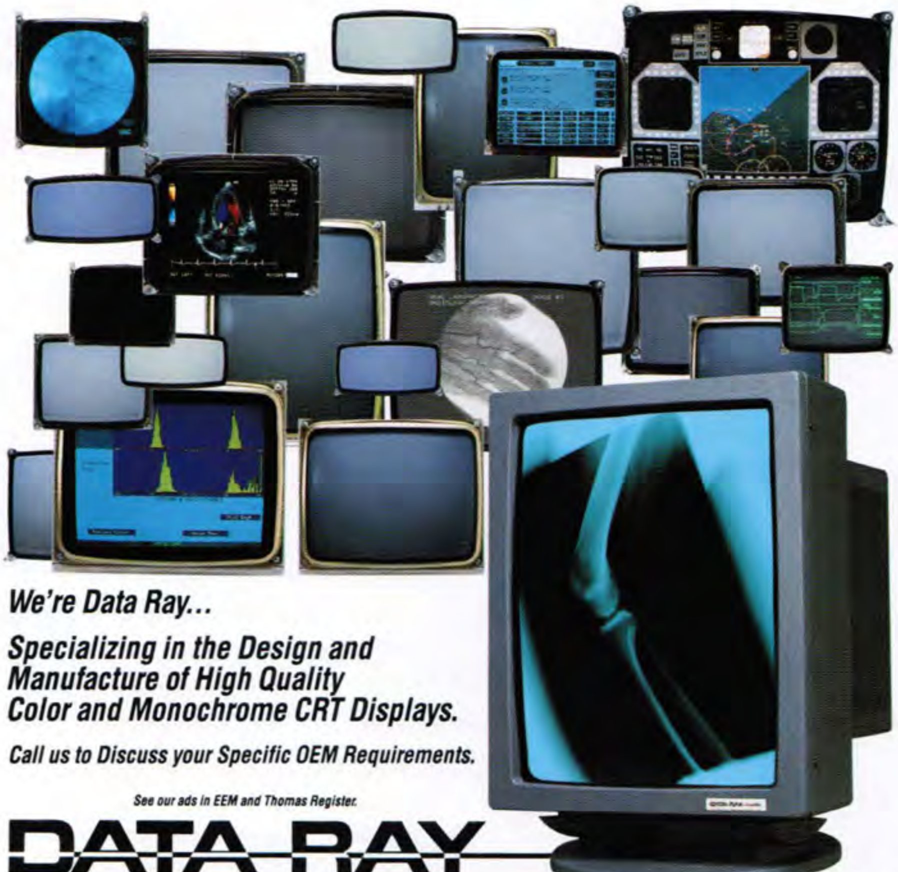

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Circle no. 26

Edited by JOAN GORMAN

Next-generation FP inspection system

Photon Dynamics, Milpitas, California, has announced the FIS-250, a flat-panel inspection system with automation and full cell contacting options that provides the flat-panel manufacturer with the ability to inspect and measure displays at the cell and module assembly levels prior to shipment to customers. The FIS-250 evaluates optical qualities such as mura, pixel and line defects, contrast, and chromaticity using parameters set by the manufacturer. The system can perform tests on all major display technologies, including TFT, STN, passive matrix, FED, plasma, EL, and MIM. Test time is reduced by over 40%, making it the fastest system available, and requires less than 4 s per test for pixel-defect detection, line-defect detection, mura detection, and gross non-uniformities. In addition, the sensitivity of pixel- and line-defect detection has been significantly improved to offer 16 levels of gray-scale detection.

Information: Becky H. Takeda, Photon Dynamics, Inc., 1504 McCarthy Blvd., Milpitas, CA 95035. 408/433-3922 x225, fax 408/433-3925.

Circle no. 1

Ultra-compact computer

Laversab, Inc., Houston, Texas, has introduced the Model 2522, a small, lightweight, totally sealed all-condition computer that can withstand harsh working environments in a package smaller than an attaché case. The unit has a built-in NEMA-4 keyboard and mouse, and is sealed on all sides to meet NEMA-4 standards, thus eliminating the need for additional enclosures. The Model 2522 weighs only 11.5 lbs., and its 14.75 (W) × 13 (H) × 3.59 (D) in. size features a variety of options in 9.5-in. flat-panel displays. Despite its small size, two full-size expansion slots are available for users to customize for special applications. Powered by ac or choices of Vdc, this all-condition computer can be carried, installed in vehicles, or mounted on walls. Model 2522 is available with a 386SX, 486SX, or 486DX33 CPU with up to 16 MB of RAM. Hard drives are available in sizes up to 524 MB. Additional options include PCMCIA, touch screens, barcode input, and rf capabilities.

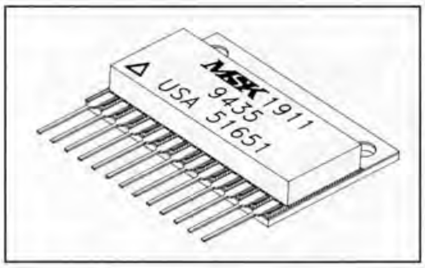
Information: John C. Hemphill, V.P. Sales, Laversab, Inc., 10503 Rockley Road, Suite 103, Houston, TX 77099. 713/568-8394, fax -8399.

Circle no. 2

Ultra-high-performance CRT driver

M. S. Kennedy Corp., Cicero, New York, has announced the MSK 1911, a low-cost ultra-high-performance video amplifier capable of 2.0-ns transition times, with 50-V_{p-p} output swings, and a bandwidth of 225 MHz. Its open collector output is designed to directly drive high-resolution video displays. Other offered features include dc coupled differential inputs and linearly adjustable gain with an output offset adjustment. The MSK 1911 also has an onboard buffered dc reference output, provided for gain and offset adjustment, that can source up to 4 mA of current. A 200-Ω load resistor is provided internally to minimize parasitic reactances and improve transient response times. Packaged in a convenient single in-line package, pricing starts at under $20.

Information: Greg Overend, Sales Manager, M. S. Kennedy Corp., 8170 Thompson Road, Cicero, NY 13039. 315/699-9201, fax -8023.

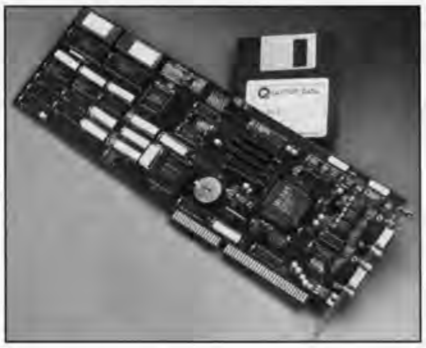


Circle no. 3

Plug-in video test generator

Quantum Data, Elgin, Illinois, has converted its 801 Series generator into a new video test generator on a plug-in card for PCs. The new plug-in model provides the capability of using multiple generators in a single PC, which translates into substantial savings over stand-alone units in the production and life-test environment. The 801GC-ISA offers an easy-to-use MS Windows® user interface. The 801 G-Series are the only generators available with self-calibrating analog video outputs, providing accurate output levels within millivolts to assure perfect video output levels and color precision for monitors. The user can also create custom formats, test patterns, and test sequences that can be saved to the PC's hard drive and to the onboard nonvolatile RAM.

Information: Quantum Data, 2111 Big Timber Road, Elgin, IL 60123. 708/888-0450, fax -2802.



Circle no. 4

Industrial touch monitor

Nortech Engineering, Inc., Medfield, Massachusetts, has announced the CM1710, a 17-in. industrial video monitor available with resistive, capacitive, or SAW touch screens. The monitor is comprised of a 17-in. ultra-high-resolution autoscan CRT display and a touch screen housed in a sheet metal enclosure with a front panel sealed according to NEMA-4 ratings. The unit is available in either a rack- or panel-mounted configuration and operates at 50°C with fan cooling. The monitor is self-contained, with a power supply for fan and touch-screen serial controller. The CM1710 uses digital controls to preset or change video modes and to optimize video image quality. The CRT display has a resolution of 1280 × 1024, non-interlaced, and uses a 17-in. flat square CRT, allowing image adjustment to the edge of the screen. It is compatible with all of the IBM, VESA, Apple Macintosh II family, and Sun workstation standards. A model without a touch screen is also available. The price of the touch-screen model is $2485, and $1595 without touch screen. Delivery is 2–4 weeks ARO.

Information: Mel Silverstein, Nortech Engineering, Inc., 19 Whichita Road, Medfield, MA 02052. 508/359-6063, fax -7746.

Circle no. 5

Full-color VGA AMLCD

Philips Components, Eindhoven, The Netherlands, has announced the LDH102T-10, a new active-matrix LCD module that offers VGA resolution on a 10.4-in.-diagonal screen and 24-bit driver electronics displaying up to 16.7 million colors. These features provide the necessary picture performance and color purity for today's high-end notebook computers, particularly those specializing in multimedia applications. Each pixel is addressed by diodes instead of TFTs, allowing for larger apertures and hence brighter pictures or lower-power backlighting. The backlight tube of the LDH102T-10 offers lifetimes up to 40,000 hours, equivalent to about 20 years of normal operation of a notebook computer. The LDH102T-20 industrial version is also available, which is intended for applications such as medical equipment and industrial terminals.

Information: John den Holder, Philips Components, Marketing Communications, Bldg. BAE-1, P.O. Box 218, 5600 MD, Eindhoven, The Netherlands. 31-40-72-27-90, fax 31-40-72-45-47.

Circle no. 6

Flat square touch monitor

MicroTouch Systems, Inc., Methuen, Massachusetts, has introduced the TruePoint-DP15, a 15-in. flat square touch monitor designed for PC or Macintosh kiosk, multimedia, and business applications. The DP15 integrates the high-resolution Mitsubishi Diamond Pro® 15FS display with the MicroTouch capacitive touch screen and controller and all required touch drivers. The 15-in. monitor features an on-screen control panel that allows easy adjustments to setup parameters. An MPU-based 30–64 kHz autoscan range incorporated into the touch monitor supports many of the available graphics standards up to 1280 × 1024 at 60 Hz or 1024 × 768 at high refresh rates up to 76 Hz, and incorporates an ultra-fine 0.28-mm dot pitch. A TruePoint-DP15 evaluation unit is guaranteed to ship within 24 hours. The list price for the TruePoint-DP15 is $1445; volume and dealer discounts are available. The touch sensor and controller each have a 5-year warranty; the monitor has a 3-year warranty.

Information: Annette Petagna, MicroTouch Systems, Inc., 300 Griffin Park, Methuen, MA 01844. 1-800-642-7686, fax 508/659-9100.

Circle no. 7

Multi-headed display board

Dome Imaging Systems, Waltham, Massachusetts, has announced the release of the Md2/PCI, a high-resolution multi-headed display board for PCI-based computers and workstations. The board is intended for imaging applications requiring exceptionally high-quality displays and support for multiple display monitors, and supports a variety of resolutions up to 1600 × 1200 pixels (2 Mpixels) in either landscape or portrait mode. A single board can drive one or two display monitors, saving valuable PCI slots in multi-headed systems. The Md2/PCI also features a 10-bit DAC and a luminance calibrator port, allowing the monitor to be accurately corrected for gray-scale fidelity. The board's 10-bit DAC can send up to 1024 distinct analog values to the monitor, compared to the 256 values provided by most competitive 8-bit boards.

Information: Dome Imaging Systems, 400 Fifth Ave., Waltham, MA 02154. 617/895-1155, fax -1133.

Circle no. 8

Second-generation mini-CRT displays

Gritz's Emporium, Inc., Carlsbad, California, has announced a line of second-generation miniature-CRT displays manufactured by Miyota Co., Ltd., Japan. The color series, available in 1.0 and 1.5 in., exhibits a resolution of 600 TV lines utilizing liquid-crystal shutters. The pixelated color saturation, resolution, and contrast now far exceed those of color LCDs. The power consumption of these units is slightly over 6 W, and a brightness of 50–60 nits can be obtained. Fiber-optic displays measuring 1.5 in. diagonally are also available for addressing liquid-crystal light valves. These new series will extend the application of miniaturized CRT displays in all disciplines of display technology, from virtual reality to projection.

Information: Edward Gritz, Gritz's Emporium, Inc., 2708/2711 Via Roberto, Carlsbad, CA 92008. 619/434-4676, fax -7875/4758.
Circle no. 9

Dual-scan passive color FPD

Computer Dynamics, Greer, South Carolina, has announced the DisplayPac-DScan, a compact flat-panel computer offering brilliant high-contrast color in a dual-scan passive color LCD. The complete system with the display, a powerful 486 PC platform, and touch screen is only 2.5 in. thick and is priced comparably with monochrome display units. The dual-scan passive-matrix color LCD offers a 10.4-in.-diagonal viewing area, the largest of any passive display, and a resolution of 640 × 480. A potentiometer for contrast control is standard with the unit, and its newly designed rugged metal OEM frame allows easy interchangeability with other FPDs in the DisplayPac line, including the 10.4-in. color TFT-LCD and others soon to be announced. A resistive or IR touch screen is optional; the IR touch screen provides a NEMA-12 seal. The DisplayPac-DScan is priced at $3359 (OEM quantity) for the 25-MHz 486SX-based system with dual-scan passive-matrix color LCD and resistive or IR touch screen.

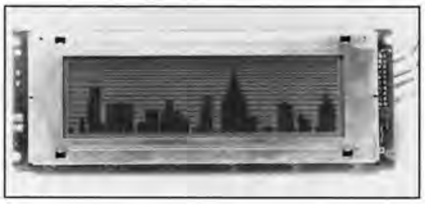
Information: Computer Dynamics, Sales Department, 107 S. Main Street, Greer, SC 29650. 803/877-8700, fax 803/879-2030.

Circle no. 10

Intelligent graphics module

AND, a Division of William J. Purdy Co., has announced the AND711AST-EO, an intelligent LCD graphics module intended for hand-held terminals, point-of-sale displays, and measurement instruments. The supertwist module has a dot resolution of 240 × 64 with alphanumeric capabilities of 40 characters × 8 lines and a built-in character-generator ROM. The AND711AST-EO includes a controller with standard 8-data-bit CPU interface and 8-KB display RAM, as well as an electroluminescent backlight panel. The module offers the designer compact size, built-in backlight, and low power consumption in a unit that is easy to read in all lighting environments.

Information: Gloria Sayers, AND, 770 Airport Blvd., Burlingame, CA 94010. 415/347-9916, fax 415/340-1670.



Circle no. 11 ■

6 **96**

FEBRUARY

Display Works '96
SAN JOSE, CALIFORNIA
FEBRUARY 6 – 8, 1996

An international conference addressing all aspects of Display Manufacturing including:
- Flat Panel and CRT Manufacturing
- Large-Area Processing
- Display Materials
- Cost Reduction and Yield Improvement
- Manufacturing Equipment
- Quality Management
- Test, Repair, and Measurement

7 **95**

NOVEMBER

3rd Color Imaging Conference: Color Science, Systems, & Applications
SCOTTSDALE, ARIZONA
NOVEMBER 7 – 10, 1995

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

display continuum

continued from page 4

popular spokesperson for the "new order." Here are a few sample paragraphs from this interview:

> "They're arguing about atoms, when this is really about bits. Atoms are the products of the old order – tangible objects like cars, clothes, soft drinks or compact disks. Bits are products of the new order – information or entertainment in digital form, able to take shape on personal computers, TVs, paper or any medium."
>
> "Everyone believes in public libraries. In a library, words (bits) are in books (atoms). Anybody can borrow the books to read the words, and it's free. But a library will carry only a copy or two of a book. If the copies are out, other people have to wait to read the words. The bits don't move around very quickly, so book publishers aren't threatened. A lot of people will still go out and buy books, which is how publishers and writers get paid."
>
> "Because libraries are based on atoms, they are inefficient and sluggish, and it works. But let's say you set up a digital library. Anyone can tap in and pull down a book over a phone line and read it on a PC. Suddenly, 30 million people from around the world could read a book at one time from one library. They'd find it so easy to get the free book, they'd be less likely to buy a copy."

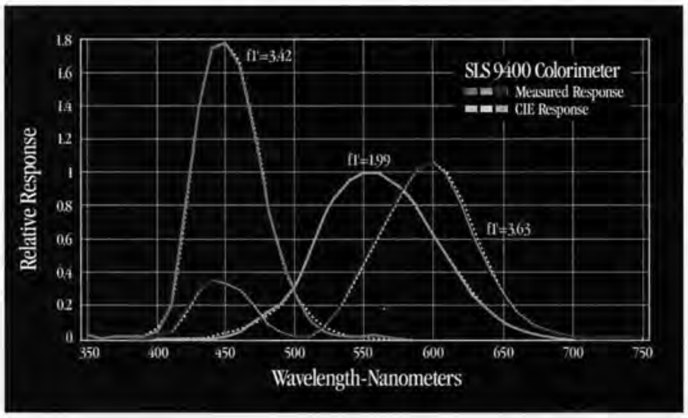
Can anyone tell me when this new order came into being and when we changed over from atoms to bits? Or is it still to happen on some magic date in the impending future? Will I know it from the pile of bits that suddenly avalanche-like bury me?

When I run across too many articles like these, then I too get overly excited. (That's a polite way of saying what I'm really thinking.) But it's not about the technology. What gets me so upset are these stories that make it sound as if we have been living in the Dark Ages until just a few days ago. I want to jump up and down and shout: STOP OVERPROMOTING, STOP OVERSIMPLIFYING, STOP WITH THE SOUND BITES, CALM DOWN, FIND REALITY! But then that doesn't make good press – or the *New York Times* Bestsellers list.

However, in this column we are allowed to write stuff that may not appeal to readers of the popular press but may come a bit closer to what we are likely to experience.

So here's my conclusion: **The Information Age, as currently being experienced through the growth of personal computers and the Information Superhighway, is about as significant as the advent of television – not much more, and not much less.**

The Next Wave In Handheld Colorimeters.



Looking for lab-grade colorimeter performance in an affordable, handheld package?

Look into the SLS 9400 from Graseby.

Ideal for CRT-display applications, the 9400 does what no other handheld can: closely mirror the CIE tri-stimulus curve for a level of measurement accuracy you'd expect from a benchtop system.

That's because the 9400 employs four proprietary detector/filter combinations (others use only three) to capture the blue-wavelength region with exacting precision—an area often measured inaccurately by other handheld colorimeters.

What's more, measurement's a snap with menu-driven commands, on-screen graphics, a bright LCD display tipped for easy viewing, and vacuum-seal suction cup that's easily deactivated.

The SLS 9400 is shipping now at an easy-to-grasp price. For details, call (407) 282-1408. Fax (407) 273-9046. Or write Graseby Optronics, 12151 Research Parkway, Orlando, FL 32826.

GRASEBY OPTRONICS

Circle no. 31

That is still plenty significant, but it's not going to tie our psyches, our businesses, or our society into "Third Wave" knots.

Reducing the world to atoms and bits is, in my humble opinion, the most useless of oversimplifications. You and I are not just piles of atoms. We are living, highly organized beings. We and the world around us may be made up of atoms, but that's hardly useful information when we have to interact with it. It's only the intricate and intelligent combinations of those atoms that have any meaning. In the same way, a pile of bits is meaningless: random ones and zeros. It's only their intelligent combinations and the media by which we interact with them that give them meaning.

In the universe as we know it, there are no sharp dividing lines between atoms and bits, between matter and intelligence. They are intricately and irrevocably intertwined – kind of as in quantum mechanics. We live in a continuum from the simplest atom to the most complex and intelligent being. And as we evolve to higher levels, we will indeed place greater emphasis on the value of creating, transmitting, assimilating, and processing information than we do on the more traditional goods of commerce. But just as television did not eliminate radio and the movies, and photography did not eliminate art works and painting, and the telephone did not eliminate people visiting each other, and the Industrial Revolution did not eliminate food production but instead made it possible to grow more with less effort, so will the Information Age enhance what we have and not disrupt it beyond our recognition.

The change will be a gradual and rather pleasant one – and one over which we will have quite adequate control. Here's a wonderful illustration of the point. To further describe the new order based on bits, Nicholas Negroponte has written a book with the appropriate title, *Being Digital*. After all the talk about bits and atoms and the new order, he wrote a BOOK. No CD-ROM, no INTERNET, no floppy disk, no electronic media, but a book. A 500-year-old technology – the ultimate irony.

This contradiction apparently bothered Dr. Negroponte enough for him to devote the opening chapter to a rationalization of why a book was really the best way to go. I don't doubt that it was, but it sure made my day to have none other than the spokesperson of the "new digital order" find that the existing atomic order may not be so bad after all.

For any of the predicted Information Age changes to happen, there is much that has to take place to build an industry and the accompanying infrastructure. And each month in this column we try to describe just a few of the many events that eventually add up to the introduction of new technologies and new products. Here is the information that I have assembled for this month.

Superior clarity, right in the palm of your hand.

Only Klein Optical has this finely calibrated, handheld instrument which measures convergence error between colors on CRT displays. It's easily manipulated to identify the degree of error, placing superior clarity right in the palm of your hand.

Also available are Klein's IMX, MX and GMX Inspection Microscopes modified to enhance CRT phosphor and faceplate inspection. They allow you to view your CRT like never before, with powers of 25x and 50x.

More information on Klein's advance quality assurance products is just a phone call away. We'd love to hear from you.

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Circle no. 32

The **United States Display Consortium (USDC),** a government/industry-backed effort aimed at establishing U.S. leadership in critical information-display technology, has announced the receipt of $25 million from the **Advanced Research Projects Agency (ARPA)** of the U.S. Department of Defense. Malcolm Thompson, board chairman of USDC, has also announced that **Michael Ciesinski** will succeed **Peter Mills** as CEO of USDC. Mills has held the position since USDC's inception in 1993, when he accepted the post on the condition that it be for only a 2-year term. Prior to taking the USDC post, he had spent 4 years as chief administrative officer of SEMATECH. Peter's future plans are to start a new venture-capital partnership that will invest in early-stage high-technology companies. Michael Ciesinski comes to the USDC from his former position as vice-president and director of North American operations for Semiconductor Equipment and Materials International (SEMI).

Henry Lewinsohn and **Paul Gulick,** who were the co-CEOs of **Motif, Inc.,** Wilsonville, Oregon, have both left the company. Paul has also resigned from his position as a member of the Board of Directors of **In Focus Systems.** Henry Lewinsohn has returned to Motorola and assumed a management position based in Singapore. Motif has also reduced its staff from eighteen to six, retaining the core research team headed by **Terry Scheffer.** With Motif's announcement in October, 1994, that it would shut down the LCD-manufacturing portion of the company, **Motorola** no longer considered its equity interest in In Focus Systems to be a strategic investment. As a result, In Focus Systems recently repurchased 1 million shares of its stock from Motorola for $18 million in cash, and Motorola expects to sell portions of its remaining 1.2 million shares of In Focus stock from time to time. However, Motorola continues to endorse Motif's Active Addressing™ technology, which was originally developed by In Focus, and is evaluating the market for integrated circuits incorporating the Motif technology. Motif is also continuing to evaluate the best ways to accomplish commercialization of its technology.

David A. Ketchum was elected President of **Thomas Electronics, Inc.,** Wayne, New Jersey, at the annual stockholders meeting on March 14, 1995. David has been with Thomas Electronics for 19 years in various capacities of increasing responsibility at the Los Angeles, California; Clyde, New York; and Wayne, New Jersey facilities. He has served as Vice President and General Manager of all plants since 1985. In a related development, **Douglas C. Ketchum** was promoted to Executive Vice President. Douglas has served as Vice President of Design Engineering since joining the company in 1980. He will assume additional financial and operational responsibilities for all Thomas operations. **Mr. H. A. Ketchum,** owner of Thomas Electronics, will continue in his present capacity as Chairman of the Board and CEO.

Planar Advance, Inc., of Beaverton, Oregon, a wholly owned subsidiary of **Planar Systems, Inc.,** and **Xerox Corporation** have announced the completion of a joint development, manufacturing, and marketing agreement to supply active-matrix liquid-crystal displays (AMLCDs) for use in defense applications. Xerox and Planar Advance will co-develop AMLCD products for certain military programs. These products will satisfy the special performance requirements for military use and utilize the high-volume commercial expertise of both Planar and Xerox. Xerox will provide active-matrix-display glass to Planar Advance, and Planar will militarize the displays, including backlighting and packaging technology, for defense systems builders. Key participants from the respective organizations in arranging this business partnership were **Malcolm Thompson,** Chief Technologist at Xerox Palo Alto Research Center, and **Al Herman,** General Manager of Planar Advance.

Planar Systems, Inc., has also announced a licensing agreement with the **David Sarnoff Research Center,** Princeton, New Jersey, whereby Planar will have broad access to Sarnoff's intellectual property for use in the development and sale of active-matrix electroluminescent (AMEL) image devices. This agreement is intended to give Planar a strategic advantage in the developing market for small high-resolution displays. Market opportunities include applications in defense, surgery, computing, and entertainment.

SI Diamond Technology, Inc., Houston, Texas, has announced the acquisition of a large number of Russian patents and intellectual property in the field of displays and related diamond technology. The technology agreement is part of a long-term partnership agreement with **DiaGasCrown** and **Gazcomplektimpex,** the export subsidiary of the multibillion-dollar Russian gas concern, **Gazprom.** The agreements call for DGC to license its patent and technology rights in the field of flat-panel displays (FPDs) to SI Diamond. DGC's 200-member diamond-technology team will direct its efforts toward the development of SIDT's FPD production. In addition, SIDT will gain use of DGC's flat-panel-manufacturing facility in Fryazino, Russia.

Colin Waters has been appointed to the newly created position of head of the Pigments and Security Products business sector by **Flex Products, Inc.,** of Santa Rosa, California. He came to Flex in 1993, on temporary assignment from **Imperial Chemical Industries** (ICI), England (60% owner of Flex Products), to work on new-product development. In his new capacity, Dr. Waters will report to **Michael Sullivan,** President and CEO. Flex Products, Inc., was formed in 1988 as a joint venture between ICI Americas and **Optical Coating Laboratories, Inc.,** of Santa Rosa. Flex Products specializes in thin-film-coating technologies and provides a variety of products for anti-counterfeiting protection, photocopiers, and solar-energy control films.

Tosoh SMD, Inc., of Grove City, Ohio, a supplier of sputtering targets, has announced the appointment of **Lee Glowinski** as Sales Manager for O.E.M. and Asia. The significance in the appointment stems from Tosoh SMD's anticipated growth in the semiconductor sputtering-target market in Korea, Taiwan, China, and Singapore. Tosoh SMD, Inc., specializes in advancing the technology of thin films. The company operates a 140,000-sq.-ft. "focused factory," which is 9001 registered, in Grove City, Ohio.

I appreciate getting your feedback and your comments. These interactions often provide the news that appears in future columns. I can be reached by e-mail at aris_silzars@maca.sarnoff.com, by telephone at 609/734-2949, by fax at 609/734-2127, or by old technology (the mail) c/o Jay Morreale at Palisades Institute for Research Services, Inc., 201 Varick Street, Suite 1006, New York, NY 10014. ■

Edited by Joan Gorman

LCD seminar in Brazil

The First Ibero-American Liquid Crystal Seminar (I Seminário em Mostradores da Cristal Liquido) will be held June 20–23, 1995, in Campinas, SP, Brazil, at the Centro de Pesquisa e Desenvolvimento da Telebrás. The LCD seminar will be held in conjunction with the Second Seminar on Quality in Microelectronics (II Seminário em Qualidade em Microeletrônica), and is promoted by the Ibero-American Network on LCDs of the Microelectronics Program of CYTED. (CYTED is a program supported by Spain to promote the development of science and technology in the 21 countries of Ibero-America.) The seminar is also supported by the Instituto de Microeletrônica of the Centro Tecnológico para Informática (a Federal laboratory of the Brazilian Ministry of Science and Technology), and Programa RHAE/MCT – Human Resources (a Brazilian Federal program for the development of human resources).

The seminar will include a tutorial overview of information displays and technical sessions on TFT-LCDs, MIM-addressed LCDs, rapid prototyping, liquid-crystal materials, new packaging technologies, optoelectronics, quality, metrology, and product certification.

Information: Dr. Alaide Pellegrini Mammana, Laboratório de Mostradores de Informação, Instituto de Microeletrônica, Centro Tecnológico para Informática, Rodovia D. Pedro I, km 143,6 13089-500 Campinas, SP, Brasil. 55-192-40-2150, fax 55-192-40-1365, e-mail alaide@ic.cti.br.

Bradley fighting-vehicles upgrade

Litton Systems Canada, Ltd., Toronto, Canada, has been awarded a contract for the development of advanced instrument-panel displays that will significantly upgrade the combat capability of the U.S. Army's Bradley fighting vehicles. The contract was awarded by United Defense LP, a vehicle manufacturer in San Jose, California, to provide multi-function flat-panel color displays that generate bright high-resolution images with very low power consumption. The contract calls for 6 × 8-in. AMLCD units to be installed at both the commander and squad-leader stations in the vehicle. The units will display high-definition digital map presentations, tactical data, and forward-looking infrared (FLIR) sensor data that will help maintain awareness of tactical situations. Current plans are for about 1600 Bradley vehicles to be modernized to what the U.S. Army identifies as an A3 configuration. These displays would be manufactured in a new Litton Canada facility to be completed later this year.

FED Corp. joins consortia

FED Corp., Hopewell Junction, New York, has announced that it has recently joined the United States Display Consortium (USDC) as a governing board member and is also joining the American Display Consortium (ADC). "Both consortia play critical roles toward strengthening the U.S. flat-panel display infrastructure, which will help enable FED Corp. and the other consortia members to effectively compete for their share of the fast-growing flat-panel market, which is currently dominated by Asian manufacturers," said Gary Jones, President and CEO of FED Corp. To further strengthen its technology-development activities, the company also announced that it has signed a cooperative R&D agreement (CRDA) with Sandia National Laboratories worth more than $1 million for the development of low-voltage phosphors suitable for FPDs. In 1994, FED Corp. announced the establishment of the first dedicated U.S. manufacturing facility for the production of FEDs, located in a former IBM manufacturing center. The privately held company is currently working toward development of its proprietary versions of FEDs for a variety of high-resolution custom applications.

Projectors to become cheaper than panels

"Today, users pay a substantial premium for integrated LCD projectors compared with LCD projection panels. But by the end of the decade, many designs of projectors will actually become cheaper than panels despite their need to provide their own lamp, optical system, and other components," claims Dr. William L. Coggshall, President of Pacific Media Associates, Mountain View, California. This finding is among many from the just-published report, *Manufacturing Cost Trends for LCD Projection Systems: 1994–2001*, which analyzes the costs of making 12 different projection-panel configurations, 29 one-panel projectors, and 17 three-panel projectors, all capable of at least 640 × 480 resolution. It constructs the total product-manufacturing costs by analyzing the trends in the six principal groups of components that comprise these projection products: the LCD glass itself; interface electronics; mechanical structure and product assembly; optical assembly; lamp and power supply; and packaging, accessories, shipping, and warranty. The report was written by Manx Research and published by Pacific Media Associates. "Passive-matrix-based products will be all but wiped out by active-matrix ones," says William K. Bohannon, Manx Research's Chief Scientist and the author of the report. "Not only do the costs of the two different technologies come much closer to each other over time, but they also both decrease faster than other components. Thus, the total product cost difference becomes so small that most consumers will opt for the better image quality and higher speed of active matrix." The biggest decreases in manufacturing costs will show up in the one-panel projectors, thanks to both declining LCD-glass costs and rapid improvements in other components for which it is still early on the learning curve. By 2001, for example, a simple projector based on a 6.5-in. panel will be manufacturable for about $650, which could translate into a street price to buyers as low as $2000. The downward cost trend is also very pronounced for higher resolutions, either 1024 × 768 or 1280 × 1024 pixels. Here, the effect of declining LCD-glass cost is particularly pronounced, as this material is very expensive to manufacture today, but in a half-dozen years process improvements will have brought the cost down substantially. Although the manufacturing costs for three-panel projectors will not decline as rapidly as those of the two other groups, their greater brightness will allow them to be sold at prices at least commensurably as high as their relative manufacturing costs. And when their superior image quality and lower power requirements (and thus "greener" operation) are taken into account, they should remain quite competitive.

Pacific Media Associates specializes in the commercial aspects of the large-screen displays industry. Its *Large-Screen Displays Industry Service* gives in-depth coverage of technology, products, companies, and markets. It conducts an annual *North American Large-Screen Displays Reseller Survey*. The company also performs confidential custom research studies tailored to the needs of individual clients, based on databases of industry information, personal knowledge, and industry contacts. Pacific Media Associates is headquartered at 1121 Clark Avenue, Mountain View, CA 94040; 415/948-3080, fax -3092.

Manx Research specializes in the technical aspects of the large-screen displays industry. In addition to its syndicated study, *Manufacturing Cost Trends for LCD Projection Systems: 1994–2001*, it performs confidential custom studies and advises manufacturers regarding technology, product design, component sourcing, and business strategy. Manx is headquartered at 2060 Ridge Crest, Escondido, CA 92025; 619/735-9678, fax -8987.

Largest LCD color TV

Matsushita Electronics Corp., Osaka, Japan, has introduced 10.4-in. color LCD TVs in Japan. The display, priced at $2760, has 921,600 pixels and can be ac-powered with an adaptor. Its power consumption is only 20 W, about half that of their 11-in. CRT set. The unit weighs about 6 lbs. and measures 11.7 × 11.7 × 7.5 in. The company plans to produce 500 units monthly.
Television Digest, Vol. 35, No. 12, 3/20/95

Wide-screen tube production to double

Toshiba Corp., Osaka, Japan, has announced plans to double its production of wide-screen tubes at its Himeji factory near Osaka. An investment of 1 billion yen ($11 million) will

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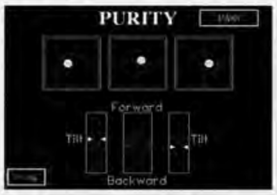

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be required to modernize production lines in order to produce either 16:9 or standard 4:3 tubes. When completed this summer, the project will increase the plant's wide-screen output to 100,000 units monthly.
Television Digest, Vol. 35, No. 12, 3/20/95

Reflective cholesteric LC viewer

Kent Display Systems, Farmington Hills, Michigan; Kent State University, Kent, Ohio; and the University of Stuttgart, Stuttgart, Germany, exhibited a prototype of their jointly developed full-page-size reflective cholesteric liquid-crystal viewer at SID '95. Designed for paper-like viewing without a backlight, the prototype displays monochrome (black on yellow) images on an 8½ × 11-in. area at 100 dpi, requiring power only to write a new image, not to retain it. In a separate paper presented at SID '95, Kent State University introduced a technology for multiple reflective color and a new drive scheme that would provide subsecond page-turn rates. The device's developers see the prototype as a significant step toward the long-awaited electronic newspaper, as well as toward soft-fax devices on lightweight, flexible plastic substrates.

Tamarack awarded USDC contract

The United States Display Consortium (USDC), San Jose, California, announced that it has awarded a major contract to Tamarack Scientific Co., Inc., Anaheim, California, to design and develop a large-area high-throughput exposure tool for the manufacture of FPDs. According to USDC, the photolithographic stepper, which has been the primary exposure tool used for patterning the features on the display glass plates, offers precision and resolution capability often not required for many display features or display-technology types. Bob Pinnel, Chief Technical Officer of USDC, explained there are alternative approaches that can be far more cost-effective. "There is a growing need to manufacture on very large glass plates, such as 840 × 1025 mm for ac plasma displays, and to achieve throughput rates of at least 60 panels/hour for the many lithography process steps used in the manufacture of all display types. Since feature resolution requirements are 5-μm or greater for many of these applications, projection scanning technology appears to be an ideal match," stated Pinnel. Ron Sheets, President of Tamarack Scientific, stated, "this technology will provide a low cost-of-ownership tool for the manufacture of color filters and can also provide the 5-μm or greater resolution lithography levels required for all display types." He concluded that the FPD industry in the U.S. is on the verge of significant growth and indicated that Tamarack Scientific intends to be a recognized partner and supplier to the display manufacturers.

Planar captures ARPA funding

A display consortium led by Planar Systems, Inc., Beaverton, Oregon, completed an agreement with ARPA for a $30 million cost-shared effort to develop manufacturing technologies for electroluminescent (EL) displays. The 2-year effort calls for the development of manufacturing technology for active-matrix EL (AMEL) color displays.
EE Times, 3/27/95, p. 2.

License to exploit new SPD technology

Research Frontiers, Inc., Woodbury, New York, announced that it has entered into a license agreement for display products with Sanyo Electric Co., Ltd. The agreement gives Sanyo the non-exclusive right to manufacture and sell flat-panel displays (FPDs) worldwide using Research Frontiers' patented suspended-particle-device (SPD) technology. In late January, Research Frontiers announced that it had successfully developed, with the collaboration of London's Imperial College of Science, Technology, and Medicine, a new type of high-information-content FPD that can offer display manufacturers and users an attractive alternative to LCDs. SPD displays offer high information content as well as good brightness, good contrast, and an excellent angle of view due to the elimination of light-absorbing sheet polarizers. This makes SPD displays simpler to construct than LCDs and reduces backlighting requirements.

Resistors with a TCR of Zero

Materials Research Corp., Orangeburg, New York, a wholly owned subsidiary of Sony Corporation of America, has announced a landmark breakthrough in what has long been considered unattainable in the development of thin-film resistors – a temperature coefficient of resistance (TCR) guaranteed not only to be essentially zero across the wafer substrate but also reproducible from wafer to wafer in high-volume production quantities. As a result, resistor manufacturers may soon look forward to producing virtually reject-free lots of thin-film devices with superior resistance qualities guaranteed to be virtually unaffected by any temperature variations.

TI named as finalists

Two technologies that are more than "smoke and mirrors" are finalists in the Sight category of *Discover* magazine's fifth annual Technological Innovation Awards. *Discover* editors chose two vision and imaging technologies from Texas Instruments: its Digital Light Processing (DLP) technology, which uses the Digital Micromirror Device (DMD) with over 400,000 small mirrors to project images, and the Nightsight Thermal Vision System infrared camera that can see in the dark and find objects through smoke. These technologies were chosen from more than 4000 entries as inventions that can improve the quality of everyday life. As finalists, the DLP and Nightvision technologies will be featured in the June issue of *Discover*. ■

book review

Electronic Displays

by Sol Sherr
Second edition, 1993
John Wiley & Sons
ISBN 0-471-63616-9
624 pp.
Price: $94.95

Reviewed by ROBERT L. DONOFRIO

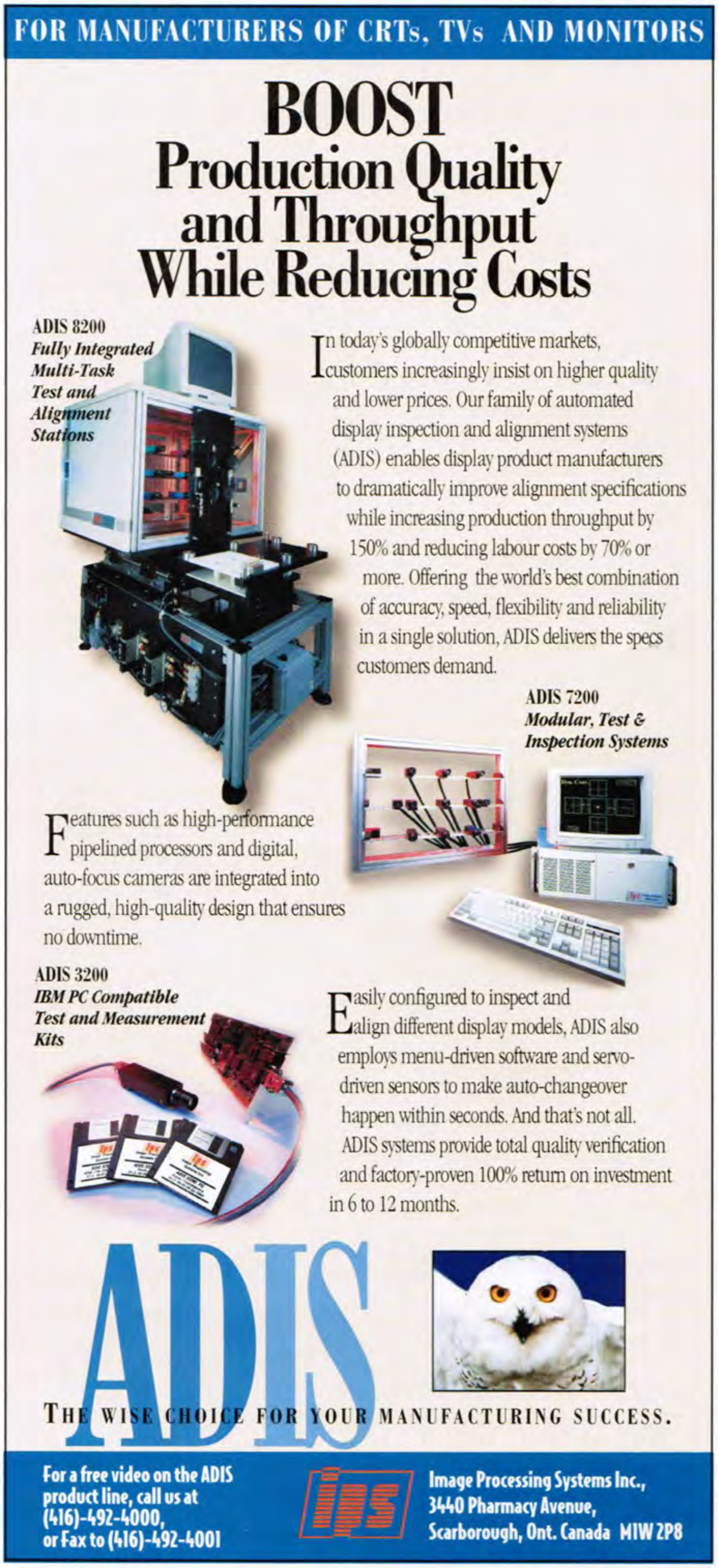
This is the second edition of Sol Sherr's massive work on the field of electronic displays. Fourteen years have passed since the publication of the first edition (1979), and many new technological developments have occurred in the interim.

It is important to recognize that this work – a distillation of many articles and books on display technology – has been written by one person. The selection of topics and examples is thus highly subjective and, as such, can be controversial. The book has been "written for professional engineers involved in design and maintenance of electronic displays and for graduate or advanced undergraduate students in electrical engineering".

The book is divided into seven chapters. Chapter 1, similar in content to the 1979 edition, discusses human factors related to "the characteristics of the human observer that affect the requirements placed on the visual image." This chapter contains sections on photometry, non-photometric visual parameters such as resolution, flicker, color, and unified measures of image quality. The electrophysiology of the visual system is covered, with sections on acuity, brightness, and flicker. There is a detailed discussion of the visual appearance of fonts, followed by two sections on specifications. This portion of the chapter is enlarged from the 1979 text, and now includes the work of Dr. Peter Barten and Dr. Carlo Infante.

There are a number of typographical errors throughout this chapter, and some could be confusing. On page 19, the red x color coordinate is stated as being 0.325. On page 64, the character height in Eq. 1.30 should have been squared. On page 68, there is a reference to Figure 1.29, which was correct for the first edition, but the same figure is now Figure

Robert L. Donofrio *is an Engineering Group Leader with Philips Display Components in Ann Arbor, Michigan.*



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1.38 in the second edition. Typographical errors aside, the reviewer would have liked to see some mention of spot decay and raster decay in the flicker portion of this chapter. Both decay methods are mentioned in the 1990 JEDEC Phosphor Designation Registrations and are important in the assessment of flicker and smear. A discussion of diffuse reflectivity and "contrast figures of merit" should also have been included. Much work has been done in the cathode-ray-tube (CRT) industry using tube-face reflectivity equipment (seen in TEPAC Publication TEP 105-12, April 1987) to control or monitor the color-CRT product, but this was omitted in the chapter's discussion.

Chapter 2 is concerned with CRT devices. The physical principles are discussed with a brief introduction to electron-gun theory and electron deflection. Cathodoluminescence is discussed with a number of tables showing luminous efficiency, decay time, and characteristics and color on the JEDEC Phosphors using the "P#" nomenclature.

The phosphor aging section has a typographical error in Pfahnl's relationship, which was carried over from the first edition. The problem is a simple interchange of I and I(0). The reviewer would have liked to see more references (more than just Fig. 2.11b) discussing the fact that not all phosphors follow Pfahnl's relationship and that aging parameters for short- and long-term aging – as seen in data sheets published by Clinton Electronics – are used.

Monochrome CRTs are discussed with a return (in greater detail) to electron-beam focusing. A discussion of CRT-luminance factors, followed by discussions of various masks and CRTs, are reviewed. Much of this chapter is directly from the 1979 edition except for the addition of more-recent developments, such as the liquid-crystal (LC) shutter, matrix-driven flat-panel CRT, and a very nice discussion of the Sony, Sinclair, and Northrop flat CRTs and field-emissive CRTs.

Non-viewing scan converters, image-pickup devices, and solid-state imagers are covered next. The old monoscope, covered nicely in the first edition, was omitted from this one. This reviewer would have liked the phosphor designations to include not only the older P#s but also the newer Worldwide Designation System. The EIA, through work done by JT-31, now supplies a floppy disk containing a great deal of phosphor information so that electronic design engineers can perform easy computer evaluation.

Chapter 3, "Matrix and Alphanumeric Devices," discusses a number of flat-panel displays (FPDs) through a general survey. The author then rapidly reviews the physical principles that govern the operation of these devices. Electroluminescence, gas discharge, vacuum fluorescence, liquid-crystal displays (LCDs), ferroelectric ceramic displays, electrophoretic displays, suspended-particle displays, electromagnetic displays, and incandescent displays are discussed.

Chapter 4 reviews CRT systems and equipment. Sections are devoted to refresh systems, color systems, large-screen systems, and equipment. This reviewer would have included (modestly) in the discussion of projection tubes, Philips' development of the non-lambertian-screen projection tube.

Chapter 5 reviews alphanumeric and matrix-panel equipment, and gives information on the structure of LED, gas-discharge, plasma, vacuum-fluorescent, LCD, and projection systems. This is a revised and updated chapter that includes a wealth of information in the device construction diagrams.

Chapter 6, "Input and Output Devices and Systems," has also been updated and contains many new reference citations. Six of the 1988 references cited in this chapter are from books edited by Mr. Sherr.

Chapter 7 discusses how system performance is measured and reviews photometry. It is unfortunate that the chapter's two photographs do not show photometric equipment that is more up to date. The Weston foot-candle (fC) meter on page 583 and the Gamma Scientific Digital Telephotometer on page 585 are both obsolete.

Writing *Electronic Displays* was a Herculean enterprise for one person to have done alone. The book contains a wealth of knowledge, which its owners will use for years, but the publisher should insert one or more errata pages in each book to help the reader. With the inclusion of the errata, I believe this is a good book for the display engineer's library and a needed replacement for the first edition. The many references at the end of each chapter can give the reader a choice of articles to read for a deeper understanding of the various topics. ■

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editorial

continued from page 2

It may be a bit early to do substantial business directly on the Internet, but it is not at all too early to provide important information and useful services. That "data highway thingamajig" is turning out to be not so stupid after all.

– Ken Werner

**From the comic strip "Outland" by Berkeley Breathed.*

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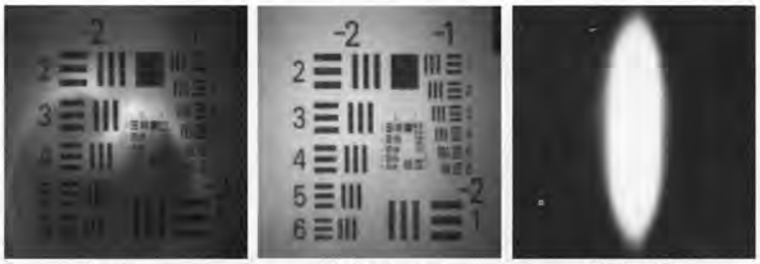

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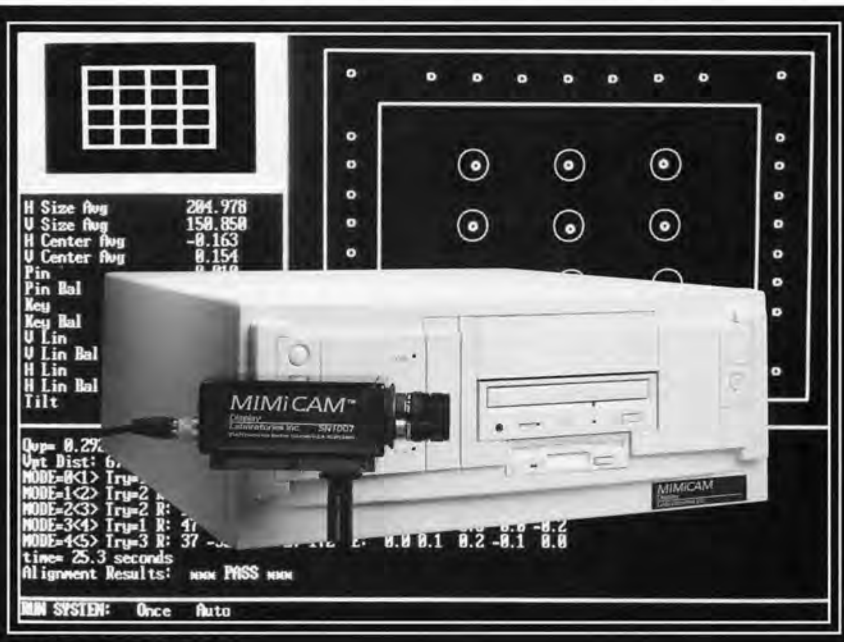

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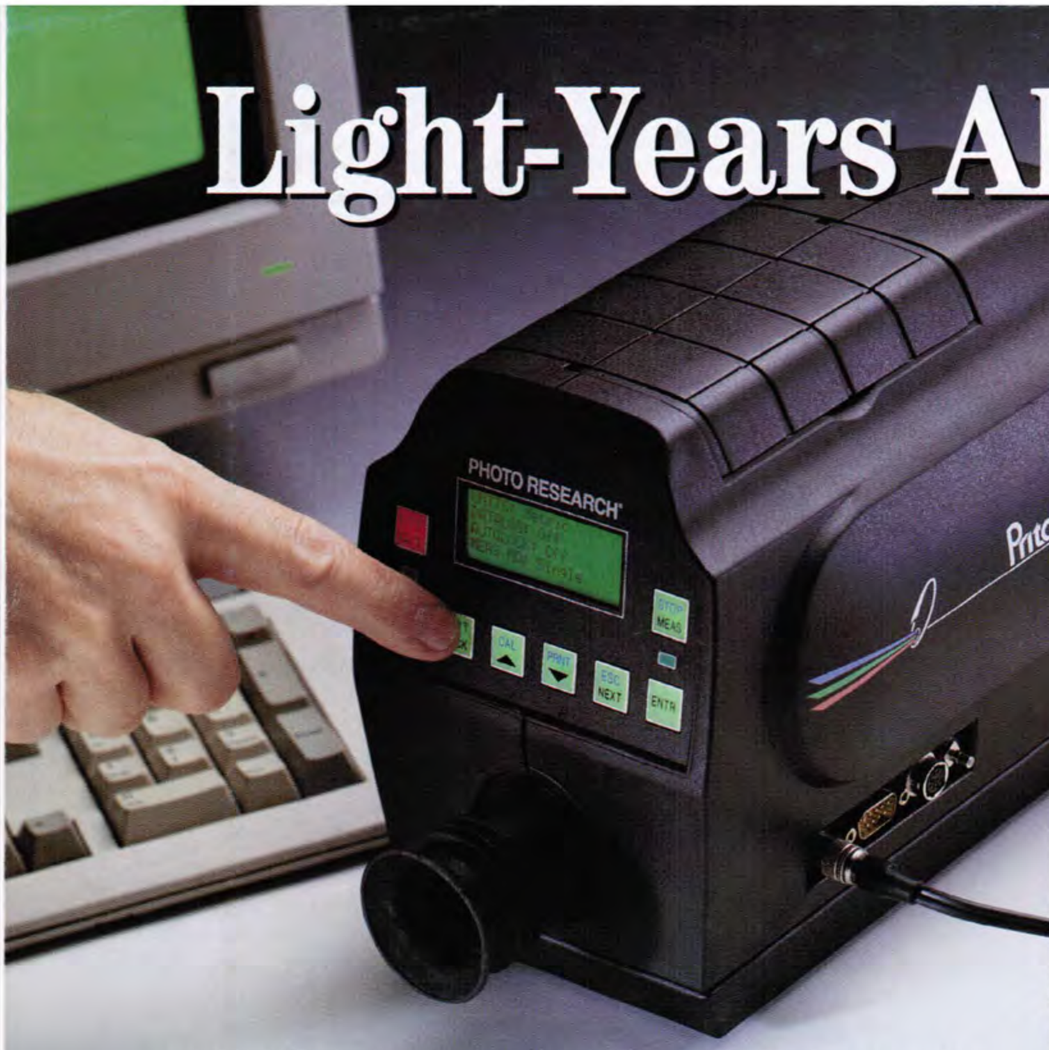

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- Aircraft Panel Luminance & Color
- Color Temperature Determination
- Automotive Lighting
- Electroluminescent Panel Evaluation
- CRT Luminance & Contrast

Fittingly, the PR-880 weighs less, costs less, and takes less to operate than any photometer in its class. And, its rugged, single-component design does more of the work, while you do less.

Leap ahead... to ultimate versatility in brightness and color measurement.

The PR-880... "Ahead– Automatically."

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