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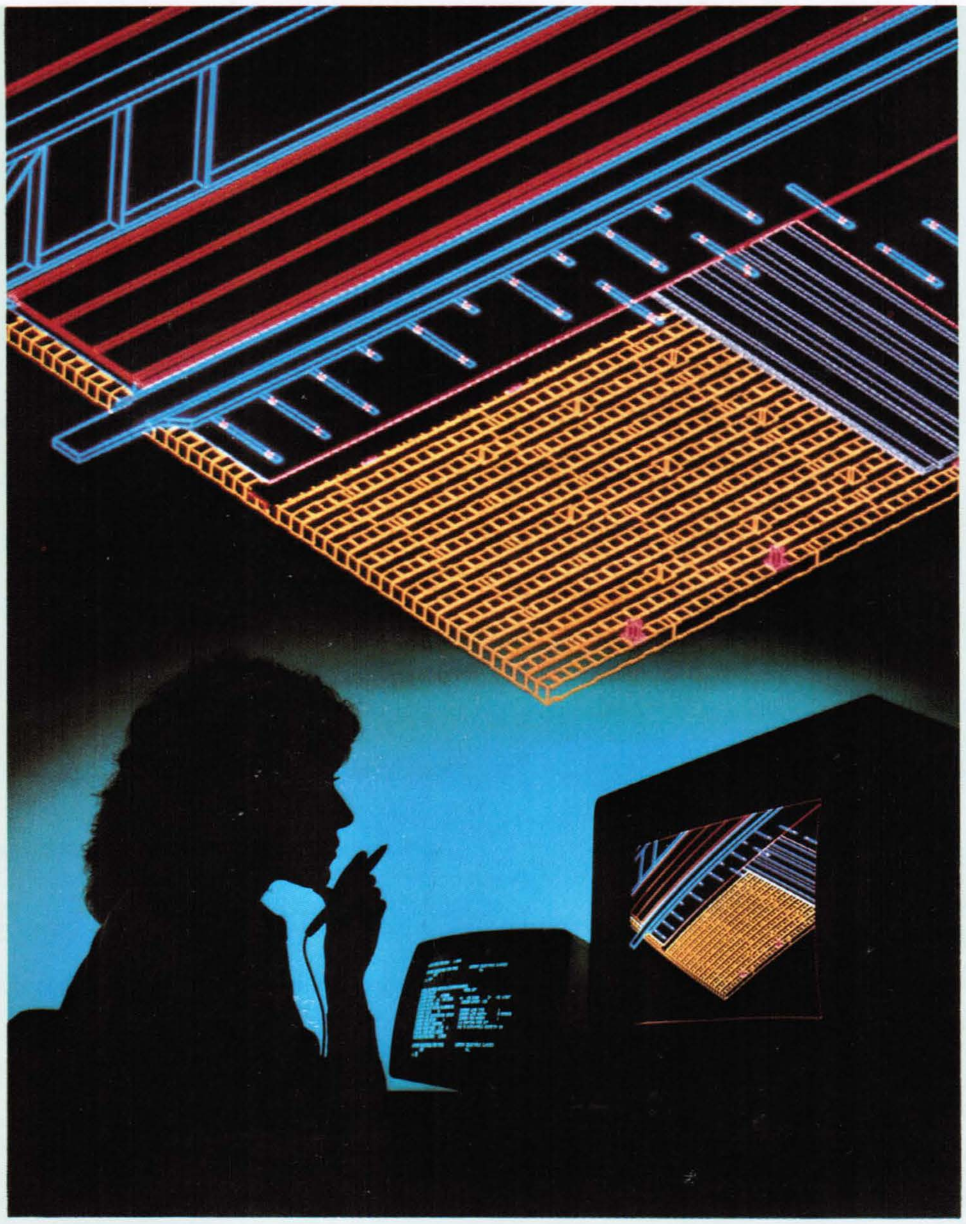
Engineering Workstations



Workstation markets
Workstation displays
Graphics standards

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Cover: Engineering workstations are powerful design tools that can also provide compelling design environments—as shown in this prize-winning photograph by Ken Gatherum of Boeing Computer Services Richland, Inc. Cheri Scott (in photo) worked with colleagues Rick Gerald and Jennie DeVine at the Westinghouse Hanford Company to design the displayed 3D graphics model of the Hanford 100-N nuclear reactor's graphite core stack so the reactor's chain reaction can be optimally moderated when operating conditions change.

Photo: Ken Gatherum

Next Month in Information Display

1988 Technology Roundup

- CRTs
- Flat displays: plasma, EL, LCD
- Large displays
- Printers

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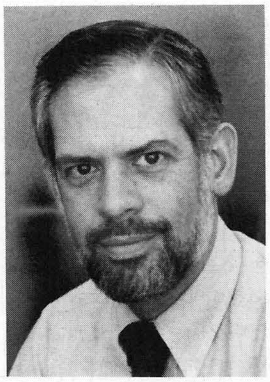
editorial



Pictures to the people—squared

Cynics aside, the explosive growth of computing with pictures stems not only from the tendency of our universities to graduate students who are both illiterate and innumerate. Even skilled wordsmiths and equation mongerers manipulate graphics interfaces and images with a remarkable, intuitive proficiency. And well we should. As children, we manipulate mud pies, not the equations that describe their shapes. Put those mud pies on a workstation display and provide the tools to change their displayed shapes directly, and engineers can have their childlike intuition restored to them.

But graphical computing, and the overlapping displayed windows that have grown up with it, places heavy demands on display and graphics technology. In this issue, Paul Breen provides an overview of workstation technology, and Hugh Masterman challenges the display industry to follow where that technology is leading. Despite the vitality of personal workstations, the market for them has barely been penetrated. One reason, says Chuck Hafemann, is the lack of an adequate nonproprietary graphics interface. In our third article, he sketches the history of graphics standards and tells us that the long-awaited solution is nearly at hand in the form of PHIGS+.

Pictures to the people who compute may be a revolution still in its early stages, but the broadcasting of pictures to people who wish to be entertained and informed has already transformed the world. The major technical issue in broadcast television today is whether those pictures are of sufficiently high quality. If you are in the habit of viewing your 35-mm slides next to your television screen, the answer is obviously no.

"Near-35-mm quality" has become the rallying cry of those who feel Tom Brokaw's warts should be seen more clearly. The result has been a variety of proposals for advanced television systems (ATV). On September 1, the U.S. Federal Communications Commission issued a "Tentative Decision and Further Notice of Inquiry" concerning advanced television systems in the United States. The FCC concluded that any ATV system adopted for terrestrial transmission (as opposed to direct satellite or cable distribution) must operate within the presently allocated TV transmission frequency bands and must be compatible with existing sets. The FCC said it wishes to encourage ATV systems and keep regulatory baggage to a minimum.

Thus, of the contending systems, only the Japanese NHK MUSE-E system, which uses a 9-MHz incompatible channel, is disqualified. This surprises nobody, least of all NHK, which also has compatible systems under development. Nonetheless, the other proponents of compatible systems can take deep breaths because MUSE-E (after 17 years of work) is the most highly developed of all the proposals. In fact, 200 selected Japanese households viewed the Seoul Olympics on MUSE-E receivers—200 more than used any other advanced system.

continued on next page

editorial

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Now comes the hard part: selecting from among the competing compatible systems. In addition, the FCC has tossed at least two jokers into the deck by inquiring into the feasibility of (1) not setting any regulatory standard, and (2) adopting an open-architecture-receiver approach (Paragraph 122).

Would an open-architecture receiver be digital? Would it use a VME bus? Will my PHIGS+ graphics board fit into my Dumont advanced television? My questions are not entirely serious, but the point is. If the FCC is inclined to escape from its standards-setting responsibilities by using open architecture as a getaway car, someone will still have to standardize the bus that ties the open architecture together.

However the technical issues confronting workstation and television designers are resolved, makers of display, graphics, and video systems are not likely to face a shortage of new challenges or new opportunities.

—Kenneth I. Werner

Acknowledgement: I would like to thank Jack Fuhrer, director of television research at the David Sarnoff Research Center, and William Glenn, director of the Science and Technology Research Center of the New York Institute of Technology, for invaluable information and insights concerning advanced television systems. However, they should not be held responsible for the opinions I've expressed.

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Workstations—new environment, new market

BY PAUL T. BREEN

WORKSTATIONS are an integral part of today's industrial society. While the workstation industry itself is less than 10 years old, its products have been cast into a broad array of tools that designers use daily. A workstation enables its user to increase productivity in familiar tasks and to perform new tasks that could not even be contemplated prior to the introduction of this technology.

The most dramatic of these is nothing less than a major change in the design culture. A designer can now simulate, integrate, and test potential designs for machines, tools, and software before anything is actually produced. Going even further, manufacturing processes can be integrated with design and testing. Here, the proposed design is placed within a computer-accessible file that can be assessed by all members of the design, test, and manufacturing team. The integration process often uncovers nonfunctional manufacturing operations before any tooling has been ordered, before any metal has been cut, before any photoresist has been exposed.

What are they, and for whom?

The most obvious feature of workstations is a stylized user interface incorporating push-down, pull-up menus and appropriate graphic symbols—called icons—to indicate operator functions. High-resolution color displays, 32-bit microprocessors processing between two and ten million instructions per second (MIPS), extensive mass storage, and access to remote computational and storage services via a local area network complete the basic workstation package [Fig. 1].

U.S. Census figures show that three million professionals are potential workstations users. Market research indicates that 62,000 workstations were installed in 1986, and that just a year later the number of workstations had doubled. While some of the market will be serviced by low-end personal computers, a significant number of professionals will require the power of a purpose-built engineering workstation.

Users generally expect their workstations to perform functions in two broad but distinct categories. The first involves the generation of reports through word processing and related support software, communication via electronic mail, and the running of spreadsheets. Resource-sharing via a network is assumed. These functions are typical of personal computers, and many workstation vendors are now offering them through emulations of specific popular personal computers.

The second category involves the creation and manipulation of high-resolution graphic pictures in either two or three dimensions. Generally, "3D capability" refers to 2D displays utilizing perspective to show 3D objects. But recent entries in the workstation market offer 3D stereo displays.

The soul of the machine

A workstation's hardware consists of a graphics subsystem and a host computer subsystem. The graphics subsystem contains an image generation unit that converts display commands from the host into the bit pattern stored in the refresh buffer memory array—a process called scan conversion or rasterization. The refresh buffer maintains the current content

Table 1: Trendgram of 3D Graphics Picture Complexity

Date	CPU (MIPS)	Flat-shaded non-Z-buffered (polygons/sec)	Gouraud-shaded Z-buffered (polygons/sec)
September 1987	2	5K	1K
January 1988	10	27.5K	5.5K
April 1988	10	600K	120K
January 1989	40	2M	400K

Source: M. Zyda, Naval Postgraduate School

Paul T. Breen is a department head at The MITRE Corporation in Bedford, Massachusetts. He is well-known as a watcher of and commentator on the workstation industry.

of the display image, with one or more bits of memory corresponding to each picture element on the display surface. The video generator unit triggers the periodic readout of the refresh buffer's content, thus refreshing the display surface. The video generator also generates the control signals needed to convert this data stream into a displayed image. An interaction control section accepts operator inputs for processing by the application program.

The workstation's host computer subsystem can be a single microcomputer, a cluster of supercomputers, or anything in between. The host subsystem generates appropriate display commands for the graphics subsystem on behalf of application programs. It also processes interaction requests for operator inputs and forwards these requests to the application program.

Each workstation contains a general-purpose central processing unit along with associated support chips. The 32-bit Motorola 68000 microprocessor family is one of the more commonly implemented microcomputers employed in workstations today. The quest for additional performance fosters the development and adoption of faster chips. The 68020 is currently popular, and the 68030 has recently been introduced. But not satisfied with the pace of performance gains from new chips, workstation manufacturers have introduced a variation on classic computer architecture known as the Reduction Instruction Set Computer (RISC). This design provides for a much smaller set of instructions than are typical in conventional mini- and microcomputers, and it offers substantially greater computational speed. Four times the speed of conventional processor designs of the same class has been claimed.

A workstation's processing power is frequently characterized by the speed, in millions of operations per second (MOPS) or millions of floating-point operations per second (MFLOPS), with which it performs certain benchmark programs. Because of the large number of multiplication operations needed to create a typical workstation's graphic presentation, floating-point performance is critical (and some benchmark programs are designed to be floating-point-calculation intensive). Recognizing this, designers often incorporate within their workstations a special processor known as a floating-point accelerator. The relative effectiveness of these accelerators can make a large difference

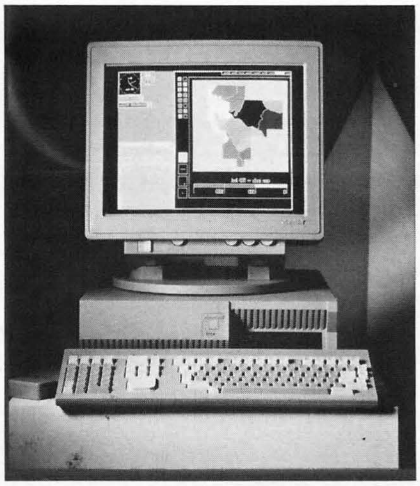

Photo: Tektronix, Inc.

Fig. 1: A typical workstation incorporates a windowed icon-based interface, a high-resolution color display, a 32-bit microprocessor, and extensive mass storage. Connection to other workstations and shared resources via a local area network completes the package.

in the relative performance (and price) of two workstations utilizing the same host processor.

Workstations are typically provided with random access memory ranging from 2 to 32 Mbytes. Memory management and caches—fast temporary memories for frequently used data—are employed to improve efficiency. Recognizing that memory demands in the mid-1990s may well approach multiple gigabytes and that application programs may exploit many gigabytes of that memory, caching and memory management will become increasingly important vehicles for delaying a workstation's obsolescence.

Current workstations may contain local fixed discs with storage capacities ranging from 70 to 380 Mbytes. Discless configurations are also available for users who wish to share discs located elsewhere on their networks. With optical discs now entering the market, the data bases locally available at each workstation can be expected to grow by one or two orders of magnitude.

Ethernet and the Institute of Electrical and Electronics Engineers (IEEE) 802.3 local area network interfaces dominate the workstation market today. These systems support data bandwidths on the order of a few Mbits/sec.

Workstation monitors are dominated by CRT technology, and this is expected to continue for the next decade. Addressable resolutions on the order of 1280 × 1000 pixels with up to 24 bits/pixel are routinely available today in a variety of CRT sizes ranging up to 19 in. on the diagonal.

Graphics system CRTs typically provide 60 Hz refresh rates (noninterlaced). Larger CRTs of up to 25 in. diagonal with the same performance are available. Very-high-resolution graphics monitors (2000 lines × 2000 pixels), some with surface areas of approximately 400 $in.^2$, are available from third parties. These monitors should be available in workstations within the next few years, assuming an increasing demand for this capability.

The bus is the means by which information is passed internally between the various portions of the workstations. Three buses are in common use today: VME, Multibus and the proprietary Qbus. The two public buses support bandwidths on the order of 10 Mbits/sec, while the DEC Qbus supports bandwidths in the range of 2 Mbits/sec.

Input devices range from mice and touch panels through keyboards, trackballs, and cursor controls.

Command, communication, and open architecture

Users are finding that software and network capabilities—including graphics standards, operating systems, window managers, networks, and network file systems—are increasingly important to a workstation's function. Therefore, users will increasingly need to plug new workstations into their existing networks and run their existing software on them.

As a result, three conditions are needed for the development of a viable workstation market. First, there is a need for open architecture to provide for the needed interfacing of workstation hardware and software by independent third parties using publicly defined interfaces. Second, there is a need for heterogeneous multivendor workstation networks that can provide individuals with access to the computational and storage assets within a specific network. Third, the market cries out for reliable reusable software.

Recent studies show that software engineering resources within the United States are greatly overtaxed and likely to remain so, despite the use of high-level languages. Established graphics standards could aid in resolving this problem because they would allow common application software to be run on a number of workstation platforms resulting in lower cost per application. Even greater efficiency would result from an ad hoc standard operating system that would allow access to UNIX as well as proprietary operating systems.

Three graphics standards are available today: Graphical Kernel System (GKS), Programmer's Hierarchical Graphics Standard (PHIGS), and Computer Graphics Interface (CGI). PHIGS, which is just beginning its evolutionary cycle, is aimed at 3D applications, while GKS is focused on 2D. (CGI is an increasingly popular ANSI low-level graphics standard interface that supports basic graphics operations.) Graphics standards have chiefly been developed by and for an industry that has been developing CAD/CAE/CAM applications. As a result, they are not necessarily optimized for other applications, such as real-time ones. Several vendors offer extensions that provide the required features, but the effect of these extensions is to obviate the portability implied by the term "graphics standard."

The most popular operating systems for workstations are variations of UNIX. POSIX is an IEEE standard which is being developed to deal with the variations of UNIX. Vendors of proprietary operating systems for workstations are developing ways of accessing UNIX.

The window manager presents a comprehensive view of the resources available to the workstation user regardless of whether these resources are local or remote to the workstation itself. Two windowing systems are commercially supported—the X-Window system and NEWS. There is a move in the industry to merge the capabilities of both systems into one product.

One of the benefits of a workstation network is the transparency of on-line resources, enabling the user, for example, to execute an application program in a remote workstation. Network standards and network-transparent distributed file systems provide for file transfer across networks of heterogeneous workstations without requiring recompilation.

Trends

A short-term view of workstation trends is illustrated by the performance data for four workstation products offered over the past 18 months by a single workstation vendor [Table 1]. The polygons-per-second metric indicates a rapid growth in graphics rendering capability. The growth of computational capability tracks this increase at a lower rate, with 10-MIPS workstations entering the market within the next few years. The next five years could bring us truly real-time heterogeneous networks. Combined with this, we should also expect to see 100-Mbits/sec local area networks in the form of fiber data distribution networks. With added improvements in processing capabilities, real-time animation will be possible using solid models with a graphics standard layer to support software portability.

Notes

This article is a condensed version of the workstation tutorial presented by the author at the 1988 Society for Information Display International Symposium. A written version of the tutorial appears in Vol. 2 of the SID '88 *Seminar Lecture Notes.* ■

Displays for workstations

BY HUGH C. MASTERMAN

THE DEVELOPMENT of personal workstations has radically altered the nature of human-computer interaction. And because graphics have become the preeminent mode of interaction for workstation applications, workstation evolution has been both fostered and constrained by display technology.

The earliest workstations used the newly developed high-resolution raster CRT monitors to provide a radically new user interface. The later development of high-resolution shadow-mask color CRTs established the current standard for workstation displays [Fig. 1].

But several application areas are challenging the adequacy of this standard. These new requirements are being satisfied by alternate display technologies, but at the expense of generality. The challenge to the display industry is to bridge these requirements with a single technology and thereby establish a new standard workstation display.

The workstation concept

In early batch-processing machines, the primary mode of man-machine interaction was paper—punched cards for input; cards and line printers for output. With the rise of interactive time sharing in the 1960s came alphanumeric terminals. The

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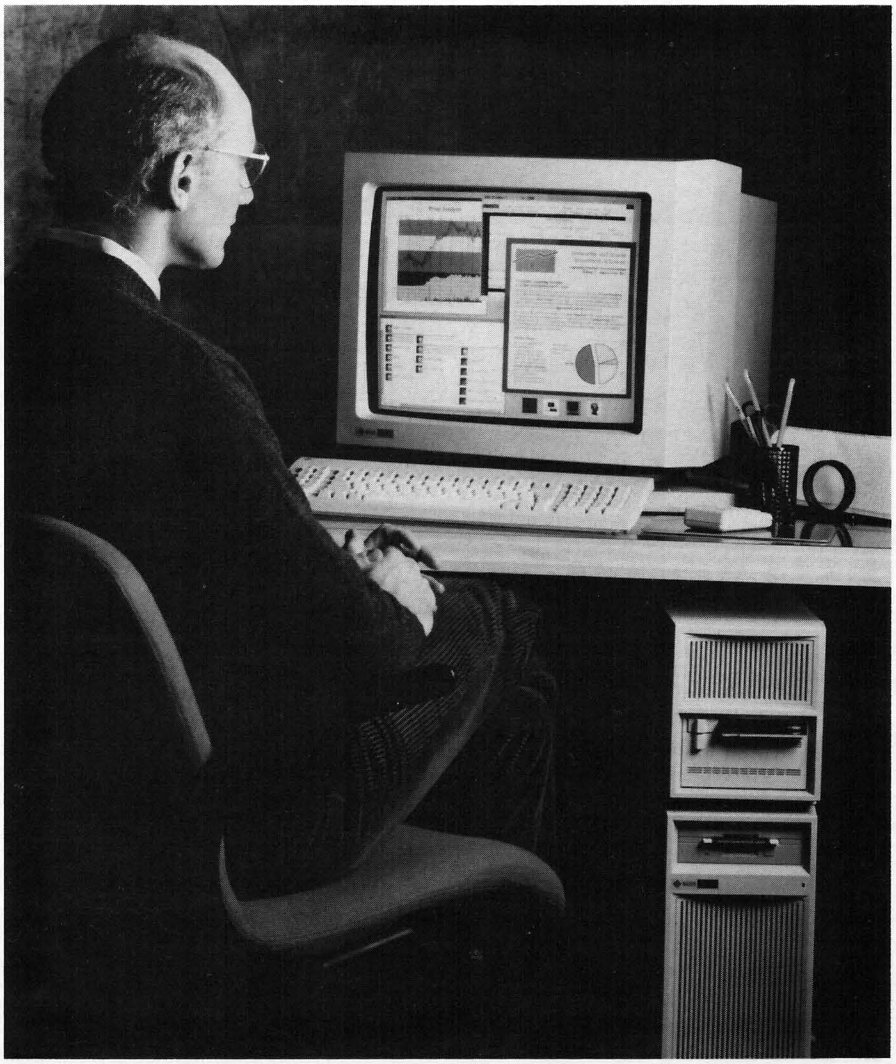

Photo: Sun Microsystems, Inc.

Fig. 1: *Today's de facto standard workstation display is based on a 19-in.-diagonal full-color shadow-mask CRT and has sufficient resolution for an effective windowed user interface.*

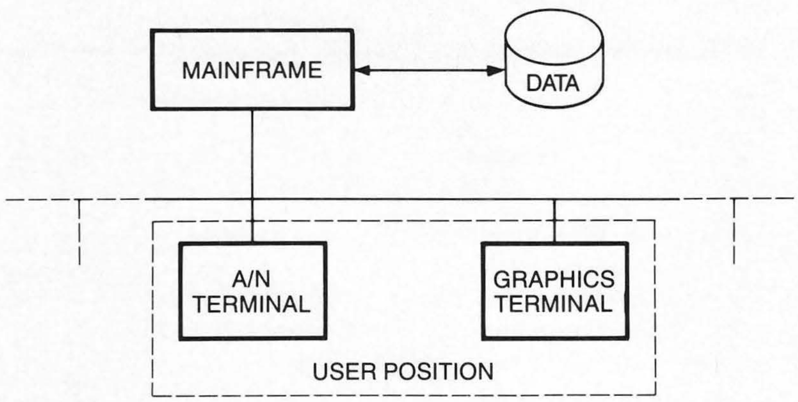

Fig. 2: Interactive mainframe architectures are characterized by a low-bandwidth connection between the host processor and graphics generator.

first of these were based on teleprinters; later terminals utilized CRTs as display devices. These "video display terminals" forever changed the character of computing.

Most early video display terminals employed raster technology. The standard data load of 25 rows of 80 characters evolved primarily because it could be accommodated at television scan rates using components that were mass produced for the entertainment industry. As computer graphics developed into an important interactive medium, a second type of terminal device developed. These early graphics terminals employed stroke-written CRT technology.

A typical user's terminal in a time-shared mainframe environment was linked to the host computer by a low-bandwidth connection. This severely limited the speed with which the user could modify and interact with the displayed data [Fig. 2]. In graphics terminals, storage CRTs were dominant because the images they displayed did not require refreshing from data resident at the host.

Several concurrent developments in computer technology engendered the modern workstation. An exponential decrease in the cost and size of processing elements, memory, and mass storage made it practical to decentralize computing resources. With more computer resources situated at the user's station, it became possible to couple the graphics generation function more tightly with the storage and processing functions via a high-speed bus [Fig. 3]. The high-speed bus is essential to this workstation architecture, which is typified by a graphics subsystem that becomes a real-time, interactive window into the application program running on the general processor.

A software development that has shaped the modern workstation is the multitasking, single-user operating system. Multiprogramming had been used since the early time-sharing era, but the concept of a single user interacting with multiple concurrent applications was revolutionary.

Window to the soul

If "the eye is the window to the soul" and the display is the window to the soul of the machine, the display techniques that had served in early graphics and alphanumeric terminals required rethinking for the new workstations. Researchers at Xerox Palo Alto Research Center (PARC) and elsewhere envisioned a new concept in human-computer interaction. Application programs and data were to be treated as objects and the user's view of these objects was to be analogous to his view of papers on a desk. Objects could overlay each other and be shuffled according to current needs.

This view had several implications for the display system that was to implement the interface. First, the display surface would have to be larger than that used for conventional alphanumeric terminals. Second, the display technology should readily support area fill and masking to implement multiple objects or "windows" on the screen surface. Third, the display should have sufficient resolution to display multiple alphanumeric and graphical objects concurrently. The area fill requirement, coupled with the rapid drop in the cost of high-speed semiconductor memory, led to the adoption of bit-mapped graphics and matrix (or raster) display devices as the standards for workstation use.

CRT raster monitors offered the only viable solution to these requirements in the late 1970s, but presented several limitations that had to be overcome. Magnetic deflection components were inefficient at the high deflection frequencies (over 50 kHz) required to achieve 1-million-pixel (1000-line) resolution. Semiconductor devices capable of implementing the required 100-MHz video rates were not available, nor were the high-speed digital-to-analog converters required to achieve video gray shades. Color shadow-mask CRTs with sufficiently small spot size and sufficiently fine mask pitch to achieve 1000-line resolution were still under development. For these reasons, the earliest workstation displays were monochrome, offered slightly less than 1-million-pixel resolution, and provided only a single-pixel luminance level. This standard became the basis for the graphical system of Smalltalk, the object-oriented workstation environment developed at Xerox PARC that subsequently became the basis of the Apple Macintosh computer. Smalltalk builds all of its graphical entities from a class of objects known as "forms," which consist of rectangular matrices of ON or OFF pixels. Shades of gray are created by halftone techniques.[1] A 19-in. monochrome CRT affording a screen area of approximately 150 $in.^2$ became the standard workstation display device.

Developing a standard display

This single-level monochrome display continues to meet the needs of several workstation applications, such as software development, schematic and mechanical drawing CAE, and halftone desktop publishing. But the workstation's close coupling of application programs and computer graphics soon stimulated a demand for more display capability. Specifically, the ability of graphics processors to render a data model of an object forced workstation display technology in the direction of full color. To achieve full color with the size and resolution demanded by workstation applications required the maturity of three display technologies: the 64-kHz deflection system, 100-MHz linear video amplifier, and the 0.31-mm pitch 19-in. color shadow-mask CRT. These technologies were in fact developed in the early 1980s, and have combined to form today's de facto standard for workstation display devices. Each of the major workstation suppliers provides a standard display configuration using a 19-in. shadow-mask CRT with addressable resolutions ranging from 1024 × 864 to 1280 × 1024 pixels [Table 1, column 1].

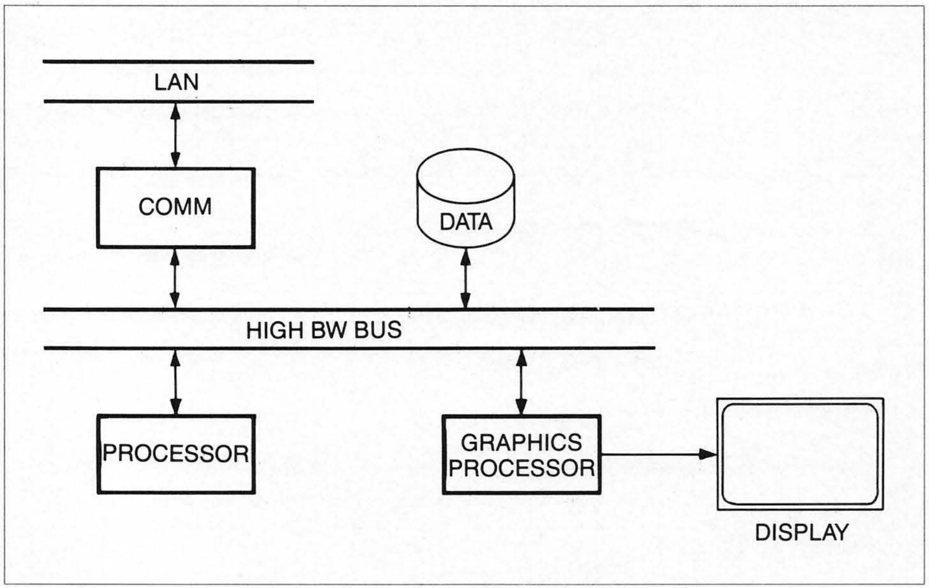

Fig. 3: *Workstation architectures are characterized by a high level of connectivity between the processing and graphics-generation functions.*

Divergent requirements

Although this de facto display standard satisfies a broad class of workstation applications, evolving applications are motivating the development of display solutions that exploit alternative technologies. Three such solutions are shown in the third row of blocks in Fig. 4 and in the middle three columns of Table 1.

Several evolving applications require pixel resolution in excess of the 90 pixels/in. provided by the current standard. Medical imaging, intelligence data analysis, and desktop publishing, for example, would drive addressable resolution to the limits of human visual acuity to minimize sampling artifacts. At normal viewing distances, this requires a resolution approaching 300 pixels/in.[2] Solving this problem has required a reversion to monochrome CRT technology because of the limitations of shadow-mask CRT mask pitch. Several commercial implementations utilize ultra-high-resolution bipotential-focus CRTs and video bandwidths ranging from 200 MHz to 1.5 GHz. A Tektronix monochrome CRT for such applications utilizes internal dynamic astigmation to maintain spot size at less than 5 mils over the CRT surface.[3] MegaScan of Gibsonia, Pennsylvania, has pushed addressable resolution to the limits of visual acuity with a 3300-line (13-Mpixel) monitor utilizing single-level video and a novel technique for cooling the deflection yoke at the 244-kHz horizontal scan rate.[4]

Workstation architectures are being increasingly applied to surveillance and command-and-control applications. Because of the extraordinary quantity of data presented to a user in these applications, there is a demand for display sur-

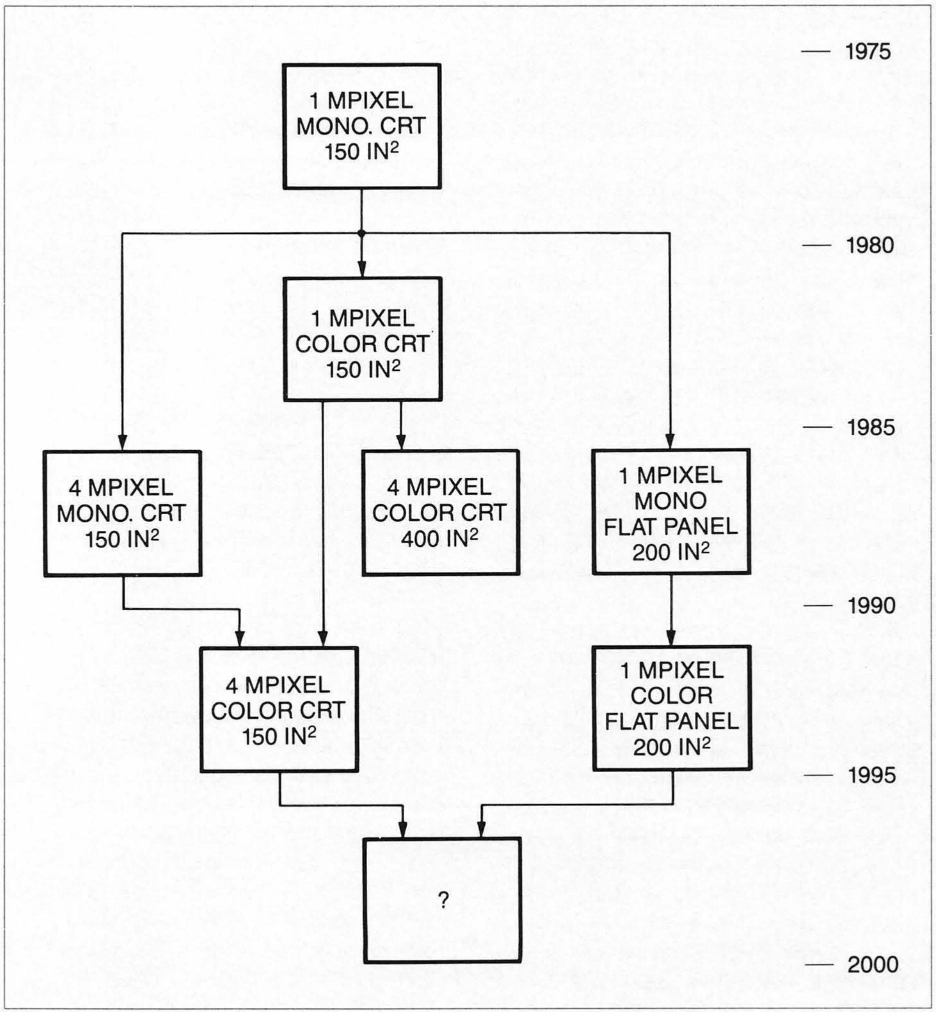

Fig. 4: *The evolution of workstation displays may be represented as a tree. Alternative solutions driven by diverse applications may combine into a unified standard when technology permits.*

Table 1: Workstation Displays

	Current Standard	High Resolution	Large Screen	Portable	Ideal
Screen Area	150 $in.^2$	150 $in.^2$	400 $in.^2$	150 $in.^2$	200 $in.^2$
Depth	22 in.	22 in.	30 in.	2 in.	< 10 in.
Resolution	1 Mpixel	13 Mpixel	4 Mpixel	1 Mpixel	4 Mpixel
Luminance	20 fL	50 fL	15 fL	20 fL	20 fL
Color	full-color	monochrome	full-color	monochrome	full-color
Power	150 W	140 W	450 W	60 W	<100 W
Cost (unit)	$3K	$5K	$40K	$10K	<$5K
Technology	SM CRT	CRT	SM CRT/ Trinitron	EL/Plasma	?

face areas in excess of the 150 $in.^2$ provided by the standard. A notable example is the Advanced Automation System (AAS) under development for the Federal Aviation Agency. This air-traffic-control application spawned development of a 20-in.-square display by Sony that utilizes Trinitron technology to achieve 2048 × 2048 pixel resolution in full color. Hitachi has developed a 25-in.-diagonal 1280 × 1024 monitor for surveillance and CAD workstation applications.

Business applications and tactical military problems are also migrating to workstations, creating a requirement for portability and ruggedness in workstation displays. Two flat-panel technologies are capable of providing portable displays with the required display area and resolution. Planar Systems of Beaverton, Oregon, has developed an 18-in.-diagonal thin-film electroluminescent (TFEL) device capable of displaying 1024 × 864 pixels. This device occupies a package less than 1.5 in. deep and consumes less than 60 W of power. SAIT of San Diego, California, has developed a plasma monitor targeted at military workstation applications.

Approximate specifications for each of these special-purpose deviations from the display standard appear in Table 1. Compromises are required to achieve the special application requirements. In both the high-resolution and portable cases, color is sacrificed. Achieving large screen area requires a heavy penalty in depth, weight, and power consumption. The most significant compromise is cost.

Production volume and technical simplicity of the standard 19-in. shadow-mask monitor has reduced its cost to less than $3000. In contrast, the cost of specialized displays is significantly greater—nearly an order of magnitude greater for large-screen displays.

The challenge

Workstations are challenging the display industry to provide color, very high resolution, and portability in a single technology. Such a technology would then lead to the ideal workstation display device [Table 1, last column]. The ideal device would provide a surface area of approximately 200 $in.^2$, with the capability of expanding to meet command-and-control requirements. It would be a matrix device with pixel resolution approaching the limit of visual acuity. It would deliver sufficient luminance to provide adequate contrast in a normal office environment. Finally, it would present minimal thickness, low power consumption, and reasonable weight.

Although such a technology is far from realization, several developments point to its eventual feasibility. Dramatic breakthroughs in flat-panel color have recently been reported.[5,6] Advances in electron-gun and deflection yoke technology have enabled yet another quantum jump in color shadow-mask CRT performance.[7,8] If designers can overcome the factors limiting the reduction of mask pitch, the CRT may remain a contender well into the next decade. But for any technology to replace the current standard, its cost must ultimately be low enough to represent no more than 10–20% of the total cost for a single operator's workstation. As the cost/performance ratio of computing elements continues to plummet, this may be the greatest challenge of all.

Notes

[1]A. Goldberg and D. Robson, *Smalltalk-80* (Reading, Massachusetts: Addison-Wesley, 1983), pp. 330–413.

[2]G. Murch et al., "Resolution and Addressability: How Much is Enough?," *Proceedings of the SID*, Vol. 26, No. 4 (1985), pp. 305–308.

[3]C. Odenthal, "A 19-in. Very High Resolution Display CRT," *SID Digest*, Vol. 15 (1984), pp. 258–261.

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[5]W. B. Barrow et al., "Matrix-Addressed Full-Color TFEL Display, *SID Digest*, Vol. 19 (1988), pp. 284–286.

[6]M. Gay et al., "Color Plasma Display Panels with Simplified Structure and Drive," *SID Digest*, Vol. 19 (1988), pp. 157–159.

[7]S. Ashizaki et al., "In-Line Gun with Dynamic Astigmatism and Focus Correction," *Proceedings of Japan Display* (1986), pp. 44–47.

[8]T. Kuramoto et al., "The SSC Deflection Yoke for In-Line Color CRTs," *SID Digest*, Vol. 19 (1988), pp. 132–135. ■

Graphics workstation standards

BY CHARLES HAFEMANN

IN OUR harshly competitive world, companies that buy computer-based systems often need state-of-the-art equipment. At the same time, these purchasers of expensive hardware and software would like their systems to be based on standards, which would provide them with some confidence that they are investing in long-term, upgradeable components. Standards-based components also allow existing applications to be ported, migrated, or upgraded with little or no additional investment on the part of the computer-graphics workstation user.

But in a dynamic technological environment, the state of the art can move at a faster pace than standards evolution can. Fortunately, workstation graphics standards are emerging that can answer today's performance requirements and are expandable enough to meet tomorrow's demands.

The benefits of standards

Standards allow users to acquire cost-effective hardware and software in a competitive, multivendor marketplace. A modern computer-graphics workstation typically consists of a workstation platform that includes a microprocessor, operating system, language, network, window system, system bus, and graphics interface. In a standards-based system, each of these components will be consisttent with an existing, emerging, or de facto standard. Typical choices are one of the open-architecture workstation platforms, such as those made by Sun and Apollo; a UNIX operating system; the well-established VMEbus; a network based on Ethernet; and the emerging PHIGS+ graphics standards.

When commercial high-performance graphics systems first appeared, they were heralded as a major productivity enhancement. Yet the predicted potential of these systems has not been fully realized, primarily because of the limited availability of applications software. This, in turn, stems partly from a lack of common programming practices among the software departments of the various manufacturers. As a result, applications programmers have been forced to learn new methodologies for each graphics system, dramatically extending the time it takes to bring new graphics software to market.

Without accepted standards, competing companies waste valuable resources implementing and reimplementing similar technologies. Suppliers to these companies can suffer similarly, trying to keep pace with each company as it develops new prod-

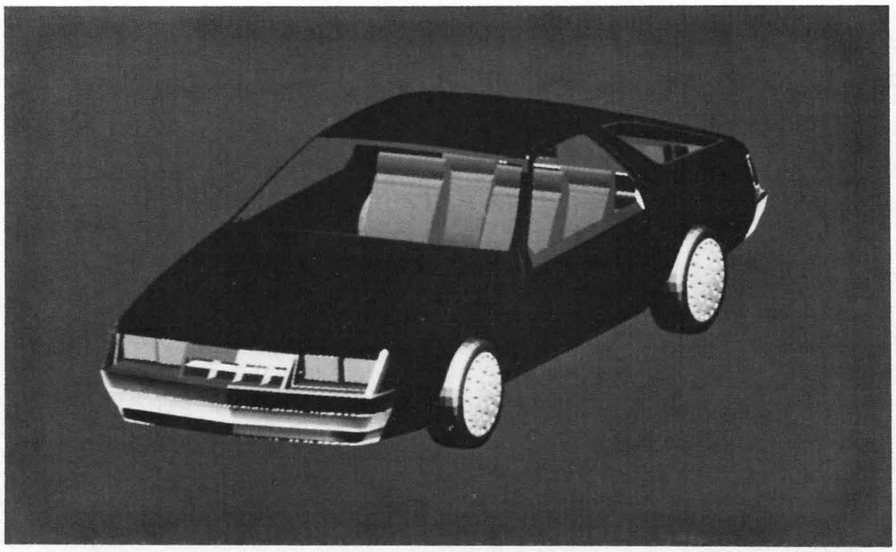

Fig. 1: The realistic rendering of complex objects such as this automobile model is easier with the extended set of "primitives" offered by the non-proprietary graphics interface system called PHIGS+. The extensions, which are not included in PHIGS itself, include shading, lighting, and advanced curve and surface commands. PHIGS is about to become an ANSI standard. PHIGS+ is under development.

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ucts, each with a different set of specifications. Graphics standards should help bring high-performance graphics systems to more applications faster.

Originating and approving standards

Any given technical field will evolve acceptable practices based on experience and theory. It is productive for manufacturers and users of a product to accept a consistent set of these practices as standards. Standards can be formally approved, or de facto standards such as UNIX can evolve from a broad-based popularity. A formally approved standard represents a combination of practices and technical knowledge that has been put on paper, revised, modified, tested, and widely accepted—generally through a long and laborious process. There are several organizations involved in the preparation of graphics standards.

ANSI, the American National Standards Institute, was founded in 1918 to coordinate the federated standards system of the United States. ANSI is not responsible for developing standards, but rather for identifying what standards are needed and providing a set of procedures for standards-writing organizations to follow.

ISO is the International Organization for Standardization, for which ANSI is the U.S. representative. ANSI is responsible for managing, coordinating, financing, and supporting U.S. participation in ISO.

X3 is the standards development committee accredited by ANSI for information processing. Within X3 is a technical committee labeled X3H3, responsible for all computer-graphics standards. X3/SPARC, the Standards Planning and Requirements Committee, oversees all X3 technical committees and approves new project proposals before these proposals are given to the X3 technical group.

X3 draft standards undergo a lengthy public review process and are not adopted by ANSI until all public comments have been incorporated.

The road to PHIGS

The computer-graphics industry has been moving toward standardization since the early 1970s when the Association for Computing Machinery's Special Interest Group on Graphics (SIGGRAPH), and subsequently ANSI and ISO, developed standards to define logical workstation capabilities and high-level language bindings.

Developed in the late 1970s by SIGGRAPH, CORE was one of the first proposed 3D graphics standards. It was developed to specify a graphics system model that simulates the capabilities of 3D graphics terminals and pen plotters. Since then, certain drawbacks to the CORE graphics interface have become apparent. Among these is its support for only one output device, whereas many of today's applications use multiple output devices. Also, CORE does not specify a standard language binding—a language-specific interface—between an applications program and the subroutine library that implements the standard. Therefore, an applications program often requires extensive modification when it is moved from one CORE-based library to another.

The 2D Graphical Kernel System (GKS) was developed jointly by ANSI and ISO and formally adopted by these organizations in 1985 as a U.S. and international standard. While only a 2D standard, GKS goes beyond CORE by specifying support for multiple workstations and by defining standard language bindings for major high-level languages including FORTRAN and C.

GKS allows an application programmer to send graphics output to and accept graphics input from a variety of independent devices. These devices include monochrome and color displays utilizing either vector or raster technology, printers, plotters, mice, data tablets, joysticks, and digitizers. Over two dozen commercial implementations of GKS are available from American and European suppliers.

The Programmer's Hierarchical Interactive Graphics System (PHIGS), goes beyond the older CORE and GKS standards to provide 3D primitives such as polyline and fill area, as well as hierarchical data structures. PHIGS offers many of the same graphical input and output primitives and attributes as GKS, but it differs from GKS by building and managing a graphical data base that is hierarchically structured.

For example, in the hierarchy, programmers define structures to PHIGS, and these structures may invoke other structures in several different ways. The manipulations on structures (e.g., scale, rotate, translate, change element, change view) may be specified. PHIGS capabilities include:

- *control functions* for workstation properties;
- *output primitives* such as polyline, symbol marker, text, fill area (or polygon), fill area set (complex polygons with edges), cell array (or color grid), and generalized drawing primitives (implementation defined, non-standard primitives);
- *attribute selection* to control the appearance of output primitives such as color and thickness of lines;
- *modeling and viewing transformations* describing the orientation of an object with respect to a coordinate system;
- *structure editing, control, and display functions;*
- *input device handling;*
- *inquiry functions*, which return to the applications program data contained in the state lists, description tables, or structures.

PHIGS, as a graphics interface standard, is under development and review and has been approved by ANSI as a Draft International Standard. It was developed specifically to support highly dynamic, highly interactive application areas such as scientific visualization, CAD/CAM/CAE, command and control, molecular modeling, and simulation, and it seems well on its way to becoming the dominant nonproprietary interface for these applications. Major computer manufacturers, including IBM and DEC, have introduced PHIGS-based products. And Carl Machover of Machover Associates Corp. has predicted that, because users want to remain as device independent as possible, "PHIGS is probably going to be the dominant graphics standard over the next few years."

Extending PHIGS

Although it is by general agreement the most advanced graphics standard currently available, PHIGS in its current form lacks the sophisticated shading and lighting capabilities now common in high-end graphics systems. A consortium of graphics professionals from major system manufacturers and universities have therefore proposed extensions to PHIGS, called PHIGS+. The new standard is now under consideration by X3H3.

Extensions to the PHIGS standard allow for realistic rendering of complex objects through shading and lighting, and advanced curve and surface primitives. Until the PHIGS+ additions, these capabilities were available only in the proprietary command sets of high-end graphics terminals and workstations. PHIGS+ allows applications developers to deliver realistic models without committing themselves to a single platform [Fig. 1].

PHIGS+ is intended as an extension to PHIGS, so it uses PHIGS features and mechanisms wherever possible. PHIGS

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software notes

Tornado, Version 1.80

by Micro Logic Corporation, 100 Second Street, P.O. Box 70, Hackensack, NJ 07062. $99.95 plus $3.50 shipping ($10.00 outside the United States and Canada).

Reviewed by Kenneth I. Werner

Information Display's software reviews normally focus on programs that perform technically oriented tasks—the kind of programs that are not extensively reviewed in general publications. *Tornado* is an exception.

Though extensively advertised and favorably reviewed in the general personal computing press, *Tornado* does not seem to be widely known in the technical community. And that's a pity, because this program is not only a remarkable "productivity enhancer" for technical professionals, it can also enhance the effectiveness of many programs that professionals use.

Micro Logic calls *Tornado* a "random information processor." Using it, you can quickly type random notes having no common format or style. The notes appear on screen as overlapping windows that emulate overlapping memos on a desktop. Using cursor keys, you can flip your way through the pile. Each pile can have as many as 500 notes, and 50 piles are possible—a maximum of 25,000 notes.

The key feature that makes *Tornado* effective is its ability to search through all of its stored notes for any character string you type in. If you've been using the program for design notes on a focus coil, and remember only that the note you want contained a reference to "ellipsoidal spots," type "G" for get, "ellipso," and a carriage return. All the notes containing the character string "ellipso" will pop up on the screen, with virtually no delay. I keep my "to do" memos on *Tornado* and preface each one with "TO DO." "G," "TO DO" brings up the "to do" list. I call up the program in my AUTOEXEC.BAT file so my "to do" list stares at me whenever I turn on the computer.

The program strikes me as being most useful when used in its memory-resident or "pop-up" mode. It is then possible to "hot-key" out of your main applications program to make a note or comment, or hunt for previously recorded information. Obvious uses are explaining a spreadsheet cell or recording the source of an equation in that article you're writing. You

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Kenneth I. Werner is the editor of Information Display.

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programs should run unchanged in the PHIGS+ environment and should be easily modified to incorporate the PHIGS+ extensions. Future expansions to PHIGS+ are expected to address additional surface properties, global environmental effects (shadows and reflections, for example), primitive solids, and constructive solid geometry.

Raster Technologies, convinced that PHIGS+ is fated to be an influential standard, recently introduced the first workstation to use PHIGS+ as its native command set. The GX4000 is a board set designed to provide PHIGS+ acceleration on the Sun Microsystems Sun-3 and Sun-4 workstations, and has also been tightly integrated into the Alliant Computer Systems family of mini-supercomputers.

Notes

The following publications treat some of the subjects presented in this article in more detail, and are available without charge from Raster Technologies, An Alliant Computer Company, Monarch Drive, Littleton, MA 01460. Telephone: 508/486-4950. *PHIGS/PHIGS+ Functional Description* (PHIGS+/87-SR6, 1987); *Extending PHIGS for Lighting and Shading—PHIGS+* (1987); *Computer Graphics Workstations: A Look at Emerging Standards* (1988). ■

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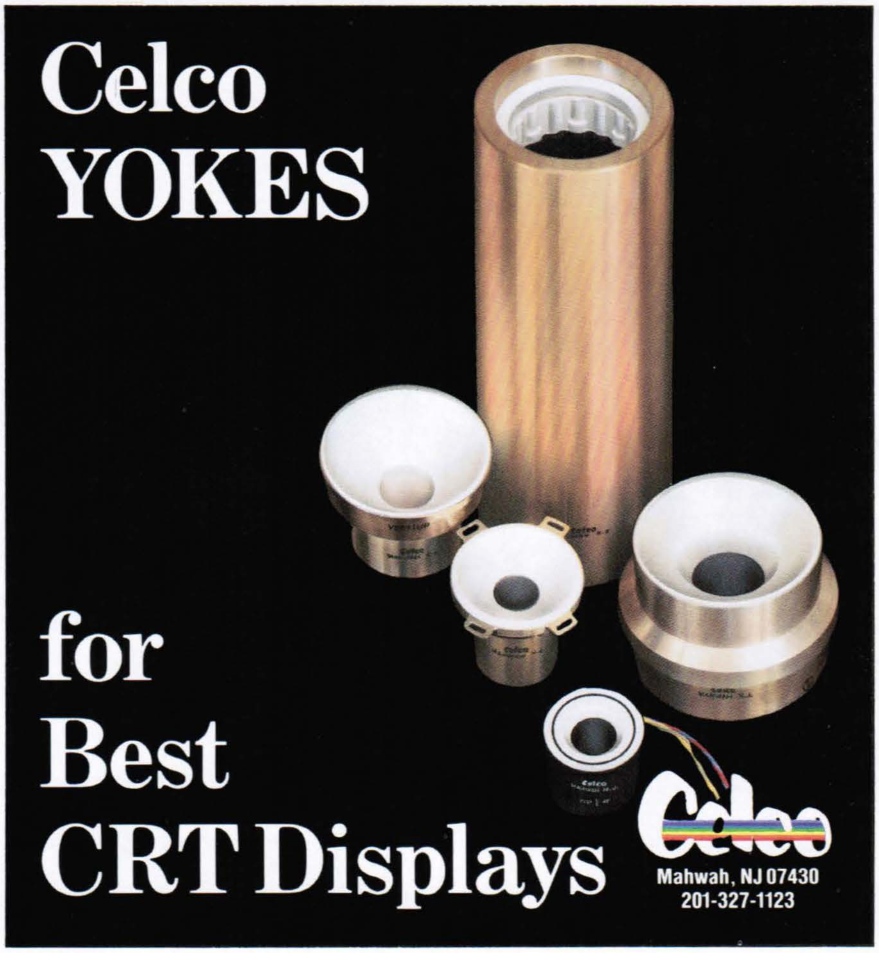

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can keep a list of the articles you cite most frequently, and almost instantly call up those having any given author or any given character string in their titles or any given year of publication. (Combined searches are possible, too, such as for any citation including both "C. Infante" and "1988.")

There are a variety of special features, including the ability to "grab" the last screen from the program you've just hot-keyed out of and make it a new note. But what makes *Tornado* so useful is its directness, flexibility, and utter naturalness of use. Used in the most obvious way, it can clean up most of the odd bits of paper lying around a desk. Organizing larger tasks around the program's strengths is a later step. Maintaining an easily accessible "rolodex," a glossary of technical terms, a record of components and suppliers, and "flashcards" of Japanese phrases and their translations are all possibilities.

I am not generally a software enthusiast. If a piece of software does its job reasonably well, I'm willing to adapt myself to its deficiencies—just so long as I can get my job done and avoid learning another program. But *Tornado* is one computer tool I'm glad I don't have to work without.

Tornado requires an IBM PC/XT/AT/PS2 or fully compatible computer running under MS-DOS version 2.0 or later; MDA, CGA, EGA, or Hercules display; 54K RAM plus what is required for data storage (6K minimum). The program is supplied on either a single 5¼-in. or 3½-in. disc. It was tested on a Leading Edge Model D with 640K, hard drive, and Hercules graphics, and on a Sanyo MBC 775 with 265K, 5¼-in. floppy drives, and CGA graphics. ■