Technical Report

NetApp All Flash FAS Solution for Persistent Desktops with VMware Horizon View

Joe Scott and Chris Gebhardt, NetApp
May 2017 | TR-4540

Abstract

This document describes the solution components used in the 1,500-user Horizon View deployment on NetApp All Flash FAS reference architecture validation. It covers the hardware and software used in the validation, the configuration of the hardware and software, use cases that were tested, and performance results of the completed tests. It also contains sections focusing on the new platforms in the AFF product line, the NetApp AFF A-Series, and their relative performance to the previous generation. It includes workload profiles that allow customers to see the different IO profiles that make up each different test performed in this reference architecture.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 Executive Summary

The decision to virtualize desktops affects multiple aspects of an IT organization, including infrastructure and storage requirements, application delivery, end-user devices, and technical support. In addition, correctly architecting, deploying, and managing a virtual desktop infrastructure (VDI) can be challenging because of the large number of solution components in the architecture. Therefore, it is critical to build the solution on industry-proven platforms such as NetApp® storage and industry-proven software solutions from VMware. VMware and NetApp provide leading desktop virtualization and storage solutions, respectively, for customers to successfully meet these challenges. A desktop virtualization solution provides workspace mobility, centralized management, consolidated and secure delivery of data, and device independence.

The criteria for determining the success of a virtual desktop implementation must include the end-user experience. The end-user experience must be as good as or better than any previous experience on a physical PC or virtual desktop.

As a workload, desktop virtualization is highly variable, and it includes cycles of heavy reads, heavy writes, and everything in between, along with varying block sizes for writes. Therefore, it should be no surprise that storage is often the leading culprit of unmet end-user performance expectations. The NetApp All Flash FAS (AFF) solution, easily handles highly variable desktop virtualization workloads to deliver an end-user experience that exceeds expectations.

Another criterion of project success is solution cost. Storage has often been the most expensive part of the virtual desktop solution, especially when storage efficiency and flash acceleration technologies were lacking. It was also common practice to forgo an assessment. Skipping this critical step meant that companies often overbought or undersized the storage infrastructure because information is the key to making sound architectural decisions that result in wise IT spending.

NetApp has many technologies that help customers reduce the storage cost of a virtual desktop solution. Technologies such as inline deduplication, inline compression, data compaction, advanced drive partitioning, and thin provisioning help reduce the total amount of storage required for VDI. Storage platforms that scale up and scale out with NetApp ONTAP® software deliver the right architecture to meet the customer's price and performance requirements. NetApp helps customers achieve their cost and performance goals while providing rich data management features.

With the NetApp All Flash FAS solution, customers might pay as little as US$29 per desktop (AFF A200) for storage when deploying at scale. This figure includes the cost of NetApp hardware and software and three years of 24/7 premium support with four-hour parts replacement. A similarly low ratio of dollars per desktop can be achieved within the portfolio of All Flash FAS platforms.

With VMware and NetApp, companies can accelerate the virtual desktop end-user experience by using NetApp All Flash FAS storage for VMware Horizon View. NetApp All Flash FAS storage, powered by the AFF8000 and AFF A-Series systems, is the optimal platform for using high-performing solid-state drives (SSDs) without adding risk to desktop virtualization initiatives.

When a storage failure prevents users from working, that inactivity translates into lost revenue and productivity. That is why what used to be considered a tier 3 or 4 application is now critical to business operations. Having a storage system with a robust set of data management and availability features is key to keeping the users working and lessens the risk to the business. ONTAP has multiple built-in features, such as active-active high availability (HA) and nondisruptive operations, to help improve availability and to seamlessly move data in the storage cluster without affecting users.

NetApp also provides the ability to easily increase storage system capacity by simply adding disks or shelves. There is no need to purchase additional controllers to add users when additional capacity is required. When the platform requires expansion, additional nodes can be added in a scale-out fashion and managed within the same management framework and interface. Workloads can then be nondisruptively migrated or balanced to the new nodes in the cluster without users ever noticing.

2 Reference Architecture Objectives

The reference architecture described in this document is a 1,500-desktop design using NetApp AFF8040, VMware Horizon View 7, and VMware vSphere 6.0. The reference architecture validates a persistent, full-clone, 1,500-desktop architecture created with the NetApp Virtual Storage Console (VSC) and imported into Horizon View. The testing covered common administrative tasks, including boot storms, login storms, patching, and steady-state operations. These tests determined time to complete, storage response, and storage utilization.

In all tests, end-user login time, guest response time, and maintenance activities performance were excellent. The NetApp All Flash FAS system performed well, averaging less than 50% controller utilization during most operations for both use cases. All test categories demonstrated that, based on the 1,500-user workload and maintenance operations, the AFF8040 system is capable of supporting 2,666 users while still being able to fail over in the event of a failure. At a density of 2,666 VMs on an AFF8040 system with the same I/O profile, storage for VDI can be as low as US$39 per desktop. This figure includes the cost of hardware, software, and three years of 24/7 premium support with four-hour parts replacement. A similarly low ratio of dollars per desktop can be achieved within the broader portfolio of All Flash FAS platforms. Table 1 lists the results of testing for 1,500 persistent desktops.

Table 1) Test results for 1,500 persistent desktops.

Test	Time to Complete	Peak IOPS	Peak Throughput	Average Storage Latency
Provision	~80 min	81,002	2693MBps	1.45ms
Boot storm test	~12 min	117,752	3082MBps	2.26ms
Boot storm test during failover	~14 min	75,772	1802MBps	12.1ms
Login VSI: Monday morning login and workload	20.78 sec/VM	31,088	533MBps	441µs
Login VSI: Monday morning login and workload during failover	19.12 sec/VM	40,000	915MBps	468µs
Login VSI: Tuesday morning login and workload	19.27 sec/VM	21,874	490MBps	446µs
Login VSI: Tuesday morning login and workload during failover	19.36 sec/VM	30,653	1054MBps	503µs
Patching desktops with ~900MB of patches (3 sec delay)	~110 min	42,172	1402MBps	810µs

Note: During the boot storm test, View Administrator was used to power on the virtual machines.

3 Introduction

This section provides an overview of the NetApp AFF solution for Horizon View, explains the purpose of this document, and introduces Login VSI.

3.1 Document Overview

This document describes the solution components used in the 1,500-user Horizon View deployment on the NetApp All Flash FAS reference architecture validation. The document covers the hardware and software used in the validation, the configuration of the hardware and software, use cases that were tested, and performance results of the completed tests. During these performance tests, many different scenarios were tested to validate the performance of the storage during the lifecycle of a virtual desktop deployment.

The testing included the following criteria:

- Provisioning 1,500 VMware Horizon View full-clone desktops by using VMware vSphere vStorage APIs for Array Integration (VAAI) cloning offload to high-performing, space-efficient NetApp FlexClone® desktops
- Boot storm test of 1,500 desktops (with and without storage node failover)
- Monday morning login and steady-state workload with Login VSI (with and without storage node failover)
- Tuesday morning login and steady-state workload with Login VSI (with and without storage node failover)
- Patching 1,500 desktops

Storage performance and end-user acceptance were the main focus of the testing. If a bottleneck occurred in any component of the infrastructure, it was identified and remediated if possible. Best practices were followed to perform staggered patching and maintenance during nonproduction periods of time. NetApp does not recommend patching all desktops at the same time during production hours.

3.2 NetApp All Flash FAS

NetApp ONTAP has evolved to meet the changing needs of customers and help drive their success. ONTAP provides a rich set of data management features and clustering for scale-out, operational efficiency, storage efficiency, and nondisruptive operations to offer customers one of the most compelling value propositions in the industry. The IT landscape is undergoing a fundamental shift to IT as a service. This model requires a pool of computing, network, and storage resources to serve a range of applications and deliver a range of services. Innovations such as ONTAP are fueling this revolution.

The 1,500 desktops were hosted on a 2-node NetApp All Flash FAS active-active storage system running NetApp ONTAP 9 configured with 24 800GB SSDs.

3.3 NetApp ONTAP FlashEssentials

NetApp ONTAP FlashEssentials is the power behind the performance and efficiency of All Flash FAS. ONTAP is a well-known operating system, but it is not widely known that ONTAP, with its WAFL® (Write Anywhere File Layout) file system, is natively optimized for flash media.

ONTAP FlashEssentials encapsulates key features that optimize solid-state-drive (SSD) performance and endurance, including the following:

- NetApp data-reduction technologies, including inline compression, inline deduplication, and inline data compaction, can provide significant space savings. Savings can be further increased by using NetApp Snapshot® and NetApp FlexClone technologies. Studies based on customer deployments have shown that total data-reduction technologies have enabled up to 933-times space savings.
- Inline data compaction provides continued innovation beyond compression and deduplication, further increasing storage efficiency.
- Coalesced writes to free blocks maximize performance and flash media longevity.
- Flash-specific read path optimizations enable consistently low latency.
- Parallelized processing handles more requests at once.

- Software-defined access to flash maximizes deployment flexibility.
- New advanced drive partitioning (ADPv2) increases storage efficiency and further increases usable capacity by almost 20%.
- Data fabric readiness enables live workload migration between flash and hard disk drive (HDD) tiers on the premises or to the cloud.
- Quality-of-service capability safeguards service-level objectives in multiworkload and multitenant environments.

3.4 NetApp ONTAP 9

NetApp ONTAP 9 is a major advance in the industry's leading enterprise data management software. ONTAP 9 combines new levels of simplicity and flexibility with powerful capabilities and efficiencies. Customers can integrate the best of next-generation and traditional technologies, incorporating flash, cloud, and software-defined architectures while building a foundation for their data fabric. Plus, new customers and existing Data ONTAP 8.3 environments can quickly and easily use the rich data services delivered by ONTAP 9.

An essential feature for VDI deployed on shared enterprise storage is the ability to deliver consistent and dependable high performance. High performance must be coupled with nondisruptive operations, high availability, scalability, and storage efficiency. Customers can depend on ONTAP 9 and All Flash FAS to provide these essential elements.

Built on ONTAP unified scale-out architecture, All Flash FAS consistently meets or exceeds the high-performance demands of VDI. All Flash FAS also provides rich data management capabilities, such as Integrated Data Protection and nondisruptive upgrades and data migration. These features allow customers to eliminate performance silos and seamlessly integrate All Flash FAS into a shared infrastructure. ONTAP delivers enhanced inline deduplication and a completely new inline data-compaction capability that significantly reduces the amount of flash storage required, with no effect on system performance. It also provides industry-leading ecosystem integration with database applications that makes the administration of databases and storage systems far more efficient than other flash storage solutions on the market.

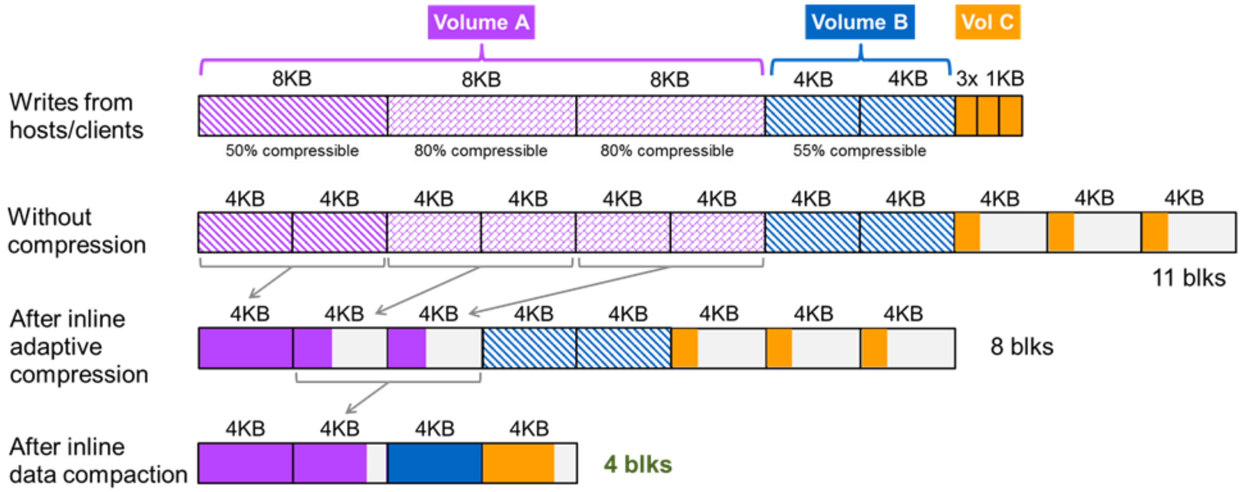
NetApp is a global enterprise scale-out storage and data management fabric provider, and ONTAP has been an industry-leading operating system since 2012. On-site ready but cloud connected, ONTAP is a complete solution that is future-proof in a rapidly changing technology environment.

3.5 Storage Efficiency

Simply stated, storage efficiency enables you to store the maximum amount of data within the smallest possible space at the lowest possible cost. The following NetApp storage efficiency technologies can help you realize maximum space savings:

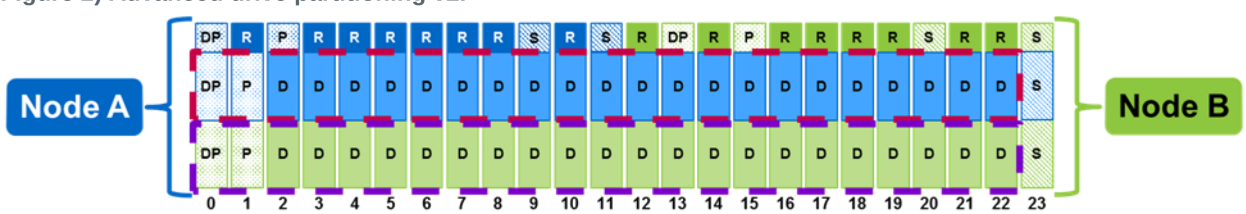
- **Inline compression**. Data compression reduces the disk space required, regardless of storage protocol, application, or storage tier. Inline compression also reduces the data that must be moved to SSDs, thereby reducing the wear on SSDs. Furthermore, the reduced amount of data being written can deliver an overall performance increase.
- **Inline deduplication.** Data deduplication cuts storage requirements by reducing redundancies in primary, backup, and archival data. Inline deduplication of zeros speeds up VM provisioning by 20% to 30%. Further improvements to inline deduplication in ONTAP 9 provide additional efficiency by extending elimination of duplicate data to blocks in memory and SSDs.
- **Inline data compaction.** New in ONTAP 9, NetApp inline data compaction provides significant storage savings by compressing and coalescing small I/O together into single-block writes. This change further reduces the disk space required and the associated wear on SSDs. Figure 1 demonstrates how compressed data that is smaller than 4K can be stored in a block with other data smaller than 4K.

Figure 1) Visual representation of inline compression and data compaction.



- **Snapshot technology.** NetApp Snapshot technology provides low-cost, instantaneous, point-in-time, space-efficient copies of the file system (volume) or LUN by preserving ONTAP architecture and WAFL consistency points without affecting performance. NetApp SnapManager® software for Oracle automates and simplifies Oracle database management with backup, recovery, restore, and cloning features with no downtime.
- **Thin provisioning.** Thin provisioning, implemented by NetApp at the NetApp FlexVol® volume and LUN level, defers storage purchases by keeping a common pool of free storage available to all applications.
- **Thin replication.** Thin replication is at the center of the NetApp data protection software portfolio, which includes NetApp SnapMirror® and NetApp SnapVault® software. SnapVault thin replication enables more frequent backups that use less storage capacity because no redundant data is moved or stored. SnapMirror thin replication protects business-critical data while minimizing storage capacity requirements.
- **RAID DP.** NetApp RAID DP® technology protects against double disk failure without sacrificing performance or adding disk-mirroring overhead.
- **FlexClone volumes.** FlexClone virtual cloning reduces the need for storage by enabling multiple, instant, space-efficient writable copies.
- **Advanced drive partitioning (v2).** As is shown in Figure 2, advanced SSD partitioning with the latest ONTAP 9 release further increases usable capacity by almost 20%.

Figure 2) Advanced drive partitioning v2.

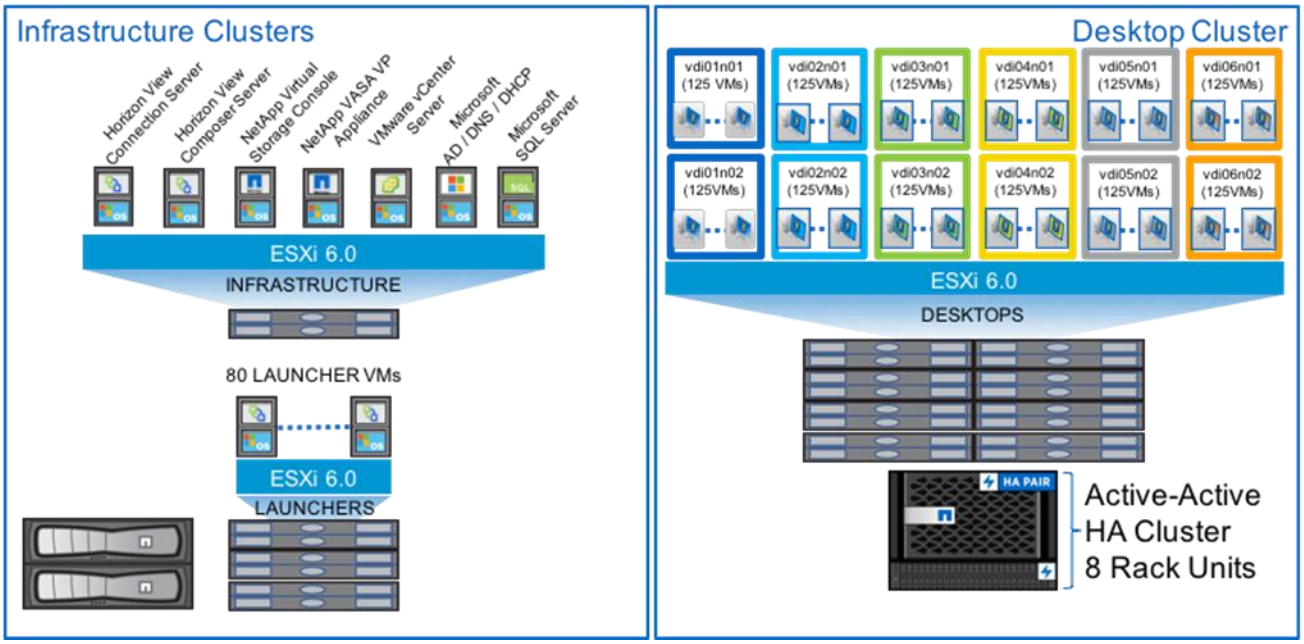


4 Solution Infrastructure

This section describes the software and hardware components of the solution. Figure 3 shows the solution infrastructure, which includes the Horizon View Connection Server VM and the Horizon View Composer Server VM.

Scale performance tests, such as boot, login, and steady-state tests, were performed to help validate that this All Flash FAS array is capable of hosting 1,500 users with the standard configuration of 2 storage controllers.

Figure 3) Solution infrastructure for persistent desktops.



4.1 Hardware Infrastructure

During solution testing, 25 servers were used to host the infrastructure and the desktop VMs. The desktops and infrastructure servers were hosted on discrete resources so that the workload to the NetApp All Flash FAS system could be measured precisely. It is both a NetApp and an industry best practice to separate the desktop VMs from the infrastructure VMs. That is because noisy neighbors or bully virtual desktops can affect the infrastructure and have a negative impact on all users, applications, and performance results.

Options to neutralize this problem include leveraging intelligent quality-of-service policies in ONTAP to eliminate noisy neighbor behavior and using intelligent sizing to account for infrastructure VMs. Options also include putting infrastructure VMs on an existing or separate NetApp FAS storage system. For this lab validation, we used a separate NetApp FAS storage system (not shown) to host the infrastructure and the launcher. In the real world, infrastructure VMs can be on the same All Flash FAS system that is hosting the virtual desktops. Table 2 lists the hardware specifications of each server category.

Table 2) Hardware components of server categories.

Hardware Components	Configuration
Infrastructure Servers and Launcher Servers	
Server quantity	10 Fujitsu Primergy RX300 S8
CPU model	Intel Xeon CPU E5-2630 v2 at 2.60GHz (6-core)
Total number of cores per server	12 cores (24 with hyperthreading)
Memory per server	64GB to 256GB

Hardware Components	Configuration
Desktop Servers	
Server quantity	Mix of 15 Fujitsu Primergy RX2540 M1
CPU model	Intel Xeon CPU E5-2670 v2 at 2.30GHz (12-core)
Total number of cores per server	16 to 24 cores (32 to 48 with hyperthreading)
Memory per server	256 to 512GB
Storage	
NetApp controller	AFF8040A
Disk shelf	1 DS2246
Disk drives	24 800GB SSDs

4.2 Software Components

This section describes the purpose of each software product used to test the NetApp All Flash FAS system and provides configuration details. Table 3 lists the software components and identifies the version of each component.

Table 3) Solution software components.

Software	Version
NetApp FAS	
NetApp ONTAP	9.0 RC
NetApp VSC for VMware	6.2
VMware Software	
VMware ESXi	6.0.0, 2494585
VMware vCenter Server	6.0.0
VMware Horizon View Administrator	7.0.0, 3633490
VMware Horizon View Client	4.0.0, 3677815
VMware Horizon View Agent	7.0.0, 3634043
VMware vSphere PowerCLI	6.3, 3737840
Workload Generation Utility	
Login VSI Professional	Login VSI 4.1.4.2
Database Server	
Microsoft SQL Server	11.12.1 build 14008
Microsoft SQL Server Management Studio	2.6.0.5031

4.3 Login VSI

Login Virtual Session Indexer (Login VSI) is the industry-standard load-testing tool for testing the performance and scalability of centralized Windows desktop environments such as server-based computing (SBC) and VDI.

Login VSI is used for testing and benchmarking by all major hardware and software vendors and is recommended by both leading IT analysts and the technical community. Login VSI is vendor independent and works with standardized user workloads; therefore, conclusions based on Login VSI test data are objective, verifiable, and replicable.

SBC-oriented and VDI-oriented vendor organizations that are committed to enhancing the end-user experience in the most efficient way use Login VSI as an objective method of testing, benchmarking, and improving the performance and scalability of their solutions. VSImax provides proof (vendor independent, industry standard, and easy to understand) to innovative technology vendors of the power, the scalability, and the gains of their solutions.

Login VSI–based test results are published in technical white papers and are presented at conferences. Login VSI is used by end-user organizations, system integrators, hosting providers, and testing companies. It is also the standard tool used in all tests executed in the internationally acclaimed Project Virtual Reality Check.

For more information about Login VSI or for a free test license, refer to the Login VSI website.

4.4 Full-Clone Virtual Desktops

The desktop VM template was created with the virtual hardware and software listed in Table 4. The VM hardware and software were installed and configured according to Login VSI documentation.

Table 4) Virtual desktop configurations.

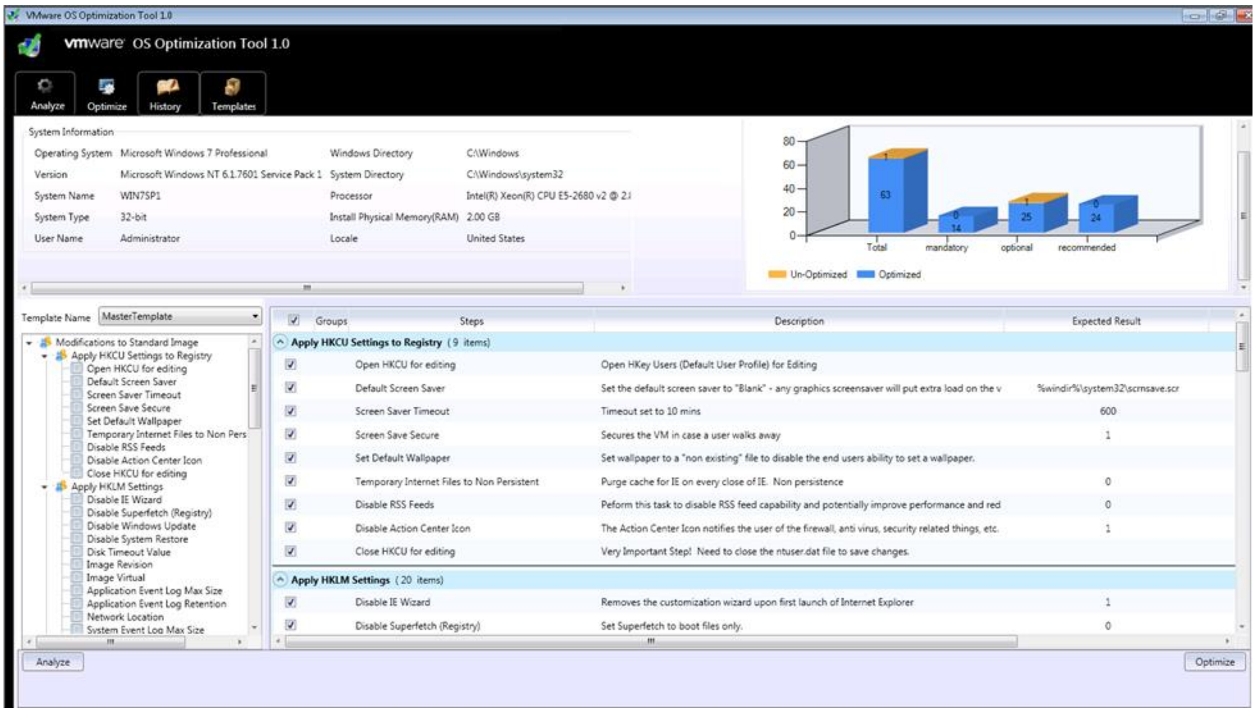
Desktop	Configuration
Desktop VM	
VM quantity	1,500
VM hardware version	11
vCPU	2 vCPUs
Memory	2GB
Hard disk size	32GB
Hard disk type	Thin provisioned
Desktop Software	
Guest OS	Windows 10 (64-bit)
VM hardware version	ESXi 6.0 and later (VM version 11)
VMware tools version	9.10.0.2476743
Microsoft Office	2016 version 16.0.4266.1001
Adobe Acrobat Reader	11.0.00
Adobe Flash Player	11.5.502.146
Java	7.0.130

Desktop	Configuration
Doro PDF	1.82
VMware Horizon View Agent	7.0.0, 3634043
Login VSI target software	4.1.4.2

Guest Optimization

Guest OS optimizations were applied to the template VMs used in this reference architecture. Figure 4 shows the VMware OS optimization tool that was used to perform the guest optimizations.

Figure 4) VMware OS optimization tool.



Although it might be possible to run desktops without guest optimizations, the impact of not optimizing must first be understood. Many recommended optimizations address services and features (such as hibernation, Windows updates, and system restores) that do not provide value in a virtual desktop environment. Running services and features that do not add value would decrease the overall density of the solution and increase cost. That is because these services and features would consume CPU, memory, and storage resources in relation to both capacity and I/O.

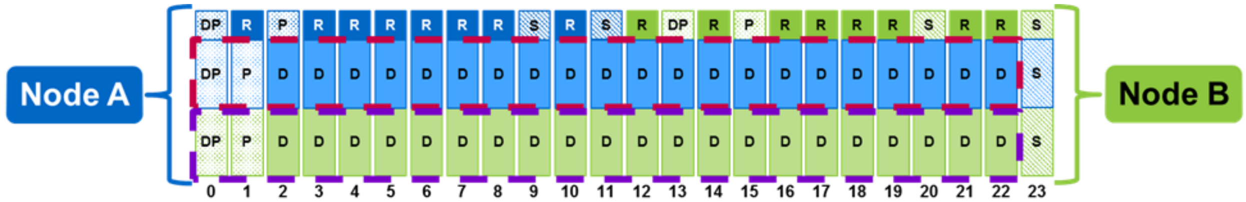
5 Storage Design

This section provides an overview of the storage design, aggregate layout, volume layout, and Virtual Storage Console (VSC).

5.1 Aggregate Layout

In this reference architecture, we used 24 800GB SSDs divided across the 2 nodes of an AFF8040 controller. This architecture is shown in Figure 5.

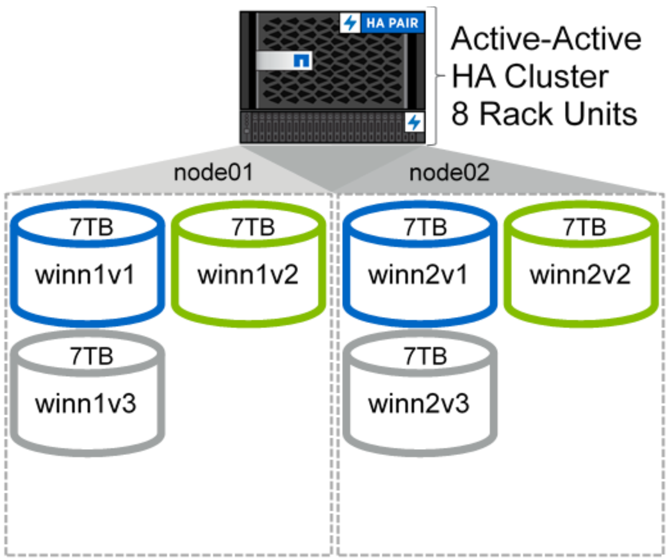
Figure 5) SSD layout.



5.2 Volume Layout

To adhere to NetApp best practices, all volumes were provisioned with the NetApp VSC. Figure 6 shows how the volumes were arranged.

Figure 6) Volume layout for persistent desktops.



Note: A root volume for the virtual desktop SVM is present but is not depicted.

5.3 NetApp Virtual Storage Console for VMware vSphere

NetApp VSC was used to provision the datastores in this reference architecture. NetApp VSC for VMware vSphere provides integrated, comprehensive, end-to-end virtual storage management for your VMware infrastructure, including discovery, health monitoring, capacity management, provisioning, cloning, backup, restore, and disaster recovery.

5.4 Creating VMware Horizon View Desktop Pools

The Windows PowerShell script shown in Figure 7 creates 10 pools named win10n#v#. In the tested reference architecture, these 10 pools were created across 2 nodes of the NetApp All Flash FAS cluster. This approach allowed the best parallels across the storage system. The Login VSI Active Directory group was then entitled to the created pools. The Windows PowerShell script was run from the VMware Horizon View PowerCLI located on the VMware Horizon View server. Concurrent provisioning and power-on operations were set to 5 for Horizon View during the provisioning phase.

Figure 7) Windows PowerShell script to create 10 pools of 150 desktops each.

```
$vcserver = "vcsa6.vdi.rtp.netapp.com"
$domain = "vdi.rtp.netapp.com"
```



```
$username = "administrator"
$sleep = "300"

function CreatePersistentPool ($poolid, $dataStorePaths, $numvms, $templatePath)
{
$templatePathBase = "/VDI/vm/"
$vmFolderPath = "/VDI/vm"
$resourcePoolPath = "/VDI/host/Desktops/Resources"
$persistance = "Persistent"
$OrganizationalUnit = "OU=Computers,OU=LoginVSI"
$customizationSpec = "win10vdi"


Write-Host "Creating $numvms desktops named" $poolid "in datastores " $dataStorePaths
Get-ViewVC | Get-ComposerDomain -domain $domain -Username $username | Add-AutomaticPool -
Pool_id  $poolid -displayName $poolid -namePrefix $poolid"-{n:fixed=3}" -TemplatePath
$templatePathBase$templatePath -vmFolderPath $vmFolderPath  -resourcePoolPath $resourcePoolPath -
dataStorePaths $dataStorePaths -HeadroomCount $numvms -minimumCount $numvms -maximumCount $numvms
-PowerPolicy "AlwaysOn" -SuspendProvisioningOnError $false -CustomizationSpecName
$customizationSpec
}

#Create pools below
CreatePersistentPool -poolid "pooln1v1" -dataStorePaths "/VDI/host/Desktops/win10n1v1" -numvms
130 -templatePath win10n1v1
CreatePersistentPool -poolid "pooln2v1" -dataStorePaths "/VDI/host/Desktops/win10n2v1" -numvms
130 -templatePath win10n2v1
CreatePersistentPool -poolid "pooln1v2" -dataStorePaths "/VDI/host/Desktops/win10n1v2" -numvms
130 -templatePath win10n1v2
CreatePersistentPool -poolid "pooln2v2" -dataStorePaths "/VDI/host/Desktops/win10n2v2" -numvms
130 -templatePath win10n2v2
CreatePersistentPool -poolid "pooln1v3" -dataStorePaths "/VDI/host/Desktops/win10n1v3" -numvms
130 -templatePath win10n1v3
CreatePersistentPool -poolid "pooln2v3" -dataStorePaths "/VDI/host/Desktops/win10n2v3" -numvms
130 -templatePath win10n2v3
CreatePersistentPool -poolid "pooln1v4" -dataStorePaths "/VDI/host/Desktops/win10n1v1" -numvms
130 -templatePath win10n1v1
CreatePersistentPool -poolid "pooln2v4" -dataStorePaths "/VDI/host/Desktops/win10n2v1" -numvms
130 -templatePath win10n2v1
CreatePersistentPool -poolid "pooln1v5" -dataStorePaths "/VDI/host/Desktops/win10n1v2" -numvms
130 -templatePath win10n1v2
CreatePersistentPool -poolid "pooln2v5" -dataStorePaths "/VDI/host/Desktops/win10n2v2" -numvms
130 -templatePath win10n2v2
CreatePersistentPool -poolid "pooln1v6" -dataStorePaths "/VDI/host/Desktops/win10n1v3" -numvms
130 -templatePath win10n1v3
CreatePersistentPool -poolid "pooln2v6" -dataStorePaths "/VDI/host/Desktops/win10n2v3" -numvms
130 -templatePath win10n2v3

sleep $sleep

#Entitle pools below
Get-Pool | Add-PoolEntitlement -sid (Get-User -IncludeUser $false -IncludeGroup $true -Name
"LoginVSI").sid
```

Prerequisites

Before testing began, the following requirements were met:

- 1,500 users and a group were created in Active Directory by using the Login VSI scripts.
- Datastores were created on NetApp storage by using the NetApp VSC plug-in.

6 Testing and Validation: Persistent Full-Clone Desktops

This section describes the testing and validation of persistent VMware Horizon View full-clone desktops.

6.1 Test Results Overview

Table 5 lists the high-level results that were achieved during the reference architecture testing. One item to note is that throughout the paper, graphs displaying system utilization are shown. With ONTAP, system utilization is not absolute. What this means is that during a given workload, system utilization on both nodes could exceed 50% and during failover could perform excellently without increasing latency. For example, node 1 runs at 70% and node 2 runs at 60%; during failover, the combined controllers might run at 85% and still serve data in <1ms.

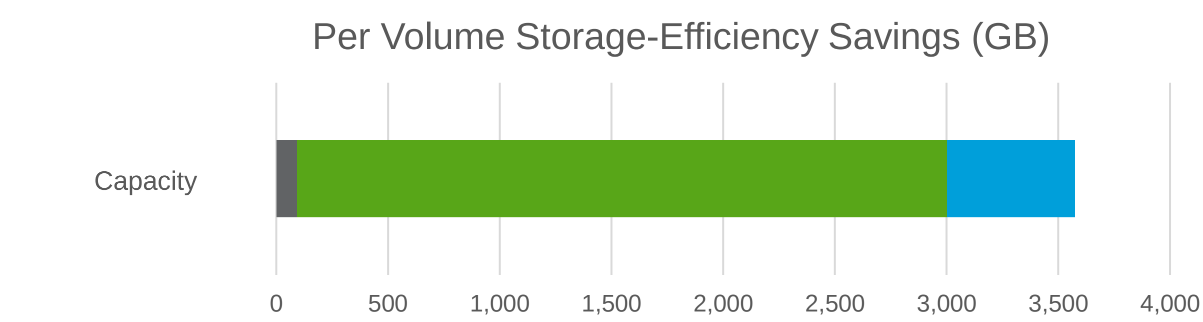
Table 5) Test results overview.

Test	Time to Complete	Peak IOPS	Peak Throughput	Average Storage Latency
Provision	~80 min	81,002	2693MBps	1.45ms
Boot storm test	~12 min	117,752	3082MBps	2.26ms
Boot storm test during failover	~14 min	75,772	1802MBps	12.1ms
Login VSI: Monday morning login and workload	20.78 sec/VM	31,088	533MBps	441µs
Login VSI: Monday morning login and workload during failover	19.12 sec/VM	40,000	915MBps	468µs
Login VSI: Tuesday morning login and workload	19.27 sec/VM	21,874	490MBps	446µs
Login VSI: Tuesday morning login and workload during failover	19.36 sec/VM	30,653	1054MBps	503µs
Patching desktops with ~900MB of patches (3 sec delay)	~110 min	42,172	1402MBps	810µs

6.2 Storage Efficiency

During the tests, FlexClone technology was used to provision the VMs and deduplication was enabled. On average, a 50:1 deduplication efficiency ratio, or 98% storage efficiency, was observed. This means that 50 virtual desktops consumed the storage of one desktop on disk. These high rates are due not only to inline deduplication but also to the ability of FlexClone technology to instantaneously create storage-efficient virtual desktops. Without these technologies, traditional storage environments would have consumed 20.3TB of storage. With deduplication and FlexClone technology, 1,500 desktops consumed only 558GB of storage, a savings of over 97%. At the aggregate level, which accounts for physical blocks stored, we saw an additional 8% savings from compaction in addition to the 97% seen at the FlexVol level. Figure 8 shows the significant difference in storage efficiency savings.

Figure 8) Storage efficiency savings.



	Capacity
Capacity Used	93
Dedupe Savings	2909
Compression Savings	572

Because of the synthetic nature of the data used to perform these tests, these results are not typical of real-world savings. In addition, although thin provisioning was used for each volume, thin provisioning is not a storage-reduction technology and therefore was not reported. Table 6 lists the efficiency results from the testing after steady state but before patching.

Table 6) Efficiency results for each FlexVol volume.

Capacity Used	Total Savings	Dedupe Savings	Compression Savings
93GB	3481GB	2909GB	572GB

6.3 Test for Provisioning 1,500 VMware Horizon View Full Clones (Offloaded to VAAI)

This section describes test objectives and methodology and provides the results from testing the provisioning of 1,500 VMware Horizon View full clones.

Test Objectives and Methodology

The objective of this test was to determine how long it would take to provision 1,500 VMware Horizon View virtual desktops being offloaded to VAAI. This scenario is mostly applicable to the initial deployment of a new POD of persistent desktops.

To set up for the tests, 1,500 VMware Horizon View native full clones were created with VAAI using a Windows PowerShell script for simplicity and repeatability.

Figure 9 shows one line of the script filled out to demonstrate what was done for one pool of 150 VMs. The script shown in Figure 7 (in section 5.4 Creating VMware Horizon View Desktop Pools) contains the entire script that was used to create the pools.

Figure 9) Creating 150 VMs in one pool.

```
Write-Host "Creating $numvms desktops named" $poolid "in datastores " $dataStorePaths
Get-ViewVC | Get-ComposerDomain -domain $domain -Username $username | Add-AutomaticPool -Pool_id
$poolid -displayName $poolid -namePrefix $poolid"-{n:fixed=3}" -TemplatePath
$templatePathBase$templatePath -vmFolderPath $vmFolderPath  -resourcePoolPath $resourcePoolPath -
dataStorePaths $dataStorePaths -HeadroomCount $numvms -minimumCount $numvms -maximumCount $numvms
-PowerPolicy "AlwaysOn" -SuspendProvisioningOnError $false -CustomizationSpecName
$customizationSpec}
```


For this testing, we chose specific pool and provisioning settings that would stress the storage while providing the most granular reporting capabilities. NetApp does not advocate using or disabling these features because each might provide significant value in the correct use case. NetApp recommends that customers test these features to understand their impacts before deploying with these features enabled. These features include, but are not limited to, persona management, replica tiering, user data disks, and disposable file disks. Table 7 lists the provisioning data that was gathered.

Table 7) Results for full-clone provisioning of 1,500 virtual desktops.

Time	Average Latency	Peak IOPS	Avg. IOPS	Peak Throughput	Avg. Throughput	Peak Storage CPU	Avg. Storage CPU
~80 min	1.45ms	81,002	43,172	2693MBps	1216MBps	100%	68%

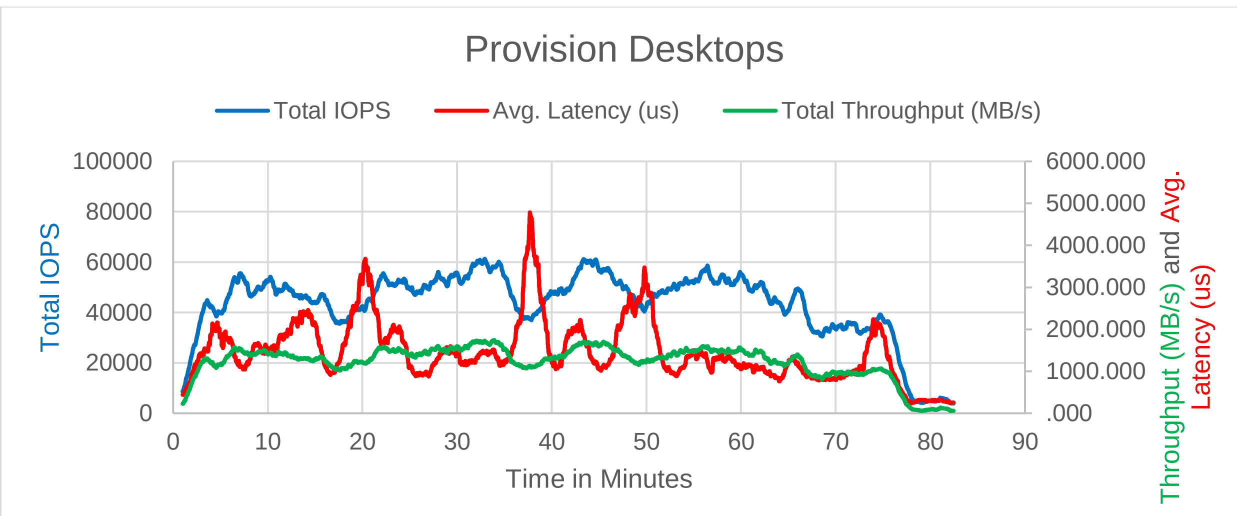
Note: All desktops had the status Available in VMware Horizon View.

Note: CPU and latency measurements are based on the average across both nodes of the cluster. IOPS and throughput are based on a combined total of each.

Throughput and IOPS

During the provisioning test, the storage controllers had a combined peak of 81,002 IOPS, 2693MBps throughput, and an average of 68% utilization per storage controller, with an average latency of 1.45ms. Figure 10 shows the throughput and IOPS for full-clone creation.

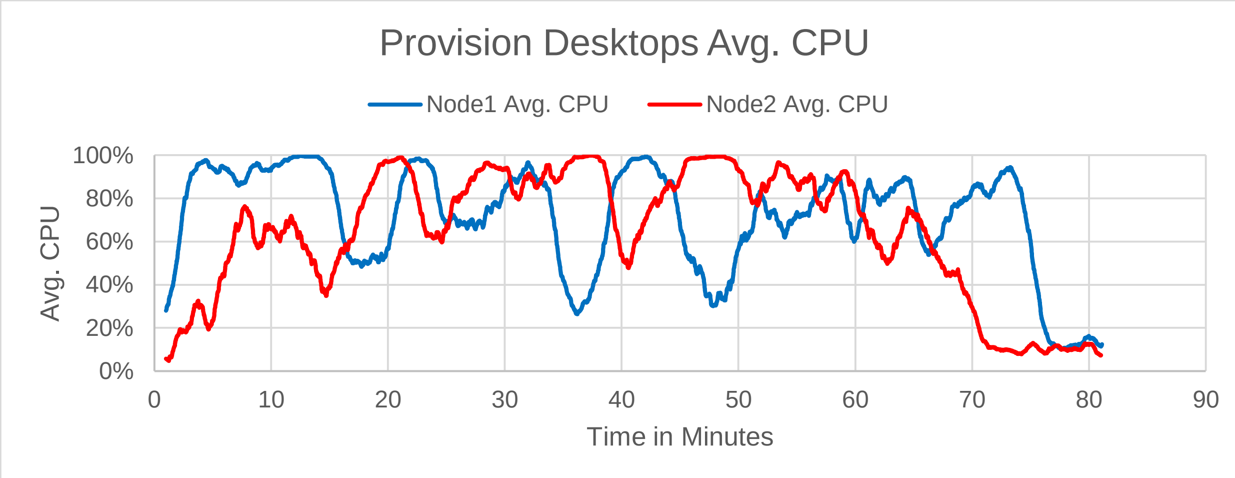
Figure 10) Throughput and IOPS for full-clone creation.



Storage Controller CPU Utilization

Figure 11 shows the storage controller CPU utilization across both nodes of the two-node NetApp cluster. The utilization average was 68% with a peak of 100%.

Figure 11) Storage controller CPU utilization for full-clone creation.



Customer Impact (Test Conclusions)

During the provisioning of 1,500 persistent desktops, the storage controller had enough headroom to perform a significantly greater number of concurrent provisioning operations. On average, the NetApp All Flash FAS system provisioned VMs at a rate of 18s per VM. Because provisioning is a one-time operation, we allowed provisioning to fully utilize the resources of the controller to provision as quickly as possible. Slower provisioning would result in better efficiencies per FlexVol volume but longer overall provisioning time.

The offload of the clone creation from the ESXi host to VAAI allowed each of the clones to be created in a fast and storage-efficient manner. Cloning through VAAI for Virtual Machine File System does not copy each block on the storage but instead clones block ranges within the LUN that reference only the original blocks. Therefore, the VMs are prededuplicated. This process delivers faster cloning, less impact on the host, and a reduction in space during provisioning. The rate at which the storage acknowledges clone requests can exhaust the default throttling limits employed by the Horizon View Provisioning process. So that provisioning completes in a smooth and successful manner, adjustments to the default throttling setting might be necessary. In our tests, the maximum concurrent provisioning and power-on settings were set to 5 simultaneous operations.

6.4 Boot Storm Test

This section describes test objectives and methodology and provides results from boot storm testing.

Test Objectives and Methodology

The objective of this test was to determine how long it would take to boot 1,500 virtual desktops. This situation might occur, for example, after maintenance activities and server host failures.

This test was performed by powering on all 1,500 VMs from within the VMware vCenter and observing when the status of all VMs in VMware Horizon View changed to `Available`. Table 8 lists the boot storm data that was gathered.

Table 8) results for full-clone boot storm.

Time	Average Latency	Peak IOPS	Avg. IOPS	Peak Throughput	Avg. Throughput	Peak Storage CPU	Avg. Storage CPU
~12 min	2.26ms	117,752	57,231	3082MBps	1469MBps	100%	58%

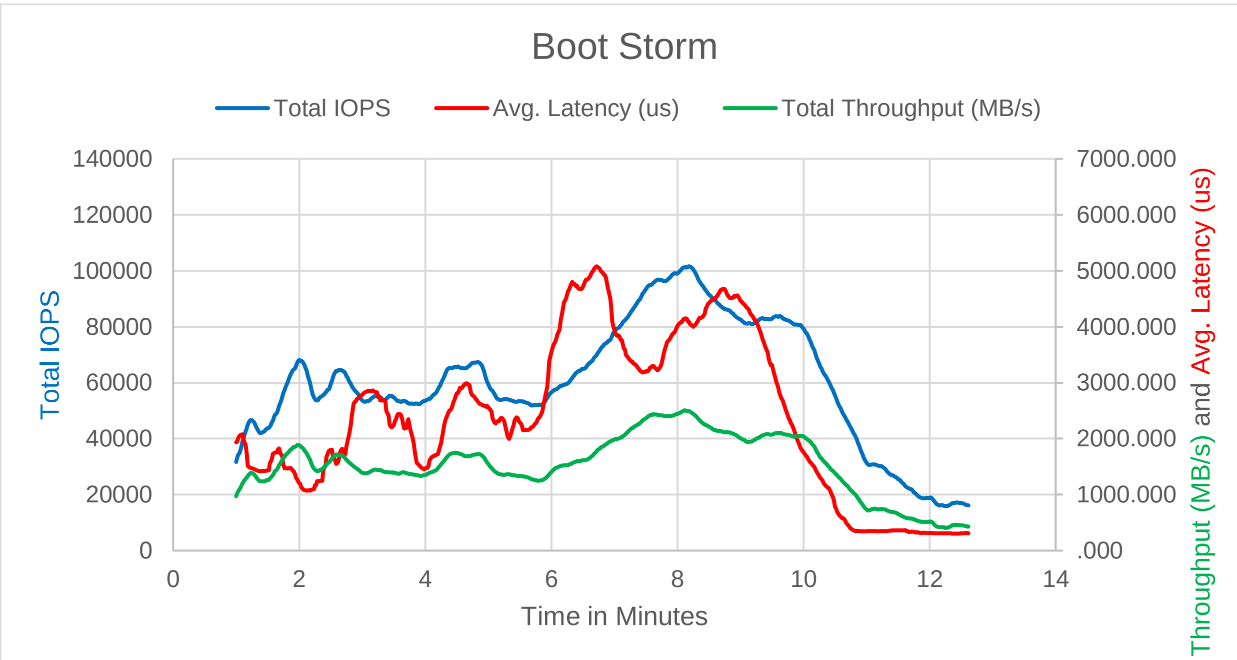
Note: All desktops had the status Provisioned in VMware Horizon View.

Note: CPU and latency measurements are based on the average across both nodes of the cluster. IOPS and throughput are based on a combined total of each.

Throughput, IOPS, and Latency

Figure 12 shows throughput and IOPS for a full-clone boot storm.

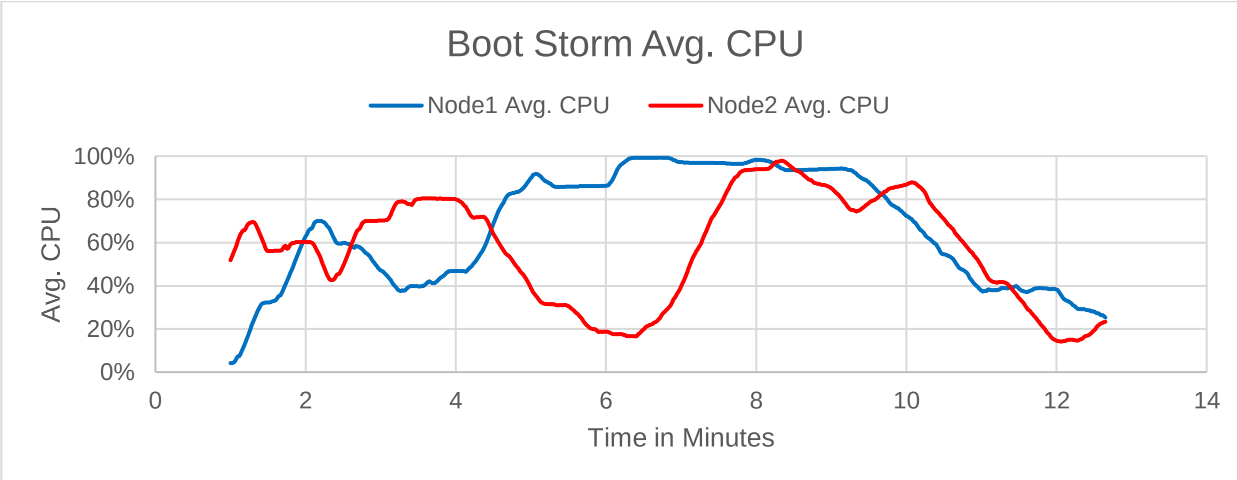
Figure 12) Throughput and IOPS for full-clone boot storm.



Storage Controller CPU Utilization

Figure 13 shows storage controller CPU utilization for a full-clone boot storm.

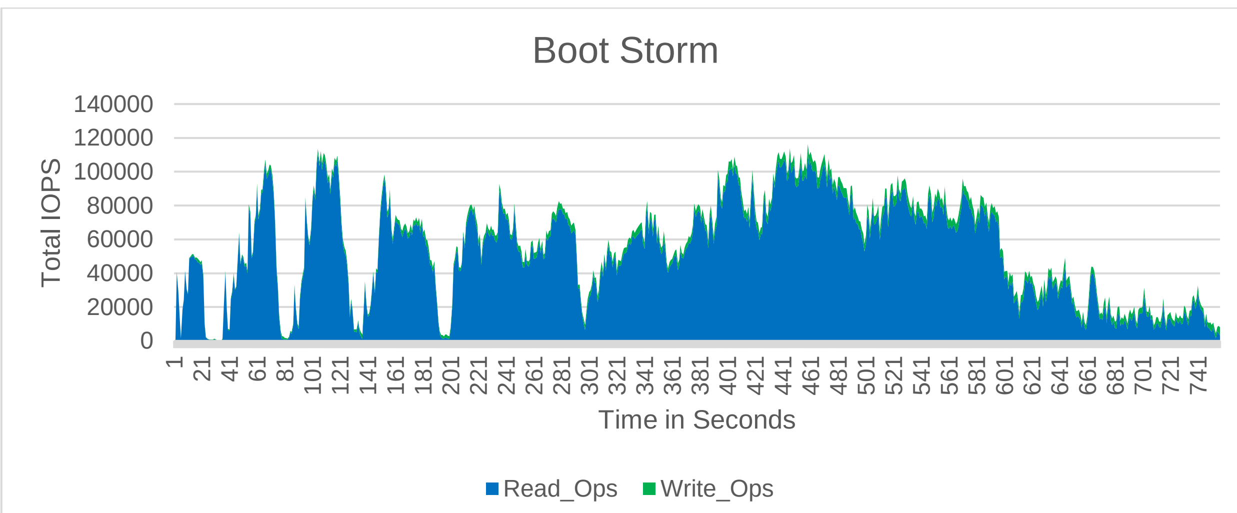
Figure 13) Storage controller CPU utilization for full-clone boot storm.



Read/Write IOPS

Figure 14 shows read and write IOPS for a full-clone boot storm.

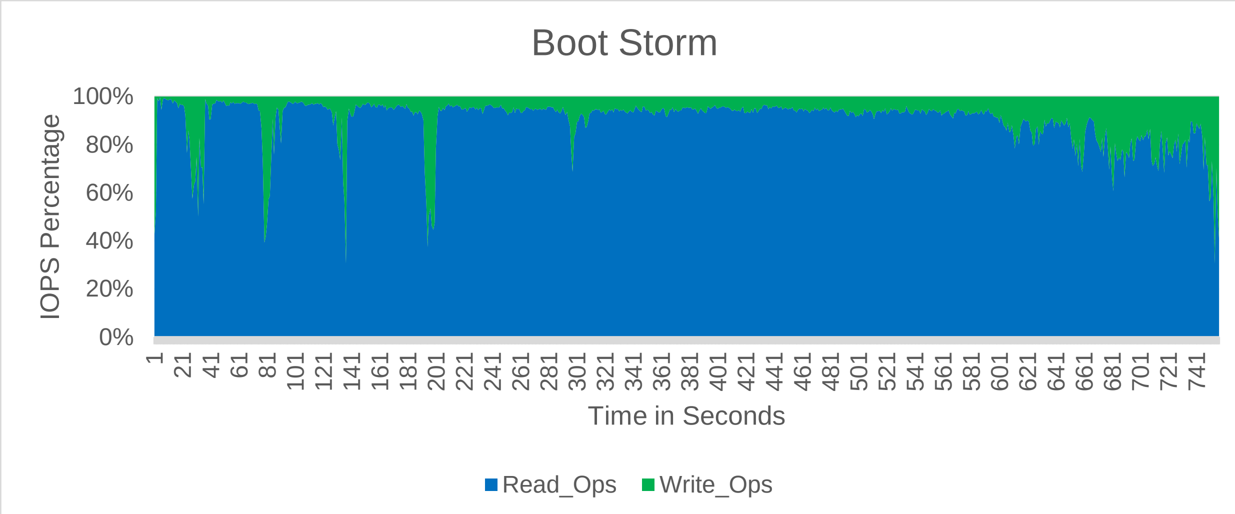
Figure 14) Read/write IOPS for full-clone boot storm.



Read/Write Ratio

Figure 15 shows the read and write ratio for a full-clone boot storm.

Figure 15) Read/write ratio for full-clone boot storm.



Customer Impact (Test Conclusions)

During the boot of 1,500 persistent desktops, the storage controller reached about the max number of concurrent boot operations. However, booting more desktops might take longer as utilization increases. The focus of this test, however, was not on client latency but on restoring the users' desktops as quickly as possible.

6.5 Boot Storm Test During Storage Failover

This section describes test objectives and methodology and provides results from boot storm testing during storage controller failover.

Test Objectives and Methodology

The objective of this test was to determine how long it would take to boot 1,500 virtual desktops if the storage controller had a problem and was failed over. This test used the same methodologies and processes that were used in section 6.4 Boot Storm Test. Table 9 shows the data that was gathered for the boot storm during storage failover.

Table 9) Results for full-clone boot storm during storage failover.

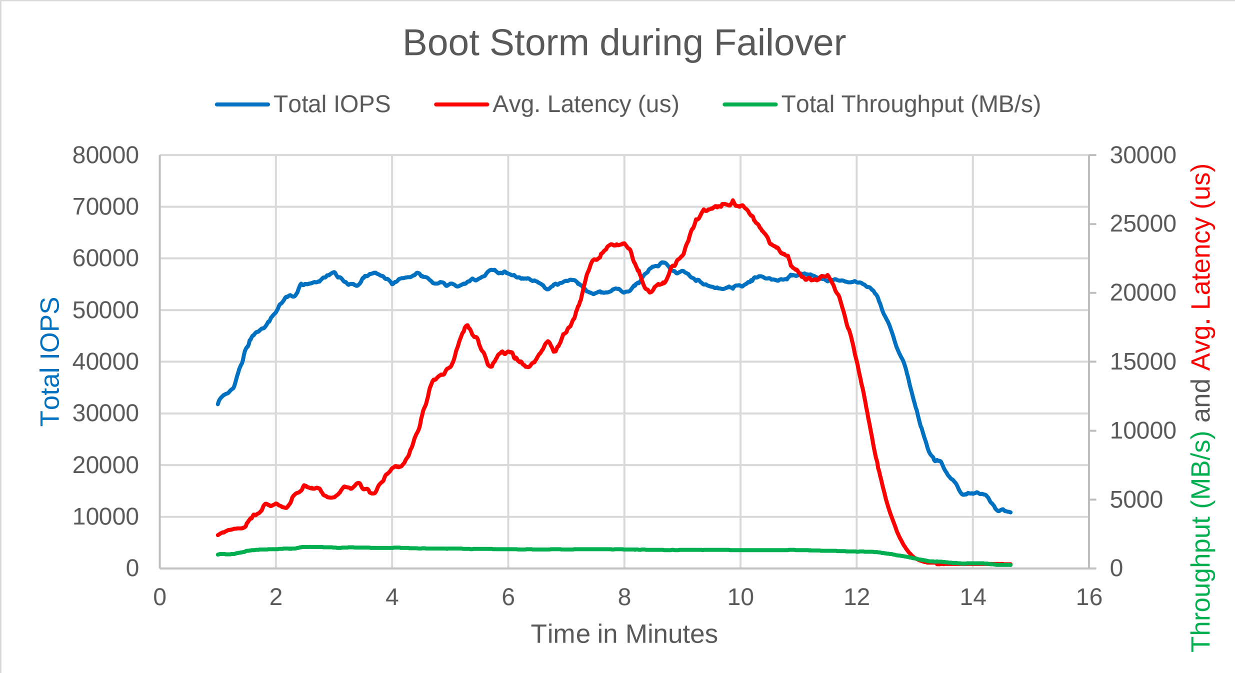
Time	Average Latency	Peak IOPS	Avg. IOPS	Peak Throughput	Avg. Throughput	Peak Storage CPU	Avg. Storage CPU
~14 min	12.1ms	75,772	47,234	1802MBps	1193MBps	100%	82%

Note: All desktops had the status of Provisioned in VMware Horizon View.

Throughput, IOPS, and Latency

Figure 16 shows throughput, IOPS, and latency for a full-clone boot storm during storage failover.

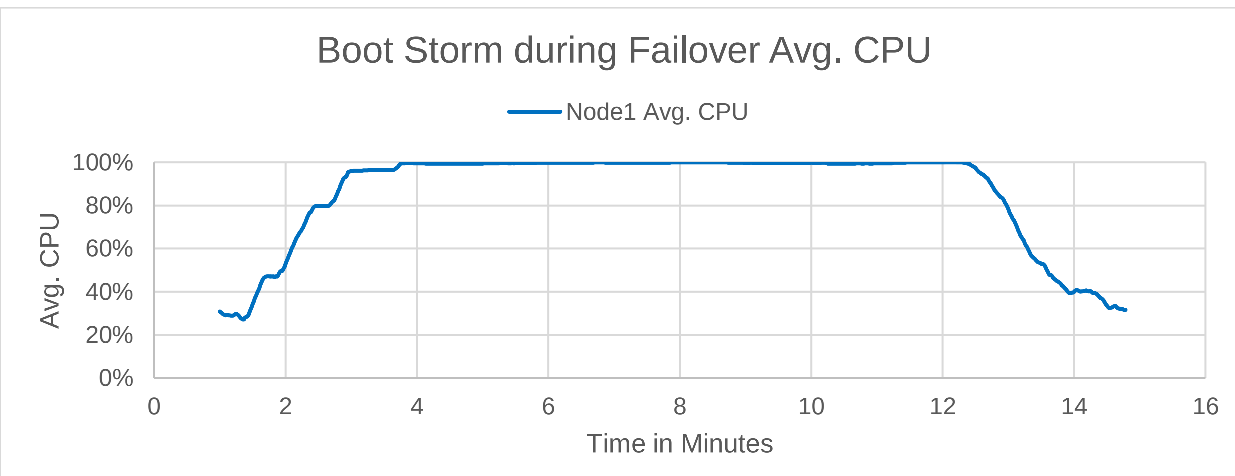
Figure 16) Throughput, IOPS, and latency for a full-clone boot storm during storage failover.



Storage Controller CPU Utilization

Figure 17 shows storage controller CPU utilization for a full-clone boot storm during storage failover.

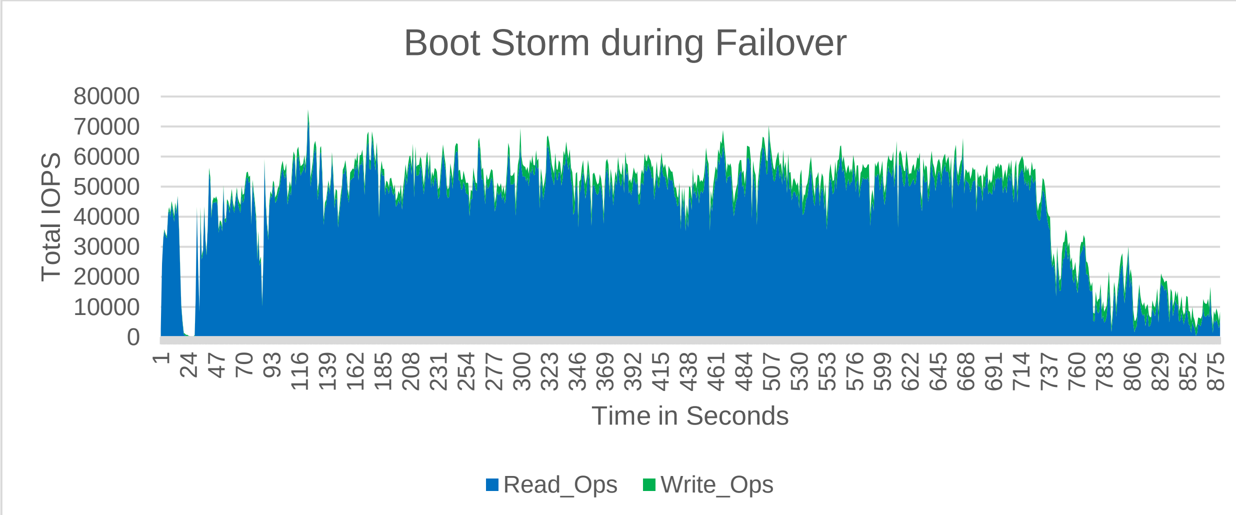
Figure 17) Storage controller CPU utilization for full-clone boot storm during storage failover.



Read/Write IOPS

Figure 18 shows read and write IOPS for a full-clone boot storm during storage failover.

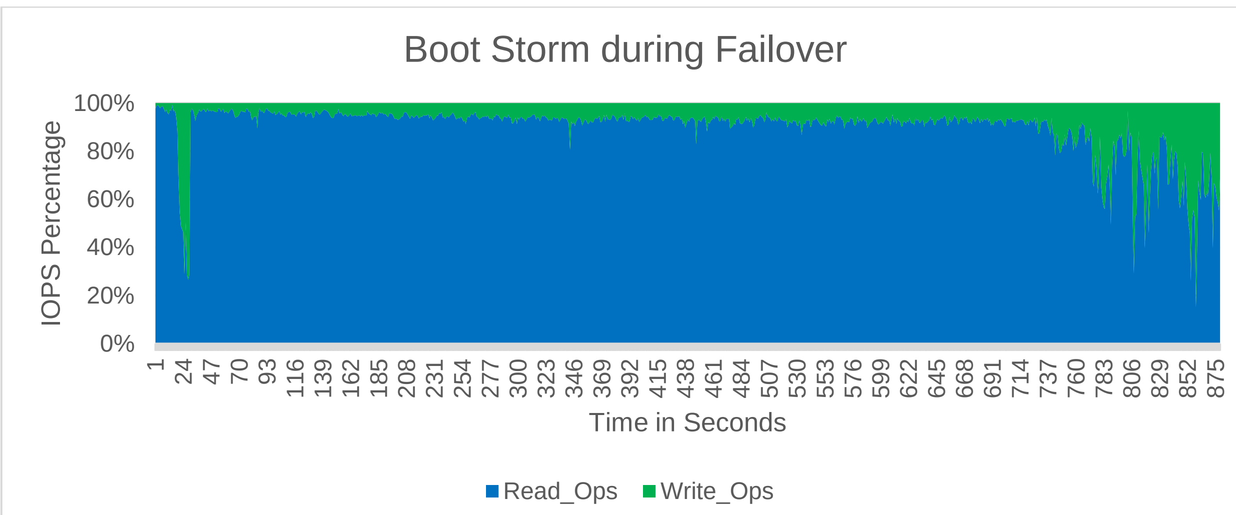
Figure 18) Read/write IOPS for full-clone boot storm during storage failover.



Read/Write Ratio

Figure 19 shows read and write ratios for a full-clone boot storm during storage failover.

Figure 19) Read/write ratio for full-clone boot storm during storage failover.



Customer Impact (Test Conclusions)

During the boot of 1,500 persistent desktops with storage failed over, the storage controller was able to boot 1,500 desktops on 1 node in approximately 14 minutes. Tests were conducted to measure the impact of using VMware Horizon View to boot the desktops. The focus of this test, however, was not on client latency but on restoring the users' desktops as quickly as possible.

6.6 Login and Steady-State VSI Test

This section describes test objectives and methodology and provides results from Login and steady-state VSI testing.

Test Objectives and Methodology

The objective of this test was to run a Login VSI office worker workload to determine how the storage controller performed and evaluate the end-user experience. This Login VSI workload first had the users log in to their desktops and begin working. The login phase occurred over a 75-minute period.

Three different login scenarios were included because each has a different I/O profile. We measured storage performance as well as login time and VSImax, a Login VSI value that represents the maximum number of users who can be deployed on a given platform. VSImax was not reached in any of the Login VSI tests. The following sections define the login scenarios.

Monday Morning Login and Workload Test

In this scenario, 1,500 users logged in after the VMs had already been logged into once, the profile had been created, and the desktop had been rebooted. During this type of login, user and profile data, application binaries, and libraries had to be read from a disk because they were not already in the VM memory. Table 10 shows the results for a full-clone Monday morning login and workload.

Table 10) Results for full-clone Monday morning login and workload.

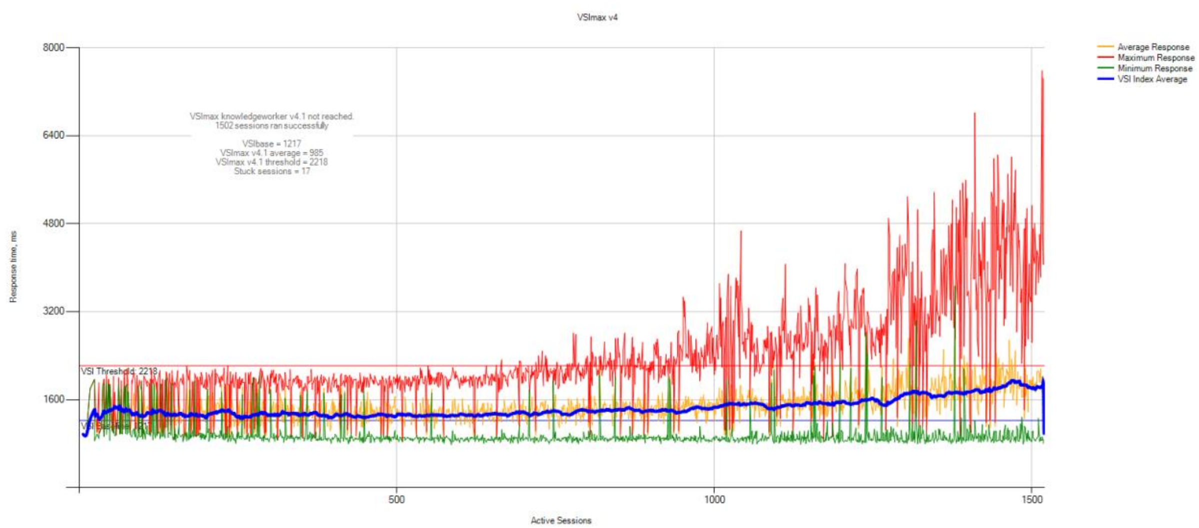
Desktop Login Time	Average Latency	Peak IOPS	Avg. IOPS	Peak Throughput	Avg. Throughput	Peak Storage CPU	Avg. Storage CPU
20.78 sec/VM	441µs	31,088	9,865	533MBps	197MBps	87%	24%

Note: CPU and latency measurements are based on the average across both nodes of the cluster. IOPS and throughput are based on a combined total of each.

Login VSI VSImax Results

Because the Login VSI VSImax was not reached, more VMs could be deployed on this infrastructure. Figure 20 shows the VSImax results for Monday morning login and workload.

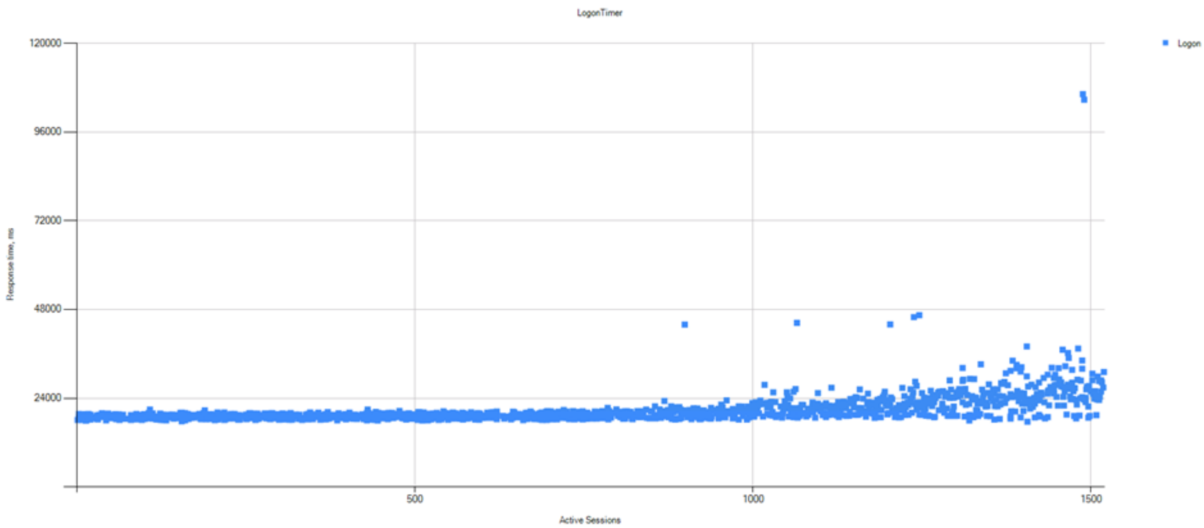
Figure 20) VSImax results for full-clone Monday morning login and workload.



Desktop Login Time

Average desktop login time was 20.78 seconds, which is considered an excellent login time. Figure 21 shows a scatterplot of the Monday morning login times.

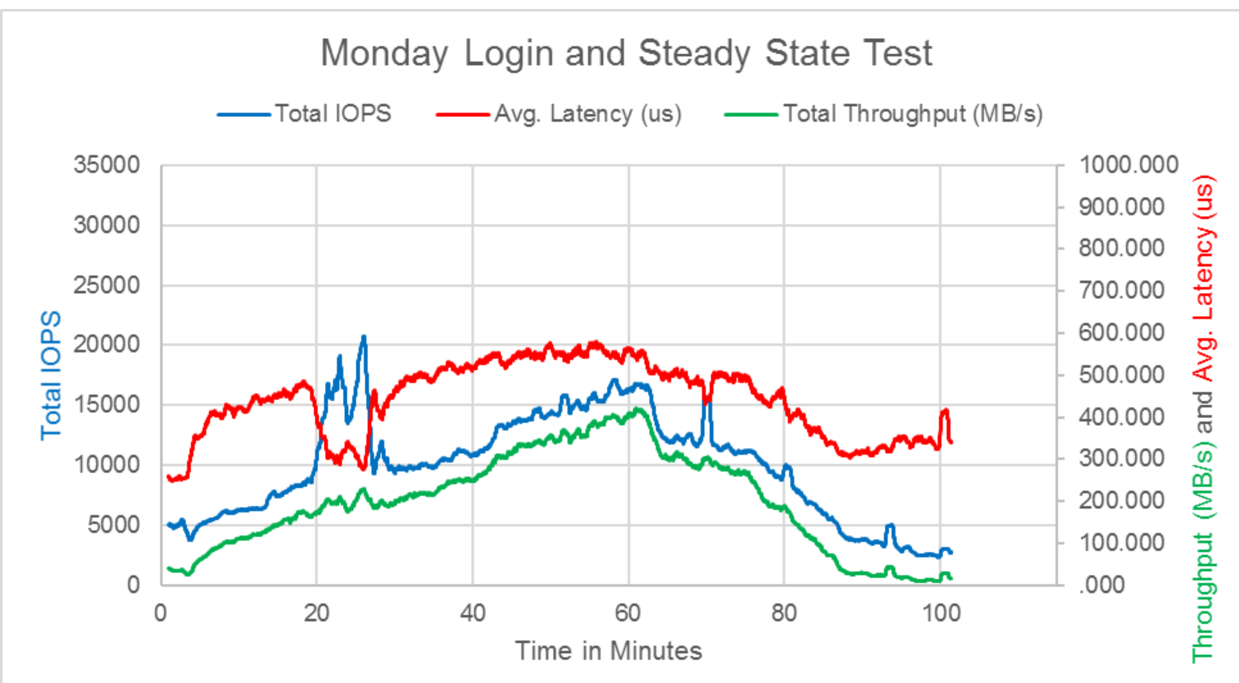
Figure 21) Scatterplot of full-clone Monday morning login times.



Throughput, IOPS, and Latency

Figure 22 shows throughput, IOPS, and latency for full-clone Monday morning login and workload.

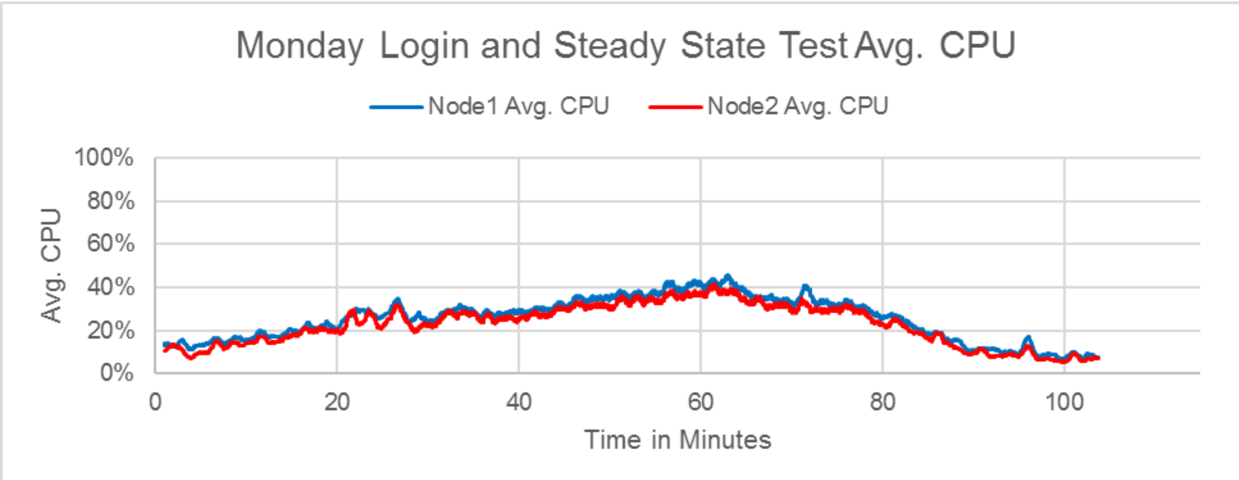
Figure 22) Throughput, IOPS, and latency for full-clone Monday morning login and workload.



Storage Controller CPU Utilization

Figure 23 shows storage controller CPU utilization for full-clone Monday morning login and workload.

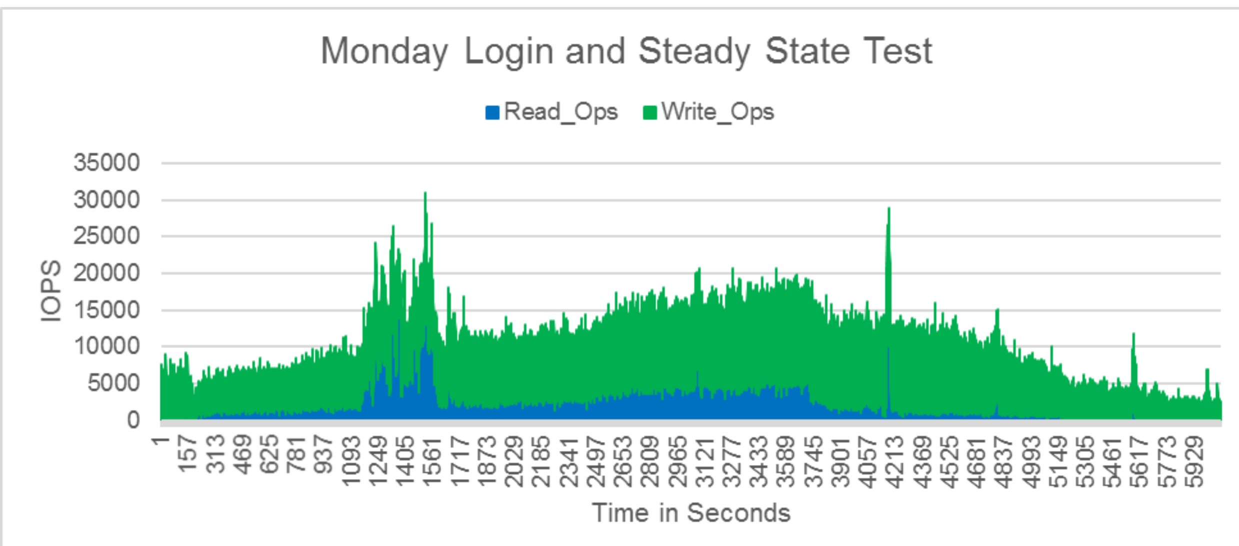
Figure 23) Storage controller CPU utilization for full-clone Monday morning login and workload.



Read/Write IOPS

Figure 24 shows read and write IOPS for full-clone Monday morning login and steady state.

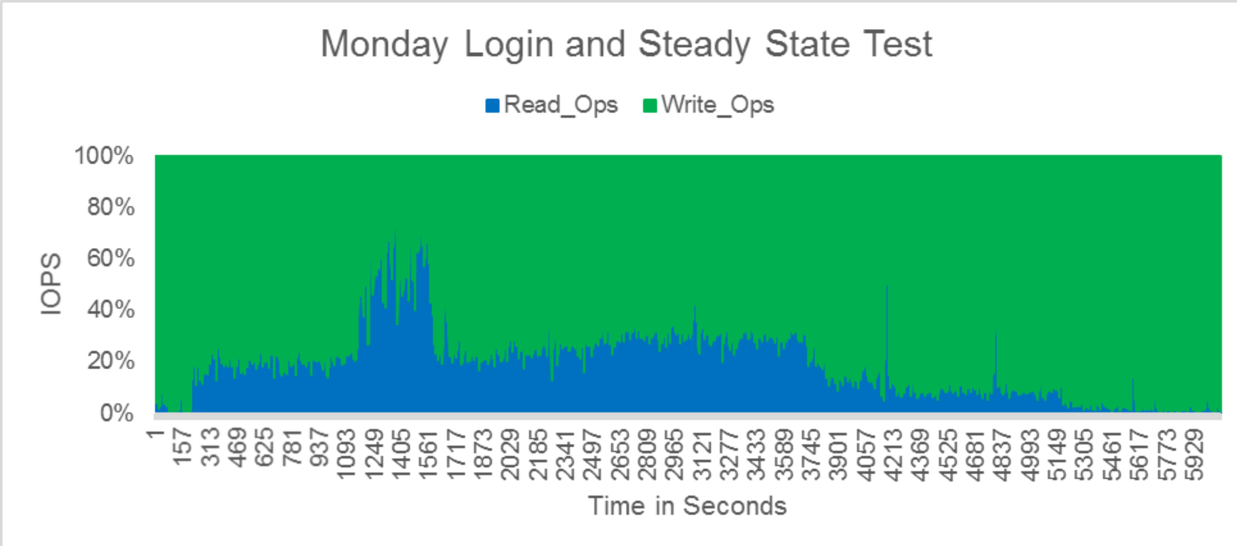
Figure 24) Read/write IOPS for full-clone Monday morning login and workload.



Read/Write Ratio

Figure 25 shows read and write ratios for full-clone Monday morning login and workload.

Figure 25) Read/write ratio for full-clone Monday morning login and workload.



Customer Impact (Test Conclusions)

During the Monday morning login test, the storage controller performed very well. The CPU utilization was not high during this test, latencies were under 1ms, and desktop performance was excellent. These results suggest that it might be possible to double the storage controller workload to 3,000 users or more and still maintain excellent end-user performance. The Monday morning login during storage failover test described in the following section reinforces that point.

Monday Morning Login and Workload During Storage Failover Test

In this scenario, 1,500 users logged in after the VMs had already been logged into once, the profile had been created, and the desktops had been rebooted, but during a storage failover event. During this type of login, user and profile data, application binaries, and libraries had to be read from a disk because they were not already in the VM memory. Table 11 lists the results for Monday morning login and workload during storage failover.

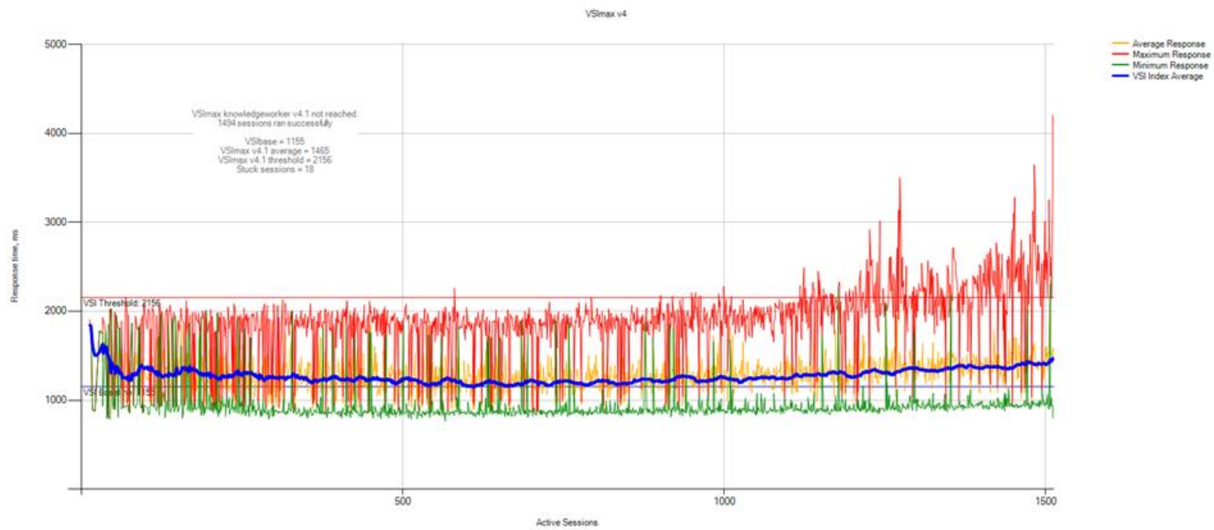
Table 11) Results for full-clone Monday morning login and workload during storage failover.

Desktop Login Time	Average Latency	Peak IOPS	Avg. IOPS	Peak Throughput	Avg. Throughput	Peak Storage CPU	Avg. Storage CPU
19.12 sec/VM	498µs	40,000	8,302	915MBps	176MBps	99%	40%

Login VSI VSImax Results

Because the Login VSI VSImax v4.1 limit was not reached, more VMs could be deployed on this infrastructure. Figure 26 shows the VSImax results for Monday morning login and workload during storage failover.

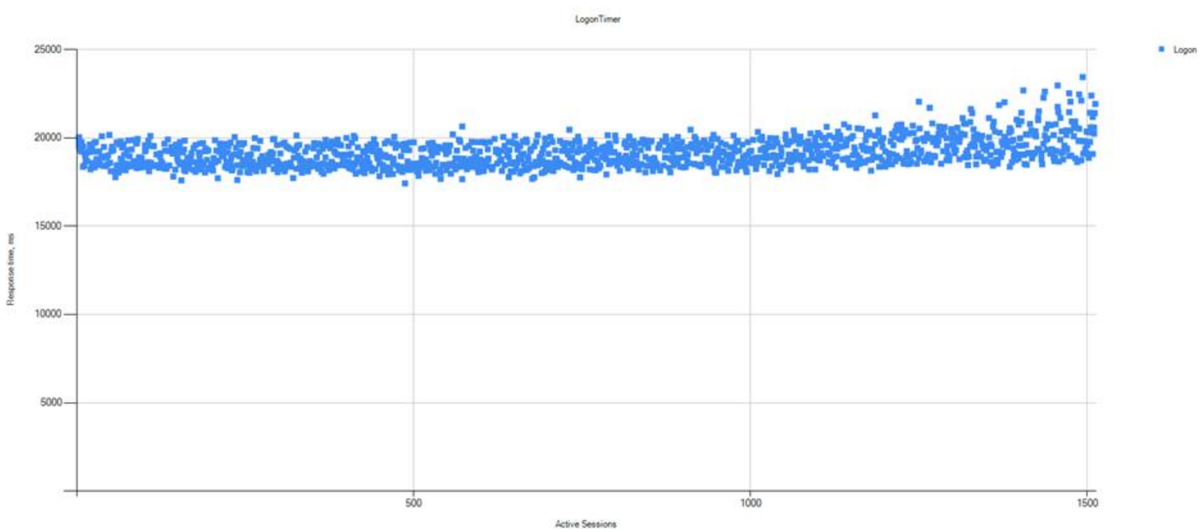
Figure 26) VSImax results for full-clone Monday morning login and workload during storage failover.



Desktop Login Time

Average desktop login time was 19.12 seconds, which is considered an excellent login time, especially during a failover situation. Figure 27 shows a scatterplot of the Monday morning login times during storage failover.

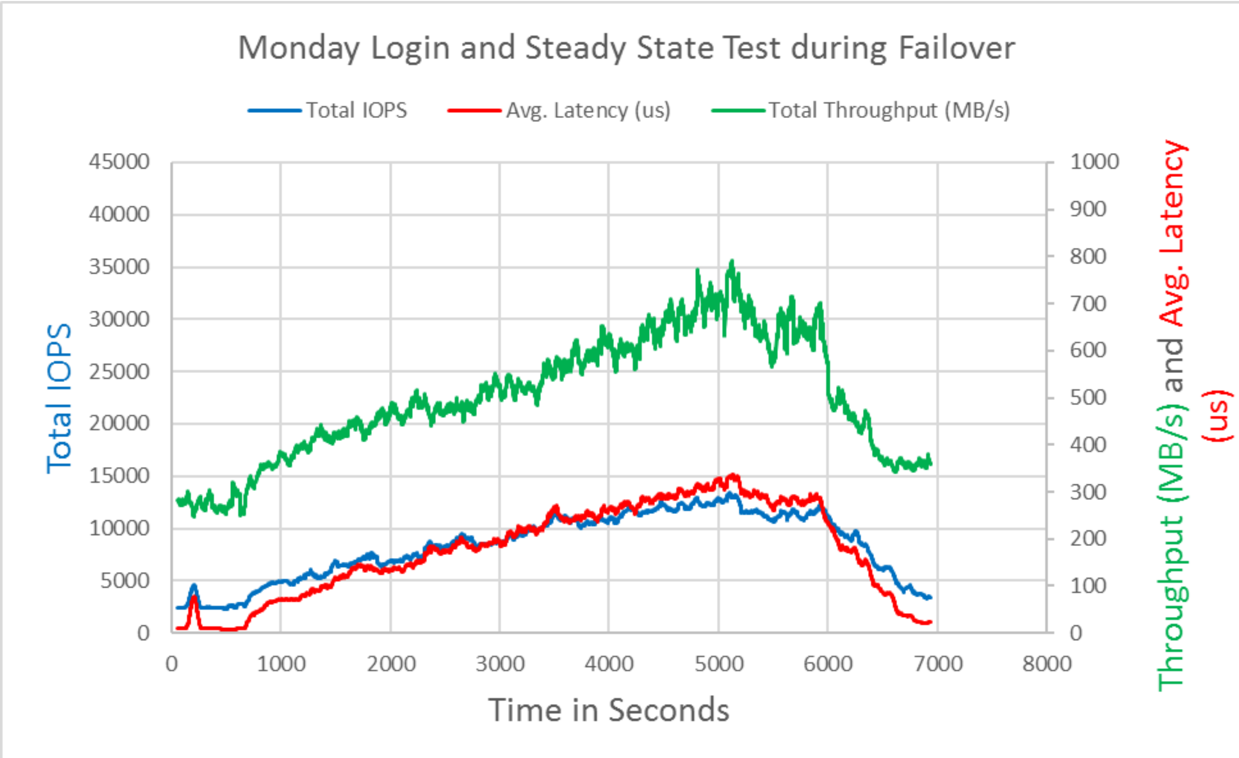
Figure 27) Scatterplot of full-clone Monday morning login times during storage failover.



Throughput, IOPS, and Latency

Figure 28 shows throughput, IOPS, and latency for full-clone Monday morning login and workload during storage failover.

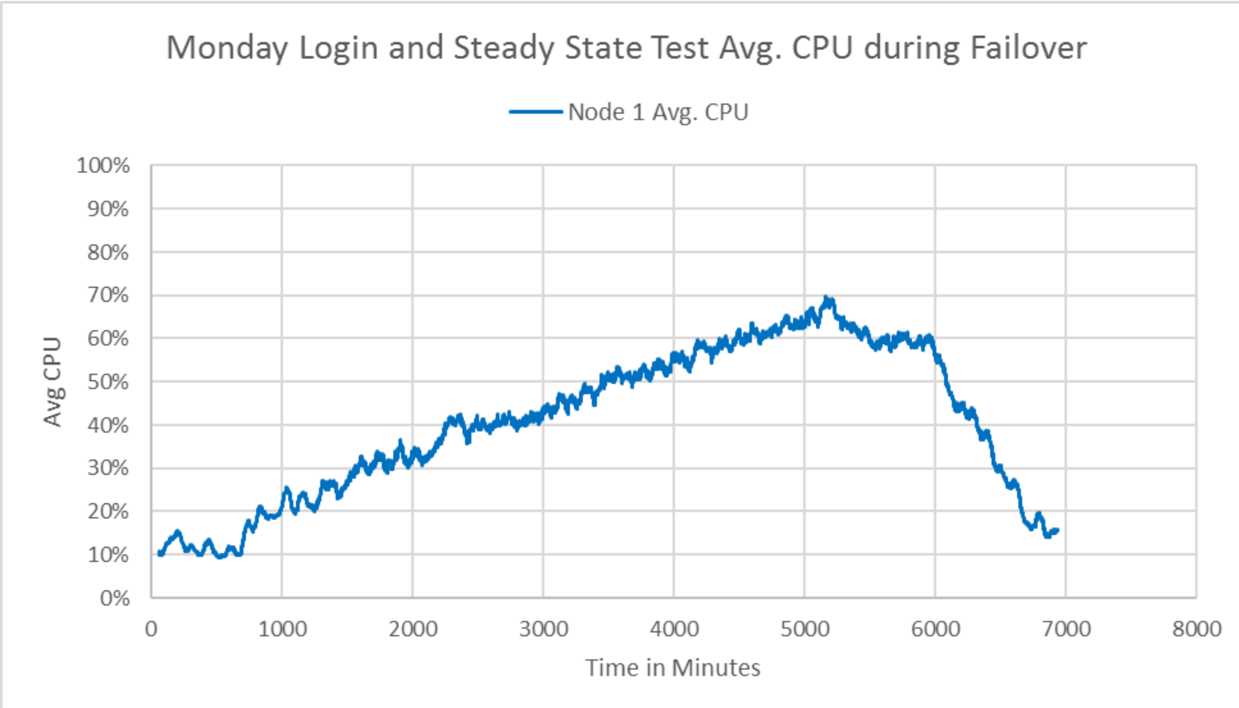
Figure 28) Throughput, IOPS, and latency for full-clone Monday morning login and workload during storage failover.



Storage Controller CPU Utilization

Figure 29 shows storage controller CPU utilization for full-clone Monday morning login and workload during storage failover.

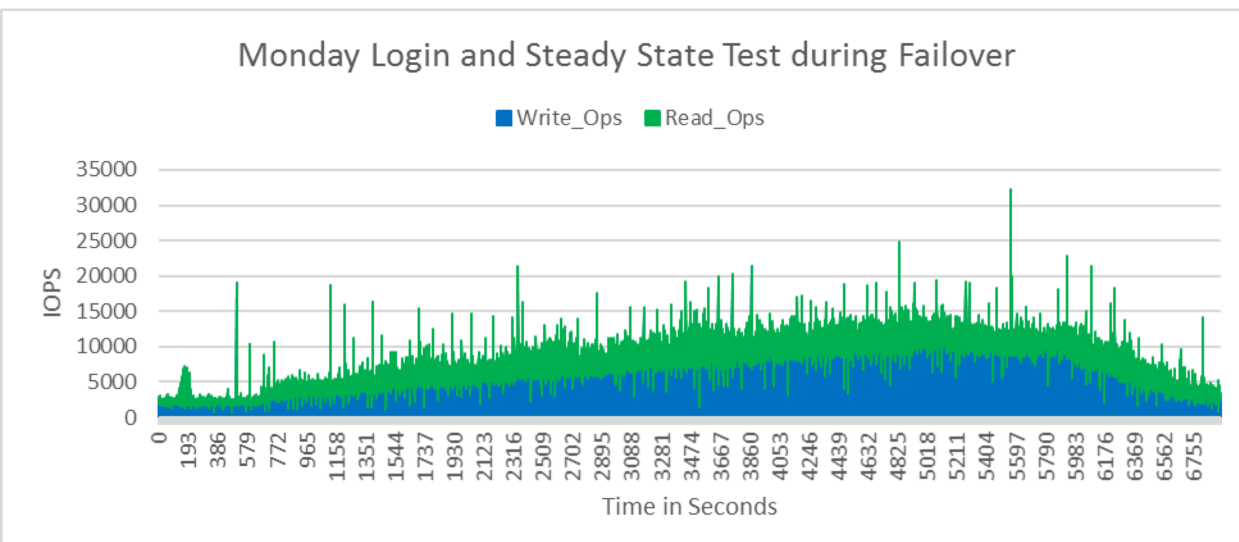
Figure 29) Storage controller CPU utilization for full-clone Monday morning login and workload during storage failover.



Read/Write IOPS

Figure 30 shows read and write IOPS for full-clone Monday morning login and workload during storage failover.

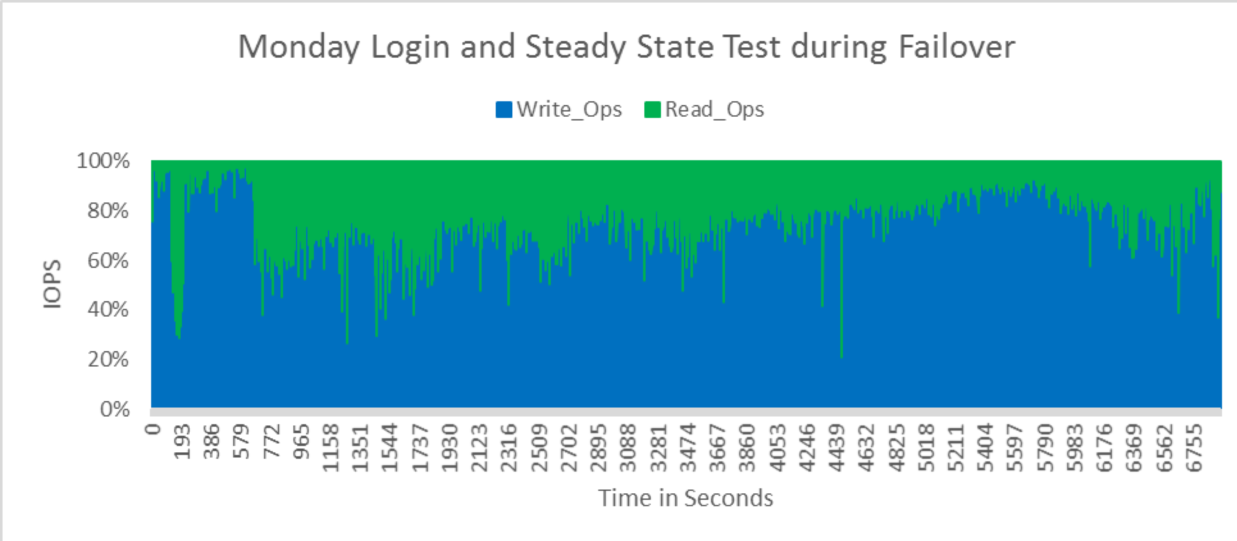
Figure 30) Read/write IOPS for full-clone Monday morning login and workload during storage failover.



Read/Write Ratio

Figure 31 shows read and write ratios for full-clone Monday morning login and workload during storage failover.

Figure 31) Read/write ratio for full-clone Monday morning login and workload during storage failover.



Customer Impact (Test Conclusions)

During the Monday morning login test during storage failover, the storage controller performed very well. The CPU utilization averaged less than 50%, latencies were under 1ms, and desktop performance was excellent. These results suggest that for this type of workload it might be possible to double the storage controller workload to 3,000 users total (1,500 per node) with excellent end-user performance and with the ability to tolerate a storage failover.

Tuesday Morning Login and Workload Test

In this scenario, 1,500 users logged in to virtual desktops that had been logged into previously and that had not been power-cycled. In this situation, VMs reduce the impact on storage by retaining in memory user and profile data, application binaries, and libraries. Table 12 lists the results for Tuesday morning login and workload.

Table 12) Results for full-clone Tuesday morning login and workload.

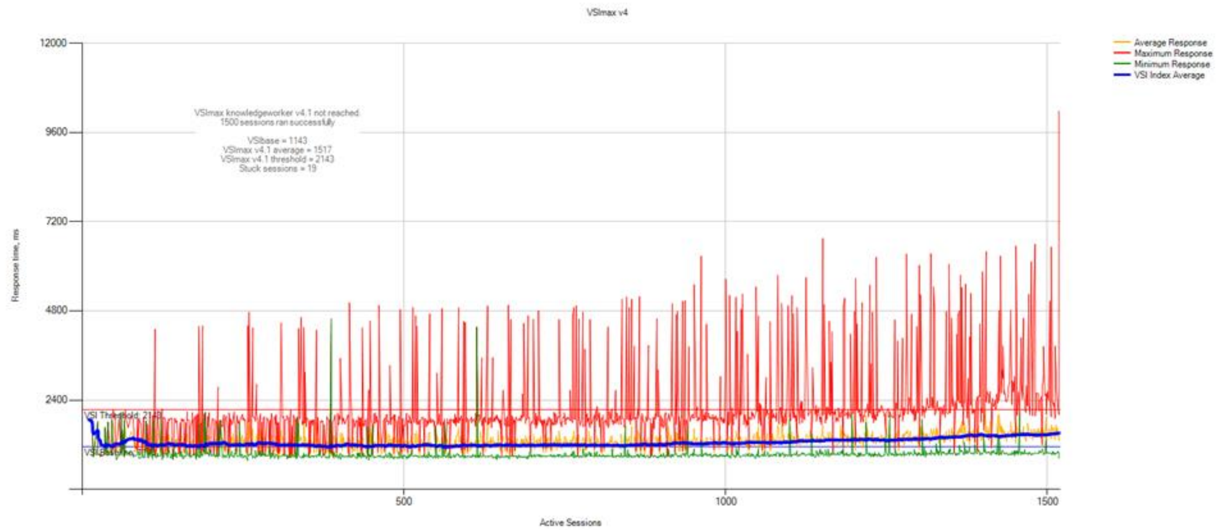
Desktop Login Time	Average Latency	Peak IOPS	Avg. IOPS	Peak Throughput	Avg. Throughput	Peak Storage CPU	Avg. Storage CPU
19.27 sec/VM	446µs	21,874	7,586	490MBps	172MBps	90%	23%

Note: CPU and latency measurements are based on the average across both nodes of the cluster. IOPS and throughput are based on a combined total of each.

Login VSI VSImax Results

Because the Login VSI VSImax v4.1 was not reached, more VMs could be deployed on this infrastructure. Figure 32 shows the VSImax results for Tuesday morning login and workload.

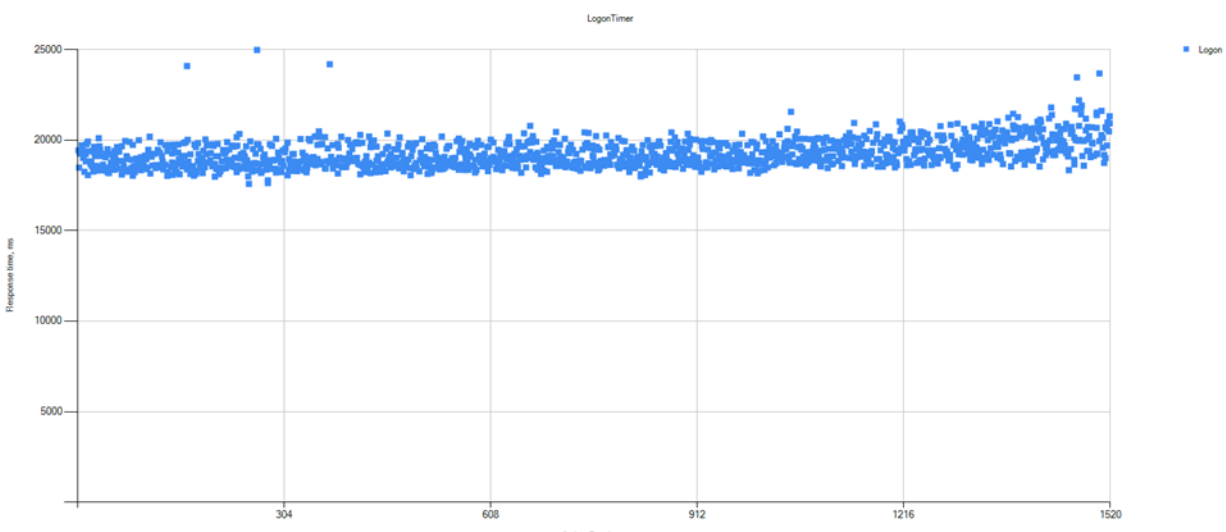
Figure 32) VSImax results for full-clone Tuesday morning login and workload.



Desktop Login Time

Average desktop login time was 19.27 seconds, which is considered an excellent login time. Figure 33 shows a scatterplot of the Tuesday morning login times.

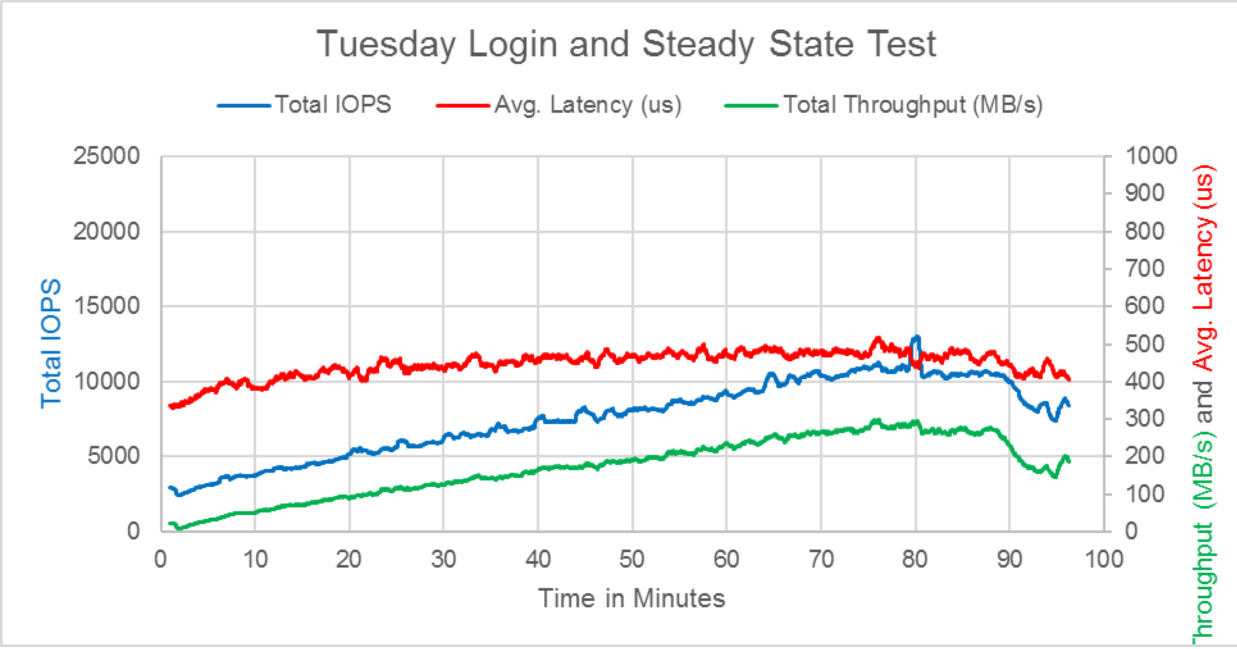
Figure 33) Scatterplot of full-clone Tuesday morning login times.



Throughput, IOPS, and Latency

Figure 34 shows throughput, IOPS, and latency for full-clone Tuesday morning login and workload.

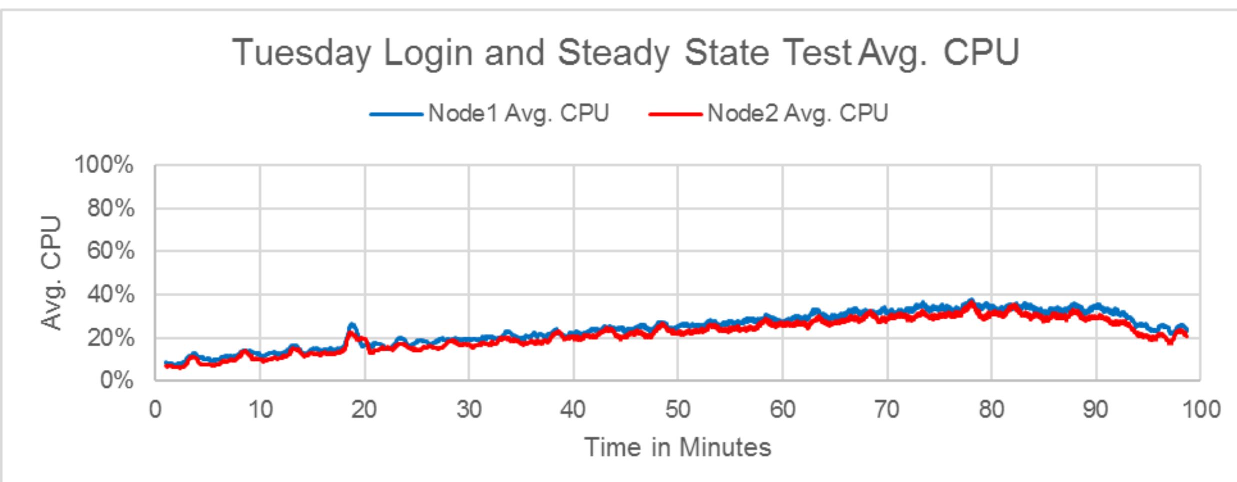
Figure 34) Throughput, IOPS, and latency for full-clone Tuesday morning login and workload.



Storage Controller CPU Utilization

Figure 35 shows storage controller CPU utilization for full-clone Tuesday morning login and workload.

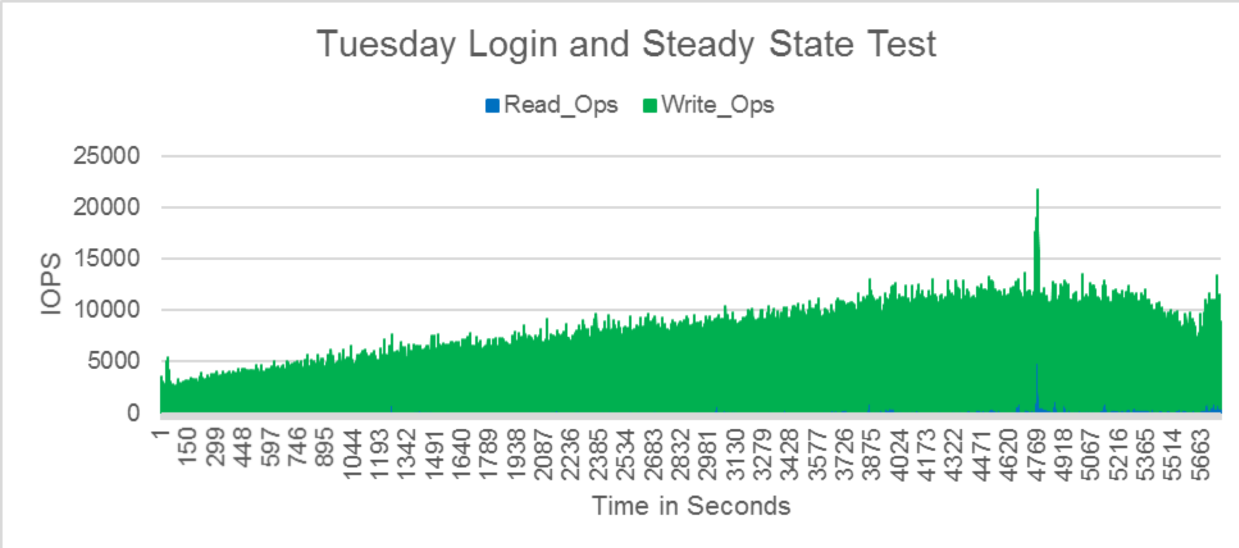
Figure 35) Storage controller CPU utilization for full-clone Tuesday morning login and workload.



Read/Write IOPS

Figure 36 shows read and write IOPS for full-clone Tuesday morning login and workload.

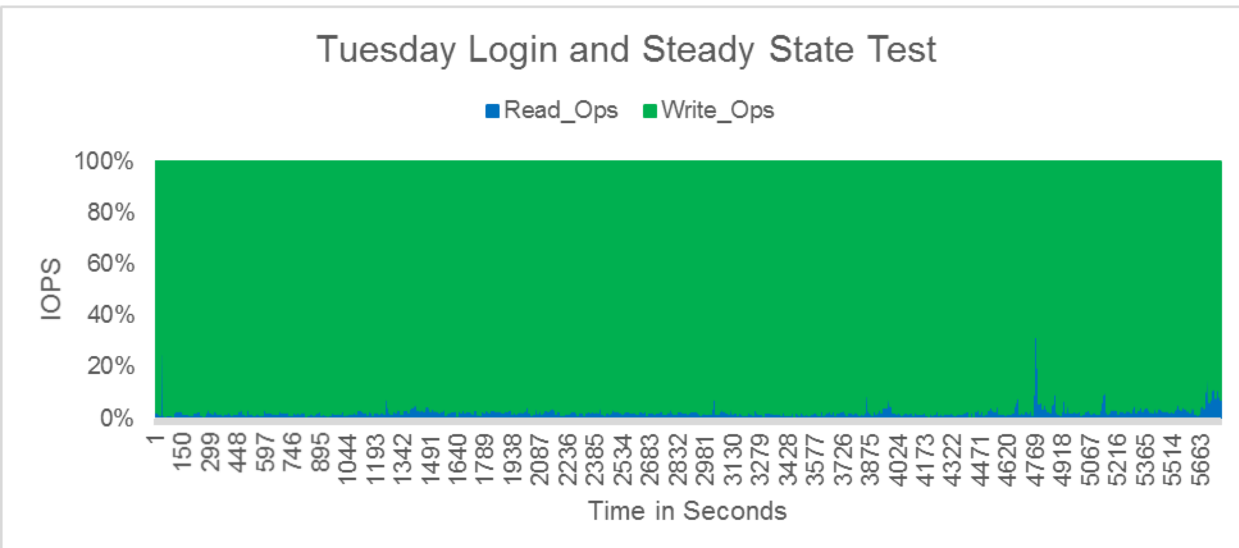
Figure 36) Read/write IOPS for full-clone Tuesday morning login and workload.



Read/Write Ratio

Figure 37 shows read and write ratios for full-clone Tuesday morning login and workload.

Figure 37) Read/write ratio for full-clone Tuesday morning login and workload.



Customer Impact (Test Conclusions)

During the Tuesday morning login test, the storage controller performed very well. The CPU utilization was not high during this test, latencies were under 1ms, and desktop performance was excellent. These results suggest that it might be possible to double the storage controller workload to 3,000 users or more and still maintain excellent end-user performance. The Tuesday morning login during storage failover test described in the following section reinforces that point.

Tuesday Morning Login and Workload During Storage Failover Test

In this scenario, 1,500 users logged in to virtual desktops that had been logged into previously and that had not been power-cycled, and the storage controller was failed over. In this situation, VMs retain user and profile data, application binaries, and libraries in memory, which reduces the impact on storage. Table 13 lists the results for Tuesday morning login and workload during storage failover.

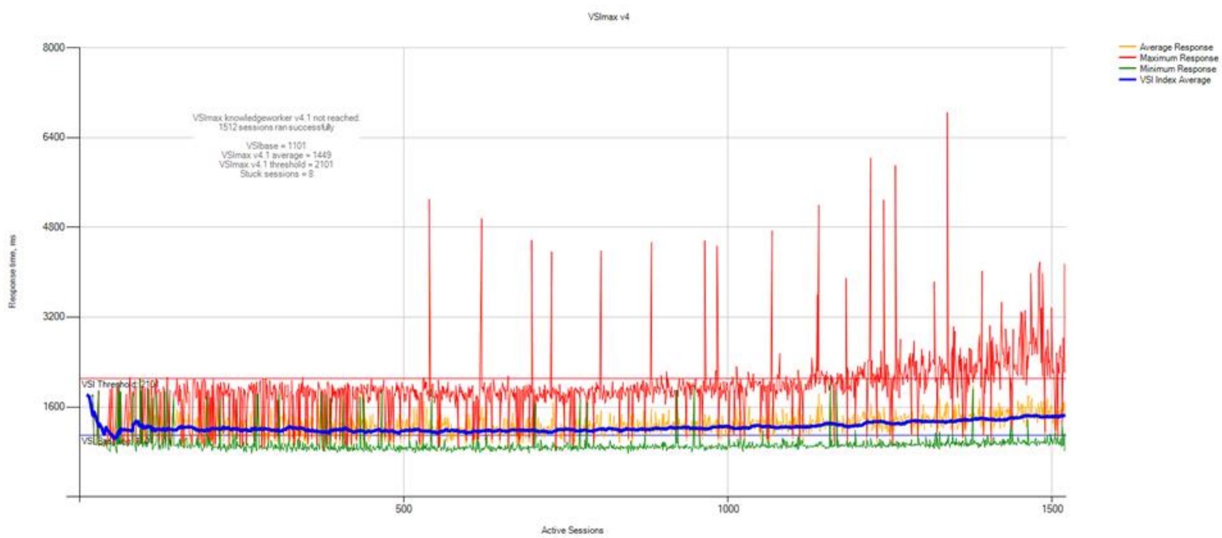
Table 13) Results for full-clone Tuesday morning login and workload during storage failover.

Desktop Login Time	Average Latency	Peak IOPS	Avg. IOPS	Peak Throughput	Avg. Throughput	Peak Storage CPU	Avg. Storage CPU
19.36 sec/VM	503µs	30,653	7,416	1054MBps	163MBps	99%	38%

Login VSI VSImax Results

Because the Login VSI VSImax v4.1 was not reached, more VMs could be deployed on this infrastructure. Figure 38 shows the VSImax results for Tuesday morning login and workload during storage failover.

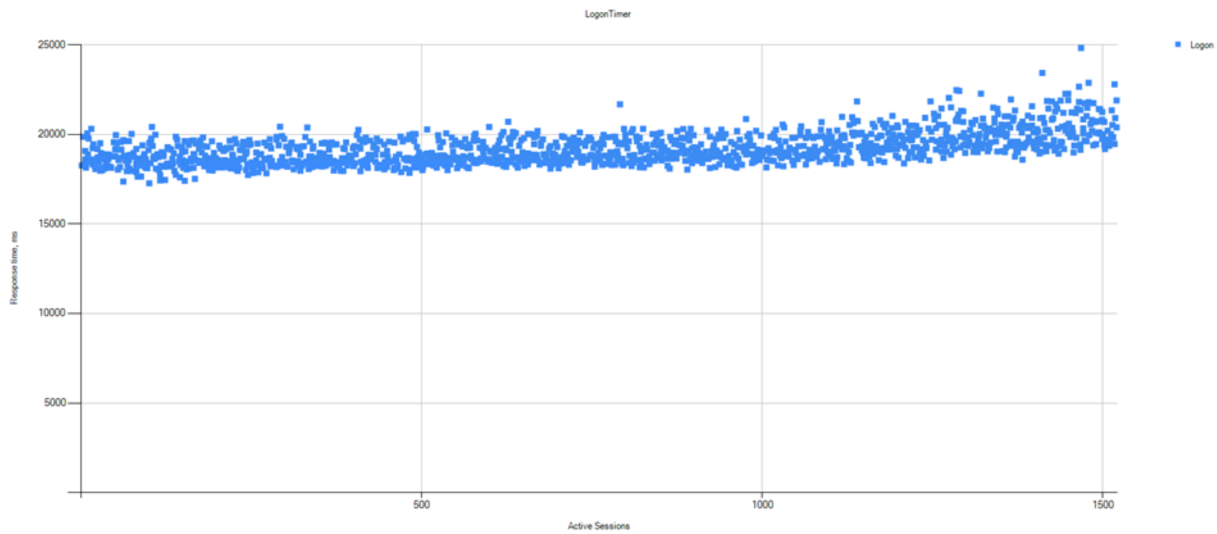
Figure 38) VSImax results for full-clone Tuesday morning login and workload during storage failover.



Desktop Login Time

Average desktop login time was 19.36 seconds, which is considered an excellent login time. Figure 39 shows a scatterplot of the Tuesday morning login times during storage failover.

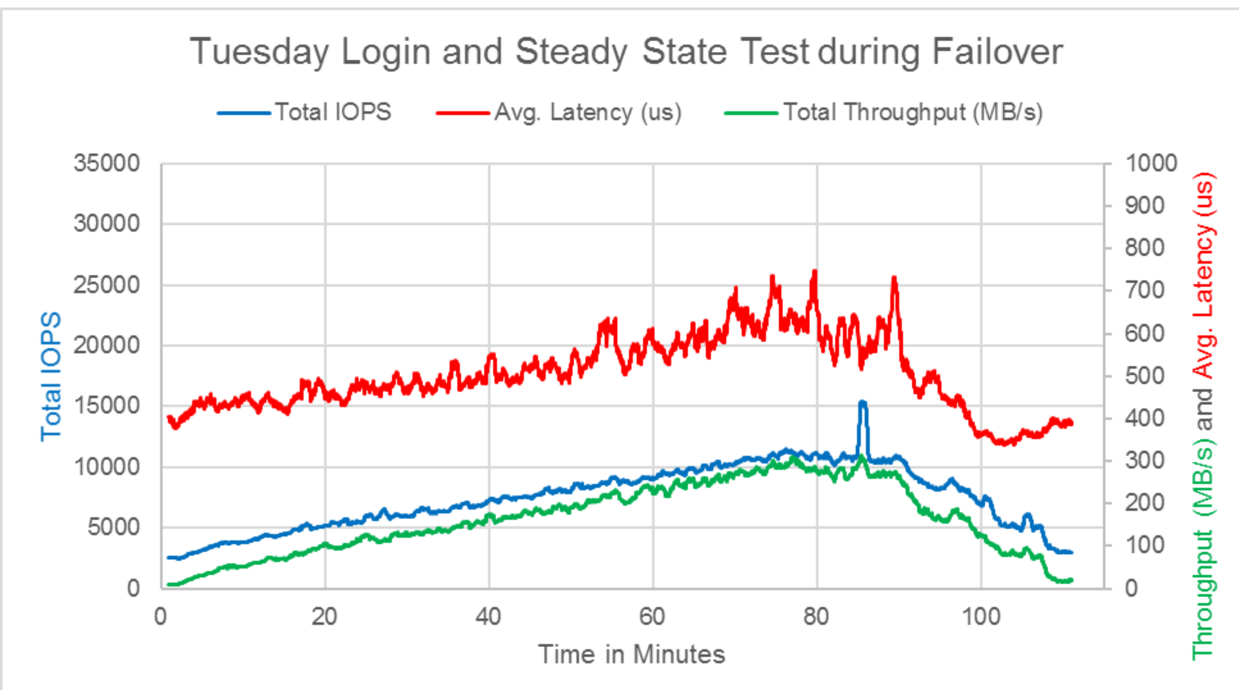
Figure 39) Scatterplot of full-clone Tuesday morning login times during storage failover.



Throughput, IOPS, and Latency

Figure 40 shows throughput, IOPS, and latency for a full-clone Tuesday morning login and workload during storage failover.

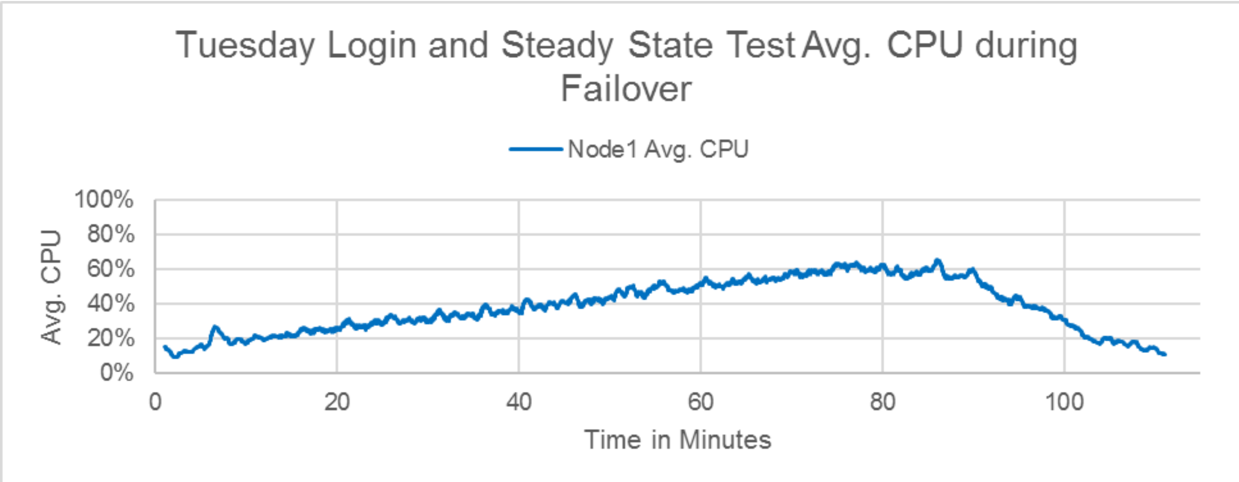
Figure 40) Throughput, IOPS, and latency for full-clone Tuesday morning login and workload during storage failover.



Storage Controller CPU Utilization

Figure 41 shows storage controller CPU utilization for a full-clone Tuesday morning login and workload during storage failover.

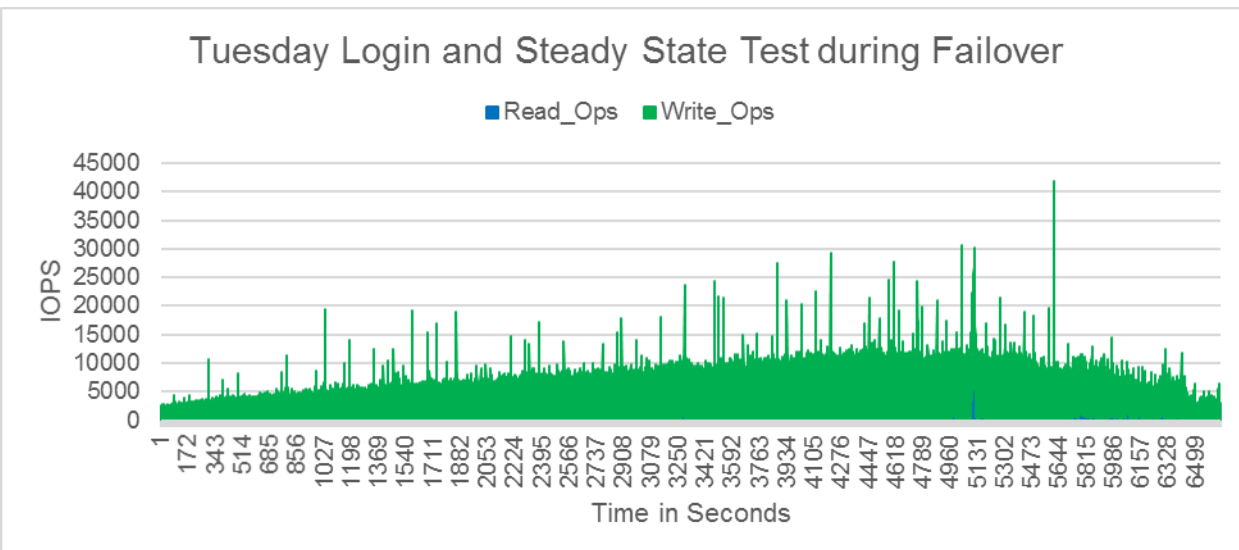
Figure 41) Storage controller CPU utilization for full-clone Tuesday morning login and workload during storage failover.



Read/Write IOPS

Figure 42 shows read and write IOPS for a full-clone Tuesday morning login and workload during storage failover.

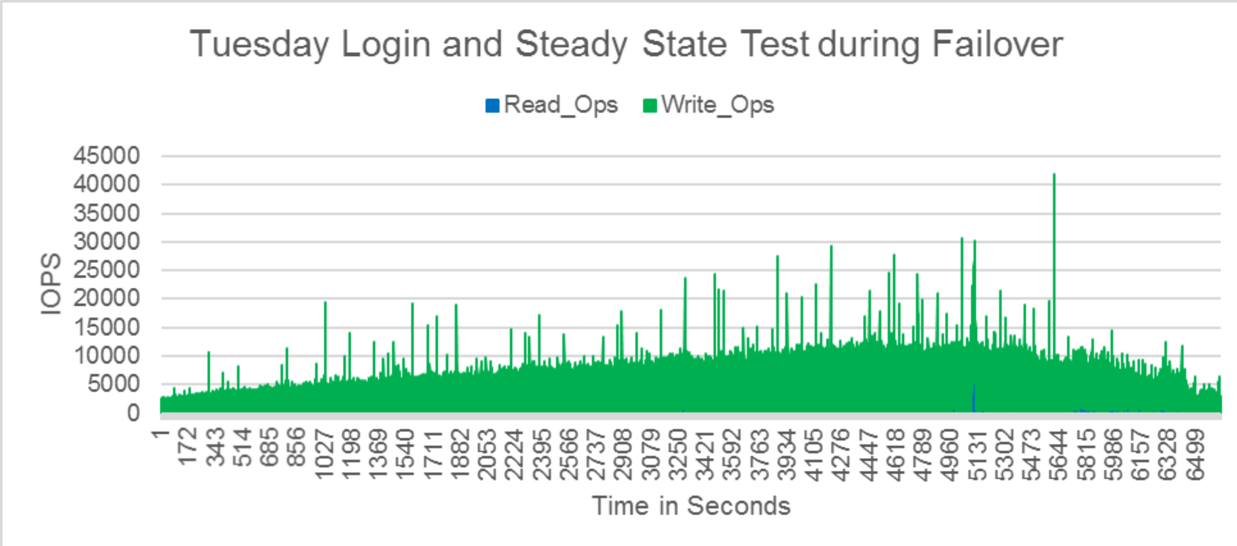
Figure 42) Read/write IOPS for full-clone Tuesday morning login and workload during storage failover.



Read/Write Ratio

Figure 43 shows the read-to-write ratio for a full-clone Tuesday morning login and workload during storage failover.

Figure 43) Read/write ratio for full-clone Tuesday morning login and workload during storage failover.



Customer Impact (Test Conclusions)

The purpose of this test was to demonstrate that an ordinary login and workload can be performed during a failover event. This is one of the easier workloads for the storage controller to perform.

6.7 Test for Patching 1,500 Desktops

This section describes test objectives and methodology and provides results from patch testing.

Test Objectives and Methodology

In this test, we patched 1,500 desktops across both nodes of the storage infrastructure. We were cautious and did not want the server host's CPU to become a bottleneck during this test and thus we inserted a delay of 10 seconds between each desktop's update start.

For testing, we used Windows Server Update Server (WSUS) to download and install patches to the 1,500 desktops. A total of approximately 1.1GB of patches was downloaded and installed on each machine. The patch update was initiated from a Windows PowerShell script that directed each VM to find available updates from the WSUS and apply the patches. Table 14 lists the test results for patching 1,500 desktops on one node.

Table 14) Results for patching 1,500 persistent full clones on one node.

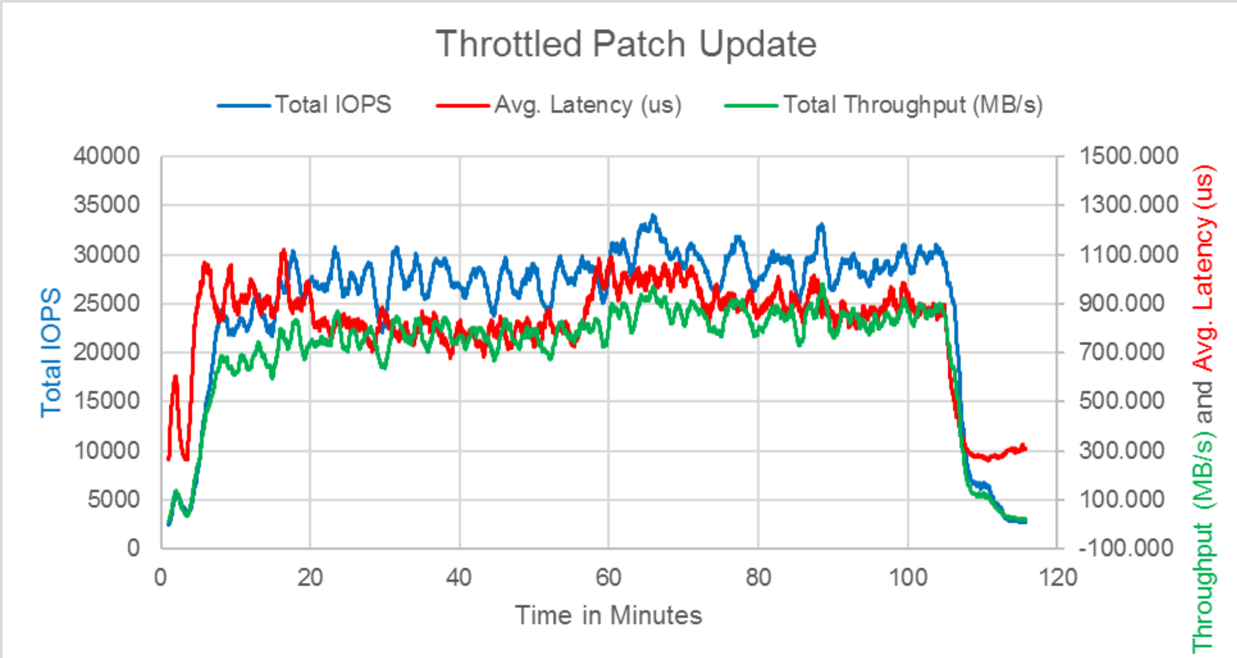
Time	Average Latency	Peak IOPS	Avg. IOPS	Peak Throughput	Avg. Throughput	Peak Storage CPU	Avg. Storage CPU
~110 min	810µs	42,172	24,904	1402MBps	703MBps	99%	51%

Note: CPU and latency measurements are based on one node of the cluster.

Throughput, IOPS, and Latency

Figure 44 shows throughput, IOPS, and latency for patching 1,500 persistent full clones.

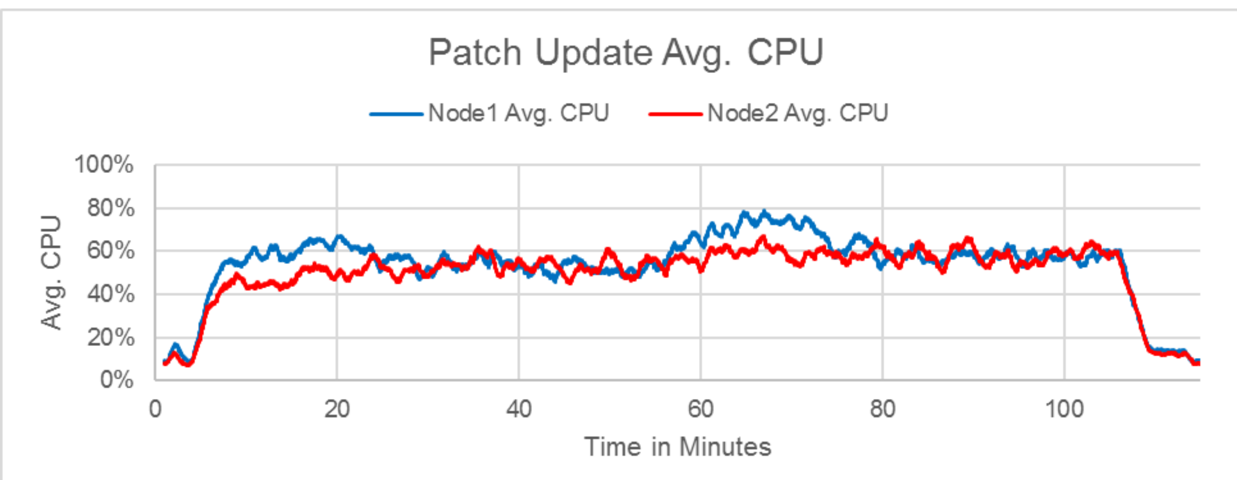
Figure 44) Throughput, IOPS, and patency for patching 1,500 persistent full clones.



Storage Controller CPU Utilization

Figure 45 shows storage controller CPU utilization for patching 1,500 persistent full clones.

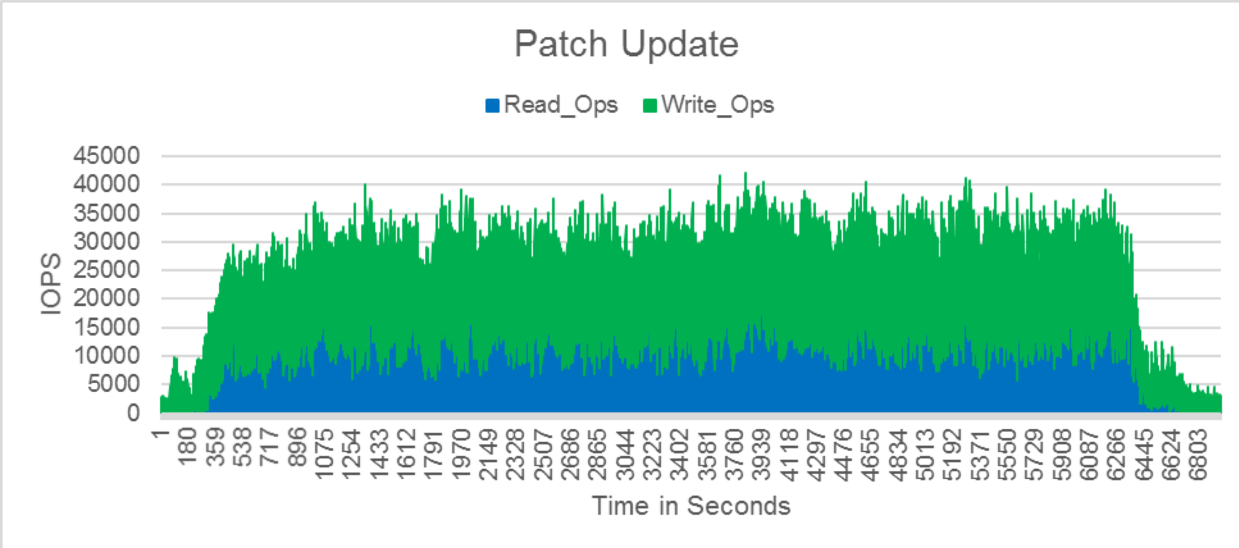
Figure 45) Storage controller CPU utilization for patching 1,500 persistent full clones.



Read/Write IOPS

Figure 46 shows read and write IOPS for patching 1,500 persistent full clones.

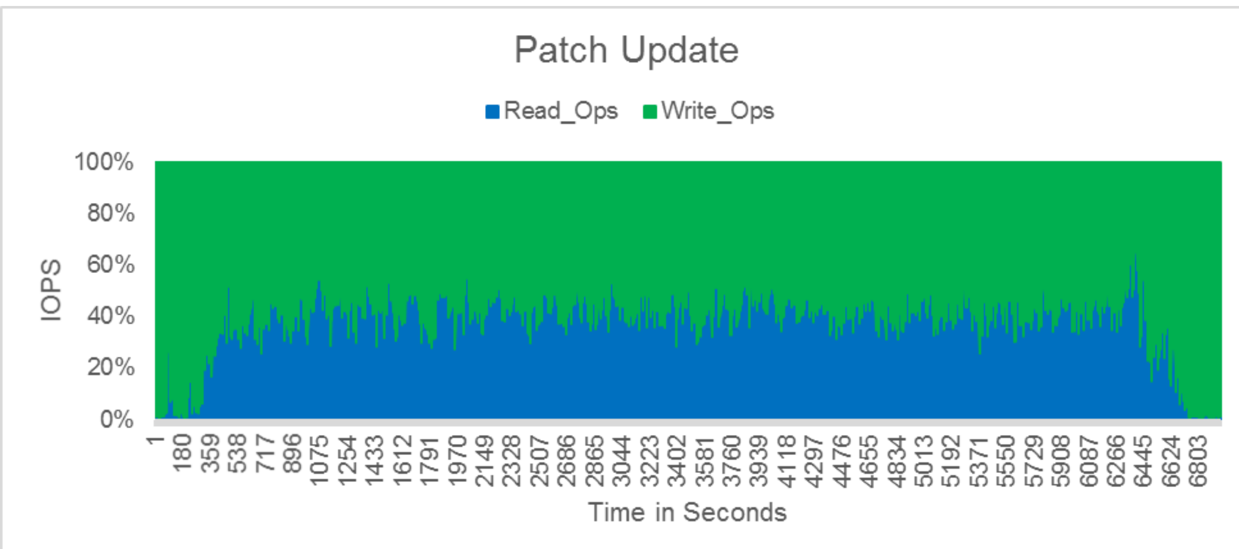
Figure 46) Read/write IOPS for patching 1,500 persistent full clones.



Read/Write Ratio

Figure 47 shows the read-to-write ratio for patching 1,500 persistent full clones.

Figure 47) Read/write ratio for patching 1,500 persistent full clones.



Efficiency During Patch Update

For the patch update use case, we performed a postprocess deduplication operation to establish a perfectly deduplicated efficiency landscape. We then applied a cumulative Windows 10 update with a total size of 1.1GB to each desktop. Figure 48 and Figure 49 show that, with ONTAP 9, inline deduplication provided significant space savings and reduces the need for postprocess deduplication tasks.

Figure 48) Savings in ONTAP 9 (in GB) per FlexVol volume before applying patches.

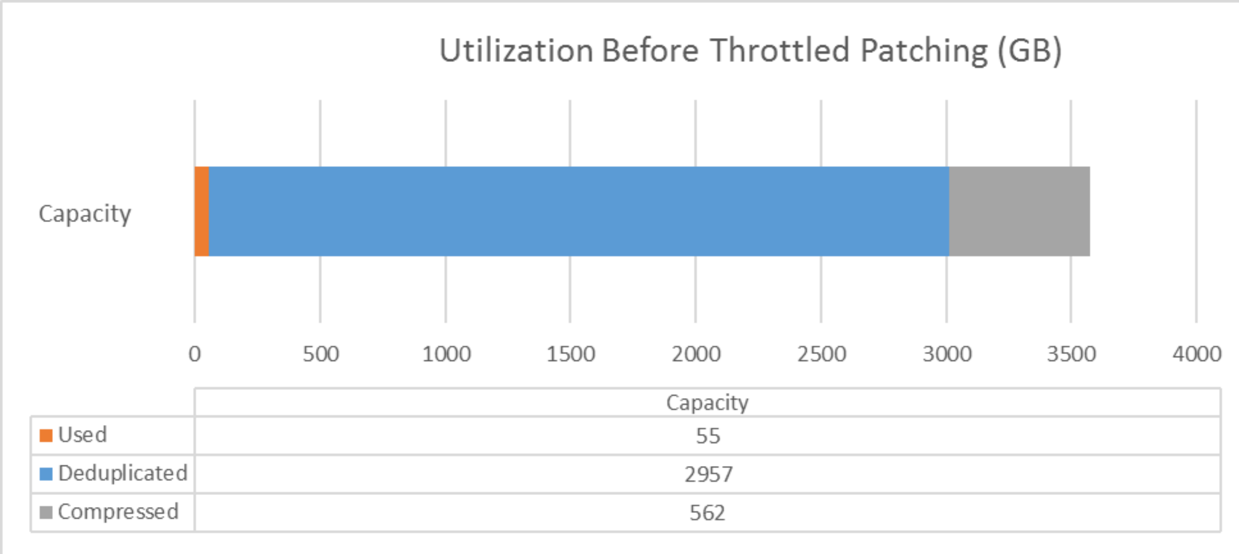
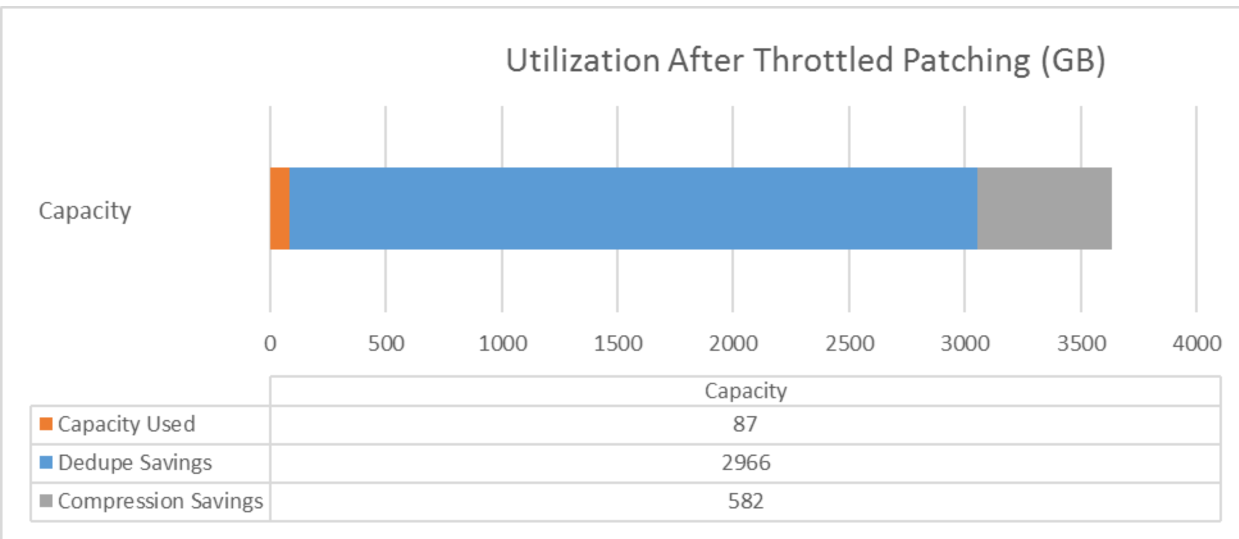


Figure 49) Savings in ONTAP 9 (in GB) per FlexVol volume after applying patches.



Customer Impact (Test Conclusions)

The patching of 1,500 virtual desktops with 1.1GB per VM took approximately 110 minutes to install. Latency or CPU was not a concern during this test. In production environments, NetApp recommends staggering the patching over a longer period of time to reduce latency and CPU utilization. Inline efficiencies dramatically reduced the space needed to apply the patches and reduced the need for postprocess deduplication.

7 Conclusion of Testing and Validation

In all desktop use cases, end-user login time, guest response time, and maintenance activities performance were excellent. The NetApp All Flash FAS system performed very well during the variety of tests. All test categories demonstrated that with the 1,500-user workload tested in this solution, the

AFF8040 storage system can be doubled up to 3,000 users while still being able to fail over in the event of a failure.

For persistent desktops, the following key findings were observed during the reference architecture testing:

- The NetApp All Flash FAS solution was able to very easily meet all IOPS requirements of the 1,500-user workload (boot, login, steady state, logout, patch storms) at an ultralow latency of approximately 1ms. The solution delivered an excellent end-user experience. The storage configuration can easily support up to 3,000 users.
- During all login and workload scenarios, the Login VSI VSImax was not reached.
- During boot storm testing, throttled booting was able to produce an excellent boot time of 10 minutes for all 1,500 VMs.
- For all of the nonfailover tests, almost twice as many users could have been deployed with the same results. Only in the cases of the failed-over boot storm and initial login and workload did the CPU average over 50% of performance utilization.
- Inline deduplication, inline compression, data compaction, and FlexClone technology storage efficiency saved over 24TB of storage, which translates into a savings of 50:1, or 98%.

8 Data Center Efficiency with AFF A-Series

In February 2017, NetApp released its latest AFF platform, the A700s. The AFF A700s is a 4U All Flash array that can support 24 internal SSDs and can support up to 192 additional drives (8 external shelves). Due to the dramatic change in both performance and capacity, we conducted performance tests on both the AFF8000 and AFF A-Series systems.

Capacity Density

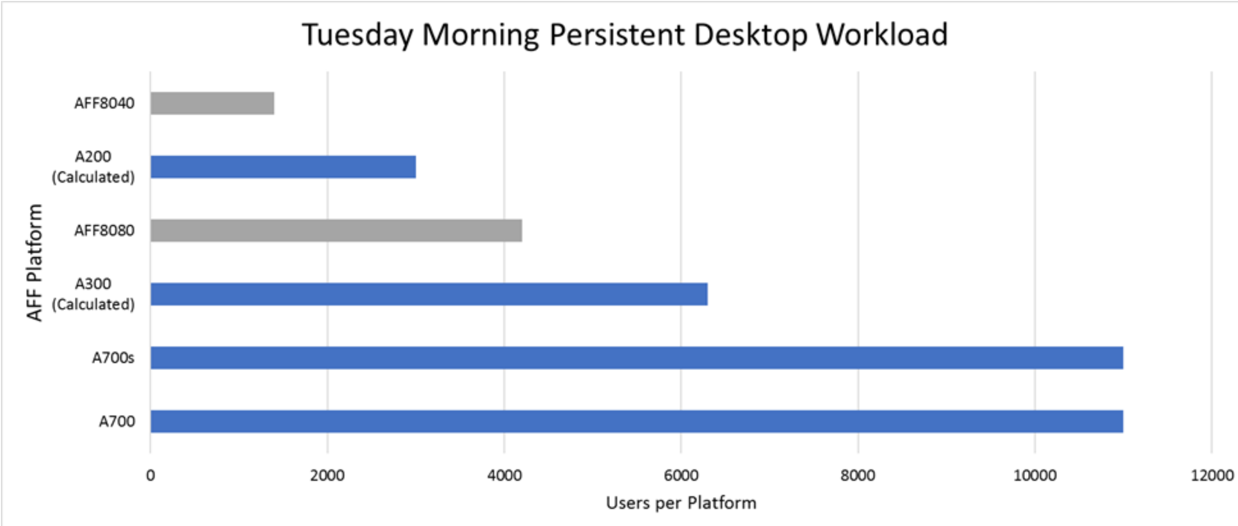
Table 15) Capacity density of A-Series systems.

Platform	SSDs (15.3TB)	Datacenter Footprint	Usable Capacity	Effective Capacity (4:1)
A700s	24 internal drives	4U	287TB	1.15PB
A700s plus 8 shelves	24 internal drives 192 external drives	20U	2.6PB	10.3PB

Performance Density

Using the Tuesday Morning Workload Profile in the Appendix, we found that the A700/A700s could perform nearly 8 times the IOPS of the AFF8040. This number demonstrates that over 11,000 desktops can be supported in a 4U form factor. While we used 960GB SSDs for our testing, the 15.3TB SSDs are available and provide an effective capacity of 1.15PB.

Figure 50) User per platform density.



Note: The data was generated using the Tuesday Morning Workload Profiles with VDBench provided in the Appendix.

Figure 51) Data center density for AFF8040 and A700s.

The A700/A700s provide lower latencies and all of the feature-rich data management capabilities of ONTAP in a hyper dense form factor.

Appendix: Workload Profiles

In this section we break down the different I/O profiles for each of the different workloads in this paper. These I/O profiles were seen by vscsiStats at the ESXi layer. This information demonstrates that each workload is different, and each workload affects the storage controller differently.

These workload profiles can be used across different platforms as a standard workload for proof of concept. Many vendors just use a single block size to replicate what VDI is. As you can see from the following profiles, there are many different I/O sizes and read-write ratios during each of the test cases. Using tools such as Login VSI allows customers to generate loads that are more representative than a single I/O size. However, if an existing VDI deployment is in use, vscsiStats can be captured and replayed with vdbench to match the storage workload closely.

What this methodology does not capture is the real data and how factors such as deduplication, compression, and compaction affect the workload and storage efficiency. Nor does this capture the end-to-end server and network impact of the workloads. This is where tools such as Login VSI can bring reality to a given workload.

Boot

Here is a workload profile that matches what was observed from ESXi.

Table 16) Boot workload profile.

Operation Size	Workload Percentage	Read Percentage	Seek Percentage
4KB	17	83	100
8KB	7	90	100
16KB	7	93	100
32KB	17	99	50
48KB	18	100	.1
64KB	33	100	.1
512KB	1	91	.1

Monday Morning Login and Steady State Workload Profile

Here is a workload profile that matches what was observed from ESXi. Notice that the read percentages are higher than that of the Tuesday workload below. This difference is due to the user logging in for the first time after a reboot and the profile being read as well as the applications being loaded.

Table 17) Monday morning login and steady state workload profile.

Operation Size	Workload Percentage	Read Percentage	Seek Percentage
512B	2	88	100
1KB	1	61	100
2KB	2	50	100
4KB	37	36	100
8KB	8	43	100
16KB	17	90	100
32KB	19	93	50
48KB	1	57	.1
64KB	9	94	.1
128KB	3	63	.1
256KB	1	75	.1

Tuesday Morning Login and Steady State Workload Profile

Here is a workload profile that matches what was observed from ESXi. The Tuesday workload occurs when a user has already logged in once prior to doing any work. The profiles and applications are already in memory.

Table 18) Tuesday morning login and steady state workload profile.

Operation Size	Workload Percentage	Read Percentage	Seek Percentage
512B	2	40	100
1KB	2	13	100
2KB	4	3	100
4KB	54	4	100
8KB	11	5	100

16KB	9	33	100
32KB	9	63	50
48KB	2	4	.1
64KB	2	17	.1
128KB	4	4	.1
256KB	1	13	.1

References

The following references were used in this technical report:

- NetApp All Flash FAS Overview Data ONTAP 8.3.2
  http://www.netapp.com/us/media/tr-4505.pdf
- VMware vSphere 6 on NetApp Clustered Data ONTAP
  http://www.netapp.com/us/media/tr-4333.pdf
- TR-4181: VMware Horizon View 5 Solutions Guide
  http://www.netapp.com/us/media/tr-4181.pdf
- TR-4335: NetApp All Flash FAS Solution for Persistent Desktops with VMware Horizon View
  http://www.netapp.com/us/media/tr-4335.pdf
- NetApp All Flash FAS Datasheet
  http://www.netapp.com/us/media/ds-3582.pdf
- VMware Horizon View 6 Performance and Best Practices
  http://www.vmware.com/files/pdf/view/vmware-horizon-view-best-practices-performance-study.pdf
- Documentation for VMware Horizon with View
  https://www.vmware.com/support/pubs/view_pubs.html

Acknowledgements

The authors thank Eric Lacell, Scott Lane, and Rob McDonald for their contributions to this document.

Version History

Version	Date	Document Version History
Version 1.0	September 2016	Initial release
Version 1.1	May 2017	Added data center efficiency section to include A700 testing and added workload profiles.

Refer to the Interoperability Matrix Tool (IMT) on the NetApp Support site to validate that the exact product and feature versions described in this document are supported for your specific environment. The NetApp IMT defines the product components and versions that can be used to construct configurations that are supported by NetApp. Specific results depend on each customer's installation in accordance with published specifications.

NetApp