

Real-world server consolidation: 35 HP ProLiant DL385 servers onto 5 Dell PowerEdge M610 blade servers with VMware vSphere

Executive summary

Dell Inc. (Dell) commissioned Principled Technologies (PT) to consolidate 35 4-year-old HP ProLiant DL385 server and storage solutions onto 5 Dell™ PowerEdge™ M610 blade server and storage solutions using VMware vSphere 4 (vSphere). Unlike studies that estimate the potential consolidation factor based on a small sample, we consolidated the full set of server and storage solutions, allowing us to confirm the consolidation factor.

Our testing involved the following two solutions:

- 35 AMD Opteron 254-based HP ProLiant DL385 G1 servers with 4 GB of memory each and 18 HP StorageWorks MSA30 storage (HP ProLiant DL385 solution)
- 5 Intel® Xeon® Processor X5570-based Dell PowerEdge M610 blade servers with 72 GB of memory, each using vSphere, and 5 arrays of Dell™ EqualLogic™ PS5000XV storage (Dell PowerEdge M610 solution)

KEY FINDINGS

- Five Dell PowerEdge M610 solutions with VMware vSphere could replace 35 legacy HP ProLiant DL385 solutions, yielding a payback in under 11 months.¹ (See Figures 1 and 2.)
- The 5 Dell PowerEdge M610 solutions with vSphere used little more than 1/4th of the power, about 1/7th of the software costs, and 1/5th the data center rack space of the 35 legacy HP ProLiant DL385 solutions.¹ (See Figures 1, 3, and 6.)
- The 5 Dell PowerEdge M610 solutions with vSphere achieved over 50 percent more throughput, delivering an average OPM for each VM of 13,798 compared to 9,005 average for each legacy HP ProLiant DL385 solution.¹ (See Figure 4.)



Figure 1: Five Intel Xeon Processor X5570-based Dell PowerEdge M610 solutions with vSphere allow you to consolidate 35 AMD Opteron 254-based HP ProLiant DL385 solutions, with an initial investment payback period of under 11 months and delivering over 50 percent more throughput. We base this estimation on our specific database workload.

Our test case modeled a typical enterprise datacenter with 35 legacy HP ProLiant DL385 servers and 18 HP StorageWorks MSA30 storage arrays—each approximately four years old—running high-demand database workloads. The legacy servers each used 4 GB of memory. The enterprise in this test case seeks to consolidate

¹Source: Principled Technologies, Inc., “Real-world server consolidation: 35 HP ProLiant DL385 servers onto 5 Dell PowerEdge M610 blade servers with VMware vSphere” an October 2009 report commissioned by Dell.

these legacy workloads onto five Dell PowerEdge M610 blade servers and five Dell EqualLogic storage solutions using vSphere, configured with sufficient processors, memory, and storage to handle these workloads. We assume the enterprise is running SQL Server 2005 Enterprise Edition on Windows Server 2003 R2 Enterprise Edition x64 on each of the HP ProLiant DL385 solution servers. We kept those same versions in the vSphere guests on the Dell PowerEdge M610 solution. Our test case is a specific migration scenario: For our calculations, we assume the use of VMware vCenter Converter to perform our physical to virtual (P2V) migration in order to minimize migration time, and to keep the legacy software, including the operating system, as is. This models an organization that wishes to reap the benefits of virtualization without incurring the maintenance and redesign costs that sometimes accompany an operating system or application upgrade; the P2V process allows for this. The organization can then upgrade individual virtual machines as time and resources allow.

We used benchmark results from the Dell DVD Store Version 2.0 (DS2) performance benchmark to determine the number of older servers with accompanying storage that a Dell PowerEdge M610 solution could replace for our test scenario. To define the replacement factor, we measured the number of orders per minute (OPM) that the HP ProLiant DL385 solution could perform when running a demanding DS2 workload. We then ran DS2 in virtual machines (VMs) on the Dell PowerEdge M610 solution and measured how many VMs this newer solution could run, while obtaining OPM in each VM greater than that of each HP ProLiant DL385 solution, with both solutions demonstrating a heavy load. The total number of VMs the Dell PowerEdge M610 solution could handle determines the replacement factor. Based on our specific workload, the replacement factor was seven.

Figure 1 shows the conclusions of our consolidation testing. We replaced 35 HP ProLiant DL385 servers and 18 HP StorageWorks MSA30 storage arrays with 5 Dell PowerEdge M610 blade servers and 5 Dell EqualLogic PS5000XV storage arrays. The Dell PowerEdge M610 solution delivered over 50 percent more throughput than did the HP ProLiant DL385 solution. Additionally, we calculated an investment return of under 11 months.

Figure 2 graphs the payback period and the cost savings of the five Dell PowerEdge M610 solutions. Savings continue after the initial investment payback period. By the end of year one, we project a savings of \$37,820. The line representing the Dell PowerEdge M610 solution accumulates the initial investment cost and the monthly costs of the solution. The initial investment cost includes the list price of the servers and three-quarters of the cost of the shared storage², as well as the costs of migrating from the 35 HP ProLiant DL385 solutions to the 5 newer Dell PowerEdge M610 solutions. The line for the 35 HP ProLiant DL385 solutions shows the accumulated monthly costs of 35 HP ProLiant DL385 solutions. The lines cross at the end of the payback period. Appendix C describes the payback period calculation.

² We include five arrays of Dell EqualLogic PS5000XV storage in the next generation solution. Our test databases do not use all of the storage. We therefore do not assign all storage costs for the five arrays to this solution. **We estimate at least 25 percent of this storage is available for other uses at other non-peak times, and assign 75 percent of the acquisition and on-going costs of the storage arrays to this solution. The Dell EqualLogic PS5000XV storage stripes data across all spindles. Thus, our tests benefited from the full performance of the arrays and simulate how the arrays would be used during peak times.** For the legacy solution, we use 35 of the available 36 server connections from the 18 storage arrays so we include costs related to 17 ½ arrays.

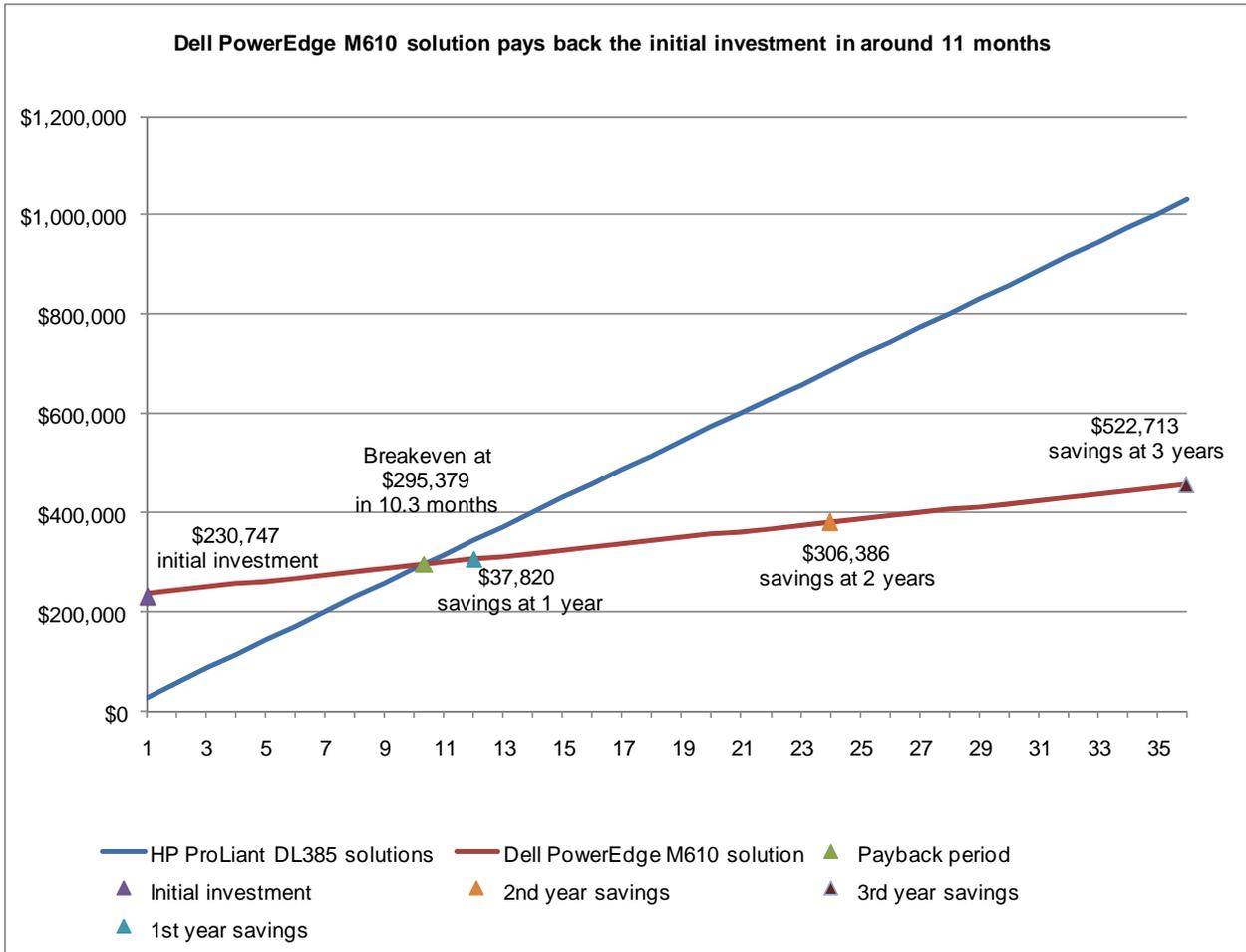


Figure 2: The payback period and cumulative estimated costs³ for the 35 HP ProLiant DL385 solutions and the 5 Dell PowerEdge M610 solutions with vSphere. Lower costs and higher savings are better.

Costs for the Dell PowerEdge M610 solutions include the initial investment of \$230,747 plus annual costs of \$75,225, for a total year-one cost of \$305,972. These solutions could save approximately \$37,820 in year one over the \$343,792 one-year costs for the 35 HP ProLiant DL385 servers and 18 HP StorageWorks MSA30 storage arrays that these 5 solutions can replace. Figure 3 shows the specific areas of savings. It shows that, for this workload and cost scenario, the investment costs of buying the server and storage hardware and of migrating from the older to the newer solution are offset in under 11 months due to savings for the Dell PowerEdge M610 solutions in hardware support costs, software licenses, software support agreements, facility costs (including switch costs), energy costs, and management costs.

For this workload and test scenario, the 5 Dell PowerEdge M610 solutions not only replaced 35 HP ProLiant DL385 solutions, but also provided over 50 percent better throughput for users. Thus, the Dell PowerEdge M610 solution delivers not only data center savings, but also improved performance for end users.

³ We divide annual costs by 12 and do not adjust for inflation.

One year costs of 35 HP ProLiant DL385 solutions and 5 Dell PowerEdge M610 solutions with VMware vSphere

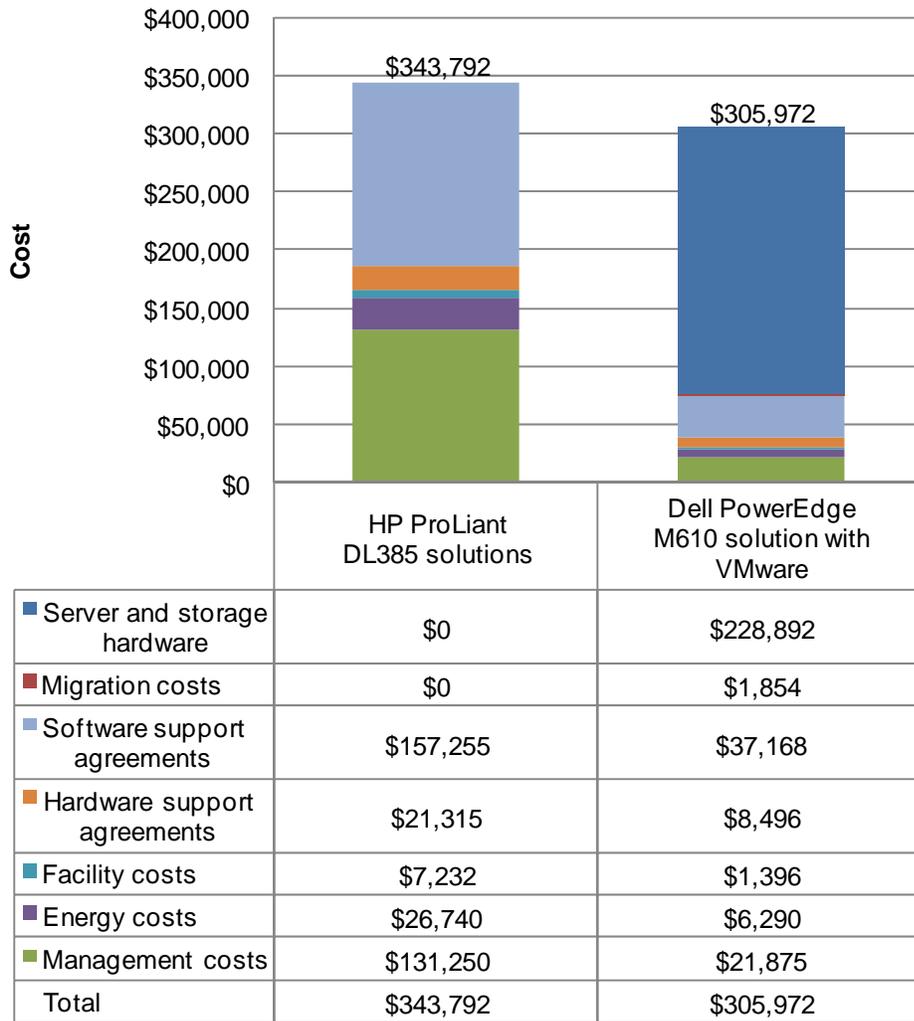


Figure 3: Estimated year-one costs for the 35 HP ProLiant DL385 solutions and the 5 Dell PowerEdge M610 solutions with vSphere. Lower costs are better.

Five benefits of the Dell PowerEdge M610 solution contribute significantly to the cost savings for this solution:

- **Replaces 35 HP ProLiant DL385 servers and 18 HP StorageWorks MSA30 storage arrays.** The increased I/O capacity, database performance, and memory efficient design of the Dell PowerEdge M610 solutions enables consolidation of multiple older systems for the specific workload we tested.
- **Uses around one-fourth of the power of the 35 HP ProLiant DL385 solutions they replace.** The Intel Xeon Processor 5500 series provides several new features specific to energy efficiency, such as the power control unit (PCU) and Turbo Boost technology. The consolidated Dell PowerEdge M610 solutions, leveraging these energy-efficient features, provide considerable energy savings because they require on average a little less than 28 percent of the power of the older HP ProLiant DL385 solutions that they

replace. (See Figure 7.) This calculation includes the cost of the power usage for the solutions we measured during our testing.

- **Requires around one-seventh the software license costs.** Consolidation provides software savings if the organization maintains software assurance agreements or can reuse elsewhere the licenses that consolidation frees. We do not include license costs for either group of solutions, as the enterprise would already have paid for the licenses used on the older solutions and would transfer them to the new solutions. For the calculations in this paper, we assume that the target organization maintains software assurance agreements for guest OS and database software and that it can choose to renew, transfer, or cancel them at the time of consolidation. We move from having 35 servers licensed per-server for Windows Server 2003 Enterprise Edition to 5 servers licensed per-processor for Windows Server 2008 R2 Datacenter Edition. For SQL Server 2005, we move from having 35 servers licensed per-processor for SQL Server 2005 Enterprise Edition, to 5 servers licensed per-processor for SQL Server 2005 Enterprise Edition.⁴ Savings on SQL Server software assurance agreements account for over \$100,000 of the cost savings in this model. Enterprises with different Windows Server editions, different price plans, or those without software assurance agreements would see different savings. Another \$27,500 in savings results from the reduction in the number of Windows server licenses needed for the consolidated solution. These savings dwarf the costs of the VMware vSphere 4 Advanced licenses and of the annual service agreements, which we spread over three years.
- **Requires one-fifth of the data center rack space.** The consolidated Dell PowerEdge M610 solutions require a blade chassis that consumes 10u of rack space for the servers and 3u for each of the five storage arrays, for a total of 25u for our five server and storage solutions. The older HP ProLiant DL385 solutions require 2u for each of the 35 servers and 3u for each of the 18 drive arrays plus 1u for a KVM, for a total of 125u, which requires almost three full racks. By contrast, the five Dell PowerEdge M610 solutions consume only 25u or just over one ½ rack
- **Reduces management costs.** We assume a reduction in server and storage management costs because of the reduction in the number of servers and storage arrays in the consolidated solution. We calculate one administrator per 40 servers or storage arrays to handle hardware and operating systems. Based on this, the legacy solution requires a total of 1.31 administrators and the consolidated solution requires .22 administrators. We assume that the number of SQL Server database administrators stays the same between the two solutions because this consolidation does not change the number or composition of the SQL Server instances.

See [Appendix C](#) for more details of the payback period calculations, including software licensing and other costs.

In addition to the cost savings we highlight above, the newer Dell PowerEdge M610 solution has several significant performance benefits over the legacy HP ProLiant DL385 solution. These include:

- **Dell PowerEdge M610 blade server**
 - Enhanced memory capacity - 12 DIMM slots per blade.
 - DDR3 memory - Offers higher bandwidth and lower power consumption than previous RAM technologies.
 - Designed for increased energy efficiency.
 - High I/O throughput - Up to 40GB per second per port mezzanine card I/O throughput.

For more information on the Dell PowerEdge M610 Blade Server, see

<http://www.dell.com/us/en/enterprise/servers/server-poweredge-m610/pd.aspx?refid=server-poweredge-m610&s=biz&cs=555>.

⁴ Our calculations include the costs for Windows Server 2003 R2 Enterprise Edition software assurance for the older solution and for the upgraded Windows Server 2008 Datacenter Edition for the Dell PowerEdge M610 solution, as the organization upgrades some of the licenses to Windows Server 2008 Datacenter Edition in order to gain unlimited virtualization rights. With Datacenter Edition per-processor licensing, the organization may run any number of virtual operating system environments on the server. We assume the five upgraded licenses transfer between the solutions, and we base the upgrade of only five licenses on the replacement factor of seven, as we discuss in the Executive Summary section. The organization saves on SQL Server Enterprise licenses because each of those licenses allows any number of SQL Server software instances in one physical server when licensed per-processor. We do not include the costs of CAL (Client Access Licenses) in this model because the number of these would not change between solutions; we do assume the enterprise maintains Software Assurance Agreements for the CALs and is therefore able to upgrade them at no cost.

- **Dell PowerEdge M1000e chassis**

- High-density chassis - Supports up to 16 Dell PowerEdge M610 half-height blade servers and six I/O modules for the blade servers.
- Energy-efficiencies -The enclosure also includes six power-efficient, hot-pluggable, and redundant power supplies and nine power-efficient, hot-pluggable, N+1 redundant fan modules.
- I/O Modules -The enclosure provides three redundant fabrics using six I/O modules that you select to match performance and workload requirements.

For more information on the Dell PowerEdge M1000e chassis, see

http://www.dell.com/us/en/enterprise/servers/pedge_m1000e/pd.aspx?refid=pedge_m1000e&cs=555&s=biz.

- **Intel Xeon Processor 5500 series**

- Intel Turbo Boost Technology - Increases performance during peak usage periods by increasing processor frequency.
- Intel QuickPath Technology - Delivers bandwidth improvement for data intensive applications.
- Intel Hyper-Threading Technology - Boosts performance for multi-threaded applications.
- Shared L3 cache - Boosts performance while reducing traffic to the processor cores.
- Intel Intelligent Power Technology - Helps reduce operating costs and energy usage by proactively putting your server into lower power states when demand decreases and reduces idle power consumption.
- Intel Virtualization Technology - Enhances virtualization performance and reduces roundtrip virtualization latency.

For more information on the Intel Xeon Processor 5500 series, see

<http://www.intel.com/Assets/PDF/prodbrief/322355.pdf>.

- **Dell EqualLogic PS5000XV iSCSI SAN storage system**

The Dell EqualLogic PS5000XV is a high capacity storage system with 16 hard disk drives per array and supports 146GB, 300GB or 450GB Serial Attached SCSI (SAS) 15K RPM drives to deliver high performance for databases. Features include the following:

- EqualLogic Multi-Path Input/Output (MPIO) support - I/O travels over many paths simultaneously for improved performance and lower latency.
- Automatic load balancing - Built-in software functionality balances capacity and performance across disks, controllers, cache, and network ports to help optimize performance.
- VMware vSphere integration - Supports VStorage API's which enable VMware to communicate directly with the storage platform.
- RAID 10 mode - Provides high capacity, performance, and 100 percent redundancy through a combination of data striping and data mirroring.

For more information on Dell EqualLogic PS5000xv storage, see

<http://www.equallogic.com/products/view.aspx?id=2509>.

- **VMware vSphere**

Consolidation using VMware vSphere allows an organization to save money on hardware, software licenses, and management costs.

- Memory allocation and overcommitment - VMware vSphere allows you to adjust the memory allocated to virtual machines, and allows oversubscription of memory. The maximum amount of memory you can allocate to a VM is 255 GB.
- CPU allocation - You can assign one or more virtual processors to a virtual machine. In VMware vSphere, you can assign up to eight vCPUs per VM.

- Varied SCSI controllers - VMware vSphere offers various virtual SCSI controllers for VMs: LSI Logic Parallel and SAS for reliable boot disks. For enhanced I/O performance, VMware vSphere offers a Paravirtual SCSI controller.

For more information on VMware vSphere 4, see <http://www.vmware.com/products/vsphere/>.

Workload

We conducted our testing using DVD Store Version 2, an open-source application with a back-end database component, a front-end Web application layer, and a driver layer that actually executes the workload. DS2 models an online DVD store. Simulated customers log in; browse movies by actor, title, or category; and purchase movies. The workload also creates new customers. Browsing movies involves select operations, some of which use full-text search and some of which do not. The purchase, login, and new customer stored procedures involve update and insert statements, as well as select statements. The workload's main reporting metric is orders per minute.

Because our goal was to isolate and test database server and storage, we did not use the Web application layer. Instead, we ran the driver application on client machines directly via its command-line interface. To simulate a heavily loaded environment, the load-generating systems ran with no think time, blasting requests as quickly as the server could handle them. We used the default DS2 parameters and setup configuration, with the exceptions we note in the DVD Store setup section in the Test methodology section of this report.

For client machines, we used desktop systems running Windows Server 2003 R2 with SP2. Each of these client machines ran a single instance of DS2, which spawned 12 threads against the HP ProLiant servers and 32 threads against the Dell PowerEdge M610 server virtual machines. This simulated a heavily loaded environment on both server solutions. Our goal was to represent the consolidation of older servers facing a demanding workload, so we adjusted the DVD Store thread count to 12 on the older server in order to reach heavy processor utilization throughout the test. While under full load, the "% Processor Time" counter was 72 percent on average on the HP ProLiant solution, while on the vSphere hosts, the "% Processor Average," the "% Util Avg," and the "% Core Util Time Avg" counters were 51 percent, 61 percent, and 93 percent respectively.

On the HP ProLiant servers, we used four internal hard drives that we configured in two RAID1 volumes on all servers, installing the OS on one volume and using the other volume for SQL Server logs, which we stored on a 15GB partition. We configured the external storage as one large RAID 5 LUN with a small 50GB partition for SQL Server data.

Note: The HP controller supports RAID5 and RAID10. Our goal was to emulate a three-to-five year-old database server so we chose RAID5 as a real-configuration for this timeframe. In addition, choosing RAID10 would have sacrificed at least one spindle from both sides of each array as we used a split backplane with seven drives per side.

On each Dell PowerEdge M610 server, we used two internal hard drives in a RAID 1 configuration, installing the host operating system on that internal volume. We configured each tray of external Dell EqualLogic storage as having one large 400GB LUN for VM OS virtual disk files, and then two other large LUNs – one at 370GB for SQL Server data virtual disks, and one at 120GB for SQL Server log virtual disks. We performed this storage configuration on each of our five trays of Dell EqualLogic PS5000XV storage. We configured the vSwitch, VMkernel ports, and vmnics as we discuss in the Configuring VMware vSphere software iSCSI with Dell EqualLogic PS Series Storage section, and we provide more details in the Test methodology section.

The DS2 driver application creates an orders-per-minute performance counter on each client machine. While the DVD Store client application visually outputs OPM at 10-second intervals, we chose to collect this OPM metric via a performance monitor counter on each client machine at 1-second intervals.

For more details about the DS2 tool, see <http://www.delltechcenter.com/page/DVD+Store>.

We ran this workload on the Dell PowerEdge M610 servers and the HP ProLiant DL385 servers for 30 minutes.

Our test case modeled a typical enterprise datacenter with 35 legacy HP ProLiant DL385 solutions running high-demand database workloads. The enterprise in this test case seeks to consolidate the workloads of 35 of these legacy systems onto 5 Dell PowerEdge M610 solutions that run vSphere, and wants to yield a payback in under 11 months. The enterprise seeks to balance performance and cost.

We ran the DS2 benchmark to verify that, using our test workload, the newer solutions would outperform the legacy solutions they would replace. On all machines, physical or virtual, we used a 10GB database. Each VM on the newer system delivered better performance than did a single legacy system with the same workload. We then estimated the monthly costs for maintaining the 35 legacy and 5 new systems and estimated the payback period for the investment in the newer solutions.

To model this test case, we did not compare identical solutions but instead configured the newer solutions with sufficient processors, memory, and storage to not only match or improve on the performance that the legacy solutions deliver for the test workload, but to also yield a payback in 11 months.

We selected 4GB RAM for the legacy solutions as it is a realistic amount of memory for a four-year-old solution. We configured the newer solutions as we expect an IT manager would when purchasing an Intel Xeon Processor 5500 series-based database solution intended to replace 35 HP ProLiant DL385 systems running the high-demand databases modeled by our workload. We selected and priced five Intel Xeon Processor X5570-based Dell PowerEdge M610 servers with two processors, 72GB RAM, and modern storage. As we expect an IT manager would, we balanced performance and cost to define the newer configuration.

We used nearly the maximum available memory per VM that the new server could support with 72 GB of memory, allocating 9 GB of memory per VM for a total allocation of 63 GB for the seven VMs. We expected that the IT administrator in our test case would take advantage of the memory capacity of modern servers in order to improve performance and consolidation and would select 9 GB of memory per VM, enough memory that most of the 10GB database would be likely fit into memory.

We tested the 35 legacy solutions with 18 HP StorageWorks MSA30 storage arrays, which had 14 146GB 10,000 RPM U320 SCSI disks each. We configured the five newer solutions with modern storage, selecting five Dell EqualLogic PS5000XV storage arrays with 16 146GB 15,000 RPM SAS disks each. The list price for that array is \$43,001. We assumed that the solution we modeled would require 75 percent of that storage and included that percentage of the costs of the storage array, including \$32,251 of the investment costs, in the payback analysis.

We tested the legacy solutions with 4-year old software versions and the newer solution with current software versions at the host level, assuming that the IT department in the test case would take advantage of the performance benefits of newer software. Inside the guest, however, to show ease of migration to a virtualized environment with no application upgrades, we kept the older software versions, expecting that this migration would be less volatile for IT engineers. We tested the Dell PowerEdge M610 solution running VMware vSphere 4 and the HP ProLiant DL385 solution running Windows Server 2003 x64 R2 Enterprise Edition. The guests on the vSphere host ran Windows Server 2003 x64 R2 Enterprise Edition to match the HP ProLiant systems. The HP ProLiant DL385 solution used Microsoft SQL Server 2005 x64. We also installed Microsoft SQL Server 2005 x64 in each VM on each Dell PowerEdge M610 server.

Our results show the advantage in performance, cost, and workload consolidation that modern hardware, operating systems, and virtualization technologies can offer over legacy hardware and software solutions for this database workload.

Test results

We tested the 35 legacy solutions with a single database instance running a 10 GB DS2 database, which alone nearly fully utilized the system's CPU; additional instances yielded unacceptable results. To achieve maximum DS2 results on the five Dell PowerEdge M610 solutions, we installed one instance of SQL Server 2005 x64 on each of seven VMs on the five servers and ran one 10GB DS2 database on each virtual machine, resulting in 35 simultaneous database tests. We show the number of OPM each solution achieved during our test. We calculate OPM as the number of overall orders divided by the elapsed seconds multiplied by 60. We report the last OPM

score the benchmark reported while all VMs and servers were simultaneously running. Each of the 35 VMs on the 5 Dell PowerEdge M610 solutions delivered performance better than the performance of the 35 HP ProLiant DL385 solutions.

Figure 4 shows the specific performance results, in OPM, for the 5 Dell PowerEdge M610 blade servers with the Dell EqualLogic PS5000XV storage solution and for the 35 HP ProLiant DL385 servers with the HP StorageWorks MSA30 storage solution while running the DVD Store tests. Results are from the test run that produced the median of three OPM results. Higher OPM numbers are better.

Performance	
System	Median run average OPM
5 Dell PowerEdge M610 solutions (35 VMs)	13,798
35 HP ProLiant DL385 solutions	9,005
Average throughput improvement for the Dell PowerEdge M610 solutions	53%

Figure 4: Average per database OPM performance results per server or virtual server for the 5 Dell PowerEdge M610 solutions and the 35 HP ProLiant DL385 solutions while running the DVD Store workload. Higher OPM numbers are better.

Figure 5 shows the individual VM OPM and server OPM scores from the median run for the 5 Dell PowerEdge M610 solutions and the 35 HP ProLiant DL385 solutions. Higher OPM numbers are better.

System	Dell PowerEdge M610 solution	HP ProLiant DL385 solution
VM/Server 1 OPM	13236	8,998
VM/Server 2 OPM	14822	8,672
VM/Server 3 OPM	12842	9,465
VM/Server 4 OPM	13235	9,321
VM/Server 5 OPM	13144	9,875
VM/Server 6 OPM	13894	8,893
VM/Server 7 OPM	14998	8,500
VM/Server 8 OPM	13203	8,166
VM/Server 9 OPM	13313	8,683
VM/Server 10 OPM	13696	9,007
VM/Server 11 OPM	13248	8,662
VM/Server 12 OPM	13277	8,976
VM/Server 13 OPM	13411	8,703
VM/Server 14 OPM	13555	8,954
VM/Server 15 OPM	15539	9,208
VM/Server 16 OPM	12851	8,905
VM/Server 17 OPM	14886	10,388
VM/Server 18 OPM	15474	8,526
VM/Server 19 OPM	15354	8,845
VM/Server 20 OPM	14749	8,922
VM/Server 21 OPM	13476	8,872
VM/Server 22 OPM	14035	8,845
VM/Server 23 OPM	14016	8,998
VM/Server 24 OPM	13929	9,379
VM/Server 25 OPM	13584	9,722
VM/Server 26 OPM	12707	8,784
VM/Server 27 OPM	13074	9,552
VM/Server 28 OPM	13256	9,093
VM/Server 29 OPM	12903	9,616
VM/Server 30 OPM	14246	8,515

System	Dell PowerEdge M610 solution	HP ProLiant DL385 solution
VM/Server 31 OPM	14410	9,055
VM/Server 32 OPM	13375	8,891
VM/Server 33 OPM	15107	8,559
VM/Server 34 OPM	13282	8,863
VM/Server 35 OPM	12811	8,754
Total OPM	482,938	315,167

Figure 5: Individual VM scores and the total VM score for the 5 Dell PowerEdge M610 solutions and the 35 HP ProLiant DL385 solutions. Higher OPM numbers are better.

Figure 6 shows the specific power results during the median run of the 5 Dell PowerEdge M610 blade servers with the 5 Dell EqualLogic PS5000XV storage arrays and the 35 HP ProLiant DL385 servers with the 18 HP StorageWorks MSA30 storage arrays. Lower numbers are better.

To calculate the power, we average the power we recorded during our peak stable workload period, minutes 24 through 29 of the test, for both server and storage on the HP ProLiant solution, and for both blade chassis and storage on the Dell PowerEdge M610 solution. For the total solution power, we averaged the server and storage power and then took the sum as total. For the idle power, we allowed the system to sit for 10 minutes after booting to the console and then started 2 minutes of idle power capture. As we note in Appendix C, we calculate the average of the active and idle power from the benchmark runs, then we use that for our payback analysis. We include both the storage and servers in all power measurements. Thus, the idle power is relatively high compared to the workload power, especially in the case of the HP solution with its 18 arrays.

	Power in Watts (median results)		
	Workload	Idle	Average
5 Dell PowerEdge M610 solutions	4,503	3,611	4,057
35 HP ProLiant DL385 solutions	14,796	14,328	14,562
Usage of 5 Dell PowerEdge M610 solutions relative to 35 HP ProLiant DL385 solutions	30%	25%	28%

Figure 6: Median power results, in watts, for the 5 Dell PowerEdge M610 solutions and the 35 HP ProLiant DL385 solutions while running the DVD Store workload and while idle. These results are from the runs that produced the OPM scores in Figure 5. Lower numbers are better.

Test methodology

Adjusting BIOS settings

We used the default BIOS settings on the HP ProLiant DL385 server. We enabled Virtualization Technology on the Dell PowerEdge M610 blade server, allowing us to take advantage of the Intel VT virtual memory management features that vSphere leverages, such as Virtual Processor ID (VPID), Extended Page Tables (EPT), and VT-x. We used the latest released BIOS updates on both solutions.

Setting up and configuring the Dell PowerEdge M610 blade server and Dell EqualLogic PS5000XV storage

Dell PowerEdge M610 and Dell EqualLogic PS5000XV storage configuration

We installed two internal drives in each Dell PowerEdge M610 blade server. We attached each server to a Dell EqualLogic PS5000XV containing 16 drives. We cabled each Dell EqualLogic PS5000XV to a Dell™ PowerConnect™ 6248 switch via its three available ports, and we cabled the server to the switch using three of the four server NICs. We split the Dell PowerConnect 6248 switch into five virtual LANS (VLANs) to separate out the five server/storage solutions' iSCSI traffic. Each Dell PowerEdge M610 had two on-board NICs, and we installed a mezzanine card with an additional two NICs, for a total of four NICs. We setup each vSphere host to

use native multipathing. We enabled jumbo frames on each server's three iSCSI-dedicated NICs, the Dell PowerConnect 6248 switch, and each NIC on the Dell EqualLogic storage. We left the default maximum transmission unit (MTU) for the client/server NIC. Figure 7 shows the storage layout we used on the Dell PowerEdge M610 blade server and the Dell EqualLogic PS5000XV storage.

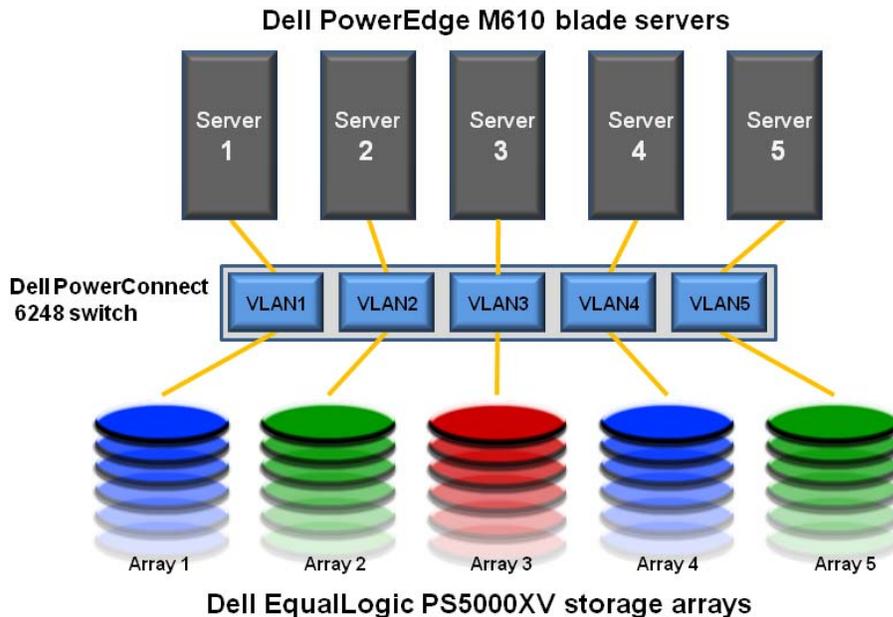


Figure 7: The storage layout we used on the Dell PowerEdge M610 blade server and Dell EqualLogic PS5000XV storage.

We configured the internal drives on each server in one RAID 1 volume. Each Dell EqualLogic PS5000XV contained 16 146GB 15,000RPM drives. We configured each Dell EqualLogic PS5000XV in RAID 10 mode, and created one larger 400GB LUN for VM operating system virtual disk files, one 370GB LUN for VM SQL Server data virtual disk files, and one 120GB LUN for VM SQL Server log virtual disk files. We repeated this procedure on each of our five trays of Dell EqualLogic storage.

On each Dell PowerEdge M610, we installed VMware vSphere 4 on the mirrored internal volume, and placed the virtual machine operating system virtual disks and SQL Server database data and logs on its associated Dell EqualLogic PS5000XV volumes.

Setting up the internal storage for host operating system installation

1. Enter the RAID controller BIOS by pressing Ctrl+R at the prompt.
2. Highlight Controller 0, and press F2.
3. Select Create New VD.
4. Select the two drives, select RAID level 1, tab to the OK button, and press Enter. Accept the warning regarding initialization.
5. Select the new virtual drive, press F2, and select Initialization, Start Init.
6. Wait for the initialization operation to complete.
7. Press Escape, and choose to Save and Exit to return to the boot sequence.
8. Repeat steps 1 through 7 for the four remaining blade servers.

Setting up the external storage

1. Using the command line, reset the Dell EqualLogic PS5000XV, and setup a storage group, with the following IP address scheme:
 - a. Group IP address: 192.168.#.10 (# being the tray number 1 through 5)
 - b. Primary NIC address: 192.168.#.11 (# being the tray number 1 through 5)
 - c. Subnet mask: 255.255.255.0
 - d. Groupname: testgroup# (# being the tray number 1 through 5)
2. Using the EqualLogic web interface to enable all network connections on the Dell EqualLogic PS5000XV using the following IP address scheme:
 - a. IP Address: 192.168.#.11, 12, 13 (# being the tray number between 1 through 5)
 - b. Subnet Mask: 255.255.255.0
3. Create one 400GB volume in the default storage pool with no snapshot reserve, and name it `vm-os`
4. Create one 370GB volume in the default storage pool with no snapshot reserve, and name it `vm-sqldata`
5. Create one 120GB volume in the default storage pool with no snapshot reserve, and name it `vm-sqllog`
6. Enable shared access to the iSCSI target from multiple initiators on the volume.
7. Create an access control record for the volume without specifying any limitations.
8. Create a read-only SNMP community name to use for group monitoring.
9. Repeat steps 1 through 8 for the remaining five trays of Dell EqualLogic PS5000XV storage.

Configuring the Dell PowerConnect 6248 switch with jumbo frames

1. Obtain the IP address to the switch from your system administrator and connect a workstation to the switch via an Ethernet cable.
2. Using Internet Explorer, navigate to the switch IP address and login.
3. Click the first port you will use for iSCSI traffic.
4. Modify the port settings as follows: Max Frame size 9216, which is the maximum.
5. Click Switching, Ports, Port Configuration table.
6. Choose Copy Parameters from unit 1, port g1.
7. Select all other ports you will use for iSCSI traffic.
8. Click Apply.

Configuring VLANs on the Dell PowerConnect 6248 switch

1. Obtain the IP address to the switch from your system administrator, and connect a workstation to the switch via an Ethernet cable.
2. Using Internet Explorer, navigate to the switch IP address, and login.
3. Click Switching, VLAN, VLAN membership.
4. Click Add.
5. Enter a VLAN id and name, and click Apply Changes. Note the minimum VLAN id is 2, as the switch reserves VLAN number 1.
6. Repeat steps 4 and 5 to add four additional VLANs.
7. Click VLAN membership.
8. Select the relevant VLAN id.
9. In the VLAN membership table, toggle the value to U to indicate that this port is assigned to this VLAN.
10. Repeat for other applicable ports. Note, in our configuration, we configured three ports for the Dell EqualLogic PS5000XV storage, three ports for the server, and left two ports for management of the VLAN, for a total of eight ports per VLAN.
11. Click Apply Changes.
12. Repeat steps 7 through 11 for the remaining four VLANs.

Setting up the Dell PowerEdge M610 servers

We installed a fresh copy of VMware vSphere 4 on each Dell PowerEdge M610.

Installing VMware vSphere 4 on the host

1. Insert the ESX DVD, and restart the computer.
2. While booting, press F11 to enter Boot Menu.
3. Press the down arrow to navigate to the appropriate boot device, and press Enter.

4. To start ESX in graphical mode, press Enter.
5. On the Welcome screen, click Next.
6. Click the checkbox to accept the terms of the license agreement, and click Next.
7. Accept the default keyboard layout, and click Next.
8. On the Custom Drivers screen, choose No to install custom drivers, and click Next.
9. You will receive a warning if you chose No. Click Yes to proceed. Drivers will load at this point.
10. Click Next.
11. Enter your serial number now, or choose to enter one later. Click Next.
12. On the Network Configuration screen, choose the NIC that you will use for system tasks and also the client/server test traffic. Click Next.
13. On the next Network Configuration screen, set your IP addressing information, subnet mask, DNS, and hostname. Click Next.
14. On the Setup Type screen, choose standard setup.
15. Select the virtual disk you wish to install ESX on, and click Next.
16. On the Data Loss warning screen, click OK.
17. On the Time Zone Settings screen, choose your appropriate time zone, and click Next.
18. On the Date and Time screen, modify the date and time as you wish, and click Next.
19. Assign a root password for ESX. Optionally, add additional users if you wish, and click Next.
20. On the Summary screen, click Next to install.
21. When the installation is complete, click Next.
22. Click Finish to reboot the system.
23. Repeat steps 1 through 22 for each server.

Enabling secure shell (ssh) access for the root user

1. Log in as root to the ESX console
2. Type the following command to change to the appropriate directory:
cd /etc/ssh
3. Edit the sshd_config file using vi. Use the following command:
vi sshd_config
4. Press the down arrow key to move the cursor to the PermitRootLogin line, and move the cursor to the word no. Press the i key to insert text.
5. Type the word yes and delete the word no.
6. Press the Escape key to return to command mode.
7. Type the following command to save and exit the file:
:wq
8. Type the following command to restart the ssh service:
service sshd restart
9. Repeat steps 1 through 8 for each server.

Installing vSphere on a management workstation

1. Configure your management workstation to be on the same subnet as your ESX server. In Internet Explorer, navigate to the IP address of your ESX Server.
2. Accept certificate warnings, and continue.
3. Click vSphere to download the vSphere client.
4. Choose Run to install.
5. Choose your language, and click OK.
6. On the Welcome screen, click Next.
7. Accept the license terms, and click Next.
8. Enter user and organization details, and click Next.
9. Optionally, click the checkbox to install the update utility. Click Next.
10. On the Destination Folder screen, click Next.
11. Click Install.
12. Click OK.
13. Repeat steps 1 through 12 for each server.

Connecting the storage to the host

We attached the database volumes on each Dell EqualLogic PS5000XV storage array to their respective Dell PowerEdge M610 blade server by connecting all three NICs available on the PS5000XV array to the Dell PowerConnect 6248 switch, on the relevant VLAN. We describe these steps above in the Dell PowerEdge M610 and Dell EqualLogic PS5000XV storage configuration section.

Setting up the iSCSI configuration with native multipathing on the ESX host

We used the procedures Dell describes in the Dell EqualLogic paper titled, "Configuring VMware vSphere software iSCSI with Dell EqualLogic PS Series Storage."

1. Log into the console.
2. Create the following shell script and execute it to do the following: create a new vSwitch, enable jumbo frames, create the necessary VMkernel ports, apply them to the iSCSI vSwitch, attach physical NICs to the vSwitch, and bind the vmnics to the VMkernel ports. Note that we used vSwitch1 for iSCSI traffic, and vmnics 1, 2, and 3 in our iSCSI configuration.

```
echo "Creating new vSwitch and enabling jumbo frames"
#create a new vSwitch for iSCSI
esxcfg-vswitch -a vSwitch1
#enable jumbo frames on the iSCSI vSwitch
esxcfg-vswitch -m 9000 vSwitch1

echo "Creating VMkernel Ports"
#create a VMkernel port and put them on the iSCSI vSwitch
esxcfg-vswitch -A iSCSI1 vSwitch1
#assign the IP addresses for your iSCSI network to each VMkernel port
esxcfg-vmknic -a -i 192.168.1.5 -n 255.255.255.0 -m 9000 iSCSI1

#create a VMkernel port and put them on the iSCSI vSwitch
esxcfg-vswitch -A iSCSI2 vSwitch1
#assign the IP addresses for your iSCSI network to each VMkernel port
esxcfg-vmknic -a -i 192.168.1.6 -n 255.255.255.0 -m 9000 iSCSI2

#create a VMkernel port and put them on the iSCSI vSwitch
esxcfg-vswitch -A iSCSI3 vSwitch1
#assign the IP addresses for your iSCSI network to each VMkernel port
esxcfg-vmknic -a -i 192.168.1.7 -n 255.255.255.0 -m 9000 iSCSI3

echo "Attaching NICs to vSwitch"
#assign the physical nics to the iSCSI vSwitch
esxcfg-vswitch -L vmnic1 vSwitch1
esxcfg-vswitch -L vmnic2 vSwitch1
esxcfg-vswitch -L vmnic3 vSwitch1

echo "Binding vmnics to VMkernel Ports"
esxcfg-vswitch -p iSCSI1 -N vmnic1 vSwitch1
esxcfg-vswitch -p iSCSI2 -N vmnic2 vSwitch1
esxcfg-vswitch -p iSCSI3 -N vmnic3 vSwitch1
```

3. Log into the vSphere client.
4. Click the Configuration tab, and click Networking.
5. On the iSCSI vSwitch, click on Properties.
6. Click the first VMkernel port, and click Edit.
7. Click the NIC teaming tab.
8. Select the checkbox to Override vSwitch Failover Order.

9. Move the vmnic you wish to pair with this VMkernel port to the Active area, and move other vmnics to the unused category. Apply the changes.
10. To enable the iSCSI software initiator, click Configuration, Storage Adapters.
11. Select the iSCSI initiator, and click Properties.
12. Click the General tab, and click Configure.
13. Select the checkbox to enable iSCSI on the host.
14. At the console, run the following commands to bind the VMkernel ports to the iSCSI software initiator. Note that these VMkernel numbers and HBA number were specific to our environment. Yours may need to change.

```
esxcli swiscsi nic add -n vmk0 -d vmhba32
esxcli swiscsi nic add -n vmk1 -d vmhba32
esxcli swiscsi nic add -n vmk2 -d vmhba32
```

15. In vSphere, to connect to the Dell EqualLogic storage, click Configuration, Storage Adapters.
16. Click the iSCSI software adapter, and click Properties.
17. Click the Dynamic Discovery tab.
18. Click Add.
19. Enter the Dell EqualLogic group IP address and click OK.
20. Right-click the LUN, and choose Manage Paths.
21. Select Round Robin from the drop down, and click OK.
22. Repeat steps 20 and 21 for each LUN.
23. Repeat steps 1 through 22 on each Dell PowerEdge M610 server.

Adding the external LUNs as datastores to ESX storage

1. In vSphere, click the Configuration tab.
2. In the Hardware pane, click Storage.
3. Click Add Storage...
4. Choose Disk/LUN. Click Next.
5. Select the appropriate LUN. In our case, this was our large 400GB OS-LUN. Click Next.
6. Click Next.
7. Enter a name for the datastore. Click Next.
8. Click Next to accept the defaults for block size.
9. Click Finish to complete the addition of the LUN.
10. Repeat steps 3 through 9 on the remaining two LUNs that you will use for SQL Server data virtual disks and SQL Server log virtual disks.
11. Repeat steps 1 through 10 on each Dell PowerEdge M610 server.

Creating the virtual machine with vSphere

1. Click Start, All Programs, VMware, VMware vSphere client.
2. Enter the IP address or hostname, user name, and password. Click Login.
3. Click the Virtual Machines tab.
4. Right-click, and choose New Virtual Machine.
5. Choose Custom, and click Next.
6. Assign a name to the virtual machine. Click Next.
7. Select a datastore for the virtual machine files. We chose the OS Datastore. Click Next.
8. Choose Virtual Machine Version 7. Click Next.
9. Choose Microsoft Windows, then Microsoft Windows Server 2003 (64-bit). Click Next.
10. Choose two virtual processors. Click Next.
11. Choose 9216MB RAM. Click Next.
12. Click 1 for the number of NICs and select vmxnet3. Click Next.
13. Leave the default virtual storage controller. Click Next.
14. Choose to create a new virtual disk. Click Next.
15. Make the OS virtual disk size 30 GB, specify the OS datastore on the external storage, and click Next.
16. Keep the default virtual device node, and click Next.
17. Click Finish.

18. Right-click the VM, and choose Edit Settings.
19. On the Hardware tab, click Add...
20. Click Hard Disk, and click Next.
21. Click Create a new virtual disk for SQL Server data, and click Next.
22. Specify 50GB for the virtual disk size, and specify the datastore for SQL Server data.
23. Choose SCSI(1:0) for the device node, and click Next.
24. On the Hardware tab, click Add...
25. Click Hard Disk, and click Next.
26. Click Create a new virtual disk for the SQL Server log, and click Next.
27. Specify 15GB for the virtual disk size, and specify the datastore for SQL Server log virtual disks.
28. Choose SCSI(1:1) for the device node, and click Next.
29. Click SCSI Controller 1, and choose Change Type.
30. Choose Paravirtual, and click OK.
31. Click Finish, and click OK.

Installing the guest operating system

1. Insert the installation CD for Windows Server 2003 x64 R2 into the DVD drive.
2. In vSphere, right-click the virtual machine, and choose CD/DVD drive.
3. Click the Host Device radio button, and choose the appropriate drive.
4. Click OK.
5. Right-click the machine, and choose Power, Power On.
6. Right-click the machine, and choose Open console.
7. At the Welcome to Set Up screen, press Enter to begin the installation.
8. At the Windows Licensing Agreement screen, press F8 to agree to the terms.
9. Press Enter to install in the default location.
10. Select Format the partition using the NTFS file system (Quick), and press Enter to continue.
11. At the Regional and Language Options screen, click Next.
12. Enter Name and Organization, and click Next. Note: Organization is an optional field, while username is required.
13. At the Your Product Key screen, enter your product key, and click Next.
14. At the Licensing Modes screen, click Next.
15. At the Computer Name and Administrator Password screen, type `Password1` as the new password in both fields, and click Next.
16. At the Date and Time Settings screen, change the Date & Time and Time Zone if appropriate, and click Next.
17. After the system restarts automatically, follow the prompt to log into the server.
18. At the Windows Setup screen, the installer will prompt you to insert the second installation CD. Insert the appropriate CD, and click OK.
19. At the Windows Server 2003 R2 Setup Wizard Welcome screen, click Next.
20. At the Windows Server 2003 R2 Setup Wizard Summary screen, click Next.
21. When the installer prompts you, click Finish to end the installation.
22. After the guest installation is complete, choose VM, Guest, Install/Upgrade VMware Tools.
23. Proceed through the VMware Tools installation. Restart the VM.

Configuring networking in the VM

1. Power on the VM, and open the console.
2. Click Start, Control Panel, right-click Network Connections, and choose Open.
3. Right-click the NIC, and choose properties.
4. Select TCP/IP (v4), and choose properties.
5. Set the IP address, subnet, gateway, and DNS server for this NIC, which will handle outgoing server traffic (e.g., the public IP). Click OK, and click Close.
6. Note that you must reconfigure all IP addresses after cloning VMs.

Installing SQL Server 2005 x64 on the VM

1. Insert the installation DVD for SQL Server 2005 x64 into the DVD drive.

2. Power on the VM, and open the console.
3. Navigate to the SQL Server 2005 DVD, and double-click. Choose the appropriate edition if the installer prompts you with a menu.
4. Click the Server components link under the Install section to begin the installation.
5. At the End User License Agreement, accept the licensing terms, and click Next.
6. After installing the prerequisites, click Next.
7. At the Welcome screen, click Next.
8. At the System Configuration Check, click Next. For this installation, you may ignore the possible warning regarding IIS, as it is unnecessary for this configuration.
9. At the Registration Screen, enter the appropriate name and company.
10. At the Components to Install screen, select SQL Server Database Services and Workstation components.
11. Click Advanced.
12. Uncheck Business Intelligent Development Studio, uncheck Replication, and uncheck Books Online & Sample Databases.
13. Click Next to start the installation.
14. At the Instance Name screen, click the Default instance radio button, and click Next.
15. At the Service Account screen, select the Use the built-in System account radio button.
16. Select Local system, and click Next.
17. At the Authentication Mode screen, select Mixed Mode.
18. Specify the "sa" logon password by entering a password in both fields, and click Next.
19. At the Collation Settings screen, click Next.
20. Accept the default Error and Usage Report Settings, and click Next.
21. At the Ready to Install screen, click Install to begin the installation.
22. At the end of the installation in the Setup Progress screen, click Next.
23. Click Finish to complete the installation.
24. Click Start, All Programs, Microsoft SQL Server, SQL Server Management Studio. Connect to the SQL Server instance.
25. Create an SQL Server login for the ds2user (see the DVD Store setup section below for the specific script to use).
26. Click Start, Administrative Tools, and Local Security Policy.
27. Double-click Perform Volume Maintenance Tasks, and add the System account.
28. Double-click Lock Pages in Memory, and add the System account.
29. Reboot the VM before installing SQL Server SP3.

Installing Service Pack 3 for Microsoft SQL Server 2005 in the VM

Service Pack 3 is available for download from

<http://www.microsoft.com/downloads/details.aspx?FamilyID=ae7387c3-348c-4faa-8ae5-949fdbe59c4&displaylang=en>.

1. Power on the VM, and open the console.
2. Run SQLServer2005SP3-KB955706-x64-ENU.exe.
3. At the Welcome screen, click Next.
4. At Accept the License Agreement, click Next.
5. At the Feature Selection screen, keep the defaults, and click Next.
6. At the Authentication screen, click Next.
7. At the Error and Usage Reporting Settings screen, click Next.
8. At the Running Processes screen, click Next.
9. Click Install.
10. If a compatibility error occurs during the installation, click Run program.
11. Click Next.
12. At the Installation Complete screen, click Next.
13. Click Finish.
14. Reboot the VM.

Installing system updates in Windows Server 2003 x64 in the VM

We installed the following updates on the VM using the Microsoft Windows Update feature:

- Update to .NET Framework 3.5 Service Pack 1 for the .NET Framework Assistant 1.0 x64 (KB963707)
- Update for Windows Server 2003 x64 Edition (KB961118)
- Microsoft .NET Framework 3.5 Service Pack 1 and .NET Framework 3.5 Family Update for .NET versions 2.0 through 3.5 (KB951847) x64
- Microsoft .NET Framework 3.5 Service Pack 1 and .NET Framework 3.5 Family Update for .NET versions 2.0 through 3.5 (KB951847) x64
- Microsoft .NET Framework 3.5 Service Pack 1 and .NET Framework 3.5 Family Update for .NET versions 2.0 through 3.5 (KB951847) x64
- Security Update for Microsoft XML Core Services 6.0 Service Pack 2 for x64-based Systems (KB954459)
- Update for Windows Server 2003 x64 Edition (KB970653)
- Security Update for Windows Server 2003 x64 Edition (KB973869)
- Security Update for Windows Server 2003 x64 Edition (KB971657)
- Security Update for Windows Server 2003 x64 Edition (KB973815)
- Security Update for Windows Server 2003 x64 Edition (KB960859)
- Security Update for Windows Server 2003 x64 Edition (KB973507)
- Security Update for Windows Server 2003 x64 Edition (KB973354)
- Security Update for Windows Server 2003 x64 Edition (KB958469)
- Security Update for Windows Server 2003 x64 Edition (KB973540)
- Security Update for Windows Server 2003 x64 Edition (KB971557)
- Security Update for Windows Server 2003 x64 Edition (KB971032)
- Update for Windows Server 2003 x64 Edition (KB968389)
- Security Update for Windows Server 2003 x64 Edition (KB961371)
- Windows Malicious Software Removal Tool x64 - August 2009 (KB890830)
- Cumulative Security Update for Internet Explorer 6 for Windows Server 2003 x64 Edition (KB972260)
- Cumulative Security Update for ActiveX Killbits for Windows Server 2003 x64 Edition (KB973346)
- Security Update for Windows Server 2003 x64 Edition (KB971633)
- Security Update for Windows Server 2003 x64 Edition (KB970238)
- Security Update for Windows Server 2003 x64 Edition (KB968537)
- Security Update for Windows Server 2003 x64 Edition (KB961501)
- Security Update for Windows Server 2003 x64 Edition (KB959426)
- Security Update for Windows Server 2003 x64 Edition (KB960803)
- Security Update for Windows Server 2003 x64 Edition (KB952004)
- Security Update for Windows Server 2003 x64 Edition (KB956572)
- Security Update for Windows Server 2003 x64 Edition (KB923561)
- Update for Windows Server 2003 x64 Edition (KB967715)
- Security Update for Windows Server 2003 for x64 Edition (KB938464)
- Security Update for Windows Server 2003 x64 Edition (KB960225)
- Security Update for Windows Server 2003 x64 Edition (KB958687)
- Security Update for Windows Server 2003 x64 Edition (KB956802)
- Security Update for Windows Server 2003 x64 Edition (KB954600)
- Security Update for Windows Server 2003 x64 Edition (KB952069)
- Security Update for Windows Server 2003 x64 Edition (KB957097)
- Security Update for Windows Server 2003 x64 Edition (KB955069)
- Security Update for Windows Server 2003 x64 Edition (KB958644)
- Security Update for Windows Server 2003 x64 Edition (KB956803)
- Security Update for Windows Server 2003 x64 Edition (KB950974)
- Security Update for Windows Server 2003 x64 Edition (KB952954)
- Security Update for Outlook Express for Windows Server 2003 x64 Edition (KB951066)
- Security Update for Windows Server 2003 x64 Edition (KB944338)
- Security Update for Windows Server 2003 x64 Edition (KB951748)
- Security Update for Windows Server 2003 x64 Edition (KB950762)
- Security Update for Windows Server 2003 x64 Edition (KB945553)
- Update for Windows Server 2003 x64 Edition (KB948496)

- Security Update for Windows Server 2003 x64 Edition (KB943055)
- Security Update for Windows Server 2003 x64 Edition (KB946026)
- Security Update for Windows Server 2003 x64 Edition (KB944653)
- Security Update for Windows Server 2003 x64 Edition (KB941569)
- Security Update for Windows Server 2003 x64 Edition (KB943460)
- Security Update for Windows Server 2003 x64 Edition (KB938127)
- Security Update for Windows Server 2003 x64 Edition (KB926122)
- Security Update for Windows Media Player 6.4 (KB925398)
- Cumulative Security Update for Outlook Express for Windows Server 2003 x64 Edition (KB929123)
- Security Update for Windows Server 2003 x64 Edition (KB924667)
- Update for Windows Server 2003 x64 Edition (KB927891)
- Security Update for Windows Server 2003 x64 Edition (KB932168)
- Security Update for Windows Server 2003 x64 Edition (KB930178)
- Security Update for Windows Server 2003 x64 Edition (KB925902)

Configuring additional drives in Disk Management

1. Power on the VM, and open the console.
2. Log into the VM.
3. Click Start, Run, type `cmd` and press Enter.
4. Type `diskpart`
5. Type `list disk`
6. Type `select disk #` (where # is the disk number of the first SQL volume).
7. Type `create partition primary align=1024`
8. Type `assign letter=E` for the first SQL volume.
9. Type `list disk`
10. Type `select disk #` (where # is the disk number of the second SQL volume).
11. Type `create partition primary align=1024`
12. Type `assign letter=F` for the first SQL volume.
13. Type `list disk`
14. Type `select disk #` (where # is the disk number of the SQL log volume).
15. Type `create partition primary align=1024`
16. Type `assign letter=G` for the external volume.
17. Exit the command prompt.
18. Click Start, Administrative Tools, Computer Management.
19. Click Disk Management.
20. Right-click the uninitialized disks (if any), and choose Initialize Disk.
21. Choose MBR.
22. Right-click the first SQL volume, and choose New Simple Volume. Click Next.
23. Keep the default drive space, and click Next.
24. Keep the default drive letter assignment, and click Next.
25. Choose NTFS, 64KB allocation unit size, and check the Perform a quick format checkbox. Click Next.
26. Click Finish.
27. Repeat steps 22 through 26 for the remaining SQL volume and SQL log volume.
28. Create the folders necessary for the database. We used `<driveletter>:\SQLLog` for the SQL Server transaction log volume and `<driveletter>:\SQLData` for the SQL Server data volumes.

Creating the additional VMs on each host server

After installing and configuring the initial VM, we cloned that VM using a combination of the `vmkfstools` and `vmware-cmd` utilities on the VMware ESX Server platform. Below is a sample shell script to clone VMs containing three virtual disks, such as our configuration.

```
# cp -reply=yes /sourcepath/VM1.vmx /destpath/VM2.vmx
# sed -i "s/VM1/VM2/g" /destpath/VM2.vmx
# sed -i `sched.swap.derivedName/d` /destpath/VM2.vmx
```

```
# sed -i '/checkpoint.vmState/d' /destpath/VM2.vmx
# vmkfstools -i /sourcepath/VM1.vmdk /destpath/VM2.vmdk
# vmkfstools -i /sourcepath/VM1_1.vmdk /destpath/VM2_1.vmdk
# vmkfstools -i /sourcepath/VM1_2.vmdk /destpath/VM2_2.vmdk
# vmware-cmd -s register /destpath/VM2.vmx
```

Configuring the additional VMs after cloning

1. Power on the VM, and open the console.
2. Click Start→Control Panel→Right-click Network Connections, and double-click the Local Area Connection.
3. Select Internet Protocol Version 4 (TCP/IPv4), and click Properties.
4. In the Internet Protocol Version 4 (TCP/IPv4) Properties screen, select the Use the following IP address radio button.
5. Enter a valid static IP address for this new VM, subnet mask, and default gateway.
6. Click OK, and click Close to exit.
7. Click Start→Control Panel→System.
8. Click Change Settings to change the computer name.
9. Click the Change button.
10. Enter the new computer name.
11. Click OK, and click OK again.
12. Restart the VM.
13. Repeat steps 2 through 13 for each VM.
14. Repeat steps 1 through 14 on each Dell PowerEdge M610 blade server.

Setting up and configuring the HP DL385 server and HP Modular Smart Array 30 storage

We setup 35 HP ProLiant DL385 servers and 18 Modular Smart Array 30 (MSA30) storage arrays in identical fashion, as we describe below.

We installed a fresh copy of Windows Server 2003 R2 x64 Enterprise Edition with Service Pack 2 on the HP ProLiant DL385 servers.

We installed four internal drives in each HP DL385. We attached each server to a Modular Smart Array 30 (MSA30). We cabled the MSA30 to the Smart Array 6400 storage adapter in the server via one SCSI cable. The I/O module on the MSA30 was a dual port I/O module. Each array contained the drives relevant to two servers, with each server getting 7 of the 14 drives in the server.

We configured the internal drives in two RAID 1 volumes, with two disks per volume. The MSA30 contained 14 146GB 10,000 RPM U320 SCSI drives. As we note above, using the dual port I/O module, we split each MSA30 in half, with seven drives going to each server. We configured the MSA30 volumes in a RAID 5 array for each seven drive set, resulting in approximately an 800GB volume at the operating system level, which we then partitioned, using a 50GB partition for SQL Server data on the external storage. We used a 15GB partition for SQL Server logs on the second RAID 1 set internally. Given that we allocated seven drives from each array to each server, we opted to use RAID 5 for the MSA30 storage, as RAID 10 requires an even number of drives, and so this would have left one of our seven drives unused.

We installed Windows Server 2003 R2 x64 Enterprise Edition and SQL Server 2005 x64 software on the first mirrored internal volume, configured the SQL Server transaction logs on the second internal volume, and placed the SQL Server database data on the MSA30 volume.

Setting up the internal storage for operating system installation

1. Enter the RAID controller BIOS by pressing F8 at the HP Smart Array 6i Controller prompt.
2. Select Create Logical Drive.
3. Select the two drives to use for this RAID 1 volume.
4. Press F8 to save this configuration.
5. Press Enter to continue.

6. Press Escape to return to the boot sequence.
7. Repeat steps 1 through 6 on each HP ProLiant Server.

Setting up the external storage

We configured each MSA30 storage array via the HP Array Configuration Utility after installing the operating system. See the steps in Adding additional drives to the server via the HP Smart Array Configuration Utility, DISKPART utility, and Disk Management Utility for details.

Installing Windows Server 2003 R2 x64 Enterprise Edition with Service Pack 2

1. Boot the server, and insert the Windows Server 2003 R2 x64 installation CD in the DVD-ROM drive.
2. At the Welcome to Set up screen, press Enter to begin the installation.
3. At the Windows Licensing Agreement screen, press F8 to agree to the terms.
4. Press Enter to install in the default location.
5. Select Format the partition using the NTFS file system (Quick), and press Enter to continue.
6. At the Regional and Language Options screen, click Next.
7. Enter Name and Organization, and click Next. Note: Organization is an optional field, while username is required.
8. At the Your Product Key screen, enter your product key, and click Next.
9. At the Licensing Modes screen, click Next.
10. At the Computer Name and Administrator Password screen, type `Password1` as the new password in both fields, and click Next.
11. At the Date and Time Settings screen, change the Date & Time and Time Zone if appropriate, and click Next.
12. After the system restarts automatically, follow the prompt to log into the server.
13. At the Windows Setup screen, the installer will prompt you to insert the second installation CD. Insert the appropriate CD, and click OK.
14. At the Windows Server 2003 R2 Setup Wizard Welcome screen, click Next.
15. At the Windows Server 2003 R2 Setup Wizard Summary screen, click Next.
16. When the installer prompts you, click Finish to end the installation.
17. Repeat steps 1 through 16 on each HP ProLiant Server.

Setting up network configuration on the server

1. Click Start→Control Panel→Network Connections→Local Area Connection.
2. Click Properties.
3. Select Internet Protocol (TCP/IP), and click Properties.
4. In the Internet Protocol (TCP/IP) Properties screen, select the Use the following IP address radio button.
5. Enter a valid static IP address, subnet mask, and default gateway.
6. Select the Use the following DNS server addresses radio button, and enter at least one valid DNS server address.
7. Click OK, and click OK to exit.
8. Repeat steps 1 through 7 on each HP ProLiant Server.

Installing system updates in Windows Server 2003 R2 x64 Enterprise Edition

We installed the following updates on the machines using the Microsoft Windows Update feature:

- Update to .NET Framework 3.5 Service Pack 1 for the .NET Framework Assistant 1.0 x64 (KB963707)
- Update for Windows Server 2003 x64 Edition (KB961118)
- Microsoft .NET Framework 3.5 Service Pack 1 and .NET Framework 3.5 Family Update for .NET versions 2.0 through 3.5 (KB951847) x64
- Microsoft .NET Framework 3.5 Service Pack 1 and .NET Framework 3.5 Family Update for .NET versions 2.0 through 3.5 (KB951847) x64
- Microsoft .NET Framework 3.5 Service Pack 1 and .NET Framework 3.5 Family Update for .NET versions 2.0 through 3.5 (KB951847) x64
- Security Update for Microsoft XML Core Services 6.0 Service Pack 2 for x64-based Systems (KB954459)
- Update for Windows Server 2003 x64 Edition (KB970653)

- Security Update for Windows Server 2003 x64 Edition (KB973869)
- Security Update for Windows Server 2003 x64 Edition (KB971657)
- Security Update for Windows Server 2003 x64 Edition (KB973815)
- Security Update for Windows Server 2003 x64 Edition (KB960859)
- Security Update for Windows Server 2003 x64 Edition (KB973507)
- Security Update for Windows Server 2003 x64 Edition (KB973354)
- Security Update for Windows Server 2003 x64 Edition (KB958469)
- Security Update for Windows Server 2003 x64 Edition (KB973540)
- Security Update for Windows Server 2003 x64 Edition (KB971557)
- Security Update for Windows Server 2003 x64 Edition (KB971032)
- Update for Windows Server 2003 x64 Edition (KB968389)
- Security Update for Windows Server 2003 x64 Edition (KB961371)
- Windows Malicious Software Removal Tool x64 - August 2009 (KB890830)
- Cumulative Security Update for Internet Explorer 6 for Windows Server 2003 x64 Edition (KB972260)
- Cumulative Security Update for ActiveX Killbits for Windows Server 2003 x64 Edition (KB973346)
- Security Update for Windows Server 2003 x64 Edition (KB971633)
- Security Update for Windows Server 2003 x64 Edition (KB970238)
- Security Update for Windows Server 2003 x64 Edition (KB968537)
- Security Update for Windows Server 2003 x64 Edition (KB961501)
- Security Update for Windows Server 2003 x64 Edition (KB959426)
- Security Update for Windows Server 2003 x64 Edition (KB960803)
- Security Update for Windows Server 2003 x64 Edition (KB952004)
- Security Update for Windows Server 2003 x64 Edition (KB956572)
- Security Update for Windows Server 2003 x64 Edition (KB923561)
- Update for Windows Server 2003 x64 Edition (KB967715)
- Security Update for Windows Server 2003 for x64 Edition (KB938464)
- Security Update for Windows Server 2003 x64 Edition (KB960225)
- Security Update for Windows Server 2003 x64 Edition (KB958687)
- Security Update for Windows Server 2003 x64 Edition (KB956802)
- Security Update for Windows Server 2003 x64 Edition (KB954600)
- Security Update for Windows Server 2003 x64 Edition (KB952069)
- Security Update for Windows Server 2003 x64 Edition (KB957097)
- Security Update for Windows Server 2003 x64 Edition (KB955069)
- Security Update for Windows Server 2003 x64 Edition (KB958644)
- Security Update for Windows Server 2003 x64 Edition (KB956803)
- Security Update for Windows Server 2003 x64 Edition (KB950974)
- Security Update for Windows Server 2003 x64 Edition (KB952954)
- Security Update for Outlook Express for Windows Server 2003 x64 Edition (KB951066)
- Security Update for Windows Server 2003 x64 Edition (KB944338)
- Security Update for Windows Server 2003 x64 Edition (KB951748)
- Security Update for Windows Server 2003 x64 Edition (KB950762)
- Security Update for Windows Server 2003 x64 Edition (KB945553)
- Update for Windows Server 2003 x64 Edition (KB948496)
- Security Update for Windows Server 2003 x64 Edition (KB943055)
- Security Update for Windows Server 2003 x64 Edition (KB946026)
- Security Update for Windows Server 2003 x64 Edition (KB944653)
- Security Update for Windows Server 2003 x64 Edition (KB941569)
- Security Update for Windows Server 2003 x64 Edition (KB943460)
- Security Update for Windows Server 2003 x64 Edition (KB938127)
- Security Update for Windows Server 2003 x64 Edition (KB926122)
- Security Update for Windows Media Player 6.4 (KB925398)
- Cumulative Security Update for Outlook Express for Windows Server 2003 x64 Edition (KB929123)

- Security Update for Windows Server 2003 x64 Edition (KB924667)
- Update for Windows Server 2003 x64 Edition (KB927891)
- Security Update for Windows Server 2003 x64 Edition (KB932168)
- Security Update for Windows Server 2003 x64 Edition (KB930178)
- Security Update for Windows Server 2003 x64 Edition (KB925902)

Connecting the storage arrays to the servers

We attached the database volumes on each HP MSA30 storage to their respective HP ProLiant DL385 servers by using a SCSI cable connected from the Smart Array 6400 Controller in the server to one SCSI connector on the back of the HP MSA30 dual port I/O module. As we noted above, two servers shared one HP MSA30 array, with each server occupying one port of the I/O module.

Adding additional drives to the servers via the HP Smart Array Configuration Utility, DISKPART utility, and Disk Management Utility

1. Download and install the HP Smart Array Configuration Utility (ACU) from <http://h18000.www1.hp.com/products/servers/proliantstorage/software-management/acumatrix/index.html>.
2. Open the ACU, and select the internal controller.
3. Click Create Array.
4. Select the remaining two available drives, and click OK.
5. Click Create Logical Drive.
6. Leave Fault tolerance at RAID 1+0, leave the default stripe size, and click OK.
7. Click Save.
8. Select the Smart Array 6400 external controller.
9. Click Create Array.
10. Select the seven available drives, and click OK.
11. Click Create Logical Drive.
12. Choose RAID 5 for the fault tolerance selection, leave the default stripe size, and click OK.
13. Click Save.
14. Exit the ACU utility.
15. Click Start, Run, type `cmd` and press Enter.
16. Type `diskpart`
17. Type `list disk`
18. Type `select disk #` (where # is the disk number of the internal volume).
19. Type `create partition primary size=15360 align=1024`
20. Type `assign letter=F` for the internal volume.
21. Type `list disk`
22. Type `select disk #` (where # is the disk number of the external MSA30 volume).
23. Type `create partition primary size=51200 align=1024`
24. Type `assign letter=E` for the external volume.
25. Exit the command prompt.
26. Click Start, Administrative Tools, Computer Management.
27. Click Disk Management.
28. Right-click the volume, and select Format. Choose 64KB allocation unit size, NTFS file system, select Perform Quick Format, and press OK.
29. Repeat steps 27 and 28 for the external MSA30 volume.
30. Create the folders necessary for the database. We used E:\SQLData for the SQL Server database volume and F:\SQLLog for the SQL Server transaction log volume.
31. Repeat steps 1 through 30 on each HP ProLiant Server.

Installing SQL Server 2005 x64 on the server

1. Navigate to the SQL Server 2005 DVD, and double-click. Choose the appropriate edition if the installer prompts you with a menu.
2. Click the Server components link under the Install section to begin the installation.

3. At the End User License Agreement, accept the licensing terms, and click Next.
4. After installing the prerequisites, click Next.
5. At the Welcome screen, click Next.
6. At the System Configuration Check, click Next. For this installation, you may ignore the possible warning regarding IIS, as it is unnecessary for this configuration.
7. At the Registration Screen, enter the appropriate name and company.
8. At the Components to Install screen, select SQL Server Database Services and Workstation components.
9. Click Advanced.
10. Uncheck Business Intelligent Development Studio, uncheck Replication, and uncheck Books Online & Sample Databases.
11. Click Next to start the installation.
12. At the Instance Name screen, click the Default instance radio button, and click Next.
13. At the Service Account screen, select the Use the built-in System account radio button.
14. Select Local system, and click Next.
15. At the Authentication Mode screen, select Mixed Mode.
16. Specify the "sa" logon password by entering a password in both fields, and click Next.
17. At the Collation Settings screen, click Next.
18. Accept the default Error and Usage Report Settings, and click Next.
19. At the Ready to Install screen, click Install to begin the installation.
20. At the end of the installation in the Setup Progress screen, click Next.
21. Click Finish to complete the installation.
22. Click Start, All Programs, Microsoft SQL Server, SQL Server Management Studio. Connect to the SQL Server instance.
23. Right-click the instance in Object explorer, and choose Properties.
24. Click Processors, and select the Boost SQL Server Priority checkbox. Click OK.
25. Restart the SQL Server by right-clicking the instance and choosing restart.
26. Create a SQL Server login for the ds2user (see DVD Store setup section below for the specific script to use).
27. Click Start, Administrative Tools, and Local Security Policy.
28. Double-click Perform Volume Maintenance Tasks, and add the System account.
29. Double-click Lock Pages in Memory, and add the System account.
30. Reboot the server before installing SQL Server SP3.

Installing Service Pack 3 for Microsoft SQL Server 2005

Service Pack 3 is available for download from

<http://www.microsoft.com/downloads/details.aspx?FamilyID=ae7387c3-348c-4faa-8ae5-949dfbe59c4&displaylang=en>.

1. Run SQLServer2005SP3-KB955706-x64-ENU.exe.
2. At the Welcome screen, click Next.
3. At Accept the License Agreement, click Next.
4. At the Feature Selection screen, keep the defaults, and click Next.
5. At the Authentication screen, click Next.
6. At the Error and Usage Reporting Settings screen, click Next.
7. At the Running Processes screen, click Next.
8. Click Install.
9. If a compatibility error occurs during the installation, click Run program.
10. Click Next.
11. At the Installation Complete screen, click Next.
12. Click Finish.
13. Reboot the server.

DVD Store setup

Data generation overview

We built the database schema using the scripts in the DS2 distribution package, though we made a few minor modifications. The DS2 stress tool provides options to generate 10MB, 1GB, or 100GB datasets. To get the tool to generate the 10 GB of user data we used in this test, we had to make a few straightforward changes to the source code and to the DVD Store application's scripts. Note: We created our test data on a Linux system to take advantage of the larger RAND MAX.

Editing the ds2_create_orders.c module

The module ds2_create_orders.c defines constants that define the maximum values for the customer ID and the product ID. The constants for the 10GB database size did not exist. We added the constants for this size.

On the command line for the ds2_create_orders.c module, we specified the size. The available options were S (small), M (medium), and L (large). We added the case T for the 10GB database. In the switch statement that sets the values for the variables max_cust_id and max_prod_id, we added cases that assigned them the proper values for the 10GB database size.

We recompiled the ds2_create_orders.c module on Linux, following the instructions in the header comments. We used the following command line:

```
gcc -o ds2_create_orders ds2_create_orders.c -lm
```

Editing the ds2_create_cust.c module

We had to make the same changes to the ds2_create_cust.c module that we made to the ds2_create_orders.c module. On the command line for the ds2_create_cust.c module, we specified the size. The available options were S (small), M (medium), and L (large). We added the case T for the 10GB database. In the switch statement that sets the values for the variables max_cust_id and max_prod_id, we added cases that assigned them the proper values for the 10GB database size.

We recompiled the ds2_create_cust.c module on Linux, following the instructions in the header comments. We used the following command line:

```
gcc -o ds2_create_cust ds2_create_cust.c -lm
```

Generating the data for the 10GB database

We used shell scripts to run all four of the executables that generate the data. The distribution did not include shell scripts for the 10GB size. We wrote shell scripts based on the ds2_create_cust_large.sh and ds2_create_orders_large.sh scripts. The ds2_create_prod and ds2_create_inv executables did not ship with associated shell scripts, so we created shell scripts using the instructions in the readme files. We ran the shell scripts in the following order to generate the data for the 10GB database:

1. ds2_create_orders_10gb.sh
2. ds2_create_inv_10gb.sh
3. ds2_create_prod_10gb.sh
4. ds2_create_cust_10gb.sh

We waited until the processes finished before we moved onto the next step.

Creating the database

We modified the database creation SQL Server scripts in the DVD Store distribution package to build the database schema, which includes the file structure, tables, indices, stored procedures, triggers, and so on. We built a master copy of the 10GB database version for SQL Server 2005, and then used that master copy to restore our test database to the HP ProLiant DL385 solution and Dell PowerEdge M610 solution between each test run. We stored the backup file on the C: drive of each server or virtual machine for quick access.

We followed these steps to create the database:

1. We created the database and file structure using database creation scripts in the DS2 download. We made size modifications specific to our 10GB database and the appropriate changes to drive letters.

2. We created database tables, stored procedures, and objects.
3. We set the database recovery model to bulk-logged to prevent excess logging.
4. We loaded the data we generated into the database. For data loading, we used the import wizard in SQL Server Management Studio. Where necessary, we retained options from the original scripts, such as Enable Identity Insert.
5. We created indices, full-text catalogs, primary keys, and foreign keys using the database-creation scripts.
6. We updated statistics on each table according to database-creation scripts, which sample 18 percent of the table data.
7. On each SQL Server instance, we created a ds2user SQL Server login using the following Transact SQL (TSQL) script:

```
USE [master]
GO
CREATE LOGIN [ds2user] WITH PASSWORD=N'',
DEFAULT_DATABASE=[master],
DEFAULT_LANGUAGE=[us_english],
CHECK_EXPIRATION=OFF,
CHECK_POLICY=OFF
GO
```

8. We set the database recovery model back to full.

We made the following changes in the build scripts:

- Because we varied the size of the datasets, we sized the files in our scripts to reflect the database size and the number of files per filegroup. We allowed for approximately 40 percent free space in our database files to ensure that filegrowth activity did not occur during the testing.
- We followed Microsoft's recommendation of having 0.25 to 1 file per filegroup per core. We used two files per filegroup on the HP ProLiant DL385 server and in the virtual machines on the Dell PowerEdge M610 blade server.
- We did not use the DBCC PINTABLE command for the CATEGORIES and PRODUCTS tables, both because Microsoft recommends against this practice and because the commands do nothing in SQL Server 2005.
- We created a SQL Server login we called ds2user and mapped a database user to this login. We made each such user a member of the db_owner fixed database role.
- Using the DVD Store scripts as a reference, we created the full-text catalog and index on the PRODUCTS table manually in SQL Server Management Studio.

We then performed a full backup of the database. This backup allowed us to restore the databases to a pristine state relatively quickly between tests.

Editing the workload script - ds2xdriver.cs module

To use the 10GB database we created earlier, we had to change the following constants:

- In the routine Controller(), we changed the string sizes. We added the T option for the 10GB database size. DS2 uses the sizes string to interpret the db_size_str option.
- In the class Controller, we changed the arrays MAX_CUSTOMER and MAX_PRODUCT. To each, we added values specifying the bounds for the customer and product IDs. The Controller() routine uses these arrays.
- We added a command line parameter for the database name:

```
-database_name
```

Editing the workload script - ds2sqlserverfns.cs module

We changed the connection string to increase the number of available connections, to not use the default administrator ("sa") account, and to include a parameter for the database name. We raised the available connections limit from the default of 100 to 200 to allow room for experimentation. We created a user account we called `ds2User` and used that account.

The `ds2connect` routine in the `ds2sqlserverfns.cs` module defines `sConnectionString`. We used the following string; the changes we made appear in bold:

```
string sConnectionString = "User ID=ds2User;Initial Catalog="+dbname+";Max  
Pool Size=200;Connection Timeout=120;Data Source=" + Controller.target;
```

Recompiling the ds2sqlserverdriver.exe executable

We recompiled the `ds2xdriver.cs` and `ds2sqlserverfns.cs` module in Windows by following the instructions in the header comments. Because the DS2 instructions were for compiling from the command line, we used the following steps:

1. Open a command prompt.
2. Use the `cd` command to change to the directory containing our sources.
3. Run the batch file `C:\Program Files\Microsoft Visual Studio 9.0\Common7\Tools\vsvars32.bat`. This sets up the environment variables for us.
4. Execute the following command:

```
csc /out:ds2sqlserverdriver.exe ds2xdriver.cs ds2sqlserverfns.cs  
/d:USE_WIN32_TIMER /d:GEN_PERF_CTRS
```

Conducting the test

To perform the test, we used a series of batch files and shell scripts. We stored these scripts either under the `\home` folder on the vSphere server, the `C:\ServerShare` folder on each virtual machine, or under the `C:\ClientShare` folder on the clients, and we used the `PsExec`, `WinSCP`, and `Plink` utilities to coordinate the test procedures amongst the client machines, server machines, virtual machines, and controller. We used simple file sharing to copy files from machine to machine, as we needed.

The testing procedure consisted of the following steps:

1. Execute batch files and shell scripts to clean up prior outputs on client machines, the server machine, the virtual machines, and the controller.
2. Drop the database on each SQL Server instance.
3. Restore the database on each SQL Server instance.
4. Pause briefly to wait for background tasks to complete before the scripts shut down the VMs, and reboot the server.
5. The scripts shut down the virtual machines, reboot the client machines and server machine, and wait for a ping response from all test machines. In the case of the HP ProLiant DL385 solution, there were no virtual machines.
6. After all servers and virtual machines respond, wait 10 additional minutes for any background tasks to complete.
7. Measure idle power for 2 minutes.
8. Start the counter logs on client machines, and start the data collector set on the server under test.
9. Start the workload connections.
10. Start the workload ramp-up period.
11. Start the workload on the server, and run it for 30 minutes.
12. Stop the workload.
13. Copy all output files to the controller.

Measuring power

To record each solution's power consumption during each test, we used up to nine Extech Instruments (www.extech.com) 380803 Power Analyzer/Dataloggers. For the 35 HP ProLiant solutions, we connected all power distribution units (PDU) from the three racks containing the HP ProLiant DL385 servers to the Power Analyzers' output load power outlets. We then plugged the power cords from the Power Analyzers' input voltage connection into a power outlet. The storage arrays' power was also distributed through the PDU system in the racks, so the nine Extech Power Analyzers measured the aggregate total of power usage of the server and storage solution. For the five Dell PowerEdge M610 solutions, we configured the power measurement similarly, but used only five power meters because the five Dell PowerEdge M610 solutions required less power.

We used the Power Analyzer's Data Acquisition Software (version 2.11) to capture all recordings. We installed the software on two separate Intel processor-based PCs, which we connected to the Power Analyzers via RS-232 cables. We captured power consumption at one-second intervals.

To gauge the idle power usage, we recorded the power usage for 2 minutes while all systems were running the host operating system and VM operating systems, but otherwise idle, meaning the systems were not running any test workloads. To ensure the systems were idle, we allowed the systems to sit for 10 minutes after booting before starting the 2 minutes of idle power capture.

We then recorded the power usage (in watts) for all systems and storage during the testing at 1-second intervals. To compute the average power usage, we averaged the power usage during the time the systems were producing the peak performance results. Because we measured the power using nine Power Analyzers and multiple PDUs, we added the average power of all Power together to get the total power. We call this time the power measurement interval. See Figure 6 (idle and workload power results) for the results of these measurements.

Appendix A – Test server information

Figure 8 presents detailed information for the test servers we used in this report.

Servers	5 Dell PowerEdge M610	35 HP ProLiant DL385
Enclosure		
Blade Enclosure	Dell PowerEdge M1000e	N/A
General dimension information		
Height (inches)	17.3	3.4
Width (inches)	17.6	17.5
Depth (inches)	29.7	26.0
U size in server rack (U)	10	2
Power supplies		
Total number	6	2
Wattage of each (W)	2,360	575
Cooling fans		
Total number	9	7
Dimensions (h x w) of each	3.1" x 3.5"	2.5" x 2.5"
Voltage (V)	12	12
Amps (A)	7.00	1.10
General processor setup		
Number of processor packages	2	2
Number of cores per processor package	4	1
Number of hardware threads per core	2	1
System power management policy	OS control	Always On
CPU		
Vendor	Intel	AMD
Name	Xeon X5570	Opteron 254
Stepping	D0	E4
Socket type	LGA1366	Socket 940
Core frequency (GHz)	2.93	2.80
L1 cache	128 KB (4 x 32 KB per core)	64 KB + 64 KB
L2 cache	1 MB (4 x 256 KB)	1 MB
L3 cache	1 x 8 MB	N/A
Platform		
Vendor and model number	Dell PowerEdge M610	HP ProLiant DL385 G1
Motherboard model number	0N582M	N/A
BIOS name and version	Dell 1.2.7 (8/31/2009)	HP A05
BIOS settings	Virtualization enabled	Default
Memory modules		
Total RAM in system (GB)	72	4
Number of types of memory modules	2	1

Servers	5 Dell PowerEdge M610	35 HP ProLiant DL385
First type of memory modules		
Vendor and model number	Samsung M393B1K70BH1-CF8 (3 servers) / Hynix HMT31GR7AFR4C-H9 (2 servers)	Hynix HYMD512G726CFP4Q-D43
Type	PC3-8500R (Samsung) / PC3-10600R (Hynix)	PC-3200
Speed (MHz)	1,066 (Samsung) / 1,333 (Hynix)	200
Speed in the system currently running @ (MHz)	1,066	200
Timing/latency (tCL-tRCD-iRP-tRASmin)	8-8-8-24 (Samsung) / 9-9-9-36 (Hynix)	3-3-4-8
Size (GB)	48 (all servers)	4
Number of RAM modules	6 x 8 GB (all servers)	4 x 1 GB
Chip organization	Double-sided (all servers)	Double-sided
Second type of memory modules		
Vendor and model number	Samsung M393B5170EH1-CH9	N/A
Type	PC3-10600R	N/A
Speed (MHz)	1,333	N/A
Speed in the system currently running @ (MHz)	1,066	N/A
Timing/Latency (tCL-tRCD-iRP-tRASmin)	8-8-8-24	N/A
Size (GB)	24	N/A
Number of RAM modules	6 x 4 GB	N/A
Chip organization	Double-sided	N/A
Hard disk		
Vendor and model number	Seagate ST973452SS	HP BF072863BA
Number of disks in system	2	4
Size (GB)	73	72
Buffer size (MB)	16	8
RPM	15,000	15,000
Type	SAS	U320 SCSI
Operating system		
Name	VMware vSphere 4	Windows Server 2003 Enterprise Edition x64 R2 with SP2
Build number	164009	5.2.3790
File system	vmfs	NTFS
Language	English	English
Network/storage subsystem		
Vendor and model number	Broadcom NetXtreme II 5709 Dual-Port Ethernet	Broadcom NetXtreme Gigabit Ethernet
Type	Integrated	Integrated
Vendor and model number of additional network card	Broadcom NetXtreme II 5709 Dual-Port Ethernet	N/A

Servers	5 Dell PowerEdge M610	35 HP ProLiant DL385
Type	Discrete Mezzanine Card	N/A
Blade pass-through modules	Four Gigabit Ethernet Pass-Through Modules	N/A
USB ports		
Number	2 on the blade, 4 on the chassis (2 on the iKVM)	3
Type	USB 2.0	USB 1.1

Figure 8: Detailed system configuration information for the two test configurations.

Appendix B – Test storage information

Figure 9 presents detailed information for the test storage we used in this report.

Enclosure	5 Dell EqualLogic PS5000XV	18 HP StorageWorks MSA30
General dimension information		
Height (inches)	5.25	5.20
Width (inches)	19.0	19.0
Depth (inches)	21.5	16.5
U size in server rack	3	3
Power supplies		
Total number	2	2
Wattage of each	450	499
Cooling fans		
Total number	4	2
Dimensions (H x W) of each	4" x 4"	4" X 4"
Voltage (V)	12.0	12.5
Amps (A)	1.8	2.0
Hard disk		
Vendor and model number	Seagate ST3146855SS Maxtor 8k147S0087511	HP BD14685A26 HP BD1468856B HP BD14686225 HP BD146863B3
Number of disks in system	16	14
Size (GB)	146	146
Buffer Size (MB)	16	8
RPM	15,000	10,000
Type	SAS	SCSI U320
Storage connectivity (Fibre Channel, SAS, SATA, iSCSI, SCSI)	iSCSI	SCSI U320
Firmware revision	v4.1.4	N/A
Storage cache (GB)	1	N/A
Number of storage controllers	2 (1 active)	1
Number of storage ports	3 per controller	2
Maximum Network bandwidth of storage connectivity to host	1 Gb x 3	N/A
Switch type/model/firmware revision	Dell PowerConnect 6248 v2.2.0.3	N/A

Figure 9: Detailed system configuration information for the test storage.

Appendix C – Payback period calculation

In calculating the estimated payback period, we assume that investment costs occur at the beginning of the year and we spread annual costs evenly throughout the year. Dell provided the components of the Dell PowerEdge M610 solution and list price data for that solution. The investment costs include the following:

- Intel Xeon Processor X5570-based Dell PowerEdge M610 blade server with 72 GB of memory and two four-core processors. The list price for this server is \$12,955.00.
- Dell EqualLogic PS5000XV storage with 16 146GB 15,000 RPM disks. The list price of the storage array is \$43,001. We assign three-fourths (\$32,251) of the storage array acquisition costs to this solution based on the assumption that the array is a resource that can be shared with other workloads at other non-peak times. We base the three-fourths estimate on the approximate storage capacity that the VMs used. During testing, we use all available spindles and thus all results have the advantage of the extra spindles.
- Migration costs. We assume a migration cost of \$667, based on our estimate of 12 person hours required for planning and migration tasks at a burdened hourly rate of \$55.61. We also assume a training cost of \$1,188 for administrator training.

Figure 10 shows the payback calculation for the 5 Dell PowerEdge M610 solutions and the 35 HP ProLiant DL385 solutions.

	5 Dell PowerEdge M610 solutions	35 HP ProLiant DL385 solutions	Difference
One-time initial investment (includes server, storage hardware, and migration costs)	\$230,747	\$0	\$230,747 (HP ProLiant DL385 is lower)
Monthly cost (annual costs divided by 12; includes hardware support, maintenance and service contracts, software licenses and support agreements, facility costs, energy costs, and management costs)	\$6,269	\$28,649	\$22,380 (Dell PowerEdge M610 is lower)
Payback period	10.3 months ($\$230,747/\$22,380=10.3$)		

Figure 10: Payback calculation for the 5 Dell PowerEdge M610 solutions and the 35 HP ProLiant DL385 solutions.

The server and storage hardware costs for the 5 Dell PowerEdge M610 solutions included the list price of the Dell PowerEdge M610 blade servers and the list price of the Dell EqualLogic PS5000XV storage solution multiplied by the 75 percent of that solution that the test databases require. For the 35 HP ProLiant DL385 solutions, these costs included the replacement costs for failed disks. We made the following assumptions in estimating these costs:

- The enterprise would dedicate the entire newer Dell PowerEdge M610 blade servers to the tasks that the servers it was replacing carried out; we therefore included the entire cost of the newer Dell PowerEdge M610 blade servers in our analysis.
- Other servers in the data center would share the storage alongside the Dell PowerEdge M610 solutions. The enterprise would apportion storage costs based on the percentage of the storage solution used. Balancing the available storage and IOPS, we estimated that one-fourth of the storage capacity would be available for low-demand storage or for off-hours processing.
- The enterprise would dedicate all 35 HP ProLiant DL385 solution servers and 17½ of the storage enclosures to the tasks our benchmark tests model.
- The migration costs included an estimate of staff time to migrate software and data from the HP ProLiant DL385 solutions to the newer Dell PowerEdge M610 solutions.

We made the following assumptions in estimating the support, maintenance, and service contract costs for hardware:

- The enterprise would typically select a 3-year support package with 7-day, 24-hour coverage, and 4-hour response time for newer hardware, and would take over support internally after those agreements expire. Therefore, for the Dell PowerEdge M610 solutions, we included the costs for 3 Year ProSupport for IT and Mission Critical 4HR 7x24 Onsite Pack in our cost estimates and divided those costs by three to show the year-one cost.
- For the HP ProLiant DL385 solutions, we estimated an annual in-house support cost of \$400 per server and \$300 per storage array, plus costs to replace failed disks based on PT estimates of a 4 percent annual disk replacement rate.
- Support agreements, the costs for which we include in the next category, would cover replacement of failed disks for the Dell PowerEdge M610 solutions.

We made the following assumptions in estimating the costs of software licenses and software support agreements:

- The HP ProLiant DL385 solutions used Windows Server 2003 R2 Enterprise Edition with per-server licenses and SQL Server 2005 Standard Edition with per-server licenses, and the enterprise kept up-to-date software assurance agreements for that software.
- The newer Dell PowerEdge M610 solutions used VMware vSphere for the host operating system, and in addition, were licensed on a per-processor basis for Windows Server 2008 R2 Datacenter Edition, to gain the advantage of unlimited virtualization rights.
- The newer Dell PowerEdge M610 solutions used existing per-processor licenses for SQL Server 2005, and support agreements for unused licenses were discontinued.
- The enterprise used their Software Assurance new version rights to upgrade the licenses they needed for the newer solutions. They saved the cost of the remaining software assurance agreements. These agreements were due for renewal at the time of the solution acquisition.
- The enterprise already owned the necessary CALS and maintained software assurance agreements for them; thus, they fell outside the scope of the solutions.
- Costs include VMware vSphere 4 Advanced with a list price of \$2,245 per processor and VMware vSphere 4 Advanced Support and Subscription (SnS) at \$472 per year. The enterprise spreads the cost of the VMware vSphere 4 Advanced license over 3 years.

We made the following assumptions in estimating facility costs, which include rack-based space costs and Ethernet port costs:

- We estimated a fixed data center cost per rack, prorated by the percentage of the rack the solutions used. The older HP ProLiant DL385 solutions each require 2u for each of the 35 servers and 3u for each of the 18 storage arrays plus an additional 1u for a KVM, for a total of 125u, filling 1u less than three total racks; By contrast, each of the five Dell PowerEdge M610 solution storage arrays requires 3u and the single blade server enclosure uses 10u for a total of 25u, filling just over 1/2 rack, just 1/5th of the rack space of the older solution. We allocate storage costs to these solutions based on the percentage of the storage used by the solution. As we describe earlier in the report, we assign 75 percent of the acquisition and on-going costs of the Dell EqualLogic PS5000XV storage arrays to this solution. For the legacy solution, we use 35 of the available 36 server connections from the 18 storage arrays so we include costs related to 17 ½ arrays. We include costs for the 5/16th of the enclosure that the Dell PowerEdge M610 servers use.
- We estimated an annual per-server cost for data center ports of \$129 based on PT experience.
- We included costs for Dell PowerConnect 6248, 48 GbE Ports, and managed switches for the Dell PowerEdge M610 solution.

We made the following assumptions in estimating energy costs:

- We calculated energy costs for active and idle power consumption values (shown in Figure 7).
- The server and storage array have an average year-round power utilization that is the average of the active and idle power from the benchmark runs, adjusted for the percentage of the storage array the solution uses.

- Average cost per kWh of power. Source: National commercial average for June 2009 from http://www.eia.doe.gov/cneaf/electricity/epm/table5_6_a.html. The June average was \$10.51.
- We estimated the energy cost of cooling the servers and storage arrays to be equal to the energy cost required for running the solutions. The total energy cost was therefore twice the cost of running the solution.

We used the following assumptions in estimating the management costs:

- Each server administrator managed 40 servers.
- We included an additional cost per storage array for storage array management. These costs were in addition to the support costs under support, maintenance, and service contract costs for hardware.
- We assume that SQL Server database administration costs stay the same for the two solutions because consolidation does not change the number or complexity of the SQL Server instances.

About Principled Technologies

We provide industry-leading technology assessment and fact-based marketing services. We bring to every assignment extensive experience with and expertise in all aspects of technology testing and analysis, from researching new technologies, to developing new methodologies, to testing with existing and new tools.

When the assessment is complete, we know how to present the results to a broad range of target audiences. We provide our clients with the materials they need, from market-focused data to use in their own collateral to custom sales aids, such as test reports, performance assessments, and white papers. Every document reflects the results of our trusted independent analysis.

We provide customized services that focus on our clients' individual requirements. Whether the technology involves hardware, software, Web sites, or services, we offer the experience, expertise, and tools to help you assess how it will fare against its competition, its performance, whether it's ready to go to market, and its quality and reliability.

Our founders, Mark L. Van Name and Bill Catchings, have worked together in technology assessment for over 20 years. As journalists, they published over a thousand articles on a wide array of technology subjects. They created and led the Ziff-Davis Benchmark Operation, which developed such industry-standard benchmarks as Ziff Davis Media's Winstone and WebBench. They founded and led eTesting Labs, and after the acquisition of that company by Lionbridge Technologies were the head and CTO of VeriTest.



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