

# CLOUD STUDY: DELL EMC & VMWARE HYBRID CLOUD SOLUTION COMPARED TO A PUBLIC CLOUD-ONLY APPROACH



Save money over five years, maintain flexibility, and retain control of applications and data with an on-premises Dell EMC and VMware hybrid-ready cloud

UP TO  
**45% LOWER**  
**FIVE-YEAR TCO**

Cloud computing has become the norm for today's businesses. Those that aren't in the cloud yet are looking to offer some sort of cloud service soon to their users.<sup>1</sup> Some companies are intimidated by the investment and training needed to host an on-premises hybrid cloud, but choosing this path over a public cloud-only approach can actually save money while letting the company maintain complete control over data and applications to achieve the right balance of public and private cloud capability. Your business can see positive effects from an investment in even a few server nodes and storage modules that serve as the foundation for an on-premises hybrid cloud and can rapidly scale as demand increases.

At Principled Technologies, we created and ran an on-premises Dell EMC™ and VMware hybrid-ready cloud supporting 22 database virtual machines (VMs) to contrast and compare to a comparable public cloud-only option. We found that implementing this solution and managing the hardware could cost less over five years than running 22 similar Amazon Web Services (AWS) Elastic Cloud Computing (Amazon EC2) database instances. The Dell EMC hybrid cloud lets you keep control of your critical workloads and most sensitive data on site, while giving you the option to leverage a public cloud when necessary. This combination of performance, security, and flexibility can help your organization lower its bottom line while meeting demand.

<sup>1</sup> Of the more than 1,000 North American and European enterprise infrastructure technology decision-makers recently questioned by Forrester Research, roughly 30 percent plan to implement some form of cloud technology in the next 12 months: [www.cio.com/article/3137946/cloud-computing/6-trends-that-will-shape-cloud-computing-in-2017.html](http://www.cio.com/article/3137946/cloud-computing/6-trends-that-will-shape-cloud-computing-in-2017.html)



## MAINTAINING CONTROL WHILE AVOIDING BUDGET OVERAGES

IT budgets often have little flexibility. Unexpected usage out of the purview of IT can exceed allotted funds and hurt an organization's bottom line. An example of this is shadow IT operations where users venture to the public cloud for infrastructure-as-a-service (IaaS). Companies can find themselves overpaying each month because they haven't optimized this public cloud usage.

In addition, the pricing and tiering of public cloud usage can be very hard to understand and without proper governance and control, costs can change unexpectedly. Navigating the multiple hardware, performance, and billing options can make budgeting a challenge. We analyzed two different AWS payment options and the significant cost difference between them exemplifies the kinds of disparities in public cloud pricing that are not always readily apparent.

The Dell EMC hybrid cloud can give your users, including developers who run test/dev projects, the managed virtual resources they need in an on-demand, on-premises, flexible environment that can make budgeting easier. A hybrid approach also allows for much tighter control over data and applications to provide the right cloud capability at the right cost for the organization. Your CIO gets a more comprehensive view of the IT budget and your organization avoids any unexpected IT costs related to public cloud usage. Plus, you can clearly define the cost of the Dell EMC hardware and VMware software in your IT budget, so the financial side of your business can plan precisely how to pay for your hybrid cloud.

In addition to helping you stick to your IT budget, the Dell EMC hybrid cloud lets your business:

- Keep your data on premises to address security, compliance, and performance concerns for critical applications
- Continue using familiar VMware virtualization tools such as VMware vSphere® and VMware vRealize Suite cloud management platform to help create and deliver on-demand datacenter resources
- Retain control of data, which database admins can manage on site
- Leverage public cloud resources to meet requirements of data and applications that are best suited to an off-premises model

This study demonstrates how a flexible hybrid and multi-cloud model can be the right choice to achieve cloud benefits.

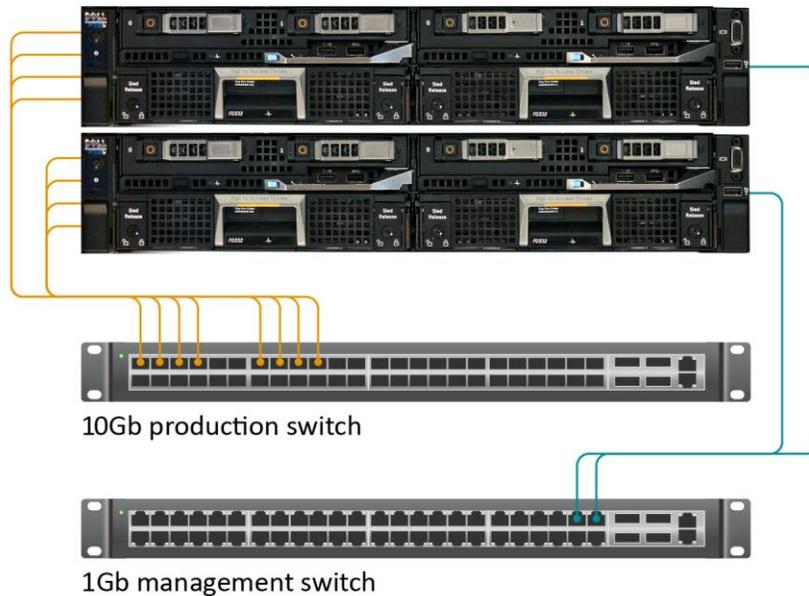
## A LOOK AT OUR PERFORMANCE TESTING

Before calculating the total cost of ownership (TCO) for our on-premises Dell EMC hybrid cloud solution and the Amazon EC2 public cloud environment, we needed to determine the size and number of the virtual machines the two solutions would support. Establishing equivalent performance between the two solutions was necessary for us to fairly generate comparable costs.

We chose an online transaction processing (OLTP) workload to determine an acceptable baseline level of database application performance that VMs in both cloud environments could equally support. We first configured a single Amazon EC2 instance (or VM) with Windows Server® 2012 R2 and SQL Server® 2016 Standard edition. The single instance achieved a total of 33,000 orders per minute (OPM).

We then set out to determine how many similarly configured VMs our Dell EMC PowerEdge™ FX2 solution could support at this same level of performance. We used Windows Server 2012 R2 for the host and guest operating systems, SQL Server 2016 Standard edition for the database software, and VMware vCloud Suite® standard for cloud management. Figure 1 shows our test hardware configuration.

2x Dell EMC PowerEdge FX2s, each with 2x Dell EMC PowerEdge FC630 servers and 2x Dell EMC PowerEdge FD332 storage blocks



**Figure 1: The Dell EMC solution network diagram.**

With the Dell EMC hybrid cloud solution, we scaled out the number of VMs until the number of OPM that each VM achieved fell below the threshold of 33,000. This occurred at 23 VMs. This meant that with 22 VMs on our Dell EMC-powered hybrid cloud, each VM could perform the database work equivalent to that of a single AWS EC2 instance. Based on that finding, we compared the costs of the Dell EMC solution to the costs of running 22 AWS EC2 instances.

To create our database workload, we used the DVD Store Version 2.1 (DS2) benchmarking tool, which models an online DVD store and its database. DS2 has a back-end database component, a front-end web application layer, and a driver layer that executes the workload. For detailed system information, see [Appendix A](#). For complete details on what we tested, see [Appendix B](#). For complete details on how we tested, see [Appendix C](#).

## SAVE MONEY WITH AN ON-PREMISES VMWARE HYBRID CLOUD FROM DELL EMC

After configuring the 22 VMs on four Dell EMC PowerEdge FC630 server modules to provide the same expected performance as the public cloud provider VMs, we set out to determine the estimated five-year TCO for each solution. As we mentioned previously, the pricing structures for public cloud services can be complex and varied. We looked at two payment options for Amazon:

- **The 3 Year All Upfront Reserved billing option for the Amazon EC2 Reserved Instances with Amazon Elastic Block Store (EBS) storage volumes** requires a long-term commitment and a significant up-front capital expenditure. Compared to our On-Demand configuration, this approach offered lower costs over the five-year period. At the time of our analysis, this option was the longest commitment available that offered the overall best Amazon EC2 pricing.
- **Amazon EC2 On-Demand Instances with EBS storage volumes** is a pay-as-you-go approach that offers greater flexibility with no up-front capex cost. Avoiding this capex outlay may appeal to many customers.

Figure 2 outlines costs for both Amazon approaches and shows that purchasing and running the Dell EMC hybrid cloud solution could deliver as much as \$593,908 in savings—a 45 percent lower projected five-year TCO than using Amazon EC2 On-Demand Instances with EBS storage volumes for the 22 virtualized SQL Server 2016 instances.

Figure 2: The five-year TCO for the Dell EMC VMware-based hybrid cloud, the Amazon EC2 Reserved Instances with EBS storage volumes, and the Amazon EC2 On-Demand Instances with EBS storage volumes to host 22 VMs or instances. Lower numbers are better.

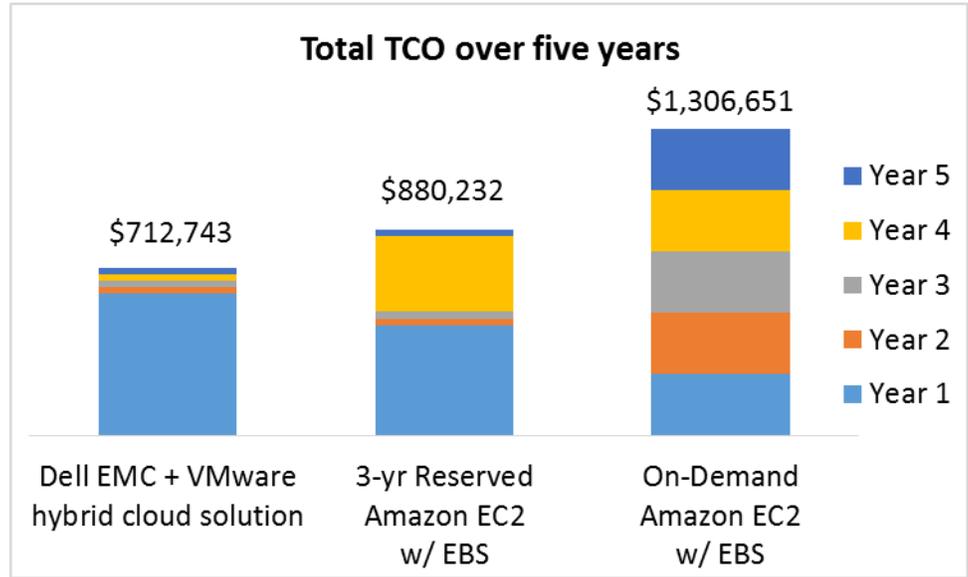


Figure 3 provides more detail on the yearly costs associated with the Amazon EC2 Reserved Instances solution. This option includes an up-front fee of \$441,138 to reserve the EC2 instances for a three-year period and monthly payments of \$2,416.70 (totaling \$29,000.40 per year).<sup>2</sup> We have included the full fee of \$441,138 for the first year and have pro-rated this fee for the fourth year (two-thirds of the three-year fee would cover years 4 and 5). The total five-year cost for this solution would be \$880,233. We included AWS Business Support costs, any reservation costs, and monthly subscriptions.

	Cost to reserve the instances	Ongoing costs	Total yearly costs
Year 1	\$441,138.00	\$29,000.40	\$470,138.40
Year 2		\$29,000.40	\$29,000.40
Year 3		\$29,000.40	\$29,000.40
Year 4	\$294,092.00	\$29,000.40	\$323,092.40
Year 5		\$29,000.40	\$29,000.40
<b>Total</b>	<b>\$735,230.00</b>	<b>\$145,002.00</b>	<b>\$880,232.00</b>

Figure 3: Five-year costs for our 22-instance scenario using the Amazon EC2 3 Year Reserved Instances solution.

<sup>2</sup> We based the Amazon EC2 projections on costs for a single instance multiplied by 22.

Although utilizing the All Upfront Reserved billing option produces the lowest possible cost for consuming the AWS services, many organizations may look to the public cloud to avoid up-front capex costs and select a more flexible option from AWS—the no-money-upfront, On-Demand billing option with no contract or time commitments. For those utilizing this pay-as-you-go option, the five-year cost estimate increases to \$1,306,651, 1.48 times as much as the total with All Upfront Reserved billing option. Figure 4 breaks down this total per year. Although there is no up-front cost, using this option for all 22 instances would cost \$21,777.52 per month assuming prices remain constant. These costs include AWS Business Support as well. The ongoing costs would be the yearly costs for this solution.

	Ongoing/total yearly costs
Year 1	\$261,330.24
Year 2	\$261,330.24
Year 3	\$261,330.24
Year 4	\$261,330.24
Year 5	\$261,330.24
<b>Total</b>	<b>\$1,306,651.20</b>

Figure 4: Five-year costs for our 22-instance scenario using the Amazon EC2 On-Demand Instances solution.

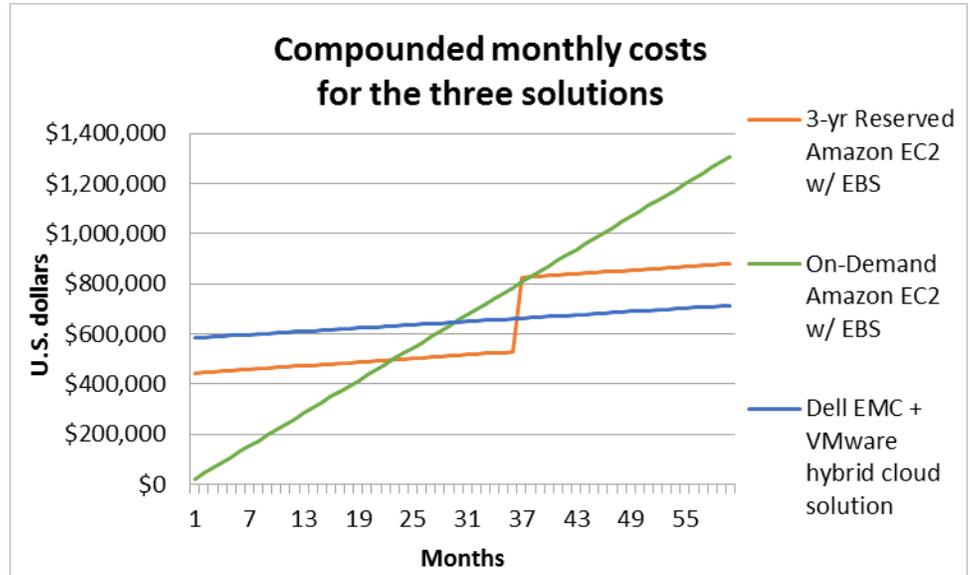
Figure 5 provides more detail on the yearly costs associated with the Dell EMC hybrid cloud solution. Our cost analysis included up-front acquisition costs for hardware, software, and Mission Critical support. However, after that investment, the yearly costs, which include datacenter space, power, and cooling; hardware administration; and other associated costs for only an on-premises hybrid cloud, are modest.

	Hardware, software, and support	Ongoing datacenter costs	Total yearly costs
Year 1	\$581,243.08	\$26,300.00	\$607,543.08
Year 2		\$26,300.00	\$26,300.00
Year 3		\$26,300.00	\$26,300.00
Year 4		\$26,300.00	\$26,300.00
Year 5		\$26,300.00	\$26,300.00
<b>Total</b>	<b>\$581,243.08</b>	<b>\$131,500.00</b>	<b>\$712,743.08</b>

Figure 5: Five-year costs for our 22-VM scenario using the Dell EMC and VMware solution.

Figure 6 shows the compounded monthly costs for the three solutions. For complete details of our TCO analysis, see [Appendix D](#).

Figure 6: The compounded monthly costs of the Dell EMC hybrid cloud, the Amazon EC2 Reserved Instances with EBS storage volumes, and the Amazon EC2 On-Demand Instances with EBS storage volumes supporting 22 VMs and instances. Lower numbers are better.



## CONCLUSION

Pooling and delivering resources on demand via the cloud offers a number of benefits to your users and organization. But for some businesses, the investment needed to host an on-premises hybrid cloud may be intimidating. We found that implementing a Dell EMC and VMware hybrid cloud featuring Dell EMC PowerEdge FC630 server modules and PowerEdge FD332 storage nodes in a PowerEdge FX2s chassis could save \$593,908 compared to running database applications in the Amazon EC2 public cloud. That’s a 45 percent lower five-year TCO for the Dell EMC hybrid cloud solution. In addition, you’ll be able to extend your VMware virtual environments to the public cloud. Having your own Dell EMC hybrid cloud can help your business meet data and application goals while implementing a sound strategy to leverage the benefits of off-premises cloud capability. This in turn can optimize your budget to control IT expenditures while meeting compliance, regulatory, and security requirements.

## APPENDIX A – SYSTEM CONFIGURATION INFORMATION

Figure 7 provides detailed configuration information for the Dell EMC PowerEdge FC630 server nodes.

System	Dell EMC PowerEdge FC630
<b>Platform</b>	
BIOS name and version	Dell EMC BIOS 2.1.7
Non-default BIOS settings	Virtualization enabled
OS and version/build number	Windows Server 2012 R2 SP1
Date of last OS update/patch applied	09/15/16
Power management policy	Performance
<b>Processor</b>	
Number of processors	2
Vendor and model	Intel® Xeon® E5-2690 v3
Core count (per processor)	12
Core frequency (GHz)	2.60
Stepping	M1
<b>Memory modules</b>	
Total memory in system (GB)	384
Number of memory modules	24
Vendor and model number	Samsung® M393A2G40DB0-CPB
Size (GB)	16
Type	PC4-17000
Speed (MHz)	2,133
Speed running in the server (MHz)	2,133
<b>Storage controller</b>	
Vendor and model number	Dell EMC PERC H730 mini
Firmware version	25.4.1.0004
Cache size (GB)	1
<b>Local storage</b>	
Vendor and model number	Dell EMC 0NWH7V
Number of drives	2
Size (GB)	300
RPM	15K
Interface	SAS
Type	HDD
<b>Network adapter</b>	
Vendor and model number	Intel X520/I350 rNDC
Number and type of ports	2 × 10Gbe, 2 × 1Gbe
Firmware version	17.5.10

Figure 7: Detailed configuration information for the Dell EMC PowerEdge FC630 server nodes.

Figure 8 provides detailed storage configuration information for the Dell EMC solution.

Storage configuration information	Dell EMC PowerEdge FX2 solution with VMware Virtual SAN™
<b>First drive type</b>	
Vendor and model number	Intel SSD DC S3710 SSDSC2BA80
Number of drives	8
Drive size (GB)	800
Drive type	6Gb SATA SSD
<b>Second drive type</b>	
Vendor and model number	Intel SSD DC S3510 SSDSC2BB01
Number of drives	8
Drive size (GB)	1,600
Firmware version	6Gb SATA SSD

Figure 8: Detailed storage configuration information for the Dell EMC solution.

Figure 9 provides detailed configuration information for the Dell EMC Networking N4032F switch.

Network switch configuration information	Dell EMC Networking N4032F
Firmware revision	1.0
Number and type of ports	24 × SFP+ 10GbE
Number and type of ports used in test	8 × SFP+ 10GbE
Non-default settings used	LAG, LACP

Figure 9: Detailed configuration information for the Networking N4032F switch.

## APPENDIX B – WHAT WE TESTED

### About the Dell PowerEdge FX2 enclosure

The shared infrastructure approach of the Dell PowerEdge FX2 enclosure is flexible, scalable, and can help you make the most of your datacenter space by maximizing density. The Dell PowerEdge FX2 enclosure has a standard 2U footprint and features a modular design that can hold different combinations of compute and storage nodes to meet your specific goals. The PowerEdge FX2 fits four half-width or eight quarter-width compute nodes to increase the compute density in your rack and optimize the space in your datacenter. You can deploy the FX2 solution like a traditional rack-mounted server while gaining the benefits and features that more expensive blade solutions provide. Important features of the FX2 enclosure include the following:

- Up to eight low-profile PCIe expansion slots
- Two pass-through or optional networking FN I/O Aggregator modules
- Embedded network adapters within the server nodes
- Offers both chassis-based management through the Chassis Management Controller and rack-based management through Integrated Dell Remote Access (iDRAC) with Lifecycle Controller on each compute node

The Dell PowerEdge FX2 enclosure fits a number of server and storage options, including the PowerEdge FM120, FC430, FC630, and FC830 servers, and PowerEdge FD332 storage node—all powered by Intel Xeon processors. For more information on Dell Solutions, including the Dell PowerEdge FX2, visit

<http://dell.to/enterprise>.

### About VMware vRealize Suite Cloud Management Platform

According to VMware, “VMware vRealize Suite is an enterprise-ready cloud management platform purpose-built for the hybrid cloud, delivering and managing infrastructure and applications quickly while maintaining IT control. It provides a comprehensive management stack for IT services on VMware vSphere® and other hypervisors, physical infrastructure, containers, OpenStack®, and external clouds such as VMware vCloud Air, Microsoft Azure®, and Amazon Web Services, all with a united management experience.”

For more information on VMware hybrid cloud, see

[www.vmware.com/content/dam/digitalmarketing/vmware/en/pdf/products/vrealize/vmware-vrealize-cloud-management-platform.pdf](http://www.vmware.com/content/dam/digitalmarketing/vmware/en/pdf/products/vrealize/vmware-vrealize-cloud-management-platform.pdf).

### About our test tool, DVD Store 2

DVD Store 2 (DS2) models an online DVD store, where customers log in, search for movies, and make purchases. DS2 reports these actions in OPM that the system could handle, to show what kind of performance you could expect for your customers. The DS2 workload also performs other actions, such as adding new customers, to exercise the wide range of database functions you would need to run your ecommerce environment. For more information about the DS2 tool, see [www.delltechcenter.com/page/DVD+Store](http://www.delltechcenter.com/page/DVD+Store).

## APPENDIX C – HOW WE TESTED

### Setting up the hardware and configuring the virtual infrastructure

We installed and configured VMware vSphere 6.0 U2 on the Dell EMC PowerEdge FX2 enclosure with FC630 servers using two 300GB drives on the Dell EMC PERC H730 Mini controller in a RAID1 configuration. We created an all-flash VMware Virtual SAN cluster using all four FC630 servers and configured each FC630 server to access four disk slots on the assigned FD332 storage block. We built two VSAN local-disk groups per server, and each disk group consisted of one 800GB SSD used as a caching device and one 1.6TB SSD used as a capacity drive. We also used the default VSAN storage policy, which uses the following settings:

- Number of failures to tolerate = 1
- Number of disk stripes per object = 1
- Object space reservation = 0%
- Flash read cache reservation = 0%
- Force provisioning = NO

We connected all four Dell EMC PowerEdge FC630 servers to a Dell EMC Networking S4032F switch. The controllers on the Dell EMC PowerEdge FD332 storage blocks were set up in pass-through/HBA mode to support the VSAN configuration.

We configured 22 SQL Server virtual machines, each with 16 GB of memory, four vCPUs, a 60GB drive for OS, and a 100GB drive for database files and database logs.

### Installing the cloud platform

#### Installing VMware ESXi™ 6.0 U2

1. Attach the installation media.
2. Boot the server.
3. At the VMware Installer screen, press Enter.
4. At the EULA screen, press F11 to Accept and Continue.
5. Under Storage Devices, select the appropriate virtual disk, and press Enter.
6. Select US as the keyboard layout, and press Enter.
7. Enter the root password twice, and press Enter.
8. Press F11 to start installation.
9. After the server reboots, press F2, and enter root credentials.
10. Select Configure Management Network, and press Enter.
11. Select the appropriate network adapter, and select OK.
12. Log into the server using the VMware vSphere client.
13. Select the Configuration tab, and click Networking.
14. Click Add Networking...
15. Create the Mgmt\_Net network for management.
16. Click Add Networking...
17. Create the PRIV\_NET network for private traffic.
18. Click Add Networking...
19. Create the Storage-Net network for storage traffic.
20. Select the configuration tab, and click Storage.
21. Click Add Storage, and add the necessary datastores to all available servers.
22. Click the Configuration tab, and select Time configuration to configure server time.
23. Click DNS and Routing, and confirm the settings.

### Creating a Windows Server 2012 R2 VM template for deployment

1. Add a server to an existing VMware vCenter® server's inventory.
2. In the VMware vSphere client, under Basic Tasks, select Create a new virtual machine.
3. Choose Custom, and click Next.
4. Assign the name `template vm` to the virtual machine, and click Next.
5. Select infrastructure as the host, and click Next.
6. Select the appropriate storage, and click Next.
7. Select Virtual Machine Version 11, and click Next.
8. Select Windows, select Microsoft Windows Server 2012 (64-bit), and click Next.
9. For CPUs, select one virtual processor socket and four cores per virtual socket, and click Next.
10. Choose 4 GB RAM, and click Next.
11. Click 1 for the number of NICs, select VMXNET3, connect to the PRIV-NET network, and click Next.
12. Leave the default virtual storage controller, and click Next.
13. Choose to create a new virtual disk, and click Next.
14. Make the OS virtual disk size 100 GB, choose thick-provisioned lazy zeroed, specify external storage, and click Next.
15. Keep the default virtual device node (0:0), and click Next.
16. Click Finish.
17. Connect the VM virtual CD-ROM to the Microsoft Windows Server 2012 R2 installation disk.
18. Start the VM.

### Installing Microsoft Windows Server 2012 R2 Datacenter Edition

1. When prompted to boot from DVD, press any key.
2. When the installation screen appears, click My language is English (United States).
3. Leave language, time/currency format, and input method as default, and click Next.
4. Click Install now.
5. When the installation prompts you, enter the product key.
6. Select Windows Server 2012 R2 Datacenter (Server with a GUI), and click Next.
7. Check I accept the license terms, and click Next.
8. Click Custom: Install Windows only (advanced).
9. Select Drive 0 Unallocated Space, and click Next, at which point Windows begins automatically and restarts automatically after completing.
10. When the Settings page appears, fill in the Password and Reenter Password fields with the same password.
11. Log in with the password you set up previously.
12. Install VMware Tools. For more information, see [kb.vmware.com/selfservice/microsites/search.do?language=en\\_US&cmd=displayKC&externalId=340](http://kb.vmware.com/selfservice/microsites/search.do?language=en_US&cmd=displayKC&externalId=340).
13. Reboot the server.

### Configuring Windows Update

1. In the left pane of the Server Manager window, click Local Server.
2. In the main frame, next to Windows Update, click Not configured.
3. In the Windows Update window, in the main pane, click Let me choose my settings.
4. Under Important updates, select Never check for updates (not recommended), and click OK.
5. In the left pane, click Check for updates, and install all available updates.
6. Close the Windows Update window.
7. Reboot the server when required.

### Converting VM into a template

1. Right-click the `template vm`, and select Template.
2. Select Convert to template.

## Deploying a VM to host Microsoft Active Directory® Domain Services

1. Select Inventory→VMs and Templates.
2. Right-click the `template vm` and select Deploy Virtual Machine from this Template...
3. Under the name field, type `DC1`, and select a server as the inventory and host location. Click Next.
4. Select the appropriate storage destination, and click Next.
5. Select Power on this virtual machine after creation.
6. Select Customize using an existing customization specification, and select one. Click Next.
7. Click Finish.
8. After the server reboots, log in using administrator credentials.
9. Click Start→Control Panel→Network Connections→View network status and tasks→Change adapter settings.
10. Right-click the PRIV-NET NIC, and select Properties.
11. Double-click Internet Protocol Version 4 (TCP/IPv4)
12. Select Use the following IP address, and set the appropriate IP address, Subnet mask, Default gateway and DNS server.
13. Click OK twice.

## Installing Active Directory Domain Services and DNS on DC1

1. Open Server Manager.
2. On the Welcome screen, click manage, and click Add roles and features.
3. At the initial Before you begin screen, click Next three times.
4. At the Server Roles screen, select Active Directory Domain Services.
5. On the pop-up window, click Add Features.
6. Click Next three times.
7. Verify the desired role is being installed, and click Install.
8. Once installation has finished, close the Add roles and features wizard.
9. In Server Manager, click the flag at the top, and select the Promote this server to a domain controller link.
10. Select Add a new forest, enter a root domain name of `test.local`, and click Next.
11. On the Domain Controller Options window, enter a password, and click Next.
12. On the DNS Options screen, click Next.
13. On the Additional Options screen, click Next.
14. On the Review Options screen, click Next.
15. On the Prerequisites screen, verify all prerequisites have passed, and click Install.
16. Once Active Directory Domain Services finishes installing, click Finish, and restart the system.

## Deploying vCenter Server Appliance 6.0

1. On a Windows server or VM, locate the installer image `VMware-VCSA-all-6.0.0-3634788.iso`.
2. Mount the image, navigate to the `vcsa` folder, and launch `VMware-ClientIntegrationPlugin-6.0.0.exe`.
3. In the wizard that appears, click Next.
4. Accept the terms of the license agreement, and click Next.
5. Leave the default installation directory, and click Next.
6. Click Install.
7. Click Finish.
8. In the mounted image's top directory, open `vcsa-setup.html`.
9. When prompted, click Allow.
10. Click Install.
11. Accept the terms of the license agreement, and click Next.
12. Enter the FQDN or IP address of the host onto which the vCenter Server Appliance will be deployed.
13. Provide a username and password for the system in question, and click Next.
14. Accept the certificate of the host you chose to connect to by clicking Yes.
15. Select the appropriate datacenter, and click Next.

16. Select the appropriate resource, and click Next.
17. Provide a name and password for the virtual machine, and click Next.
18. Select Install vCenter Server with an Embedded Platform Services Controller, and click Next.
19. Select Create a new SSO domain.
20. Provide a password, and confirm it.
21. Provide an SSO Domain name and SSO Site name, and click Next.
22. Set an appropriate Appliance Size, and click Next.
23. Select an appropriate datastore, and click Next.
24. Select Use an embedded database (PostgreSQL), and click Next.
25. At the Network Settings page, configure the network settings as appropriate for your environment, and click Next.
26. Review your settings, and click Finish.
27. When installation completes, click Close.
28. Using the vSphere web client, log into the vCenter server using the credentials previously provided.
29. Right-click the root of vCenter, and click New Data center.
30. Name the new datacenter `datacenter`
31. Add the servers under test to the datacenter.

#### Deploying vRealize® Operations Manager™ (vROM)

1. In the vSphere web client, log into the vCenter server.
2. Click File, and select Deploy OVF template....
3. Browse for the OVA file, and click Open.
4. Click Next.
5. Verify the details, and click Next.
6. Accept the End User License Agreement, and click Next.
7. Enter a name, and choose the inventory location. Click Next.
8. Choose the deployment size, and click Next.
9. Select the resource pool, and click Next.
10. Select the storage and disk format, and click Next.
11. Select the destination network, and click Next.
12. Choose the time zone, and enter the hostname, the default gateway, DNS, IP address, and netmask. Click Next.
13. Click Finish.
14. After deployment completes, click Close.

#### Setting up vROM

1. Power on the VM.
2. Open a web browser, and navigate to the vROM IP address.
3. Select New Installation.
4. Click Next.
5. Enter a password for the admin account, and click Next.
6. Use the default certificates, and click Next.
7. Enter a Master Node Name and an NTP Server Address, and click Add.
8. Click Next.
9. Click Finish. Click Start vRealize Operations Manager.
10. After vROM goes online, log into the online client to continue setup.
11. Choose New Environment, and click Next.
12. Accept the End User License Agreement, and click Next.
13. Enter the product license key, and click Next.
14. Click Next.
15. Click Finish.

### Adding the vCenter to vROM

1. Open a web browser, and navigate to vROM.
2. Log in using the credentials you created previously.
3. In Solutions, select VMware vSphere, and click the Configure icon.
4. Enter the IP address of the vCenter server. To add Credentials, click the green plus sign.
5. Enter the credentials for the vCenter server, and click OK.
6. Click Test Connection.
7. After successful connection, click Save Settings.
8. Click Next, and click Finish.

### Deploying vRealize Log Insight™ (vRLI)

1. From the vSphere web client, click File, and select Deploy OVF template.
2. Choose Local file, and browse to the OVA file. Click Next.
3. Review the details, and click Next.
4. Accept the EULA, then click Next.
5. Enter a name, choose the datacenter, and click Next.
6. Choose the deployment size, and click Next.
7. Select the host, and click Next.
8. Select the storage and disk format, and click Next.
9. Select the destination network, and click Next.
10. Enter the hostname, network IP, netmask, default gateway, DNS, and DNS domain. Click Next.
11. Enter a root password.
12. Click Finish.
13. After deployment completes, click Close.

### Starting vRLI

1. Open a web browser, and navigate to vRLI.
2. To begin configuring, click Next.
3. Click Start New Deployment.
4. Enter an email address and password, then click Save and Continue.
5. Enter the license key, then click Save and Continue.
6. Click Save and Continue.
7. Choose NTP servers, and click Save and Continue.
8. Enter desired SMTP configuration, and click Save and Continue.
9. Click Finish.

### Deploying vRealize Infrastructure Navigator™ (vRIN)

1. From the vSphere client, click File, and select Deploy OVF template.
2. Choose Local file, and browse to the OVA file. Click Next.
3. Review the details, then click Next.
4. Accept the EULA, then click Next.
5. Enter a name, choose the datacenter, and click Next.
6. Select the storage, and click Next.
7. Select disk format, and click Next.
8. Enter a password, confirm the password, and enter networking properties. Click Next.
9. Click Next.
10. Click Finish.

## Starting vRIN

1. Open a web browser, and type `https://ip-of-vRIN:5480/` to navigate to the vRIN management page.
2. Log into root using the password you previously created.
3. Click Time Zone, and choose the correct time zone.
4. Open a new tab or window in the browser, and navigate to the vSphere web client.
5. From the vSphere web client, click Administration.
6. Click Licenses, click the green plus sign to add a license, and enter the license key.
7. Select Assets, select Solutions, and click Assign License.
8. Choose the license for vRIN, then click OK.

## Deploying vRealize Business™ for Cloud

1. In the vSphere client, log into the vCenter server.
2. Click File, and select Deploy OVF template.
3. Browse to the OVA file, and click Open.
4. Click Next.
5. Verify the details, and click Next.
6. Accept the End User License Agreement, and click Next.
7. Enter a name, and choose the inventory location. Click Next.
8. Select the resource pool, and click Next.
9. Select the storage, and click Next.
10. Select disk format, and click Next.
11. Enter and confirm a password, choose the appropriate currency, and enable SSH.
12. Enter the default gateway, domain name and searchpath, DNS, IP address, and netmask. Click Next.
13. Click Finish.
14. After deployment completes, click Close.
15. Power on the VM.

## Configuring vRBC

1. Open a web browser, navigate to `https://IP-of-appliance:5480/`, and log in.
2. Enter the hostname, default tenant, admin user, and admin password for vRA. Click Register.
3. Click Administration, and click Time Settings. Select Use Time Server, and enter the same time server that the rest of the environment uses. Click Save Settings.
4. Log out of vRBC configuration.
5. Log into the vRBC console using root and appropriate password.
6. Type the command `monit restart itbm-server`
7. Log out of the vRBC console.
8. Navigate to the vRA web console, and log in using the default configuration admin.
9. Click Administration, click Users and Groups, and click Custom Groups. If there is no custom group, create a new custom group.
10. Name the group (if creating a new custom group), and add roles to this group. Ensure that Business Management Administrator and Business Management Controller are present and checked.
11. Add the configuration admin as a member, and click Finish.
12. Log out of vRA, then log back in using the same configuration admin credentials.
13. When a new tab titled Business Management appears, click it.
14. Enter the license key, and click Save.

## Configuring VMware Virtual SAN 6.0

1. Using ESXCLI, flag the SSDs that will be used for data persistence.
2. Log into vCenter via the vSphere Web Client.
3. Add a VMkernel Network Adapter, and enable the Virtual SAN traffic service on the adapter on all servers.
4. Right-click the datacenter, and select New Cluster.

5. Name the cluster Dell EMC VSAN, and turn on the Virtual SAN feature.
6. Click OK.
7. Move all four FC630 servers into the cluster.
8. Select the new cluster, and under Manage, select Virtual SAN.
9. Under General, select Edit.
10. Select Turn on Virtual SAN, and chose to manually add disks to storage.
11. Select Disk Management, and click the Create a Disk Group icon.
12. Select one 800GB SSD as cache and one 1,600GB SSD as capacity to create a disk group per server.
13. Click OK to add the group to VSAN.
14. Repeat steps 9 through 11 to create two disk groups per server.

#### Deploying SQL Server virtual machine

1. Select Inventory→VMs and Templates.
2. Right-click the `template vm`, and select Deploy Virtual Machine from this Template...
3. Under the name field, enter `SQLVM_temp`, and select a server as the inventory and host location. Click Next.
4. Select the appropriate storage destination, and click Next.
5. Select Power on this virtual machine after creation.
6. Select Customize using an existing customization specification, and select one. Click Next.
7. Click Finish.
8. After the server reboots, log in using administrator credentials.
9. Click Start→Control Panel→Network Connections→View network status and tasks→Change adapter settings.
10. Right-click the PRIV-NET NIC, and select Properties.
11. Double-click Internet Protocol Version 4 (TCP/IPv4).
12. Select Use the following IP address and set the appropriate IP address, subnet mask, default gateway, and DNS server.
13. Click OK twice.
14. Power off the server, and from the VM console, select Edit settings...
15. Increase the memory size to 16GB, and change the number of cores per socket to 4. Click OK.

#### Installing SQL Server 2016 on SQL virtual machine

1. Power on the server.
2. Insert the SQL Server 2016 installation media into the DVD drive.
3. Click Run SETUP.EXE. If Autoplay does not begin the installation, navigate to the SQL Server 2016 DVD, and double-click it.
4. In the left pane, click Installation.
5. Click New SQL Server stand-alone installation or add features to an existing installation.
6. Select the Enter the product key radio button, and enter the product key. Click Next.
7. Click the checkbox to accept the license terms, and click Next.
8. Click Use Microsoft Update to check for updates, and click Next.
9. Click Install to install the setup support files.
10. If no failures are displayed, click Next.
11. At the Setup Role screen, choose SQL Server Feature Installation, and click Next.
12. At the Feature Selection screen, select Database Engine Services, Full-Text and Semantic Extractions for Search, Client Tools Connectivity, Client Tools Backwards Compatibility, Management Tools – Basic, and Management Tools – Complete. Click Next.
13. At the Installation Rules screen, after the check completes, click Next.
14. At the Instance Configuration screen, leave the default selection of default instance, and click Next.
15. At the Server Configuration screen, choose NT Service\SQLSERVERAGENT for SQL Server Agent, and choose NT Service\MSSQLSERVER for SQL Server Database Engine. Change the Startup Type to Automatic. Click Next.

16. At the Database Engine Configuration screen, select the authentication method you prefer. For our testing purposes, we selected Mixed Mode.
17. Enter and confirm a password for the system administrator account.
18. Click Add Current user. This may take several seconds.
19. Click Next.
20. At the Error and usage reporting screen, click Next.
21. At the Installation Configuration Rules screen, check that there are no failures or relevant warnings, and click Next.
22. At the Ready to Install screen, click Install.
23. After installation completes, click Close.
24. Close the installation window.
25. Shut down the virtual machine.

### Converting SQL Server virtual machine into a template

1. Right-click the SQLVM\_temp and select Template.
2. Select Convert to template.

### Deploying SQL Server virtual machines from SQL VM template

1. Deploy a total of 22 SQL Server virtual machines using the following VMware vSphere PowerCLI command:
 

```
1..22 | Foreach {
New-vm -vmhost <server_name> -Name SQLVM0$_ -Template SQLVM_temp -Datastore
<datastore_name>
}
```
2. Migrate VMs to the appropriate host using the Migrate feature on vCenter Server.

### Creating an AWS EC2 instance

1. Log into the AWS console.
2. From the top drop-down menu, click Services.
3. Mouse-over Compute, and select EC2.
4. On the EC2 Dashboard, on the sidebar, click Instances.
5. On the Instances page, at the top, click Launch Instance.
6. On Step 1, scroll down to Microsoft Windows Server 2012 R2 with SQL Server Standard - ami-f4049fe3, and click Select.
7. On Step 2, fill the box next to m4.xlarge with 4 vCPUs and 16 GiB of memory, and click Next: Configure Instance Details.
8. On Step 3, keep all default settings, and click Next: Add Storage.
9. On Step 4, click Add New Volume, change the size to 1000 GiB, check the box for Delete on Termination, and click Review and Launch.
10. On Step 7, click Launch.
11. On the dialog box, select Create a new key pair from the first drop-down menu.
12. Under Key pair name, enter a name and click Download Key Pair.
13. Click Launch Instances.
14. On the Launch Status page, at the bottom of the page, click View Instances.
15. On the Instances page, wait for the instance to start.
16. Wait for Instance State to change to running, select the newly created instance, and click Connect.
17. On the dialog box, click Download Remote Desktop File, and click Get Password.
18. In the next dialog box, click Choose File, browse to the downloaded .pem file, and click Open.
19. Click Decrypt Password, record the provided password, and click Close.
20. Open the downloaded .rdp file with Remote Desktop Connection, and accept the security warning.
21. Enter the provided password in the Windows Security window, check the Remember me box, and click OK.
22. If prompted with a security certificate warning, click Yes.

23. Once the desktop has loaded, click Start, and open SQL Server Management Studio.
24. Log in using the same password used to log in to Windows.
25. In the navigation tree, right-click the server name, and click Properties.
26. Change Authentication to Mixed Mode, and click OK.

## Configuring the database (DVD Store)

### Data generation overview

We generated the data using the Install.pl script included with DVD Store version 2.1 (DS2), providing the parameters for our 20GB database size and the database platform we used. We ran the Install.pl script on a utility system running Linux® to generate the database schema.

After processing the data generation, we transferred the data files and schema creation files to a Windows-based system running SQL Server 2016. We built the 20GB database in SQL Server, then performed a full backup, storing the backup file remotely for quick access. We used that backup file to restore the database when necessary.

The only modification we made to the schema creation scripts were the specified file sizes for our database. We explicitly set the file sizes higher than necessary to ensure that no file-growth activity would affect the outputs of the test. Other than this file size modification, we created and loaded the database in accordance to the DVD Store documentation. Specifically, we followed these steps:

1. Generate the data, and create the database and file structure using database creation scripts in the DS2 download. Make size modifications specific to our 20GB database, and make the appropriate changes to drive letters.
2. Transfer the files from our Linux data generation system to a Windows system running SQL Server.
3. Create database tables, stored procedures, and objects using the provided DVD Store scripts.
4. Set the database recovery model to bulk-logged to prevent excess logging.
5. Load the data we generated into the database. For data loading, use the import wizard in SQL Server Management Studio. Where necessary, retain options from the original scripts, such as Enable Identity Insert.
6. Create indices, full-text catalogs, primary keys, and foreign keys using the database-creation scripts.
7. Update statistics on each table according to database-creation scripts, which sample 18 percent of the table data.
8. On the SQL Server instance, create 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
```
9. Set the database recovery model back to full.
10. Create the necessary full text index using SQL Server Management Studio.
11. Create a database user, and map this user to the SQL Server login.
12. Perform a full backup of the database. This backup allows you to restore the databases to a pristine state.

## Running the DVD Store tests

### Test start and run times

We ran all workloads concurrently to start and record all performance counters for this report. The specific testing parameters we used are included in the setup section, and the following section describes specifics for launching the test.

### About running the DVD Store tests

We created a series of batch files, SQL scripts, and shell scripts to automate the complete test cycle. DVD Store outputs an orders-per-minute metric, which is a running average calculated through the test. In this report, we report the last OPM reported by each client/target pair.

Each complete test cycle consisted of general steps:

1. Clean up prior outputs from the target system and the client driver system.
2. Drop the database from the target.
3. Restore the database on the target.
4. Shut down the target.
5. Reboot the host and client system.
6. Wait for a ping response from the server under test and the client system.
7. Let the test server idle for 10 minutes.
8. Start the DVD Store driver on the client.

We used the following DVD Store parameters for testing:

```
ds2sqlserverdriver.exe --target=<target_IP> --ramp_rate=10 --run_time=30 --n_threads=32 --db_size=20GB --  
think_time=0.000 --detailed_view=Y --warmup_time=5 --report_rate=1 --csv_output=<drive path>
```

## APPENDIX D – TCO CALCULATIONS

We compared costs for solutions that support 22 SQL Server 2016 Standard edition VMs, each using four vCPUs, 16 GB of memory, and running Windows Server 2012 R2 Datacenter edition operating system. Our hardware configuration for the Dell EMC and VMware hybrid-ready cloud solution used two Dell EMC PowerEdge FX2 chassis containing four Dell EMC PowerEdge FC630 servers for the VMs and Dell EMC PowerEdge FD332 storage modules for storage.

The Dell EMC and VMware hybrid cloud solution performed 22 times the work of a single Amazon EC2 Instance.

Using the OPM result of the Dell EMC and VMware hybrid cloud to size the AWS solution, we compared five-year costs for the Dell EMC and VMware solution to the costs for 22 copies of our EC2 instance with Amazon EBS Volumes, which provide storage for the instances (see Figure 10).

### Five-year cost summary

	Dell EMC and VMware solution	AWS EC2	
		22 Three-Year Reserved Instances	22 On-demand Instances
Hardware and hardware support	\$80,137.08		
VMware and Microsoft software licenses and support	\$501,106.00		
Datacenter space	\$15,000.00		
Power and cooling	\$30,000.00		
Server, storage, and VM management	\$86,500.00		
<b>Total costs over five years</b>	<b>\$712,743.08</b>	<b>\$880,232.68</b>	<b>\$1,306,651.20</b>
<b>Difference in cost compared to Dell EMC hybrid-ready cloud solution</b>		<b>\$167,489.60</b>	<b>\$593,908.12</b>
<b>Percentage cost increase over Dell EMC hybrid-ready cloud solution</b>		<b>23.5%</b>	<b>83.3%</b>

Figure 10: Monthly cost savings for using 22 SQL Server 2014 instances with the Dell EMC solution as compared to Amazon EC2.

### TCO assumptions

- We used the annual average of AWS three-year all upfront reserved costs to estimate five-year costs.
- We included costs for a hybrid cloud networking switch, but did not include other networking costs for either the public or hybrid cloud.
- We omitted database management costs, which we estimated would be the same for on-premises and public cloud.
- We included additional assumptions where necessary in the following sections.

## AWS configuration

For our AWS tests, we used a Windows operating system and Standard SQL Server m4.xlarge (see Figure 11).<sup>3</sup>

Name	vCPU	Memory (GiB)	I/O	EBS Opt
m4.2xlarge	4	16.0	High	Yes

Figure 11: Our configuration for the AWS EC2 instance.

For storage, we used a 1000GB general-purpose SSD volume (gp2) to balance price and performance (3,000 base performance IOPS). In addition, using the 1000GB SSD volume avoided the I/O credit model and burst performance limitations imposed on Amazon EBS volumes smaller than 1,000 GB.<sup>4</sup>

## AWS costs

We used the AWS Simple Monthly Calculator to estimate the five-year costs of the Amazon EC2 instances with AWS Business Support and EBS volumes. We first used the following parameters to define EC2 reserved instances and EBS volumes:

### Compute: Amazon EC2 Instances:

Description	Instances	Usage	Type	Billing Option	Monthly Cost
Test	22	100 % Utilized/Mc	Windows and Std. SQL Server on m4.xlarge	3 Yr All Upfront Rese	\$ 0.00

### Storage: Amazon EBS Volumes:

Description	Volumes	Volume Type	Storage	IOPS	Baseline Throughput	Snapshot Storage
Test	22	General Purpose SSD (gp2)	1000 GB	3000	160 MBs/sec	0 GB-month of Storage

We selected the three-year All Upfront Reserved billing option. This All Upfront Reserved contract offers greater savings compared to on-demand, partial reserved, or shorter-term contracts. For the usage level, we selected 100 percent utilized per month, assuming 24/7 usage.

We did not include snapshot storage because we were not including backups in this model.

The AWS tool generated the following estimate for upfront and monthly costs on 2/3/2017:

Amazon EC2 Service (US-East)	\$	423940.00
AWS Support (Business)	\$	19618.11
<b>Free Tier Discount:</b>	\$	-3.00
<b>Total One-Time Payment:</b>	\$	441138.41
<b>Total Monthly Payment:</b>	\$	2416.70

The three-year cost would include a one-time, upfront payment of \$441,138.41 and 36 monthly payments of \$2,416.70. Three-year costs would total \$528,139.61, an average of \$176,046.54 per year. We used that average to estimate a five-year cost of \$880,232.68. This assumes no changes in AWS pricing over that time.

<sup>3</sup> Source: [calculator.s3.amazonaws.com/index.html](http://calculator.s3.amazonaws.com/index.html)

<sup>4</sup> For more information on the I/O credit model, see [docs.aws.amazon.com/AWSEC2/latest/UserGuide/EBSVolumeTypes.html](http://docs.aws.amazon.com/AWSEC2/latest/UserGuide/EBSVolumeTypes.html).

We then selected the AWS no-money-upfront, On-Demand billing option without a contract and time commitments. We used the following parameters to define EC2 on-demand instances and EBS volumes:

**Storage: Amazon EBS Volumes:**

Description	Volumes	Volume Type	Storage	IOPS	Baseline Throughput	Snapshot Storage
Test	22	General Purpose SSD (gr)	1000 GB	3000	160 MBs/sec	0 GB-month of Storage

**Compute: Amazon EC2 Instances:**

Description	Instances	Usage	Type	Billing Option	Monthly Cost
Test	22	100 % Utilized/!	Windows and Std. SQL Server on m4.xlarge	On-Demand (No Cor)	\$ 17875.44

This contract would increase the five-year cost estimate to \$1,306,651.20, which is almost 1.5 times more expensive than choosing the All Upfront Reserved billing option.

The AWS tool generated the following estimate on 2/3/2017 for monthly payments in the pay-as-you-go model:

Amazon EC2 Service (US-East)	\$ 20075.44
AWS Support (Business)	\$ 1705.08
<b>Free Tier Discount:</b>	\$ -3.00
<b>Total Monthly Payment:</b>	\$ 21777.52

### Dell EMC and VMware hybrid-ready cloud costs

We estimated the costs of running the Dell EMC and VMware hybrid-ready cloud in an enterprise datacenter for five years. We included upfront costs for hardware purchase and software licenses as well as ongoing costs for 5 Year ProSupport and Mission Critical 7x24 support (including four-hour support for servers and next day support for the storage arrays), five-year software support, datacenter space, power and cooling, and server/software defined storage and VM administration costs.

### Hardware and hardware support costs

We used prices from the Dell EMC online store tools for hardware and hardware support costs as of 2/10/17. The total cost reflects components from our solution and currently available equivalent where necessary (see Figure 12).

Again, the following costs for compute, storage, and networking hardware include five-year ProSupport and Mission Critical four-hour 24x7 Onsite hardware support.

Category	Item	Quantity	Unit cost	Total cost
Server chassis	Dell EMC PowerEdge FX2 chassis	2	\$3,651.12	\$7,302.24
Servers	Dell EMC PowerEdge FC630	4	\$10,595.22	\$42,380.88
Storage	Dell EMC PowerEdge FD332 storage nodes with 16 2.5" disk bays	4	\$5,326.24	\$21,304.96
Networking	Dell EMC Networking N4032F switch	1	\$9,149.00	\$9,149.00
<b>Total</b>				<b>\$80,137.08</b>

Figure 12: A breakdown of the hardware and hardware support costs for the Dell EMC solution.

### Software and software support costs

We included costs for Microsoft SQL Server 2016 Standard edition, Microsoft Windows Server 2012 R2 Datacenter edition, and VMware vCloud Suite Standard as of 11/15/16. We selected SQL Server 2016 Standard edition to match the version on the AWS instance we tested. We selected Microsoft Windows Server Datacenter edition because it's less expensive for the number of VMs we tested than Standard editions would be. Figure 13 breaks down the software and software support costs for the Dell EMC solution.

	License five-year software assurance	Quantity	Five-year cost
Microsoft SQL Server 2016 Standard edition	\$7,906.50	44	\$347,886.00
VMware vCloud Suite Standard edition	\$12,365.00	8	\$98,920.00
Microsoft Windows Server Datacenter edition	\$13,575.00	4	\$54,300.00
<b>Total</b>			<b>\$501,106.00</b>

Figure 13: A breakdown of the software and software supports costs for the Dell EMC solution.

We estimated the license counts on the following assumptions:

- **Microsoft SQL Server 2016 Standard edition.** We included one of these core license packs for each pair of vCPUs in each VM so 44 license packs would support the 22 VMs, which each use four vCPUs.
- **VMware vCloud Suite Standard edition.** The licenses are per processor, so this solution would require eight licenses for four dual-socket servers.
- **Microsoft Windows Server 2012 R2 Datacenter edition.** Each license pack licenses two processors in a single server. We included one pack for each of the four servers in the test bed.

We used the following sources for pricing:

- **Microsoft SQL Server 2016 Standard edition.** We used the cost as reported by the Microsoft License Advisor tool at OLP Level-C pricing for a license plus two-year software assurance from the Microsoft License Advisor. We added three years of additional software assurance at a rate of 25 percent of the license cost per year.
- **VMware vCloud Suite Standard (includes vRealize suite management and vSphere computer virtualization).** We used the cost as reported at [roitco.vmware.com/vmw/CP/CP?tbx=0](http://roitco.vmware.com/vmw/CP/CP?tbx=0) for the license and annual Support and Subscription (SnS) service.
- **Microsoft Windows Server 2012 R2 Datacenter edition.** We used the cost as reported by the Microsoft License Advisor tool at OLP Level-C pricing for a license plus two-year software assurance. We added three years of additional software assurance at a rate of 25 percent of the license cost per year.

### Other costs

Five-year costs of the in-house hybrid cloud would also include ongoing datacenter costs, power and cooling costs, and server, software-defined storage, and VM management costs as of 11/15/16 (see Figure 14). These will vary

for your business depending on the level of experience of management staff, the datacenter cooling efficiency, regional space and power costs, staff salaries and benefit packages, and other factors.

Other costs	
Datacenter costs	\$15,000.00
Power and cooling	\$30,000.00
Server, storage, and VM management	\$86,500.00
<b>Total</b>	<b>\$131,500.00</b>

Figure 14: A breakdown of other necessary costs for the Dell EMC solution.

- **Datacenter cost estimate.** We calculated datacenter costs based on the amount of rack space the solution uses and an estimate of \$1,500 per month per 42U rack. This hardware solution uses 5U; we added a free rack unit above and below and calculated a five-year cost of \$15,000 based on one-sixth of a rack.
- **Power and cooling estimate.** We estimated power and cooling costs at \$1,500 per year on average for each server (rounding up the estimate from [www.zdnet.com/article/toolkit-calculate-datacenter-server-power-usage/](http://www.zdnet.com/article/toolkit-calculate-datacenter-server-power-usage/)) with costs divided equally between power and cooling. The five-year total for the four servers in this testbed would be \$30,000.
- **Server and software-defined storage management estimate.** We estimated that a system administrator could manage an average of 40 servers and a software defined storage solution. Based on compensation (salary plus benefits) of [a system administrator II](#) of \$107,000 per year, each server would cost \$2,675 per year. The five-year total for the four servers in this testbed would be \$53,500. We estimated a higher compensation of \$120,000 (salary plus benefits) for a VM administrator and assumed each administrator could manage 400 VMs, yielding a cost per VM per year of \$300. Over five years, 22 VMs would cost \$33,000.

## APPENDIX E – DETAILED PERFORMANCE RESULTS

Figures 15 and 16 presents our findings in detail. We ran each test three times and present the median.

AWS	
One m4.xlarge AWS instance with 20GB database	
Total database operations per minute (OPMs) on one AWS instance (0ms think time, 32 threads)	33,700
AWS options:	<ul style="list-style-type: none"> <li>• m4.xlarge instance</li> </ul>
	<ul style="list-style-type: none"> <li>• US-East / US Standard (Virginia) region</li> </ul>
	<ul style="list-style-type: none"> <li>• 4 vCPUs</li> </ul>
	<ul style="list-style-type: none"> <li>• 16GB memory</li> </ul>
	<ul style="list-style-type: none"> <li>• I/O high</li> </ul>
	<ul style="list-style-type: none"> <li>• EBS optimized</li> </ul>
	<ul style="list-style-type: none"> <li>• 100% usage</li> </ul>
	<ul style="list-style-type: none"> <li>• 1000GB general purpose SSD (gp2) EBS storage volume</li> </ul>
	<ul style="list-style-type: none"> <li>• 0 snapshot storage</li> </ul>

Figure 15: AWS EC2 results from the DS2 test and the options we selected for the instance.

Dell EMC and VMware hybrid-ready cloud	
22 VMs with 20GB database	
Total database operations per minute (OPM) with 22 VMs (0ms think time, 32 threads)	898,131
Average OPM	40,824
Minimum OPM	34,652
Maximum OPM	47,632
VM options:	<ul style="list-style-type: none"> <li>• 4 vCPUs</li> </ul>
	<ul style="list-style-type: none"> <li>• 16GB memory</li> </ul>
	<ul style="list-style-type: none"> <li>• 100GB of storage</li> </ul>

Figure 16: Dell EMC and VMware hybrid cloud results from the DS2 test and the options we used for the VMs.

## ABOUT PRINCIPLED TECHNOLOGIES



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