Enabling Large-Scale VDI Deployments with Citrix XenDesktop

Executive Summary

Traditional storage systems were not designed for the unique challenges presented by large-scale virtual desktop infrastructure deployments. In VDI deployments, the performance, scale and management requirements are different from traditional enterprise settings. The SolidFire storage system has been architected specifically to address these issues, delivering significant advancements in the Quality of Service, scale and cost of the storage infrastructure behind your Citrix XenDesktop VDI environment.

The key to a successful storage deployment in a real-world VDI use case is a well-planned design in combination with the advanced functionality available from storage platform like SolidFire. The purpose of this guide is to provide a validated reference design for customers evaluating SolidFire storage for their VDI infrastructure. When we embark upon our testing we had two very specific goals;

1. Validate SolidFire's ability to power a 750 desktop environment with XenDesktop
2. Prove that the SolidFire architecture would deliver an exceptional administrative experience

This document specifically walks through the test configuration, highlights best practices and reviews the validation results from running Login VSI against a 750 desktop environment using XenDesktop with SolidFire. Also highlighted throughout are key design considerations to help maximize end-user and administrative experience, simplify management and improve scalability while minimizing infrastructure costs.

Introduction

With penetration rates of the professional PC market estimated between 2% to 2.5%, virtual desktop infrastructure (VDI) has struggled to achieve broader market acceptance across enterprises and service providers. Despite a seemingly compelling value proposition for both IT departments and Desktop-as-a-Service offerings, the inability of the VDI ecosystem to adequately address the challenges of user experience and infrastructure costs has constrained adoption rates. Storage in particular, historically accounting for a disproportionate share of VDI infrastructure dollars, has been a prime suspect in the failure of many VDI projects. Traditional storage systems lack the performance, flexibility and scalability to keep pace with the unpredictable demands of VDI environments as they grow from proof-of-concept to production. The resulting capital and operating expenditures, and user experience impact of the various workarounds deployed to circumvent these storage deficiencies (e.g. underprovisioning), effectively destroys the ROI of any VDI project.

More recently, however, key advancements from the next generation storage systems in the areas of performance, quality of service, density and data reduction techniques has completely changed the economics of the storage infrastructure needed to ensure a successful VDI buildout.

SolidFire provides granular Quality of Service controls for its scale-out block storage system that are uniquely suited to harness the mixed and unpredictable workload profiles that exist in a VDI environment. SolidFire's ability to guarantee storage performance, dynamically adjust storage resources on the fly without hardware reconfiguration, and linear and nondisruptive scale translates to significant user experience and infrastructure cost benefits throughout the lifecycle of a VDI deployment.

Audience

This document is intended to assist solution architects, field engineers, consultants or IT administrators with a basic proof of concept design for a Citrix XenDesktop environment using SolidFire as the storage system. This document assumes the reader has a working knowledge of Microsoft Hyper-V, Citrix XenDesktop and related infrastructure components.

Validation Overview

As part of validation as a Citrix ready solution, SolidFire is participating in the VDI Capacity Program introduced by Citrix in Q1 of 2014. VDI presents multiple types of data, each with its own unique storage requirements. To simulate the range and variation representative of VDI, Citrix constructed a turnkey "VDI Capacity" test environment in their Santa Clara Solutions Lab with the capability to generate a 750 reference XenDesktop workload.

The VDI Capacity Program utilizes the highly regarded Login VSI tool for standardized VDI performance/capacity testing. It focuses on provisioning the appropriate amount of storage capacity and utilizes a simple, binary pass/fail methodology. If a storage solution can successfully support "a day's" run without reaching the latency limit or "VSI Max" the partner passes and the test ends. Once passed, Citrix describes the storage partner as "750 User Verified" for XenDesktop. More about Login VSI can be found here:

Summary of Key Findings

- **Strong End User Experience** - Our testing simulated a 750 desktop environment. We leveraged "Login VSI" to generate load and validate the user experience. Our testing proved that SolidFire could deliver satisfactory performance for 750 desktops while consuming LESS than 10% of the available storage resources and keeping average latency well under under 1ms.
- **Low Cost per Desktop** - The SolidFire SF-3010 storage system tested easily supports a density of 1000 desktops per 1 rack unit (RU). Each node delivers 50,000 provisionable IOPS and 12TB of usable capacity. In a base configuration this equates to under $50/desktop capital cost with provisionable IOPs remaining for additional desktops or other business applications. By leveraging SolidFire's cluster wide data reductions techniques this cost per desktop can be realized across XenServer pooled, streamed and dedicated desktop approaches.
- **Dedicated Performance with Shared Infrastructure Economics** - SolidFire's QoS allows an administrator to isolate and guarantee performance to each application, eliminating the need to use dedicated storage system for a resource hungry workloads like VDI.
- **Simplicity of Scale** - The SolidFire architecture allows users to scale at a very granular level without downtime. Scaling performance and capacity to accommodate additional desktops is as simple as adding another node into the storage cluster and provisioning additional storage volumes to your virtual infrastructure.
- **Design Adaptability** - SolidFire provides the ability to adjust performance and capacity on the fly. This means that design requirements can be more dynamic, adjusting over time without penalty as workload profiles change.

- **Controlling Unpredictable Workloads** – SolidFire has the ability to provision minimum, maximum and burst IOPS settings to each volume on the cluster. This storage performance control ensures a quality user experience during steady state operations, while also accommodating for unexpected performance spikes without impacting other desktop or workload IOPS demands.
- **Economical Dedicated Desktops** - By leveraging in-line compression and deduplication, VDI deployments using full dedicated desktops for each user will realize data reduction efficiencies comparable to what you would see from streamed desk

Solution Overview

Figure 1 shows the topology of the test environment. The test environment consisted of the following core components networked to the SolidFire storage system.

- Infrastructure Hosts (x2)
  - Citrix Provisioning Services (PVS) x.x
  - Citrix Desktop Delivery Controller (DDC)
  - SQL Server
  - Citrix StoreFront
  - Active Directory / DNS / DHCP
  - Login VSI Share (Fileshare)
- Desktop Hosts (x11)
  - 750 desktops (~70 desktops per host)
- Login VSI Hosts (x3)
  - Login VSI Launchers (15 Launchers per Host)
- SolidFire Storage Cluster (1)
  - One (1) 1TB volume for the infrastructure VMs
  - Ten (10) 1TB volumes for the desktops

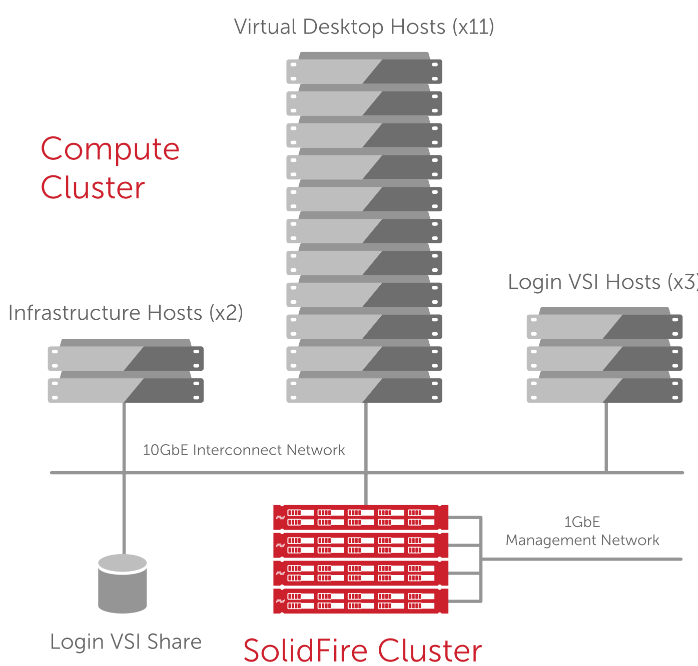


Figure 1: Solution Overview

Component Selection

The following section outlines the hardware used for the test environment.

Servers

The server infrastructure is made up of sixteen blade servers with identical configurations. Two servers were dedicated to the infrastructure virtual machines (VMs), three servers were dedicated to the LoginVSI test tool and eleven servers were used to host the virtual desktops. The servers had the following specs.

Enclosure	HP C7000
Servers	HP ProLiant BL460c G7 (x16)
Processor	Dual Intel Xeon 5650 2.67Ghz
RAM	192GB
HBA	Integrated NC553i Dual Port FlexFabric 10Gb Adapter

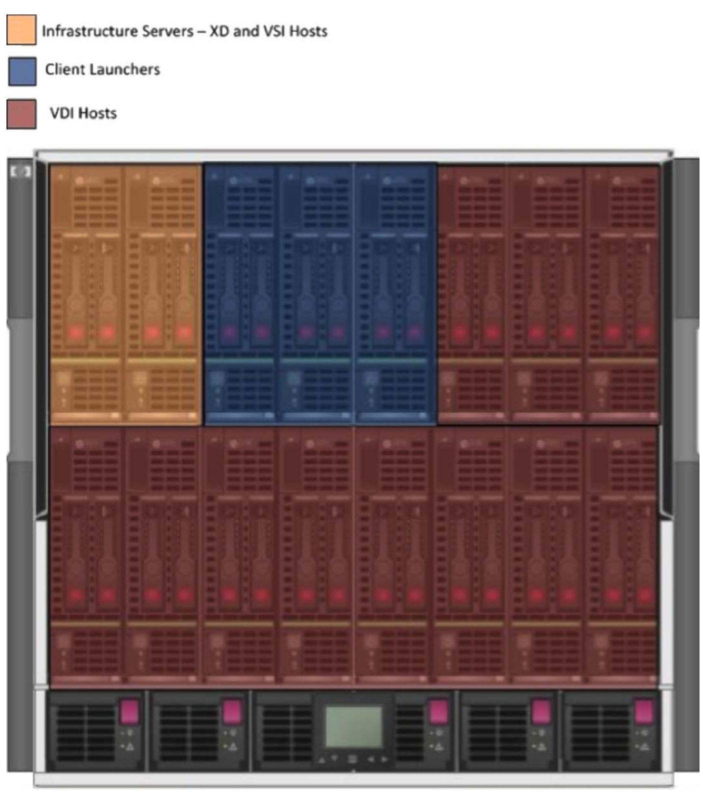


Figure 2: Server Layout

Network

In this design we configured the HP FlexFabric to support both the Production and PXE network within the compute chassis. The FlexFabric also provided connectivity to the storage network.

All SolidFire nodes on the storage network were connected to the 10GbE storage switch and configured for ALB link aggregation to maximize throughput and provide link redundancy.

Note: A highly available production deployment would require redundant 10GbE storage switches to be truly fault tolerant.

Production & PXE Networks	10GbE Interconnect Switch
Storage Network	10GbE Dedicated Switch
Management Network	1GbE Dedicated Switch

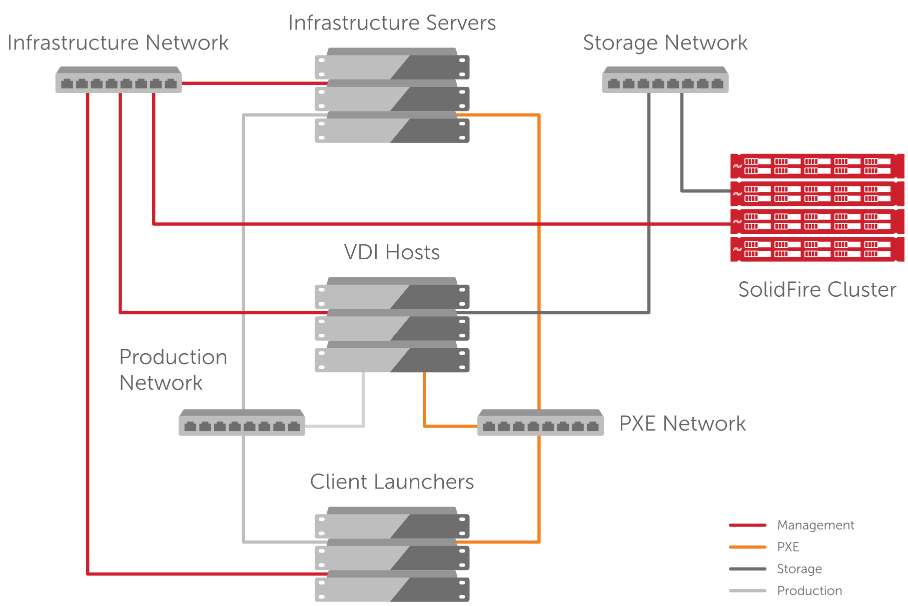
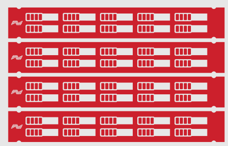


Figure 3: Network Layout

Storage

For this validation effort we used the minimum SolidFire storage configuration to provide volumes to both the infrastructure VMs as well as the virtual desktops. SolidFire is a clustered storage system, requiring a minimum of four nodes to operate in a highly available state. A 4-node SF3010 cluster is able deliver 200,000 provisionable IOPS and provides a usable capacity of 48TB. The table below outlines the hardware specs for a SF3010 node.

Model	SolidFire SF3010 (x4) 
Drives	300 GB 2.5 SSD (x10)
Write Cache	72GB Shared
Processor	8GB Non-Volatile DRAM
Networking	10GbE SFP+ iSCSI (x2) 1GbE RJ45 Management (x2)
Power Supply	Hot-plug Redundant High-Efficiency 750W
Average Watts	150W to 450W, depending on IO load
Rack Support	4 post rack, tool-less sliding rails
Weight	17.2 kg (38 lbs)

Infrastructure and Management Virtual Machines

In order to configure a XenDesktop environment and use Login VSI for performance and capacity testing, we needed to provision the following virtual machines:

Virtual Machine	Citrix PVS	Citrix DDC	Citrix StoreFront	MS SQL Server	MS System Center VMM	Domain Controller	Login VSI Launcher
OS	Windows 2008 R2	Windows 2008 R2	Windows 2008 R2	Windows 2008 R2	Windows 2008 R2	Windows 2008 R2	Windows 2008 R2
vCPU	2	2	2	4	1	1	2
RAM	8	2	4	10	8	4	10
Provisioned Disk Size	60	60	60	250	120	60	60

The XenDesktop provisioning was done with the Citrix Provisioning Service (PVS) version 7.0, Citrix Desktop Delivery Controller (DDC) and Citrix StoreFront 2.1. The PVS server is used to create and provisions the desktops. The DDC server is used to manage, maintain, and optimize the virtual desktop connections. The Citrix StoreFront component was used for authenticating users to Microsoft Active Directory.

To simulate desktop load with XenDesktop, we used Login VSI 3.7. Login VSI is an industry standard load testing tool for virtualized desktop environments. Configuration and administration details for Citrix XenDesktop and Login VSI can be found here:

Citrix XenDesktop

Login VSI

The Citrix PVS, DDC and StoreFront components along with the Microsoft SQL Database, System Center and Domain Controller VMs were placed on two dedicated infrastructure hosts. Meanwhile, the Login VSI launchers were spread out across three dedicated hosts each with 15 launchers.

Virtual Desktops

The following table describes the configuration of the desktops.

Desktop OS	Windows 7 32-bit
vCPU	1
Memory	1.5
XenDesktop	Virtual Desktop Agent
Applications	MS Office, Adobe Reader, Internet Explorer

Test Environment Configuration

For the configuration of the test environment we will specifically call out where the configuration strays from the standard installation and configuration guides provided by Citrix, Microsoft, and SolidFire. In this process there are several validation specific configuration steps to be noted;

1. Virtualization Environment

2. Storage Network Configuration
a. SolidFire Volume Configuration
b. Infrastructure VMs Volume

3. Write Cache File Volumes

4. Citrix Provisioning Services Configuration

5. Login VSI Test Setup

Virtualization Environment

For the test environment, we used Microsoft System Center's Virtual Machine Manager to deploy the Hyper-V hosts and to configure and manage the virtual desktop clients. No special tuning was required here.

Storage Network Configuration

Each SolidFire Node has dual 10G ports for redundancy. These can either be configured for ALB or LACP link aggregation based upon the switching capabilities available. In this environment LACP link aggregation was used.

SolidFire Volume Configuration

With SolidFire all storage resources are virtualized making volume configuration extremely simple. For each volume, administrators simply need to specify how large (GBs) and how fast (IOPS). Within the performance configuration, administrators are able to set minimum, maximum, and burst IOPS values for each volume. The minimum IOPS guarantees a volume will always get that level of performance. Max and burst settings allow applications to use free resources to spike as needed without impact to other volumes on the storage system.

Infrastructure VMs Volume

For the infrastructure volume we provisioned 200GB of capacity. For performance we set the min to 1,000 IOPS, max to 4,000 IOPS and burst to 8,000 IOPS. Based on the test results these numbers could have been optimized to match the actual usage, but in this case there was little benefit in doing this as the resource consumptions was minimal in the context of the overall system.

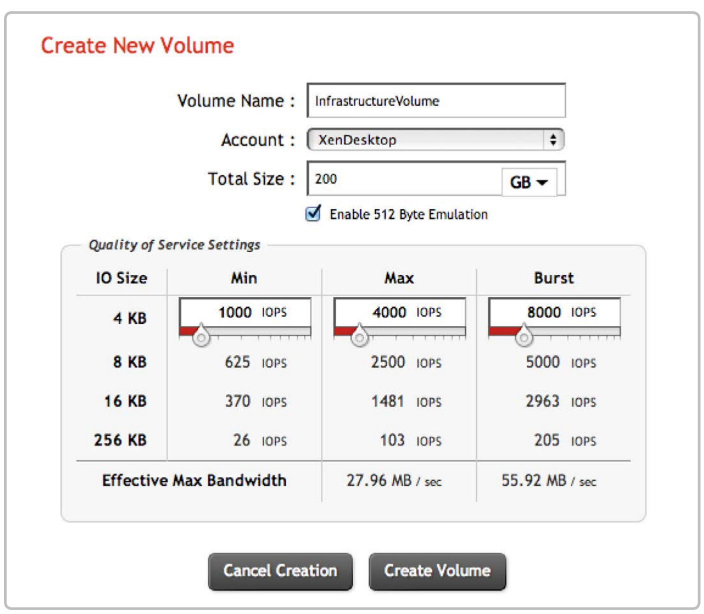


Figure 4: Infrastructure Volume Provisioning

Write Cache File Volumes

To support the XenDesktop write cache files, we provisioned 11 SolidFire volumes, each with 1TB of capacity. Performance for each write cache volume was set to a min of 1,750 IOPS, max at 7,000 IOPS and burst at 17,500 IOPS. Each cache file was 6GB in size and each volume supported up to 70 users. The required storage for each host was 420GB, but since SolidFire thin provisions globally, we choose to simply provision 1TB volumes across all hosts to leave room for overhead.

Extensive testing was performed to determine the most appropriate QoS settings for the write cache volumes based on their performance characteristics. Based on the defined workload, approximately 25 IOPS were needed per VM. However, these amounts may be higher or lower depending on the desktop profile. Based upon this workload the QoS should be set as follows:

minIOPS = (Number of VM's per Volume) * 25

maxIOPS = (Number of VM's per Volume) * 100

burstIOPS = (Number of VM's per Volume) * 250

In the current setup we used 70 VM's per volume. The resulting Write Cache File Volume Settings were: minIOPS=1750, maxIOPS=7000, burstIOPS=17500. These allocations ensure consistent, guaranteed performance with the ability to burst during boot storms and also accommodate other high performance activities.

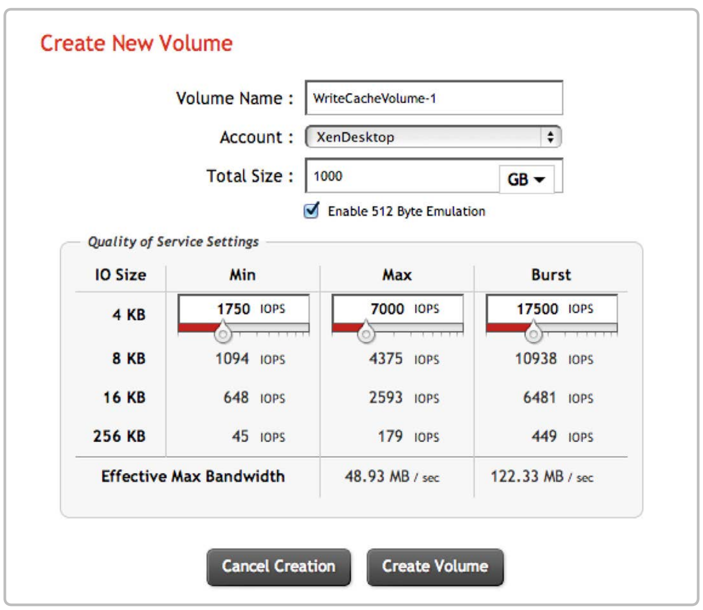


Figure 5: Write Cache Volume Provisioning

Citrix Provisioning Services Configuration

Citrix Provisioning Services (PVS) provisions desktops from a single image. It uses a software streaming approach to provision desktops in real-time from a single image. In our test environment the PVS service was installed on a Windows 2008 R2 VM with 2 vCPU and 8 GB of RAM. The vDisk (virtual desktop disk image) was stored on the PVS server and streamed across the network to the virtual desktop hosts infrastructure during boot. Using a pooled-random deployment model, there is only one copy of the desktop image. The reads occur from locally from RAM and the writes take place on the cache files. The PVS write cache file was located on the target-device's hard drive and stored on SolidFire storage. This write cache option frees up the Provisioning Server since it does not have to process write requests and is not limited to the finite RAM resources.

Login VSI Test Setup

VSIshare

To store the results gathered by Login VSI, a networked file share (VSIshare) is required. The file share also serves as a single storage repository for the Login VSI binaries. For our testing a 1TB VSIshare was provided as network attached storage using OpenFiler and attached via CIFS to the infrastructure hosts.

Launchers

Each Login VSI launcher is capable of driving up to 50 desktops. To ensure we didn't bottleneck during load generation, we dedicated three physical hosts for the launcher VMs. Each host had 15 launchers giving us 45 total launchers. We then evenly distributed the 750 desktops across all of the launchers.

Results

There were two key objectives identified at the outset of the testing:

1. Validation - Validate SolidFire's ability to easily handle the load of a 750 desktop environment with XenDesktop
2. Simplified Administration - Prove that the SolidFire architecture would deliver an exceptional administrative experience

Validation

Our first objective was to demonstrate our ability to support a minimum of 750 users with Citrix XenDesktop 7. For this test we used Login VSI to generate load and validate performance on 750 virtual desktops in parallel.

The first step in this process was to provision the 750 desktops. Microsoft System Center was configured to do this sequentially across the 11 hosts in batches of 10 desktops at a time. The first 10 hosts were each provisioned with 70 desktops each. The final remaining host received the last 50 desktops.

As observed in Figure 6 the peak performance during the desktop provisioning process was 1,500 IOPS. SolidFire easily handled the IO, while maintaining sub 1ms latency. Handling the IO with low latency is critical for booting large quantities of desktops quickly and predictably.

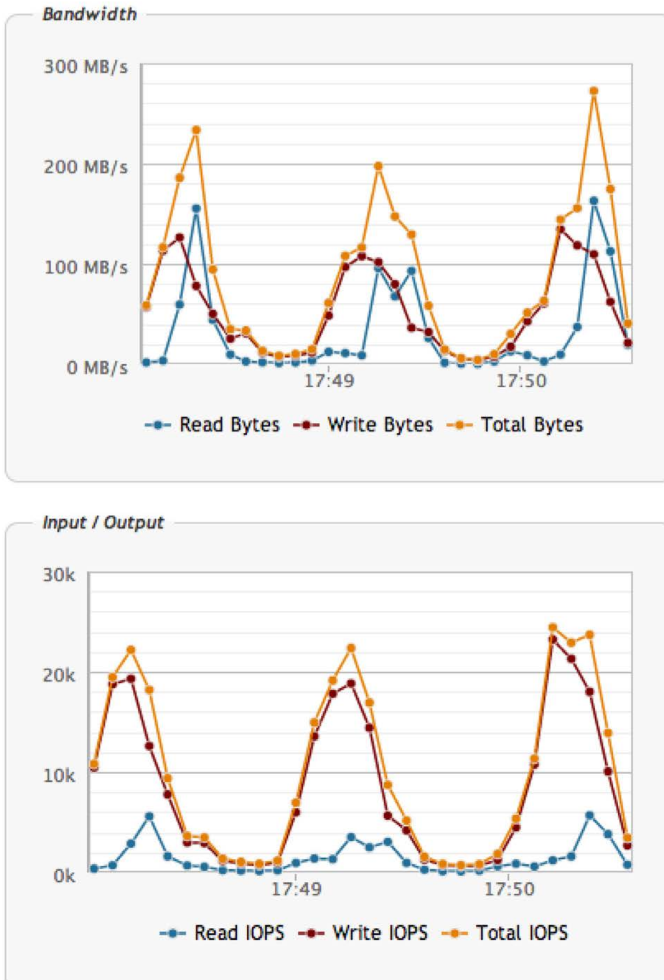


Figure 6: SolidFire Cluster Performance During Desktop Provisioning

Following the provisioning process, we used Microsoft System Center to boot the desktops. Our expectation was that the boot process would generate the most IO load in this testing process. System Center was scheduled to boot all 750 desktops within a 40 minute span. The peak load observed during this process was 25,000 IOPS (Figure 7). The simulated boot storm used 1/8 of the provisionable performance available from a 4-node SF-3010 cluster leaving plenty of room to scale desktops or add additional applications.

The boot storm workload was distributed across all 11 of the desktop volumes. Traffic was very bursty in nature, ranging from minimal performance to spikes of up to several thousand IOPS as each cluster of desktops was powered on.

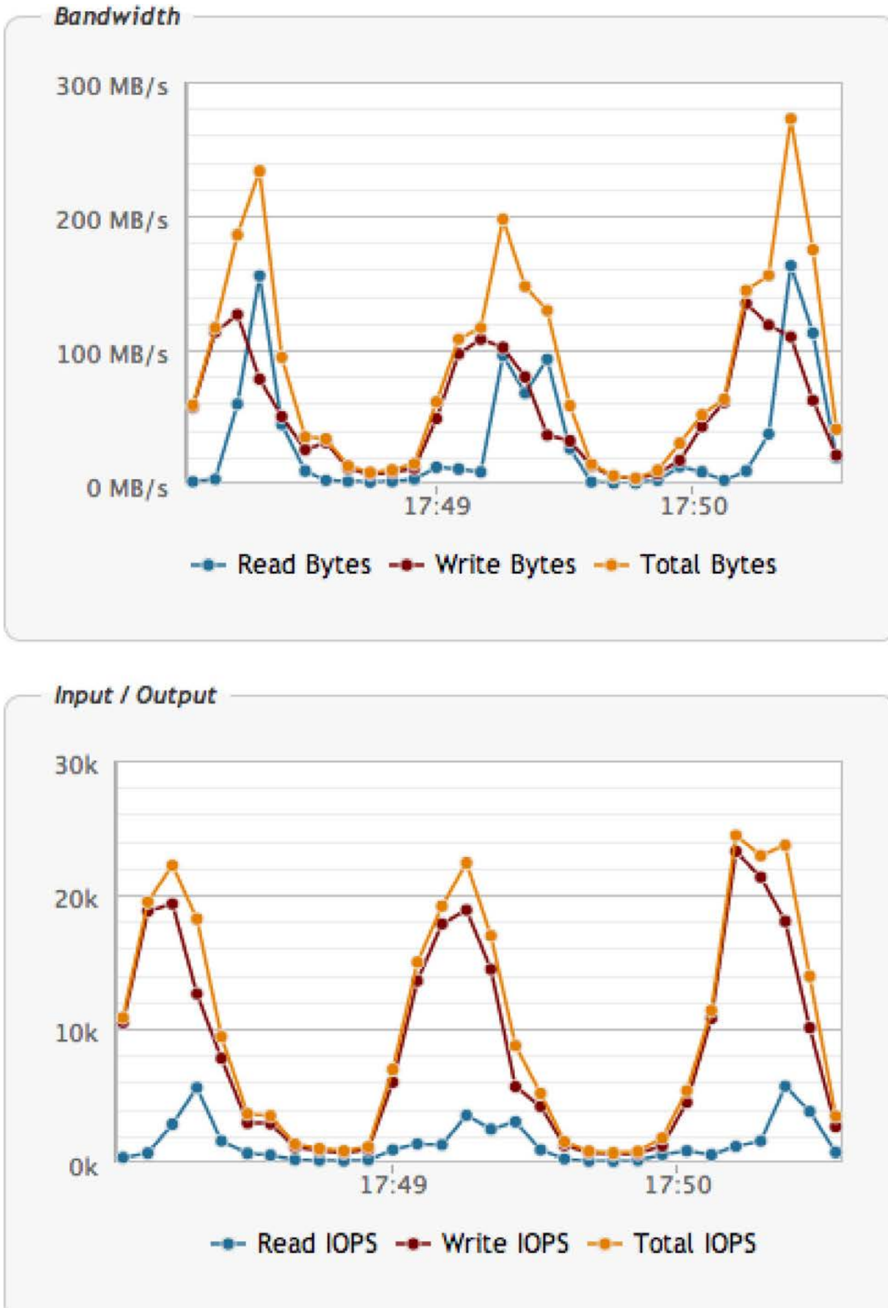


Figure 7: SolidFire Cluster Performance During Boot

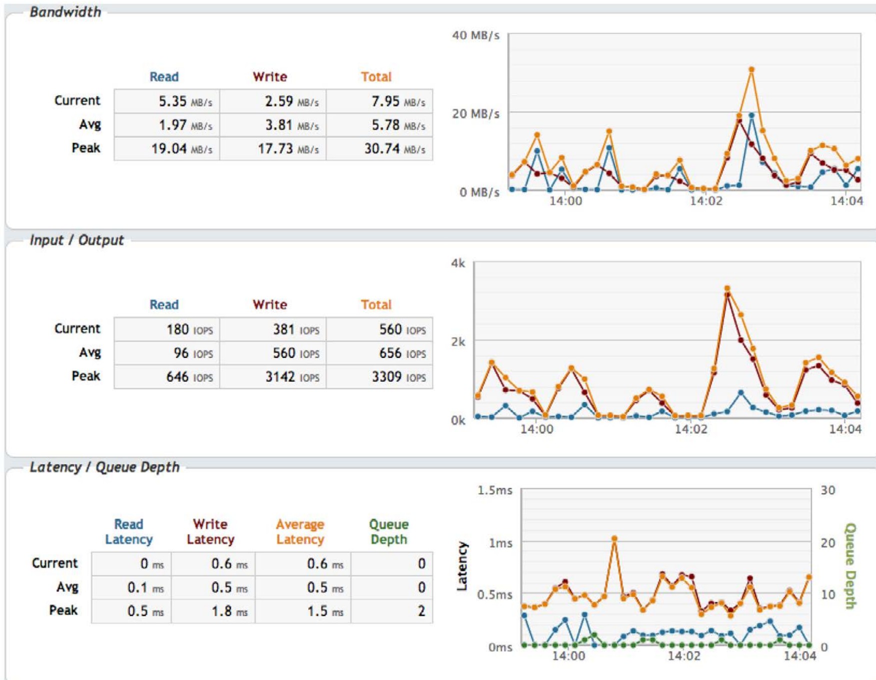


Figure 8: SolidFire Volume Performance During Boot

After all 750 desktops were up and running we used Login VSI to drive load and validate desktop performance. To validate SolidFire, Login VSI applied a "medium workload" as outlined in Table 1 to all 750 desktops. The Login VSI medium workload emulates common knowledge worker tasks using Office, Internet Explorer (IE), PDF and Java/FreeMind as illustrated in Figure 8. The Login VSI launchers continued to loop the workload test until all 750 desktops were running in parallel.

Login VSI outlines the following workflow for the validation.

- Once a session has been started the workload will repeat (loop) every 48 minutes.
- The loop is divided in 4 segments, each consecutive Login VSI user logon will start a different segments. This ensures that all elements in the workload are equally used throughout the test. During each loop the response time is measured every 3- 4 minutes.
- The medium workload opens up to 5 applications simultaneously.
- The keyboard type rate is 160 ms for each character.
- Approximately 2 minutes of idle time is included to simulate real–world users.

Each loop will open and use:

- Outlook, browse messages.
- Internet Explorer, browsing different webpages and a YouTube style video (480p movie trailer) is opened three times in every loop.
- Word, one instance to measure response time, one instance to review and edit a document.

- Doro PDF Printer & Acrobat Reader, the word document is printed and reviewed to PDF.
- Excel, a very large randomized sheet is opened.
- PowerPoint, a presentation is reviewed and edited.
- FreeMind, a Java based Mind Mapping application.

Source: http://www.loginvsi.com/documentation/index.php?title=All_settings

Figure 9: Login VSI Workflow

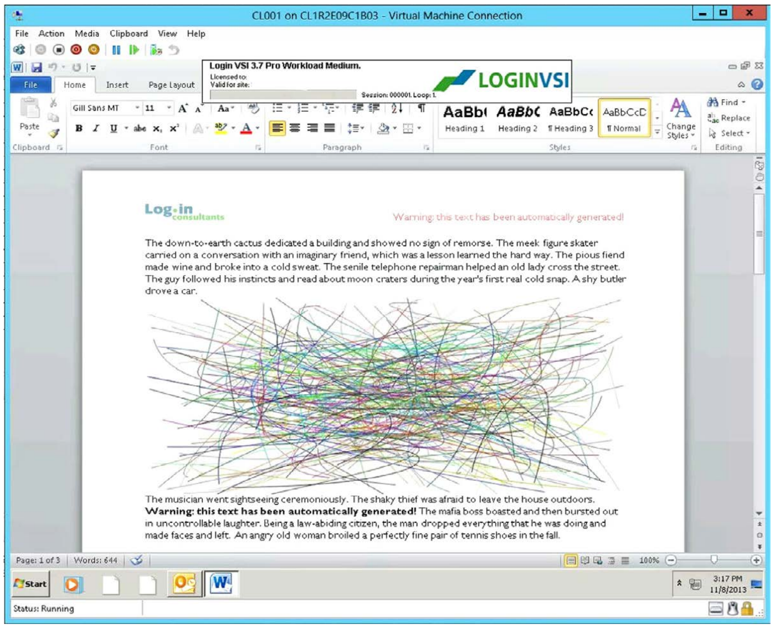


Figure 10: Login VSI Simulating Work in a Word Document

During the test Login VSI continues to monitor desktop response time to determine if the desktop is receiving an adequate level of system resources (compute, network and storage) to function properly. As soon as response time drops below an acceptable level, regardless of which resource is saturated, the system is considered to be at its max. Login VSI reports the number of desktops as the VSImax when this occurs. Our objective here was to ensure that the SolidFire storage system was capable of handling 750 desktops without reaching VSImax. Specifically, we wanted to demonstrate load to 750 desktops without a storage resource bottleneck. Figure 11 shows our results from Login VSI. The key takeaway here is that VSImax was not reached.

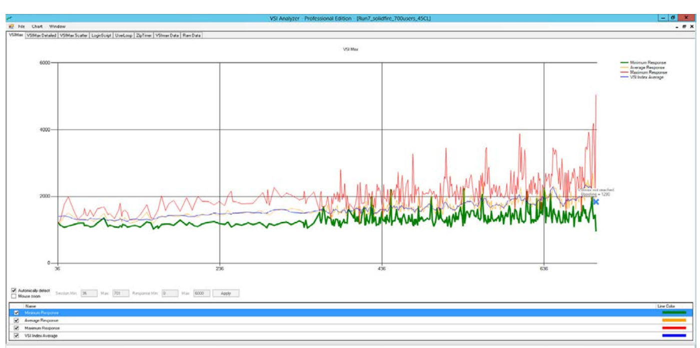


Figure 11: Login VSI Baseline

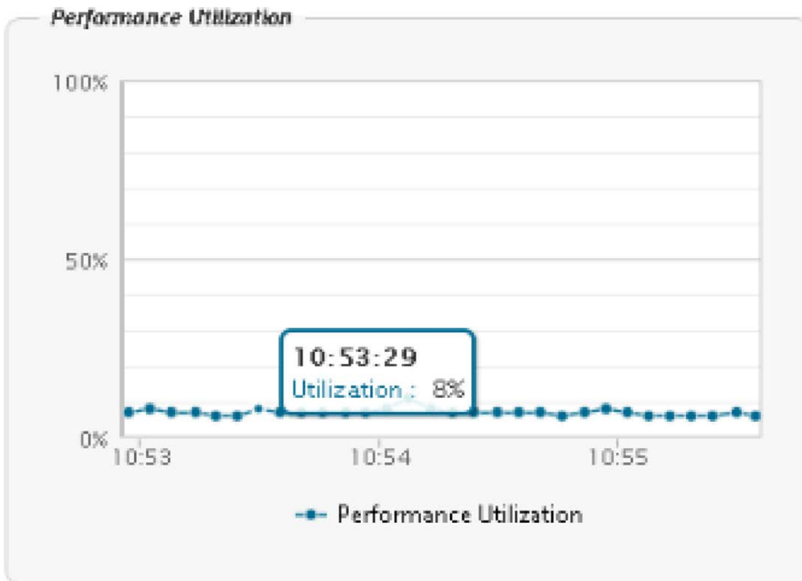


Figure 12: Performance Utilization at the End of the Run

To understand how much further SolidFire could go before maxing out storage resources, we studied total system performance (IOPS and latency) as well as capacity (GBs used) from the SolidFire UI during the test. This analysis implies SolidFire is capable of support 1000+ virtual desktops per node. This specific test setup validated 750 desktops. At max load the 750 desktops consumed approximately 8% of the performance available on the SolidFire cluster (Figure 11) and latency consistently averaged at or below 1ms (Figure 12).

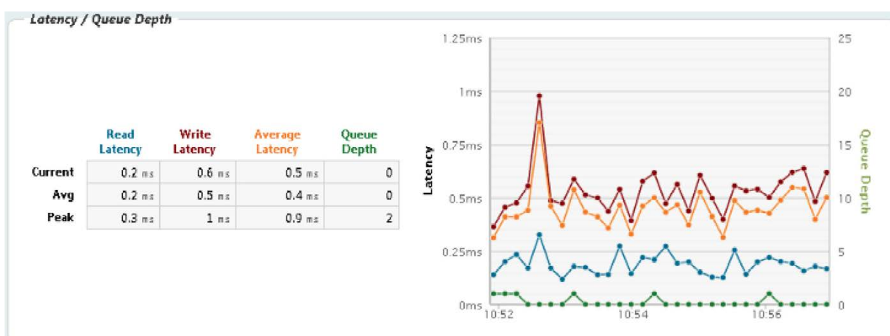


Figure 13: Volume Latency at the End of Run

Storage capacity requirements in large scale XenDesktop deployments can vary greatly depending on the type of desktop and provisioning method. Environments that have persistent desktops will consume significantly more capacity than environments that discard the desktop after use. Using a storage system like SolidFire, which has the ability to perform in-line compression, deduplication and thin provisioning ensures optimized capacity regardless of machine type or provisioning method.

This test environment used PVS to provision a pool of 750 desktops. Using PVS automatically eliminates desktop image file duplication. This process removes any measurable benefit from SolidFire's data reduction on the desktop template. As a result, the majority of the SolidFire data reduction benefit in our test environment came from the desktop write cache files, and the infrastructure and management VMs. Even in a VDI environment where the desktop image is already deduplicated, the SolidFire cluster was able to realize an additional 18x data reduction (factoring in both deduplication and compression) (Figure 14). Total used capacity for the 750 desktops was slightly under 25GB (Figure 15).

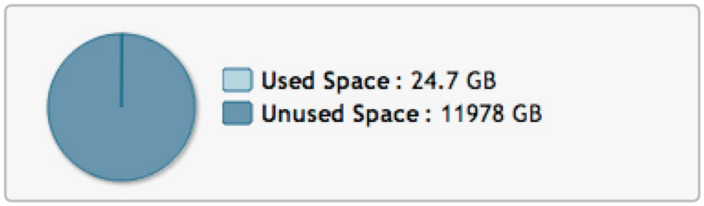


Figure 14: Storage Capacity for Desktops

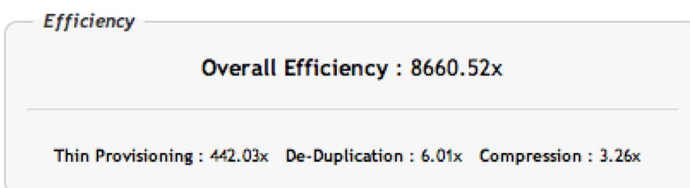


Figure 15: Cluster Capacity Efficiency

All remaining system performance (IOPS) and capacity (GBs) can be easily provisioned to support additional desktops or applications. The table below is provided to help administrators envision the scale potential of the SolidFire system to accommodate larger desktop environments.

Nodes	Per node	5 Node Cluster	5 Node Cluster	5 Node Cluster
Desktops	1,000	5,000	10,000	15,000
Capacity	12 TB	60 TB	120 TB	180 TB
IOPS	50,000	250,000	500,000	750,000

Simplified Administration

VDI projects can get derailed in a number of different ways. Most often, projects go awry when storage performance can't keep up with desktop growth and the end user experience suffers. Desktop profiles can change and the new requirements can require downtime or a massive reconfiguration of the backend storage subsystem. Budgets can be strained when a VDI PoC moves into production and the additional storage resources needed to accommodate additional desktops wasn't budgeted for. SolidFire's all flash scale-out architecture with granular performance controls, makes it easy to:

- Manage Unknown Performance Requirements
- Handle Unpredictable Workloads
- Stay on Budget

Eliminate Storage Management Complexities

Manage Unknown Performance Requirement With SolidFire, these dynamic resource requirements are easily handled through the SolidFire UI or the non-disruptive addition of more performance and/or capacity. As unforeseen requirements surface, administrators can tune performance and/or capacity on the fly to accommodate the additional demand.

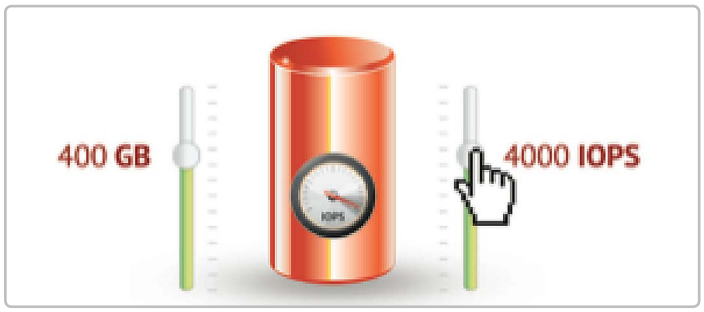


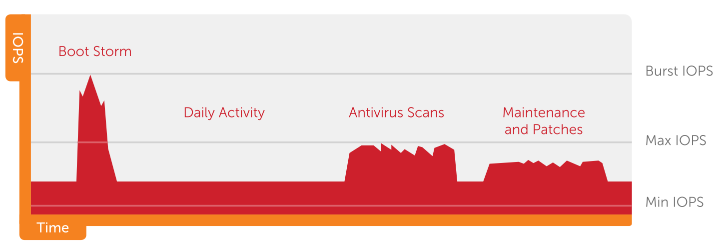
Figure 16: SolidFire Performance Virtualization

In VDI environments, storage performance is typically the bottleneck to scale. With SolidFire, each 1U storage node in a SolidFire array is capable of 50,000 IOPS and scales linearly with each node. So we can simply calculate the max number of desktops per node and then scale nodes as more desktops are needed.

Handle Unpredictable Workloads

SolidFire's QoS functionality lets administrators set and control fine-grain performance levels for every volume. For each volume a minimum, maximum and burst number of IOPS can be set. In VDI environments, having the ability to guarantee the minimum amount of I/O, yet be able to burst performance for short periods ensures that your desktops will get the performance they require without compromise.

Controlling Unpredictable Workloads



Stay on Budget

SolidFire leverages three in-line data reduction techniques: deduplication, compression, and thin provisioning. Each technique operates in real-time across the system. With this combination of in-line data reduction and high capacity utilization, the SolidFire system costs the same or less than traditional disk-based solutions and requires a fraction of the space, power, and cooling. As tested, a fully utilized SolidFire SF-3010 system can achieve a storage cost per desktop of less than $50.00 in a VDI environment with additional IOPs available to accommodate other business applications.

# of Desktops	Peak IO (Boot)	Est. $ per Desktop	Remaining Available IOPs
4,000	51%	$50	98,667
3,000	38%	$67	124,000
2,000	25%	$100	149,333
750	9.5%	$267	181,000

Note: Remaining available IOPS can be used for additional desktops or any other business application(s)/workload(s)

In addition to delivering more optimal storage efficiency, SolidFire enables administrators to grow the cluster in small 1U increments without downtime or performance impact. To grow the cluster you simply add another node containing both capacity and performance. Sized for 1000 desktops today, if there is suddenly a need to add 200 desktops this growth can be accommodated without any performance degradation or change to user experience. Most importantly, there is no need to investment in an additional storage controller to accommodate the expanded desktop infrastructure.

Eliminate Storage Management Complexities

The days of planning out your RAID groups, LUNs, pools and drive spares are gone. With SolidFire, when creating a volume you simply specify the capacity requirement along with a minimum, maximum and burst IOPS setting for that volume. In addition, all storage management tasks can be handled directly through the SolidFire UI. Alternatively, system management can be completely automated, or integrated into 3rd party management tools, through SolidFire's comprehensive REST-based APIs.

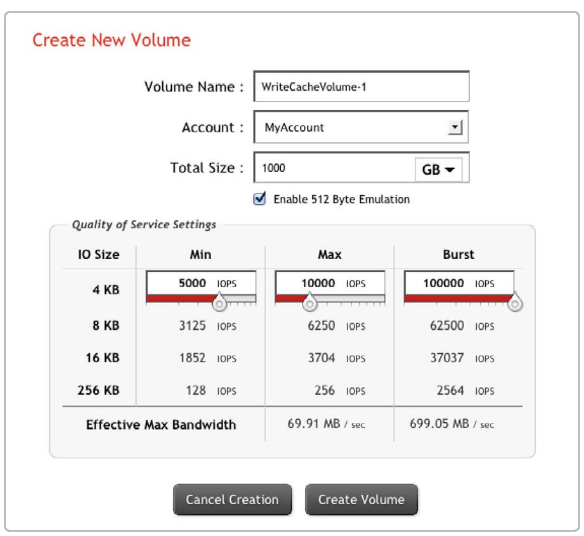


Figure 17: SolidFire QoS Settings

Summary

The 750 desktop test with Login VSI documented within this report was designed to prove interoperability with XenDesktop and demonstrate SolidFire's ability to easily handle a large scale virtual desktop deployment. The resulting SolidFire performance validated above, along with the key design considerations outlined at the outset of this document, should help you gain increased confidence in deploying SolidFire storage in your VDI infrastructure. Leveraging the features of SolidFire helps deliver significant advancements in the end user desktop experience in tandem with a scalable, dynamic and cost effective storage infrastructure whose benefits span the entire organization.

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Hong Kong, China

About Citrix Ready

Citrix Ready identifies recommended solutions that are trusted to enhance the Citrix Delivery Center infrastructure. All products featured in Citrix Ready have completed verification testing, thereby providing confidence in joint solution compatibility. Leveraging its industry leading alliances and partner eco-system, Citrix Ready showcases select trusted solutions designed to meet a variety of business needs. Through the online catalog and Citrix Ready branding program, you can easily find and build a trusted infrastructure. Citrix Ready not only demonstrates current mutual product compatibility, but through continued industry relationships also ensures future interoperability. Learn more at **www.citrix.com/ready**.

About SolidFire

SolidFire is the market leader in high-performance data storage systems designed for large-scale public and private cloud infrastructure. Leveraging an all-flash scale-out storage architecture with patented volume-level Quality of Service (QoS) controls, providers can now guarantee storage performance to thousands of applications within shared infrastructures. By using real-time data reduction techniques and system-wide automation, SolidFire is fueling new and profitable block-storage services that are advancing the way the world uses the cloud.