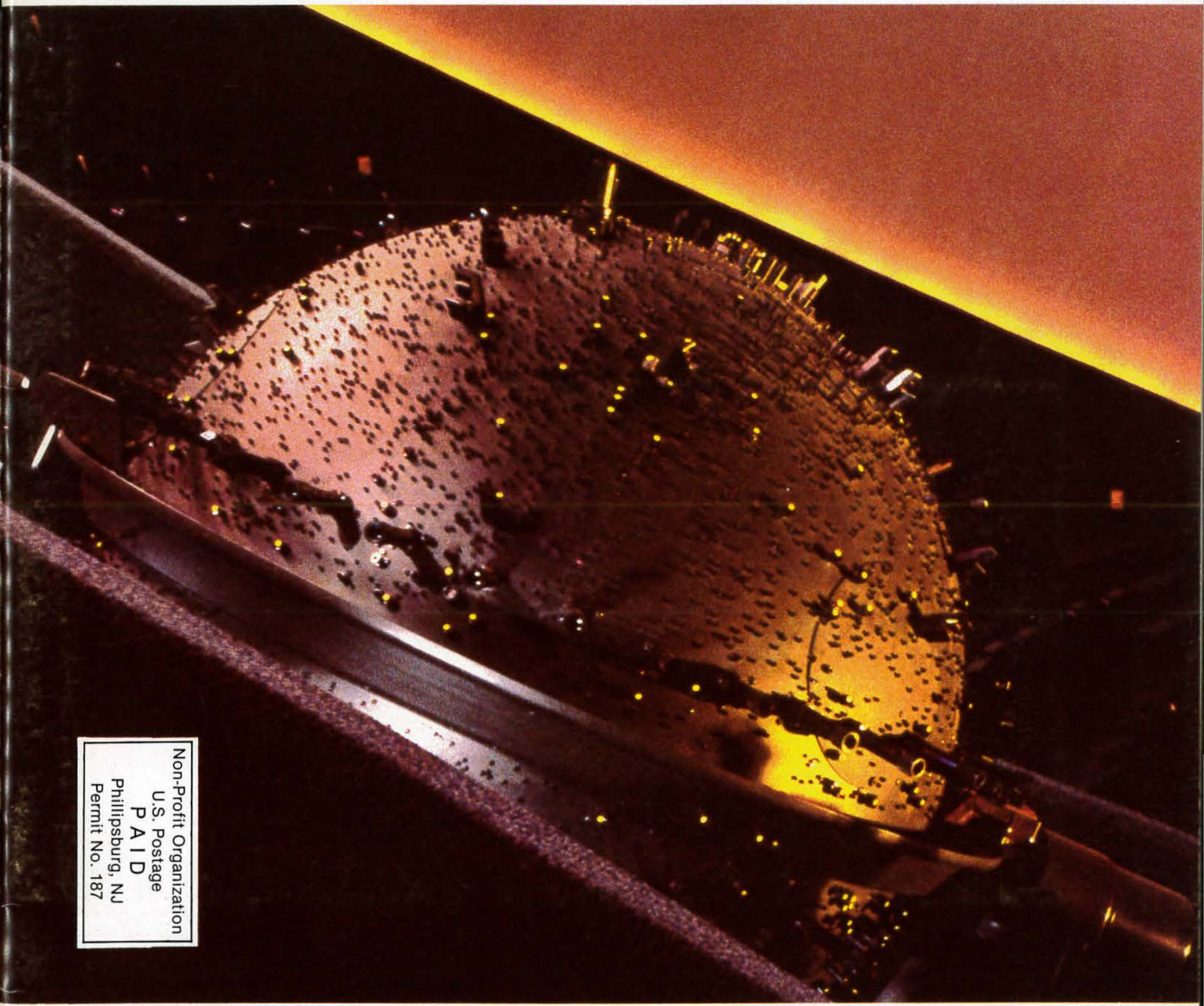
≡ Official Monthly Publication of the Society for Information Display

INFORMATION DISPLAY

February 1987
Vol. 3, No. 2



Space voyagers
New York's Grand Central Terminal
Laser scanners and printers
Vision science and HDTV

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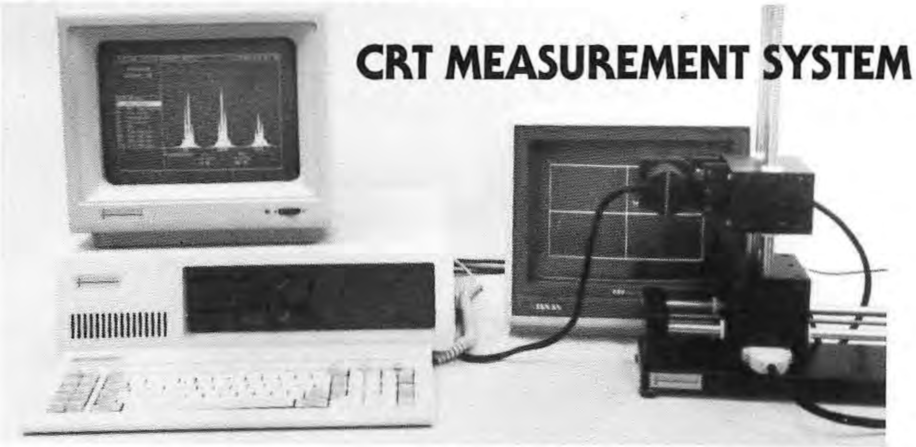

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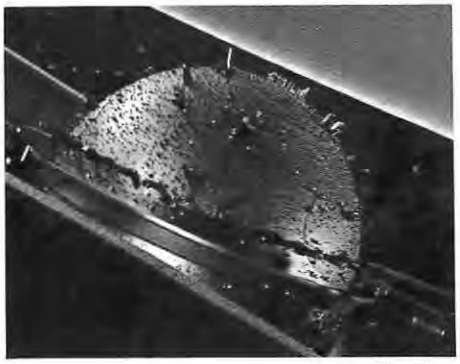
Cover: close-up of the starball on the Spitz "Space Voyager" planetarium projector (page 8)



Mike Bruno

Next Month in Information Display

SID '87 highlights: preview of the papers to be presented in New Orleans

Human factors in flat-panel design

industry news

Original Holofacet laser scanner acquired by Smithsonian

One of the earliest and most acclaimed holographic scanners is now part of the permanent collection at the Smithsonian Institution, Division of Electricity and Modern Physics. In 1971 this invention was awarded U.S. Patent No. 3,614,193, granted to Leo Beiser, the Staff Scientist and Director of the Dennis Gabor Labs of CBS Laboratories, and now president of his consultation company, Leo Beiser Inc. Following pioneering research started in 1965, this prototype model recorded the highest performance of any optical scanner: measured in combined resolution and speed—20,000 pixels/scan at over 200 million pixels/sec. This corresponds to a high-quality laser printer outputting over 20 pages/sec. Leo Beiser is renowned for his pioneering and continuing work in laser beam information handling.

Scholarship offered in optical engineering

The William H. Price Scholarship in Optical Engineering is open to all full-time graduate and undergraduate students in the areas of optical design and engineering who submit an application and technical summary of original research by April 1, 1987. The amount of the scholarship is $4,000. For an application and full instructions write to William H. Price Scholarship in Optical Engineering, c/o SPIE, P.O. Box 10, Bellingham, WA 98227-0010, or telephone Margie Price, 818/889-1078.

Interstate awarded FAA display contract

Interstate Electronics Corporation, Anaheim, CA, has been awarded a $1.3 million contract from the Federal Aviation Administration (FAA) to supply 40 flat-panel plasma display terminals and supporting items during 1987 for installation in new aircraft to be used in the FAA's Automated Flight Inspection System (AFIS). AFIS is a program designed to test the accuracy of U.S. navigational aids facilities. The Interstate-supplied terminals will be used on board the new aircraft to display processed data received regarding these facilities.

Interstate has been a prime contractor on the U.S. Navy's Fleet Ballistic Missile Program (Polaris/Poseidon/Trident) for over 30 years.

Official Monthly Publication of the Society for Information Display

INFORMATION DISPLAY

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INFORMATION DISPLAY (ISSN 0362-0972) is published monthly for the Society for Information Display by Palisades Institute for Research Services, Inc., 201 Varick Street, New York, NY 10014; David Slater, Chief Executive Officer; Leonard H. Klein, President; Harold R. Summer, Vice President; Hildegarde Hammond, Secretary; Laura Mangone, Treasurer.

EDITORIAL AND BUSINESS OFFICES: Palisades Institute for Research Services, Inc., 201 Varick Street, New York, NY 10014; telephone 212/620-3371. Send manuscripts to the attention of the Editor, ID.

WEST COAST SALES OFFICE: c/o Ted Lucas, P.O. Box 852, Cedar Glen, CA 92321; telephone 714/337-6627.

SID HEADQUARTERS, for correspondence on subscriptions and membership: Society for Information Display, 8055 West Manchester Avenue, Suite 615, Playa del Rey, CA 90293; telephone 213/305-1502.

SUBSCRIPTIONS: Information Display is distributed without charge to those qualified and to SID members as a benefit of membership (annual dues $35.00). Subscriptions to others: U.S. & Canada: $36.00 one year, $64.00 two years, $90.00 three years, $3.00 single copy; elsewhere: $72.00 one year, $128.00 two years, $180.00 three years, $6.00 single copy.

POSTMASTER: Send address changes to Society for Information Display, 8055 West Manchester Avenue, Suite 615, Playa del Rey, CA 90293.

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editorial

To the world at large, information display is a narrow technical discipline. Even in the more specialized worlds of electrical and optical engineering, display design is often seen as an interesting tributary rather than part of the main stream.

But from the inside, information display is rich, varied, and not particularly well defined. Notwithstanding this lack of definition, when many of us think of displays we tend to think of those that are electronic and fit on a desk or in a pocket. We tend also to think of the hardware alone—the display head. That's understandable, given the size of the market for this hardware and the number of us who serve that market. It's understandable . . . and can be counterproductive.

In this month's *Information Display*, we attempt to expand those unconscious, self-imposed boundaries. In doing so, we range from a single component in a desk-top laser printer to the elegant interior of New York City's Grand Central Terminal. Not adventurous enough? We range also from the fovea of the human eye to the depths of the universe.

Our lead article discusses a system that displays information on a cosmic scale—the Spitz "Space Voyager" planetarium. The innovation here is not the optics *per se*, but that this planetarium uses digital control to replace the traditional clockwork. The result is a startlingly flexible display. Our thanks to Dick Seifert, Chairman of SID's Delaware Valley Chapter, for introducing *ID*'s editors to the author of this article.

When it became necessary last year to replace the aging electromechanical arrivals/departures board at Grand Central Terminal, the new display was—electromechanical. Non-technical considerations in the form of requirements from New York's Landmarks Preservation Commission weighed heavily in the selection, but a sophisticated display management system is anything but old-fashioned.

Perceptual psychologist Karen Glenn and display engineer Bill Glenn combine their expertise to discuss the requirements the human visual system places upon CRT displays, particularly those for high-definition television (HDTV). They also discuss those areas where current designs for HDTV systems provide more information than the visual system can use, thus indicating opportunities for bandwidth conservation.

These three different articles have a single idea in common: a successful display head can be a relatively small part of a complex display system. That system always includes the human eye and brain, and increasingly includes complex signal processing and information processing subsystems.

None of this means that good engineering of the display itself is any less important that it used to be. In our fourth article, the omnipresent Leo Beiser discusses the technical factors that face designers when they select a scanning element for a laser printer. He concludes that with current techniques for enhancing vertical resolution, the rotating reflective polygon remains a strong and cost-effective candidate. Please do not confuse this article with another Leo wrote recently for the monthly publication of a well-known optical society. There, in keeping with that distinguished organization's philosophical character, his article discussed principles with such elegant abstraction that even physicists could understand it. We, on the other hand, get the good stuff—the details that can help engineers make design decisions.

sid '87 program

The SID '87 Program Committee met at the Hyatt Regency in New Orleans last month to organize the program for SID '87 that will be held there May 11–15. A total of 96 papers were selected from 145 submitted abstracts. The program again will present the latest news in information display, and for the first time will include sessions on automotive displays and workstations. The Symposium will feature two keynote speakers: **Abel Farnoux** of Electronics International Corp. on *Minitel and Its Applications*; and **Ralph V. Wilhelm, Jr.** of Delco Electronics on the *Automotive Instrumentation Explosion.* **George Reed** of Spitz, Inc., co-author of this month's cover story, will speak at the Wednesday luncheon.

Programs and registration forms will be mailed March 1.

Symposium sessions (May 12–14)

Tues. morning: Business Meeting • Formal Opening and Awards • Keynote Addresses

Tues. afternoon: VDT Standards and Issues • Automotive Displays • Large-Screen Projection Displays • Plasma and Vacuum Fluorescent Displays

Tues. evening: Panel Discussions: Automotive Display Requirements for the 1990's • Failure Mechanisms in Displays • Advanced TV Systems • Workstation Printers

Wed. morning: Visual Displays and Human Performance • Active-Matrix LCDs • Ink-Jet Printing • Advances in CRT Technology

Wed. afternoon: Display Measurement Techniques • Color EL • Printer Materials • Display Systems

Wed. evening: Special Event: Riverboat "Gambling"

Thurs. morning: EL Technology • Color Display Applications • CRT Performance Analysis • Liquid Crystal and Magnetic Print Heads

Thurs. afternoon: LCD Technology • Printer Technologies • Workstation Technologies

Seminar sessions (May 11 and 15)

Mon. morning: Display Industry Overview • Electroluminescence • Visual Perception

Mon. afternoon: Direct-Multiplexed LCDs • Active-Matrix LCDs • Display Measurement Techniques • CRTs

Fri. morning: Colorimetry • Avionics • Plasma Displays • Color Hard Copy

Fri. afternoon: Image Processing for Art, Medicine, and Mapping • Projection Displays • Computer-Generated Animation • Touch Input

president's message

I mentioned in one of my earlier columns that Dr. Robert Durbeck and I had traveled to Beijing immediately following the Japan Display '86 conference in Tokyo to discuss the possibility of holding the 1989 International Display Research Conference (IDRC '89) in Beijing, China. We had extensive discussions with Mr. Zheng Wenhao of the Chinese Institute of Electronics (CIE), the proposed co-sponsors of this conference, and other representatives of the CIE and the Beijing Vacuum Electron Devices Research Institute, the proposed secretariat. We also had an opportunity to see, first hand, the facilities and resources that are available in Beijing for such a conference. Last month (January 11, 1987) the SID Board of Directors met in New Orleans for its bi-annual meeting and selected the site for IDRC '89.

This decision was particularly difficult because we felt that the Beijing option was eminently practical and attractive for technical, business, and cultural reasons. On the other hand, the past successes of Japan Display '83 and '86 were clear indications that Japan was an attractive site for a very large number of SID members.

In the end, after long deliberation, the Board decided to return to Japan in 1989 primarily because of the larger anticipated attendance. At the same time, we did not want to lose the benefits of a Chinese display conference altogether. Accordingly, we are proposing to the CIE in China that we jointly organize a display conference/workshop in Beijing just after IDRC '89. This conference would feature a number of original (mostly Chinese) display papers that could not be presented at the IDRC, and provide some IDRC highlights for Chinese engineers who could not attend the IDRC in Japan.

The idea of a one- or two-day workshop in conjunction with the IDRC was originally advanced by the Japan chapter should Beijing have been selected. We are confident, therefore, that the Japan Chapter will now strongly support the workshop proposal for Beijing. In addition, we believe that a Beijing conference should be particularly attractive to European or American IDRC attendees who can visit Beijing at minimal extra cost and take advantage of technical and business opportunities, visits to research laboratories and industrial facilities organized by the CIE, and enjoy some exceptional sightseeing as well.

We will, of course, keep you informed of our progress in organizing these two conferences in the future. Based on Bob Durbeck's and my experiences in visiting Beijing, I sincerely hope that the CIE will accept our proposal for such a conference in the fall of 1989.

Sincerely,

JvRaalte

Society for Information Display
8055 West Manchester Avenue, Suite 615
Playa Del Rey, CA 90293
213/305-1502

Digital image control recreates the universe

BY GEORGE REED, DAVID MILLARD, AND ERIC JOHNSON

ON OCTOBER 21, 1923 an electromechanical optical creation opened its conical eyes and a new universe was born. The interior surface of a 32-ft. (9.8-m) dome became alive with 4500 stars. The world's first public planetarium show had taken place at the Munich Deutsches Museum in Germany, and outer space had been captured and brought indoors to an environment free of the constraints weather and time imposed upon stargazers.

The projection planetarium was the Mark I, the invention of Dr. Walther Bauerfeld (1879–1959) of the Zeiss Optical Company. Under his guidance, improvements were made in the design of the original single starball projector.

The Zeiss Mark II featured two hemispheres, one for the northern sky stars and one for the southern sky stars. The mechanical planet cage was then placed at the center of the two-hemisphere dumbbell planetarium instrument. Projectors for the meridian, celestial equator, and ecliptic were added. With the Mark II, an audience could view the entire sky from anywhere on earth.

The first Zeiss planetarium came to the United States in 1930 when philanthropist Max Adler donated a Mark II to the City of Chicago. This move was countered by Adler's friend, Samuel Fels of Philadelphia. Fels presented a Zeiss Mark II planetarium to the new Franklin Institute that was opened in early 1934. It was the impact of the Fels planetarium on a staff member that spawned the development of a new model star projector and the founding of the first American planetarium manufacturer, now known as Spitz, Inc.

The Henry Ford of planetariums

Armand Spitz was Director of Education at the Fels Planetarium of the Franklin Institute in the 1940s, when he decided the planetarium was "the greatest single teaching instrument ever invented." His dream was to produce an inexpensive star projector that would make planetariums available to smaller cities, schools, and colleges.

Forty years ago, Spitz solved the cost problem with the Spitz Model A. This planetarium was a simulation device designed for teaching astronomy and consisted of 12 black perforated plastic pentagons forming a dodecahedron. The resulting starfield, created by light shining through small holes, did not produce a realistic illusion, but in 1947 500 Spitz Model As could be purchased for the same price as a single Zeiss instrument. The Model A was followed by a succession of more complex optical-lens models that eventually achieved a realistic view of the night sky. In the process, Armand Spitz's company became one of the world's six leading designers and manufacturers of astronomical simulation systems and projection domes.

Computers instead of clockwork

In 1973, the company was challenged to design a system that could show the sky as seen not only on earth, but from any point in our solar system, and traditional planetarium technology could not achieve this.

From the inception of the Zeiss Mark I, the principle behind planetarium designs had remained constant. A star projector, or pair of star projectors, was attached to a clockwork planet projection mechanism. The planet projectors were driven in fixed motion patterns by gear systems called analogs. This allowed the operator to demonstrate the annual motion of the planets against the starfield as seen from earth, but there was no way such a system could offer its audiences anything but an earthly point of view.

The solution to the problem was found in computer control. Planet images were derived from discrete projectors having no mechanical coupling to the star projector, and the motions of all the projectors were to be tied together electronically. This approach allowed not only the simulation of space travel, but also the projection of almost any hypothetical orbital system. Any relationship between celestial bodies that could be calculated by the computer could now be projected on the dome. The speed and versatility of the computer system also provided fully automated control of a vast array of special-effects projectors.

The new system, called the Space Transit Simulator (STS), was installed in 1973 at the Rueben H. Fleet Space Theater in San Diego. Over the following decade, computer and servo-control technology

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George Reed is a Professor of Astronomy on leave from West Chester University currently serving as Director of Worldwide Planetarium Operations for Spitz, Inc., Chadds Ford, Pennsylvania. David Millard is the Space Voyager Project Manager, and Eric Johnson is a Space Voyager Software Engineer.

Glenn Smith

Fig. 1: The digitally controlled planetarium system, Spitz's Space Voyager, was opened to the public in October, 1986. It was a major attraction of the world's largest science center, the Parc de la Villette, Cité des Sciences et de l'Industrie Museum, Paris, France.

advanced dramatically. Spitz, Inc. utilized the new technology in 1986 with the installation of the first new-generation system, called the "Space Voyager," at the Cité des Sciences et de l'Industrie Museum in Paris, France [Fig. 1].

The Space Voyager

The Space Voyager utilizes a system of three computers to perform the astronomical simulation, with a fourth computer operating in parallel to control house lighting, special effects, slide projectors, and sound levels. The modular computer arrangement replaces a large number of discrete-component circuits used in the older STS, resulting in greater reliability and ease of service.

The astronomical simulation system employs a Data General Nova 4X, an Intel 380, and an IBM PC-XT. The Data General machine performs the complex calculations of planetary motions and observer viewing angles. Its software allows the operator to create automated presentations or use the planetarium in real time, both without requiring any computer programming experience. The Nova 4X cycles through its calculations every 80 msec and transmits to the Intel 380 the orientation of the starfield and the position of each planet relative to the starfield.

The Intel 380 accepts data from the Nova 4X together with feedback from all of the projector axes and drives the starball axes directly to the positions specified by the Nova 4X through pulse-width-modulated servoamplifiers. Before driving the planet axes, the data sent by the Nova 4X is run through an offset calculation to correct for the fact that the planet projectors are not located in the center of the dome. A subsequent matrix calculation determines the projectors' correct orientations based on feedback from the star projector.

The IBM PC-XT monitors the status of all activities of the Intel 380 through a shared memory link. Pertinent data is made available to the operator on a color graphics monitor; modifications or changes to the displayed data are performed with a mouse [Fig. 2].

10,164 stars

To project the complex images calculated by the computer system, the Space Voyager utilizes hardware designed and manufactured by Spitz, Inc. The basic projector array includes a starball, five unveiling planet projectors, a sun projector, and an image projector. Modular design allows for expansion of the basic equipment complement, so the system can be tailored to the specific needs of each customer.

The Space Voyager's 48-in.-diameter starball uses a three-axis gimbal system with servo-driven torque motors and a sophisticated lensed optical system to project 10,164 accurately positioned stars and to individually set each star's brilliance and color.

The light source consists of dual xenon 150-W arc lamps and special optics to provide a point light source for each hemisphere. Overall brightness is controlled by two irises, one in each hemisphere, that work in unison. The 10,164 stars include all stars brighter than magnitude 6.2 as seen under optimum

Larry Albee

Fig. 2: By using a mouse, keyboard, joystick, and knobs, a Space Voyager operator can record, edit, and play back astronomical simulations. The status of the entire planetarium system is displayed on the CRTs behind the joystick.

conditions from earth, and 3,702 selected stars down to magnitude 6.8. The resulting starfield is a crisp, accurate, and aesthetically beautiful rendering of the night sky as seen above the earth's light-absorbing atmosphere.

Each of the three axes used to position the starball has an angular velocity range of 0–36 degrees/sec with a repeatable positional accuracy of 15 min of arc. The motors are directly coupled to each axis without gear drives or indirect mechanical links.

Sun, moon, and planets

The unveiling planet projector consists of an optical projector barrel mounted on a two-axis gimbal system driven by servomotors [Fig. 3]. The angular position and velocity of each axis is monitored by an encoder and a tachometer. The incandescent illumination source has an intensity variable from zero to maximum by a frequency-controlled intensity modulator. The projected planet image varies in size over a ratio of 3:1, allowing changes from its naked-eye point-source appearance to a disk with telescopic surface features.

The disk, or sun projection system, like the planet projection system, is a two-axis device driven by servomotors and monitored by encoders mounted on each axis. The incandescent illumination source also has a variable intensity. The projected image of the sun is continuously variable between 0.5 (the apparent size of the solar disk) and 1.5 degrees of arc.

The image projection system for representing the moon and other selected bodies consists of a xenon light source and projector assembly. Phasing of projected images is accomplished by a servo-driven mechanism allowing continuous changes in the shadow on the projected image. The shadow coverage on the image is determined by the computers based on the relative positions of the sun, the body being projected, and the observer. A Geneva-wheel image selector is used to position any one of eight 0.75-in.-diameter slides in the light path, while an 18:1 zoom provides a variable magnification of the image with constant focus. The system is capable of projecting an image anywhere on the dome screen using a two-axis gimballed-mirror assembly with servomotor drives and encoder feedback.

Theater of the imagination

When the entire projector array is tied together through the computer system to operate as a unified instrument, the resulting capabilities are impressive. The Space Voyager can produce an accurate and realistic projection of the stars and solar system as viewed by an observer anywhere within 100 astronomical units (AUs) from the sun (1 AU equals the average distance between the sun and the earth). It can present the sky as seen from any position on the surface of the earth, or any position on the surface of any body in the solar system. It can also present the motion of the stars, moon, sun, and planets as they would be seen from any planet or natural satellite as the body rotates on its axis, revolves around the sun, or as the observer moves about the surface of the body. But this is not all.

The operator has complete freedom of orientation with views not limited to the natural bodies of the solar system. The Space Voyager permits the operator to generate artificial satellites, operator defined bodies, or to modify the paths of the natural bodies by console inputs. The system can even simulate interplanetary flight. It can move the audience through an orbit at any angle of inclination about the sun, or through the orbit of any planet or satellite in the solar system. The simulations then may be recorded, edited and played back via computer control. Shows may be presented exactly as developed or shown with desired real-time operator modifications.

Show playback may be synchronized to a sound track using the 24-, 25-, or 30-frame/sec Society of Motion Picture and Television Engineers (SMPTE) standard time codes. Show playback may also be performed from an internal clock and started, stopped, or paused as desired by the operator. Pre-programmed shows may be played back in segments using random access time features. The wide variety of playback options allows the Space Voyager to be used as a sophisticated theatrical system, as well as an effective interactive teaching environment.

The theatrical aspect of the Space Voyager is further enhanced by its physical construction. Unlike traditional mechanical planetariums, the Space Voyager is designed to maintain a very low profile in the room, permitting virtually no obstruction of audience sight lines. Panoramas and wide-angle motion picture projections may be combined with the astronomical projectors with no occlusions for any of the images.

A dramatic architectural improvement to planetariums was initiated by Spitz when the first STS was developed. The system was designed to operate in a dome with the horizon line tilted up to 30°. This placed the audience inside the projection, as opposed to horizontal "flat dome" theaters in which the audience looks up at the projection dome. In the new "tilted dome" theaters the entire audience faces one direction allowing show producers to design effects for a primary viewing area. The new architectural concept, together with the new unified control system, has come to be known as the "Space Theater." These theaters have attracted audiences worldwide.

Beyond planetariums

There are other applications for this kind of display technology. Spitz designs and manufactures projection domes ranging in diameter from 10 to 100 ft. They are used in theme parks and commercial displays, as well as in planetariums. They are also used by the aerospace industry and the military as projection surfaces for computer simulation systems used for pilot training. Spitz, Inc. has now entered the real-time flight-simulation market as a turnkey system supplier.

Armand Spitz's dream has been expanded to include a wide variety of simulated environments, and technological developments continually expand the possibilities for the "greatest single teaching instrument ever invented." ■

Larry Albee

Fig. 3: Close-up view of planet projectors.

New York's Grand Central Terminal

modern information display with a classic face

BY CHRISTOPHER K. BENNETT

WHICH of today's information display technologies could provide up-to-the-minute information on 500 trains for 90,000 daily commuters in New York's Grand Central Terminal, while being architecturally and aesthetically consistent with the terminal's landmark status? For Metro-North Commuter Railroad, the answer was not one technology but a mixture of two very different technologies driven by a single computer system.

The Grand Central Terminal Visual Information System (VIS) consists of electromechanical split-flap schedule boards and gate indicators, and a network of video monitors that repeat the departure information shown on the main schedule boards. A set of smaller video monitors provides arrival and departure information in a modified format to train operation and maintenance personnel.

The 1½-year-old system was designed and installed by Advanced Computer Systems, Dayton, Ohio, under a $2 million contract with Metro-North.

A city landmark

Grand Central Terminal, with its 125-ft.-high zodiac ceiling and 80,000-ft.^{2} main concourse, was constructed on its present site between 1911 and 1913. It has a history resplendent with memories of such classic trains as the Broadway Limited, the 20th Century Limited, the Mayflower, the Berkshire, and the Yankee Clipper. The architect was Whitney Warren, a cousin of the Vanderbilts; he also designed the Consolidated Edison Tower and many of the buildings surrounding the terminal.

The terminal's track network was designed by William J. Wilgus, chief engineer of the New York Central Railroad in the late 1890s, and later its vice president. Mr. Wilgus conceived a two-level track system: an upper "express" level of 66 tracks to handle the popular intercity express trains pulled by steam locomotives and a lower "suburban" level of 57 tracks for electric commuter trains. In 1987, most of the trains pulling into the station are electric, and both levels serve them. Grand Central is the southern terminus of Metro-North's Harlem, Hudson, and New Haven commuter lines and Amtrak's services from such places as Albany, Montreal, and Chicago.

In September 1980, the terminal was officially designated a landmark. The city's Landmarks Preservation Commission cited its interior as "one of the finest examples of railroad station interior design in the world, that it is a truly impressive, richly detailed, and grandly scaled example of the Beaux-Arts style. . ." Included in the terminal's landmark designation were the sign-boards and signs.

Blackboards and gate curtains

The original 1913 information system consisted of a large blackboard in the incoming train room. The blackboard can still be seen today. Cloth train-information gate curtains were posted at the platform entrances and announcements were made from the information booths and by ushers. Teleautograph machines, electromechanical devices for reproducing handwritten messages at a remote site, were used to communicate actual track assignments from the control towers to various locations for railroad personnel.

With the exception of the blackboard, train arrival and departure information was disseminated much the same way until 1962, when a new automated information system, manufactured by Solari, was installed. This consisted of two split-flap display panels, one for New Haven Line trains and the other for Harlem-Hudson and long-distance trains. Each board displayed both arrivals and departures. The system was controlled from a console in the upper-level information booth. The booth clerk manually entered train information when he had the time between answering commuters' questions. The board frequently displayed blank lines or out-of-date information. As the system grew older, the flap units became less efficient. A replacement was needed.

Agreeing on system parameters

Preliminary planning for the VIS began in 1979, but not until May 1983, under the newly created Metro-North Commuter Railroad, did work begin on a detailed technical performance specification for the VIS.

Meetings with various railroad departments and the Landmarks Preservation Commission resulted in agreement on a set of specifications for the new system:

Christopher K. Bennett is a senior facilities engineer for Metro-North Commuter Railroad in New York City. A civil engineer by training, he was project manager for Grand Central's Visual Information System from design through construction.

Fig. 1: Omega Board installed in the main concourse of Grand Central Terminal. A traditional split-flap design in keeping with the building's landmark status conceals sophisticated display electronics.

- *Fully automatic operation*, requiring a minimum of data input by operating personnel.
- *Simplicity of operation*, so noncomputer-oriented operators could maintain the system.
- *Flexibility*, to accommodate immediate changes of information.
- *Visibility* from any point in the terminal's main concourse and legibility from a distance.
- *Economical construction, maintenance, and operation.*
- *Architectural harmony* with the building, maintaining wherever possible the original information system structures, such as gate curtain frames.
- *Limitation of board size* to the area occupied by the previous Solari boards.
- *Heavy-duty vandal-resistant housing* for all components, finished in such a way as to blend in with the architecture.
- *Component subsystem design*. Various elements should be designed to operate as separate systems so that if one portion of the system malfunctioned, the rest of the system would still operate.

During the preliminary engineering phase, various information systems were investigated—LEDs, video monitor arrays, electromagnetic signs, and split-flap signs. In evaluating these systems, two requirements weighed heavily in the final selection of the split-flap module construction: the Landmarks Commission's insistence on limiting the size of the main boards and the limited space available for replacement units for the gate curtains. The split-flap design met these requirements and had long been established in the terminal with the Solari Board. It was looked on by the Commission as more consistent with the aesthetics of the terminal than a LED display or a video array.

Building the system

In May 1984, a $2 million contract was awarded to Advanced Computer Systems (ACS) of Dayton, Ohio, for the design, furnishing, and installation of the VIS. ACS designed the software for the system, and subcontractors assisted in the coordination, design, fabrication, and installation of the display units. The entire system took 13 months to complete. The new Omega Board, so called because it was manufactured by a division of the famous Swiss watchmaking company, began operating in time for the evening rush hour on May 22, 1985 [Fig. 1]. Installation of the gate indicators and other components was completed by the first week of June 1985.

The new information system is driven by two fully redundant DEC Model PDP 11/73 microprocessors. One processor operates the system while the other remains in standby condition in the event of a microprocessor failure. In case of a power failure, a Computer Power, Inc. (Model UPS-48-1500) uninterruptible power system will provide emergency power for up to 4 hours.

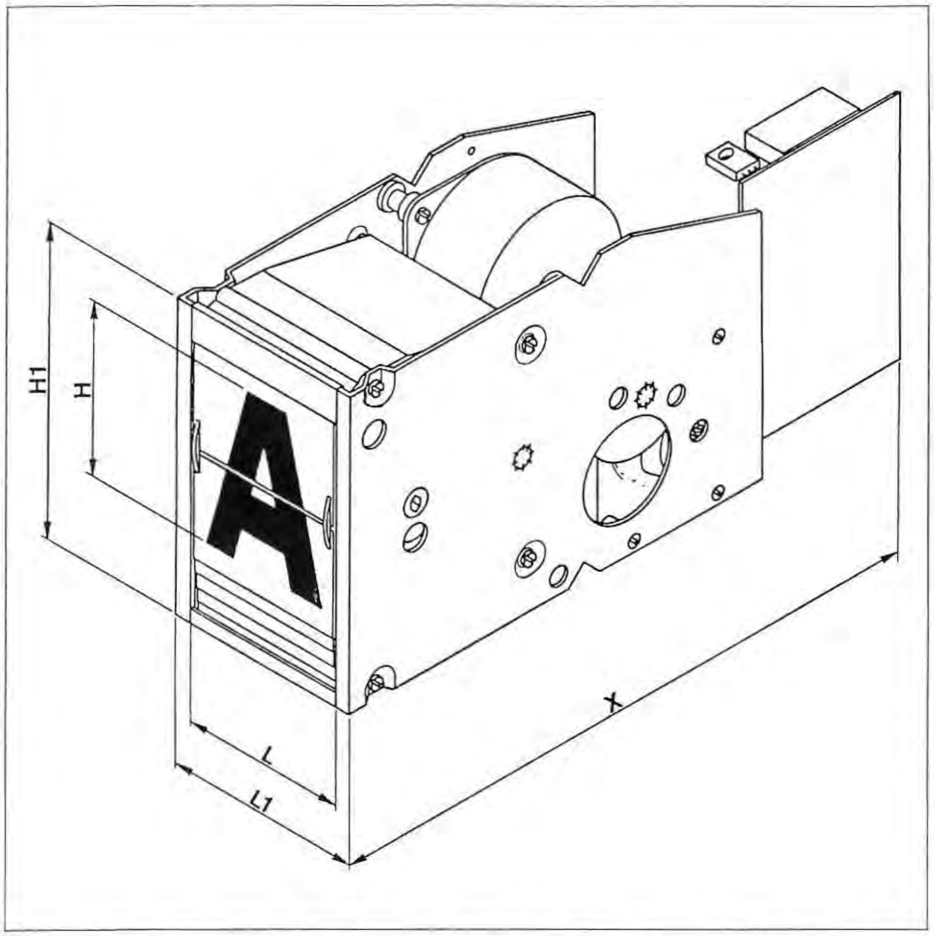

Fig. 2: Split-flap module. H = 50–96 mm. H1 = 65.3–107.4 mm. L = 45–726 mm. L1 = 48–736 mm. X = 150 mm.

A menu-driven fully automatic software program was developed that uses approximately 50 screens to perform various operating, maintenance, and reporting functions. The menu-driven system was selected because it permits any operator, regardless of previous computer experience, to control the system without extensive training and without being intimidated by computer jargon.

The data base's stored schedule consists of two railroad documents—the weekly track assignment sheets and the schedules for more than 500 daily trains. The track assignment sheets identify the arrival and departure tracks for each train and enable the tower operators to route trains through Mr. Wilgus' network of switches and tracks. The schedule can accommodate up to 1000 Metro-North and Amtrak trains. Information on each train includes outbound station stops, scheduled arrival or departure time, and appropriate remarks.

The fully automatic system runs itself 95% of the time. Operator input is required only on an exception basis—when there is a deviation from the programmed schedule, a track change, or a delay. This frees information booth personnel to answer customers' questions.

Three component subsystems

The VIS consists of three subsystems, each of which is capable of operating independently.

- *Omega Board*: The largest information units and the ones most often used by the public are the main schedule boards perched above the main concourse's ticket office. These boards, constructed by Omega Electronic Equipment of Switzerland using split-flap modules, are over 38 ft. long and stand 11½ ft. high. There are two panels for departures (one displays the New Haven Line and the other the Harlem Line, the Hudson Line, and Amtrak), and a third panel for arrivals. The separation of New Haven Line departures is a carryover from the days when the New Haven was a separate railroad. Each panel has fifteen lines of train arrival and departure information. The computer program is arranged so that all lines are constantly filled. The viewing angle of the main boards exceeds 130°, and the 4-in. nominal height lettering is readable for 20/20 vision at 75 ft.

Each flap module [Fig. 2] has either 62 or 40 pallets fixed on drums, connected by an axle driven by a 48-V ac motor. The flap position is selected by a mechanical coder that receives data communications from the gate indicator's controller—actually a small microprocessor with its own memory, a 9600-baud serial interface with the mainframe computer, and parallel interfaces for internal data and flap modules. The coder itself is a printed-circuit disk with seven tracks, six for each character's ASC11 code and one for feedback to the controller to verify the display's accuracy.

- *Gate indicators*: An extension of the main schedule boards is the gate indicator [Fig. 3] located at each of the 49 track gates. Each gate indicator has 12 lines of split-flap modules capable of displaying detailed departure information, including departure time, destination, station stops, and remarks. The indicator can display any combination of station stops on all rail lines including Amtrak. Omega claims a life of more than 4 million rotations for each module, or 100 years as the displays are used at Grand Central.

The split flaps are made of PVC sheeting cut horizontally in half. Train information is silk-screened onto the sheeting in a European typeface known as Univers 57. All silk screening was done by Omega in Switzerland. The delicate weight balance required for proper operation of the flap modules caused several minor problems during fabrication. Flaps for the departure and arrival boards have white lettering on a black background for maximum visibility and legibility. One exception is the colors of the Amtrak logo, which required three coats of paint overlayed to produce the red, white, and blue field. Surprisingly, the extra weight of this paint caused an imbalance that was identified in early testing. Further experimentation was needed to arrive at a workable weight combination.

The other gate indicator flaps are color coded to match the colors of the timetables of the various lines (red for New Haven, green for Hudson, blue for Harlem, and black for Amtrak).

- *Video monitors*: The third component subsystem is the series of public video monitors [Fig. 4] located at each major entrance to the terminal. At 10 locations, pairs of 23-in.-diagonal black-and-white video monitors duplicate the departure information displayed on the main boards. These monitors, manufactured by Electrohome of Canada, show departure time, track number, destination, and remarks. The addition of these monitors has allowed rushing commuters to get the information they need and go to the proper track without having to check the Omega Board in the main concourse.

New equipment to be installed in Grand Central Terminal faces unique problems. It must be vandal resistant and durable. With these requirements in mind, housings for the video monitors were specially designed and fabricated of structurally reinforced aircraft aluminum (T6061) with a dark bronze anodized finish to comply with the Landmarks Commission's request to have the new units become part of the architecture.

Fig. 4: One of the ten public video monitors placed strategically throughout the terminal, each with a separate screen for New Haven trains. Other monitors, for railroad personnel only, display train information in real time rather than scheduled time.

What the public doesn't see

In addition to the public monitors, other subsystem video monitors were installed at 16 locations, where a teleautograph machine was formerly used to provide train information to various operating personnel.

The data-to-video converters (DVCs) that translate the data from the mainframe computer into video characters can store information on up to 100 trains in a local memory. The DVCs also allow personnel to scroll back into this memory to double-check train locations or remarks. The system can automatically print out all arrival and departure information, including remarks on the hour for the previous 1-hour period at critical locations. This provides a history file that can then be used to verify and compile several types of data, including mechanical failures, injuries, and track assignment changes.

Control and data input is possible from five locations simultaneously. DEC VT220 terminals are located in the station master's office, the upper level information booth, the Track 25 transportation department office, Tower A (controlling the upper level switching), and Tower B (controlling the lower level). An alternate terminal located in the computer room transfers computer access by means of a remote/local switch from the station master's office to the computer room for software maintenance and system rebooting.

Fig. 3: A new gate indicator in an old gate curtain frame. The terminal's landmark designation extended to signs and sign-boards.

VIS operation

The VIS computer can store train information for up to 150 different schedules. At present, less than 10% of the possible schedules have been used. Each schedule is identified by a user-specified name, which usually indicates the appropriate date for use of that schedule. New or modified schedules can be created far in advance of actual use.

The microcomputer selects the coming day's programmed schedule from a hard disk. Schedules are selected by day of the week or by specific calendar date. Starting at midnight, the information is transmitted to the main schedule boards, public monitors, gate indicators, and internal monitors. All display units are immediately filled with the first most-current 15 lines of train information.

With minimum input from station personnel, the system runs through each 24-hour period, then automatically selects the next day's schedule. Several different types of information are passed through the system and verified by the microcomputer in milliseconds.

Incoming trains were historically monitored and manually recorded by Towers A and B, which route the trains onto the various platform tracks. The arrival track information was relayed to various locations in the terminal by teleautograph machines. The VIS system greatly simplifies this procedure and provides a permanent record of train routings. As the yardmaster determines the actual track for an approaching train, the tower operator enters the train number and assigned track number into the VIS terminal, and does so for each train whether or not it is routed to its scheduled track. If the track number is not entered by the scheduled arrival time, a beep signals the station master's office and the information booth. An operator at either location then calls the tower operator to determine the status of the train. If the train has not reached the tower, a delay message will be placed on the main arrival board.

The departure and arrival boards function on 5-min dwell times during off-peak hours and 2-min dwell times during peak hours. Once the microcomputer's internal clock reaches the scheduled arrival time of a given train, it holds that train on the board for the appropriate dwell time. When the schedule time plus dwell time elapses, the train information automatically rolls off the top of the board and internal monitors, and a new train appears on the bottom line.

The departure board and public monitors also depend on input from operating personnel. When cloth curtains were used at the track gates to inform passengers of the station stops and destination for a specific train, an usher would display the curtain 20 min before departure. In keeping with this tradition, the system is programmed to automatically display each train at its appropriate gate 20 min before departure time. When the scheduled departure time arrives, the usher closes the gate to the platform and, using a key-off mechanism in the indicator housing, clears the gate indicator, which tells the computer the train has departed. The system then automatically displays "Departed" in the remarks columns on the departure boards and public monitors. This train then rolls off the displays when the necessary dwell time has elapsed. If a train is not keyed off by 5 min after the scheduled departure time, a message alerts the information booth to seek verification.

The internal monitors are exclusively for use by railroad personnel. The information displayed is unique because it ranks trains in real-time chronological order. Any train delayed on either arrival or departure is shifted to include the period of delay. All the other subsystems operate on schedule time.

The system incorporates several maintenance and cross-checking functions. In addition to instantly verifying the position of each flap throughout the system, the system prints out all "exceptions" to the basic programmed information along with the time the change was made and the operator and location from which the change was entered. This ensures that all operators are accountable for their input. It also provides a hardcopy record. Among the reports that may be requested is the problem report, geared toward system maintenance. It lists all flap units that are stuck or out of calibration as well as failures due to power or communications problems.

Modifications to the system

The system has been in operation for 18 months and already several software changes have been made to improve the operation and make it more flexible. It soon became obvious that during peak periods the flaps on the Omega Board appeared always to be rolling because only one line changed at a time and as many as five trains would be shown as departed and held for the 5-min dwell time. To speed the roll-off during peak hours, two adjustments were made in the software. First, the method of roll-off was changed so that all 15 lines were updated simultaneously, thereby reducing the time to completely update the boards from more than 30 sec to less than 3 sec. Second, the dwell time during peak hours was reduced to 2 min so that the trains cleared faster, allowing more current information to be displayed.

The gate indicator subsystem logic was changed to display information 30 min before departure time whenever time between trains permits.

Several emergencies have led to adding the capability of completely overriding all programmed schedules, blacking out the boards and permitting manual input of one train at a time when the equipment is available. The system's flexibility has been an asset during emergencies. A fire one Sunday evening completely destroyed Tower B. Damage to the electric and mechanical systems that control the switches made the entire lower level of the terminal unusable. A new schedule was quickly created for the evening peak using only the upper level tracks and four lower level tracks. Although there were major delays on Monday morning, rush hour was considerably less confusing for the commuters than it could have been.

A routine last-minute track change used to mean a 100-yard sprint by the usher in an attempt to move the gate curtain to the reassigned location. Now a track change is entered by the operator at the information booth or the station master's office, and changed automatically on the departure board and the public monitors, where a remark indicates "Track Change." Data is cleared from the gate indicator and displayed on the new track's gate indicator. If the change is made within 15 min of departure time, the public monitor line displaying the new track blinks to further alert passengers that there has been a change.

What's next for VIS?

Plans are under way for several satellite information systems at suburban stations where the high passenger volume and connecting services require an information network. Using the same basic technology, this system would be further enhanced to include voice synthesizers to make audio announcements based on the computer programmed information.

The system will also be expanded to accommodate the North End Access program that will provide entrance to the north ends of all platforms from new cross passageways at 45th and 47th Streets.

Grand Central's VIS is only the beginning of what promises to be a successful love affair between Metro-North and automated information systems. ■

Laser scanners and printers: development and trends

BY LEO BEISER

LASER printing is establishing itself as the preferred high-speed method for storing and displaying information on print media. The term laser printer now usually suggests a desk-top computer-output machine, imprinting high-quality text and graphics on plain paper at high speed. Such devices derive from a far more general class of instruments – laser scanners and recorders.[1] The number of disciplines encompassed by this technology is as impressive as its 23-year-old heritage [Table I].

The diverse functions implemented by the scanned laser beam are distinguished by only three basic technical differences: resolution, speed and the sensing medium. Even major differences in format – 35-mm slide images and graphic arts lithographic plates, for example – do not prove to be fundamental distinctions.

Almost all of these applications are implemented with a raster; a regular array of closely spaced straight-line scans that cover the area of interest. When x-y coordinates are assigned with the x-direction horizontal and the y-direction vertical, it is the x-directed scan line that dominates the characteristics of all systems. Indexing in the y-direction is often provided by moving the medium rather than by executing an actual x-y beam scan. Certain real-time applications do, however, require composite x-y beam scan. Among these are robot vision and laser display. But the majority of situations that allow moving the medium under the scanned beam provide a major relaxation of some design burdens while still requiring the designer to maintain stringent requirements for positional uniformity.

All of this may seem familiar. The concept of flying-spot scanning, most frequently associated with CRTs, applies equally to laser beams. With few exceptions, the applications listed in the left-hand column of Table I are examples of flying-spot scanners, in which the incident light beam is scattered from the scanned object and then detected and interpreted. Similarly, those in the right-hand column result from modulating the intensity while scanning the light beam, thus imparting spatial information upon a storage medium.

The fundamental process of organizing the data in x-y format emulates CRT line and raster scanners. Lasers, however, provide almost unlimited beam intensity, independent of spot size. They can therefore free designers from the interdependence between beam intensity and spot size

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Table I: Applications of Laser Scanning and Recording
A Partial Listing

Scanning	Recording
Image Digitizing	Laser Printing
Bar Code Reading	Medical Imaging
Facsimile Scanning	Video Recording
Electronic Mail	Data Marking
Optical Inspection	Phototypesetting
Printed-Circuit-Board Inspection	Facsimile Recording
Optical Character Recognition	Electronic Mail
Reconnaissance Scanning	Photolithography
Graphic Arts Process Camera	Graphic Arts Platemaking
Laser Radar	Reconnaissance Recording
Scanning Microscopy	Printed-Circuit-Board Exposure
Color Separation	Color Image Reproduction
Ophthalmology	35-mm Slide Preparation
Robot Vision	Color Printing
Quality Control	Electronic Cinema
Laser Displays	Optical Data Storage
Light Shows	Computer-Output Microfilm Recording
Optical Data Read-Out	Map Printing
Mensuration	Earth Resources Imaging

in electron beams, and the resulting compromise between energy and resolution for medium exposure. But laser technology, which allows almost unbounded resolution and speed, is not without its own additional requirements. A CRT's electron beam is remarkably responsive to deflection and modulation. The laser beam is not. Overcoming this inconvenient consequence of fundamental physics has inspired dedicated activity by the author and other researchers for almost a quarter of a century.

Resolution

In scanned systems, resolution is most often defined as N spots subtended by the scanned line.[1] The smaller the spot and/or the longer the line, the higher the resolution. Almost all high-speed scanners change the angle of the laser beam, which contrasts with translating a lens across an image surface. The beam may be prefocused or focused subsequent to scanning by a flat-field lens, which transforms the angular change to a linear displacement of the focal point on the information medium.

Two principles allow a concise expression of scanned resolution that allows us to avoid dealing directly with the spot size. While the basic definition of resolution is N diffraction-limited δ-sized spots subtended by the format width W, it can also be expressed as the number of diffraction-limited angles $\Delta\theta$ contained within the full scanned angle θ; that is

$$N = \frac{W}{\delta} = \frac{\theta}{\Delta\theta} . \qquad (1)$$

Ideally, $\Delta\theta$ is due to diffraction alone. If so, $\sin\Delta\theta = a\lambda/D$, where λ is the wavelength, D is the deflector's aperture width and a is the shape factor of the illumination upon D.[1,3] When D is much greater than λ, the diffraction angle is small, $\sin\Delta\theta = \Delta\theta$, and

$$N = \frac{\theta D}{a\lambda} . \qquad (2)$$

This is the basic equation for angular scanner resolution.

The second principle, the Lagrange Invariant, explains the resolution's independence upon subsequent optics, which is the reason format size is relatively unimportant. The Lagrange Invariant may be expressed as

$$n\theta D = n'\theta' D' , \qquad (3)$$

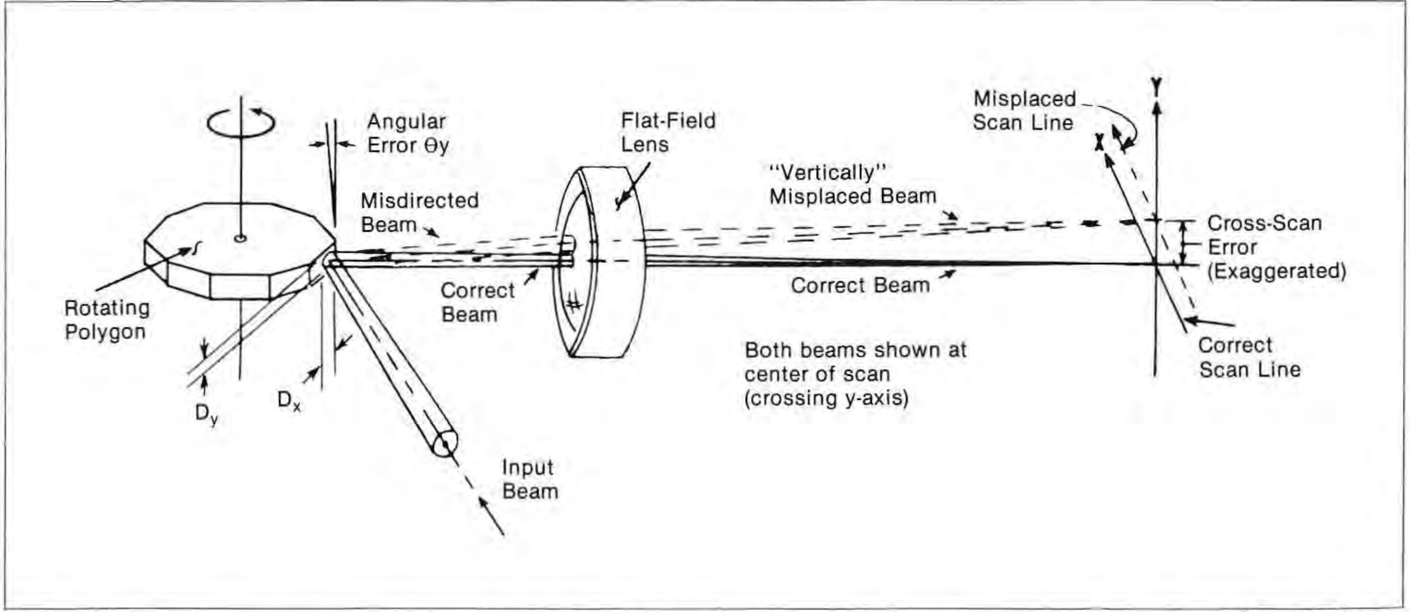
where the primed terms are the refractive index, angular deviation and aperture width in final image space, respectively. In air, $n = n'$ and the θD product and resolution N do not change with optical expansion or compression that follows the deflector. This means that it is as challenging to make a printer of 35-mm computer output microfilm images having $N = 5{,}000$ elements/scan as it is a laser printer covering 350 mm and having the same $N = 5{,}000$ elements/scan. The format differences can be normalized with transfer optics, within the bounds of effective optical design.

Deflectors that execute small angles (such as AO devices subsequently discussed) need a large aperture D and require optical transformation to traverse a large image format.

Resolution implies accuracy and repeatability; unless the pixel placement is within a small fraction of pixel spacing, the image becomes perturbed with artifacts that look like noise. When this apparent noise is pseudo-random, as is the case with grouped scan lines, the effect on visual perception can be far more annoying than that due to information loss alone. So, the challenge of high resolution is not only obtaining the required magnitude of N, but also the integrity of positioning its elements over the full image field.

The tenacious rotating polygon

Why has a seemingly mundane deflector, the rotating polygon, sustained its mastery in the laser printer community – and perhaps in the wider laser scanner world as well? It is certainly not for lack of research and development effort seeking alternatives. We see here another similarity to the CRT. About 20 years ago, massive R&D attention was independently directed toward developing alternatives to what were considered as "awkward characteristics" of the rotating polygon and the CRT. The rotating polygon was too mechanical and the CRT was too electron beam. The polygon required unelegant mechanics and the CRT re-



Source: Leo Beiser Inc.

Fig. 1: This rotating polygon scanner exhibits angular error θ_y that misplaces scan lines in the y-direction. The input beam is typically symmetric ($D_y \approx D_x$), leading to a round focal spot.

quired a non-flat bottle. Progress on both R&D paths was somewhat productive, but arduous and costly.

Today, alternatives are beginning to surface, but it is likely to be another several decades before either technology is reduced to the history books. In their modern forms, both are just too effective – in performance and cost. The inelegant mechanics of the polygon were seldom a practical issue unless the user had to contend with, for example, high inertial, aerodynamic or gyroscopic forces. Otherwise, properly designed, rotating polygons hum along quite inobtrusively.

But one problem was appreciated at the outset that eluded mastery for several years. Of the three principal multifacet non-uniformities, reflectance variations and angular facet errors in the direction of scan are controllable with good fabrication and electronic compensation. Angular facet errors in the direction perpendicular to the scan direction (wobble) are very costly to control, for they require precision bearings and precise facet fabrication and assembly to confine the pyramidal error within tolerable bounds. Depending upon the information scanned, the resulting cross-scan displacement tolerance is between 20% and 1% of the line-to-line spacing, which is very demanding when printing a continuous-tone image.

Active subsystems have been developed to counter this angular error with auxiliary small-angle high-speed deflection. However, a particularly powerful technique, popular in many laser printers, operates to compensate optically by means of a purely passive process that requires no determination of the detailed error function and no dynamic programming of a compensating subsystem.

Separate Eq. (2) into x any y variables, expressing $N_x = k\theta_x d_x$ as the desired resolution and

$$N_y = k\theta_y d_y \qquad (4)$$

as the undesired component in the y-direction. The source of the problem is the angle θ_y which erroneously directs the nominal beam so that it lands misplaced on the image (x-y) plane [Fig. 1]. Since the horizontal deflector is to impart *no* vertical misplacement, we require N_y, the resolution in the y-direction, to approach 0. This requires $\theta_y D_y$ approach 0. But θ_y is the problem – the angular error of the deflector that may be reduced only with significant added fabrication and assembly cost. The only remaining variable is D_y, the scanner aperture subtense in the error direction.

The solution is to compress the input beam vertically by a cylindrical lens so that it illuminates a much smaller subtense D_y upon the facet [Fig. 2]. After deflection from the facet, the beam expands vertically and is restored to its nominal (round) cross section by the second cylindrical lens (shown in the figure as toroidal). The vertical error is reduced by a factor equal to the reduction ratio of D_y, which could be one to two orders of magnitude.

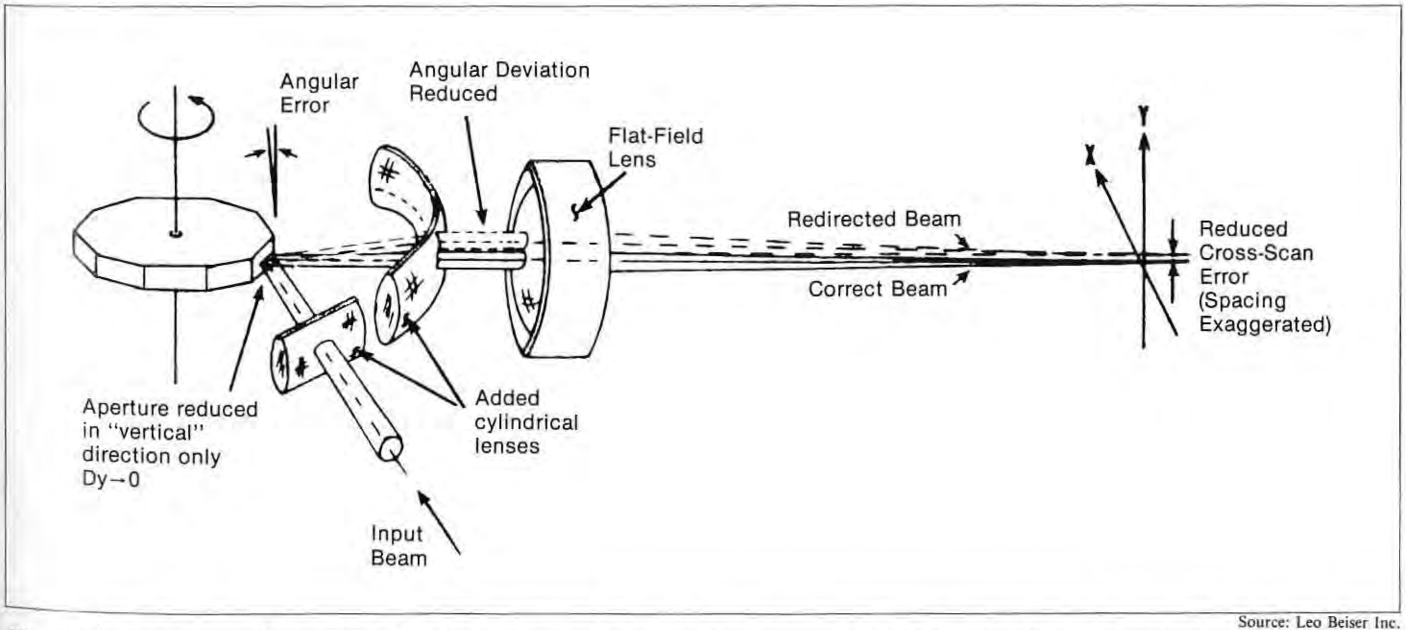
Many variations of this process have appeared since its introduction over a decade ago,[2] and involve placing the output cylinder in different portions of the optical path. In some designs, the cylinder and flat field (objective) lens are integrated into a single element. Another variant uses only a single cylindrical lens in an arrangement where input and output beams both traverse the same optical element.

Alternatives to the rotating polygon

When one considers the resolution and speed demands of a laser printer, $N \approx 3{,}000$ elements/scan at about 2-kHz line scan rate (approx. 30 pages/min), there really are very few alternatives to the rotating polygon.

The acousto-optic deflector[1,3] – a device which deflects optical beams by acoustic waves – could serve well, except that it is limited to about a 2000-element resolution. Also, because of its intrinsically narrow deflection angle, beam shaping and relay optics are required to condition the illumination upon the device and to expand the deflection angle optically to cover the required image format.

Similarly, both broadband and resonant galvanometers[1,3] are limited. The broadband type, though capable of reasonably linear scan at 70% duty cycle, will not



Source: Leo Beiser Inc.

Fig. 2: The input beam is compressed in the y-direction by adding a cylindrical lens. This makes $D_y \ll D_x$ and reduces cross-scan error proportionately. A second (toroidal) cylindrical lens restores approximate beam symmetry.

match typical printer line rates. The resonant type, which provides sinusoidal scan, has difficulty matching the required resolution and speed simultaneously and requires compensation for its extreme non-linearity and short duty cycle.

Other approaches that once attracted attention, such as electro-optic, piezoelectric, and internal laser scan, are even farther removed from printer performance requirements.[3] The one attractive alternative that remains is holographic scanning.

Holographic scanners

The holographic scanner emulates the rotating polygon, replacing mirrored facets with holograms. Since the hologram is a form of diffraction grating, an incident beam is redirected by diffraction rather than by reflection. Most of the optical properties of reflective or refractive surfaces can be imparted to holograms. Yet, the hologram surface can remain simple, since the diffractive properties are determined primarily by the grating spacing rather than by surface shape. This is the principal attraction of holographic scanning – rotating simple substrates that support the holographic surfaces.

While the substrate can be simple and rotationally symmetrical, its surface quality must still be extremely high to restrict aberration of the diffracted beam. This is one of the main limitations to economical production. The surfaces that can be formed with lowest deformation are the sphere and the plane. Thus, the first announced holographic scanner – the Holofacet scanner – was formed upon a rotating sphere. It was invented by the author in 1969 and tested in 1973 to provide the highest performance yet recorded for any optical scanner: 20,000 pixels/scan at 10.4-kHz line rate. At 300 pixels/in., or about 10^7 pixels/page, that is the equivalent of printing more than 20 pages/sec. The widely reported developmental model of that scanner is now in the permanent collection of the Smithsonian Institution.

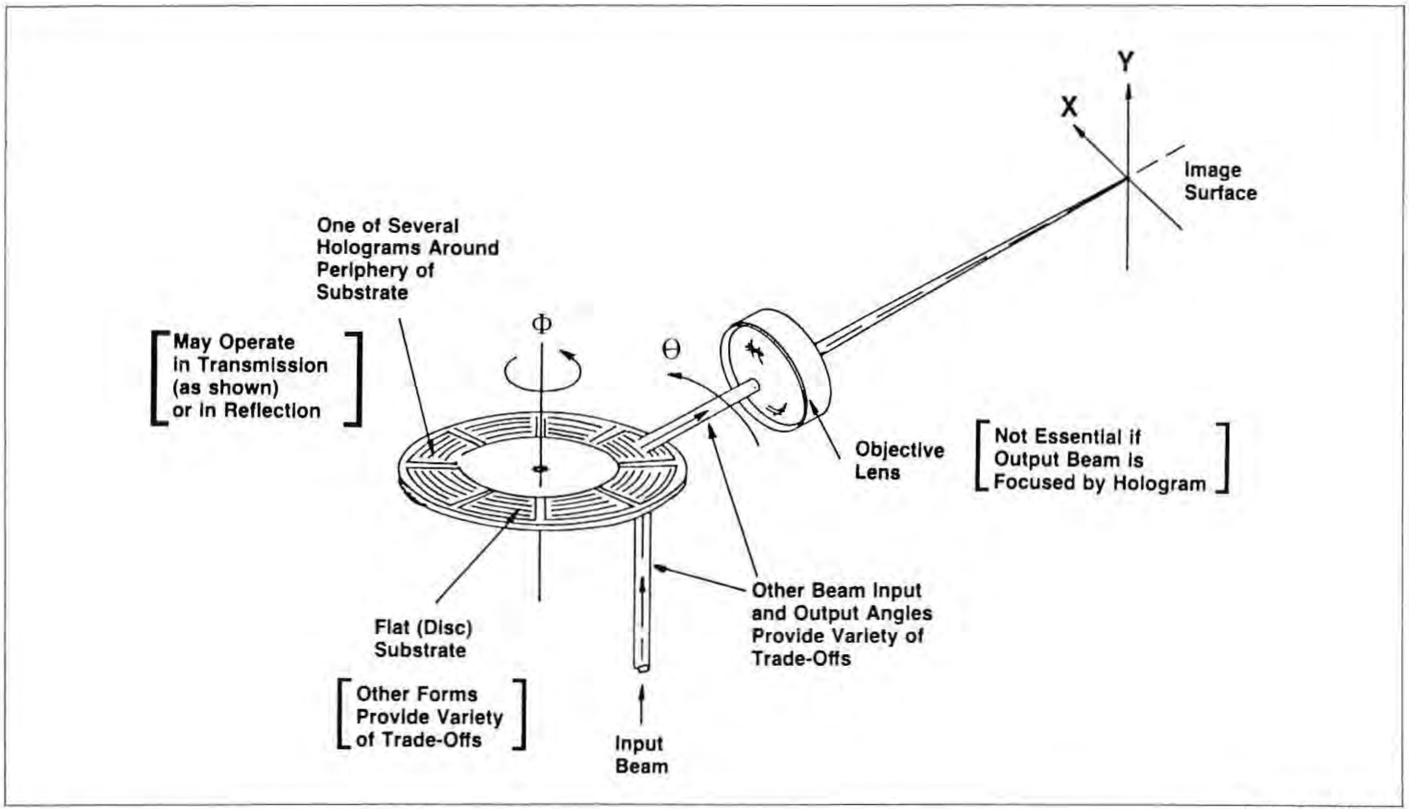
A solid beryllium sphere was used as the Holofacet's substrate to minimize inertial deformation at the high rotational speed of 52,000 rpm. Thus, the holograms were reflective. With the much lower speed requirements of typical laser printers, transmissive substrates may be used. If appropriately oriented with respect to input and output beam angles, such substrates can offer significantly reduced sensitivity to substrate wobble.[4]

Holographic scanners [Fig. 3] can be made with many variations of substrate shape and input and output angles. The different combinations provide various tradeoffs. The holograms may have lenticular (optical) power to focus the beam directly, or be plane linear gratings which create an output beam requiring subsequent focusing by an objective lens, as shown. In either case the goal is to provide a sufficiently linear scan line on a flat surface, while satisfying many additional criteria, such as exposing the holograms at one wavelength and reconstructing at another.

Holographic scanning is still a maturing technology. Allowed reasonable opportunity for development, holographic scanners could offer the laser printer community significant benefits, as they do for the point-of-sale scanners – a much less demanding task.[1] Care need be exercised, however, in addressing the inevitable complications relating to economical high production of a new family of higher performance components.

The storage medium

Electrophotography utilizes temporary image storage; commonly in drum form. The laser beam exposes a modulated



Source: Leo Beiser Inc.

Fig. 3: In this holographic scanner, the diffracted output beam executes an angle θ due to hologram rotation through an angle Φ. The comments on the figure express other possible configurations.

raster upon a pre-charged rotating photosensitive drum and selectively discharges the surface, leaving a latent image of varying electric charge. A deposition of toner particles adheres to the drum depending upon the local charge, and is then transferred and fused to plain paper as a real image, while the drum is prepared for the next exposure. What is required of the laser source is primarily spectral match with the drum surface material and photosensitivity. These considerations are crucial, especially with the trend toward diode lasers having efficient radiant outputs in the spectral range beyond 700 nm.

Drum surface materials include organic photoconductors, selenium, and possibly amorphous silicon if the cost comes down. These materials are deposited in one, two, three and even four layers in various approaches to increasing drum lifetimes and extending spectral sensitivity. The popular and optically stable organic photoconductor drums (even the new double-layer ones) roll off in sensitivity well under 700 nm, making them marginally useful for He-Ne (red) laser exposure and useless for exposure by current laser diodes which emit in the infrared. Selenium, sensitized with tellurium, can extend spectral response into the 700-800 nm range, where laser diodes do produce significant radiation.

The addition of color

Adapting the electrophotographic process to color does not change any of the preceding discussion – except the page printing rate. Modern toners provide highly saturated colors for sequential deposition upon the page. Thus, a 30-page/min monochrome printer can become a 10-page/min three-color printer. The logistics of toner orientation and processing is a complication, but no more than any other sequential color-forming process. For those media, such as photographic color film, that require selective spectral exposure, the story is quite different. There, each light source must match the spectral response of each layer of the medium. Three laser sources, selected to match the spectral sensitivity of the recording material and minimize color crosstalk, are individually modulated and then combined into a single beam for simultaneous placement upon and exposure of the medium. This approach was used in the 1960s by the author and others to develop the first high-speed laser color printer, which exposed cinema film[5] at 30 frames/sec (real time) at broadcast quality. Equivalent speed at laser color printer resolution (10^7 pixel triads/page) would be approximately 90 pages/min.

What can we expect?

There are certainly alternatives to laser printing for information storage and display upon the ubiquitous printed page. But they lack laser printing's speed and often compromise monochrome and color quality at the same time. A place is reserved for alternatives, however, in the hierarchy of performance-price tradeoffs, for laser printing is still relatively expensive as a result of the joint demands of speed and precision. The cost is now declining, however, because of the economics resulting from good engineering for high production.

Laser diodes will continue to be the dominating light source, and electrophotographic drum sensitizations will accommodate their optical spectra. For simultaneous color, however, we must wait for the unpredictable development of green and blue laser diodes that offer adequate power and efficiency.

Color is an enigma. While all agree we need the capability, few really need the machine. Text is effective in classic black and white. But as graphics become more popular, so will color – perhaps more for competitive than for aesthetic or informational advantage. The limited number of users who really need color will pay a premium for it.

With all of these considerations, laser printer equipment designers and manufacturers can be expected to form an expanding segment of the dynamic information display community.

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From vision science to HDTV: bridging the gap

BY KAREN G. GLENN AND WILLIAM E. GLENN

EVOLUTION has provided humans with an exquisitely designed system for extracting visual information from the physical world. With new research methods, vision scientists are beginning to unravel the complexities of sight.

In a separate but related enterprise, electrical engineers are developing a new television technology aimed at improving the clarity and realism of video images. Those who have seen these new high-definition television (HDTV) systems agree that their expanded field of view and high resolution are remarkable, particularly when compared with present NTSC 525-line standard television.

Although the appearance of electronically produced images has been subjectively evaluated for many years, seldom has this process been reversed, with the visual system taken as a basis for the design of an electronic image-producing system.

Starting with the knowledge provided by vision science, production of electronic images that match the real world, as it is visually perceived, can be achieved. On one hand, to produce improved video images, we need to meet the stringent requirements imposed by the human visual system, e.g., wide field of view, good spatial resolution, and good temporal response for motion rendition. Less well appreciated is the fact that visual perception is not a faithful representation of the physical world. We humans are rarely aware of what we do not see. The human visual system perceives only a part of the information transmitted by light energy. The structure of receptors in the eye and the neural circuits connected to them govern what we perceive.

Because there is no point in designing an HDTV system that transmits visual information that cannot be perceived, HDTV system designers have an opportunity to conserve transmission bandwidth, a commodity in short supply.

Karen Gross Glenn, an experimental psychologist on the faculty of the University of Miami School of Medicine, designed the psychophysical experiments that provided the basis for a bandwidth-reduced HDTV transmission system developed by the New York Institute of Technology. William E. Glenn, a display designer and holder of 88 patents, is Director of the Science and Technology Research Center at the New York Institute of Technology in Dania, Florida.

Vision research

Absorption of light by photoreceptors and its transduction into electrical signals occurs at the retina in the eye. Unlike other sensory structures, the retina is not a peripheral organ, but is considered a direct extension of the central nervous system.

There are many levels of processing in the transfer of neural information from the retina through the optic nerve to the regions in the brain that handle visual information. Knowledge about the structure and function of the central visual system has come mainly from two sources: neuroanatomical and neurophysiological experiments in animals, and psychophysical studies in humans. Human and non-human mammalian visual systems are enough alike that the latter provides a suitable model for the former.

To study the functional organization of the visual system, neural activity has been recorded with microelectrodes implanted in single cells along the visual pathway in monkeys and cats. Cells in different regions have been found to respond to distinctive parameters of the visual stimulus. For example, some only respond when a target moves in a particular direction, at a particular velocity, and across a particular region of the field of view. But all visual cells have one thing in common: they read contrasts. Change in the distribution of light energy across time and/or space is what is needed to modulate a cell's firing rate. For example, continuously present diffuse light is an ineffective stimulus for a visual cell.

Human visual sensitivity also varies with physical parameters of the stimulus. Researchers have measured sensitivity to spatial and temporal contrast using various visual stimuli. Much work has been done using sine-wave luminance grating patterns of varying spatial frequency [Fig. 1]. First, complex waveforms are reduced into their simple components according to the principles of Fourier analysis.[1]

Although Otto Shade decribed the filter characteristics of vision nearly 30 years ago,[2] recent advances in computer and electronic technology have made it possible for visual scientists to gain better control of experimental procedures and explore the range of human visual sensitivities more fully. As data from human and animal studies of vision converge, many of the mysteries of perception are gradually receding. They are being replaced by an understanding of the complex ways in which the eye and brain work together to form the basis for what we perceive.

Spatial and temporal frequency tradeoffs

The visual field of the eye is divided into areas of specialized performance. Light coming from the center of the field of view reaches photoreceptors in the fovea, an area with high spatial resolution. About one-half of the neural mass of the central visual system is devoted to analyzing information derived from the fovea.[3] This information is transmitted to the brain primarily via "sustained" neurons, which have a relatively slow response time. Outside this small central region, acuity falls off rapidly. Beyond about 10°, peripheral vision is characterized by low spatial resolution, but good motion and flicker detection. Central connections from the peripheral retina are primarily via "transient" neurons, which have faster response times.

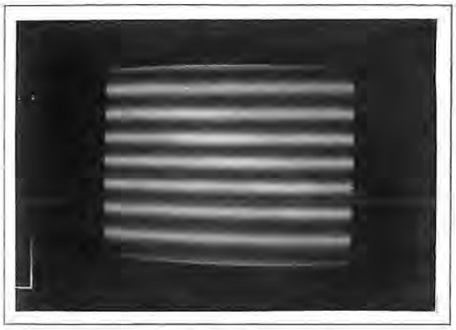


Fig. 1: A sine-wave luminance grating pattern, typical of those used in visual psychophysical experiments. Spatial frequency, in cycles/degree, is varied by changing the width of the bars (cycles of light and dark) for a given extent of viewing angle (degrees).

Recent research suggests the existence of at least two parallel visual channels from the retina to the visual regions of the brain. These channels differ in sensitivity to variations in spatial and temporal frequency of the physical stimulus.[4, 5] One system—the sustained system—is specialized for high spatial frequency or detailed pattern detection, but has rather poor temporal response [Fig. 2, top]. The transient system is specialized for motion detection and has the opposite sensitivities: good temporal response combined with poor spatial resolution [Fig. 2, bottom].

For stationary achromatic grating patterns, the peak sensitivity of the human visual system is about 3 cycles/degree of visual angle. Spatial frequencies lower or higher than this require more contrast to be perceived [Fig. 3]. The introduction of motion (counterphase alternation of bright and dark bars, for example) greatly enhances perception of lower spatial frequencies, although it makes high spatial frequencies (above 3–4 cycles/degree) more difficult to see. This reflects the spatial-temporal tradeoffs of the two visual channels.

Visual masking

When two visual stimuli occur close together in time, perception of one may interfere with the perception of the other. This masking phenomenon, of which scene changes in television are examples, has received a great deal of experimental study. Because sustained visual channels respond more slowly than do transient ones, high-spatial-frequency information in a target can be significantly masked by a transient luminance change that occurs either just before or just after it. Both luminance and chromaticity information can be masked in this way.[6]

Perhaps the apparent primacy of transient over sustained channels reflects an evolutionary advantage. Escape from predatory animals may have been more likely for those creatures possessing fast-acting large-object-detecting (i.e., transient) visual systems.

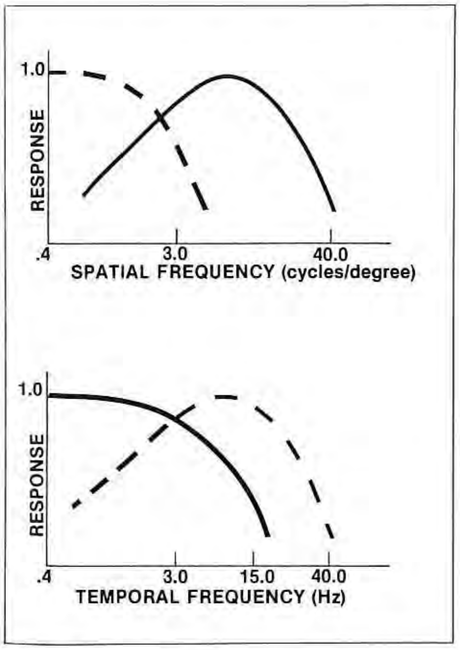


Fig. 2: Curves from pyschophysical experiments, replotted to illustrate the better spatial response of "sustained" visual channels (top), and the better temporal response of "transient" channels (bottom).

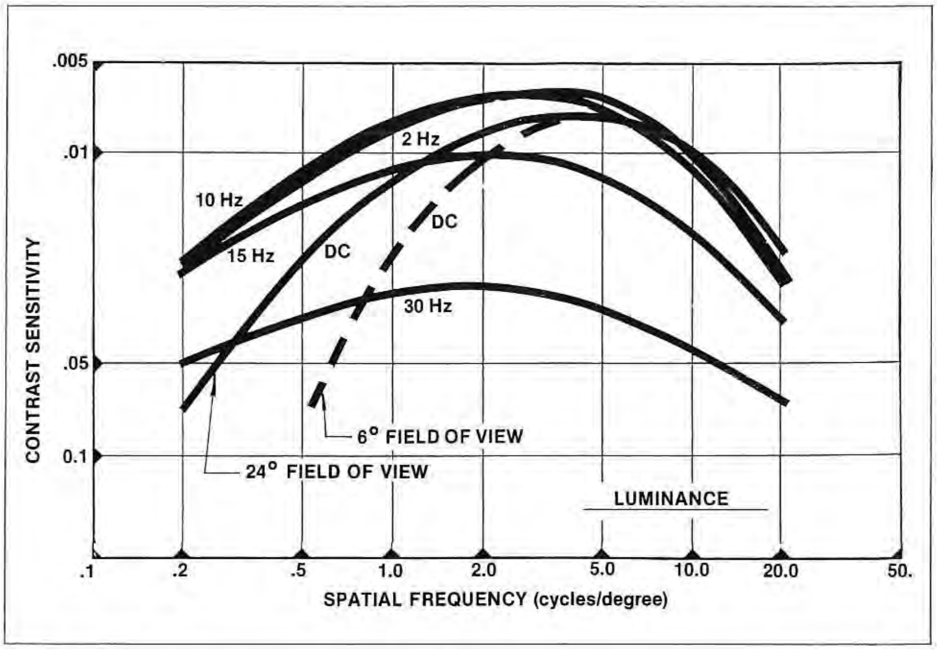


Fig. 3: Contrast sensitivity (the amount of contrast needed for detection) as a function of the pattern's spatial frequency. A stationary (DC) grating has a different sensitivity curve than gratings that are made to flicker by alternating light and dark bars at varying temporal rates (2–30 Hz). The dashed line indicates the reduced sensitivity for low spatial frequencies when the field of view is narrowed horizontally from 24° to 6°.

Applications to HDTV

The best image-display system is likely to be one that is well matched to the visual system. HDTV does not simply require increased spatial resolution of televison images. The preferred viewing distance for HDTV keeps its limiting spatial resolution the same as normal television. Good spatial resolution, although important, is only half the story, as it takes into account only the sustained portion of the visual system. HDTV will typically be displayed on large screens. This means that viewers will perceive more low-spatial-frequency information in the peripheral field of view than is the case with smaller displays. Thus, the low spatial resolution, or transient, portion of the visual system will become relatively more important, and good motion depiction, or temporal resolution, will be a critical factor in improving image quality.

A corollary to the principle of matching the image-display system to the visual system is the notion that one does not need to devise display systems to transmit information that is not received by the visual system. For example, perception of high-spatial-frequency information is not instantaneous, but requires time to build up. This, plus its vulnerability to masking by activity in the transient visual channel, means that detail information need not be updated as rapidly as information of lower spatial resolution. The authors have used these ideas as the basis for developing an HDTV system in which high-spatial-frequency information is displayed at lower frame rates than low-spatial-frequency information. The system was demonstrated at the 1986 National Association of Broadcasters annual convention in Dallas, Texas.

Color sensitivity

Eyes of individuals with normal color vision have cones with three different types of visual pigments, which absorb light energy at wavelengths in different portions of the visible spectrum. The perception of color involves not only the action of these sensory receptors, but the neural interactions among the output from cones at post-retinal stage(s) of information processing along the central visual pathway.

The addition of color sensitivity to the visual system vastly improves its discriminative powers. Humans can distinguish about 500 levels of brightness (gray scale), 200 varieties of hue (wavelength), and about 20 levels of saturation (color purity). These combined visual capabilities endow us with a sensitivity to more than 10^6 gradations ($50 \times 200 \times 20$) for detecting the contours of objects in the external world.[7] This may explain why the addition of color to the television signal makes such a dramatic difference in the quality of the perceived image. Remarkably, such improvement requires only about 20% additional channel capacity.

Chromatic spatial resolution

As with static achromatic gratings, sensitivity to chromatic gratings decreases at both high and low spatial frequencies. However, for color, peak sensitivity is for gratings of lower spatial frequency. Relative to luminance, the spatial frequency at which chromatic sensitivity peaks is a factor of 2 lower for red-cyan gratings, and a factor of 4 lower for blue-yellow gratings [Fig. 4]. This difference suggests that the human color-detecting system may have evolved not for detection of fine detail, but rather for detecting large figures from backgrounds that would otherwise make them hard to see.[7]

Consistent with this idea is the color-ambiguity phenomenon. Color becomes increasingly difficult to perceive as grating spatial frequency increases. At high spatial frequencies, chromatic grating patterns are indistinguishable from black-and-white ones; that is, the form is detectable, whereas its color is not.[8, 9]

Chromatic temporal response

Neural conduction in the visual system is generally slower along pathways that transmit color information than along

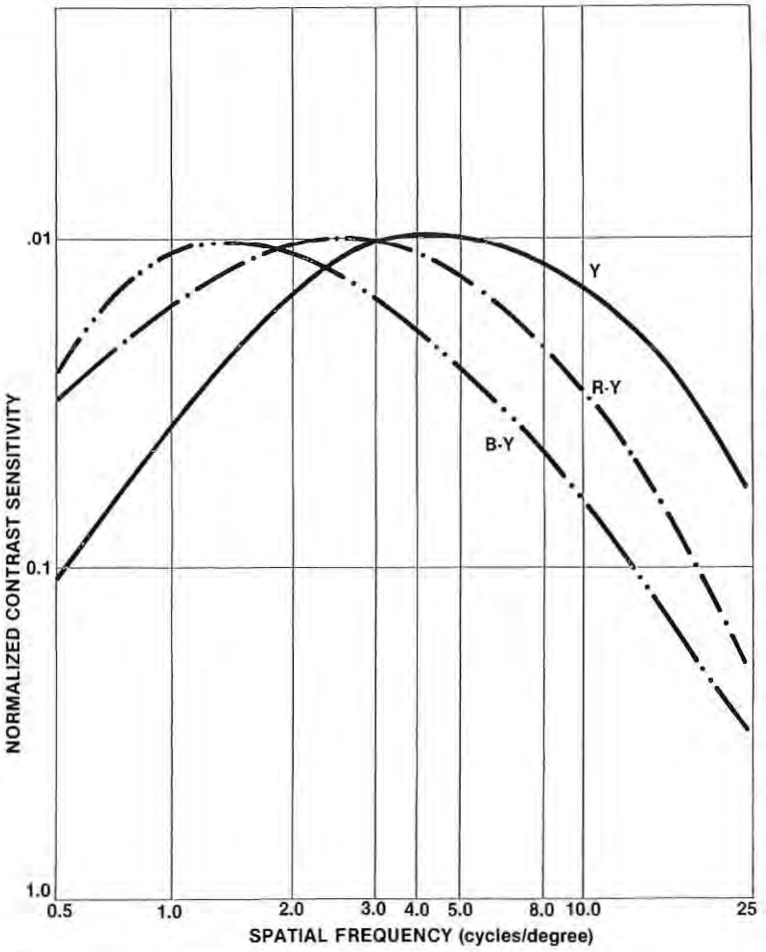


Fig. 4: When contrast sensitivity is normalized by setting the curve peaks to (0.001) for stationary luminance (Y), isobright red-cyan (R-Y), and isobright blue-yellow (B-Y) sine-wave grating patterns, the very different spatial frequencies at which the respective maximum contrast sensitivities occur become evident. For chromatic gratings, increasing "contrast" is obtained by increasing the saturation of the complementary color pairs.

those that transmit luminance information.[10] This may explain why temporal factors such as flicker affect perceptibility of chromatic and achromatic patterns differently.

The authors have studied this problem psychophysically by varying the saturation of sine-wave gratings of varying spatial frequency, made up of complementary color pairs, e.g., red-cyan and blue-yellow. (Luminance was adjusted so that the two colors appeared equally bright.) When chromatic gratings were flickered in counter-phase alternation (bright and dark bands alternating) between 10 and 30 Hz, their perceptibility was generally poorer than when they were viewed as stationary patterns. This effect was most pronounced at low spatial frequencies, in contrast to the relative enhancement in perceptibility produced by flicker for low-spatial-frequency achromatic gratings.[9]

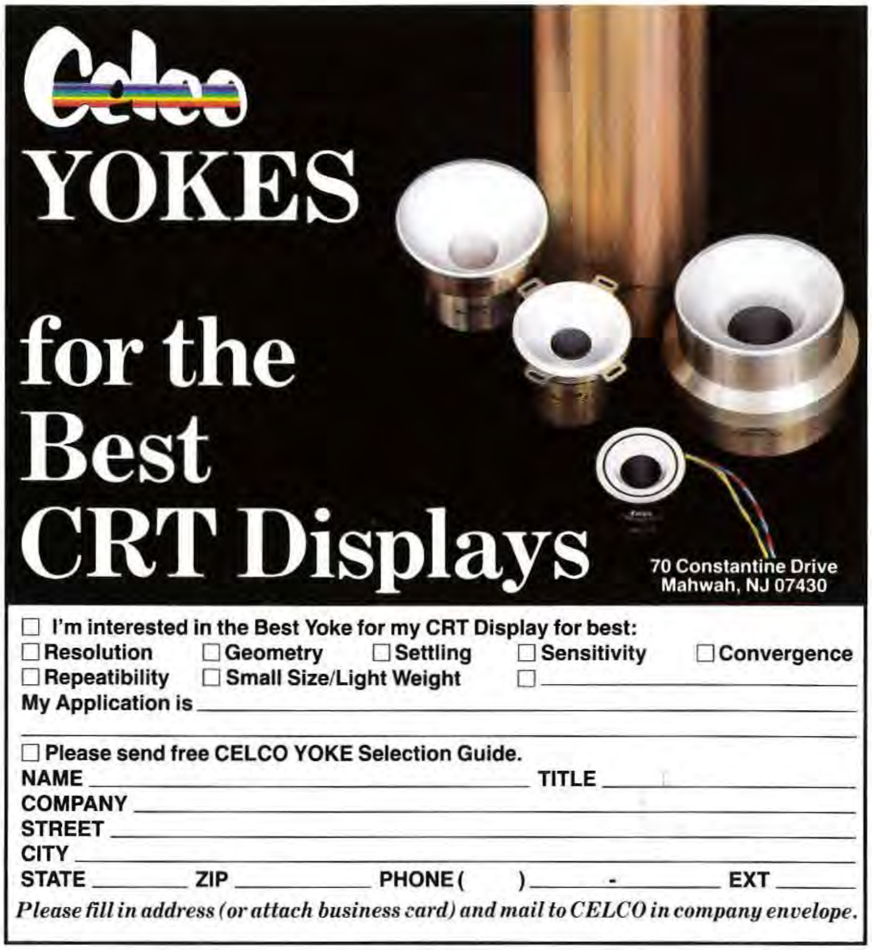
Color in HDTV

An imaging system designed without the need for color resolution compromises would allocate spectrum bandwidth for color signals according to their relative spatial sensitivities in the visual system. Resolution of the red-cyan information would thus need to be about one-half that of luminance, and that of the blue-yellow signal about one-quarter that of luminance.

Ideally, color information should be in the form of color ratios rather than color differences. This would prevent the lower resolution color information from degrading performance of the higher resolution luminance signal.

The temporal response of the visual system to changes in color is slower than it is to low-resolution "transient" luminance information. Therefore, color information need not be updated at as high a frame rate as that required for low-resolution luminance information. Color can be changed at about one-half the rate of luminance without sacrificing good motion rendition.

Currently, 525-line color video signals are not arranged to take optimum advantage of the spatial and temporal characteristics of the visual system. They have excess vertical color resolution, inadequate horizontal color resolution, and excess temporal response. Better image quality at reduced bandwidth can be obtained by producing the video signals that correspond to the known spatio-temporal properties of the color visual system.



To summarize, the application of knowledge gained from the study of vision to the design of new imaging systems will pay off handsomely, both in conservation of channel bandwidth and in the creation of video images that more nearly reflect the world we see.

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Portable battery-operated data line monitor

The CST DataProbe$^{\text{TM}}$ I is a portable battery-operated data line monitor for solving hardware and software communications problems. This book-sized unit is reported to match or exceed the capabilities of monitors three times its cost and four times its weight. Designed for traveling field service representatives, large terminal networks, and software development organizations, the DataProbe is available with asynchronous and optional synchronous protocols. Prices range from $1195 to $1495, depending on model.

For further information contact Control Systems Technology, Inc., 19045 Cherry Bend Dr., Germantown, MD 20874. 301/540-8614.
Circle no. 9

Low-power electroluminescent display

The new Finlux MD512.256-40 low-power electroluminescent (EL) display is now available in prototyping and preproduction quantities. The reduction in power of plus 30% results from a proprietary energy recovery circuit implemented in this new display. The power consumption of the display, including its power unit, for typical use is 11 W with a maximum of 16 W. The manufacturer reports an average decrease of 10°C in the display driver temperature, resulting in higher reliability, longer life, and higher brightness than earlier versions.

The unit is designed to display crisp stable flicker-free images in a pleasing yellow color, produced by means of a sub-wavelength thin light-emitting EL phosphor layer. The display supports both text—25 lines of 80 characters—and detailed high-resolution graphics. The approximately 4 × 8 in. display area has 512 × 256 pixels with a resolution of 67 lines. The initial sample price for the display and power converter is $1115, and for quantities of 100, $590.

For more information contact Ulf J. Strom, Finlux, Inc., 20395 Pacifica Dr., Suite 109, Cupertino, CA 95014. 408/725-1972.
Circle no. 10

High-resolution multiscreen color terminal

Modgraph, Inc. announces the availability of four full-color graphics screens for its GX-1105 Tektronix emulating terminal. The standard model includes one alphanumeric screen and one color screen. Addition of the other three color screens is $400.

Multiple graphics screens can be stored in the terminal, and by a single command or keystroke the entire display can be repainted in a single raster cycle. One plane of information with 16 colors can be loaded while a different plane is being displayed. This has particular use when the application requires that the operator's information display change instantly, without waiting for typical communication transmission delays.

The GX-1105 is a 14-in. high-resolution color graphics terminal offering a 1024 × 768 display with a selection of 16 colors from a palette of 4096. It emulates the Tektronix 4105 (4010/4014) in graphics mode, as well as the VT-100 alphanumeric terminal. In addition to the primary communications port, a printer output, and a secondary RS-232C port (mouse/data tablet) are standard.

For more information contact Les E. Silvern, Vice President Sales/Marketing, Modgraph, Inc., 56 Winthrop St., Concord, MA 01742. 617/371-2000.
Circle no. 11

Color display automatically adjusts to varying scan rates

Magnavox has introduced a new multiple scan-rate color display to the Magnavox professional line of computer monitors. Known as the multimode color display (8CM873), this model can automatically switch scan frequencies to display a wide variety of graphics formats.

The multimode display is designed to work with signals requiring horizontal scan rates in a range of 15–34 kHz. The multimode display will automatically configure itself to operate at the correct scan rate and can accept either digital (RGBI, RGBrgb) or analog signals.

The multimode display (8CM873) uses a 0.31-mm fine-pitch CRT and fast 25-MHz amplifier to produce image resolution up to 926 dots (H) × 580 lines (V). The display features audio input capability, has a 1-year limited warranty, and comes complete with interface cable. The suggested retail price is $900.

For more information contact David W. Berger, Director of Marketing, NAP Consumer Electronics Corp., Interstate 40 and Straw Plains Pike, P.O. Box 14810, Knoxville, TN 37914-1810. 615/521-4494.
Circle no. 12

High-voltage switching power supply

Converter Concepts, Inc. announces a new 100-W high-voltage switching power supply. The unit is designed for high-resolution color monitors and gas-discharge displays.

Other features include: automatic degausing circuit, 20-mA constant current loop—LED indicator driver, adjustable output from 75 to 100 V_{ac}, open and enclosed package. The HV 100 is designed to meet UL 478, 1012, VDE 0804, 0806, Class I SELV, IEC 380.

For further information contact Darrell Gilbertson, Sales Manager, Converter Concepts, Inc., Industrial Parkway, Pardeeville, WI 53954. 800/253-5227.
Circle no. 13

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Sperry's commercial flight systems operation in Phoenix will soon become a part of Honeywell, Inc. The combination of Sperry and Honeywell aerospace operations creates a stronger market force offering both a larger line of products and systems for commercial aviation and more opportunities for career growth. Sperry in Phoenix offers you opportunities in both our air transport and business aviation areas where our current projects have created openings for professionals in CRT display technology:

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Circle no. 19

LCD bargraph meter with LED backlighting

A new 2.5% LCD bargraph panel meter, Model #IDA-2050-1 × 42-1 from UCE, features variable LED backlighting to improve visability in all lighting conditions and enhance viewing angle. The meter's slimline profile facilitates use in both panel mounts and hand-held instrumentation.

The meter features: 40 bars (2.5% resolution) plus "zero" bar; over-range and negative input flags; very low power (1.1 mW), excluding backlight; thin profile (0.500) and compact size; variable long-life LED backlighting (0–5 V, 180 mA); two full-scale voltages (0–2 V and 0–200 mV); horizontal or vertical mounting option; and 0.9-V operation.

The active area of the display has large borders for custom printing of scale and legends. The overall dimensions are 2.1 × 3.1 × 0.5 in. with a large active area, 0.86 × 2.4 in. and bars of 0.85 × 0.05 in. Custom meters and LCD panels are available on request. Sample IDA-2050-1X41-1 meters are priced at $120 each.

For further information contact Richard Eicher, UCE, Inc., 24 Fitch St., Norwalk, CT 06855. 203/838-7509.
Circle no. 14

LCD digital panel meter with red or green LED backlighting

Modutec's new LCD "Big-Little" digital panel meters (DPMs) use LEDs with 100K hours of life for backlighting, thus combining high visibility with low power consumption. Modutec DPMs are designed to be sunlight readable and not to wash out or "ghost" like other power-consuming LED digital panel meters.

The backlighting power requirement is 5, 12, or 24 V_{dc} or 115 V_{ac}. Displays, with a choice of red or green backlighting, are −20°C to +65°C operating storage with 3½ digits, ½-in. high, and full scale of 1999. The DPMs, which are made in America, measure 2.36 in. (L) × 0.95 in. (H) × 0.51 in. (D). Other features include: ±200 mV or ±2 V input; three power options (9 V battery, ±5 V_{dc} or +5 V_{dc}); window or bezel mount; accuracy of ±(0.1% + 1 count).

Delivery is 8–10 weeks and prices start at $54.

For more information contact C.E. Altschul, V-P Marketing, Modutec, Inc., 18 Marshall St., Norwalk, CT 06856. 203/853-3636 or 1-800-METERS-1.
Circle no. 15

Circle no. 20

chapter notes

Bay Area Chapter

The Bay Area Chapter met December 16 at the Beverly Heritage Hotel. **Makoto Maeda** of **Sony Corp.** gave a talk on the beam-index color CRTs under development at Sony. The Sony Indextron™ is a high-luminance color CRT that can be used for displays under conditions of high ambient illumination. The beam-index design avoids many of the disadvantages of conventional shadow-mask and aperture-grill CRTs. This new technology promises to have far reaching effects on high-performance color displays.

Los Angeles Chapter

The Los Angeles Chapter met December 8 at the Proud Bird Restaurant in Los Angeles to hear an illustrated lecture by **Larry Tannas, Jr.**, entitled "Japan and the Four Tigers," based on his recent trip to the IDRC in Japan and on to Korea, Hong Kong, Singapore, and Taiwan.

Mr. Tannas not only described the outstanding technical achievements he had seen, but discussed the underlying socio-economic factors—such as employer-employee stability and a strong work ethic—that have helped the Asiatic countries to compete so successfully in the electronics industry. Among the Japanese products featured were an outstanding variety of LCDs; 8-mm VCRs; 3-D TVs; electronic cameras; color printers with quality better than 35-mm color prints; a 43-in. CRT (Panasonic); a rear projection TV with a 12-ft.-diagonal screen (Hitachi); and LCD tiles for subway signs (Seiko-Epson).

The Chapter held elections recently. The results are as follows: Chairman, **Peter Baron**; Treasurer, **Don McMichael**; Secretary, **John Sutton**; and Program Chairman, **Robert Schmahl**.

Mid-Atlantic Chapter

The Mid-Atlantic Chapter met December 2 at the CUNY Graduate Center in New York City. **Bernard Lechner** of **RCA Laboratories** addressed the joint SID-SMPTE meeting on the topic, "The Future of Television." High definition television (HDTV) has been a goal of both the Japanese and U.S. Governments for several years, but its 20 MHz-bandwidth requirement has made it unsuitable for broadcast transmission. Mr. Lechner described several ways of achieving "extended defintion TV" without the high signal-bandwidth of HDTV. These methods include digital TV receivers with digital filters and line or frame buffers; two-channel transmission systems; and bandwidth reduction techniques such as MUSE. Broadcast HDTV may ultimately be realized through direct satellite transmisison or fiber optic cabling. Meanwhile, HDTV could make its consumer product debut in the form of VCRs, since production studios can already record the HDTV format. Members were left with a sense of anticipation about the many improvements coming in the world of television and the associated opportunities for display development.

SID-MAC Vice Chairman Terry Nelson (left) thanks Bernard Lechner for his talk on "The Future of Television."

San Diego Chapter

The San Diego Chapter held its December 2 meeting at the Salmon House in Mission Bay. Chapter Chairman **John Lipscombe** of **Hughes Aircraft Co.** gave a talk titled "Twenty-five Years of Displays."

February

IEEE 1987 Aerospace Applications Conference. Warren A. Schwarzmann, 4 Aurora Dr., Rolling Hills, CA 90274. 213/973-1121.
Feb. 7–14 Vail, CO

Fundamentals & Applications of Lasers—Short Course. Laser Institute of America, 5151 Monroe St., Toledo, OH 43623. 419/882-8706.
Feb. 9–13 Orlando, FL

Electronic Imaging '87: International Electronic Imaging Exposition & Conference. Ed Martin, MG Expositions Group, 1050 Commonwealth Ave., Boston, MA 02115. 617/232-EXPO.
Feb. 16–19 Anaheim, CA

CSC '87: 1987 ACM Computer Science Conference. Association for Computing Machinery, CSC-87-PR, 11 West 42nd St., New York, NY 10036. 212/869-7440
Feb. 17–19 St. Louis, MO

COMPCON Spring '87. IEEE Computer Society, 1730 Massachusetts Ave. N.W., Washington, DC 20036. 202/371-0101.
Feb. 23–26 San Francisco, CA

Flat-Panel and CRT Display Technologies—Short Course. (Sponsored by UCLA and SID.) UCLA Extension, Short Course Program, 10995 Le Conte Ave., Los Angeles, CA 90024. 213/825-1295.
Feb. 23–27 Los Angeles, CA

March

Office Automation Conference. AFIPS, 1899 Preston White Dr., Reston, VA 22091. 703/620-8900.
Mar. 9–11 Dallas, TX

Computer Graphics '87. Craig Stewart, National Computer Graphics Association, 2722 Merrilee Dr., Suite 200, Fairfax, VA 22031. 1-800/225-NCGA.
Mar. 22–26 Philadelphia, PA

Advances in Semiconductor and Semiconductor Structures. SPIE, P.O. Box 10, Bellingham, WA 98227-0010. 206/676-3290. Telex: 46-7053.
Mar. 23–27 Bay Point, FL

SOUTHCON '87. Dale Litherland, Electronic Conventions, Inc., 8110 Airport Blvd., Los Angeles, CA 90045. 213/772-2965.
Mar. 24–26 Atlanta, GA

4th International Symposium on Optical and Optoelectronic Applied Science and Engineering. SPIE, P.O. Box 10, Bellingham, WA 98227-0010. 206/676-3290. Telex: 46-7053.
Mar. 30–Apr. 3 The Hague, Netherlands

ADEE WEST: Automated Design and Engineering for Electronics West. Wendy Geller, ADEE WEST, Cahners Exposition Group, 1350 Touhy Ave., P.O. Box 5060, Des Plaines, IL 60017-5060. 312/299-9311, ext. 2486.
Mar. 31–Apr. 2 Anaheim, CA

April

CHI&GI 1987: Special Combined Conference on Human Factors in Computing Systems (CHI '87) and Graphics Interface (GI '87). Wendy Walker, Computer Systems Research Institute, University of Toronto, 10 Kings College Rd., Rm. 2002, Toronto, Ontario, Canada M5S 1A4. 416/978-5184.
April. 5–29 Toronto, Canada

ELECTRO '87. Dale Litherland, Electronic Conventions, Inc., 8110 Airport Blvd., Los Angeles, CA 90045. 213/772-2965.
Apr. 7–9 New York, NY

Third Photoreceptor Industry Conference. Diamond Research Corp., P.O. Box 128, Oak View, CA 93022. 805/649-2209.
Apr. 12–14 Santa Barbara, CA

Display Workshop on CRTs, Flat Panels, and Touch Entry. (Sponsored by SID, New England Chapter.) Melvin Silverstein, Chairman, SID N.E. Chapter, 19 Whichita Rd., Medfield, MA 02052. 617/359-6063.
Apr. 15 Sudbury, MA

IEEE Computer Society Symposium on Office Automation. Vincent Lum, Dept. of Computer Science, Naval Postgraduate School, Monterey, CA 90045. 408/646-2449.
Apr. 27–29 Gaithersburg, MD

CLEO '87: Conference on Lasers and Electro-Optics. Optical Society of America, 1816 Jefferson Pl. N.W., Washington, DC 20036. 202/223-8130.
Apr. 27–May 1 Baltimore, MD

IQEC '87: International Quantum Electronics Conference. Optical Society of America, 1816 Jefferson Pl. N.W., Washington, DC 20036. 202/223-8130.
Apr. 27–May 1 Baltimore, MD

Call for Papers

Human Factors Society 31st Annual Meeting. Oct. 19–23, New York, NY. For a copy of the Call for Papers contact the Human Factors Society, P.O. Box 1369, Santa Monica, CA 90406. 213/394-1811. Deadline for abstracts: Mar. 1

45th Annual Device Research Conference. June 22–24, Santa Barbara, CA. Papers on the following topics are solicited: Advanced silicon processing; bipolar devices; isolation technology, submicron devices and structures; in situ processing and device applications; thin insulators and hot electron effects; SOI and 3D devices; power devices; physics of ultrasmall devices; sensors and transducers; device and process models; device characterization and new techniques; CMOS devices and technology; interconnect technology; integrated optoelectronics; microwave devices; novel infrared devices; III-V FET and bipolar devices; active guided wave devices; optical sources and detectors; multilayered heterostructures; III-V device processing; radiation effects (soft errors); contact technology; quantum effect devices. Authors should submit 22 copies of a 1-page summary (containing name, address, and phone no.; objective, background, techniques, results, impact, references, and prior publications, but no figures) to: Gregory E. Stillman, Dept. of Electrical and Computer Engineering, University of Illinois, 1406 W. Green St., Urbana, IL 61801. 217/333-3097. Deadline for abstracts: Mar. 13

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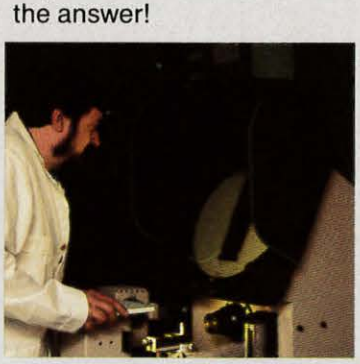

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