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PRO E THE MAGAZINE™

Workstation benchmark 1999

$24.95

Compaq Tops Workstation Benchmarks

Compaq submitted three Windows NT systems for testing. The summary of results is shown below:

#1 Fastest Windows NT workstation: the Compaq Professional Workstation XP1000 (667Mhz) with a Compaq PowerStorm 300 graphics card...
See "The Systems" . . . . . Page 20
See "Chart 1" . . . . . Page 11

#1 Fastest CPU: the Compaq Professional Workstation XP1000 (667Mhz) with a Compaq PowerStorm 300 graphics card...
See "The Systems" . . . . . Page 20
See "Chart 3" . . . . . Page 11

#1 Price/Performance and Best Value: The Compaq Professional Workstation AP200 with an Oxygen GVX1 graphics card...
See "Conclusions" . . . . . Page 22
See "Chart 4" . . . . . Page 15

"The Compaq AP200 is the best price and the best value. It sacrifices nothing in terms of its hardware configuration, allowing users to run Pro/ENGINEER on a top-notch NT workstation"...
See "Conclusions" . . . . . Page 22

The XP1000 is "an excellent choice for those users with big assemblies, huge drawings and complex models with long regeneration times"...
See "The Systems" . . . . . Page 20

"The systems that did well in the review are the ones sold by companies with the most experience putting together Pro/ENGINEER systems... It is advisable to go to the experts when making a purchase"...
See "Conclusions" . . . . . Page 22

COMPAQ

Korhan Tekin

Fifth annual Pro/ENGINEER workstation benchmark

Every Pro/ENGINEER user is familiar with the axiom "You can never have too much power." Pro/ENGINEER is one of the most demanding workstation applications, capable of bringing even the most powerful computer hardware to a dreadful crawl. Users are constantly finding themselves pushing against the upper limits of performance, and more often than not, they find their computers to be a hindrance to progress, not moving fast enough to keep pace with their imaginations and intents.

However, in recent years, Pro/ENGINEER users are finding that high-performance, workstation-class computer hardware is extremely accessible. The cost of hardware has decreased to the point where a powerful workstation can readily be placed on the desktop of most users. Such systems are equipped well enough for the majority of design tasks and cost just a fraction of what their predecessors cost only a few years ago. As never before, users needing access to the most powerful computer systems running the most powerful mechanical design software are finding they can get exactly what they want without breaking the bank.

But how does one go about selecting a workstation for running Pro/ENGINEER? It is not simply a matter of picking the fastest or the cheapest workstation. Indeed, it is a question that requires careful consideration, weighing the factors specific to the needs, desires and limitations of the organization. It is a question that is critical to the success of both the utilization of Pro/ENGINEER within your company and perhaps to the success of the company as a whole.

This is the question that we attempt to answer in this year's workstation benchmark. This year's "bench99" counts 23 systems among its participants, submitted from nine different vendors. Whereas in past workstation benchmarks, Windows systems struggled to gain ground against the UNIX veterans, the systems in this year's review were of a decidedly "Wintel" dominated mix. Among the competing systems, there were only two systems running Pro/ENGINEER under UNIX, while the rest were running Pro/ENGINEER under Windows NT. Of the NT machines, all but three were running Intel Pentium III processors. Two were running the Alpha processor, and one system used an older Pentium II. The Intel offerings also included a good number of systems using Intel's Pentium III Xeon chip.

This year's benchmark is the first opportunity many will get to take a look at the latest in workstation-class hardware. In fact, many of the products reviewed were not publicly released at the time the review was conducted. This will be the first opportunity to witness the performance of the Pentium III architecture and to see whether or not it delivers any significant performance increase over its predecessor, the Pentium II. It will also mark the first chance for users to witness the performance of the Xeon Processor with Pro/ENGINEER, determining whether or not users should choose the more expensive Xeon processor over the basic Pentium III.

The benchmark also includes some exciting new developments in 3D graphics performance. Though users will be familiar with the GMX2000 graphics boards, 3Dlabs was also represented by their new Oxygen GVX1 graphics accelerator (which will be released by the time this article is published). Another new product is the Diamond FireGL-1, which is based on a new graphics chipset designed by IBM. Both these products claim to offer unprecedented professional 3D graphics power for under $1,000, a previously unheard-of price for this level of performance. Both of Hewlett Packard's systems used their FX4 Visualize graphics architecture, which continues to reside at the high-end of both the price and performance spectrums. Also featured in the review is the Intergraph Wildcat 4000, a high-end, fully-

continued on page 4

continued from page 3

featured 3D graphics subsystem from the traditional leader in graphics workstation computing on Windows NT.

This group of systems delivers a broad range of price points and performance, representing the high-end of workstation Pro/ENGINEER computing in addition to the high end of price/performance. This year's fastest system was twice the speed of the slowest, and the system with the best value had a price/performance ratio over six times that of the worst value. Therefore, regardless of whether you are on a tight budget or require the fastest system possible, there is certainly a system available to satisfy the most demanding user constraints.

Background

In 1988, the early days when Pro/ENGINEER had just entered into the CAD market, a Silicon Graphics Corp.'s (SGI) machine was considered the primary choice of hardware for Pro/ENGINEER. SGI was the pioneer of workstation 3D graphics, emerging just in time to provide a viable platform on which Pro/ENGINEER could run. At that time, nearly 90 percent of Pro/ENGINEER users were running on SGI systems.

As the Pro/ENGINEER market began to mature, SGI lost some of its market share to other UNIX vendors such as Sun, IBM, Digital and Hewlett Packard. Around 1996, UNIX vendors began to experience a significant loss in market share as Windows NT systems moved into the workstation market and fast OpenGL graphics hardware became available for NT. The UNIX systems were eventually outpaced and out-priced by their Windows NT counterparts, as a thriving NT workstation marketplace delivered blisteringly fast technology at price points well below those of UNIX systems.

The aggressive delivery of new workstation technology into this market, combined with the emergence of Windows NT as a mainstream, workstation-class operating system, has permanently altered the Pro/ENGINEER landscape. The competitiveness of the market has resulted in the delivery of workstation hardware that has significantly outpaced the growing complexity of Pro/ENGINEER. Consequently, users no longer need the absolute fastest system on the market to get the bulk of their work done. The low cost of hardware has also increased the competitiveness of the CAD software marketplace.

The price pressures brought on by Windows NT have especially hurt UNIX hardware vendors. These vendors have been forced to drop their prices significantly to compete, but even with the lower prices, these systems are being outsold by NT. Two years ago, the most expensive UNIX system in the workstation benchmark was almost $45,000. This year's UNIX offerings max out at just over $18,000. NT has, at the very least, given the UNIX world better prices, a huge benefit for an enterprise still reliant on UNIX. Though the price/performance ratio of UNIX is still not generally competitive with that of NT systems, the custom architecture of a UNIX workstation can still outperform even the best systems running Windows NT.

One final consequence of the competitiveness in the workstation market is a consolidation and elimination of vendors selling systems for Pro/ENGINEER users. Several vendors who have participated in past benchmarks and were once major players in the review are no longer in business. There are also far fewer UNIX systems in this year's review than ever before. Vendors who could have been expected to submit a UNIX system but did not include SGI, Sun, and Digital Equipment Corp. (DEC), which was acquired last year by Compaq. This year, Compaq chose not to submit one of its Tru64 UNIX Alpha systems for the review, instead submitting three NT systems running both Intel and Alpha processors (all vendors were limited to a maximum of three submissions).

Compaq is in an interesting position as a workstation vendor. They now own the Alpha processor, which they acquired when they bought DEC last year. As such, Compaq is now offering the only competing architecture to Intel for workstation computing on Windows NT. Pro/ENGINEER users have been closely watching the fate of the Alpha chip during the transition of DEC to the Compaq fold. During this time, the introduction of the next generation Alpha chip was significantly delayed. This delay caused Alpha to slip in the performance race with Intel, and it put the fate of the Alpha as the leader in computing performance in question. However, with the introduction of Compaq's Alpha-based XP1000 systems in February of this year, it seems that the Alpha chip is back on track, though with a narrower performance lead than before over Intel.

A notable re-entry into this year's review is SGI, who did not participate in last year's workstation benchmark. At that time they were busy developing their new Visual Workstation architecture for Windows NT. With the new systems, SGI overhauled the Windows NT workstation architecture to eliminate bottlenecks to performance.

The graphics acceleration industry has also seen a good amount of consolidation in the face of severe competition. Intergraph has spun out its graphics hardware sales into a separate division and, unlike before, is now selling its best graphics technology to OEM vendors like Dell and IBM. AccelGraphics, one of the first 3D graphics vendors into the 3D Pro/ENGINEER market, was bought by Evans & Sutherland. This year, they are represented only by the Compaq PowerStorm 300. Dynamic Pictures, once considered one of the leaders of providing 3D graphics for NT workstations, was acquired by 3Dlabs. Finally, 3Dlabs transformed itself from a chip supplier to a graphics board manufacturer, consolidating the market of graphics board manufacturers using their chips under their own roof.

Though graphics technology on the NT platform has not moved forward much since the last benchmark, graphics technology has become refined and prices have come way down. Improvements have been made to 2D performance, texturing modes and supported color depths and resolutions. Now there is even support for digital flat-panel displays, which are finally at a price where they are beginning to be to be affordable. Most interesting is the new 3Dlabs Oxygen GVX1 card. It succeeds the GMX2000 and promises to deliver the same performance for under a $1000.

These changes to the marketplace leave

the majority of users with fewer choices in terms of hardware. Still, most users will probably opt for the fastest clock speed processor available, the fastest hard disk and the most memory they can afford (384 Mb is the recommended minimum for running bench99), which leaves choosing the graphics board as the only major hardware decision left to make. What becomes equally important then is the choice of vendors. Users will need to consider the experience, reputation and support that each vendor offers, in addition to the performance of their hardware and its price.

The benchmarking process

This year, there were 23 machines participating in the review. As in the past, the benchmarking process involved submitting the Bench99 script to the vendors for testing on their own machines and having the submitted results audited by the reviewer.

The same basic script, tests and models were used as in bench98, which were the "Radome" models created by reviewer Steve Levin in past benchmarks. Before the testing could begin, the script had to be substantially reworked to function properly with the altered user interface of release 20. This required a complete rewrite, as virtually none of the menu picks worked with the new user interface.

Some additional changes were made to this year's benchmark to improve its robustness, repeatability and portability. All graphics operations were rolled into a stand-alone subscript called gBench99. This part of the benchmark tests performance and support for Pro/ENGINEER 3D graphics features, including Gouraud-shading, double-buffered dynamic spinning, anti-aliasing, alpha-blending, texture-mapping, dithering, depth-cueing, depth-clipping, transparency and other OpenGL operations. Also, there will no longer be a separate graphics board benchmark as in the past. Readers curious about 3D graphics options can review *Chart 5* for a ranking of graphics architectures.

The portion of the script not devoted to testing graphics performance was also consolidated into a stand-alone script called CPU/1099. This portion of the script tested primarily CPU, memory and disk input/output related operations. It is important to note that graphics performance is still heavily reliant on the processor and other architectural elements of the system, though the opposite is not true. CPU/1099 rankings are also provided separately for users to compare the various Pro/ENGINEER architectures (*Chart 6*).

The specific tests in bench99 are as follows:

CPU/1099 tests:

- Load model into memory
- Export 300 DPI 24-bit color image
- Export assembly to IGES file
- Modify layout and regenerate assembly
- Compute mass properties
- DBMS backup
- Remodify layout and regenerate assembly
- **Drawing Mode** tests
- Generate Postscript plot file

gBench99 tests:

- Wireframe named views w/repaints
- Wireframe zooming and panning
- Wireframe spinning
- Wireframe anti-aliased spinning
- Shaded named views w/repaints
- Shaded zooming and panning
- Shaded spinning
- Shaded clipping and depth-cueing
- Shaded spinning with edges shown
- Shaded spinning with transparency
- Shaded spinning with texture mapping

Once the script was complete, the bench99 files were then made available to participating vendors, who were responsible for running the benchmark on their systems and submitting the unedited results to the reviewer.

To qualify for participation in the review, machines were required to have 384 Mb of

continued on page 10

Publisher
Dale Bennie

Senior Editor
Dianne Hastings
505/474-5152
e-mail: dhastings@hmp.com

Director of Manufacturing and Production
Andy Lowenthal
505/474-5183
e-mail: alowenthal@hmp.com

Designers
Mike Button, Production Artist
505/474-5187
e-mail: mbutton@hmp.com

Cammi Noah, Production Artist
505/474-5133
email: cnoah@hmp.com

Advertising Director
Nadine Choppin
505/474-5155
nchoppin@hmp.com

Advertising Representative
Valerie Hinderliter
505/474-5148
vhinderliter@hmp.com

Circulation
Denise Miller, Director of Marketing
505/474-5132
dmiller@hmp.com

Customer Service
505/474-5150
e-mail: orders@hmp.com

WWW Page
http://www.proe.com

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Table 1. Retail Configuration and Price Information

Vendor & Machine Name	Compaq AP200	Compaq SP700	Compaq XP1000	Core PhEnix-450/III Duo	Core PhEnix-500/III Duo
Vendor Website	www.compaq.com	www.compaq.com	www.compaq.com	www.coremicro.com	www.coremicro.com
Phone Number	800-345-1518	800-345-1518	800-345-1518	408-383-9090	408-383-9090
Processor	Pentium III 500 MHz	Pentium III Xeon 550 MHz	Alpha 21264 EV6 667 MHz	Pentium III 450 MHz	Dual Pentium III 500 MHz
Graphics Option	Oxygen GVX1	PowerStorm 600	PowerStorm 300	Oxygen GVX1	Oxygen GMX 2000
***Price As Configured** (without monitor)	$3,336	$7,607	$12,250	$4,050	$5,250
Secondary Processor Cache	512 KB L2	512 KB L2	4 MB L2	512 KB L2	512 KB L2
Cache Speed	250 MHZ	550 MHz	222 MHz	225 MHz	250 MHz
Main Memory	384 MB	384 MB	384 MB	384 MB	384 MB
Memory Type & Speed	100 MHz Unregistered SDRAM	100 MHz Registered SDRAM	100 MHz Registered SDRAM	SDRAM, 8 ns (PC100)	SDRAM, 8 ns (PC100)
ECC Memory?	No	Yes	Yes	No	No
Maximum Memory Capacity	768 MB	4 GB	2 GB	1024 MB	1024 MB
Hard Disk Capacity	4.3 GB	9.1 GB	4.3 GB	9.1 GB	9.1 GB
Hard Disk Type	Wide-Ultra SMART SCSI	Wide-Ultra SMART SCSI	Wide-Ultra SMART SCSI	Ultra2-Wide SCSI	Ultra2-Wide SCSI
Hard Disk RPM	10,000	10,000	10,000	7,200	7,200
Disk Controller	Adaptec 2940 Wide-Ultra SCSI	Integrated Dual Channel Wide-Ultra SCSI Controller	Wide-Ultra SCSI	Adaptec AIC7890 (Ultra2Wide SCSI)	Adaptec AIC7890 (Ultra2Wide SCSI)
Disk Controller Bandwidth	40 MB/sec Burst	40 MB/sec Burst	40 MB/sec Burst	80 MB/sec Burst	80 MB/sec Burst
Network Card Speed	100Base-T (also supports 10BaseT)	100Base-T (also supports 10BaseT)	100Base-T (also supports 10BaseT)	100Base-T (also supports 10BaseT)	100Base-T (also supports 10BaseT)
Graphics Memory	32 MB SGRAM	16 MB Frame Buffer, 64 MB Texture Memory	15 MB 3D RAM, 16 MB CDRAM	32 MB SGRAM	16 MB VRAM Frame Buffer, 80 MB EDO Texture Memory
Maximum Supported Resolution	1920x1200	1280x1024	1280x1024	1920x1200	1920x1080
Color Depth at Maximum Suppported Resolution	32 bits (True Color plus Alpha Channel)	32 bits (True Color plus Alpha Channel)	32 bits (True Color plus Alpha Channel)	32 bits (True Color plus Alpha Channel)	32 bits (True Color plus Alpha Channel)
Maximum Refresh Rate at Maximum Suppported Resolution	96 Hz	85 Hz	85 Hz	60 Hz	60 Hz
Additional Graphics Features	Full geometry and lighting acceleration via GLINT Gamma processor; Virtual Texture Memory; Volumetric Textures accelerated in silicon; PowerThreads SSE OpenGL Drivers; Digital Flat Panel Connector; Stereo Connector; Bundled Soft Engine 4 AutoCAD Driver; Bundled Sonnetech Color Correction Software			Full geometry and lighting acceleration via GLINT Gamma processor; Virtual Texture Memory; Volumetric Textures accelerated in silicon; PowerThreads SSE OpenGL Drivers; Digital Flat Panel Connector; Stereo Connector; Bundled Soft Engine 4 AutoCAD Driver; Bundled Sonnetech Color Correction Software	HDTV support, Gouraud shading, tri-linear mip-mapped texture mapping with perspective correction, anti-aliasing, translucency with destination alpha buffer, fogging, 8-bit OpenGL stencil buffers, full graphics overlays

*Due to the time differation in publication and when price quotes were received, manufacturing prices may vary by the time this benchmark is published. Furthermore, *Pro/E: The Magazine* and its affiliates are not responsible for prices reported by the manufacturers.

Dell Precision WorkStation 410	Dell Precision WorkStation 410	Dell Precision Workstation 610	Hewlett Packard C3000	Hewlett Packard Visualize P500	IBM IntelliStation E Pro
www.dell.com	www.dell.com	www.dell.com	www.hp.com/unixwork	www.hp.com/kayak	www.ibm.com/intellistation
512-728-0885	512-728-0885	512-728-0885	800-637-7740	800-752-0900	888-411-1WEB
Pentium III 500 MHz	Pentium III 500 MHz	Pentium III Xeon 550 MHz	PA8500 400 MHz	Pentium III 500 MHz	Pentium III 500 MHz
Intergraph Wildcat 4000	Diamond FireGL-1	Intergraph Wildcat 4000	FX4 Visualize	FX4 Visualize	Diamond FireGL-1
$5,796	$3,696	$6,544	$18,180	$8,515	$3,850
512 KB L2	512 KB L2	512 KB L2	1.5 MB (on-chip)	512 KB L2	512 KB L2
250 MHz	250 MHz	550 MHz	400 MHz	250 MHz	250 MHz
384 MB	384 MB	384 MB	384 MB	384 MB	384 MB
SDRAM (PC100)	SDRAM (PC100)	SDRAM (PC100)	SDRAM	SDRAM, 8 ns (PC100)	SDRAM, 8 ns (PC100)
Yes	Yes	Yes	Yes	Yes	Yes
1024 MB	1024 MB	2 GB	2 GB	768 MB	786 MB
9.1 GB	9.1 GB	9.1 GB	9.1 GB	6.1 GB	9.1 GB
Ultra2-Wide SCSI	Ultra2-Wide SCSI	Ultra2-Wide SCSI	Ultra2-Wide SCSI	Ultra-Wide SCSI	Ultra2-Wide SCSI
7,200	7,200	10,000	10,000	10,000	10,000
Adaptec 7890 (Ultra2/Wide SCSI)	Adaptec 7890 (Ultra2/Wide SCSI)	Adaptec 7890 (Ultra2/Wide SCSI)	Ultra2-Wide SCSI	UltraWide SCSI	Adaptec 2940 Ultra2-Wide SCSI
80 MB/sec Burst	80 MB/sec Burst	80 MB/sec Burst	80 MB/sec Burst	40 MB/sec Burst	80 MB/sec Burst
100Base-T (also supports 10BaseT)	100Base-T (also supports 10BaseT)	100Base-T (also supports 10BaseT)	100Base-T (also supports 10BaseT)	100Base-T (also supports 10BaseT)	100Base-T (also supports 10BaseT)
16 MB Frame Buffer, 64 MB Texture Memory	32MB Unified Frame Buffer and Texture Memory	16 MB Frame Buffer, 64 MB Texture Memory	18 MB Frame Buffer, 16 MB Texture Memory	18 MB Frame Buffer, 16 MB Texture Memory	32 MB Frame Buffer
1280x1024	1920x1200	1280x1024	1280x1024	1600x1200	1920x1200
32 bits (True Color plus Alpha Channel)	32 bits (True Color plus Alpha Channel)	32 bits (True Color plus Alpha Channel)	24 bits (True Color)	24 bits (True Color)	24 bits (True Color)
85 Hz	76 Hz	85 Hz	75 Hz	75 Hz	75 Hz
All standard graphics APIs, including OpenGL, 2D GDI, and RenderGL; 10-bit gamma correction; Four video look-up tables; Eight stencil planes; Eight overlay planes (double-buffered); 32-bit Z buffer at resolutions up to 1 M pixels; 24-bit Z buffer at 1.3 M pixels; High-performance DACs that directly drive display devices; YUV-to-RGB color conversion; Hardware cursor; DDC2B Display Data Channel standard; DPMS (Display Power Management Signaling); Multiple display configurations; Frame sequential and interlaced stereo required for head-mounted displays and shutter glasses		All standard graphics APIs, including OpenGL, 2D GDI, and RenderGL; 10-bit gamma correction; Four video look-up tables; Eight stencil planes; Eight overlay planes (double-buffered); 32-bit Z buffer at resolutions up to 1 M pixels; 24-bit Z buffer at 1.3 M pixels; High-performance DACs that directly drive display devices; YUV-to-RGB color conversion; Hardware cursor; DDC2B Display Data Channel standard; DPMS (Display Power Management Signaling); Multiple display configurations; Frame sequential and interlaced stereo required for head-mounted displays and shutter glasses	Supports stereo vision; opt. 16MB texture memory; video out	Supports stereo vision; opt. daughtercard provides 16MB texture memory	

Table 1. Retail Configuration and Price Information *(continued from page 7)*

Vendor & Machine Name	IBM RS/6000 43P-150	IBM IntelliStation Z Pro	Intergraph TDZ2000 GL2	Intergraph TDZ2000 GX1	MaxVision Symbion MAX5200	MaxVision Symbion MAX5200
Vendor Website	www.austin.ibm.com/hardware	www.ibm.com/intellistation	www.intergraph.com/ics	www.intergraph.com/ics	www.maxvision.com	www.maxvision.com
Phone Number	512-838-6197	888-411-1WEB	800-763-0242	800-763-0242	800-533-5805 or 256-533-5800	800-533-5805 or 256-533-5800
Processor	PowerPC 604e 375 MHz	Pentium III Xeon 550 MHz	Pentium III 500 MHz	Pentium III Xeon 550 MHz	Pentium III Xeon 550 MHz	Pentium III Xeon 550 MHz
Graphics Option	GXT 2000	Intergraph Wildcat 4000	RealiZm VX113A	Intergraph Wildcat 4000	Oxygen GVX1	Intergraph Wildcat 4000
***Price As Configured** (without monitor)	$15,225	$7,850	$4,890	$7,680	$5,195	$8,195
Secondary Processor Cache	1 MB L2	512 KB L2	512 KB L2	512 KB L2	512 KB L2	512 KB L2
Cache Speed		550 MHz	250 MHz	550 MHz	550 MHz	550 MHz
Main Memory	384 MB	384 MB	384 MB	384 MB	384 MB	384 MB
Memory Type & Speed	SDRAM	SDRAM, 8 ns (PC100)	SDRAM, 8 ns (PC100)	SDRAM, 8 ns (PC100)	SDRAM, 8 ns (PC100)	SDRAM, 8 ns (PC100)
ECC Memory?	Yes	Yes	Yes	Yes	Yes	Yes
Maximum Memory Capacity	1024 MB	2 GB	1024 MB	2 GB	2 GB	2 GB
Hard Disk Capacity	Dual 4.5 GB	9.1 GB	4.3 GB	9.1 GB	Dual 4.5 GB	Dual 4.5 GB
Hard Disk Type	Ultra SCSI	Ultra2-Wide SCSI	Ultra-Wide SCSI	Ultra2-Wide SCSI	Ultra2-Wide SCSI	Ultra2-Wide SCSI
Hard Disk RPM	7,200	10,000	7,200	10,000	10,000	10,000
Disk Controller	IBM Ultra SCSI	Adaptec 2940 Ultra2-Wide SCSI	Ultra2-Wide SCSI	Ultra2-Wide SCSI	Adaptec 7896 Ultra2-Wide Dual Channel SCSI	AMI MegaRAID Express Plus Ultra2-Wide SCSI
Disk Controller Bandwidth	20 MB/sec Burst	80 MB/sec Burst	80 MB/sec Burst	80 MB/sec Burst	80 MB/sec Burst	80 MB/sec Burst
Network Card Speed	100Base-T (also supports 10BaseT)	100Base-T (also supports 10BaseT)	100Base-T (also supports 10BaseT)	100Base-T (also supports 10BaseT)	100Base-T (also supports 10BaseT)	100Base-T (also supports10BaseT)
Graphics Memory	32MB Frame Buffer, up to 16MB texture memory	16 MB Frame Buffer, 64 MB Texture Memory	16 MB Frame Buffer, 16 MB Texture Memory	16 MB Frame Buffer, 64 MB Texture Memory	32 MB SGRAM	16 MB Frame Buffer, 64 MB Texture Memory
Maximum Supported Resolution	1920x1200	1280x1024	1280x1024	1280x1024	1920x1200	1280x1024
Color Depth at Maximum Suppported Resolution	32 bits (True Color plus Alpha Channel)	24 bits (True Color)	32 bits (True Color plus Alpha Channel)	32 bits (True Color plus Alpha Channel)	32 bits (True Color plus Alpha Channel)	32 bits (True Color plus Alpha Channel)
Maximum Refresh Rate at Maximum Suppported Resolution	76 Hz	85 Hz	75 Hz	75 Hz	96 Hz	90 Hz
Additional Graphics Features	Supports video output	All standard graphics APIs, including OpenGL, 2D GDI, and RenderGL; 10-bit gamma correction; Four video look-up tables; Eight stencil planes; Eight overlay planes (double-buffered); 32-bit Z buffer at resolutions up to 1 M pixels; 24-bit Z buffer at 1.3 M pixels; High-performance DACs that directly drive display devices; YUV-to-RGB color conversion; Hardware cursor; DDC2B Display Data Channel standard; DPMS (Display Power Management Signaling); Multiple display configurations; Frame sequential and interlaced stereo required for head-mounted displays and shutter glasses		All standard graphics APIs, including OpenGL, 2D GDI, and RenderGL; 10-bit gamma correction; Four video look-up tables; Eight stencil planes; Eight overlay planes (double-buffered); 32-bit Z buffer at resolutions up to 1 M pixels; 24-bit Z buffer at 1.3 M pixels; High-performance DACs that directly drive display devices; YUV-to-RGB color conversion; Hardware cursor; DDC2B Display Data Channel standard; DPMS (Display Power Management Signaling); Multiple display configurations; Frame sequential and interlaced stereo required for head-mounted displays and shutter glasses	Full geometry and lighting acceleration via GLINT Gamma processor; Virtual Texture Memory; Volumetric Textures accelerated in silicon; PowerThreads SSE OpenGL Drivers; Digital Flat Panel Connector; Stereo Connector; Bundled Soft Engine 4 AutoCAD Driver; Bundled Sonnetech Color Correction Software	All standard graphics APIs, including OpenGL, 2D GDI, and RenderGL; 10-bit gamma correction; Four video look-up tables; Eight stencil planes; Eight overlay planes (double-buffered); 32-bit Z buffer at resolutions up to 1 M pixels; 24-bit Z buffer at 1.3 M pixels; High-performance DACs that directly drive display devices; YUV-to-RGB color conversion; Hardware cursor; DDC2B Display Data Channel standard; DPMS (Display Power Management Signaling); Multiple display configurations; Frame sequential and interlaced stereo required for head-mounted displays and shutter glasses

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MaxVision Symbion Pro5200	NTSI Contender	NTSI Contender ZE	NTSI Formula TS4	Silicon Graphics 320	Silicon Graphics 320
www.maxvision.com	www.ntsi.com	www.ntsi.com	www.ntsi.com	visual.sgi.com/products/320/index.html	visual.sgi.com/products/320/index.html
800 533-5805 or 256 533-5800	978-851-0801	978-851-0801	978-851-0801	650-960-1980	650-960-1980
Pentium III 500 MHz	Pentium III 500 MHz	Pentium III Xeon 550 MHz	Alpha 21264 EV6 600 MHz	Pentium III 500 MHz	Pentium II 400 MHz
Oxygen GVX1	Oxygen GVX1	Omnicomp GMX 2000	Omnicomp GMX 2000	Cobalt Graphics	Cobalt Graphics
$4,295	$4,495	$5,495	$7,995	$5,484	$4,404
512 KB L2	512 KB L2	512 KB L2	2 MB L2	512 KB L2	512 KB L2
250 MHz	250 MHz	550 MHz	333 MHz	250 MHz	200 MHz
384 MB	384 MB	384 MB	384 MB	384 MB	384 MB
SDRAM, 8 ns (PC100)	Synchronous DRAM, Unbuffered	Synchronous DRAM, Registered	Synchronous DRAM, Registered	SDRAM, 8 ns (PC100)	SDRAM, 8 ns (PC100)
Yes	Yes	Yes	Yes	Yes	Yes
2 GB	768 MB	2 GB	4 GB	1024 MB	1024 MB
Dual 4.5 GB	4.5 GB	4.1 GB	4.1 GB	9.1 GB	10.1 GB
Ultra2-Wide SCSI	Ultra ATA	Ultra-Wide SCSI	Fast-Wide SCSI	Fast-Wide SCSI	Ultra ATA
10,000	5,400	7,200	7,200	10,000	7,200
Adaptec 7896 Ultra2-Wide Dual Channel SCSI	UltraDMA	Adaptec 2940 Ultra SCSI	IntraServer Ultra-Wide SCSI	Qlogic 1080 Ultra2 SCSI Controller	UltraDMA
80 MB/sec Burst	33.3 MB/sec Burst	80 MB/sec Burst	80 MB/sec Burst	80 MB/sec Burst	33 MB/sec Burst
100Base-T (also supports 10BaseT)	100Base-T (also supports 10BaseT)	100Base-T (also supports 10BaseT)	100Base-T (also supports 10BaseT)	100Base-T (also supports 10BaseT)	100Base-T (also supports 10BaseT)
32 MB SGRAM	32MB SGRAM	16 MB Frame Buffer, 80 MB Texture Memory	8 MB Frame Buffer, 20 MB Texture Memory	Uses System Memory	Uses System Memory
1920x1200	1900x1080	1600x1200	1920x1080	1920x1200	1920x1200
32 bits (True Color plus Alpha Channel)	32 bits (True Color plus Alpha Channel)	16 bits (True Color plus Alpha Channel)	16 bits (32,768 Colors)	32 bits (True Color plus Alpha Channel)	32 bits (True Color plus Alpha Channel)
96 Hz	85 Hz	85 Hz	85 Hz	66 Hz	66 Hz
Full geometry and lighting acceleration via GLINT Gamma processor; Virtual Texture Memory; Volumetric Textures accelerated in silicon; PowerThreads SSE OpenGL Drivers; Digital Flat Panel Connector; Stereo Connector; Bundled Soft Engine 4 AutoCAD Driver; Bundled Sonnetech Color Correction Software	Full geometry and lighting acceleration via GLINT Gamma processor; Virtual Texture Memory; Volumetric Textures accelerated in silicon; PowerThreads SSE OpenGL Drivers; Digital Flat Panel Connector; Stereo Connector; Bundled Soft Engine 4 AutoCAD Driver; Bundled Sonnetech Color Correction Software	Dual head support		Shared memory architecure enable texture allocattion up to 90% of system memory (900MB texture memory capacity); Full OpenGL 1.1 specification, Volume clip hint Occlusion test feedback for scene visibility culling, Color space conversions through color matrix, Specular highlights post texturing, Video compositing and warping, Depth offset generation	Shared memory architecure enable texture allocattion up to 90% of system memory (900MB texture memory capacity); Full OpenGL 1.1 specification, Volume clip hint Occlusion test feedback for scene visibility culling, Color space conversions through color matrix, Specular highlights post texturing, Video compositing and warping, Depth offset generation

continued from page 5

NT versus UNIX: Which choice is right for you?

Korhan Tekin

UNIX was, until recently, considered the only choice for running workstation-class applications. Windows NT has emerged clearly as being competitive for running these same applications, especially Pro/ENGINEER. So why would an organization continue using UNIX?

UNIX, despite its higher price, has clear advantages over Windows NT. NT is so inexpensive that the price of the OS is negligible in the cost of the workstation, being only a few hundred dollars. However, NT is generally not as robust, mature or reliable as the commercial versions of UNIX. System reliability is one of the largest costs of ownership for any computer, and with NT these costs can be considerable. UNIX systems can be counted on for running for months on end without any problems. They are easier to automate and administer remotely. Security is more solid on UNIX. With some NT systems, rebooting on a weekly basis is typical, and most NT administrators are familiar with the dreaded "blue screen of death," which occasionally and inexplicably confounds a user when something has gone terribly wrong with the system. Many MIS administrators are also familiar with the process of reinstalling the whole O/S from scratch as a solution to certain problems with NT. Security holes in NT are reported regularly, exposing an enterprise to dangerous viruses, hackers and other threats. Finally, UNIX is more proven in the enterprise in large implementations. It scales without degradation in performance or stability. NT is not as proven in such environments. Any of these difficulties can quickly eat up the cost savings of NT, especially in time-constrained or mission-critical environments. UNIX is superior in terms of scalability and reliability, and in certain environments this can contribute to an overall lower cost of ownership.

Windows NT offers obvious advantages in terms of initial startup costs and ease of implementation. The learning curve on NT, though shallow, is gentle compared to UNIX. UNIX systems are intimidating, arcane and unfathomable to many users, preventing them from being able to do much other than use Pro/ENGINEER on their systems. The interface on Windows NT is far more friendly and familiar. Also, most users need access to office productivity applications, meaning that they will not be able to avoid having to use a PC. Why not use a PC that runs Pro/ENGINEER as well? The compatibility question is one of the most compelling reasons to use Windows NT in a Pro/ENGINEER implementation. Most organizations are already using Windows in their enterprises, and they will find that Windows NT fits into their existing infrastructure quite well. These are compelling factors for choosing Windows NT in a Pro/ENGINEER implementation.

But where can system administrators and Pro/ENGINEER users expect to find themselves in a few years from now? Indeed, UNIX faces a serious threat from Windows NT. Windows NT has clearly demonstrated its strength as a platform for running Pro/ENGINEER, offering a price/performance ratio with which UNIX has not been able to compete. This is driving the UNIX systems into a small corner of the Pro/ENGINEER market, putting the fate of UNIX in jeopardy. MIS administrators making large investments in computing infrastructure are always concerned about the future viability of their technologies, and the concern about whether or not their UNIX systems will continue to be supported as a Pro/ENGINEER platform is a serious one. But UNIX clearly has staying power as a leader in high-performace computing, assuring it a significant place in the Pro/ENGINEER market for many years to come.

memory and use the production Build Code 9902 of Pro/ENGINEER release 20, installed from the vendor's own legal copy of Pro/ENGINEER. All machines were also to be available to the reviewer for auditing. Each vendor was allowed to submit a maximum of three machines, at the vendor's discretion. Most vendors submitted at least their fastest machine in addition to a machine with a good price/performance ratio.

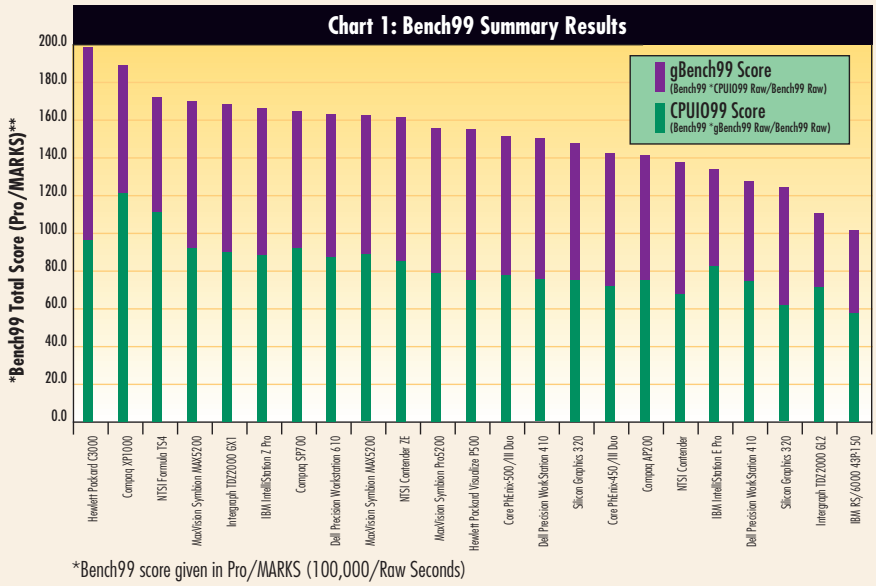
All vendors were required to use the same build code. The consistency in Pro/ENGINEER build code is important because performance can vary widely between build codes. For the NT systems, vendors were required to use NT Workstation 4.0 with Service Pack 3 or 4 installed. For UNIX systems, the operating system release had to be currently supported and available to end-users.

All systems were tested using hardware-accelerated graphics. X-Windows performance was not tested this year; it no longer makes sense to run Pro/ENGINEER from an X-Terminal or without a 3D graphics accelerator now that there are fully capable Pro/ENGINEER systems costing just above $3,000. Additionally, there were only two UNIX systems submitted this year. The graphics card in each system was set to either 24 or 32 bits-per-pixel color at Pro/ENGINEER's recommended resolution of 1280x1024. If the accelerator could not support this color depth and resolution, the benchmark was conducted for that particular machine at the maximum supported double-buffered color depth at this resolution.

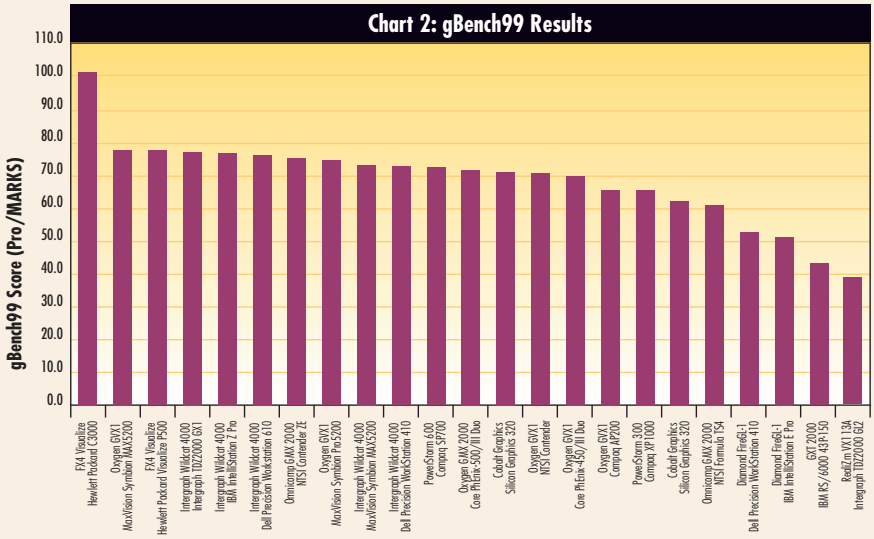
It was recommended that each system be configured with a 4.0 Gb or larger Ultra2-Wide SCSI disk drive. All systems in the review were equipped with a 100Base-T Fast Ethernet network adapter and a CD-ROM.

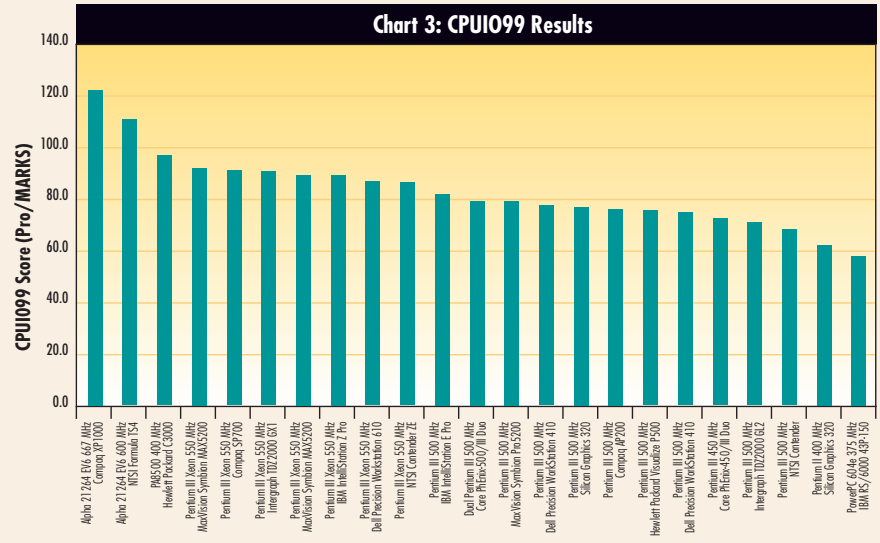
The vendors were asked to run the script on their machine as many times as they wished and submit the best results they came up with, though those results had to be repeatable and easily verified by this reviewer in an audit process. This auditing was conducted on machines with fast performance or performance not consistent with expectations.

continued on page 14



*Bench99 score given in Pro/MARKS (100,000/Raw Seconds)





**Higher score on charts indicates better performance

[1] Price shown refers to U.S. estimated selling price. Monitor not included. Reseller prices may vary. [2] For hard drives, GB = billion bytes. [3] 32X Max CD-ROM drive data transfer rates may vary from 150 to 4800 Kbps. [4] As reported by Parametric Technology Corporation as of August 6, 1999. Compaq is not liable for pictorial or typographical errors in this advertisement. Compaq and the Compaq logo are registered trademarks and Better answers is a service mark of Compaq Computer Corporation. Intel, the Intel logo and Pentium are registered trademarks of Intel Corporation. Microsoft and Windows NT are registered trademarks of Microsoft Corporation. Other products mentioned herein may be trademarks or registered trademarks of their respective companies.

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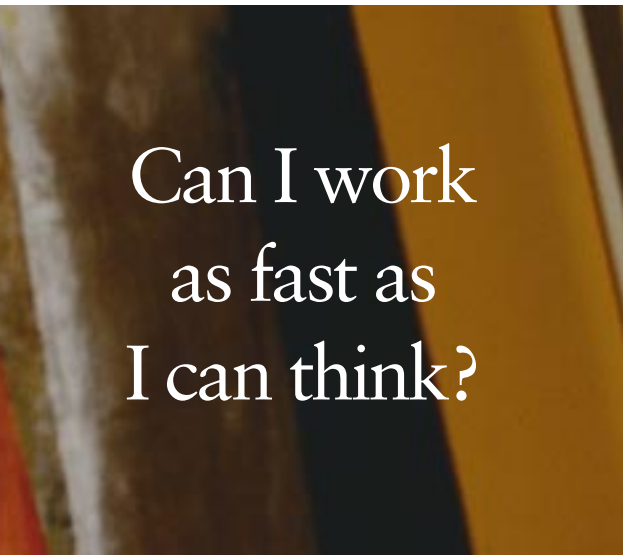

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continued from page 11

Machines were also audited based on their price/performance or uniqueness of the hardware configuration.

Vendors were also asked to fill out system configuration worksheets for each system submitted, giving the detailed configuration information and price. This information is reported in *Table 1*. Because users have a wide range of choices on monitors and also because the choice of monitor has no effect on the performance of the system, vendors were asked not to include the price of the monitor in their quote.

The results of the bench99 script were compiled with a Perl script that extracted the timestamps from the resulting trail files and subtotaled them into raw scores for CPU/1099, gBench99 and bench99 (see *Charts 1*, *2* and *3*). The gBench99 results were further broken down into a Wireframe Subset, a Shaded Subset and a Textured Subset. The final results were converted from a raw time score into an inverted time score (as in bench99 = 100,000/bench99 raw). This means that a higher score indicates a faster system, which is a break from the reported results from past benchmarks. This was done to be consistent with the reporting systems of other benchmarks used in the computing industry.

The final results for each system are reported in *Table 3*, ranked by overall bench99 performance. Raw results for each individual test are reported in *Table 2*. The systems are ranked in the charts by their bench99, gBench99 and CPU/1099 scores, respectively. *Chart 4* ranks the systems by their overall price/performance. *Charts 5* and *6* rank the various systems and graphics architectures, comparing only the fastest results from each.

Because the weighting process is somewhat arbitrary, especially when determining whether CPU or graphics performance is more important, both were weighted in the script as evenly as possible in the final bench99 results. There was no secondary weighting of the final results. The individual results have been included separately for both CPU and graphics performance to allow users to determine which is more important for them and to choose a system on that basis.

Glossary of terms

Most Pro/ENGINEER users have probably heard some of the following terms used in describing the performance of workstations without necessarily understanding what they mean. They are defined in the following section:

Integer and floating point: Pro/ENGINEER relies on the central processor to handle both floating point and integer math operations, depending on the kind of computation. Computationally intensive processes, such as the creation of solid geometry, the tessellation of a model (as in **Shaded Mode**) or the solving of a finite element analysis problem (Pro/MECHANICA), heavily tax a processor's floating point capabilities. Other more basic operations rely mainly on integer computations. The Alpha 21264 processor, though generally faster, has excellent floating-point characteristics, making it ideal for handling complex models and large assemblies. Intel's Pentium III and Pentium III Xeon processors have decent floating-point performance and excellent integer performance. The HP PA-8500 RISC architecture performs slightly faster than the fastest Intel Xeon and has well-balanced floating point and integer performance characteristics. The PowerPC 604e processor is comparatively slow.

L2 cache: All processors have some memory cache on the chip for short-term memory storage of small bits of data, but the primary L2 (Level 2) cache usually resides outside the central processor. This cache is usually between 512 KB and 4 Mb and serves as interim data storage between the processor and main memory. The speed of this cache will determine whether or not the CPU will suffer a performance penalty each time cache is accessed. This is the primary benefit of the Xeon processor over a standard Pentium III. Its cache operates at the same speed as the processor, meaning that a cache access does not impose a loss of a CPU cycle. The HP PA8500 has its cache on the CPU, meaning it runs at the same speed as the processor. Pro/ENGINEER relies mostly on access to main memory, so beyond a certain size, added cache delivers marginal returns on performance.

Memory: The memory type and speed helps determine the bandwidth between the processor and the memory pool. Most of the systems in the review used 64-bit Synchronous DRAM compliant with the PC100 specification, meaning that it runs at 100 MHz or faster and is fully compatible with the Pentium II/III architecture. Though the speeds of the memory may be slightly different from one system to the next, this makes no difference in performance, as the speed of the memory bus does not change. Pro/ENGINEER relies heavily on access by the CPU to main memory, and the speed and width of the memory bus plays an important role in performance. The Alpha and SGI Cobalt architectures each use a 256-bit wide memory bus. The HP uses a 128-bit bus (plus another 16 bits for ECC parity, described next). The Xeon and Pentium III systems rely on a narrower 64-bit wide memory bus.

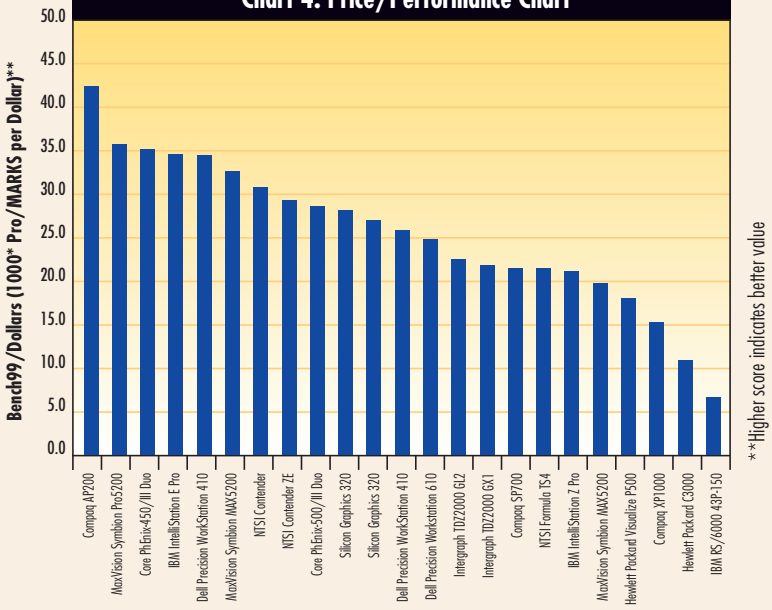
ECC (Error Correction and Control): ECC is a protocol for memory error management. Standard memory allows for single-bit memory errors, which will alert the system once they occur and cause the system to hang rather than proceed with a memory error. With ECC, the error can be corrected and the system can proceed with normal operation, making ECC the ideal choice for systems requiring high stability. ECC is usually only 10 percent more expensive than regular memory. It requires a single bit of parity for each eight bits of data. Therefore, a 64-bit memory bus with ECC will have a total of 72-bits.

Network speeds: All the systems came equipped with 100-BaseT Ethernet cards, which run at 100 Mbit/sec. Gigabits Ethernet cards that run at 1 Gb/sec are currently available but were not submitted for the review. Most networks will not be ready to take advantage of gigabit speeds until their network hardware is replaced, which may not be for awhile. However, with gigabit network speeds, Pro/ENGINEER users will be nearly able to achieve performance on the network equal to local disk access.

Hard drives, SCSI buses, and RPMs: Most Pro/ENGINEER users are running Pro/ENGINEER from networked computers, making hard disk access of relatively minimal importance. When running Pro/ENGINEER on the network, the network becomes the primary bottleneck to

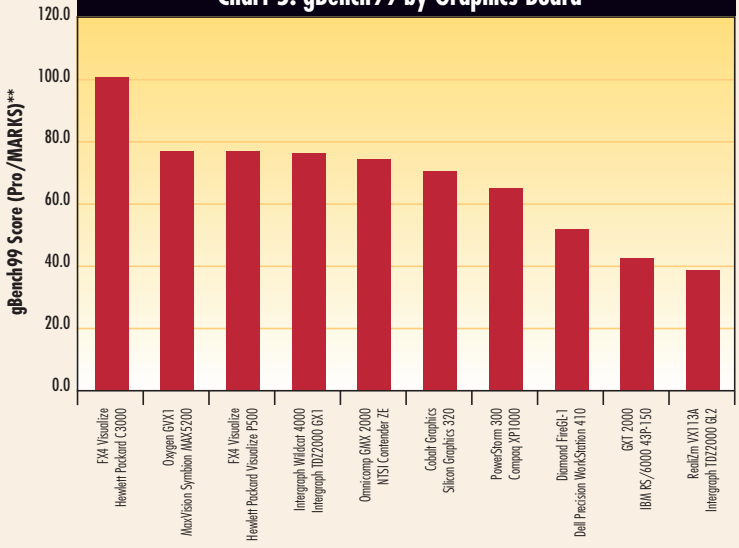
continued on page 20

Chart 4: Price/Performance Chart



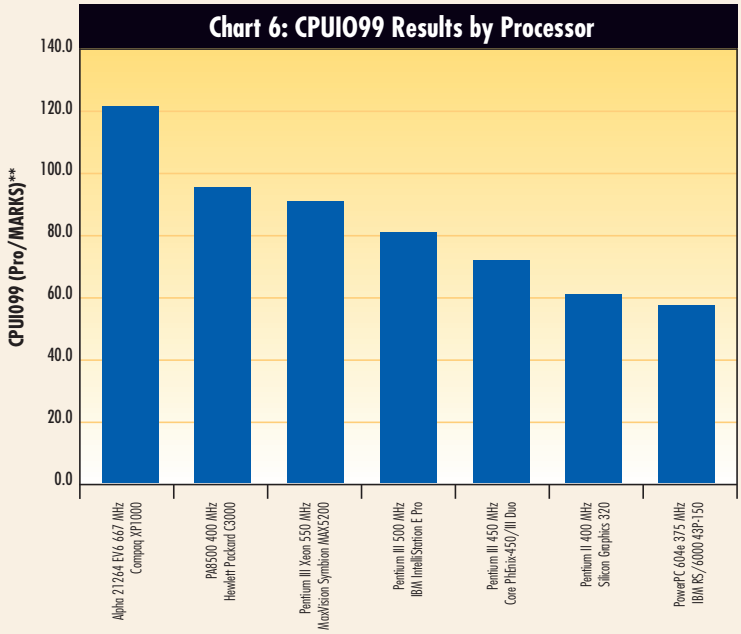
**Higher score indicates better value

Chart 5: gBench99 by Graphics Board



**Higher score indicates better performance

Chart 6: CPUIO99 Results by Processor



**Higher score indicates better performance

Table 2 Detailed Results

Vendor & Machine Name	Compaq AP200	Compaq SP700	Compaq XP1000	Core PhEnix-450/III Duo	Core PhEnix-500/III Duo	Dell Precision WorkStation 410	Dell Precision WorkStation 410	Dell Precision Workstation 610	Hewlett Packard C3000
Processor	Pentium III 500 MHz	Pentium III Xeon 550 MHz	Alpha 21264 EV6 667 MHz	Pentium III 450 MHz	Dual Pentium III 500 MHz	Pentium III 500 MHz	Pentium III 500 MHz	Pentium III Xeon 550 MHz	PA8500 400 MHz
Graphics Option	Oxygen GVX1	PowerStorm 600	PowerStorm 300	Oxygen GVX1	Oxygen GMX 2000	Intergraph Wildcat 4000	Diamond FireGL-1	Intergraph Wildcat 4000	FX4 Visualize
Price As Configured (without monitor)	$3,336	$7,607	$12,250	$4,050	$5,250	$5,796	$3,696	$6,544	$18,180
Bench99 Total Score (100,000/Bench99 Raw)	**141.6**	**163.7**	**188.0**	**142.7**	**150.8**	**150.2**	**127.6**	**163.1**	**198.4**
CPU/IO 99 Score (Bench99 * gBench99 Raw/Bench99 Raw)	76.2	91.3	122.6	72.6	79.4	77.6	75.0	87.0	97.2
gBench99 Score (Bench99 * CPU/IO 99 Raw/Bench99 Raw)	65.4	72.3	65.4	70.0	71.4	72.6	52.5	76.1	101.2
Price Performance Score (1,000 * Bench99/Price)	**42.5**	**21.5**	**15.3**	**35.2**	**28.7**	**25.9**	**34.5**	**24.9**	**10.9**
CPU/1099 Test:									
1) Load Model into Memory	16	13	8	15	15	14	14	13	13
2) Export 300 DPI 24-Bit Color Image	17	15	8	23	23	20	21	18	25
3) Export Assembly to IGES File	150	121	90	154	139	149	149	132	109
4) Modify Layout & Regenerate Assembly	23	18	14	23	21	21	21	18	17
5) Compute Mass Properties	17	16	13	18	16	17	16	15	16
6) DBMS Backup	13	10	6	13	12	12	12	12	8
7) Remodify Layout & Regenerate Assembly	11	10	7	13	11	11	12	10	9
8) Drawing Mode Tests	42	35	22	44	40	41	41	35	31
9) Generate Postscript Plot File	37	32	17	41	37	37	37	33	29
gBench Test:									
1) Wireframe Named Views w/Repaints	33	33	29	34	35	33	33	32	29
2) Wireframe Zooming & Panning	38	37	37	41	39	38	41	37	34
3) Wireframe Spinning	27	26	26	30	27	29	38	25	18
4) Wireframe Antialiased Spinning	13	9	8	13	16	9	12	8	6
5) Shaded Named Views w/Repaints	31	28	27	30	30	28	30	28	27
6) Shaded Zooming & Panning	27	23	22	24	24	23	20	23	13
7) Shaded Spinning	70	53	58	54	54	54	62	53	36
8) Shaded Clipping & Depthcueing	25	28	22	24	23	27	65	27	16
9) Shaded Spinning with Edges Shown	84	75	90	79	74	74	131	66	42
10) Shaded Spinning with Transparency	16	17	14	14	14	17	14	16	8
11) Shaded Spinning with Texture Mapping	16	12	14	14	13	12	15	12	18
CPU/IO Bench99 Raw Score	326	270	185	344	314	322	323	286	257
gBench99 Raw Score	380	341	347	357	349	344	461	327	247
gBench99 Wireframe Subset	111	105	100	118	117	109	124	102	87
gBench99 Shaded Subset	253	224	233	225	219	223	322	213	142
gBench99 Textured Subset	16	12	14	14	13	12	15	12	18
Bench99 Raw Score	706	611	532	701	663	666	784	613	504

Hewlett Packard Visualize P500	IBM IntelliStation E Pro	IBM RS/6000 43P-150	IBM IntelliStation Z Pro	Intergraph TDZ2000 GL2	Intergraph TDZ2000 GX1	MaxVision Symbion MAX5200	MaxVision Symbion MAX5200	MaxVision Symbion Pro5200	NTSI Contender	NTSI Contender ZE	NTSI Formula TS4	Silicon Graphics 320	Silicon Graphics 320
Pentium III 500 MHz	Pentium III 500 MHz	PowerPC 604e 375 MHz	Pentium III Xeon 550 MHz	Pentium III 500 MHz	Pentium III Xeon 550 MHz	Pentium III Xeon 550 MHz	Pentium III Xeon 550 MHz	Pentium III 500 MHz	Pentium III 500 MHz	Pentium III Xeon 550 MHz	Alpha 21264 EV6 600 MHz	Pentium III 500 MHz	Pentium II 400 MHz
FX4 Visualize	Diamond FireGL-1	GXT 2000	Intergraph Wildcat 4000	RealiZm VX113A	Intergraph Wildcat 4000	Oxygen GVX1	Intergraph Wildcat 4000	Oxygen GVX1	Oxygen GVX1	Omnicomp GMX 2000	Omnicomp GMX 2000	Cobalt Graphics	Cobalt Graphics
$8,515	$3,850	$15,225	$7,850	$4,890	$7,680	$5,195	$8,195	$4,295	$4,495	$5,495	$7,995	$5,484	$4,404
153.1	**133.2**	**101.1**	**166.1**	**110.1**	**167.8**	**169.8**	**162.6**	**153.6**	**138.7**	**161.6**	**171.8**	**147.9**	**124.4**
75.7	82.1	58.0	89.4	71.0	90.9	92.2	89.6	79.3	68.3	86.6	111.0	77.0	62.3
77.4	51.1	43.1	76.7	39.2	76.9	77.5	73.0	74.3	70.4	74.9	60.8	70.9	62.0
18.0	**34.6**	**6.6**	**21.2**	**22.5**	**21.8**	**32.7**	**19.8**	**35.8**	**30.9**	**29.4**	**21.5**	**27.0**	**28.2**
14	14	22	13	14	12	12	13	16	14	13	8	15	19
18	20	47	20	22	17	16	15	18	22	15	13	20	27
155	127	154	123	145	124	121	127	143	185	137	105	143	178
21	19	33	18	22	18	18	18	21	21	18	12	24	29
19	15	28	15	17	15	15	15	16	17	15	12	18	22
12	11	14	11	14	10	10	11	12	17	11	8	12	15
12	11	16	10	12	10	10	10	11	12	10	7	13	14
41	37	61	35	41	35	35	35	41	41	35	22	41	52
38	34	47	33	36	32	32	32	37	37	33	19	38	45
33	33	41	32	36	31	31	31	32	35	32	30	34	36
44	39	50	36	45	37	37	41	38	40	37	40	40	43
36	35	59	24	50	25	23	28	26	27	25	29	34	38
11	11	18	8	15	8	13	9	13	15	15	25	11	12
26	32	36	28	36	27	27	27	28	31	27	28	28	30
16	22	24	23	37	22	23	25	22	25	24	27	14	16
38	70	74	53	112	53	52	55	53	57	53	65	37	41
15	59	59	27	45	27	22	27	22	24	22	26	21	27
79	131	171	64	156	64	67	66	75	74	71	76	116	142
8	15	17	17	29	17	13	17	14	14	13	16	9	9
17	16	18	12	24	12	12	13	13	13	13	14	8	9
330	288	422	278	323	273	269	276	315	366	287	206	324	401
323	463	567	324	585	323	320	339	336	355	332	376	352	403
124	118	168	100	146	101	104	109	109	117	109	124	119	129
182	329	381	212	415	210	204	217	214	225	210	238	225	265
17	16	18	12	24	12	12	13	13	13	13	14	8	9
653	751	989	602	908	596	589	615	651	721	619	582	676	804

Table 3. Summary Results (Ranked by bench99 performance)

Vendor & Machine	Processor	Graphics Option	Price As Configured (without monitor)	Overall Ranking	gBench99 Ranking	CPUI099 Ranking	Price Performance Ranking	Bench99 Total Score (100,000/ Bench99 Raw)	gBench99 Score (Bench99 * CPUI099 Raw/Bench 99 Raw)	CPUI099 Score (Bench99 * gBench99 Raw/Bench 99 Raw)	Overall Price Performance Score (1,000 * Bench99/ Price)
Hewlett Packard C3000	PA8500 400 MHz	FX4 Visualize	$18,180	1	1	3	22	198.4	101.2	97.1	10.9
Compaq XP1000	Alpha 21264 EV6 667 MHz	PowerStorm 300	$12,250	2	17	1	21	188.0	65.4	122.6	15.3
NTSI Formula TS4	Alpha 21264 EV6 600 MHz	Omnicomp GMX 2000	$7,995	3	19	2	17	171.8	60.8	111.0	21.5
MaxVision Symbion MAX5200	Pentium III Xeon 550 MHz	Oxygen GVX1	$5,195	4	2	4	6	169.8	77.5	92.2	32.7
Intergraph TDZ2000 GX1	Pentium III Xeon 550 MHz	Intergraph Wildcat 4000	$7,680	5	4	6	15	167.8	76.9	90.9	21.8
IBM IntelliStation Z Pro	Pentium III Xeon 550 MHz	Intergraph Wildcat 4000	$7,850	6	5	8	18	166.1	76.7	89.4	21.2
Compaq SP700	Pentium III Xeon 550 MHz	PowerStorm 600	$7,607	7	11	5	16	163.7	72.3	91.3	21.5
Dell Precision Workstation 610	Pentium III Xeon 550 MHz	Intergraph Wildcat 4000	$6,544	8	6	9	13	163.1	76.1	87.0	24.9
MaxVision Symbion MAX5200	Pentium III Xeon 550 MHz	Intergraph Wildcat 4000	$8,195	9	9	7	19	162.6	73.0	89.6	19.8
NTSI Contender ZE	Pentium III Xeon 550 MHz	Omnicomp GMX 2000	$5,495	10	7	10	8	161.6	74.9	86.6	29.4
MaxVision Symbion Pro5200	Pentium III 500 MHz	Oxygen GVX1	$4,295	11	8	13	2	153.6	74.3	79.3	35.8
Hewlett Packard Visualize P500	Pentium III 500 MHz	FX4 Visualize	$8,515	12	3	17	20	153.1	77.4	75.7	18.0
Core PhEnix-500/III Duo	Dual Pentium III 500 MHz	Oxygen GMX 2000	$5,250	13	12	12	9	150.8	71.4	79.4	28.7
Dell Precision WorkStation 410	Pentium III 500 MHz	Intergraph Wildcat 4000	$5,796	14	10	14	12	150.2	72.6	77.6	25.9
Silicon Graphics 320	Pentium III 500 MHz	Cobalt Graphics	$5,484	15	13	15	11	147.9	70.9	77.0	27.0
Core PhEnix-450/III Duo	Pentium III 450 MHz	Oxygen GVX1	$4,050	16	15	19	3	142.7	70.0	72.6	35.2
Compaq AP200	Pentium III 500 MHz	Oxygen GVX1	$3,336	17	16	16	1	141.6	65.4	76.2	42.5
NTSI Contender	Pentium III 500 MHz	Oxygen GVX1	$4,495	18	14	21	7	138.7	70.4	68.3	30.9
IBM IntelliStation E Pro	Pentium III 500 MHz	Diamond FireGL-1	$3,850	19	21	11	4	133.2	51.1	82.1	34.6
Dell Precision WorkStation 410	Pentium III 500 MHz	Diamond FireGL-1	$3,696	20	20	18	5	127.6	52.5	75.0	34.5
Silicon Graphics 320	Pentium II 400 MHz	Cobalt Graphics	$4,404	21	18	22	10	124.4	62.0	62.3	28.2
Intergraph TDZ2000 GL2	Pentium III 500 MHz	RealiZm VX113A	$4,890	22	23	20	14	110.1	39.2	71.0	22.5
IBM RS/6000 43P-150	PowerPC 604e 375 MHz	GXT 2000	$15,225	23	22	23	23	101.1	43.1	58.0	6.6

continued from page 15

Architectural discussion

Korhan Tekin

The chief determinant of performance with Pro/ENGINEER is the central processor unit. Performance on Pro/ENGINEER will scale almost linearly with the clock speed of the processor, until other system architectural elements become critical paths in the performance loop. 3D graphics cards also rely on the CPU for handling the front end of the OpenGL pipeline. For most users, the primary consideration when choosing a system will be the processor. This choice in turn will determine the memory, input/output and system bus architecture. Though the clock speed of the processor is a key indicator of performance, it is not the sole determinant of performance. Different processors can yield drastically different performance at the same clock speeds.

The second most important element (though for some users it may be of chief importance) is the 3D graphics architecture of the system. There are more options for graphics subsystems available than processors, and this is the one element of most systems that can give highly variable performance depending on the choice of cards. It is vitally important that the proper graphics option is selected, as a poor choice can severely impair the overall performance of a system.

Finally, the system architecture contributes to the overall performance of the system. This refers to the connections along the various system buses between the processor, processor cache, main memory and the graphics subsystem. These buses impose limitations on performance, depending on the width of the bus and its speed. Any one of these pathways can create bottlenecks that impose a ceiling on performance. For a system to have a continued ramp up in performance, these bottlenecks need to be cleared at every point along the computing path. These buses are governed by the host chipset and act as the central processor's primary support system.

The Pentium III systems use the Intel 440BX chipset. The 440BX chipset provides a 64-bit wide 100 MHz system bus between the host CPU and memory, providing a peak memory bandwidth of 800 Mb/sec. It also gives the CPU and memory access to the 32-bit wide 2x AGP bus running at 133 MHz. This gives a peak AGP bandwidth of 528 Mb/sec, devoted exclusively to the graphics card. AGP 4x will be available soon, increasing the available bandwidth to over 1 Gb/sec, but the likely benefit of this will only be to texture performance. The bandwidth of AGP 2x is already enough to allow the Oxygen GVX1 graphics card to effectively utilize the system's main memory as the texture memory store.

The 440GX chipset is used by the Xeon processor. It delivers some additional performance enhancements over the 440BX. Mainly, it allows up to 2 Gb of addressable main memory.

The Silicon Graphics 320 workstations are also based on Intel's Pentium II and III processors. The system architecture on the 320 is totally customized, based on SGI's proprietary Cobalt chipset. This set of three customized ASICs replaces Intel's 440BX chipset and the graphics card. Cobalt improves access to main memory by quadrupling the memory bus width to 288-bits, giving peak performance of 3.2 Gb/sec. This pipeline to main memory is available to the graphics subsystem, which is six times the bandwidth of 2x AGP. Instead of using a devoted cache of memory for the graphics frame buffer, it relies on this fat pipeline to main memory. Overall, this kind of approach to design is extremely cost effective, eliminating additional boards for each of the peripherals. Despite the wide path to memory, the CPU still only has a 64-bit path to the Cobalt chip, limiting its bandwidth to only 800 Mb/sec and ultimately limiting 3D graphics performance. This element of the architecture is out of SGI's control, determined solely by the CPU itself. And this puts the graphics performance of the SGI platform in Intel's hands.

Aside from graphics performance, Pro/ENGINEER performance ramps linearly with the clock speed of the chip. Graphics performance usually ramps up as well, but not at the same rate. Graphics performance bottlenecks quickly become a problem. These can take place along any number of paths. It is because of these architectural limitations that graphics performance gets throttled, which is probably why most of the graphics cards on the Intel platform are peaking at about the same level of performance. Also unusual is the fact that performance has not improved much in the last year. Until now, graphics performance could be expected to double nearly every year. Until Intel resolves these architectural bandwidth problems, users can expect graphics performance to stagnate.

Intel released its new Pentium III processor in January, a minor improvement over the Pentium II. It includes an enhanced instruction set, called Single Instruction Multiple Data, or SIMD for short (its codename was "Katmai"). The Pentium III includes some instructions for boosting 3D performance and it promises higher clock speeds than the Pentium II. From the results of this benchmark, it appears the Pentium III delivers no

continued on page 21

continued from page 14

performance when storing or retrieving models into the system's memory. The disk is only accessed when swap space is needed or when a user first starts a Pro/ENGINEER session. When it comes to hard drive technology, users have a choice between UltraATA, with peak speeds of 33 Mb/sec, Ultra2-Wide SCSI, which peaks at 80 Mb/sec, or just Ultra-Wide SCSI, which peaks at 40 Mb/sec.

For most users, peak speeds are not as important because the drives using these buses will never achieve them. More important is the speed of the drive itself. The drive platters usually spin at either 7,200 RPMs or 10,000 RPMs. This is the primary variable that determines the speed of disk access, and not the SCSI bus itself. SCSI has distinct benefits over UltraATA, such as faster transfer speeds between SCSI devices, greater expandability and availability of niche devices such as tape drives and CD-ROM burners. However, UltraATA provides adequate disk-performance at a lower price point. Most of the systems in the review were equipped with Ultra2-Wide SCSI drives, with a mix of 7,200 RPM and 10,000 RPM drives. To see specifically which drives fared well on which systems, users can look at CPU/IO Test No. 6 in *Table 2*, which is the DBMS Backup operation.

Refresh rate: This term refers to the speed at which the graphics card refreshes the screen. Typically, this happens in the range of 60 to 90 Hz. The eye can perceive faint flickering at up to about 70 Hz, which can cause some eye fatigue, so it is recommended that the graphics card support at least 75 Hz at the resolution in which Pro/ENGINEER is being used. Most of the graphics cards in the review can support well above 75 Hz at the standard Pro/ENGINEER resolution of 1280x1024. Users with ultra-wide displays will be interested in the refresh rates at the higher resolutions.

Color depth: This term refers to the number of bits-per-pixel used in the display of colors. Ideally, users want eight bits of color for red, green and blue, and eight bits of alpha (transparency), for a total of 32 bits-per-pixel. This is called true color because the eye cannot perceive greater gradations of color than given by 24 bits, which results in over 16 million colors.

Frame buffer: This is the portion of the graphics memory pool that contains the image of what is currently on the screen. It is accessed by the RAMDAC (RAM Digital-to-Analog Converter), which converts the digital image to an analog signal that is sent to the monitor. To support true color displays at the standard Pro/ENGINEER resolution, a graphics card needs at least 15 Mb of frame buffer memory. All but two of the graphics cards in this review supported true color at the standard Pro/ENGINEER resolution of 1280x1024.

The systems

Compaq: XP1000, SP700, AP200

Compaq entered three systems in this year's benchmark, one targeted at each of the performance and price niches of Pro/ENGINEER users.

The XP1000 is an Alpha processor workstation, running a 21264 chip that clocks at 667 MHz, the fastest of any processor in the review. This chip is also clearly the fastest chip in terms of performance. It employs 4 Mb of cache running at 222 MHz, four times as much as a standard Pentium III processor. This system was also equipped with a 10,000 RPM Ultra-Wide SCSI hard disk.

If compatibility is an issue, the Alpha architecture is risky. The Alpha employs a technology called FX!32, which allows Alpha NT users to run Intel code on their system, both in emulation and **Translation Mode**. It gives adequate Intel application performance on the Alpha, but it does not run perfectly and has a few associated hassles, including increased memory utilization. FX!32 will be integrated into Windows 2000, which should significantly improve the robustness of this technology, but Windows 2000 has been delayed several times, and industry pundits are predicting that it will also miss its summer release. Also, graphics performance on the Alpha with the PowerStorm 300 does not keep pace with the graphics offerings on the Intel platform. This is due to a lack of the AGP bus, somewhat handicapping this architecture in overall performance. However, for Pro/ENGINEER users seeking the ultimate processing performance, the Compaq XP1000 provides the fastest processor for Pro/ENGINEER and fastest overall performance on NT. For users with big assemblies, huge drawings and complex models with long regeneration times, the Compaq XP1000 is an excellent choice.

The SP700 is part of Compaq's Scalable Performance line of systems. It is a Xeon-based workstation running at 550 MHz. It is equipped with a PowerStorm 600 board, which is based on the Intergraph Wildcat 4000 architecture. The graphics performance on this system is slower than other Xeon systems with Wildcat graphics, ranking just average on gBench99. It also had below average price/performance. However, this system was the second fastest Xeon in the review.

The AP200 is part of Compaq's Affordable Performance line, costing $3,336. This made it the least expensive system in the review. This system comes equipped with the 3Dlabs Oxygen GVX1 and a 10,000 RPM Ultra2-Wide SCSI Hard Drive with 4.3 Gb of capacity, sacrificing nothing in terms of its hardware configuration. It is likely that Compaq has leveraged its considerable economies of scale in bringing their component pricing down, and this benefit carries through to their AP line of systems. In spite of the fast Oxygen GVX1 card, the graphics performance on this system was mediocre. Overall, the system ranked just below average in CPU, graphics and overall rankings. However, due to its price, it rated first on the price/performance chart. The AP200 system delivers a strong configuration and balanced performance at a rock-bottom price.

Conclusions

For years, PTC has been openly discussing the idea of implementing multi-threaded code, allowing Pro/ENGINEER to take advantage of more than one processor. This has never been fully implemented, however. Considering that there was one dual processor system submitted for the review, there was the opportunity to evaluate whether or not Pro/ENGINEER actually takes advantage of multi-threading. At this point,

there is virtually no parallelism in Pro/ENGINEER's code, and this is evidenced in the performance of the Core PhEnix Dual 500 system submitted for the benchmark. Among the Pentium III systems in the review, this system performed as well and as a fast Pentium III system could be expected to perform and gained no apparent benefit from the second processor. Also, adding a second processor requires reinstalling Windows NT 4.0 from scratch with a dual-processor kernel, making upgrading later very difficult.

As in previous benchmarks, the Alpha reigned as the fastest processor for use with Pro/ENGINEER. The 667 MHz 21264 Alpha processor was 33 percent faster on CPU/1099 than Intel's 550 MHz Xeon chip. The Hewlett Packard PA8500 processor at 400 MHz was also faster than the fastest Xeon, but by a lesser margin. The IBM PowerPC 604e running at 375 MHz ranked at the bottom of the chart (see *Chart 6* for a ranking of the different processor architectures).

The results of CPU/1099 indicate that the Xeon processor does not give any appreciable boost in performance as compared to a standard Pentium III. The Xeon chips were all running at 550 MHz, and the Pentium IIIs peaked at 500 MHz, making an objective comparison between the two processors difficult. However, it is clear that the majority of this performance increase from a Xeon can be attributed to the higher clock speed of the processor and not to the faster cache. Additionally, Pentium IIIs running at 550 MHz should be available by the time this article is published.

As the systems running Pro/ENGINEER have become increasingly similar, the graphics options are becoming their only significant distinguishing feature. Of all the graphics cards in this review, the HP FX4 Visualize running on the C3000 was clearly the leading technology. It delivered performance that was 30 percent faster than the next fastest graphics card, which was the 3Dlabs Oxygen GVX1 running on the MaxVision Symbion 5200 Xeon. On the NT systems, the 3Dlabs card and the Intergraph Wildcat 4000 gave the highest graphics performance and quality overall. On each of these cards, the shaded images were clean and without display artifacts or flickering in dynamic modes of manipulation, anti-aliasing was clean and smooth, and the performance was outstanding. Because it is a dual-card solution with several geometry processors and a huge on-board memory store, the Intergraph Wildcat 4000 is expensive. The 3Dlabs Oxygen GVX1 delivers the fastest Pro/ENGINEER performance on NT for under $1000 MSRP.

One observation that emerges clearly is that systems configured identically in terms of hardware specifications can still vary widely in performance. Systems with the same CPUs, same speed hard drives and same graphics cards often outperformed one another by significant margins. Mainly, this can be attributed to each vendor's particular expertise at config-

continued on page 22

Architecture *continued from page 19*

appreciable performance improvement over the Pentium II for CPU-related Pro/ENGINEER operations (see *Chart 6*). Though the added 3D instructions should improve the performance of graphics cards, most vendors prefer to have their own on-board geometry engines doing the 3D number crunching, regardless of the new SIMD instructions. SGI makes use of SIMD because it does not have its own geometry engine in its graphics chipset. However, from the results of the review, it is clear that the SGI 320's graphics are outclassed by graphics cards that have on-board geometry processors.

(Author's Note: There is something for Pentium III users to be aware of. Each Pentium III is etched with a unique Processor Serial Number on the silicon. This PSN will allow a person to be positively identified on the Internet. Web sites will potentially have access to the name and Processor Serial Number of each person visiting their site. This information can be forwarded to the appropriate marketing, corporate or governmental entity, by which such an entity can precisely track a person's activity on the Internet. This PSN promises to lead way to a GIUIN - a Global Universal Identification Number - that will be used in any kind of electronic transaction.)

Intel also manufactures a processor called Xeon. The Pentium III is Intel's main processor line for performance computing and is aimed at the majority of its consumers. The Pentium III Xeon is primarily for workstations and servers. It has a faster and optionally larger cache than the standard Pentium III. It is also more expensive, for as the cache gets larger the price of the processor increases significantly. None of the vendors in the review submitted Xeon systems with more that 512 KB of cache. The Xeon is also a very large processor with a massive heatsink. It runs hotter and requires more space and more cooling, which increases the size and noise of the chassis.

continued from page 21

uring their systems to work well with Pro/ENGINEER. It is obvious that having expertise with tuning a system to perform well with Pro/ENGINEER makes a significant difference in that system's performance. The systems that did well in the review are the ones sold by the companies with the most experience putting together Pro/ENGINEER systems. Obviously, special expertise is required in configuring a Pro/ENGINEER workstation, and it is advisable to go to the experts when making a purchase, especially when prices are as low as they are.

Overall, the Hewlett Packard C3000 running HP-UX emerged at the top of the review, giving the best graphics performance and the best overall performance, though for a premium price. Among the vendors selling Windows NT systems, Compaq and MaxVision both deliver consistently compelling performance and competitive pricing. The Alpha-based Compaq XP1000 was the fastest system for running Pro/ENGINEER on Windows NT. The MaxVision Symbion MAX5200 with the Xeon 550 MHz and Oxygen GVX1 delivered the best performance on the Intel platform for a reasonable price. Intergraph's TDZ2000 GX-1 and IBM's IntelliStation Z Pro also delivered excellent all-around performance for a Xeon system, though their Intergraph Wildcat 4000 graphics option pushed them to a higher price. Among the Pentium III 500 MHz systems, the MaxVision Symbion Pro5200 with the Oxygen GVX1 delivered the best performance and the second best price/performance. For value-conscious users, the Compaq AP200 is the best price and best value. It sacrifices nothing in terms of its hard-

Some speculation, and a look into the future

Korhan Tekin

Pro/ENGINEER users currently have a limited choice of processors and operating systems (OS) that run Pro/ENGINEER well. In this review, the only truly viable architectures are the Alpha 21264, the PA8500 and the Pentium III (see *Chart 6*), and the only practical operating systems are Windows NT and HP-UX. But what can be expected in the future?

Alpha lost some of its momentum with the acquisition last year of Digital Equipment Corp. (DEC) by Compaq. The new Alpha products were released late, and unlike the earlier generation of Alphas, they are currently not competitive from a price perspective. Compaq hopes to change its Alpha fortunes this summer when it rolls out a new motherboard architecture developed together with AMD. These new systems will use a Slot B interface for the processors, similar to the Intel Pentium IIIs Slot 1 connector. This will give a dedicated processor bus of 200 MHz to each chip, as opposed to a 100 MHz shared processor bus on the Intel systems. This promises to give a boost to memory bandwidth in addition to improving dual processor performance. It will also help keep the prices of these motherboards low by increasing the volumes sold. Finally, the new boards will include a 2x AGP slot, which has been a critical missing element on the Alpha architecture for quite some time. Vendors will no longer have to support separate PCI versions of their graphics cards to run on Alpha. They will only have to write new drivers for their boards, finally making a wider range of 3D graphics cards available for Alpha. This will also remove the most severe impediment to graphics performance on the Alpha platform. Alpha Processor, Inc., which was formed by Samsung and Compaq to support the Alpha processor, claims that systems using the new motherboards and processors will compete dollar for dollar with their Intel counterparts.

The new motherboards will also be compatible with the AMD K7 chip, which will be released at around the same time. AMD currently manufactures chips that are x86 compatible with Intel's processors. Their current K6-III is fast for office applications and priced lower than Intel's processors, but its floating-point performance is not as good, making it difficult for an application like Pro/ENGINEER to perform well. The AMD K7 hopes to change this with a redesigned, higher-performance floating-point unit. AMD promises that these new chips will compete head-to-head with Intel's fastest offerings, but at a lower price. This could provide another platform choice for Pro/ENGINEER users to consider.

Intel is planning to release its new 820 chipset, code-named "Camino," at the end of 1999. This new chipset will use RAMBUS memory, which is faster than SDRAM. It will also introduce a 133 MHz system bus and new processor slot architecture, which should remove some of the limitations to graphics performance on the Intel platform. Around the same time, Intel should be releasing its higher speed Pentium IIIs (code-named "Coppermine"), at around 600 MHz.

At present, Intel has a strong hold on the current workstation market. However, the immediate future may be less Intel-centric, as the time frame approaches for rolling out Intel's 64-bit processor, Merced (also called IA-64). To

continued on page 23

ware configuration, allowing users to run Pro/ENGINEER on a top-notch NT workstation for a price of $3,336.

The final word

1999 marks the year that Pro/ENGINEER users will be able to put supercomputing 3D graphics workstations on their desktops. The Pro/ENGINEER systems submitted in this year's review are powerful, while at the same time priced to be accessible to the majority of CAD users. 3D workstations running Windows NT are becoming commodity items, benefiting Pro/ENGINEER users with ample horsepower and compatibility at near-PC prices. Additionally, UNIX workstations, though showing a diminished presence in this market, can still deliver unbeatable performance for Pro/ENGINEER. They still command their place at the peak of workstation computing in niche applications such as designing and managing complex parts and assemblies, such as engine housings with thousands of features, or massive aircraft assemblies (also see the related sidebar "NT versus UNIX").

Though there are fewer options than there have been in past years, Pro/ENGINEER users have an unrivaled opportunity to get the computing tools they need, leaving only their abilities, intents and imaginations between them and getting the job done.

Korhan Tekin is president of damgudesign, inc., an engineering design firm in Sunnyvale, Calif. He can be reached at **korhan@damgudesign.com**.

Some speculation

continued from page 22

continue reaping improved performance from their chips, Intel will eventually have to transition over to a higher performance, 64-bit architecture. This is currently scheduled to take place in mid-2000, but Intel has acknowledged that Merced may not ship in time. This could delay Intel's implementation of a 64-bit processor until McKinley, which is not scheduled for release until late 2001.

Alpha and most other RISC architecture processors are already 64-bit and have a clear roadmap in front of them, meaning they should be able to ramp up their clock speeds regularly without having to significantly change their architecture. Intel's future is not as clear, as it will eventually have to force the transition to an as-yet-unknown IA-64 architecture. This transition could be painful for Intel users, but it could also open up the market to a wider choice of viable processors for Pro/ENGINEER users in the future.

Currently, Windows NT appears to be the OS of choice for the majority of Pro/ENGINEER users. All of the major UNIX vendors but Sun are also selling NT systems. Does this mean that UNIX will disappear from the Pro/ENGINEER market? In all likelihood, it will continue to stick around for quite some time in one form or another, as Microsoft's flagship OS faces growing pains of its own. Microsoft will also have to make some significant changes to NT before its performance is hampered by architectural limitations. Windows 2000 is scheduled for release this summer, but it has already been delayed several times. There are also plans for 64-bit Windows NT, which is most likely to ship first on Alpha, the only NT-ready chip that is currently 64-bit. 64-bit NT will also cause software difficulties when it is eventually introduced. HP-UX is already 64-bit, as is Compaq's Tru64, SGI's IRIX and Sun's Solaris.

There are some new UNIX operating systems on the horizon worth considering. Linux and OS X promise to finally deliver serious competition to Windows NT in the enterprise. The performance and growing widespread acceptance of Linux makes it a candidate platform for running Pro/ENGINEER in the future. Linux, or GNU/Linux, is an open-source version of UNIX that is robust, stable, delivers excellent performance across a variety of platforms and is free. It is receiving a tremendous amount of favorable press, and some computer pundits are predicting that it can displace Windows NT in the corporate enterprise. Both Dell and IBM have started shipping their systems with Linux installed. SGI and Hewlett Packard have also announced support for Linux. It may be quite easy to port Pro/ENGINEER over to Linux considering that OpenGL implementations are available on Linux (for the 3Dlabs architecture, in fact) and Linux has much in common with its UNIX ancestors. Apple is showing signs of renewed life. Its forthcoming OS X is also built around a completely modern UNIX core (BSD UNIX, another free UNIX OS), and initial reports of its performance are promising. Because the approach of developing a custom version of UNIX is too expensive for vendors to compete effectively with a commodity OS such as Windows NT, the only hope for UNIX to survive may in fact be Linux. Additionally, Windows NT lacks many of the high-end tools and functions that UNIX has had for years, and it is far less mature, leaving room for another operating system to step into the breach. Stay tuned.

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