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VISUALIZATION: STATE OF THE ART
UPDATE

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VISUALIZATION: STATE OF THE ART
UPDATE
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VIDEOTAPE TRANSCRIPT

Many segments in this program were captured by re-scanning display screens with a high-quality NTSC video camera. Temporal aliasing (strobing and banding) sometimes occurs due to differences between the camera scan rate and screen refresh rates.

INTRODUCTION

Hello. My name is Laurin Herr and I will be your host for the next 60 minutes as we review interesting recent developments in computer graphics. This tape is an update of the 160-minute Special Issue 30 of the SIGGRAPH Video Review entitled Visualization: State of the Art.

Our major stories this time around are:

- high-end workstations and parallel processors
- new advances in rendering
- the emergence of color desktop pre-press systems
- the blossoming of color I/O peripherals
- video and how it affects visualization
- and scientific visualization, one of this year's hottest themes.

We have candid commentary from important people, like Carl Machover, Henry Fuchs, Turner Whitted and even Benoit Mandelbrot, the father of fractals.

Remember, this tape comes with a companion text that includes additional information about products shown and people interviewed.

<u>ANIMATION - 3-D TERRAIN MAPPING</u>

PIXAR - 1988
Data courtesy of U.S. Geological Survey

HIGH PERFORMANCE PROCESSORS

(LAURIN HERR on camera)

Our lead story is about high performance. It's a story with serious implications for people interested in workstations, rendering and parallel processing.

(HENRY FUCHS on camera)

I think that what is exciting at the high end is that this year for the first time parallel processing has come to the exhibit floor in a big way. Last year there was virtually no workstation that offered interactive graphics that was using parallelism.

IMAGE - MEIKO COMPUTING SURFACE

(HENRY FUCHS off camera)

You could say that the Meiko computing surface, with many hundreds of thousands of dollars and had lots of transputers, was parallel and in some sense a workstation, but not in the sense that most people understand it.

IMAGE - AT&T PIXEL MACHINE 964d

You could perhaps argue that the AT&T Pixel Machine, which made its debut here last year, which was a very interesting machine that you covered so well in your tape, was a workstation, but to most people it wasn't really; it was a special purpose graphics engine.

But now we have not only the AT&T Pixel Machine.

IMAGE - STELLAR GS1000

We have the Stellar.

IMAGE - ARDENT TITAN

We have the Ardent.

IMAGE - PIXAR RenderMan

We have Transputer boards in the Pixar machine.

IMAGE - SUN TAAC-1

We have the TAAC accelerator integrated with Sun, since Sun bought out Transcept.

And so all these companies, plus some others, are showing us much higher performance graphics than we had previously at that high end, at sort of the $75,000 to $100,000 range.

(HENRY FUCHS on camera)

And what's exciting about that is that this is one of these ages with a thousand flowers blooming and it's hard to tell, because each one is almost a new species in its own right.

I think that when we look back on this conference 10 years from now, I think that will be one of the things that we'll recognize, that parallel interactive graphic systems finally arrived.

Additional Product Information
MEIKO COMPUTING SURFACE(see page A-1)
AT&T PIXEL MACHINE 964 d (see pages A-3, A-4)
STELLAR GS-1000 (see page A-13)
ARDENT TITAN (see page A-12)
SUN 4/150 (see page A-20)
SUN TAAC-1 (see page A-19)

APOLLO DN-10000

(LAURIN HERR off camera)

Apollo, for example, has developed the DN-10000, a parallel reduced instruction set multiprocessor featuring 64-bit architecture and sophisticated data flow compiler techniques. There can be up to 4 RISC-based CPUs, each with an independent floating point co-processor. Each CPU module generates up to 30 MIPS and 36 MFLOPS.

Here the DN-10000 is being used under Apollo's Network Compute Server to help generate a ray traced image. The ray tracing computations are being distributed to all available workstations on the network, with each workstation being sequentially assigned a part of the job. The effect is a kind of loose, but very cost-effective parallelism.

Additional Product Information
APOLLO SERIES 10000 PERSONAL SUPERCOMPUTER
(see page A-5)

HEWLETT-PACKARD TurboSRX

Hewlett-Packard has upgraded its SRX graphics sub-system with multiple transform engines that allow parallel processing of geometry transformations. As a result, the new TurboSRX is three to 10 times faster than its predecessor, capable of 80,000 to 85,000 polygons per second. It also features improved Z-buffering and support for higher order B-splines.

The TurboSRX also has enhanced pixel pan and zoom. Notice the anti-aliasing quality of HP's current state of the art.

Additional Product Information
HEWLETT-PACKARD TurboSRX MODELS 370 AND 835
(see page A-7)

HEWLETT-PACKARD TurboSRX GRAPHICS ANIMATION INTERFACE CARD

HP has also introduced the NIMBUS card for high speed DMA access that allows downloading of pixels from physical memory to frame buffer memory at the rate of 12 megabytes per second. The 835 TurboSRX seen here is capable of storing 96 megabytes in host memory. The user can specify frame resolution and bit depth, thus varying the number of frames that can be stored and their rate of playback.

ANIMATION - DINOSAUR STUFF
John Donkin - 1988
Ohio State University ACCAD

Additional Product Information
HEWLETT-PACKARD TurboSRX GRAPHICS ANIMATION INTERFACE CARD
(see page A-9)

SILICON GRAPHICS IRIS 4D/GTX

Silicon Graphics' new GTX upgrade for its family of IRIS 4D/GT workstations is rated at 20 MIPS and 2 MFLOPS. It adds a second CPU, enabling graphics processing and analysis processing to run in parallel. The 4D/GTX can draw 100,000 independent 4-sided Gouraud shaded, Z-buffered polygons per second. This represents a doubling of polygon performance over the IRIS 4D/80GT.

Here is a demonstration of a pre-computed radiosity room. It took about 15 minutes to calculate each frame using the GTX. We are seeing an interactive fly-through built with a total of 40 frames computed at 1280 x 1024 x 24 bits/pixel displayed with double buffering.

In this demonstration, the 2 CPUs of the 4D/GTX operate in parallel to compute a very complex ray-traced image. The top processor does analysis and graphics display, while the bottom processor does only analysis, allowing it to race ahead due to the lighter processing load. Total elapsed time is 79 seconds.

Additional Product Information
SILICON GRAPHICS 4D/GTX
(see page A-10)

(THOMAS JERMOLUK on camera)

We've made some very major breakthroughs in the parallel aspect of the algorithms on the host CPUs. A user no longer has to know how many processors are in the box. When they write their application for the system, it automatically parallelizes behind them, both with the compiler and with the UNIX system itself, to spread that application across the entire processor complex. Therefore, if they're running on our four-processor complex or our one-processor complex, it still does the work for them and they never know which one they're on, other than the fact that it runs faster.

SILICON GRAPHICS POWER IRIS SERIES

(LAURIN HERR off camera)

Silicon Graphics has also introduced what it calls its POWER Series of multiprocessor workstations capable of accommodating two of the dual processor boards seen here, making a total of four CPUs delivering 80 MIPS and 16 MFLOPS. Each board contains a pair of 25 MHz MIPS R3000 CPU chips, companion floating point coprocessors and memory.

Here again is the same ray tracing example, this time running on a 4 CPU POWER series. Elapsed time is 42 seconds, not quite half that of the 2 CPU GTX seen earlier. This real time demonstration on a 4 CPU POWER series incorporates full dynamic interplay between shape, weight, surface area, flexibility, elasticity, gravity, and air pressure to create an interactive visualization.

Additional Product Information
SILICON GRAPHICS POWER IRIS SERIES
(see page A-11)

ARDENT TITAN

(LAURIN HERR off camera)

The Titan graphics supercomputer from Ardent is another new product extending the definition of high performance. It uses a 64-bit parallel architecture found in supercomputers like the CRAY X-MP to achieve a peak processing rate of 64 MFLOPS. It also incorporates 52 image planes and parallel pixel processors. It is reportedly capable of displaying 200,000 full-color 3-D shaded polygons per second.

Additional product information
ARDENT TITAN
(see page A-12)

STELLAR GS1000

(LAURIN HERR off camera)

Competing head to head with Ardent's Titan is the Stellar GS1000. This system utilizes an innovative architecture known as Synchronous-Pipeline Multi-Processor, implemented with application-specific integrated circuits. It has a peak performance of 25 MIPS and 40 MFLOPS. It can reportedly display 150,000 gouraud shaded, Z-buffered polygons or 600,000 3-D vectors per second.

Additional Product Information
STELLAR GS1000
(see page A-13)

(TURNER WHITTED on camera)

If you characterize the high-end workstations, you should group Stellar and Ardent together. They're quite similar in their design. One thing that distinguishes them from other workstations that we've seen is that they have high speed vector floating point units. If your application can take advantage of that high speed vector floating point unit, you're going to get tremendous throughput. Well, it turns out that, for instance, the geometric calculations that are typically done in the graphic pipeline will fit into that very nicely. That means that you've eliminated the need for any kind of specialized geometry processor at that point and can just run it through your general purpose floating point unit.

Both machines also have specialized raster processors that are quite different. In the case of Ardent, they use off-the-shelf tiling chips, made by Raster Technology. In the case of Stellar, they've built their own footprint processor, which was described in the technical session.[1] There are great differences and similarities between the way those engines work, but to a great extent that's hidden from an application.

(LAURIN HERR off camera)

We also asked Henry Fuchs to characterize the key architectural points of first the Stellar and then the Ardent.

(HENRY FUCHS on camera)

The Stellar has four interleaved processing streams that do essentially all the general purpose calculations plus most of the calculations that you would normally associate with the front end of a graphics system.

(HENRY FUCHS off camera)

It's a general purpose system in the sense you have four completely distinct processors there and you could use one, two, three or four of these for whatever you want, dynamically switching between them. It has then a graphic component which is basically for rendering except that both the input and the output of that graphics component is from memory. And so you have in the Stellar machine for perhaps the first time a situation in which you can re-use the output of the graphic rendering of the image at very efficient rates, because it is no longer at the end of a graphics pipeline close to the monitor; it is in main memory just as close as any other part of main memory.

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[1] see the ACM/SIGGRAPH '88 conference proceedings Computer Graphics, Vol. 2, Number 4, August 1988, page 255. "A Display System for the Stellar Graphics Supercomputer Model GS 1000," by Apgar, Bersack, and Mammen.

(HENRY FUCHS off camera)

The Ardent is an organization that starts with, I believe, the assumption that what you want to do is build the best possible machine with essentially off-the-shelf parts. You have a common bus and you have a shared memory. You have several processors on that common bus and you have a graphics system on that common bus also. And you can run multiple jobs on the various processors, and the assumption is that they are relatively independent jobs in that so collisions between the jobs running on different processors will occur only infrequently. And if that is the case, and you have enough bandwidth to the memory, then two processors will run almost twice as fast as one processor. And you might be able to put in three and four and five processors and so on.

(HENRY FUCHS on camera)

Now, of course, at a certain point the access to memory by all these different processors going at the same time is going to saturate the available memory bandwidth, and so you're going to get some slowdown. And you have collisions also if jobs running on two processors want to access the same piece of memory. And so the designers built in some hardware mechanisms to make sure that when these collisions occurred that they are handled in the appropriate way.

ALLIANT VFX/80

(LAURIN HERR off camera)

An even higher performance integration of general purpose computing with graphics comes from Alliant Computer Systems which recently acquired Raster Technologies.

They have integrated the Alliant FX/Series of parallel processing mini-supercomputers with the Raster Technologies GX4000 parallel processing 3-D color graphics system. The result is the VFX series of so-called "visual supercomputers." The VFX/80 running here can simultaneously support up to eight visualization users and 64 computational users. It has a rated performance of nearly 190 general purpose MFLOPS and 160 graphics MFLOPS. Eight 64-bit parallel vector processors are tightly coupled to eight parallel graphics arithmetic processors via high speed shared memory.

Additional Product Information
ALLIANT VFX/80
(see page A-14)

ALLIANT/RASTER TECHNOLOGIES GX4000

Alliant also supplies the GX4000 family of graphic accelerators for the Sun-3 and Sun-4 platforms. Here we see the real time output of an eight-processor GX4000 running concurrent tasks under the Sun NeWS windowing environment with PHIGS+.

Additional Product Information
ALLIANT/RASTER TECHNOLOGIES GX4000 GRAPHICS ACCELERATOR SUBSYSTEM
(see page A-15)

(TURNER WHITTED on camera)

If you're evaluating parallel architectures for your application, you must pay careful attention not just to interprocessor communications, but memory bandwidth, of all things.

REAL-TIME EXAMPLES - APOLLO NETWORK COMPUTE SERVER
ALLIANT/RASTER TECHNOLOGIES GX 4000
SILICON GRAPHICS IRIS 4D/GTX
HEWLETT-PACKARD TurboSRX
SUN TAAC-1
STELLAR GS1000
ARDENT TITAN
AT&T PIXEL MACHINE 964d

(TURNER WHITTED off camera)

In graphics, we have had such an appetite for cycles that that's all we thought about for so long. When we didn't have cycles, we went for memory intensive solutions. Now we do have cycles, we're going to CPU intensive solutions but we've maintained that memory appetite as well.

Now that we are processing things faster and faster, we find that we've got bottlenecks caused by memory bandwidth. I'll give you a good example. No one graphics architecture or display architecture that I've seen handles texture mapping efficiently. You can put up as many Phong shaded triangles as you want, but when you start texture mapping them in any of these specialized rendering boxes, you've got a serious memory bandwidth problem. And that is, how are we going to page texture maps, especially if we go with lots of multiple texture maps? I've heard people talk about putting texture mapping into tiling engines. Fine. That handles the CPU side of things. How are you going to get the texture maps to the processing engine? I don't know how to do it. Now if you distribute your rendering engine over several processors, how do you know you've got the right texture map in the right processor?

(TURNER WHITTED on camera)

So in that sense anything other than shared global memory gives you serious texture mapping bottlenecks. And until somebody comes up with a solution to that, I'm not really sure that this massive parallelism that we're seeing is going to help the real high end applications.

On the other hand, if you just want to put up a few Phong -- I'll give them credit. You can put up hundreds of thousands of Phong shaded triangles very fast. Okay. Next year they'll worry about the texture mapping bottleneck.

(CARL MACHOVER on camera)

One of the issues the industry constantly faces is how do we define a low priced, medium and high priced or performance unit? And we -- every time we try to define it by specific levels of performance -- an 8-bit microprocessor versus a 16-bit microprocessor, a 1-MIP unit versus a 4-MIP unit -- every time we do that, we get a new product announcement that changes scale. What I think happens is that the price spans stay constant. We constantly have a range of products in the $10,000 range. We will constantly have a mid-range product at $20,000 to $40,000. And we'll constantly have a high range product in the $50,000 to $100,000 range. From a computing standpoint, whatever the high range product was today, the mid-range product will be in a year-and-a-half from now and the low range product will be in a year-and-a-half from then. There is a difference, however, between computational performance and graphic performance. The time cycle for the graphic performance is not as aggressive. And whatever is the graphic performance of the high end unit today, it's probably going to take three years to become the graphic performance of the mid-range, and another three years to become the graphic performance of the low range.

IMAGE - WATER STRIDER
Softimage - 1988

Additional Product Information
SOFTIMAGE 4D CREATIVE ENVIRONMENT
(see page A-16)

RENDERING

(LAURIN HERR on camera)

Rendering has always been one of the great "cycle hogs" of computer graphics. Despite the overall trend to faster general purpose hardware, there has been considerable development of special-purpose processors that are designed to accelerate specific critical aspects of the rendering task--things like tiling engines, shading engines, and pixel arrays. Increasingly, these are implemented in parallel to increase throughput. As a result, it is perhaps now reasonable to consider for the first time the practical implementation of photorealistic synthetic image generation on desktop systems.

PROGRESSIVE REFINEMENT RADIOSITY ON HP TurboSRX

(LAURIN HERR off camera)

Already, Hewlett-Packard has implemented a progressive refinement approach to fast radiosity image generation developed at Cornell that takes advantage of the special-purpose rendering hardware in the HP TurboSRX.

This new approach is described in the SIGGRAPH '88 proceedings as capable of providing "a useful solution almost immediately which progresses gracefully and continuously to the complete radiosity solution. In this way, the competing demands of realism and interactivity are accommodated. The technique brings the use of radiosity for interactive rendering within reach..."[2]

Additional Product Information
HP TurboSRX (see page A-7)

[2]see the ACM/SIGGRAPH '88 conference proceedings Computer Graphics, Vol. 2, Number 4, August 1988, page 75. "A Progressive Refinement Approach to Fast Radiosity Image Generation," by Cohen, Chen, Wallace, and Greenberg.

PIXAR RenderMan WITH PROTOTYPE ACCELERATOR BOARD

Another approach to issues of photorealistic rendering comes from Pixar which has introduced what it calls the RenderMan interface, demonstrated here in real time running on an accelerator board developed by Pixar which uses multiple T-800 Transputers. We talked with Tom Porter of Pixar about RenderMan.

(THOMAS PORTER on camera)

Renderman is an interface proposal that Pixar has made to the industry. It is an interface between a 3-D modeling system and a 3-D rendering system, an interface suitable for photorealistic image synthesis. It's a way of passing 3-D scene description information down to a renderer.

ANIMATION - VOLUME RENDERED CYLINDER HEAD
PIXAR - 1988
Data courtesy of ARACOR

(THOMAS PORTER off camera)

What it means for the user -- what we see coming down the line two or three years from now, perhaps five years from now, is that an architect, for example, will sit down at a workstation, at a graphics machine, at a CADD system, and he will effectively be riffling through a digital catalog of architectural styles, of materials, for example, of brick textures, and an interior decorator would riffle through a digital catalog of wallpaper or rug styles. I foresee, just as the clip-art world exists in the Macintosh domain, I expect many opportunities for modeling companies and other third parties to come in with their own tools built on top of the Renderman interface.

(THOMAS PORTER on camera)

Pixar is in the business, long term, of building rendering systems, whether it's software running on a workstation or on a smaller machine or hardware accelerators for a workstation or for a PC -- in fact, we've come to SIGGRAPH this year not announcing any products, but with a technology exhibit showing off accelerator boards on a Silicon Graphics machine, on Sun workstations, on in fact a Compaq 386 to indicate that we as a company will be building rendering accelerators, building them faster, better, cheaper over time, and we will forevermore be using this RenderMan interface.

Additional Product Information
RenderMan INTERFACE
(see page A-18)

(LAURIN HERR off camera)

The other major development in rendering is volume visualization. Henry Fuchs explains some basic concepts and the role of parallelism in this new research area.

(HENRY FUCHS on camera)

Basically, volume rendering is rendering of data sets which are represented by volume rather than by surface.

So imagine, for instance, a set of CT scans of the body. Each one of those slices really represent not a single slice, but a little slab, almost like a slice of bread. So it represents some fixed increment. When you have a hundred slices what you have is like a whole loaf of bread and you would like to represent that as a volume.

SUN 4/150 TAAC-1

EXAMPLES OF VOLUME RENDERING

1. SUN 4/150 TAAC-1
2. ANIMATION - VOLUME RENDERED FEMALE HEAD
   Fuchs - Levoy - 1988
   University of North Carolina, Chapel Hill
   Note: This animation was done by Mark Levoy as part of his doctoral dissertation; H. Fuchs, advisor.

(HENRY FUCHS off camera)

That is you would like to be able to melt away the skin and see the muscles underneath. For exploration what you would like is to deal with the original data, but the original data is an enormous amount of data points, because imagine that you've got 400 by 400 points and you've 50 or 100 slices and you've got many, many millions of data points.

And until recently, we haven't had the general purpose computation power or the graphics systems which could deal with that.

Additional Product Information
SUN TAAC-1 APPLICATION ACCELERATOR
(see page A-19)
Additional Product Information
SUN 4/150CXP WORKSTATION
(see page A-20)

(HENRY FUCHS on camera)

Without parallelism there isn't enough compute power to generate volume rendered images of sufficient detail sufficiently fast to make them regularly available. It's as simple as that.

If we had some magic technology which could give us factors of 10 and 20 within a year or two, then we wouldn't need parallelism as much. But it turns out that we've pushed the technology very hard as it is, and the cycle time of memories is not getting all that much faster. And what that means is, if you want more compute cycles, if you want to do more multiplications in a second, more additions or comparisons, more of whatever in a second, you need to use multiple processors. And without that kind of capability you simply can't get these kind of renderings done fast enough.

ANIMATION - RAY-TRACED DIAMONDS
Toshiyasu L. Kunii - 1988
The University of Tokyo

COLOR DESKTOP PUBLISHING

(LAURIN HERR on camera)

Our next story is about color pre-press, an integral part of the publishing industry, itself an enormous market worth more than $20 billion per year in the U.S. alone. To date, computers have penetrated primarily the upper end of this business, capturing significant market share in color separation and retouching. More recently, desktop systems have developed rapidly to the point where publication-quality production is now practical. Now, color is moving to the desktop; a vertical integration is beginning.

IMAGE - A MUSEUM OF CONSTRUCTIVIST ART [ACM SIGGRAPH '88 CONFERENCE PROCEEDINGS - COVER IMAGE]
Cornell University - 1988
Program of Computer Graphics

(LAURIN HERR off camera)

One aspect of this integration is the ability to directly produce color separations from synthetic images in digital form.

(RICHARD J. BEACH on camera)

The cover of this year's SIGGRAPH '88 Proceedings is an example of an image that has never been photographed but appears on the proceedings cover in the print medium from a laboratory where it was designed as a photorealistic synthetic image. With that kind of technology of going from a monitor in a laboratory at some distant point from a production site where it can be produced in the quantity and the copy quality that has come to be a trademark of the SIGGRAPH proceedings, it's an important advance of being able to extend the range of where the images that are created in computer graphics laboratories can actually be presented, viewed either in a video presentation or in a slide presentation, as well as in a printed piece.

CROSFIELD STUDIO 875 PRE-PRESS SYSTEM

(LAURIN HERR off camera)

Once the SIGGRAPH '88 cover image had been carefully converted from the original RGB frame buffer data into YCMK color separation data, it was processed on a Crosfield digital color system to produce the four film negatives and a color proof needed for the actual printing.

The Crosfield pre-press system seen here, the Studio 875, manages both the geometric dimensions required for interactive page composition, and the high-resolution color data required to do interactive color correction, retouching and full color page design.

Full feature color pre-press systems like this one from Crosfield, and others from companies like Scitex, Hell and Dainippon Screen have been in use for more than a decade and are capable of the finest graphic arts quality.

But the high price of entry has prevented them from spreading much beyond their initial market niche of large-scale professional color printing companies.

Additional Product Information
CROSFIELD STUDIO 875 PRE-PRESS SYSTEM
(see page A-21)

CROSFIELD SYNERVISION II COMPOSITION CENTER

Now, though, Crosfield, like its major competitors, is offering lower-priced desktop systems based on PC/AT and MAC II platforms that can communicate with each other and with full-feature pre-press systems.

The Crosfield Synervision II system allows interactive positioning, color correction and retouching of continuous tone images input via color scanner or imported electronically from another system. Synervision II is built around a PC/AT enhanced with Crosfield's custom-designed 40 MIPS Raster Image Processor board and a 1024 x 768 resolution color frame buffer.

Additional Product Information
CROSFIELD SYNERVISION II COMPOSITION CENTER
(see page A-23)

CROSFIELD LIGHTSPEED COLOR LAYOUT SYSTEM

The Crosfield Lightspeed Color Layout System is built around a MAC II and allows interactive page layout using the Postscript page description language. This system allows flexible layout of headline and body text in various fonts, and the incorporation of color images either input via scanner or imported via Ethernet from the Synervision II system. Output can be to color printers, film recorders or other pre-press systems.

Additional Product Information
CROSFIELD LIGHTSPEED COLOR LAYOUT SYSTEM (version 1.5)
(see page A-24)

CROSFIELD PRODUCERxp

Other Crosfield software packages running on personal computers can be used to feed the PRODUCERxp slide making system for creation of presentation quality graphics. The PRODUCERxp can combine charting formats with spreadsheet data and text. Screen resolution is 640 x 434, but output resolution is either 8,000 or 4000 lines, depending on which film recorder is used to create the final slide.

Images can also be sent via modem to the Synervision II system for further photo-composition work.

Additional Product Information
CROSFIELD PRODUCERxp
(see page A-25)

PANSOPHIC STUDIOWORKS
LINOTRONIC L300

Pansophic has chosen to build its desktop color publishing system on a Compaq 386 integrated with a Howtek 300 dpi flatbed scanner and the PostScript-capable Linotronics L300 film recorder with its associated raster image processor and developing unit.

Additional Product Information
PANSOPHIC STUDIOWORKS
(see page A-26)
Additional Product Information
LINOTRONIC L300
(see page A-30)

The Pansophic software is broken into sub-packages. Brushwork is used for color retouching of images scanned in or imported from other computer graphics systems. It supports features like masking, zooming, area move and variable brushes.

Pagework is the software for page layout and text composition. This is where column formats, margins, and gutters can be specified. Images can be called from disk and placed on the page. Headlines can be inserted. Run-around lines can also be set to allow text to flow freely around the images when it is brought in from disk.

The final stage of the process uses the Presswork software to set color separation parameters and perform color correction. The user can interactively make gamma corrections, adjust contrast and alter brightness. Here we see the cyan color component being increased as we watch.

AVALON PHOTOMAC

The MAC II is the platform of choice for the Avalon PhotoMac system, targeted at in-house desktop publishing departments, photographers, catalog houses and smaller graphic design companies.

PhotoMac provides a variety of graphic arts tools, accessible from within the familiar MacIntosh user interface environment. These include the use of masks, or friskets, to separate different parts of an image for color manipulation or image retouching. Images can be pasted onto page layouts by exporting file formats common to other Macintosh applications.

Virtual memory architecture means very large images up to 32,000 x 32,000 can be handled with just two megabytes of RAM. The PhotoMac displays images on the MAC II using only eight bits per pixel. But it can accept 24-bit full color images from scanners or other systems, and it can output 24-bit full color images to color proofing devices. It can also generate color separation files with full dynamic range for export to the Linotronics. Here, an Eikonix 1435 color slide scanner is used for image input. And a Kodak SV6500 is used for color proofing.

Additional Product Information
AVALON PHOTOMAC
(see page A-32)

(LAURIN HERR on camera)

As good as the [desktop color pre-press] systems we've just looked at are, they only represent the first wave of product. Significant technical issues remain.

(RICHARD J. BEACH on camera)

The reality of desktop color has to confront a number of scale issues. A color image is certainly three times more information than a black-and-white gray image. It's also the case that those images are a great deal more information than line art and typography, because it takes a lot more information to provide the data at each of the sample points than it does just to determine the end points of vectors.

And so as a consequence, you have this evolution from line art to black-and-white gray scale images to color images. And that's an increasing quantity of data.

Therefore, you need to be able to provide a better substrate that's able to deal with the larger volume of data on file storage devices, the larger volume of data on scanning systems, the larger volume of data in communications systems.

And what you'll see is an evolution to a variety of innovative architectures that try and attack those kinds of problems--for instance, bringing the scanning and printing stations together and keeping that bulk of data in that location where there is high bandwidth communication.

And it's possible to conceive of other kinds of architectures that rely on innovations and high speed communications. Parallel architectures seem like a natural for color rendering problems. You have the very vast amount of data that needs to be imaged and it seems reasonable to expect parallel architectures to be able to take that data and do different color transformations on the way out to a marking device.

IMAGE - A LILAC TWIG

Przemyslaw Prusinkiewicz
James Hanan
F. David Fraccia
University of Regina - 1988
Department of Computer Graphics

COLOR INPUT/OUTPUT PERIPHERALS

I. Input Scanners

HOWTEK SCANMASTER DIGITAL COLOR SCANNER

(LAURIN HERR off camera)

Inexpensive color scanners, such as this 300 dpi flatbed unit from Howtek, are already a popular component of desktop color publishing systems.

Additional Product Information
HOWTEK SCANMASTER
(see page A-29)

EIKONIX MODEL 1435 SLIDE SCANNER

More recently, higher resolution 35 mm slide scanners have become commercially available. This Eikonix 1435 uses a 4096-element linear CCD array and a color filter wheel to attain scanning resolution of 2800 dpi with dynamic range of up to 12 bits per pixel per color.

Additional Product Information
EIKONIX 1435 SCANNER
(see page A-33)

NIKON LS-3500 SCANNER

Nikon is another company introducing a high-resolution 35 mm slide scanner. The LS-3500 offers scanning resolution of nearly 4400 dpi with a dynamic range of 8 bits per pixel per color.

Additional Product Information
NIKON LS-3500 SCANNER
(see page A-34)

II. Thermal Ink Transfer Printers

QMS COLORSCRIPT 100

QMS, a company well-known for its monochrome PostScript laser printers, has integrated a 300 dpi thermal ink transfer marking engine from Mitsubishi Electric with its own external color PostScript controller.

The new printer, called the QMS ColorScript 100, accepts color PostScript files and is capable of outputting seven primary colors [three primaries, complementaries, and black] and a large number of dithered secondary colors onto either paper or transparency film. Output of an 8 1/2 x 11 inch page takes approximately one minute. An 11 x 17 inch page takes approximately two minutes.

Additional Product Information
QMS COLORSCRIPT 100
(see page A-35)

HITACHI PROTOTYPE THERMAL INK TRANSFER PRINTER ENGINE

Hitachi's new 400 dpi thermal ink transfer engine promises to further extend the application of this particular printing technology.

In addition to its higher resolution, color dot registration of the Hitachi unit has been improved to better than 30 microns using a new rotating drum-type paper path that also helps increase output speed to approximately one minute for an 11 x 17 page.

Additional Product Information
HITACHI PROTOTYPE THERMAL INK TRANSFER PRINTER ENGINE
(see page A-36)

III. Thermal Dye Sublimation Printers

KODAK SV6500 THERMAL DYE TRANSFER PRINTER

(LAURIN HERR off camera)

Much richer color is possible with new thermal sublimation dye transfer printers appearing from various manufacturers, such as the Kodak SV6500 seen here.

Thermal sublimation dye transfer technology permits variable color density at each pixel. In this case, 256 levels per color per pixel for up to 16.7 million colors per pixel, yielding high quality continuous tone prints.

The SV6500 accepts NTSC and RGB video signals or digital data as input to an internal 512 x 512 x 24 bit frame buffer. It outputs a 4 x 5 inch print at 135 dpi in about 90 seconds. Cost per print is $1.

Additional Product Information
KODAK SV6500 THERMAL DYE TRANSFER PRINTER
(see page A-37)

NIKON CP-2 THERMAL DYE TRANSFER PRINTER

Nikon also offers a thermal sublimation dye transfer printer called the CP-2. Images can be input through a GP-IB or SCSI interface or as an analog RGB video signal.

Print size is 6 x 7 inches with a resolution of 200 dpi and 256 intensity levels per color per pixel. Printing time is 2 minutes 40 seconds on pre-cut coated paper.

Additional Product Information
NIKON CP-2 THERMAL DYE TRANSFER PRINTER
(see page A-38)

SONY MAVIGRAPH UP-5000 THERMAL DYE TRANSFER PRINTER

Sony's thermal sublimation dye transfer printer, the Mavigraph UP-5000, outputs an image slightly less than 6 x 8 1/2 inches in size onto paper or transparency film. Output time is about one minute. Pixel resolution is 720 x 466, with 256 intensity levels per color per pixel.

Additional Product Information
SONY MAVIGRAPH UP-5000 THERMAL DYE TRANSFER PRINTER
(see page A-39)

IV. Ink Jet Printers

IRIS GRAPHICS 3024 COLOR PRINTING SYSTEM

The Iris Graphics 3024 printer uses patented continuous-flow variable-spot-size inkjet technology to print high quality 300 dpi color images that are suitable for color proofing and pre-production presentations.

Four water-soluble inks--cyan yellow magenta and black--are pumped at 600 pounds per square inch through four glass capillary nozzles with interior diameters of slightly more than 10 microns -- about one third the size of a human hair. Each nozzle is stimulated by a crystal vibrating at 1 MHz to produce one million droplets of ink per second, each 15 microns in diameter.

As many as 31 droplets for each color can be deposited on the paper at each pixel location, resulting in a variable dot size that effectively produces 32 intensity levels per color per pixel. Color look-up tables for 4x4 pixel matrices can be used to increase effective dynamic range. Interpixel and global color averaging in software further enhance continuous tonal quality of the print.

Any water-absorbing media can be printed on as long as it can be taped to the drum. Maximum sheet size is 24 inches square. A 12 x 18 inch image can be produced in as little as 6 minutes. Cost per image is about $2, depending upon the size.

[Note: Average cost per typical image is 65 cents, according to the manufacturer's most current estimates.]

Additional Product Information
IRIS GRAPHICS 3024 COLOR PRINTING SYSTEM
(see page A-40)

V. Color Copiers

ILFORD CIBACOPY CC-120 COLOR COPIER

(LAURIN HERR off camera)

Ilford, a major manufacturer of photographic films, offers a photographic copier that makes color copies from 35 mm slides, chromes and flat reflective art. The CC-120 model seen here requires six minutes for the first copy but has a maximum throughput of 120 copies per hour.

Print resolution is extremely high at 450 dpi. Output is 8 1/2 x 11 inches. The maximum size for flat art input is 12 x 17 inches with built-in reduction/enlargement from 65 to 145 percent.

The cost is 92 cents per copy on paper, $1.84 per copy on transparency film.

Additional Product Information
ILFORD CIBACOPY CC-120 COLOR COPIER
(see page A-41)

COLOROCS COLOR COPIER

Colorocs has demonstrated prototypes of a new type of color laser printer packaged as both a color copier and as a color printer. The final production models will reportedly be able to make continuous tone images similar to what is currently available from thermal ink transfer printers, but at higher speeds and greater resolution.

The print engine is rated at just under six pages per minute for an 8 1/2 x 11 page and just under three pages per minute for an 11 x 17 inch page.

A key aspect of the Colorocs print engine is assembly of the full color image on an intermediate photosensitive belt before it is transferred to the paper in a single pass. This permits a short, straight paper path which in turn increases reliability and speed. OEM customers already include Sharp, Texas Instruments and QMS.

Additional Product Information
COLOROCS SERIES 1 COLOR PRINT ENGINE: COPIER AND PRINTER
(see pages A-42, A-43)

(CARL MACHOVER on camera)

The problem with color historically was fourfold -- devices to show color were expensive, devices to produce color were too expensive, the cost per color copy was too expensive, and the cost for multiple copies was too expensive. In the last few years we've broken three of those barriers. I can buy devices that show color for costs that are negligibly different than monochromatic. Like hard copy devices, there's essentially no difference in cost between color and black and white hard copy. My cost per copy in some areas is still less in black and white. If I want to go to a laser output, my cost for black and white is still considerably less. It still costs me considerably more to get high volume color. But three out of four ain't bad, okay? With the development of products that you see here at the show, like Colorocs, for example, it looks like within a year or two relatively inexpensive, high volume color hard copy will be available. Once I have high volume, inexpensive color hard copy, the inevitability of color electronic publishing, it seems to me, is obvious.

(RICHARD J. BEACH on camera)

The advances in the devices give the system integrator a variety of choices as to what color proofing systems he might choose. You've got the inkjet devices with larger formats. You've got the thermal transfer with photographic quality. You've got the color Xerography for multiple copies. You're beginning to see the system integrated with a lot of choices, especially in the advances of device-independent graphics and the page description language capabilities in dealing with color. You've got a much richer set of choices for the people who are integrating systems and producing the kinds of color pre-press, color publication systems.

(JOEL ORR on camera)

PostScript has emerged as an important standard page description language. Now I don't know if we should use the word "standard" since it is a private product and not a public domain product. Nevertheless, a lot of people are adopting it and this is because of Apple. Now that there are color PostScript hard copy output devices, such as the QMS device that has been shown here, I think that is going to contribute significantly to the pre-press arena.

And we're seeing a number of products--the Avalon, the Crosfield and several others--that are tying together the front end, that is, the image creation, the image generation, the image manipulation, the electronic darkrooming and all of that, and doing the kinds of things that hitherto you could only do on a half-million-dollar Scitex system. You're now able to do them on a system that costs a small number of tens of thousands of dollars that is essentially a desktop system. I think that's very important. That's very significant. Just like desktop publishing at large--the ability to use book quality typefaces on the desktop and to produce them trivially in a business letter has led to a radical change in the published materials that we see. I think the ability to output in color using PostScript in this way is going to make a big change. However, we've seen a lot of garbage as a result of desktop publishing and I think we're also going to see a lot of *color* garbage now as a result of having color PostScript output.

EKTRON LASER IMAGE RECORDER MODEL 811

(LAURIN HERR off camera)

All this is not to say that black and white printing technology isn't developing at the same time. This is the EKTRON 811 laser image recorder. It can output an 8 1/2 x 11 inch black and white image using either dry silver halide paper or film in less than two minutes.

Image quality is outstanding. Resolution is 535 dpi. 4200 x 5500 pixels can be recorded on a page with 256 grey levels per pixel. Price per copy is 35 cents on paper and $1.30 on film.

Additional Product Information
EKTRON LASER IMAGE RECORDER MODEL 811
(see page A-44)

The whole area of hard copy output is bubbling with innovation. Even new types of 3-D color reproduction are being explored, as Dan Sandin explains.

PHSCOLOGRAMS

(DAN SANDIN on camera)

This is a phscologram. It is a three-dimensional stereo free-viewing output device. It's essentially a grown-up luscious 3-D postcard. This image is of a polio virus, and Art Olsen wished to communicate some details of the 3-D structure of this to his colleagues at a molecular graphics conference. So he brought this box with this image in it and was able to communicate those details without bringing either an animated video tape or a $100,000 workstation.

Additional Information
PHSCOLOGRAMS
(see page A-45)

VIDEO

(LAURIN HERR on camera)

The fusion between computer graphics and video picked up steam this year. There are now a number of products for the PC/AT and the MAC II that allow you to feed video in and get video out, recordable in NTSC and PAL. There are also a number of companies that offer scan converters that give you recordable NTSC out of popular workstations.

FOLSOM RESEARCH AURORA/300 BOARD SET

For example, the Aurora/300 board set from Folsom Research seen here outputs NTSC from the HP 360 TurboSRX workstation. The full screen NTSC image on the right has been scan converted in real time from the higher resolution 1280 x 1024 workstation screen on the left.

Additional Product Information
FOLSOM RESEARCH AURORA/300 BOARD SET
(see page A-46)

PARALLAX 1280 SERIES VIDEOGRAPHIC PROCESSOR BOARD SET

Scan converters can turn the screen display signal into video. But the Parallax board set manages to neatly insert live video inside an on-screen window. The board set was originally developed for the PC/AT. We are looking here at the newer version designed to fit into a VME bus slot on the SUN 3 or Sun 4.

A key advantage to the Parallax approach is that the full power and flexibility of the Sun windowing system is preserved, including resizing, layering, graphic overlay, and repositioning.

Additional Product Information
PARALLAX 1280 SERIES VIDEOGRAPHIC PROCESSOR BOARD SET
(see page A-47)

(JUDSON ROSEBUSH on camera)

Video is the medium of mass communications of moving pictures in the West. It is a cheap, portable, easy to present, relatively low cost way of doing things.

And the interfaces between computer and video are well worked out. They're cost effective. They're not complicated. And so video is perhaps a preferred way to record images, not just for the professional production company, but for the university, the researcher, for the scientist and for the artist, as well. Makes a lot of sense.

(DAN SANDIN on camera)

The role of video in scientific visualization is communication, similar to the role that notetaking has to informal communications with other researchers and formal publishing. It has the role to be able to show things that move and change in time. It's extremely difficult to communicate music, for instance, in print. It's important to be able to show other people your research. If you can't show the research to other people, it's not research. And that translates to...if you can't record the visual output of your visualization device, it's not an important part of your research.

TEST IMAGE - 20TH GENERATION QUALITY: D2 vs. 1" NTSC

(LAURIN HERR off camera)

This year, digital video recorders reached the market. D-1 records component video. D-2 records composite NTSC video. Both of these digital formats obviate the problem of the generational picture quality loss inherent in layering or duplicating of analog video.

Additional Product Information
D2 VIDEO
(see page A-48)

(DEAN WINKLER on camera)

There's a link between the NTSC television world and particularly the digital television world and the digital computer graphics world that I've been looking for and I haven't seen yet. And that is what I would call a D-2 frame buffer, a computer graphics frame buffer that lets you write data in via one of the various standards and actually puts out directly in the digital D-2 format, a D-2 signal. And I think that will emerge in the next year or so, I hope. I know a lot of people on the floor have been talking about it, although no one has it yet. Currently, to go from the world of computer graphics into the digital world of NTSC, one must make an analog step. And that's okay, but it would be better if we had -- I think a D-2 frame buffer is a very marketable product.

ANIMATION - ANTI-LOGO

Post Perfect - 1988

SCIENTIFIC VISUALIZATION

(LAURIN HERR on camera)

Scientific visualization continues to gather momentum as a major new field.

The growing importance of computational science, especially with supercomputer capabilities, is creating a commensurate need for more sophisticated visual representations of natural phenomena across time.

ANIMATION - CONSTRAINED DYNAMICS
John Platt and Al Barr - 1988
California Institute of Technology
The Caltech Graphics Group

(LAURIN HERR off camera)

The concept implies expanded use of interactive computer graphics and image processing in order to do data exploration in the visual domain. This, in turn, requires the development of new tool sets for image generation, visual communication and analysis.

But is it a business? We asked Carl Machover.

(CARL MACHOVER on camera)

I don't think there's any question about it. It's a hardware market in terms of providing the physical resources to do more and more of these things in real time, because one of the things I think the industry has always known, is that I make better intuitive decisions if I can track through iteratively and I don't have to wait for the hardware to delay my study from one to the other. Of course the problem with very complex problem solving is that it takes me too long to go from frame to frame. I have to then organize them and then play them back. So scientific visualization is going to create an enormous hardware push for higher and higher capability.

ANIMATION - PRESIDENT'S DAY STORM
William Hibbard, Dave Santek - 1988
Space Science and Engineering Center
University of Wisconsin

(CARL MACHOVER off camera)

The second issue is that most of our present software that we classically have used in business graphics, the kinds of things, you normally would say, "What I'm doing is charting empirical data." But the problem is that most of the empirical data we've dealt with in the past has been 2-D and at best 3-D. What comes out of the scientific visualization realm is multidimensional scatter point data that much of our present software is not equipped to handle.

(CARL MACHOVER on camera)

So I think not only does it represent an opportunity for new hardware development, but it opens up some absolutely brand-new opportunities for software development. These are not only from the standpoint of handling the data, but now I have to give the scientists a new set of tools on how they describe to the system what it is they want it to look like.

(CHARLES CSURI on camera)

I think one of the reasons I'm intrigued by scientific visualization is because it gives me access to scientists. I have a chance to talk with them about particular models. I have a great deal of curiosity about whether or not I can use a computational model involving fluid flow and apply it to some other process, let's say, by changing some parameters, to get a certain kind of visual effect. Or, let's say the simulation of a flame coming out of a jet--that kind of thing--or a hurricane representation. And how, instead of points in free space, those could be attached to some other symbols. And I rather suspect that, at least visually and artistically, it should be very interesting.

ANIMATION - MUSCLE MODELING
John Chadwick - 1988
Ohio State University ACCAD

ANIMATION - HUMAN DYNAMICS
John Chadwick - 1988
Ohio State University ACCAD

(CHARLES CSURI off camera)

At Ohio State presently I have a graduate student by the name of John Chadwick who is working on the representation and control of muscles. For example, where you might have an arm with a muscle on it. And as you bend the arm, it can expand and contract. One of his motivations is to be able to represent the skin in general, but also clothing.

We've got to take a fresh look at what we have available to us in technology and try to rethink the problem, try to restructure our attitudes about how we're going to deal with computer graphics and computer technology.

(CHARLES CSURI on camera)

I am disappointed at how conservative the field is now becoming It's as if all the problems had been solved, ok? Which is outrageous. It's not true! I think that's the most important thing. I think the other aspect is that--and part of it linked to my first comment--we need to more effectively take advantage of the real time interactive potential of computer graphics. But we really have to redefine the problems. We have to rethink the user interface. I don't know, I just feel the need for things that are more outrageous, more off the wall. It's too pat. It's too narrowly focused. Maybe that's what happens in fields as they mature they become much more narrowly focused. And we've got to find a way to break that apart again.

(DONNA COX on camera)

There is this push, particularly in the graphics industry towards realism representing that which we can optically see and understand and grasp.

ANIMATION - NCSA SCIENTIFIC VISUALIZATION 1988
National Center for Supercomputing Applications
University of Illinois at Urbana-Champaign

1. LORENZ ATTRACTORS
   Scientific Research: David Hobill, Michael Weige, Daniel Simkins, NCSA
   Visualization: Jeffrey Yost, Scientific Visualization Program, NCSA
2. PLASTIC INJECTION MOLDING
   Scientific Research: Richard Ellson, Eastman Kodak
   Visualization: Ray Idaszek and Donna Cox, RIVERS, and Stephan Fangmeier, Scientific Visualization Program, NCSA
3. NUMERICAL RELATIVITY: BLACK HOLE SPACE TIMES
   Scientific Research: Larry Smarr and David Berstein, Departments of Astronomy and Physics, University of Illinois Urbana-Champaign; David Hobill, NCSA
   Visualization: Ray Idaszek and Donna Cox, RIVERS, and Stephan Fangmeier, Scientific Visualization Program, NCSA

4. "VENUS" from "METAMORPHOSIS: SHADOWS OF A HIGHER DIMENSION"
Scientific Research: George Francis, Department of Mathematics, University of Illinois Urbana-Champaign
Visualization: Donna Cox and Ray Idaszek, RIVERS, and Stephan Fangmeier, Scientific Visualization Program, NCSA

(DONNA COX off camera)

Now in scientific visualization, in the scientific community, there are a lot of disciplines in dealing with issues of space, time, and parameters that cannot be represented by any optical way. We need to understand very complex abstract dynamics. And so in the graphics community, where we see this push towards realism -- that could in fact lead us into a very impotent node, because we are constrained by reality. If this is the only way that we can go, we are constrained by reality. it is the visual study of nature that reveals the hidden laws of nature. But we must go beyond what we can see. That is why mathematics can take us to n-dimensional space. We can't represent n-dimensional space, but we can conceptualize n-dimensional space.

(DONNA COX on camera)

And, therefore, in the scientific visualization we can develop paradigms that are going to give us abstract information about multivariant data. They will allow us to go much further than just the three dimensions that we see and can touch and can understand visually. We must go beyond that. We must take it steps further, and use these techniques and these algorithms that we've developed for realism, and take it into this direction of going into the abstract and understanding relationships of numbers.

(JAMES BLINN on camera)

I went through a period where I worked on photorealism as a goal, just to make interesting-looking pictures. And that was just a phase. I've gone beyond that now. In fact sometimes I look at a lot of the photorealistic pictures that people are working on nowadays with some degree of wistfulness, saying, "Gee, I used to do that sort of stuff."

<u>ANIMATION - MATHEMATICA; THE THEOREM OF PYTHAGORAS (excerpt)</u>

Animation: James Blinn, Sylvie Rueff - 1988
Project Director: Tom Apostol
Computer Graphics Laboratory/JPL
California Institute of Technology

(JAMES BLINN off camera)

But primarily what I'm interested in now is communicating ideas that don't have a realistic representation.

The theorem of Pythagoras is an abstract geometric idea. In vector algebra, ideas of relativity and space-time diagrams, there's no real physical, concrete object. So trying to make them look realistic is not necessarily required. In fact I'm attempting to try to come up with what amounts to the simplest possible image that will get the idea across, rather than the most complex possible image. Besides, it's cheaper to render that way!

(JAMES BLINN on camera)

I think mathematics is the key to most any technological subject. And people who find mathematics scary are not going to be able to really be in command of the technology. And so if I go into the technical sessions and I see a lot of mathematics on the screen that people from my generation are understanding and appreciating, that's good. But if younger generations go in and they flee screaming from the room whenever they see an equation on the screen, that's going to be too bad. We're not going to have anybody else to carry it to the next stage.

ANIMATION - "THE SCIENCE OF FRACTAL IMAGES" (excerpt)
H.-O. Peitgen, H. Juergens, D. Saupe - 1987
University of Bremen
University of California at Santa Cruz

(LAURIN HERR off camera)

One of the most far-reaching contributions from pure mathematics to the visualization repertoire has been the concept of fractals: that is, the recognition that the self-similar relationship between large scale structure and small scale detail is an inherent aspect of natural phenomena. We asked Benoit Mandelbrot, the father of fractals, what impact he thought the application of fractals has had.

(BENOIT MANDELBROT on camera)

The principal impact of the computer and the fractal geometry on mathematics and the sciences has been to put the eye back into these disciplines. For a very long time, the eye has, at least in appearance, vanished from mathematics. Abstraction was valued above everything and problems which abstraction suggests were valued highest. The idea that by looking at pictures, by playing interactively with very complicated shapes, the mathematician could then get new ideas to prove the conjectures to work on--that idea had vanished and, in fact, was dismissed as ridiculous.

ANIMATION - FRACTAL LANDSCAPES

Richard F. Voss - 1987
IBM T.J. Watson Research Center

(BENOIT MANDELBROT off camera)

The phrase fractal geometry as a language comes from a very famous quote by Galileo. He said that the great book of nature which is open in front of our eyes, namely the universe, could only be understood by understanding the language of mathematics, by understanding its letters, its alphabet, which is that of circles, triangles and the like without which one wanders endlessly through the obscure labyrinth. The main idea here is that one cannot speak of nature without the language.

Now the language with which one spoke of nature in Galileo now had been Euclid's. And this language had been extraordinarily successful and continued to be successful, but had its extraordinary visual failures. Because, as I said in my book, mountains are not cones, clouds are not spheres, rivers do not run straight, lightning does not go straight, etc., etc. The objects around us, the objects of most meaningful consequence to us are very far from the shapes of Euclid.

(BENOIT MANDELBROT on camera)

The fact that millions of people would be enchanted by shapes which, after all, are -- pure mathematical shapes which are of very, very simple nature in terms of their construction, but overwhelming complication in nature in terms of their appearance. That finding has been very heartwarming for those, who, like myself, don't see boundaries between the disciplines of feeling and of knowing.

ANIMATION - DNA MOLECULE

Dave Pensak, John Cristy, Karen Rogers - 1988
E.I. du Pont de Nemours & Company
Central Research and development Department

(LAURIN HERR on camera)

Three-dimensional data input has always been a thorny creative problem. Over the past few years, we have seen the creative application of 3-space digitizers, data gloves and space balls.

CYBERWARE LABORATORY 4020/PS

(LAURIN HERR off camera)

Now, a small California company called Cyberware has resurrected a "laser range-finding" technique to rapidly digitize a 3-D object. The Cyberware system works by placing a 3-D object inside a scanning space. The scanning camera moves around the object a full 360 degrees, producing a series of 512 vertical contours around the object with 512 values generated along each contour line.

Additional Product Information
4020/PS CRANOFACIAL SCANNER
(see page A-49)

Here you see SIGGRAPH Co-Chairs Adele Newton and Andy Goodrich being scanned in real time. The resulting data matrix of so-called "polar zels" is similar to a pixel array, except that the data values represent surface elevations rather than luminance. The data is easily convertible to xyz coordinate geometry for image display or may be used to drive a numerically-controlled milling machine. This makes possible the quick and easy scaled reproduction of three-dimensional shapes.

(ADELE NEWTON and ANDY GOODRICH on camera)

Remember, you saw it at SIGGRAPH!

(LAURIN HERR on camera)

And remember, if you didn't see it at SIGGRAPH, you saw it here. I'm Laurin Herr.

ANIMATION - HAIR
Jerry Weil - 1988
AT&T Bell Laboratories

VISUALIZATION: STATE OF THE ART
UPDATE

APPENDIX A

ADDITIONAL PRODUCT INFORMATION

ADDITIONAL PRODUCT INFORMATION

INDEX TO ADDITIONAL PRODUCT INFORMATION
(Alphabetical)

ADDITIONAL PRODUCT INFORMATION

ADDITIONAL PRODUCT INFORMATION

MEIKO COMPUTING SURFACE

Performance:

The performance of the Computing Surface is dependent upon the configuration--each card has four 1.5 MFLOP or 10 MIPS processors. There is no upper limit to the number of cards used to configure a system, so no upper limit to the performance. The system used for generating the image had seven cards for a total of 28 processors, delivering 42 MFLOPS, 280 MIPS.

Configuration:

Seven MK042 cards, each with four computing elements
One MK015 graphics display controller/frame buffer
One MK014 local host system
One M10 enclosure box
One Compaq PC as a file server/front end
Each of the four computing elements on the MK042 card has:

- 32-bit 1.5 MFlop or 10 MIPS transputer
- 2 MBytes error checked DRAM
- Eight unidirectional message channels at 5, 10 or 20 MBaud
- Global communications and error handling

The graphics display controller MK015 has:

- Up to 73.9 MHz pixel rates
- 200 MByte/s external pixel highway
- CCIR/RS-343 compatible video with programmable sync generator and genlocking to an external source
- 1.5 MByte frame buffer which can be viewed as one frame of 0.5 MPixels at 24 bits/pixel, one frame of 1.5MPixels at 8 bits/pixel, or three frames of 0.5MPixels at 8 bits/pixel

ADDITIONAL PRODUCT INFORMATION

MEIKO COMPUTING SURFACE (cont)

The MK014 local host system has:

- 32-bit 1.5 MFLOP or 10 MIPS transputer
- 3MBytes 13.3MByte/second error checked DRAM
- 128KBytes 13.3Mbyte/second EPROM
- Eight unidirectional message channels at 5, 10 or 20 MBaud
- IEEE-488 and dual RS232 serial asynchronous lines

Prices:

The basic system, an M10 with local host, is $15,525. Compute boards start at $9,000 (four, 32-bit integer processors, each with 256 Kbytes). That works out to $225/MIPS according to company representatives). The system used to generate the image seen would cost $135,000.

ADDITIONAL PRODUCT INFORMATION

AT&T PIXEL MACHINE, MODEL 916

Performance:
- 125 MIPS
- 250 peak MFLOPS
- 91 Mbytes/second to frame buffer memory
- 182 Mbytes/second to pixel data memory
- 16 Mbytes/second Broadcast Bus
- 321 Mbytes/second Pixel Funnel

Features:
- 9 transformation nodes
- 16 pixel nodes
- 4x4 pixel interleaving pattern
- 256 x 256 pixels per pixel node
- 1024 x 1024 buffer resolution
- 2 displayable frame buffers, 8 Mbytes total
- 1 pixel data buffer, 4 Mbytes total
- 12 Mbytes total memory
- 96 total bits/pixel
- 32 bits/pixel RGB

Price:
- $49,500

ADDITIONAL PRODUCT INFORMATION

AT&T PIXEL MACHINE, MODEL 964(d) (dual transformation pipes)

Performance:
- 410 MIPS
- 820 peak MFLOPS
- 365 Mbytes/second to frame buffer memory
- 731 Mbytes/second to pixel data memory
- 16 Mbytes/second Broadcast Bus
- 321 Mbytes/second Pixel Funnel

Features:
- 18 transformation notes
- 64 pixel nodes
- 8x8 pixel interleaving pattern
- 128 x 128 or 160 x 128 pixels per pixel node
- 1024 x 1024 or 1280 x 1024 buffer resolution
- 2 displayable frame buffers, 32 Mbytes total
- 2 or 4 additional frame buffers
- 2 or 4 pixel data buffers, 16 Mbytes total
- 48 Mbytes total memory
- 384 or 304 total bits/pixel
- 32 bits/pixel RGB

Price:
- $149,500

ADDITIONAL PRODUCT INFORMATION

APOLLO SERIES 10000 PERSONAL SUPERCOMPUTER

- DSP10000 Compute and File Server
- DN10000-E Computational Workstation

  Performance:

    DN10000-E: 9 single precision, 5 double precision MFLOPs per processor, 15 to 100 MIPS

    Unit shown in videotape: 30 MIPS/36 MFLOPs per processor, up to 4 CPUs for a maximum of 120 MIPS/145 MFLOPS

  Configuration in common; two models:

    Symmetrical multiprocessor design with up to four CPUs
    Large dual caches
    High-speed 150-megabyte/second system X-bus
    Data flow compilers
    Up to 128-megabyte main memory
    Shared virtual memory
    VME and IBM PC/AT-compatible buses are supported
    Up to four 5 1/4-inch ESDI fast actuator disk drives
    Disk striping for two to four drives
    Scan path technology for VLSI verification
    Apollo Token Ring, Ethernet, and FDDI connectivity

  DN10000-E graphics features:

    8 bits per pixel graphics display
    1024 x 800 resolution
    256 colors simultaneously displayed/palette of 16.7 million

ADDITIONAL PRODUCT INFORMATION

APOLLO SERIES 10000 PERSONAL SUPERCOMPUTER (cont)

Prices:

DSP10000 series
(entry-level Series 10000 high-performance server configurations include 8 MByes of memory and a 348 Mbyte disk

DSP10010 (with 1 processor)	$69,900
DSP10020 (with 2 processors)	$89,900
DSP10030 (with 3 processors)	$109,900
DSP10040 (with 4 processors)	$129,900

DN10000 series
(entry-level Series 10000 computational workstation configurations include 8 MBytes of memory, a 348 Mbyte disk, 8 planes of color, and a 19" 1024 x 800 color display.

DN10010 (with 1 processor	$79,900
DN10010 (with 2 processors)	$99,900
DN10030 (with 3 processors)	$119,900
DN10040 (with 4 processors)	$139,900

ADDITIONAL PRODUCT INFORMATION

HEWLETT-PACKARD TurboSRX, MODELS 370 AND 835

Performance:
- TurboSRX:
  - 900,000 transformations/second
  - 50,000 clipped, checked, 50-pixel triangles per second with Z-buffer and Gourand shading
- CPUs:
  - 370: 8 MIPS, 0.7 MFLOPS
    240,000 3D vectors/second
  - 835: 14 MIPS, 2 MFLOPS
    340,000 3D vectors/second

Features:
- Can grow from from an eight-plane low cost color system to a 24-plane high performance system with 16.7 million colors.
- Radiosity and ray tracing supported
- Hardware support for Gouraud shading
- 16 colored ambient, directional, and positional light sources
- Dithering, transparency, diffuse and specular reflections, Gamma correction, and wireframe lighting
- Polygon mesh primitive, hardware cursors, frame buffer blending
- 6th order NURBS (non-uniform rational B-splines) with trimming
- MOMA (Multiple Obscurable Movable Accelerated) windows
- Starbase graphics library, NS-ARPA services, and NFS software come with HP-UX

Configuration:
- CPU--Motorola 68030 running at 33 MHz for the 370;
- HP-PA (HP's RISC-based architecture) for the 835
- I/O expander
- 8 Mbytes RAM
- High speed HP-IB
- DMA
- LAN
- HP-UX
- 1280 x 1024 display
- Three custom VLSI transform engines
- 16-bit Z buffer
- Eight to 24 planes of frame-buffer memory and 4 overlay planes
- Option: (for 370)
  - RGB to NTSC scan converter

ADDITIONAL PRODUCT INFORMATION

HEWLETT PACKARD TurboSRX MODELS 370 AND 835 (cont)

Prices:

$70,000 Model 370 TurboSRX
$91,000 Model 835
(this 835 price is for a fully-configured system with 3 transform engines and a 16-bit Z buffer.)

ADDITIONAL PRODUCT INFORMATION

HEWLETT-PACKARD TurboSRX GRAPHICS ANIMATION INTERFACE CARD (NIMBUS CARD)

Performance:
- Image transfer at the rate of 12.1 Mbytes/second in the 825 and 12.0 Mbytes/second on the 835
- Delivers playback of from 4.4 to 52.4 frames/second on the 835, depending on the resolution and number of bit planes

Features:
- Easy variability of resolution and number of bit planes

Configuration:
- Two-card set can be installed in the 825 and 835 TurboSRX models

Price:
- Two-card set $4100.

ADDITIONAL PRODUCT INFORMATION

SILICON GRAPHICS 4D/GTX

Performance:
- 8 million pixels per second frame buffer access
- Fills 80 million pixels per second
- 20 MIPS and 2 MFLOPS CPU performance

Base configuration/CPU subsystem:
- Two 16.7 MHz RISC processors
- Two floating point coprocessors
- Five proprietary VLSI parts
- 8 MB ECC memory
- 380 MB to 9.6 GB disk capacity
- Ethernet and IRIX

Graphics subsystem:
- Seven proprietary VLSI parts
- 64 image bit planes (24 color bit-planes and 8 alpha bit-planes, double-buffered)
- 24-bit Z-buffer for hidden surface removal
- 4 bit-planes for overlay or underlay
- 4 window ID bit-planes
- Access to 16.7 million colors in double-buffered RGB mode
- 1280 x 1024 screen resolution

Hardware graphics features:
- Alpha blending capability for transparency effects
- Advanced lighting models
- Pan and zoom capabilities
- Multimode windowing environment
- Flat and Gouraud shading
- Anti-aliased lines

Prices:
- The GTX upgrade is $25,000 for the IRIS 4D/80GT, $40,000 for the IRIS 4D/70GT, and $55,000 for the IRIS 4D/50GT.
- The IRIS 4D/80GT is $89,000.

ADDITIONAL PRODUCT INFORMATION

SILICON GRAPHICS POWER IRIS SERIES

Performance:
- Each of four chip sets can generate 20 MIPS and 8 MFLOPS

Features:
- POWERpath multi-processing architecture
- Five new proprietary VLSI chips
- Automatic parallelizing compiler
- IRIX
- Can be configured with either two or four RISC CPU/FPU chip sets (two CPUs per CPU card)
- Utilizes the R3000 from MIPS Computer Systems
- Graphics processed on a dedicated subsystem

Prices:
- Vary according to model and configuration (graphics or server); starting at about $60,000.

ADDITIONAL PRODUCT INFORMATION

ARDENT TITAN

Performance:

- 16 MFLOPs per processor for a total of 64 MFLOPS per system
- 16 MIPS per processor for a total of 64 MIPS peak per system
- 6.5 MFLOPS on 100 x 100 compiled Fortran LINPACK on one processor
- 24 MFLOPS on 1000 x 1000 compiled Fortran LINPACK with two processors

Features:

- Configuration of up to four 64-bit vector processors paired with an equal number of general-purpose integer processors
- Up to 32,000 64-bit-wide vector registers
- Aggregate bus bandwidth of 256 megabytes per second
- Up to 128 megabytes of 16-way interleaved memory
- 52 graphic image planes organized as 24-bit, double-buffered true color with four overlay planes
- Screen resolution of 1280 x 1024
- UNIX, Ethernet, NFS support
- Disk striping for throughput of 1000 kilobytes/second
- Automatic compiling of Fortran and C code written for other machines
- X-windows Version 11
- Includes Ardent's Dynamic Object-Rendering Environment (Dore') software library and PHIGS+
- UNIX Navigator graphical interface bundled with system

Prices:

A single-processor model starts at $79,000 and prices range up to $150,000 for a full-function four processor version.

ADDITIONAL PRODUCT INFORMATION

STELLAR GS1000

Performance:
- Multi-Stream Processor
  - 20-25 MIPS
- Vector/Floating-Point Processor
  - 40 MFLOPS
  - 8.6 MFLOPS LINPACK (order 100)
  - 800,000 transformations/second
- Rendering Processor (Stellar custom SIMD array)
  - 80 million pixels/second
  - 150,000 Gouraud shaded, Z-buffered pixels/second
  - 30,000 Phong shaded polygons/second
- Bus bandwidth
  - 1.28 GB/second to cache
  - 320 MB/second to main memory

Configuration:
- 16 to 128 Mbytes of main memory, 1 Mbyte cache memory
- 16 to 32 planes of frame buffer memory
- One to four 380 or 760 Mbyte disks, expandable to 28 GB

Features:
- Ethernet, TCP/IP, NFS support, committment to FDDI and ISO/OSI
- Vectorizing/parallelizing/optimizing compilers for Fortran-77 and C automatically detect parallelism in user source code
- Stellix operating system, based on Unix V.3
- Stereo graphics capability
- Control dials
- Broadcast video output
- Scan-path diagnostic testing capability for all system components
- DataPath -- multiple 512-bit wide datapaths provide multiple transfers between functional units and memory at rates as high as 1.28 Gbytes/second
- Virtual Pixel Maps -- render images into virtual memory rather than into the frame buffer

Price:
- Prices start at $104,900. This is the approximate cost of the system used for the demos included in this videotape.

ADDITIONAL PRODUCT INFORMATION

ALLIANT VFX/80

Performance:
- Up to 240 Whetstone MIPS
- Shading rates of up to 50 million pixels/second

Configuration:
- Separate dedicated processors for simultaneous application and graphic processing
- Application processing done by up to eight 64-bit parallel vector Advanced Computational Elements (ACEs)
- Graphics processing done by up to eight parallel high-performance scalar and floating-point Graphics Arithmetic Processors (GAPs)
- I/O handled by up to nine Interactive Processors (IPs) that utilize three cache memories
- 188 Mbytes/sec system memory bus
- Auto-parallelizing and auto-vectorizing compilers for standard languages
- UNIX-based Concentrix OS
- Ethernet, TCP/IP, NFS, NCS, X-Window, NeWS and Hyperchannel support
- VAX environment compatibility
- Supports 16 visualization displays and 128 computational users, in dual configuration;
  16 visualization and 64 computational users in single configuration (used for generating image on the videotape)
- Graphics subsystem:
  - 20 MIPS processor for display list management and traversal
  - Eight to 32 Mbytes of display list memory
  - PHIGS and PHIGS+ implemented in hardware/firmware; executed by GAPs as their native graphics instruction set
  - Up to 1280 x 1024 x 24 bit images
  - 16-bit Z-buffer performs hidden surface removal at the full drawing rate of the system
  - 24 bits true color and 8 bits double buffered pseudo color are standard
  - VISEDGE software
    Each Image Memory Unit (IMU) contains a frame buffer, multiple custom VLSI drawing processors, and a video output section
  - Can support multiple simultaneous video displays

Price:
- $75,000 to $125,000 per graphics seat depending on configuration, for multi-user system

ADDITIONAL PRODUCT INFORMATION

ALLIANT/RASTER TECHNOLOGIES
GX4000 GRAPHICS ACCELERATOR SUBSYSTEM

Performance:

- Maximum of nearly one million 10-pixel, 32-bit floating point vectors, transformed, clip-checked, and rendered (with eight processors)
- Maximum of 220,000 patches per second (with eight processors)
- 220,000 vectors per second with one processor; 430,000 with two

Features:

- PHIGS/PHIGS+ native command set (performance numbers all use this as software interface to device)
- X.11/NeWS window system support
- Architecture fully integrated with the Sun-3 and Sun-4 workstations
- The display list processor board has 8 to 32 MBytes high speed display list memory
- VME bus architecture supported

Configuration:

- Three-board configuration: display list memory, graphics arithmetic processor, image memory unit
- Four-board: Add a Z-buffer memory unit
- Five-board: Add a graphics processor
- Maximum eleven boards (eight processors)

Prices:

- A three-board configuration is $36,000
- A typical configuration of five boards and a monitor is $50,000

ADDITIONAL PRODUCT INFORMATION

SOFTIMAGE 4D CREATIVE ENVIRONMENT

Features:

- Consists of five modules: Model, Actor, Motion, Matter, Action
- Model:
  - Interactive modelling
- Actor:
  - Addition of internal skeletal structures
- Motion:
  - Placement and animation of objects, lights, cameras
- Matter:
  - Interactive material editor and renderer of photo-realistic images
- Action:
  - For launching the rendering of scenes while working in other modules and for tranfer of images to video, HDTV, or film
- User-selectable patch or polygonal mesh
- Object clipping and symmetry
- Unlimited multi-level hierarchy
- Automatic bevelling
- Local and global rounding
- Volume and surface measurement
- Compact binary storage format
- Independent time and space controls
- Linear/spline interpolation
- Quaternion rotations
- Multiple, animated cameras and unlimited, animated light sources
- Real time playback and editing
- Animated material and light properties
- Unlimited hierarchical motion
- Fast scanline rendering
- Softcast shadows and soft reflections
- Texture mapping

ADDITIONAL PRODUCT INFORMATION

SOFTIMAGE (cont)

Configuration:
- Platforms:
  - Silicon Graphics Iris 4D and 3130 family
  - Pixar rendering engine also used when running on the 3130 family
  - (Now porting to other platforms)
- Output options:
  - Postscript printer
  - Video
  - HDTV
  - Film

Prices:
- $49,000 (U.S) for entire package
- $15,000 Model
- $10,000 Actor
- $15,000 Motion
- $20,000 for Matter and Action together

ADDITIONAL PRODUCT INFORMATION

THE RenderMan 3-D SCENE DESCRIPTION INTERFACE

RenderMan is a Pixar proposal as a standard interface between modeling systems and rendering systems. The interface features a large set of geometric primitives for specifying the shape of objects, inlcuding polygons, patches and CSG. The interface features a Shading Language for specifying arbitrary visual attributes of a scene, including surface materials, deformations, lights and atmospheric conditions. Copies of the RenderMan interface specification can be obtained from Pixar.

THE RenderMan DEVELOPERS TOOLKIT

The Toolkit is a copy of the Reyes rendering software running on a standard graphics workstation, along with dedicated technical support from Pixar.
The Toolkit is available to qualified developers for evaluating the use of the RenderMan interface and Pixar's rendering system adhering to the interface.

Features:

- Three parts:
  - A set of geometric primitives for specifying the shape of objects, including curved surface patches and CSG
  - A Shading Language for specifying the full complexity of surface attributes to lighting conditions
  - Coherent mechanisms for attaching surface attributes to shapes
- Visual attributes include such properties as material, texture, reflectivity, and gloss
- Compatible with PHIGS and the NURBS and trim surfaces added by PHIGS+
- Compatible with interactive graphics environments like Dore'
- Can be used with off-line and real-time rendering systems
- Provides a framework for a renderer to achieve a range of capabilities --- antialiasing, ray tracing, motion blur, volumetric display

ADDITIONAL PRODUCT INFORMATION

SUN TAAC-1 APPLICATION ACCELERATOR

Performance:
- Interactive 3-D graphics:
  - 112,000 transformed 3-D 10-pixel vectors/second
  - 55,000 anti-aliased, transformed 3-D 10-pixel vectors/second
  - 27,500 anti-aliased, depth cued, transformed 3-D 10-pixel vectors/second
  - 15,000 Z-buffered, Gouraud-shaded polygons/second
  - 4,000 Z-buffered, Gouraud-shaded 300-pixel spheres/second
  - 400 wiggle traces/second, 512 samples each
- Volume imaging:
  - 128,000 trilinear interpolations/second
  - .033 second/extraction and display of a 256 x 256 orthogonal slice
  - .125 second/extraction and display of a 256 x 256 oblique slice

Features:
- Realtime and near-realtime performance for image processing and interactive 3-D graphics
- VLIW (Very Long Instruction Word) architecture
- Three memories: data/image, program, and scratchpad/stack
- Bi-directional vector data ports between the data/image memory and the processor
- User programmable in C
- TAAC-1 basic graphics and image-processing libraries
- Special memory-access hardware allows programs to work in their natural (X,Y,Z) data space without 3-D array addressing overhead.
- 8 Mbyte on-board memory tightly coupled to processor for fast pixel and voxel data access
- Flexible display supports full color, 24 bits/pixel and 256-color images with 8-bit/pixel overlays in various display formats
- Genlock to external sync sources
- Can store and play back 32 512 x 512 x 8 bits/pixel images and longer sequences with its special hardware for run-length decoding and display

Prices:

	Diskless	With disk
SUN-3/160 TAAC	$59,900	$71,500 w/141 MB SCSI disk, 60 MB tape
SUN-3/260 TAAC	$66,900	$85,500 w/280 MB SMD disk, 60 MB tape
SUN-4/150 TAAC	$63,400	$72,800 w/327 MB SCSI disk, 60 MB tape
SUN-4/260 TAAC	$77,900	$111,500 w/32 MB memory, 280 MB disk, 60 MB tape

ADDITIONAL PRODUCT INFORMATION

SUN 4/150CXP WORKSTATION

Performance:
- 7 MIPS
- 1.1 single-precision/.8 double-precision MFLOPS
- 200,000 2-D vectors/second
- 150,000 3-D vectors/second
- 20,000 shaded polygons/second

Features:
- Double-buffering standard
- Z-buffering standard
- Static Column Random Access Memory (SCRAM)
- Memory Management Unit for rapid switching between 8 register-resident processes
- VME master bus for VME option support
- SunOS advanced UNIX with advanced graphical user interface
- Open Systems Network/Open Network Computing (OSN/ONC)
- SunLink data communications

Configuration:
- 32-bit SPARC processor at 14.28 MHz
- Weikek1164/1165 floating-point processor
- 8 to 16 Mbytes main memory
- 141 Mbytes to 1.3 GBytes disk capacity
- GP2 graphics processor
- Six card-cage slots
- 60 Mbyte 1/4 inch tape backup
- 16 inch color monitor (1152 x 900) (19 inch color also available at 1152 x 900 resolution)

Prices:
- Sun 4/150 CXP base price $44,900
- With 141 Mbyte disk and 60 Mbyte tape $51,400
- With 327 Mbyte disk and 60 MByte tape $54,300
- (All systems include SunOS, Ethernet, 16 inch color monitor, keyboard, optical mouse, 2 serial ports, NFS)

ADDITIONAL PRODUCT INFORMATION

CROSFIELD STUDIO 875 PRE-PRESS SYSTEM

- Features:
  - Grid planning
  - Regular/irregular cutouts and features
  - Borders with merge
  - Tints/vignettes
  - Electronic masking
  - Localized unsharp masking
  - Comprehensive retouch
  - Image edit at scanner resolution
  - Detail zoom
  - Grip (shrinks and spreads)
  - Color swap
  - Inset/dropout of images
  - Full color soft proofing with 16.7 million colors
  - Options:
    - Textran
    - Transform
    - Airbrushing
  - Same size A2 planning format
  - Scaled and sideways planning
  - Page plan, command sequence storage
  - Multi-tasking
- Configuration:
  - Composition console
  - 1024 x 1024 color monitor
  - High-speed DEC PDP 11/73 processor
  - Image database on three disk drives
  - 340 Mbyte or optional 690 Mbyte fixed disk drives
  - Tape drive for archival storage
  - Input options:
    - Quadracolor Magnascans, SDT level Magnascans
    - Video
    - Design systems
    - Front-end text composition systems
    - Networking

ADDITIONAL PRODUCT INFORMATION

CROSFIELD STUDIO 875 PRE-PRESS SYSTEM (cont)

Output options:
- Magnascan output scanners
- Proofing output
- Transparencies
- Gravure cylinders
- Compressed data for communication

Price:
$269,000 for a basic system

ADDITIONAL PRODUCT INFORMATION

CROSFIELD SYNERVISION II COMPOSITION CENTER

Performance:
- Up to 20 times the throughput acceleration over standard AT and 386-based products

Features:
- Custom-designed color RIP board
- Digital signal processing technology
- Synervision composition software including object-oriented graphics, full color high-resolution paint and rendering software, 22 fonts
- NTSC and PAL compatible, RGB component video signal
- Raster tape interfaces to pre-press systems

Configuration:
- Custom integrated Intel 80386 CPU
- Intel 80387 co-processor
- 2.5 Mbyte RAM
- 155 Mbyte disk drive
- 32-bit full color high resolution frame buffer
- 1024 x 768 resolution display
- 12 X 17 inch, 1000 dpi digitizing surface
- Optional Ethernet interface to Lightspeed Color Layout System
- Optional Instant Capture video camera
- Optional 300 dpi color input scanner
- Optional Matrix QCR/Z 2/4K line resolution film recorder
- Optional HP LaserJet II or CalComp Plotmaster Color Thermal Printer
- Optional 1/2" magnetic tape drive

Prices:
- Base price $55,900.
- Synervision II with tape drive and 300 dpi scanner $80,000

ADDITIONAL PRODUCT INFORMATION

CROSFIELD LIGHTSPEED COLOR LAYOUT SYSTEM (version 1.5)

Features:
- Full-color interactive page layout with color images and text
- Rotation, skewing, stretching and condensing of all elements, including graphics shapes, images, and type
- Image scanning via flatbed scanner
- Direct importation of TIFF and PICT2 image files
- Library of over 200 high-resolution fonts
- Bitstream screen fonts for WYSIWYG display
- Full-color outline drawing tools
- Captures digital production specifications during design
- Runs all Mac II software for other applications
- Options:
  - Monochrome drivers for all Postscript output devices, including Linotronic 100, 300, and 500
  - Driver for Apple LaserWriter II SC
  - Drivers for Scitex, Hell, and Crosfield color prepress systems
  - Ethernet interface to Synervision II system

Turnkey system configuration:
- Lightspeed Color Layout System software and 20 standard fonts
- Macintosh II
- 5 Mbyte RAM
- 40 Mbyte hard disk
- 19" high resolution color monitor with graphics card
- color monitor stand
- 300 dpi color flatbed scanner
- 300 dpi 11 x 17" color thermal transfer printer
- PixelPaint software
- Options:
  - Output to analog and digital film recorders
  - Networking
  - Remote communications
  - Extended storage
  - Additional fonts

Prices:
- $39,500 turnkey system
- $17,500 base system (excludes color scanning and printing options)
- $6,000 software only

ADDITIONAL PRODUCT INFORMATION

CROSFIELD PRODUCERxp

Features:

- Automatic editing of graphic elements for entire slide series
- Multi-image animation sequences with figure interpolation
- Background communications functions
- Overlay plane and realtime rubberbanding
- Image library (1600 images/symbols)
- Color palette of over 16 million with realtime color mixing and automatic color matching
- Multiple scalable typefaces
- Customizable charting formats
- Automatic smooth curves (Bezier-defined)

Configuration:

- 16-bit CPU
- 1 Mbyte RAM
- Bit-slice graphics processor
- 46 Mbyte hard disk and 2 5.25" floppy disk drives
- 19 inch 640 x 480 color monitor
- 11 x 17 inch digitizing surface with 4-button mouse
- DICOMEDIA II PRODUCERxp graphics software

Price:

- Approximately $50,000, depending on exact configuration

ADDITIONAL PRODUCT INFORMATION

PANSOPHIC STUDIOWORKS

Features:
- Integrated graphics tools:
  - Artwork, Chartwork, Brushwork, Pagework, Videowork and Filework
- Scanline output program
- Fonts package
- Sharing of graphic elements betwen art, paint, chart, and video functions
- Artwork features include:
  - Metamorphosis, text animation, light sources, Z-plane clipping, high-speed 3-D object rendering, text kerning, one-keystroke italicizing
- Brushwork features include:
  - Scanner/camera input, multiple screen buffers, high contrast, masking, air brush, clipping, rock 'n roll, exposure adjustment, custom nibs
- Chartwork features include:
  - Integration with Artwork and Brushwork, standard 2-D and 3-D chart styles, style selection, custom bulleting, templates, exploding 3-D pie, logo drop-in, word charts
- Pagework features include:
  - WYSIWYG page composition, scanner input, flexible output formats, font specifications, run-arounds, drawing
- Videowork features include:
  - scene page, metamorphosis, videowork interface, pencil tests, command editing, animation of texture maps, high-speed antialiasing
- Option:
  - Presswork pre-press software
  - Presswork features include:
    - Generation of color separation negatives, interactive color balance and correction, combines color vector, raster, and type all on one page
- Supports Computer Graphic Metafile (CGM) standard
- Import of AutoCAD and DXF compatible files
- Videotape, 35 mm slide, and hardcopy output
- Supports image transfer between Studioworks and Pansophic's D-PICT software family, STARBURST II workstation, and 35mm Express
  - Imports Lotus and flat ASCII files

ADDITIONAL PRODUCT INFORMATION

PANSOPHIC STUDIOWORKS (cont)

Configuration:
- Standard Intel 80286 platform:
  - PSI 286/12 MHz CPU
  - 40 MB hard drive
  - 5/10 MHz coprocessor
  - 2.0 MB EMS board
  - monochrome monitor
  - 13" Electrohome color monitor
  - Kurta tablet and pen (or puck at same price)
  - Targa card with overscan and all cabling
- Standard Intel 80386 platform:
  - All the above peripherals and boards,
  - except the CPU is a Compaq 386/20 including the following:
  - 60 MB hard drive
  - 20 MHz coprocessor
  - 1 MB on-board RAM
- Optional hardware:
  - GPIB board
  - MVP plus board
  - 130 MB hard disk
  - 19" Hitachi color monitor
- Optional output:
  - Matrix PCR, QCR-Z film recorders
  - Oxberry MX35, PC35 cameras
  - 4x5, 8x10 film backs
  - Calcomp Plotmaster
  - HP Laserjet
  - PSW-Shooter 286/386 output station
  - Output interfaces for film recorders, printers
  - Bencher M2 camera stand
  - Lyon-Lamb encorder
  - BCD single frame controller
  - Cello film recorder
  - Solitaire film recorder
  - Mitsubishi G650 thermal printer
- Optional input:
  - Howtek Scanner
  - JVC TK-870 video camera and stand
  - JVC BY 110 video camera

ADDITIONAL PRODUCT INFORMATION

PANSOPHIC STUDIOWORKS (cont)

Prices:

$39,900 for a turnkey system on an Intel 80286 platform
$46,900 for a turnkey system on an Intel 80386 platform
$10,000 for Pressworks option

ADDITIONAL PRODUCT INFORMATION

HOWTEK SCANMASTER

Features:
- Variable scan rate of 75, 100, 150, 300 dpi or adjustable 30 to 300 dpi
- 256 grey scale levels per color
- 8 bit A/D coversion, 6-bit accuracy
- 11 x 17 inch effective scanning area on paper, (8.2 x 11.4 inches on transparency)
- Image upload at host request eliminates interference with realtime user interface tasks
- Accepts downloaded lookup tables for color balance correction
- Edge correction commands for globally sharpening or softening the scanner's edge response
- Windowing/cropping and zooming of scanned material
- Scans an 8 1/2 x 11 inch document in less than 15 seconds, at 75 dpi
- With the transparency option, the scanner calibrates the appropriate white balance for the image to compensate for image variability
- Scan-It Applications Programs:
  - For IBM PC or MAC II platforms
  - TARGA 16, 32, Howtek, PICT2, or RIFF file formats
  - User selectable scanning area
  - Contrast and color correction
  - Sharpness selection
  - Image type menu

Configuration:
- Single CCD sensor in conjunction with three RGB fluorescent bulbs
- GPIB 8 bit, parallel interface

Prices:
- $6,995 for the Scanmaster
- $8,195 for Scanmaster with Scan-It
- $659 for transparency option

ADDITIONAL PRODUCT INFORMATION

LINOTRONIC 300

- Performance:
  - 2.3 inches/minute high resolution
  - 4.5 inches/minute standard resolution
  - 9.0 inches/minute proof resolution
- Features:
  - 72 picas/12 inches 305 mm line length
  - 154.8 picas/25.8 inches depth
  - 1 to 186 points in 1/10 point increments
  - 2540, 1270, 635 lines per inch vertical output resolution
  - 2540, 1270, 1270 pixels per inch horizontal output resolution
  - Options:
    - Top Speed on-line processor
    - Raster Data Port
    - Tints and patterns generator
    - Postscript RIP 2
  - Over 2000 digital typefaces from the Mergenthaler Font Library
  - More than 10,000 pi characters
  - CRTronic regular and super fonts
  - Linotype laser fonts
  - Postscript fonts (with Postscript RIP 2)
  - Film, paper, positive, negative, right/wrong reading media
  - Typefaces can be electornically modified, condensed or expanded, or slanted to left and right in 1 degree increments to 45 degrees.
  - Charcter and graphic rotation
  - Direct exposure of plates
  - Halftones
- Configuration:
  - Based on helium-neon laser
  - Motorola 68000 10 MHz CPU
  - 4 Mbyte memory
  - Disk options
    - 2 mini-floppy
    - 20, 67 MByte hard disk (formatted)
  - Input sources:
    - Series 300, Series 2000
    - Linotype Graphics System
    - Postscript compatible devices
      (via Postscript RIP 2)
    - CORA compatible front-end systems
    - Externally-generated raster data

ADDITIONAL PRODUCT INFORMATION

LINOTRONIC 300 (cont)

Prices:

L300 (DENSY)	$39,950
L300 (DENSY) 2 floppy	$45,950
L300 (DENSY) 20 Mbyte disk	$50,950
L300 (DENSY) 67 Mbyte disk	$55,950
L300 (CORA) 2 floppy	$50,950
L300 (CORA) 20 Mbyte disk	$55,950
L300 (CORA) 67 Mbyte disk	$60,950

ADDITIONAL PRODUCT INFORMATION

AVALON PHOTOMAC

Features:
- LHS and RGB color correction of all or part of an image
- Four-color separations for printing
- Multiple photographs can be combined in a single montage
- Special effects: automatically sharpen, smooth, negative-to-positive, monochrome, rotate, resize
- Retouching with opaque or transparent paint
- Windowing for cut-and-paste features nine magnification levels
- Color display shows near 24-bit quality on the 8-bit Mac II monitor
- Compatible with PICT, PICT2, TIFF-24, and TARGA file formats

Configuration:
- Apple System software version 6.0 or later
- Macintosh II with color monitor
- 40 Mbyte hard disk
- 2 to 8 Mbytes RAM
- Standard or high-resolution (1024 x 768 x 8 bits/pixel) video expansion card
- Options:
  - Data Translation ColorCapture framegrabber board with video input or output
  - 35 mm color slide scanner
  - Flatbed color scanner
  - Color thermal printer

Price:
- $695 for the software package;
  hardware must be purchased separately

ADDITIONAL PRODUCT INFORMATION

EIKONIX MODEL 1435 SLIDE SCANNER

Features:

- Patented scanning technique involving movement of the camera's sensor array
- Microprocessor-controlled scanning and communication electronics
- Scans slides, negatives, film strips, roll film, 35 mm sections of up to 70 mm/90 mm film, and aperture cards
- Scanning software allows simplified menu-driven scanning
- Autocalibration, autoexposure, autocolor balance, gamma correction
- 12/8/1 bit scan
- Imaging software allows simplified menu-driven image editing and enhancement
- File formats: IOPIC, TIFF, PICT2, TARGA/Vista
- A 24-bit RGB scan takes less than three minutes. A future model called the Eikonix 1490 will cut RGB scanning time to one minute.

Configuration:

- GBIP interface standard
- Optional interfaces for the IBM/PC/XT/AT, PS/2 and compatibles, Apple Mac II, DEC Unibus and Q-bus, VME bus systems including Sun3 and Sun 4
- Flexible film-holding mechanism
- Fixed-focus 75 mm Rodenstock lens
- Red/green/blue color filter wheel
- High-intensity diffused light source

Prices:

- $8,900 including a GPIB interface
- $2,195 for optional PC/AT or XT interface with cable and device driver
- $2,195 for optional Mac II interface with cable and device driver

ADDITIONAL PRODUCT INFORMATION

NIKON LS-3500 SCANNER

Performance:
- Scans a high-resolution 72 Mbyte file in 8.5 minutes

Features:
- Scans variable resolution up to 4096 x 6144 pixels over a 24 mm x 36 mm area with no interpolation
- Reads direct from positive or negative film, including color and monochrome
- Sequential RGB scanning
- Responds to more than 60 commands in ASCII code to specify scanning area and tint, register gamma curve, color balance, etc.
- Image processing functions:
  - Negative/positive reversal
  - Shading correction
  - Subsampling or culling
  - Binary processing (threshold level selectable) for creating high-contrast black and white images from continuous-tone
  - Seven types of spacial dither matrices (3x3 to 6x6)
  - Cropping
  - Other types of processing by command from host computer
- Image correction for exposure and color balance
- Complete gamma control in red, green, and blue to eliminate color cross-curves and bumps
- In a typical configuration, a 24-bit RGB image can be scanned to disk in less than 2 1/2 minutes.

Configuration:
- RS-232C (for commands) and GPIB (for image transmission) standard interfaces
- High-resolution fixed-focus lens

Price:
- $9,995

ADDITIONAL PRODUCT INFORMATION

QMS COLORSCRIPT 100

Features:
- Can print from black, three color, or four color thermal ink films
- Prints directly on transparency film or paper
- Downloadable font capability--35 typefaces standard
- Easily changeable color film

Configuration:
- 8 Mbytes RAM
- 1 Mbyte ROM
- Motorola 68020 MPU operating at 16.67 MHz
- 20 MByte hard disk
- Adobe Postscript version 49 code based controller
- RS-232, Centronics parallel and RS-422/AppleTalk interfaces

Price:
- $21,995

ADDITIONAL PRODUCT INFORMATION

HITACHI PROTOTYPE THERMAL INK TRANSFER PRINTER ENGINE

Shipments are expected to start in Spring of 1989.
Pricing and additional specifications are not yet available.

ADDITIONAL PRODUCT INFORMATION

KODAK SV6500 THERMAL DYE TRANSFER PRINTER

Features:

Makes prints from video signals sent by the Kodak SV5000 video transfer stand, SV7400 still video recorder, SV7500 still video multidisk recorder, SV9600 still video tranceiver, VCRs, optical disk players, video cameras, framestores, and computers

Framestore directly accessible for computer input through parallel interface port

Unterminated feed-through capability for both NTSC and RGB video

Prints field or frame images

Price:

$4,800

ADDITIONAL PRODUCT INFORMATION

NIKON CP-2 THERMAL DYE TRANSFER PRINTER

Features:
- Can print up to ten A5 copies in sequence
- Dot density of 8 dots/mm
- Optical density control performed dot by dot--256 shades per dot
- Images output at a resolution of 1024 x 1280 pixels
- Yellow, magenta, cyan coated web
- Dye is transferred onto pre-cut coated paper

Price:
- To be announced, for release in 1989.

ADDITIONAL PRODUCT INFORMATION

SONY MAVIGRAPH UP-5000 THERMAL DYE TRANSFER PRINTER

Features:
- Can print overhead projector transparencies
- Range of print modes from full size to 1/4 split and 1/9 split to composite mode
- Input signals include NTSC, analog RGB, component video (ProMavica, Betacam, etc.) and S-video
- Framestore for use in adjusting color values

Configuration:
- RS-232C computer interface
- Remote control key pad for operation control
- Optional frame memory as print buffer

Price:
- $6,900

ADDITIONAL PRODUCT INFORMATION

IRIS GRAPHICS 3024 COLOR PRINTING SYSTEM

Features:
- Averaging of color shades between addressable spot locations
- Consistent repeatability of digital images
- Control logic by Intel 8088 microprocessor
- Variable resolution--200, 240 or 300 dpi factory installed

Configuration:
- 8-bit parallel interface standard
- Optional interfaces to many systems are available:
  - Crosfield, Scitex, Hell, and many others

Price:
- $75,000

ADDITIONAL PRODUCT INFORMATION

ILFORD CIBACOPY CC-120 COLOR COPIER

Features:
- Preloaded daylight paper cassettes with light weight pearl finish, medium weight pearl finish, glossy finish, and overhead transparency film
- Bar code scanning system to sense cassette type for automatic color corrections, exposures, and media types, etc.

Configuration:
- Optional integrated slide copying attachment
- Light box attachment available in 1988

Price:
- $16,995 for base unit

ADDITIONAL PRODUCT INFORMATION

COLOROCS SERIES 1 COLOR PRINT ENGINE

This print engine has been implemented in two Colorocs products: a copier and a printer. The copier is shown in action in the videotape, but the printer specifications are also included here for reference.

Engine features:

- Modular structure
- Asyncronous operation
- Direct digital control by a microprocessor
- Controlled image development through the use of an intermediate storage medium (transfer belt)
- Uses yellow, cyan, magenta, and black toners for copies in full color with continuous tones and in any single color including true black

COLOROCS COLOR LIGHT LENS COPIER

Features:

- Copies in full color, and in any single color including true black
- Copy speed is 7.5 pages per minute in full color, 8 1/2 x 11 inches or smaller
- Copy speed is 22.5 pages per minute in black only, 8 1/2 x 11 inches or smaller
- Originals as large as 11 x 17 inches can be copied
- Copies can be as large as 11 x 17 inches
- Reduction and enlargement can be zoomed with presets for standard sizes -- 64 percent reduction to 154 percent enlargement
- Uses conventional 115 volt 15 amp electrical service
- Small size
- Full-color copy cost is less than 25 cents, or 11 cents per copy in a mixed mode of 20 percent full color and 80 percent black only
- Straight paper path of only 18 inches

Price:

- $18,000 targeted end user price

ADDITIONAL PRODUCT INFORMATION

COLOROCS COLOR PRINTER

Features:
- 300 dpi resolution
- Prints on 16- to 32-pound plain paper or on transparencies
- High speed turbo mode produced 45 pages per minute in black and white on 8 1/2 x 11 inch paper

Configuration:
- Uses an Intel 80386-based PC as a host and controller

Price:
- Targeted end user price under $25,000 to $35,000 depending on configuration

ADDITIONAL PRODUCT INFORMATION

EKTRON LASER IMAGE RECORDER MODEL 811

Features:
- Software selectable pixel sizing between 40 and 535 pixels per inch
- Daylight operation including media loading, exposing, and processing
- Programmable 14-bit look-up table performs both density mapping and calibration functions
- Records on both paper and film
- Heat development obviates need for wet chemicals

Configuration:
- IEEE-488 interface standard

Price:
- $22,300

ADDITIONAL PRODUCT INFORMATION

PHSCOLOGRAMS

A Phscologram is a multi-media, high-tech art form; the technique combines Photography, Holography, Sculpture, Computer Graphics and Video to produce 3-D transparencies. Objects can be either real or simulated -- they are either physical constructIons or they are creations made using computer graphics or video technology.

Phscolograms provide an alternative to traditional presentation materials, because 3-D data may be displayed in 3-D and not projected onto a 2-D viewing area.

Applications include both science and art.

A phschologram is created by using a room-sized camera to photograph a real or stimulated object/environment (sculpture, computer graphic environments, or video object. In the case of sculpture, the actual object is photographed; in the case of computer graphics or video, a monitor is photographed. In each case, a photographic technique called barrier-strip auto-stereography is utilized. The images are transferred onto transparency film which, when processed, is inserted into a light box for viewing. As you move in front of the phscolograms, you see a 3-D object.

Computer graphics post-processing was provided by the Electronic Visualization Laboratory at the University of Illinois at Chicago. Phscologram is a trademark of (Art)^n Laboratory, Illinois Institute of Technology (IIT), 319 Wishnick Hall, Chicago, IL 60616. Phscolograms are courtesy of Feature, Chicago, IL.

ADDITIONAL PRODUCT INFORMATION

FOLSOM RESEARCH AURORA/300 BOARD SET

Features:
- Supports HP 330, 350, 360, and 370 workstations
- Realtime filtering and compression of input 1280 x 1024 images to 640 x 484 video
- RS-170A RGB and NTSC outputs
- Genlockable output
- Three 640 x 484 x 8 bit planes of memory
- Frame buffer access via HP DIO-II bus, allowing users to port a non-compressed 640 x 484 image from the host high-resolution memory directly to the 24-bit frame buffer of the Aurora/300
- Supports Wavefront animation software
- Transparent to the workstation
- 24 bit/pixel output
- Weighted-average interpolation algorithm for output image color fidelity

Configuration:
- Two-card, single-slot board set

Price:
- $4,995

ADDITIONAL PRODUCT INFORMATION

PARALLAX 1280 SERIES VIDEOGRAPHIC PROCESSOR BOARD SET

Performance:
- 12 MIPS programmable bit-slice processor
- 25 Mpix/second solid and pattern drawing
- 45,000 vectors/second
- 12 Mpix/second BLock Image Transfer (BLIT)

Features:
- Integrated NTSC Block video and high-resolution graphics processor
- 2048 x 2048 addressable memory
- User microprogrammable
- VME, Q-bus and IBM RT PC bus compatibility
- Dual RS-232 serial ports
- Operating system drivers and GKS support available
- Digital time base correction
- High-speed DMA capability
- 1280 x 1024 x 8 bit display
- 16,384 colors for video
- 1 to 16 x zoom along X and/or Y axis
- Smooth 1-pixel pan, smooth scrolling
- 2 switchable video inputs and advanced filtering (VME bus)
- 16 and 24 bit versions available (Q-bus)
- Support Parallax's PNeWS windowing system and X Windows Version 11.3
- Optional Extended Instruction Set microcode

Prices:

1280-V-8VN	$8,700
1280-Q-8VN	$8,300
1280-R-8VN	$7,500
1280-SUN3-8VN	$11,000 (with mounting kit and PNeWs windowing software)

ADDITIONAL PRODUCT INFORMATION

D2 vs. 1-INCH NTSC VIDEO
20TH GENERATION QUALITY COMPARISON

This split-screen comparison of the video quality of 20th generation D2 digital composite NTSC and 20th generation 1-inch Type C analog composite NTSC was produced exclusively for this program by Dean Winkler at Post Perfect in New York. D2 is shown in the upper half of the screen. 1" i s shown in the lower half.

Color bars and the "scientist" were recorded from the same source materials to a Sony BVH-2000 1-inch VTR and to a Sony DVR-10 VTR, respectively. The color bars were generated using a Leitch digital test signal generator. The "scientist" came from a D2 master originally produced by transferring 35 mm color negative to D2 video tape using a 4:2:2 Rank Flying Spot Scanner and DaVinci color corrector.

The resulting 1-inch and D2 tapes were considered "masters" which were then copied back and forth between two record/playback machines to create 20 generation copies in the two respective formats. These 20 generation copies were recorded split-screen onto 1-inch tape which was then inserted into the 1-inch edit master of *Visualization: State of the Art UPDATE.*

ADDITIONAL PRODUCT INFORMATION

CYBERWARE 4020/PS CRANOFACIAL SCANNER

Performance:

- 17,000 samples/second, one 360 degree scan in approximately 15 seconds

Features:

- Average measurement resolution 0.7 mm
- Resolution can be increased by decreasing field of view or through other methods
- Live subjects or those with intricate surfaces may be scanned quickly
- Output to numerically-controlled machine tools is possible

Ethernet interface to:

- Silicon Graphics Iris Workstations
- Sun 3/workstations
- Mac II
- HP 9807A
- (CPU platform is determined by the degree of image manipulation required.)

A linear digitizer for planar or relief object scanning is available, and other specialized body part scanners are also under development

Prices:

- $40,000 for the cranofacial scanner model, including the input device, operating software,
  and an Ethernet link that allows digitizer operation while the platform computer is accessing the data at the same time.
- $33,000 for the linear digitizer model
- $45,000 for combination 4020/PS scanner and linear digitizer
- No prices available for models under development

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APPENDIX B

BIOGRAPHICAL INFORMATION
ON-CAMERA SPEAKERS

(note: the speakers are listed here in alphabetical order, not in the order in which they appeared on the tape)

Richard J. Beach
Xerox Palo Alto Research Center (PARC)

Richard J. Beach is Principal Scientist and Laboratory Manager of the Electronic Documents Laboratory at the Xerox Palo Alto Research Center (PARC). Beach jointed PARC in 1982 to research the application of interactive computer graphics and digital typography to document composition and illustration systems. Beach serves as the editor-in-chief for ACM/SIGGRAPH and publishes their journal, Computer Graphics, including the full-color proceedings of the annual SIGGRAPH conference. He also co-edits the Wiley Interscience journal Electronic Publishing: Origination, Dissemination and Design. He has organized and taught several tutorials on electronic publishing, scholarly publishing and documentation graphics. His research interests and publications lie in the areas of document composition, digital typography, interactive illustrators, color reproduction, table formatting, document interchange, digital cartography and software engineering. Beach holds BMath, MMath and Ph.D. degrees in computer science, all from the University of Waterloo.

James F. Blinn
California Institute of Technology

Dr. James F. Blinn holds a B.S. in Physics and an M.S. in Computer Science from the University of Michigan, and a PhD. from the University of Utah. While enrolled at Utah he worked the summer of 1976 in the Computer Graphics Lab of the New York Institute of Technology. His PhD. Dissertation on the "Computer Display of Curved Surface" is recognized as a landmark in the field. He began working in computer graphics at the Jet Propulsion Laboratory (JPL) in 1977. He spent a brief time at Lucasfilm, Ltd. in 1980 helping to plan what was to be the first Pixar machine. Dr. Blinn has also taught at University of California/Berkeley, The Art Center College of Design, and Caltech.

Over his career Dr. Blinn has worked on almost ten hours of computer graphic animation. His animation works for NASA include simulations of Voyager encounters with planets. He led the effort to produce animation for the Cosmos series for PBS. His major accomplishment is almost eight hours of animation for the 52-episode series entitled The Mechanical Universe, which is designed to help teach physics to college freshmen. For the series Dr. Blinn designed new metaphors for representing mathematics and physics; it received a citation by the Los Angeles Times, eight CINDYs, and the Japan Prize.

In 1983 Dr. Blinn was awarded the NASA Exceptional Service Medal as well as ACM/SIGGRAPH's Computer Graphics Achievement Award. He has contributed extensively to ACM/SIGGRAPH's conference tutorials, panels, technical documents, and video exhibitions. He writes a regular column for the IEEE Computer Graphics and Applications Journal.

Donna J. Cox
University of Illinois at Urbana-Champaign
National Center for Supercomputing Applications

Donna J. Cox has exhibited static computer images and computer graphics animations in more than 50 invitational and juried exhibits int he past four years, both in the U.S. and internationally. Her work has appeared in many cable television programs, and she was featured as a pioneer artist in scientific visualization on a national PBS special program, "The Infinite Voyage: Unseen Worlds." She has authored several papers on computer graphics, including one on scientific visualization on supercomputers and has received awards for her art and computer graphics work. In the past three years she has made over 10 presentations on her art and academic research. He work has been reviewed and has appeared in many major national publications. She is an active member of (Art)^n in Chicago where she collaborates and translates supercomputer graphics into a new visual technology. She has received grants from the NSF, Kodak Research Division, and AT&T.

Cox holds B.A. and M.F.A degrees from the University of Wisconsin-Madison. Since 1985 she has served as Visiting Assistant Professor in the School of Art and Design, University of Illinois, and as Adjunct Professor for Supercomputing Applications at the National Center for Supercomputing Applications.

Charles A. Csuri
The Ohio State University

A pioneer in computer animation and graphics, Charles A. Csuri is a Professor of Art Education and of Computer and Information Science at The Ohio State University. As the Director of the University's Advanced Computing Center for the Arts and Design (ACCAD), he has provided a conceptual framework for new directions in art. Csuri has developed an experimental program of graduate study for artists and animators at Ohio State, attracting world-wide interest.

With support from the National Science Foundation, the Navy, and the Air Force Office of Scientific Research, he has directed basic research in computer graphics for the past 20 years, involving 15 major projects. The research results have been applied to flight simulators, computer-aided design, science education, anatomy, education for the deaf, architecture, and special effects for television and films. He received a Distinguished Research Award from Ohio State in 1983. Most recently, Csuri has been involved with the Ohio Supercomputer Center, developing an integrated graphics environment for scientific visualization.

Henry Fuchs
University of North Carolina, Chapel Hill

Henry Fuchs is Federico Gil Professor of Computer Science and Adjunct Professor of Radiation Oncology at the University of North Carolina, Chapel Hill. He received his Ph.D. in Computer Science in 1975 from the University of Utah. Fuchs is also currently a member of the technical advisory board of Stellar Computer Inc., a firm manufacturing high-performance graphics workstations. He is the principal investigator for research projects supported by the Air Force, DARPA, NFS, and NIH, most of which involve the development of high-performance 3-D graphics systems and algorithms for radiology, radiation therapy, and other medical applications.

Laurin Herr
Pacific Interface Inc.

Laurin Herr has worked in computer-related areas since the mid-1960's and has consulted to both Japanese and American corporations since the late 1970's. He founded Pacific Interface in 1980 as an international consulting company, developing an extensive network of professional contacts in Japan and elsewhere through his work on industrial study missions, international conferences, events, industry and market research projects, and other consulting assignments. Clients have included Du Pont, Honeywell, AT&T, Mitsubishi Corporation, Hitachi Ltd., and Seiko Electronic Instruments. Herr produced and directed a series of video and text reports on computer graphics with Raul Zaritsky that were published by Frost & Sullivan in 1986 and 1987. These were followed in 1988 by the 160-minute report titled "Visualization: State of the Art," published as Special Issue 30 of the SIGGRAPH Video Review. Mr. Herr organized the first international VISUALIZATION IN SCIENTIFIC COMPUTING Workshop in Tokyo, Japan in August 1988 under the auspices of the Institute for Supercomputing Research. He also co-authored with Carl Machover a 1500-page study titled "Japanese Computer Graphics: Industry and Market" published in 1985 by the Institute for Graphic Communications. He has served as the official liaison with Japan for the ACM/SIGGRAPH organization since 1982, and was also appointed to the International Relations Committee of the National Computer Graphics Association (NCGA) in 1987. Herr received a Bachelor of Arts degree in government from Cornell University in 1972.

Thomas Jermoluk
Silicon Graphics

Tom Jermoluk is Vice President and General Manager, Advanced Systems Division of Silicon Graphics. Mr. Jermoluk is responsible for the development of Silicon Graphics' high-end workstations including graphics and CPU hardware, as well as operating system and graphics software. Previously, he was with Hewlett-Packard as head of hardware and software development for one of the new RISC computers of the HP Precision Architecture; his efforts focused on UNIX enhancements and bus development. Prior to HP, Mr. Jermoluk managed a group at Bell Laboratories in the UNIX Development lab, concentrating on areas such as multiprocessing and OS support for very high speed networking and distributed processing.

Jermoluk received a B.S.C.S./E.E. degree in 1978 and an M.S.C.S. in 1979, both from Virginia Tech. Studying under a grant from the Ford Foundation, he completed work used nationally for graphic representations of pollution simulations.

Carl Machover
Machover Associates Corporation

Carl Machover is President of Machover Associates Corporation, a consultancy which provides a broad range of management, engineering, marketing and financial services to computer graphics users, suppliers and investors. Mr. Machover is an internationally recognized expert on computer graphics with a long list of clients served and professional groups addressed. He is the President-Elect of the National Computer Graphics Association, and serves on the advisory board of the Pratt Center for Computer Graphics in Design, Datapro, and The Boston Film and Video Foundation. He has written numerous articles on computer graphics and is on the editorial boards of "IEEE Computer Graphics and Applications," "Computers and Graphics," "Visual Computer," and "Computers for Design and Construction." He is also Chairman of the Editorial Board of the "S.Klein Newsletter." He served for two years as the National President of the Society for Information Display (SID) and was formerly Executive Vice President of Information Displays Inc. Mr. Machover graduated as an electrical engineer from Rensselaer Polytechnic Institute.

Benoit B. Mandelbrot
IBM Thomas J. Watson Research Center
Yale University

Benoit B. Mandelbrot is best known as the author of the books Les Objets fractals, 1975 and 1984 (translated into Italian, Spanish, and Hungarian), and The Fractal Geometry of Nature, 1982 (translated into Japanese and German). He is IBM Fellow at the IBM Thomas J. Watson Research Center and the first Abraham

Robinson Adjunct Professor of Mathematical Sciences at Yale. He is a fellow of the American Academy of Sciences; a Foreign Associate of the U.S. National Academy of Sciences; and a Membre Titulaire de l'Academie Europeenne des Sciences, des Arts et des Lettres. He was awarded the 1985 F. Barnard Medal by the U.S. National Academy of Sciences and Columbia University, the 1986 Franklin Medal by the Franklin Institute of Philadelphia, the 1988 Charles Proteus Steinmetz Medal by IEEE and Union College, and the 1988 Moet-Hennessy-Louis Vuitton Prize. Graduate of the Paris Ecole Polytechnique, he holds M.S. and Ee.E degrees in Aeronautics from California Institute of Technology and a Docteur es Sciences Mathematiques from the University of Paris. He holds honorary Doctor of Science degrees from Syracuse University, Laurentian University, Boston University, State University of New York, Pace University, University of Guelph, and Universitat Bremen. He was awarded the Distinguished Service Award by Caltech and the Humboldt Preis, A. von Humboldt Stiftung.

Dr. Mandelbrot's positions before IBM were with the CNRS in Paris, Philips Electronics, M.I.T., the Institute for Advanced Study, the University of Geneva, the University of Lille and Ecole Polytechnique. On leave from IBM, he had been an Institute Lecturer at M.I.T. and a Visiting Professor of Economics, later of Applied Mathematics, and then of Mathematics at Harvard, of Engineering at Yale, of Physiology at the Albert Einstein College of Medicine, and of Mathematics at Universite de Paris-Sud, and a Professor of the Practice of Mathematics at Harvard.

Joel N. Orr
Orr Associates, Inc.

Joel N. Orr is a CADD/CAM and computer graphics consultant. He is chairman of Orr Associates, Inc. (OAI), one of the most active consulting firms of its type in the world, and is the director of the CADD/CAM Institute, a seminar and publishing firm. OAI clients include IBM, Burroughs, the U.S. Air Force and Navy, Hasbro, Xerox, Applicon, TA Associates, the Government of Israel, and many others. OAI provides both technical and marketing counsel to users and vendors of CADD/CAM and computer graphics equipment and services, as well as to investors.

Orr is a contributing editor for Computer Graphics Today, Computer Graphics World, Datapro, Communications Consultant, Software Digest, and CADWorld. He is a founding member and president of the National Computer Graphics Association. He frequently addresses the Society for Manufacturing Engineers, the American Production and Inventory Control Society, and many other professional groups. He has written and edited several books on CADD and CIM.

Orr holds a Ph.D. in mathematics and computer science from State University of New York at Stonybrook.

Thomas Porter
Pixar

Thomas Porter is Director of Advanced Technology for Pixar, responsible for new engineering projects in the company. Tom received an M.S. in Computer Science from Stanford in 1975. His initial work in computer graphics was at the National Institutes of Health, using one of the first commercial frame buffers to do molecular modeling. At Ampex, Tom wrote the software for AVA, the first commercial digital paint system. Tom spent five years on the computer graphics research staff at Lucasfilm. He developed algorithmic research that lead to the Pixar Image Computer, and he headed up the hardware research team. Tom spent 18 months as Pixar's Director of Marketing; most recently, he has been responsible for Pixar's RenderMan project.

Judson Rosebush
Rosebush Visions Corporation

Judson Rosebush has produced and/or directed hundreds of computer animation pieces. He is a pioneer in the business and was the founding president of Digital Effects in New York in 1978, the company which virtually introduced computer animation to the commercial market place. In 1985 he started his own company, Rosebush Visions Corp., where he produces and directs a wide variety of special effect work in film and video, and consults on software and facility planning. He has exhibited drawings in numerous museum shows and his computer drawings have been reproduced in many books. He is the author of Computer Graphics for Designers and Artists, published in 1986 by Van Nostrand Reinhold Co., and is currently writing a book on Computer Animation. Rosebush holds an M.S. degree in Television and Radio from Syracuse University, and is currently a doctoral candidate at the same university, where he is studying Communications Research Methods.

Daniel J. Sandin
Electronic Visualization Laboratory, School of Art and Design
University of Illinois at Chicago
National Center for Supercomputing Applications
University of Illinois at Urbana-Champaign

Daniel J. Sandin is a Professor of Art and Co-Director of the Electronic Visualization Laboratory in the School of Art and Design at the University of Illinois at Chicago, and an Adjunct Professor at the NCSA, University of Illinois, Urbana-Champaign. His early interest in computer graphics/video image processing and interactive computing environments motivated his pioneering work in video synthesizers and continues to influence his research efforts in the field of 3-D phscolography today. Sandin's computer/video art has been exhibited worldwide and has received many awards; he has received many grants and fellowships from such distinguished organizations as the Rockefeller Foundation, the Guggenheim Foundation and the National Endowment for the Arts; and, he has work included in the first collection of video art at the Museum of Modern Art in New York. Sandin received a B.S. in 1964 from Shimer College and an M.S. from the University of Wisconsin/Madison in 1967, both in physics.

Turner Whitted
Numerical Design, Ltd.

Turner Whitted was educated at Duke University, receiving a B.S.E.E. degree in electrical engineering in 1969 and an M.S.E.E. degree the following year. He was granted the Ph.D. degree in electrical engineering by North Carolina State University. For the next five years Whitted was a member of the Computer Systems Research Laboratory of Bell Laboratories. While at Bell Labs, he developed the simple and elegant algorithm that made ray tracing more efficient and widely useable, as first shown in his 1979 film "The Complete Angler." Returning to North Carolina in 1983, he became the founder and president of Numerical Design, Ltd., a firm which produces image rendering software. Since 1982, he has been an Adjunct Professor of Computer Science at the University of North Carolina at Chapel Hill. In 1986, Turner Whitted received the ACM/SIGGRAPH Computer Graphics Achievement Award.

Dean Winkler
Post Perfect

Dean Winkler is Vice President and Director of Creative Services at Post Perfect. He designed Post Perfect's 40,000 square foot electronic special effects facilities in New York City--the first New York facility with a D2 editing suite. The firm can do film transfers. 2D and 3D computer generated image mastering, videotaping and optical compositing on D1 and D2. From 1981 to 1986 he was with VCA Teletronics, holding the positions of Design Engineer and Director of Computer Graphics/Optical Services.

Winkler has produced many pieces of video art which have been exhibited in major museums. An active member of SMPTE, and the author of "Editing Suite Design," published in the 1983 SMPTE Journal, Winkler also holds a patent for a programmable ramp/special reference digital to analog converter. He holds Bachelor's and Master's degrees in Communications and Electrical Engineering from Rensselaer Polytechnic Institute.

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APPENDIX C

IMAGE AND ANIMATION CONTRIBUTORS

(Note: The animations and images are listed in the order of their appearance in the videotape.)

ANIMATION - 3-D TERRAIN MAPPING
PIXAR - 1988
Data courtesy of U.S. Geological Survey

ANIMATION - DINOSAUR STUFF
John Donkin - 1988
Ohio State University ACCAD

IMAGE - WATER STRIDER
Softimage - 1988

ANIMATION - VOLUME RENDERED CYLINDER HEAD
PIXAR - 1988
Data courtesy of ARACOR

ANIMATION - VOLUME RENDERED FEMALE HEAD
Fuchs - Levoy - 1988
University of North Carolina, Chapel Hill
Note: this animation was done by Mark Levoy as part of his docutoral dissertation; H. Fuchs, advisor

ANIMATION - RAY-TRACED DIAMONDS
Toshiyasu L. Kunii - 1988
The University of Tokyo

IMAGE - A MUSEUM OF CONSTRUCTIVIST ART (ACM SIGGRAPH '88 CONFERENCE PROCEEDINGS - COVER IMAGE)
Cornell University - 1988
Program of Computer Graphics

IMAGE - A LILAC TWIG
Przemyslaw Prusinkiewicz
James Hanan
F. David Fraccia
University of Regina - 1988
Department of Computer Graphics

ANIMATION - ANTI-LOGO
Post Perfect - 1988

ANIMATION - CONSTRAINED DYNAMICS

John Platt and Al Barr - 1988
California Insitute of Technology
The Caltech Graphics Group

ANIMATION - PRESIDENT'S DAY STORM

William Hibbard, Dave Santek - 1988
Space Science and Engineering Center
University of Wisconsin

ANIMATION - MUSCLE MODELING

John Chadwick - 1988
Ohio State University ACCAD

ANIMATION - HUMAN DYNAMICS

John Chadwick - 1988
Ohio State University ACCAD

ANIMATION - NCSA SCIENTIFIC VISUALIZATION 1988

National Center for Supercomputing Applications
University of Illinois at Urbana-Champaign

1. LORENZ ATTRACTORS
   Scientific Research: David Hobill, Michael Weige, Daniel Simkins, NCSA
   Visualization: Jeffrey Yost, Scientific Visualization Program, NCSA
2. PLASTIC INJECTION MOLDING
   Scientific Research: Richard Ellson, Eastman Kodak
   Visualization: Ray Idaszek and Donna Cox, RIVERS, and Stephan Fangmeier, Scientific Visualization Program, NCSA
3. NUMERICAL RELATIVITY: BLACK HOLE SPACE TIMES
   Scientific Research: Larry Smarr and David Berstein, Departments of Astronomy and Physics, University of Illinois at Urbana-Champaign; David Hobill, NCSA
   Visualization: Ray Idaszek and Donna Cox, RIVERS, and Stephan Fangmeier, Scientific Visualization Program, NCSA
4. "VENUS" from "METAMORPHOSIS: SHADOWS OF A HIGHER DIMENSION"
   Scientific Research: George Francis, Department of Mathematics, University of Illinois at Urbana-Champaign
   Visualization: Donna Cox and Ray Idaszek, RIVERS, and Stephan Fangmeier, Scientific Visualization Program, NCSA

ANIMATION - MATHEMATICA; THE THEOREM OF PYTHAGORAS (excerpt)
Animation: James Blinn, Sylvie Rueff - 1988
Project Director: Tom Apostol
Computer Graphics Laboratory/JPL
California Institute of Technology

ANIMATION - "THE SCIENCE OF FRACTAL IMAGES" (excerpt)
H.-O. Peitgen, H. Juergens, D. Saupe - 1987
University of Bremen
University of California at Santa Cruz

ANIMATION - FRACTAL LANDSCAPES
Richard F. Voss - 1987
IBM T.J. Watson Research Center

ANIMATION - DNA MOLECULE
Dave Pensak, John Cristy, Karen Rogers - 1988
E.I. du Pont de Nemours & Company
Central Research and Development Department

ANIMATION - HAIR
Jerry Weil - 1988
AT&T Bell Laboratories

VISUALIZATION: STATE OF THE ART
UPDATE

APPENDIX D

PRODUCT SUPPLIER ADDRESSES AND TELEPHONE NUMBERS

ALLIANT COMPUTER SYSTEMS CORPORATION
One Monarch Drive
Littleton, Massachusetts 01460
(617) 486-4950

APOLLO COMPUTER
330 Billerica Road
Chelmsford, Massachusetts 01824
(617) 256-6600

ARDENT COMPUTER
880 West Maude Avenue
Sunnyvale, California 04086
(408) 732-0400

(ART)^n LABORATORY
Illinois Institute of Technology
319 Wishnick Hall
3255 South Dearborn Avenue
Chicago, Illinois 60616
(312) 567-3762

AT&T PIXEL MACHINES
Room 4L213
Crawfords Corner Road
Holmdel, New Jersey 07733
(201) 949-0965

AVALON DEVELOPMENT GROUP
1000 Massachusetts Avenue
Cambridge, Massachusetts 02138
(617) 661-1405

COLOROCS CORP.
2830 Peterson Place
Norcross, Georgia 30071
(404) 448-9799

CROSFIELD DICOMED INC./DESIGN SYSTEMS
11401 Rupp Drive
P.O. Box 246
Minneapolis, Minnesota 55440-0246
(602) 895-3000

CROSFIELD ELECTRONICS, INC.
65 Harristown Road
Glen Rock, New Jersey 07452
(201) 447-5800

CROSFIELD LIGHTSPEED INC.
47 Farnsworth Street
Boston, Massachusetts 02210
(617) 338-2173

CYBERWARE LABORATORY, INC.
2062 Sunset Drive
Pacific Grove, California 93950
(408) 373-1441

EASTMAN KODAK COMPANY
Electronic Photography Division
343 State STreet
Rochester, New York 14650

EIKONIX DIVISION OF EPPS KODAK
15 Wiggins Avenue
Bedford, Massachusetts 01730
(617) 275-3232

EKTRON APPLIED IMAGING, INC.
23 Crosby Drive
Bedford, Massachusetts 01730
(617) 275-0475

FOLSOM RESEARCH INC.
526 East Bidwell Street
Folsom, California 95630
(916) 985-2481

HEWLETT-PACKARD
3404 East Harmony Road
Fort Collins, Colorado 80525
(303) 229-3800

HITACHI AMERICA LTD.
50 Prospect Avenue
Tarrytown, New York 10591-4698

HOWTEK, INC.
21 Park Avenue
Hudson, New Hampshire 03051
(603) 880-3843

ILFORD PHOTO CORPORATION
West 70 Century Rd.
Paramus, New Jersey 07653
(201) 265-6000

IRIS GRAPHICS, INC.
12 Jacob Way
Reading, Massachusetts 01867
(617) 438-1500

LINOTYPE COMPANY
425 Oser Avenue
Hauppauge, New York 11788
(516) 434-2000

MEIKO SCIENTIFIC CORPORATION
6201 Ascot Drive
Oakland, California 94611
(415) 530-3055

NIKON INC.
623 Stewart Avenue
Garden City, New York 11530
(516) 222-0200

PANSOPHIC GRAPHIC SYSTEMS
709 Enterprise Drive
Oak Brook, Illinoise 60521
(312) 572-6000

PARALLAX GRAPHICS, INC.
2500 Condensa Street
Santa Clara, California 95051

PIXAR
3240 Kerner Boulevard
San Rafael, California
(415) 258-8100

QMS, INC.
One Magnum Pass
Mobile, Alabama 36618
(205) 633-4300

RASTER TECHNOLOGIES
2 Robbins Road
Westford, Massachusetts 01886
(508) 692-7900

SILICON GRAPHICS INC.
2011 N. Shorline Boulevard
P.O. Box 7311
Mountain View, California 94039-7311
(415) 962-3365

SOFTIMAGE
3510 Boul. St. Laurent, Ste 214
Montreal, Quebec, Canada H2X 2V2
(514) 845-1636

SONY CORPORATION OF AMERICA
15 Essex Road
Paramus, New Jersey 07652
(201) 368-5000

STELLAR COMPUTER INC.
75 Wells Avenue
Newton, Massachusetts 02159
(617) 964-1000

SUN MICROSYSTEMS
2550 Garcia Avenue
Mountain View, California 94043
(415) 960-1300