SID JOURNAL

The Official Journal of the Society For Information Display

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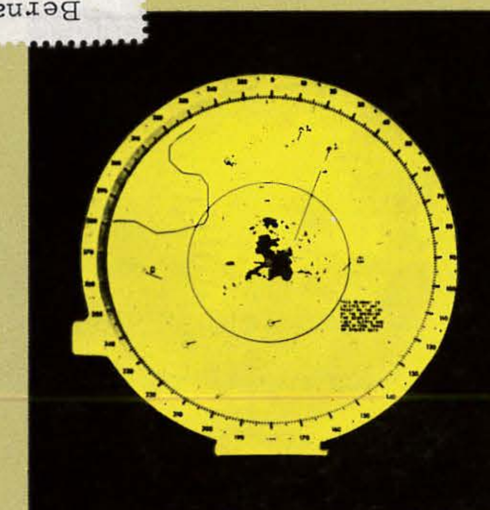

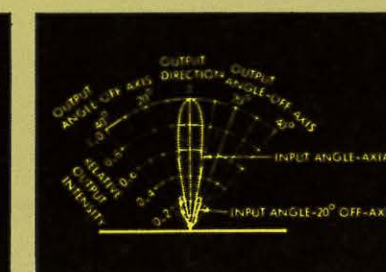

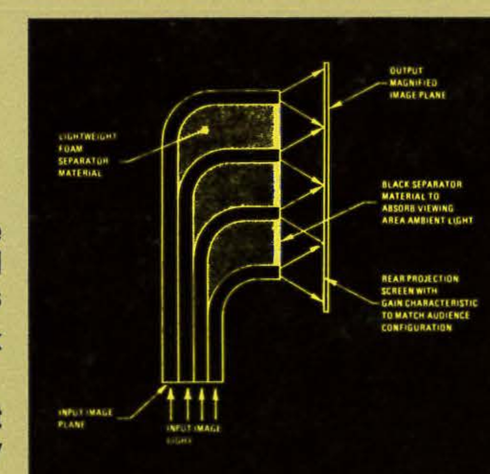

fiber optic

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ENT'S MESSAGE PRESIDENT'S ME

The Impact of New Technology on Display System Architecture

In the last ten years, continuous and significant advances have been made in display system design all the way from high performance, real-time graphics systems to the low cost, alphanumeric "teletype" replacements. It now appears that the rate of advancement may well increase in the next few years, urged on by new types of display devices, faster and lower cost memory elements, MOS "computers-on-a-chip", and reliable magnetic mass storage devices. At the same time, the function of the display terminal in the system is being re-defined with general purpose devices giving way to more application oriented units.

The CRT in its many forms has been the mainstay of nearly all display systems up to the present. Now plasma panels are available and it is likely in one to two years liquid crystal and laser display devices will be commercially offered. Each of the new devices will have unique characteristics; the question arises as to how valuable these unique features are. For example, plasma panels are flat, distortion free, allow rear projected overlaps, and have inherent image memory. They are also low resolution devices and relatively costly. It is not yet obvious that the advantages so outweigh the disadvantages that the CRT will be seriously displaced. Within the family of CRT techniques, a number formerly accepted procedures are being reconsidered. Graphic displays have traditionally used random scan deflection systems but there is a trend toward raster scan because of the simplicity of distributing video signals, the lower cost of monitors, and the higher reliability of "all digital" systems. On the other hand, a number of real time operations such as rotation or scaling are difficult to perform in a raster-scan system and it is not clear that in the near future techniques or circuitry for such real time manipulation will be available.

For several years in low cost graphics terminals it has been deemed desirable to use display devices with inherent image memory (i. e. the display image is stored by the display device itself and does not require the image to be refreshed). This inherent memory created a problem because it made it difficult to change the image but since an inherent memory eliminated the need for an expensive refresh memory, it was felt to be worthwhile. Recently, however, semiconductor memory costs have fallen so far that it is possible to question the value of inherent memories. It is now possible to refresh low cost CRT's from separate memories for a system cost comparable to using an inherent memory device such as a panel or direct-view storage tube and problems of modifying the image are much simpler. Even if a designer decides that he wants to use semi-conductor memory in his display, there are further questions to be resolved. For example, should he use random access or serial memories. MOS random access memories are slightly more expensive and somewhat slower but much more versatile. At the same time, the trade journals are very enthusiastic about the expected low cost of magnetic "bubble" memories and charge coupled devices — and these devices are inherently serial. Should the designer plan ahead to use the new devices and do serial designs or take advantage of the power of random access devices.

Alphanumeric terminals have been progressing along two paths. One is to produce the lowest possible cost "universal" I/O terminal that would replace electro-mechanical equivalents by being quieter, faster, and more reliable — but is "dumb". The other path is to build "smart" or "intelligent" terminals that can edit and even perform some computation without interrupting their associated computer. With the advent of large scale integrated circuits, adding processing power to each terminal is reasonably economical. The alternate school of thought is that computing power should be concentrated at the host computer and that the terminals need no intelligence. A third road is to cluster "dumb terminals" near a mini-processor that acts as a collective processor for all the terminals and communicates back to the host computer. Compounding the confusion is the issue of the desirability or need for bulk storage as part of the computer configuration. And if local storage is preferred, should be the media cassettes (of various types) or "floppy" disks.

These comments outline only a few of the many new choices in designing display architecture that have been made possible by new technology.

Thomas B. Cheek
Adage, Inc.

By S. B. SCHUCK
Raytheon Company
Sudbury, Mass

The Changing Architecture of radar command and control Displays

The evolution of command and control displays seems to be accelerating. The author describes this evolution and how modularity impacts it. This paper has been adapted from the writer's recent presentation at NEREM.

■ This paper describes the architecture and display characteristics for a family of multi-purpose, computer controlled interactive radar displays.

The display characteristics for upgrading the total control performance is described, with emphasis on the characteristics, organization of displays and their impact on the architecture. Improvement is discussed using general purpose processing capability internal to the display.

Introduction

Radar situation displays have evolved from simple PPI scopes to large man-machine information systems involving a network of radar sensors, computers and displays. The increasing integration of computers and displays and development of improved hardware and software techniques for real-time man-machine interaction has led the way to increased application of displays for a variety of real time control applications. Emerging new applications include coordinated air traffic control, traffic situation displays, area navigation-cockpit displays and operator displays in industrial and military command and control applications.

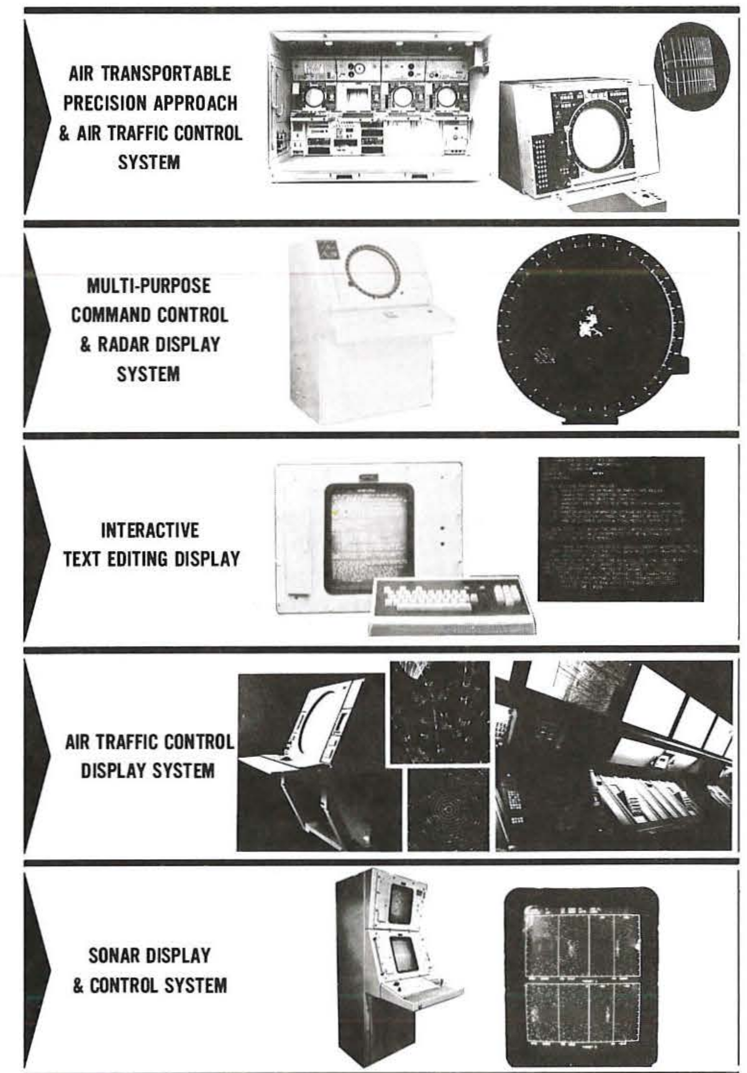

Figure 1. State of the Art Situation Displays in C&C Applications

By S. B. SCHUCK

The broad set of potential display applications in highly automated systems, has stimulated various design alternatives and system configurations. Systems range from simple alphanumeric TV raster displays to high capacity, dynamic displays capable of multimode operation. Figure 1 depicts various operator displays and presentation formats used in air traffic control, precision landing, sonar and tactical command and control applications.

The general composition of elements comprising the class of systems to be discussed is shown in Figure 2. It consists of interconnected data processing, display and data entry equipment, coupled to the system sensors and controlled elements via video processors, data converters and communication links.

The system sensors include various search and track radars, IR and sonar sensors. The display subsystem interfaces with both sensors and computers to provide a continuous display of the tactical situation and means for entering operator decisions and requests to the system.

The sections following discuss the broad considerations and display design criteria for upgrading the C&C display system performance. A design approach is outlined configured about a programmable display controller; using off-the-shelf, state-of-the-art display hardware. The salient display characteristics and advantages gained by novel application of stored program capability internal to the display console will be described.

System Design Considerations

The critical problem in display system design is tailoring the display performance to satisfy operational requirements involving the interaction of man and machine, operating in a time restricted environment. A complicating factor is that display systems are invariably subsystems of large systems with the result that display criteria formulated in terms of primary system operational requirements must be translated into display performance requirements. Since there are no hard rules for allocation of system functions between various portions of the system or quantitative criteria for measuring system effectiveness, there is a lack of standardization in system structure.

In the past system enhancement was generally achieved by advancing the state-of-the-art in display technology, coupled with design of special purpose display hardware.

Display techniques and hardware have now reached the stage where few problems are encountered in system implementation and incremental advancement in the state-of-the-art of display quality no longer guarantees improvement in the total display performance.

To help define the basis for our design objectives, some of the more important constraints in the design of displays in a command and control environment are examined in detail.

Concern for Organizational Flexibility

The traditional design of displays in large command and control (C&C) systems was based on a "hardware approach". Display subsystems are designed as special purpose peripherals to large command control information systems. To achieve desired performance, the display requirements are optimized to reflect specific mission operating requirements.

The difficulty is that these systems have a broad and complex scope of operation requiring extensive display processing support from the host C&C system.

In military systems, the problem is compounded by the lack of stability in the military environment. Changes in mission, threat and defensive capability alter the specific operational procedure, man-machine interaction and the display information requirements. As mission requirements become more complex, additional performance requirements are placed on both C&C computers and displays.

Because the above pattern is typical, lack of flexibility for meeting changing requirements results in degradation in total system performance and premature display obsolescence.

Our approach to satisfying the mission requirements for advanced, high performance systems, is predicated on the design of a highly versatile, mission independent display, using general purpose processing capability internal to the display. To the extent that the stored program capability is included in the display console, it frees the last CPU from display oriented tasks and provides a new dimension for system organizational flexibility.

Concern for Improved System Controllability

Closely aligned with the requirements for high level, real time operator interaction are the often overlooked considerations associated with operational structure of the user.

The formulation of the information structure, bearing in mind the demands and constraints of the system problem is fundamental to the control of large scale man-machine systems. In general, these systems contain multiple stations, and require multiple information sets to support a wide range of operations.

The display processing system must handle a large number of independent operator requests and decisions simultaneously. The system must further respond to these requests in real time demanding dynamically varying processing and display loads.

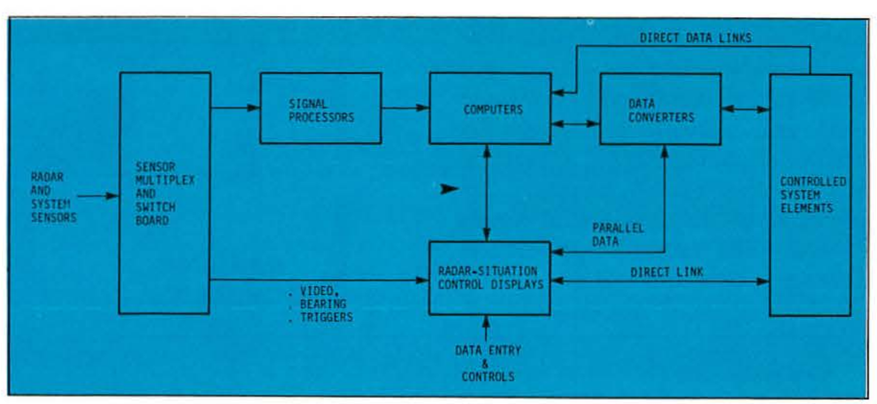

Figure 2. Typical C&C System

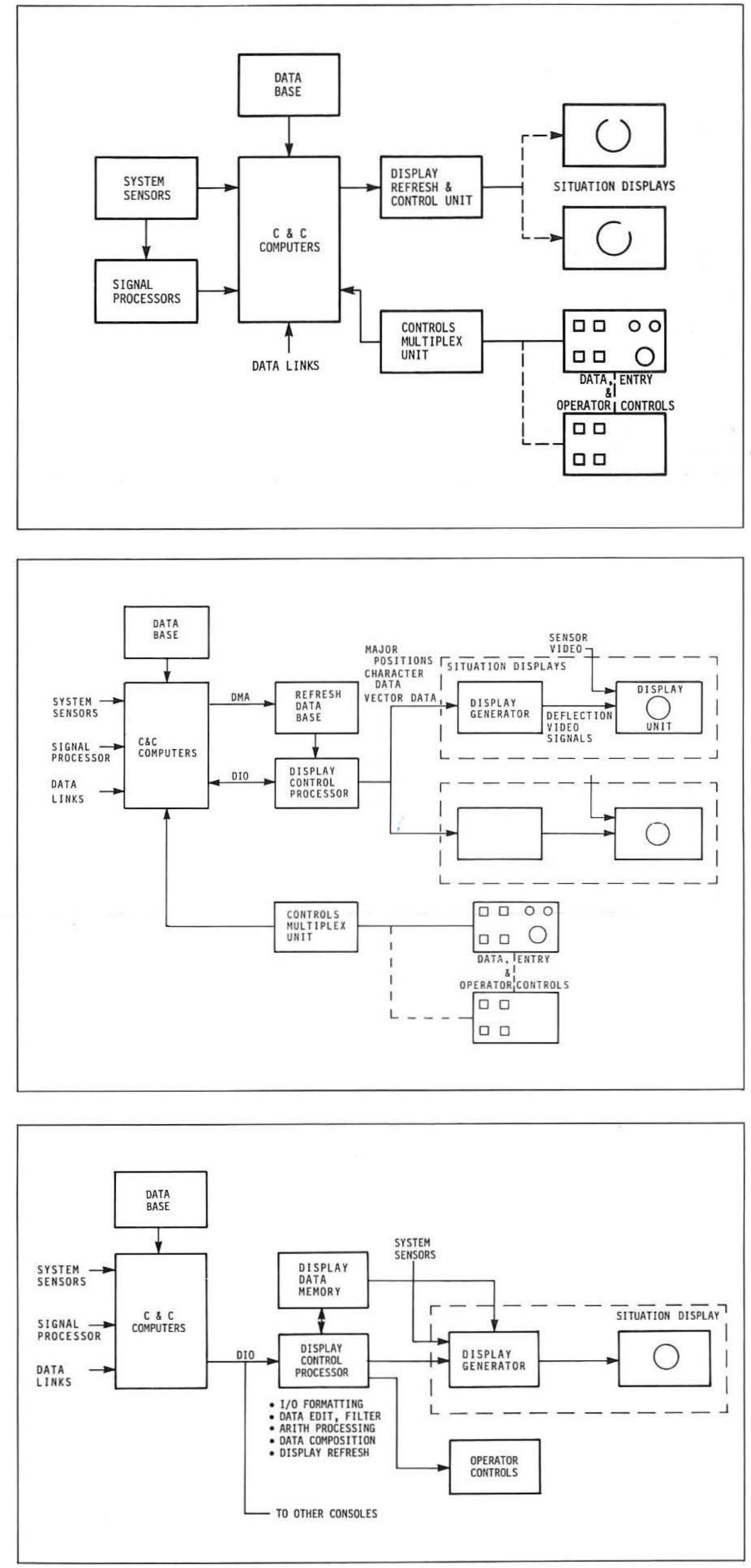

Figure 3. Display Subsystem Configurations

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To support a wide range of operations, the system must have sufficient versatility to provide controlled selectivity over the total formation available to the operator and flexibility in display format, optimized for human factor consideration.

Specific Considerations

Along with the broad considerations discussed above, the following key system parameters are identified as primary determinants of display configuration; system response time requirements, display load and data format and levels of system interaction necessary to support mission requirements.

Display design is further complicated by a variety of application and environmental constraints. Some of the major display requirements include: good modulation transfer function at high resolution, compatible interfacing capability with appropriate input/output components and suitable brightness under varying ambient light conditions and low product life cycle costs. In military systems the display configuration is strongly influenced by the common requirements characteristic of military hardware, i.e., environmental constraints, high system reliability, maintainability, low weight, volume and power.

Alternate System Structures

Figure 3 shows the organizational alternatives in the design of computer driven display systems. Due to the diversity of applications that must be supported, no single display device or system structure can satisfy all of the foregoing requirements. In the following sections we describe the considerations in system architecture and our display objectives for a family of radar command and control systems.

In the architecture of present day control systems, the preferred approach for satisfying the mission

By S. B. SCHUCK

requirements is to centralize the data management, information processing and system control functions into a single integrated computer facility. The control computers coordinate the collection and correlation of data from the system sensors, signal processing subsystem and operator display consoles. In addition, in most centrally controlled systems, the host computers perform the required display and control processing for integrating the display with the controlled systems. In some cases the display refreshing is performed directly from the computer's internal refresh memory.

Except for the large systems designed with excess capability to accommodate a high level of man-machine inter-action, the data processing required for the coordination and maintenance of the display is beyond present computer capability.

In the past, the design of military displays was based on a hardware approach, with the decision to centralize the computing, display generation and data storage being one of economics. Large systems using multi-station displays, were configured around a centralized display control unit and large refresh memories.

With early integrated circuits and magnetic memories — low cost was achieved by having large memory arrays driven by a small amount of electronics and systems were optimized to minimize the total circuit count. The accepted dictum was that a large processor provided more performance/per unit cost.

With present trends in digital equipment costs, there is no longer a severe penalty in distributing storage and processing capability to individual consoles.

The availability of MSI/LSI memories and complex digital units drastically alters the balance between different parts of the system, and suggests new organizational concepts for improving the performance and flexibility of displays relative to the system operational requirements.

Multipurpose Display System Objectives

In the design of the Modular Programmable Display System (MPDS) the following design goals were formulated for effecting a functionally versatile, mission independent display system, capable of multimode operation:

1) Modular system organization capable of functional reconfiguration and future expansion
2) One basic console design used at all operating positions. Each console capable of independent operation and reconfiguration under program control
3) Provide processing capability internal to the display, using a modular programmable display controller, to reduce the display load on the control computer
4) Provide internal refresh memory, to minimize computer display servicing times
5) Improve man-machine interaction through a flexible display format, controlled by internal processor and easily adopted to system requirements

MPDS System Description

Figure 4 shows a development model of the multipurpose Display System (MPDS), configured for stand alone operation.

The console provides full interactive capability with a complement of sensors, control subsystems and host computers. Using internal processing and refresh capability the MPDS processes and displays real time radar video and computer generated synthetic data, which includes target tracks, operation cues and programed data.

The salient operational features of the MPDS console include:

- Dual color situation display consisting of an accurately co-registered presentation of time compressed radar video and computer generated data in PPI, B-Scan or RHI formats
- Flexibility in the make up and categories of display data: controlled by operator switch actions of the console
- Dynamically updated tabular displays of operational routines, system status, track queues and keyboard entries; appearing in operator relocatable sterile area on the situation display
- Improved man-machine interaction by cueing operator decisions of the recommended use of the system elements in engageability of targets and operation doctrines.
- Display oriented processing, such as data filtering, editing, display range scaling and radar display processing performed entirely internal to the console
- Flexible display format that allows the control computer to communicate with the display console in a format the system understands
- On line diagnostic and fault isolation capability using self test programs contained in the MPDC

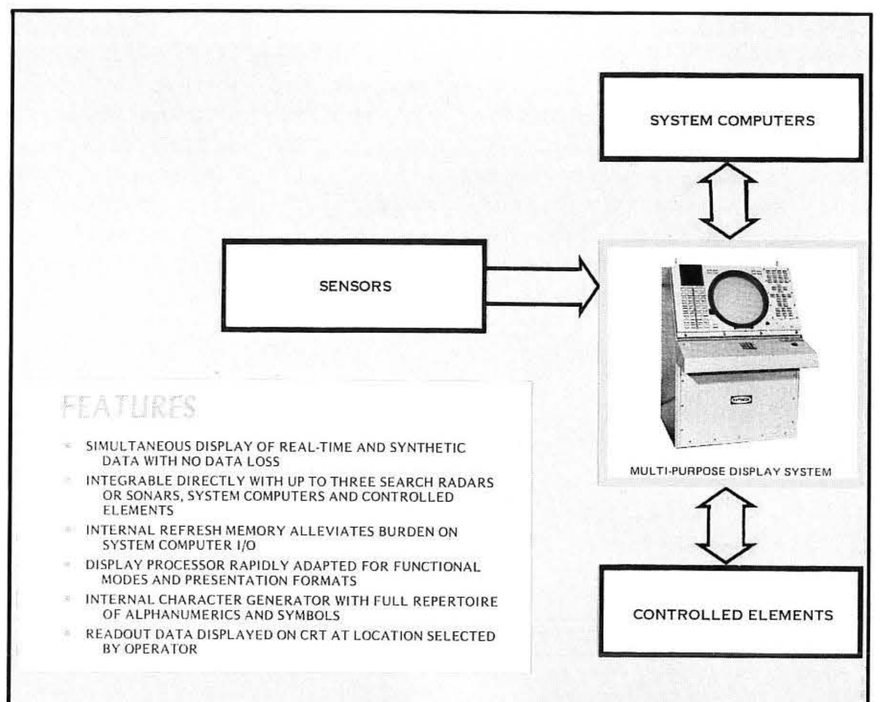

Figure 4. Multipurpose Display System

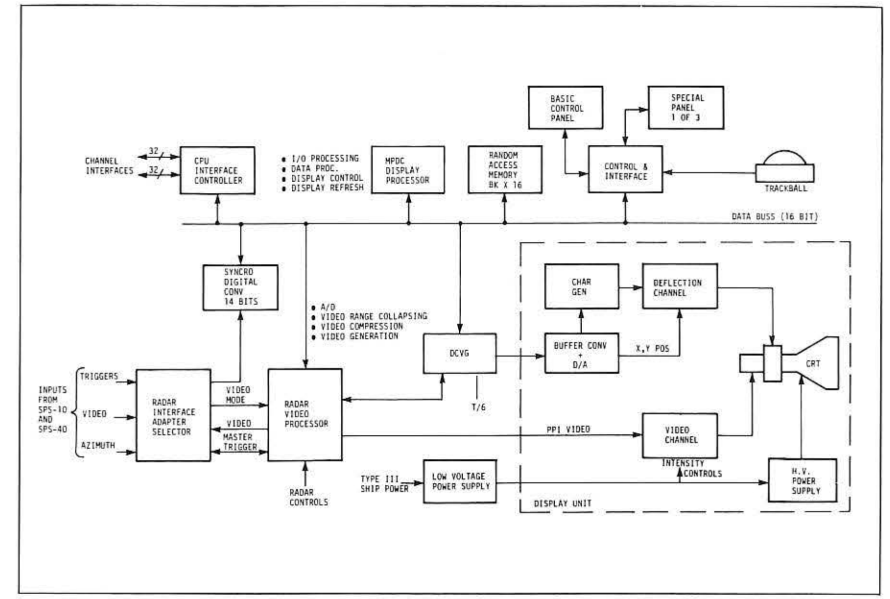

Figure 5. MPDS Overall Block Diagram

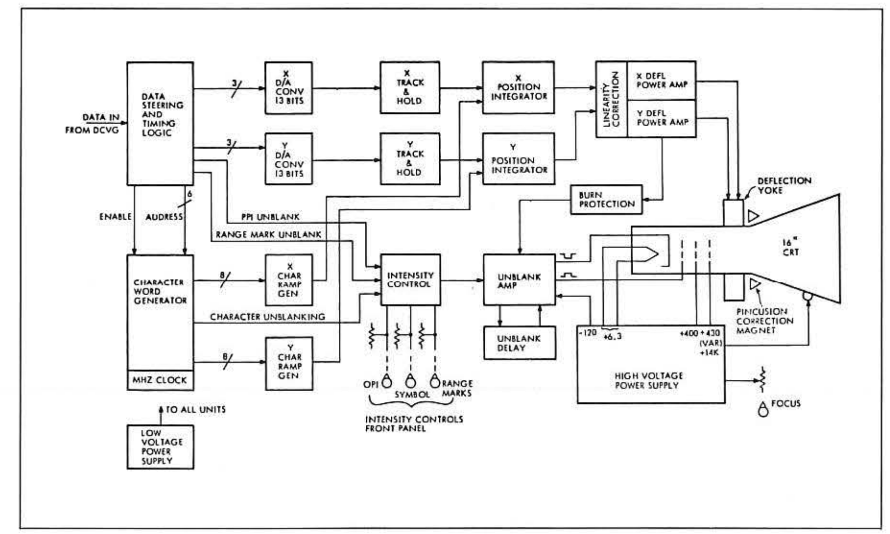

Figure 6. Display Subsystem

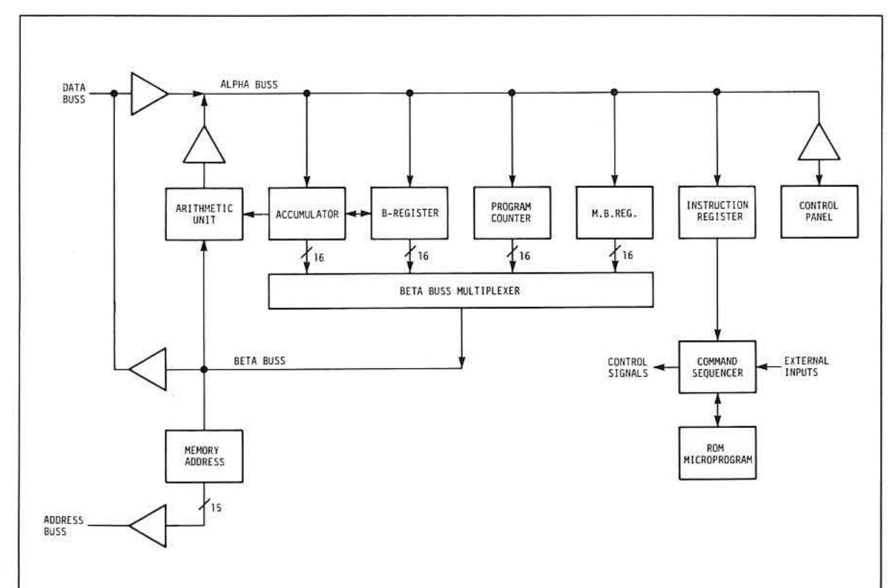

Figure 7. MPDS Processor

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The console's internal functional architecture is based on a novel design approach for PPI display generation using an integrated hardware-software scheme. The major areas to be highlighted are:

- All digital PPI raster generation, using the MPDC for real time radar sweep vector processing
- Time shared use of a common vector and display waveform generation hardware for display of radar video and computer data
- Use of video time compression to increase the amount of displayable synthetic information.

Optimization of the display to the job function is achieved through the use of modular hardware and software systems operating under control of a real time executive processor.

The classes of display data processing and data management and control functions performed at the console are largely determined by the relationship between the console and the Controlled System. To minimize the total display dependency on the host CPU, the following processing is performed in the MPDS:

1. Computer I/O Processing
   Function decode
   Message formatting
   Data routing
2. Display Control Processing

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Display refresh
Trackball processing
Operator controls processing

3. Data Processing
   PPI sweep vector computation
   Display range scaling, and offset
   Coordinate transformations
4. Data Manipulation
   Data filtering and editing by category
   Display composition — from read only representations

MPDS System Architecture

The architecture of the MPDS is based on a modular design philosophy, composed of a small set of compatible hardware and software functional units. Modules in the right combinations are assembled from established product lines to satisfy a variety of radar command-control applications.

The MPDS hardware block diagram is shown in Figure 3. The equipment is comprised of the following major display building blocks:

- CRT display & display generation hardware
- Display processor and refresh memory
- Radar video processor subsystems
- Control processing subsystems

Each of these areas constitutes an operational subsystem only after the hardware and software associated with the command and control functions have been integrated.

The MPDS subsystems are structured about the "Modular Programmable Display Controller" (MPDC). Under program control, the MPDC performs the data processing functions required to integrate the operation of the special function controllers and display generation hardware.

The design of the display subsystems, emphasizes distributed control and logic partitioning, to make the operation of the special function controller asynchronous with the data processing functions.

Communication between the MPDC and the special function peripherals is via a common I/O bus. The peripherals, and memory both interface with the bus, so that the device to memory communications may occur without program intervention. and need of a separate DMA unit. High speed DMA data transfer is used for efficient display refresh and I/O operation between the display and the host computer. Direct I/O transfer under program control is limited to initial addressing control and handshaking functions.

Because the interfaces with the bus have been standarized, the internal bus structure provides practically unlimited configuration flexibility to add or delete modules to satisfy different display requirements.

MPDS Equipment Description

1. CRT Display Subsystem

A block diagram of the Display Subsystem is shown in Figure 6. The Display unit is a high performance, random position CRT display designed to display real time compressed radar video and computer generated synthetic data.

The console provides dual color presentation so that computer generated background data is displayed without obscuring radar video information even at high luminescence levels.

Capability is included to generate a variable set of 128 symbols and alphanumerics generated using cursive constant writing rate generation techniques. Under program control symbols and characters may be written in two sizes, at either of two brightness levels and are drawn either solid or flashing. These features are used to provide warning of critical situations requiring operator action.

2. Processor Subsystem (MPDC)

The processor subsystem is structured about a Modular Programmable Display Controller (MPDC). The MPDC is a stored program, 2's complement, 16 bit general purpose processor, configured from a coordinated set of random access read/write and read only memories, arithmetic logic units and micro-programmed control unit, using a single bus I/O system.

The MPDC central processing unit takes full advange of MSI technology and attributes of higher capability processors including multilevel indirect addressing, hardware multiply and divide, multiple hardware interrupts and flexible capability.

Figure 7 shows a simplified block diagram of the processor subsystem. The programmable processor is comprised of an arithmetic unit, a micro-programmed controller, 6 basic registers, and decoding network.

The interrupt processor contains a real time clock which provides capability for an interrupt of the program at specified programmed intervals. It also generates interrupts upon detection of internal faults, power failure, restart conditions and MPDS subsystem service requests.

The MPDS features a sub-microsecond solid state memory system expandable to 16K words. A typical application would employ a memory system divided between read only memory modules to store fixed operation program, programmable logic sub-routines, and random access read-write (RAM) memory modules containing data buffers and refresh data.

3. Display Control and Vector Generation Hardware (DCVG)

The DCVG is the logical interface between the refresh memory, and the Display Subsystem. The DCVG operates on preformatted display data resident in refresh memory. It decodes display data words, transfers position data vector increment and symbol data to the Display Subsystem. The DCVG also produces all control sequences required to generate constant writing rate, accurately coregistered PPI display. Data transfer between the refresh memory and the DCVG is on a cycle stealing basis and is independent of the MPDC processor.

For optimum registration a single channel all digital display unit is employed for writing radar video, computer generated lines and random position symbology. To achieve the high positional resolution necessary for a quality PPI display presentation, data are computed to 13 bits accuracy and displayed on an 8192 x 8192 element display grid.

4. Radar Video Processor (RVP)

In the past, designs were constrained by the state-of the art in display generation hardware and high cost of digital logic. Sweep stealing techniques were widely used for simultaneous display of radar PPI and computer data. Systems designed around these techniques did not provide acceptable refresh rates when a high volume of computer generated data was required.

In the MPDS, Video Time Compression is used to reduce the radar writing time, thus providing adequate time for writing of synthetic data.

The RVP digitizes and stores quantized video from a single radar transmission. The stored radar video is displayed at constant CRT writing rate on a digitally produced sweep with proper range and display offset.

Summary

Our goals for a cost effective command and control display system were based on a combination of modular system architecture and stored program capability internal to the display. This resulted in an extremely flexible and versatile system capable of functional reconfiguration with minimum redesign, cost and time.

Modularity is achieved by designing the CPU, memory and subsystems as separate functional building blocks to permit expansion and modular substitution for upgrading. This allows new cost-performance tradeoffs to optimize the total system configuration as more efficient LSI modules become available.

Inclusion of a programmable display controller contributes to lower applications cost and system flexibility by solving virtually all external compatibility problems and optimizing the processing utilization of the host computer.

Beyond these primary considerations, the ability to do a large portion of the display processing locally enhances the total operation by allowing selectivity of the information displayed to the operator with flexibility in display formats, improved operator interaction and system response times. ■

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about the author

Simcha B. Schuck is a senior staff engineer at the Digital Systems and Display Laboratory of Raytheon Company's Equipment Division, where he is responsible for systems engineering; technical coordination and development of data processing and display systems for radar command-control and TV graphics applications. A Professional Engineer (Mass.), he is a member of SID and author of several papers on design of displays and memory systems. He has a BEE from City College of New York, a MSEE and MS degrees in Engineering Management from Northeastern University.

Machover Appointed Genl. Mgr. of IDI

Carl Machover has been made Vice President/General Manager of Information Displays, Inc., Mt. Kisco, N.Y. Mr. Machover, formerly the company's Vice President for Marketing, has been with IDI since 1960. He is well known in the computer graphics field, frequently writes and lectures on the subject.

Information Displays, Inc. is a leading manufacturer of computer graphics systems.

Eliminates Small Computer Need

Aiming to stimulate the growing trend toward centralized computer power, Computer Transmission Corp. (TRAN), El Segundo, Cal., has unveiled a new remote processing system that eliminates the need for small or medium-scale computers at remote I/O sites. Called the Multitran 4000, TRAN's new system controls multiple remote peripherals as though they were operating in the central, or "host," computer facility — and it does the job without teleprocessing software or adding any more to operating system overhead than with a local device, says firm.

Photo Research Appoints Walker

Richard A. Walker has been named Vice President/Engineering of Photo Research Div., Kollmorgen Corp., Burbank (Cal.). With firm since 1970, he is credited with development of numerous Photo Research products now on the market, is the author of many technical papers.

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fiber optic Flat Panel Display

Philco-Ford Western Development Laboratories
Palo Alto, California

■ Dynamic large screen displays are cost-effective today when produced by projectors. Commercial movie theatres, pilot training simulators, and closed-circuit television sports theaters find the cost-effectiveness to be achieved by a combination of the high display impact of the large screen plus the ability to divide the cost of a single display device among a large number of users. The same effect occurs in utility, civilian government, and military control centers where key personnel must work in synchronization to solve rapidly changing, very difficult command and control problems.

Large Screen Display Projectors Problem

There are many situations where the cost of the physical volume necessary for the cone of light from a projector to the large screen is so high that large screen display projectors cannot effectively be used. Such situations exist not only in military ships, vans, planes, and hardened control centers, but also in any structure where installations are currently crowded and structural members make rearrangements to accommodate the projector light cone volume not practical.

To solve this problem, the display industry has pursued flat panel display technology of many types including arrays of electrochemical cells, plasma cells, liquid crystal cells, mechanical cells, incandescent cells, light-emitting diodes, and electroluminescent cells. At this time the incandescent cells dominate for sport stadium scoreboards and outdoor news ticker and time-temperature displays. Mechanical elements dominate for traffic control and indoor stock price, ticker displays. At present, such approaches all have as serious limitations most of the following:

1. Inability to make picture elements overlap.
2. Inability to make picture elements change through choice of several colors.
3. Slow update rate.
4. High power consumption.
5. High initial cost.
6. Limited life.
7. High cost of maintenance.
8. Complex driving electronics.

Eliminate Limitations

The Philco-Ford Western Development Laboratories Division has undertaken a program to eliminate these limitations, preserve the flat panel on the wall advantage, and make use of all existing projector technology. In addition, the planned full color, dynamic, flat panel on the wall array had as its goals unusual ruggedness, no failable components, essentially zero maintenance, wide environmental range so as to be applicable to full military applications, yet be less costly than commercial matrix arrays of the same resolution.

Resolution of Digital Lens

The basic concept was that of a fiber optic "digital lens" made of non-tapered optical fibers so arranged as to allow passive rotation, translation, and magnification of monochrome or color images with a total array of depth of only a few inches. The resolution of the digital lens can be exactly controlled by the number of optical fibers fabricated per dimension. The magnification or reduction can be exactly controlled by the center-to-center spacing of optical fibers at the large versus the small end. Translation and rotation can be exactly controlled by the bending of each individual fiber. Picture element size versus fiber center-to-center spacing (fiber pitch) can be exactly controlled by intercepting the cone of light leaving each optical fiber at the appropriate distance from the end of the fiber with a diffusing screen.

The principle of operation of the fiber optic digital lens is shown in Figure 1. As can be seen from the figure, the total depth of the digital lens is essentially the fiber center-to-center spacing times the number of fibers.

For the first lens constructed, the depth was made six inches by using one thousand 6-mil optical fibers.

The costs of large screen display projectors in some situations is too high to justify. The authors describe a solution, using the fiber optic "digital lens."

By HERBERT C. HENDRICKSON
and BRYAN E. LOUCKS

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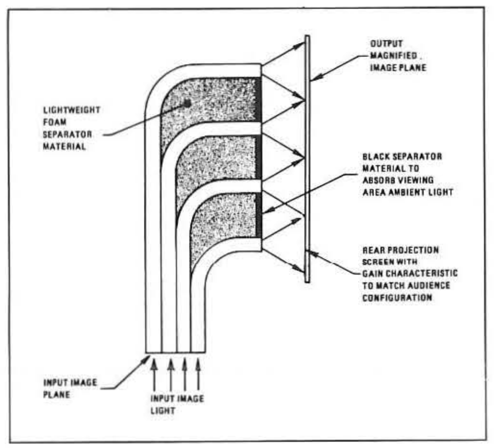


Figure 1. Construction of Digital lens with non-tapered optical fibers.

As can also be seen from the figure, the output image magnification is determined by the ratio of fiber pitch on the output end to the pitch on the input end. For the first large screen lens constructed, the magnification was made to be ten by making the output end center-to-center spacing be 60 mils. The result was an image expansion from six inches to five feet in a total depth of only six inches. A photograph of the first large screen digital lens is shown in Figure 2.

One of the interesting parameters of this lens is that adjustment of the position of the output image plane rear projection screen allows the display system designer to choose between small extremely bright picture elements which do not touch or larger picture elements which overlap but are dimmer. Typical specifications for symbol legibility are usually stated in

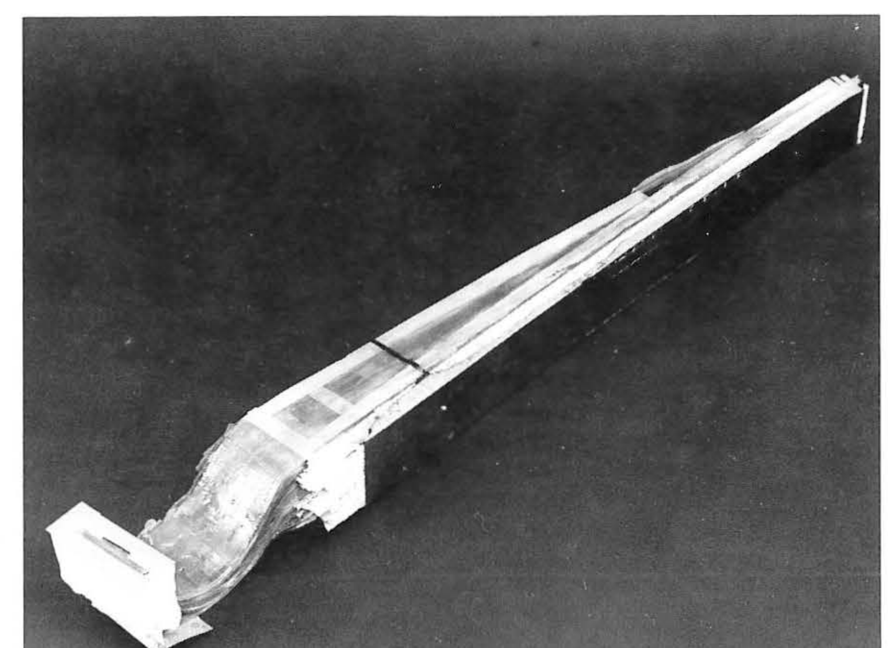


Figure 2. Six inches to five feet magnification digital lens.

By HERBERT C. HENDRICKSON
& BRYAN E. LOUCKS

terms of the contrast ratio between the bright and dark areas of a symbol. However, brightness cannot be the controlling factor for small areas since the areas could be made smaller and smaller until, near the limit, one could obtain legibility with almost zero total light. At some point, the total light emitted from the area must be of significance. Ricco's law[1] states that the total light emitted becomes the controlling factor when the diameter of the area subtends a "few minutes of arc at the eye."

In order to further define the region of transition between brightness perception and total illumination perception, experimental data by Luckiesh and Moses[2] were analyzed. Figure 3 shows the combinations of target size and background brightness required for target discrimination. The targets used were parallel bars. The relative total illumination absorbed by parallel bars at different sizes and contrast ratios is given by:

$$R = S_1^2\, C_1 / S_2^2\, C_2$$

where R is the relative total illumination, S is the size of the arc in minutes, and C is the contrast.

A plot of this ratio with respect to total illumination required at 6 minutes of arc size is shown in Figure 4. It can be seen that the total light absorbed by small targets (below 3 minutes of arc) remains nearly constant. There appears to be a minimum at 2 minutes of arc. This result corroborates Ricco's law and indicates that the total illumination of an area becomes controlling at about 2 minutes of arc. This light level represents the minimum total flux which which will produce a recognizable area.

Figure 4 indicates that a considerable savings in total light flux required to produce a legible matrix display may be achieved by using point sources rather than area sources as matrix elements. For example, at 30 feet, a minute of arc is 0.10 inch; a quarter-inch matrix subtends (diagonally) about 3.5 minutes of arc. Such an element required approximately twice the total light as does a point source. (Philco-Ford's experimental results show that, at a reading distance of 2 feet, point source images may produce a total light flux savings of a factor of from 10 to 12.) However, use of this gain may in the long run degrade symbol recognition because picture elements do not overlap. We would welcome human factors studies regarding best use of this ability to control picture element size on the large screen independent of optical fiber pitch. If we extrapolate the digital TV experience, we would predict that output picture element size should be approximately 1.4 times output optical fiber pitch and that area brightness rather than individual picture element brightness should be used when designing well human-factored systems. However, at longer viewing distances, the spots will be so small that the rear projection screen can be eliminated and the angular dispersion of the fibers themselves can be used. In this case, it is possible to achieve an effect similar to screen gain of approximately 4 without many of the bend angle problems at corners and edges. The total light which is emitted from a fiber is highly directional. When viewed end on, the brightness of the fiber is comparable to that of the light source. This directivity corresponds to that of a high gain screen.

Figure 5 shows the directivity of the light coming from a fiber with a numerical aperture of 0.66. ■

It can be readily seen that the problem is to scatter the light into an angle of 45° both sides of the axis. This scattering can be achieved by bonding a layer of clear plastic to the front surface of the screen to provide the desired termination to the fiber.

The thickness of the required layer is about that of the diameter of the fiber. The optimum thickness and refractive index will be determined. The effective gain of the fiber images over area sources (which are essentially lambert sources) from this contribution is conservatively estimated to be a factor of 2.

Thus, the total light requirements for optical fiber point sources are estimated to be about one-eighth of the total flux requirements for area sources.

Element Luminance

The major factors, other than the input source, that determine the

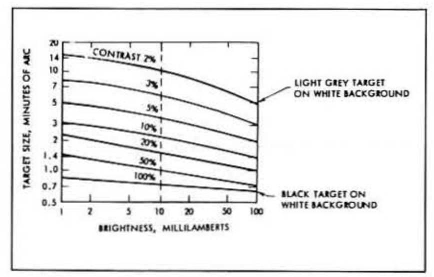


Figure 3. Combination of brightness and target size required for discrimination of various contrasts.

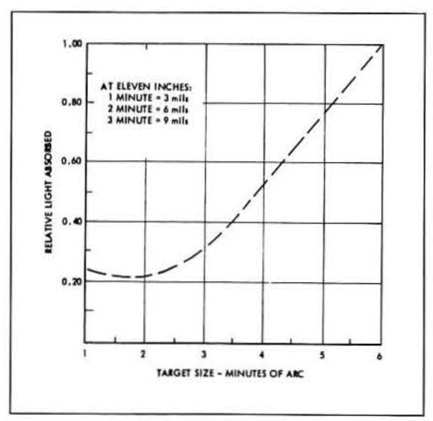


Figure 4. Light absorbed for discrimination of target.

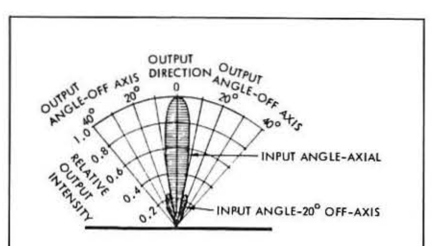


Figure 5. Relative output intensity vs output direction.

[1] J. W. T. Walsh, "Photometry," Dover Publications, Inc., New York, 1958, page 78.

[2] E. J. McCormick, "Human Factors Engineering," 2nd Edition, McGraw-Hill Book Company, Inc., New York, 1964.

display element luminance are the losses associated with the collection and transmission of light by optical fibers. These losses are as follows:

1. *Aperture Loss*—The collection angle ϕ for a light ray incident on a core of refractive index N_C with a jacket of refractive index N_J and coming from a media of refractive index N_0 is given by:

$$N_o \sin \phi_c = \sqrt{(N_c)^2 - (N_J)^2}$$

This term is commonly called the numerical aperture of the fiber. Since $N_0 = 1$ for air, a fiber in air has a collection angle ϕ_C given by

$$\sin \phi_c = \sqrt{(N_2)^2 - (N_J)^2}$$

Figure 6, shows the longitudinal section of a typical optical fiber.

Light rays coming from outside the acceptance cone are lost. With good systems design, all rays from the driving projector will fall within the acceptance cone. Scattering losses are negligible since the input end of the fiber is optically polished.

2. *Jacket Area Loss*—In addition to the aperture loss, the light falling on the front face of the jacket is considered lost. The ratio of jacket loss to the total light falling on the end of the fiber is given by:

$$\text{Percent jacket loss} = \frac{\pi}{4}\left[D_o^2 - D_c^2\right] \div \frac{\pi}{4} D_o^2 = 1 - \left(\frac{D_c}{D_o}\right)^2$$

where

D_0 = outer diameter of optical fiber

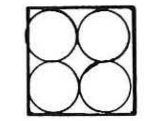
D_C = diameter of optical fiber core

A typical diameter ratio is 0.975. The corresponding jacket loss is 5%.

Figure 6. Longitudinal section of an optical fiber.

Figure 7. Propagation loss of optical fibers.

3. *Packing Loss*—When round optical fibers are packed into bundles, the end areas of the fibers cannot occupy all of the end area of the bundle. If the fibers are packed in square fashion, as shown below, then the fibers occupy 78.6% of the total area. A typical packing loss is 21.4%.



Area of Circular Quadrant = $(\pi/4)D^2$

Area of Square = D^2

Ratio = $\pi/4 = 0.786$

Experiments with a "honeycomb-type" packing and the resultant 30° and 60° rows of fibers caused rejection of this approach because of interference patterns set up with predominantly horizontal and vertical symbols.

4. *Tolerance Loss*—In practice, optical fibers when drawn have a small variation in fiber diameter resulting in an additional packing loss when such fibers are used to construct a precision scanning bundle. If we assume that the fiber centers are located at the corners of a square grid, then the squares must be large enough to accommodate the largest fibers. Any smaller fibers will leave additional space between fibers. If we let it represent the percentage variation in diameter between the largest diameter D_L and the smallest diameter D_S, then the percentage loss in end area is

$$\text{Tolerance Loss} = \frac{\pi}{4}\left[D_L^2 - D_S^2\right]^2 \div \frac{\pi}{4}\left[D_L\right]^2 \cong 2t$$

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If the distribution of tolerance errors is linear, then the average tolerance loss is simply t. Since this error is in general very small compared to other errors, a linear model of tolerances will be used. A typical diameter tolerance is ±1% for glass fibers and ±6% for plastic fibers. The corresponding tolerance loss is 2% or 12%.

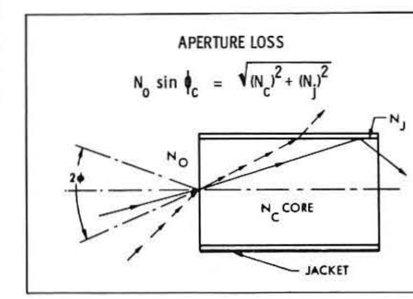
5. *Propagation Losses*—The previous paragraphs discussed input losses. These losses are followed by propagation losses through the fiber bundle. Only part of the light which is collected by the fiber is transmitted through the fiber to the other end. The principal sources of the light propagation loss are scattering by imperfections in the jacket, absorption by contaminants in the core and jacket, and absorption by the molecular structure of the core material. These mechanisms are usually combined and their total effect measured as an effective absorption coefficient. The intensity at the output I_0 is related to the intensity I_N at the input by

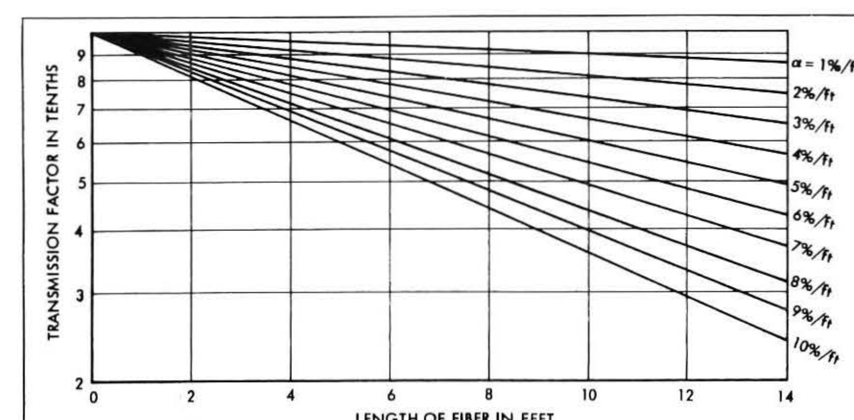
$$I_o = I_{IN} e^{-aL}$$

where

a = effective absorption coefficient (ft^{-1})

L = length of the optical path





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The absorption coefficient is, of course, a function of the wavelength of the light being transmitted. However, for visible wavelengths in the blue-green region, this dependence is insignificant for both lucite and glass optical fibers.

The percentage effective transmission for various lengths and absorption coefficients is shown in Figure 7. The absorption coefficient for typical glass optical fibers with a numerical aperture of 0.55 is about 4% per foot. For plastic fibers, a typical absorption coefficient is about 10% per foot.

6. *Reflection Losses*—Polishing the ends of each fiber to reduce scattering loss does not eliminate reflection loss. This loss can typically be 5% at each end.

The losses of light in the array are tabulated as follows for glass fibers:

Loss Type	Per Cent Lost	Per Cent Transmitted
Input Reflection	5	95
Aperture Mismatch	0	100
Area (Jacket+Packing +Tolerance)	(5+21+2)=28	72
Transmission (per foot)	4	$(.96)^{10}=66$ for 10 feet
Output Reflection	5	95

The total light transmitted as a fraction of input light is:

$t=(0.95)\ (1.00)\ (0.72)\ (0.66)\ (0.95)=0.43$ or 43%

If plastic fibers are used instead of glass fibers, the effect of losing 10% per foot rather than only 4% per foot is to reduce light transmission as follows:

$t=(0.95)\ (1.00)\ (0.72)\ (0.35)\ (0.95)=0.23\%$ or 23%

Conclusions

1. It is now practical to make dynamic, full shaded color, flat panel on the wall displays which can show high resolution computer generated images, film images, or television.

2. The fiber optic digital lens using non-tapered fibers permits exact independent specifications of resolution, magnification, and degree of picture element overlap.

3. Digital lenses can be expected to be resistant to military environments, essentially maintenance free, and to have a lifetime comparable to that of analog lenses.

4. The weight of the fibers themselves is relatively small, with most of the volume consisting of foamed separation and adhesive material. This will allow movement of finished flat panel displays into ships, vans, helihuts and constrained fixed sites using the same manual means as for associated electronics cabinets.

5. The passive nature of the flat panels resulting from digital lens technology together with the high efficiency of newer CRT projectors, light valves, and film projectors should allow 100% duty cycle continuous tone color images to be produced with electrical power inputs significantly less than that required to for other current discrete element matrix panel display approaches.

About the Authors

Mr. Hendrickson is the manager of the Data Control and Display Engineering Activity of the Philco-Ford Western Development Laboratories Division. He was responsible for the design and implementation of the display/control system for the NASA Mission Control Center-Houston which has controlled the Gemini, Apollo, and Skylab missions. Recently, Mr. Hendrickson has directed the design of new full graphics display systems for other NASA centers, U.S. Marine Corps tactical control centers, and most large U.S. Air Force Control Centers. He is a guest lecturer in the UCLA course "Display Systems Engineering" and was General Chairman of the 1972 SID International Symposium. Mr. Hendrickson is a national director of SID.

Mr. Loucks is a mechanical engineer and has been with Philco-Ford's Western Development Laboratories for seven years. During that time he has made optical and mechanical contributions to many display systems produced by Philco-Ford. His areas of special interest are optical imaging systems and their mechanical requirements. Mr. Loucs is a member of the Bay Area Chapter of SID.

SPSE Conference

The Society of Photographic Scientists and Engineers will hold its 27th Annual Conference in Boston, Mass., at the Boston Sheraton Hotel, April 28 - May 3.

The conference will cover a wide range of subjects of particular relevance to today's photographic scientists and engineers. Technical details of the Polaroid SX-70 are expected; recent advances in the special problems of in-water photography will be presented; the current understanding of photographic pollutants and the present methods of elimination will be discussed. For information contact Raymond A. Eynard, P.O. Box 2001, Teterboro, N.J. 07608.

SID Symposium To Be Held in May

Members of the Society for Information Display and others involved in or interested in the discipline of information display, are reminded that SID holds its 1974 International Symposium in San Diego, Cal., May 21-23, 1974, at the Town & Country Hotel. For immediate information on registration, etc. contact SID National Headquarters, Violet Puff, Office Manager, 654 N. Sepulveda Bl., Los Angeles, California 90049.

Key Decisions in DESIGNING THE PICTURE SYSTEM

How major decisions were made during the design of a new high performance computer system, and the reasoning that lay behind the decisions. Emphasis lay on inclusion of all worthwhile capabilities while holding cost at modest levels.

By JAMES F. CALLAN
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▪ In the spring of 1973, Evans & Sutherland Computer Corporation decided to cease production of its current line of graphics systems (1, 2), and to offer instead a completely new system — one that combined all the features important to a good graphics system with a low price (3). By the end of that year, the new system was designed; its prototype was built and tested; its software support specified and developed; a plan for its maintenance developed and implemented; and the first production version was built, tested, and delivered to a paying customer.

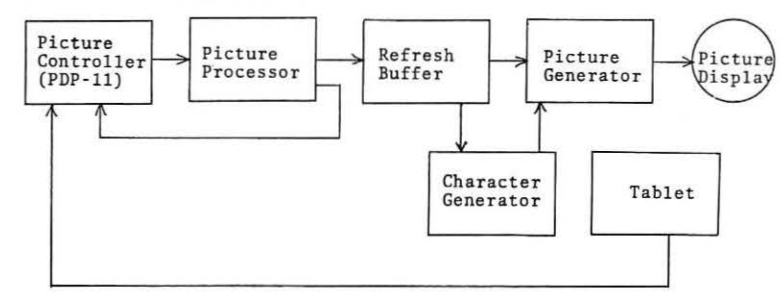
And to make this achievement even more remarkable, this new system—dubbed "The Picture System"—received widespread acclaim from users and critics throughout the world.

Evans & Sutherland was in a unique position to perform an effort of this magnitude in such a short time. We had been supplying high-performance graphics systems since 1969, and through user feedback had learned which of those earlier systems' features were worthwhile, which were not, and what additional features would be useful. Furthermore, through associations with leading graphics institutions, we had amassed a large collection of state-of-the-art ideas about graphics. Thus, once the decision was made design proceeded deliberately through planned stages to implementation. Following is a discussion of the major decisions reached during this design and the reasoning behind them.

To achieve the dual goal of full capabilities and low price, it was imperative for us to start by enumerating all the desirable features, and then to discover the optimal system organization to implement them at lowest cost. The key features decided upon were the following:

1. capable of stand-alone operation
2. ease of programming
3. availability of compatible computer I/O and storage devices
4. economy of core consumption
5. convenience of object description
6. 2-D or 3-D pictures
7. dynamic motion
8. perspective or orthographic 3-D
9. rotation about any axis in 3-space
10. translation in any direction
11. scaling in any dimension
12. any combination of rotations, translations, and scalings
13. zooming
14. windowing
15. accurate results of transformation
16. availability of hard copy
17. large line and character capacities
18. good line quality
19. convenient interaction
20. good physical appearance

To achieve all these features at minimal cost, the following configuration was used:



The Picture Controller contains data which describes objects to be viewed on the Picture Display. It also computes parameters used by the other components in the system, as well as performing I/O and other functions required to support "The Picture System."

In addition, the Picture Controller passes parameters to the Picture Processor to indicate how subsequent coordinate data is to be interpreted and what transformations are to be made to the data. The data interpretation parameters indicate connectivity (i.e., how points are to be connected), and point of origin (i.e., whether the coordinate data is absolute or relative to preceding coordinates).

The Picture Processor receives data sent by the Picture Controller in the form of two- or three-dimensional line end-point coordinates. It performs several digital operations on this data, starting with rotations, translations, reflections, and changes in scale. These transformations are directed by parameters passed by the Picture Controller.

The next operation performed by the Picture Processor is to check the transformed coordinate data for visibility by comparison with a two- or three-dimensional viewing window. Lines or portions of lines outside the window are removed by a clipping process so that only visible segments are processed further. At this point three-dimensional data is converted to two dimension by computing perspective or, if desired, orthographic views.

The final stage in the Picture Processor's digital processing is a linear mapping of points from the objects' coordinate system into that of the Picture Display.

Processed data, still in digital form, is now deposited in the Refresh Buffer, either over-writing the previous picture (single buffering) or in a separate area from the previous picture (double buffering). Processed data may also be returned to the Picture Controller's memory to drive a hard copy plotter, for example, or as data for further computation.

At the same time the Picture

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Controller and Picture Processor are creating one frame of the picture and depositing it in the Refresh Buffer, the Picture Generator is reading coordinate and intensity information from the Refresh Buffer, converting it to analog signals, and drawing the picture on the Picture Display.

Packaged Character Codes

Character strings from the Picture Controller pass through the Picture Processor unmodified, and are deposited in the Refresh Buffer as packed character codes. When character words are read out of the Refresh Buffer, the Character Generator unpacks them into codes which access a read-only memory containing character stroking data. The strokes are read out of the read-only memory one by one, multiplied by a pre-specified sizing parameter, and drawn by the Picture Generator on the Picture Display.

The Tablet serves as the standard, general-purpose graphic input device in the system. Associated with the Tablet is a pen whose coordinates are read by the Picture Controller. Normally a "cursor" is drawn on the Picture Display to indicate the position of the pen on the Tablet. The Tablet can be used for positioning or pointing to picture elements, and can perform the interactive functions usually reserved for such graphic input devices as light pens, joysticks, and function switches.

Now let us return to the list of key features and state why each is desirable (where not obvious) and how each is implemented in the system configuration.

1. *Capable of Stand-Alone Operation*

   Anyone who does not immediately recognize the desirability of this feature has never had to depend on a "host" computer for operation. Even if such a computer were a perfect "host" for a graphics system and even if it were standard from installation to installation, it would still be an essential ingredient of the system that is out of our control. This can create great inconvenience in software development, test, and installation; and it can mean disaster for maintenance. And the situation becomes many times worse if several different "hosts" are allowed: it becomes impossible to supply good software support; diagnostics must be rewritten for each new computer; new hardware interfaces must be developed each time, etc., etc., etc. Nor was the answer to design and build our own general purpose computer for the system. There is no way that a relatively small, highly specialized company like Evans & Sutherland can match the excellent small computers available today on a price/performance basis, or develop the peripherals and system software required.

   So we determined to select a computer and incorporate it into the system. We chose the D.E.C. PDP-11 because its architecture made it ideal as a system controller and because many in our potential user community were already familiar with it. Standardization on one computer has the added advantage that large scale interchange of programs and information between users can take place.

   One final note: the stand-alone feature does not preclude interfacing the system with large background computers. Many applications require high-horsepower computations with which the system's controller should not be saddled.

2. *Ease of Programming*

   To achieve this obviously desirable goal, we created a graphics software support package that runs under FORTRAN — the language familiar to the largest number of users — and that allows programmers to deal in high-level parameters instead of bothersome system details (4). A programmer using this package can think in terms of angles of rotation, scale factors, etc., and does not need to learn all about the matrix arithmetic involved.

   Furthermore, having only one programmable processor in the system (the PDP-11) greatly simplifies writing and debugging programs.

3. *Availability of Standard I/O and Storage Devices*

   This was another reason for selecting a widely-used general purpose computer as the system's controller. We did not modify the PDP-11 at all, so that the full spectrum of peripherals available for the PDP-11 family can be utilized.

4. *Economy of Core Consumption*

   In order to conserve core, and for other good reasons, the following measures were taken. First, we arranged for a single data base in PDP-11 memory to suffice; second, facilities were implemented to permit similar structures to be stored only once and replicated several times, in different sizes, shapes and orientations if desired; and third, all common picture preparation steps (transformations, etc.) were implemented in hardware rather than software. As a result these and other features, surprisingly large graphics programs can be held in the minimum configuration (4K words of memory), although, of course, core size can be enlarged to the PDP-11 maximum.

5. *Convenience of Object Description*

   It is very important in many applications for objects to be defined in the PDP-11 in a manner that is natural to the application, not constrained by idiosyncrasies of the graphics system. In planning the system we made every effort to make object description an easy, natural and fast process; as a result, even existing data bases — created without thought of computer graphics portrayal — can usually be utilized without change. To facilitate object description, we implemented several features. First, we arranged for our hardware to convert from a program-specified coordinate system to that of the scope so that object definition can take place in its own most convenient coordinate system. Second, we included transformation hardware that permits an object to be defined in a size, position and orientation that is quite irrespective of the eventual size, position, and orientation of the picture of that object. Third, we decided to store data one coordinate per word, with no "opcode" bits in the word; two or three contiguous words comprise two- or three-dimensional point; and a set of contiguous points comprise a set of connected lines, disconnected lines, or dots, as specified elsewhere. (In short, coordinate data is stored separately from the instructions for drawing that data.) And fourth, the coordinates of a point may be specified as absolute or as relative to the preceding point, and this choice has no bearing on flexibility of operations that may be performed on such points or on the accuracy of the eventual coordinates of such points in the picture, problems sometimes found in graphics systems.

6. *Choice of Two or Three Dimensions*

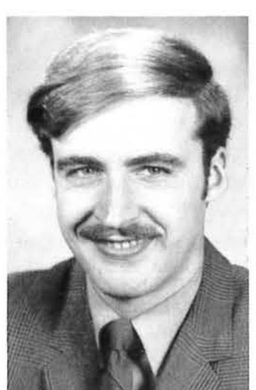
   Real-world objects are three-dimensional, and therefore, graphic portrayals of them should be three-dimensional as well. On the other hand, there are many well-established two-dimensional applications where a third dimension is nothing but an expensive burden. Hence, the programmer should be able to choose to enter three dimensions in some cases and to save core and bother by entering only two in others.

   One useful ramification of the systems way of implementing this choice is that planar objects in three-space can be defined two-dimensionally, saving core, and then fit into the three-dimensional scene. It is interesting to note that two-dimensional and three-dimensional data are treated exactly the same by the processing hardware. A third coordinate program-specificable) is appended to two-dimensional data at the entrance to the Picture Processor, and all operations from that point are carried out in three dimensions. This unified treatment simplifies both the hardware and the process of learning the system.

7. *Dynamic Motion*

   The capacity for real-time dynamic motion has long been among the principal appeals of Evans & Sutherland graphic systems; therefore, we made sure that the system had the same capabilities as our earlier systems.

   To provide the illusion of motion in a computer-generated display, it is necessary to compute new



about the author

James F. Callan has both a bachelors and a masters degree in mathematics from the State University of New York at Buffalo. After graduation, he worked for two years for Xerox Corp. as a programmer specializing in scientific applications. Mr. Callan joined Evans & Sutherland in 1969, and has served a variety of roles in software, marketing, and program management. Most recently he was involved in setting specifications for the firm's new "Picture System."

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frames very frequently, preferably at least twenty times per second. The computations involved in picture preparation can be extensive, and so if a great many points need to be processed, the challenge becomes one of minimizing the time required to process a point.

Our answer is to implement in hardware all the repetitious, lengthy calculations required to perform operations that arise over and over in graphics: rotation, translation, scaling, windowing, and perspective computation. Not only is hardware intrinsically much faster than equivalent software, but by relieving the PDP-11 of these burdens we allow these operations to be overlapped with application-specific operations in software.

8. *Perspective or Orthographic 3-D*

In some applications, such as flight simulation, it is imperative that perspective be imparted to graphic portrayals of three-dimensional scenes. In others, like display of engineering drawings, it is sometimes unnecessary or even undesirable to show perspective; orthographic—or its special case, isometric—views are required. The ability to show true perspective views of complex, dynamically moving objects has long been exclusive feature of Evans & Sutherland graphic systems, but the method of obtaining perspective in "The Picture System" is more general than in our earlier systems, permitting the degree of perspective to vary from an extreme wide-angle view to an orthographic view.

9. *Rotation about Any Axis in 3-Space*

Rotation about any of the three principal axes is easily expressed in a 3 x 3 submatrix of the Picture Processor's 4 x 4 matrix. Data base vectors are multiplied by this matrix to produce rotated vectors.

Furthermore, rotation about an arbitrary axis through the origin can be expressed as a sequence of rotations about the principal axes. Finally, rotation about any arbitrary axis can be expressed as a pre-translation, a rotation about an axis through the origin, and a post-translation. Mechanisms for performing all these steps are included in the system, as discussed in the following points.

10. *Translation in Any Direction*

When a fourth row is appended to the 3 x 3 rotation matrix, translational terms (post-translation terms, to be precise) can be expressed as well. Pre-translation calls for a matrix of its own.

11. *Scaling in Any Dimension*

The matrix representation of transformation lends itself well to scaling the size of objects up or down, in any or all dimensions, and at any point in a sequence of transformations. A scale matrix contains zeroes off the diagonals and scale factors for each dimension in their respective positions along the diagonal.

12. *Any Combination of Rotations, Translations, and Scalings*

As the preceding paragraphs have noted, it is usually necessary to impart more than one transformation to data base coordinates to prepare them for display. In "The Picture System," 4 x 4 matrices are used to represent all transformation, including simple rotations, pre- and post-translations, scalings, degree of perspective, establishment of windowing boundaries, and others. A sequence of transformations could be imparted, at considerable expense, by multiplying each vector by the first matrix, multiplying the result by the second, multiplying that result by the third, and so forth. However, since matrix multiplication is associative, it is equivalent to multiply all the matrices together first, and then to multiply each point to be so transformed by the composite matrix. This transformation concatenation philosophy, implemented in hardware, introduces substantial economies into the system.

A related feature which enhances the value of matrix concatenation is the ability to push matrices onto a stack and pop them back off. This capability allows intermediate composite matrices to be saved prior to concatenation of further matrices unique to one set of vectors, and then to be retrieved later for use with another set of vectors. A four-deep matrix stack is maintained in the Picture Processor, with overflow into PDP-11 memory.

13. *Zooming*

Often a scene is so large that when it is depicted in its entirety on a graphics system, details are obscured. When the details are to be shown, it becomes necessary to show only a portion of the scene but to show that portion in greatly increased scale. Abrupt changes in scale are visually unappealing and sometimes leave the viewer "lost"—not knowing where in the scene he is looking. A far better alternative is to smoothly and rapidly vary the scale. This "zooming" feature is implemented in the system by introducing small changes to the windowing boundaries each time a new frame is begun. This part is fairly easy; the difficult part is accounting for lines that pass out of the viewing region, and doing this fast enough to make zooming smooth. This calls for a highly sophisticated windowing mechanism.

14. *Windowing*

The ability to window—i.e., to select a region of the drawing space whose contents are to be viewed—is an important feature in many graphics applications and should be supported by any high-performance system.

Considerable thought has been given to windowing mechanisms over the last few years. The main problem, of course, is the elimination of picture viewing area. Lines partially outside are particularly troublesome. The graphics community (5) has known for some time that the best way to accomplish windowing is hardware clipping, which entails computing the intersection of partially visible lines and window boundaries. But the algorithm for performing clipping in "The Picture System" (7) underwent great improvement in generality from the method employed in our earlier systems (6).

15. *Accurate Results of Transformations*

Naturally it is important that the lines drawn on the scope appear where they are supposed to, which implies that the transformation process should be carried out without introducing large errors. But it is also important, and much more ticklish, to assure accuracy in results which are to be fed back into PDP-11 memory for purposes of obtaining hard copy or as data for further computation. Only the most significant twelve bits of computed coordinates are used for drawing on the scope, but full sixteen bit words are returned to the PDP-11.

How is accuracy maximized in the system? Most importantly, all computation is done in digital hardware, avoiding the inherent inaccuracy and drift problems associated with analog hardware.

Several measures were also taken to avoid accumulating roundoff errors. Relative vectors are converted to absolute upon entering the Picture Processor, before computation has a chance to introduce any inaccuracies. Also, because the homogenious coordinate nature of our 4 x 4 matrices permits multiplication of all sixteen elements by any constant without affecting the transformation represented, we "normalize" composite matrices after each concatenation. When two matrices are multiplied together, the product is held in a twenty-bit wide intermediate matrix. (Twenty bits was found to be the optimal word length for maintaining precision without incurring undue cost.) Then, before the contents of the intermediate matrix are transferred back into the 16-bit wide drawing matrix, the intermediate matrix is normalized, i.e., all its elements are shifted left until some element would lose a significant bit by further shifting.

16. *Availability of Hard Copy*

No hard copy device is standard in the system, since different applications call for different speeds and quality levels in hard copy, and many require no hard copy at all. But any standard hard copy device can be interfaced to the PDP-11. Data for obtaining hard copy is made available to the PDP-11 by activating the "feedback to memory" route in the system, which transmits transformed and clipped coordinates (still digital) into PDP-11 memory, where it can be accessed by routines to generate the hard copy.

17. *Large Line and Character Capacities*

A basic problem with refresh displays is that the picture must be redrawn very frequently—at least thirty and preferably forty times per second—to avoid flicker (the unsightly effect seen when the picture visibly fades before being redrawn).

All line generation techniques require a certain amount of time to stroke out a line, and also involve a certain settling time between lines. Quite a science has been developed to get maximum mileage of "The Picture System" line generator (called the Picture Generator) while preserving good line quality.

It is bad enough that line generation speeds impose a limit on line and character capacities, but to make matters worse in many graphics systems (our earlier systems, for example), the line generator spends a lot of time sitting idle while coordinate data is being fetched or massaged. It is unnecessary and wasteful to update a picture every time it is refreshed; even in applications calling for the most stringent requirements for dynamic motion, and update every two refresh cycles is adequate, and in other applications updating can be performed very infrequently. Sustaining a flicker-free picture, on the other hand, is universally necessary.

In "The Picture System" we contrived a way to allow both updating and refreshing to take place at their respective optimal rates and get maximum mileage out of all system components. We put a memory, the Refresh Buffer, between the picture preparation stage and the picture generation stage. The Picture Generator can fetch new coordinates from this memory as soon as it is ready to accept them; meanwhile, a new frame is being computed and deposited elsewhere in the Refresh Buffer.

18. *Good Line Quality*

All the known techniques for maintaining good linearity, end-point match, etc. were incorporated into our Picture Generator. Several features are worthy of special note.

First, all lines, regardless of length, can be drawn in the same intensity. This feature is achieved by drawing lines at a constant rate.

Second, completely separate intensity and contrast controls are provided.

Third, swim in the picture is avoided by synchronizing the refresh rate with the power line. This is a widely used technique, but unfortunately most implementations are based on a 60 cycle clock, which gives the user the unpleasant choice of refreshing 60 times per second, which is wasteful of line capacity, or at 30 times per second, which causes marginal flicker. The ideal refresh rate is 40 times per second, and this is pos-

turn to page 29

By JAMES F. CALLAN

NEW PRODUCTS

SID SID SID SID

Angle Indicators

A series of budget, "high accuracy" multichannel binary angle data indicators have been introduced by Computer Conversions Corporation. The new devices convert 16 bits of binary data to BCD and produce a 5 digit display.

The converters have a resolution of 0.01° and an accuracy of ±.02°. The BCD data and readout can be scaled to any desired format from 0 to 99999 (i.e. azimuth, elevation, weight, pressure, temperature, etc.) They are available in a rack mounting case (19″ W x 1.75″ H x 12″ Deep), or on a 4.5″ x 6.5″ PC card which requires external DC power.

Units can also be supplied to accept serial, other types of digital angle data, or 3-wire synchro data.

Circle #101 on Readers Service Card

New Memory Device

Development of a memory-storage device containing microscopic "bubbles" that can store vast amounts of information in a tiny wafer of magnetic material announced by GTE Laboratories Inc., Waltham Mass. Device, known as a magnetic domain memory, has been developed to the point where it will be turned over to a manufacturing organization for testing and evaluation.

Circle #102 on Readers Service Card

Digital Image Display

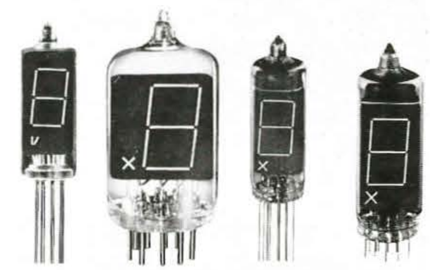
Comtal Corp. has announced a new series of digital image displays which operate as stand alone systems or serve as a computer peripheral device. The new Comtal 5000 Series of digital image display systems is said to offer a wide variety of options and "true" image processing capabilities not previously available. "The storage, restoration, enhancement and processing of true images is one of the most exciting areas under development today. New application possibilities ranging from earth resource studies to law enforcement, and almost everything imaginable in between, are being uncovered utilizing these new digital image processing techniques," says a spokesman.

All Comtal digital image display systems work on a 512 x 512 picture matrix, coupled with a special picture tube, to produce a bright flicker-free picture with highest real-time spatial resolution. Large screen, full color presentation has a maximum resolution of 256 brightness levels for each of the three primary colors.

Comtal Systems are plug compatible with all major mini computers.

Circle #103 on Readers Service Card

IEE-Apollo Display



Industrial Electronic Engineers, introduces the IEE-Apollo incandescent digital display. Available in 5V (1500 Ft L) and 12V (85,000 Ft L), Five basic series provide alpha-numeric, decimal point and plus/minus one (1) capabalities in sub-miniature sizes. Each single-plane readout tube consists of seven incandenscent segments on a black ceramic base sealed in a a glass envelope. The sharp contrast inherent in this construction provides superb readability with an extra wide viewing angle. Brightness is fully adjustable from zero to a level easily viewed in direct sunlight by simply varying the voltage. Filters produce displays in any color.

Rugged construction and long life expectancy (more than 10,000 hours at 5V) combine with IEE-Apollo's viewing characteristics to make it the ideal display for a wide variety of applications. IEE-Apollo operates AC or DC.

Circle #104 on Readers Service Card

New Literature

Newly revised and illustrated literature providing data and suggested applications of SPECTRA® Model 1980 Pritchard® Photometer is offered by Photo Research, manufacturer of super-sensitive instrument with automatic computation of readings for all combination of built-in filter, aperture and range settings. Full-scale sensitivity ranges from 0.00001 to 10,000,000 (10^{-5} to 10^{7}) footlamberts at distances from 0.001″ to infinity, with built-in apertures allowing selection of measuring fields from 2 minutes to 3.2 degrees, and complete freedom from polarization error are among features of instrument.

Circle #105 on Readers Service Card

Lenox "Mini-Probes"

A new series of inspection devices, developed by Lenox Instrument Company, Inc., makes it possible for an inspector to view a TV monitor in performing close-up inspections inside small tubes or other confined areas. The firm has combined small diameter borescopes with highly sensitive TV cameras.

A spokesman cited advancements in the sensitivity of TV cameras, optical coatings and development of image intensifiers as primary reasons new inspection technique has become feasible.

The new Lenox mini-probe can penetrate deep into normally inaccessible areas and rapidly obtain close-up images regardless of the angles required. Borescopes with diameters as small as 0.118″ can provide a right angle view, a straight ahead view or a panoramic view.

Circle #106 on Readers Service Card

CRT Option

A new optional cathode-ray tube, Option 005, for the Hewlett-Packard Model 183B Oscilloscope mainframe, makes possible photographic transient recordings at writing speeds as high as 28 cm/nanosecond.

Film recording speeds of 24 cm/ns are said to be achieved with P11 phosphor (blue trace, medium persistence), post-fogging ASA 10,000 film with a built-in pulsed flood gun, exposing 2 seconds with an HP Model 195A high-speed camera (F/1.3 lens, object-to-image ratio 1:05). 17% more speed, pressing the state of the art to 28 cm/ns, can be achieved with cameras having the 17%-faster F/1.2 lens, available from some other manufacturers. These fast writing speeds are useful mainly for studies of fast, high-level transients in high-energy physics; here, every bit of improvement in speed has been eagerly sought, even at the cost of high skill requirements.

To assure exact resettability of 'scope controls and thus to promote repeatability of results, an additional option (020) provides multi-turn controls for intensity, flood gun, focus, and astigmatism adjustments. Two of the most critical of these, flood gun and intensity, are 10-turn locking dials. The oscilloscope mainframe with both options is designated Hewlett-Packard Model 183B Option 005/020.

Circle #108 on Readers Service Card

new products

Rotator/Translator

Newport Research Corporation has added a rotational stage and a vertical translator to its budget University Series optical mounts which now include rod mounted mirror tilters, beamsplitter mounts, tilt tables, element holders and various accessories. The compact rotational stage can be side mounted to a post or attached to any mounting surface and is available in two configurations. One has a solid mounting surface with tapped holes and the other has a clear aperture for use as an element rotator. Rotation is 360° with either coarse or fine adjustment and it can easily be locked in place. The vertical translator is designed for fine positioning of mounts along the vertical axis without changing the settings in the azimuth direction.

Circle #109 on Readers Service Card

Alphanumeric CRT Display System

Lexicon, Inc. announces a new alphanumeric CRT display system for Nova series computers. The new display system, called Lexiscope 2000A, features high speed operation and highly flexible "intelligent terminal" capabilities through CPU program control. Options include 96-character *upper and lower case* display capability, blink and underline attribute features, and a 15-inch monitor.

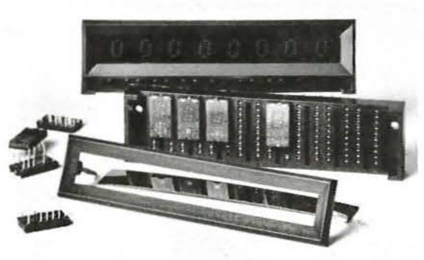
Software instruction set allows highly sophisticated editing including split screen and multiple cursor operation, as well as scrolling, tabbing, field protection, and other advanced editing functions.

Basic system includes a 2,000-character random access display memory in an 80x25 character format, fully addressable cursor, and a 200,000-character/second read-write speed. The entire control and interface electronics are contained on a single Nova plug-in board.

Circle #107 on Readers Service Card

new products

LED Mounting Hardware



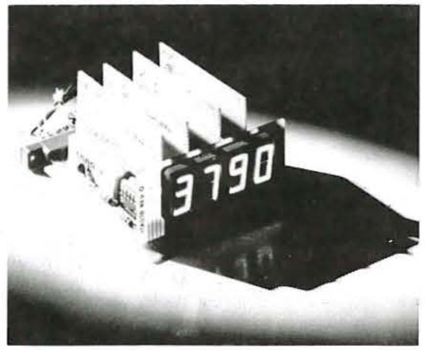
Industrial Electronics Engineers, Van Nuys, California, manufacturer of displays and readout devices, introduces a unique universal LED mounting hardware package. The attractive universal panel mount accepts any Dual-In-line LED display packaged with .3″ row spacing, regardless of manufacturer. The mounting hardware package consists of a one piece nylon bezel, a circular polarizing window and a one piece behind-the-panel socket assembly *which eliminates all individual DIP sockets.* Dual-in-line displays with 14 or 16 pins can be accommodated in presentations from 2 to 8 units.

The one piece IEE socket assembly has wire wrap-terminations that permit economical wiring of any display arrangements. Mechanically, the integral sockets have a 20 pin capacity so that either 14 or 16 pin display characters can be centered in the viewing window regardless of the digits mechanical relationship to the pins.

The attractive display package requires only a single panel cutout; no other mounting holes are needed. After installing the bezel into the cutout, the IEE display package automatically aligns itself.

Circle #110 on Readers Service Card

Mini-Diget Counter



Instrument Displays, Inc., announces the availability of the Mini-Diget, Model MDBC Bi-Directional Counter, redesigned for OEM applications. This unit is the latest addition to the Mini-Diget Series of integrated circuit counters and displays. The circuits can have the Nixie, Sperry or 7-Segment display all with ½" characters.

The counter features all plug-in card construction with T^2L logic and is available from 2 - 6 decades wide. Its unique construction permits the user to obtain a custom-built counter through the use of the plug-in card construction. With this approach, only those features required are actually ordered.

This unit features high noise immunity through a specially designed buffer card and its standard form will accept input on two lines — one add and one subtract. With the use of an optional quadrature card, it will accept information in quadrature form from most incremental encoders and will also provide multiplication logic of times 1, 2 or 4. A polarity detector module is also available to enable the user to determine on which side of an established zero reference point the count lies. Preload input in BCD form is standard as are buffered BCD outputs. The unit also contains memory, where a constant unchanging display is required without losing track of the number of pulses being received.

Circle #111 on Readers Service Card

Communications to the Editor, SID Journal, should be addressed to him, c/o SID Journal, 1605 Cahuenga Blvd., Los Angeles, Cal. 90028.

Metric Converter

Summit International Corporation introduces hand held computer that changes U.S. Standard Weights and Measures into metric measurements (or the other way) while it doubles as a five-function miniature calculator with memory. Underneath each number on the keyboard is a subscript abbreviation that selects a program. These programs become operable as soon as the change key is pressed. To use any of the 36 possible programs, enter a number, press the change key, and then press the key with the subscript conversion program you desire. The number in the readout immediately changes from U.S. terms to the correct metric measurement. The program is reversed by pressing the "reverse" key after the "change" key to convert metric measurements to U.S. terms.

Subscripts on the "=" and "=" keys modify the terms by changing the number to cubic or square measurements. The subscript program on the "3" key changes the Fahrenheit temperature scale to Centigrade degrees. The other program keys change weights and lengths from U.S. system to metric terms.

Circle #112 on Readers Service Card

High-Speed Printers

Dot matrix impact printers operating at speeds generally associated with computer output devices are announced by Wang Laboratories, with their System 2200 Advanced Programmable Calculators. With the Model 2221 and 2231 High-Speed Printers, the calculator user gets complete alphanumeric printing in two selectable type sizes on standard computer printout forms. The Model 2221 prints a maximum 132-character line at a rate of approximately 150 characters per second (200 lines per minute), The Model 2231, for those who prefer a maximum 80-character line, prints approximately 100 characters per second (150 lines per minute).

Both Models can print as many as four carbons.

Circle #113 on Readers Service Card

The Social Implications Of The USE of COMPUTERS ACROSS NATIONAL BOUNDARIES

■ Large time sharing systems and distributed networks of computers are already major factors in tying together decentralized national operations in both the public and the private sectors. In the public sector, the marriage of computers and communications is apparent in such systems as the ARPA Network, the Air Defense System, law enforcement systems, weather forecasting and the like. In the private sector, there are many such systems used for tying together sales offices and warehouses or ticket offices and data banks of reservations systems, as well as serving various other scheduling, financial control or logistics operations in large corporations.

In addition to these developments, we are beginning to see the use of these kinds of computers and communication networks *across* national boundaries. When we speak of a "multinational computer system" we mean any arrangement whereby computers in one country are directly linked to other computers, data bases, or computer users in one or more other countries. The use of computers in this manner at the present time is certainly not widespread. However, as one projects ahead ten to twenty years and contemplates on the one hand, the rising tide of multinationalism in both corporations and governmental organizations, and on the other hand, the rapid increase in capabilities and decrease in cost of computers/communications networks, one can conjecture that it is only a matter of time (and probably not very much time) when these kinds of applications will proliferate. But while the national use of computer networks is just a logical extension of current trends and capabilities, the multinational use opens a whole new realm of considerations in the technical, as well as the social, political and economic spheres. These issues have not yet even been identified, let alone explored or addressed in any meaningful way.

In order to begin an inquiry in this area, the Social Implications Committee of AFIPS sponsored a year-long study at the Center for Futures Research of the University of Southern California. This document, which is the final report of the study, is summarized briefly below.

Methodology

The study began with a brief literature search in which more than forty already existing applications of the multinational computer in both the public and the private sectors were identified. The methodology chosen for the study was the Delphi technique of successive questionnaires sent to a group of carefully selected participants. With the assistance of AFIPS officers, an outstanding panel was assembled consisting of fifty eight corporate officers, government officials and computer experts. A carefully prepared list of questions was developed from an examination of the existing literature and extensive discussions with members of the AFIPS Social Implications Committee and other computer experts. Three iterations of the Delphi questionnaire were necessary to clarify issues and to develop a preliminary understanding of the reasons for the positions that the panel took on the issues.

by
BURT NANUS
University of Southern California

LELAND M. WOOTON
Southern Methodist University

HAROLD BORKO
University of California at Los Angeles

A Technical Report to the AFIPS Committee on the Social Implications of the Computer May, 1973

Dr. Harold Sackman, Chairman
The Rand Corporation

One word of caution is necessary before summarizing the results. The study suffers from all the well-documented limitations of the Delphi approach. Moreover, it was not intended to be a comprehensive or systematic (much less scientific) examination of the issues than can arise from the use of multinational computers. This will require a far more detailed study than was possible here and one that observes all the established scientific rules for rigorous validation, reliability testing, item analysis, etc. Finally, since the panel had to consist of computer-knowledgeable people, it would be surprising if the data did not reveal an optimistic bias favoring the spread of computer usage. Thus, the reader is cautioned not to consider the findings as valid predictions, but rather simply as the first crude attempt to define a new field of inquiry by collecting the opinions of knowledgeable people about what might be important to examine further.

Major Conclusions

The clearest lesson from the study was that there will indeed be some major impacts of the multinational computer and many of them will occur in the next ten years, but that the nature of these impacts are still only vaguely perceived. In fact, the use of computers across national boundaries in both the public and and the private sectors will expand very greatly in the next two decades as the costs of computation decline, new applications are proven economic, and the scope and influence of multinational organizations increase. On the technical side, there appear to be few barriers to the development of these systems that are not now already close to solution. The problems that do exist are more in the nature of political or scio-cultural and while there is no guarantee that all these barriers can be swept away in the next two decades, there are promising starts already.

In the public sector, the use of computers across national boundaries will strengthen multinational public enterprises in such areas as public health, criminal justice, pollution, weather and disaster control, with major impacts before 1985. New institutions will be required at the multinational level to resolve disputes over the transmission of data across national boundaries, to develop regulations concerning the activities of multinational data banks, to provide individual safeguards, and to deal with problems of standardization of data transmission facilities and capabilities. In the private sector, progress may be even faster because such can be done within individual companies. As a result, the use of MNCS is already beginning to enhance the power of multinational corporations vis-a-vis the nation-state while at the same time contributing to a growing uniformity of business practices throughout the world.

These developments are likely to have their most profound and least understood impacts on the socio-cultural level. Within the highly industrialized societies, many people will find themselves in some form of man-machine relationship, often involving multinational communications, within the next decade. These interactions may be for educational, health, library, business, or other reasons but the net effect will be the enhancement of shared beliefs and values and a growing sense of interdependence on matters of the most fundamental nature. One effect of this, for example, might be to create new problems of national citizenship and organizational loyalty whereby individuals will be asked to make decisions in a multinational context that may not be consistent with the policies of their own governments.

In the developing nations, the widespread use of multinational computer systems may be considerably delayed, perhaps for fifteen or twenty years, but when it happens it will have enormous impacts. In the short run, the use of multinational computers may tend to enhance the economic interests of the information-rich, wealthier nations at the expense of the information-poor, but in the long run, the use of MNCS will increase the technological options available to the LDCs and speed up their ability to industrialize and to take advantage of the latest developments in education, management, medicine or public administration. The danger to the developing nations is that the MNCS may distort their investment priorities or lead to policies that favor multinational as opposed to national patterns of socioeconomic change. This provides a new challenge to the developed nations to create international organizations and agreements that strengthen the position of the developing countries in regard to all flows of science and technology, particularly the use of multinational computer systems.

In the long run, we may find that the use of computers across national boundaries will be one of the three or four most important factors tending to bring the world closer together through the creation of new multinational institutions and interdependencies. If this should happen, the impact on human society will have been truly revolutionary—perhaps equal to the impact of the invention of the printing press or of human language itself. The main contribution of the data developed in this study is to suggest that these impacts may begin to be felt sooner rather than later—before 1985 for many of them—and that it is not too early to begin to plan how to avoid the obvious traps and to assure the greatest benefit for the world's peoples. ■

Information About SID Membership

To any of you who may be unfamiliar with SID Policy in providing financial assistance to each Chapter, as additional funds being furnished to assist you in carrying out Chapter activities, we would like to provide you with the following information:

1. A $2.50-per-member rebate of the annual membership dues is provided quarterly.
2. For each Technical Meeting, a $15.00 rebate is provided *upon receipt of properly executed Technical Meeting Report Form.* These reports should be submitted within a reasonable length of time following each meeting and are reimbursed quarterly. Technical Meeting Report forms are furnished by National Office.
3. Each *active* Chapter receives a $50.00 rebate, annually. This rebate is paid at the end of the Third Quarter period.

It is important to have National Office included with every Chapter mailing. Thereby, regular meeting notices, news, and election of new officers are kept current and included with the Chapter News in SID JOURNAL. Photographs taken at your meetings are welcomed and serve as a feature plus for the journal. Note: *Color photos cannot be used.*

SID Membership applications, publication brochures, etc., are provided to each chapter, upon request, and are very helpful in promoting new members, either in a special mailing to non-members, or at your regular meetings.

SID Chapter mailing labels can be obtained, at cost, from the SID mailing house, with approval from from National Office. — Vi Puff, National Office Manager, 654 N. Sepulveda Blvd., Los Angeles, Cal. 90049.

Computer Merit Badge

Computers is a new merit badge offered by the Boy Scouts of America. A pamphlet is available, BSA, Div. 0163, New Brunswick, N.J. 08902.

By JAMES F. CALLAN

continued from page 23

sible in "The Picture System" because we implemented a 120 cycle clock and gave the programmer the ability to specify the number of clock ticks to elapse between refreshes.

19. *Convenient Interaction*

In planning the system, we decided to avoid the proliferation of graphic input devices, both to save our customers money and because all these input devices are seldom necessary. We also have a strong aversion to light pens, because of both human factors reasons and system architecture reasons, but we recognized that the pointing function they are used for must somehow be implemented.

We managed to get the best of all worlds by incorporating a tablet as our standard input device, and equipping the system with a hardware "hit-testing" feature that allows the tablet to be used for pointing, in a much more general way than the light pen in fact.

Options like function switches and control dials are available on the system, but we feel that the tablet makes them unnecessary except in extraordinary cases.

20. *Good Physical Appearance*

An ironic twist of graphic systems is that even though all their electronics are designed for the sake of the human eye, they are often housed in ugly cabinets with no regard at all for physical appearance.

We were determined from the outset to house "The Picture System" in a visually appealing and functional physical configuration. The packaging we selected is a handsome L-shaped desk where the electronics reside beneath the desk top (but are very accessible), and the scope, tablet, and other input devices are arranged conveniently on top. A place is reserved above the desk top for the PDP-11 console, DEC-tapes, and other items which must be frequently accessed.

Conclusion

Evans & Sutherland has always believed that there is a certain "right" way to approach graphics, that the desirable way to fulfill a need from one point of view tends to be desirable from other points of view as well. We believe that "The Picture System" is in fact the implementation of that right approach to graphics. ■

References

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4. Callan, J. F., "Programming a General-Purpose Graphics System", Record of the 1973 Northeast Electronics Research and Engineering Meeting, Vol. 15, Part 4, pp. 68-77.
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6. Sproull, R. F., and Sutherland, I. E., "A Clipping Divider", Proceedings of the 1968 Fall Joint Computer Conference, Thompson Books, Washington, D.C., 1968.
7. Sutherland, I. E., and Hodgman, G. W., "Reentrant Polygon Clipping", Communications of the Association for Computing Machinery, January 1974.

If You Heard 'Em Lucky, If You Didn't, Too Bad

Readers will note that some of the reports below present considerable detail on program content. SID Journal *is glad to receive as much detail as Chapter reporters wish to send re technical programs, and will either use it in this space; or, if in great enough detail, will present it separately elsewhere in the issue following its receipt. We welcome detailed reports.* — Editor

S.F. BAY AREA CHAPTER

December 13, 1973

Speaker: Wayne D. Stewart, Monsanto Chemical

Subject: Light Emitting Diodes in Alphanumeric Displays

MINNEAPOLIS-ST. PAUL CHAPTER

December 13, 1973

Speaker: Annual Motorola Yule-In

Subject: Annual Motorola Yule-In

SAN DIEGO CHAPTER

Speaker: Dick Winner, Manager, Advanced Controls and Displays Project, Hughes Aircraft, Culver City (Cal.)

Subject: A High Visibility Miniaturized Avionics Display Method for utilizing mianiaturized CRTs in conjunction with suitable magnifying optics to provide avionics display inside flight helmet, superior or equivalent to large screen monochrome or panel mounted color displays.

NEW ENGLAND CHAPTER

November 20, 1973

Speakers: Robert T. Marcus, Rensselaer Color Measurement Lab, Troy, N.Y. Dr. Ronald Robinder, Raytheon Industrial Components Div.

Subject: Tutorial on Color in Information Systems. Mr. Marcus dealt with psychophysical qualities of color; color mixing systems; color classification systems; and tristimulus colorimetry and spectrophotometry. Dr. Robinder gave a presentation on Principles of Color Instrumentation.

The New England Chapter was to hold tutorials on Integrated Circuits in Display Systems (January); and Display System Parameters (February). V. Fowler, GTE Labs, 40 Sylvan Rd., Waltham, Mass.

Microelectronics Call

Call for papers, 1974 Intl. Microelectronics Symposium, Boston, October 21-23, 1974, has been issued by T. B. Gillis, Program Chairman, Raytheon Co., 465 Center St., Quincy, Mass. 02169.

In-Helmet Display For L.A. Chapter

On November 27, 1973, some 50 people of L. A. Chapter of SID enjoyed a presentation by R. N. Winner, Manager of Advanced Display Projects for Hughes Aircraft Company, on the Helmet Mounted Display programs at Hughes Culver City. The evening was arranged by Miss P. DuPuis, Secretary-Treasurer of the L. A. Chapter, and was enhanced by the presence of the SID executive Committee, who had just completed a Board Meeting in the area.

The excellent technical presentation and demonstration showed the great strides recently made in producing a high resolution image as part of a pilot's flight helmet. Advanced work on holographic optics was also described which promises even further refinements for such a compact display system.

Bill Lichty, Hughes Aircraft Project Engineer for Helmet Mounted Displays, shows how the device would be worn by a pilot, during the demonstration phase of the November L. A. Chapter Meeting.

Dick Winner, Hughes Aircraft Advanced Display Projects Manager, demonstrating a holographic lens element to be used in the next generation Helmet Mounted Display. This demonstration followed a formal presentation by Mr. Winner on the Helmet Mounted Display developments at Hughes.

L. J. Schaefer, Vector General, Inc. views the high resolution image of the Hughes Helmet Mounted Display at the November L. A. Chapter Meeting.

Bill Lichty, Hughes Aircraft Project Engineer for Helmet Mounted Displays, demonstrates the high resolution image to Vi Puff, SID National Office Manager, at the November L. A. Chapter Meeting.

SID Sustaining Members

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BURROUGHS CORPORATION
Defense, Space & Special Systems Group
Paoli, Pennsylvania

CHERRY ELECTRICAL PRODUCTS CORP.
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CONRAC CORPORATION
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New York, New York 10017

DIACON, INC.
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DuMONT ELECTRON TUBES AND DEVICES CORPORATION
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FERRANTI ELECTRIC COMPANY
Plainview, New York

GML CORPORATION
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