



Technical Report

# NetApp and VMware vSphere Storage Best Practices

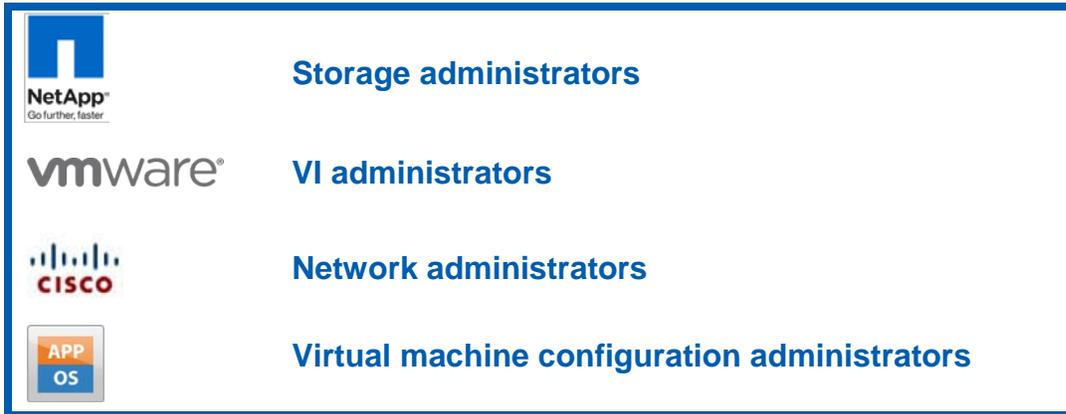
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# 1 INTRODUCTION



## 1.1 EXECUTIVE SUMMARY

NetApp® technology enables companies to extend their virtual infrastructures to include the benefits of advanced storage virtualization. Our unified storage platforms provide industry-leading technologies in the areas of storage efficiencies, instantaneous virtual machine (VM) and datastore cloning for virtual servers and virtual desktops, and virtual data center backup and business continuance solutions.

This technical report reviews the best practices for implementing VMware® vSphere™ with NetApp unified storage arrays. NetApp has been providing advanced storage features to VMware solutions since 2001. During this time, NetApp has developed operational guidelines for storage arrays running Data ONTAP® and ESX/ESXi Server. These techniques, which are described in this report, have been documented and are referred to as “best practices.”

## 1.2 IMPLEMENTING BEST PRACTICES

Unless stated otherwise, the recommendations and best practices presented in this document should be considered as deployment requirements. NetApp and VMware will still provide support even if you do not implement all of the contained best practices. However, disregarding any of these practices commonly results in the need to implement them at a later date, on a much larger environment, and often with the requirement of application downtime. For these reasons, NetApp recommends implementing all of the best practices defined within this document as a part of your initial deployment or migration.

All recommendations in this document apply specifically to deploying vSphere on NetApp. Therefore, the contents of this document supersede all recommendations and best practices expressed in other NetApp documents.

**Note:** Data ONTAP version 7.3.1.1 or later is required to implement the NetApp vSphere plug-ins. If you plan to run an older version of Data ONTAP, you might need to use a manual process to apply some of the configuration changes described in this document.

In addition to this document, NetApp and our partners offer professional services to architect and deploy the designs contained within this document. These services can provide optimal virtual storage architecture for your virtual data center.

### **1.3 INTENDED AUDIENCE**

This best practice document is part of the NetApp Technical Library and is intended for use by individuals responsible for architecting, designing, managing, and supporting VMware virtual infrastructures. Readers of this content should, at a minimum, be familiar with concepts pertaining to VMware ESX/ESXi Server 4.0, vCenter™ Server 4.0, and NetApp Data ONTAP 7G.

We have identified individuals in specific roles who will find the content in this document useful. The administrative roles required to implement the technology and/or configurations are presented at the beginning of each section.

### **1.4 DOCUMENT ROADMAP**

This document, TR-3749, is the main document in a set of documents from NetApp covering virtualization on NetApp, specifically with VMware products. This document is specifically in reference to VMware vSphere 4. Earlier versions of this document contained manual processes that were later replaced by plug-in tools and the manual processes were moved to appendixes. The manual processes have now been moved to a separate companion document, [TR-3880 CLI Configuration Processes for NetApp and VMware vSphere Storage Arrays Running Data ONTAP and ESX/ESXi Server](#).

Additional documents on specific technologies and solutions are listed in section 9 Document References.

## 2 AN OVERVIEW OF VMWARE STORAGE OPTIONS

This section applies to:



Storage administrators



VI administrators

### 2.1 AN INTRODUCTION TO STORAGE IN A VIRTUAL INFRASTRUCTURE

VMware ESX supports three types of storage configurations when connecting to shared storage arrays: VMware Virtual Machine File System (VMFS) datastores, network-attached storage (NAS) datastores, and raw device mappings (RDMs). It is assumed that customers understand that shared storage is required to enable high-value VMware features such as high availability (HA), Distributed Resource Scheduler (DRS), VMotion®, and fault tolerance. The goal of the following sections is to provide customers with the information required to design their virtual data center.

VMware virtualization technology makes it easy for customers to leverage all of these storage designs at any time or simultaneously. The following section reviews these storage options and summarizes the unique characteristics of each technology within a virtual architecture.

### 2.2 THE VALUE OF MULTIPROTOCOL STORAGE ARRAYS

The virtualization of a data center results in physical systems being virtualized as part of a cost-savings effort to reduce both capex and opex through infrastructure consolidation and increased operational efficiencies. These efforts result in multiple VMs sharing physical resources, including shared storage pools known as datastores. Virtualizing demanding, business-critical applications such as e-mail or database servers results in gains in operational efficiencies. This latter group of systems might share server resources but is typically configured with exclusive access to the storage it requires.

VMware and NetApp both offer technologies that natively support multiple storage protocols. These technologies allow customers to deploy best-in-class virtual data centers that leverage the strengths inherent when using these technologies together. This discussion goes beyond the comparison of storage area network (SAN) versus NAS and is rather a consideration of the operational value based on the type of storage network interconnect available to a virtual data center.

Whether your storage network is Fibre Channel (FC) or Ethernet (NFS, iSCSI, and FCoE), these technologies combine with NetApp storage to scale the largest consolidation efforts and to virtualize the most demanding applications without sacrifice or the need to deploy separate hardware to meet the needs of either environment. This is virtualization, which is valuable in a storage array platform.

### 2.3 THE 80/20 RULE

When designing the storage architecture for a virtual data center, you can apply what we refer to as the 80/20 rule, which is that 80% of all systems virtualized are for consolidation efforts. The remaining 20% of the systems are classified as business-critical applications. Although these applications can be virtualized successfully, they tend to be deployed on shared storage pools but in what we refer to as isolated datasets.

## THE CHARACTERISTICS OF CONSOLIDATION DATASETS

Consolidation datasets have the following characteristics:

- The VMs do not require application-specific backup and restore agents.
- The dataset is the largest in terms of the number of VMs and potentially the total amount of storage addressed.
- Individually, each VM might not address a large dataset or have demanding IOP requirements; however, the collective whole might be considerable.
- These datasets are ideally served by large, shared, policy-driven storage pools (or datastores).

## THE CHARACTERISTICS OF ISOLATED DATASETS (FOR BUSINESS-CRITICAL APPLICATIONS)

Isolated datasets have the following characteristics:

- The VMs require application-specific backup and restore agents.
- Each individual VM might address a large amount of storage and/or have high I/O requirements.
- Storage design and planning apply in the same way as with physical servers.
- These datasets are ideally served by individual, high-performing, nonshared datastores.

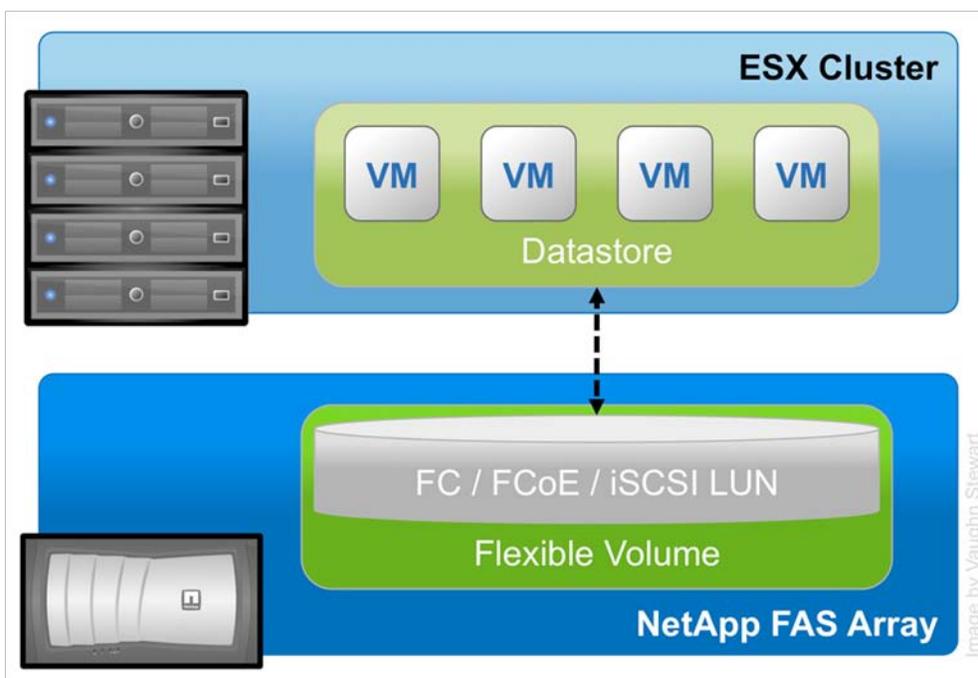
Consolidated datasets work well with Network File System (NFS) datastores because this design provides greater flexibility in terms of capacity than SAN datastores when managing hundreds or thousands of VMs. Isolated datasets run well on all storage protocols; however, some tools or applications might have restrictions around compatibility with NFS and/or VMFS.

Unless your data center is globally unique, the evolution of your data center from physical to virtual will follow the 80/20 rule. In addition, the native multiprotocol capabilities of NetApp and VMware will allow you to virtualize more systems more quickly and easily than you could with a traditional storage array platform.

## 2.4 VMFS DATASTORES

The VMware VMFS is a high-performance clustered file system that provides datastores, which are shared storage pools. VMFS datastores can be configured with logical unit numbers (LUNs) accessed by FC, iSCSI, or Fibre Channel over Ethernet (FCoE). VMFS allows traditional LUNs to be accessed simultaneously by every ESX server in a cluster.

Figure 1) ESX cluster connected to a VMFS datastore using FC, FCoE, or iSCSI LUNs.



VMFS provides the VMware administrator with a fair amount of independence from the storage administrator. By deploying shared datastores, the VMware administrator can provision storage to VMs as needed. In this design, most data management operations are performed exclusively through VMware vCenter Server.

Applications traditionally require storage considerations to make sure their performance can be virtualized and served by VMFS. With these types of deployments, NetApp recommends deploying the virtual disks on a datastore that is connected to all nodes in a cluster but is only accessed by a single VM.

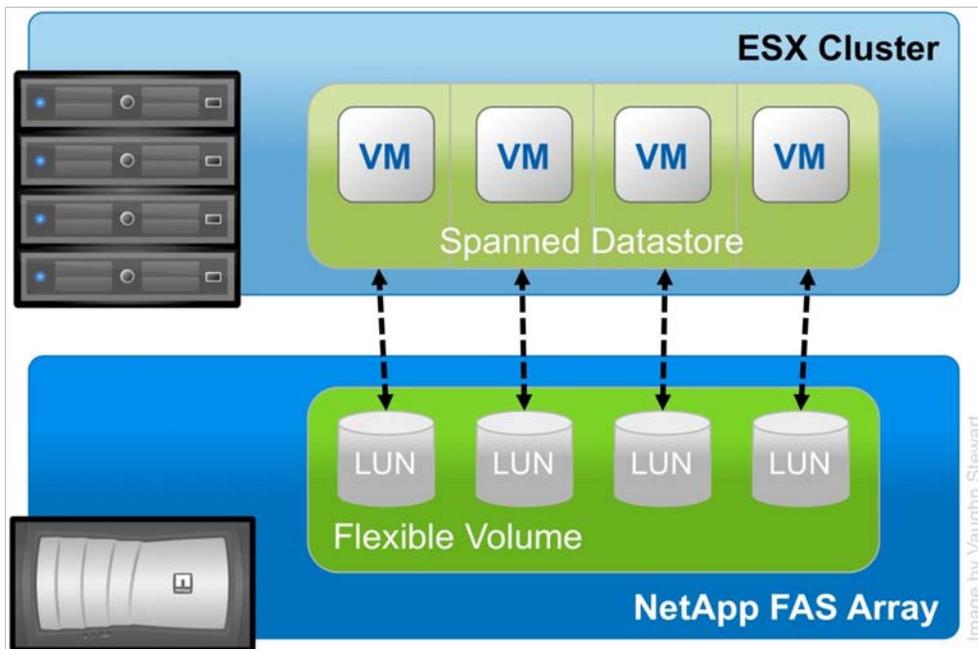
This storage design can be challenging in the area of performance monitoring and scaling. Because shared datastores serve the aggregated I/O demands of multiple VMs, this architecture doesn't natively allow a storage array to identify the I/O load generated by an individual VM.

### SPANNED VMFS DATASTORES

VMware provides the ability of VMFS extents to concatenate multiple LUNs into a single logical datastore, which is referred to as a spanned datastore. Although spanned datastores can overcome the 2TB LUN size limit, they are most commonly used to overcome scaling limits imposed by storage arrays that use per LUN I/O queues. These traditional architectures place a limit on the number of simultaneous commands that can be sent to a LUN at a given time, which can impede overall I/O performance in a datastore.

Storage arrays powered by Data ONTAP are free of this legacy architecture; therefore, NetApp does not recommend the use of spanned VMFS datastores.

Figure 2) ESX cluster connected to a spanned VMFS datastore.



## VMFS DATASTORES ON NETAPP LUNS

NetApp enhances the use of VMFS datastores through many technologies, including array-based thin provisioning; production-use data deduplication; immediate zero-cost datastore clones; and integrated tools such as Site Recovery Manager, SnapManager<sup>®</sup> for Virtual Infrastructure, the Rapid Cloning Utility (RCU), the Virtual Storage Console (VSC), and SANscreen<sup>®</sup> VM Insight. Our queue depth free LUN architecture allows VMFS datastores to scale greater than with traditional array architectures in a natively simple manner.

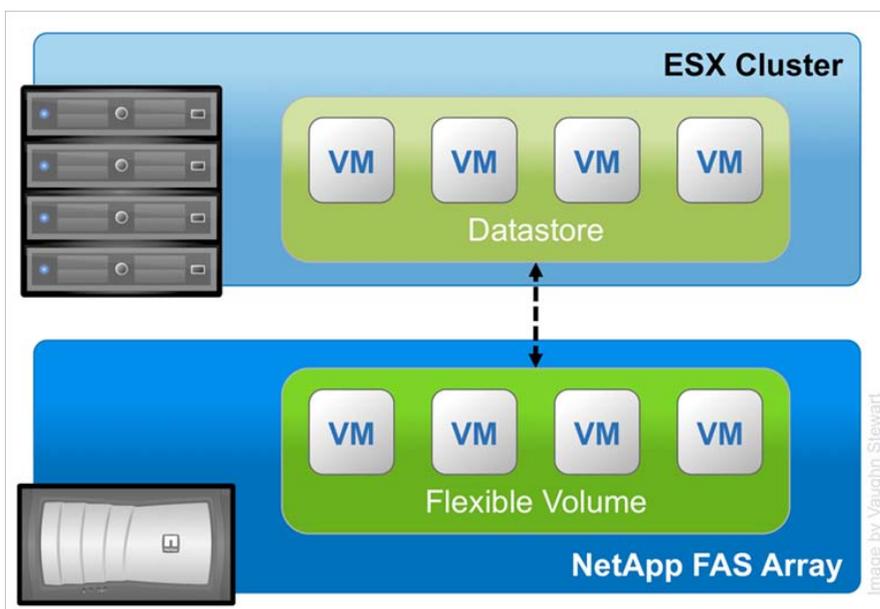
## 2.5 NFS DATASTORES

vSphere allows customers to leverage enterprise-class NFS arrays to provide datastores with concurrent access by all of the nodes in an ESX cluster. This access method is very similar to the one with VMFS. The NetApp NFS provides high performance, the lowest per-port storage costs, and some advanced data management capabilities.

Figure 3 displays an example of this configuration.

**Note:** The storage layout appears similar to a VMFS datastore; however, each virtual disk file has its own I/O queue directly managed by the NetApp FAS system.

Figure 3) ESX cluster connected to an NFS datastore.



## NFS DATASTORES ON NETAPP

Deploying VMware with the NetApp advanced NFS results in a high-performance, easy-to-manage implementation that provides VM-to-datastore ratios that cannot be accomplished with other storage protocols such as FC. This architecture can result in a 10x increase in datastore density with a correlating reduction in the number of datastores. With NFS, the virtual infrastructure receives operational savings because there are fewer storage pools to provision, manage, back up, replicate, and so on.

Through NFS, customers receive an integration of VMware virtualization technologies with WAFL<sup>®</sup> (Write Anywhere File Layout), which is a NetApp advanced data management and storage virtualization engine. This integration provides transparent access to VM-level storage virtualization offerings such as production-use data deduplication, immediate zero-cost VM and datastore clones, array-based thin provisioning, automated policy-based datastore resizing, and direct access to array-based Snapshot<sup>®</sup> copies. NetApp provides integrated tools such as Site Recovery Manager, SnapManager for Virtual Infrastructure (SMVI), the RCU, and the VSC.

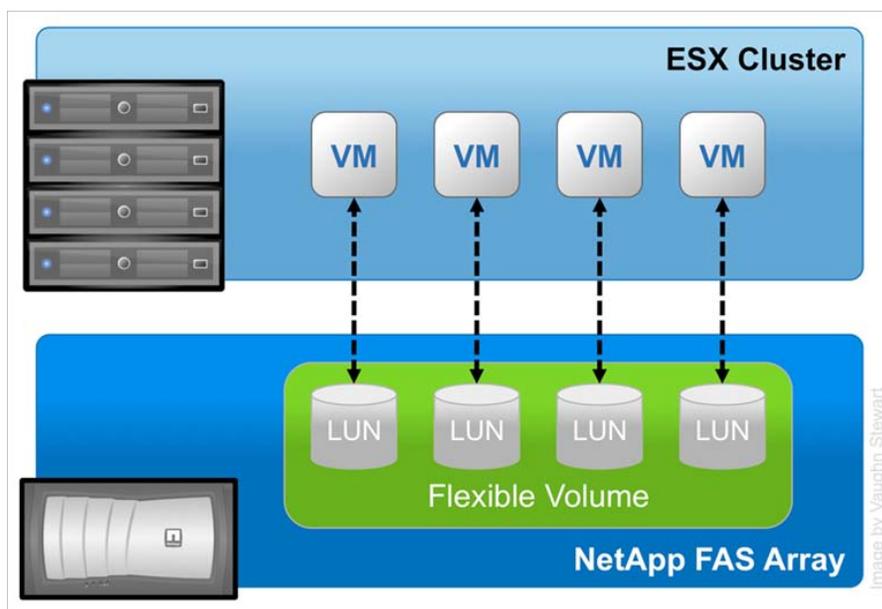
## 2.6 SAN RAW DEVICE MAPPINGS

ESX gives VMs direct access to LUNs for specific-use cases such as P2V clustering or storage vendor management tools. This type of access is referred to as a raw device mapping (RDM) and can be configured with FC, iSCSI, and FCoE. In this design, ESX acts as a connection proxy between the VM and the storage array.

Unlike VMFS and NFS, RDMs are not used to provide shared datastores. Figure 4 shows an example of this configuration.

RDMs are an enabling technology for solutions such as VM and physical-to-VM host-based clustering, such as with Microsoft<sup>®</sup> Cluster Server (MSCS). RDMs provide traditional LUN access to a host; therefore, they can achieve high individual disk I/O performance and can be easily monitored for disk performance by a storage array.

Figure 4) ESX cluster with VMs connected to RDM LUNs using FC or iSCSI.



## RDM LUNS ON NETAPP

RDMs are available in two modes: physical and virtual. Both modes support key VMware features such as VMotion and can be used in both HA and DRS clusters. The key difference between the two technologies is the amount of SCSI virtualization that occurs at the VM level. This difference results in some limitations around MSCS and VMware snapshot use-case scenarios.

NetApp enhances the use of RDMs by providing array-based LUN-level thin provisioning, production-use data deduplication, advanced integration components such as SnapDrive<sup>®</sup>, application-specific Snapshot backups with the SnapManager for applications suite, and FlexClone<sup>®</sup> zero-cost cloning of RDM-based datasets.

**Note:** VMs running MSCS must use the path selection policy of Most Recently Used (MRU). Round Robin is documented by VMware as unsupported for RDM LUNs for MSCS.

## 2.7 DATASTORE COMPARISON TABLES

Differentiating what is available with each type of datastore and storage protocol requires considering many points. Table 1 compares the features available with each storage option. A similar chart for VMware functionality is available in the VMware ESX and ESXi Server Configuration Guide.

Table 1) Datastore supported features.

Capability/Feature	FC/FCoE	iSCSI	NFS
Format	VMFS or RDM	VMFS or RDM	NetApp WAFL
Maximum number of datastores or LUNs	256	256	64
Maximum datastore size	64TB	64TB	16TB or 100TB*
Maximum LUN/NAS file system size	2TB minus 512 bytes	2TB minus 512 bytes	16TB or 100TB*

Capability/Feature	FC/FCoE	iSCSI	NFS
Optimal queue depth per LUN/file system	64	64	N/A
Available link speeds	4 and 8Gb FC and 10-Gigabit Ethernet (10GbE)	1 and 10GbE	1 and 10GbE

\* 100TB requires 64-bit aggregates.

Table 2) VMware supported storage-related functionality.

Capability/Feature	FC/FCoE	iSCSI	NFS
VMotion	Yes	Yes	Yes
Storage VMotion	Yes	Yes	Yes
VMware HA	Yes	Yes	Yes
DRS	Yes	Yes	Yes
VCB	Yes	Yes	Yes
MSCS within a VM	Yes, using RDM for shared LUNs	Initiator in GOS is supported by NetApp	Not supported
Fault tolerance	Yes with eager-zeroed thick VMDKs or virtual mode** RDMs	Yes with eager-zeroed thick VMDKs or virtual mode** RDMs	Yes with eager-zeroed thick VMDKs
Site Recovery Manager	Yes	Yes	Yes
Thin-provisioned VMs (virtual disks)	Yes	Yes	Yes*
VMware native multipathing	Yes	Yes	N/A
Boot from SAN	Yes	Yes with HBAs	No

\* This is the default setting for all VMs on NetApp NFS.

\*\* NetApp SnapDrive for Windows® software does not support virtual-mode RDM devices.

Table 3) NetApp supported storage management features.

Capability/Feature	FC/FCoE	iSCSI	NFS
Data deduplication	Savings in the array	Savings in the array	Savings in the datastore
Thin provisioning	Datastore or RDM	Datastore or RDM	Datastore
Resize datastore	Grow only	Grow only	Grow, autogrow, and shrink
Thin provisioning	Datastore or RDM	Datastore or RDM	Datastore
SANscreen VM Insight	Yes	Yes	Yes
SnapDrive (in guest)	Yes	Yes	No*

Capability/Feature	FC/FCoE	iSCSI	NFS
ESX Host Utilities Virtual Storage Console (VSC 2.0)	Yes	Yes	Yes
VM backup and recovery using VSC 2.0	Yes	Yes	Yes
Provisioning and cloning using VSC 2.0	Yes	Yes	Yes

\* Support for NFS-managed VMDKs in SnapDrive is targeted for a future release of SnapDrive.

Table 4) Supported backup features.

Capability/Feature	FC/FCoE	iSCSI	NFS
Snapshot backups	Yes	Yes	Yes
Replicated backups support SRM	Yes	Yes	Yes
SnapMirror®	Datastore or RDM	Datastore or RDM	Datastore or VM
SnapVault®	Datastore or RDM	Datastore or RDM	Datastore or VM
VMDK image access	VCB	VCB	VCB, VIC File Explorer
VMDK file-level access	VCB, Windows only	VCB, Windows only	VCB and third-party apps
NDMP granularity	Datastore	Datastore	Datastore or VM

## 2.8 VMWARE VIRTUAL DISK FORMATS

Three types of virtual disks are available to VMs in vSphere. You should become familiar with all of them, including their similarities, differences, weaknesses, and strengths.

### THICK VIRTUAL DISK

The thick virtual disk is the traditional virtual disk format that most of us have deployed with most of our VMs. This format preallocates the capacity of the virtual disk from the datastore at the time it is created. This format does not format the VMDK at the time of deployment. This means that data, which needs to be written, must pause while the blocks required to store the data are zeroed out. The operation occurs on demand any time an area of the virtual disk, which has never been written to, is required to store data.

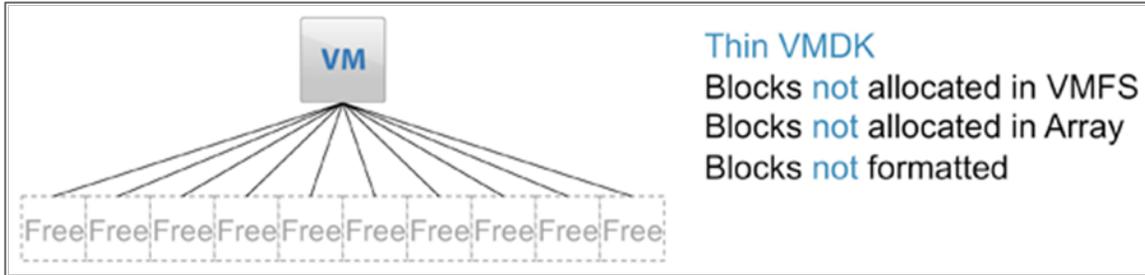
Figure 5) A thick VMDK as it relates to storage blocks on an array.



## THIN VIRTUAL DISK

The thin virtual disk is very similar to the thick format, with the exception that it does not preallocate the capacity of the virtual disk from the datastore when it is created. When storage capacity is required, the VMDK allocates storage in chunks equal to the size of the file system block. For VMFS, this is between 1MB and 8MB (size selected at deployment), and for NFS it is 4KB. The process of allocating blocks on a shared VMFS datastore is considered a metadata operation and as such executes SCSI locks on the datastore while the allocation operation is executed. Although this process is very brief, it does suspend the write operations of the VMs on the datastore.

Figure 6) A thin VMDK as it relates to storage blocks on an array.



Similar to the thick format, thin VMDKs are not formatted at the time of deployment. Therefore, data that needs to be written must pause while the blocks required to store the data are zeroed out. The process of allocating blocks from within the datastore occurs on demand any time a write operation attempts to store data in a block range inside the VMDK that has not been written to by a previous operation.

To summarize the zeroing out and allocation differences between a thick and thin virtual disk, just remember that both suspend I/O when writing to new areas of disk that need to be zeroed. However, before this can occur with a thin virtual disk, it might also have to obtain additional capacity from the datastore.

## EAGER-ZEROED THICK VIRTUAL DISK

The eager-zeroed thick virtual disk is similar to the thick format because it preallocates the capacity of the virtual disk from the datastore when it is created. However, unlike the thick and thin formats, an eager-zeroed thick virtual disk actually formats all of its data blocks at the time of deployment. This virtual disk format does not include or require the allocation and zeroing on-demand processes.

Figure 7) An eager-zeroed thick VMDK as it relates to storage blocks on an array.



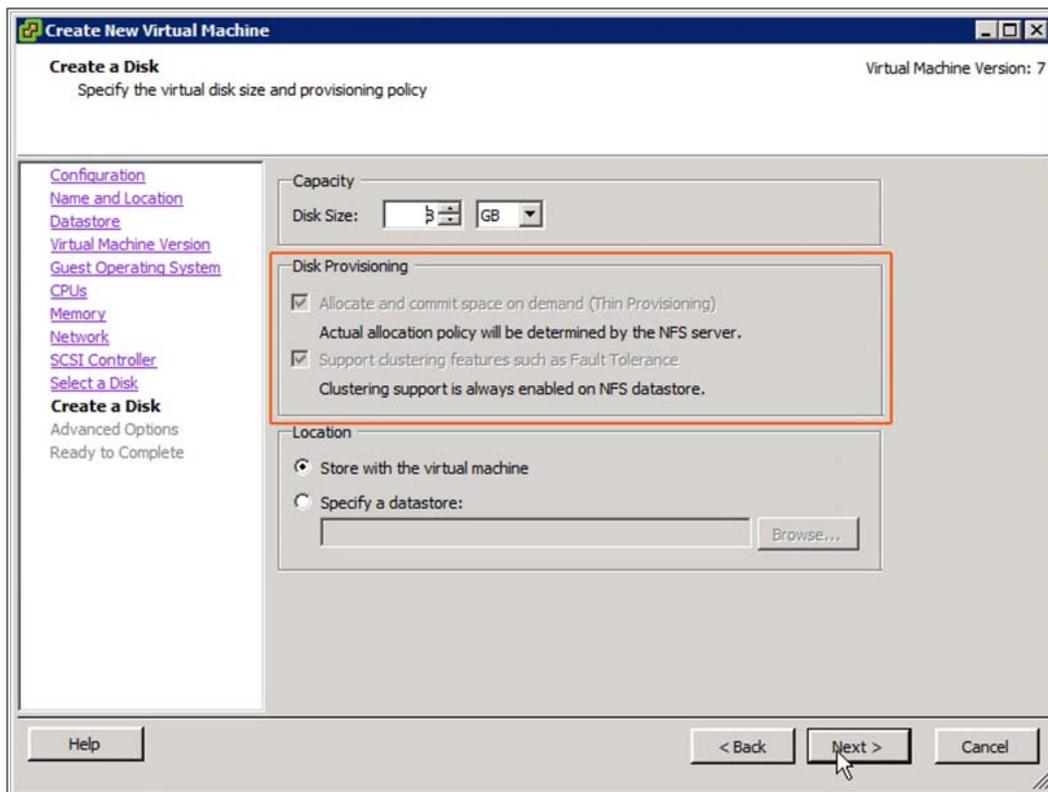
## 2.9 INCREASING STORAGE USE

NetApp offers storage virtualization technologies that can enhance the storage savings provided by VMware thin-provisioning technology. FAS data deduplication and thin provisioning for VMFS datastores and RDM LUNs offer considerable storage savings by increasing storage use of the FAS array. Both of these technologies are native to NetApp arrays and do not require any configuration considerations or changes to be implemented within the ESX servers.

By using the storage savings technologies of NetApp with VMware, you can increase server hardware use to match that of its physical servers. Reducing storage hardware results in reduced acquisition and operational costs.

**Note:** All virtual disks stored on NetApp NFS are thin-provisioned VMDKs and provide VMware clustering support.

Figure 8) VMs deployed on NetApp NFS are always thin provisioned and provide clustering support.



## 2.10 STORAGE ARRAY THIN PROVISIONING

You should be very familiar with traditional storage provisioning and with the manner in which storage is preallocated and assigned to a server or, in the case of VMware, a VM. It is also a common practice for server administrators to overprovision storage to avoid running out of storage and the associated application downtime when expanding the provisioned storage. Although no system can run at 100% storage use, methods of storage virtualization allow administrators to address and oversubscribe storage in the same manner as with server resources (such as CPU, memory, networking, and so on). This form of storage virtualization is referred to as *thin provisioning*.

Traditional provisioning preallocates storage; thin provisioning provides storage on demand. The value of thin-provisioned storage is that storage is treated as a shared resource pool and is consumed only as

each individual VM requires it. This sharing increases the total usage rate of storage by eliminating the unused but provisioned areas of storage that are associated with traditional storage. The drawback to thin provisioning and oversubscribing storage is that (without the addition of physical storage) if every VM requires its maximum possible storage at the same time, there will not be enough storage to satisfy the requests.

## NETAPP THIN-PROVISIONING OPTIONS

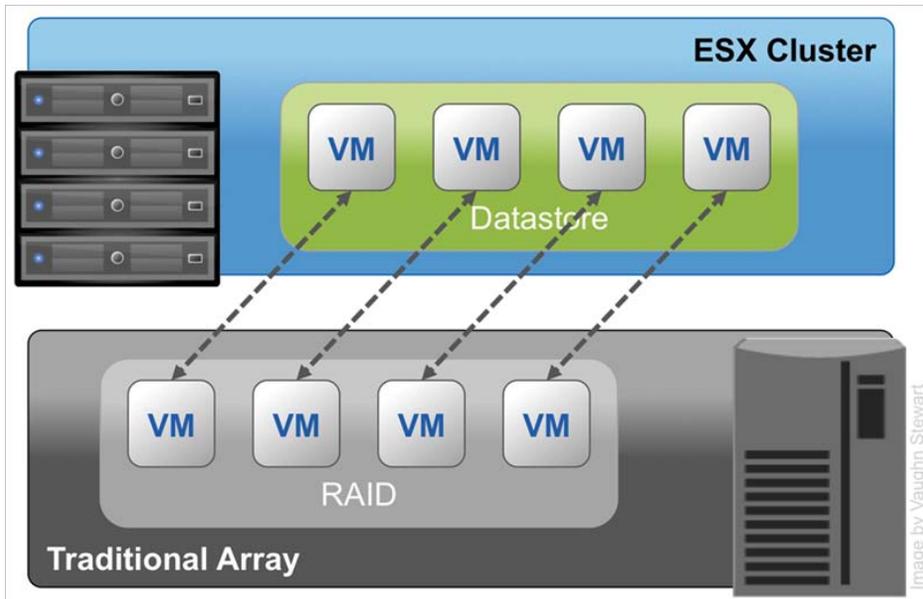
NetApp thin provisioning extends VMware thin provisioning for VMDKs. It also allows LUNs that are serving VMFS datastores to be provisioned to their total capacity while consuming only as much storage as is required to store the VMDK files (which can be either a thick or thin format). In addition, LUNs connected as RDMs can be thin provisioned.

When you enable NetApp thin-provisioned LUNs, NetApp recommends deploying these LUNs in FlexVol<sup>®</sup> volumes that are also thin provisioned with a capacity that is 2x the size of the LUN. By deploying a LUN in this manner, the FlexVol volume acts merely as a quota. The storage consumed by the LUN is reported in FlexVol and its containing aggregate.

## 2.11 STORAGE ARRAY DATA DEDUPLICATION

One of the most popular VMware features is the ability to rapidly deploy new VMs from stored VM templates. A VM template includes a VM configuration file (.vmx) and one or more virtual disk files (.vmdk), which include an operating system, common applications, and patch files or system updates. Deploying from templates saves administrative time by copying the configuration and virtual disk files and registering this second copy as an independent VM. By design, this process introduces duplicate data for each new VM deployed. Figure 9 shows an example of typical storage consumption in a vSphere deployment.

Figure 9) Storage consumption with a traditional array.

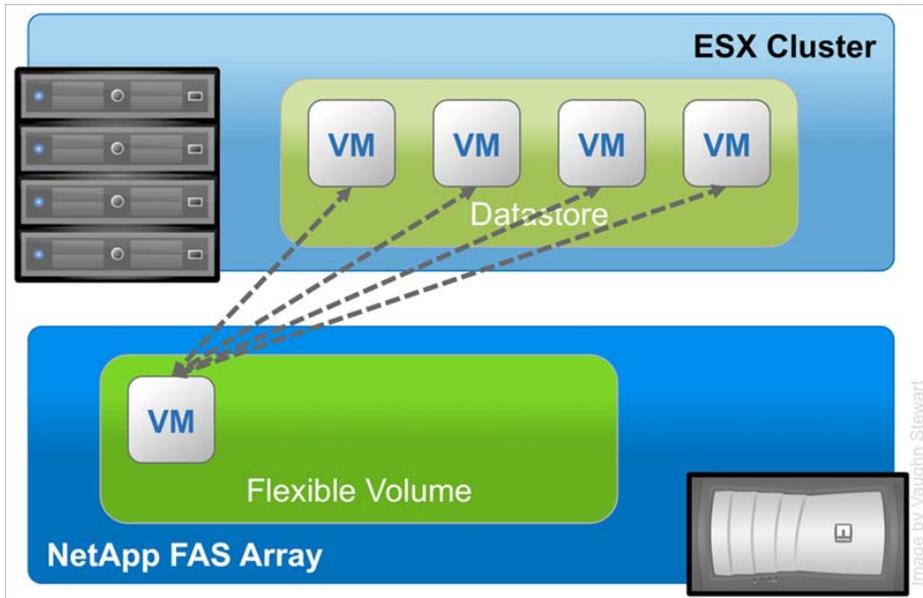


NetApp offers a data deduplication technology called *FAS data deduplication*. With NetApp FAS deduplication, VMware deployments can eliminate the duplicate data in their environment, enabling greater storage use. Deduplication virtualization technology enables multiple VMs to share the same physical blocks in a NetApp FAS system in the same manner that VMs share system memory. It can be seamlessly introduced into a virtual data center without having to make any changes to VMware

administration, practices, or tasks. Deduplication runs on the NetApp FAS system at scheduled intervals and does not consume any CPU cycles on the ESX server. Figure 10 shows an example of the impact of deduplication on storage consumption in a vSphere deployment.

Deduplication is enabled on a volume, and the amount of data deduplication realized is based on the commonality of the data stored in a deduplication-enabled volume. For the largest storage savings, NetApp recommends grouping similar operating systems and similar applications into datastores, which ultimately reside on a deduplication-enabled volume.

Figure 10) Storage consumption after enabling FAS data deduplication.



### DEDUPLICATION CONSIDERATIONS WITH VMFS AND RDM LUNS

Enabling deduplication when provisioning LUNs produces storage savings. However, the default behavior of a LUN is to reserve an amount of storage equal to the provisioned LUN. This design means that although the storage array reduces the amount of capacity consumed, any gains made with deduplication are for the most part unrecognizable, because the space reserved for LUNs is not reduced.

To recognize the storage savings of deduplication with LUNs, you must enable NetApp LUN thin provisioning.

**Note:** Although deduplication reduces the amount of consumed storage, the VMware administrative team does not see this benefit directly, because its view of the storage is at a LUN layer, and LUNs always represent their provisioned capacity, whether they are traditional or thin provisioned. The NetApp Virtual Storage Console (VSC) provides the VI administrator with the storage use at all layers in the storage stack.

When you enable dedupe on thin-provisioned LUNs, NetApp recommends deploying these LUNs in FlexVol volumes that are also thin provisioned with a capacity that is 2x the size of the LUN. By deploying the LUN in this manner, the FlexVol volume acts merely as a quota. The storage consumed by the LUN is reported in FlexVol and its containing aggregate.

### DEDUPLICATION ADVANTAGES WITH NFS

Unlike with LUNs, when deduplication is enabled with NFS, the storage savings are immediately available and recognized by the VMware administrative team. The benefit of dedupe is transparent to storage and VI administrative teams. Special considerations are not required for its usage.

## DEDUPLICATION MANAGEMENT WITH VMWARE

Through the NetApp vCenter plug-ins, VMware administrators have the ability to enable, disable, and update data deduplication on a datastore-by-datastore basis. The details on this capability are covered in the [vSphere Dynamic Storage Provisioning and Management](#) section of this report.

### 2.12 VSTORAGE ARRAY INTEGRATION IN VMWARE VSPHERE 4.1

With the release of vSphere 4.1, VMware has delivered a set of storage constructs enhancing storage array integration in vSphere. These enhancements consist of three main components:

- vStorage APIs for array integration
- Storage I/O control
- Storage performance statistics

#### VSTORAGE APIS FOR ARRAY INTEGRATION

vStorage APIs for array integration (VAAI) provides a mechanism for the acceleration of certain functions typically performed at the hypervisor by offloading these operations to the storage array. The goal of VAAI is to enable greater scalability at the host layer by freeing hypervisor resources (CPU, memory, I/O, and so on) during operations such as provisioning and cloning. This first release of VAAI provides support for new features only in VMFS datastores. In the case of NFS datastores on NetApp storage, many operations with respect to VM provisioning and cloning are already offloaded to the storage array with the combined capabilities of the VSC and file-level FlexClone. The initial release of VAAI expands VMFS to include similar capabilities. The current release of VAAI has three capabilities:

- **Full copy.** When a data copy is initiated from the ESX/ESXi host, VAAI enables the storage array to perform that copy within the array, without the host having to read and write the data. This reduces the time and network load of cloning and migrating VMs with VMotion.
- **Block zeroing.** When a new virtual disk is created, such as an eager-zeroed thick VMDK, the disk must be formatted and written full of zeroes. VAAI allows the storage array to format zeroes into the disks, removing this workload from the host.
- **Hardware-assisted locking.** VMFS is a shared cluster file system. Therefore, it requires management of metadata and locking to make sure that multiple hosts do not gain write access to the same data simultaneously. VAAI provides an alternative method of locking to that of SCSI-2 reservations used in previous releases. This new method of locking is managed automatically by the host and storage array and allows for greater scalability of VMFS datastores.

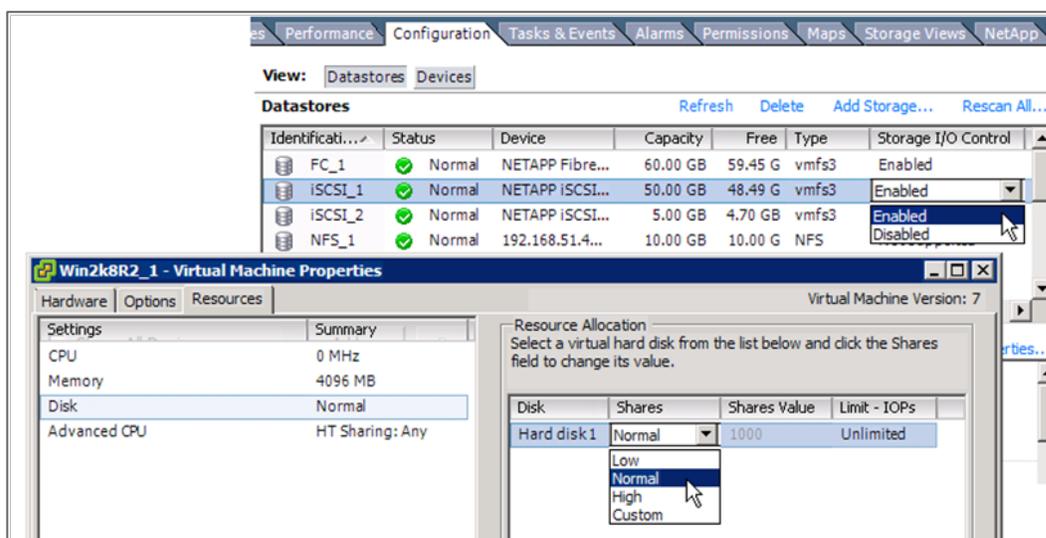
VAAI support requires that the storage array is running an operating system version that provides support. To use VAAI, the NetApp array must be running NetApp Data ONTAP version 8.0.1. VAAI is enabled by default in Data ONTAP and in ESX/ESXi. Version 2.0 of the VSC indicates whether or not a storage array supports VAAI and if VAAI is enabled on that array.

#### STORAGE I/O CONTROL

The Storage I/O Control (SIOC) feature introduced in vSphere 4.1 enables quality of service control for storage using the concepts of shares and limits in the same way CPU and memory resources have been managed in the past. SIOC allows the administrator to make sure that certain VMs are given priority access to storage compared to other VMs, based on the allocation of resource shares, maximum IOPS limits, and whether or not the datastore has reached a specified congestion threshold. SIOC is currently only supported on FC or iSCSI VMFS datastores.

To use SIOC, it must first be enabled on the datastore, and then resource shares and limits must be applied to the VMs in that datastore. The VM limits are applied on the Resources tab in the VM Edit Settings dialog window. By default, all VMs in the datastore are given equal resource shares and unlimited IOPS.

Figure 11) Enabling SIOC on a datastore and VM in vSphere 4.0.



SIOC does not take action to limit storage throughput of a VM based on the value of its resource shares until the datastore congestion threshold is met. As long as the overall performance of the datastore is sufficient, according to the threshold, all VMs on the datastore have equal access to the storage. The congestion threshold is set per datastore in a value of milliseconds of latency. The default value is 30ms, and most environments do not need to adjust this value. Storage resource shares are set in values of low, normal, and high (these values are 500, 1,000, and 2,000, respectively), or a custom value might be set.

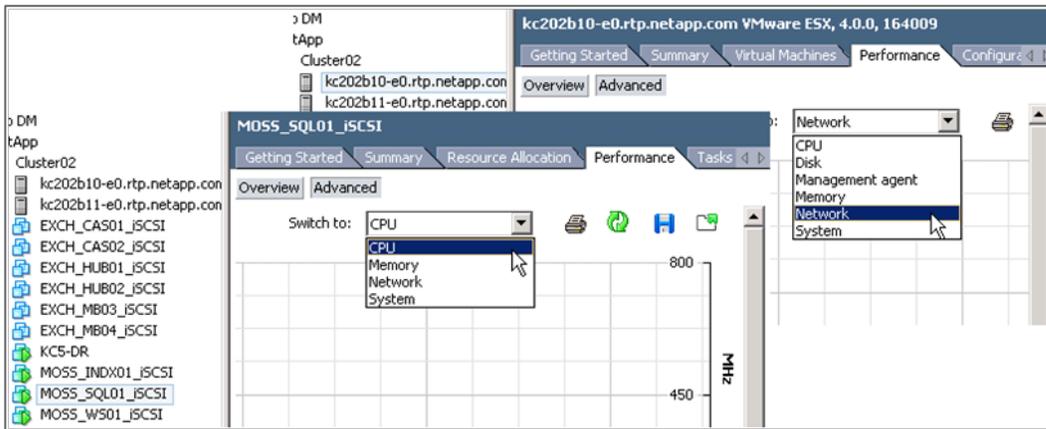
The amount of resource shares is used to determine how much throughput one VM is given compared to another VM on the same datastore in which SIOC is enabled. For example, when SIOC limitations are imposed on the datastore, a VM with 1,000 shares is entitled to twice the access to resources as a VM with 500 shares. The actual amount of throughput achievable by each VM is dependent on the demands of the VMs. Viewing the share settings of multiple VMs can be done in the vSphere client datastores view by selecting a datastore and then the Virtual Machine tab.

The access of a VM to a datastore can also be limited to a maximum storage IOPS. Setting a maximum IOPS limit on a VM causes vSphere to continuously limit the throughput of that VM to that number of IOPS, even if the congestion threshold has not been surpassed. To limit a VM to a certain amount of throughput in MB/sec, you must use the IOPS limit by setting an appropriate maximum IOPS value according to the VM's typical I/O size. For example, to limit a VM with a typical I/O size of 8k to 10MB/sec of throughput, set the maximum IOPS for the VM to 1,280. The following formula might be used: MB/sec ÷ I/O size = IOPS. For example: 10,240,000 ÷ 8,000 = 1,280.

## STORAGE PERFORMANCE STATISTICS

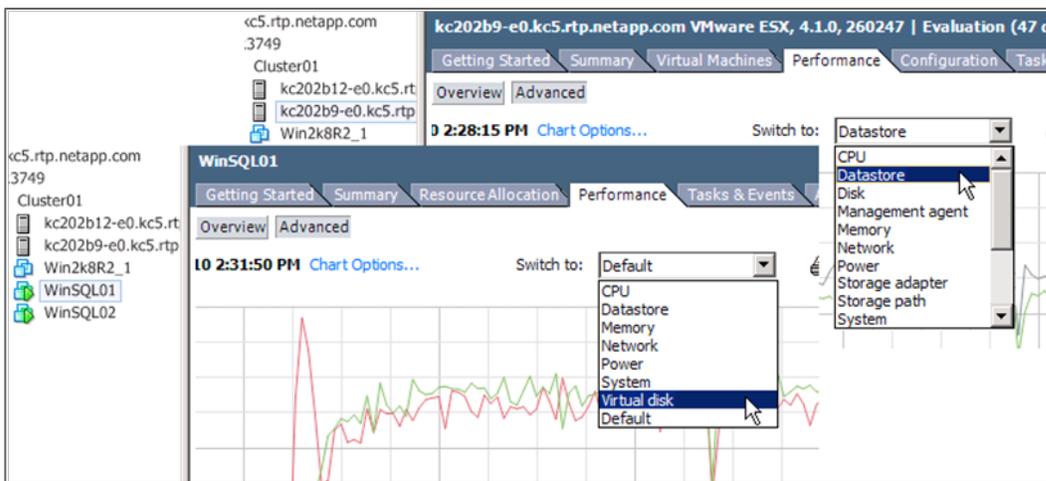
An additional storage enhancement in vSphere 4.1 is an increase in available storage performance statistics available both in vCenter and by using the `esxtop` command. In VI3 environments, gathering storage performance metrics directly in vCenter was limited to viewing the performance of specific physical disks. This allowed some monitoring of storage performance per datastore on NetApp storage arrays because a typical FC datastore in a NetApp environment is made up of one LUN presented from the storage system and would be represented as one physical disk in the vCenter performance monitor. Isolating complete datastore performance was difficult when multiple disks or LUNs were used to make up one datastore. This limitation continued into vSphere 4.0. Additionally, the ability to view metrics per NFS datastore or individual virtual disks attached to VMs was not available in both VI3 and vSphere 4.0. The metrics viewable for hosts and VMs in vSphere 4.0 are shown in Figure 12.

Figure 12) Performance statistics available in vSphere 4.0.



The additional performance statistics available in vSphere 4.1 allow the virtual administrator to view host I/O statistics per datastore storage path and per storage adapter in FC environments. Datastore performance reporting is available with all storage protocols: FC, iSCSI, and NFS. VM performance metrics now include datastore performance per VM and performance per virtual disk. Figure 13 shows the additional performance metrics available in vSphere 4.1.

Figure 13) Additional performance statistics available in vSphere 4.1.



A particular challenge in NAS environments has been the inability to determine which NFS datastores are most active or which virtual disks of a VM are most active. Figure 14 shows an example of the per virtual disk metrics in vSphere 4.1.

Figure 14) Per virtual disk performance statistics available in vSphere 4.1.

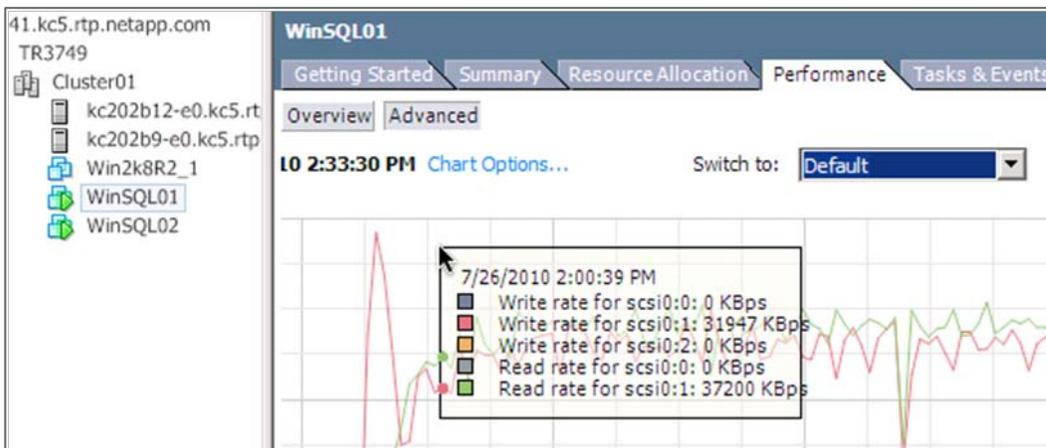


Table 5 shows the storage performance statistic capabilities by protocol and by vSphere version.

Table 5) Storage performance statistic capabilities by protocol and vSphere version.

Object	Component	Statistic	Storage Protocol	Available in	
				vCenter	ESXTOP*
ESX/ESXi Host	Datastore	Throughput and latency	FC, iSCSI, NFS	4.1	4.1
	Storage adapter	Throughput and latency	FC	4.1	4.0+
	Storage path	Throughput and latency	FC	4.1	4.0+
	LUN	Throughput and latency	FC, iSCSI	4.0+	4.0+
Virtual machine	Datastore	Throughput and latency	FC, iSCSI, NFS	4.1	4.1
	Virtual disk	Throughput and latency	FC, iSCSI, NFS	4.1	4.1

\* Access to **esxtop** for ESXi hosts requires the use of the vSphere command line interface (CLI) **resxtop** command.

### 3 STORAGE NETWORK DESIGN AND SETUP

This section applies to:



Storage administrators



VI administrators



Network administrators

The goal of any storage network is to provide uninterrupted service to all nodes that connect to it. In this section, we focus primarily on how to establish a highly available Ethernet storage network. The reasons for focusing on Ethernet are twofold. First, FC storage networks provide a single service, Fibre Channel. Therefore, these single-purpose networks are simpler to design and deploy in a highly available configuration. Second, the current industry trend is solely focused on multipurposed Ethernet networks (converged networks) that provide storage, voice, and user access.

#### PRODUCTION STORAGE NETWORKS

Regardless of protocol, a storage network must address the following three goals:

- Be redundant across switches in a multiswitch environment.
- Use as many available physical paths as possible.
- Be scalable across multiple physical interfaces or ports.

#### 3.1 SAN AND NAS STORAGE NETWORKING BASICS

With vSphere, the primary difference between SAN and NAS is in the area of multipathing. In the current versions of ESX/ESXi, NFS requires manual static path configuration, whereas, iSCSI, FC, and FCoE are available with both manual and automated multipathing options.

**Note:** iSCSI requires additional configuration options prior to implementing.

Multipathing and datastore security in the form of NFS exports (iSCSI, FC, and FCoE) and LUN masking are dynamically assigned when the VMware administrative team provisions storage. The details of this automation are covered with the Rapid Cloning Utility (RCU) in the [vSphere Dynamic Storage Provisioning and Management](#) section of this report.

## 3.2 FIBRE CHANNEL STORAGE NETWORKING BASICS

FC storage networks make up a large percentage of mature VMware storage infrastructures. This market share is attributed to FC being the first networked-attached storage (NAS) protocol supported by ESX in version 2.0. Although FC is a well-known and mature technology, this section covers best practices for deploying VMware on FC with NetApp storage arrays.

### CONNECTIVITY BASICS

ESX servers and NetApp storage arrays connect to a SAN fabric using host bus adapters (HBAs). Connectivity to FCoE fabrics is enabled through converged network adapters (CNAs). Each HBA/CNA can run as either an initiator (ESX/ESXi) or a target (NetApp). Each adapter has a global unique address referred to as a World Wide Name (WWN). Each WWN must be known to configure LUN access on a NetApp storage array.

Both NetApp and VMware highly recommend that as a best practice each ESX/ESXi host should have at least two adapter ports. For more information on VMware FC best practices and recommendations, refer to the [VMware Fibre Channel SAN Configuration Guide](#).

### FABRIC ZONING RECOMMENDATION

Many devices and nodes can be attached to a SAN. Implementing zones is a method used to secure access and optimize I/O access to these devices. SAN zoning is a method of arranging FC devices into logical groups over the physical configuration of the fabric or FC network.

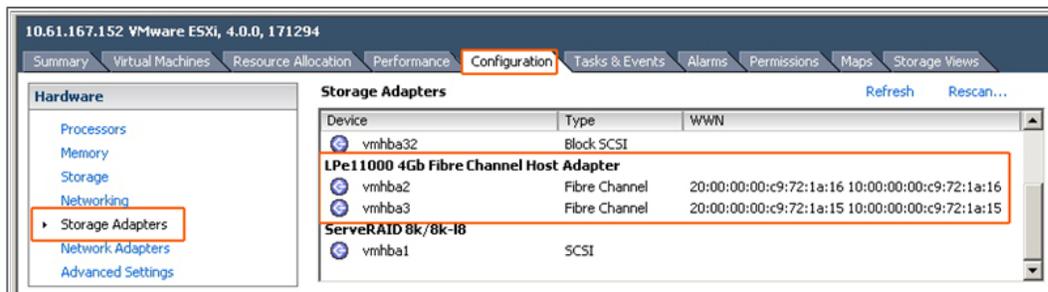
Zoning is available in hardware (hard zoning) or in software (soft zoning). An option available with both implementations is port zoning. With this option, physical ports define security zones. A host's access to a LUN is determined by what physical port it connects to. With port zoning, zone information must be updated every time a user changes switch ports. In addition, port zoning does not allow zones to overlap.

Another form of zoning is WWN zoning, where the fabric leverages its name servers to either allow or block access to particular World Wide Port Names (WWPNs) in the fabric. A major advantage of WWPN zoning is the ability to recable the fabric without having to modify the zone members.

NetApp and VMware highly recommend that customers implement “single-initiator, multiple storage target” zones. This design offers an ideal balance of simplicity and availability with FC and FCoE deployments. For assistance in identifying the WWN or IQN of the ESX server, complete the following steps:

1. Select Storage Adapters on the Configuration tab for each ESX/ESXi host in vCenter Server.
2. Refer to the WWN identifier column.

Figure 15) Identifying WWPN and IQN numbers in the vCenter client.



## 3.3 ETHERNET STORAGE NETWORKING BASICS

### 10GBE OR DATA CENTER ETHERNET

NetApp Data ONTAP and VMware ESX/ESXi 4 both provide support for 10GbE. An advantage of 10GbE is the ability to reduce the number of network ports in the infrastructure, especially for blade servers. To verify support for your hardware and its use for storage I/O, refer to the [VMware Compatibility Guide](#).

### VLAN TAGGING OR 802.1Q

When segmenting network traffic with VLANs, interfaces either can be dedicated to a single VLAN or can support multiple VLANs with VLAN tagging.

For systems that have fewer NICs, such as blade servers, VLANs can be very useful. Channeling two NICs together provides an ESX server with physical link redundancy. By adding multiple VLANs, you can group common IP traffic onto separate VLANs for optimal performance. NetApp recommends that the service console access with the VM network should be on one VLAN, and the VMkernel activities of IP storage and VMotion should be on a second VLAN.

VLANs and VLAN tagging also play a simple but important role in securing an IP storage network. NFS exports can be restricted to a range of IP addresses that are available only on the IP storage VLAN. In addition, NetApp storage also allows the restriction of the iSCSI protocol to specific interfaces and/or VLAN tags. These simple configuration settings have an enormous effect on the security and availability of IP-based datastores. If you are using multiple VLANs over the same interface, make sure that sufficient throughput can be provided for all traffic.

### FLOW CONTROL

Flow control is the process of managing the rate of data transmission between two nodes to prevent a fast sender from overrunning a slow receiver. Flow control can be configured on ESX/ESXi servers, FAS storage arrays, and network switches. NetApp recommends configuring the endpoints, ESX servers, and NetApp arrays with the flow control set to "send". Flow control can be set on FAS storage ports using FilerView®, NetApp System Manager, or the command line as follows:

```
f35> ifconfig e2a flowcontrol send
```

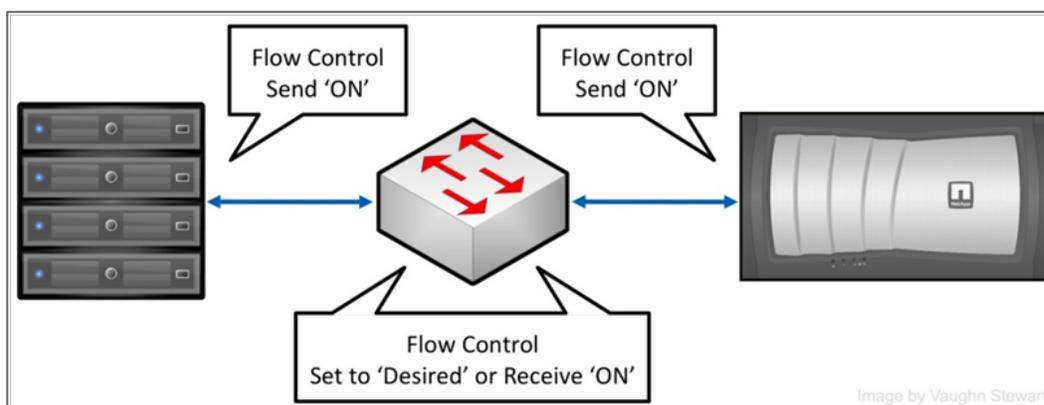
Remember that settings on the command line must be added to `/etc/rc` in order to be persistent across reboots.

After these settings have been configured on the storage controller and network switch ports, it results in the desired configuration without modifying the flow control settings in ESX/ESXi. For details on setting flow control in vSphere, refer to [VMware KB 1013413](#).

For network switches, NetApp recommends either setting the switch ports connecting to the ESX hosts and FAS storage arrays to "Desired" or, if this mode is not available, setting these ports to "send off" and "receive on."

**Note:** The switch ports are configured with settings opposite to those of the ESX/ESXi and FAS systems.

Figure 16) Configuring flow control settings.



## SPANNING TREE PROTOCOL

Spanning Tree Protocol (STP) is a network protocol that provides a loop-free topology for any bridged LAN. In the OSI model for computer networking, STP falls under the OSI Layer-2. STP allows a network design to include spare (redundant) links to provide automatic backup paths if an active link fails, without the danger of bridge loops or the need for manual enabling or disabling of these backup links. Bridge loops must be avoided because they result in flooding the network.

When connecting ESX and NetApp storage arrays to Ethernet storage networks, NetApp highly recommends configuring the Ethernet ports to which these systems connect as either RSTP edge ports or by using the Cisco® feature portfast. If your environment uses the Cisco portfast feature and you have 802.1q VLAN trunking enabled on either the ESX server or the NetApp storage arrays, NetApp recommends enabling the spanning-tree portfast trunk feature.

When a port is configured as an edge port on an RSTP-enabled switch, the edge port immediately transitions its forwarding state to active. This immediate transition was previously recognized as a Cisco proprietary feature named portfast. Ports that connect to other switch ports should not be configured with the edge port or portfast feature.

## ROUTING AND IP STORAGE NETWORKS

Whenever possible, NetApp recommends configuring storage networks as a single network that does not route. This model helps to provide good performance and a layer of data security.

## ENABLING JUMBO FRAMES

In Ethernet networking, the maximum transmission unit (MTU) is the size of the largest unit that the layer can forward. The standard MTU size is 1,500 bytes. In an effort to reduce the number of data units and the processing associated with each, some prefer to use a large packet size. This is referred to as a jumbo frame, and it is commonly 9,000 bytes.

Enabling jumbo frames requires making manual changes to all networking devices, and therefore its use should be considered prior to being enabled.

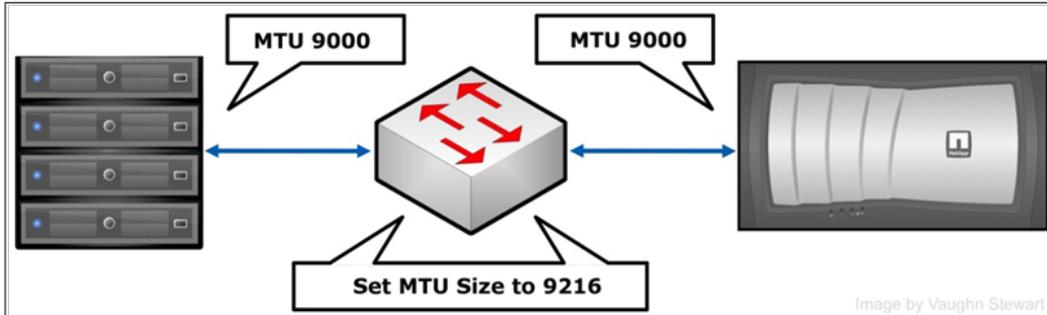
**Note:** FCoE uses what is referred to as a baby jumbo frame (MTU size of 2,112), and its use is automatically enabled by network devices that support FCoE.

When enabling jumbo frames throughout an infrastructure, there are two classifications of devices. Those classifications are devices that transmit jumbo frames (NetApp storage, ESX server) and devices that transport jumbo frames (Ethernet switches). Some devices that transmit jumbo frames are configured to use VLAN trunking, and other devices are not. An Ethernet frame consists of a payload, Ethernet header (18 bytes), and sometimes a VLAN tag (4 bytes, if enabled). Generally, a user administratively defines the

payload size for devices that transmit jumbo frames. The system then appends the Ethernet header and VLAN tag, causing the frame, which is transmitted from the device, to range from 9,018 bytes or 9,022 bytes (with VLAN tagging). Because of this frame size variation, a best practice is to set the devices that transport jumbo frames (Ethernet switches) to their maximum allowable setting.

That maximum is typically 9,216 bytes in today's modern data center class switches. If the switching infrastructure being used does not accommodate this size, you must verify the endpoint frame size you configure and append the Ethernet header and VLAN tag. If your infrastructure is not configured to accommodate the payload plus header and VLAN tag, your environment either will not successfully negotiate communications or will suffer severe performance penalties.

Figure 17) An overview of the MTU size required with jumbo frames.



ESX/ESXi hosts require creating a vSwitch that supports jumbo frames followed by a VMkernel port, which is assigned to the vSwitch.

To enable jumbo frames on a vSwitch and set the appropriate MTU size, complete the following steps:

1. Connect to an ESX/ESXi host (using the vSphere CLI).
2. Execute the following command to configure the MTU size:

```
vicfg-vswitch -m <MTU> <vSwitch>
```

This command sets the MTU for all uplinks on that vSwitch. Set the MTU size to the largest MTU size among all the virtual network adapters connected to the vSwitch.

3. Execute the following command to verify the configuration:

```
vicfg-vswitch -l
```

To enable jumbo frames on a VMkernel port, complete the following steps:

1. Connect to an ESX/ESXi host (using the vSphere CLI).
2. Execute the following command to configure the MTU size:

```
esxcfg-vmknic -a -I <ip address> -n <netmask> -m <MTU> <port group name>
```

This command creates a VMkernel port with jumbo frame support.

3. Execute the following command to verify the configuration:

```
esxcfg-vmknic -l
```

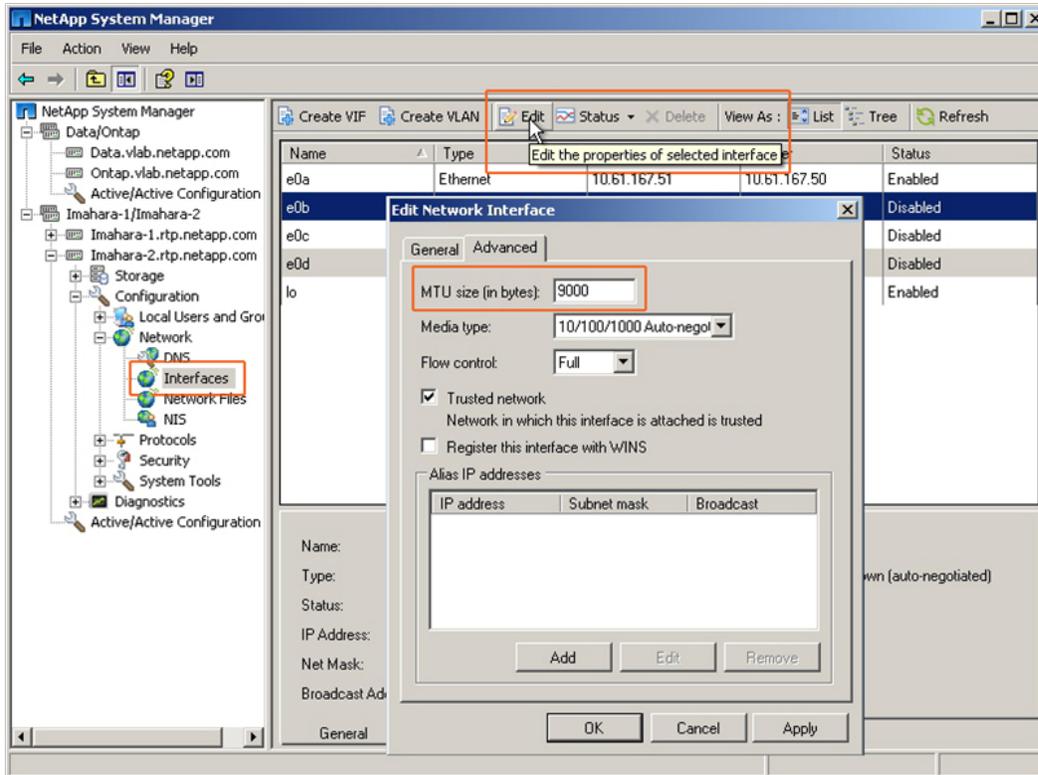
To set the MTU size on a FAS array, complete the following steps (as shown in Figure 18):

1. Open NetApp System Manager.
2. Select the network configuration for the array and the interface.
3. Select Edit.
4. Repeat these steps for each array and interface requiring jumbo frames.

Note that in these steps and elsewhere in this document, the `esxcfg-` and `vicfg-` commands are equivalent. The command that you use depends on whether you are logged into an ESX server via SSH (or on the physical console) or vSphere CLI (available as an installable package for Windows and Linux and as an appliance VM—vSphere Management Assistant or vMA) to manage ESX or ESXi. In fact, on the vMA, the `esxcfg-*` commands are symlinks to the same `vicfg-*` command. For more information on vMA and vSphere CLI is available, see:

- vMA: <http://www.vmware.com/appliances/directory/178973>
- vSphere CLI docs: <http://www.vmware.com/support/developer/vcli/>

Figure 18) Configuring jumbo frames in NSM settings.



## SEPARATE ETHERNET STORAGE NETWORK

As a best practice, NetApp recommends separating IP-based storage traffic from public IP network traffic by implementing separate physical network segments or VLAN segments. This design follows the architecture of SCSI and FC connectivity.

Creating a second network in ESX requires creating a second vSwitch to separate the traffic onto other physical NICs. The ESX server requires a VMkernel port to be defined on the new vSwitch.

A VMware best practice for HA clusters is to define a second service console port for each ESX server. The network use for IP-based storage is a convenient network that you can use to add this second SC port.

With this design, NetApp recommends not allowing routing of data between the storage or VMkernel and other networks. In other words, do not define a default gateway for the VMkernel storage network. With this model, NFS deployments require defining a second service console port on the VMkernel storage virtual switch within each ESX server.

IP storage network, or VMkernel, connectivity can be verified by the use of the `vmkping` command. With NFS connected datastores, the syntax to test connectivity is `vmkping <NFS IP address>`.

## NETAPP VIRTUAL INTERFACES (ETHERCHANNEL)

A virtual network interface (VIF) or EtherChannel is a mechanism that supports aggregation of network interfaces into one logical interface unit. Once created, a VIF is indistinguishable from a physical network interface. VIFs are used to provide fault tolerance of the network connection and in some cases higher throughput to the storage device.

NetApp enables the use of two types of load-balancing VIFs: manual multimode and dynamic LACP (IEEE 802.3ad). NetApp also provides an active-passive form of VIF, referred to as a single-mode VIF. NetApp VIFs might also be grouped and layered into a form of a second-level VIF, referred to in this document as layered multimode EtherChannel.

Multimode VIFs are static configured EtherChannels. In a multimode VIF, all of the physical connections in the VIF are simultaneously active and can carry traffic. This mode requires connecting all of the interfaces to a switch that supports trunking or aggregation over multiple port connections. The switch must be configured to understand that all the port connections share a common MAC address and are part of a single logical interface. If a physical interface failure results in the loss of link, the VIF automatically transmits traffic onto the surviving links in the VIF without loss of connectivity.

LACP VIFs are dynamic (IEEE 802.3ad) compliant EtherChannels. In an LACP VIF, all of the physical connections are simultaneously active and carry traffic, similar to the previously described multimode VIFs. LACP VIFs introduce signaling transmissions between the storage controller and the network switch. This signaling informs the remote channeling partner of the link status. If a failure or inability to transmit data on a link is observed, the device identifying this problem informs the remote channeling partner of the failure, causing the removal of the interface from the EtherChannel. This feature differs from standard multimode VIFs in that there is no signaling between channel partners to inform the remote partner of link failure. The only means for an interface to be removed from a standard multimode VIF is a loss of link.

Multimode and LACP EtherChannels both use the same algorithms for determining IP load balancing. These algorithms are based on source and destination IP, MAC address, or TCP/UDP port number. NetApp recommends using IP-based source and destination load balancing, especially when the network is designed to route storage traffic as it provides load-balancing capabilities, which works in the broadest set of storage network configurations.

In a single-mode VIF, only one of the physical connections is active at a time. If the storage controller detects a fault in the active connection, a standby connection is activated. A configuration is not necessary on the switch to use a single-mode VIF, and the physical interfaces that make up the VIF do not have to connect to the same switch.

**Note:** IP load balancing is not supported on single-mode VIFs.

## 3.4 CISCO NEXUS 1000V VNETWORK DISTRIBUTED SWITCH RECOMMENDATIONS

### CISCO NEXUS 1000V SYSTEM VLAN

When deploying the 1000V vNetwork Distributed Switch (vDS), be aware that it is composed of two components, the Virtual Supervisor Module (VSM) and the Virtual Ethernet Module (VEM).

The VSM runs as a VM and is the brains of the operation with a 1000V. Traffic continues if the VSM fails; however, management of the vDS is suspended. VSMS should be deployed in an active-passive pair. These two VSAs should never reside on the same physical ESX server. This configuration can be controlled by DRS policies.

The VEM is embedded in all ESX/ESXi hosts, and it is managed by the VSM. One exists for each host in the cluster that is participating in the Cisco Nexus<sup>®</sup> 1000V vDS.

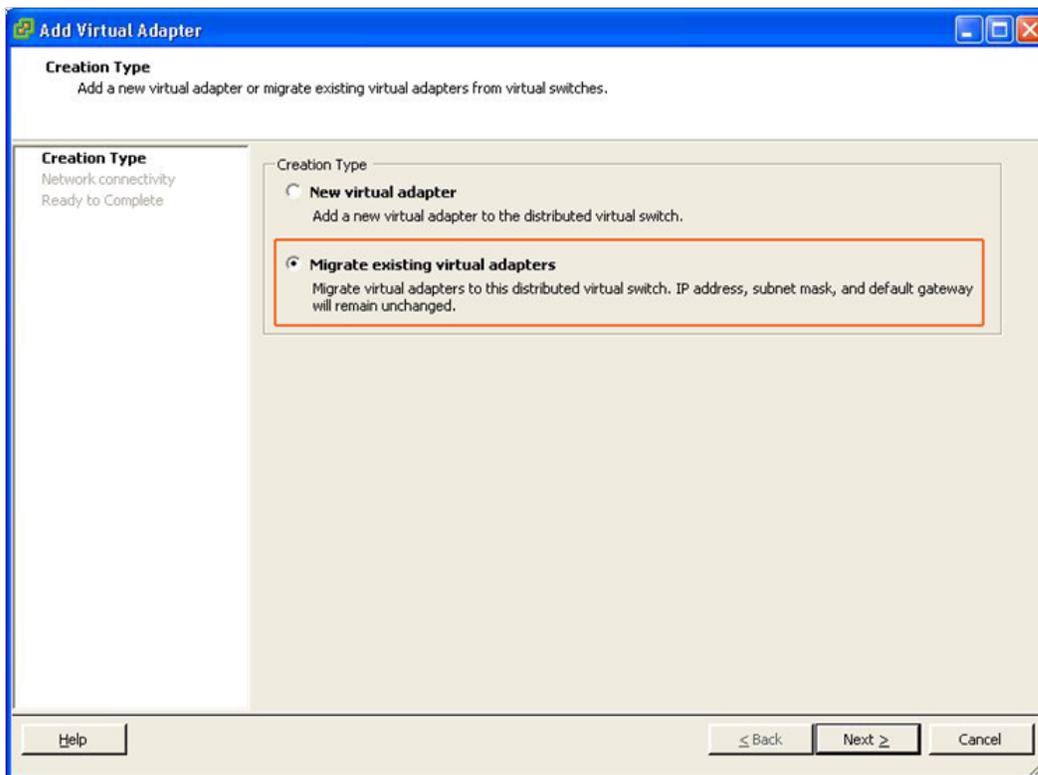
If a VSM is managing the links to the datastore that stores the VSM VM, the VSM failover process might possibly not occur. To avoid this scenario, NetApp and Cisco recommend making sure that all service console and VMkernel interfaces (vswif and vmknic) reside on a system VLAN. System VLANs are defined by an optional parameter that can be added in a port profile. Do not configure a VM network as a system VLAN.

### ENABLING JUMBO FRAMES

Although the Cisco Nexus 1000V vDS supports the use of jumbo frames, it lacks the ability to create or enable jumbo frames on VMkernel interfaces. To use jumbo frames with VMkernel ports, you must first create a traditional vSwitch and VMkernel port, enable support for jumbo frames, and import these ports into a 1000V vDS. To enable jumbo frames on a vSwitch, complete the following steps:

1. Configure a vSwitch and VMkernel ports for jumbo frame support ([section 3.3](#)).
2. Connect to the ESX/ESXi host using the vCenter client.
3. Assign the VMkernel port (following the steps in the previous paragraph) to the vSwitch (created previously).
4. Migrate the vSwitch to a 1000V vDS (as shown in Figure 19).

Figure 19) Migrating a virtual adapter from a vSwitch to a 1000V.

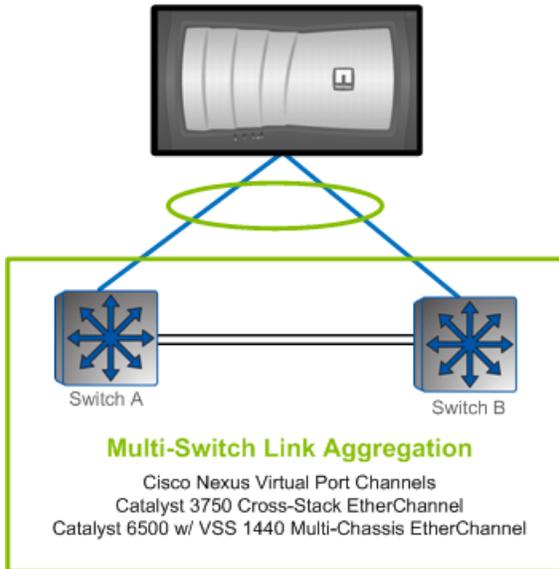


### 3.5 SWITCHING CAPABILITIES DETERMINE THE STORAGE NETWORK ARCHITECTURE

The storage design you implement is dictated based on the capabilities of your network switches. The ideal configuration is to have Ethernet switches that support multiswitch link aggregation (MSLA). If you have a switch with this capability such as Cisco Nexus (virtual port channels), Cisco Catalyst® 3750 series (cross-stack EtherChannel), or Cisco Catalyst 6500 series with VSS 1440 modules (multichassis EtherChannel), the design and architecture required for your network will be rather simple.

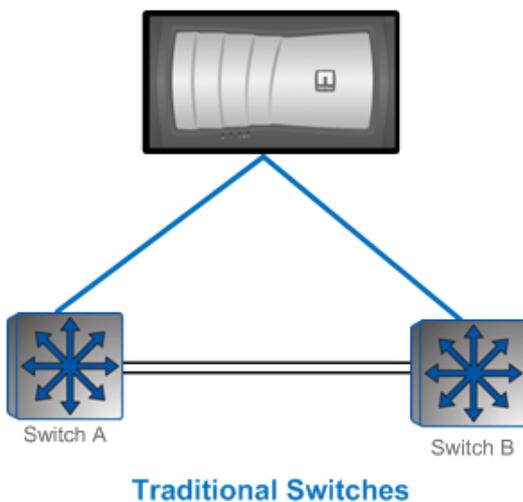
Proceed to [section 3.6](#) to configure this type of switching technology.

Figure 20) An overview of multiswitch link aggregation.



Alternatively, if your network operates with more traditional switching technology, such as one that lacks multiswitch link aggregation, you must complete additional configuration steps in ESX/ESXi, Data ONTAP, and the switch configuration.

Figure 21) An overview of traditional switches.



Proceed to [section 3.7](#) to configure this type of switching technology.

### 3.6 STORAGE NETWORK ARCHITECTURE WITH MULTISWITCH LINK AGGREGATION

In this configuration, the IP switches used for the Ethernet storage network support multiswitch link aggregation. Therefore, each storage controller requires one physical connection to each switch. The two ports connected to each storage controller are then combined into one multimode LACP VIF with IP load balancing enabled. This design provides multiple active connections to each storage controller, provides a means to scale throughput by simply adding more connections, requires multiple IP addresses per controller, and each connection uses two physical links for each active network connection to achieve path high availability (HA).

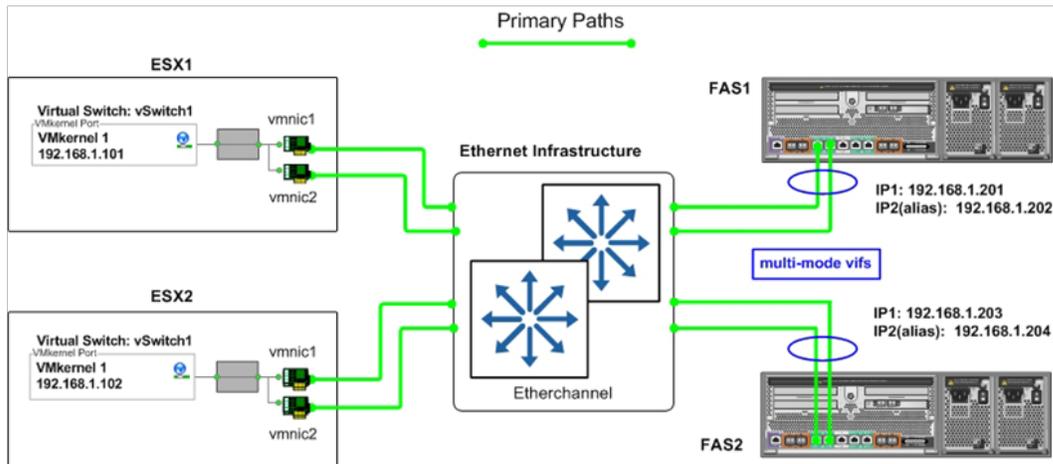
#### ADVANTAGES OF MSLA

MSLA has the following advantages:

- Provides multiple active connections to each storage controller
- Easily scales to more connections by adding NICs and aliases
- Provides two active connections to each storage controller
- Easily scales using more connections
- Storage controller connection load balancing are automatically managed by IP load-balancing policy
- Requires only one VMkernel port for IP storage to make use of multiple physical paths

Storage controller connection load balancing is automatically managed by the EtherChannel IP load-balancing policy.

Figure 22) Storage side multimode VIFs using multiswitch EtherChannel.

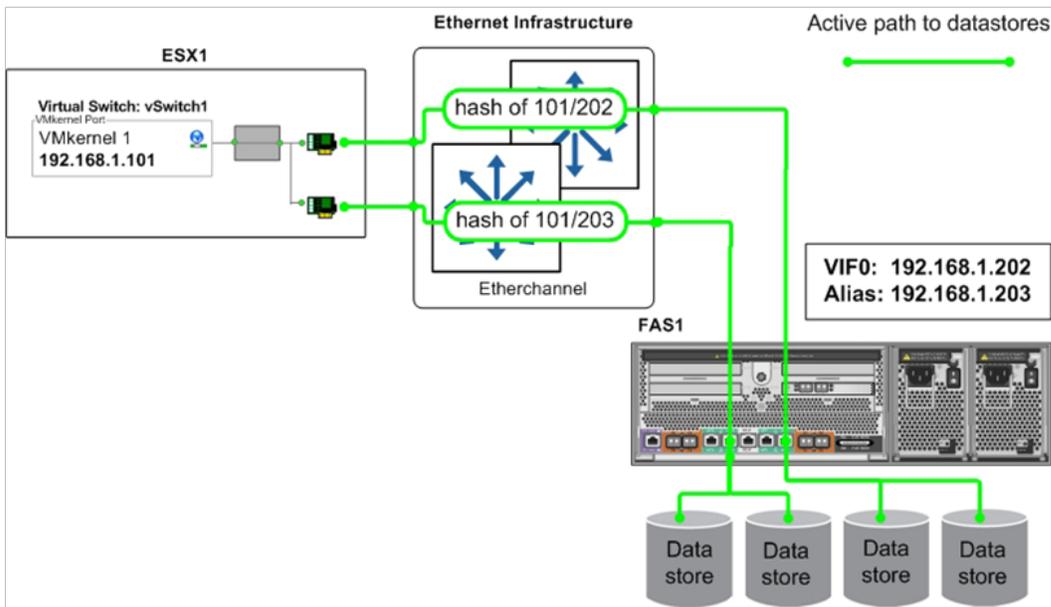


#### STORAGE LOAD BALANCING

Using multiple physical paths simultaneously on an IP storage network requires EtherChannel ports and multiple IP addresses on the storage controller. This model results in a design that balances datastore connectivity across all interfaces. This balancing is handled by the RCU at the time the datastore is provisioned.

Figure 23 shows an overview of storage traffic flow when using multiple ESX servers and multiple datastores.

Figure 23) Datastore connections with multiswitch EtherChannel.



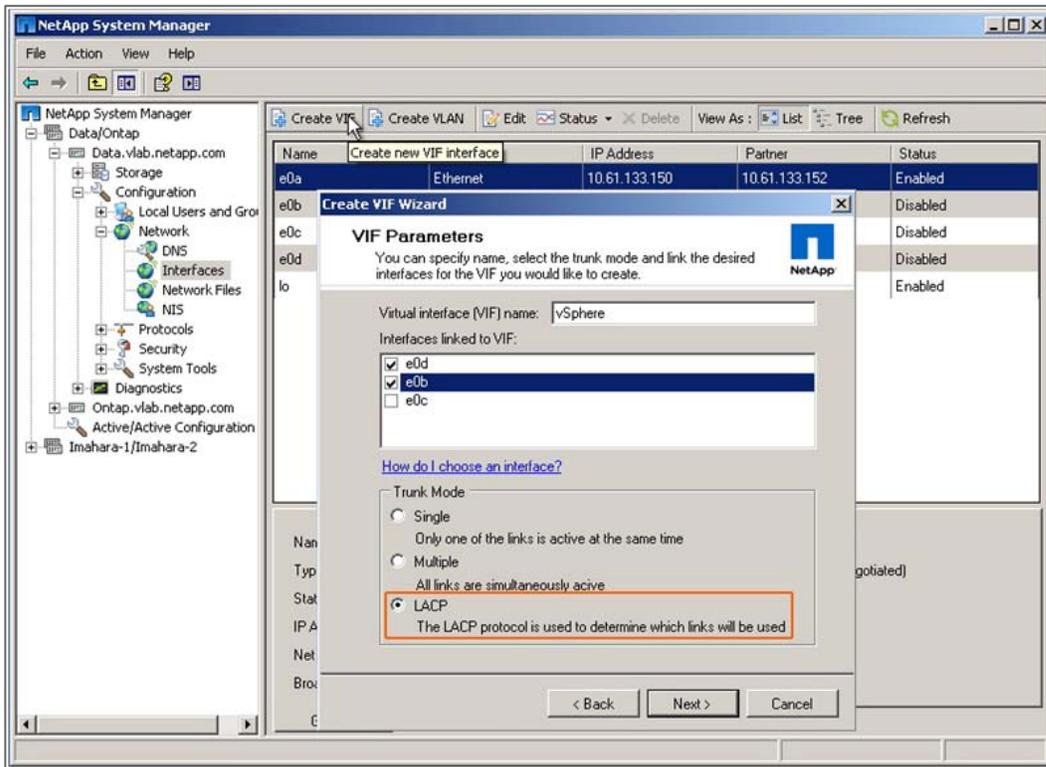
### CONFIGURING NETAPP STORAGE NETWORK PORTS

If you plan to deploy with IP-based storage access, NFS, or iSCSI, then you must configure multiple Ethernet links to operate together as an EtherChannel. EtherChannel provides aggregated bandwidth and link availability from the network switches to the storage controller. This design is recommended, because the storage controller handles the aggregated I/O load from all ESX/ESXi nodes.

NetApp supports all modes of EtherChannels that are compliant with 802.3ad LACP and/or static EtherChannels. In Data ONTAP, EtherChannels are referred to as virtual interfaces (VIFs). NetApp recommends that you configure your EtherChannel or VIFs as LACP whenever possible.

For use in an MSLA configuration, you must create a multilink EtherChannel or VIF that is configured with multiple IP addresses. The number of IP addresses should be roughly equal to the number of vmnics used for storage I/O in the ESX/ESXi hosts. This process is completed in the NetApp Systems Manager (NSM).

Figure 24) Creating an LACP EtherChannel port with two physical NICs on the first storage controller.



**Note:** There is one peculiar aspect when creating the first half of an EtherChannel on an HA storage array: You have to select a physical network interface card (NIC) when assigning the partner interface because an EtherChannel is not configured on the second storage controller. After the EtherChannel is configured, you have to return to the first controller and edit the partner interface for the EtherChannel created on the first controller.

Figure 25) Completing the process of creating an LACP EtherChannel port with two physical NICs on the first storage controller.

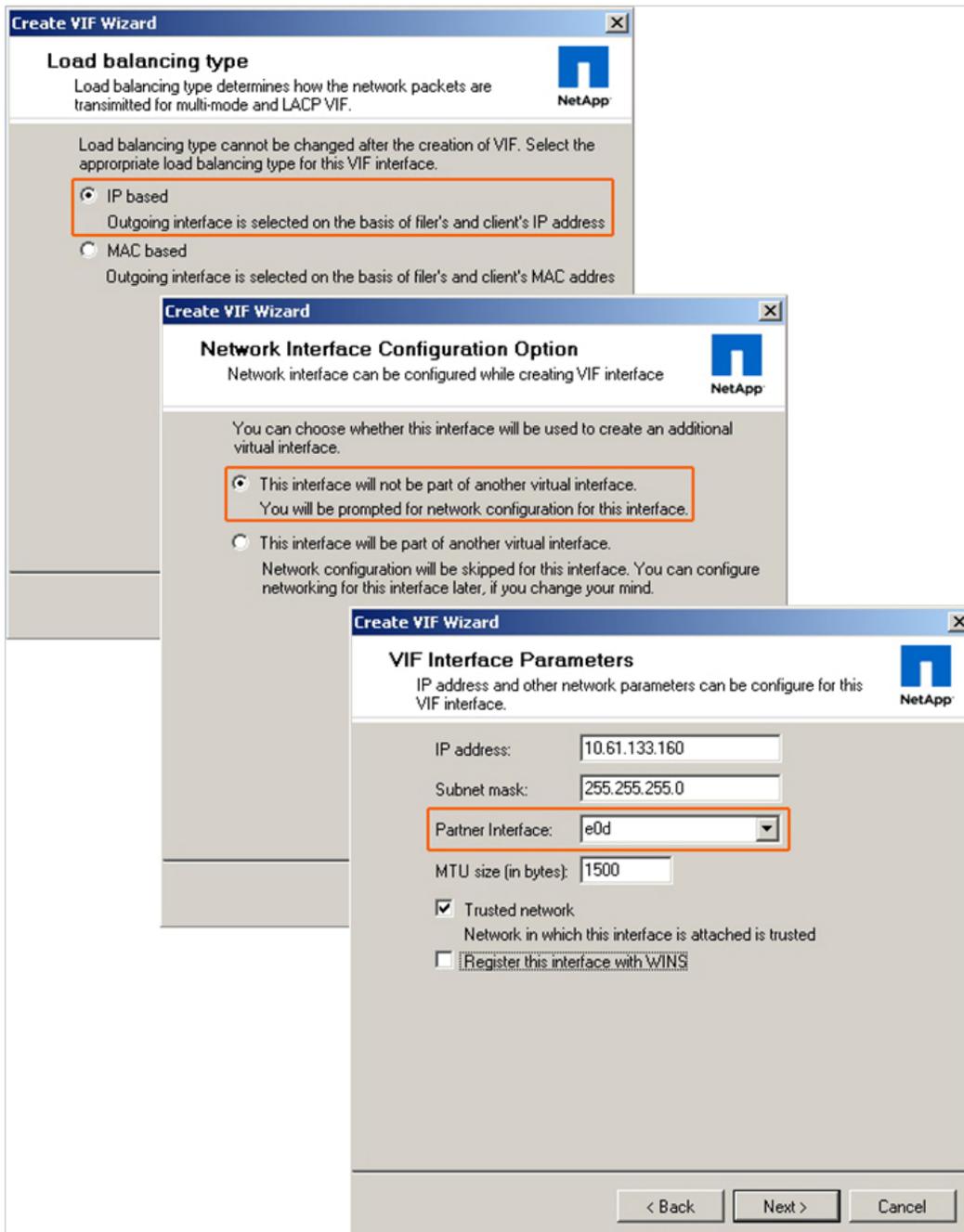


Figure 26) Completing the process of creating an LACP EtherChannel port with two physical NICs on the second storage controller.

Note that the EtherChannel on the first controller can be selected as a partner interface.

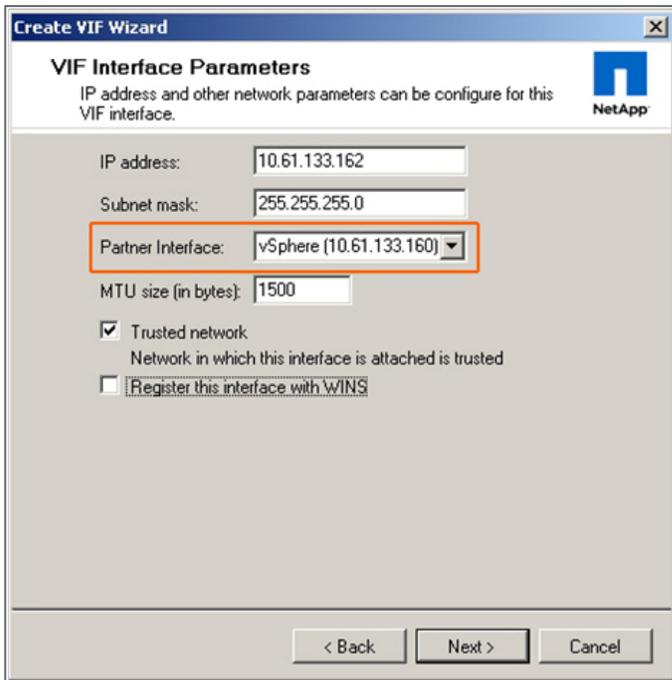
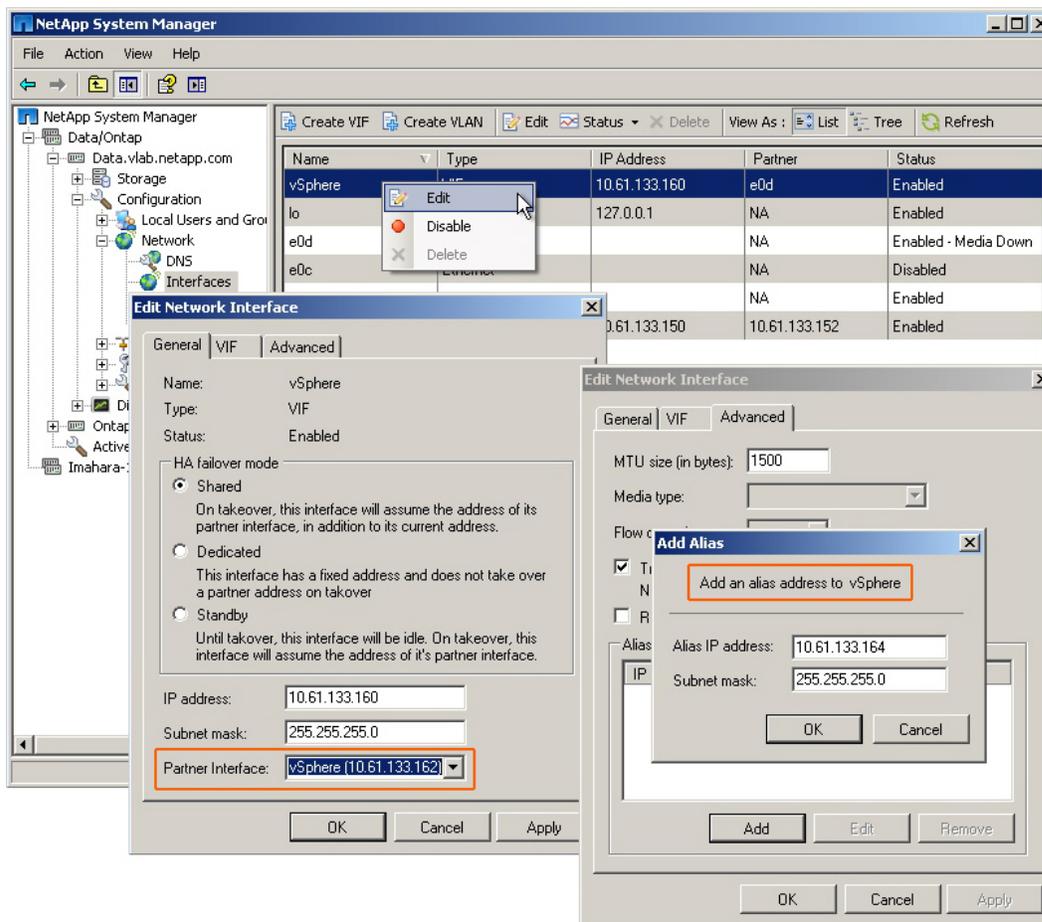


Figure 27) Completing the process of creating an LACP EtherChannel.

On the first controller, the partner interface is set to the EtherChannel configured on the second array. Additional IP addresses can also be added by editing the EtherChannel.



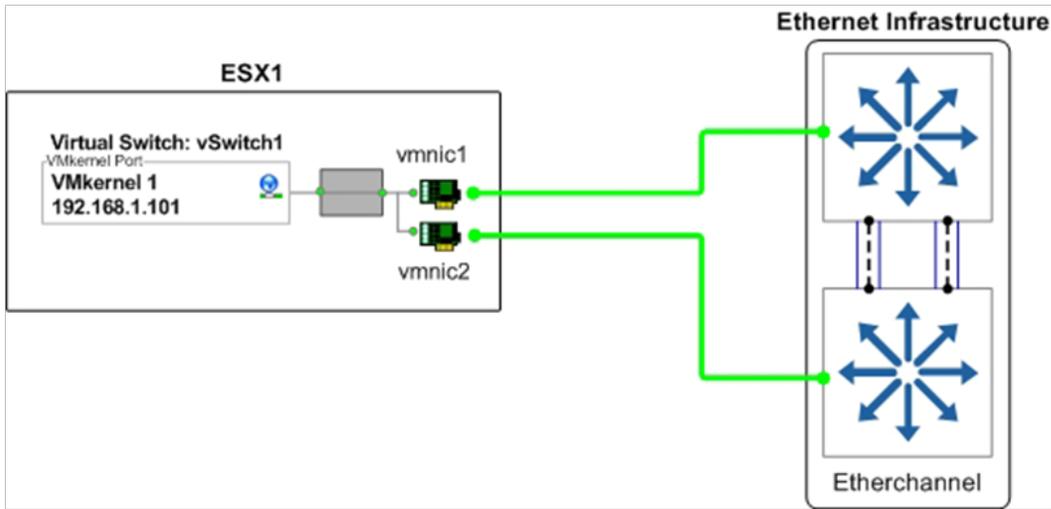
## CONFIGURING ESX/ESXI VMKERNEL STORAGE NETWORK PORTS

If the switches used for IP storage networking support multiswitch EtherChannel trunking or virtual port channeling, then each ESX server needs one physical connection to each switch in the stack with IP load balancing enabled. One VMkernel port with one IP address is required. Multiple datastore connections to the storage controller using different target IP addresses are necessary to use each of the available physical links.

In the ESX server configuration, shown in Figure 28, a vSwitch (named vSwitch1) has been created specifically for IP storage connectivity. Two physical adapters have been configured for this vSwitch (in this case, vmnic1 and vmnic2). Each of these adapters is connected to a different physical switch, and the switch ports are configured into a cross-stack EtherChannel trunk.

**Note:** At this time, VMware does not support LACP, or IEEE 802.3ad, which is the dynamic negotiation of Ethernet trunks.

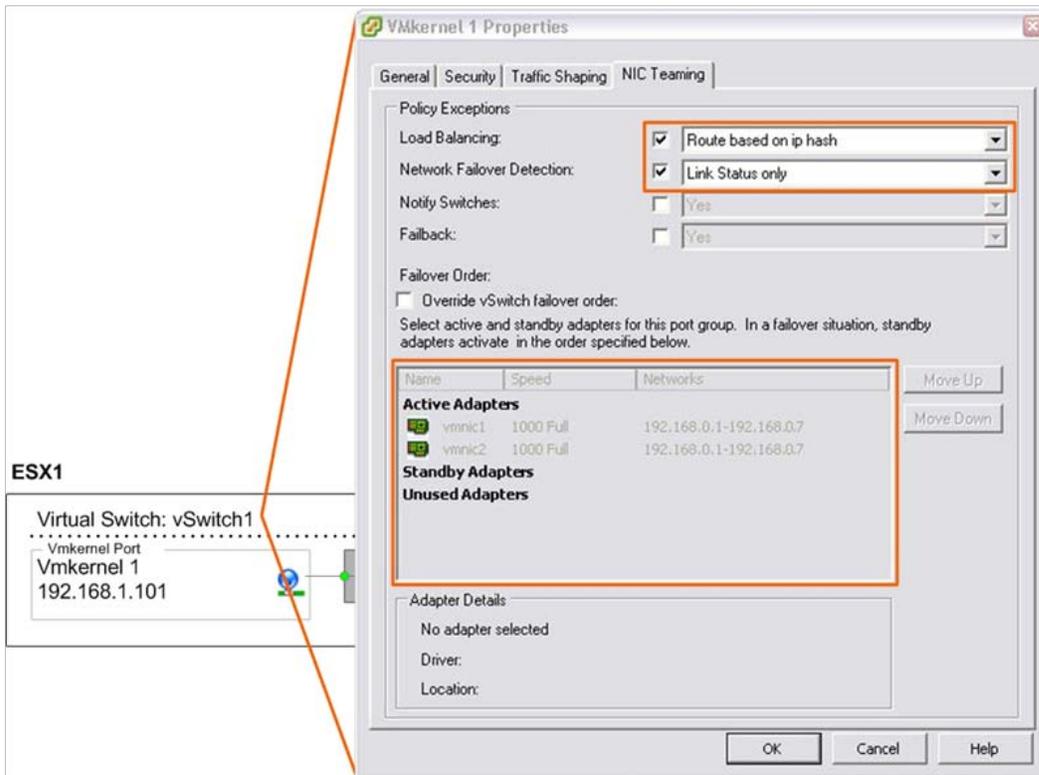
Figure 28) ESX server physical NIC connections with multiswitch EtherChannel.



In vSwitch1, one VMkernel port has been created (VMkernel 1) and configured with one IP address, and the NIC teaming properties of the VMkernel port have been configured as follows:

- **VMkernel 1.** IP address set to 192.168.1.101.
- **VMkernel 1 port properties.** Load-balancing policy set to “Route based on IP hash.”

Figure 29) ESX server VMkernel port properties with multiswitch EtherChannel.



### 3.7 STORAGE NETWORK ARCHITECTURE WITH TRADITIONAL ETHERNET SWITCHES

In this configuration, the IP switches do not support multiswitch link aggregation, so each storage controller requires four physical network connections. This design provides multiple active connections to each storage controller, provides a means to scale throughput by simply adding more connections, and requires multiple IP addresses per controller. Each host uses two physical links for each active network connection to achieve path HA.

#### SINGLE-MODE DESIGN

The single-mode design requires configuring each pair of network links as a single-mode (active-passive) EtherChannel or VIF. Each VIF has a connection to both switches and has a single IP address assigned to it, providing two IP addresses on each controller. The `vif favor` command is used to force each VIF to use the appropriate switch for its active interface. This option is preferred due to its simplicity and the lack of any special configuration on the network switches.

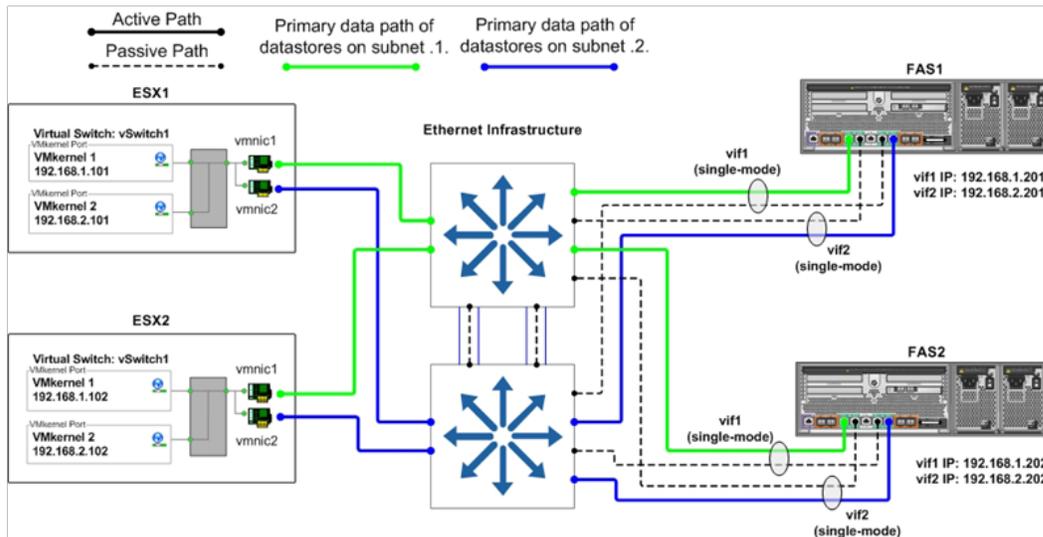
#### ADVANTAGES OF USING SINGLE-MODE ETHERCHANNEL

- Provides two active connections to each storage controller (but only one active path per datastore).
- Easily scales to more connections.
- Storage controller connection load balancing is automatically managed virtual port load-balancing policy. This is a non-EtherChannel solution.
- Switch-side configuration is not required.
- Access from the ESX/ESXi to the datastore does not require a multiswitch hop.

#### DISADVANTAGES OF USING SINGLE-MODE ETHERCHANNEL

- Requires the configuration of at least two VMkernel IP storage ports.
- Data I/O to a single IP is not aggregated over multiple links without adding more links.

Figure 30) Storage side single-mode VIFs.



#### LAYERED MULTIMODE DESIGN

A network diagram that depicts a layered multimode storage network architecture is shown in [TR-3880: CLI Configuration Processes for NetApp and VMware vSphere Storage Arrays Running Data ONTAP and ESX/ESXi Server](#) for customers who prefer that type of design.

## STORAGE LOAD BALANCING

Using multiple physical paths simultaneously on an IP storage network requires EtherChannel ports and multiple IP addresses on the storage controller and multiple VMkernel ports defined for storage I/O in the ESX/ESXi hosts. This model results in a design that balances datastore connectivity across all interfaces. This balancing is handled by the RCU at the time the datastore is provisioned.

## MULTIPLE VMKERNEL PORTS

The use of multiple VMkernel ports is a defined standard method developed by NetApp and repeated by other storage vendors offering arrays with multiprotocol access. NetApp recommends defining a separate VMkernel for each storage protocol. This method makes the configuration of iSCSI with NFS very simple. Each of these VMkernel ports supports IP traffic on a different subnet. Using different subnet addressing schemes for iSCSI and NFS provides the benefit of being able to control which VMkernel ports are used for communication of each protocol. (An example is shown in Figure 31.) Because the two VMkernel ports are in the same vSwitch, they can share the vmnics in a vSwitch.

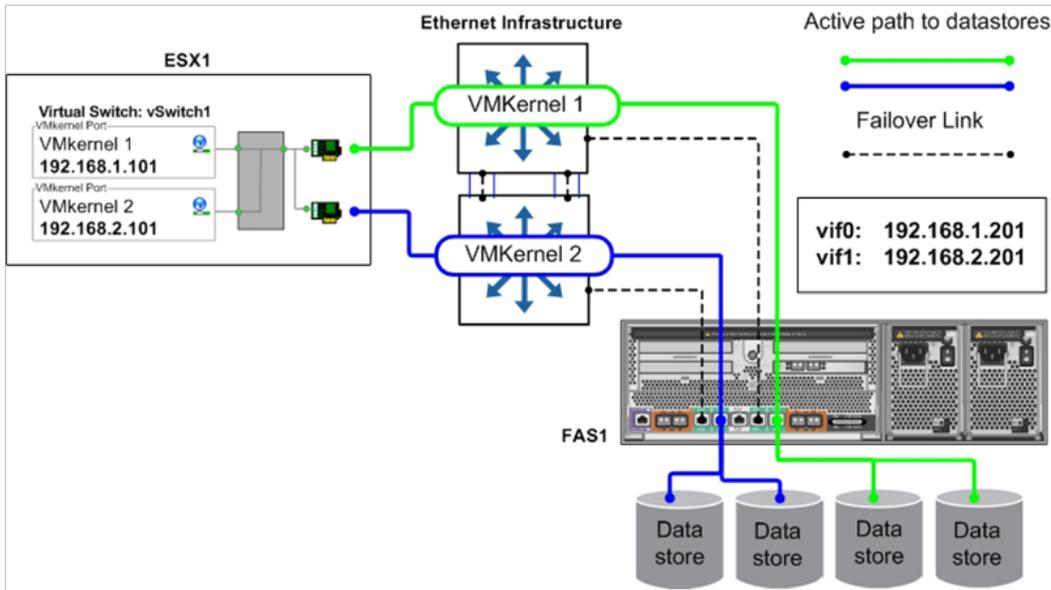
For NFS datastores, each VMkernel port is configured with a single active vmnic, with one or more standby vmnics defined. This allows the administrator to control which vmnic is used for traffic by each VMkernel port.

Figure 31) Displaying multiple VMkernel ports for iSCSI and NFS.



Figure 32 shows an overview of storage traffic flow when using multiple ESX servers and multiple datastores.

Figure 32) Datastore connections with traditional EtherChannel.



### ESX SERVER ADAPTER FAILOVER BEHAVIOR WITH ISCSI

In the case of ESX server adapter failure (due to a cable pull or NIC failure), traffic originally running over the failed adapter is rerouted and continues using the second adapter. This failover is managed by VMware native multipathing; therefore, network failover configuration is not needed on the switch or VMkernel. Traffic returns to the original adapter when service to the adapter is restored.

### ESX SERVER ADAPTER FAILOVER BEHAVIOR WITH NFS

In the case of ESX server adapter failure (due to a cable pull or NIC failure), traffic originally running over the failed adapter is rerouted and continues using the second adapter, but on the same subnet where it originated. Both subnets are now active on the surviving physical adapter. Traffic returns to the original adapter when service to the adapter is restored. In this scenario, EtherChannel provides the network failover.

### SWITCH FAILURE

Traffic originally running to the failed switch is rerouted and continues using the other available adapter, through the surviving switch, to the NetApp storage controller. Traffic returns to the original adapter when the failed switch is repaired or replaced.

Figure 33) ESX vSwitch1 normal mode operation.

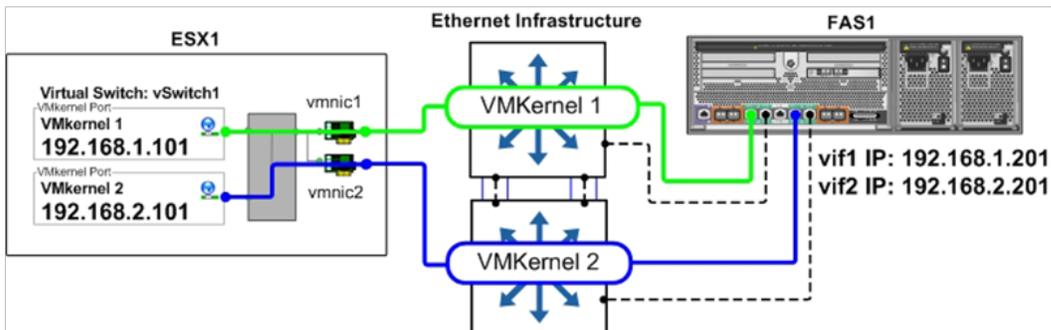
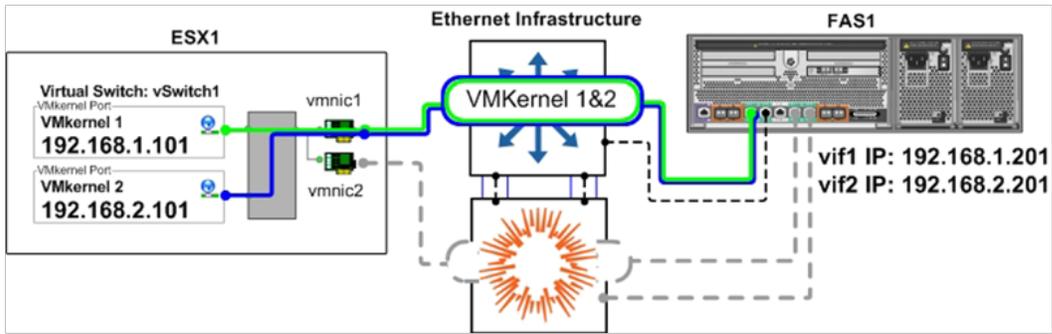


Figure 34) ESX vSwitch failover mode operation.



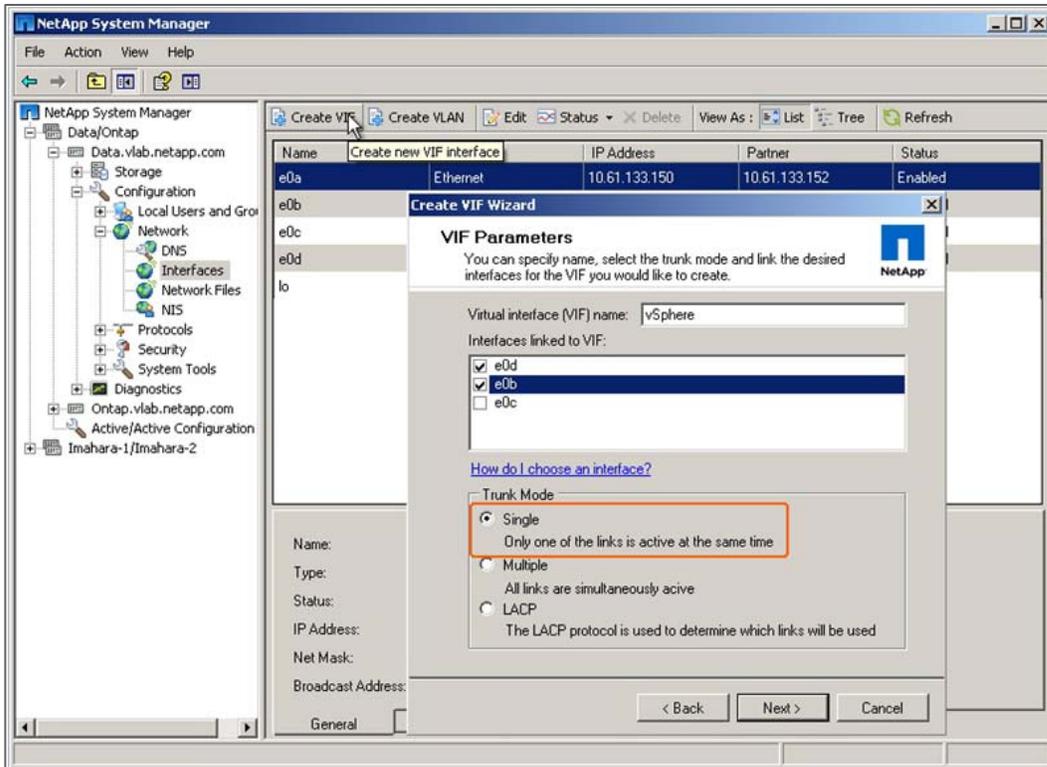
### CONFIGURING NETAPP STORAGE NETWORK PORTS

If you plan to deploy with IP-based storage access, NFS, or iSCSI, then you must configure multiple Ethernet links to operate together as an EtherChannel. EtherChannel provides aggregated bandwidth and link availability from the network switches to the storage controller. This design is recommended, because the storage controller handles the aggregated I/O load from all ESX/ESXi nodes.

NetApp supports all modes of EtherChannels that are compliant with 802.3ad LACP and/or static EtherChannels. In Data ONTAP, EtherChannels are referred to as virtual interfaces (VIFs). NetApp recommends that you configure your EtherChannel or VIFs as single mode with traditional switches, because this is the simplest network architecture.

For use in a traditional switch configuration, you must create a single-mode EtherChannel or VIF that is configured with a single IP address. This process is completed in the NSM.

Figure 35) Creating an LACP EtherChannel port with two physical NICs on the first storage controller.



**Note:** There is one peculiar aspect when creating the first half of an EtherChannel on an HA storage array: You have to select a physical NIC when assigning the partner interface because an EtherChannel is not configured on the second storage controller. After the EtherChannel is configured, you have to return to the first controller and edit the partner interface for the EtherChannel created on the first controller.

Figure 36) Completing the process of creating a single-mode EtherChannel port with two physical NICs on the first storage controller.

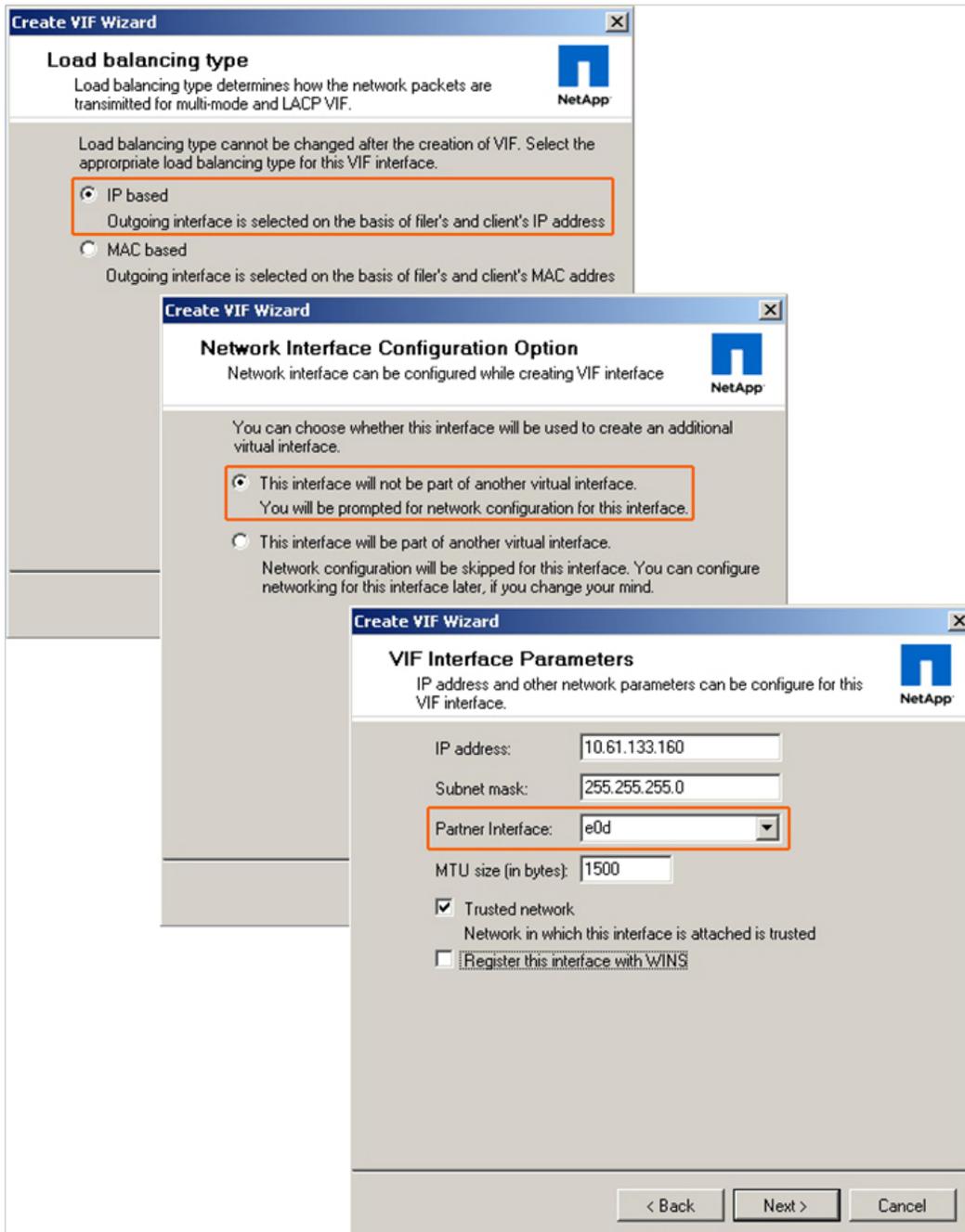


Figure 37) Completing the process of creating a single-mode EtherChannel port with two physical NICs on the second storage controller. Note that the EtherChannel on the first controller can be selected as a partner interface.

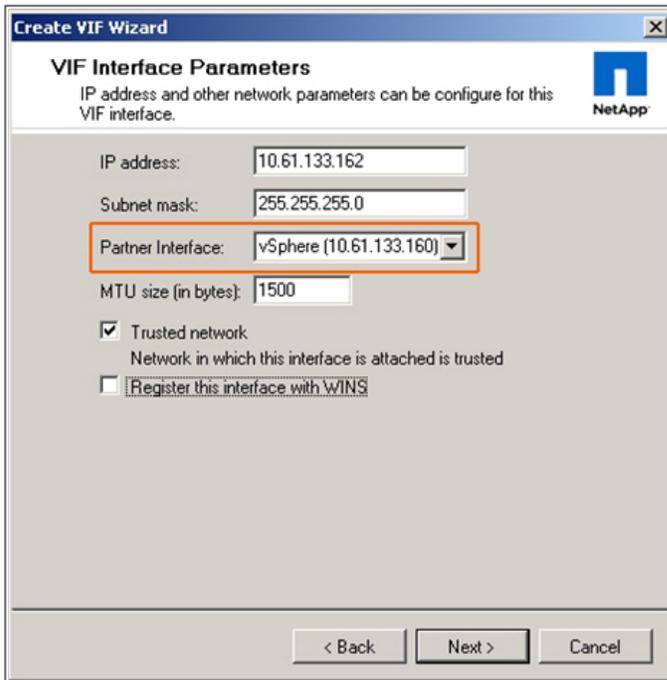
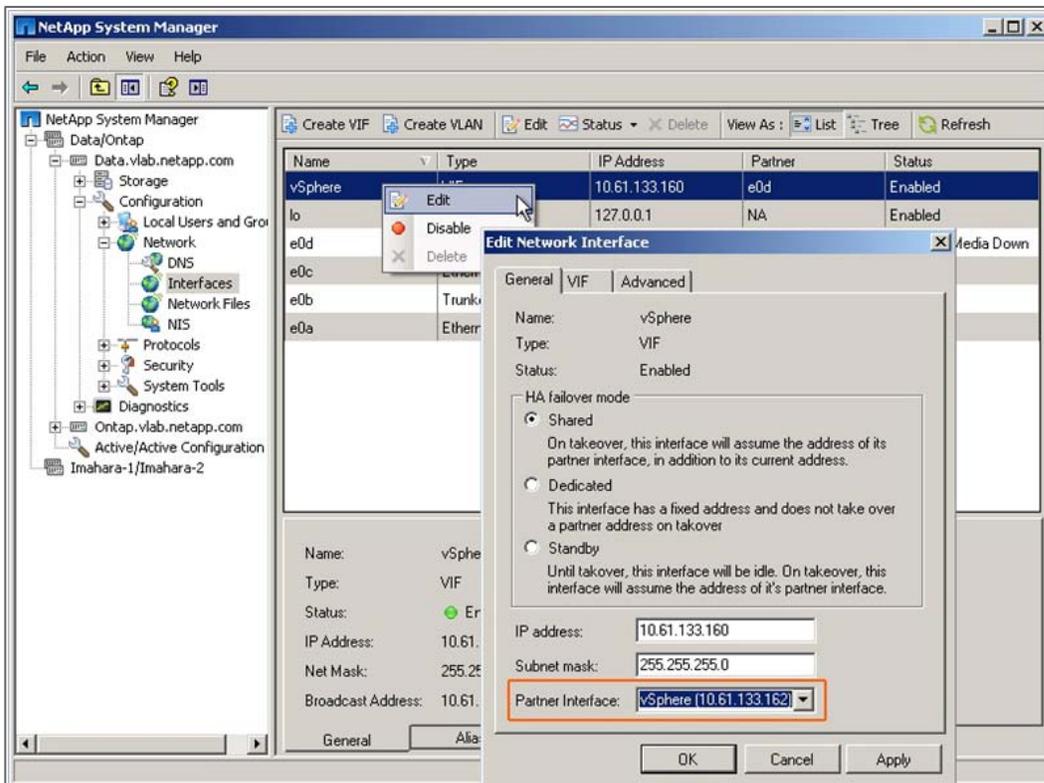


Figure 38) Completing the process of creating a single-mode EtherChannel. On the first controller the partner interface is set to the EtherChannel configured on the second array.

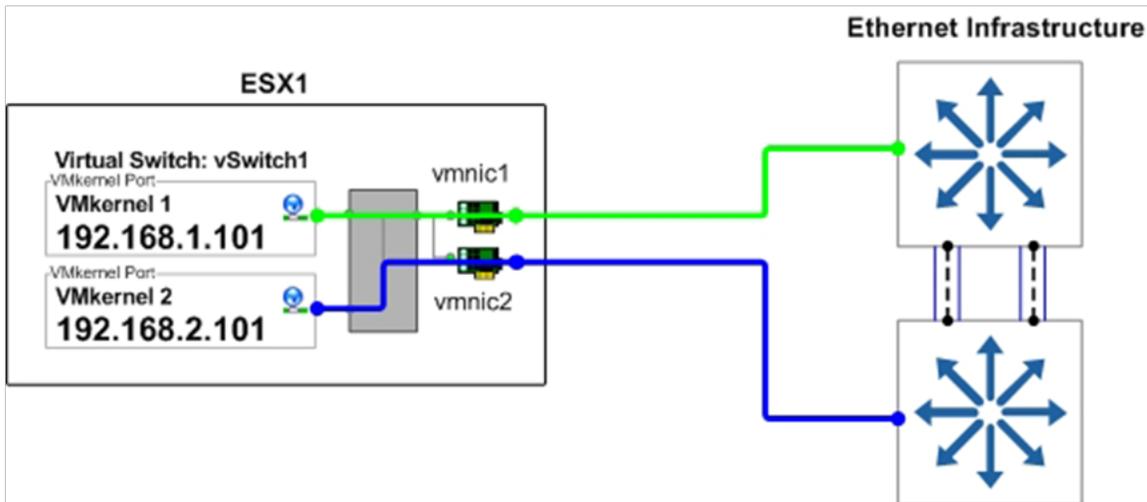


## CONFIGURING ESX/ESXi VMKERNEL STORAGE NETWORK PORTS

With traditional storage switches, each ESX/ESXi host must be configured with at least two VMkernel IP storage ports addressed on different subnets. As with the previous option, multiple datastore connections to the storage controller are necessary using different target IP addresses. Without the addition of a second VMkernel port, the VMkernel would simply route all outgoing requests through the same physical interface, without making use of additional vmnics on the vSwitch. In this configuration, each VMkernel port is set with its IP address on a different subnet. The target storage system is also configured with IP addresses on each of those subnets, so the use of specific vmnic interfaces can be controlled.

In the ESX/ESXi host configuration, shown in Figure 39, a vSwitch (named vSwitch1) has been created specifically for IP storage connectivity. Two physical adapters have been configured for this vSwitch (in this case, vmnic1 and vmnic2). Each of these adapters is connected to a different physical switch.

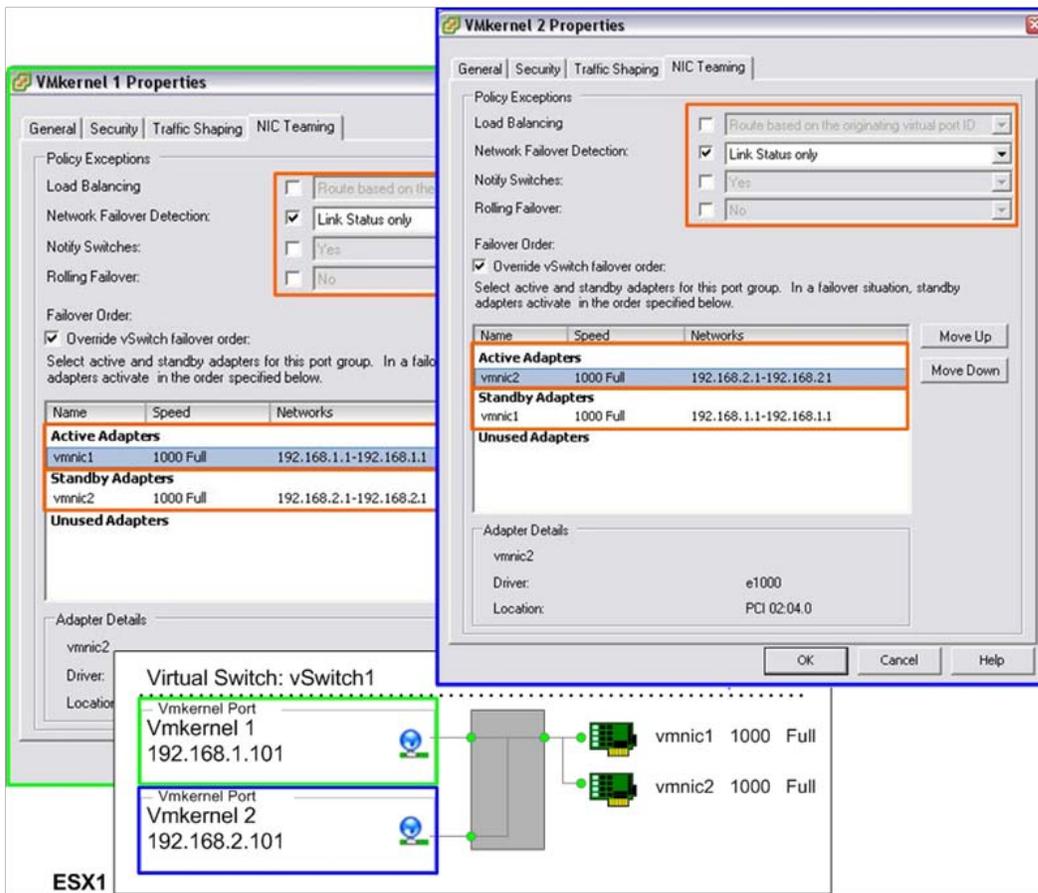
Figure 39) ESX server physical NIC connections with traditional Ethernet.



In vSwitch1, two VMkernel ports have been created (VMkernel 1 and VMkernel 2). Each VMkernel port has been configured with an IP address on a different subnet, and the NIC teaming properties of each VMkernel port have been configured as follows.

- **VMkernel 1:** IP address set to 192.168.1.101.
- **VMkernel 1 port properties:**
  - Enable the override vSwitch failover order option.
  - For NFS and iSCSI, set the active adapter to vmnic1.
  - For NFS, set the standby adapter to vmnic2.
  - For iSCSI, set the other adapters to unused.
- **VMkernel 2:** IP address set to 192.168.2.101.
- **VMkernel 2 port properties:**
  - Enable the override vSwitch failover order option.
  - For NFS and iSCSI, set the active adapter to vmnic2.
  - For NFS, set the standby adapter to vmnic1.
  - For iSCSI, set the other adapters to unused.

Figure 40) ESX server VMkernel port properties with traditional Ethernet.



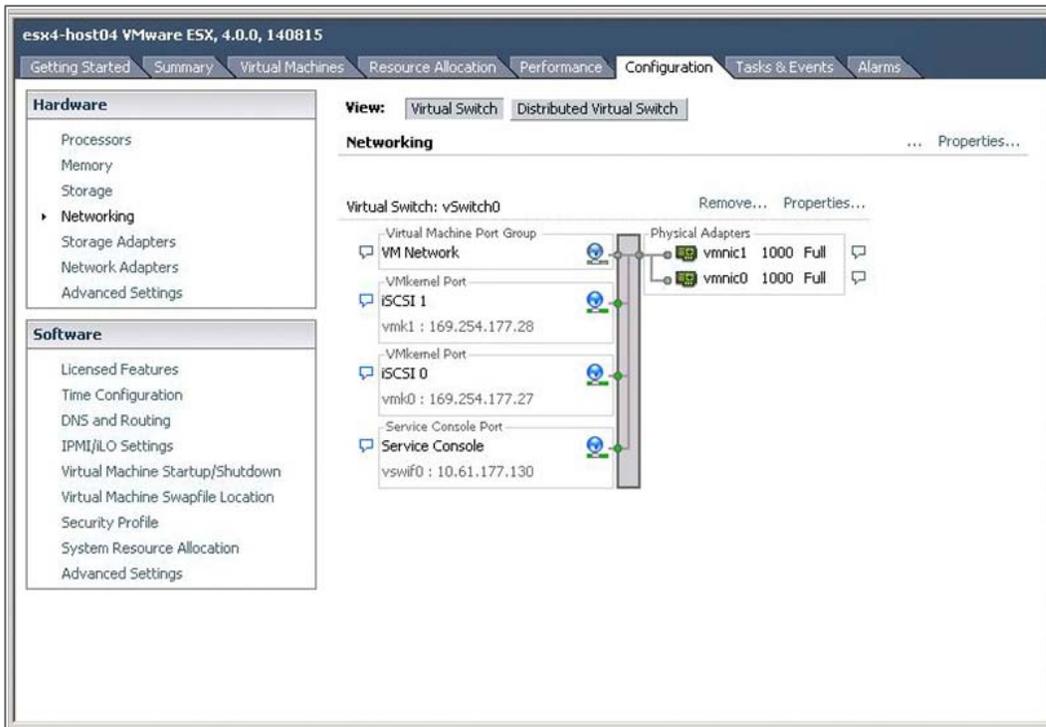
### 3.8 ENABLING MULTIPLE TCP SESSION SUPPORT FOR ISCSI

vSphere has the option of enabling the use of multiple TCP sessions with iSCSI. This feature enables round robin load balancing using VMware native multipathing and requires defining a VMkernel port for each vmnic assigned to iSCSI traffic.

For iSCSI datastores, each VMkernel port is configured with a single vmnic. Standby vmnics cannot exist in the VMkernel.

Configuring iSCSI VMkernel ports, as described in this section, results in the individual iSCSI VMkernel ports being configured without NIC teaming and therefore without any network layer redundancy. In this configuration, iSCSI redundancy is provided by the native multipathing layer in ESX/ESXi. This configuration provides iSCSI redundancy in the same way as FC redundancy. Enabling multiple TCP session support for iSCSI on ESX/ESXi hosts that also connect with NFS is not supported and should not be done, because it might result in NFS mounts occurring over the iSCSI VMkernel ports, which do not have network layer redundancy. NetApp recommends that hosts requiring the concurrent use of both iSCSI and NFS rely on the TCP layer of the network using NIC teaming for storage path redundancy, as described previously.

Figure 41) Displaying multiple VMkernel ports for iSCSI with support for multiple TCP sessions.



**Note:** ESX/ESXi 4 supports a maximum of four iSCSI ports per host.

### CREATE MULTIPLE ISCSI VMKERNELS TO SUPPORT MULTIPLE TCP SESSIONS WITH ISCSI

To create multiple iSCSI VMkernels to support multiple TCP sessions with iSCSI, complete the following steps:

1. Open vCenter Server.
2. Select an ESX host.
3. Select the Configuration tab in the right pane.
4. Select Networking in the Hardware box.
5. Click Add Networking, in the upper-right corner, to open the Add Network wizard.
6. Select the VMkernel radio button and click Next.

**Note:** Create a VMkernel for every Ethernet link that you want to dedicate to iSCSI traffic. VMkernels can be on different IP subnets.

7. Configure the VMkernel by providing the required network information. A default gateway is not required for the VMkernel IP storage network.
8. Configure each VMkernel to use a single active adapter that is not used by any other iSCSI VMkernel. Also, each VMkernel must not have any standby adapters. Refer to Figure 42 and Figure 43.

The software iSCSI daemon must be bound to each VMkernel. This step can only be completed using the CLI.

9. Connect to an ESX or ESXi console and run the following command:

```
esxcli swiscsi nic add -n <VMkernel ID> -d <Virtual HBA ID>
```

For example:

```
esxcli swiscsi nic add -n vmk0 -d vmhba33
esxcli swiscsi nic add -n vmk1 -d vmhba33
```

10. Verify the iSCSI-to-VMkernel bindings. Connect to an ESX or ESXi console and run the following command:

```
esxcli swiscsi nic list -d <Virtual HBA ID>
```

For example:

```
esxcli swiscsi nic list -d vmhba33
```

Refer to Figure 44.

Figure 42) iSCSI VMkernel 0: Note active adapter vmnic0.

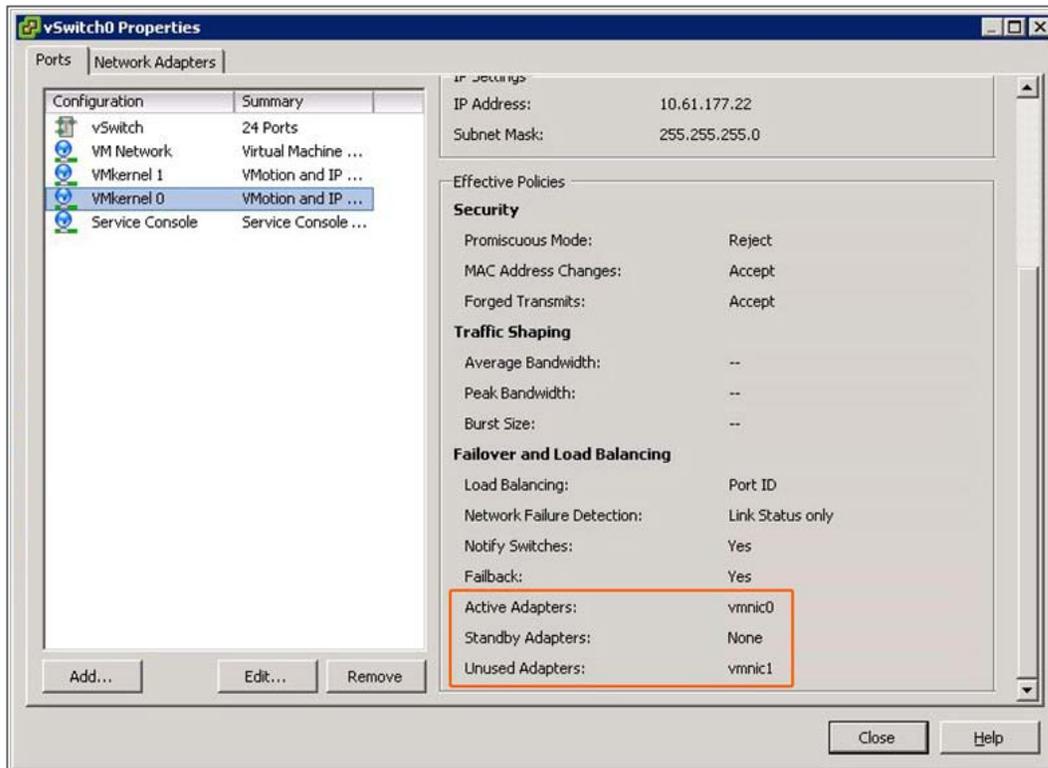


Figure 43) iSCSI VMkernel 1: Note active adapter vmnic1.

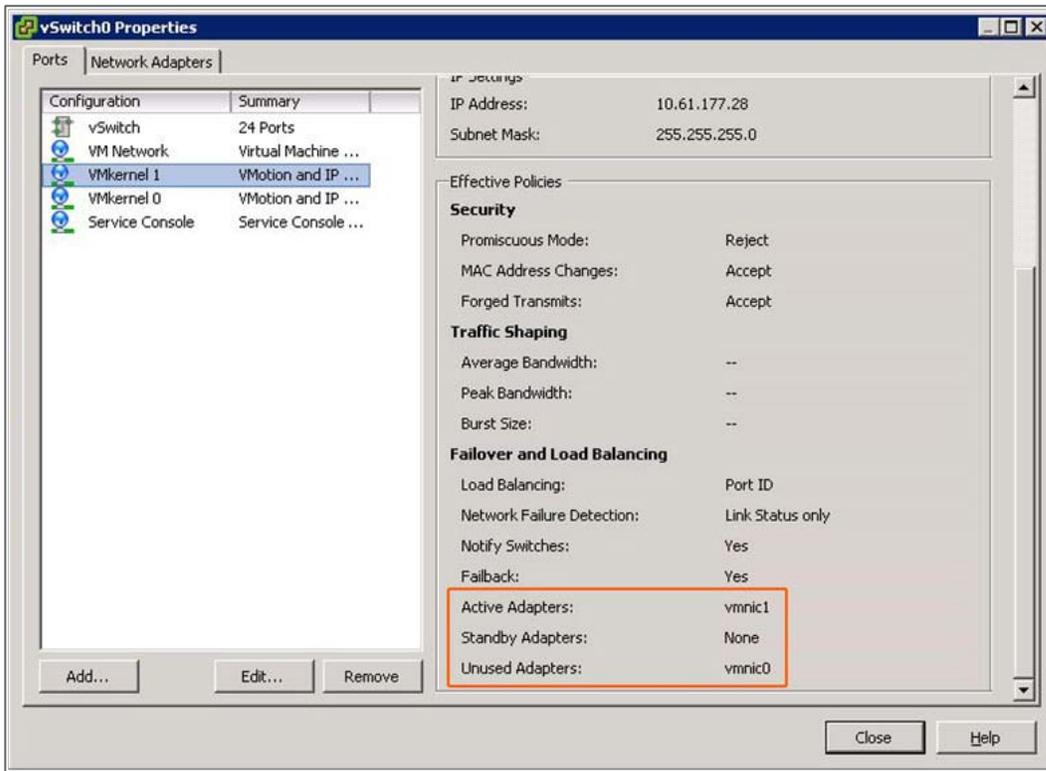
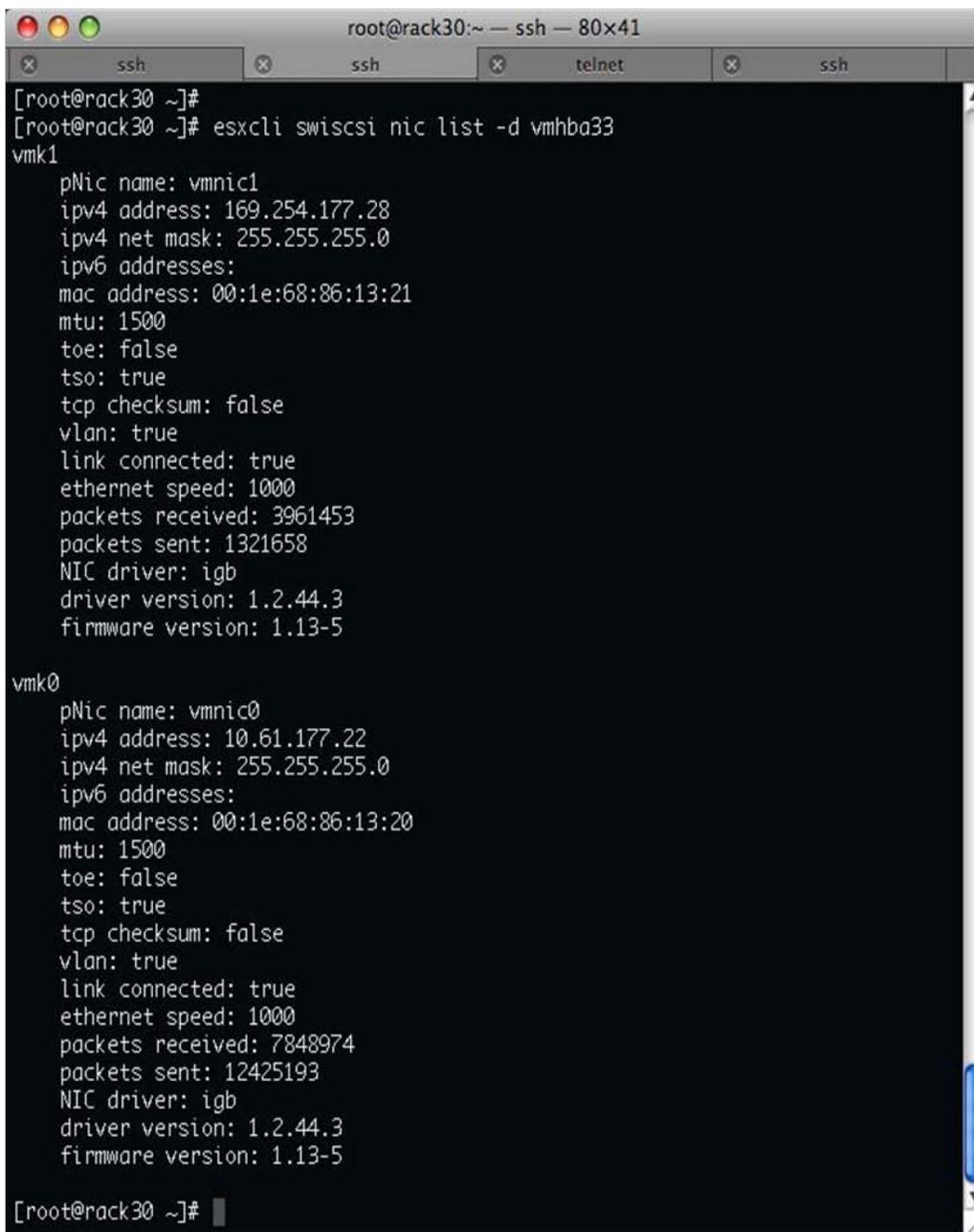


Figure 44) iSCSI to VMkernel bindings for use with multiple TCP sessions.



```
root@rack30:~ -- ssh -- 80x41
ssh ssh telnet ssh
[root@rack30 ~]#
[root@rack30 ~]# esxcli swiscsi nic list -d vmhba33
vmk1
  pNic name: vmnic1
  ipv4 address: 169.254.177.28
  ipv4 net mask: 255.255.255.0
  ipv6 addresses:
  mac address: 00:1e:68:86:13:21
  mtu: 1500
  toe: false
  tso: true
  tcp checksum: false
  vlan: true
  link connected: true
  ethernet speed: 1000
  packets received: 3961453
  packets sent: 1321658
  NIC driver: igb
  driver version: 1.2.44.3
  firmware version: 1.13-5

vmk0
  pNic name: vmnic0
  ipv4 address: 10.61.177.22
  ipv4 net mask: 255.255.255.0
  ipv6 addresses:
  mac address: 00:1e:68:86:13:20
  mtu: 1500
  toe: false
  tso: true
  tcp checksum: false
  vlan: true
  link connected: true
  ethernet speed: 1000
  packets received: 7848974
  packets sent: 12425193
  NIC driver: igb
  driver version: 1.2.44.3
  firmware version: 1.13-5

[root@rack30 ~]#
```

## 4 STORAGE ARRAY DESIGN AND SETUP

This section applies to:



Storage administrators

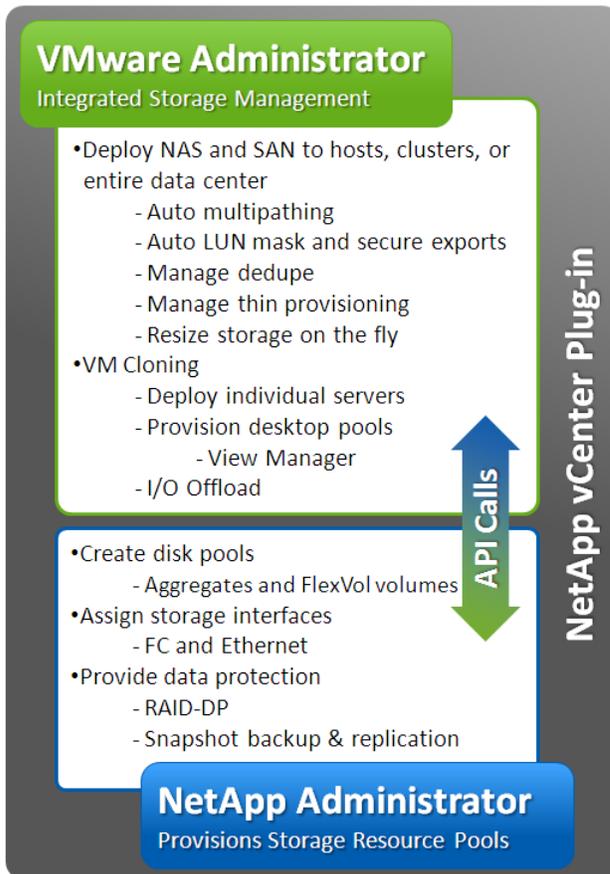


VI administrators

### 4.1 A NEW OPERATIONAL MODEL: PROVISIONING RESOURCE POOLS

The technologies available from NetApp, which are covered in this document, provide the means for a new operational model. Storage administrators can use this model to significantly simplify the support required for virtual infrastructures.

Figure 45) NetApp vCenter plug-in responsibilities.



In this new model, storage administrators are responsible for configuring the physical storage array enabling data protection and storage connectivity. Once the physical architecture is deployed, NetApp administrators supporting VMware can simply provision pools of “raw” storage resources (aggregates, FlexVol volumes, and storage network interfaces) directly for use in the virtual infrastructure.

This model significantly simplifies the tasks required by the storage administrator. It also enables the VMware administrator to provision and manage datastores and the storage constructs associated with them, such as LUN masking and storage I/O path management, directly from the physical resources assigned to the virtual infrastructure by the NetApp administrator.

This design does not prohibit IT staff from deploying and managing storage in a traditional manner, which can be described as a method in which the storage administrator creates specific storage objects and the VMware administrative team connects to and uses these objects.

All administrative teams within a virtual data center will benefit from using our VMware integration to run their business more simply and with a higher degree of efficiency, which is in line with the NetApp motto of "go further, faster."

## NETAPP VCENTER PLUG-INS

The NetApp vCenter plug-ins, the Virtual Storage Console (VSC), and the Rapid Cloning Utility (RCU) have been combined into one NetApp plug-in framework with the release of VSC version 2.0. Additionally, VSC 2.0 now includes access to all of the capabilities of the NetApp SnapManager for Virtual Infrastructure (SMVI) product directly in the vSphere client interface.

The VSC nondisruptively sets storage-related configurations to their recommended values on ESX/ESXi hosts. In addition, VSC 2.0 provides automated provisioning of storage resource pools as datastores in a dynamic means by the VMware administrators. This provisioning model configures all storage access to follow NetApp recommended best practices in terms of availability, access control, and storage path management.

## 4.2 STORAGE ARCHITECTURE CONCEPTS

Prepare the following information before you configure your storage array to run a virtual infrastructure:

- Separate the networks for storage array management and storage I/O. This concept applies to all storage protocols, but is very pertinent to Ethernet-based deployments (NFS, iSCSI, FCoE). The separation can be physical (subnets) or logical (VLANs), but it must exist.
- If leveraging an IP-based storage protocol I/O (NFS or iSCSI), you might need more than a single IP address for the storage target. This determination is based on the capabilities of your networking hardware.
- With IP-based storage protocols (NFS and iSCSI), you channel multiple Ethernet ports together. NetApp refers to this function as a VIF. NetApp recommends creating LACP VIFs over multimode VIFs whenever possible.

## 4.3 NETAPP STORAGE CONSTRUCTS

A byproduct of any consolidation effort is the increased risk if the consolidation platform fails. As physical servers are converted to VMs and multiple VMs are consolidated onto a single physical platform, the impact of a failure to the single platform could be catastrophic. Fortunately, VMware provides multiple technologies that enhance availability of a virtual data center. These technologies include increased VM availability and load balancing with VMware HA and DRS clustering, zero-loss application availability with fault tolerance, and the ability to nondisruptively migrate running VMs and their datasets between physical ESX servers with VMotion and storage VMotion, respectively.

When focusing on storage availability, many levels of redundancy are available for deployments, including purchasing physical servers with multiple storage interconnects or HBAs, deploying redundant storage networking and network paths, and leveraging storage arrays with redundant controllers. A deployed storage design that meets all of these criteria can eliminate all single points of failure.

## DATA PROTECTION AND RAID-DP

The reality is that data protection requirements in a virtual infrastructure are greater than those in a traditional physical server infrastructure. Data protection is a paramount feature of shared storage devices. NetApp RAID-DP<sup>®</sup> is an advanced RAID technology that is provided as the default RAID level on all FAS systems. RAID-DP protects against the simultaneous loss of two drives in a single RAID group. It is very economical to deploy; the overhead with default RAID groups is a mere 12.5%. This level of resiliency and storage efficiency makes data residing on RAID-DP safer than data stored on RAID5 and more cost effective than RAID10. NetApp recommends using RAID-DP on all RAID groups that store VMware data.

Figure 46) NetApp RAID-DP.



## AGGREGATES

An aggregate is the NetApp virtualization layer, which abstracts physical disks from logical datasets that are referred to as *flexible volumes*. Aggregates are the means by which the total IOPS available to all of the physical disks are pooled as a resource. This design is well suited to meet the needs of an unpredictable and mixed workload.

NetApp controllers store their files required to run the array on a root aggregate. Whenever possible, NetApp recommends using a dedicated two-disk aggregate. By default, the root aggregate is composed of three disks due to the overhead of RAID-DP. To reduce the disk total from three to two, you must modify the RAID type from RAID-DP to RAID4.

**Note:** This recommendation is very difficult to implement when you have a small number of disk drives. In this scenario, deploying with a dedicated root aggregate is not recommended.

The remaining storage should be placed into a small number of large aggregates. The overall disk I/O from VMware environments is traditionally random by nature, so this storage design gives an optimal performance because a large number of physical spindles are available to service I/O requests. On smaller FAS arrays, having more than a single aggregate might not be practical because of the restricted number of disk drives on the system. In this case, it is acceptable to have only a single aggregate.

## FLEXIBLE VOLUMES

Flexible volumes contain either LUNs or virtual disk files that are accessed by VMware ESX servers.

NetApp recommends a one-to-one relationship between VMware datastores and flexible volumes when deploying virtual servers. For virtual desktops, NetApp recommends a one-to-one relationship between VMware desktop pools and flexible volumes.

This design offers an easy means to understand the VMware data layout when viewing the storage configuration from the FAS array. This mapping model also makes it easy to implement Snapshot backups and SnapMirror replication policies at the datastore level, because NetApp implements these storage-side features at the flexible volume level.

## LUNS

LUNs are units of SCSI addressed storage (FC, iSCSI, and FCoE) that, when connected to an ESX/ESXi cluster, are used as a shared VMFS datastore or raw device mapping (RDM). For more information, refer to the iSCSI or Fibre Channel SAN configuration guides.

## STORAGE NAMING CONVENTIONS

NetApp storage systems allow human or canonical naming conventions. In a well-planned virtual infrastructure implementation, a descriptive naming convention aids in the identification and mapping through the multiple layers of virtualization from storage to the VMs. A simple and efficient naming convention also facilitates the configuration of replication and disaster recovery processes.

NetApp recommends the following naming guidelines:

- **Name of aggregate.** Can be any name that the storage administrator selects.
- **Name of FlexVol volume.** Should match the name of the datastore.
- **LUN name for VMFS.** Should match the name of the datastore.
- **LUN name for RDMs.** Should include both the host name and the volume label or name.

## 4.4 NETAPP ARRAY CONFIGURATION

This section covers the steps required to configure and provision a NetApp storage array into physical resource pools.

### NETAPP SYSTEMS MANAGER

NetApp provides the NetApp Systems Manager (NSM) as a convenient means to deploy a new storage array or manage a moderate number of storage arrays. Additional methods are available to manage storage arrays powered by Data ONTAP. These include legacy array-based methods such as FilerView<sup>®</sup> and the command line interface (CLI) all the way up to global monitoring and management using Operations Manager.

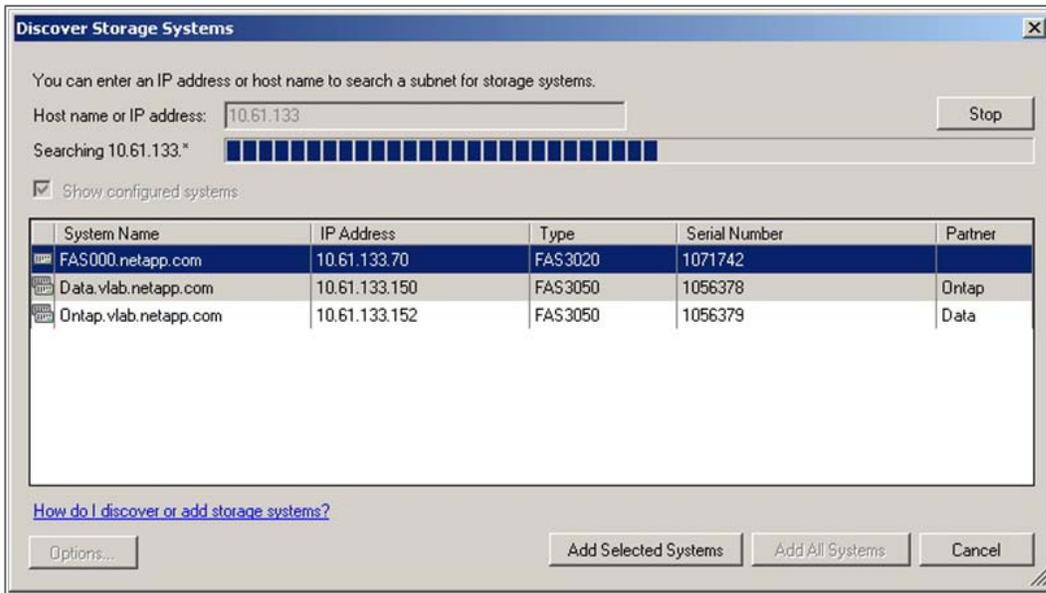
In this document, we use the NSM exclusively for array-based configuration by the storage administrative team. The traditional configuration steps from previous versions of this document are included in [TR-3880: CLI Configuration Processes for NetApp and VMware vSphere Storage Arrays Running Data ONTAP and ESX/ESXi Server](#).

### DISCOVERING ARRAYS POWERED BY DATA ONTAP

To discover arrays powered by Data ONTAP, start by downloading and installing the NSM from [NOW™](#) onto a server or VM based on Microsoft Windows. Rack and cable your NetApp array. You are required to connect at least one Ethernet port to complete a network-based setup that requires the assignment of a temporary IP address using Dynamic Host Configuration Protocol (DHCP). Alternatively, you can connect a serial cable to the array and complete the command line setup wizard that launches when the power is turned on.

In either scenario, you can launch the NSM and allow it to autodiscover your storage arrays by entering either the IP address of the array or the IP subnet on which the array resides. For more information on setting up a new array using the NSM, refer to the [NetApp Systems Manager Quick Start Guide](#).

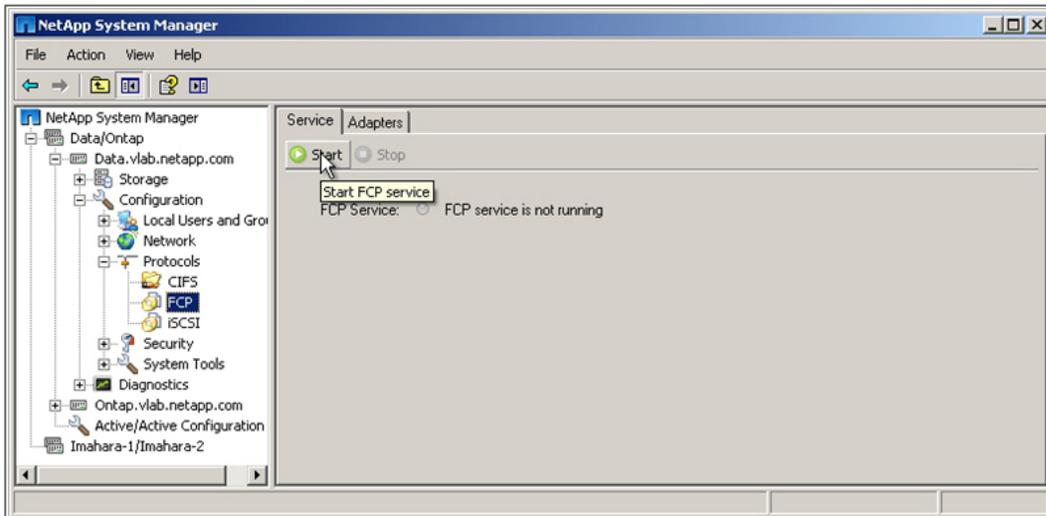
Figure 47) Discovering arrays using the NetApp Systems Manager.



## CONFIGURING STORAGE NETWORK INTERFACES

If you plan to deploy an FC or FCoE configuration, the only configuration requirement on the storage array is to enable the FC storage protocol. The RCU handles all LUN creation, masking, and other options.

Figure 48) Starting a storage protocol using the NetApp Systems Manager.



If you plan to deploy with IP-based storage access, NFS, or iSCSI, then you must configure multiple Ethernet links to operate together as an EtherChannel. The determining factor of how your network ports are configured is based on the capabilities of your network switches. These capabilities and the process for completing the network port configuration are covered in [section 3](#).

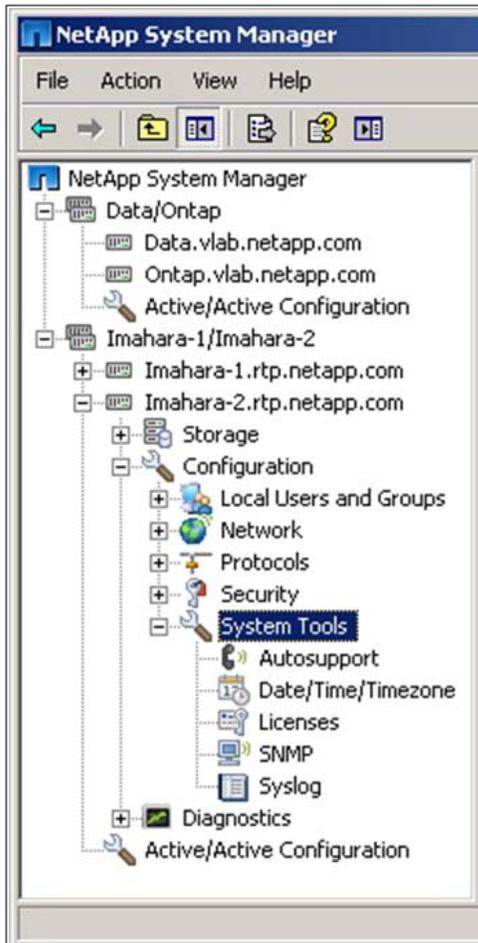
## MONITORING STORAGE USE WITH NETAPP SYSTEMS MANAGER

NetApp Systems Manager can monitor, manage, and generate reports on current generation NetApp FAS systems in small to medium size organizations.

When using storage savings technologies, such as thin provisioning and deduplication, it is very important to monitor the free space available in storage aggregates. Proper notification of the available free space means that additional storage can be made available before the aggregate becomes completely full.

NetApp recommends setting up e-mail and pager notifications to the appropriate administrators and Simple Network Management Protocol (SNMP) monitoring. These can both be configured in the NSM.

Figure 49) Setting up monitoring in the NetApp Systems Manager.



## MONITORING STORAGE USE WITH NETAPP OPERATIONS MANAGER

NetApp Operations Manager monitors, manages, and generates reports on all of the NetApp FAS systems in medium to large size organizations. When using NetApp thin provisioning, NetApp recommends deploying Operations Manager and setting up e-mail and pager notifications to the appropriate administrators. With thin-provisioned storage, it is very important to monitor the free space available in storage aggregates. Proper notification of the available free space means that additional storage can be made available before the aggregate becomes completely full. For more information about setting up notifications, refer to the [DataFabric Manager Server: Operations Manager Administration Guide](#).

Firewalls and TCP/IP Ports Required by VSC

VSC uses standard protocols to communicate between the vSphere client, vCenter server, VSC server and NetApp storage controllers. However, some of the communication uses less common ports. VSC requires the ports in Table 6 to be open between the client, vCenter server and VSC server.

Table 6) TCP/IP ports used by VSC.

Port	Purpose
80	VMware vCenter Server and the NetApp storage systems listen for standard, unencrypted communication via standard HTTP on this port.
443	VMware vCenter Server and the NetApp storage systems listen for secure communications via secure HTTP (SSL) on this port.
8043	Backup and recovery plug-in listens for secure communication on this port. The backup and recovery restore agent and CLI also make use of this port.
8143	VSC plug-in listens for secure communication on this port.

## 4.5 CREATING A SERVICE ACCOUNT FOR THE CORE FEATURE OF THE VIRTUAL STORAGE CONSOLE 2.0

Although you can use the NetApp root user account as the VSC service account, it is typically not a recommended practice. This section covers how to create a user account within Data ONTAP for use as the service account within the VSC. This account is only granted the rights required to enable the functionality of the VSC 2.0 core features using NetApp role-based access controls (RBACs) on the storage array.

**Note:** This section only describes the RBAC rights necessary to enable the VSC core features in the VSC 2.0 framework.

### ARRAY-SIDE CONFIGURATION

The first part of enabling RBAC is to create a new user, group, and role. The group contains the user and has the role assigned to it. To complete this process, you must complete the following steps using the Data ONTAP CLI (SSH, console connection, or telnet).

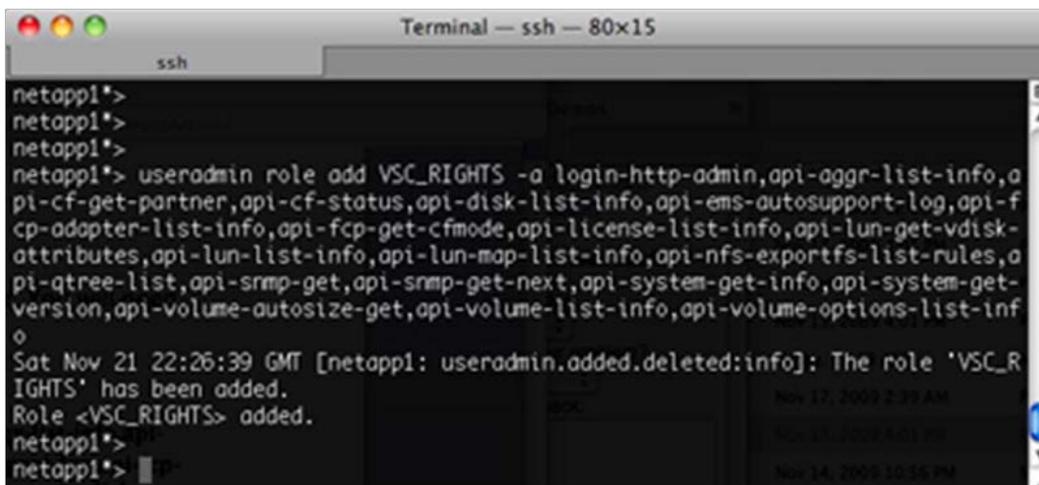
**Note:** Copying and pasting commands from this document might result in incorrectly transferred characters caused by end-of-line breaks or carriage returns. These types of errors cause the commands to fail. NetApp recommends copying and pasting the given commands into a text editor so the characters can be verified and corrected before being pasted into the NetApp CLI console.

### STEP 1: CREATE A ROLE DEFINING THE RIGHTS REQUIRED FOR VSC CORE FEATURES

1. Create a name for this role.
2. Enter the following command on each storage controller.

```
useradmin role add "role_name" -a login-http-admin,api-aggr-list-info,api-cf-get-partner,api-cf-status,api-disk-list-info,api-ems-autosupport-log,api-fcp-adapter-list-info,api-fcp-get-cfmode,api-license-list-info,api-lun-get-vdisk-attributes,api-lun-list-info,api-lun-map-list-info,api-nfs-exportfs-list-rules,api-qtree-list,api-snmp-get,api-snmp-get-next,api-system-get-info,api-system-get-version,api-volume-autosize-get,api-volume-list-info,api-volume-options-list-info
```

Figure 50) Creating the role for the VSC core feature service account.



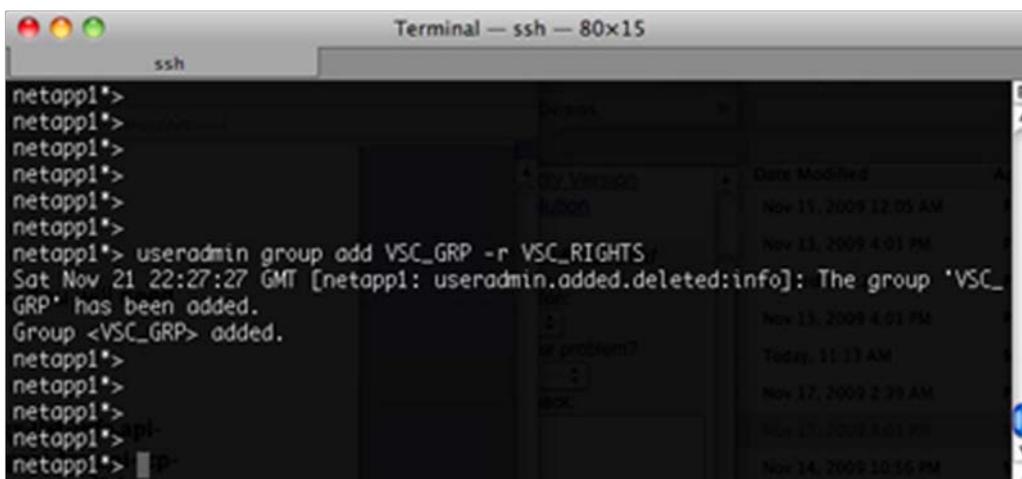
```
Terminal — ssh — 80x15
ssh
netapp1*>
netapp1*>
netapp1*>
netapp1*> useradmin role add VSC_RIGHTS -a login-http-admin,api-aggr-list-info,api-cf-get-partner,api-cf-status,api-disk-list-info,api-ems-autosupport-log,api-fcp-adapter-list-info,api-fcp-get-cfmode,api-license-list-info,api-lun-get-vdisk-attributes,api-lun-list-info,api-lun-map-list-info,api-nfs-exportfs-list-rules,api-qtree-list,api-srmp-get,api-srmp-get-next,api-system-get-info,api-system-get-version,api-volume-autosize-get,api-volume-list-info,api-volume-options-list-info
Sat Nov 21 22:26:39 GMT [netapp1: useradmin.added.deleted:info]: The role 'VSC_RIGHTS' has been added.
Role <VSC_RIGHTS> added.
netapp1*>
netapp1*>
```

### STEP 2: CREATE A USER GROUP AND ASSIGN THE ROLE TO THE GROUP

1. Create a name for this group and reference the role name created in the previous step.
2. Enter the following command on each storage controller.

```
useradmin group add "group_name" -r "role_name"
```

Figure 51) Creating the group for the VSC core feature service account.



```
Terminal — ssh — 80x15
ssh
netapp1*>
netapp1*>
netapp1*>
netapp1*>
netapp1*>
netapp1*> useradmin group add VSC_GRP -r VSC_RIGHTS
Sat Nov 21 22:27:27 GMT [netapp1: useradmin.added.deleted:info]: The group 'VSC_GRP' has been added.
Group <VSC_GRP> added.
netapp1*>
netapp1*>
netapp1*>
netapp1*>
netapp1*>
```

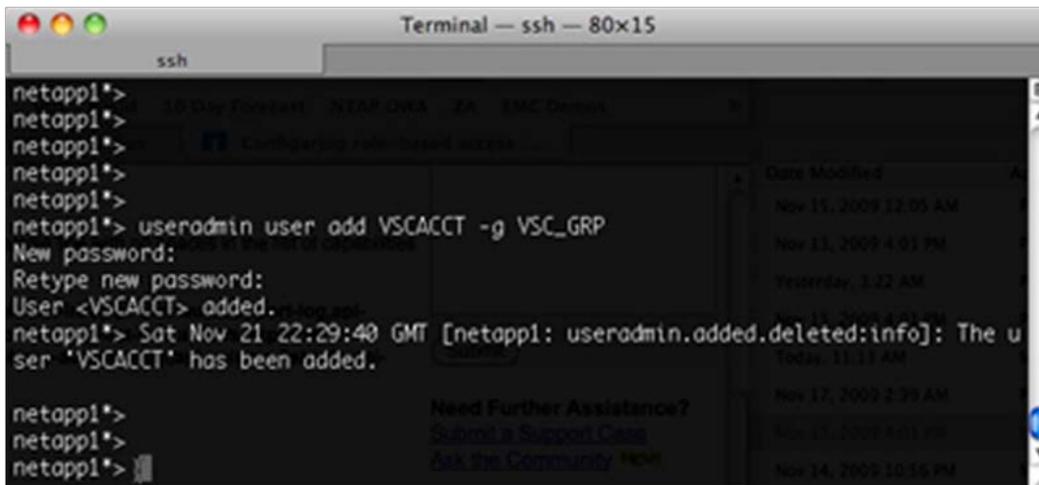
### STEP 3: CREATE A USER ACCOUNT IN THE GROUP THAT WILL BE USED BY THE VSC

1. Create a name and password for this user account and reference the group name created in the previous step.
2. Enter the following command on each storage controller.

```
useradmin user add "user_name" -g "group_name"
```

**Note:** You will be prompted to create the account password.

Figure 52) Creating the user for the VSC core feature service account.



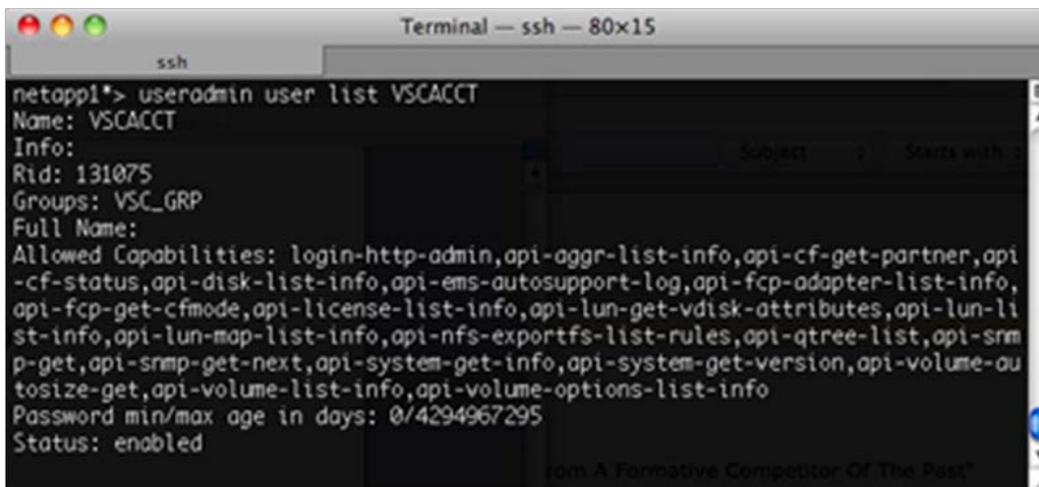
```
Terminal — ssh — 80x15
ssh
netapp1*>
netapp1*>
netapp1*>
netapp1*>
netapp1*> useradmin user add VSCACCT -g VSC_GRP
New password:
Retype new password:
User <VSCACCT> added.
netapp1*> Sat Nov 21 22:29:40 GMT [netapp1: useradmin.added.deleted:info]: The u
ser 'VSCACCT' has been added.
netapp1*>
netapp1*>
netapp1*>
```

#### STEP 4: VERIFY YOUR WORK

1. Reference the user account created in the previous step.
2. Enter the following command on each storage controller.  
useradmin user list "user\_name"

The user and group information is displayed and should match the entries in the previous three steps.

Figure 53) Verifying the creation of the VSC core feature service account.



```
Terminal — ssh — 80x15
ssh
netapp1*> useradmin user list VSCACCT
Name: VSCACCT
Info:
Rid: 131075
Groups: VSC_GRP
Full Name:
Allowed Capabilities: login-http-admin,api-aggr-list-info,api-cf-get-partner,api
-cf-status,api-disk-list-info,api-ems-autosupport-log,api-fcp-adapter-list-info,
api-fcp-get-cfmode,api-license-list-info,api-lun-get-vdisk-attributes,api-lun-li
st-info,api-lun-map-list-info,api-nfs-exportfs-list-rules,api-qtree-list,api-srmp
p-get,api-srmp-get-next,api-system-get-info,api-system-get-version,api-volume-au
tosize-get,api-volume-list-info,api-volume-options-list-info
Password min/max age in days: 0/4294967295
Status: enabled
```

Use this restricted service account with the VSC during the installation phase.

## 4.6 SETTING STORAGE MANAGEMENT OPTIONS FOR THE PROVISIONING AND CLONING FEATURE OF VSC 2.0

The ability to provision storage resources to the VI administrative team can enable a very dynamic infrastructure, which greatly simplifies storage operations and accelerates the virtualization of the data center. This new model doesn't have to be an all-or-nothing enablement because the functionality of the RCU can be restricted to one of four roles.

Today, these roles are global to the functionality available to all administrators in vCenter. A future update will enable these roles to be assigned to individual vCenter users or groups.

### THE AVAILABLE ROLES

The Provisioning and Cloning feature of the VSC 2.0 enables the storage administrator to delegate capabilities to the virtual administrator by creating one of the four roles listed in Figure 54. Each role builds on the functionality available to lower role(s). The functionality enabled in the VSC increases as more RBAC rights are enabled for the virtual administrator.

Figure 54) The four provisioning and cloning roles available to the VSC.

<b>Destroy Datastores:</b> Disconnects and deletes
<b>Modify Datastores:</b> Resize & dedupe
<b>Create Datastores:</b> Provision SAN & NAS
<b>Create Clones:</b> Pre-deduplicated VMs

These roles are enabled by creating a service account on the storage array that is entered as the service account in the Provisioning and Cloning interface. This account can be modified at any time on the storage array, and these changes will become apparent in vCenter. This enables the storage administrative team to have root control of the array while enabling the VMware team to manage its storage resource pools.

Refer to [section 5.3](#) for directions on how to enter this account in the VSC.

To create this account, complete the following steps.

### STEP 1: CREATE THE REQUIRED PROVISIONING AND CLONING ROLE

This section covers the role required by the VSC for basic Provisioning and Cloning functionality. This role is created on the array and is required for higher level functionality by the VSC. Enter the following command on each storage controller. For examples on how to create roles, refer to [section 4.5](#).

```
useradmin role add create_clones -a login-http-admin,api-system-get-version,api-system-get-info,api-system-cli,api-license-list-info,cli-ifconfig,api-aggr-list-info,api-volume-list-info,api-lun-list-info,api-lun-map-list-info,api-igroup-list-info,api-ems-autosupport-log,api-file-get-file-info,api-clone-*,api-file-create-directory,api-file-read-file,api-file-delete-file,api-file-write-file,cli-mv,api-file-delete-directory,cli-ndmpd,cli-ndmpcopy,api-useradmin-user-list,api-cf-status,api-snapshot-list-info,api-volume-autosize-get,api-iscsi-session-list-info,api-iscsi-portal-list-info,api-fcp-service-status,api-iscsi-service-status,cli-df,api-snapmirror-get-volume-status,api-quota-report,api-qtrees-list,api-system-api-list,api-vfiler-list-info
```

## STEP 2: ADD ADDITIONAL OPTIONAL ROLES

This section covers how to create three additional roles on the array and how to assign the Provisioning and Cloning user account used by the VSC to the desired role. Enter the following command on each storage controller. For examples on how to create roles, refer to [section 4.5](#).

```
useradmin role add create_datastores -a api-volume-create,api-volume-set-
option,api-volume-autosize-set,api-sis-enable,api-sis-start,api-snapshot-
create,api-snapshot-set-reserve,api-volume-clone-create,api-nfs-exportfs-
list-rules-2,api-nfs-exportfs-modify-rule-2,api-nfs-exportfs-load-
exports,api-igroup-create,api-lun-create-by-size,api-lun-map,api-lun-set-
comment,api-igroup-add,cli-qtrees,cli-iscsi
useradmin role add modify_datastores -a api-volume-create,api-volume-set-
option,api-volume-autosize-set,api-sis-enable,api-sis-start,api-snapshot-
create,api-snapshot-set-reserve,api-volume-clone-create,api-nfs-exportfs-
list-rules-2,api-nfs-exportfs-modify-rule-2,api-nfs-exportfs-load-
exports,api-igroup-create,api-lun-create-by-size,api-lun-map,api-lun-set-
comment,api-igroup-add,cli-qtrees,cli-iscsi ,api-volume-size,api-sis-
disable,api-sis-stop,api-lun-resize
useradmin role add destroy_datastores -a api-volume-create,api-volume-set-
option,api-volume-autosize-set,api-sis-enable,api-sis-start,api-snapshot-
create,api-snapshot-set-reserve,api-volume-clone-create,api-nfs-exportfs-
list-rules-2,api-nfs-exportfs-modify-rule-2,api-nfs-exportfs-load-
exports,api-igroup-create,api-lun-create-by-size,api-lun-map,api-lun-set-
comment,api-igroup-add,cli-qtrees,cli-iscsi,api-volume-size,api-sis-
disable,api-sis-stop,api-lun-resize,api-volume-offline,api-volume-
destroy,api-lun-offline,api-lun-destroy
```

## STEP 3: CREATE A USER GROUP AND ASSIGN PROVISIONING AND CLONING ROLES

1. Create a name for this group and reference the role name created in the previous step.
2. Enter the following command on each storage controller.

```
useradmin group add "group_name" -r "role1_name" "role2_name"
```

Remember to add the required role of `create_clones` and any optional roles. For examples on how to create roles, refer to [section 4.5](#).

## STEP 4: CREATE A USER ACCOUNT IN THE GROUP FOR THE VSC

1. Create a name and password for this user account and reference the group name created in the previous step.
2. Enter the following command on each storage controller. For examples on how to create a user account, refer to [section 4.5](#).

```
useradmin user add "user_name" -g "group_name"
```

**Note:** You will be prompted to create the account password.

## STEP 5: VERIFY YOUR WORK

1. Reference the user account created in the previous step.
2. Enter the following command on each storage controller.

```
useradmin user list "user_name"
```

The user and group information is displayed and should match the entries in the previous three steps.

Use this restricted service account as the account entered when adding storage controllers in the Provisioning and Cloning area of the VSC 2.0.

## 5 VSPHERE DYNAMIC STORAGE PROVISIONING AND MANAGEMENT

This section applies to:



Storage administrators



VI administrators



Network administrators

### 5.1 STORAGE PROVISIONING AND MANAGEMENT BASED ON VCENTER

As discussed previously (refer to Figure 45), with the release of vSphere, NetApp introduced a new model of storage provisioning and management that allows the VI administrative team to directly deploy and manipulate datastores and VMs from raw storage pools provided by the NetApp administrator.

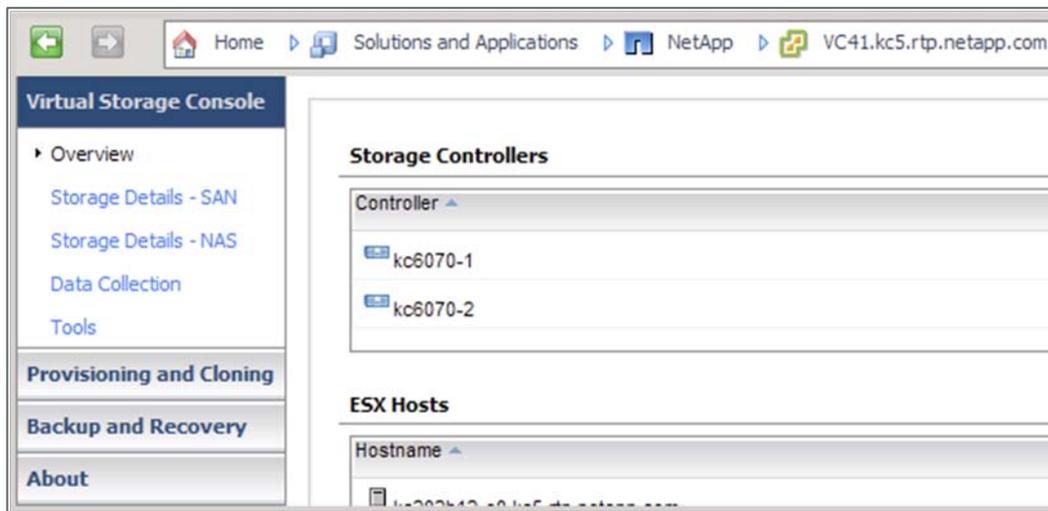
Therefore, this functionality is provided by the Provisioning and Cloning feature of the Virtual Storage Console 2.0 vSphere plug-in.

#### INTRODUCING THE NETAPP VIRTUAL STORAGE CONSOLE 2.0 VCENTER PLUG-IN

The Virtual Storage Console (VSC) 2.0 is a free product available to NetApp customers. Once installed, the VSC is accessed using the NetApp icon on the vSphere client Home screen. Each of the capabilities in the VSC plug-in framework is presented as follows:

- **Virtual Storage Console.** The core features of the VSC prior to version 2.0 are available in this console. These features are free to NetApp customers.
- **Provisioning and Cloning.** This feature provides the capabilities that were previously available in the separate plug-in called the NetApp RCU. Features such as provisioning datastores and managing deduplication settings, as well as others, are available free within the tool. The rapid cloning capabilities provided by the Provisioning and Cloning feature require a NetApp FlexClone license on the storage array where the clones are being created.
- **Backup and Recovery.** The capabilities of the NetApp SMVI in the VSC 2.0 plug-in framework are available in this feature. A VMware supported storage protocol, an SMVI license, and a SnapRestore<sup>®</sup> license are required for this feature. A SnapMirror license is required for storage-based replication, and FlexClone is required for NFS deployments.

Figure 55) The Virtual Storage Console 2.0.



The core feature of the VSC provides optimal availability and performance with ESX/ESXi hosts. The VSC has the following core abilities:

- Identify and configure optimal I/O settings for FC, FCoE, iSCSI, and NFS in ESX/ESXi hosts.
- Identify and configure optimal path selection policies for existing FC, FCoE, and iSCSI datastores.
- Identify VAAI-capable storage arrays and determine if those arrays are enabled for VAAI.
- Identify which ESX/ESXi hosts are connected to a particular storage array.
- Monitor and report storage use at levels from the datastore to the physical disks.
- Provide a central interface to collect data from the storage controller, network switches, and ESX/ESXi hosts to aid in the resolution of I/O-related case issues.

The provisioning and cloning capability of the VSC provides a means to optimally provision and manage NetApp SAN and NAS datastores along with a means to provision zero-cost VMs directly from within vCenter. The following provisioning and cloning capabilities are available in VSC 2.0:

- Delegate authority from the storage administrator to the virtual administrator for provisioning and cloning functions.
- Provision FC, FCoE, iSCSI, and NFS datastores.
- Automate assignment of multipathing policies to datastores with the VMware pluggable storage architecture for LUNs and ALUA-enabled LUNs and distribute NFS path connections based on a path round-robin policy.
- Implement automated storage access control security when datastores are provisioned. Access control is in the form of LUN masking and NFS exports.
- Dynamically resize FC, FCoE, iSCSI, and NFS datastores on the fly.
- Provide a central interface to collect data from the storage controller, network switches, and ESX/ESXi hosts to aid in the resolution of I/O-related case issues.

## 5.2 INSTALLING THE VIRTUAL STORAGE CONSOLE 2.0

The VSC provides full support for hosts running ESX/ESXi 4.0 and later and provides limited reporting functionality with hosts running ESX/ESXi 3.5 and later. Before downloading and installing the VSC, make sure that your deployment has the required components:

- A vCenter Server version 4.0 or later. The VSC can be installed on the vCenter Server or on another server or VM.
- If installing on another server or VM, this system should run 32- or 64-bit Windows Server 2008, 2003 SP1 and later, or a 32-bit version of XP Professional SP2 and later.
- A storage array is required to run Data ONTAP 7.3.1.1 or later.

For a list of supported storage adapters and firmware, refer to the [NetApp Interoperability Matrix](#).

### INSTALLING THE VSC 2.0

Complete the following steps to install the VSC 2.0:

1. Download the installation program to the Windows server.
2. Run the installation wizard.
3. Follow the onscreen instructions.

**Note:** During the installation process, a prompt displays to select the features of the VSC 2.0 that will be enabled in the environment. The core VSC must be selected. The Provisioning and Cloning and Backup and Recovery features are the former RCU and the SMVI interfaces, and certain subfeatures might require licensing, as described previously. At a minimum, NetApp recommends the installation of the Provisioning and Cloning capabilities because the procedures in this document are dependent on using these interfaces.

4. Register the VSC as a plug-in in the vCenter Server in the window that opens when the process is complete.

**Note:** This final step requires a user with vCenter administrator credentials to complete the registration process.

Figure 56) Selecting the VSC 2.0 features to be enabled.

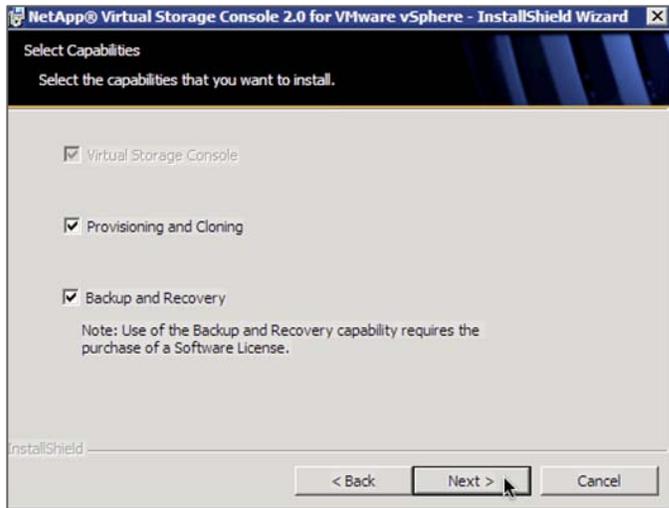


Figure 57) The install process launches the vCenter registration process.

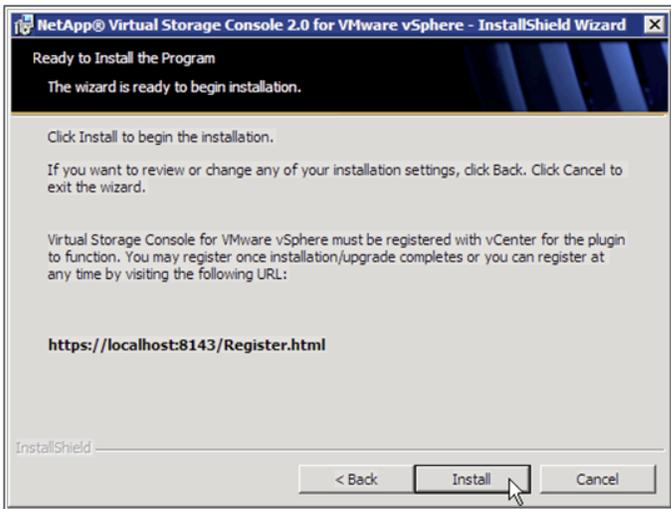
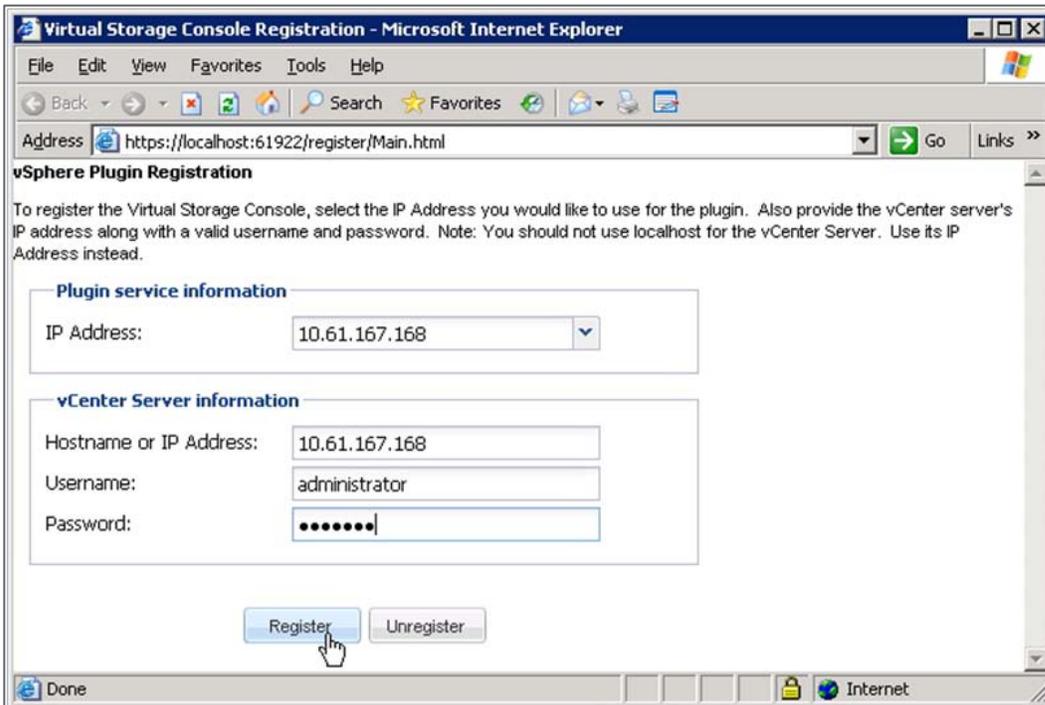


Figure 58) Registering the VSC with a vCenter Server.



### 5.3 ADDING STORAGE CONTROLLERS TO THE VIRTUAL STORAGE CONSOLE

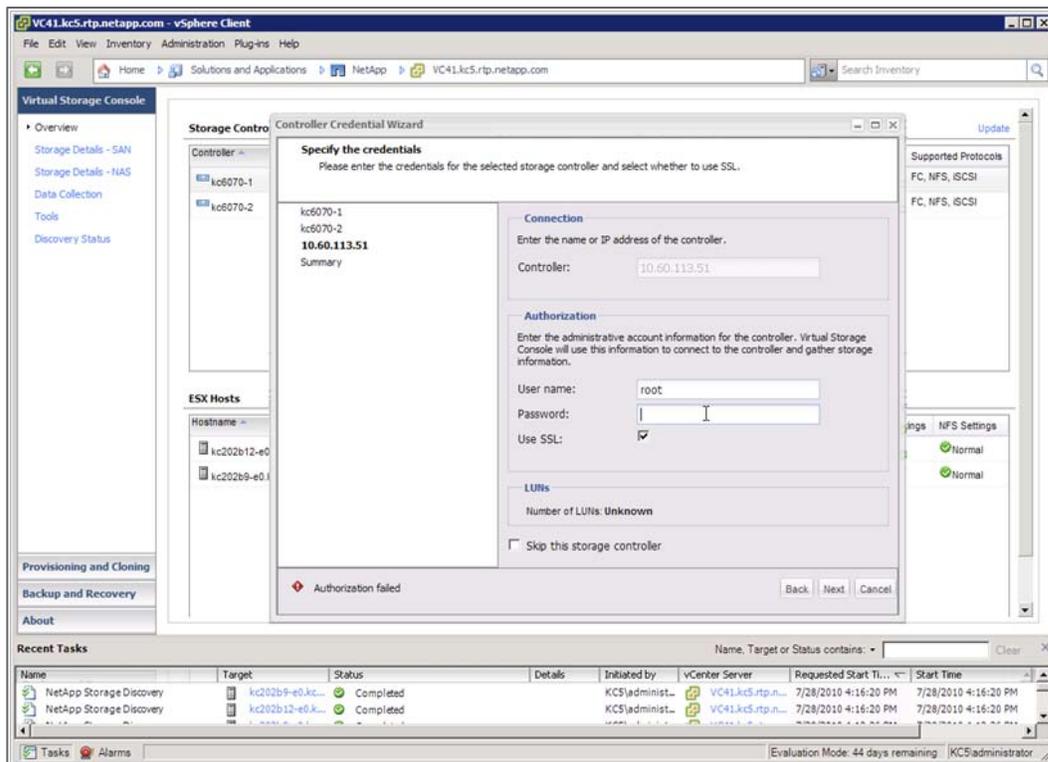
Adding the storage controllers that host the virtual infrastructure to the VSC is fairly simple.

1. Connect to vCenter by using the vSphere client.
2. Double-click the NetApp icon on the Home screen.
3. Select the Virtual Storage Console tab on the left.

After these steps are completed, the VSC launches and automatically identifies all storage controllers powered by Data ONTAP with the storage connected to the ESX/ESXi hosts in the environment. As an alternative to running discovery for the entire environment, you can select an ESX/ESXi host or cluster in the vSphere client and then select the NetApp tab in the left panel. The VSC then begins discovery of all storage controllers with storage connected to the host or cluster that was selected.

The Controller Credentials wizard starts, allowing you to enter the user or service account assigned for VSC management on the storage controller. This account can be the root account or one created specifically for the VSC core feature, as described previously.

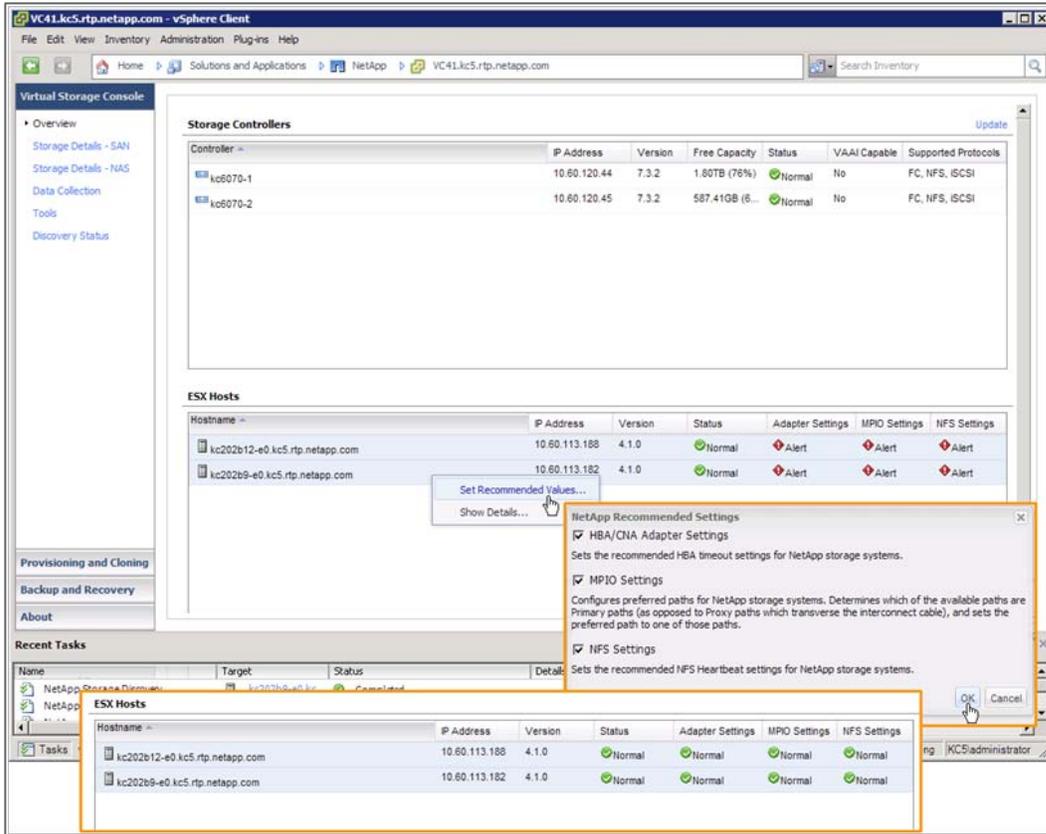
Figure 59) Adding storage controller access in the VSC.



## 5.4 OPTIMAL STORAGE SETTINGS FOR ESX/ESXI HOSTS

The VSC enables the automated configuration of storage-related settings for all ESX/ESXi 4.x hosts connected to NetApp storage controllers. VMware administrators can right-click individual or multiple ESX/ESXi hosts and set recommended values for these hosts. This functionality sets values for HBAs and CNAs, sets appropriate paths and path selection plug-ins, and provides appropriate settings for software-based I/O (NFS and iSCSI).

Figure 60) Setting recommended storage settings for ESX/ESXi 4.x hosts, including multipathing for existing LUNs, in the VSC.

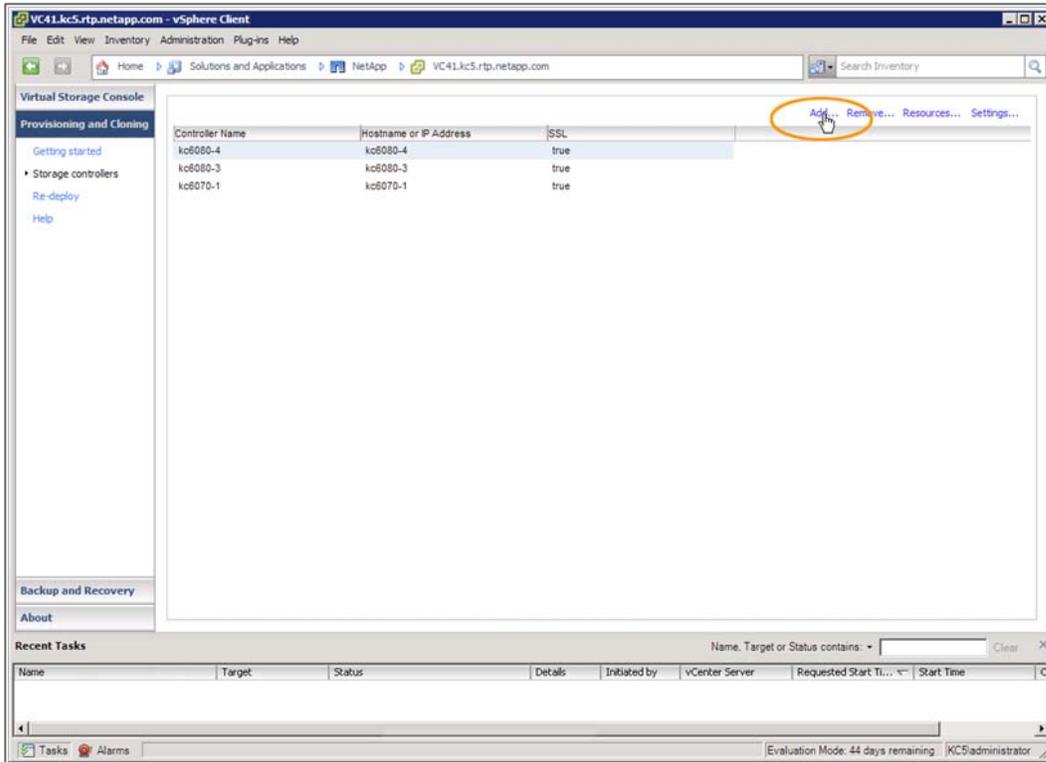


## 5.5 ADDING STORAGE CONTROLLERS FOR PROVISIONING AND CLONING

The Provisioning and Cloning feature of the VSC 2.0 currently requires reauthentication of storage arrays by specifying the credentials necessary for communication. To do this using the vSphere client, complete the following steps:

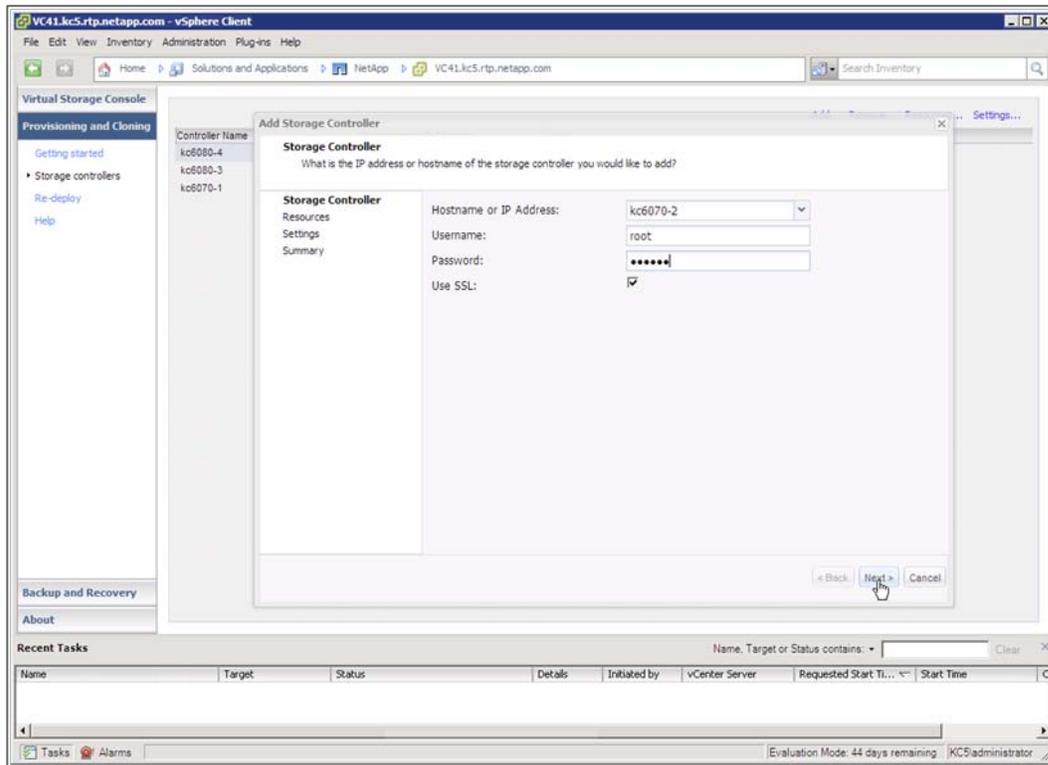
1. Connect to vCenter.
2. Select the NetApp icon on the Home screen.
3. Select the Provisioning and Cloning tab on the left-hand side.
4. Click the Add button to begin the Controller Configuration wizard.

Figure 61) Launching the Provisioning and Cloning Add Controller wizard.



5. Select the Storage Controllers tab.
6. Select Add. This process allows you to manually add the storage controllers that you would like to use to deploy storage and clone VMs within vCenter.
7. Enter the user or service account assigned on the storage controller being added. This account can be the root account or one created earlier specifically for the Provisioning and Cloning feature.

Figure 62) Adding storage controllers for management by the RCU.



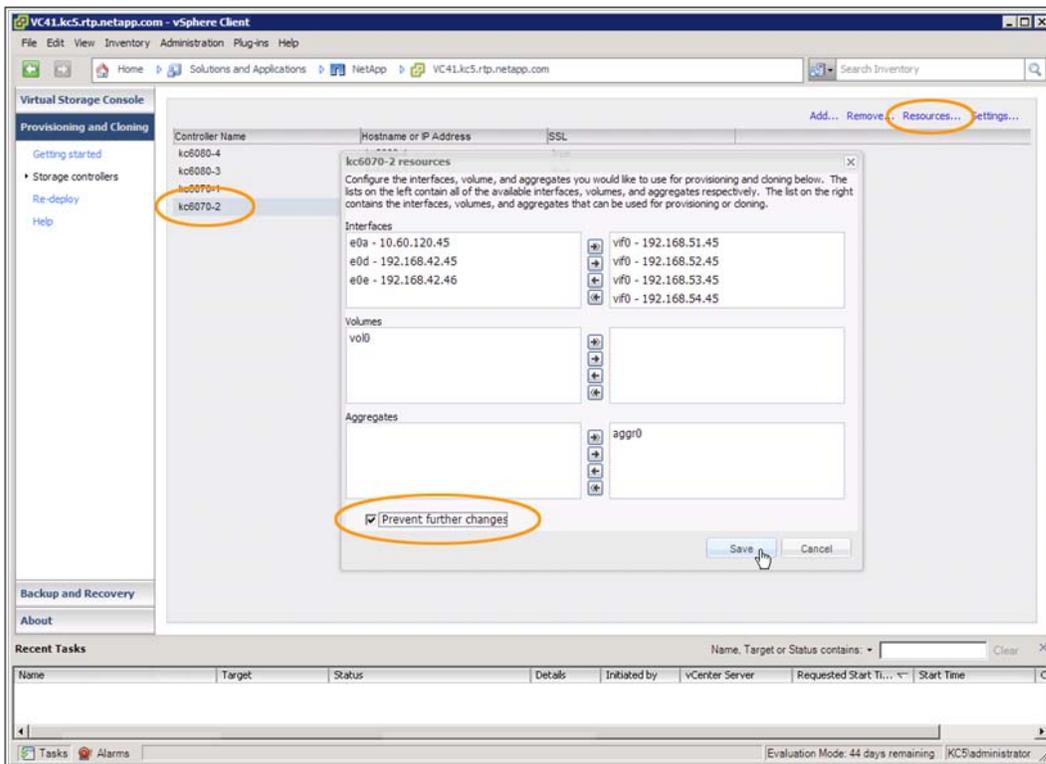
## 5.6 ASSIGNING STORAGE RESOURCES FOR PROVISIONING AND CLONING

After the RCU is installed, the storage administrator can assign storage resources for use by the virtual infrastructure. These resources include network interfaces, FlexVol volumes (for SAN use), and aggregates (for NAS use). To assign these resources:

1. Open the Provisioning and Cloning tab in the VSC.
2. Select a controller.
3. Click the Resources button.
4. Assign resources for use by the virtual infrastructure.

As shown in Figure 63, the storage administrator can lock or restrict the ability to assign resources by selecting the Prevent further changes box and by entering a user name and password. The account used to lock these settings is created the first time this option is selected and stored securely inside the VSC.

Figure 63) Assigning storage resources in the VSC with the option to restrict these settings to the storage administration team.



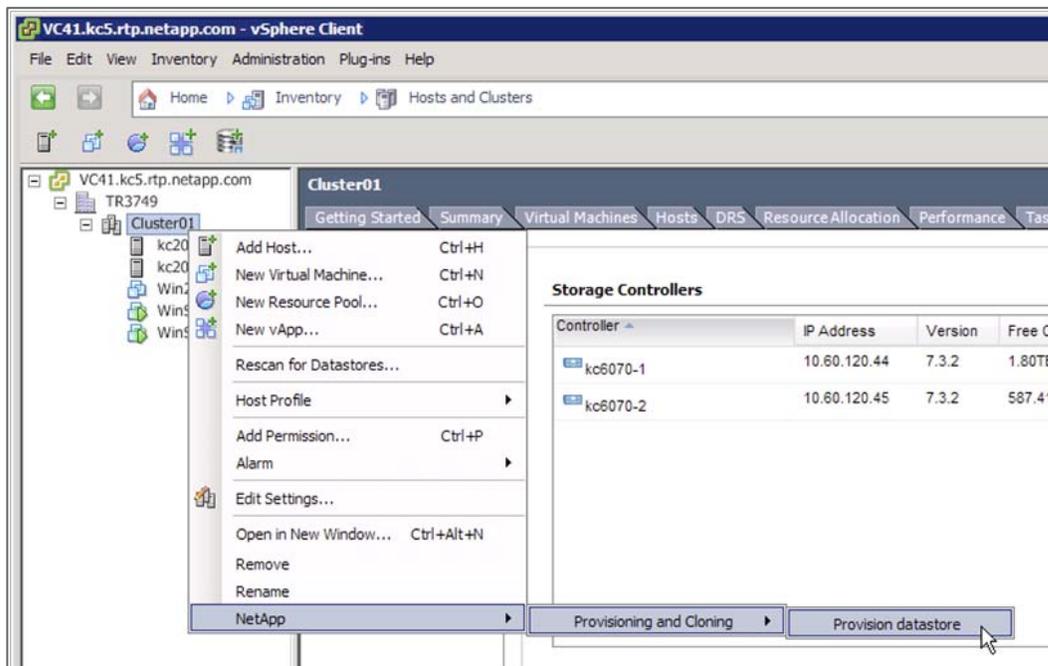
## 5.7 END-TO-END PROVISIONING OF DATASTORES IN VCENTER

After arrays and storage resources have been assigned for provisioning and cloning use in the VSC, VMware administrators can provision datastores from within vCenter.

Complete the following steps to start the provisioning process:

1. Select and right-click a data center, a cluster, or an ESX/ESXi host.
2. Select the NetApp menu option.
3. Click Provisioning and Cloning.
4. Click Provision datastore.

Figure 64) Starting the process to provision a new datastore on all hosts in a cluster.



This process launches the NetApp Datastore Provisioning wizard, which allows you to select the following:

- Storage controller
- Type of datastore (VMFS or NFS)
- Datastore details, including storage protocol and block size (if deploying a VMFS datastore)
- Whether the LUN should be thin provisioned

The provisioning process connects the datastore to all nodes within the selected group. For iSCSI, FC, and FCoE datastores, the VSC handles storage access control by:

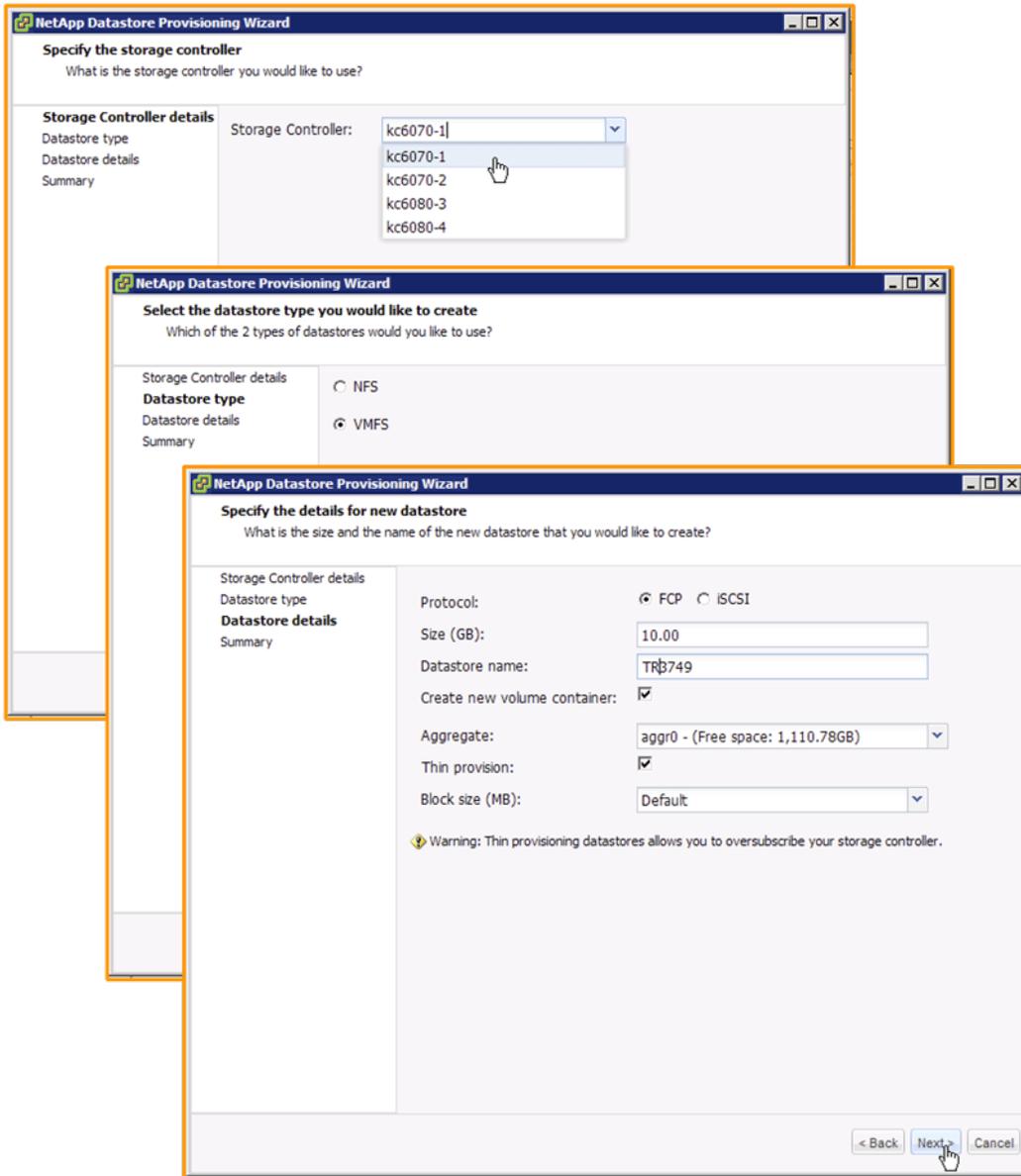
- Creating initiator groups
- Enabling ALUA
- Applying LUN masking
- Applying path selection policies
- Formatting the LUN with VMFS

For NFS datastores, the VSC handles storage access control by managing access rights in the exports file, and it balances the load across all available interfaces.

**Note:** Remember, if you plan to enable data deduplication, then thin-provisioned LUNs are required to return storage to the free pool on the storage controller.

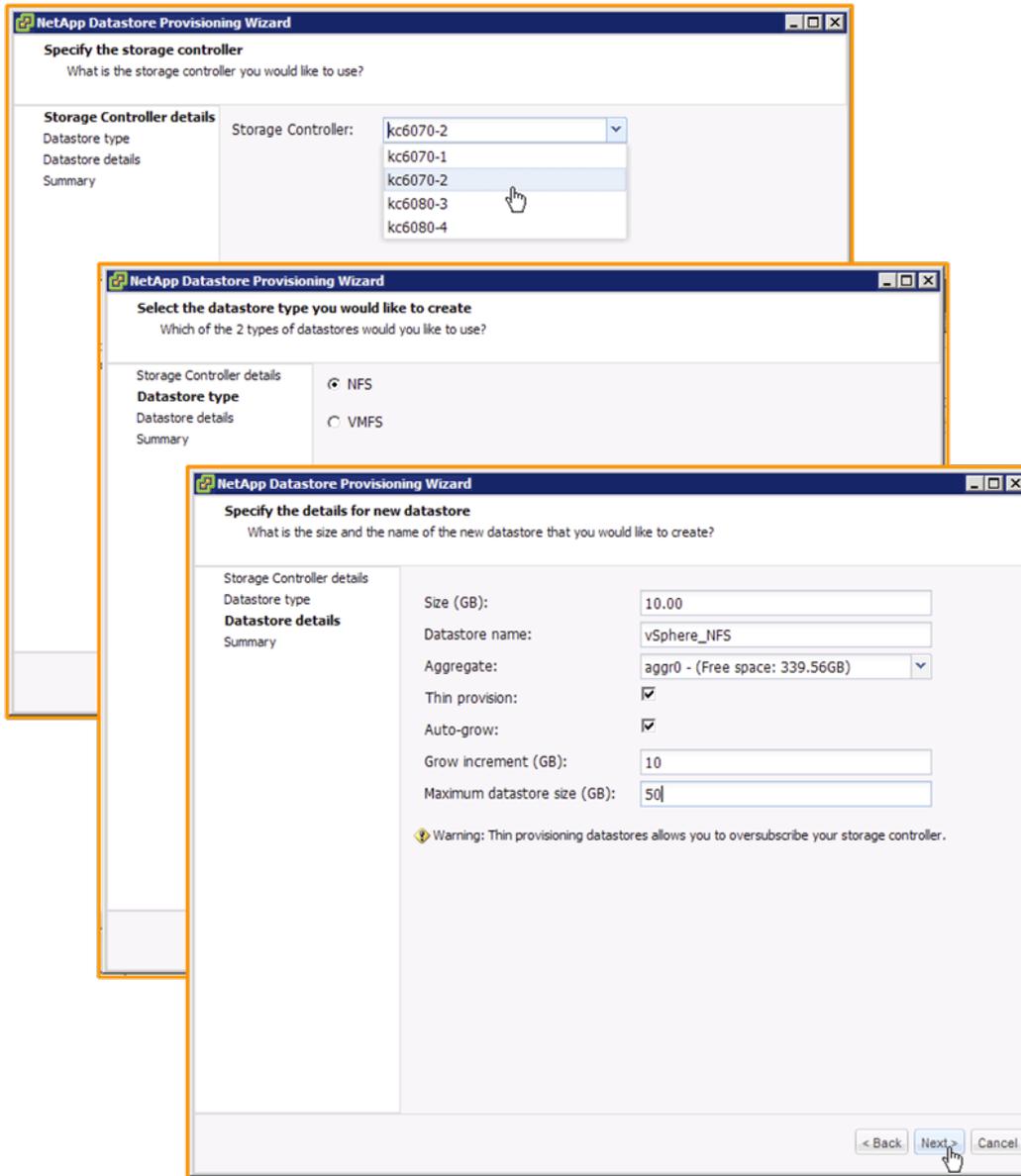
Figure 65 shows the provisioning of an FC datastore, named TR3749, on a thin-provisioned LUN that resides in an allocated FlexVol volume.

Figure 65) Provisioning a new VMFS datastore with the NetApp Datastore Provisioning wizard.



The provisioning process of NFS datastores is very similar to that of VMFS. One additional option is available to NFS datastores: They can be configured to autogrow based on datastore capacity. Figure 66 shows an example of provisioning an NFS datastore that is configured as thin provisioned and set to autogrow.

Figure 66) Provisioning a new NFS datastore with the NetApp Datastore Provisioning wizard.



## 5.8 CHOOSING A VIRTUAL MACHINE DATA LAYOUT

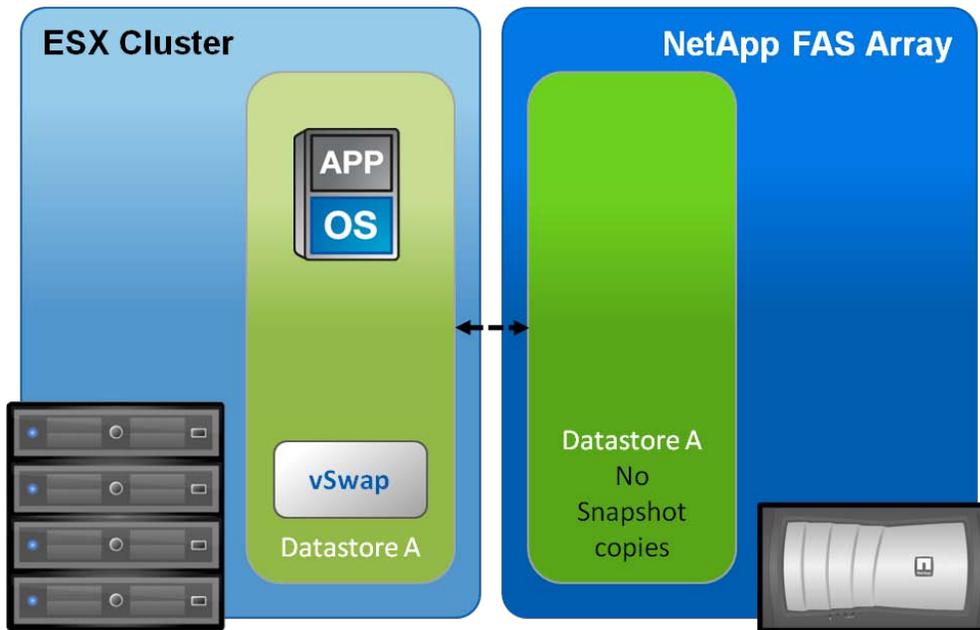
Before creating any storage objects, which is described in a later section, you must determine the data layout required for your VMs. The following section describes common data layout scenarios. The one you implement depends on whether or not you want to eliminate the capacity required by transient data, which could be captured in Snapshot copies or replicated over the WAN.

### DEFAULT DATA LAYOUT

When a VM is provisioned, the VMware administrator must select a datastore in which to store the files that compose the VM. The directory that is created is referred to as the VM Home directory. By default, all of the files for a single VM reside in the VM Home directory. The VM Home directory includes, but is not limited to, the configuration file for the VM, the virtual disk and virtual disk descriptor files, the VMkernel swapfile, Snapshot files, nonvolatile RAM (NVRAM), and so on.

From a simplicity standpoint, this design works well in situations in which a VM Home directory is a virtual machine. Figure 67 shows a high-level conceptual view of this layout.

Figure 67) VMware default virtual machine and vSwap layout.



### VIRTUAL MACHINE LAYOUT WITH NETAPP SNAP TECHNOLOGIES

This section reviews a data layout design that is recommended when integrating VMware with NetApp snap technologies such as SnapManager Snapshot backups or disk-to-disk replication using SnapMirror and/or SnapVault. In these use case scenarios, NetApp recommends separating transient and temporary data from the production data by implementing architecture that separates these two data types into multiple datastores.

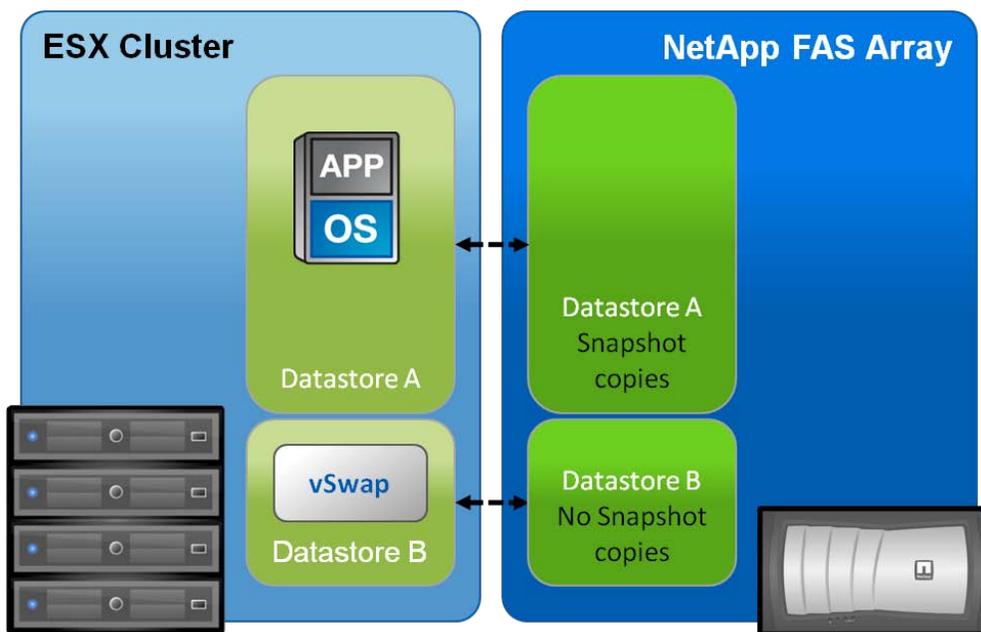
**Note:** This design is not NetApp specific, but instead is an optimal consideration when deploying VMware on any storage array providing Snapshot backup or disk-based replication.

These types of technologies manage the files that make up a VM, not the content inside of these files, and therefore consume a substantial amount of additional disk and/or bandwidth if the temporary data and transient data are not separated from the production data.

## RECOMMENDED LAYOUT: IMPLEMENT A CENTRAL VMKERNEL SWAP DATASTORE

ESX servers create a VMkernel swap or vswap file for every running VM. The file sizes are considerable; by default, the vswap is equal to the amount of memory configured for each VM. Because this data is transient in nature and is not required in the case of recovering a VM either from a backup copy or by using Site Recovery Manager, NetApp recommends relocating the VMkernel swap file for every VM from the VM Home directory to a datastore on a separate NetApp volume dedicated to storing VMkernel swap files. Figure 68 shows a high-level conceptual view of this layout.

Figure 68) Recommended virtual machine layout: a central vswap datastore for the entire cluster.

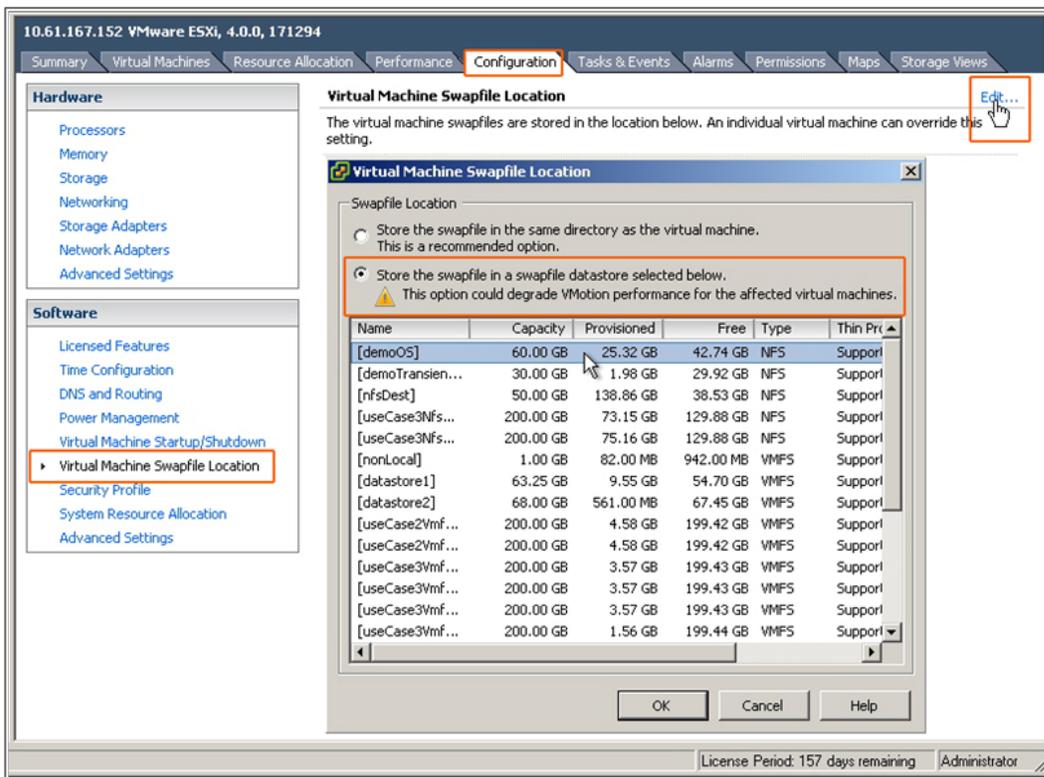


Creating a datastore to store the swap files is a prerequisite to making this change. Because the VMware swap file storage requirements are dynamic, NetApp recommends creating either a large thin-provisioned LUN or a FlexVol volume with the autogrow feature enabled. Thin-provisioned LUNs and autogrow FlexVol volumes provide a large management benefit when storing swap files. This design removes the need to micromanage the swap space or to reduce the usage rate of the storage. Consider the alternative of storing VMware swap files on traditional storage arrays. If you undersize the swap space, the VMs fail to start; conversely, if you oversize the swap space, you have provisioned but unused storage.

The datastore that stores the vswap file is a single datastore for an entire cluster. NetApp does not recommend implementing local datastores on each ESX/ESXi host to store vswap because this configuration has a negative impact on VMotion migration times.

Figure 69 depicts the simplicity in configuring a central datastore for VMkernel swap in vCenter Server.

Figure 69) Configuring a central location for VMkernel swap files.

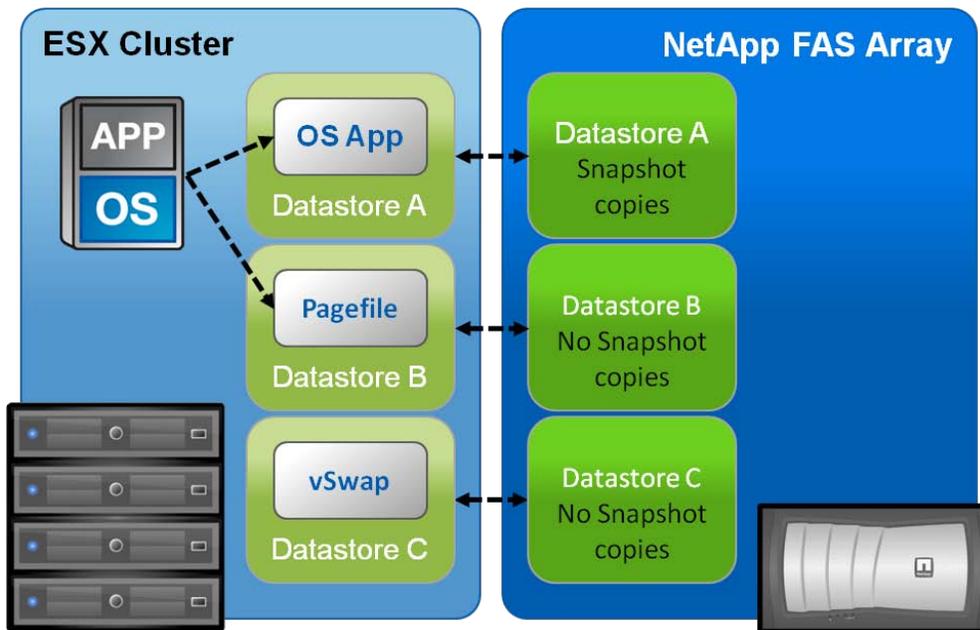


## OPTIONAL LAYOUT: LOCATE VM SWAP/PAGEFILE ON A SECOND DATASTORE

This design layout builds on the layout described in the previous section, [Recommended Layout: Implement a Central VMkernel Swap Datastore](#). However, in this design, the swap or pagefile of the VM is relocated in an alternate datastore. This section covers the architecture and the pros and cons of this design.

Each VM creates a swap or pagefile that is typically 1.5 to 2 times the size of the amount of memory configured for each VM. Because this data is transient in nature, we can save a fair amount of storage and/or bandwidth capacity by removing this data from the datastore, which contains the production data. To accomplish this design, the swap or pagefile of the VM must be relocated to a second virtual disk stored in a separate datastore on a separate NetApp volume. Figure 70 shows a high-level conceptual view of this layout.

Figure 70) Optional virtual machine layout. VM pagefile has been separated to a pagefile datastore and a central vswap datastore for the entire cluster.



This design has both benefits and disadvantages, which should be understood before implementation. The benefit is that temporary and transient data is not contained in either a Snapshot backup or a replicated dataset, thus conserving some amount of storage.

The disadvantage is that this design affects customers who implement VMware vCenter Site Recovery Manager. The intent is to avoid replicating the pagefile datastore to the DR site. This design imposes some administrative overhead because an additional SRM setting must be applied to each VM. This setting specifies a preexisting pagefile VMDK at the DR site in the SRM recovery plan. For more information on the details of this design with SRM, refer to the appendix of [TR-3671: VMware vCenter Site Recovery Manager in a NetApp Environment](#).

## 5.9 RESIZING DATASTORE CAPACITY IN VCENTER

By using VSC 2.0, the VMware administrator can dynamically resize datastores on the fly without disruption to the production environment. VSC supports the expansion of VMFS and NFS datastores and the reduction, or shrinking, of NFS datastores. To modify the size of a datastore:

1. Right-click a datastore object within vCenter.
2. Select NetApp.
3. Select Provisioning and Cloning.
4. Select Resize.
5. Enter the new datastore size.
6. Click OK.

Figure 71) Selecting a datastore to resize.

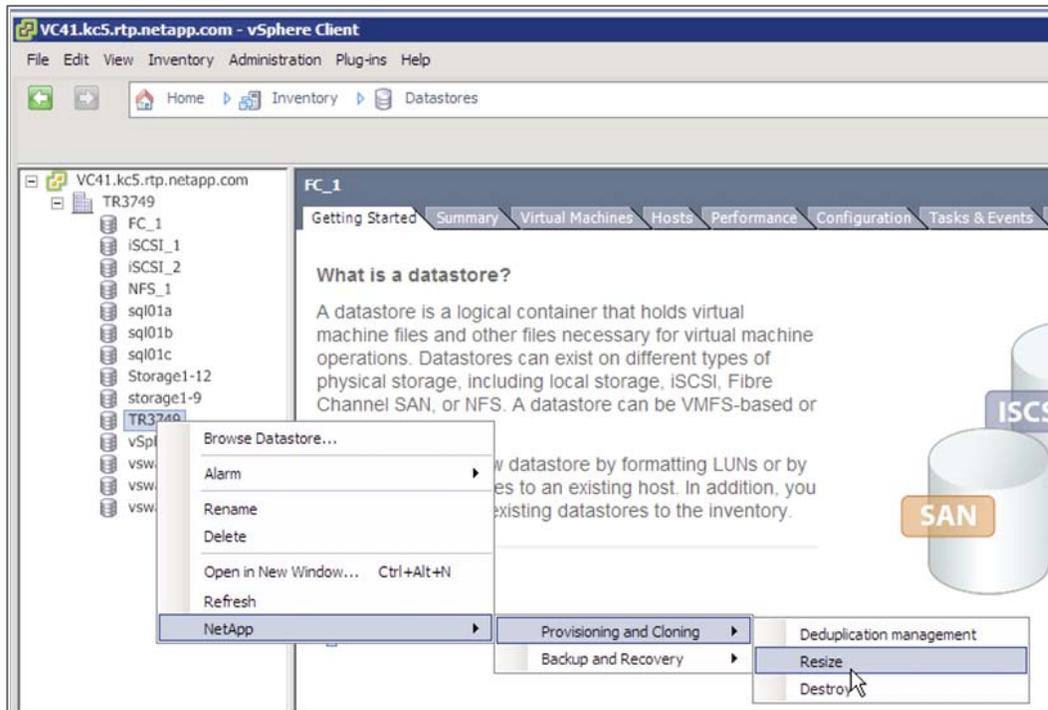
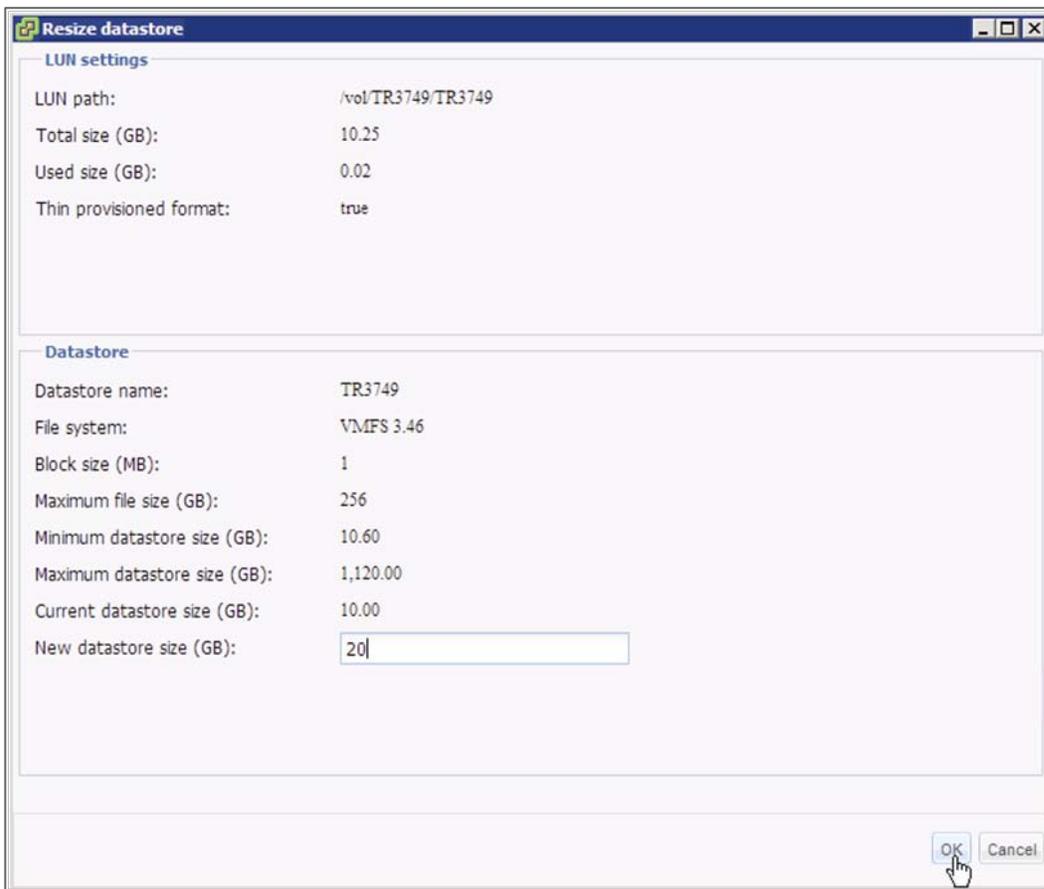


Figure 72) Entering the new size of a VMFS datastore.



## 5.10 MONITORING DATASTORE AND STORAGE ARRAY CAPACITY IN VCENTER

The VSC provides VMware administrators with a way to monitor storage resource usage as measured in a datastore through the various layers, including the physical disk layer. At a high level, the SAN and NAS reports appear very similar, but we should highlight a few differences and points of interest.

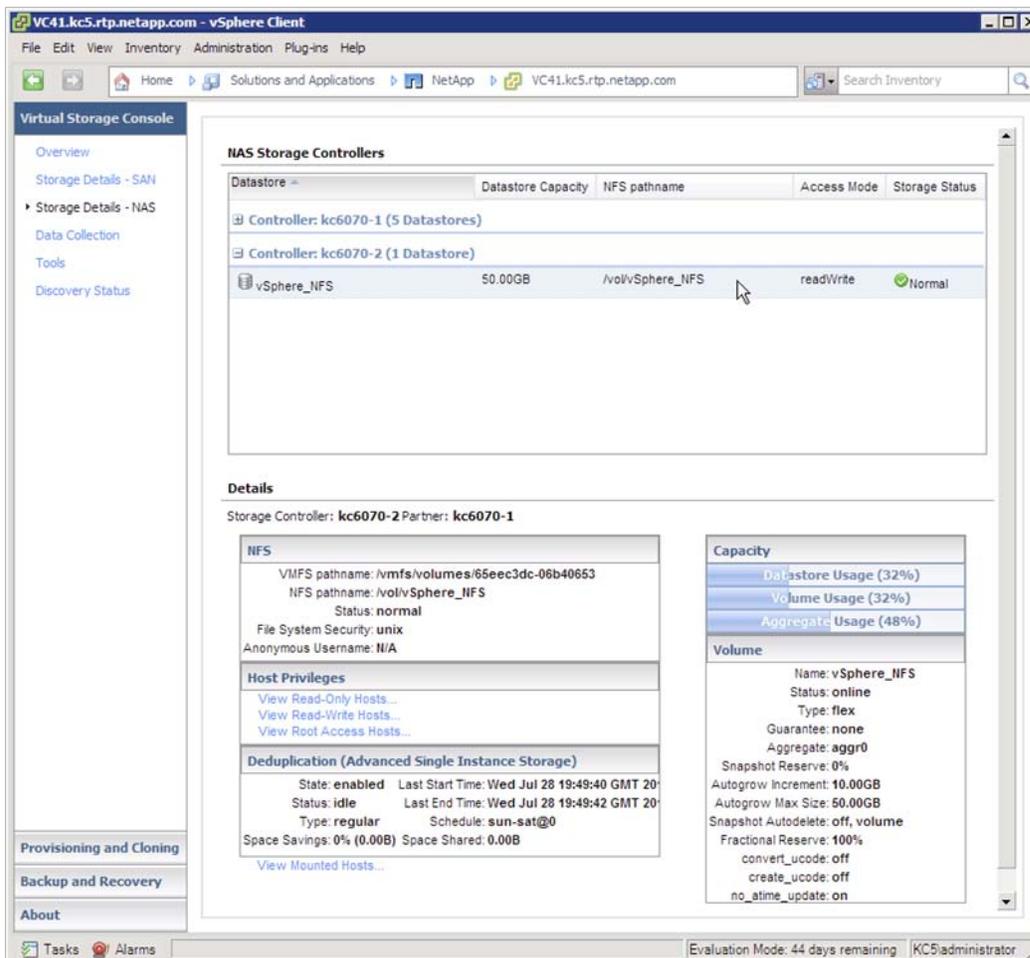
### NFS STORAGE MONITORING

To view information about your datastores:

1. Select the NetApp tab in vCenter.
2. Select either the Storage Details-NAS or Storage Details-SAN link in the VSC tab.

When you select an individual datastore, additional details are displayed regarding the configuration of the datastore. The following sections describe a few key elements of NFS datastores.

Figure 73) Viewing the details of a datastore in the Storage Details page of the VSC.



## CAPACITY BOX

The capacity box lists the usage of the datastore, FlexVol volumes, and aggregate or physical disks. With NFS, the datastore and FlexVol volumes always display the same capacity because they are the same objects. A key component to monitor is the capacity of the aggregate because it is composed of physical disk drives.

For VMFS datastores, the datastore and LUN always display the same capacity, because they are the same objects. The capacity of the FlexVol volume and the aggregate are two key components that should be monitored. The FlexVol volume contains the LUN. If the LUN is thin provisioned, configuring the FlexVol volume to autogrow is critical to store the total capacity of the LUN. If the LUN grows larger than the FlexVol volume, then the LUN will go offline until more capacity is provided in the FlexVol volume.

Plans should be in place for when an aggregate nears 85% of its capacity. Options for this scenario include:

- Adding more disk drives to the aggregate
- Migrating either VMs or datastores to another aggregate or array

NetApp provides NetApp Data Motion as a nondisruptive method to migrate entire datastores between arrays to the hosted VMs.

## VOLUME BOX

The volume box includes some key details about the selected FlexVol volume. All of the available options are set automatically when the Provisioning and Cloning feature is used. The VSC addresses NFS datastores provisioned before the use of the VSC and updates any settings that do not match NetApp recommendations.

## DEDUPLICATION BOX

Storage savings obtained by data deduplication are reported in the deduplication box. For NFS datastores, the space savings provided by dedupe are returned directly within the datastore for immediate use by the running VMs or for provisioning additional VMs. To select dedupe savings, complete the following steps:

1. Right-click a datastore.
2. Select NetApp.
3. Select Deduplication management.

Figure 74) Viewing the details of NetApp dedupe on a datastore.

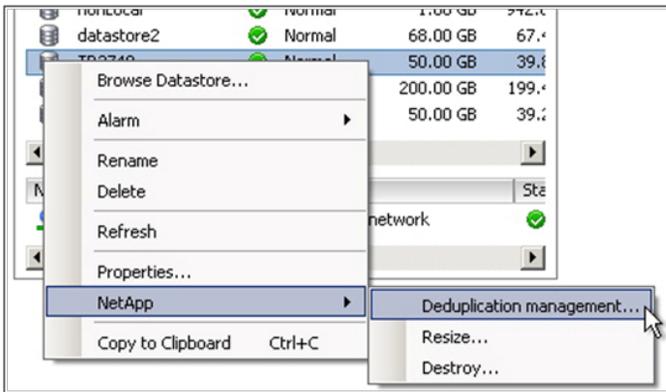


Figure 75) Viewing the amount of space saved with NetApp dedupe on a datastore.

The screenshot shows a window titled "Datastore deduplication management" with a table and two configuration panels. The table lists deduplication statistics for two datastores: "aggr0" and "vSphere\_NFS". The "vSphere\_NFS" row is highlighted, showing 50.00GB total, 10.16GB used, 39.84GB available, 21.69GB deduplicated, and 68% deduplicated. Below the table, the "Deduplication status" panel shows the deduplication state as "Enabled", status as "active", space saved as 21.69 GB, and percent saved as 68. The "Deduplication settings" panel includes checkboxes for "Disable deduplication?" and "Stop deduplication?".

Name	Total	Used	Available	Deduplicated	Deduplicated %
aggr0	624.36GB	296.70GB	327.66GB	21.69GB	6
vSphere_NFS	50.00GB	10.16GB	39.84GB	21.69GB	68

**Deduplication status**

Datastore name: vSphere\_NFS  
Volume name: vSphere\_NFS  
Deduplication state: Enabled  
Deduplication status: active  
Space saved (GB): 21.69  
Percent saved: 68  
Last deduplication start: Wed Jul 28 21:37:48 GMT 2010  
Last deduplication end: Wed Jul 28 21:51:19 GMT 2010

**Deduplication settings**

Disable deduplication?   
Stop deduplication?

OK Cancel

## 6 VIRTUAL MACHINE CONFIGURATION AND OPTIMAL SETTINGS

This section applies to:



Storage administrators



VI administrators



Virtual machine configuration administrators

### 6.1 WINDOWS VM FILE SYSTEM PERFORMANCE

#### OPTIMIZING WINDOWS FILE SYSTEM FOR OPTIMAL I/O PERFORMANCE

If your VM is not acting as a file server, consider implementing the following change to your VMs, which disables the access time updates process in Microsoft Windows NT<sup>®</sup> File System (NTFS). This change reduces the amount of IOPS occurring within the file system. To make this change, complete the following steps:

1. Log into a Windows VM.
2. Select Start, select Run, and enter `CMD`.
3. Enter `fsutil behavior set disablelastaccess 1`.

#### DISK DEFRAGMENTATION UTILITIES

VMs stored on NetApp storage arrays should not use disk defragmentation utilities because the WAFL file system is designed to optimally place and access data at a level below the guest operating system (GOS) file system. If a software vendor advises you to run disk defragmentation utilities inside of a VM, contact the NetApp Global Support Center before initiating this activity.

### 6.2 OPTIMUM VM AVAILABILITY

#### OPTIMIZING VM SCSI BUS

One of the components of the VSC is the GOS timeout scripts. These scripts are a collection of ISO images that can be mounted by a VM to configure its local SCSI to values that are optimal for running in a virtual infrastructure.

To install the GOS timeout scripts, complete the following steps:

1. Mount the ISO image provided by the VSC.
2. Select a VM to upgrade from within vCenter Server.
3. Right-click the selected VM and select edit settings.
4. Select CDROM and the ISO radio button.
5. Select the appropriate ISO that matches the OS of the VM you are configuring.
6. Select OK.
7. Connect to the VM console.

8. Run the script for the OS of the VM.
9. Exit and unmount the ISO image.
10. Repeat these steps as necessary for each VM.

## 6.3 OPTIMAL STORAGE PERFORMANCE

### ALIGNMENT OF VM PARTITIONS AND VMFS TO STORAGE ARRAYS

VMs store their data on virtual disks. Similar to physical disks, these virtual disks contain storage partitions and file systems, which are created by the guest operating system of the VM. To provide optimal disk I/O within the VM, you must align the partitions of the virtual disks to the block boundaries of VMFS and the block boundaries of the storage array. Failure to align all three of these items results in a dramatic increase of I/O load on a storage array and negatively affects the performance of all VMs being served on the array.

NetApp, VMware, other storage vendors, and VMware partners recommend aligning the partitions of VMs and the partitions of VMFS datastores to the blocks of the underlying storage array. For more information about VMFS and GOS file system alignment, refer to the following documents from various vendors:

- **Citrix, Microsoft, NetApp, and VMware.** [TR-3747: Best Practices for File System Alignment in Virtual Environments](#)
- **Dell.** [Designing and Optimizing SAN Configurations](#)
- **EMC.** [Celerra IP Storage with VMware Virtual Infrastructure](#)
- **EMC.** [CLARiiON Integration with VMware ESX Server](#)
- **IBM.** [Storage Block Alignment with VMware Virtual Infrastructure](#)
- **Vizioncore.** [vOptimizer Pro FAQ](#)
- **VMware.** [Recommendations for Aligning VMFS Partitions](#)

Links to all documents can be found in the [Document References](#) section of this report.

### DATASTORE ALIGNMENT

NetApp systems automate the alignment of VMFS with NetApp iSCSI, FC, and FCoE LUNs. This task is automated during the LUN provisioning phase of creating a datastore when you select the LUN type "VMware" for the LUN. Customers deploying VMware over NFS do not need to align the datastore. With any type of datastore, VMFS or NFS, the virtual disks contained within should have the partitions aligned to the blocks of the storage array.

### VIRTUAL MACHINE PARTITION ALIGNMENT

When aligning the partitions of virtual disks for use with NetApp FAS systems, the starting partition offset must be divisible by 4,096. For example, the starting partition offset for Microsoft Windows 2000, 2003, and XP operating systems is 32,256. This value does not align to a block size of 4,096.

Virtual machines running a clean installation of Microsoft Windows 2008, Windows 7, or Windows Vista<sup>®</sup> operating systems automatically have their starting partitions set to 1,048,576. By default, this value does not require any adjustments.

**Note:** If your Windows 2008 or Windows Vista VMs were created by upgrading an earlier version of Microsoft Windows to one of these versions, then it is highly probable that these images require partition alignment.

## 6.4 VM PARTITION ALIGNMENT

### STORAGE ALIGNMENT IS CRITICAL

Aligning the file system within the VMs to the storage array is very important. This process should not be considered optional. Misalignment at a high level results in decreased usage.

Failure to align the file systems results in a significant increase in storage array I/O to meet the I/O requirements of the hosted VMs. Customers might notice this impact when:

- Running high-performance applications
- Achieving less than impressive storage savings with deduplication
- Perceiving a need to upgrade storage array hardware

The reason for these types of issues is misalignment results in every I/O operation executed within the VM to require multiple I/O operations on the storage array.

Simply put, you can save your company a significant amount of capital expenditures by optimizing the I/O of your VMs.

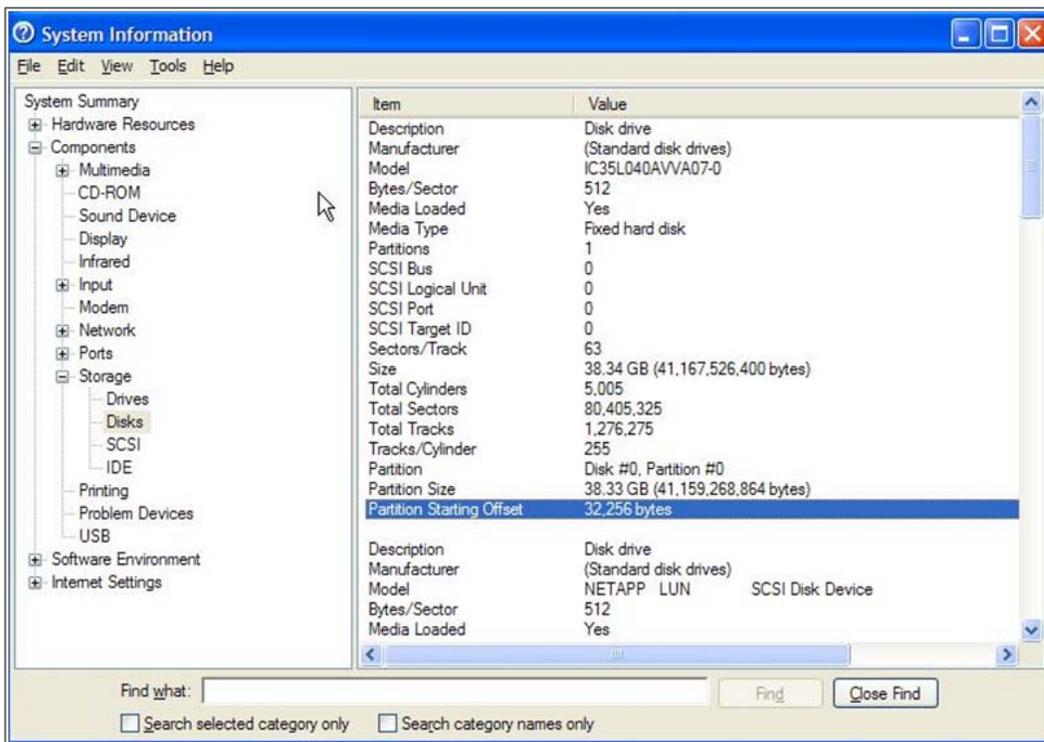
## 6.5 IDENTIFYING PARTITION ALIGNMENT

### VERIFYING PARTITION ALIGNMENT WITH WINDOWS OPERATING SYSTEMS

To verify the starting partition offset for a VM based on Windows, complete the following steps:

1. Log in to the VM.
2. Run the system information utility (or msinfo32) to find the starting partition offset setting. To run msinfo32:
  - a. Select Start.
  - b. Select All Programs.
  - c. Select Accessories.
  - d. Select System Tools.
  - e. Select System Information.

Figure 76) Using system information to identify the starting partition offset.



## NETAPP MBRTOOLS: IDENTIFICATION OF PARTITION ALIGNMENT STATUS

NetApp provides a tool, MBRScan, that runs on an ESX host and can identify if partitions are aligned with Windows and Linux<sup>®</sup> VMs running within VMFS and NFS datastores. MBRScan runs against the virtual disk files that compose a VM. Although this process only requires a few seconds per VM to identify and report on the status of the partition alignment, each VM must be powered off. For this reason, it might be easier to identify the file system alignment from within each VM, because this action is nondisruptive.

MBRScan is an integrated component of the VSC.

## 6.6 CORRECTIVE ACTIONS FOR VMS WITH MISALIGNED PARTITIONS

### BEGIN BY CORRECTING THE VM TEMPLATES

After you identify that your VMs have misaligned partitions, NetApp recommends correcting the partitions in your templates as the first corrective action. This step makes sure that any newly created VM is properly aligned and does not add to the I/O load on the storage array.

### CORRECT PARTITION MISALIGNMENT WITH NETAPP MBR TOOLS

As part of the VSC tools, NetApp provides a tool, MBRAAlign, that runs on an ESX host and can correct misaligned primary and secondary master boot record-based partitions. When using MBRAAlign, the VM that is undergoing the corrective action must be powered off.

MBRAAlign provides flexible repair options. For example, it can be used to migrate and align a virtual disk as well as change the format from a thin to thick vmdk. NetApp highly recommends creating a Snapshot copy before executing MBRAAlign. This Snapshot copy can be safely discarded after a VM has been corrected, powered on, and the results have been verified.

MBRAAlign can be obtained from the Tools Download link in the VSC. NetApp recommends contacting the NetApp Global Support Center for assistance with implementing the corrective actions.

Linux VMs that boot using the GRUB boot loader require the following steps after MBRAAlign has been run.

1. Connect a Linux CD or CDROM ISO image to the Linux VM.
2. Boot the VM.
3. Select to boot from the CD.
4. Execute GRUB setup to repair the boot loader, when appropriate.

## CORRECTING PARTITION MISALIGNMENT WITH THIRD-PARTY TOOLS

NetApp endorses the use of many industry-leading third-party tools that can correct misaligned VMDKs. If you prefer a GUI tool that includes features such as job scheduling and reporting, you might want to use Vizioncore vOptimizer Pro.



## 6.7 CREATE PROPERLY ALIGNED PARTITIONS FOR NEW VMS

### CREATING A PROPERLY ALIGNED VMDK FOR A NEW VM WITH DISKPART

Virtual disks can be formatted with the correct offset at the time of creation by simply booting the VM before installing an operating system and manually setting the partition offset. For Windows guest operating systems, consider using the Windows Preinstall Environment boot CD or the alternative "live DVD" tools. To set up the starting offset, complete the following steps (refer to Figure 77).

1. Boot the VM with the Microsoft WinPE CD.
2. Select Start, select Run, and enter `diskpart`.
3. Enter `select disk 0`.
4. Enter `create partition primary align=32`.
5. Reboot the VM with the WinPE CD.
6. Install the operating system as normal.

Figure 77) Running `diskpart` to set a proper starting partition offset.

A screenshot of a Windows Command Prompt window titled "Command Prompt - diskpart". The window has a black background with white text. The text shows the following sequence of commands and responses:

```
C:\>diskpart
Microsoft DiskPart version 5.1.3565
Copyright (C) 1999-2003 Microsoft Corporation.
On computer: USTEWART01-LXP
DISKPART> select disk 0
Disk 0 is now the selected disk.
DISKPART> create partition primary align=32_
```

You can also create properly aligned VMDKs with `fdisk` from an ESX console session. Refer to [TR-3880: CLI Configuration Processes for NetApp and VMware vSphere Storage Arrays Running Data ONTAP and ESX/ESXi Server](#) for details.

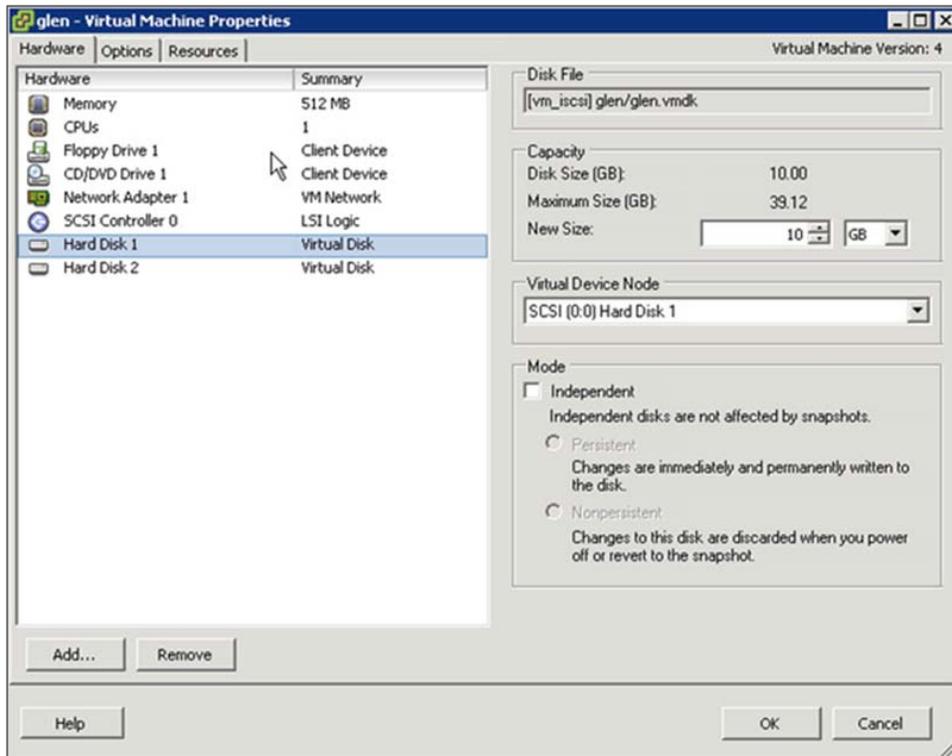
## 6.8 ADDING STORAGE CAPACITY TO A VM

### GROWING A VIRTUAL DISK (VMDK)

With ESX/ESXi 4, virtual disks can be extended while the VM is powered on and running. Growing the virtual disk is only half of the equation for increasing available storage; you still need to grow the file system after the VM boots. Root volumes such as `C:\` in Windows and `/` in Linux cannot be grown dynamically or while the system is running. For these volumes, refer to [Growing Bootable Volumes Within a Guest Operating System](#) section of this report. For all other volumes, you can use the native operating system tools to grow the volume. To grow a virtual disk, complete the following steps:

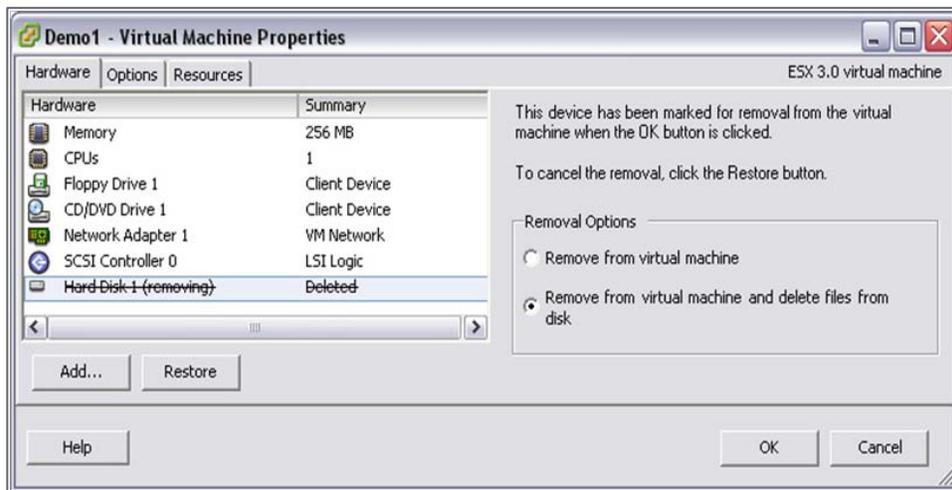
1. Open vCenter Server.
2. Select a VM.
3. Right-click the VM and select Properties.
4. Select a virtual disk and increase its size (refer to Figure 78).
5. Click OK.
6. Start the VM.

Figure 78) Increasing the size of a virtual disk.



For more information about extending a virtual disk, refer to the VMware ESX and ESXi Server Configuration Guide.

Figure 79) Deleting a VMDK from a VM.



## GROWING A FILE SYSTEM WITHIN A GUEST OPERATING SYSTEM (NTFS OR EXT3)

When a virtual disk or RDM has been increased in size, you still need to grow the file system residing on it after booting the VM. This process can be done live while the system is running by using native or freely distributed tools.

1. Remotely connect to the VM.
2. Grow the file system.
  - For Windows VMs, you can use the `diskpart` utility to grow the file system. For more information, refer to <http://support.microsoft.com/default.aspx?scid=kb;en-us;300415>.
  - For Linux VMs, you can use `ext2resize` to grow the file system. For more information, refer to <http://sourceforge.net/projects/ext2resize>.

In VMs running Microsoft Windows, the NetApp SnapDrive disk management software can be used to expand the size of an RDM disk from within the VM.

## GROWING BOOTABLE VOLUMES WITHIN A GUEST OPERATING SYSTEM

Depending on which guest operating system you are running, the root or system volume might support live expansion. As of the time this document was written, we have confirmed that Windows 2008 supports dynamic capacity expansion. Root volumes for all other GOS such as `C:\` in Windows VMs and `/` in Linux VMs cannot be grown on the fly or while the system is running.

These file systems can be expanded using a simple method that does not require the acquisition of any additional software (except for `ext2resize`). This process requires connecting the VMDK or LUN that has been resized to another VM of the same operating system type by using the processes defined in [section 6.8](#). After the storage is connected, the hosting VM can run the utility to extend the file system. After the file system is extended, this VM is shut down, and the storage is disconnected. Connect the storage to the original VM. When you boot, you can verify that the boot partition now has a new size.

## 7 DISK-BASED SNAPSHOT BACKUPS FOR VMWARE

This section applies to:



Storage administrators



VI administrators

### 7.1 COMPLEMENTARY SNAPSHOT TECHNOLOGIES

VMware vSphere provides the ability to create Snapshot copies of VMs. Snapshot technologies allow the creation of point-in-time copies that provide the fastest means to recover a VM to a previous point in time. NetApp has been providing customers with the ability to create Snapshot copies of their data since 1992. Although the basic concept of a Snapshot copy is similar for both NetApp and VMware, you should be aware of the differences between the two and when you should use one rather than the other.

VMware Snapshot copies provide simple point-in-time versions of VMs, enabling a quick recovery. The benefit of VMware Snapshot copies is that they are easy to create and use, because they can be executed and scheduled from within vCenter Server. VMware does not recommend leveraging the Snapshot technology in ESX as a means to back up vSphere. For more information about native VMware Snapshot copies, including usage guidelines, refer to the [vSphere Basic System Administration](#) guide.

NetApp Snapshot technology can easily be integrated into VMware environments, where it provides crash-consistent versions of VMs for the purpose of full VM recovery, full VM cloning, or site replication and disaster recovery. This is the only Snapshot technology that does not have a negative impact on system performance.

VMware states that for optimum performance and scalability, hardware-based Snapshot technology is preferred over software-based solutions. The shortcoming of this solution is that it is not managed within vCenter Server, requiring external scripting and/or scheduling to manage the process. For more information, refer to the [vSphere Basic System Administration](#) guide and the VMware ESX and ESXi Server Configuration Guide.

### 7.2 NETAPP SNAPSHOT BACKUPS FOR VSPHERE

The ability to quickly back up tens of hundreds of virtual machines without affecting production operations can accelerate the adoption of VMware within an organization. NetApp offers a means to do this in the Backup and Recovery capability of the Virtual Storage Console 2.0. This feature was formerly provided in a separate interface and was called SnapManager for Virtual Infrastructure (SMVI). It builds on the NetApp SnapManager portfolio by providing array-based backups, which only consume block-level changes to each VM and can provide multiple recovery points throughout the day. The backups are an integrated component within the storage array; therefore, SMVI provides recovery times that are faster than those provided by any other means.

Figure 80) Scheduling a datastore backup with the Backup and Recovery capability of the VSC.

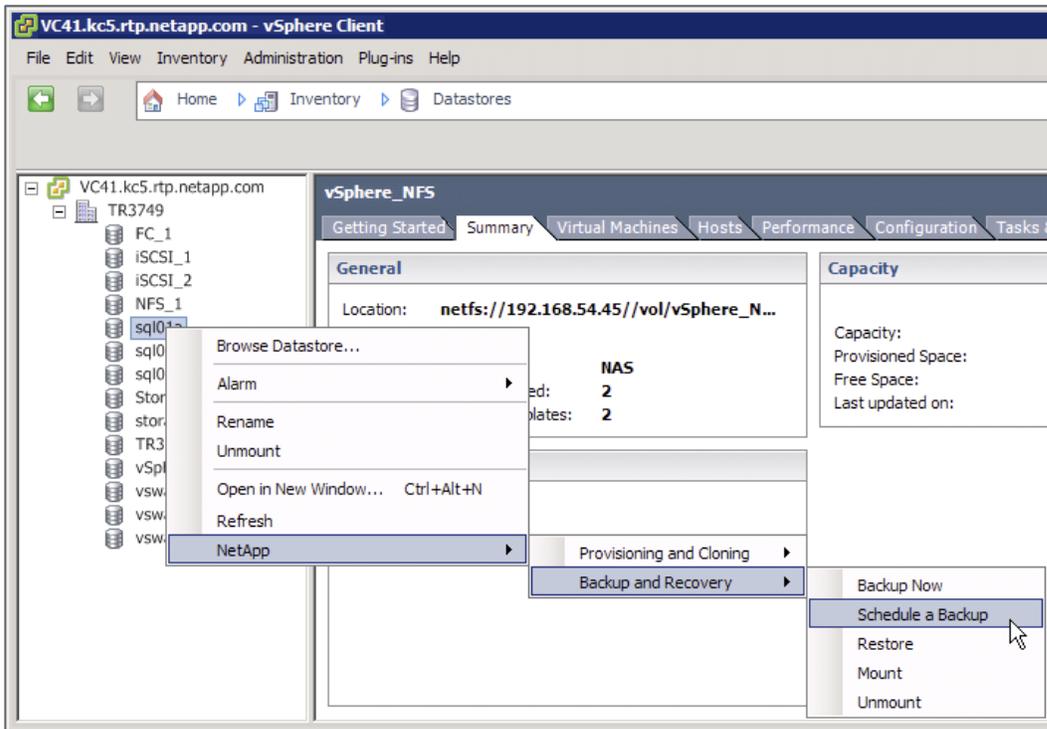
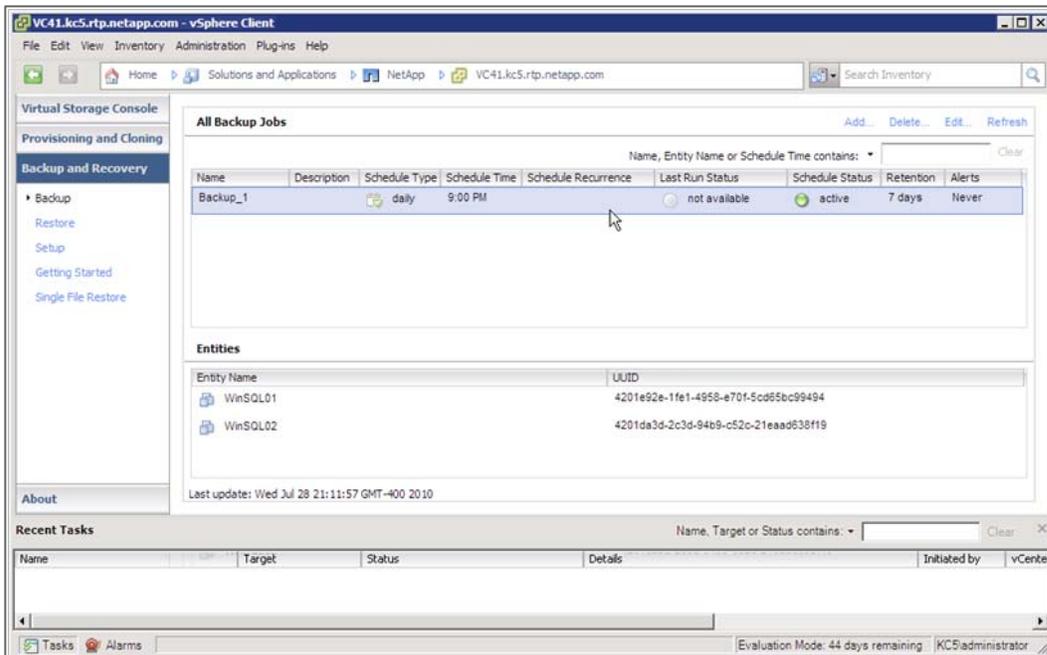


Figure 81) New backup job created with the Backup and Recovery capability of the VSC.



For information and best practices about NetApp Snapshot backups for vSphere, refer to [TR-3737: SnapManager 2.0 for Virtual Infrastructure Best Practices](#).

## 8 SUMMARY

VMware vSphere offers customers several methods of providing storage to VMs. All of these storage methods give customers flexibility in their infrastructure design, which in turn provides cost savings, increased storage use, and enhanced data recovery.

This technical report is not intended to be a definitive implementation or solutions guide. Expertise might be required to solve user-specific deployment issues. Contact your local NetApp representative to make an appointment to speak with a NetApp VMware solutions expert.

Comments about this technical report are welcome. Feel free to contact the authors by sending an e-mail to [xdl-vgibutmevmtr@netapp.com](mailto:xdl-vgibutmevmtr@netapp.com). Refer to TR-3749 v2.2 in the subject line of your e-mail.

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## 10 VERSION HISTORY

Version	Revision Date	Revision Comments
1.0	May 2009	<ul style="list-style-type: none"><li>• Original document</li></ul>
1.0.1	August 2009	<ul style="list-style-type: none"><li>• Minor edits</li><li>• Reformatted for publishing</li></ul>
2.0	January 2010	<ul style="list-style-type: none"><li>• Major update focusing on vCenter integrated tools for provisioning and configuration</li><li>• Removed all manual storage configurations to the appendix section</li><li>• Replaced these sections with the NSM, RCU, and VSC</li><li>• Reorganized the document from 16 sections to 8</li></ul>
2.1	August 2010	<ul style="list-style-type: none"><li>• Minor edits</li><li>• vSphere 4.1 updates</li><li>• Added statement about no support for combining iSCSI multiple TCP sessions and NFS in the same hosts</li><li>• Removed appendixes for legacy manual processes and placed in TR-3880</li></ul>
2.2	September 2011	<ul style="list-style-type: none"><li>• Minor edits</li><li>• Additional references</li><li>• Additional notes on configuring flow control, vicfg vs. esxcfg and TCP ports used by VSC.</li></ul>

## 11 ACKNOWLEDGMENTS

### 11.1 ABOUT THE AUTHORS AND CONTRIBUTORS

The authors of this technical report are members of either the NetApp Virtual Architecture Team or the Cloud Solutions Team based in Sunnyvale, California, and Research Triangle Park, North Carolina.

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The authors and contributors of this content have presented topics on the integration of server and storage virtualization technologies at various VMworld events. Their breakout sessions are posted online at [www.VMworld.com](http://www.VMworld.com).

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