SiliconGraphics
Computer Systems

Silicon Graphics® Visual Workstations for Windows NT Integrated Visual Computing Architecture (IVC)

White Paper

Contents

Abstract

The Silicon Graphics® 320 and Silicon Graphics® 540 visual workstations are built upon an Integrated Visual Computing (IVC) architecture that supports an optimized, native implementation of Microsoft® Windows NT®. The highly tuned IVC architecture leverages a unified memory infrastructure and takes advantage of multiple Intel® Pentium® II/III and Pentium III Xeon™ processors, high-speed buses, and integrated I/O functions to deliver workstation-class performance while maintaining full compatibility with the Windows NT operating system and supported application software. Featuring hardware-accelerated graphics and built-in audio and video capabilities, the visual workstation solutions are ideally suited to visual computing professionals and a broad range of visual information-based applications.

This paper discusses the technical features and architectural design philosophies of the Silicon Graphics® visual workstations for Windows NT as they apply to modeling and design, image manipulation, video editing, analysis, visual simulation, and other applications that require high visual quality and performance.

1.0 Introduction to Silicon Graphics 320 and Silicon Graphics 540

The Silicon Graphics family of visual workstations for Windows NT leverages Silicon Graphics' expertise in high-performance visual systems and brings many high-end characteristics and features to the Windows NT/Intel platform. Based on an exclusive high-bandwidth, highly integrated workstation architecture, these systems combine high-throughput system architecture with built-in graphics and digital media functionality. While the systems provide complete compatibility with Windows NT based software, the built-in capabilities result in systems with unprecedented performance improvements compared with traditional PCs and enhanced quality, precision, and flexibility for visual data operations.

Silicon Graphics 320 and Silicon Graphics 540 support and accelerate the performance of standard APIs, including OpenGL® 1.1, OpenGL Optimizer™ 1.1, Direct X, GDI, Video for Windows, and QuickTime® 3.0. Silicon Graphics will also provide OpenGL extensions for ISV partners to write to for the release of their Windows NT applications, providing even further performance and feature gains. Designed to maximize execution of the most common tasks performed by visual computing professionals, the visual workstation for Windows NT platforms define a new archetype for visual data systems.

1.1 The System for Visual Computing

Silicon Graphics 320 and Silicon Graphics 540 extend the capabilities of traditional PC-based systems with the IVC architecture that simultaneously maximizes system, graphics, and media performance. This differentiation is achieved through the implementation of multiple high-bandwidth buses and a highly accessible central memory pool; high-speed multiprocessing; chip-level imbedded graphics functions; and motherboard-level integration of critical I/O and audio/video functionality.

Because of thier integrated hardware-accelerated graphics, built-in audio/video, and efficient handling of large amounts of data, the systems are particularly suited to applications that require the creation, processing, and manipulation of complex, real-time visual data. Tight integration of system components provides both the bandwidth (see Table 1-1) and the processing power to support extremely large models, visual databases, and full-size, full-rate video to and from disk storage.

Table 1-1. Critical Paths Performance (Peak Throughputs)

Graphics to Memory	3.2GB/sec
Digital Video to Memory	1.6GB/sec
Analog Video to Memory	1.6GB/sec
Fast Ethernet to Memory (PCI-64)	267MB/sec
Display to Memory	1.6GB/sec
CPU to Memory	800MB/sec
2 x PCI-64	534MB/sec*
IEEE 1394	400Mb/sec

Noncoherent "sustained" coherent bandwidth is approximately 2x 120MB/sec = 240MB/sec.

The visual workstation I/O engine is capable of handling all of the bandwidth of two uncompressed streams of NTSC or PAL video in and two streams of uncompressed NTSC or PAL video out, without taxing the rest of the system. This equates to four streams of simultaneous video streams. It also allows the use of video as a graphics component, not only supporting high-quality uncompressed video stream input, editing, and storage, but also allowing mixing of video with 2D and 3D graphics—all in real time.

1.2 Architected for Performance

The IVC design incorporates standard Intel Pentium II/III or Pentium III Xeon processors, but the architecture differs significantly from standard PCs with the inclusion of:

- A highly efficient Cobalt™ graphics chipset operating in synchronous mode of operation clocked at 100 MHz
- An innovative Cobalt graphics chipset that incorporates hardware acceleration for rendering and texturizing functions
- A dynamically allocated memory pool available to all components and subsystems as a common resource
- A high-speed, low-latency 256-bit wide memory bus achieving 3.2GB per second of memory bandwidth
- Tightly integrated video and IEEE 1394 functions
- Two, dedicated 64-bit 33 MHz PCI buses with available PCI slots

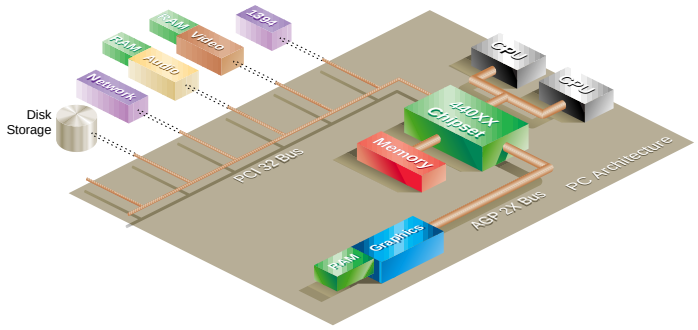
The platforms include built-in stereo 16-bit audio and composite video input and output. The systems support advanced digital media features such as dual-channel serial digital video input/output, dual-channel motion JPEG compression, and multichannel digital audio.

The result of this implementation is a visual computing system that delivers data throughput—especially for graphics and media operations—much more efficiently than any other system in its price class. The overall high system performance, bandwidth, and range of built-in functionality enable the execution of more sophisticated tasks and applications than previously practical on standard PCs.

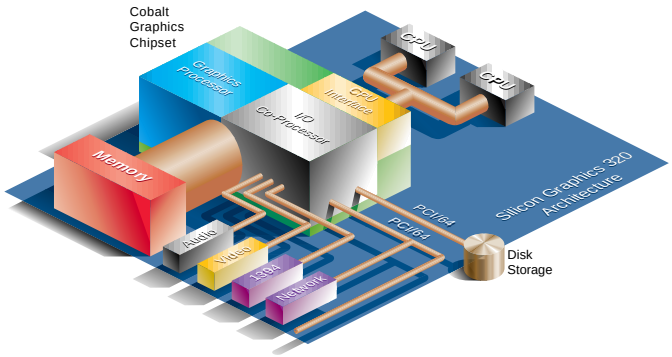
1.3 Comparison with the Traditional PC Architecture

As illustrated in Figure 1-1, the IVC architecture differs significantly from the standard PC architecture. PCs use a single 133MB-per-second PCI bus for all network, disk, and add-on audio, video, and graphics cards. (Note that if the Intel AGP bus—currently the AGP 2X—is implemented, the bandwidth for graphics improves to 512MB per second. The planned year-2000 introduction of the AGP Pro, or the AGP 4X, will increase that number to 1GB per second.)

Traditional PC Architecture



Silicon Graphics 320 Architecture



Silicon Graphics 540 Architecture

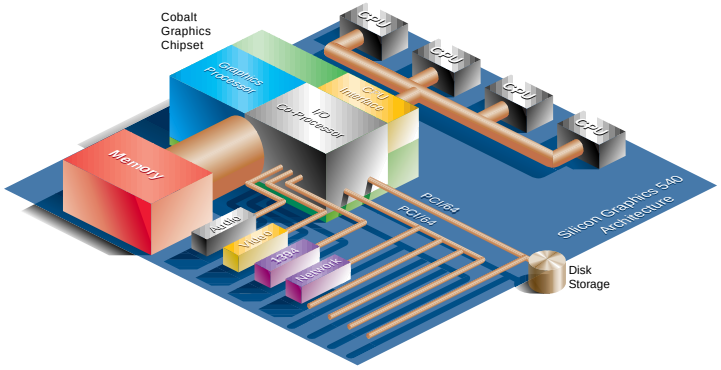


Figure 1-1. An Architecture Optimized for Visual Computing

In contrast, the Silicon Graphics IVC architecture links the system chipset directly with the CPU, the audio and video I/O, the network, and two built-in IEEE 1394 400Mb ports. Each subsystem is tied to a central memory pool via a 3.2GB-per-second very high bandwidth connection, eliminating many of the congested bus bottlenecks associated with traditional PC architecture. At 3.2GB per second, the IVC graphics-to-memory connection operates at six times the capacity of AGP. The systems also support two PCI buses (each achieving peak bandwidth of up to 266MB per second in 64-bit mode), allowing for separation of networking, storage, and digital media devices to avoid bus contention delays and maximize available system throughput.

The Silicon Graphics 320 and the Silicon Graphics 540 platform achieves superior system performance by placing all major system functions together at the motherboard level. Each of the tightly coupled subsystems are tailored to deliver high-performance digital media functionality:

- Cobalt graphics engine: A customized ASIC incorporates geometry acceleration, hardware-based texture mapping, and 2D image acceleration.
- I/O coprocessor: The chipset is optimized for performance with two dedicated PCI-64 buses, one IEEE 1394 (two ports via transceiver), S-Video, and composite video I/O. The I/O co-processor supports analog and digital video, delivering enough system I/O for dual-stream uncompressed video. The I/O coprocessor supports analog video, with two channels of serial digital available. (For this document, one stream of data is defined to be a single real-time video input or output at 601/NTSC/PAL resolution.)
- Processing: Silicon Graphics 320 can be configured with up to two Pentium II or Pentium III processors, and Silicon Graphics 540 can be configured with up to four Pentium III Xeon processors. The processors can operate up to 550 MHz, and the Pentium III Xeon processor supports up to 2MB of L2 cache memory. Performance of the Intel Pentium III Xeon processor will be faster even at the same clock rate due to the larger and faster L2 cache memory that is implemented. The Pentium L2 cache memory is operating at half the speed of the core of the processor, whereas the Xeon L2 cache memory is operating at full speed.

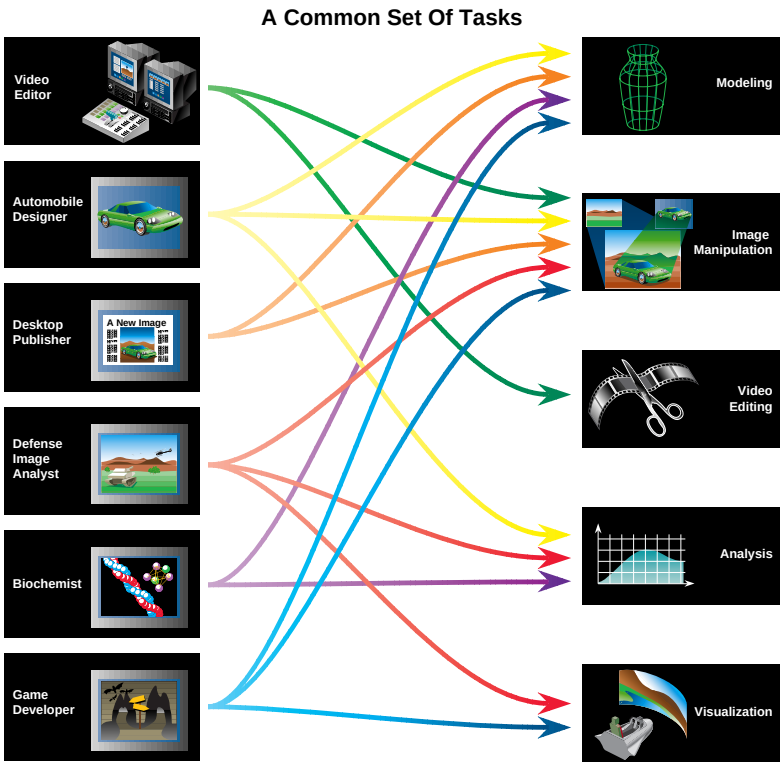
Most PCs require the use of PCI plug-in cards for networking and many other I/O interface or device connections. In contrast, the visual workstation for Windows NT system board integrates essential communications and device links that both improve overall I/O performance and conserve always-scarce I/O slots.

Traditional PC systems, while inexpensive, are very limited in their ability to process large amounts of data. Bus contention, inadequate memory and I/O bandwidth, restricted memory access, nonintegrated graphics, and I/O functionality make the standard PC poorly matched to visual computing applications.

Visual computing professionals will find that the Silicon Graphics 320 and Silicon Graphics 540 design eliminates each of these limitations without sacrificing PC compatibility. The workstation is a native implementation of Windows NT, comes preconfigured with Windows NT Workstation 4.0, runs all Windows certified applications, and supports Universal PCI cards and PC-standard peripherals. At the same time, the workstation platform handles data efficiently and provides enhanced graphics and media functionality. Utilizing the workstation immediately improves the quality of existing PC applications and presents significant opportunities to expand the scope of visual computing tasks.

1.4 Built for Visual Computing Tasks

The Silicon Graphics visual workstations for Windows NT effectively address the five most common tasks practiced in visual computing applications—modeling and design, image manipulation, video editing, analysis, and visual simulation.



1.4.1 Modeling and Design

Tasks in these areas typically include assembly, texturization, and manipulation of large, complex models, often composed of more than 100,000 polygons. Sophisticated shading, lighting, and real-time capabilities are highly desirable. The features that address these requirements include:

- High system bandwidth, including a high-speed, low-latency memory bus, that facilitates rapid transfer of textures in and out of memory
- Dynamically allocated memory that supports the use of nearly a full gigabyte of system memory for model textures (we have determined that the amount of memory that can be used for textures is 85% of total available memory)
- Hardware-accelerated 3D geometry with hardware acceleration of lighting, transforms, setup, texturing, and rasterization
- Extremely fast pixel fill
- OpenGL extensions for optimized performance and quality, including occlusion test and occlusion correct, post-production texture specular highlights, and p-buffers for off-screen rendering

1.4.2 Image Manipulation

Similar in requirements to modeling tasks, imaging jobs need support for the creation and manipulation of large, high-resolution image files such as maps, photos, and other 2D data files. The features that address these requirements include:

- High-performance processing
- Rapid data movement via the high-speed memory bus
- Extremely fast pixel fill
- 2 PCI-64 buses for fast access to offline storage

1.4.3 Video Editing

The system must handle the real-time input/output, manipulation, and storage of high-quality, uncompressed video. The features that address these requirements include:

- Support for real-time transfer of two simultaneous streams of video I/O
- Multistream compositing with the ability to use video as a texture map on a 3D object
- Support for serial digital video I/O
- Integrated compression algorithms
- Integrated IEEE 1394 for high-speed connection of devices such as digital video decks or camcorders

1.4.4 Analysis

Most analysis problems require the ability to rapidly process extremely large amounts of engineering or scientific data, typically in the form of models or designs. Powerful processing and accurate visualization capabilities are critical to achieving dependable results. The features that address these requirements include:

- Fast floating point performance
- Up to four Intel Pentium III Xeon CPUs (Silicon Graphics 540 only)
- High-speed buses, with extremely low CPU-to-memory latency
- Hardware-accelerated 3D graphics
- Support for high resolution (up to 1920x1200)
- Rapid, concurrent processing and I/O operations

1.4.5 Visual Simulation

Visual simulation tasks generally call for the ability to walk through complex 3D scenes, whether they are architectural structures, battlefield diagrams, or game environments. In order for a system to be used in this setting, it must be capable of real-time display and manipulation of realistic, highly textured spaces. The features that address these requirements include:

- High-bandwidth, high-capacity memory
- High-quality display capabilities
- Hardware-accelerated 3D graphics
- Support for large texture maps
- Support for fully textured, real-time simulations

1.5 Packaged for Professionals

The Silicon Graphics 320 and Silicon Graphics 540 incorporate technical functionality for professional-level visual applications that until now has only been available in higher-end (typically UNIX®) graphics systems. The system reflects Silicon Graphics' extensive experience in the design of high-quality graphics platforms, while it lets users take advantage of the wide array of Windows NT certified graphics and digital media-based tools and applications.

2.0 Advanced, Integrated Functionality

The Silicon Graphics visual workstation for Windows NT system architecture and each functional component have been optimized for performance and visual computing value. Borrowing many of its design characteristics from Silicon Graphics' higher-end systems, the workstations eliminate the performance bottlenecks associated with traditional PCs and extend standard PC feature sets to accommodate the requirements of professional-level visual computing applications.

2.1 Efficient Memory Structure

The Silicon Graphics visual workstation for Windows NT memory system leverages proven architecture features from previous high-performance Silicon Graphics systems. Unlike typical PC architectures, where data must be transferred between main memory and graphics, video, and imaging memory located on separate interface cards, all the of the visual workstation for Windows NT data resides in main memory, where memory for the system, frame buffer, z-buffer, texturing, rendering, imaging, and video are dynamically allocated so that no portion of the system is starved for data. The OS, OpenGL drivers, and Cobalt memory controller allocate the memory. This is in contrast to dedicated pools of memory on PCI cards populated throughout the computer (a design that forces data movement and therefore degrades performance). The Cobalt graphics memory controller automatically (dynamically) allocates the appropriate amount of memory from a central pool. With the memory controller integrated on the graphics chip itself, memory instructions are communicated extremely fast. This memory structure gives quick memory access to applications that involve complex 3D graphics, large images, or heavy data sets like multiple streams of video.

The unified memory system, with a 256-bit bus, achieves data rates of up to 3.2GB per second from the synchronous DRAM (SDRAM) implementation. Employing high-speed (50 ns) chips, the memory is configured in banks of 128, 256, or 512MB DIMMs for up to 2GB total on Silicon Graphics 540 (up to 1GB on Silicon Graphics 320). ECC protection corrects all single-bit and detects all double-bit errors. The workstations utilize high-speed 50-ns memory components.

2.2 High-Performance Multiprocessing

Silicon Graphics 540 accommodates as many as four 450 MHz Pentium III Xeon processors, making the platform one of the fastest PC implementations available. High-speed 512KB, 1MB, or 2MB cache can operate at 100% speed of the processor clock (depending upon system configuration) to provide optimized application performance.

2.3 Full-Function, Hardware-Accelerated Graphics

Connected directly to the memory system—with extremely high bandwidth for fastest performance—is the Cobalt graphics chipset. This graphics engine provides hardware-accelerated performance for the most commonly used graphics functions and is architected to provide the fastest graphics processing possible.

2.4 Built-In Digital Media Functionality

Among the most demanding of computational requirements are those associated with the input processing and distribution of digital media types. Digitized media data—data originating from film, video, or camera sources—is moved into, through, and out of the system in encoded digital data streams. Each stream contains coding and timing information, as well as material frames, each with voluminous bits of data that describe the color, intensity, and other attributes of the clip or shot(s). Depending upon the quality of the image (based on color depth, pixel resolution, etc.), a single picture frame can consume hundreds of thousands of kilobytes of storage and require tremendous bandwidth for playback.

Most PC systems rely on add-on cards or third-party components to provide basic digital media functionality such as media streaming or digital audio/video synchronization. Integration of these components can be difficult and time-consuming, and typically they only enable or accelerate a limited set of operations. In contrast, the visual workstations for Windows NT provide a full set of built-in audio and visual functionality, including:

- S-Video I/O
- Composite video I/O
- Stereo analog audio I/O
- Stereo headphone and speaker output
- Microphone input

The system also supports a series of interfaces that extend support for full-motion video, serial digital video, and digital audio.

In addition to built-in hardware functionality, the workstations include Silicon Graphics developed audio-visual software for digital media operations:

- Standard Windows NT 4.0 WAVE drivers for on-board audio and digital audio interface
- Audio control panel
- High-performance video driver software capable of sustaining four streams (two stream in and two stream out simultaneously) of uncompressed CCIR-601 video in or out
- Video control panel
- Optimized software CODECs—motion JPEG encode/decode and DV decode
- OpenGL 1.1
- Apple® QuickTime for Windows® support
- Microsoft Video for Windows support
- Microsoft DirectX Media 5.1 (DirectShow) support

2.5 High-Speed I/O

The Silicon Graphics visual workstation for Windows NT architecture facilitates high-speed input/output by providing multiple high-throughout data paths from the system chipset directly to the PCI bus(es), as well as to networking, audio, video, and IEEE 1394 components. By placing each of the major I/O functions on its own separate bus, the workstations deliver significantly greater performance than is achievable on systems that combine these functions on a single, typically congested bus. The systems also support both hardware- and software-based compression algorithms that allow for faster or higher-quality media data throughput.

2.6 Support for 64-Bit PCI

The Silicon Graphics visual workstations for Windows NT is one of the first major PC-compatible platforms to take advantage of the 64-bit PCI bus standard, the emerging standard in the industry, which offers the high-bandwidth throughput (266MB per second) required for graphics and digital media applications.

2.7 Super I/O

The IVC architecture leverages the Intel Fix 4 Chip to drive the visual workstation standard I/O ports, including USB connections, Ultra/DMA33, and internal bus for super I/O-based floppy, parallel, and serial ports.

3.0 Leading-Edge Performance through Silicon Implementation

The Silicon Graphics visual workstations for Windows NT leverage the best of available silicon technology, utilizing leading-edge processing technology from Intel combined with state-of-the-art graphics ASIC technology from Silicon Graphics.

In addition to incorporating the Intel Pentium II/III or Intel Pentium III Xeon processor, the workstations contain the Cobalt graphics chipset, which consists of three special-function integrated circuits that control the motherboard. These ASICs provide built-in graphics acceleration, display, digital media I/O, and additional functionality, including analog video, digital video, and IEEE 1394.

4.0 Advanced Communications, Peripherals, and Packaging

The motherboard integrates networking and peripheral I/O connections, high-speed storage devices, and graphics and media equipment such as video cameras, A/V cards, audio tape, and microphones. Tables 4-1 and 4-2 list the system board connections and rear-panel connections.

Table 4-1. System Board Connections

Ultra DMA/33	One Ultra DMA/33 channel for 51/4"x1.6" CD or DVD drive and one optional 31/2"x1" removable media drive.
FDI	One floppy drive interface for 31/2"x1" floppy drive.
USB	Two Universal Serial Bus (USB) ports.
Monitor Port	VGA connector to CRT or analog-interface flat panel monitor. Supports monitor ID and control via DDC2B interface.
Flat Panel Port	One optional digital interface connector supporting Silicon Graphics® 1600SW flat panel display
IEEE 1394 Port	One IEEE 1394 connector at 400Mb/sec
Serial Port	One RS-232 serial port with separate DMA channels for input and output. Each channel is capable of up to 115K baud and is full duplex.

Table 4-1 continued

Parallel Port	One IEEE 1284-compliant parallel port.
Ethernet Port	One 10/100Mb auto-sensing Ethernet interface.
Analog Audio Ports	The audio subsystem has one input channel that can be sourced from the microphone input; the stereo line-level inputs, or the internal CD-ROM drive analog audio outputs. The audio subsystem has two output channels that drive the stereo line-level outputs and the stereo variable-level headphone/speaker output.
Analog Video Ports	The video subsystem has two channels and two signal formats. The input channel can take data from a composite input or a Y/C (S-Video) input, and the output channel can send data to a composite output and a Y/C (S-Video) output simultaneously.
Digital Video Port (Silicon Graphics 540 only)	The system module has a proprietary connector for the Digital Video Option that accesses the graphics engine CCIR 601 digital video input and output streams. The Digital Video Slot has an I/O panel that supports up to eight BNC connectors.

Table 4-2. Rear Panel Connections

Monitor Out	Mini-DB15 VGA with DDC2B control	**Flat Panel**	Optional digital interface to flat panel display with DDC2B control
Line In	2 x RCA (female) stereo line-level audio input	**Line Out**	2 x RCA (female) stereo line-level audio output
Microphone In	3.5 mm mini-jack (female) mono microphone level input	**Speaker/ Headphone**	3.5 mm mini-jack (female) stereo variable-level output
Composite Video In	RCA (female) NTSC/ PAL composite video input	**Composite Video Out**	RCA (female) NTSC/PAL composite video output
S-Video In	MDIN4 NTSC/PAL Y/C video input	**S-Video Out**	MDIN4 NTSC/PAL Y/C video output
IEEE 1394	Dual IEEE 1394 400Mb/sec connectors	**USB**	Dual USB interface to keyboard/mouse plus another device
Ethernet	RJ45 10/100Base-TX	**PCI**	6 64-bit PCI slots (Silicon Graphics 540) 2 64-bit, 1 32-bit PCI slot (Silicon Graphics 320)

Table 4-2 continued

Serial	DB9 (male) RS-232 to 115K baud	**Parallel**	DB25 1284 EPC
Digital Video (Silicon Graphics 540 only)	Optional digital video interface 2 BNC for SDI inputs A&B 2 BNC for SDI outputs A and B 2 BNC for house sync and loopthrough 2 BNC for GPI in and out		

The Silicon Graphics visual workstations for Windows NT incorporate Ultra ATA storage (Silicon Graphics 320 only) and can also support a single or dual port Ultra2 SCSI, with each port capable of 80MB-per-second peak data transfer. This interface can be used to drive software RAID or to connect external RAID storage cabinets to support the bandwidth and capacity requirements of dual streams of uncompressed digital video. A dual Fibre Channel interface, each channel capable of 200MB-per-second peak data transfer, can also be used for this purpose.

The system incorporates one 400Mb IEEE 1394 port that is ideal for rapid transfer of data from a digital video deck or camcorder. Data is maintained in its native digital format, ensuring that the data remains in true digital form without the loss normally associated with analog conversion. (IEEE 1394 will be available in a future release of Windows NT.)

A 1.44MB floppy drive and a 32X ATAPI CD-ROM are standard.

4.6 Monitors and Flat Panels

The Silicon Graphics visual workstations for Windows NT offer a selection of large-screen displays, including a 17-inch CRT, a 21-inch CRT (Trinitron), and the new Silicon Graphics 1600SW flat panel monitor. This revolutionary 17.3-inch TFT digital flat panel is developed especially for the Silicon Graphics 320 and Silicon Graphics 540. The display offers:

- OpenLDI digital interface that extends visual capabilities for photo-realism and enhanced color saturation
- True color 16.7M (8-bit sub pixel) and 110 dots per inch
- Wide 1600x1024 resolution
- High contrast ratio (250:1)
- 120° (viewing angle)
- ColorLock™ color management systems for color calibrating the Silicon Graphics 1600SW flat panel monitor

4.7 Packaging

Designed to be ergonomic, highly serviceable, and fast to set up, the visual workstations for Windows NT offer:

- A slim-line ATX or extended WTX form-factor
- Switch-selectable power supply
- Low-noise, variable-speed fans for optimal temperature control and air flow
- CFC-free manufacturing
- Simplified service with internal components easily accessible and replaceable by tool-less access
- Fast, screwless chassis access
- Power-on self test that displays startup errors and suggests solutions

In each of the system models, removable media drives are at the front top of the system enclosure for easy access. PCI option slots, disk drive slots, memory module slots, and processor module slots are accessible by simply removing the side cover of the enclosure. Internal fans (two to four) plus a fan in the power supply provide cooling.

5.0 Enhancing Visual Computing Applications with the Silicon Graphics Visual Workstations for Windows NT

Silicon Graphics 320 and Silicon Graphics 540, from their conception, were architected to enhance visual computing applications. In particular, the systems enable improved operation of traditional PC-based projects, as well as provide a cost-effective platform for doing professional-class work that is simply not feasible on standard PCs. The innovative architecture makes it easy to combine graphics and digital media functionality to accomplish the most common tasks associated with visual computing applications.

In summary, the visual workstation system delivers substantial benefits, including:

- **Flexibility.** While PCs and their add-on components offer a limited selection of operations, the visual workstations for Windows NT provide a wider array of seamlessly integrated graphics/digital media features.
- **Quality.** Applications that run on a standard PC in a low-performance mode automatically run with better quality on the workstations. The system offers better overall performance, as well as the ability to handle uncompressed streams, display to larger screens, deliver better resolution, etc.
- **Productivity.** Integrated functionality translates to faster setup and predictable results. Additionally, the high system performance allows users to get more work done in the same amount of time, giving them time to incorporate new effects, develop and run more sophisticated graphics, and create a better overall end product.
- **Power.** The visual workstations for Windows NT incorporate many unique features and capabilities—precision audio-video synchronization, state-of-the-art digital display, real-time character generation, real-time dual-stream video editing—that either are not available on standard PCs or are offered through prohibitively expensive add-on components.
- **Value.** The workstations integrate more functions and performance than any other system in their price class.