

**Up to 40% more IOPS\*†**

Support data-intensive workloads



**29% greater data reduction\***

Use storage more efficiently



**36% faster recovery\***

Recover quicker from a controller failure



**94% faster bulk storage provisioning\***

Save IT admin time and steps

## Maximize your storage capacity with the Dell EMC Unity 550F All-Flash array

This Dell EMC solution handled higher IOPS on data-intensive workloads and reduced data more efficiently than a competitor

“Sink or swim” makes for a good business mantra. But in the midmarket space, IT teams often find themselves mired in a third option: trading water just to stay afloat. IT departments struggling with inadequate storage and aging equipment need a modern, powerful storage solution that helps them maximize storage usage and capacity.

We tested two storage arrays to see which could best help organizations meet these goals: the Dell EMC™ Unity™ 550F and the array of a competitor (“Vendor A”), an all-flash offering in the entry-level market that uses SAS storage. The Dell EMC Unity array processed 40 percent more input/output operations per second (IOPS),† reduced 29 percent more data, and recovered from a simulated controller failure 36 percent faster than its competitor. It also carried out common management tasks faster, cutting deployment steps in half and completing bulk storage provisioning in 94 percent less time than the Vendor A array.

Forget trading water—with the storage and management advantages of the Dell EMC Unity 550F, your company can continue moving forward.

\* compared to the array of Vendor A

† in an 8KB random write test



## The Dell EMC Unity 550F

According to Dell EMC, the Dell EMC Unity 550F array “delivers the ultimate in simplicity and value, enabling your organization to speed deployment, streamline management and seamlessly tier unified storage workload to the cloud.”<sup>1</sup> Powered by Intel® Xeon® Scalable processors, this all-flash platform is designed to “optimize SSD performance and efficiency, with fully integrated SAN and NAS capabilities.”<sup>2</sup> Learn more about the Dell EMC Unity 550F array: [DellEMC.com/Unity](http://DellEMC.com/Unity).

## Finding the storage that fits your needs

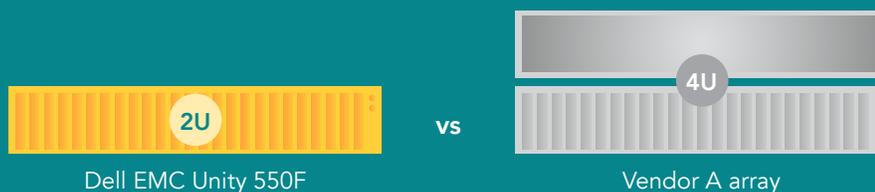
Small to medium businesses (SMBs) can't afford to make mistakes about where and how they allocate resources. Every dollar counts, which means you need to use your storage arrays efficiently. If you're worried about this issue, you're not alone—storage is top of mind for many companies. In a 2018 Enterprise Storage Forum survey of 374 IT and business leaders, the top two challenges were “aging equipment and inadequate storage capacity.”<sup>3</sup>

The Dell EMC Unity 550F All-Flash storage array targets these challenges with:<sup>4</sup>

- Block, file, and VMware® Virtual Volumes support in a single array
- All-Flash storage from 7.7 TB to 8.0 PB max raw capacity
- Inline data reduction and 15.38 TB flash drives
- Dell EMC Unisphere™, a single HTML5 graphical user interface for management, monitoring, and analysis

## Space usage: A comparison

In the data center, businesses are constantly looking for ways to maximize rack and floor space. The Dell EMC Unity packs its performance into just 2U of rack space. By contrast, the array from Vendor A takes up twice this amount of space (4U), despite its poorer performance on the tests we outline in the following pages. With its more compact form factor, the Dell EMC Unity array could help organizations save on data center costs by delaying the need to expand to new rooms or even buildings.



## How we tested

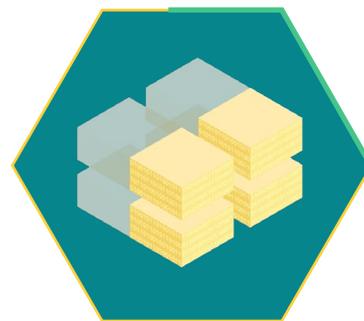
We configured two separate testbeds, one each for the Dell EMC Unity 550F and the Vendor A array. Each testbed had a total of six Dell EMC PowerEdge™ R740 servers, all grouped into a single VMware vCenter™ 6.5 server cluster. We also deployed an additional Dell EMC PowerEdge R740 server with VMware ESXi™ 6.5 as an infrastructure server.

For storage provisioning, management, and monitoring on the Dell EMC Unity solution, we used Dell EMC Unisphere. For the solution from Vendor A, we used their recommended management GUI software. We tested each solution's IOPS, latency, and usable storage capacity using the Vdbench benchmarking tool. We also measured how well each solution performed on data reduction, failover ability, array deployment, and storage provisioning. We used default configuration settings on both storage solutions, as recommended by each vendor's published best practices. As we outline below, the Dell EMC Unity 550F beat out the Vendor A array on every one of these tasks. For a more detailed review of our testing process, see [Appendix C](#).

## Stronger storage performance

We used a common benchmarking tool called Vdbench to measure each solution's block storage performance. Benchmark testing offers insight into storage performance by showing:

- How many input/output operations per second (**IOPS**) a solution can handle, indicating whether it can process a high volume of data
- Whether a solution can simultaneously provide fast response times (**latency**) that protect users and applications from experiencing wait times
- How much information a solution can process per second (**bandwidth**), helping to prevent bottlenecks during periods of heavy traffic



Support heavier workloads with up to

**40% more**

IOPS in an 8KB random write test

In our hands-on testing, we first ran an 8KB random 100% write test. This workload was representative of how quickly the arrays could commit or save data to the disks. The Dell EMC Unity array supported 40 percent more IOPS with 36 percent lower latency compared to the array of Vendor A. Lower latency means faster response times, reducing the chance that users are left waiting for their applications to respond. As you can see in the chart below, both solutions maintained roughly equivalent response times until around 80,000 IOPS. At this point, in order to serve more IOPS, response times on the Vendor A array rapidly slowed. The Dell EMC Unity solution, on the other hand, handled more IOPS (for a total of 157,909) while slowing response times in a more controlled manner.

### IOPS

8KB random 100% write workload | Higher is better

#### Dell EMC Unity 550F



#### Vendor A array



### Latency

8KB random 100% write workload | Lower is better

#### Dell EMC Unity 550F

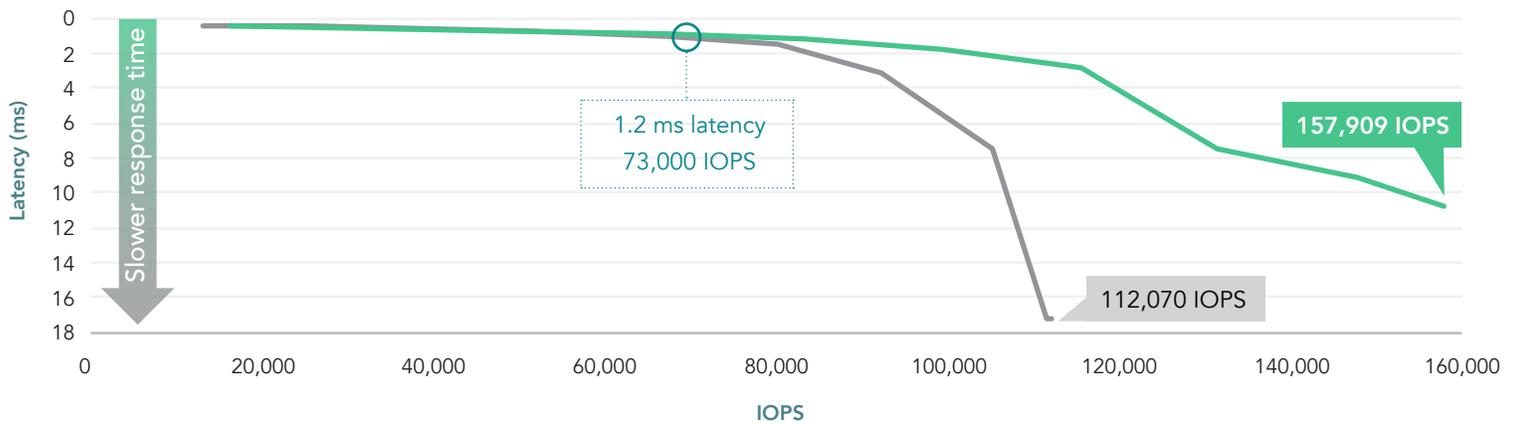


#### Vendor A array



### Latency and IOPS

8KB random 100% write workload | Lower latency and higher IOPS are better



- Dell EMC Unity 550F
- Vendor A array

For insight into the other end of the spectrum (how quickly each solution could retrieve information from their disks), we ran an 8KB random 100% read test. The Dell EMC Unity solution outperformed the Vendor A array here as well, processing 48,569 more IOPS and responding 19 percent faster. Similarly to our first test, response times on the Dell EMC Unity solution got slower at a steadier pace; latency performance on the Vendor A array, by contrast, plummeted around the 340,000 IOPS mark.

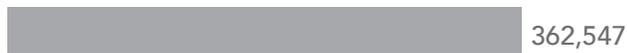
### IOPS

8KB random 100% read workload | Higher is better

Dell EMC Unity 550F



Vendor A array



### Latency

8KB random 100% read workload | Lower is better

Dell EMC Unity 550F

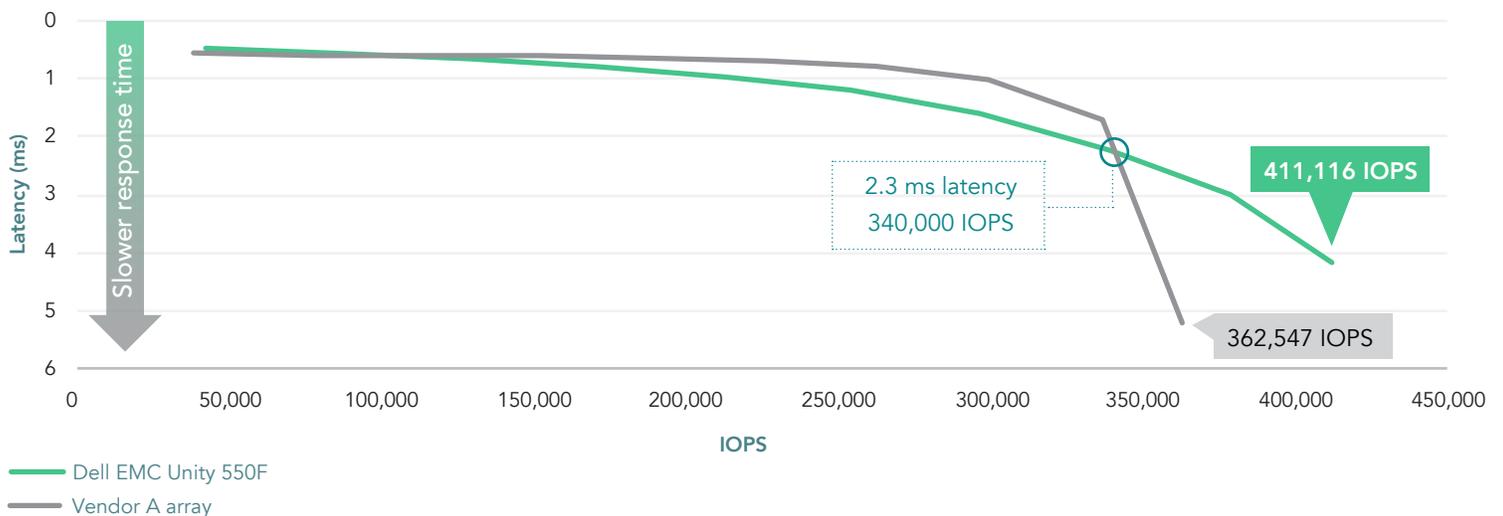


Vendor A array



### Latency and IOPS

8KB random 100% read workload | Lower latency and higher IOPS are better





To see how well the solutions could handle large block transactions, we ran a 256KB sequential 100% write test. The Dell EMC Unity solution excelled with this heavier workload, supporting 3.3 times the IOPS and bandwidth of the Vendor A array.

### IOPS

256KB sequential write workload | Higher is better

Dell EMC Unity 550F



Vendor A array



### Bandwidth

256KB sequential write workload | Higher is better

Dell EMC Unity 550F



Vendor A array



Finally, we ran an 8KB random 70/30 read/write test. This test was representative of an online transaction processing (OLTP) database profile, something that storage arrays commonly handle (e.g., processing customer orders). Although the Vendor A array handled 5 percent more IOPS than the Dell EMC Unity solution, the Dell EMC Unity array responded 2 percent faster. In the context of the other IOPS tests we ran, this test shows that the Dell EMC Unity solution could perform comparably to the Vendor A array on an OLTP workload while maintaining superior performance on more data-intensive 100% read and write workloads. Overall, these metrics indicate that the Dell EMC Unity 550F could better support periods of heavier activity than the Vendor A array.

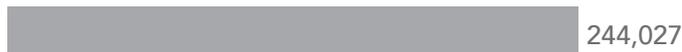
### IOPS

8KB random 70/30 workload | Higher is better

#### Dell EMC Unity 550F



#### Vendor A array



### Latency

8KB random 70/30 workload | Lower is better

#### Dell EMC Unity 550F

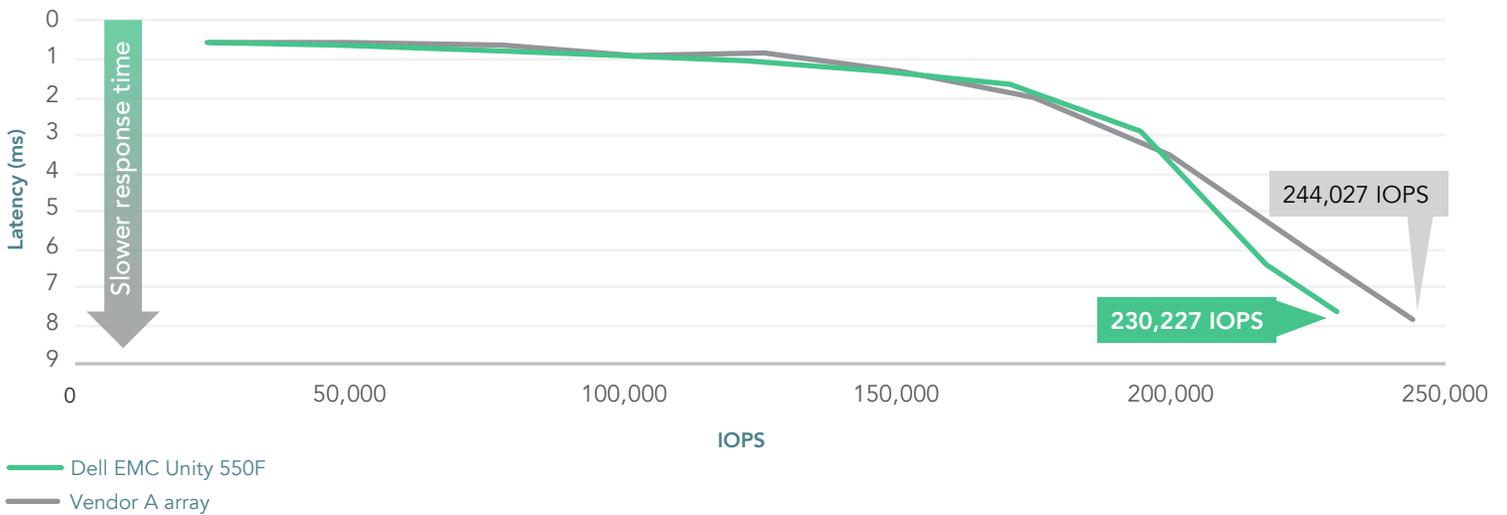


#### Vendor A array



### Latency and IOPS

8KB random 70/30 workload | Lower latency and higher IOPS are better



## More efficient data reduction

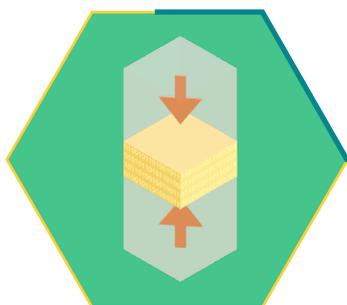
Typically, data in a storage system contains multiple versions of the same blocks of data. To reduce overall storage utilization, different storage arrays use different data reduction methods. The Dell EMC Unity array reduces data in real time, all the time. The solution from Vendor A, by contrast, is more beholden to CPU utilization: its array must wait to reduce incoming data until the storage CPU has available cycles. If heavy storage utilization continued, storage on the Vendor A array would bypass data reduction and continue to take up valuable storage space. This could force an organization to expand their storage to gain additional capacity, potentially increasing costs, infrastructure complexity, and management time.

To gauge the data reduction ability of the two arrays, we first had to provision storage LUNs and fill them with 29.2 TB of data. We used 60 LUNs, each of which contained a data set with a 4:1 data reduction ratio. Next, we measured how well each solution deduplicated and compressed the data; that is, how much duplicate data it recognized and eliminated, and how much data it compressed, reducing storage utilization. We did this by running an 8KB random 100% write test on the data set. (Write operations indicate how well an array's disks commit or save new information to storage, as opposed to read operations, which show how well each solution's disks retrieve information.) The Dell EMC Unity solution outperformed the Vendor A array, reducing 29 percent more data.

If your organization is heavily utilizing storage, you need a solution that can keep up with your demands. As our testing demonstrated, the Dell EMC Unity array reduced data more efficiently, potentially providing more usable storage capacity.

## What is a LUN?

Physical disks in a storage array are typically grouped into pools. Storage resources that are made available to end users are carved out of these storage pools. When storage resources are presented to end users using a block-level storage protocol (we used Fibre Channel in our testing), those resources are called Logical Unit Numbers (LUNs).



Maximize storage capacity with  
**29% greater**  
data reduction

### Data reduction

*Lower is better*

#### Dell EMC Unity 550F



#### Vendor A array



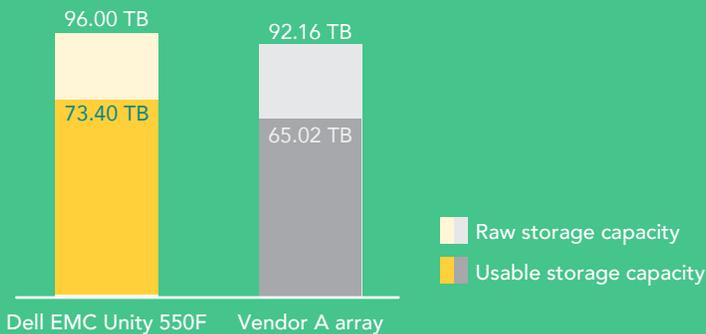


## Greater usable storage

When you're considering a new storage array, storage capacity should be top of mind. How much raw storage does a solution contain? And, more importantly, how much of this storage is usable? Any unusable storage is simply overhead—something that your company is paying for without being able to use.

To test the usable storage on both solutions, we configured the arrays with 3.84TB disks until they reached their maximum storage capacity. While usable storage of the Vendor A array maxed out at just over 65 TB, the Dell EMC Unity solution provided 73.4 TB of usable storage—an improvement of 12 percent over the array from Vendor A. With more usable storage at your disposal, your organization will be able to maximize your current storage capacity for longer. This could lead to cost savings for your company, especially across multiple arrays, by allowing your organization to delay or forgo costly storage expansion.

### Usable storage



Get the most out of your storage with **12% greater** usable storage capacity

## Scaling on the Dell EMC Unity 550F

Both arrays use a dual controller approach. But the Dell EMC Unity solution groups its disks into a single unified storage pool, while the Vendor A array splits its disks into multiple smaller pools. Admins managing the Vendor A array would need to manage these pools individually. By contrast, on the Dell EMC Unity solution, admins would need only manage one storage pool. For organizations scaling up their arrays to meet growing storage needs, the architecture of the Dell EMC Unity solution could translate to less time and hassle for IT admins.

### Improved platform resiliency

When you're serving clients 24/7 or running demanding workloads, it's important to know that unexpected hardware failures won't impact your business. The Dell EMC Unity 550F and Vendor A array both have dual storage controllers, which perform a wide range of processing and storage functions. In theory, having two controllers instead of one builds resiliency into a system: If one controller fails, the other can pick up its functions, ensuring users' access to data remains steady. But even with two controllers, important questions remain. How responsive is the storage array during the failure (that is, do users and applications experience any lag)? And how quickly does a system return to normal operations (allowing your systems to work at full capacity)?

### Time to return to normal operations

min:sec | Lower is better

Dell EMC Unity 550F



Vendor A array



Recover more quickly with  
**36% faster**  
recovery from a controller failure

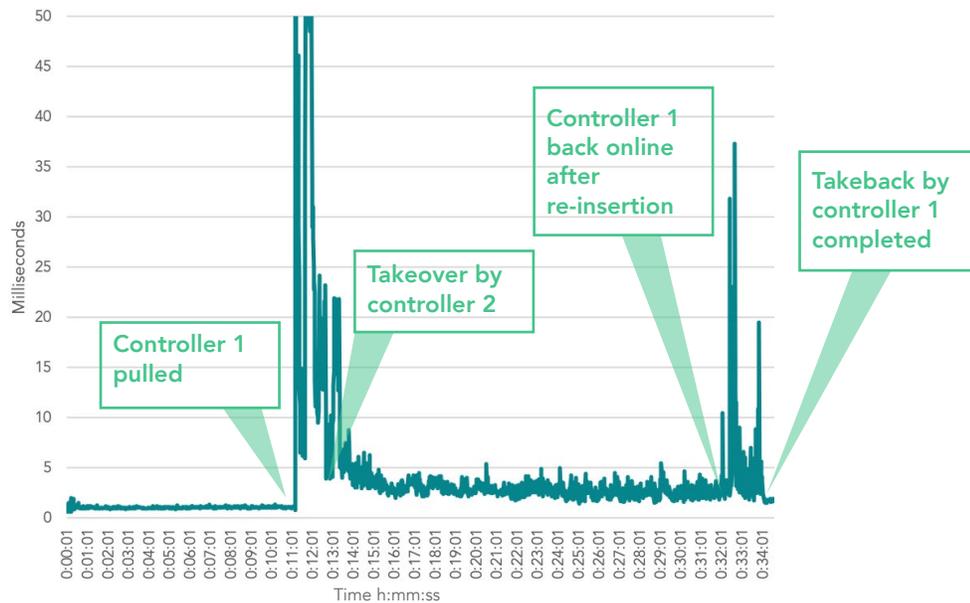
We simulated a storage controller failure by pulling one controller from each system and measuring how quickly the remaining controller took over the failed controller's workload (we called this "takeover by controller 2"). We then plugged the controller back in and timed how long this controller took to restore to its full operations ("takeback by controller 1"). (Note: Since we did not experience VM or application failures during testing, we measured the response times of the VMs' storage.)

Although the Vendor A array completed the initial takeover in less time than the Dell EMC Unity array, the Dell EMC solution performed better on the takeback test, resuming normal operations in under 2 minutes. The array from Vendor A, by contrast, took almost 3 minutes. With faster takeback times, your storage arrays could return to their full power sooner, ensuring that users could continue their business as usual.

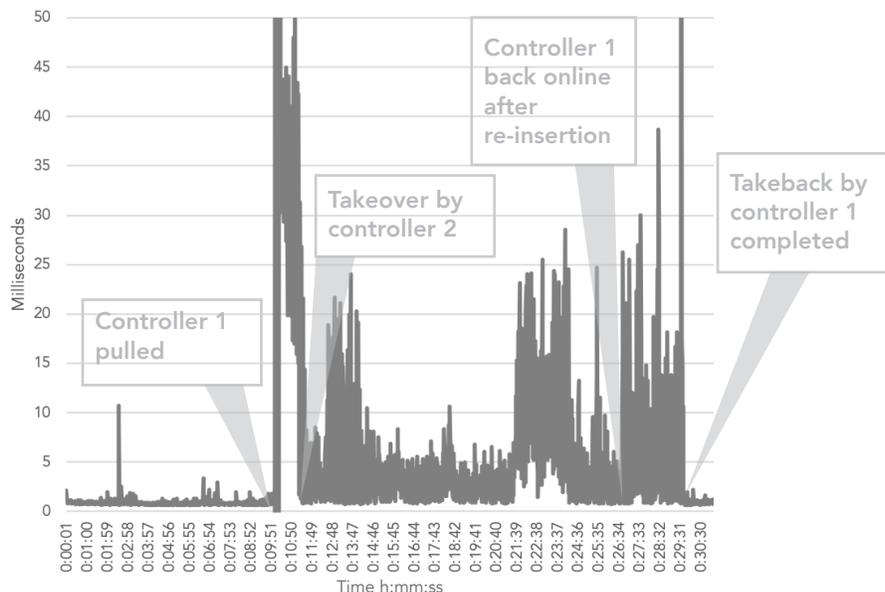
Crucially, the Dell EMC Unity array also maintained drastically faster VM disk response times (78 percent) throughout the failover and recovery process. By contrast, latency on the array from Vendor A spiked throughout the test (meaning it took longer to respond—for a visual reference, see the second graph below). On the Dell EMC Unity solution, users would be unlikely to experience high wait times, even in the event of a storage controller failure.

The benefits of having a robust and responsive system are numerous. In a 24-hour workplace like a hospital or call center, time spent waiting is time in which core operations slow down, possibly missing completion windows or service-level agreements. Any downtime could cost your organization in lost labor, revenue, or both. By contrast, faster response and recovery times allow users to quickly access important information.

### Dell EMC Unity 550F single VM disk latency



### Vendor A array single VM disk latency



## Faster and more efficient management

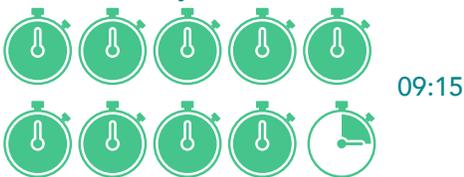
Deploying and provisioning hardware is a common management task—one that IT departments with limited resources want to make as quick and painless as possible. To gauge both solutions' time-saving abilities, we tested two everyday management tasks: deploying a storage array and provisioning storage. While admins would generally only deploy a storage array once, they might provision storage on a daily basis; together, these tasks give us important insight into the efficiencies the Dell EMC Unity solution can offer to IT departments. To test these tasks, we used the Dell EMC Unity solution's graphical user interface (GUI), Unisphere. This intuitive, web-based platform did not require specialized knowledge, making it a good choice for overstretched IT generalists in the midmarket space.

In our testing, we found that the Dell EMC Unity 550F could allow IT staff to spend 26 percent less time and half as many steps on deployment versus the Vendor A array (using the Vendor A GUI). While the Unity solution took just over 9 minutes and 18 steps to complete the task, the array from Vendor A stretched the task out to over 12 and a half minutes and 36 steps.

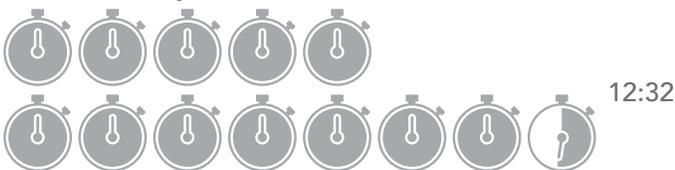
### Time to deploy storage array

min:sec | Lower is better

#### Dell EMC Unity 550F



#### Vendor A array



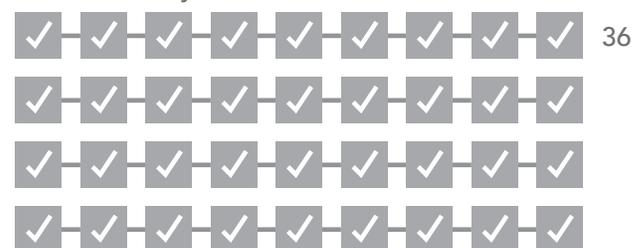
### Steps to deploy storage array

Lower is better

#### Dell EMC Unity 550F



#### Vendor A array



### About Unisphere for Dell EMC Unity

With its HTML5 interface, Unisphere helps users provision, manage, and monitor storage on their Dell EMC Unity 550F arrays. Unisphere allows users to configure and schedule protection for stored data, and includes advanced features like replication and host I/O limits.

Additionally, we measured how long it took to provision a single storage LUN. We used the Unisphere GUI on the Dell EMC Unity, while on the Vendor A array we used their GUI solution. The Dell EMC Unity solution beat the array from Vendor A, enabling us to provision a single LUN 41 percent faster, in just 30 seconds.

### Time to provision a single LUN

min:sec | Lower is better

Dell EMC Unity 550F



Vendor A array



### Steps to provision a single LUN

Lower is better

Dell EMC Unity 550F



Vendor A array



When we expanded our testing to bulk LUN provisioning, the Dell EMC Unity outstripped its competitor dramatically. To provision 60 LUNs at once, we used a Dell EMC feature called consistency groups, which allowed us to deploy multiple LUNs with minimal steps. This feature helped yield substantial time savings: The Dell EMC Unity array enabled our admins to complete the task in under three minutes (compared to over 50 minutes on the array from Vendor A), making the Dell EMC Unity solution 94 percent faster. This increased efficiency also held true for the number of steps involved. The Dell EMC solution required only 12 steps compared to 780 on the Vendor A array, a difference of 98 percent.

With the Dell EMC Unity solution's time savings mounting each time your admins perform routine tasks, such as deploying storage arrays and provisioning LUNs, your admins can turn to the work that matters—like implementing strategic measures that make your data center run more efficiently. And, with fewer steps involved in both processes, your IT staff will encounter fewer opportunities for error and inefficiency.

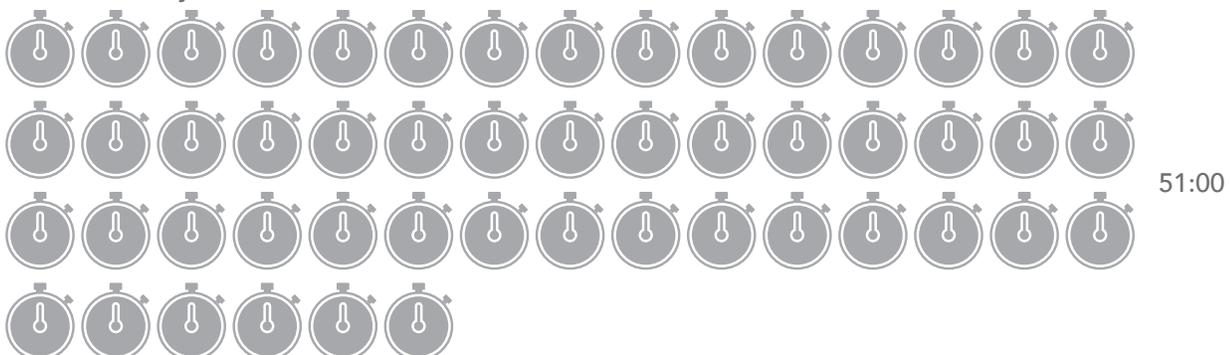
### Time to provision 60 LUNs

min:sec | Lower is better

Dell EMC Unity 550F

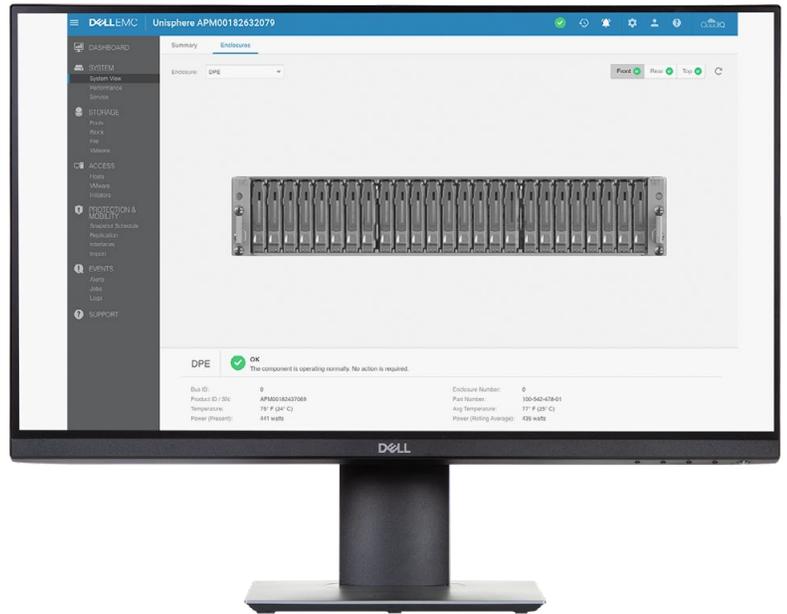


Vendor A array

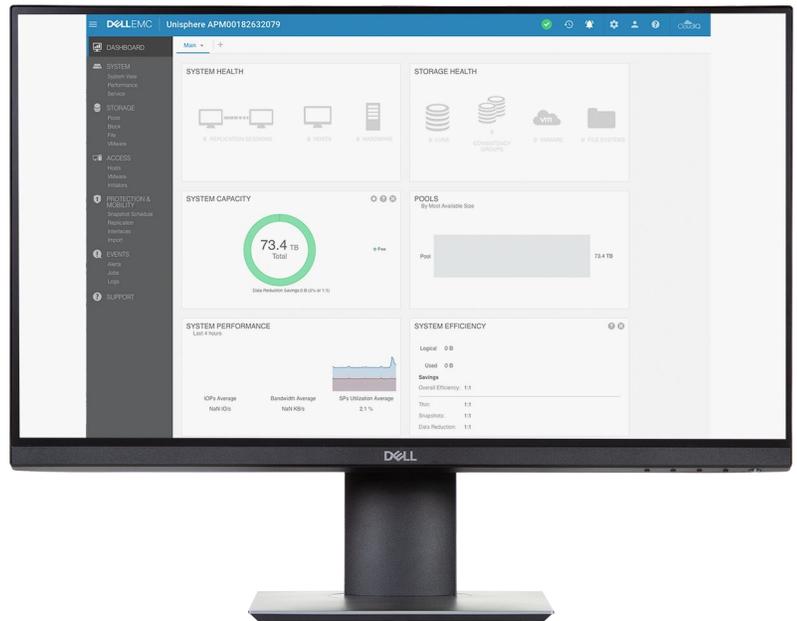


## A modern interface for the modern IT department

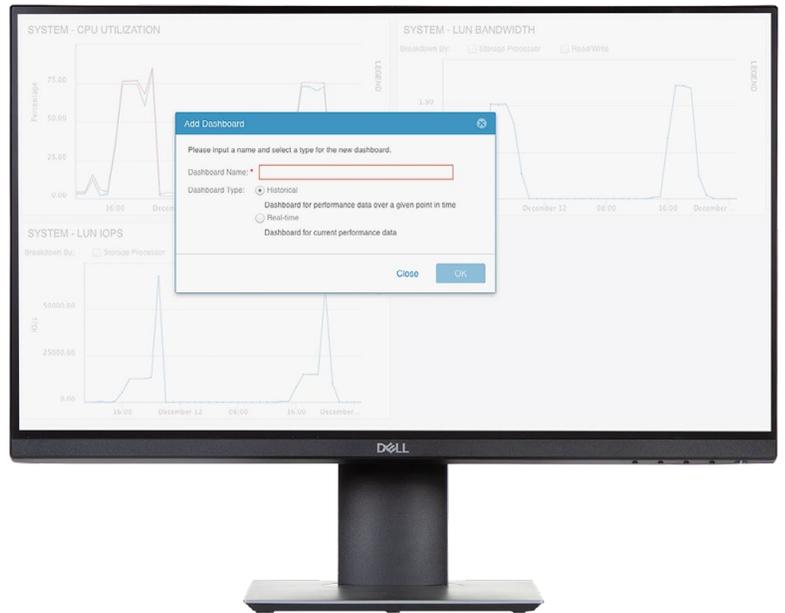
We administered and managed the Dell EMC Unity solution using a single GUI (Unisphere), although users could also carry out management tasks via command line interface or REST API. Unisphere allows users to securely manage Dell EMC Unity storage systems using a web browser that supports HTML5 technology.



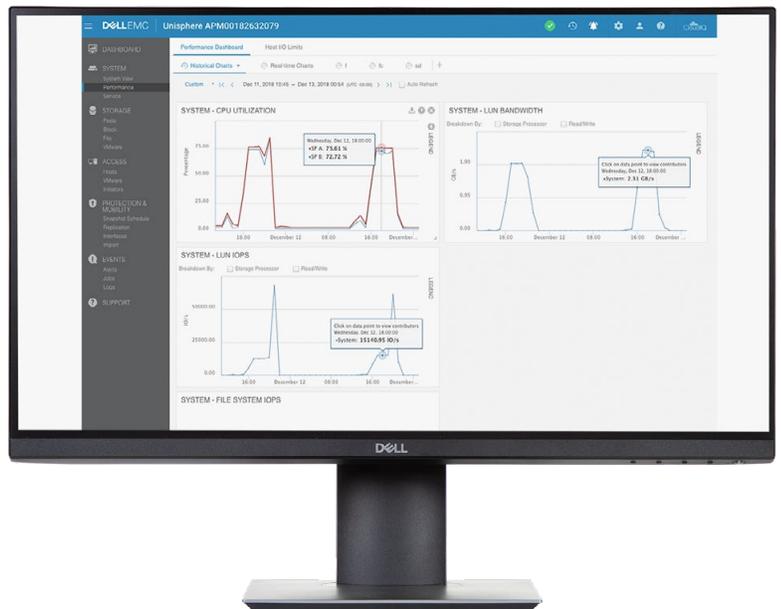
Unisphere presents a complete view of all relevant information needed to assess storage health and performance. The intuitive navigation pane allowed us to visualize content, while the sub-menus let us quickly access multiple storage features and configuration options. With Unisphere, we could efficiently view the storage system status, retrieve system notifications, and display alarm details from the main dashboard.



The main dashboard is fully customizable, allowing users to organize the display into blocks of information that let them easily view what they care most about. These blocks can include storage usage statistics, the health of the storage system and resources, system alerts, and overall performance.



Admins can further analyze storage performance in the Unisphere GUI by interacting with dynamic charts that display historical and real-time performance metrics. The charts, which show detailed network traffic, bandwidth, and throughput data, can display data at various granular levels. While the Vendor A array requires admins to install additional software and use multiple panes to view performance statistics, the Dell EMC Unity solution allows admins to view performance statistics in one place. Admins can also export data to a .csv file for analysis or customize the performance dashboards to efficiently assess storage performance.





## Conclusion

If your business is like most SMBs or departments operating their own storage, your storage capacity is stretched to the limits—meaning that your arrays need to do the most work they can. In our testing of the Dell EMC Unity 550F against the Vendor A array, the Dell EMC Unity solution supported more IOPS, reduced data more efficiently, recovered faster with more predictable response times, and deployed in half the steps of the Vendor A array. If your business is looking for a solution to aging hardware and maxed-out storage, the Dell EMC Unity offers system specifications, storage reduction features, and performance capabilities that can help you meet these challenges.

To learn more about Dell EMC Unity, visit [DellEMC.com/Unity](https://www.dell.com/unity).

- 1 Dell EMC, "Dell EMC Unity All-Flash Unified Storage," accessed January 3, 2019, <https://www.dell.com/en-us/storage/unity.htm>.
- 2 "Dell EMC Unity All-Flash Unified Storage."
- 3 Enterprise Storage Forum, "Survey Reveals Tech Trends Reshaping Data Storage," accessed January 3, 2019, <https://www.enterprisestorageforum.com/storage-management/survey-reveals-tech-trends-reshaping-data-storage.html>.
- 4 Dell EMC, "Dell EMC Unity 550F All-Flash Storage," accessed January 3, 2019, <https://shop.dell.com/en-us/Product-Family/Unity-Products/Dell-EMC-Unity-550F-All-Flash-Storage/p/EMC-Unity-500F-All-Flash-Storage>.

We concluded our hands-on testing on December 29, 2018. During testing, we determined the appropriate hardware and software configurations and applied updates as they became available. The results in this report reflect configurations that we finalized on November 15, 2018 or earlier. Unavoidably, these configurations may not represent the latest versions available when this report appears.

## Appendix A: Our results

### Storage performance with Vdbench

	Dell EMC™ Unity™ 550F	Vendor A array	Percentage win
8KB 100% random write			
IOPS	157,909	112,070	40%
Latency (ms)	10.85	17.18	36%
8KB 100% random read			
IOPS	411,116	362,547	13%
Latency (ms)	4.15	5.16	19%
256KB 100% sequential write			
IOPS	22,164	6,698	3.3X
Bandwidth (MB/s)	5,541	1,674	3.3X
8KB 70/30 random read/write			
IOPS	230,227	244,027	N/A
Latency (ms)	7.66	7.86	2%

### Data reduction

	Dell EMC Unity 550F	Vendor A array	Percentage win
4:1 data set			
Physical used (TB)	10.0	14.1	29%

### Usable capacity

The Dell EMC Unity solution offered 96.00 TB of raw storage, while the Vendor A array offered 92.16 TB.

	Dell EMC Unity 550F	Vendor A array	Percentage win
Usable storage capacity (TB)	73.40	65.02	12%

## Failover and recovery

	Dell EMC Unity 550F	Vendor A array	Percentage win
Task			
Takeover by controller 2 complete (min:sec)	02:10	01:26	N/A
Takeback by controller 1 complete (min:sec)	01:47	02:49	36%
VM latency			
Average latency (ms)	2.63	12.36	78%

## Initial deployment

	Dell EMC Unity 550F	Vendor A array	Percentage win
Total steps	18	36	50% fewer steps
Total time (min:sec)	09:15	12:32	26% faster

## LUN provisioning

	Dell EMC Unity 550F	Vendor A array	Percentage win
Time			
Provisioning a single LUN (min:sec)	00:30	00:51	41% faster
Provisioning 60 LUNs (min:sec)	02:45	51:00	94% faster
Steps			
Provisioning a single LUN	8 steps	13 steps	38% fewer steps
Provisioning multiple LUNs	12 steps	780 steps	98% fewer steps

## Appendix B: System configuration information

The tables below present detailed information on the systems we tested.

Storage configuration information	Dell EMC Unity 550F	Vendor A array
Operating system	4.3.1	9.4
Number of storage shelves	1 (Integrated disk processor enclosure)	1
Number of drives per shelf	25	24
Drive vendor and model number	Toshiba PX05SRB384	Samsung PM1643
Drive size	3.84 TB	3.84 TB

Server configuration information	12 x Dell EMC PowerEdge™ R740 servers
BIOS name and version	Dell EMC PowerEdge R740 1.4.9
Non-default BIOS settings	Virtualization enabled
Operating system name and version	VMware ESXi™ 6.5.0 build-10175896
Date of last OS updates/patches applied	10/1/2018
Power management policy	Performance
Processor	
Number of processors	2
Vendor and model	Intel® Xeon® Platinum 8168
Core count (per processor)	24
Core frequency (GHz)	2.70
Memory module(s)	
Total memory in system (GB)	256

Server configuration information	12 x Dell EMC PowerEdge™ R740 servers
Number of memory modules	8
Vendor and model	Samsung® M393A4k40CB2-CTD
Size (GB)	32
Type	DDR4
Speed (MHz)	2,666
Speed running in server (MHz)	2,666
Storage controller	
Vendor and model	Dell EMC PERC H740p
Cache size (GB)	8
Firmware version	50.3.0-1512
Driver version	7.7.03.18.00
Local storage	
Number of drives	2
Drive vendor and model	Dell/Toshiba PGNy6
Drive size (GB)	120
Drive information (speed, interface, type)	6Gb, SATA, SSD
Network adapter	
Vendor and model	Intel Ethernet Converged Network Adapter X520-2
Number and type of ports	2 x 10GbE
Driver version	4.1.1.1-iov
Storage adapter	
Vendor and model	QLogic QLE2742 32Gb FC Adapter
Number and type of ports	2 x 32Gb
Firmware version	8.07.80
Power supply	
Vendor and model	Dell EMC DD1100E-S0
Number of power supplies	2
Wattage of each (W)	1,100

# Appendix C: How we tested

## Detailed testing procedure

We configured two separate testbeds, one for each storage array under test. Each testbed had a total of six Dell EMC PowerEdge R740 servers with VMware ESXi 6.5 and dual-port 32Gb QLogic fibre channel adapters. All six servers on each testbed were grouped into a single VMware vCenter® 6.5 server-cluster. We also deployed an additional Dell EMC PowerEdge R740 server with VMware ESXi 6.5 to serve as an infrastructure server.

For most of our tests, we created 60 thinly provisioned LUNs on each storage array, then added those LUNs to ESXi servers as VMFS6 datastores. For failover testing, we increased the number of thin-provisioned LUNs to 420.

We used the open-source benchmarking tool Vdbench v5.04.07 as a disk I/O workload generator and employed VMware HCBench v1.6.7.2 to deploy VMs, coordinate workloads, and aggregate test results. We ran our IOPS testing on Vdbench with data reduction disabled.

We deployed 60 VMs per server cluster, with each VM having access to a single LUN for most of our tests. For failover testing, each VM had access to seven LUNs. We added all LUNs to the ESXi servers as VMFS6 datastores. For the Dell EMC Unity 550F, we used publicly available best practices published by [Dell EMC](#) to optimize ESXi servers. As recommended by the Vendor A published best practices for VMware vSphere in document TR-4597, we used the Vendor A Virtual Storage Controller to optimize ESXi multipathing and HBA timeout settings.

We configured the storage arrays using out-of-box defaults. On the Dell EMC Unity 550F, we deployed all LUNs under a single storage pool on the extreme performance tier, using all 25 disks on a RAID-5 configuration. On the Vendor A array, we used the OnCommand System Manager storage recommendation to create two all-flash-optimized RAID-DP data aggregates with two spare disks out of the 24 available disks. For the Vendor A array, we also created one LUN per volume, distributing the volumes evenly across both data aggregates.

We used Dell EMC Unisphere™ software for storage provisioning, management, and monitoring on the Dell EMC Unity 550F. On the Vendor A array, we used the Vendor A Virtual Storage Console (VSC) to optimize ESXi hosts and OnCommand System Manager for storage provisioning, management, and monitoring.

## Configuring Fibre Channel

We zoned and optimized server paths following vendor best practices to maximize HBA throughput. For both solutions, we used 12 x 16 Gbps ports and 12 server-HBA ports per testbed. We created multiple single-initiator zones, zoning a single host initiator to a single port on each storage controller. To spread workloads evenly, we used all 12 ports on both storage arrays.

## Installing VMware ESXi 6.5

We installed and configured 13 servers in total: 12 servers as servers under test, and an additional server as an infrastructure server. We installed ESXi 6.5 on all 13 hosts, accepting defaults and naming each server appropriately. We used the following installation steps:

1. Attach the installation media to the server.
2. Boot the server.
3. At the VMware Installer screen, press Enter.
4. At the EULA screen, to accept and continue, press F11.
5. Under Storage Devices, select the appropriate disk, and press Enter.
6. Select US as the keyboard layout, and press Enter.
7. Enter a root password twice, and press Enter.
8. To start the installation, press F11.
9. To reboot the server, remove the installation media, and press Enter.
10. After the server reboots, press F2, and enter root credentials.
11. Select Configure Management Network, and press Enter.
12. Select IPv4 Configuration, and enter the desired configuration details. Press Enter.
13. Select DNS Configuration, and enter the Primary DNS Server. Press Enter.
14. Press Esc. To accept changes, press Y.

## Deploying VMware vCenter Server 6.5 Appliance

Once we installed ESXi on the 13 hosts, we deployed VMware vCenter Server® Appliance™ on our infrastructure server, created two separate server clusters, and added six ESXi hosts to each vCenter server cluster.

1. Open the installation media folder.
2. Select vcsa-ui-installer, and right-click the installer application.
3. Click Run as Administrator.
4. Click Yes.
5. In the Appliance 6.5 Installer window, click Install.
6. At the Introduction, click Next.
7. Accept the terms of the license agreement, and click Next.
8. Select vCenter Server with an Embedded Platform Services Controller, and click Next.
9. Enter the IP address for the ESXi target server. Enter the username and password, and click Next.
10. To accept the certificate, click Yes.
11. Enter and confirm a root password for the appliance, and click Next.
12. Select the deployment size, and click Next.
13. Check the box to enable thin disk mode, and click Next.
14. Enter the desired network information (including IP address of the application, subnet, gateway, and DNS), and click Next.
15. Review the stage one information, and click Finish.
16. To move to stage two of deployment, click Continue.
17. At the introduction, click Next.
18. Enter the NTP servers for synchronization, enable SSH, and click Next.
19. Enter a domain name, password, and site name, and click Next.
20. For CEIP, click Next.
21. Review the stage two settings, and click Finish.
22. After setup completes, click Close.
23. Log onto <http://vcenterip:8443>, using the credentials previously provided.
24. On left-hand pane, right-click the vCenter server, and select New Datacenter.
25. Right-click Datacenter, and select New Cluster.
26. Enter a Cluster name, and click OK.
27. Repeat the previous two steps to create the additional cluster.
28. Right-click the newly created cluster and add all 6 ESXi servers to each cluster.

## Configuring and provisioning storage on the Dell EMC Unity 550F

### Downloading and installing the Dell EMC Unity Connection Utility

1. Visit <https://community.emc.com/docs/DOC-51785>, and download the Dell EMC Unity Connection Utility.
2. When the download has finished, click Run.
3. At the Select Setup Language screen, select English, and click OK.
4. At the Welcome screen, click Next.
5. At the Choose Install Folder screen, accept defaults, and click Next.
6. At the Pre-Installation Summary screen, click Install.
7. Check Run Connection Utility, and click Finish.

### Connecting to the storage and configuring the management IP address

1. In the connection utility, select Auto Discover, and click Next.
2. Select the system, and click Next.
3. Enter the management IP information, and click Next.
4. Review the information provided, and click Next.
5. Click Deploy.

## Running the initial configuration wizard

1. At the Introduction screen, click Next.
2. Enter the DNS server address, and click Next.
3. At the NTP server screen, click Add.
4. Enter the NTP server IP, and click Next.
5. Apply the Unisphere license, and click Next.
6. Click Next until the initial configuration wizard has been completed.

## Creating a storage pool

1. On the left-hand Unisphere pane, under Storage, click Pools.
2. Click the "+" sign.
3. Enter a Pool name and description.
4. Select Extreme Performance Tier, and click Next.
5. Select all available drives, and click Next.
6. At the Capability Profile Name, click Next.
7. At the Summary screen, click Finish.

## Discovering and adding multiple ESXi hosts

1. On the left-hand Unisphere pane, under Access, click VMware.
2. To connect to the vCenter server, click the "+" sign.
3. At the Find ESXi Hosts screen, enter vCenter credentials, and click Find.
4. Select the appropriate ESXi hosts, and click Next.
5. At the VSA Provider screen, click Next.
6. At the Summary screen, click Finish.

## Provisioning a single storage LUN

1. On the left-hand Unisphere pane, under Storage, click Block.
2. To launch the create LUN wizard, click the "+" icon.
3. Enter a LUN name, select a Pool, and enter LUN Size. Select Thin, Data Reduction, and Host I/O Limits if necessary. Click Next.
4. At the Access screen, to select the host that can access resources, click the "+" sign.
5. Select the appropriate hosts, and click OK. Click Next.
6. At the Snapshot screen, enable snapshots if necessary. Click Next.
7. At the Replication screen, enable snapshots if necessary. Click Next.
8. At the Summary screen, click Finish.

## Provisioning multiple storage LUNs using consistency groups

1. On the left-hand Unisphere pane, under Storage, click Block.
2. Click Consistency Groups.
3. To launch the consistency groups wizard, click the "+" sign.
4. Enter a name for the group.
5. At the storage screen, click the "+" sign, and select Create new LUNs.
6. Enter the appropriate number of LUNs, Name, Description, Pool, and Size. Select Thin, Data Reduction, and Host I/O Limits if necessary. Click OK.
7. Select the appropriate consistency group, and click Next.
8. At the Access screen, to select the host that can access resources, click the "+" sign.
9. Select the appropriate hosts, and click OK. Click Next.
10. At the Snapshot screen, enable snapshots if necessary. Click Next.
11. At the Replication screen, enable replication if necessary. Click Next.
12. At the summary screen, click Finish.

## Configuring and provisioning storage on the Vendor A array

### Connecting to storage and configuring management IP addresses

1. Connect the serial cable to node-1.
2. To enable AutoSupport, type `Yes`
3. Enter the node management interface port.
4. Enter the node management interface IP address.
5. Enter the node management interface netmask.
6. Enter the node management interface default gateway.
7. Connect the serial cable to node-2.
8. To enable AutoSupport, type `Yes`
9. Enter the node management interface port.
10. Enter the node management interface IP address.
11. Enter the node management interface netmask.
12. Enter the node management interface default gateway.
13. To open OnCommand System Manager and complete storage setup, open the web browser session.

### OnCommand System Manager guided setup

1. At the welcome screen, click Guided Setup.
2. At the cluster screen, enter a storage cluster name.
3. Enter the password.
4. Confirm the password.
5. Click Submit and Continue.
6. At the Network screen, select the IP address range.
7. Enter the starting address, ending address, netmask and gateway, clicking Apply after each.
8. Click Browse, and select a port for cluster management.
9. Enter the DNS domain name.
10. Enter the DNS IP address.
11. Enter the IP of the primary NTP server.
12. At the support screen, under Event Notifications, select Email.
13. Enter the SMTP mail host details.
14. Enter the email addresses.
15. Click Submit and Continue.
16. At the Storage screen, to accept the OnCommand System Manager storage recommendation, click Submit and Continue.
17. At the Aggregates Created screen, click Close.
18. At the SVM screen, select FC/FCoE data protocol.
19. Enter licenses.
20. Under FC, click Browse and, select FC ports for each node.
21. Click Submit and Continue.
22. At the Summary screen, to log into OnCommand System Manager, click Manage Your Cluster.

### Deploying Virtual Storage Console (VSC) 7.2 for VMware vSphere

We downloaded Virtual Storage Console 7.2 from the Vendor A support site and deployed it onto our infrastructure server.

1. Log into the vCenter server.
2. Right-click Datacenter.
3. Click Deploy OVF Template.
4. Select Local file, and click Browse.
5. Select unified-virtual-appliance-for-vsc-vp-sra-7.2.ova, and click Open.
6. Click Next.
7. At the Select name and location screen, click Next.
8. Select the infrastructure host, and click Next.
9. At the Review details screen, click Next.
10. At the Accept license agreement screen, click Accept, and click Next.
11. At the Select storage screen, choose a datastore to host the appliance, and click Next.
12. At the Select network screen, select the destination network, and click Next.

13. At the Customize template screen, enter administrator password, NTP server, vCenter IP, vCenter credential, and network settings, and click Next.
14. At the Ready to complete screen, click Finish.
15. Power on the VSC appliance.
16. Right-click the appliance, and click Install VMware Tools.
17. To confirm your vCenter plugin registration details, go to [https://<appliance\\_ip>:8143/Register.html](https://<appliance_ip>:8143/Register.html).

## Configuring Virtual Storage Console for VMware vSphere

1. Log into vCenter server.
2. Click Home→Virtual Storage Console.
3. On the left-hand panel, select Storage Systems.
4. Click Add, and enter Storage array IP and credentials.

## Optimizing ESXi hosts using Virtual Storage Console

1. Log into vCenter server.
2. Click Home→Virtual Storage Console.
3. Under Host Systems, click Edit Settings.
4. Select all the appropriate hosts.
5. Select the HBA/CAN, MPIO, and NFS settings checkboxes.
6. Click OK.

## Provisioning storage LUNs using OnCommand System Manager

1. On the left-hand side of OnCommand System Manager, click Storage.
2. Under Storage, click LUNs.
3. Click the Create icon, and select FlexVol.
4. Under the LUN Management tab, click the Create icon.
5. Select the appropriate SVM, and click Select.
6. At the Welcome to Create LUN Wizard screen, click Next.
7. At the General Properties screen, enter a LUN name, select the OS type, and enter a LUN size. Click Next.
8. At the LUN Container screen, select Create a new flexible volume in..., and click Choose.
9. Select the appropriate aggregate, click OK, and click Next.
10. At the Initiators Mapping screen, select the appropriate Initiator group name, and click Next.
11. At the Storage Quality of Service Screen, select Next.
12. At the LUN Summary screen, click Next.
13. Click Finish.
14. Repeat steps 1 through 13 as necessary to create 60 volumes and LUNs.

## Deploying the HCIBench controller VM

We downloaded HCIBench v1.6.7.2 from <https://labs.vmware.com/flings/hcibench> and deployed it onto our infrastructure server. We also downloaded Vdbench 5.04.07 from <https://www.oracle.com/technetwork/server-storage/vdbench-downloads-1901681.html>.

1. Log into vCenter server.
2. Right-click Datacenter.
3. Click Deploy OVF Template.
4. Select Local file, and click Browse.
5. Select HCIBench\_1.6.7.2.ova, and click Open.
6. Click Next.
7. At the Select name and location screen, click Next.
8. Select the infrastructure host, and click Next.
9. At the Review details screen, click Next.
10. At the Accept license agreement screen, click Accept twice, and click Next.
11. At the Select storage screen, choose a datastore to host the appliance, and click Next.
12. At the Select network screen, select the VM and Management networks, and click Next.
13. At the Customize template screen, enter Network Settings and Root credentials, and click Next.
14. At the Ready to complete screen, click Finish.

## Configuring HCIBench

1. Navigate to [http://HCIBench\\_IP:8443/](http://HCIBench_IP:8443/) and log in using root credentials.
2. Provide the following vSphere environment information:
  - vCenter hostname or IP
  - vCenter username and password
  - Datacenter name
  - Cluster name
  - Network name
  - Datastore name
  - Hosts
  - Host username and password
3. Under Upload the Vdbench File, click Choose File, and select the vdbench50407.zip file.
4. Select Open, and click Upload Vdbench.
5. Click Save Configuration.

## Deploying Vdbench guest VMs and running the test

For most of our tests, we deployed 60 VMs with one data disk each. For failover testing, we deployed 60 VMs with seven data disks. The size of the data disk varied; see below for detailed Vdbench parameter files.

1. Navigate to [http://HCIBench\\_IP:8443/](http://HCIBench_IP:8443/) and log in using root credentials.
2. Provide the following guest VM specifications:
  - VM name prefix
  - Number of VMs
  - Number of data disks
  - Size of data disks
3. Under Upload a Vdbench parameter file, click Choose File.
4. Select the appropriate parameter file, and click Open.
5. Click Upload Parameter File.
6. Under Select a Vdbench parameter file, click Refresh.
7. Select the appropriate parameter file, and click Save Configuration.
8. Click Test.

We performed SSD preconditioning and aging cycles to ensure that both storage arrays were properly seasoned before any performance testing. We used the same test procedures, sequences, and configuration files for both storage arrays. We prefilled LUNs with data prior to any performance testing, and conducted all testing with data reduction disabled (except during our data reduction tests).

## Preconditioning the SSDs

To eliminate temporary elevated fresh out of the box (FOB) performance, we deployed 60 LUNs to consume all available storage and ran a sequential mixed I/O size (50% each of 128KB and 256KB) through the whole SSD space twice.

```
sd=sd1,lun=/dev/sda,openflags=o_direct
wd=wd_precondition,sd=(sd1),xfersize=(128k,50,256k,50),rdpct=0,seekpct=eof
rd=fill_1,wd=wd_precondition,iorate=max,interval=100h,elapsed=100h,forthreads=4
rd=fill_2,wd=wd_precondition,iorate=max,interval=100h,elapsed=100h,forthreads=4
```

## Prefilling LUN data

We used 256KB sequential writes with single thread to fill the LUNs with data.

```
sd=sd1,lun=/dev/sda,openflags=o_direct
wd=wd_prefill,sd=(sd1),xfersize=256k,rdpct=0,seekpct=eof
rd=prefill_1,wd=wd_prefill,iorate=max,interval=30,elapsed=100h,threads=1
```

## Running aging cycles

We ran mixed I/O size random writes to the system for three hours to put the storage arrays into production stage.

```
sd=sd1,lun=/dev/sda,openflags=o_direct
wd=wd_1,sd=(sd1),xfersize=(4k,9,8k,47,16k,21,32k,17,64k,6),rdpct=0,seekpct=100
rd=aging_1,wd=wd_1,iorate=max,interval=30,elapsed=3h,forthreads=16
```

## Testing 8KB and 256KB Vdbench performance

For these tests, we deployed 60 x 1TB LUNs and configured Vdbench to only access 700 GB of each LUN. We ran a Vdbench curve test with 10% to 100% scaling of IOPS, random 8KB, and 256KB sequential I/Os.

```
sd=sd1,lun=/dev/sda,openflags=o_direct,size=700g
wd=wd_default,sd=*
wd=wd_seq_256KB,sd=*,seekpct=0
rd=default,curve=(10-100,10),iorate=curve,interval=5,elapsed=2m,warmup=30
rd=wd_rand_curve_small,wd=wd_default,forxfersize=8k,forrdpct=(0,70,100),seekpct=100,forthreads=32
rd=wd_seq_curve_256KB,wd=wd_seq_256KB,forxfersize=(256k),forrdpct=0,forthreads=1
```

## Prefilling data reduction for a 4:1 data set

For these tests, we deployed 60 x 500GB LUNs with data reduction enabled.

```
compratio=4
dedupunit=8k
dedupratio=4
dedupsets=5%
sd=default,openflags=directio
sd=sd1,lun=/dev/sda
wd=wd_default,sd=*
wd=wd_256k_fill,sd=*,rdpct=0,seekpct=EOF
rd=default,iorate=max,interval=30,elapsed=100h
rd=data_prefill,wd=wd_256k_fill,xfersize=256k,threads=1
```

## Testing data reduction for a 4:1 data set (70,000 IOPS)

For these tests, we configured Vdbench to generate a 70,000 IOPS workload using 8KB random writes. We performed the data reduction tests immediately after the data reduction prefill completed.

```
compratio=4
dedupunit=8k
dedupratio=4
dedupsets=5%
sd=sd1,lun=/dev/sda,openflags=o_direct
wd=s1w,sd=(sd1),xfersize=8k,seekpct=100,rdpct=0
rd=8k_rand_w_32T,wd=s1w,iorate=1167,interval=10,elapsed=1h,warmup=60,threads=32
```

## Prefilling failover data

For failover testing, we deployed 420 x 100GB LUNs without data reduction enabled. On the Vendor A array, the LUNs were distributed evenly across both data aggregates. We deployed 60 VMs, each with seven data disks.

```
sd=sd1,lun=/dev/sda,openflags=o_direct
sd=sd2,lun=/dev/sdb,openflags=o_direct
sd=sd3,lun=/dev/sdc,openflags=o_direct
sd=sd4,lun=/dev/sdd,openflags=o_direct
sd=sd5,lun=/dev/sde,openflags=o_direct
sd=sd6,lun=/dev/sdf,openflags=o_direct
sd=sd7,lun=/dev/sdg,openflags=o_direct
wd=wd1,sd=(sd1,sd2,sd3,sd4,sd5,sd6,sd7),xfersize=256k,rdpct=0,seekpct=EOF
rd=run1,wd=wd1,iorate=max,interval=30,elapsed=48h,threads=1
```

## Testing failover recovery

For this test, we configured Vdbench to generate a 50,000 IOPS workload using a 70/30 read/write 32KB random I/O mix.

```
sd=sd1,lun=/dev/sda,openflags=o_direct,hitarea=0,range=(0,100),threads=5
sd=sd2,lun=/dev/sdb,openflags=o_direct,hitarea=0,range=(0,100),threads=5
sd=sd3,lun=/dev/sdc,openflags=o_direct,hitarea=0,range=(0,100),threads=5
sd=sd4,lun=/dev/sdd,openflags=o_direct,hitarea=0,range=(0,100),threads=5
sd=sd5,lun=/dev/sde,openflags=o_direct,hitarea=0,range=(0,100),threads=5
sd=sd6,lun=/dev/sdf,openflags=o_direct,hitarea=0,range=(0,100),threads=5
sd=sd7,lun=/dev/sdg,openflags=o_direct,hitarea=0,range=(0,100),threads=5
wd=wd1,sd=(sd1,sd2,sd3,sd4,sd5,sd6,sd7),xfersize=32k,rdpct=70,seekpct=100
rd=run1,wd=wd1,iorate=833,elapsed=3600,interval=1
```

This project was commissioned by Dell EMC.



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