Chapter 1

Introducing VMware vSphere 6

Now in its sixth generation, VMware vSphere builds on previous generations of VMware's enterprise-grade virtualization products. vSphere 6.0 extends fine-grained resource allocation controls to more types of resources, enabling you to have even greater control over how resources are allocated to and used by virtual workloads. With dynamic resource controls, high availability, unprecedented and further improved fault-tolerance features, distributed resource management, and backup tools included as part of the suite, IT administrators have all the tools they need to run an enterprise environment ranging from a few servers to tens of thousands of servers.

In this chapter, you will learn to

- Identify the role of each product in the vSphere product suite
- Recognize the interaction and dependencies between the products in the vSphere suite
- Understand how vSphere differs from other virtualization products

Exploring VMware vSphere 6.0

The VMware vSphere product suite is a comprehensive collection of products and features that together provide a full array of enterprise virtualization functionality. The vSphere product suite includes the following products and features:

- VMware ESXi
- VMware vCenter Server
- vSphere Update Manager
- VMware vSphere Desktop Client and vSphere Web Client
- VMware vCenter Orchestrator
- vSphere Virtual Symmetric Multi-Processing
- vSphere vMotion and Storage vMotion
- vSphere Distributed Resource Scheduler (DRS)
- vSphere Storage DRS
- Storage I/O Control and Network I/O Control
- Storage-Based Policy Management (SBPM)

- vSphere High Availability (HA)
- vSphere Symmetric Multi-Processing Fault Tolerance (SMP-FT)
- vSphere Storage APIs
- VMware Virtual SAN (VSAN)
- vSphere Replication
- vSphere Flash Read Cache
- vSphere Content Library

Rather than waiting to introduce these products and features in their own chapters, I will introduce each product or feature in the following sections. This will allow us to explain how each one affects the design, installation, and configuration of your virtual infrastructure. After I cover the features and products in the vSphere suite, you'll have a better grasp of how each of them fits into the design and the big picture of virtualization.

Certain products outside the vSphere product suite extend the vSphere product line with new functionality. These additional products include VMware Horizon View, VMware vRealize Automation, and VMware vCenter Site Recovery Manager, just to name a few. VMware even offers bundles of vSphere and these other products in the vCloud Suite to make it easier for users to purchase and consume the products in their environments. However, because of the size and scope of these products, they are not covered in this book.

As of this writing, VMware vSphere 6.0 is the latest release of the VMware vSphere product family. This book covers functionality found in version 6.0. Where possible, I've tried to note differences between vSphere versions. For detailed information on other vSphere versions, refer to the previous books in the *Mastering VMware vSphere* series, also published by Sybex.

To help simplify navigation and to help you find information on the breadth of products and features in the vSphere product suite, I've prepared Table 1.1, which contains cross-references to where you can find more information about a particular product or feature elsewhere in the book.

First we'll look at the products that make up the VMware vSphere suite, and then we'll examine the major features. Let's start with the products in the suite, beginning with VMware ESXi.

Table 1.1: Product and feature cross-references

VMware vSphere product or feature	More information found in this chapter
VMware ESXi	Installation—Chapter 2 Networking—Chapter 5 Storage—Chapter 6
VMware vCenter Server	Installation—Chapter 3 Networking—Chapter 5 Storage—Chapter 6 Security—Chapter 8
vSphere Update Manager	Chapter 4

Table 1.1: Product and feature cross-references *(continued)*

VMware vSphere product or feature	More information found in this chapter
vSphere Desktop Client and vSphere Web Client	Installation—Chapter 2 (vSphere Desktop Client) Installation—Chapter 3 (vSphere Web Client) Usage—Chapter 3
VMware vRealize Orchestrator and PowerCLI	Chapter 14
vSphere Virtual Symmetric Multi-Processing	Chapter 9
vSphere vMotion and Storage vMotion	Chapter 12
vSphere Distributed Resource Scheduler	Chapter 12
vSphere Storage DRS	Chapter 12
Storage I/O Control and Network I/O Control	Chapter 11
Profile-driven storage	Chapter 6
vSphere High Availability	Chapter 7
vSphere Fault Tolerance	Chapter 7
vSphere Storage APIs for Data Protection	Chapter 7
VMware Data Protection	Chapter 7
VMware Virtual SAN	Chapter 6
vSphere Replication	Chapter 7
vSphere Flash Read Cache	Installation—Chapter 6 Usage—Chapter 11
vSphere Content Library	Chapter 9

Examining the Products in the vSphere Suite

In the following sections, I'll describe and review the products found in the vSphere product suite.

VMware ESXi

The core of the vSphere product suite is the hypervisor, which is the virtualization layer that serves as the foundation for the rest of the product line. In vSphere 5 and later, including vSphere 6.0, the hypervisor comes solely in the form of VMware ESX*i*.

Longtime users of VMware vSphere may recognize this as a shift in the way VMware provides the hypervisor. Prior to vSphere 5, the hypervisor was available in two forms: VMware

ESX and VMware ESXi. Although both products shared the same core virtualization engine, supported the same set of virtualization features, leveraged the same licenses, and were considered bare-metal installation hypervisors (also referred to as Type 1 hypervisors; see the sidebar "Type 1 and Type 2 Hypervisors"), there were still notable architectural differences. In VMware ESX, VMware used a Red Hat Enterprise Linux (RHEL)-derived Service Console to provide an interactive environment through which users could interact with the hypervisor. The Linux-based Service Console also included services found in traditional operating systems, such as a firewall, Simple Network Management Protocol (SNMP) agents, and a web server.

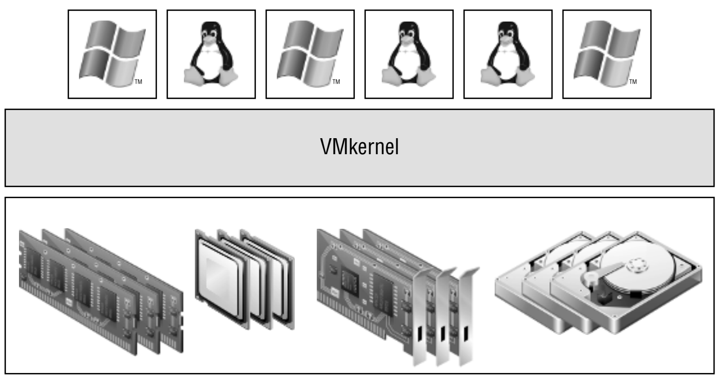
Type 1 and Type 2 Hypervisors

Hypervisors are generally grouped into two classes: Type 1 hypervisors and Type 2 hypervisors. Type 1 hypervisors run directly on the system hardware and thus are often referred to as *bare-metal* hypervisors. Type 2 hypervisors require a host operating system, and the host operating system provides I/O device support and memory management. VMware ESXi is a Type 1 bare-metal hypervisor. (In earlier versions of vSphere, VMware ESX was also considered a Type 1 bare-metal hypervisor.) Other Type 1 bare-metal hypervisors include KVM (part of the open source Linux kernel), Microsoft Hyper-V, and products based on the open source Xen hypervisor like Citrix XenServer and Oracle VM.

VMware ESXi, on the other hand, is the next generation of the VMware virtualization foundation. Unlike VMware ESX, ESXi installs and runs without the Linux-based Service Console. This gives ESXi an ultralight footprint of approximately 130MB. Despite the lack of the Service Console, ESXi provides all the same virtualization features that VMware ESX supported in earlier versions. Of course, ESXi 6.0 has been enhanced from earlier versions to support even more functionality, as you'll see in this and future chapters.

The key reason that VMware ESXi is able to support the same extensive set of virtualization functionality as VMware ESX without the Service Console is that the core of the virtualization functionality wasn't (and still isn't) found in the Service Console. It's the *VMkernel* that is the foundation of the virtualization process. It's the VMkernel that manages the virtual machines' access to the underlying physical hardware by providing CPU scheduling, memory management, and virtual switch data processing. Figure 1.1 shows the structure of VMware ESXi.

Figure 1.1
The VMkernel is the foundation of the virtualization functionality found in VMware ESXi.



I mentioned earlier that VMware ESXi 6.0 is enhanced, and one such area of enhancement is in the configuration limits of what the hypervisor can support. Table 1.2 shows the configuration maximums for the last few versions of VMware ESX/ESXi.

Table 1.2: VMware ESXi maximums

Component	VMware ESXi 6.0 maximum	VMware ESXi 5.5 maximum	VMware ESXi 5.0 maximum	VMware ESX/ESXi 4.0 maximum
Number of virtual CPUs per host	4,096	4,096	2,048	512
Number of logical CPUs (hyperthreading enabled)	320	320	160	64
Number of virtual CPUs per core	32	32	25	20 (increased to 25 in Update 1)
Amount of RAM per host	6 TB	4 TB	2 TB	1 TB

These are just some of the configuration maximums. Where appropriate, future chapters will include additional values for VMware ESXi maximums for network interface cards (NICs), storage, virtual machines (VMs), and so forth.

Given that VMware ESXi is the foundation of virtualization within the vSphere product suite, you'll see content for VMware ESXi throughout the book. Table 1.1, earlier in this chapter, tells you where you can find more information about specific features of VMware ESXi elsewhere in the book.

VMware vCenter Server

Stop for a moment to think about your current network. Does it include Active Directory? There is a good chance it does. Now imagine your network without Active Directory, without the ease of a centralized management database, without the single sign-on capabilities, and without the simplicity of groups. That's what managing VMware ESXi hosts would be like without using VMware vCenter Server. Not a very pleasant thought, is it? Now calm yourself down, take a deep breath, and know that vCenter Server, like Active Directory, is meant to provide a centralized management platform and framework for all ESXi hosts and their respective VMs. vCenter Server allows IT administrators to deploy, manage, monitor, automate, and secure a virtual infrastructure in a centralized fashion. To help provide scalability, vCenter Server leverages a backend database (Microsoft SQL Server and Oracle are both supported, among others) that stores all the data about the hosts and VMs.

In previous versions of VMware vSphere, vCenter Server was a Windows-only application. Version 6.0 of vSphere still offers this Windows-based installation of vCenter Server but also offers a prebuilt vCenter Server Appliance (a virtual appliance, in fact, something you'll learn about in Chapter 10, "Using Templates and vApps") that is based on SUSE Linux. Having a Linux-based vCenter Server Appliance is a great alternative for organizations that don't want to deploy a Windows Server instance just to manage the vSphere environment.

vCenter Server not only provides configuration and management capabilities—which include features such as VM templates, VM customization, rapid provisioning and deployment of VMs, role-based access controls, and fine-grained resource allocation controls—it also provides the tools for the more advanced features of vSphere vMotion, vSphere Distributed Resource Scheduler, vSphere High Availability, and vSphere Fault Tolerance. All of these features are described briefly in this chapter and in more detail in later chapters.

In addition to vSphere vMotion, vSphere Distributed Resource Scheduler, vSphere High Availability, and vSphere Fault Tolerance, using vCenter Server to manage ESXi hosts enables a number of other features:

- Enhanced vMotion Compatibility (EVC), which leverages hardware functionality from Intel and AMD to enable greater CPU compatibility between servers grouped into vSphere DRS clusters
- Host profiles, which allow you to bring greater consistency to host configurations across larger environments and to identify missing or incorrect configurations
- Storage I/O Control, which provides cluster-wide quality of service (QoS) controls so you can ensure critical applications receive sufficient storage I/O resources even during times of congestion
- vSphere Distributed Switches, which provide the foundation for networking settings and third-party virtual switches that span multiple hosts and multiple clusters
- Network I/O Control, which allows you to flexibly partition physical NIC bandwidth and provide QoS for different types of traffic
- vSphere Storage DRS, which enables VMware vSphere to dynamically migrate storage resources to meet demand, much in the same way that DRS balances CPU and memory utilization

vCenter Server plays a central role in any sizable VMware vSphere implementation. In Chapter 3, "Installing and Configuring vCenter Server," I discuss planning and installing vCenter Server as well as look at ways to ensure its availability. Chapter 3 will also examine the differences between the Windows-based version of vCenter Server and the Linux-based vCenter Server virtual appliance. Because of vCenter Server's central role in a VMware vSphere deployment, I'll touch on vCenter Server in almost every chapter throughout the rest of the book. Refer to Table 1.1, earlier in this chapter, for specific cross-references.

vCenter Server is available in two packages:

- vCenter Server Essentials is integrated into the vSphere Essentials kits for small office deployment.
- vCenter Server Standard provides all the functionality of vCenter Server, including provisioning, management, monitoring, and automation.

You can find more information on licensing and product editions for VMware vSphere in the section "Licensing VMware vSphere."

vSphere Update Manager

vSphere Update Manager is an add-on package for vCenter Server that helps users keep their ESXi hosts and select VMs patched with the latest updates. vSphere Update Manager provides the following functionality:

- Scans to identify systems that are not compliant with the latest updates
- User-defined rules for identifying out-of-date systems
- Automated installation of patches for ESXi hosts
- Full integration with other vSphere features like Distributed Resource Scheduler

vSphere Update Manager works with the Windows-based installation of vCenter Server as well as the prepackaged vCenter Server virtual appliance. Refer to Table 1.1 for more information on where vSphere Update Manager is described in this book.

VMware vSphere Web Client and vSphere Desktop Client

vCenter Server provides a centralized management framework for VMware ESXi hosts, but it's the vSphere Web Client (and its predecessor, the Windows-based vSphere Desktop Client) where you will spend most of your time.

With the release of vSphere 5, VMware shifted its primary administrative interface to a web-based vSphere Client. The vSphere Web Client provides a dynamic, web-based user interface for managing a virtual infrastructure and enables you to manage your infrastructure without needing to install the Windows-based vSphere Desktop Client on a system. In its initial release, the vSphere Web Client provided a subset of the functionality available to the "full" Windows-based vSphere Desktop Client. However, in subsequent releases—including the 6.0 release—the vSphere Web Client has been enhanced and expanded to include almost all the functionality you need to manage a vSphere environment. Further, VMware has stated that the vSphere Web Client will eventually replace the Windows-based vSphere Desktop Client entirely. For this reason, I'll use screen shots of the vSphere Web Client throughout this book unless it is impossible to do so.

The Windows-based vSphere Desktop Client is still available to allow you to manage individual ESXi hosts, either directly or through an instance of vCenter Server. You can install the vSphere Desktop Client by browsing to the URL of an ESXi host or vCenter Server and selecting the appropriate installation link (although keep in mind that Internet access might be required in order to download the client in some instances). The vSphere Desktop Client provides a rich graphical user interface (GUI) for all day-to-day management tasks and for the advanced configuration of a virtual infrastructure. Although you can connect the vSphere Desktop Client either directly to an ESXi host or to an instance of vCenter Server, the full set of management capabilities are available only when you are connecting the vSphere Desktop Client to vCenter Server.

As I mentioned earlier, the vSphere Web Client is the stated future direction for VMware vSphere's management interface. For that reason, I focus primarily on how to use the vSphere

Web Client throughout this book. Tasks in the vSphere Desktop Client should be similar, but note that some tasks can be performed only in the vSphere Web Client, not the Windows-based vSphere Desktop Client.

VMware vRealize Orchestrator

VMware vRealize Orchestrator (previously named VMware vCenter Orchestrator) is a workflow automation engine that is automatically installed with every instance of vCenter Server. Using vRealize Orchestrator, you can build automated workflows for a wide variety of tasks available within vCenter Server. The automated workflows you build using vRealize Orchestrator range from simple to complex. VMware also makes vRealize Orchestrator plug-ins to extend the functionality to include manipulating Microsoft Active Directory, Cisco's Unified Computing System (UCS), and VMware vRealize Automation. This makes vRealize Orchestrator a powerful tool to use in building automated workflows in the virtualized datacenter.

Now that we've discussed the specific products in the VMware vSphere product suite, I'd like to take a closer look at some of the significant features.

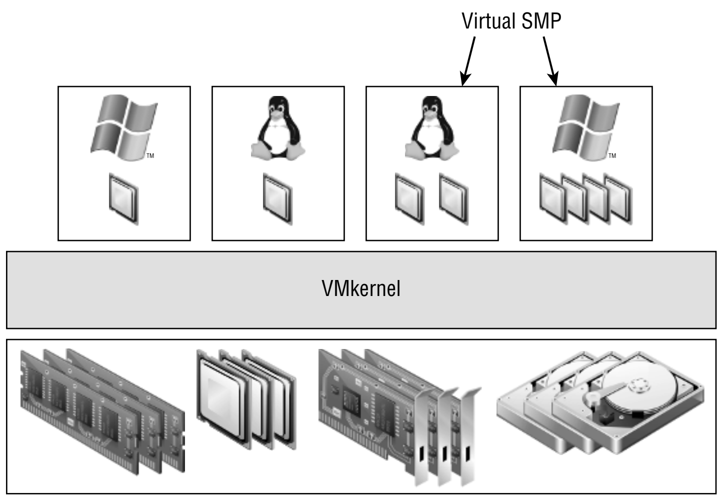
Examining the Features in VMware vSphere

In the following sections, we'll take a closer look at some of the features that are available in the vSphere product suite. We'll start with Virtual SMP.

vSphere Virtual Symmetric Multi-Processing

The vSphere Virtual Symmetric Multi-Processing (vSMP or Virtual SMP) product allows you to construct VMs with multiple virtual processor cores and/or sockets. vSphere Virtual SMP is *not* the licensing product that allows ESXi to be installed on servers with multiple processors; it is the technology that allows the use of multiple processors *inside* a VM. Figure 1.2 identifies the differences between multiple processors in the ESXi host system and multiple virtual processors.

Figure 1.2
vSphere Virtual SMP allows VMs to be created with more than one virtual CPU.



With vSphere Virtual SMP, applications that require and can actually use multiple CPUs can be run in VMs configured with multiple virtual CPUs. This allows organizations to virtualize even more applications without negatively impacting performance or being unable to meet service-level agreements (SLAs).

In vSphere 5, VMware expanded this functionality by also allowing users to specify multiple virtual cores per virtual CPU. Using this feature, a user could provision a dual "socket" VM with two cores per "socket" for a total of four virtual cores. This approach gives users tremendous flexibility in carving up CPU processing power among the VMs.

vSphere vMotion and vSphere Storage vMotion

If you have read anything about VMware, you have most likely read about the extremely useful feature called vMotion. vSphere vMotion, also known as *live migration*, is a feature of ESXi and vCenter Server that allows you to move a running VM from one physical host to another physical host without having to power off the VM. This migration between two physical hosts occurs with no downtime and with no loss of network connectivity to the VM. The ability to manually move a running VM between physical hosts on an as-needed basis is a powerful feature that has a number of use cases in today's datacenters.

Suppose a physical machine has experienced a nonfatal hardware failure and needs to be repaired. You can easily initiate a series of vMotion operations to remove all VMs from an ESXi host that is to undergo scheduled maintenance. After the maintenance is complete and the server is brought back online, you can use vMotion to return the VMs to the original server.

Alternately, consider a situation in which you are migrating from one set of physical servers to a new set of physical servers. Assuming that the details have been addressed—and I'll discuss the details of vMotion in Chapter 12, "Balancing Resource Utilization"—you can use vMotion to move the VMs from the old servers to the newer servers, making quick work of a server migration with no interruption of service.

Even in normal day-to-day operations, vMotion can be used when multiple VMs on the same host are in contention for the same resource (which ultimately causes poor performance across all the VMs). With vMotion, you can migrate any VMs facing contention to another ESXi host with greater availability for the resource in demand. For example, when two VMs contend with each other for CPU resources, you can eliminate the contention by using vMotion to move one VM to an ESXi host with more available CPU resources.

vMotion moves the execution of a VM, relocating the CPU and memory footprint between physical servers but leaving the storage untouched. Storage vMotion builds on the idea and principle of vMotion: you can leave the CPU and memory footprint untouched on a physical server but migrate a VM's storage while the VM is still running.

Deploying vSphere in your environment generally means that lots of shared storage—Fibre Channel or iSCSI SAN or NFS—is needed. What happens when you need to migrate from an older storage array to a newer storage array? What kind of downtime would be required? Or what about a situation where you need to rebalance utilization of the array, either from a capacity or performance perspective?

With the ability to move storage for a running VM between datastores, Storage vMotion lets you address all of these situations without downtime. This feature ensures that outgrowing datastores or moving to a new SAN does not force an outage for the affected VMs and provides you with yet another tool to increase your flexibility in responding to changing business needs.

vSphere Distributed Resource Scheduler

vMotion is a manual operation, meaning that you must initiate the vMotion operation. What if VMware vSphere could perform vMotion operations automatically? That is the basic idea behind vSphere Distributed Resource Scheduler (DRS). If you think that vMotion sounds exciting, your anticipation will only grow after learning about DRS. DRS, simply put, leverages vMotion to provide automatic distribution of resource utilization across multiple ESXi hosts that are configured in a cluster.

Given the prevalence of Microsoft Windows Server in today's datacenters, the use of the term *cluster* often draws IT professionals into thoughts of Microsoft Windows Server clusters. Windows Server clusters are often active-passive or active-active-passive clusters. However, ESXi clusters are fundamentally different, operating in an active-active mode to aggregate and combine resources into a shared pool. Although the underlying concept of aggregating physical hardware to serve a common goal is the same, the technology, configuration, and feature sets are quite different between VMware ESXi clusters and Windows Server clusters.

Aggregate Capacity and Single Host Capacity

Although I say that a DRS cluster is an implicit aggregation of CPU and memory capacity, it's important to keep in mind that a VM is limited to using the CPU and RAM of a single physical host at any given time. If you have two ESXi servers with 32GB of RAM each in a DRS cluster, the cluster will correctly report 64 GB of aggregate RAM available, but any given VM will not be able to use more than approximately 32 GB of RAM at a time.

An ESXi cluster is an implicit aggregation of the CPU power and memory of all hosts involved in the cluster. After two or more hosts have been assigned to a cluster, they work in unison to provide CPU and memory to the VMs assigned to the cluster (keeping in mind that any given VM can only use resources from one host; see the sidebar "Aggregate Capacity and Single Host Capacity"). The goal of DRS is twofold:

- At startup, DRS attempts to place each VM on the host that is best suited to run that VM at that time.
- Once a VM is running, DRS seeks to provide that VM with the required hardware resources while minimizing the amount of contention for those resources in an effort to maintain balanced utilization levels.

The first part of DRS is often referred to as *intelligent placement*. DRS can automate the placement of each VM as it is powered on within a cluster, placing it on the host in the cluster that it deems to be best suited to run that VM at that moment.

DRS isn't limited to operating only at VM startup, though. DRS also manages the VM's location while it is running. For example, let's say three servers have been configured in an ESXi cluster with DRS enabled. When one of those servers begins to experience a high contention for CPU utilization, DRS detects that the cluster is imbalanced in its resource usage and uses an internal algorithm to determine which VM(s) should be moved in order to create the least imbalanced cluster. For every VM, DRS will simulate a migration to each host and the results will be compared. The migrations that create the least imbalanced cluster will be recommended or automatically performed, depending on the DRS configuration.

DRS performs these on-the-fly migrations without any downtime or loss of network connectivity to the VMs by leveraging vMotion, the live migration functionality I described earlier. This makes DRS extremely powerful because it allows clusters of ESXi hosts to dynamically rebalance their resource utilization based on the changing demands of the VMs running on that cluster.

Fewer Bigger Servers or More Smaller Servers?

Recall from Table 1.2 that VMware ESXi supports servers with up to 320 logical CPU cores and up to 6 TB of RAM. With vSphere DRS, though, you can combine multiple smaller servers for the purpose of managing aggregate capacity. This means that bigger, more powerful servers might not be better servers for virtualization projects. These larger servers, in general, are significantly more expensive than smaller servers, and using a greater number of smaller servers (often referred to as "scaling out") may provide greater flexibility than a smaller number of larger servers (often referred to as "scaling up"). The key thing to remember is that a bigger server isn't necessarily a better server.

vSphere Storage DRS

vSphere Storage DRS takes the idea of vSphere DRS and applies it to storage. Just as vSphere DRS helps to balance CPU and memory utilization across a cluster of ESXi hosts, Storage DRS helps balance storage capacity and storage performance across a cluster of datastores using mechanisms that echo those used by vSphere DRS.

Earlier I described vSphere DRS's feature called intelligent placement, which automates the placement of new VMs based on resource usage within an ESXi cluster. In the same fashion, Storage DRS has an intelligent placement function that automates the placement of VM virtual disks based on storage utilization. Storage DRS does this through the use of datastore clusters. When you create a new VM, you simply point it to a datastore cluster, and Storage DRS automatically places the VM's virtual disks on an appropriate datastore within that datastore cluster.

Likewise, just as vSphere DRS uses vMotion to balance resource utilization dynamically, Storage DRS uses Storage vMotion to rebalance storage utilization based on capacity and/or latency thresholds. Because Storage vMotion operations are typically much more resource intensive than vMotion operations, vSphere provides extensive controls over the thresholds, timing, and other guidelines that will trigger a Storage DRS automatic migration via Storage vMotion.

Storage I/O Control and Network I/O Control

VMware vSphere has always had extensive controls for modifying or controlling the allocation of CPU and memory resources to VMs. What vSphere didn't have prior to the release of vSphere 4.1 was a way to apply these same sort of extensive controls to storage I/O and network I/O. Storage I/O Control and Network I/O Control address that shortcoming.

Storage I/O Control (SIOC) allows you to assign relative priority to storage I/O as well as assign storage I/O limits to VMs. These settings are enforced cluster-wide; when an ESXi host detects storage congestion through an increase of latency beyond a user-configured threshold, it will apply the settings configured for that VM. The result is that you can help the VMs that need priority access to storage resources get more of the resources they need. In vSphere 4.1, Storage I/O Control applied only to VMFS storage; vSphere 5 extended that functionality to NFS datastores.

The same goes for Network I/O Control (NIOC), which provides you with more granular controls over how VMs use network bandwidth provided by the physical NICs. As the widespread adoption of 10 Gigabit Ethernet (10GbE) continues, Network I/O Control provides you with a way to more reliably ensure that network bandwidth is properly allocated to VMs based on priority and limits.

Policy-Based Storage

With profile-driven storage, vSphere administrators can use storage capabilities and VM storage profiles to ensure VMs reside on storage that provides the necessary levels of capacity, performance, availability, and redundancy. Profile-driven storage is built on two key components:

- Storage capabilities, leveraging vSphere's storage awareness APIs
- VM storage profiles

Storage capabilities are either provided by the storage array itself (if the array can use vSphere's storage awareness APIs) and/or defined by a vSphere administrator. These storage capabilities represent various attributes of the storage solution.

VM storage profiles define the storage requirements for a VM and its virtual disks. You create VM storage profiles by selecting the storage capabilities that must be present for the VM to run. Datastores that have all the capabilities defined in the VM storage profile are compliant with the VM storage profile and represent possible locations where the VM could be stored.

This functionality gives you much greater visibility into storage capabilities and helps ensure that the appropriate functionality for each VM is indeed being provided by the underlying storage. These storage capabilities can be explored extensively by using VVOLs or VSAN.

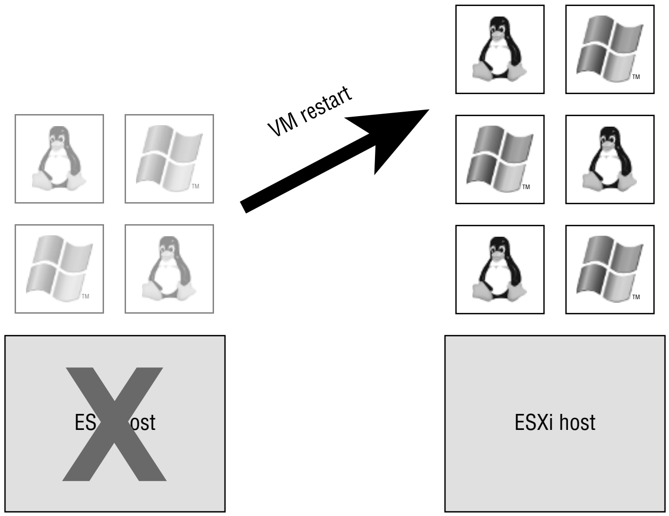
Refer to Table 1.1 to find out which chapter discusses profile-driven storage in more detail.

vSphere High Availability

In many cases, high availability—or the lack of high availability—is the key argument used against virtualization. The most common form of this argument more or less sounds like this: "Before virtualization, the failure of a physical server affected only one application or workload. After virtualization, the failure of a physical server will affect many more applications or workloads running on that server at the same time. We can't put all our eggs in one basket!"

VMware addresses this concern with another feature present in ESXi clusters called vSphere High Availability (HA). Once again, by nature of the naming conventions (clusters, high availability), many traditional Windows administrators will have preconceived notions about this feature. Those notions, however, are incorrect in that vSphere HA does not function like a high-availability configuration in Windows. The vSphere HA feature provides an automated process for restarting VMs that were running on an ESXi host at a time of server failure (or other qualifying infrastructure failure, as I'll describe in Chapter 7, "Ensuring High Availability and Business Continuity"). Figure 1.3 depicts the VM migration that occurs when an ESXi host that is part of an HA-enabled cluster experiences failure.

Figure 1.3
The vSphere HA feature will restart any VMs that were previously running on an ESXi host that experiences server or storage path failure.



The vSphere HA feature, unlike DRS, does not use the vMotion technology as a means of migrating servers to another host. vMotion applies only to planned migrations, where both the source and destination ESXi host are running and functioning properly. In a vSphere HA failover situation, there is no anticipation of failure; it is not a planned outage, which means there is no time to perform a vMotion operation. vSphere HA is intended to minimize unplanned downtime because of the failure of a physical ESXi host or other infrastructure components. I'll go into more detail in Chapter 7 on what kinds of failures vSphere HA helps protect against.

vSphere HA Improvements from vSphere 5

vSphere HA received a few notable improvements in the vSphere 5.0 release. First, scalability was significantly improved; you could run up to 512 VMs per host (up from 100 in earlier versions) and 3,000 VMs per cluster (up from 1,280 in earlier versions). Second, vSphere HA integrated more closely with the intelligent placement functionality of vSphere DRS, giving vSphere HA greater ability to restart VMs in the event of a host failure. The third and perhaps most significant improvement is the complete rewrite of the underlying architecture for vSphere HA; this entirely new architecture, known as Fault Domain Manager (FDM), eliminated many of the constraints found in earlier versions of VMware vSphere.

By default, vSphere HA does not provide failover in the event of a guest OS failure, although you can configure vSphere HA to monitor VMs and restart them automatically if they fail to respond to an internal heartbeat. This feature is called VM Failure Monitoring, and it uses a combination of internal heartbeats and I/O activity to attempt to detect if the guest OS inside a VM has stopped functioning. If the guest OS has stopped functioning, the VM can be restarted automatically.

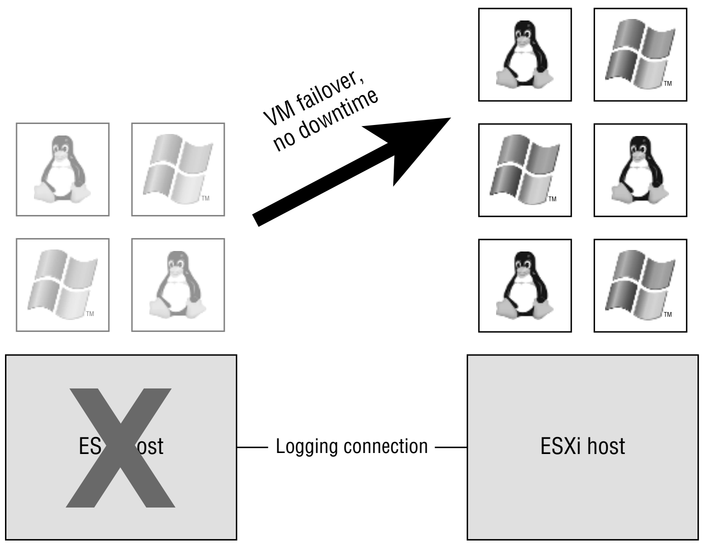
With vSphere HA, it's important to understand that there will be an interruption of service. If a physical host or storage device fails, vSphere HA restarts the VM, and while the VM is restarting, the applications or services provided by that VM are unavailable. For users who need even higher levels of availability than can be provided using vSphere HA, vSphere Fault Tolerance (FT), which is described in the next section, can help.

vSphere Fault Tolerance

Although vSphere HA provides a certain level of availability for VMs in the event of physical host failure, this might not be good enough for some workloads. vSphere Fault Tolerance (FT) might help in these situations.

As I described in the previous section, vSphere HA protects against unplanned physical server failure by providing a way to automatically restart VMs upon physical host failure. This need to restart a VM in the event of a physical host failure means that some downtime—generally less than 3 minutes—is incurred. vSphere FT goes even further and eliminates any downtime in the event of a physical host failure. For a single vCPU VM, the older vLockstep technology is used that is based on VMware's earlier "record and replay" functionality, vSphere FT maintains a mirrored secondary VM on a separate physical host that is kept in lockstep with the primary VM. vSphere's newer Fast Checkpointing technology supports FT of VMs with one to four vCPUs. Everything that occurs on the primary (protected) VM also occurs simultaneously on the secondary (mirrored) VM, so that if the physical host for the primary VM fails, the secondary VM can immediately step in and take over without any loss of connectivity. vSphere FT will also automatically re-create the secondary (mirrored) VM on another host if the physical host for the secondary VM fails, as illustrated in Figure 1.4. This ensures protection for the primary VM at all times.

Figure 1.4
vSphere FT provides protection against host failures with no downtime experienced by the VMs.



In the event of multiple host failures—say, the hosts running both the primary and secondary VMs failed—vSphere HA will reboot the primary VM on another available server, and vSphere FT will automatically create a new secondary VM. Again, this ensures protection for the primary VM at all times.

vSphere FT can work in conjunction with vMotion. As of vSphere 5.0, vSphere FT is also integrated with vSphere DRS, although this feature does require Enhanced vMotion Compatibility (EVC). VMware recommends that multiple FT virtual machines with multiple vCPUs have 10GbE networks between hosts.

vSphere Storage APIs for Data Protection and VMware Data Protection

One of the most critical aspects to any network, not just a virtualized infrastructure, is a solid backup strategy as defined by a company's disaster recovery and business continuity plan. To help address organizational backup needs, VMware vSphere 6.0 has two key components: the vSphere Storage APIs for Data Protection (VADP) and VMware Data Protection (VDP).

VADP is a set of application programming interfaces (APIs) that back up vendors leverage in order to provide enhanced backup functionality of virtualized environments. VADP enables functionality like file-level backup and restore; support for incremental, differential, and full-image backups; native integration with backup software; and support for multiple storage protocols.

On its own, though, VADP is just a set of interfaces, like a framework for making backups possible. You can't actually back up VMs with VADP. You'll need a VADP-enabled backup application. There are a growing number of third-party backup applications that are designed to work with VADP, and VMware also offers its own backup tool, VMware Data Protection (VDP). VDP leverages VADP and technology based on EMC Avamar to provide a full backup solution for smaller VMware vSphere environments.

Using VMware Data Recovery?

In vSphere 5.1, VMware phased out its earlier data protection tool, VMware Data Recovery (VDR), in favor of VMware Data Protection. Although VDR was provided with vSphere 5.0, VDR is not supported with vSphere 5.1 and later, and you should use VDP instead.

Virtual SAN (VSAN)

VSAN is a major new feature included with, but licensed separately from, vSphere 5.5 and later. It is the evolution of work that VMware has been doing for a few years now, building on top of the work of the vSphere Storage Appliance (VSA). VSAN lets organizations leverage the internal storage found in individual compute nodes and turn it into—well, a *virtual SAN*.

VSAN requires at least three ESXi hosts (or nodes) but will scale to as many as 32. VSAN also requires solid-state storage in each of the compute nodes providing VSAN storage; this is done to help improve I/O performance given that most compute nodes have a limited number of physical drive spindles present. (Note that the solid-state storage in the servers used by VSAN is separate from solid-state storage that would be used by vSphere's vSphere Flash Read Cache caching functionality. See the section vSphere Flash Read Cache later in this chapter for more details on using solid-state storage for caching.) VSAN pools the storage across the compute nodes, allowing you to create a datastore that spans multiple compute nodes. VSAN employs algorithms to help protect against data loss, such as ensuring that the data exists on multiple participating VSAN nodes at the same time.

More information on VSAN is found in Chapter 6, "Creating and Configuring Storage Devices."

vSphere Replication

vSphere Replication brings data replication, a feature typically found in hardware storage platforms, into vSphere itself. It's been around since vSphere 5.0, when it was only enabled for use in conjunction with VMware Site Recovery Manager (SRM) 5.0. In vSphere 5.1, vSphere Replication was decoupled from SRM and enabled for independent use without VMware SRM.

vSphere Replication enables customers to replicate VMs from one vSphere environment to another vSphere environment. Typically, this means from one data center (often referred to as the primary or production data center) to another datacenter (typically the secondary, backup, or disaster recovery [DR] site). Unlike hardware-based solutions, vSphere Replication operates on a per-VM basis, so it gives customers very granular control over which workloads will be replicated and which workloads won't be replicated.

You can find more information about vSphere Replication in Chapter 7.

vSphere Flash Read Cache

Since the release of vSphere 5.0 in 2011, the industry has seen tremendous uptake in the use of solid-state storage (also referred to as flash storage) across a wide variety of use cases. Because solid-state storage can provide massive numbers of I/O operations per second (IOPS) it can handle the increasing I/O demands of virtual workloads. However, solid-state storage is typically more expensive on a per-gigabyte basis than traditional, hard-disk-based storage and therefore is often deployed as a caching mechanism to help speed up frequently accessed data.

Unfortunately, without support in vSphere for managing solid-state storage as a caching mechanism, vSphere architects and administrators have had difficulty fully leveraging solid-state storage in their environments. With the release of vSphere 5.5, VMware addresses that limitation through a feature called *vSphere Flash Read Cache*.

vSphere Flash Read Cache brings full support for using solid-state storage as a caching mechanism to vSphere. Using this feature, you can assign solid-state caching space to VMs in much the same way as you assign CPU cores, RAM, or network connectivity to VMs. vSphere manages how the solid-state caching capacity is allocated and assigned as well as how it is used by the VMs.

Hardware vendors that provide solid-state storage devices have partnered with VMware to make their products fully support vSphere Flash Read Cache.

VMware vSphere Compared to Hyper-V and XenServer

It's not possible to compare some virtualization solutions to others because they are fundamentally different in approach and purpose. Such is the case with VMware ESXi and some of the other virtualization solutions on the market.

To make accurate comparisons between vSphere and others, you must include only Type 1 ("bare-metal") virtualization solutions. This would include ESXi, of course, Microsoft Hyper-V and Citrix

XenServer. It would not include products such as VMware Server and Microsoft Virtual Server, both of which are Type 2 ("hosted") virtualization products. Even within the Type 1 hypervisors, there are architectural differences that make direct comparisons difficult.

For example, both Microsoft Hyper-V and Citrix XenServer route all the VM I/O through the "parent partition" or "dom0." This typically provides greater hardware compatibility with a wider range of products. In the case of Hyper-V, for example, as soon as Windows Server 2012—the general-purpose operating system running in the parent partition—supports a particular type of hardware, Hyper-V supports it also. Hyper-V "piggybacks" on Windows' hardware drivers and the I/O stack. The same can be said for XenServer, although its "dom0" runs Linux and not Windows.

VMware ESXi, on the other hand, handles I/O within the hypervisor itself. This typically provides greater throughput and lower overhead at the expense of slightly more limited hardware compatibility. To add more hardware support or updated drivers, the hypervisor must be updated because the I/O stack and device drivers are in the hypervisor.

This architectural difference is fundamental, and nowhere is it more greatly demonstrated than in ESXi, which has a small footprint yet provides a full-featured virtualization solution. Both Citrix XenServer and Microsoft Hyper-V require a full installation of a general-purpose operating system (Windows Server 2012 for Hyper-V, Linux for XenServer) in the parent partition/dom0 in order to operate.

In the end, each of the virtualization products has its own set of advantages and disadvantages, and large organizations may end up using multiple products. For example, VMware vSphere might be best suited in the large corporate datacenter, whereas Microsoft Hyper-V or Citrix XenServer might be acceptable for test, development, or branch office deployment. Organizations that don't require VMware vSphere's advanced features like vSphere DRS, vSphere FT, or Storage vMotion may also find that Microsoft Hyper-V or Citrix XenServer is a better fit for their needs.

As you can see, VMware vSphere offers some pretty powerful features that will change the way you view the resources in your datacenter. vSphere also has a wide range of features and functionality. Some of these features, though, might not be applicable to all organizations, which is why VMware has crafted a flexible licensing scheme for organizations of all sizes.

Licensing VMware vSphere

Beginning with VMware vSphere 4, VMware made available new licensing tiers and bundles intended to provide a good fit for every market segment. That arrangement continued with vSphere 5.0. However, with vSphere 5.1 (and continuing with vSphere 6.0), VMware refined this licensing arrangement with the vCloud Suite—a bundling of products including vSphere, vRealize Automation, vCenter Site Recovery Manager, and vRealize Operations Management Suite.

Although licensing vSphere via the vCloud Suite is likely the preferred way of licensing vSphere moving forward, discussing all the other products included in the vCloud Suite is beyond the scope of this book. Instead, I'll focus on vSphere and explain how the various features discussed so far fit into vSphere's licensing model when vSphere is licensed stand-alone.

vSphere or vSphere With Operations Management?

VMware sells "standalone" vSphere in one of two ways: as vSphere, with all the various kits and editions, and as vSphere with Operations Management. vSphere with Operations Management is the same as vSphere but adds the vRealize Operations Management product. In this section, we are focused on standalone vSphere only, but keep in mind that vSphere with Operations Management would be licensed and packaged in much the same way.

You've already seen how VMware packages and licenses VMware vCenter Server, but here's a quick review:

- VMware vCenter Server for Essentials, which is bundled with the vSphere Essentials kits (more on the kits in just a moment).
- VMware vCenter Server Standard, which includes all functionality and does not have a preset limit on the number of vSphere hosts it can manage (although normal sizing limits do apply). vRealize Orchestrator is included only in the Standard edition of vCenter Server.

In addition to the two editions of vCenter Server, VMware offers three editions of VMware vSphere:

- vSphere Standard Edition
- vSphere Enterprise Edition
- vSphere Enterprise Plus Edition

No More vRAM and No vCPU Limits

If you've been around the VMware vSphere world for a while, you might recall that VMware introduced the idea of vRAM—the amount of RAM configured for a VM—as a licensing constraint with the release of vSphere 5.0. As of vSphere 5.1, and continuing into vSphere 6.0, VMware no longer uses vRAM entitlements as a licensing mechanism. VMware has removed any licensing limits on the number of vCPUs that can be assigned to a VM.

These three editions are differentiated primarily by the features each edition supports, although there are some capacity limitations with the different editions. Notably missing from the licensing for vSphere 6.0 are limits on vRAM (see the sidebar "No More vRAM and No vCPU Limits").

Table 1.3 summarizes the features that are supported for each edition of VMware vSphere 6.0.

TABLE 1.3: Overview of VMware vSphere product editions

	Essentials Kit	Essentials Plus Kit	Standard	Enterprise	Enterprise Plus
vCenter Server compatibility	vCenter Server Essentials	vCenter Server Essentials	vCenter Server Standard	vCenter Server Standard	vCenter Server Standard
vCPUs per VM	128	128	128	128	128
Cross vSwitch vMotion		X	X	X	X
Cross vCenter/Long Distance vMotion					X
High Availability		X	X	X	X
Data Protection		X	X	X	X
vSphere Replication		X	X	X	X
vShield Endpoint		X	X	X	X
Hot Add			X	X	X
Fault Tolerance			2 vCPU	4 vCPU	4 vCPU
Storage vMotion			X	X	X
Virtual Volumes and Storage Policy-based Management			X	X	X
Distributed Resource Scheduler and Distributed Power Management				X	X
Storage APIs for Array Integration, Multipathing				X	X
Big Data Extensions				X	X
Reliable Memory				X	X
Distributed Switch					X

TABLE 1.3: Overview of VMware vSphere product editions *(CONTINUED)*

	Essentials Kit	Essentials Plus Kit	Standard	Enterprise	Enterprise Plus
I/O Controls (Network and Storage) and SR-IOV					X
Host Profiles					X
Auto Deploy					X
Storage DRS					X
Flash Read Cache					X
Content Library					X

Source: "VMware vSphere 6.0 Licensing, Pricing and Packaging" white paper published by VMware, available at `www.vmware.com`.

It's important to note that all editions of VMware vSphere 6.0 include support for thin provisioning, vSphere Update Manager, and the vSphere Storage APIs for Data Protection. I did not include them in Table 1.3 because these features are supported in all editions. Because prices change and vary depending on partner, region, and other factors, I have not included any pricing information here. Also, I did not include VSAN in Table 1.3 because it is licensed separately from vSphere.

For all editions of vSphere, VMware requires at least one year of Support and Subscription (SnS). The only exception is the Essential Kits, as I'll explain in a moment.

In addition to the different editions described previously, VMware offers some bundles, referred to as *kits*.

Essentials Kits are all-in-one solutions for small environments, supporting up to three vSphere hosts with two CPUs each. To support three hosts with two CPUs each, the Essentials Kits come with six licenses. All these limits are product-enforced. Three Essentials Kits are available:

- VMware vSphere Essentials
- VMware vSphere Essentials Plus

You can't buy these kits on a per-CPU basis; they are bundled solutions for three servers. vSphere Essentials includes one year of subscription; support is optional and available on a per-incident basis. Like other editions, vSphere Essentials Plus requires at least one year of SnS; this must be purchased separately and is not included in the bundle.

The Retail and Branch Offices (RBO) Kits are differentiated from the "normal" Essentials and Essentials Plus Kits only by the licensing guidelines. These kits are licensed per pack of 25 virtual machines. Central management of all the sites via vCenter Server Standard is possible, though vCenter Server Standard must be purchased separately. vCenter Server Essentials is included.

Now that you have an idea of how VMware licenses vSphere, I'll review why an organization might choose to use vSphere and what benefits that organization could see as a result.

Why Choose vSphere?

Much has been said and written about the total cost of ownership (TCO) and return on investment (ROI) for virtualization projects involving VMware virtualization solutions. Rather than rehashing that material here, I'll instead focus, briefly, on why an organization should choose VMware vSphere as their virtualization platform.

Online TCO Calculator

VMware offers a web-based TCO calculator that helps you calculate the TCO and ROI for a virtualization project using VMware virtualization solutions. This calculator is available online at `www.vmware.com/go/calculator`.

You've already read about the various features that VMware vSphere offers. To help you understand how these features can benefit your organization, I'll apply them to the fictional XYZ Corporation. I'll walk you through several scenarios and show how vSphere helps in these scenarios:

Scenario 1 XYZ Corporation's IT team has been asked by senior management to rapidly provision six new servers to support a new business initiative. In the past, this meant ordering hardware, waiting on the hardware to arrive, racking and cabling the equipment once it arrived, installing the operating system and patching it with the latest updates, and then installing the application. The time frame for all these steps ranged anywhere from a few days to a few months and was typically a couple of weeks. Now, with VMware vSphere in place, the IT team can use vCenter Server's templates functionality to build a VM, install the operating system, and apply the latest updates, and then rapidly clone—or copy—this VM to create additional VMs. Now their provisioning time is down to hours, likely even minutes. Chapter 10 discusses this functionality in detail.

Scenario 2 Empowered by the IT team's ability to quickly respond to the needs of this new business initiative, XYZ Corporation is moving ahead with deploying updated versions of a line-of-business application. However, the business leaders are a bit concerned about upgrading the current version. Using the snapshot functionality present in ESXi and vCenter Server, the IT team can take a "point-in-time picture" of the VM so that if something goes wrong during the upgrade, it's a simple rollback to the snapshot for recovery. Chapter 9, "Creating and Managing Virtual Machines," discusses snapshots.

Scenario 3 XYZ Corporation is impressed with the IT team and vSphere's functionality and is now interested in expanding its use of virtualization. To do so, however, a hardware upgrade is needed on the servers currently running ESXi. The business is worried about the downtime that will be necessary to perform the hardware upgrades. The IT team uses vMotion to move VMs off one host at a time, upgrading each host in turn without incurring any downtime to the company's end users. Chapter 12 discusses vMotion in more depth.

Scenario 4 After the great success it has had virtualizing its infrastructure with vSphere, XYZ Corporation now finds itself in need of a new, larger shared storage array. vSphere's support for Fibre Channel, iSCSI, and NFS gives XYZ room to choose the most cost-effective storage solution available, and the IT team uses Storage vMotion to migrate the VMs without any downtime. Chapter 12 discusses Storage vMotion.

These scenarios begin to provide some idea of the benefits that organizations see when virtualizing with an enterprise-class virtualization solution like VMware vSphere.

What Do I Virtualize with VMware vSphere?

Virtualization, by its very nature, means that you are going to take multiple operating systems—such as Microsoft Windows, Linux, Solaris, or Novell NetWare—and run them on a single physical server. While VMware vSphere offers broad support for virtualizing a wide range of operating systems, it would be almost impossible for us to discuss how virtualization impacts all the different versions of all the operating systems that vSphere supports.

Because the majority of organizations that adopt vSphere are primarily virtualizing Microsoft Windows, that operating system will receive the majority of attention when it comes to describing procedures that must occur within a virtualized operating system. You will see coverage of tasks for a virtualized installation of Linux as well, but the majority of the coverage will be for Microsoft Windows.

If you are primarily virtualizing something other than Microsoft Windows, VMware provides more in-depth information on all the operating systems it supports and how vSphere interacts with those operating systems on its website at `www.vmware.com`.

The Bottom Line

Identify the role of each product in the vSphere product suite. The VMware vSphere product suite contains VMware ESXi and vCenter Server. ESXi provides the base virtualization functionality and enables features like Virtual SMP. vCenter Server provides management for ESXi and enables functionality like vMotion, Storage vMotion, vSphere Distributed Resource Scheduler (DRS), vSphere High Availability (HA), and vSphere Fault Tolerance (FT). Storage I/O Control and Network I/O Control provide granular resource controls for VMs. The vStorage APIs for Data Protection (VADP) provide a backup framework that allows for the integration of third-party backup solutions into a vSphere implementation.

Master It Which products are licensed features within the VMware vSphere suite?

Master It Which two features of VMware ESXi and VMware vCenter Server together aim to reduce or eliminate downtime due to unplanned hardware failures?

Master It Name two storage-related features that were introduced in vSphere 5.5.

Recognize the interaction and dependencies between the products in the vSphere suite. VMware ESXi forms the foundation of the vSphere product suite, but some features require the presence of vCenter Server. Features like vMotion, Storage vMotion, vSphere DRS, vSphere HA, vSphere FT, SIOC, and NIOC require ESXi as well as vCenter Server.

Master It Name three features that are supported only when using vCenter Server along with ESXi.

Master It Name two features that are supported without vCenter Server but with a licensed installation of ESXi.

Understand how vSphere differs from other virtualization products. VMware vSphere's hypervisor, ESXi, uses a Type 1 bare-metal hypervisor that handles I/O directly within the hypervisor. This means that a host operating system, like Windows or Linux, is not required in order for ESXi to function. Although other virtualization solutions are listed as "Type 1 bare-metal hypervisors," most other Type 1 hypervisors on the market today require the presence of a "parent partition" or "dom0" through which all VM I/O must travel.

Master It One of the administrators on your team asked whether he should install Windows Server on the new servers you purchased for ESXi. What should you tell him, and why?