



# **Groundbreaking Benchmarks from IBM, Intel and Microsoft**

*Combining technologies for breakthroughs in server performance and scalability*

## **Executive Summary**

This paper documents how cooperation among industry leaders IBM<sup>®</sup>, Microsoft<sup>®</sup> and Intel<sup>®</sup> has yielded enterprise-class scalability and performance from industry-standard hardware and software. By designing and implementing a technology infrastructure based on industry-standard components, a very real competitive advantage has been achieved.

Three new results were achieved on the TPC Benchmark C<sup>®</sup> (TPC-C<sup>®</sup>)<sup>1</sup>, which measures the ability of a system to process new order transactions while also executing payment, order-status, delivery and stock-level transactions in an online transaction processing (OLTP) environment, while meeting strictly defined response times. The TPC-C results achieved demonstrate how the combination of Microsoft SQL Server 2000 Enterprise Edition and Windows<sup>®</sup> 2000 Datacenter Server running on x370 servers using Intel's latest Pentium<sup>®</sup> III Xeon<sup>™</sup> processor at 900MHz provides the performance and scalability required for strategic implementation.

Two new results were achieved with the TPC Benchmark H<sup>®</sup> (TPC-H<sup>®</sup>), which can provide the user with a view of a system's ability to process the decision support queries necessary to support sound business decisions. Just as a system's ability to gather online transaction processing data is important, so is a system's ability to process that data so that it can be used to make business decisions. The TPC-H benchmark provides IBM customers with the information they need to choose the best performing decision support system available.

What makes the benchmarks significant is that a growing number of businesses of all sizes need to deploy industry hardware and software that meets today's demanding e-business applications, and has the ability to meet tomorrow's platform needs. Customers want to know that these solutions can handle the performance requirements of the present as well as grow to meet performance needs in the future. The benchmark numbers are strong reassurance that industry leaders such as IBM, Intel and Microsoft have carefully integrated hardware and software to create robust solutions. Customers know these solutions are verified by an impartial third party who is widely recognized by the industry. Finally, IBM, Intel and Microsoft bring decades of proven innovation and experience to these solutions, and their combined efforts translate into the best products and services on the market, customized to the needs of the customer.

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## **Benchmark Results**

### ***32-node sets a new world record for TPC-C performance (Super Nova)***

Super Nova set a new world record on March 23, 2001, achieving 688,220.90 transactions per minute or tpmC, which places it first in the Top Ten TPC-C by Performance for *all* results. The benchmark configuration used 32 x370 database servers, with a total of 256 Pentium III Xeon 900MHz<sup>2</sup> processors, running Microsoft Windows 2000 Datacenter Server and Microsoft SQL Server 2000 Enterprise Edition. With more than 116TB<sup>3</sup> (terabytes) of physical disk capacity configured for high availability using a combination of RAID-1E and RAID-10 arrays and more than 7,000 disk drives, the benchmark configuration is one of the largest OLTP databases in existence. It achieved a new TPC-C record of 688,220.90 tpmC at \$28.89/tpmC, shattering previous TPC-C performance records for any hardware, operating system or database<sup>4</sup>. The total solution availability date is May 31, 2001.

### ***16-node ranks in Top Ten TPC-C by Performance (Nova)***

The 16-node benchmark configuration achieved 363,129.75 tpmC, ranking it in the Top Ten TPC-C by Performance for all results as of March 23, 2001. The benchmark used 16 x370 database servers with a total of 128 Pentium III Xeon 900MHz processors, running Microsoft Windows 2000 Datacenter and Microsoft SQL Server 2000 Enterprise Edition. The configuration, with more than 3,500 disk drives, represented 58TB of physical disk capacity configured for high availability using a combination of RAID-1E and RAID-10 arrays. Price performance was \$28.10/tpmC; total solution availability date is May 31, 2001.

### ***4-node ranks in Top Ten Clustered TPC-C by Performance (Tsunami)***

Tsunami, a 4-node configuration, achieved 121,319.23 tpmC, placing it in the Top Ten Clustered TPC-C by Performance. The benchmark configuration used four x370 servers with a total of 32 Pentium III Xeon 900MHz processors, running Microsoft Windows 2000 Datacenter Server and Microsoft SQL Server 2000 Enterprise Edition, with a total of 728 drives, representing more than 9TB of physical disk storage. Price/performance was \$25.47/tpmC; total solution availability date is May 31, 2001.

### ***x350 achieves Top Ten TPC-H Results by Performance at 100GB***

The x350 has achieved leading TPC-H performance for a 4-way system: 1,169.7 QphH @100GB at price/performance of \$166/QphH. This result places the new x350 in the Top Ten TPC-H Results by Performance at 100GB. The benchmark configuration used one x350 server with four Pentium III Xeon 900MHz processors, running Microsoft SQL Server 2000 and Windows 2000 Advanced Server. Total solution availability date is May 31, 2001.

### ***x250 achieves Top Ten TPC-H Results by Performance at 100GB***

The x250 has achieved leading TPC-H performance for a 4-way system: 1,147.9 QphH @100GB at price/performance of \$169/QphH. This result places the new x250 in the Top Ten TPC-H Results by Performance at 100GB. The benchmark configuration used one x250 server with four Pentium III Xeon 900MHz processors, running Microsoft SQL Server 2000 and Windows 2000 Advanced Server. Total solution availability date is April 13, 2001.

TPC-C Performance Results

## TPC-C Performance Results

	Operating System	Database	Hardware System Model	tpmC	Date Avail.	Price/tpmC	Total Price
1	Microsoft Windows 2000 Datacenter Server	MS SQL Server 2000 EE	IBM eServer xSeries 370 (32 nodes)	688,220.9	5/31/01	\$28.89	\$19.9M
2	Microsoft Windows 2000	Microsoft SQL Server 2000	Compaq Proliant 8500 - X700-192P	505,302	11/30/00	\$19.80	\$10M
3	Microsoft Windows 2000 Advanced Server	IBM DB2 UDB 7.1	IBM Netfinity 8500R c/s (32 nodes)	440,879	12/07/00	\$32.28	\$14.2M
4	Microsoft Windows 2000 Datacenter Server	Microsoft SQL Server 2000 EE	IBM eServer xSeries 370 (16 nodes)	363,129.75	5/31/01	\$28.10	10.2M
5	Microsoft Windows 2000	Microsoft SQL Server 2000	Compaq Proliant 8500 - X550-96P	262,243	9/30/00	\$20.24	\$5.3M
21	Microsoft Windows 2000 Datacenter Server	MS SQL Server 2000 EE	IBM eServer xSeries 370 (4 nodes)	121,319.23	5/31/01	\$25.47	\$3.1M

*Source: Transaction Processing Performance Council. Data current as of 3/23/01*

## **Combining Technology for Exceptional Performance**

Industry leaders formed a joint effort to combine technology that yields unsurpassed performance and scalability of industry-standard based servers reflected by these benchmarks.

### ***IBM eServer* - new xSeries servers**

IBM has dramatically expanded the role of industry-standard computing with highly available and scalable clustering solutions. Through the IBM X-architecture strategy of bringing proven, enterprise class capabilities to industry-standard computing, xSeries servers are the choice for Windows 2000 users seeking a powerful, reliable and scalable platform optimized for mission-critical solutions.

#### **x370**

The three TPC-C benchmark configurations discussed in this paper all used the 8-way x370, a high-performance, Intel-based enterprise server built to tame even the most demanding applications. With up to 12 Active™ PCI slots and support for up to 32GB of memory, the server easily handles data-intensive processing tasks.

#### **x350 and x250**

TPC-H performance benchmarks described in this paper used the high-performance, 4-way, Intel-based x350 and x250 servers to achieve superior results. Built for speed and reliability in a sleek 4U design, the x350 is ideal for any enterprise involved with databases, e-commerce, security, data mining or directory services. Impressive I/O features, Chipkill memory and IBM X-architecture make the x350 both extremely dependable and scalable. The x250 is built to run business-critical applications and for companies anticipating rapid growth. This high-performance server is ideal for corporate e-mail, messaging and workgroup collaboration solutions, as well as data mining, data warehousing and other heavy-duty business analysis.

Find out more about IBM eServer [www.ibm.com/pc/us/eserver/xseries](http://www.ibm.com/pc/us/eserver/xseries)

### **IBM Datacenter Solution Program**

The 32-node, 16-node, and 4 node x370 TPC-C benchmarks incorporate the IBM Datacenter Solution Program, which provides a comprehensive set of offerings to deliver enterprise computing solutions based on the Microsoft Windows 2000 Datacenter Server operating system. The program includes certified hardware configurations, certified kernel mode applications and standard and extensive optional services. IBM also offers unique system attributes for the data center with IBM X-architecture that includes outstanding scalability, systems management and serviceability.

The new xSeries 370 models used in the benchmarks have already been certified by IBM for use in data center configurations. IBM can provide systems based upon either the 900MHz x370 systems utilized in these benchmarks or on the 700MHz x370 systems. We have certified single node and 4-node clusters on each of these platforms. We have also certified our systems with several large-scale fibre channel storage solutions, including the IBM FASTT500 products, the IBM Enterprise Storage Server and the EMC Symmetrix 5000.

IBM has a complete set of optional services appropriate for Datacenter customers, including High Availability Services, Operational Support Services, consolidation and migration services, IBM Testing Services for proof of concept, performance tuning and other testing, and Business Continuity and Recovery Services for disaster recovery and other planning needs. IBM can also provide custom consulting services for practically any IT requirement that a customer may have.

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Find out more about the IBM Datacenter Solution Program:  
[www.pc.ibm.com/ww/eserver/xseries/windows](http://www.pc.ibm.com/ww/eserver/xseries/windows)

### **Intel Pentium III Xeon Processor at 900MHz: The Computing Brain behind each Server Node in the Cluster**

Each server node in the TPC-C benchmarks is an 8-way symmetrical multiprocessing (SMP) capable x370 server built on Intel's Profusion<sup>®</sup> chipset architecture and populated with eight 900MHz Pentium III Xeon processors. The TPC-H benchmarks used 4-way x250 and x350 servers.

The efficient design of the .18U Pentium III Xeon processor offered at 900MHz enables Intel to build a fast, 2MB L2 cache directly into the processor itself. Unlike earlier Intel Pentium III Xeon processors, which accessed external L2 cache, the new Pentium III Xeon processor features an internal cache that runs at full speed.

The integrated design reduces memory latency by four times and improves performance across the board. The L2 cache is called the Advanced Transfer Cache (ATC), and was used because of its high level of performance via the internal full-speed cache, higher core frequency and integrated design. This L2 cache employs a 256-bit link to the processor that is four times as wide as the connection used on earlier Pentium III Xeon processors. The cache also uses higher set-associative cache than earlier L2 cache stores, speeding access to cached data. Bigger fill buffers and bus queue entries enable prompt and smooth data flow. In summary, the ATC consists of micro architectural improvements to provide a higher data bandwidth interface between the level 2 cache and the processor core that is completely scalable with the processor core frequency, resulting in improved transaction processing performance.

Features of the ATC include:

- Non-blocking, full-speed, on-die level 2 cache 0
- 8-way set-associative cache
- 256-bit data bus to the level 2 cache
- Reduced latency interface to cache data (as compared to discrete caches).

The heart of the memory and I/O at each node in the cluster was the Intel-supplied Profusion chipset and the baseboard. It blends the power of Pentium III Xeon processor base, up to 8-way SMP, with the largest memory subsystem offered today for an Intel-based server platform. The chipset also delivers a powerful I/O subsystem that balances the processor capability with powerful I/O bandwidth.

This architecture includes three 100MHz system buses connected through a crossbar switch to the CPU unit, I/O and memory. The Profusion chipset supports the latest 900MHz Pentium III Xeon processors. Of special importance in this architecture are the memory and I/O subsystems. The memory subsystem supports up to 32GB at 100MHz, two high-bandwidth SDRAM subsystems and a maximum bandwidth of 1.6GB per second. The high memory and I/O bandwidths of the Profusion architecture enable fast access to large data sets. The result is that the system responds quickly to queries represented by the TPC-C and TPC-H benchmarks. The benefit is that the systems support a large number of users and a high transaction throughput.

Additionally, the I/O subsystem is modular and expandable, based on the customer requirements for supporting either legacy PCI cards or the latest 64-bit PCI cards. This subsystem includes specifications for two 64-bit PCI expansion slots at 33MHz (expandable to

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six), two 64-bit PCI slots at a speed of 66MHz (expandable to four) and up to four peer 66MHz, 64-bit PCI buses. With a maximum bandwidth of 800MB per second, the PCI buses interface to a 100MHz dedicated PCI bus. A number of other architectural features enhance the enterprise caliber of the Profusion platform. Profusion supports Extended Server Memory Architecture (ESMA), which allows full 36-bit memory addressing for enterprise applications, allowing 32GB of memory. This feature breaks the legacy 32-bit (4GB) memory barrier, giving applications memory headroom and improving the performance of OLTP applications significantly.

Find out more about Intel: [www.intel.com](http://www.intel.com)

For more details on the Intel Pentium III Xeon Processor, visit:  
[www.intel.com/pentiumiii/xeon/home.htm](http://www.intel.com/pentiumiii/xeon/home.htm)

### **Microsoft Windows 2000 Datacenter Server**

Windows 2000 Datacenter Server is Microsoft's answer to the question, "On what operating system do I host my most demanding mission-critical applications?" Studies have shown that high availability is achieved through a combination of people, process and technology. The IBM Datacenter Solution Program brings it all together by incorporating Microsoft Windows 2000 Datacenter Server on well-tested IBM platforms designed for high availability; adding an array of outstanding IBM services appropriate for systems of this class; and maintaining the IBM focus on testing key applications on our certified systems. Companies rely on the ability of these applications and operating systems to scale and meet increasing and often unpredictable demand. With the IBM Datacenter Solution, we bring you all the benefits and features of Windows 2000 Advanced Server, but with added benefits specific to the needs of the data center environment.

Microsoft® Windows® 2000 Datacenter Server is the most powerful and functional server operating system ever offered by Microsoft. It delivers the following incremental features over Windows 2000 Advanced Server.

- Support for up to 32-way symmetric multiprocessing (SMP)
- Support for up to 64GB of physical memory
- 4-node failover clustering enabling protection for up to three consecutive server failures and N+1 configurations, which reduce the cost of ownership of clustered configurations
- WinSock Direct, which facilitates high-speed server-to-server communications in a system area network (SAN). WinSock Direct enables the use of high-performance interconnects without requiring the applications to be rewritten
- The Process Control tool, a new management tool that enables the control of resource allocations to multiple workloads running on server. Windows 2000 Datacenter Server also provides the rich Internet and core operating system services available in all the versions of Windows 2000 Server Family.

Windows 2000 Datacenter Server is optimized for both the new breed of data center applications and traditional data center workloads including: line-of-business applications, e-commerce solutions, large data warehouses, econometric analysis, large-scale simulations in science and engineering, OLTP and server consolidation.

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### **Benefits of the IBM Datacenter Solution for Microsoft Windows 2000 Datacenter Server**

**Availability:** The combination of high-availability features from IBM with stringent platform validation and high-end services result in the highest levels of end-to-end availability. The pre-testing of hardware, operating system and kernel mode components relieves customers of the burden they would normally undertake when buying components from different vendors. Joint Support Queue offered by IBM and Microsoft provides the fastest path for problem resolution, thereby minimizing unplanned downtime.

**Scalability:** Implementation of Windows 2000 Datacenter Server on x370 servers gives customers extensive scalability. Windows 2000 Datacenter Server supports large and highly scalable Intel-based servers and is designed to build and run large centralized databases and data store backends for line of business, dot-coms, and application hosting (ASPs, ISPs).

**Broad choice of applications:** The Windows platform supports the largest selection of server applications--over 4,000. Wide support and commitment from developers, software companies and Microsoft to the Windows platform assures customers that the applications they need now will be supported, and the applications they need in the future will be available from multiple vendors. IBM also has implemented a special validation testing program for Datacenter applications. ISVs can validate their applications on IBM-certified Datacenter configurations in several locations worldwide.

**Better investment:** The IBM Datacenter Solution Program with Windows 2000 Datacenter Server gives organizations a powerful and scalable alternative to more expensive proprietary solutions.

**Industry-standard platforms from IBM:** The new rack-based x370 servers provide an outstanding hardware platform for data center implementations. Available in both 700MHz and 900 MHz processor speeds, standard data center configurations on the x370 provide 4 processors with 2MB cache and 2GB of system memory; they can scale to support 8 processors and up to 32GB of memory.

**Lower total cost of ownership:** Windows 2000 Datacenter Server offers higher or comparable performance to leading RISC/UNIX solutions at a fraction of the cost.

**Powerful roadmap for future growth:** With a clear path toward Microsoft's .NET vision and IA-64 based computing, Windows 2000 Datacenter Server is the best high-end operating environment to ensure long-term investment protection against technology obsolescence. Customers can deploy today with the confidence that the platform will evolve to meet their capacity and technology needs tomorrow.

Find out more about the Windows 2000 Datacenter:  
[www.microsoft.com/windows2000/datacenter](http://www.microsoft.com/windows2000/datacenter)

### **Microsoft Windows 2000 Advanced Server**

The Windows<sup>®</sup> 2000 Advanced Server operating system contains all the functionality and reliability of the standard version of Windows 2000 Server, plus additional features for applications that require higher levels of scalability and availability. This makes Advanced Server the right operating system for essential business and e-commerce applications that handle heavier workloads and high-priority processes.

Advanced Server helps ensure your systems are available by addressing the causes of both planned and unplanned network and server downtime. It also has features that let your applications grow to support large numbers of users and data.



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Windows 2000 Advanced Server provides the features required to create highly available and scalable systems. Because it includes features that help ensure that your systems are always available, it is the right choice for running the applications that your business depends on. It is also ideal for situations that require a high performance server that is capable of supporting multiple processors and larger amounts of memory than the Windows 2000 Server.

To increase availability, Advanced Server includes two clustering technologies: Cluster service and Network Load Balancing (NLB). Cluster service is used to connect two servers together so that one can pick up the load if the other fails. This is appropriate for any application that you need to have running without interruption. NLB lets you spread processing across as many as 32 servers to handle incoming traffic for your Web site or to support terminal services.

Regardless of the size of your organization, if you have applications that simply must be available, or if you have applications that are likely to grow significantly, Advanced Server lets you extend the reliability of Windows 2000 Server with increased availability and scalability.

### **Microsoft SQL Server 2000 Enterprise Edition**

Microsoft SQL Server 2000 Enterprise Edition, used on the benchmarks described in this paper, provides support for two scalability approaches: scale up and scale out.

Scale up solutions rely on adding more processors, memory and disk resources to a server (or moving an application to a larger single server) to increase scalability. SQL Server 2000 Enterprise Edition supports scale up by taking advantage of symmetric multiprocessing (SMP) systems through enhanced parallelism. Routine tasks such as table scans and index creation are performed in parallel among the processors in a server to speed execution. On the IBM xSeries 370, these features allow SQL Server to fully utilize up to 8 CPUs and the 32GB of RAM supported by the x370.

SQL Server 2000 Enterprise Edition also supports the complementary approach of scale out. As demonstrated in the 4-, 16- and 32-node TPC-C benchmarks, scale out allows a single database workload to be divided among a group of independent server machines. The feature in SQL Server 2000 Enterprise Edition that enables this is known as Distributed Partitioned Views.

For more information on Distributed Partitioned Views, visit:  
[msdn.Microsoft.com/msdn-online/start/features/highperform.asp](http://msdn.Microsoft.com/msdn-online/start/features/highperform.asp).

SQL Server 2000 is more than just a scalable database; it is a complete database and analysis offering for rapidly delivering e-commerce, line-of-business and data warehousing solutions. It dramatically reduces the time required to bring these applications to market while offering the scalability needed for the most demanding environments. SQL Server 2000 includes support for XML and HTTP, performance and availability features to partition load and ensure uptime, and advanced management and tuning functionality to automate routine tasks and lower total cost of ownership.

Find out more about the Microsoft SQL Server 2000 Enterprise Edition:  
[www.microsoft.com/sql](http://www.microsoft.com/sql)

### **Giganet**

Giganet, an IBM ServerProven™ partner, offers a fast interconnect that provides a streamlined protocol for internodal communication.

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Giganet develops and markets products and technology that enable the creation of flexible, high-performance Virtual Interface (VI)-based server farm networks. Server farm networks are composed of multiple rack-mounted systems linked via high-performance communications, allowing businesses to scale computing resources. Giganet products provide businesses with the ability to cost effectively deploy server farm networks that deliver on-demand scalability and unmatched availability in support of mission-critical enterprise and Internet applications.

Giganet cLAN products include a full line of ultra high-speed host adapters and cluster switches, available in 8- and 30-port configurations, that can be used as flexible, high-performance building blocks for deploying large plug-and-play server networks that meet today's demanding environments. Giganet products are based on the industry-standard VI architecture as well as TCP/IP, built on top of their VI foundation. By implementing VI in hardware, Giganet increases the speed and efficiency of server-to-server communications. Giganet server farm networks deliver high performance by allowing applications to bypass the operating system, resulting in very high throughput rates with very low latency (delay) and ultra low CPU utilization.

Giganet also incorporates RapidFlow™ architecture, which is a unique switching functionality with fast flow control, non-blocking and queuing mechanisms that bring efficiency and performance to a new level for e-commerce environments. The Giganet level of efficiency frees up valuable database and application system resources and improves overall end-user performance.

Giganet cLAN High Performance Cluster Switch and cLAN Host Adapters functionality summary:

- Native VI implementation
- Ultrahigh performance
- Eight 30-port switch configurations
- 1.25Gb/s link speed
- Switch port-to-port latency of 500 nanoseconds
- Ultralow CPU utilization, freeing up the system for application processing
- Fast flow control and queuing functionality allow for faster network speeds
- Hot-pluggable design
- Auto detecting/configuring for easy setup and administration.

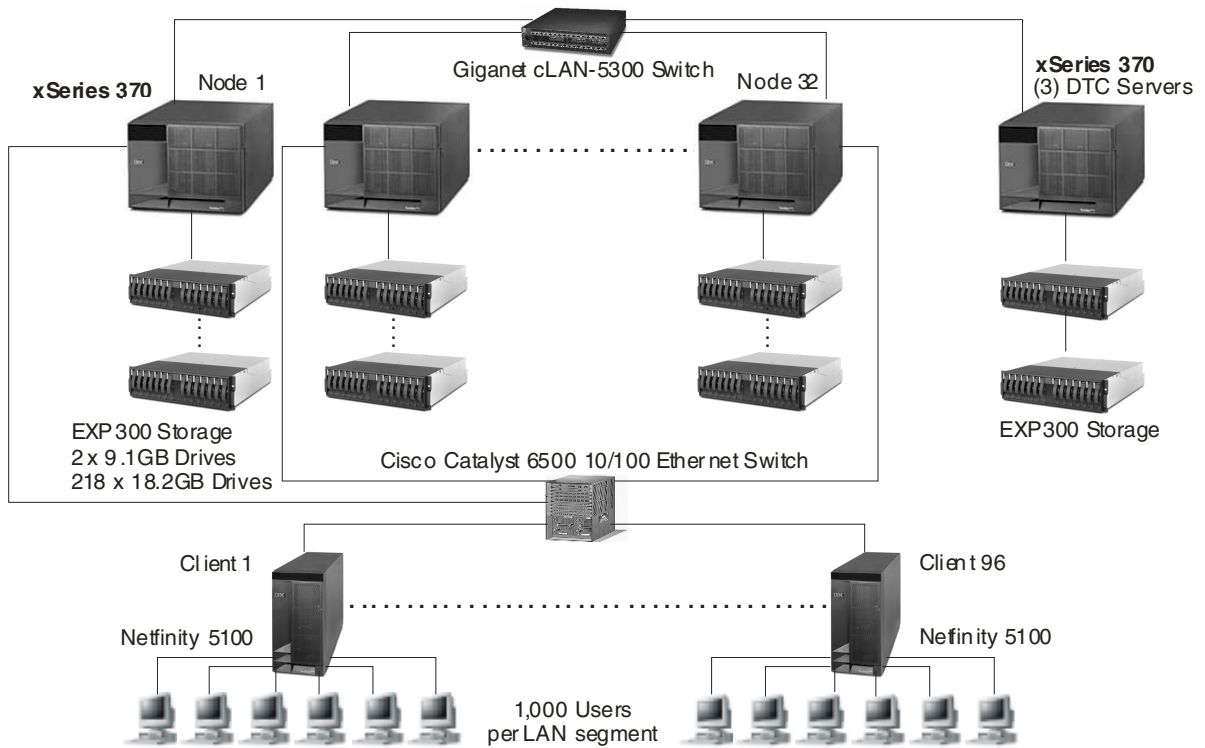
Find out more about Giganet: [www.giganet.com](http://www.giganet.com)

## *Groundbreaking Benchmarks from IBM, Intel and Microsoft*

### **32-node TPC-C Benchmark Results Summary and Configuration Diagram**

The benchmark configuration consisted of 32 x370 servers, running Microsoft Windows 2000 Datacenter Server and Microsoft SQL Server 2000 Enterprise Edition.

Performance	688,220.90 tpmC (transactions per minute C)
Price/tpmC performance	\$28.89 /tpmC
Total solution availability date	May 31, 2001
Total servers	32 xSeries 370 servers
Clients	96 IBM Netfinity® 5100 servers
Total number of disk drives	7,040
Total number of disks per node	220
Total storage	116TB (57.99TB online)
Operating system	Microsoft Windows 2000 Datacenter Server
Database	Microsoft SQL Server 2000 Enterprise Edition
Database size	57,600 warehouses = 21 billion records
Number of users	576,000
Processors per server	8 Intel Pentium III Xeon processors at 900MHz with 2MB L2 Cache
Memory per server	16GB ECC SDRAM memory
Adapters per server	8 ServeRAID™ -4H Ultra160 SCSI adapters
Rack storage per server	22 EXP300 storage expansion enclosures
Ethernet adapters per server	1 10/100 Ethernet server adapter
Host adapters per server	1 Gigaset cLAN-1000 Adapter
Interconnect	2 Gigaset cLAN-5300 switches

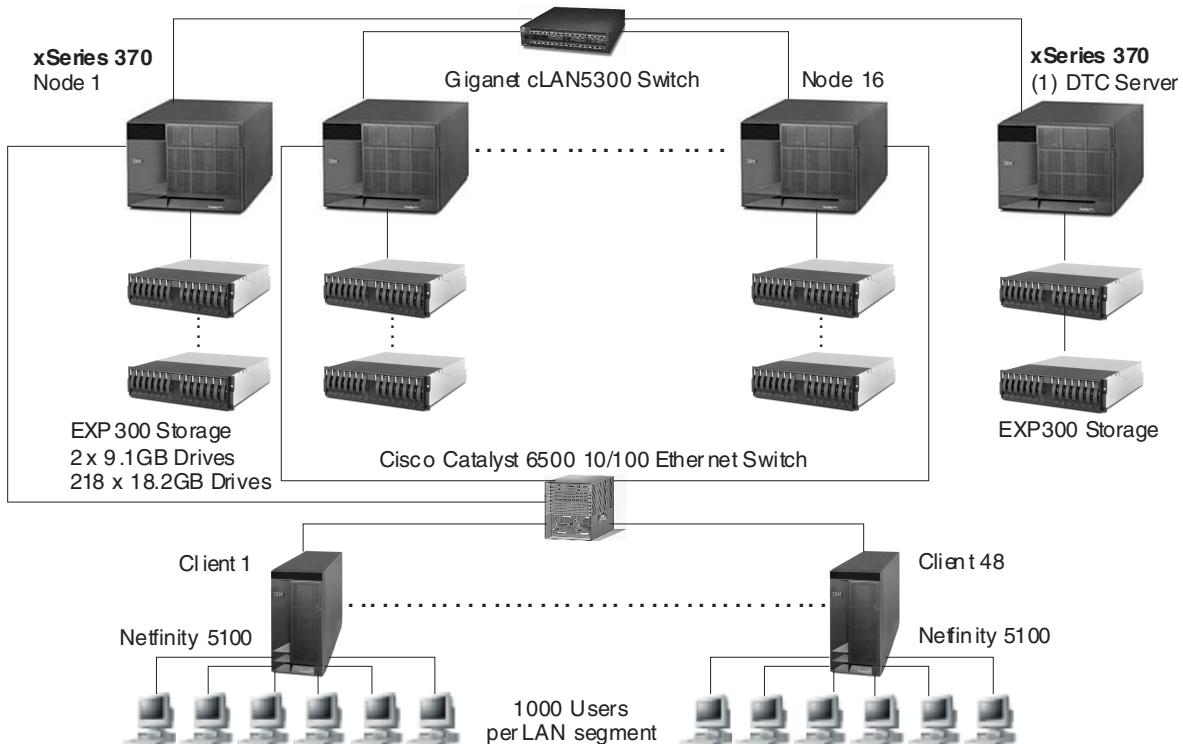


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### **16-node TPC-C Benchmark Results Summary and Configuration Diagram**

The benchmark configuration consisted of 16 x370 servers, running Microsoft Windows 2000 Datacenter Server and Microsoft SQL Server 2000 Enterprise Edition.

Performance	363,129.75 tpmC (transactions per minute C)
Price/tpmC performance	\$28.10 / tpmC
Total solution availability date	May 31, 2001
Total servers	16 xSeries 370 servers
Clients	48 IBM Netfinity 5100 servers
Total number of disk drives	3,520
Total number of disks per node	220
Total storage	58TB (28.995TB online)
Operating system	Microsoft Windows 2000 Datacenter Server
Database	Microsoft SQL Server 2000 Enterprise Edition
Database size	28,800 warehouses = 10.5 billion records
Number of users	288,000
Processors per server	8 Intel Pentium III Xeon processors at 900MHz with 2MB L2 Cache
Memory per server	16GB ECC SDRAM memory
Adapters per server	8 ServeRAID-4H Ultra160 SCSI adapters
Rack storage per server	22 EXP300 storage expansion enclosures
Ethernet adapters per server	1 10/100 Ethernet server adapter
Host adapters per server	1 Giganet cLAN-1000 Adapter
Interconnect	1 Giganet cLAN-5300 Switch

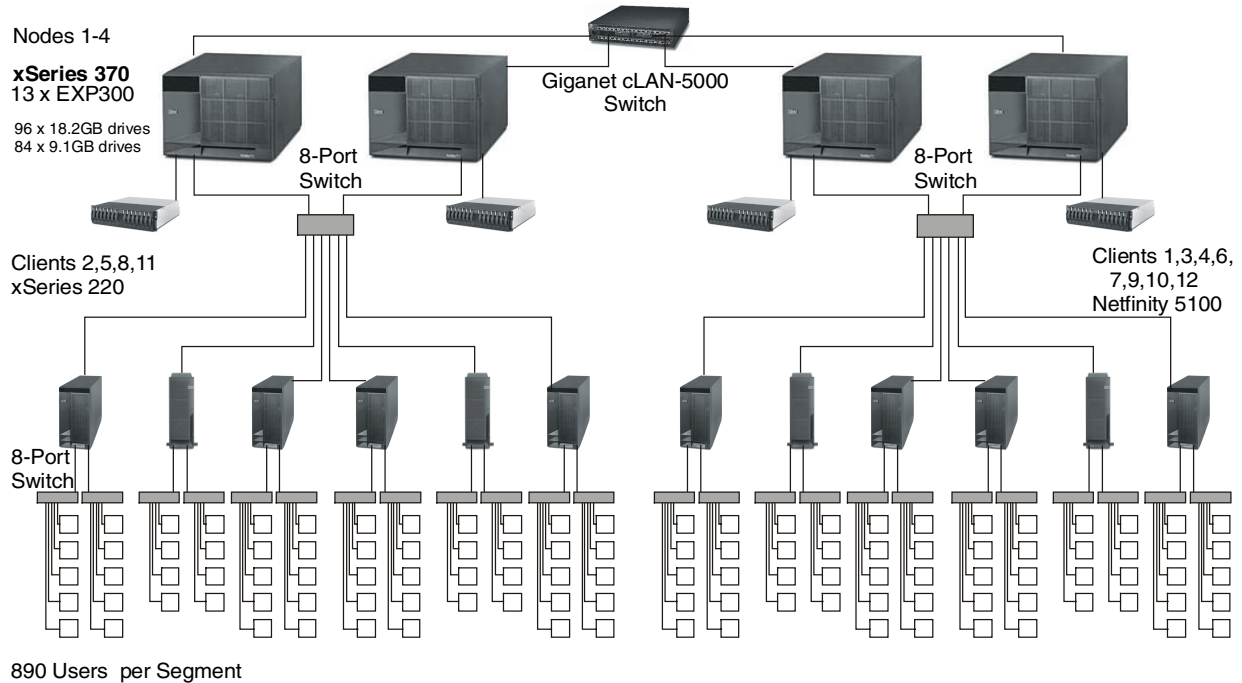


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### **4-node TPC-C Benchmark Results Summary and Configuration Diagram**

The benchmark configuration consisted of four x370 servers, running Microsoft Windows 2000 Datacenter Server and Microsoft SQL Server 2000 Enterprise Edition.

Performance	121,319.23tpmC (transactions per minute C)
Price/tpmC performance	\$25.47 /tpmC
Total solution availability date	May 31, 2001
Total Servers	4 xSeries 370 servers
Clients	4 xSeries 220 servers, 8 Netfinity 5100 servers
Total number of disk drives	728
Total number of disks per node	182
Total storage	9.2TB (8.77TB online)
Operating system	Microsoft Windows 2000 Datacenter Server
Database	Microsoft SQL Server 2000 Enterprise Edition
Database size	9,968 warehouses
Number of users	99,680
Processors per server	8 Intel Pentium III Xeon processors at 900MHz with 2MB L2 cache
Memory per server	32GB ECC SDRAM Memory
Adapters per server	7 ServeRAID-4H Ultra160 SCSI adapters
Rack storage per server	13 EXP300 storage expansion enclosures
Ethernet adapters per server	1 10/100 Ethernet server adapter
Host adapters per server	1 Gigaset cLAN-1000 Adapter
Interconnect	1 Gigaset cLAN-5000 Switch



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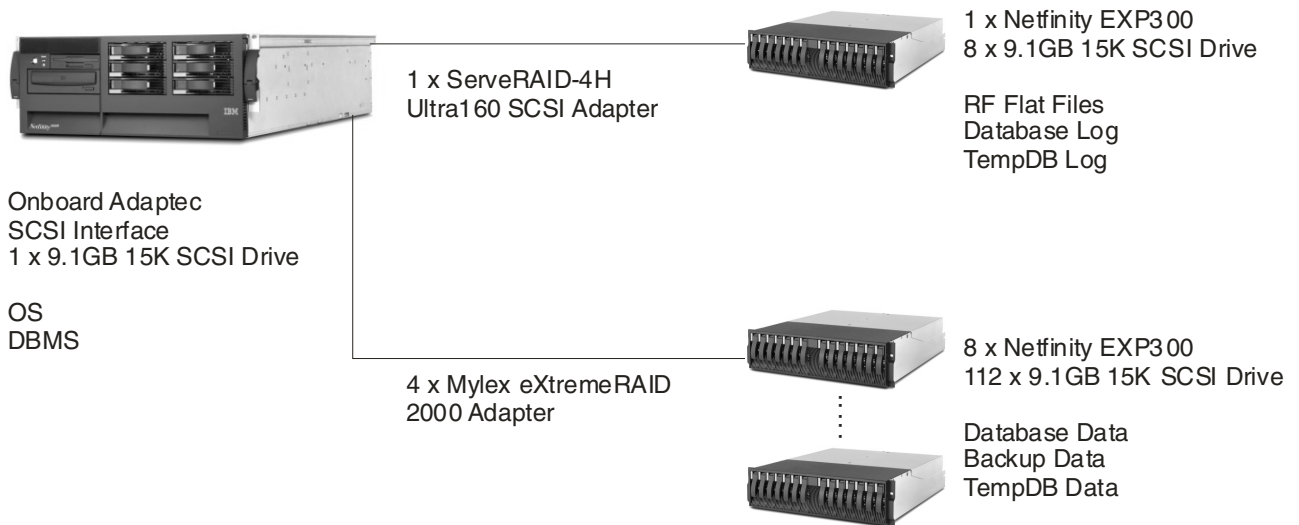
**xSeries 350 TPC-H Benchmark Results Summary and Configuration Diagram**

This TPC-H benchmark was run on the x350 server running Microsoft Windows 2000 Advanced Server and Microsoft SQL Server 2000 Enterprise Edition.

<b>Primary Metrics:</b>	
Performance	1,169.7 QphH at 100GB
Price/performance	\$166.00 per QphH at 100GB
Total solution availability date	May 31, 2001
<b>Additional Numerical Quantities:</b>	
Database size/scale factor	100GB
Database Load Time	6 hours; 59 minutes; 59 seconds
Query Streams for Throughput Test	5
TPC-H power	1,708.0
TPC-H throughput	801.1
Total system price over five years	\$193,601
<b>System Configuration:</b>	
Server	1 IBM xSeries 350 server
Processor	4 Intel Pentium III Xeon processors at 900MHz with 2MB L2 cache
Memory	4GB ECC SDRAM memory
RAID adapters	1 ServeRAID-4H Ultra160 SCSI adapter 4 Mylex eXtremeRAID 2000 adapter
Total number of disk drives	121 x 9.1GB 15K Ultra160 SCSI drive
Total storage	1024.87GB
Operating system	Microsoft Windows 2000 Advanced Server
Database	Microsoft SQL Server 2000 Enterprise Edition

**xSeries 350**

4-way 900MHz Pentium III Xeon  
with 2MB L2 Cache  
4GB Memory  
1 x Ethernet 10/100 PCI Onboard Interface



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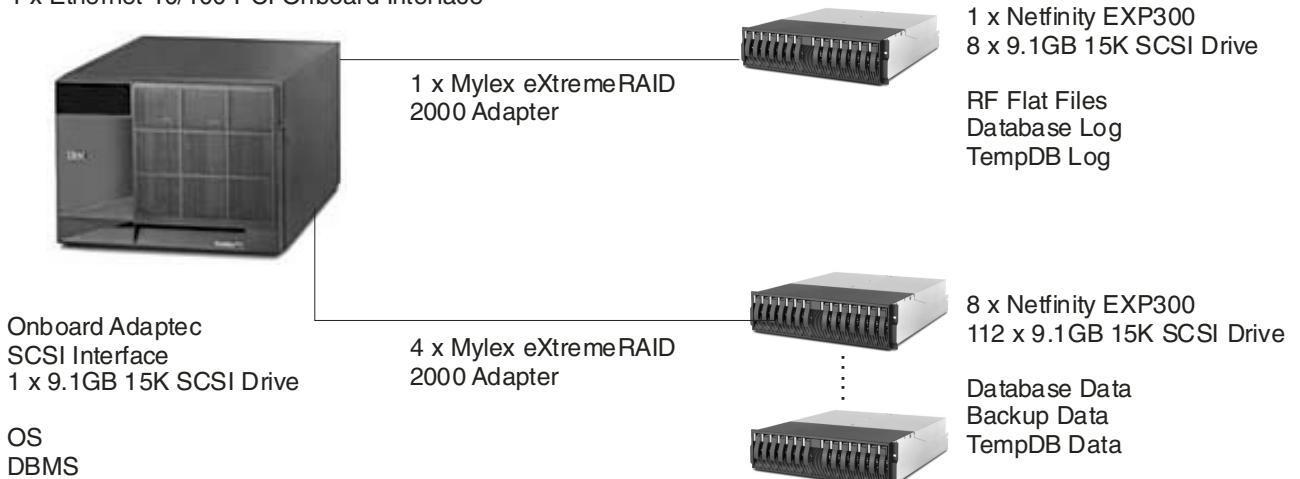
**xSeries 250 TPC-H Benchmark Results Summary and Configuration Diagram**

This TPC-H benchmark was run on the x250 server running Microsoft Windows 2000 Advanced Server and Microsoft SQL Server 2000 Enterprise Edition.

<b>Primary Metrics:</b>	
Performance	1,147.9 QphH at 100GB
Price/performance	\$169.00 per QphH at 100GB
Total solution availability date	April 13, 2001
<b>Additional Numerical Quantities:</b>	
Database size/scale factor	100GB
Database Load Time	7 hours, 29 minutes, 59 seconds
Query Streams for Throughput Test	5
TPC-H Power	1,676.5
TPC-H Throughput	785.9
Total system price over five years	\$193,958
<b>System Configuration:</b>	
Server	1 xSeries 250 server
Processor	4 Intel Pentium III Xeon processors at 900MHz with 2MB L2 cache
Memory	4GB ECC SDRAM memory
RAID adapter	5 Mylex eXtremeRAID 2000 Adapter
Total number of disk drives	121 x 9.1GB 15K Ultra160 SCSI drive
Total storage	1024.87GB
Operating system	Microsoft Windows 2000 Advanced Server
Database	Microsoft SQL Server 2000 Enterprise Edition

**xSeries 250**

4-way 900MHz Pentium III Xeon  
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## **TPC Definitions**

### **TPC-C**

The TPC Benchmark C was developed by the Transaction Processing Performance Council (TPC), which was founded to define transaction processing benchmarks and to disseminate objective, verifiable performance data to the industry. The TPC describes this benchmark in Clause 0.1 of the specification as follows: TPC Benchmark C is an OLTP workload. It is a mixture of read-only and update-intensive transactions that simulate the activities found in complex OLTP application environments. It does so by exercising a breadth of system components associated with environments, which are characterized by:

- Simultaneous execution of multiple transaction types that are complex
- Online and deferred transaction execution modes
- Multiple online terminal sessions
- Moderate system and application execution time
- Significant disk input/output
- Transaction integrity (ACID properties)
- Nonuniform distribution of data access through primary and secondary keys
- Databases consisting of many tables with a wide variety of sizes, attributes and relationships
- Contention on data access and update

The performance metric reported by TPC-C is a “business throughput” measuring the number of orders processed per minute. Multiple transactions are used to simulate the business activity of processing an order. Each transaction is subject to a response time constraint. The performance metric for this benchmark is expressed in transactions-per-minute-C (tpmC). To be compliant with the TPC-C standard, all references to tpmC results must include the tpmC rate, the associated price-per-tpmC and the availability date of the priced configuration.

Despite the fact that this benchmark offers a rich environment that emulates many OLTP applications, this benchmark does not reflect the entire range of OLTP requirements. In addition, the extent to which a customer can achieve the results reported by a vendor is highly dependent on how closely TPC-C approximates the customer application. The relative performance of systems derived from this benchmark does not necessarily hold for other workloads or environments. Extrapolations to any other environment are not recommended.

### **TPC-H**

The TPC Benchmark H is a decision support benchmark. It consists of a suite of business-oriented ad hoc queries and concurrent data modifications. The queries and the data populating the database have been chosen to have broad relevance while maintaining a sufficient degree of ease of implementation. This benchmark illustrates decision support systems that examine large volumes of data, execute queries with a high degree of complexity and give answers to critical business questions.

The TPC-H operations are modeled as follows:

- The database is continuously available 24 hours a day, 7 days a week, for ad hoc queries from multiple end users and data modifications against all tables, except possibly during infrequent (e.g., once a month) maintenance sessions.

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- The TPC-H database tracks, possibly with some delay, the state of the OLTP database through ongoing refresh functions, which batch together a number of modifications impacting some part of the decision support database.
- Due to the worldwide nature of the business data stored in the TPC-H database, the queries and the refresh functions may be executed against the database at any time, especially in relation to each other.
- The system under test must meet a set of ACID (Atomicity, Consistency, Isolation, Durability) requirements that are designed to insure a level of data integrity during normal operation and in the event of failure of the system or any single component in the system.

The minimum database required to run the benchmark holds business data from 10,000 suppliers. It contains almost 10 million rows representing a raw storage capacity of about 1GB. Compliant benchmark implementations may also use one of the larger permissible database populations (e.g., 100GB, 300GB or 1000GB).

The performance metric reported by TPC-H is called the TPC-H Composite Query-per-Hour Performance Metric (QphH@Size). It reflects multiple aspects of the capability of the system to process queries. These aspects include the selected database size against which the queries are executed, the query processing power when queries are submitted by a single stream, and the query throughput when queries are submitted by multiple concurrent users. The TPC-H Price/Performance metric is expressed as \$/QphH@Size.

The TPC-H Performance metric (QphH) incorporates the TPC-H power and TPC-H throughput measurements achieved during the benchmark measurement. It represents the system's ability to process decision support queries both serially and concurrently, while taking into account the performance impact of refreshing the data in the data warehouse.

The TPC-H Price/Performance metric represents the total cost of the system divided by the TPC-H composite query per hour performance metric.

TPC-H Power represents the raw processing power of the system in queries per hour. It is derived from the timed execution of a single stream of 22 complex business queries. Also factored into the TPC-H power measurement is the time required to execute two update functions that insert rows into and delete rows from the dynamic tables of the TPC-H database. (For this benchmark, 1.5 million rows were either added or deleted during the execution of the refresh functions.)

TPC-H Throughput represents the performance of the system while running multiple concurrent query streams. For the results discussed in this white paper, five query streams, which include the database refresh functions, were executed simultaneously. The throughput measurement is a ratio of the total number of queries executed divided by the time required to complete the query streams.

For a full disclosure report on these benchmarks and a complete listing of benchmark ratings, please see [www.tpc.org](http://www.tpc.org)

## **Conclusion**

The age-old debate of whether industry-standard platforms can deliver performance capable of driving enterprise-class applications has finally been answered--with an emphatic YES! By blending the proven enterprise know-how from IBM with Intel's microprocessor architecture and Microsoft software, we've put to rest the question of performance and advanced the debate to when and how quickly the performance envelope will move forward.

**Legal notes and endnotes**



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IBM xSeries servers are assembled in the U.S., Great Britain, Japan, Australia and Brazil and are composed of U.S. and non-U.S. parts.

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<sup>1</sup> TPC Benchmark, TPC-C, TPC-H, tpmC, QphH, \$/QphH and \$/tpmC are trademarks of the Transaction Processing Performance Council. TPC data is current as of March 23, 2001.

<sup>2</sup> MHz measures only internal clock speed; many factors affect application performance.

<sup>3</sup> TPC results reference Compaq Proliant 8500-700-192P: 505.302.77tpmC, \$19.80/tpmC, Dec. 1, 2000. Data on competitive products obtained from publicly available information and is subject to change without notice. Contact the manufacturer for the most recent information.

<sup>4</sup> When referring to hard disk drive capacity, GB equals 1,024MB and TB equals 1,024GB. Total user-accessible capacity may vary depending on operating environments.

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### **Additional Information**

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