VMware Horizon 6 with XtremIO 3.0 Design Considerations
Sizing, deploying, and analyzing VMware Horizon 6 with View desktop pools on the EMC XtremIO all-flash array

ABSTRACT
This paper describes the process and considerations involved in deploying a virtual desktop infrastructure (VDI) on the EMC XtremIO all-flash array when using the VMware Horizon 6 with View product suite.
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EXECUTIVE SUMMARY

This white paper explains the process and considerations involved in deploying a virtual desktop infrastructure (VDI) using the VMware® Horizon® 6 with View platform on the EMC® XtremIO™ all-flash array.

AUDIENCE

The target audience for this document includes storage and virtualization administrators, data center architects, field engineers, system integrators, and virtualization specialists who wish to implement VMware-based virtual desktops on XtremIO. These audiences can use this document to design, develop, build, and deploy this solution. A working knowledge of VMware vSphere®, VMware Horizon with View, as well as server, storage, network, and data center design is assumed but is not a prerequisite to read this document.

BUSINESS CASE

A number of factors contribute to the successful rollout of a VDI project. The primary goals of such a project are to provide end-users with a desktop experience which matches or exceeds that of having their own physical machines and to realize efficiencies in the costs of hosting and maintaining the required support infrastructure. While end-user experience tends be over-simplified in terms of performance alone, experienced administrators have long recognized that a successful storage solution must offer both consistent desired performance levels and a scalable, highly available, and easy-to-manage solution that ensures minimal or no disruption to established service levels. Delivering such positives for both the user and storage provider is impossible without reassessing the delivery mechanism. This paper will discuss and highlight the advantages of hosting large scale VDI deployments on the EMC XtremIO all-flash array.

The realized experience for both desktop end user and infrastructure manager is of course highly dependent on the methods utilized in delivery of the VDI solution. The most straight forward method of providing and managing VDI desktop pools—full clone deployment— has typically been challenging for storage administrators due to the requirement to maintain a full image for every provisioned desktop.

To combat the storage creep associated with large VDI deployments using full clone desktops, VMware introduced the concept of linked clones—virtual machines (VMs) linked to a read-only image of the parent VM OS with the addition of a disk that is used for user-unique data. This combination is typically much smaller in size when compared to the equivalent full clone VM. But with XtremIO always-on, in-line deduplication with no performance penalty, organizations can deploy full clones in place of the interim linked clone solution and still achieve the physical space savings that made the linked clone option desirable. Full clone usage with XtremIO offers the additional benefit of streamlining the VDI support infrastructure and required maintenance operations by removing the need to maintain a Horizon View Composer server instance or perform recompose operations—actions unique to maintaining a pool of VMware-based linked clone desktops.

This paper aims to demonstrate comparable performance between both linked clone and full clone deployments and to showcase that the reduced capacity requirements for full clone deployments when using XtremIO storage negate much of the accepted rationale associated with linked clone usage.

To achieve these goals, the paper reaffirms the current industry-wide thinking that enterprise-scale VDI deployments achieve maximum efficiency when hosted on best of breed all-flash arrays, explicitly EMC XtremIO. XtremIO is a scale-out all-flash array which transforms storage into a true enabler for VDI environments by providing industry-leading performance which can match peak IOPS requirements for mixed I/O environments and maintain sub-millisecond latencies to ensure SLAs are being met. XtremIO also offers the highest usable capacity (over 80 percent of raw) versus comparable storage arrays and provides storage efficiencies with always-on, in-line data deduplication and compression.

OBJECTIVES

The goal of this document is to showcase the benefits of deploying a large number of virtual desktops on XtremIO. These benefits include, but are not limited to: ease of setup, scalability, performance, and data storage efficiencies. Scalability, performance, and data reduction capabilities will be demonstrated through the setup of a VMware Horizon-based Windows 7 desktop VDI environment on a single XtremIO 10 TB X-Brick. 3,500 virtual desktops in full clone persistent desktop configurations will be deployed and an industry-standard load generator will simulate real user interaction and measure user experience for the VDI deployment.
In addition to the primary focus above, this paper will highlight expected sizing maximums for the various XtremIO configurations available and describe best practices in relation to configuration of the virtualized environment for use with XtremIO. The benefits of using XtremIO for VDI-based workloads will also be highlighted. These include always-on in-line data reduction through compression and deduplication and sub-millisecond latency for said workloads. This paper will show how XtremIO can dramatically improve both the end-user and administrative experience for VDI projects relative to all other options.

Figure 1.
Front profile of an EMC XtremIO X-Brick with fascia bezels

SOLUTION DESIGN PRINCIPLES
VDI deployments tend to require consistent performance at sub-millisecond I/O loads for the majority of their operational time. These deployments also have a complimentary requirement that the storage environment can absorb intermittent/periodic bursts of increased IOPS from the virtualized environment while maintaining expected performance levels. This can be due to the multiple housekeeping operations associated with managing large virtualized desktop deployments such as anti-virus scanning, desktop recompose operations, and boot or log-in storms where multiple machines are created and/or logged into in a short timeframe.

With these factors in mind, the majority of information presented in this paper will showcase the performance of multiple desktop pools of varying configuration and size during normal operation. In this paper, normal operation infers that all desktops are powered on with users logged in and there are no large-scale maintenance operations underway. During periods of normal operation, achieving maximum IOPS tends to be of secondary importance when compared to consistency of performance. Certifying that the storage can deliver consistently low latency for each of the hosted desktops will ensure the best possible experience for the end user and be a primary contributor to the success of any VDI project.

Beyond the end users’ desktop experience during normal operation, thought needs to be given to the various maintenance operations required to support the virtualized infrastructure. It is here that the virtualization and storage administrators’ user experience has to be considered. Preparing and maintaining large-scale virtual desktop infrastructures involves activities that are both storage and time intensive. During maintenance operations, if a VDI environment encounters a storage bottleneck where host-level IOPS demand outstrips the capability of the array, the time to complete those operations will grow to unwanted levels. As job completion times grow, VDI administrators become increasingly less agile in their ability to react to change in their environment and are forced into planning for increased downtime and/or settling for undesirable deploy times.

The solution(s) described in this paper will showcase the capability of XtremIO to satisfy both of these major requirements: consistently low latencies are maintained throughout and when required, increased IOPS activity is also handled without issue.

SUMMARY OF FINDINGS
For this paper, multiple virtualized desktop pool configurations were tested. Deployments consisted of native ful clone and linked clone configurations, as well as full clones using VMware AppVolumes™. The number of concurrent sessions tested ranged between 1,000 and 3,500 Windows 7 desktops, all on a single EMC XtremIO 10 TB X-Brick. Each configuration was subjected to the industry-standard performance analysis tool (LoginVSI version 4.1.2), which simulated users performing common computing tasks.
The benchmarking results displayed sub-millisecond latencies for the storage and a best-in-class user experience throughout. The realized scores indicate that the maximum desktop capacity of the storage was never reached and optimal performance was achieved for all 1,000 to 3,500 end users.

<table>
<thead>
<tr>
<th>LoginVSI scores</th>
<th>3,500 active, concurrent sessions</th>
<th>3,000 active, concurrent sessions</th>
<th>2,500 active, concurrent sessions</th>
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</thead>
<tbody>
<tr>
<td>Full Clone Desktops</td>
<td>VSI baseline: 657 ms</td>
<td>VSI max: not reached</td>
<td>VSI max: not reached</td>
</tr>
<tr>
<td></td>
<td>VSI average: 1042 ms</td>
<td>VSI average: 992 ms</td>
<td>VSI average: 877 ms</td>
</tr>
</tbody>
</table>

**Figure 2.**
Full clone desktop testing with LoginVSI results

EMC has issued guidance that 3,000 desktops be the generalized sizing limit for a single 10 TB X-Brick. This guideline is designed to be conservative in nature and is typically applied as 2,500 full clones or 3,500 linked clones per 10 TB X-Brick. Due to the number of variables involved in planning a VDI environment, neither of these recommended sizing limits will hold true for all cases. This paper proves this (in the positive) through successful deployment and testing of 3,500 full clone desktops on a single 10 TB X-Brick. For administrators planning a VDI project using XtremIO, this document includes a sizing guidelines section which details the considerations involved in determining the appropriate number of desktops.

Both full clone desktops and linked clone desktops were confirmed to offer an equally outstanding end-user experience—allowing VDI architects maximum flexibility in the design of their virtualized environments. To verify comparable performance across the different deployment options, LoginVSI tests were compared for both 1,000 linked and full clone desktops. The linked clone test mirrored the response times of those seen in the full clone test run when subjected to the same test conditions—showing that users can confidently use any combination of linked clone or full clone persistent desktops on XtremIO storage.
Incidental to the testing of actual desktop user experience is the ability to verify the storage array’s ability to handle general VDI maintenance tasks such as deploy times, linked clone recompose and refresh operations, and others. Verified performance is mentioned throughout the document for such operations, and guidelines are offered regarding best practices for VDI deployments that include endpoint anti-virus protection.

Throughout the testing, the single XtremIO 10 TB X-Brick was shown to deliver over 100,000 mixed (read and write) IOPS during VDI boot storm situations and more than 40 GB/s during large-scale desktop deployment operations via integration with VMware VAAI capabilities and the associated offload to the array of resulting data intensive operations.

**Figure 3.**
1,000 linked clone desktop testing results
This paper also shows XtremIO users how to deploy a similar environment and/or optimize their setup for use with the latest XtremIO version 3.0 releases. Finally, the paper contains supplemental material on the topics noted below.

- The performance gains of specifically configuring the alignment of XtremIO hosted VMs
- Detailed best practices concerning host setup, space reclamation, and storage monitoring
- VAAI XCOPY optimizations for increased storage efficiency
- A first look at VDI using VMware AppVolumes hosted on EMC XtremIO
INTRODUCTION

XTREMIO ALL-FLASH ARRAY

The XtremIO storage system is based on scale-out architecture—the system uses building blocks, called X-Bricks, which can be clustered together to grow performance and capacity as required. An X-Brick by itself is a high-availability, high-performance SAN storage appliance available in 5 TB, 10 TB, or 20 TB capacity configurations that can drive incredible database loads, handle thousands of virtual machines, and support thousands of virtual desktops.

The scale-out, global data reduction architecture of XtremIO is specifically optimized for flash and therefore allows for a number of multiplying affects across many aspects of the array which in turn lead to a number of key benefits. These benefits include extending the effective capacity of the array as well as minimizing the required writes to media—improving XtremIO hosted application performance and increasing the usable lifespan of the purchased flash (per host data written).

The XtremIO data reduction architecture comprises the following components.

- **Content-addressable data engine**: Enhances data reduction, balances data, augments efficiency, and increases performance.
- **Global scale-out metadata engine**: Delivers the industry’s best and most consistent performance experience across all array service for all applications.
- **Always-on in-line data services**: Provides data services which never stop working and never have to be disabled—including thin provisioning, data deduplication, compression, and space efficient writable snapshots.
- **XtremIO data protection**: Provides flash-specific data protection with no legacy from disk-based RAID, which is faster than RAID10, better than RAID6 protection, and requires less overhead than RAID5.
- **Agile Writable Snapshots**: Augments data reduction by enabling multiple writable copies of application datasets that consume zero physical data.

With XtremIO, the logical usable amount of storage available is substantially higher than the physical flash storage in place due to thin provisioning based on the array’s always-on, in-line data reduction technologies. When additional IOPS performance or capacity is required, XtremIO scales out linearly such that two X-Bricks supply twice the IOPS and four X-Bricks supply four times the IOPS. Latency remains consistently low as the system scales due to the powerful RDMA InfiniBand fabric within the system.

If required, the XtremIO all-flash array can scale out by design, and additional capacity and/or performance can be configured to meet virtually any VDI requirement. If multiple X-Bricks are used to form a cluster, XtremIO inherently maintains balance across all nodes, so all desktops benefit from the entire potential performance of the cluster at all times.
Figure 5.
Front profile of the various components comprising an EMC XtremIO X-Brick—from the top: battery backup unit (x2), storage controller 2, disk array enclosure (DAE) with 25x eMLC SSDs, storage controller 1

Each X-Brick is comprised of:
- One 2U disk array enclosure (DAE), containing:
  - 25 SED eMLC SSDs (400 GB or 800 GB SSD options)
  - Two redundant power supply units (PSUs)
  - Two redundant SAS interconnect modules
- One battery backup unit
- Two 1U storage controllers (redundant storage processors)

Each storage controller includes:
- Two redundant PSUs
- Two 8 GB/s Fibre Channel (FC) ports
- Two 10 GbE iSCSI ports
- Two 40 GB/s InfiniBand ports
- One 1 GB/s management/IPMI port

SOLUTION OVERVIEW
This EMC solution was developed using the XtremIO 10 TB X-Brick running the XtremIO operating system (XIOS) version 3.0.3, hosting components from the VMware Horizon with View 6.0 virtualization suite along with Microsoft server/desktop technologies (Microsoft Windows 2012 Server domain services, Microsoft SQL Server 2012 databases, Microsoft Windows 2008 servers, Microsoft Windows 7 desktops).

The necessary backend infrastructure components for such a deployment (Microsoft Domain and VMware vSphere/ Horizon with View components) were placed on two dedicated hosts. All components, excluding the XtremIO XMS and LoginVSI user data, were hosted on a single 10 TB X-Brick. For production VDI instances, EMC and XtremIO recommend that user data be stored on NFS data stores hosted on either EMC Isilon® scale-out storage or EMC VNX® unified storage platforms.
Best practices for each of the solution’s contributors (XtremIO, VMware, and Microsoft) were employed throughout and any deviation from said best practices is referenced later in the document along with associated reasoning.

CONFIGURATION OF VDI COMPONENTS

STORAGE

XtremIO 3.0

Based upon the test solution definition and the expected desktop hosting capabilities of the testing infrastructure, the capacity and performance envelope available for a single XtremIO 10 TB X-Brick was deemed sufficient. The XtremIO cluster is managed by XIOS. This solution will use version 3.0.3, the latest update to the 3.0 XIOS code family, which was originally released in December 2014.

XIOS is fundamental to the storage solution and performs the following functions to allow for delivery of the highest levels of performance without any requirement for administrator intervention:

• Ensures that all SSDs in the system are evenly loaded, providing both the highest possible performance as well as endurance that stands up to demanding workloads for the entire life of the array.

• Eliminates the need to perform the complex configuration steps found on traditional arrays. There is no need to set RAID levels, determine drive groupings, set stripe widths, set caching policies, or any other such configuration task. Deploying a LUN is as simple as: create, name, and map to host.

• Automatically and optimally configures every volume at all times. I/O performance on existing volumes and data sets automatically increases with large cluster sizes. Every volume is capable of receiving the full performance potential of the entire XtremIO cluster.

XtremIO provides full integration with VMware vSphere Storage APIs—Array Integration (VAAI) for tasks such as block zeroing, XCOPY, ATS, and unmap. This allows the system to provide array-based, enhanced host offloading of common VMware provisioning tasks. With VAAI integration, XtremIO can provide simplified management of massive data stores and instant cloning of VMs or vApps which can offer the desired data center agility for VDI projects comparable to that described in this document.

During the initial configuration, this XtremIO cluster underwent a successful non-disruptive upgrade (NDU) from the previously installed 3.0 codebase. If you have a cluster requiring upgrade to the latest release, please open a service ticket with your EMC representative—this non-disruptive upgrade action can be performed remotely and transparently.

Figure 6.
Information on the currently installed version can be obtained from the ‘About’ section in the XMS GUI.
Once fully deployed, the EMC XtremIO all-flash array does not require any further configuration prior to creating LUNs. For information on the steps involved in deploying an XtremIO cluster, please refer to the relevant instructional documents located on the EMC Support Web Portal, and referenced within the appendix.

**XtremIO Path Setup**

For each host connected to a single X-Brick, up to four paths per device may be configured. To ensure high availability, it is recommended that redundant switch configurations be used.

For this solution, the described best practices were followed. Refer to figure 7 which displays how to configure paths to your XtremIO array and also the appropriate XtremIO host configuration guide.

![Recommended path configuration for a single X-Brick](image)

**Figure 7.**
Recommended path configuration for a single X-Brick

Please note that for partially zoned configurations using multiple servers, you ensure the server’s I/O load is distributed equally across all the X-Bricks and storage controllers.
Storage Volumes Deployment

Creating volumes and mapping storage to connected clients is an easy, straight-forward process with XtremIO. It can be completed using the following three steps:

1. From the XtremIO ‘Configuration’ page, click ‘Add’ in the ‘Volumes’ column and create a volume of the required size.
2. From the XtremIO ‘Configuration’ page, click ‘Add’ in the ‘Initiator Groups’ column to create an initiator group and populate it with the clients that need access to the XtremIO array.
3. To associate the volume with an already configured host, you again begin at the ‘Configuration’ page and highlight the volume to be mapped. Next, highlight the desired ‘Initiator Group’ and then choose ‘Map All.’ Finally, click ‘Apply’ and the storage will be mapped.
   a. If you need to configure multiple volumes and/or hosts, it is possible to highlight multiple selections at once and then map all highlighted volumes and hosts in one simple action.
   b. If required, user-defined LUN IDs can be assigned prior to clicking ‘Apply.’ By default, XtremIO will assign the lowest available IDs for each volume being mapped.

System administrators have a complete suite of CLI tools available to them for automating the deployment and management of storage volumes on XtremIO. These commands can be used through SSH connection to the XMS server or alternatively via the ‘CLI Terminal’ which is found in the ‘Administration’ section of the XMS GUI. For details, please refer to the ‘CLI Guide’ section of the ‘XtremIO Storage Array User Guide.’
Please note the following scalability maximums when planning your XtremIO hosted deployment:

- Initiators per initiator group: 64
- Initiators per cluster: 512
- Volumes per cluster: 8,192
- Volume mappings per cluster: 16,384

**Space Reclamation**

To ensure the best possible end-user experience, it is highly recommended that anyone deploying a vSphere 5.1+ environment on XtremIO storage carefully plan for space reclamation on the physical data stores containing logically deleted data—space showing as allocated/in use after a VM has been deleted/removed.

XtremIO users have two options in this respect:

- Using the EMC XtremIO VSI plugin (since version 6.3), space reclamation is possible from within the VMware vCenter™ web client.
- To reclaim free space from a thin LUN manually, run the following commands from an SSH session:

  - `esxcli storage vmfs unmap --volume-label=volume_label / --volume-uuid=volume_uuid --reclaim-unit=number`
  - The command takes these options:
    - `-l|--volume-label=volume_label`
      - The label of the VMFS volume to UNMAP. This is a mandatory argument. If you specify this argument, do not use `-u|--volume-uuid=volume_uuid`.
    - `-u|--volume-uuid=volume_uuid`
      - The UUID of the VMFS volume to UNMAP. This is a mandatory argument. If you specify this argument, do not use `-l|--volume-label=volume_label`.
    - `-n|--reclaim-unit=number`
      - The number of VMFS blocks to UNMAP per iteration. This is an optional argument. If it is not specified, the command uses a default value of 200. EMC recommends that this value be set to 20000.

**SERVER CONFIGURATION AND PATH MANAGEMENT**

All servers used throughout this solution are verified to be VMware vSphere 5.5 compatible and configured as per the manufacturer’s communicated best practices. Each server was installed with the VMware vSphere ESXi 5.5 release (build: ESXi5.5.0-20140302001-standard).

For the rack server environment (see section: linked clone versus full clone performance analysis), each server contains a single dual ported Emulex 16 GB/s capable fiber channel host bus adapter (FC HBA), model: LPe16002-E. A supplemental install of the latest HBA firmware was required for this test setup due to non-native support for the Emulex HBA variety used. The typical symptom for running non-supported HBA firmware is experiencing intermittent path failure and occasional ESXi purple screen of death (PSOD). It is highly recommended that the VMware KB2086025 article be referenced.

Once the required HBA binaries are in place and active, associated queue depths should be altered to allow the optimal number of concurrent storage requests from vSphere. EMC recommends setting the HBA queue depth to ‘256.’ To do so, please follow the instructions listed in the XtremIO Host Configuration document or refer to VMware KB1267.

**VAAI**

The XtremIO array is fully integrated with vSphere through VAAI. A full description of VAAI functionality and configuration options is available at VMware article, KB1021976. This section will discuss confirming all the correct settings are in place as per XtremIO best practices.
To verify that VAAI is configured correctly, use the vSphere Client to navigate to the host, go to the ‘Configuration’ tab, and then choose ‘Advanced Settings’ under the ‘Software’ section.

- Select the ‘Data Mover’ section and check that the ‘DataMover.HardwareAcceleratedMove’ and the ‘DataMover.HardwareAcceleratedInit’ parameters are both set to “1”.

**Figure 9.**
XtremIO offers full integration with VMware VAAI. VAAI capabilities are shown here.

**Figure 10.**
vSphere Advanced Settings tab, where VAAI XCOPY can be confirmed to be active
Select the ‘VMFS3’ section and check that the ‘VMFS3.HardwareAcceleratedLocking’ parameter is set to “1.”

![Advanced Settings](image)

**Figure 11.** vSphere Advanced Settings tab, where the current Hardware Accelerated Locking setting for VMFS can be confirmed

If any of these parameters are set to “0”, set them to “1.”

To verify the VAAI specific settings directly on the host, check for a return value of “1” using the following commands:

- `esxcfg-advcfg -g /DataMover/HardwareAcceleratedMove`
- `esxcfg-advcfg -g /DataMover/HardwareAcceleratedInit`
- `esxcfg-advcfg -g /VMFS3/HardwareAcceleratedLocking`

Please note that if the ESXi host is also attached to non-XtremIO arrays that do not support VAAI, enabling VAAI may cause issues with those arrays.

**Host Multipathing Configuration**

XtremIO supports the native multipathing technology that is part of the VMware vSphere suite. To ensure optimal performance of the solution, it is recommended that the path selection policy be set to ‘Round Robin (VMware)’ for each of the XtremIO volumes presented to vSphere. This will ensure optimal distribution and availability of load among the I/O paths to XtremIO storage. Path selection policy can be configured using PowerCLI or through vSphere.

1. Using vSphere:
   a. From the ‘Configuration’ tab of each of the vSphere hosts, click ‘Devices,’ right click the XtremIO LUN, and then select ‘Manage Paths’
   b. In the ‘Managed Paths’ dialog box, change the ‘Path Selection’ drop down to ‘Round Robin (VMware)’ and then click change
   c. Repeat this process for each of the XtremIO LUNs
2. Using PowerCLI:
   a. Connect to the applicable vCenter using PowerCLI and run the following commands, identify the applicable naa.XXX UUID for your connected XtremIO storage volumes, and amend the code below as required
   b. Get-Datacenter $DC | Get-VMHost | Get-ScsiLun -CanonicalName "naa.XXX*" | Set-ScsiLun -MultipathPolicy "RoundRobin"
   c. $HOSTS = get-datacenter $DC | get-vmhost
      foreach ($ITEM in $HOSTS) {
         $ESXCLI = get-esxcli -VMhost $ITEM;
         $DEVICES = Get-Datacenter $DC |Get-VMhost $ITEM | Get-ScsiLun -CanonicalName "naa.XXX*";
         foreach ($ENTRY in $DEVICES){
            $ESXCLI.storage.nmp.psp.roundrobin.deviceconfig.set($null,$null,$ENTRY.CanonicalName,1,"iops",$null)
         }
      }

XtremIO also supports the use of EMC PowerPath®. PowerPath was not used with this solution, but if you require more information on XtremIO and PowerPath, please refer to the [EMC support portal](https://www.emc.com/support/).

**NETWORKING**

Networking requirements for the described solution are based on the primary requirement that the vSphere hosts and XtremIO storage exist on a subnet accessible to the wider corporate network. The requirement to have all infrastructure hardware accessible to the corporate network is due to a pre-existing hardware management layer which is used to monitor all nodes across multiple lab environments. This setup is consistent across organizations that rely on management and orchestration solutions to monitor their physical environments or converged-infrastructure solutions.

For the purposes of deploying a dynamic domain in relation to the dynamic host configuration protocol (DHCP), domain name system (DNS), and the Active Directory required to support the test environment, a non-routable private network (class-B using prescribed RFC-1918 address range) was implemented which would be confined to an isolated network switch and logically managed using a vSphere distributed switch implementation. This configuration required that some of the components be dual-homed (notably, the vCenter server) and introduced some extra complexity during deployment. However, with this configuration, all networking concerns were met and it was validated to work without issue.

Each ESXi vSphere host contains a minimum of four 1 GbE network interface cards (NICs), although 10 GbE is preferable. To satisfy required high availability demands, all NICs should be connected. However, only half of all available NICs per host should be considered active at any one time with no dynamic load balancing in place.

- Of the minimum two active physical NICs in use on an ESXi host, one NIC should be connected to the external corporate facing network and dedicated to both vmkernel/management traffic and VM network traffic for those VMs with access to corporate network.
- The second NIC is configured as a static uplink to an internal (to the described environment) only vSphere distributed switch. This second NIC connected to the distributed switch carried all traffic for the VMs on the internal VDI test domain.

The hosts used for the infrastructure components (two in relation to this solution) are installed with an additional two physical NICs due to the throughput requirements of servicing user data for the desktop pool under test. These additional NICs were used as uplinks to the vSphere distributed switch handling VDI traffic. Load balancing was employed for the three (existing one active NIC plus the additional two) active NICs and was set to be based on the physical NIC load.
**vSphere Networking**

As already mentioned, the logical management of the networking would be handled by deploying a vSphere distributed switch (dvSwitch), version 5.5. The process followed is as listed in [VMware best practices](#) with static uplinks numbering three, and a single distributed port group (dvPortGroup) created which used ephemeral binding. The dvSwitch was designed to carry VM traffic only—no management or VMware vMotion®.
The expected throughput maximums per pool VM while running LoginVSI Knowledge Worker workload is approximately 400 KB/s based on scoped maximums. This means capacity of 50 MB/s per desktop pool host and 400 MB/s per infrastructure host is required for the test load alone (not including additional network traffic for Microsoft Active Directory and Horizon with View; ESXi management traffic is segregated).

**VDI OVERVIEW**

**INFRASTRUCTURE COMPONENTS**

The tested configuration included the virtualized components shown in Figure 14 below. These components provided the logical infrastructure required to create, maintain, and monitor the desktop pools used throughout the testing process. The steps involved in deploying and constructing the various relationships for each of the components are listed later in this document.
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<th><strong>Configuration</strong></th>
<th><strong>Components</strong></th>
<th><strong>Use</strong></th>
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</thead>
<tbody>
<tr>
<td>Domain Controller (x2)</td>
<td>MS Windows Server 2012 R1 8 vCPU 16GB RAM 100GB Storage</td>
<td>Active Directory DS DNS / DHCP LoginVSI 4.1.2 Management LoginVSI Default Share</td>
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<td>vCenter</td>
<td>MS Windows Server 2012 8 vCPU 16GB RAM 105GB Storage</td>
<td>vSphere vCenter 5.5 vSphere Composer MS SQL Server 2012</td>
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<td>Connection (x2)</td>
<td>MS Windows Server 2012 4 vCPU 12GB RAM 40GB Storage</td>
<td>Horizon 6.0 View Connection MS LDS</td>
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<tr>
<td>Launchers</td>
<td>MS Windows 7 2 vCPU 4GB RAM 36GB Storage</td>
<td>LoginVSI launcher machines</td>
</tr>
<tr>
<td>NTP</td>
<td>MS Windows Server 2008 R2 2 vCPU 4GB RAM 60GB Storage</td>
<td>NTP Server NTP Client</td>
</tr>
</tbody>
</table>

**Figure 14.** Components of the tested VDI infrastructure

Along with the listed virtual machines, a number of virtual appliances and plug-ins were added to the solution. These are listed below along with their associated functions.

- **vRealize™ Operations Manager™ (vROps):** vROps is VMware’s latest virtualized environment monitoring tool which replaces the previous vCenter Operations Manager (vCOps) tool. For the purposes of this solution, vROps was used solely to monitor the extended vSphere environment.
- **EMC Storage Analytics appliance**: EMC Storage Analytics integrates with VMware vROps and allows for storage-specific metrics to be presented via the vROps dashboard. For the described solution, this functionality was used to assess capacity and performance of the attached XtremIO all-flash array hosting the vSphere data stores.

- **EMC Virtual Storage Integrator (VSI) plug-in**: The VSI plug-in integrates EMC-specific storage management tasks directly into vSphere. The plug-in was included in the solution to provide extra capabilities to the vSphere management console.

**VMware vSphere**

The primary VMware vSphere components used in this solution include:

- **VMware vSphere ESXi 5.5**: A bare-metal hypervisor that installs directly on top of the physical server and allows for the sharing of physical resources across multiple virtual machines.

- **VMware vCenter Server**: This is the central management point for vSphere and provides monitoring and management capabilities for the clusters, hosts, virtual machines, storage, and networking which comprise the virtualized infrastructure.

All hosts were installed with the latest release of VMware vSphere version 5.5 and configured as described in the ‘Host Setup’ section.

**VMware Horizon Suite**

The VMware Horizon 6.0 product suite is the follow-up release to VMware View. The suite of products is built around the function of delivering virtualized desktops and applications through a single platform. VMware Horizon with View is fully integrated with VMware vSphere and allows users to:

- Deliver desktops and applications through a single platform
- Provide a consistent end user experience across devices, locations, media, and connections
- Dynamically allocate resources with virtual storage, compute, and networking to simplify and cost effectively manage and deliver desktop services on demand
- Extend business continuity and disaster recovery features to their desktops

The solution described in this paper utilized the following Horizon View components:

- **View Connection Server**
  - Provides management functionality for the provisioning, deployment, and management of virtual desktops, and acts as a broker for client connections—authenticating and directing incoming user desktop requests. Allows the VDI administrator to centrally manage thousands of desktops from a single console.
  - A single pool hosted on a View Connection Server can support up to 2,000 simultaneous connections—the limit of this solution’s scope.
  - It is recommended that View Connection servers are deployed with a backup ‘Replica’ server. Two separate VMs are deployed for each of the View Connection servers required for this solution; one to host the primary and the other for the replica Connection Server instance.

- **View Composer Server**
  - This is an optional feature that caters for the management of linked clone desktops only.
  - For this solution, the Composer service will reside on the same Windows server VM hosting the VMware vCenter server instance.

- **View Agent**
  - This agent is installed on the guest OS of all VMs which require communication to be maintained with the View Connection server(s). The View Agent is used to monitor the health of provisioned VMs and current connections.
• Horizon Client
  - The client is installed on end-point devices that require connections to Horizon View-hosted VMs from another device. This solution utilized Horizon clients on the LoginVSI launcher machines.

**VMware vRealize Suite**

vRealize Operations Manager (vROps) 6.0 is the latest release of the integrated operations suite, converging performance, capacity, and configuration management. This product is the successor to VMware vCenter Operations Manager (vCOps) and is part of the larger VMware vRealize suite. It is used as an add-on for an existing virtualized environment, which could be based upon Microsoft Hyper-V, Amazon Web Services, or in the case of this solution, VMware vSphere.

For the purposes of this solution, VMware vRealize is used as a monitoring tool only and will deliver data visualization functionality for realtime performance metrics and resource consumption across the various physical and virtualized components. Realtime information pertaining to the performance of XtremIO will be assimilated into the metrics delivered through vRealize Operations Manager by means of integrating the latest EMC Storage Analytics plug-in.

vRealize LogInsight is also deployed within this solution. The product is used to monitor system logs of the various components of the infrastructure in real time and provide debugging capabilities as required.

**Figure 15.**
An architectural overview of the complete VMware vSphere and complimentary Horizon 6.0 suites—note that not all VMware listed components were used or required to deliver the solution contained in this paper.
EMC XtremIO Plug-ins

EMC Storage Analytics is an EMC-specific management solution that integrates with VMware vRealize Operations (vROps) manager and allows VMware and storage administrators to access realtime analytics for their connected EMC storage—in this case, the XtremIO all-flash array.

After integration with EMC Storage Analytics, the vRealize Operations Manager is updated with XtremIO statistics which detail cluster health, performance, and capacity metrics. Additional capabilities include the ability to get historical usage patterns for XtremIO hosted data stores, and the capability to fully customize the display as desired.

Additional information on the EMC Storage Analytics offering can be found on the XtremIO web portal.

Figure 16.
EMC Storage Analytics architecture

Figure 17.
XtremIO metrics are fully integrated with vRealize Operations Manager reporting capabilities

EMC Virtual Storage Integrator (VSI) is a plug-in for VMware vSphere. The VSI plug-in integrates functionality specific to the management and monitoring of EMC storage into the VMware vSphere web management GUI. This can prove beneficial to system administrators because it streamlines the overhead of having to manage multiple components through unique interfaces, and allows for one-click execution on many best practice functions.
Using the XtremIO specific module for EMC VSI allows the end-user to control the following functions from with their vSphere management console:

- Set host parameters related to XtremIO best practices
  - Round robin
  - HBA queue depth
  - I/O scheduling
- Reclaim unused thin provisioned space (UNMAP)
- Integrate with VMware Horizon with View
- Extend and provision data stores

It should be noted that employing the recommended XtremIO configuration for SAN connectivity is fundamental to achieving optimal performance for your storage. The VSI plug-in can take care of enforcing these settings with just a single user action, as opposed to having to run multiple CLI-based actions on each of the managed hosts.
Microsoft Products

Multiple Microsoft products and domain enabling features were employed throughout this solution. Microsoft OS variants deployed included Microsoft Server 2012 R2 Standard and Data Center, Microsoft Server 2008 R2 Standard, and Microsoft Windows 7 64-bit desktops.

The domain deployed to support the VDI infrastructure and solution validation included the following Microsoft Server 2012 features:

- **Active Directory (AD):** Services to manage the identities and relationships that constitute the Windows environment for the virtual desktops
- **Domain Name System (DNS):** A component of the Windows networking infrastructure used for address resolution
- **Dynamic Host Configuration Protocol (DHCP):** Centrally manages the IP address schema for the virtual desktops in the domain
- **Network Time Protocol (NTP):** Ensures that all client’s clocks are synchronized
- **Group Policy Object (GPO):** A centralized means of enforcing user settings for virtual desktops within the domain
- **Server Message Block (SMB):** A network file sharing protocol used by Microsoft

Microsoft SQL Server 2012 R2 was used to support the database requirements of a number of functional components, including: VMware vSphere vCenter Server, VMware Horizon View Composer, and VMware AppVolumes.

**STORAGE SIZING AND DATA REDUCTION RATIOS**

When deploying and using storage on the XtremIO array, two factors need to be considered to determine required capacity for the VDI solution—the logically provisioned space which the desktop pools will require and the physical capacity which the array will actually utilize in hosting the volumes.

A number of key points concerning the terminology used in capacity considerations relative to the XtremIO all-flash array need to be covered before continuing this discussion. The fact that XtremIO storage is inherently thin provisioned at the array and presented as thick to the host has already been described. This coupled with the always-on in-line data reduction techniques employed by XIOS lead to the need to define meaning and terms in relation to the capacity presented to the host, the capacity consumed on the storage media, and the capacity consumed by the host.

First, the capacity presented to the host is referred to as the ‘logically provisioned’ capacity and represents the storage volume size presented to the host. On the XMS dashboard, this can be seen as total ‘Volume Capacity.’ Relative to this solution, this is the vSphere data store size. Second, the capacity consumed on the storage media is referred to as ‘raw capacity’ consumption or in terms of physical writes to flash media. This can be seen in the XMS GUI as ‘Used Physical Capacity.’ The XMS GUI uses TB (10009 Bytes) instead of the more appropriate TiB (10249 Bytes)—misunderstanding this point can lead to approximately 10 percent of the available physical storage capacity being omitted from sizing calculations.

Last, the logical capacity consumed by the host metric will not always mirror the data store usage as shown via vSphere or ESXi metrics due to the ability of XtremIO to handle zero-block writes in memory. Without writes to the array of null data, this metric would simply be a representation of host-side consumed capacity with array-side data reduction ratios incorporated. Please refer to figure 20 below for an example of the capacity reporting dashboard available on the XMS GUI splash screen.
The expected capacity of logical provisioning is the primary guideline for sizing maximums and is the first consideration in determining the number of desktops supported per X-Brick. This is limited to 110 to 130 TiB per 10 TB X-Brick.

The volume of unique physical data contained within the logically provisioned space will vary dynamically due to environmental data patterns and associated realized compression and deduplication ratios—this determines the amount of raw capacity required.

- XtremIO offers 82 percent of the raw capacity of the array as usable storage capacity, meaning that there are 8.2 TB or 7.58 TiB of physical capacity made available

It is impossible to cover all the different virtual desktop configuration types and associated sizing considerations for determination of a single maximum limit on the number of VMs possible per X-Brick. EMC and XtremIO recommend that the following guidelines be used in the planning of your VDI infrastructure when hosted on the XtremIO all-flash array. Please note that the following guidelines are based on generalized numbers and as such, the adage of ‘your mileage may vary’ will always apply. We recommend that your local EMC XtremIO specialist be consulted to assist in the sizing exercise.

**VDI SIZING GUIDELINES FOR XTREMIO**
Based on the information recorded during the testing process of XtremIO 3.0 and the various virtualized desktop configurations employed during the course of this solution—along with extensive research across multiple in-house and customer sites—EMC wishes to make recommendations regarding sizing guidelines for the advised number of VMware desktops to be hosted per 10 TB X-Brick.
As with all recommendations of a generalized nature, it must be noted that your individual experience can (and most likely will) be unique. When planning your VDI deployment on XtremIO, you should look to use the logic contained within the following sections of this solution to determine suitable guidelines, rather than rely on a single all-encompassing number.

EMC and XtremIO-issued guidance is that 3,000 desktops be the generalized sizing limit for a single 10 TB X-Brick. This guideline is designed to be conservative in nature and can be applied to both linked clone and full clone desktops of standard configuration. Typical customer deployments tend towards 2,500 full clones or 3,500 linked clones per X-Brick.

The logical limits for a single 10 TB X-Brick exceed 110 TiB and using the capacity calculations described within this document, the infrastructure planner can confirm upper limits based on logical capacity alone. This logical capacity threshold typically exceeds the recommended guidelines for all but the largest of desktop images.

The guideline of 3,000 desktops per 10 TB X-Brick is due to a number of factors, but of primary importance is the amount of unique, uncompressible data per VM, which we estimate to be approximately two GB based on the typical allocated memory per desktop. As a 10 TB X-Brick offers 7.58 TiB of physical capacity, offering guidelines based on approximately 80 percent capacity utilization is designed with data center storage management best practices in mind. This requirement will of course vary and can be tuned further based on the amount of allocated memory per VM and the percentage of that memory reserved (refer to information contained in the solution sizing section). If a smaller virtual machine swap file (VSWP) per VM is required, then an increase in the desktop limit per X-Brick may be permissible, and vice versa for increases in the non-reserved memory per VM.

For best end-user experience, it is advised that the mixed IOPS capabilities of the XtremIO storage solution be taken into account—setting a limit of 3,000 desktops per X-Brick allows each user to exceed the VMware prescribed Power User workload requirements and still leave the throughput capacity required for typical maintenance operations.

### DEFINING DESKTOP EXPECTATIONS

To begin the sizing exercise, certain generalizations are required upon which to base the calculations. First, using the various user classifications described by VMware best practices, forecast how many of each user type is appropriate for the deployment and calculate the expected storage throughput requirements to support the desktop pool during normal operation, with the upper IOPS requirement per user number being used in any calculations.

<table>
<thead>
<tr>
<th>User Classification</th>
<th>Simultaneous Applications in Use</th>
<th>Virtual Machine Configuration</th>
<th>IOPS requirements per user</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task User (Light)</td>
<td>Limited 1-5 Apps light use</td>
<td>1vCPU 1GB RAM</td>
<td>3-7</td>
</tr>
<tr>
<td>Knowledge Worker (Medium)</td>
<td>Standard Productivity 1-5 Apps Regular Use</td>
<td>1vCPU 1GBRAM</td>
<td>8-16</td>
</tr>
<tr>
<td>Power User (Standard)</td>
<td>Compute Intensive &gt;5 Apps Regular Use</td>
<td>1vCPU 2GB RAM</td>
<td>17-25</td>
</tr>
<tr>
<td>Power User (Heavy)</td>
<td>Compute Intensive &gt;5 Apps Intense Use</td>
<td>2vCPU &gt;3GB RAM</td>
<td>25+</td>
</tr>
</tbody>
</table>

**Figure 21.**

VMware user type classifications and associated resource requirements
FULL CLONE VERSUS LINKED CLONE

Next, decide which type of VM clone is appropriate. There are two options that will be discussed here: VMware Horizon with View full clone and linked clone desktops. For each type of desktop pool, you can then have users assigned a preset desktop or any available desktop from the pool (dedicated and floating assignment, respectively). The choice of desktop type you deploy will be dependent on the requirements of the IT environment in question and should be determined using the generally available VMware Horizon with View planning documentation.

For dedicated desktop pools, the typical approach is to use full clone virtual machines. In a desktop pool of full clones, the clones are identical in size to the parent image and the logical capacity required to host a set number of full clone desktops becomes a straightforward calculation. Per full clone, logical capacity required will amount to the sum of the master image size, VSWP size, and associated overhead swap file per full clone.

- VSWP storage requirements will amount to the non-reserved vRAM per VM.
- The overhead swap file relates to space reserved for the VMX process handling the VM on the host, virtual machine frame buffer, and virtualization data structures. These files typically range between 64 MB and 256 MB and are dependent on the VM configuration (vCPU, memory, OS type).

![Figure 22. Components contributing to the capacity requirements of a VMware full clone virtualized desktop](image)

Calculating the logical storage requirement for linked clone VMs is somewhat more complex than the full clone scenario. When a linked clone desktop pool is created, a replica VM (parent) is first provisioned, and then the required numbers of desktops are created as child VMs of the replica VM. These linked clone desktops read from the replica disk and write changes to a delta disk. Unlike full clones, the logical storage requirements of linked clones will grow dynamically over time based on usage and as such, planning must be made with the upper limit of expected storage per linked clone (as opposed to the numbers seen in initial deployment which will represent absolute minimums).

For linked clones, the storage allocated per desktop will be based upon the total size of the linked clone (assume 50 percent of replica size), the expected growth per VM (assume 20 percent of linked clone with good housekeeping), and the associated VSWP and overhead swap files, as already discussed in the full clone scenario. The replica size, equal to the master image size, is taken into account on a per-LUN basis.

![Figure 23. Components contributing to the capacity requirements of a VMware linked clone virtualized desktop](image)
Account for additional storage if Windows roaming profiles or VMware Persona management are included in the solution, where the profile information is set to be stored on the same storage as the desktop pool(s).

The above sizing information can be used in determining the logically provisioned storage requirements only. Because these sizing considerations are for deploying the desktop pool on a storage architecture that was expressly architected for the unique capabilities and behaviors of flash storage, additional considerations and benefits should be understood and incorporated into any planning.

**VDI ON EMC XTREMIO**

The XtremIO all-flash array is inherently thin-provisioned. To the attached host, storage appears to be virtually thick, but exists as physically thin on the array. This is due to a number of innovative and industry-leading data storage techniques available as standard for all XtremIO users:

- Duplicate objects never translate into physical data writes, and are replaced with in-memory metadata pointers within the XtremIO scale-out metadata fabric, meaning physical capacity is not consumed with duplicate data.
- Data compression is applied in-line and in real time against all data blocks, resulting in a highly optimal flash footprint.
- XtremIO arrays do not actually need to store any zero blocks. Writing or reading of zero blocks is an in-memory only operation and does not impact the logical or physical capacity consumption.

XtremIO enables end users to get more for less—logical storage requirements necessitate a much reduced physical footprint and the flash media which acts as storage is used efficiently and without the need for post-process compression or deduplication activities, ensuring consistent performance levels and a longer life for your investment.

As the physical storage consumption required can vary dynamically due to the unique nature of a deployed VDI solution, give special consideration to deduplication and compression ratios and how these may impact sizing calculations. Based on extensive in-house testing, XtremIO offers guidelines using conservative estimates for data reduction, shown in the table below.

- Calculate the overall data reduction factor of the stored data by multiplying your deduplication and compression ratio
- The stored data will not include zero blocks, so the volume of zero blocks within the data set will not count towards either the logical or the physical capacity used, and will not be reported by XtremIO

<table>
<thead>
<tr>
<th>Clone Type</th>
<th>Deduplication</th>
<th>Compression</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full</td>
<td>5 – 15</td>
<td>1.4 – 2.2</td>
</tr>
<tr>
<td>Linked</td>
<td>2.5 – 4</td>
<td>1.3 – 2.2</td>
</tr>
</tbody>
</table>

**Figure 24.**  
Guidelines on the typical data reduction ratios enjoyed by VDIs hosted on XtremIO

The guideline data reduction ratios quoted vary depending on the environment in question. As such, it is recommended that where possible, existing data stores representative of the desired hosting profile be examined using the MiTrend tool to determine expected data reduction ratios. By using these derived data reduction ratios specific to the actual environment, you will yield a more accurate sizing calculation and a more a successful VDI deployment when using XtremIO storage.

If you do not have the opportunity to run a MiTrend analysis of your data stores, it is recommended that the data reduction ratios used in storage sizing calculations be conservative. For full clones, use deduplication of 10:1 and compression of 1.4:1. For linked clones, it is best to plan using a deduplication ratio of 2.5:1 and compression ratio of 1.4:1.
**SOLUTION SIZING**

Based on the guidelines covered above, this section describes example sizing calculations for 1,000 seat deployments, both full clone and linked clone. These calculations are based upon using the master image VM detailed within this paper (32 GB OS, 2 GB RAM—all reserved, 2vCPU) and can be used as building blocks for planning larger scale VDI instances.

For the linked clone testing, it is assumed that the (post-deployment) growth for the linked clone images between desktop pool deployments and refresh operations would at most represent no more than 15 percent. For an internal test environment, the expectation was for the growth to be much lower in reality. Based on these numbers, the following capacities have been decided upon for the upper limits of what may be required during linked clone and full clone testing of 1,000 desktops.

**Figure 25.**
Sizing calculation for the linked clone environment to be hosted on XtremIO all-flash storage

- **Linked clone calculations:**
  - Replica disk (32 GB), 15 percent growth for linked clone (5 GB), VSWP (0 GB), memory overhead swap (256 MB)
  - \(\text{Number of desktops} \times (\text{growth file} + \text{VSWP} + \text{memory overhead}) + \text{number of LUNs} \times \text{replica} = 5288 \text{ GB}\)
  - Using the minimum expected data reduction ratios (dedupe@2.5, compress@1.4 for a total: 3.5), the expected physical storage required should not exceed: 1.5 TB (5.288 TB / 3.5)

- **Full clone calculations:**
  - VM size (32 GB), VSWP (0 GB), memory overhead swap (256 MB)
  - \(\text{Number of desktops} \times (\text{VM size} + \text{VSWP} + \text{memory overhead}) = 32.256 \text{ TB}\)
  - Using the minimum expected data reduction ratios (dedupe@10, compress@1.5 for a total: 15), the expected physical storage required should not exceed: 2.15 TB
The described calculations are based on reserving all VM memory in advance to reduce the associated VSWP file size to zero. Doing so, where possible, based on available host memory resources, is advised. This has the benefit of reducing logical storage sizing requirements, which without reservation, would account for an extra 2 TB per 1,000 desktops in this solution.

It is also worth noting that the above calculations do incorporate the null space of the base image VM. As discussed, this non-used space, which is essentially zeroed blocks in relation to any I/O access (when using thick provisioned eager zero format) will not be referenced in the capacity numbers reported by XtremIO. The capacity sizing already described is related to the size of LUN required to be provisioned in order to satisfy vSphere provisioning—the amount of logical storage consumed on the array will be less and relative to consumed space of the image VM.

Multiple LUNs can (and should) be used. It should be noted that VMware recommends that no more than 140 linked clone desktops be hosted on a single VAAI-enabled VMFS data store. This is a VMware-communicated best practice and as such, placing a greater number of linked clones on a single data store may invalidate your VMware support contract. Please check with your local VMware representative and seek confirmation of continued support should you wish to deploy more than 140 linked clones per VAAI data store.

XtremIO is based upon the premise of only storing unique data to flash, so there will only ever be a single physical copy of the replica image stored on disk. Based on this knowledge, internal testing yielded comparable and acceptable results regardless of the number of linked clones placed on a single XtremIO data store. This does not mean all environments will behave in the same manner, but XtremIO testing has (so far) shown no issues in breaking this limit.

In terms of performance sizing, the number of desktops and types of users which will be using the environment are of interest. As already discussed, this solution examines desktop configurations numbering between 1,000 and 3,500. It is not expected that this number of desktops will come close to pushing the upper boundaries of throughput possible from an XtremIO X-Brick during the course of normal testing without adding some type of synthetic load generation to the mix.

For instance, based on the VMware Power User profile and a requirement of 25 IOPS per desktop, 3,000 concurrent sessions of this nature is not expected to exceed 75 percent of the performance capacity of a single X-Brick when dealing with mixed read/write I/O. In relation to boot storms, the expectation of an average 150 IOPS per desktop (mainly read), when applied to the quoted example of 3,000 virtual desktops, requires performance capacity for approximately 450,000 IOPS. This is beyond the capability of a single X-Brick. Administrators building a VDI environment comparable to that described in this paper should take note and ensure that maintenance operations of this nature are run in adequately sized batches, where the aim is to avoid exceeding available storage resources which will in turn lead to undesirable latencies.
This paper suggests that VDI maintenance tasks be limited to 1,000 simultaneous operations. This recommendation is made purely on the basis that oversubscription of array resources will lead to undesired performance, as is the case for any and all storage utilization considerations. Administrators deploying their VDI environments on XtremIO all-flash storage should note performance requirements for the various maintenance-related tasks specific to their environments and plan such operations relative to the resource availability of all components in their VDI stacks.

During the course of testing this solution, compression for full clone desktops exceeded 1.6 and the recorded deduplication across the array (after long-term run time) settled at 25, resulting in a data reduction factor of more than 40 times the used storage from a host perspective. To put this in perspective, for every 40 TB of data to be used on the host allocated LUNs, only 1 TB of raw flash capacity is in use. Prior to actual usage of the full clone desktops, you may see deduplication ratios that are near 100:1, but these should be understood in the context of all deployed desktops essentially being the same and not yet fulfilling any function.

**TESTING TOOLS**

The primary test vehicle during the course of the testing was LoginVSI 4.1.2 (the latest as of January 2015). LoginVSI is both vendor-agnostic and recognized as the industry-standard testing solution for virtualized environments, where it is used to load test and plan capacity for Windows-based virtual desktop deployments. As the determination of end-user experience for the described solution is of primary importance, LoginVSI’s method of testing the environment with virtualized users which simulate realistic user behavior was deemed to be the best fit for the delivery of reliable, relevant, and acceptable performance data.

Using LoginVSI Analyzer, the in-built tool for analyzing test data and outputting performance metrics, a number of key factors and considerations are taken into account. These include:

- Maximum capacity of the solution (VSImax)
  - LoginVSI offers a ‘VSImax’ score at the end of a successful test run. Testing with XtremIO, this number is typically the baseline response time plus one second and provides an envelope of acceptable response times relative to the end-user experience for the desktops under test. Exceeding the VSImax threshold will indicate the environment has been saturated and is operating beyond acceptable utilization levels.
  - A more accurate representation of end-user experience is the VSImax Average value. This is an average of VSImax index scores for the sessions undergoing LoginVSI tests during a defined sample window. Using this value as your guideline, you can define the likely end-user experience of the hosted desktop sessions for your VDI environment.
  - The VSImax scores are a composite index and based upon the LoginVSI specific measurements at the guest OS level. These are catalogued and described in Figure 27 (below).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>NSLD</td>
<td>Notepad starts and loads a 1500kb document</td>
<td>Notepad starts and loads a random local 1500kb document file that is copied from the content pool</td>
<td>CPU and IO</td>
</tr>
<tr>
<td>NFO</td>
<td>Measure how long it takes to show the file-open dialog in VSI notepad</td>
<td>VSI-Notepad file open [ctrl+o]</td>
<td>CPU, RAM, and IO</td>
</tr>
<tr>
<td>ZHC*</td>
<td>Create a zip file with high compression</td>
<td>Compress a local random .pst file that is copied from the content pool (5mb)</td>
<td>CPU and IO</td>
</tr>
<tr>
<td>ZLC*</td>
<td>Create a zip file with low compression</td>
<td>Compress a local random .pst file that is copied from the content pool (5mb)</td>
<td>IO</td>
</tr>
<tr>
<td>CPU</td>
<td>Calculates a large array of random data</td>
<td>Creates a large array of random data that will be used in the IO timer</td>
<td>CPU</td>
</tr>
</tbody>
</table>

**Figure 27.**
LoginVSI metrics relating to performance and used in the calculation of the VSImax score
*compression measured using 7zip*
• **VSI**max baseline response time (VSIbase)
  o VSIbase is a key metric for defining the performance capabilities of the environment, but can be non-representative of the overall end-user experience. This metric shows the averaged minimum VSI index value for a defined sample period. It can be used as a gauge of top speed, but not as an indicator of the overall performance of the solution under test. This number gives an indication of the speed of the presented desktops and how responsive they are to the load generated by the LoginVSI session users.

• **Customized workloads**
  o LoginVSI provides the ability to simulate multiple types of users, each varying in the intensity of activity required from their allocated desktops. These workloads synchronize with current VMware user-type definitions. Through simulation of high-intensity and medium-intensity users and the analysis of resulting performance data, guidance can be made available for improved capacity planning of your VDI deployment.

![LoginVSI's interpretation of VMware VDI user categories and the typical associated workloads](image)

*The Office Worker definition has no comparable precursor as with the Task/Office/Power categories.*

LoginVSI offers a selection of workloads which closely match the VMware definition of the typical types of end users for virtual desktop infrastructures. See figure 28. For VDI architecture planning, VMware categorizes end users into the following categories:

- **Task Workers**
  Task workers and administrative workers perform repetitive tasks within a small set of applications, usually at a stationary computer. The applications are usually not as CPU and memory-intensive as the applications used by knowledge workers.

- **Knowledge Workers**
  Knowledge workers' daily tasks include accessing the Internet, using email, and creating complex documents, presentations, and spreadsheets. Knowledge workers include accountants, sales managers, marketing research analysts, and others.

- **Power Users**
  Power users include application developers and people who use graphics-intensive applications.
Figure 29. Expected resource usage for the LoginVSI workload categories along with recommended vCPU and memory configurations. Listed percentages are relative to Knowledge Worker profile.

Detailed breakouts of the LoginVSI workloads are available using this link.

To monitor the performance, LoginVSI analyzer was used to generate end-of-run scores. During testing, we could monitor instantaneous performance and capacity metrics using the XtremIO GUI and the vRealize Operations Manager dashboard with EMC XtremIO plug-ins. Additional information can be discovered via XMSCLI functionality or alternatively using XtremIO fully integrated RestAPI capabilities.

**TESTING, RESULTS, AND SUMMARY**

The test methodology employed during the course of this solution is focused on the delivery of a number of key pieces of information: validation of the described architecture, understanding the sizing requirements for various VM clone configurations, and assessment of the end-user experience for virtual desktops hosted on XtremIO all-flash storage. Additional consideration is given to the performance of the desktop pool VMs in relation to deployment times, boot storms, and VMware Horizon with View clone types.

Validating the architecture described in this solution is confirmed through successful integration of the multiple components used and via performance that meets and even exceeds expectations. Calculations for guidelines on the sizing of VM pools to be hosted on XtremIO is a construct of the collected capacity-related information for the various test sequences and is described in detail later in this document. The performance analysis undertaken is fundamental to the solution and the various test sequences and resulting metrics are described in the following sections. These tests are performed on both linked clones and full clones to verify XtremIO claims on equal performance for either clone type.

**FULL CLONE DESKTOPS—LARGE SCALE VALIDATION**

The validation of the sizing guidelines shared in this paper was of primary importance to the testing schema employed. A test environment capable of hosting the generalized limit of 2,500 full clone desktops was sourced and prepared. This environment was based upon the use of forty Cisco UCS B200 blade servers and provided greater scalability than was required to manage the desired number of hosted desktops, 2,500 full clones. To provide further proof of the sizing limits and information on sizing guidelines contained within this paper, further testing with both 3,000 and 3,500 full clone desktops was carried out. LoginVSI test results detailing the performance of 2,500 to 3,500 full clone desktops hosted on a single 10 TB X-Brick are contained in the following section.
A basic overview of the large-scale test environment is shown in the diagram below. All supporting applications, software versions, and desktop configuration remained consistent with descriptions already supplied throughout the course of this paper. The only change between this test-bed and the rack-based Lenovo test environment were the host servers used.

![Diagram of components involved in the >2,500 desktop tests which were used to validate XtremIO VDI sizing guidelines](image)

**Figure 30.** Overview of the components involved in the >2,500 desktop tests which were used to validate XtremIO VDI sizing guidelines

**Up to 3,500 Full Clone Sessions**

XtremIO provides generalized guidelines stating that each 10 TB X-Brick is capable of hosting approximately 3,000 full clone desktops. To verify this claim, three separate tests were run where the session count was scaled between 2,500 and 3,500 in increments of 500 active sessions.

In theory, the tests where active sessions count was set to 2,500 and 3,000 should produce results that are both acceptable to VDI deployment end users and consistent with those shown elsewhere in this paper. The additional test run with 3,500 concurrent desktops session is used to ascertain if XtremIO X-Brick utilization limits are in danger of being breached when deploying more than the recommended number of hosted desktops per X-Brick.
Figure 31 shows LoginVSI-generated, guest-realized average response time metrics for each of the three test runs. In each case, the same LoginVSI 4.1 Knowledge Worker (2vCPU) benchmarking profile was run against the prescribed number of desktops—2,500, 3,000, and 3,500 40 GB Windows 7 full clone desktops. The response time numbers are plotted against the associated point-in-time session count.

It is clear to see that the LoginVSI-recorded response profile for each of the test cases closely mirrors one another. As the session count increases, the average response times also tend upwards. The gentle increase in average response times versus increasing session count is representative of a well-behaved and non-saturated environment. This upward slope is to be expected and is based upon the increased load placed upon the host, domain, network, storage, and test infrastructure as the concurrent session count increases.

What is of primary importance in the above graph is the fact that the VSImax average response time threshold is not exceeded (discounting the infrequent outliers which are considered acceptable behavior), thus confirming an acceptable end-user experience even when 3,500 of our template desktops were operating simultaneously.
<table>
<thead>
<tr>
<th>Number of Sessions</th>
<th>Average Response Time (Mean)</th>
<th>Average Response Time (Std.Dev)</th>
<th>Maximum Response Time (Mean)</th>
<th>Maximum Response Time (Std.Dev)</th>
<th>Minimum Response Time (Mean)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,500</td>
<td>810</td>
<td>172</td>
<td>1169</td>
<td>906</td>
<td>715</td>
</tr>
<tr>
<td>3,000</td>
<td>818</td>
<td>103</td>
<td>1244</td>
<td>980</td>
<td>728</td>
</tr>
<tr>
<td>3,500</td>
<td>878</td>
<td>176</td>
<td>1671</td>
<td>1443</td>
<td>739</td>
</tr>
</tbody>
</table>

**Figure 32.**
Table displaying LoginVSI test metrics which compliments the information shared in figure 31.

Looking at the comparable response time profile on the array shows that the XtremIO storage hosting the environment is still operating at a fraction of its capabilities. Average response times are consistently in the sub-millisecond range. Refer to figure 33.

**Figure 33.**
Viewing the on-array IOPS and associated latencies during the 3,500 session Knowledge Worker test profile. Screenshot from the XtremIO management GUI.
The fact that the VSImax threshold has not been exceeded indicates that the test environment used to host these three tests is in fact capable of hosting an increased number of sessions. This statement is clear in meaning, but must be taken in context. While the environment is indeed operating below maximum utilization during the 3,500 seat test, the desktops are operating in a steady-state and the results shown are representative of an average workload for that particular setup. When planning for your VDI infrastructure, much attention should be paid to the expected performance requirements during the periodic maintenance operations associated with hosting such a VDI environment.

For additional context regarding the results described here, please refer to figures 32 and 34. Figure 32 displays a table of LoginVSI test metrics that compliments the results shown in figure 31. Figure 34 displays the before and after capacity information from the XtremIO storage in relation to the deployment and testing of the 3,500 full clone desktops. Consistent with the information shown in this paper, you can see a data reduction ratio for our 3,500 desktops in excess of 72:1. It should be noted that a data reduction ratio this high can be typical for an internal test environment where the lifecycle of such deployments is limited and the data has not had cause to diverge too far from its initial state. When planning your VDI deployment, please refer to the data reduction ratio guidelines covered in the Sizing Guidelines section of this paper.

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**VMWARE APPVOLUMES**

While this paper was in the process of being drafted, an extremely interesting and potentially disruptive VMware feature set was released to the public. This product was released under the title 'VMware AppVolumes' (known formerly as 'CloudVolumes') and offers virtualization administrators in command of VMware VDI deployments increased control and options relating to the delivery of applications to virtualized machines. This section will touch upon the technology and carry out a minor examination to validate the product and ensure compatibility with the XtremIO all-flash array.
Briefly, VMware AppVolumes product suite offers administrators of virtualized environments the ability to detach and virtualize software above the guest OS, where the virtualized application/software can then be organized into volumes. These volumes (known as AppStacks) can be paired with specific users, computers, or active directory organizational units in accordance with the desired policy of the environment being managed.

Figure 35.
Logical model comparing the traditional virtualized desktop instance to the AppVolumes specific desktop which has writeable volumes for user data as well as virtualized and dynamically attached applications (via AppStack)

These new capabilities extend and enhance the existing deployment options for VMware VDI administrators. Using VMware AppVolumes, guest OS applications can now be provisioned using a just-in-time or subscription type model and can also be updated without impact to the linked virtual machines.

The AppStack container, once it is configured with provisioned applications, is mounted as a read-only volume to the designated entities within the hosted domain.

A second volume type also needs to be considered in relation to VMware AppVolumes. These are known as writeable volumes and are used to host local user profiles, saved files, and user-installed applications. These volumes are used to provide the end user with a persistent experience across multiple sessions and are mounted to the base image guest VM along with the AppStack(s) containing the user or computer's provisioned applications.

An overview of the steps involved in deploying an AppVolumes ready infrastructure and creating an AppVolumes desktop template are included in the Appendix of this document. A complete description of this technology can be found here.

**Testing 2,500 AppVolumes Desktops**

The test environment setup used for the examination of AppVolumes-enabled VDI was based upon the model used during testing of the 2,500 full clone desktops (see Figure 30). Once the required AppVolumes infrastructure was installed and configured as described in the VMware deployment documents, a batch of 2,500 full clone VMs was created using the AppVolumes base image template. This template was essentially the same template used in previous testing, minus the applications captured in the applicable AppStack and plus the AppVolumes guest agent. A single AppStack was used for all of the 2,500 desktops and these were assigned to the specific Active Directory users for attachment to the guest OS on next log-in. No writeable volumes were used during this test.
Running the LoginVSI Knowledge Worker (2vCPU) workload against these 2,500 sessions yielded the results shown in figure 36. The results were favorable in relation to maximum response thresholds remaining intact and the average response time profile over the course of full test sequence displaying consistent and acceptable behavior.

Figure 36.
LoginVSI 4.1 Knowledge Worker results for 2,500 concurrent AppVolumes desktop sessions

The most obvious piece of information that can be derived from this test data relates to the VSImax average (response time) numbers. When comparing results for both the 2,500 session test using default full clones versus the AppVolumes full clones, you can see >200ms difference is the average guest OS realized latencies. This comparison is made somewhat clearer in figure 37, which shows overlaid VSImax average response time data for both default full clones and their AppVolumes equivalent. As can be seen in figure 37, the relative response time envelopes and associated slopes for each of the profiles closely match, the primary difference being a consistent >200ms delta in favor of the regular VMware View full clone sessions (sans AppVolumes).

This test sequence was intended to be a first-look at the AppVolumes product suite and no bespoke performance tuning was carried out. As such, this paper cannot say for certain if the AppVolumes performance metrics copied here are representative of optimal behavior, but it is most likely that with further examination, these numbers could and would be improved upon. What can be said with certainty is that the AppVolumes product suite behaves as expected (in relation to above-the-OS application provisioning) and the performance profile for large scale deployments does not exhibit any flawed behavior when hosted on the XtremIO all-flash array.
Figure 37.
Comparing the LoginVSI VSImax average response time profile for both the 2,500 native/default desktops configuration and 2,500 AppVolumes desktops. Both test cases used the LoginVSI 4.1 Knowledge Worker workload.

From a storage-centric point of view, much consideration needs to be applied to the deployment model used when taking advantage of VMware AppVolumes in your environment.

- First, as the AppStacks are essentially read only volumes which are shared across many VMs, you should look to create these data stores on storage which can deliver consistently high IOPS and low latencies when subjected to intense random read request I/O profiles. XtremIO is by default uniformly distributed across all resources and is ideally suited to such a workload.

- Second, the I/O profile for an AppVolumes deployment will differ from that of the default (or native) clone deployment model. Based on in-house testing, it was seen (for the AppVolumes based configuration) that the overall IOPS requirement for the underlying storage was increased by approximately 15 percent. Appropriate steps should be taken during the course of AppVolumes-based solution planning to accommodate the increase in IOPS and in particular the increased number of highly localized read requests.

- Last, it should be noted that there are additional storage efficiency benefits available to administrators when using VMware AppVolumes in their environments. Even though this limited test yielded increases for both the underlying storage workload and the average response times seen at the guest OS, the solution should not be dismissed on these factors alone. An AppVolumes desktop image, when using both AppStacks and writeable volumes, can now offer a persistent experience to the end user with greater storage capacity efficiencies than were previously available. The option to provision applications across your organization in much more granular and targeted manner is of course the primary benefit.

The information contained within this section is based upon limited testing of the VMware AppVolumes product and as such, does not claim to be definitive in any manner. Based upon this testing and the fact that deploying such a solution on XtremIO appears to be optimal, a deeper examination of the technology will be carried out and a set of best practices for VMware AppVolumes with XtremIO all-flash storage will be made available within 2015.
FULL CLONE AND LINKED CLONE PERFORMANCE COMPARISON

EMC and XtremIO recommend that desktops deployed on XtremIO be configured as ‘thick provisioned eager zeroed’ full clones. The recommendation aims to optimize efficiency across the VDI solution and is based upon the benefits available because of the groundbreaking data-reduction orientated, flash-centric architecture of the underlying storage. Due to the always-on, in-line deduplication technology, full clones now become an increasingly cost-efficient solution and allow for reduced complexity in planning VDI deployments and the associated infrastructure management requirements.

Some virtualized deployments will continue to use linked clones for reasons other than the capacity savings alone (versus full clones), and as such, this solution is obliged to verify that linked clones will perform just as well as full clones on XtremIO.

This performance validation exercise was carried out using different test hardware to that described in the previous section. Figure 38 below, shows a topological view of the test environment used for the reference architecture described within this paper.

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**Figure 38.**
High level overview of the solution with the primary infrastructure components
1,000 Full Clone Desktops

This is the primary test which is used to define the baseline performance of the secondary environment. Any bottlenecks here would indicate that the test setup is insufficient for our needs. The first step is to deploy 1,000 full clone desktops via the VMware Horizon View Connection management console. The settings used during the provisioning operation are copied in the table shown.

The time to deploy all desktops was measured from initiation of the process using the View Connection manager until all desktops were powered on, reconfigured with a new SID and unique computer names, and finally made available for end-user log-in. The number of concurrent vCenter operations allowed during deployment was as described and in keeping with XtremIO best practices. Quicker deployments can be achieved by increasing the number of permissible concurrent operations. However, amending these settings without a deep understanding of the underlying VMware vSphere mechanics is not advised. A single XtremIO X-Brick will handle a doubling (and more) of the default vCenter concurrent operational values without issues, but the stability of the vCenter server may come into question if the hosting VM has not been provisioned with adequate resources. For this reason alone, this paper will avoid making any recommendations with regard to increasing these limits without controlled experimentation in a non-production environment and/or consultation with your VMware support team.
<table>
<thead>
<tr>
<th>Desktop Pool Parameter</th>
<th>Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pool Type</td>
<td>Automated Pool</td>
</tr>
<tr>
<td>User Assignment</td>
<td>Floating</td>
</tr>
<tr>
<td>Desktop Power Policy</td>
<td>Take no Action</td>
</tr>
<tr>
<td>Automatic Logoff</td>
<td>Never</td>
</tr>
<tr>
<td>Display Protocol</td>
<td>PCoIP</td>
</tr>
<tr>
<td>Monitors</td>
<td>2</td>
</tr>
<tr>
<td>Monitor Resolution</td>
<td>1920x1200</td>
</tr>
<tr>
<td>Adobe Flash Quality</td>
<td>Do not control</td>
</tr>
<tr>
<td>Adobe Flash Throttling</td>
<td>Disabled</td>
</tr>
<tr>
<td>Disposable Disk</td>
<td>None</td>
</tr>
<tr>
<td>Number of Desktops</td>
<td>1000</td>
</tr>
<tr>
<td>Number of Desktops Powered On</td>
<td>1000</td>
</tr>
<tr>
<td>Provision all Desktops up front?</td>
<td>Yes</td>
</tr>
<tr>
<td>Linked Clone Overcommit Policy</td>
<td>Conservative</td>
</tr>
<tr>
<td>Dedicated Replica Storage</td>
<td>None</td>
</tr>
</tbody>
</table>

Figure 40.
Parameters used to in the deployment of VMware Horizon View desktop pools

1,000 Horizon View full clone desktops were measured to be fully deployed and available for use within two hours of initiating the command from the View Connection management client. Once the desktops were provisioned and available for testing, the LoginVSI management console was used to prepare a 1,000-desktop test using the predefined Knowledge Worker workload. The delta between desktop log-on requests was set to four seconds and all sessions were configured to run concurrently for a minimum of 4,000 seconds before the sessions were then logged off.

The VSImax results achieved during testing of 1,000 full clones are shown below in the LoginVSI Analyzer generated graphic (figure 41). The key takeaways are that VSImax threshold was not reached for this test run and that the reported VSIbase and VSImax average numbers were 681 and 759, respectively. These numbers confirm the end-user experience while using desktops hosted on XtremIO as optimal and the associated performance as best-in-class for hosting virtualized desktop pools.
In addition to the environment-defining VSImax numbers quoted, the various host, VM (CPU, memory) and XtremIO storage performance metrics indicate that the environment and provisioned desktops are capable of more and are not being pushed to their limits. With this in mind, further tests will examine the performance of deployed desktops and underlying infrastructure when subjected to heavier workloads and/or increased desktop density.

**Figure 41.**
LoginVSI 4.1 Knowledge Worker results for 1,000 concurrent full clone sessions

**Figure 42.**
Host resource consumption statistics (per host average) during the 1,000 concurrent full clone desktop sessions undergoing LoginVSI’s Knowledge Worker test profile.
A 1,000 seat LoginVSI Power Worker test was set up with the same parameters used during the comparable LoginVSI Knowledge Worker case. When running the LoginVSI Power Worker test case, we can expect at least 25 percent higher activity both at the storage level and the host side resources.

As can be seen in the 1,000-session Power Worker test case, the VSImax threshold is still not breached and the VSImax threshold numbers remain consistent with those seen in the earlier Knowledge Worker test. These results indicate that the solution being tested is not close to exceeding acceptable utilization rates. Regardless of the increased storage demands, XtremIO still maintains sub-millisecond latencies—this is to be expected due to the fraction of array throughput resources that are required to host the 1,000 desktops during steady state operations.

![Figure 43. LoginVSI 4.1 Power Worker test results for 1,000 concurrent full clone sessions](image)

It is worth noting that the test shows that for the 2,000 session target, the physical hosts underpinning the virtualized environment may be beyond their capabilities based on the recorded CPU usage of around 65 VMs per host averaging and sometimes exceeding 50 percent of the available resources of the physical host.

### 2,000 Full Clone Desktops

To help define the performance choke point(s) of the solution being tested, the desktop pool size was increased to 2,000 full clones. Following the pool expansion, an examination of the resulting performance and capacity metrics was undertaken. To ensure consistency of performance across all hosted sessions during the 2,000 seat test, the CPU resources being made available to the full clone VMs were required to be throttled.

Based on trial runs and experimentation using different resource allocation amounts, an upper limit of 4,096 MHz was set per pool desktop VM using the `set-VMResourceConfiguration -CpuLimitMHz` PowerCLI command.

When re-running the LoginVSI Knowledge Worker test with these parameters, the overall log-on time was doubled, so log-on delta per VM remained constant. The results are shown below in figure 44. Average response times for the desktop pool have increased, as would be expected due to the reduced CPU resources and increased concurrency of consumption on the physical resources available. Regardless, the VSImax prescribed threshold remains unreached and average response times are more than acceptable.
The Knowledge Worker workload with 2,000 desktops shows the hosts exceeding advised capacity. At this point we cannot add extra desktops without increasing the host footprint.
Using the fact that both memory and CPU resource allocation has been adequately capped to remain in the bounds of the physical host capabilities, another 2,000-session test was configured, but this time the more intensive Power Worker test set was used. The results of the 2,000-seat Power Worker test are shown below in figure 46. As expected, the average response times of the desktop pool under test increased and, based on the host-side resource utilization metrics recorded, this can be attributed to saturation of the available CPU resources. At this point, the bottleneck of our solution is available CPU power and no further scaling is possible.

Figure 46.
LoginVSI 4.1 Power Worker results for 2,000 concurrent full clone sessions

Figure 47.
Host resource consumption statistics (per host average) during the 2,000 concurrent full clone desktop sessions undergoing LoginVSI’s Power Worker test profile
It is worth noting that even though the storage is still highly underutilized, the available throughput left unused during steady state operations for a particular number of desktops will typically be much greater than what is seen during vSphere and Horizon maintenance operations. It is for this reason, that all capacity planning for virtualized deployments (where host-side and interconnects are not the bottleneck) need to incorporate the likely periodic throughput maximums required of their deployment and schedule such activities accordingly.

Details of XtremIO performance during the 2,000-session test are shown in figure 48—displaying close to 12,000 mixed IOPS (in terms of both transfer size and read/write mix) being serviced at sub-millisecond latencies.

Figure 48.
Viewing the on-array performance during the 2,000-session Power Worker test profile via the XtremIO management GUI. Top to bottom showing: IOPS profile, latency per I/O request size, and bandwidth information.
1,000 Linked Clone Desktops

The following tests are a replica of the 1,000 full clone desktop case already described. Based upon the fact that the servers hosting the VDI environment displayed signs of exceeding advised utilization values during the 2,000 seat full clone tests, it was decided to test using 1,000 linked clone sessions to ensure accuracy of the comparison. Performance is consistent, however the capacity numbers vary due to the nature of linked clones.

The figures copied below show the capacity consumption of the XtremIO array under test before and after the 1,000 linked clones desktop pool has been deployed. Approximately, 88 GB of logical capacity is required to host the desktop pool post-deployment. The data reduction capabilities of XtremIO further reduce this requirement to a physical storage footprint of only 27.4 GB. vSphere believes the storage footprint of the data to be 370 GB, so it is obvious that there is a high percentage of zero blocks contained within the master desktop image. As the linked clone is thin provisioned and the associated replica is a complete duplicate of an already stored VM, XtremIO is actually using only 27.4 GB physical flash storage to host more than 20 TB of the logically allocated thin provisioned storage.

The capacity figures quoted are expected to change with continued usage of the provisioned desktops. Post completion of three 1,000 user-session tests (representing more than seven hours of usage), the revised capacity numbers begin to mirror what we would expect from a desktop pool which is no longer in a clean (or non-used) state (see figure 50). During the test, the user-generated IOPS and associated response times met predefined expectations: approximately 7 IOPS per knowledge worker user and the typical sub-millisecond latencies of XtremIO.

Figure 49.
Capacity metrics of the XtremIO array for before (left) and after (middle) the deployment of 1,000 linked clone desktops. On the right, the capacity metrics after 24 hours of runtime using the LoginVSI Knowledge Worker test profile.
The primary objective of this linked clone testing is to ensure equal performance for both linked clone and full clone desktop types. The results from the linked clone LoginVSI test run confirm this. LoginVSI Analyzer reports that the VSImax figure was not reached. The VSImax average is 769, with VSIBase at 694. Compare this to the 1,000 full clone desktops undergoing the same Knowledge Worker test in which a VSImax average of 759 and a VSIBase average of 681 were confirmed with assumptions regarding equal performance across clone types.

**Figure 50.**
On-array latencies during the 1,000-session Knowledge Worker test profile via the XtremIO management GUI

**Figure 51.**
LoginVSI 4.1 Knowledge Worker results for 1,000 concurrent linked clone sessions
Even though there are minimal performance gains in favor of the full clone desktops, these are incidental and not the correct informational take away from this comparison. Based on these results, the administrator responsible for planning and/or deploying a VDI infrastructure can be satisfied that both full clones and linked clones will perform equally well. Decisions on clone type can be made with the ability to reduce complexity of the VDI environment through use of full clones while still enjoying the space saving benefits of linked clone configurations due to the flash-specific architecture of XtremIO and its inherent data reduction capabilities.

**LINKED CLONE MAINTENANCE OPERATIONS**

**Deploy 1,000 Linked Clone Desktops**

To deploy the one thousand linked clone desktops, a snapshot of the Windows 7 base image desktop used for full clone testing was taken. As before, the desktop is 32 GB in size, and has all memory reserved. Once the initial replica image was created, desktops were recorded to come online and be available at a rate of one desktop every 3.3 seconds. In total, it took only 55 minutes from the creation of the first linked clones for the complete pool of one thousand desktops to become ready to the View Connection server.

It should be noted that the number of replica images created to support the linked clone desktop pool is dependent on the number of data stores used to host the pool. The time to deploy can vary accordingly based upon this choice.

**Figure 52.**

Time to deploy 1000 linked clone desktops using Horizon View Connection Server.

*Deployment time was measured from completed creation of the replica image until the 1,000 desktops were listed as available in the View management client.

**Refresh 1,000 Linked Clone Desktops**

A Horizon View refresh operation discards any changes made to the linked clone desktop since it was last deployed, recomposed, or refreshed. The desktop is reverted back to a clean state with any persistent user data remaining untouched. To define the time taken for the refresh operation to complete on the 1,000 linked clone desktop pool, a refresh operation was instigated from the Horizon View Connection server management client while there were no active desktop sessions. The time taken for the refresh operation to complete was measured to be 46 minutes and 20 seconds, with performance metrics at the array reporting a maximum IOPS of 17,000 with latencies consistently below 1 millisecond. Details of the operation are captured and shown in the screenshots below (figure 53).
Recompose 1,000 Linked Clone Desktops

A Horizon View recompose operation for a linked clone desktop pool deletes the existing virtual desktops and creates new ones in their place based upon a specified snapshot of the master image. This operation can be used to either roll back the deployed desktops to a previous configuration or roll out changes to the linked clone desktops through manipulation of the master image and a follow-up snapshot. To verify the time taken to recompose 1,000 linked clone desktops, all settings relating to the maximum number of concurrent vCenter operations allowed were left as defaults (which match the advised scaling limits for a single X-Brick).

To simulate a typical maintenance task, an additional vNIC was added to the master image and a new snapshot taken. The recompose operation was instigated via the View Connection management client.

The time taken to complete recomposition of the 1,000 hosted linked clone desktops was measured at 103 minutes and 22 seconds. Performance metrics for XtremIO recorded a maximum of 33,000 IOPS during the recompose operation with average latencies remaining consistently below 1 millisecond. Details of the performance are shown below in figure 54.
Figure 54.
On-array historical performance data relating to a View-initiated recompose operation via the XtremIO management GUI. Top to bottom showing: IOPS, latency, and bandwidth information.
**8 KB ALIGNMENT**

With the release of XtremIO version 3.0, the granular block size of the storage has moved to 8 KB (from the previous 4 KB format). This offers the end user greater gains in relation to logical capacity available per brick. For desktops hosted on XtremIO, it is advised that these desktops are aligned to 8 KB where possible. Having a common alignment between underlying storage and the components hosted above yields obvious benefits in terms of efficiencies through the reduction of sub-sector-size I/O requests. The process used to convert an existing VM or set appropriate alignment during OS installation is detailed in the appendix section of this document.

For the purposes of this solution and associated testing, the base VM image used for all testing was converted to an 8 KB-aligned desktop. This newly 8 KB-aligned desktop was then used as the parent image for subsequent full clone and linked clone testing to ascertain comparable performance against the default aligned VMs. The re-aligned 8 KB VM image was also used as the method of determining the recompose time for our pool of 1000 linked clone desktops.

The following section describes the performance data for 1,000 8 KB-aligned full clone desktops when re-running the previously described tests. Response time metrics are compared and contrasted with the realized benefits highlighted.

**8 KB-aligned Full-Clone Comparison**

The time to deploy 1,000 8 KB-aligned full clone desktops was measured at approximately two hours in total. The recorded time closely matched that seen during the default 4 KB-aligned full clone deployment case with any difference being negligible and discounted as inter-run noise.

The 1,000 8 KB-aligned desktops were subjected to the same test conditions as described previously, for both the default aligned linked clone and full clone case. As can be seen in the results copied below, the 8 KB-aligned full clone desktop pool performs excellently and at no point exceeds the VSI threshold, even for intermittent response spikes.

![Figure 55.](image)

**Figure 55.**
LoginVSI 4.1 Knowledge Worker results for 1,000 concurrent 8 KB-aligned full clone sessions

Comparing all three 1,000-session Knowledge Worker cases (table below), it can be seen that the recorded results and expected end-user performance is consistent regardless of choice of clone type. What is interesting and worth noting is that the 8 KB-aligned desktop generated significantly reduced response time peaks in relation to the other comparable tests.
This can be attributed to the reduced overhead of having a correctly aligned file system in relation to underlying storage, a topic which was explained well in this VMware paper on alignment best practices.

Based upon these results, EMC advises XtremIO customers to consider this alignment when deploying desktops on XtremIO. Please note that the alteration of an existing VM’s alignment is a disruptive process and cannot be performed without impact to services.

**SUMMARY OF FINDINGS**

- Validation of the architecture described in this solution was confirmed through successful integration of the multiple components used and via recorded performance metrics that met and even exceeded expectations.
- Sizing guidelines for XtremIO were confirmed and exceeded with a successful deployment and test of 3,500 concurrent full clone sessions on a single 10 TB X-Brick. Testing has shown that both full clones and linked clones will perform equally well and VDI architects can choose either option when planning their VDI deployments on XtremIO.
- The LoginVSI VSImax threshold was not exceeded for any of the various test configurations. These numbers confirm an optimal end-user experience for Horizon View desktops hosted on XtremIO.
- 1,000 Horizon View full clone desktops were measured to be fully deployed and available for use within two hours of initiating the command from the View Connection management client. These times were observed to scale in a near linear fashion relative to desktop count.
- EMC advises XtremIO customers to consider setting the alignment of their desktops to 8 KB boundaries when deploying desktops on XtremIO.

**SUPPLEMENTAL**

**XCOPY BLOCK SIZE OPTIMIZATION**

During the course of writing this paper, it was discovered that there are further storage efficiencies to be achieved when using XtremIO to host your VMware data stores. These performance improvements could be achieved by altering the VAAI XCOPY transfer size to 256 KB, rather than the default recommended value of 4 MB.

By changing the maximum transfer size associated with the VAAI XCOPY operation, desktop pool deployment time was decreased and on-array latencies were also improved. Figure 56 shows the XtremIO recorded performance profile during a VMware Horizon View full clone pool deployment operation. This graphic shows approximately 87,000 IOPS (which amounted to approximately 51 GB/s bandwidth) on-array activity, where the overall latency recorded across all operations on the array remains consistently at sub-millisecond levels.

![Figure 56.](image)

Screenshot from the XtremIO management GUI highlighting the latencies associated with VAAI XCOPY commands when MaxHWTransferSize is set to 256 KB. The 256 KB I/Os are being processed within 15us and 54us for writes and reads respectively.
Both of the listed performance benefits translate into real-world gains for VMware ESXi administrators. First, reducing the time taken to deploy desktop pools using VAAI XCOPY means that desktop come-ready times are improved and the windows of possible resource contention associated with such operations are reduced. Second, reducing the on-array latency associated with the processing of VAAI XCOPY operations minimizes the probability of any I/O contention at the array. Benefits such as those described are high impact and should not be ignored.

Please note that this setting should not be deployed without proper consideration of the requirements for your own virtualized environment. Changing the VAAI XCOPY default transfer size will affect all other VAAI-enabled storage components of the ESXi host.

To check and change this setting, you can use the ESXCLI and PowerCLI commands shown below.

- To check the current value:
  - `esxcfg-advcfg -g /DataMover/MaxHWTransferSize`
- To change the value to 256 KB:
  - `esxcfg-advcfg -s 256 /DataMover/MaxHWTransferSize`
- Using PowerCLI to change this value to 256 KB:
  - `Get-VMHost | Get-AdvancedSetting -Name DataMover.MaxHWTransferSize | Set-AdvancedSetting –Value 256`

ENDPOINT ANTI-VIRUS RECOMMENDATIONS

Based upon the pervasive nature of anti-virus scanning requirements in corporate IT infrastructures, optimizing your environment for this additional maintenance activity is highly recommended. Internal testing of SEPM (Symantec Endpoint Protection Manager) with a single group of 1,000 clients hosted on XtremIO was used to create a set of recommended optimal settings. The test data and optimized results when compared with baseline performance metrics were found to be relative to the test environment at hand only and as a result are not copied in detail here. The derived best practices are generic and should translate to the majority of endpoint anti-virus deployments. These are listed below.

XtremIO recommends the following in relation to operating your VDI-specific Symantec Endpoint Protection. This will ensure the required protection provided by the Symantec solution is enforced in the most efficient method possible. Take the following steps in order to avoid any unnecessary I/O contention at the array:

1. Make sure to exclude the base image from scanning using the ‘Virtual Image Exception’ setting
2. Make use of the SEP Insight suite (if vShield integration is possible)
3. Use active scans instead of full scans
4. Enable scan randomization
5. In relation to updates, make sure to enable ‘randomization’ (and ‘Pull’ if update directly from SEPM)
6. In relation to SEP and prescribed VDI best practices, for any non-persistent clones:
   a. Remove non-persistent VMs from SEP Manager once they are destroyed
   b. Disable scheduled scans for non-persistent desktops if the max-log-on time permissible is less than the scan period of seven days
APPENDIX

INFRASTRUCTURE CONFIGURATION STEP-THROUGH

The following provides a summarized version of the process involved in the solution described within this paper. All hosts are assumed to have VMware vSphere ESXi installed, HBA firmware updated as required, and the EMC XtremIO cluster configured with all required storage and network connectivity in place.

As our deployment has the added requirement of residing on an internal non-routable subnet, an interim step is required to facilitate the initial setup. Here, we use the VMware vCenter vApp as the initial configuration tool and install this on one of our infrastructure hosts:

- Using the vCenter vApp, base images for the required support server and Windows desktop VM types were created
- Appropriate OS versions were installed and the VMs were connected to the external facing network
- All the latest Windows updates were installed and the resulting VMs were readied for template creation using the Windows Sysprep tool with all connected devices removed as appropriate

Using the vCenter vApp, a vSphere Distributed Switch (dvSwitch) was created local to the infrastructure host in use.

First, a ‘jump box’ was created using the base Windows server image. This VM acts as the platform upon which to deploy, monitor, and manage the test environment.

- The VM name was set as ‘NTP’ and the VM was connected to the external network and given access to corporate file shares which contained the necessary files for the creation of the environment
- This VM was configured as a Windows NTP client and pointed at an externally available NTP server
- The VM also acted as an NTP server for later use in synchronizing our domain controller (and members) and the ESXi hosts which will exist on separate non-routable networks
- The ‘NTP’ VM was given a second vNIC on the internal-only dvSwitch and configured to receive IP information via DHCP

Second, a Windows 2012 server was provisioned for use as the domain controller. This VM services the Active Directory, DNS, and DHCP requirements for the internal domain.

- The VM was named ‘ActDir’ and was configured with a connection to the dvSwitch only, with no external access
- All required Windows domain features and services were installed using the common steps apart from the additional step of configuring .NET Framework 3.5 services, which are required for compatibility with the VDI test tools
- The desired domain configuration for the test environment was set up using the in-built Microsoft installation wizards, with DHCP scopes and DNS forward/reverse lookup zones being configured
- This server was made to be an NTP client of the already created ‘NTP’ server
- The additional VMDK assigned during deployment was formatted and shared amongst all domain members, with each allowed full read/write privileges
- LoginVSI data center setup was carried out as per LoginVSI configuration instructions on the ‘ActDir’ VM with the resultant Active Directory OUs and users being populated
Third, a Windows 2012 VM was provisioned for use as the primary vCenter server for the test domain.

- This VM named ‘vCenter’ has vNIC connections to both the external and internal networks
- Microsoft SQL 2012 was installed per Microsoft best practices and two new databases were created, named ‘VCENTER’ and ‘COMPOSER’
- ODBC (Open Database Connectivity) was configured for the databases prior to integration with the to-be-installed VMware components
- vCenter Server is installed (in our case, using the simple-install step-through wizard)
- During install of vCenter Server, only the internally connected NIC was left active, apart from the license verification step—ensuring that the primary IP address allocated to vCenter is for the internal domain and proved necessary for follow-up SSL verification with the internal-only Horizon components
- Following installation of vCenter, SSO and administrator privileges for the appropriate domain users or group were assigned via the vCenter client
- VMware Horizon View Composer was then installed on the same server VM and configured to use the ‘COMPOSER’ database

At this point, the virtualized hierarchy should be rearranged to make the newly created vCenter Server instance the primary point of management for the virtual infrastructure. Following this, a new data center was created, to which we migrated all vSphere ESXi hosts and networking.

- Hosts are clustered into logical groups, for infrastructure and desktop hosting.
- Additional storage volumes were defined and then mapped to the appropriate clusters; best practices as prescribed by XtremIO were verified to be in place

Next, two comparable Windows 2012 server VMs were deployed. These act as the Horizon View Connection servers for the setup.

- These VMs were given names, ‘Connection1’ and ‘Connection2’ and connected to the internal VDI domain only
- Horizon View Connection Server was installed as per best practices on both machines, one being the default initial install procedure, the other chosen to be a replica server during the install process
- The default number of permissible concurrent vCenter actions specified during install matched the best practices for a single X-Brick—if using more than a single X-Brick in your cluster, please adjust these settings accordingly (refer to the XtremIO scaling guide)
- Post-install, the main View Connection instance was connected to the primary vCenter and also to the appropriate Composer instance and associated Active Directory OU (for use with Linked Clone testing only)

At this point, the majority of the backend infrastructure was in place, with the test and monitoring tools remaining.

Windows 2008 servers were deployed and added to the internal domain to act as user-data file shares for the LoginVSI users and their to-be allocated desktops. These VMs are named ‘File{i}’ and have a shared folder made available to all domain users, on which the LoginVSI PRO libraries are installed.

The next requirement for LoginVSI was to deploy launcher machines, which are used to request desktop VMs from the Horizon View pool for use with the Active Directory LoginVSI users. The launcher VMs were deployed using a clean Windows 7 template, named in the format of ‘Launcher{i}’. The Horizon Agent was installed and then set up as per LoginVSI instructions.

VMware vRealize Operations Manager (v6.0) was deployed using the available vApp and assigned to the external facing subnet. In addition, EMC Virtual Storage Integrator (VSI v6.3) was added to the external facing domain and connected to XtremIO under test along with the primary vCenter instance.

Another Windows 7 VM was created using the template and this was to be configured as the base VM for use as the template for our linked clone and full clone desktop pools.
• Instructions on the steps to create this base image are covered in the 'Desktop Template' section below, along with modifications made to allow the creation of full clone, linked clone and App Volumes desktop pools via VMware Horizon with View.

At this point, the environment was ready to start testing using LoginVSI. It is advised to begin workload testing with a minimal number of desktops in a format where the LoginVSI orchestrated test sequence can be monitored and debugged based on any interruptions to the expected test flow and results logging.

• Fixes for any of the problems encountered during the test run are typically related to having to make changes to the Active Directory Group Policy Objects (GPO) in order to work around some of the ‘first use’ wizard issues common for new users starting Microsoft Office applications for the first time.

• Problems related to actual initialization of test connections or the launching of desired workflows may indicate an issue with the domain setup (security, networking, etc.) and the LoginVSI, Microsoft, and VMware support pages and forum should be consulted as a first step to resolution.

DESKTOP TEMPLATE
A common template was made for testing all test cases to ensure honesty of comparisons. The VM was created as a version 8 virtual machine (to ensure full compatibility with the traditional vSphere management client) and sized to 2vCPU and 2 GB RAM. Sizing was scoped on the basis that the VM should be able to accommodate the VMware-specified Power Worker user profile.

Each VM was allocated 32 GB of thick provisioned eager zeroed (TPZ) disk space. The desktop operating system was built using Windows 7 ultimate release. All updates were applied and a template was created.

Please note, VMware virtual machine hardware version 10 offers a number of improved features which include: expanded vGPU support, the ability to mount larger than 2 TB virtual disks, and USB 3.0 capabilities. This solution recommends that you consider your VMs’ use cases and plan the version type accordingly.
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**Figure 57.**
Specification for the base VM template used in the creation of Horizon View desktop pools

**Preparing for use with Symantec Endpoint Protection**

Prior to deploying Symantec Endpoint client to the desktops under test, the following changes are required. These steps are particular to the Windows 7 generation OS versions. Further information on alternate operating systems is available in the Symantec article ‘HOWTO80805’.

If the Windows client computer is part of an Active Directory domain, make sure to use domain administrator account credentials with local administrator privileges for remote push. First, either fully disable User Account Control on the client computers during the remote deployment or disable the registry key LocalAccountTokenFilterPolicy. To disable UAC remote restrictions, see Microsoft KB951016. Then, perform the following tasks:

- Disable the Windows Firewall or configure the firewall to allow the required traffic
- Disable the Sharing Wizard
- Enable network discovery by using the Network and Sharing Center
- Enable the built-in administrator account and assign a password to the account
- Verify that the account has administrator privileges
- Disable or remove Windows Defender
vSphere Optimization

The base VM to be used as the template for the remainder of testing was configured as per the information supplied in standard ‘LoginVSI’ recommendations and the ‘VMware Horizon with View Optimization Guide for Windows 7 and Windows 8’ document. These steps included:

- Running the ‘NoPersona’ VM optimization batch file included in the VMware best practices document
- Running the LoginVSI target setup script which installed the necessary test software of the base VM

Based on the testing scope which limited our desktop pool to 2,000 VMs, it was decided to fully reserve all assigned VM memory in advance.

- With 16 hosts for the desktop pool hosting a maximum 2000 VMs, 125 VMs per host, and with 320 GB RAM per host, we could easily afford to reserve all memory in advance
- This allowed the reduction of the associated VM Virtual machine Swap Files (VSWP, reserved storage equal to the VM memory allocation minus any memory reservation) to zero for our desktop pool

The various test configurations for full, linked, and 8K-aligned clone desktops were manipulations of this same template.

Full Clone/Linked Clone

The base VM was used as the foundation image for initial full and linked clone desktop pool testing. As per normal VMware operating procedure:

- A template of the base VM was cloned and stored in vSphere inventory for use with the full clone desktop pool
- A snapshot was taken of the powered down base VM image for the purpose of creating a linked clone desktop pool

8 KB-Aligned Clone

The default alignment of a Windows OS is set to 4 KB, which when accessing storage using a larger sector, can result in increased overhead for the storage array. As the latest XtremIO XIOS release uses a sector size with 8 KB granularity, secondary testing of an 8 KB-aligned desktop was used to assess what potential performance gains may be available for a desktop template using similar alignment.

Creating an 8 KB-aligned desktop image can be performed in two ways—conversion of an existing VM or alternatively, during the initial install phase. Details of both options are listed.

Converting an Existing VM

To convert an existing virtual machine to be 8 KB-aligned, use the VMware vCenter Converter Standalone product. This product allows users to automate and simplify physical to virtual machine conversions as well as conversions between virtual machine formats. The VMware vCenter Converter standalone product is freely available from VMware using this link.
To convert a pre-existing VM, open the application on a server which can access the appropriate vCenter:

1. Choose ‘Convert Machine’
2. Select source type ‘VMware Infrastructure virtual machine’
3. Choose the VM to be converted
4. Enter the required ESXi information
5. Specify a name for the newly created VM
6. Select destination host and data store
7. Choose to ‘Edit’ the ‘Data to Copy’
8. Select the volume to copy and choose ‘Advanced’
9. For the relevant OS disks to be realigned, change the ‘Type/Cluster’ option to 8 KB
10. Finish
11. After the conversion process, it is necessary to power on the new VM at least once to complete the VMware Tools install process.
During Fresh Install
During install of a Windows 7 OS, to create the VM with 8 KB alignment, please follow these steps:

1. Boot from the Windows 7 ISO image or CD and proceed through the install steps until the 'Where do you want to install Windows' dialog
2. Press 'Shift + F10' to bring up the command window
3. In the command window, enter the following commands:
   a. Diskpart
   b. Select Disk 0
   c. Create partition primary size = 400
   d. Active
   e. Format fs=ntfs label="System Reserve" quick
   f. Create partition primary
   g. Format fs=ntfs label=OS_8k unit=8192
   h. Assign
   i. Exit
4. Click the ‘Refresh’ button to refresh the dialog box
5. Select the appropriate partition—this should be ‘Disk 0 Partition 2’

![Figure 59. Dialog box which will be presented to the user after configuring an 8 KB-aligned partition during Windows install process](image)

AppVolumes Components
For VMware AppVolumes to function correctly, it is assumed there is a Microsoft Active Directory infrastructure in place that can be leveraged. It is also assumed that there is a vCenter Infrastructure Environment available and that this is tied to Active Directory for authentication and available for testing with the AppVolumes installation. It is highly recommended that there is a functioning Horizon with View 6.0 or 6.0.1 (minimum) installation in place.

The primary components required for operation of this product suite are as follows:

- **AppVolumes Manager**: A windows server used for administration and configuration purposes. This server will also act as a broker for the hosted VMs running the AppVolumes client-side agent.
- **AppVolumes Agent**: Client-side software that allows the provisioning of AppStack and Writeable volumes. This agent is also utilized during the AppStack provisioning process.
• **AppVolumes Database**: SQL database containing the configuration information relating to the AppVolumes setup.
• **AppStack**: Storage volume used in the provisioning of applications.
• **Writable Volume**: Storage volume which is used to allow the end-user to preserve data and install their own applications.
• **View Broker Service**: Service to be run on View Connection server which enables faster log-ins for AppVolumes-enabled desktops.


**AppVolume Desktop**

The steps involved in creating the AppVolume VM desktop image required that a VM comparable to the desired base VM was in place. All installed software was removed to accommodate the application install process recording and associated AppStack creation process. Full steps on the process are covered in the AppVolume documentation, but the following brief summary covers the fundamental steps:

- The AppVolume-specific base VM was reverted to a clean and AppStack create-ready state, which meant the removal of all installed applications and the VMware Horizon View agent.
- A snapshot was taken prior to any AppVolume AppStack creation. This is an important part of the process and should not be missed.
- The AppVolume prescribed process for creation of an AppStack was followed and the VM was then reverted to last snapshot.
- Once the VM was reverted to the pre-AppStack creation, the Horizon View agent was reinstalled.
- After the VMware AppVolumes AppStack had been created and the new VM was in a state to begin use as an image for desktop deployment via Horizon View, an associated template and snapshot were created to accommodate subsequent full clone and linked clone testing.

![Image](image.png)

**Figure 60.**
High-level overview of the process flow involved in deploying VMware AppVolumes
# REFERENCE MATERIAL

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