Initial investment payback analysis: Dell PowerEdge R710 solution with VMware ESX vs. HP ProLiant DL385 solution

Executive summary

Dell Inc. (Dell) commissioned Principled Technologies (PT) to estimate how many months it would take to recapture initial investment costs when consolidating multiple 4-year-old HP ProLiant DL385 server and storage solutions onto a Dell™ PowerEdge™ R710 server and storage solution using VMware ESX. In this report, we estimate both the number of older solutions each Dell PowerEdge R710 solution can replace and the payback period for replacing those older solutions. We compare the following two solutions:

- Intel® Xeon® Processor X5550-based Dell PowerEdge R710 server with 96 GB of memory using VMware ESX and Dell™ EqualLogic™ PS6000XV storage (Dell PowerEdge R710 solution)
- AMD Opteron 254-based HP ProLiant DL385 G1 server with 4 GB of memory and HP StorageWorks MSA30 storage (HP ProLiant DL385 solution)

KEY FINDINGS

- Each Dell PowerEdge R710 solution with VMware® ESX™ can replace seven HP ProLiant DL385 solutions, and could yield a payback in under 18 months. (See Figure 1.)

- The Dell PowerEdge R710 solution with VMware ESX delivered seven virtual servers, each of which yielded performance equivalent to or better than the performance of one physical HP ProLiant DL385 solution. (See Figure 4.)

- The Dell PowerEdge R710 solution with VMware ESX used little more than 1/5th of the power, about 4/5 of the software costs, and 1/7th of the data center rack space of the seven HP ProLiant DL385 solutions. (See Figures 3 and 7.)


Figure 1: A single Intel Xeon Processor X5550-based Dell PowerEdge R710 solution with VMware ESX allows you to consolidate seven AMD Opteron 254-based HP ProLiant DL385 solutions, with an initial investment payback period of under 18 months. We base this estimation on our specific database workload.

Our test case modeled a typical enterprise datacenter with multiple legacy HP ProLiant DL385 solutions running high-demand database workloads. The legacy servers each used 4 GB of memory. The enterprise in this test case seeks to consolidate several of these legacy workloads onto Dell PowerEdge R710 solutions using VMware ESX and configured with sufficient processors, memory, and storage to handle these workloads.

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 R710 solution could replace. 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 R710 solution and measured how many VMs this newer solution could run, while obtaining

OPM in each VM equivalent to that of the HP ProLiant DL385 solution. The total number of VMs the Dell PowerEdge R710 solution could handle determines the replacement factor. Based on our specific workload, the replacement factor is seven. Figure 1 depicts this replacement factor for replacing seven AMD Opteron 254-based HP ProLiant DL385 solutions with a single Intel Xeon Processor X5550-based Dell PowerEdge R710 solution, as well as the initial investment payback time of under 18 months.

Figure 2 graphs the payback period and the cost savings of the Dell PowerEdge R710 solution. Savings continue after the initial investment payback period. By the end of year two, we project a savings of $16,268. The line representing the Dell PowerEdge R710 solution accumulates the initial investment cost and the monthly costs of the solution. The initial investment cost includes the list price of the server and half of the cost of the shared storage, as well as the costs of migrating from the seven HP ProLiant DL385 solutions to the newer Dell PowerEdge R710 solution. The line for the seven HP ProLiant DL385 solutions shows the accumulated monthly costs of seven HP ProLiant DL385 solutions. The lines cross at the end of the payback period. Appendix C describes the payback period calculation.
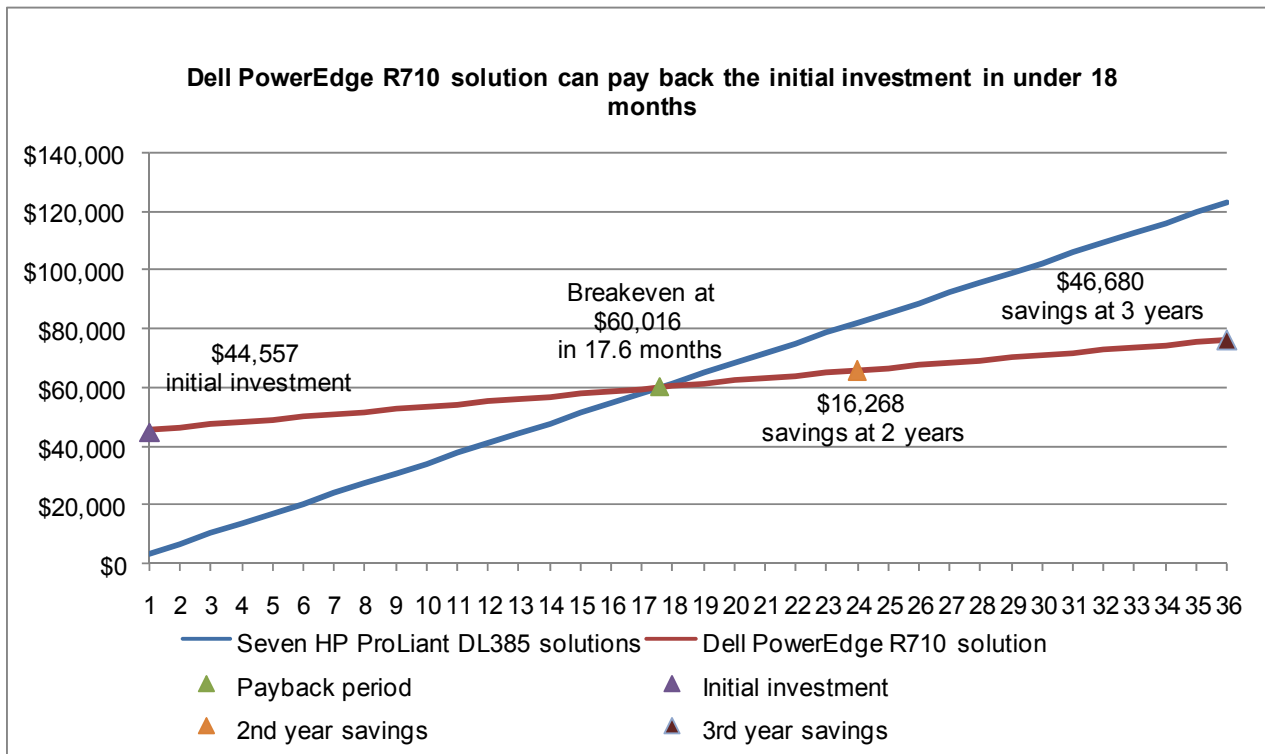
Figure 2: The payback period and cumulative estimated costs[1] for the seven HP ProLiant DL385 solutions and the Dell PowerEdge R710 solution with VMware ESX. Lower costs and higher savings are better.

Costs for the Dell PowerEdge R710 solution include the initial investment of $44,557 plus annual costs of $10,552, for a total year-one and -two cost of $65,660 for the solution. This solution could save approximately $16,268 by year two over the $81,928 two-year costs for the seven HP ProLiant DL385 servers and HP StorageWorks MSA30 storage arrays that this solution can replace. Figure 3 shows the specific areas of savings. Specifically, it shows that the investment costs of buying the server and storage hardware and of migrating from the older to the newer solution are offset by savings for the Dell PowerEdge R710 solution in hardware support costs, software licenses, software support agreements, facility costs (including switch costs), energy costs, and management costs.

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[1] We divide annual costs by 12 and do not adjust for inflation.

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Estimated year-one and -two costs for the Dell PowerEdge R710 solution and the HP ProLiant DL385 solutions

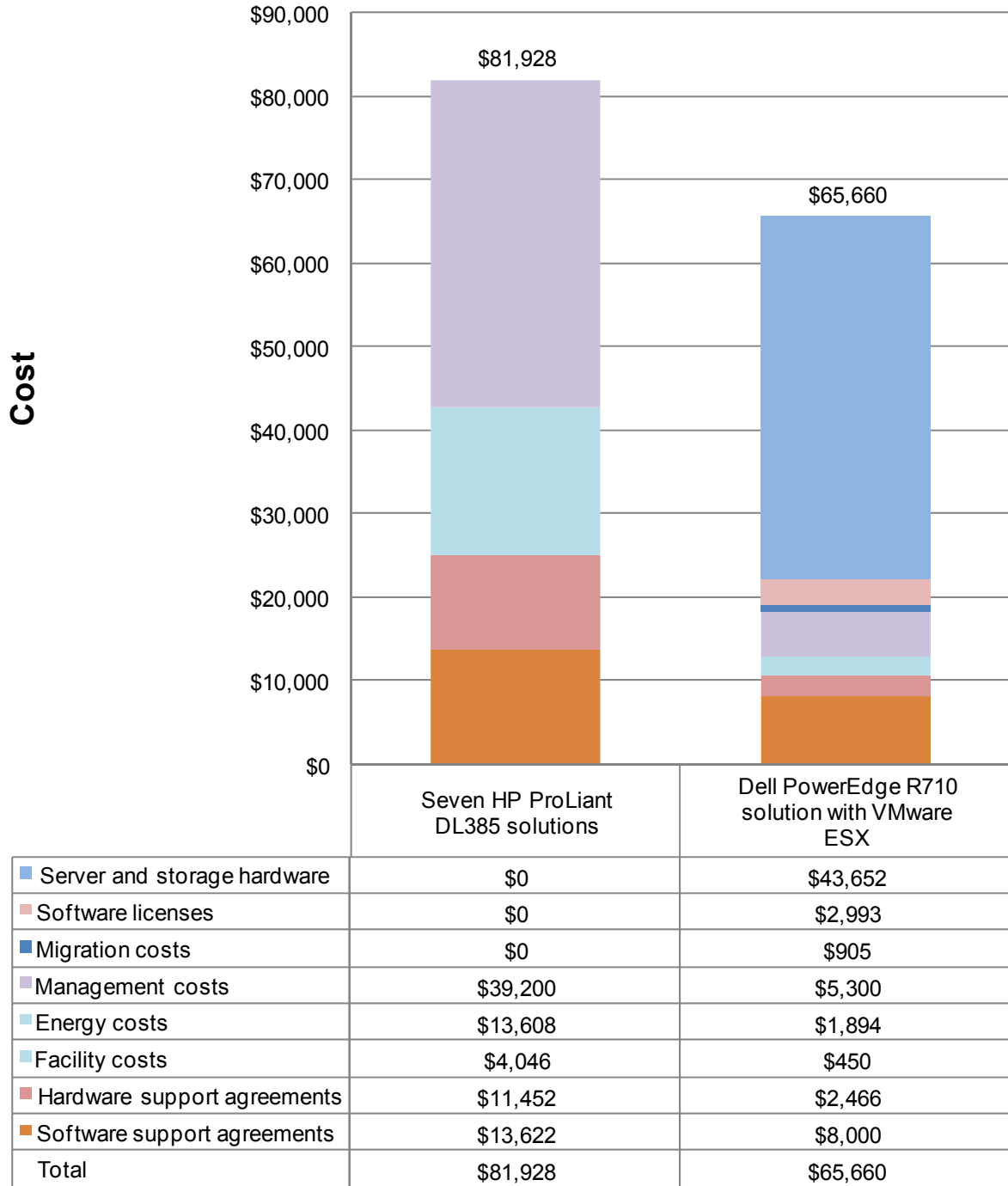|	Seven HP ProLiant DL385 solutions	Dell PowerEdge R710 solution with VMware ESX
Server and storage hardware	$0	$43,652
Software licenses	$0	$2,993
Migration costs	$0	$905
Management costs	$39,200	$5,300
Energy costs	$13,608	$1,894
Facility costs	$4,046	$450
Hardware support agreements	$11,452	$2,466
Software support agreements	$13,622	$8,000
Total	$81,928	$65,660

Figure 3: Estimated year-one and -two costs for the seven HP ProLiant DL385 solutions and the single Dell PowerEdge R710 solution with VMware ESX. Lower costs are better.

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Four benefits of the Dell PowerEdge R710 solution contribute significantly to the cost savings for this solution:

- **Replaces up to seven HP ProLiant DL385 servers with HP StorageWorks MSA30 storage arrays.** The increased I/O capacity, database performance, and memory efficient design of the Dell PowerEdge R710 solution enables consolidation of multiple older systems for the specific workload we tested.[2]
- **Uses slightly more than one-fifth of the power of the seven HP ProLiant DL385 solutions it replaces.** The consolidated Dell PowerEdge R710 solution provides considerable energy savings because it requires a little more than 20 percent of the power of the older HP ProLiant DL385 solutions that it replaces.[3] (See Figure 7.) We gain additional savings in energy costs because the test workload requires at most half the shared storage array.
- **Frees up five Windows Server® licenses.** 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 solution, as the enterprise would already have paid for the licenses used on the older solution and would transfer them to the new solution. We do include the costs of ongoing software agreements. For the calculations in this paper, we assume that the target organization maintains software agreements for OS and database software and that it can choose to renew or cancel them at the time of consolidation.[4]
- **Requires approximately one-seventh of the data center rack space.** The consolidated Dell PowerEdge R710 solution requires 2u of rack space for the server and 3u for the storage array. The older HP ProLiant DL385 solution requires 5u for each of the seven server-and-storage-array pairs, for a total of 35u; by contrast, the single Dell R710 solution consumes only 5u.

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 operates as the middle tier and 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 SQL Server 2008 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 high-end desktop systems running ESX Build 148592. Each of these client machines ran a single instance of DS2, which spawned 32 threads. This simulated a heavily loaded environment. 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 get the server to about 80 percent processor utilization throughout the test.

We used four internal hard drives (two RAID1) on all servers, installing the OS on one volume and using the other volume for DB logs. We configured the external storage as one large volume for the OS virtual machines and 14 25GB LUNs to be used for SQL Data volumes (2 for each of our 7 VMs).

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[2] The replacement factor is the number of VMs that ran on the Dell PowerEdge R710 solution, where on average each VM was equivalent to or better than the performance of the HP ProLiant DL385 solution. The Test results section of this report details those results.
[3] We multiply the replacement factor times the average power of the older server and storage solution and compare that result to the power of a single Dell PowerEdge R710 server and Dell EqualLogic PS6000 storage array.
[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 Enterprise Edition for the Dell PowerEdge R710 solution. We assume the licenses transfer between the solutions. We base this savings claim on the seven licenses required for seven older solutions versus two licenses, each supporting four VMs, for the Dell PowerEdge R710 server.

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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 R710 server and the HP ProLiant DL385 server for 30 minutes.

Our test case modeled a typical enterprise datacenter with multiple legacy HP ProLiant DL385 solutions running high-demand database workloads. The enterprise in this test case seeks to consolidate the workloads of seven of these legacy systems onto a Dell PowerEdge R710 solution that runs VMware ESX and wants to yield a payback in under 18 months. The enterprise seeks to balance performance and cost.

We ran the DS2 benchmark to verify that, using our test workload, the newer solution would outperform the seven legacy systems it would replace. We tested each legacy system and each VM on the newer solution with 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 seven legacy and single new system and estimated the payback period for the investment in the newer solution.

To model this test case, we did not compare identical solutions but instead configured the newer solution 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 also yield a payback in under 18 months.

We selected 4GB RAM for the legacy systems as it is a realistic amount of memory for a 4 year old system. We configured the newer solution as we expect an IT manager would when purchasing a Nehalem-based database solution intended to replace seven HP ProLiant DL385 solutions running the high-demand databases modeled by our workload. We selected and priced a Nehalem-based server with two processors, 96GB 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 96 GB (8 GB x 12) of memory, allocating 12GB of memory per VM for a total allocation of 84GB 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 12GB of memory per VM, enough memory that the 10GB database would be likely fit into memory,

We tested the legacy solution with HP StorageWorks MSA30 storage, which had 14 146GB 10,000 RPM disks. We configured the newer solution with modern storage selecting a Dell™ EqualLogic PS6000XV storage array with 15 450GB 15,000 RPM disks. The list price for that array is $55,000. We assumed that the solution we modeled would require half that storage and include the half the costs of the storage array, including $27,500 of the investment costs, in the payback analysis.

We tested the legacy system with 4-year old software versions and the newer system with current software versions, assuming that the IT department in the test case would take advantage of the performance benefits of newer software. We tested the Dell PowerEdge R710 solution running VMware vSphere 4 Advanced[5] and the HP ProLiant DL385 solution running Windows Server 2003 R2 Enterprise Edition. We tested the Dell PowerEdge R710 solution with Microsoft SQL Server 2008 Enterprise Edition and the HP ProLiant DL385 solution with Microsoft SQL Server 2005. We installed Windows Server 2008 Enterprise Edition and Microsoft SQL Server 2008 in each VM on the Dell PowerEdge R710.

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[5] We tested with a vSphere 4.0 prior to product release using a build from the post release candidate timeframe. We anticipate that the performance we saw with that build will be very close to that of the released product.

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Our results show the advantage in performance, cost, and workload consolidation that modern hardware, OSs, hypervisors, and database software can offer over legacy hardware and software solutions for this workload.
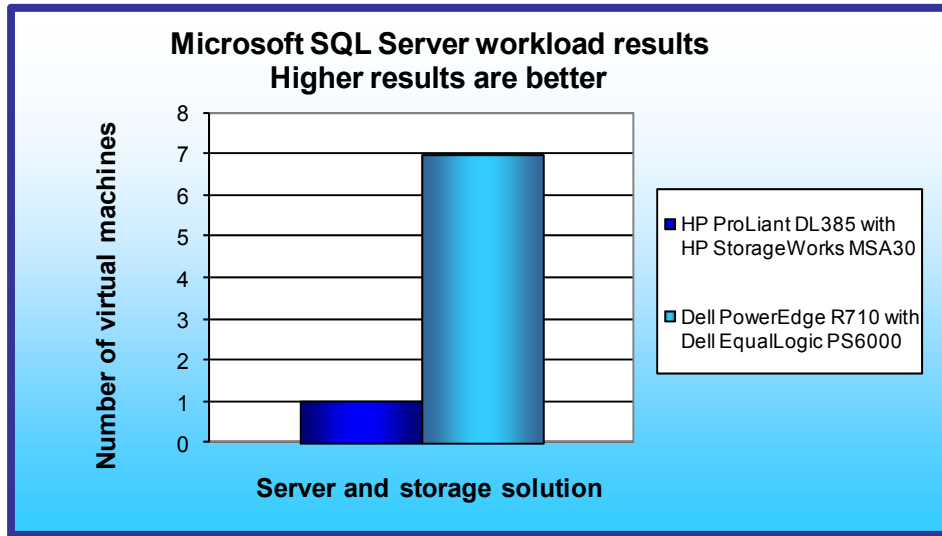
Test results

Figure 4 illustrates the number of virtual machines the Dell PowerEdge R710 solution can sustain compared to the HP ProLiant DL385 solution. The Dell PowerEdge R710 solution delivered seven virtual servers that each produced higher OPM results than the single physical HP ProLiant DL385 solution.

Figure 5 shows the specific performance results, in both OPM and CPU percentage, for the Dell PowerEdge R710 server with the Dell EqualLogic PS6000 storage solution and the HP ProLiant DL385 server with the HP

Figure 4: Number of virtual machines for the Dell PowerEdge R710 solution and HP ProLiant DL385 solution. Higher numbers are better.

StorageWorks MSA30 storage solution while running the DVD Store tests. Results are from the test run that produced the median of three OPM results. Lower CPU percentage and higher OPM numbers are better.

We tested the legacy system 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 Dell PowerEdge R710 solution, we installed one instance of SQL Server 2008 on each of seven VMs and ran one 10GB DS2 database on each. We show the number of OPM each solution achieved during our measurement period, minutes 24 through 29 of the test. We calculated the scores by averaging the OPM for each SQL instance during that period. For the Dell PowerEdge R710 solution, we show the OPM results for the lowest performing of the seven VMs. Each of the seven VMs on the Dell PowerEdge R710 solution delivered performance equivalent to or better than the performance of the HP ProLiant DL385.

Performance			
	Run 1	**Run 2**	**Run 3**
	Minimum OPM	**Minimum OPM**	**Minimum OPM**
HP ProLiant DL385 solution	15,864.5	14,466.8	15,849.3
Dell PowerEdge R710 solution	16,029.3	15,360.9	15,036.6

Figure 5: Minimum per database OPM performance results per server or virtual server for the Dell PowerEdge R710 solution and the HP ProLiant DL385 solution while running the DVD Store workload. Higher OPM numbers are better.

Figure 6 shows the specific performance results, in both individual VM OPM scores and minimum OPM scores, for the Dell PowerEdge R710 server with the Dell EqualLogic PS6000 storage array. Higher numbers are better.

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Dell PowerEdge R710 solution	Run 1	Run 2	Run 3
VM 1 OPM	16,218.6	16,233.8	15,036.6
VM 2 OPM	17,261.6	17,146.0	16,496.1
VM 3 OPM	17,012.3	16,887.3	16,289.6
VM 4 OPM	17,335.5	17,040.7	16,471.6
VM 5 OPM	17,537.8	16,795.8	15,901.0
VM 6 OPM	17,093.4	17,324.7	16,325.2
VM 7 OPM	16,029.3	15,360.9	15,697.6
Minimum OPM	16,029.3	15,360.9	15,036.6

Figure 6: Individual VM scores and the minimum VM score for the Dell PowerEdge R710 solution. Higher OPM numbers are better.

Figure 7 shows the specific power results during the median run of the Dell PowerEdge R710 server with the Dell EqualLogic PS6000 storage array and the HP ProLiant DL385 server with the HP StorageWorks MSA30 storage array. Lower numbers are better.

To calculate the power, we average the power we recorded during our workload measurement period, minutes 24 through 29 of the test, for both server and storage, with total power the sum of both. For the idle 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 desktop and then started 2 minutes of idle power capture.

Power (median results)						
	Workload			Idle		
	Server	Storage	Total	Server	Storage	Total
HP ProLiant DL385 solution	314	257	571	287	254	541
Dell PowerEdge R710 solution	374	496	869	223	475	698

Figure 7: Median power results, in watts, for the Dell PowerEdge R710 solution and the HP ProLiant DL385 solution while running the DVD Store workload and while idle. Results shown are from the runs that produced the OPM scores in Figure 5. Lower numbers are better.

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Test methodology

Adjusting BIOS settings

We used the default BIOS settings on the HP ProLiant DL385 server and enabled Virtualization Technology on the Dell PowerEdge R710 server.

Setting up and configuring the Dell PowerEdge R710 storage and Dell EqualLogic PS6000 storage

Dell PowerEdge R710 and Dell EqualLogic PS6000 storage configuration

We installed four internal drives in the Dell PowerEdge R710 server. We attached the server to a Dell EqualLogic PS6000 containing 16 drives. We cabled the PS6000 to a Dell PowerConnect™ 6248 switch via its four available ports, and we cabled the server to the switch using three of the four on-board ports. We used one network port for client data communication and one for the ESX iSCSI initiator for the OS VM drives. We then installed the Host Integration Toolkit (HIT) on each VM for storage management and for multipath I/O support. We configured the two remaining network ports for communication from VMs to individual database LUNs.

We configured the internal drives in two RAID 1 volumes, with two disks per volume. The PS6000 contained 16 450GB 15,000RPM drives. We configured the PS6000 in RAID 10 mode, and created 14 25GB LUNs to be used for SQL Data volumes (2 for each of our 7 VMs) accessed via Microsoft iSCSI Initiator, which we enabled in each VM, and one larger LUN for VM operating system virtual disks.

We installed ESX software on the first mirrored internal volume, configured the virtual disks for SQL Server transaction logs on the second internal volume, and placed the virtual machine operating system and SQL Server database data on the PS6000 volume.

Setting up the internal storage for operating system installation and virtual disks for SQL Server transaction logs

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 first 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. Repeat steps 2 through 4 for the second internal volume.
7. Wait for the initialization operations to complete.
8. Press Escape, and choose to Save and Exit to return to the boot sequence.

Setting up the external storage

1. Using the command line, setup a storage group with the following RAID policies:
   a. PS6000: RAID-10
2. Create a storage pool that you name database with the following members:
   a. PS6000-1
3. Enable all network connections on the PS6000 using the following IP address scheme:
   a. IP Address: 192.168.1.## (## being any number between 10 and 40)
   b. Subnet Mask: 255.255.248.0
4. Create one 400GB volume in the storage pool with no snapshot reserve, and name it `dvd-store`
5. Create 14 25GB volumes in the storage pool with no snapshot reserve, and name each of them `dbdataVM#@` (where `#` is the number of the VM, and `@` is the database volume – e.g., `dbdata1A`).
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.

Setting up the Dell PowerEdge R710 server

We installed build 148592 of a version of ESX still under development on the host server. ESX build 148592 supports the new virtualization technologies such as EPT. We also installed the vSphere client tool on a

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management workstation, which was an Intel Pentium 4, 630 3.00GHz running Windows Server 2003 with 2GB RAM.

Installing ESX Build 148592
1. Insert ESX Build 148592 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. 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.

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 then 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`

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.

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12. Click OK.

Connecting the storage to the host

We attached the database volumes on the Dell EqualLogic PS6000 storage to the Dell PowerEdge R710 server by connecting all four NICs available on the PS6000 array to a Dell PowerConnect 6248 switch. We used two physical NICs in the server dedicated to iSCSI traffic to connect the Microsoft iSCSI Initiator within each VM to their respective database volumes. We used the remaining NICs in the server for normal network communication and VMkernel traffic. iSCSI traffic used one subnet, while normal network communication used a separate subnet.

Adding the iSCSI storage adapter in ESX

1. On the management workstation, click Start, All Programs, VMware, VMware vSphere client.
2. Click the Configuration tab.
3. Click Networking.
4. Click Add Networking…
5. Select the VMkernel radio button, and click Next.
6. Deselect any selected NICs that vSphere shows as "down." Select the first of the available four NICs that vSphere does not show as "down" in the Speed column. Click Next.
7. Assign a label to the network. Click Next.
8. Enter a valid IP address and subnet. Click Next.
9. Click Finish.
10. Click No when the application prompts you to enter a default gateway.
11. Click the Configuration tab.
12. Click Storage Adapters under Hardware pane.
13. Click iSCSI Software Adapter. Then, click Properties.
14. Click Configure.
15. Click Enabled.
16. Click OK.
17. After the application enables the device, click the Static Discovery tab.
18. Click Add.
19. Enter the IP address of the storage group. Additionally, enter the initiator target name for the large LUN you will use for operating system virtual disks, which is accessible from the Dell EqualLogic Group Manager web application.
20. Click Close.
21. Click Yes when the application prompts you to rescan for changes.

Adding the OS storage LUN as a datastore to ESX storage

1. In vSphere, click the Configuration tab.
2. Click Storage in the Hardware pane.
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.

Setting up the iSCSI NICs with vSphere

1. Click the Configuration tab.
2. Click Networking.
3. Click Add Networking.
4. Click Virtual Machine.
5. Choose to Create a virtual switch. Assign the relevant NIC in the system. Click Next.
6. Assign a network name.
7. Click Finish.
8. Repeat steps 1 through 7 once more.

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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 to utilize build 148592 of ESX. Click Next.
9. Choose Microsoft Windows, then Microsoft Windows Server 2008 (64-bit). Click Next.
10. Choose two virtual processors. Click Next.
11. Choose 12800MB RAM. Click Next.
12. Click None for the number of NICs. Click Next.
13. Choose LSI Logic SAS as the SCSI controller. Click Next.
14. Choose to create a new virtual disk. Click Next.
15. Make the OS virtual disk size 30 GB, 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. Choose Ethernet Adapter, and click Next.
21. Choose VMXNet 3, and click Next.
22. Repeat steps 19 through 21 twice more to add the iSCSI dedicated NICs.
23. Click Finish, and click OK.

Installing the guest operating system
1. Insert the installation DVD for Windows Server 2008 x64 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. Choose the language, time and currency, and keyboard input. Click Next.
8. Click Install Now.
9. Choose Windows Server Enterprise (Full Installation). Click Next.
10. Accept the license terms, and click Next.
11. Click Custom.
12. Click the Disk, and click Drive options (advanced).
13. Click New, Apply, Format, and then click Next.
14. Let the installation process continue. The VM will reboot several times.
15. After the installation completes, click OK to set the Administrator password.
16. Enter the administrator password twice, and click OK.
17. When the operating systems finishes booting, choose VM, Guest, Install/Upgrade VMware Tools.
18. On the information Install VMware Tools screen, click OK.
19. On the autoplay menu, click Run setup.exe.
20. On the Welcome screen, click Next.
21. On the Setup Type screen, choose Typical, and click Next.
22. Click Install.
23. On the various Windows Security screens, click Install each time.
24. Click Finish to complete the installation.
25. Click Yes to reboot the VM.
26. Log into the VM after reboot.
27. Click Start, Control Panel, and double-click System.
28. Click Change Settings.
29. Click Change.
30. Enter the new computer name, and click OK.

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31. Click OK to restart, click Close, and click Restart Now.

Configuring networking in the VM
1. Power on the VM, and open the console.
2. Click Start, Control Panel, Network Connections, and click Manage Network Connections.
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. Repeat steps 2 through 5 twice more, but these NICs should be on the same network segment as the Dell EqualLogic storage.

Installing the Host Integration toolkit on the VM
1. Download the host integration toolkit (Setup64.exe).
2. Double-click Setup64.exe.
3. Accept the security warnings, and choose to run the EXE.
4. Click Next.
5. Click Accept, then Next.
6. Click Typical, then Next.
7. You will see a Windows Firewall warning; leave it open for a minute.
8. Click the Start button, and choose Administrative Tools→Windows Firewall with Advanced Security.
9. In the left panel, click Inbound Rules.
10. In the center Inbound Rules panel, right-click iSCSI Service (TCP-In), and choose Enable Rule.
11. In the center Outbound Rules panel, right-click iSCSI Service (TCP-In), and choose Enable Rule.
12. Close the Windows Firewall dialog.
13. Clear the message box.
14. Click Install.
15. Click Yes to install multipath software automatically.
16. Choose to restart the VM when the application prompts you to do so.

Installing Windows updates
1. Power on the VM, and open the console.
2. Log into the VM.
3. Click Start, Windows Update.
4. Click View Advanced Options.
5. Click Never Check for Updates.
6. Click OK.
7. Click Check for Updates.
8. Click Install Now when the application prompts you to install an update for Windows update.
9. Click View available updates to ensure you install the necessary updates.
   Note: We installed the following updates:

   - Hotfix for Windows (KB942288)
   - Microsoft .NET Framework 3.5 Service Pack 1 and .NET Framework 3.5 Family Update (KB951847) x64
   - Security Update for Windows Server 2008 x64 Edition (KB958687)
   - Update for Windows Server 2008 x64 (KB957388)
   - Security Update for Windows Server 2008 x64-based Systems (KB938464)
   - Update for Windows Server 2008 x64 Edition (KB949189)
   - Security Update for Windows Server 2008 x64 Edition (KB955069)
   - Security Update for Windows Server 2008 x64 Edition (KB954459)
   - Security Update for Windows Server 2008 x64 Edition (KB957097)
   - Security Update for Windows Server 2008 x64 Edition (KB958690)
   - Cumulative Security Update for Internet Explorer 7 for Windows Server 2008 x64 Edition (KB963027)
   - Security Update for Windows Server 2008 x64 Edition (KB960803)
   - Security Update for Windows Server 2008 x64 Edition (KB958623)

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- Update for Windows Server 2008 x64 Edition (KB959130)
- Update for Windows Server 2008 x64 Edition (KB957200)
- Security Update for Windows Server 2008 x64 Edition (KB953733)
- Security Update for Windows Server 2008 x64 Edition (KB950762)
- Windows Malicious Software Removal Tool x64 – April 2009 (KB890830)
- Update for Windows Server 2008 x64 Edition (KB955839)
- Security Update for Windows Server 2008 x64 Edition (KB958624)
- Security Update for Windows Server 2008 x64 Edition (KB950974)
- Update for Windows Server 2008 x64 Edition (KB951978)
- Update for Windows Server 2008 for x64-based Systems (KB955020)
- Security Update for Windows Server 2008 x64 Edition (KB956572)
- Security Update for Windows Mail for Windows Server 2008 x64 Edition (KB951066)
- Update Rollup for ActiveX Killbits for Windows Server 2008 x64 Edition (KB960715)
- Security Update for Windows Server 2008 x64 Edition (KB960225)
- Security Update for Windows Server 2008 x64 Edition (KB956802)
- Update for Windows Server 2008 x64 Edition (KB957321)
- Update for Windows Server 2008 x64 Edition (KB952287)
- Security Update for Windows Server 2008 x64 Edition (KB958644)
- Security Update for Windows Server 2008 x64 Edition (KB959426)
- Security Update for Windows Server 2008 x64 Edition (KB952004)
- Security Update for Windows Server 2008 x64 Edition (KB951698)
- Update for Windows Server 2008 x64 Edition (KB950050)
- Cumulative Security Update for ActiveX Killbits for Windows Server 2008 x64 Edition (KB950760)
- Update for Windows Server 2008 x64 Edition (KB955302)
- Windows Update Agent 7.2.6001.788

10. Click Install.
11. Agree to the license terms, and click Finish.
12. Reboot the VM when the application requests you do so.
13. After reboot, check Windows update again for further updates. Click Start, Windows Update.
14. Click Check for updates.
15. If Windows lists no important updates, then close the updates window.

Installing SQL Server 2008 on the VM
1. Insert the DVD into the physical DVD drive.
2. Right-click the VM, and choose Power, Power On.
3. Right-click the VM, and choose Open Console.
4. Click the Connect CD/DVD button. Choose CD/DVD Drive 1, Connect to host device…
5. Click Run SETUP.EXE on the AutoPlay menu.
6. If the application prompts you to install the .NET Framework, click OK.
7. Select the Accept radio button, and click Install.
8. When the installation finishes, click Exit.
9. If the application prompts you, click OK to install a hotfix for Windows (KB942288).
10. Click Restart now to restart the server upon completion.
11. After rebooting, log into the server.
12. Click Start, and click Computer.
13. Double-click the CD/DVD drive.
14. Click Installation.
15. Click New SQL Server stand-alone installation.
16. On the Setup support rules screen, click OK.
17. Specify the Enterprise Evaluation free edition. Click Next.
18. Click the checkbox to accept the license terms. Click Next.
19. Click Install to install the setup support files.
20. You may see a Windows Firewall warning. For now, ignore this, and click Next.
21. On the Feature Selection screen, select Database Engine Services, Full-Text Search, Client Tools Connectivity, Client Tools Backward Compatibility, Management Tools –Basic, and Management Tools – Complete. Click Next.

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22. On the Instance configuration screen, leave the default selection of default instance, and click Next.
23. On the Disk space requirements screen, click Next.
24. On the Server configuration screen, choose NT AUTHORITY\SYSTEM for SQL Server Agent, and choose NT AUTHORITY\SYSTEM for SQL Server Database Engine. Click Next.
25. On the Database Engine Configuration screen, select Mixed Mode.
26. Enter a password for the system administrator account.
27. Click Add Current user. This may take several seconds.
28. Click Next.
29. On the Error and usage-reporting screen, click Next.
30. On the Installation rules screen, click Next.
31. On the Ready to Install screen, click Next.
32. After installation completes, click Start, All Programs, Microsoft SQL Server 2008, Configuration Tools, SQL Server Configuration Manager.
33. Expand the Network Configuration node, and select the relevant instance.
34. In the right pane, right-click TCP/IP, and choose Enable.
35. In the left pane, click SQL Server Services.
36. In the right pane, right-click the SQL Server service, and select Restart.
37. Click Start, Administrative Tools, and Local Security Policy.
38. Double-click Perform Volume Maintenance Tasks, and add the System account.
39. Double-click Lock Pages in Memory, and add the System account.
40. Create a SQL Server login for the ds2user (see the DVD Store setup section below for the specific script to use).
41. Place the DVD Store backup file you prepared in the default location for SQL Server: C:\Program Files\Microsoft SQL Server\MSSQL10.MSSQLSERVER\MSSQL\Backup.

Installing SQL Server 2008 SP1
Service Pack 1 is available for download from
http://www.microsoft.com/downloads/details.aspx?FamilyID=66ab3dbb-bf3e-4f46-9559-ccc6a4f9dc19&displaylang=en.

1. Run SQLServer2008SP1-KB968369-x64-ENU.exe.
2. On the Welcome screen, click Next
3. On the License terms screen, accept the license terms, and click Next.
4. On the Features screen, select available features, and click Next.
5. On the Check files in use screen, click Next.
6. On the Update screen, click Next.
7. When the update completes, click Next, and click Close.

Adding an additional virtual drive to the VM via vSphere for SQL Server transaction logs
1. Power off the VM, right-click and choose Edit Settings.
2. Click Add.
3. Choose Hard Disk, and click Next.
4. Choose Create a new virtual disk, and click Next.
5. Choose 5GB for the size and select Specify a datastore. Click Browse.
6. Select the internal volume SQL Server log datastore. Click OK.
7. Click Next.
8. Click Next.
9. Click Finish.
10. Click OK.

Adding two additional drives to the VM for SQL Server data via the iSCSI initiator
1. Power on the VM, and open the console.
2. Click Start, Control Panel, and double-click iSCSI Initiator.
3. Click the Discovery tab.
4. Click Add Portal…
5. Add the IP address of the Dell EqualLogic storage group.

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6. Click OK.
7. Click the Targets tab.
8. Find the two relevant SQL Data volumes for this VM, and select it. Click Log On…
9. Check the checkbox to allow automatic logon on reboot, and to also enable multipath.
10. Click OK.

Configuring additional virtual disks in Disk Management inside the VM
1. Inside the VM, click Start, Administrative Tools, Computer Management.
2. Click Disk Management.
3. Right-click the uninitialized disks (if any), and choose Initialize Disk.
4. Choose MBR.
5. Right-click the SQL Server log volume, and choose New Simple Volume. Click Next.
6. Keep the default drive space, and click Next.
7. Keep the default drive letter assignment, and click Next.
8. Choose NTFS, 64KB allocation unit size, and check the Perform a quick format checkbox. Click Next.
9. Click Finish.
10. Create the folders necessary for the database log. 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 the host server
After installing and configuring the initial VM, we created the additional VMs through automated cloning scripts.

Cloning the VMs
We used a shell script on the ESX Server to copy the Virtual Disks, and to clone the VMs. This shell script copied the VM definition and virtual disks, and registered the new VM in ESX, using the vmware-cmd utility. Using these automated cloning scripts saved time and let us confirm that we configured all VMs similarly.

Configuring the additional VMs after cloning
1. In vSphere, expand the host, and click the VM.
2. Click the console tab.
3. Start the VM by right-clicking the VM, and choosing Power →Power On.
4. Click Start→Control Panel→Network and Internet→Network Connections, and double-click the Local Area Connection.
5. Select Internet Protocol Version 4 (TCP/IPv4), and click Properties.
6. In the Internet Protocol Version 4 (TCP/IPv4) Properties screen, select the Use the following IP address radio button.
7. Enter a valid static IP address for this new VM, subnet mask, and default gateway.
8. Select the Use the following DNS server addresses radio button, and enter at least one valid DNS server, if the application requires you to do so.
9. Click OK, and click Close to exit.
10. Click Start→Control Panel→System.
11. Click Change Settings to change the computer name.
12. Click the Change button.
13. Enter the new computer name.
14. Click OK, and click OK again.
15. Reboot the VM as prompted.

Setting up and configuring the HP DL385 server and HP Modular Smart Array 30 storage
We installed a fresh copy of Windows Server 2003 R2 Enterprise Edition with Service Pack 2 on the HP ProLiant DL385.

We installed four internal drives in the HP DL385. We attached the 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 single port I/O module, so all SCSI traffic flowed through the one cable.

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We configured the internal drives in two RAID 1 volumes, with two disks per volume. The MSA30 contained 14 146GB 10,000 RPM drives. We configured MSA30 in a RAID 10 array for all 14 drives, resulting in approximately a 1TB drive at the operating system level.

We installed Windows Server 2003 R2 Enterprise Edition and SQL Server 2005 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.

Setting up the external storage
We configured the MSA30 storage 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 Enterprise Edition with Service Pack 2
1. Boot the server, and insert the Windows Server 2003 R2 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. Click Start, Run, and type `notepad c:\boot.init`
18. To enable the 3GB switch, type this text at the end of the last line in the INI file: `/3GB`

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.

Installing system updates in Windows Server 2003 R2 Enterprise Edition
- Update for Windows Server 2003 (KB961118)
- Microsoft .NET Framework 3.5 Service Pack 1 and .NET Framework 3.5 Family Update (KB951847)
- Security Update for Microsoft XML Core Services 6.0 Service Pack 2 (KB954459)
- Security Update for Internet Explorer 7 for Windows Server 2003 (KB938127)
- Security Update for Windows Server 2003 (KB923561)
- Windows Malicious Software Removal Tool - April 2009 (KB890830)
- Cumulative Security Update for Internet Explorer 6 for Windows Server 2003 (KB963027)
- Security Update for Windows Server 2003 (KB959426)
- Security Update for Windows Server 2003 (KB960803)
- Security Update for Windows Server 2003 (KB952004)
- Security Update for Windows Server 2003 (KB956572)
- Security Update for Windows Server 2003 (KB961373)
- Update for Windows Server 2003 (KB967715)
- Security Update for Windows Server 2003 (KB958690)
- Security Update for Windows Server 2003 (KB938464)
- Security Update for Windows Server 2003 (KB960225)
- Update Rollup for ActiveX Kill Bits for Windows Server 2003 (KB960715)
- Security Update for Windows Server 2003 (KB958687)
- Security Update for Windows Server 2003 (KB956803)
- Security Update for Windows Server 2003 (KB925902)
- Update for Windows Server 2003 (KB955839)
- Security Update for Windows Server 2003 (KB956802)
- Security Update for Windows Server 2003 (KB954600)
- Security Update for Windows Server 2003 (KB952069)
- Security Update for Windows Server 2003 (KB957097)
- Security Update for Windows Server 2003 (KB955069)
- Security Update for Windows Server 2003 (KB958644)
- Security Update for Windows Server 2003 (KB944338)
- Security Update for Windows Server 2003 (KB950974)
- Security Update for Windows Server 2003 (KB952954)
- Security Update for Outlook Express for Windows Server 2003 (KB951066)
- Security Update for Windows Server 2003 (KB951748)
- Security Update for Windows Server 2003 (KB950762)
- Cumulative Security Update for ActiveX Killbits for Windows Server 2003 (KB950760)
- Security Update for Windows Server 2003 (KB945553)
- Update for Windows Server 2003 (KB948496)
- Security Update for Windows Server 2003 (KB943055)
- Security Update for Windows Server 2003 (KB946026)
- Security Update for Windows Server 2003 (KB941569)
- Security Update for Windows Server 2003 (KB944653)
- Security Update for Windows Server 2003 (KB943460)
- Windows Internet Explorer 7 for Windows Server 2003
- Security Update for Windows Server 2003 (KB933729)
- Security Update for Microsoft .NET Framework, Version 1.1 Service Pack 1 (KB933854)
- Security Update for Windows Server 2003 (KB938127)
- Security Update for Windows Server 2003 (KB936782)
- Security Update for Windows Server 2003 (KB926122)
- Security Update for Windows Media Player 6.4 (KB925398)
- Cumulative Security Update for Outlook Express for Windows Server 2003 (KB929123)
- Security Update for Windows Server 2003 (KB924667)
- Update for Windows Server 2003 (KB927891)
- Security Update for Windows Server 2003 (KB932168)

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- Security Update for Windows Server 2003 (KB930178)

Connecting the storage to the host
We attached the database volume on the MSA30 storage to the HP ProLiant DL385 server by using a SCSI cable connected from the Smart Array 6400 Controller in the server to the SCSI connector on the back of the MSA30.

Adding additional drives to the server 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, then repeat steps 3 through 7, choosing all 14 drives on the external MSA30 array.
9. Click Start, Run, type cmd and press Enter.
10. Type diskpart
11. Type list disk
12. Type select disk # (where # is the disk number of the internal volume).
13. Type create partition primary align=128. This aligns the partition with the default stripe size of the RAID volume. The default stripe size when using the HP storage controller was 128 KB.
14. Repeat steps 11 through 13, substituting the disk number of the external MSA30 volume this time.
15. Exit the command prompt.
16. Click Start, Administrative Tools, Computer Management.
17. Click Disk Management.
18. Right-click the first unallocated volume, and choose Change Drive letter and path. Select the drive letter.
19. Right-click the volume, and select Format. Choose 64KB allocation unit size, NTFS file system, select Perform Quick Format, and press OK.
20. Repeat steps 18 and 19 for the external MSA30 volume.
21. Create the folders necessary for the database. We used <driveletter>:\SQLData for the SQL Server database volume and <driveletter>:\SQLLog for the SQL Server transaction log volume.

Installing SQL Server 2005 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.
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, 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.

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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-8ae5-949fdfbe59c4&displaylang=en.
1. Run SQLServer2005SP3-KB955706-x86-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
```

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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 for SQL Server 2008, and then used those master copies to restore our test database to the HP ProLiant DL385 solution and Dell PowerEdge R710 solution between each test run. We stored the backup file on the C: drive of each server 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
```

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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 R710 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 and SQL Server 2008.
- In the case of SQL Server 2008, we added the FORCESEEK hint in the BROWSE_BY_ACTOR stored procedure because in initial testing we found that SQL Server 2008 was choosing an index scan instead of the preferred index seek, adding unnecessary overhead. This problem was not evident 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.

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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. We stored batch files either under the C:\ServerShare folder on each server or under the C:\ClientShare folder on the clients, and we used the PsExec utility to coordinate the test procedures amongst the client machines, server 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 to clean up prior outputs on client machines, the server machine, 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 reboot the server.
5. The scripts reboot the client machines and server machine, and wait for a ping response from all test machines.
6. 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 an Extech Instruments (www.extech.com) 380803 Power Analyzer/Datalogger. We connected the power cord from the server under test to the Power Analyzer's output load power outlet. We then plugged the power cord from the Power Analyzer's input voltage connection into a power outlet. For the storage arrays, we used a second Power Analyzer, but connected it the same way as we connected the server.

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

To gauge the idle power usage, we recorded the power usage for 2 minutes while each system was running the operating system, but otherwise idle, meaning the system was not running any test workload. To ensure the system was idle, we allowed the system to sit for 10 minutes after booting to the desktop before starting the 2 minutes of idle power capture.

We then recorded the power usage (in watts) for each system during the testing at 1-second intervals. To compute the average power usage, we averaged the power usage during the time the system was producing its peak performance results. Because we measured the power of the server and storage separately, we added the average power of both together to get the total power. We call this time the power measurement interval. See Figure 7 (idle and workload power results) for the results of these measurements.

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Appendix A – Test server information

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

Servers	Dell PowerEdge R710	HP ProLiant DL385 G1
General dimension information		
Height (inches)	3.5	3.4
Width (inches)	17.0	17.5
Depth (inches)	27.0	26.0
U size in server rack (U)	2	2
Power supplies		
Total number	2	2
Wattage of each (W)	870	575
Cooling fans		
Total number	5	7
Dimensions (H x W) of each	2.5" x 2.5"	2.5" x 2.5"
Voltage (V)	12	12
Amps (A)	1.60	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	Balanced	Always On
CPU		
Vendor	Intel	AMD
Name	Xeon X5550	Opteron 254
Stepping	D0	E4
Socket type	LGA1366	Socket 940
Core frequency (GHz)	2.66	2.80
L1 cache	32 KB + 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 R710	HP ProLiant DL385 G1
Motherboard model number	PWBYN967	4K0585
Motherboard revision number	X08	F01
BIOS name and version	Dell 0.2.15	HP A05
BIOS settings	Enabled Virtualization Technology	Default
Memory modules		
Total RAM in system (GB)	96	4
Number of types of memory modules	1	1
Vendor and model number	Samsung M393B1K70BH1-CF8	MT18VDDF1282Y

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Servers	Dell PowerEdge R710	HP ProLiant DL385 G1
Type	PC3-8500 DDR3	PC-3200 DDR
Speed (MHz)	1,066	400
Speed in the system currently running @ (MHz)	800	400
Timing/latency (tCL-tRCD-iRP-tRASmin)	6-6-6-18	3-3-3-8
Size (GB)	96	4
Number of RAM modules	12 x 8 GB	4 x 1 GB
Chip organization	Double-sided	Double-sided
Hard disk		
Vendor and model number	Seagate ST973451SS	HP BD07285A25
Number of disks in system	4	4
Size (GB)	73	72.8
Buffer size (MB)	16	8
RPM	15,000	15,000
Type	SAS	SCSI
Operating system		
Name	ESX Build 148592	Windows Server 2003 R2 Enterprise
Build number	148592	3790
File system	VMFS3	NTFS
Language	English	English
Network card/subsystem		
Vendor and model number	Broadcom 5709c NetXtreme II	Broadcom BCM5704 NetXtreme Gigabit Ethernet
Type	Integrated	Integrated
Optical drive		
Vendor and model number	TEAC DV-28S-VDB	Compaq SN-124
USB ports		
Number	4	3
Type	2.0	1.1

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

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Appendix B – Test storage information

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

Enclosure	Dell EqualLogic PS6000XV	HP StorageWorks MSA30
General dimension information		
Height (inches)	5.25	5.20
Width (inches)	19.0	19.0
Depth (inches)	21.5	20.5
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	12.5
Amps (A)	1.8	2
Hard disk		
Vendor and model number	Seagate ST3450856SS	HP BD1468856B, BD14686225, BD146863B3
Number of disks in system	16	12 x BD1468856B, 1 x BD14686225, 1 x BD146863B3
Size (GB)	450	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	v4.1.1	Model/ N/A
Storage cache (GB)	1	N/A
Number of storage controllers	2 (1 active)	1
Number of storage ports	4 per controller	1
Maximum Network bandwidth of storage connectivity to host	1 Gb x 4	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.

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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 R710 solution. The investment costs include the following:

- Intel Xeon Processor X5550-based Dell PowerEdge R710 server with 96 GB of memory and two four-core processors. The list price for this server is $16,152.
- Dell™ EqualLogic™ PS6000XV storage with 16 450GB 15,000 RPM disks. The list price of the storage array is $55,000. We assign half ($27,500) of the storage array costs to this solution based on the assumption that the array is a resource that can be shared with other workloads.
- Migration costs. We assume a migration cost of $905, based on our estimate of 12 person hours required for planning and migration tasks at a burdened hourly rate of $55.61, totaling $667, and a prorated VMware training cost of $238 for the server administrator.

Figure 10 shows the payback calculation for the Dell PowerEdge R710 solution and the seven HP ProLiant DL385 solutions.

	HP ProLiant DL385 solutions	Dell PowerEdge R710 solution	Difference
One-time initial investment (includes server, storage hardware, and migration costs)	$0.00	$44,556.55	$44,556.55 (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)	$3,413.67	$879.31	$2,534.36 (Dell PowerEdge R710 is lower)
Payback period	17.6 months ($44,556.55/$2,534.36=17.6)		

Figure 10: Payback calculation for the Dell PowerEdge R710 solution and the seven HP ProLiant DL385 solutions.

The server and storage hardware costs for the Dell PowerEdge R710 solution included the list price of the Dell PowerEdge R710 server and the list price of the Dell EqualLogic PS6000 storage solution multiplied by the 50 percent of that solution that the test databases require. For the HP ProLiant DL385 solution server, 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 R710 server to the tasks that the servers it was replacing carried out; we therefore included the entire cost of the newer Dell PowerEdge R710 server in our analysis.
- As they were in our tests, the log files would be on two internal disks on each server.
- Other servers in the data center would share the storage in the Dell PowerEdge R710 solution and the enterprise would apportion storage costs based on the percentage of the storage solution used. We estimated that the high-demand DS2 workload we used in our cost calculations would use less than 10 percent of the storage capacity of the Dell EqualLogic PS6000 storage solution but would require most of the IOPS capacity of the storage during peak load. Balancing the available storage and IOPS, we estimated that half the storage capacity would be available for low-demand storage or for off-hours processing.
- The enterprise would dedicate both the HP ProLiant DL385 solution servers and 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 solution to the newer solution.

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

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- 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 R710 solution, 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 3 to show the year-one cost.
- For the HP ProLiant DL385 solution, 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 R710 solution.

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

- The HP ProLiant DL385 solution 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 solution updated the operating system to Windows Server 2008 Enterprise Edition license by upgrading some of the licenses used by the HP ProLiant DL385 solution.
- The newer solution updated the SQL Server software to SQL Server 2008 Standard Edition by upgrading some of the licenses used by the HP ProLiant DL385 solution.
- The enterprise used their Software Assurance new version rights to upgrade the licenses they needed for the newer solution. 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; thus, they fell outside the scope of the solution.
- Costs include VMware vSphere 4 Advanced with a list price of $2,245 per processor and VMware vSphere 4 Advanced SnS at $472 per year. The enterprise spreads the cost of VMware vSphere 4 Advanced license over three 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 solution used. The older HP ProLiant DL385 solution requires 5u for each of the nine server-and-storage-array pairs, for a total of 45u; by contrast, the single Dell R710 solution consumes only 5u.
- We estimated an annual per-enclosure cost for data center ports of $179 based on PT experience.

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.
- Average cost per kWh of power. Source: National commercial average for December 2008 from http://www.eia.doe.gov/cneaf/electricity/epm/table5_6_a.html. The December average was $0.995. We rounded up to $0.10 to allow for rising prices.
- 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.

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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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