DVX Reference Architecture
VMware Horizon 7 for 500 & 1,000 Users

Datrium™
List of Figures

Figure 1. DVX Overview ............................ 9
Figure 2. DVX Split Provisioning ................. 10
Figure 3. VMware Horizon Components ........ 13
Figure 4. High Level Design .................... 14
Figure 5. Host Flash Reduction (Observed) ..... 16
Figure 6. DVX Datastore Details ............... 16
Figure 7. DVX Network Connectivity .......... 19
Figure 8. DVX Protection Groups ............... 22
Figure 9. Desktop Pool Naming Convention ..... 23
Figure 10. Protection Group Wildcard Naming Convention 23
Figure 11. Provision 125 Desktops ............. 29
Figure 12. Provision 250 Desktops ............. 30
Figure 13. Provision 500 Desktops ............. 30
Figure 14. vCenter Advanced Settings ........ 31
Figure 15. Cold Boot 125 Users ................ 32
Figure 16. Cold Boot 250 Users ................ 32
Figure 17. Cold Boot 500 Users ................ 32
Figure 18. Login VSA Profiles .................. 33
Figure 19. Login VSI VSI\text{max} 125 Knowledge Workers – 1 Host 34
Figure 20. Login VSI VSI\text{max} 250 Knowledge Workers – 2 Host 35
Figure 21. Login VSI VSI\text{max} 500 Knowledge Workers – 4 Host 35
Figure 22. VSI\text{max} Overlay – 125, 250, 500 Users 36
Figure 23. Login VSI VSI\text{max} Comparison – Scaling to 500 Users 36
Figure 24. Login Phase without Load (500) ..... 37
Figure 25. Login Phase with Load (1,000) ..... 37
Figure 26. Steady State without Load (500) ..... 38
Figure 27. Steady State with Load (1,000) ..... 38
Figure 28. Non VDI Workload Contributors ..... 38
Figure 29. VSI\text{max} Overlay - with and without Added IO Load 39
Figure 30. VSI\text{max} Run Comparison - with and without Added IO Load 39
Figure 31. ESX Host CPU Utilization - Steady State 40
Figure 32. ESX Desktop Cluster - Host Stats 40
Figure 33. DVX Performance View - 500 Users 41
Figure 34. IOPS Average - Knowledge Worker - Steady State 41
Figure 35. Fast vs. Insane Boot Impact ......... 42
Figure 36. 500 User Desktop Configuration ..... 43
Figure 37. 1,000 User Desktop Configuration 44
Figure 38. 6,000 User Maximum Configuration 44
Figure 39. 500 User Knowledge Worker Utilization 45
Figure 40. 500 User Task Worker Utilization 45
Figure 41. 500 Task User IO Results ........... 45
This tested reference architecture presents an effective solution to deploy and scale VMware Horizon 7 on the Datrium DVX Open Converged private cloud platform. Datrium simplifies the task of building robust enterprise ready desktop virtualization solutions that also meet the performance objectives of the end users. In this paper, we present design considerations for the infrastructure as well as testing results quantifying performance expectations and observations. This solution is developed to not only meet end user objectives but also address the cost, reliability and manageability that IT organizations must consider.

Some of the highlights established in constructing and testing this reference architecture are:

1] **Scale** desktop deployment from a single host (approximately 125 users) to enterprise scale (up to 1,000 users) on a DVX single Data Node architecture. Fully leverage scalable performance with host based resources, locality and isolation.

2] **Host isolation** provides near linear scalability as each host establishes its own thresholds – for example complete host VM population reboot takes less than 5 minutes independent of number of hosts or total number of VMs. Login VSI measures stay consistent as hosts and more users are added to the mix. With reads serviced by host local flash, it’s possible to reduce IO latencies and improve end-user experience with the DVX Open Converged platform.

3] **Use the reference** of the Datrium DVX Compute Node (CN2000) and Data Node (D12X4) system configuration to effectively size and design solutions based on particular end user or environment needs. With elimination of almost all storage contention with host local flash, the compute horsepower of the hosts is now the primary design variable.

4] **Understand** design options for scaling with a convenient modular desktop deployment including 500 and 1,000 user scenarios including lab testing with Login VSI. With host IO supporting sufficient steady state and burst level IOPS and latencies to meet demanding end user needs with sub-millisecond reads and writes well below the 4-5 msec thresholds.
The Datrium DVX System for Horizon 7

The Datrium DVX system is made up of Compute Nodes (vSphere servers) and Data Nodes (holding persistent data copies and backups). For this reference architecture, the following figure shows the components that were assembled for testing.

The Datrium Advantage

1. **Tier-1 Scale and Resilience**
   - Scale 10X larger, faster — no cluster config, sprawl
   - Independent scaling of performance or capacity
   - Always-on RF3 tolerance
   - Server down never affects data

2. **Built-in Backup and DR**
   - Rich VM policy and catalog infrastructure
   - Always-on erasure coding, global dedupe, compression
   - Encrypted in-use, in-flight, at-rest
   - RTO = Zero. Restart, don’t restore

3. **Cloud-Native Data Services**
   - As-a-service simplicity
   - Global cloud dedupe to minimize on-wire/at-rest cost
   - Differential and dedupe-aware restore direct to primary
Executive Summary

VMware Horizon with Datrium DVX provides a single, simple platform for delivering virtualized Windows desktops and locally installed applications. This white paper provides a reference architecture based primarily on deploying desktops with a dedicated linked clone model and tested for knowledge worker use cases. Extensive testing was conducted to evaluate and present the characteristics of this environment. The results are summarized in the notes below.

Tested Users

| 500 | Horizon Dedicated Linked Clone Users – Knowledge Worker Profile |

Hardware Deployed

| 4   | vsphere Desktop Hosts (Datrium Compute Nodes) |
| 2   | vsphere Infrastructure Hosts (Datrium 3rd Party Compute Nodes) |
| 1   | Datrium DVX Data Nodes – persistent / protected storage |

LoginVSI Results

| 706 | LoginVSI Baseline (ms) |
| 1107 | LoginVSI Index Average (ms) |
| 0   | LoginVSI Stuck Sessions |

Steady State Performance

| 105 | DVX Throughput (steady state – MBps) |
| 4,000 | DVX IOPS (steady state) |
| <3 | DVX Latency (steady state – ms) |

Boot Storm Performance

| 1180 | DVX Throughput (peak boot storm – MBps) |
| 60,000 | DVX IOPS (peak boot storm) |
| <2 | DVX Latency (peak boot storm – ms) |
Introduction

The Datrium DVX system provides an ideal virtualization platform for building a modern, state of the practice data center solution for end user computing leveraging on premise virtual desktops as the core building block. Starting as small as a single virtualization host and scaling as needed to meet the demands of business growth is easily accomplished with the Open Convergence capabilities of the Datrium solution. In this paper, we examine one such configuration for a virtual desktop solution that delivers:

1] Improved end-user experience

2] Simpler administration and management

3] Cost effective approaches to equipping the modern data center

1.1 Audience

This reference architecture is intended for solution designers, system architects or system administrators that are choosing to deploy desktop virtualization on Datrium DVX for VMware Horizon 7. We assume a working knowledge of Datrium DVX, VMware vSphere, VMware Horizon, Microsoft Windows and Login VSI. For additional information about administering, configuring and managing VDI on DVX please refer to appropriate manufacturer's documentation.

1.2 Purpose

The purpose of this reference architecture is to provide sufficient details and testing results of specific working configurations so that architects, designers and administrators can compare and deploy solutions in their own organizations as well as with other industry solutions. We have collaborated with our technology partners to focus on a solution that will meet real world needs for a large percentage of the desktop use cases and could be deployed as tested in a number of relevant situations.

A goal of this paper is to help with understanding and selecting a robust and scalable virtual desktop infrastructure. Getting the right combination of computing resources – servers, storage, software – that perform well enough for today’s demanding users while still being affordable and manageable might seem overwhelming. At Datrium we believe an Open Converged solution with the right set of integrated and tested components that performs well, is easily managed and is cost-effective – up front and as you grow – is at the heart of the Datrium’s DVX Open Convergence platform.

This reference architecture is not intended as a how-to guide for setting up the solution. It is also not intended to cover all possible configuration solutions. As a reference point it should provide sufficient detail for further project specific analyses. This document will provide an overview of the solution, basic detailed design considerations and the testing and results obtained.
Solution Overview

This desktop virtualization solution leverages the Datrium DVX platform along with VMware vSphere and Horizon capabilities to provide a scalable solution that can grow as the business requirements increase. Independent scaling for either compute or capacity give you the freedom to start with just the right amount of infrastructure when beginning a project and adding performance or capacity to support growth. DVX allows for seamless addition of additional compute nodes for performance or data nodes for capacity to the solution. You can begin from the minimum supported two nodes (one Data Node and one Compute Node) and expand from there to Petabyte Scale configurations as needed. Compute nodes – where the user desktop virtual machines run – can come in a variety of sizes and capabilities that address different organizational needs and budgets. These servers run the DVX software. They can be Datrium supplied Compute Nodes or qualified 3rd Party Compute Nodes providing a wide range of host options for deployment. This includes blade server and rack mount configurations as well as existing or net new platforms for the desktop project.

For this reference architecture, we will be narrowing the server options and focus to a fairly simple configuration in order to provide baseline capabilities and expectations for the DVX solution. This reference architecture will be constructed around the Datrium Compute Node as the primary building block to host the user desktops. We will cover details of the configuration later in this report.

The following sections provide a high-level overview of the key components of this solution. This includes the Datrium DVX system and the VMware Horizon elements.

Figure 1. DVX Overview
2.1 Datrium DVX

With Split Provisioning and Open Convergence capabilities, customers can address a wide variety of desktop workloads whether they are compute, graphics, or storage intensive. Split Provisioning allows for scalability of compute or durable capacity resources independently. Open Convergence provides flexibility in the choice of compute / server resources. For this report, we have chosen a specific set of resources to build our solution from. The desktop environment is constructed from a cluster of Datrium Compute Nodes (CN2000). The remainder of the VMware infrastructure and Login VSI are running on a pair of 3rd Party Compute Nodes running the Datrium DVX software. These ESXi hosts are attached to a single Datrium Data Node (D12X4) for durable capacity and backup / data protection. The configuration details are listed later in this report. The potential scalability of a Datrium DVX system with Split Provisioning supporting up to 6,000 user desktops is shown in Figure 2 and covered in more detail here: https://www.datrium.com/resources/datrium-split-provisioning/.

2.1.1 Compute Node

For the desktop workloads, we chose to use the Datrium Compute Node (Model CN2000) as the reference server platform. This server provides an excellent basis to address the majority of desktop virtualization scenarios. If other configurations are more applicable – for example requiring dedicated GPU or a blade based architecture – then a qualified 3rd Party Host could be used. For the testing and sizing estimations, a cluster of four (4) similar hosts was used to measure aspects from a single host behavior as well as scalability to the 500-user level across all 4 systems.

The Datrium Compute Node was populated with sufficient memory to allow a variety of Golden Image configuration options. Specific details of the test configuration and workloads will be covered later in this paper.

To support the remainder of the non-desktop virtualization infrastructure needs of our reference architecture and as part of the Open Convergence approach to building a flexible virtualization solution, we selected a pair of 3rd Party Compute Nodes to install DVX Software onto and build into the same VMware vCenter environment as the Datrium specific desktop hosts. This mix and match capability of server configurations provides the flexible foundation to build the right compute
solution for desktops, infrastructure and other applications. The DVX solution supports a variety of 3rd Party servers including both blade and rack servers, and can be leveraged with new or already installed (brownfield) servers. For this reference architecture, we will be focusing on the Datrium specific desktop hosts for configuration, performance and scalability.

Using this common system as a reference point and building block, it is possible to scale a single Data Node configuration to 1,000 user VMs by adding the desired number of Compute Nodes. For current complete specifications of the Data Node, DVX Compute Node or 3rd Party Host platform please visit DVX Compute Node Specifications or DVX Data Node Specifications.

2.1.2 Data Node

The Datrium Data Node comes preconfigured with fully redundant, hot swappable components. This includes mirrored NVRAM for fast writes, and dual 10Gb network ports with load balancing and path failover for high speed data traffic. The Data Node is capacity optimized for durable data leveraging 4TB 7.2K rpm HDDs, always-on erasure coding, compression, and global dedupe across data received from all connected compute nodes. The capacity of the Data Node is 29TB usable before reduction.

NOTE: With VDI implementations we typically see data reduction rates in the 4-6x or higher depending on size and similarity of the user population.

For this configuration, a single Data Node in the solution provides the central shared durable data needs of the user desktops under test as well as the rest of the VMware environment supporting the Horizon infrastructure. We have also included the Login VSI test environment in this mix. For many configurations, this mixed-use approach for the Data Node works well. In a typical DVX environment, the host isolation of active data and IO processing on the Compute Node is central to the DVX architecture. This approach provides scalability through adding hosts when more IO performance is needed. A single Data Node can support up to 32 connected Compute Nodes. For our testing and design planning, we expect the total number of Compute Nodes to be less than 20 per Data Node for a maximum configuration.

The Datrium DVX solution is simple to deploy and even simpler to manage. Typical storage management tasks of dealing with LUNs, RAID, or pools are a thing of the past. With Datrium, all storage monitoring and administration is VM-centric and end-to-end – vCenter to vDisk. The DVX Data Node is the right place to put all of the VDI components from user desktops, templates, images and user data to the operational components that drive the infrastructure.

2.1.3 Data Cloud Foundation

Protecting the critical parts of the solution is achieved by leveraging the Data Cloud Foundation capabilities of the DVX system. The core environment which included the VMware infrastructure (e.g., VCSA and Horizon), Golden Images and Templates, the Login VSI test bed and file share VMs presented to the other components was protected through regular Protection Group policy driven snapshot mechanisms within the Datrium solution.

Depending on specific deployment and pool provisioning options, Protection Group policies could be leveraged to protect individual instances as they are created following the pool naming conventions.

For many scenarios, the individual desktop instances may not be protected and will simply be
regenerated from the baseline images and templates that are actively covered under protection policies. To make sure there was no impact to the operations of the desktops, we also included a DVX Protection Group policy to cover the desktop VMs. This policy used the native dynamic name matching methods to pick up the evolving set of desktops based on Horizon pool naming conventions.

We also enabled Datrium’s unique Blanket Encryption to protect all desktop and infrastructure data active on the hosts and at rest on the Data Node. This capability uses AES-XTS-256 end-to-end software encryption without any performance hit to your end-users’ experience.

More information on the Data Cloud Foundation details can be found here: https://www.datrium.com/resources/data-cloud.foundation/

More information on the Datrium DVX solution can be found here: https://www.datrium.com/datrium-dvx-system/

2.2 VMware vSphere
The solution is built with VMware vSphere hypervisor and VMware Horizon End User Computing solution as the key software components. We use a VCSA (vCenter Server Appliance) VM to manage the environment. The VCSA comes with an embedded database sufficient for this level of testing and infrastructure. This Datrium DVX solution is fully integrated with VMware vCenter Server and VMware vSphere Web Client.

The vSphere ESXi hypervisor installs directly on your physical server and along with the DVX software enables the sharing of the server resources including local flash storage to the virtual machines on that host. With no underlying operating system other than the ESXi hypervisor, this is an extremely efficient approach to getting the most of the physical resources of the Compute Nodes.

With Datrium’s DVX Open Convergence platform, you can leverage your hypervisor resources like available CPU and local flash devices to increase primary storage performance for the desktop VMs on those hosts. With the DVX software running on the ESXi host, I/O performance resources are now primarily server-based.

2.3 VMware Horizon
VMware Horizon provides the virtual desktop delivery system for this solution. This includes several distributed components that simplify the creation and real-time management of the virtual desktop infrastructure such as:

1] Horizon Composer – this software service can be installed standalone or on the vCenter server and provides enablement to deploy and create linked clone desktop pools (also called non-persistent desktops). Horizon Composer runs on a separate VM and there is a separate SQL instance for the Composer and Events database functions.

2] Horizon Connection Server – this is installed on servers in the infrastructure and is responsible for brokering client connections. This function also authenticates users, manages entitlements, desktop/pool mapping, secure connections to desktops, supports single sign-on, and sets and applies policies. Only one Connection Server is used for this solution.

3] Horizon Administrator – a web portal that provides admin functions such as deploy and management of Horizon desktops and pools, set and control user authentication and more. This software / service runs on the Connection Server.
Horizon Client – installed on endpoints. Is software for creating connections to Horizon desktops that can be run from tablets, Windows, Linux, or Mac PCs or laptops, thin clients and other devices. This software is installed into the Login VSI testbed systems.

Horizon Agent - Installed on all VMs, physical machines and Terminal Service servers that are used as a source for Horizon desktops. On VMs the agent is used to communicate with the Horizon client to provide services such as USB redirection, printer support and more. This software is deployed into the user desktop Golden Image.

These components are depicted in the following figure:

![Figure 3. VMware Horizon Components](image)

While there are many alternatives to deployment within Horizon, we will be focusing on a configuration leveraging dedicated Linked Clones. This tends to address a wide range of scenarios where users’ desktops have some level of persistence and system administration options (e.g., recomposing images) can be explored. The desktop of choice is built on Microsoft Windows 10 Operating System. Alternate desktop types (e.g., Windows 7,8 or Linux) are not covered. Some analysis and testing of full desktops was conducted to observe impact of VAAI storage based cloning and as a reference to use for other key measures (e.g., boot storms). Detailed testing alternatives such as Floating Linked Clones, App Volumes, RDSH / App Volumes or Instant Clones is also left for potential future testing.

2.4 Combined Solution

The combined solution of VMware vSphere and Horizon along with Datrium DVX provides a robust and scalable virtualization solution for user desktops. The results presented in this reference architecture will show that this solution performs well, is simple to manage, provides excellent user experience measures and has the reliability needed to support today’s data center modernization initiatives.

Leverage the combination of Datrium’s Split Provisioning approach to scalability along with Open Convergence flexibility and VMware’s enterprise class virtualization platform and End User Computing solutions. Obtaining a VDI experience that works great at 100-200 users and easily scales up to as much as 1,000 users per DVX system. A modular ability to deploy what is needed today and scale to support tomorrow’s requirements is achievable through this joint solution. This reference architecture provides
the basis for understanding the key aspects of this solution and working them into enterprise level data center solutions.

Combining the Datrium DVX Open Convergence platform with your VMware software, IT teams can shift the focus to the VM level for managing applications and the infrastructure on which they run. Your VM administrator can now easily support storage tasks within the hypervisor, delivering simplicity while focusing on the desktop application.

You can also take advantage of integration with VMware and storage offload with VAAI (VCAI) and improve cloning operations throughout the environment. Consult the VMware HCL for the latest details and supported versions available here: https://www.vmware.com/resources/compatibility/search.php

Availability and resiliency are achieved through core capabilities of the VMware infrastructure along with the key aspects of the Datrium DVX solution. The data Node provides enterprise class centralized and shared durable data. The Compute Node architecture of the DVX system provides the desired isolation, scalability and simplicity.

The approach of this reference architecture is to model and test the system in buildable increments. The rest of the paper will address the specifics of the components and results as we look at:

1] Single host – tested to 125 users (QTY=1 host forming the architecture baseline)

2 ] Multiple hosts – tested to 500 users (QTY=4 hosts form the scalability baseline)

3 ] Pod design– projected to 1,000 users (QTY=8 hosts ideal for a single Data Node configuration)

The key components of a combined Datrium DVX Open Convergence platform and VMware Horizon solution can be seen in the following figure which shows a single DVX Data Node connected over a 10G data network to ESX hosts running a variety of pools supporting hundreds of virtual desktops.

The next sections outline the high-level design of the desktop solution that combines Datrium DVX with VMware vSphere and VMware Horizon to provide a robust platform for supporting Windows virtual desktops in an easy to manage and scalable architecture.

The next sections outline the high-level design of the desktop solution that combines Datrium DVX with VMware vSphere and VMware Horizon to provide a robust platform for supporting Windows virtual
Solution Design

desktops in an easy to manage and scalable architecture.

3.1 Datrium DVX
The Datrium DVX components address the server (compute) and storage (data) elements of the configuration. For this reference architecture, we are building from the following items:

This configuration exemplifies the ability of Open Convergence to mix and match servers into a common single DVX configuration to meet the requirements of the application(s) being serviced. We are running desktops, infrastructure, and test functions in the same combined solution.

<table>
<thead>
<tr>
<th>Solution Component</th>
<th>Type</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desktop Cluster (500 Users)</td>
<td>Datrium Compute Nodes</td>
<td>4</td>
</tr>
<tr>
<td>Infrastructure Cluster</td>
<td>3rd Party Compute Nodes</td>
<td>2</td>
</tr>
<tr>
<td>Shared Datastore</td>
<td>Datrium Data Node</td>
<td>1</td>
</tr>
</tbody>
</table>

While the Data Node is designed for high availability (HA) and resiliency of the durable data (e.g., dual controllers, dual power, dual network, etc.), the Compute Nodes are configured to operate independently and be scalable as user desktop population and workload dictates.

Each host will need at least one SSD (800GB minimum) to hold the active data set and can be configured with up to 10 devices (16TB maximum). For most solutions, we recommend 2 devices for improved vSphere device availability and sufficient initial capacity. We want to configure enough host flash to hold the entire active workload of all user desktops on this host and never worry about not having the active data in flash on the host. For this configuration and workload, we deployed approximately 2-3TB of local SSD (2x 960GB, 1.6TB or 1.92TB SSD) and observed about 5-6x data reduction of host data typical in VDI implementations. This translates into about 9-10TB effective host local flash capacity for up to 125 user desktop VMs per host. Considering that the base disk of the Golden Image was configured with an 80GB drive, this will support host flash resident data for all user desktop VMs if necessary. This flash design consideration is reflected in the data found in the Host Flash Data Reduction view in the DVX UI at the Host Monitoring DVX level.

The Desktop and Infrastructure vSphere clusters can be configured independently with the desired method and level of availability without impact to the overall operational combined DVX solution. For production environments where higher availability and regular maintenance operations are expected,
we suggest adding additional hosts to the vCenter clusters to support an N+1 architecture that meets your organization's needs. For the testing performed in this reference architecture, we worked only with the needed number of host resources to understand performance and basic administration behavior.

Relocating VMs from one host to another via DRS works fine within the DVX. This is in part due to the way the DVX maintains local active data that benefit from commonality and data reduction rates across large sets of common VMs typical of VDI. That commonality is often present on other hosts as well as in the shared durable data copy on the Data Node. DRS settings for DVX desktop hosts should be set to level 3 or less to avoid too much unrelated relocations.

NOTE: Because of the nature of some of the testing and collecting results, we occasionally turned off vSphere HA and DRS functions on the target clusters. We are more interested in getting repeatable results over potential optimizations under certain workloads.

3.2 VMware vSphere/Horizon Components

The VMware vSphere and Horizon components were configured to run on the Infrastructure cluster (2 nodes) on the same DVX system as the user desktops. Details on the configuration of the infrastructure VMs are shown below.

The VMware vSphere environment consisted of the following infrastructure VM to manage the environment:
This vCenter was registered to the Datrium DVX Data Node as part of normal DVX configuration setup. 
Registering the DVX Data Node with the VCSA allows for subsequent configuration and management of 
the Datrium DVX to be done from within the VCSA UI through the Datrium plug-in. 
The VMware Horizon environment consisted of one each of the following infrastructure VMs:

<table>
<thead>
<tr>
<th>VM</th>
<th>OS</th>
<th>vCPU</th>
<th>Memory (GB)</th>
<th>Disk (GB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VCSA</td>
<td>Linux (64)</td>
<td>8</td>
<td>24</td>
<td>400</td>
</tr>
</tbody>
</table>

3.3 Microsoft Infrastructure
Along with the core VMware components, the infrastructure to support a scalable Microsoft Windows 
desktop deployment was also set up on the Infrastructure cluster. This included Active Directory as well 
as DNS, DHCP and KMS volume licensing to enable consistent activation of both the desktop OS as well 
as the Microsoft Office application suite. A dedicated DNS service provided the basis for Active Directory 
and to control access to the various VMware software components. All hosts, VMs and consumable 
software components in this solution have a presence in this dedicated DNS. Some of the VMs and 
systems are set to fixed / static presence. The user desktops created through View Composer operations 
are configured via a dynamic and AD-integrated namespace. Microsoft best practices and organizational 
(OU) requirements are followed. This also helped with integrating the Login VSI test tools and selective 
User policy control.

The Microsoft desktop support environment consisted of one each of the following infrastructure VMs:

<table>
<thead>
<tr>
<th>VM</th>
<th>OS</th>
<th>vCPU</th>
<th>Memory (GB)</th>
<th>Disk (GB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary AD/DNS/DHCP</td>
<td>Windows Server 2012 R2 (64)</td>
<td>4</td>
<td>8</td>
<td>40</td>
</tr>
<tr>
<td>Backup AD/DNS/DHCP</td>
<td>Windows Server 2012 R2 (64)</td>
<td>4</td>
<td>8</td>
<td>40</td>
</tr>
<tr>
<td>KMS Licensing</td>
<td>Windows 10 (64)</td>
<td>2</td>
<td>4</td>
<td>80</td>
</tr>
<tr>
<td>VDI User Share</td>
<td>Windows Server 2012 R2 (64)</td>
<td>4</td>
<td>8</td>
<td>1,000</td>
</tr>
</tbody>
</table>
3.4 Network
For purposes of this reference architecture, we will address the 3 primary functional networks of our desktop virtualization setup. This includes:

1] **Management** - connecting the core infrastructure elements together – this is the network between the ESX hosts and the other management or administration functions

2] **Data** – connecting the ESXi hosts and the backing durable storage – this is the DVX specific 10G network between the Compute Nodes and Data Nodes

3] **Virtual Machine** – connecting the user desktops to the testing framework – this is the network the desktops connect to the infrastructure and to the user access point (Horizon Client) – in this case the Login VSI launchers

There are a couple of secondary networks to consider. This includes:

1] **vMotion** – this leverages the movement of VMs from one host to another – with a single shared DVX datastore, storage vMotion will typically not be needed so traffic will be minimal – this network is enabled on the Data network defined above

2] **Provisioning** – this network is used to quickly construct the new VMs for administration – this network is on the Data Network defined above

3] **DVX Replication** – connecting to another DVX site was not included in this solution – this network is not defined

For the reference architecture setup and general Datrium DVX implementations we do not have to worry about the following VMware networks:

1] **FT Logging** – not used

2] **vSphere Replication** – not used

3] **vSphere Replication NFC** – not used

Unless otherwise explicitly called out, other network setup and configuration can follow typical VMware practices within your data center.

On both the host side and data side, we deploy redundant NICs for both 1GbE and 10G networks. The Data Network between the Compute Nodes and the Data Node is an isolated simple, flat, layer 2 non-routed 10G data network. For this setup, we used SFP+ connectivity and simple twinax cabling. The 10G network could have been configured with SFP+ optical links or 10GBaseT type connections also available on the Data Node if that fits better with existing networks. Providing redundant data networks links allows us to take advantage of the DVX Adaptive Pathing capabilities for improved connectivity. This approach provides additional bandwidth and path failover without complex network setup between the NIC, host, switch and DVX ports.
Figure 7. DVX Network Connectivity

3.5 Desktops
The key configuration details of the Horizon pool constructed for the Dedicated Linked Clones are listed here. Where not explicitly identified in this paper, the default choices were selected during the pool creation process.

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Automated Desktop Pool</td>
</tr>
<tr>
<td>User Assignment</td>
<td>Dedicated assignment</td>
</tr>
<tr>
<td>Machine source</td>
<td>vCenter (linked clone)</td>
</tr>
<tr>
<td>Number of Machines</td>
<td>500</td>
</tr>
<tr>
<td>Persistent disk / size</td>
<td>D: / 2,048 MB</td>
</tr>
<tr>
<td>Disposable disk / size</td>
<td>Auto / 4,096 MB</td>
</tr>
<tr>
<td>View Storage Accelerator</td>
<td>Disabled</td>
</tr>
<tr>
<td>Use of VMware Virtual SAN</td>
<td>No</td>
</tr>
<tr>
<td>Guest Customization</td>
<td>QuickPrep</td>
</tr>
<tr>
<td>VAAI</td>
<td>Enabled</td>
</tr>
<tr>
<td>Storage Overcommit</td>
<td>Aggressive</td>
</tr>
<tr>
<td>Connection Server restrictions</td>
<td>None</td>
</tr>
<tr>
<td>Remote Machine Power Policy</td>
<td>Take no power action</td>
</tr>
<tr>
<td>Refresh OS disk on logoff</td>
<td>Never</td>
</tr>
<tr>
<td>Default Display Protocol</td>
<td>VMware Blast</td>
</tr>
<tr>
<td>3D Renderer</td>
<td>Disabled</td>
</tr>
<tr>
<td>Adobe Flash Quality</td>
<td>Do not control</td>
</tr>
<tr>
<td>Adobe Flash throttling</td>
<td>Disabled</td>
</tr>
</tbody>
</table>
In a real-world environment, there are a variety of scenarios of application placements and selection. The focus of this reference architecture is on the core desktop infrastructure. Testing was done with all applications installed into the Golden Image. We felt this provided a simpler baseline for comparisons and analysis of workloads.

Based on VMware HCL at the time of the setup, we used the appropriate supported Windows 10 versions with Horizon 7 referenced here: https://kb.vmware.com/selfservice/microsites/search.do?language=en-US&cmd=displayKC&externalId=2149393

Note: Because of the choice to use VMware Paravirtual SCSI control then during the installation of the OS, it was necessary to load the pvscsi driver from VMware tools mounted CD.

The use of this vmdk connection configuration is not required but recommended as discussed here: https://www.vmware.com/content/dam/digitalmarketing/vmware/en/pdf/techpaper/vmware-perfbest-practices-vsphere6-0-white-paper.pdf

The configuration of the base golden image is outlined below.

Hardware configuration of the Windows 10 Golden Image (Win10GI):

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardware version</td>
<td>11</td>
</tr>
<tr>
<td>System type</td>
<td>64-bit</td>
</tr>
<tr>
<td>vCPU</td>
<td>2 CPUs, 48 MHz</td>
</tr>
<tr>
<td>Memory</td>
<td>3.00 GB, 2.0 GB Reserved (scenario 1) 4.00 GB, 2.0 GB Reserved (scenario 2)</td>
</tr>
<tr>
<td>Hard disk 1</td>
<td>80 GB</td>
</tr>
<tr>
<td>SCSI controller</td>
<td>VMware Paravirtual</td>
</tr>
<tr>
<td>Network adapter</td>
<td>VMXNET 3</td>
</tr>
<tr>
<td>NICs</td>
<td>1</td>
</tr>
<tr>
<td>Video Card</td>
<td>128 MB</td>
</tr>
<tr>
<td>3D Graphics</td>
<td>Off</td>
</tr>
<tr>
<td>CD/DVD</td>
<td>Removed</td>
</tr>
<tr>
<td>Floppy drive</td>
<td>Removed</td>
</tr>
</tbody>
</table>
3.6 Data Protection Considerations
The Datrium DVX system has built-in snapshot and replication capabilities. To protect our environment at the basic level, we will leverage these features to cover the essentials pieces of the solution. If more stringent data protection and recovery practices are needed or existing 3rd party tools are available, they can be used in place of or in addition to the DVX methods described here. A detailed coverage of 3rd party data management tools is outside the scope of this paper.

While replication of DVX data to a secondary site is within the functionality of the solution, this reference architecture is focused on the operational considerations only at the primary site. For more information please visit the Datrium website and reference Elastic Replication.

For this solution, a simple backup and restore approach enables recovery at the local site in the event of data, VM or host failures. The Datrium DVX snapshots are lightweight, efficient and non-intrusive to the operations. The DVX Protection Group policy driven setup allows for proper granularity and coverage of critical components.
### 3.6.1 Core Infrastructure

For the core infrastructure, any Virtual Machines or VM data stored on the DVX can be protected. There are two primary Protection Groups specified for this coverage that protect the basic VMs used to run the VMware, Microsoft and Login VSI elements. They are:

1. **“Infrastructure”** – picking up the VMware VCSA, Microsoft environment VMs (AD, KMS) and jump hosts
2. **“Login VSI”** – picking up the Login VSI Manager and Login VSI Launchers

### 3.6.2 Desktop Infrastructure

For the desktop environment, we are protecting the Horizon 7 VMs used to enable the desktop management layer. This includes:

1. **“Horizon 7”** – picking up the Composer, Connection Server, SQL database for logging and the Golden Images that have been prepared

### 3.6.3 User Desktops

As a final measure, protecting the individual desktops may be desired – particularly if they are dedicated/persistent or Full in nature and there are pieces (vmdks) that would be better to not lose and restore than just provision a new desktop image. This is easily accomplished with the DVX Protection Group policy definitions and dynamic binding of member selection criteria. In this reference architecture solution, we define a nightly snapshot with appropriate (e.g., 7 day) retention and use the pool naming scheme to match the snapshot VM list. The following two figures show the correlation between the Horizon Pool desktop name and the DVX Protection Group VM selection criteria. In the DVX Protection choices we have defined:

1. **“Desktops”** – picking up the current set of desktop VMs based on naming convention – in this case the “H7RA” prefix

---

**Figure 8. DVX Protection Groups**

<table>
<thead>
<tr>
<th>Protection group</th>
<th>Snapshots</th>
<th>Last snapshot includes</th>
<th>Unique size</th>
<th>Total size</th>
<th>Schedule</th>
<th>Replicates to</th>
<th>Health</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desktops</td>
<td>8</td>
<td>126 VMs</td>
<td>176.8 GB</td>
<td>261.5 GB</td>
<td>Enabled</td>
<td>--</td>
<td>OK</td>
</tr>
<tr>
<td>Horizon7</td>
<td>14</td>
<td>21 VMs</td>
<td>14.8 GB</td>
<td>257.6 GB</td>
<td>Enabled</td>
<td>--</td>
<td>OK</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>14</td>
<td>6 VMs</td>
<td>0.0 GB</td>
<td>680.1 GB</td>
<td>Enabled</td>
<td>--</td>
<td>OK</td>
</tr>
<tr>
<td>Login VSI</td>
<td>7</td>
<td>27 VMs</td>
<td>0.0 GB</td>
<td>122.7 GB</td>
<td>Enabled</td>
<td>--</td>
<td>OK</td>
</tr>
</tbody>
</table>

Below is a screenshot of the Protection Group definitions constructed for this solution.
Testing, Validation and Benchmarking

The configuration outlined in this reference architecture was exercised through a number of different situations. The testing addressed both management activities as well as end user scenarios where user experience can be monitored.

The approach of the testing methodology was to configure and verify operations for single host, multiple hosts and scalability considerations when adding more users or hosts to the solution. The results presented later will cover scenarios of single host operations and cluster (4) host operations. The extrapolation of results to larger clusters can be derived from the linear scalability observed in the baseline testing performed.

The objective was to run through the various tests and operations and find the upper limits possible for each component under test. With this information, it is then easier to design a proper solution for the production deployments and alternatives. We realize there are a wide range of host configurations.
possible. Using the results from this reference architecture solution will help guide current and future efforts for specific needs within the range of solutions possible.

Upper limits are defined as reaching 100% of a resource limit. We are not recommending a production build to these levels but are interested in finding their points if available through the testing. These include:

1] **Physical host resources** – CPU, memory, network, or disk capacity

2] **VM resources** – CPU, memory

3] **Login VSI limits** – VSImax (user experience latency thresholds)

### 4.1 Management/Maintenance/Administration

Desktop management functions are typically performed less frequently and outside the scope of direct user involvement. They are important in their own space as simple and faster administration of the desktop environment translates into better operations and SLAs to the end users. These operations also tend to be performed in larger batches where completion time is the more important consideration than the individual operation.

We’ve broken these functions down into 3 main categories for review. This includes:

1] **Provisioning** or creating the new desktops/pools

2] **Maintenance** or updating the instances

3] **Administration** or day to day movement and running of desktops

For basic user desktop management operations, we utilized the Horizon management capabilities and augmented the testing runs with some simple VMware PowerCLI scripts (included in the Appendix).

**NOTE: Uncheck “stop provisioning on error” – let the composer work through any timing issues and continue building desktops.**

#### 4.1.1 Provisioning

Creating new desktop instances or Horizon desktop pools was performed with both Linked Clone and Full Desktop deployment methods. The majority of the testing focus was with Dedicated Linked Clone instances as these provide some of the more interesting and useful scenarios for “follow me” desktops and still have administration leverage with image and user disk management options. A discussion of the trade-offs of particular provisioning methods is outside the scope of this reference architecture solution paper.

The same base image was used for the snapshot point for Linked Clones and converted to VM template for Full Clone testing. For both scenarios, the target storage chosen was the same single Datrium DVX datastore presented to the desktop cluster of ESXi hosts.

Storage consumption and reporting will be slightly different depending on the provisioning method chosen. Full Clones tend to appear to use less storage in the datastore mainly due to the accounting
of the Linked Clone parent image and clone copies. Full Clones also appear to have higher data reduction rates over Linked Clones (e.g., 8-10x vs 3-5x) mainly due to the amount of common additional data they are each individually holding. The end result is a very similar actual capacity consumption on the DVX due to the always-on compression and deduplication. Consider that the amount of common data across 1,000 desktops is about the same in either provisioning method and the amount of unique user data across those same 1,000 desktops will amount to about the same capacity consumption.

For our reference architecture, we are working from the following assumptions and observations that for the desktops that we will have 20 TB of addressable space for 1,000 desktops at 80 GB max disk consumed and 4x reduction (minimum).

4.1.2 Maintenance (Linked Clone)

Once desktops are provisioned into inventory, they can be updated in a couple of different ways. Full Clone desktops are independent VM images and are usually managed with existing techniques used for physical desktop image updates – either by the administrators or by the end users themselves. We will not be addressing the tasks of Full Clone image maintenance in this reference architecture.

The focus is on the capabilities built into Horizon for maintaining and updating desktop images for Linked Clones, in particular the Refresh and Recompose operations. Since we are working from a single shared Datrium DVX datastore location for all desktop data, we do not need to cover any Re-balancing tasks. This single datastore configuration also simplifies the overall management and placement of the desktop pools.

Refresh operations handle reset of the operating system disk elements while Recompose operations will update the desktop to an alternate base image. Depending on desktop construction, persistent user data may or may not be affected by these operations.

4.1.3 Administration

Day to day site administration is another aspect of desktop management that we explore in this paper to understand the impact of typical VM operations. For virtual desktops configurations, boot storms are potentially troublesome activities that can impact the overall environment and end user experience.

Boot storms can arise from starting or restarting a set up desktops either under automation control (e.g., when logging off) or as part of another system administration operation such as hardware maintenance.

We examine the nature, impact and scale considerations for both cold start and restart (reboot) operations on the hosts in our configuration. Note we have observed that a boot operation is on the order of about 20,000 – 30,000 disk I/O operations per desktop VM (not IOPS).
4.2 User Experience/Production/Operations
There are two key measures of user experience with respect to desktop virtualization. The first is the login time of the user to first action and the second is the ongoing steady state behavior of a user workload. Both of these measures are directly affected by latency and processing power of the underlying system.

4.2.1 User Setup
The login period can be affected by many things outside the specific performance or setup of the individual desktop. Things like AD authentication, user profile management and initial application launches all add to the amount of operations to perform and time needed for a user to login into their desktop. There is also the consideration of whether the target (dedicated) desktop is currently powered on. An additional consideration is whether the user profile has been established (dedicated) which also increases the amount of work needed before the user gains usable access.

For the testing we conducted, much of the preparation of the desktop sessions (e.g., AD integration, initial user profile creation, etc.) was not explicitly measured. Once the sessions were established, the desktops were reset and the login times accounted for as part of the testing with the Steady State workloads.

Unless otherwise called out, we followed Login VSI recommendations for testing this aspect of the configuration.

4.2.2 User Experience
To test and verify a great user experience for the desktops in this solution, we use the Login VSI tool to run simulated workloads on each of the target user desktops. There are a wide variety of actual desktop workloads and applications possible in production environments and it may be useful to test or customize testing for them as part of any configuration setup or pilot project. For this reference architecture, we will be using the typical Knowledge Worker workload as our primary test case and measurement point. The goal of this testing was to push the ESXi host to either the CPU limit or the Login VSI max.

4.3 Considerations
With the overall simplicity of the storage setup with Datrium DVX, the one storage related consideration that we explore is the use of Insane mode host level operations. Each host in a DVX system can run in either Fast (default) or Insane (user selected) mode. The difference in these modes is the peak amount of host CPU resources allocated for IO operations. Fast mode has a maximum of 20% and Insane mode has a maximum of 40% of available CPU cycles to process IO requests for the VMs on that host.

In our testing, we found that Insane mode provided better overall response times under heavy load (e.g., boot storms) but had marginal impact in overall processing times which were tied to other non-storage related operations. Details are included in the Results section.

4.4 Login VSI Configuration
To establish key results for evaluating operational user experience we used the Login VSI testing tool to exercise the desktop workloads across a number of configurations. The use of typical settings and following best practices enables a repeatable and comparable configuration and set of results.
The driving objective with this setup was to push resource utilization to upper limits (~90-100%) and measure against VSImax results to ensure the user experience is not being adversely affected at tested limits. Actual implementations may run at lower thresholds to provide administration room for resiliency, growth and other daily operations.

### 4.4.1 Objective testing with Login VSI

Login Virtual Session Indexer (Login VSI) is the industry standard load-testing tool for measuring 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 the major hardware and software vendors and is recommended by both leading IT analysts and the technical community. Login VSI is 100% vendor independent and works with standardized user workloads—making all conclusions based on Login VSI test data objective, verifiable, and repeatable.

Login VSI-based test results are used and published in multiple technical white papers and presented at various IT-related conferences by our vendor customers. The product Login VSI is also widely used by end-user organizations, system integrators, hosting providers, and testing companies. It is also the standard testing tool used in all tests executed in the internationally acclaimed research project VDI Like a Pro (formerly known as Project Virtual Reality Check).

### 4.4.2 How Login VSI works

When used for benchmarking, the product measures the total response times of several specific user operations being performed within a desktop workload, in a scripted loop. The baseline is the measurement of the specific operational response times performed in the desktop workload, measured in milliseconds (ms). Two values, in particular, are very important: VSImax and VSImax.

1. **VSIbase** - A score reflecting the response time of specific operations performed in the desktop workload when there is little or no stress on the system. A low baseline indicates a better user experience and a well-tuned desktop image—resulting in applications responding faster within the environment.

2. **VSImax** - The maximum number of desktop sessions attainable on the host before experiencing degradation in both host and desktop performance.

Both values, VSImax and VSImax, offer undeniable proof (vendor independent, industry standard and easy to understand) to innovative technology vendors of the power, the scalability, and the benefits of their software and hardware solutions, in a virtual desktop environment.
4.5 Login VSI Configuration
The Login VSI testing infrastructure consisted of the following infrastructure VMs:

<table>
<thead>
<tr>
<th>VM</th>
<th>OS</th>
<th>vCPU</th>
<th>Memory (GB)</th>
<th>Disk (GB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Login VSI Management Console</td>
<td>Windows Server 2012 R2 (64)</td>
<td>4</td>
<td>8</td>
<td>40</td>
</tr>
<tr>
<td>Login VSI Launcher QTY=25</td>
<td>Windows Server 2012 R2 (64)</td>
<td>2</td>
<td>4</td>
<td>40</td>
</tr>
</tbody>
</table>

The Login VSI Launchers were configured to allow up to 25 user session connections yet were run to only 20 during normal testing runs. For the 500 user desktops, we used 25 launchers with 20 user sessions per launcher.

Results
This section presents the results from the setup and testing of the reference architecture configuration. For basic documentation purposes and to support an easier method for external comparisons we will focus the presented data on readily available views from the tools and components used. This includes: Login VSI, vCenter/vSphere performance charts, and Datrium DVX UI screenshots.

5.1 Management
The results of tasks performed by VDI administrators are covered in the next sections. All data is stored on the single DVX datastore. Times are measured using wall clock methods unless explicitly reported from the environment or logs examined.

5.1.1 Provisioning with View Composer
Since the base Golden Image has VMware snapshots, the initial clone cannot leverage VAAI integration (https://communities.vmware.com/thread/508714). Although this is a one-time action per pool, it still takes about 3 minutes to complete the first Golden Image copy to replica. The observed cloning throughput of the replica image on the host was approximately 350 MB/s or higher. Subsequent clones for each individual desktop derived from the replica can take advantage of the Datrium DVX VAAI/VCAI integration and take from 2-6 seconds per desktop clone.

As stated earlier in this white paper...
Using Horizon event logging we measure the time to provision 125 desktop VMs on a single host. This phase of the provisioning operation took just under 9 minutes. The total time to provision 125 user desktops was calculated at 12 minutes. For this testing, we set the maximum number of concurrent provisioning operations to 25.

Even with multiple concurrent operations configured, the provisioning operation tends to be more single threaded bounded as each new virtual machine must be coordinated with a single Horizon Composer and Windows AD regardless of the amount of CPU or speed of storage underlying the desktop servers.
After each provisioning operation completed and was measured, the pool was disabled, the VMs removed from Horizon and then the quantity of desktop hosts and target VMs to provision updated and the pool enabled. The process was repeated for 2 hosts and 250 VMs and then for 4 hosts and 500 VMs and the results shown below. After the initial pool provisioning run, the base image was cached on the host and subsequent replica cloning operations ran about 15% faster.

### Provisioning Times: Dedicated, Linked Clones

<table>
<thead>
<tr>
<th>Hosts</th>
<th>Pool Size</th>
<th>Replica clone (mins)</th>
<th>Desktops (mins)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>125</td>
<td>3:02</td>
<td>8:41</td>
</tr>
<tr>
<td>2</td>
<td>250</td>
<td>2:38</td>
<td>9:40</td>
</tr>
<tr>
<td>4</td>
<td>500</td>
<td>2:37</td>
<td>17:19</td>
</tr>
</tbody>
</table>

The following 3 figures show performance graph data for 3 separate provisioning operations of 125, 250 and 500 desktops on 1, 2 and 4 hosts respectively. The same time period was selected for continuity and then some parts masked out. What we see in this set of figures is a consistent and scalable progression as the provisioning operations increase and more desktop VMs and more hosts supporting them are deployed. The upper limits obtained are being driven primarily by the underlying VM composition methods and activities. The general shape and IO composition as observed at the DVX is consistent with a scalable approach with respect to provisioning operations.

Since we have a single AD, Composer and Connection Server in our environment, the provisioning steps must synchronize through these resources. This is in contrast to an already deployed environment where the desktop only needs to come into service and quickly register with the framework as we see in boot storms, login rates and steady state operations across broader sets of users.

![Figure 11. Provision 125 Desktops](image)
5.1.2 Maintenance

There are two key desktop maintenance operations that were tested for this reference architecture. They are Pool Refresh and Pool Recompose. Since we are using a single DVX Datastore target to hold all desktop (and infrastructure) data there is no need to review Pool Re-balance operations. This further simplifies the administration and ongoing management of the environment.

With the Horizon configuration, there is the ability to set levels for concurrent operations within the vCenter Settings. We settled on a moderate level of 25 for maintenance operations as they can potentially affect other parts of the environment (e.g., AD, VCSA, Composer, etc.) and don’t really improve the overall performance of these single threaded parts of the infrastructure.
5.1.3 Administration/Boot Storm

To understand the benefits and implications of processing most of the active data IO from flash on the host and avoiding traditional storage bottlenecks, we examine the cold boot performance for individual hosts as well as groups of hosts.

Each of our hosts is supporting 125 user desktop VMs. The sample cluster we are working with has 4 such hosts for a total of 500 VMs. Using a combination of vCenter operator actions such as selecting all VMs on a given host and issuing the start operation or simple PowerCLI scripts to initiate the startup (or shutdown) of the guest VMs, we see consistent results for the time taken to bring the guest VM from a “Provisioned” state in View Administrator to an “Available” state and ready for user login.

For example: On a single host with 125 desktop VMs @ 25,000 IO operations per boot over approximately 4 mins translates into a little over an average of 13,000 IOPS needed on that host to support the task. This is reflected in specific details of tested hosts as shown in the table below. For 500 users, the duration was only slightly longer (~7%) as all 4 hosts were handling their own workloads but still synchronizing through a central AD and Horizon Connection Server.

Example DVX dashboard screenshot excerpts reflect this processing behavior and scalable capability. The combined 4 host cluster runs about 4 times the workload of a single host without any adverse impact on the duration of the task or observed latencies.

<table>
<thead>
<tr>
<th>Host(s)</th>
<th>Users</th>
<th>Duration (mins)</th>
<th>IOPS avg (R/W)</th>
<th>Latency avg ms (R/W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>125</td>
<td>3:53</td>
<td>13,000 / 1,300</td>
<td>0.4 / 1.4</td>
</tr>
<tr>
<td>4</td>
<td>500</td>
<td>4:12</td>
<td>44,000 / 2,000</td>
<td>0.6 / 2.0</td>
</tr>
</tbody>
</table>
Observation: Even though the IO workload is predominantly read (~90%), it is also very CPU intensive hitting 100% utilization levels. As more hosts are included in the stress test, there are other points within the infrastructure that must also scale to the demands (e.g., DNS, View Administrator, VCSA, etc.) so it is challenging to get pure linear 1:1 scalability within a single environment. Results below are shown for 1, 2 and 4 host with 125, 250, and 500 VMs respectively.

**Figure 15. Cold Boot 125 Users**

**Figure 16. Cold Boot 250 Users**

**Figure 17. Cold Boot 500 Users**
5.2 User Experience/Operations

To test, measure and analyze the user experience and application operations we use the Login VSI testing tool (https://www.loginvsi.com/).

The Login VSI testing tool has a well-defined behavior during test runs. For a given test scenario there will be a period of desktop/user session launch and login and then the workloads begin running. Once all of the sessions for a run have been launched, there is a second period of each test where the user is running through the prescribed workload – in this case we chose the Knowledge Worker definition. For the launch period, we used the 2880 seconds default for the setup and then would run the entire user set for an additional 60-90 minutes to allow for steady state conditions to be achieved.

5.2.1 Login Storms

As the test ramps up, users are logged into their desktop and begin running the prescribed workload. The system performance during this period reflects the incremental addition of each user to the population and the loading of applications. We see an IO trend during this time that has higher read workloads than during the steady state period which follows.

5.2.2 Steady State

For the user desktop testing, we focused on the Login VSI Knowledge Worker profile. This provides a reasonable reference point for many installations. The steady state workload exercises the applications that are built into each desktop. During this period of operation, we see an IO trend that is predominately write heavy – sometimes as high as 90%.

---

**Figure 18. Login VSA Profiles**

<table>
<thead>
<tr>
<th>Workload Name</th>
<th>Login VSI Version</th>
<th>Applications Opened</th>
<th>Estimated CPU Usage</th>
<th>Estimated IOPS per user</th>
<th>Typical VM Memory Profile</th>
<th>Typical VM vCPU Profile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task Worker</td>
<td>4.1+</td>
<td>2-7</td>
<td>70%</td>
<td>6.0</td>
<td>1.0 GB</td>
<td>1vCPU</td>
</tr>
<tr>
<td>Office worker</td>
<td>4.1+</td>
<td>5-8</td>
<td>82%</td>
<td>8.1</td>
<td>1.5 GB</td>
<td>1vCPU</td>
</tr>
<tr>
<td>Knowledge</td>
<td>4.1+</td>
<td>5-9</td>
<td>100%</td>
<td>8.5</td>
<td>1.5 GB</td>
<td>2vCPU</td>
</tr>
<tr>
<td>Power worker</td>
<td>4.1+</td>
<td>8-12</td>
<td>119%</td>
<td>10.8</td>
<td>2.0 GB</td>
<td>2vCPU+</td>
</tr>
</tbody>
</table>
5.3 Scaling
The system was tested for scalability using a variety of tools and methods. We separated the activities into two sets – one covering the initial 500 users spread over 4 hosts and the second covering the case above 500 users on a single DVX Data Node configuration.

5.3.1 Initial 500 Users
For the initial 500 users, the testing results below show that as we scale from a single host with 125 knowledge worker users to 4 identical hosts running 500 users that the results are tied primarily to the compute capabilities of the host. In other words, the results were nearly identical for each host added to the population. This exemplifies one of the key traits of the DVX architecture – that of host workload isolation. The Login VSI VSImax charts are shown below for the 125, 250, and 500 user knowledge worker runs that were configured to 1, 2 and 4 hosts respectively. Then the 3 different sized populations are combined in a comparison view to understand the basic scalability consideration – each host supports a workload commensurate to the hosts CPU power and user workload definition.

NOTE: In all cases, VSImax was not reached during the test runs. The baseline and threshold levels are almost identical for each population (95% or better match across runs within same size or comparison).

For each configuration shown below, the baselines (around 700 ms) and threshold (around 1740 msec) values achieved indicate great user response times (around 1,000 msec) throughout each of the runs.

![Figure 19. Login VSI VSImax 125 Knowledge Workers – 1 Host](image)
It’s interesting to see the 3 runs overlaid on the same graph where the ramp up rate and peaks can be observed in perspective. For 1, 2 and 4 hosts, we see similar response characteristics scaling with the additional user population workload.
5.3.2 Scaling to 1,000 Users

To get to larger configurations, we could have simply continued to add hosts and additional user workloads until we hit the limit of the DVX configuration somewhere other than the individual host performance. To simplify our testing and also show the ability to support other, additional workloads, we constructed a micro-benchmark set of VMs that created Data Node traffic similar to the workload observed with the 500 Knowledge Worker desktop configuration.

The micro benchmark workload was configured to produce a 75% random write IO workload of between 16K and 32K block size totaling about 12K IOPS level throughout. We configured the
additional workload to be about 50% higher than peaks observed with no extra load running during just the Login VSI workload runs on the 500 user population.

These two phases are further explored below with performance graphs from the DVX UI showing overall performance data for the system during the period selected.

The following 2 graphs examine the login phase of the testing – Login VSI with and without additional IO load generation. We can see the underlying characteristics of the user desktop workload from the hosts is unhindered by the additional IO workload placed against the Data Node from other hosts. As long as the total system workload is within the operational bounds of the DVX system this will be the case.

Shifting over to examine the steady state workload and performance characteristics we can see that the user desktop workload is not affected by the additional IO workload applied. In fact, there is considerable headroom for the DVX to support 1,000 Knowledge Worker desktops and up to the 1,500 limits of the single DVX Data Node.
As a final IO reference workload reference point, the following chart shows the other non-desktop hosts and VMs that are generating the workload into the shared Data Node along with the 500 user desktops.
These capabilities are even further exemplified by looking at the Login VSI Analyzer results for the 500 user test runs with and without the background Data Node IO load. The VSImax run plots and the run thresholds are indistinguishable as shown below.

![Figure 29. VSImax Overlay - with and without Added IO Load](image1)

![Figure 30. VSImax Run Comparison - with and without Added IO Load](image2)
Based on the testing results and observations covered above, we feel confident that the DVX solution presented in this reference architecture will support up to 1,000 knowledge worker type user desktops by simply supplying the appropriate number of Compute Nodes to support the desktop VMs.

The following figure shows the CPU utilization as seen in vCenter for one of the desktop hosts. Each host deployed had similar characteristics during the test runs. In this case the 125 Knowledge Worker user desktops are pushing the available CPU resources of the ESX host into the 90% or above ranges. For a 28 core server, this is roughly the levels we would expect for this type of workload with all applications baked into the desktop images.

Collectively, we can see these CPU utilization rates applying to the 4 node desktop cluster running the 500 Knowledge Worker tests.
5.4 Considerations

The DVX System is designed to be simple to deploy and manage. From an operational perspective, the only real consideration for setup or best practice relative the DVX configuration was the desktop host setting of Fast/Insane mode. Except in the most extreme cases observed in this testing where we were pushing the limits of the systems or desktops, either mode works fine and produces similar user experiences. It is recommended to test this impact on production deployments.

5.4.1 Host Operational Mode – Fast or Insane

As shown in the following figure, when operating in Insane mode, the responsiveness to high IO situations like boot storms can be improved with the application of more server side CPU resources to the IO processing. The lowering of latency and increase in IOPS can reduce the overall time to perform certain operations affected by peak IO performance.
For this reference architecture, we also tested steady state user operations using Login VSI with both Fast and Insane settings and were able to stay below the VSImax thresholds. Most of the reference points documented are gathered with Insane mode enabled.

Note that Insane mode has no real downside effect for workloads like VDI that are periodically IO intensive and sensitive to latency considerations.

### Scenarios

Datrium DVX Open Convergence platform can easily deploy hundreds to thousands of virtual desktops with applications included. Performance is achieved with host local flash and data handling features like zero-copy clone offload. Capacity is optimized through always-on data reduction with compression, and deduplication for greater storage efficiency.

The following sections outline 3 main scenarios covered in this RA. The first is the testing of a single host to understand and establish a baseline building block of approximately 125 knowledge worker users. This reference point is used as a central consideration for the rest of the solution. From the single host, we scale up to 500 users running on 4 hosts. The Login VSI testing runs through the capabilities and results of these 2 scenarios. Then based on the linear scalability of the DVX solution we project up to a 1,000 user solution for our reference architecture. This is demonstrated in the results where we combine the 500 user workloads along with an additional Data Node workload similar to the 500 users.

### 6.1 Sizing Guidelines

During the testing of the results from single to multiple hosts, we monitored the underlying utilization of the components involved. The goal was not to exceed the following levels:
• Physical Host CPU 95-100%
• Physical Host Memory 80%
• Network Throughput 80%
• Storage IO Latency 5 msec

NOTE: Windows 10 desktop with 2 vCPU and 4GB (2GB reserved) had minimal impact – some of the desktops were observed at slightly over ~3GB of active usage – total host storage could be reduced from 512GB to 384GB for cost considerations if needed – however 78% memory utilization was reached when limits were relaxed.

6.2 Single DVX VDI Host
For a single host, we configured 125 users as a baseline for the Datrium Compute Node. This operational reference point was based on the selected server which had 28 core physical CPU with ~5 desktops/core or ~5 vCPU/thread. With roughly a 5x CPU oversubscription, we were able to reach maximum CPU utilization of over 90% and still maintain our target performance goals – user experience levels – as measured with Login VSI. The management and user operations were checked and measured on each of the 4 similar hosts for consistency.

NOTE: If the user desktops in practice need more horsepower (e.g., power users) then the oversubscription should be lowered or the underlying host CPU core count increased.

6.3 Four Host DVX VDI Block
The main focus of the empirical testing for this reference architecture is centered around the 4-host block of hosts supporting 500 desktop users. By examining this configuration in detail, and verifying the assumptions on scalability, we can use the results and observations for optimal configuration of the 500 user block of desktops and easily project into the 1,000 user configuration.

For testing purposes, we are not accounting for HA but measuring for the resources needed to support the desired workload. It should be noted that adding more hosts to support a proper N+1 production environment improves on the results obtained in this reference architecture.

Figure 36. 500 User Desktop Configuration
6.4 DVX VDI Pod - Single Data Node
The objective of this reference architecture was to show that a DVX System with a single Data Node could easily handle up to 1,000 knowledge worker desktop users. We empirically tested to the 500 user limit and benchmarked the system to the 1,000 level or beyond. For general sizing and design limits we feel the 1,000 user VDI Pod provides an operational and economical reference point for constructing solutions. The final solution using the Datrium DVX Compute Node would look like the figure below. Variations for N+1 availability are up to the individual organization requirements and budget.

![Figure 37. 1,000 User Desktop Configuration](image)

6.5 Scaling Beyond Single Data Node DVX System
The DVX System can currently scale to over 10 Data Nodes and 128 Compute Nodes. For VDI solutions constructed on the current hardware, the upper limit for a single system is 6,000 VM desktops. Using this reference architecture as a guide, such a configuration would have at least 4 DVX Data Nodes and over 50 (depending on host HA requirements) DVX Compute Nodes.

![Figure 38. 6,000 User Maximum Configuration](image)
6.6 Scaling Host Resources

Another level of testing performed was to vary the desktop use profile to better understand the host level resources. We found that the levels obtained were primarily CPU bound on the ESX host. In other words, if you had more intensive users you would need to increase the available CPU resources of the host – more / faster cores, or reduce the number of users for the particular host platform. To see this operational condition, we changed the workload run with Login VSI to capture 500 Task workers and then 500 Knowledge Workers and observed the impact in the CPU resources from the vCenter perspective. Although memory consumption remained relatively the same, the CPU consumption was significantly higher (10-15%) for the Knowledge Worker IO profile and reached our testing threshold limits.

![Figure 39. 500 User Knowledge Worker Utilization](image)

![Figure 40. 500 User Task Worker Utilization](image)

- ~7 IOPS/ user
- Reads are local
- Writes over network
- Reads < 1ms
- Writes < 2ms

![Figure 41. 500 Task User IO Results](image)
Conclusion

With Datrium DVX along with VMware Horizon, IT teams can rest assured that end-users will have access to their desktops and the applications and data they need to ensure business is not interrupted. This solution delivers the right mix of performance, manageability, scalability, and protection to meet the demanding needs of today’s modern data centers – simply.

Each host with Datrium can deliver plenty of IOPs with sub-millisecond latency to ensure your VDI end-user experience is at its best. With a DVX solution, flash is leveraged on the host and storage management and IO performance considerations are no longer an issue. Built-in VM-Centric administration and VM-level analytics will help you isolate and quickly identify application issues in a sea of virtual desktops and mixed workloads.

Consolidate hundreds or thousands of desktops quickly and simply by adding more hosts – Compute Nodes. Use the Datrium servers referenced in the report or your own servers of choice. Using server based flash, combined with always-on global deduplication and compression, and the desktop infrastructure costs less than many other competing solutions.

The Datrium architecture provides ultimate flexibility for flash placement closer to the desktop and applications and performance improvements where needed. Datrium’s DVX Open Convergence platform simplifies virtual desktop deployments and troubleshooting, handles boot and login storms as it scales from a few hundred desktops to thousands, all while maintaining compelling economics.
## Appendix

### 8.1 Reference Architecture Tested Configuration

The following table outlines the components used in the configuration and testing of this reference architecture.

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Quantity / Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>DVX Data Node</td>
<td>D12X4 – durable data component, Software version 2.0.2.0 or higher</td>
<td>1</td>
</tr>
<tr>
<td>DVX Compute Node – Desktops</td>
<td>CN2000 – 28 core – E5-2680 v4 @ 2.40GHz, 512GB RAM, 2x 960 GB SSD, 2x 10G SFP+ NIC</td>
<td>4</td>
</tr>
<tr>
<td>DVX 3rd Party Host – Infrastructure</td>
<td>HP DL380-G9 – 24 core – E5-2670 v3 @ 2.30GHz, 128GB RAM, 2x 1.6TB SSD, 2x 10G SFP+ NIC</td>
<td>2</td>
</tr>
<tr>
<td>Networking</td>
<td>Cisco Nexus 3000 C31128PQ – 10GE, NXOS version 7.0(3) I2(1), 96 ports</td>
<td>1 – NOTE: for production deployments, we recommend redundant switches with ISL</td>
</tr>
<tr>
<td>Hypervisor</td>
<td>VMware vSphere 6.0 U3, VCSA 6.5.0</td>
<td>6 hosts, 1 vCenter</td>
</tr>
<tr>
<td>Desktop Management</td>
<td>Horizon 7.1</td>
<td>1,000 user desktops</td>
</tr>
<tr>
<td>Desktop Software</td>
<td>Microsoft Windows 10, Microsoft Office 2013</td>
<td>MSDN and KMS licensing</td>
</tr>
<tr>
<td>Test Software</td>
<td>Login VSI 4.1.25</td>
<td>1,000 user level</td>
</tr>
</tbody>
</table>

### 8.2 PowerCLI Scripts

In running tests on hundreds of user's desktop VMs, sometimes it is easier to script a particular action such as a cold boot storm, restart operation or shutdown.

The following section includes a primitive script for performing such an action in the target vCenter environment. By changing the operation interval (sleep value) or the operation itself, it is possible to run a consistent task (e.g., power up) over the entire set of user desktop VMs.
8.3 About Login VSI
The company Login VSI, provides end-user performance insights for virtualized desktop and server based computing environments. Enterprise IT departments use its flagship product Login VSI (for scalability testing), and new addition Login PI (for availability testing), in the pre-production and production phases of their virtual desktop deployment, to help them build and safeguard a high performance, a high availability, and (as a result) an optimal end-user experience. With minimal configuration, Login VSI’s products work with VMware Horizon View, Citrix XenApp and XenDesktop, Microsoft Remote Desktop Services (Terminal Services), and any other Windows-based virtual desktop solution. For more information, or a free trial, please visit [www.loginvsi.com](http://www.loginvsi.com).

Login VSI accepts no responsibility regarding this publication in any way and cannot be held accountable for any damages following from, or related to, any information contained within this publication, or any conclusions that may be drawn from it.

8.4 About the Author
Mike McLaughlin is the Director, Technical Marketing at Datrium. Prior to Datrium Mike was the Sr. Manager of Technical Marketing at Nimble Storage (now part of HPE). Mike has been involved in VDI solutions for the past several years working with customer and partners like VMware and Login VSI in helping define, test and deploy desktop virtualization solutions.