EXAM OBJECTIVES

Professional ▶

Exam 70-210

- Configure and manage file systems.
  - Convert from one file system to another file system.
  - Configure file systems by using NTFS, FAT32, or FAT.
- Implement, manage, and troubleshoot disk devices.
  - Monitor and configure disks.
  - Monitor, configure, and troubleshoot volumes.

Server ▶

Exam 70-215

- Monitor, configure, and troubleshoot disks and volumes.
- Recover from disk failures.

CHAPTER

6 Working with File Systems and Disks

In this chapter I'll introduce you to the file systems supported by Windows 2000, including FAT, FAT32, and NTFS. I'll also cover the basics of configuring a Windows 2000 computer's hard disks and volumes. In this section I'll explain about various types of disks, partitions, and volumes, and then discuss how to use Disk Management to perform numerous disk management tasks on a Windows 2000 computer. I'll provide you with detailed steps to create several volume types, including simple volumes, spanned volumes, striped volumes, mirrored volumes, and RAID-5 volumes. Next, I'll explain how to use Disk Defragmenter to analyze and defragment volumes, and how to use Logical Drives to view logical drive properties and change a logical drive's label. Then I'll present some troubleshooting tips, and finally, I'll explain how to recover from disk failure when using a simple, spanned, striped, mirrored, or RAID-5 volume.

Chapter Pre-Test

1. Unless you require your computer to dual boot between Windows 2000 and another operating system, what is usually the best file system to use on a Windows 2000 computer?
2. Which is easier: converting from FAT (or FAT32) to NTFS, or converting from NTFS to FAT (or FAT32)?
3. What is the difference between a basic disk and a dynamic disk?
4. What are the five different types of volumes that Windows 2000 supports?
5. What is the name of the Windows 2000 tool used to perform most disk administration tasks?

Working with File Systems

Before you attempt to configure a computer's disks, it's important that you have a clear understanding of the different file systems that Windows 2000 supports. Windows 2000 supports five file systems: the file allocation table (FAT) file system, the FAT32 file system, the Windows NT file system (NTFS), the Compact Disc File System (CDFS), and the Universal Disk Format (UDF). Table 6-1 shows which file systems are supported by various operating systems.

TABLE 6-1 File System Support by Operating System

Operating System	File Systems Supported
Windows 2000	FAT, FAT32, NTFS, CDFS, UDF
Windows NT 4.0	FAT, NTFS, CDFS, UDF
Windows NT 3.51 (and earlier versions)	FAT, NTFS, CDFS, HPFS
Windows 98	FAT, FAT32, CDFS, UDF
Windows 95	FAT, (FAT32 on OSR2 only), CDFS, UDF
Windows 3.*x* and 3.1*x*	FAT, CDFS
OS/2 1.*x*	FAT, CDFS, HPFS
MS-DOS	FAT, CDFS

In the following sections I'll describe each of the file systems supported by Windows 2000 in detail. I'll also discuss the capabilities and limitations of each of these file systems.

FAT

The *file allocation table (FAT) file system* used by Windows 2000 is a modified version of the FAT file system used by MS-DOS. FAT (sometimes called FAT16) is the only hard disk file system supported by Windows 95 (versions prior to OSR2), Windows 3.*x*, Windows 3.1*x*, and MS-DOS. So, if you want to configure a Windows 2000 computer to dual boot between Windows 2000 and Windows 95 (versions prior to OSR2), Windows 3.1*x*, or MS-DOS, your computer's first partition on the first hard disk must use the FAT file system.

If you're not sure whether you have an OSR2 version of Windows 95, there's an easy way to find out. From the Windows 95 desktop, select Start ➪ Settings ➪ Control Panel. Then double-click the Systems application, and examine the General tab, which lists specific information about the system installed on your computer. If your system version is 4.00.950 or 4.00.950 a, then you have a version of Windows 95 that was released prior to OSR2.

Now I'll give a brief overview of the characteristics and features of the FAT file system, including security, naming conventions, speed of access to files, and volume size.

TIP

A *volume* is an area of disk space (often called a *partition*) on one or more hard disks that has been formatted with a file system.

Security

The FAT file system does not support file and folder security in Windows 2000. Because file and folder security is not supported on a FAT volume, any user who is logged on locally to a computer has full control of all of the files and folders located in the FAT volume(s) on that computer. This applies only to local access.

However, you can use share permissions to control users' access to shared folders over the network. Share permissions affect only the access of files and folders over the network, not when someone is logged on locally. So, if you need local file and folder security, you should use the NTFS file system instead of the FAT file system.

Naming Conventions

The FAT file system, as used by Windows 2000, supports the use of long filenames. Filenames can be up to 255 characters in length.

TIP

Windows 2000 supports extremely long filenames, but many applications don't. Consider the length of filename supported by the applications you use when assigning filenames.

Filenames can contain any character except `\ / : * ? " < > |` and may begin with any permitted character. Filenames can contain spaces and multiple periods, and the characters after the last period are considered the filename extension.

The FAT file system preserves uppercase and lowercase in filenames, but filenames are not case sensitive. Because of this, I can request the file `ALAN.DOC` by typing **Alan.doc**, **ALAN.DOC**, or **alan.doc**, and Windows 2000 always retrieves `ALAN.DOC`.

Speed of Access to Files

Access speed to files in a FAT volume is dependent on many factors, including volume size, number of files in a folder, and fragmentation.

Windows 2000 accesses files in FAT volumes smaller than 512MB faster than it accesses files in similar-sized FAT32 and NTFS volumes.

If the volume size is larger than 512MB, however, or when there is a large number of files in a folder, Windows 2000 accesses files in FAT32 and NTFS volumes much faster than it accesses files in a FAT volume of similar size.

Windows 2000 usually accesses files in a highly fragmented FAT volume more slowly than it accesses files in an NTFS volume of similar size.

Volume Size

The maximum size of a FAT volume on all operating systems except Windows 2000 and Windows NT is 2GB. Both Windows 2000 and Windows NT support FAT volumes up to 4GB. This is possible because Windows 2000 and Windows NT support a larger cluster size (up to 64K) than do other operating systems.

CAUTION

I recommend against dual booting between Windows 2000 (or Windows NT) and another operating system when using a FAT volume larger than 2GB. It's possible to lose some or all of the files on your FAT volume if you dual boot on a computer with this configuration.

The maximum size of a file in a FAT volume is 4GB. The FAT file system, as used by Windows 2000, does not support file compression.

TIP

Windows 2000 does not support the file compression utilities contained in Windows 98, Windows 95, and MS-DOS. If you compress files by using these utilities, Windows 2000 won't be able to access these files.

FAT32

The *FAT32 file system* used by Windows 2000 is the same as the FAT32 file system that was released with Windows 95 OSR2 and Windows 98. The FAT32 file system is only supported by Windows 2000, Windows 98, and Windows 95 OSR2.

If you want to dual boot between Windows 2000 and Windows 98 (or Windows 95 OSR2), you can use either the FAT32 or FAT file system on your computer's first volume.

In the sections that follow I'll cover the specific characteristics of the FAT 32 file system, including security, naming conventions, speed of access to files, and volume size.

Security

Like the FAT file system, the FAT32 file system does not support file and folder security in Windows 2000. Because file and folder security is not supported on a FAT32 volume, any user who is logged on locally to a computer has full control of all of the files and folders located in the FAT32 volume(s) on that computer. This applies only to local access.

However, you can use share permissions to control users' access to shared folders over the network. Share permissions affect only the access of files and folders over the network, not when someone is logged on locally. So, if you need local file and folder security, you should use the NTFS file system instead of the FAT32 or FAT file systems.

Naming Conventions

The naming conventions supported by the FAT32 file system are identical to those supported by the FAT file system:

- Filenames can be up to 255 characters in length.
- Filenames can contain any character except `\ / : * ? " < > |` and may begin with any permitted character. Filenames can contain spaces and multiple periods.
- The FAT32 file system preserves uppercase and lowercase in filenames, but filenames are not case sensitive.

Speed of Access to Files

Access speed to files in a FAT32 volume is dependent primarily on volume size and fragmentation.

Windows 2000 accesses files in FAT32 volumes larger than 512MB faster than it accesses files in similar-sized FAT volumes, but slower than it accesses files in similar-sized NTFS volumes.

Windows 2000 usually accesses files in a highly fragmented FAT32 volume more slowly than it accesses files in an NTFS volume of similar size.

Volume Size

Although the maximum size of a FAT32 volume on Windows 98 and Windows 95 OSR2 is 2 terabytes (TB), the disk management utilities contained in Windows 2000 only enable you to create and format a FAT32 volume up to 32GB. Windows 2000 does support FAT32 volumes larger than 32GB that are created by other operating systems.

The maximum size of a file in a FAT32 volume is 32GB. Like the FAT file system, FAT32 does not support file compression.

NTFS

The *Windows NT file system (NTFS)* is the most powerful file system supported by Windows 2000. Only Windows 2000 and Windows NT support NTFS — no other Microsoft operating systems currently support this file system.

Windows 2000 NTFS is a newer version than Windows NT NTFS, and supports several features not supported by Windows NT NTFS. Because of this, if you want to dual boot between Windows 2000 and Windows NT, you must have Windows NT 4.0 with Service Pack 4 or later installed.

When it comes to security, naming conventions, speed of access to files, and volume size, NTFS in Windows 2000 has its own unique characteristics. Additionally, NTFS has some features not supported by the FAT or FAT32 file systems.

Security

NTFS provides file and folder security for both local and remote users on a network. NTFS is the only file system discussed here that permits the assigning of permissions to individual files and folders.

So how does NTFS security actually work? NTFS security controls access to files on an NTFS volume by utilizing the user's security identifier (SID) to determine which files that user can access. Each file and folder on an NTFS volume has an access control list (ACL) associated with it. The *ACL* is a list that contains user and group SIDs, with the associated privileges of each user and group.

CROSS-REFERENCE

NTFS and share security are covered in depth in Chapter 11.

NTFS supports the *Encrypting File System* (EFS). EFS enables you to store files on an NTFS partition in an encrypted format so that even if an unauthorized user removes a hard drive from your computer, that user will be unable to access the sensitive data contained in the encrypted file.

In addition to the security provided by NTFS, remember that because Windows 2000 requires a user to log on before accessing files, Windows 2000's security is greater than operating systems that don't require the user to log on.

Naming Conventions

Like the FAT and FAT32 file systems, NTFS supports the use of long filenames. Filenames can be up to 255 characters in length.

Filenames can contain any character except `\ / : * ? " < > |` and may begin with any permitted character. Filenames can contain spaces and multiple periods, and the characters after the last period are considered the filename extension.

NTFS preserves uppercase and lowercase in filenames. Filenames are not case sensitive (except when used by a POSIX application). For example, a Win32 application does not distinguish between `Money.DOC`, `MONEY.DOC`, and `money.doc` — it treats all three names as though they were the same file.

The POSIX subsystem, however, is case sensitive with respect to filenames, because it does not translate a request for a file into all uppercase letters as the Win32 and other subsystems do. A POSIX application treats the filenames in the previous paragraph as though they were three separate files: `Money.DOC`, `MONEY.DOC`, and `money.doc`. You must use a POSIX application if you want to access these three different files — if you attempt

to access `Money.DOC` with a Win32 application (no matter how you type the file name), you will always retrieve the `MONEY.DOC` file because the Win32 Subsystem translates file requests into all uppercase letters.

Speed of Access to Files

NTFS usually provides faster access than the FAT or FAT32 file systems to files stored on a large volume that contains many files. NTFS is able to access files in this situation faster than the FAT or FAT32 file systems because NTFS uses an enhanced binary tree to locate files. A binary tree search is a faster mechanism for searching through a large number of filenames than the sequential read mechanism used on FAT and FAT32 volumes.

Volume Size

The maximum theoretical size of an NTFS volume is 16 exabytes (an *exabyte* is one billion billion bytes, or a giga-gigabyte). However, when you actually implement NTFS on current standard industry hardware, there is a functional limitation of 2TB.

The maximum size of a file in an NTFS volume is limited only by the amount of free space in the NTFS volume.

Additional Features Not Supported by FAT or FAT32

NTFS has several other unique attributes and features that are not found in, nor supported by, the FAT or FAT32 file systems.

- NTFS supports a compression attribute for each file. You can choose which files to compress and which ones to leave uncompressed. The compression algorithm NTFS uses is similar to the one used by Drivespace in MS-DOS. Using compression provides an approximately 40 to 50 percent increase in hard disk space.

TIP

Compression can cause some performance degradation on volumes with substantial write activity. Additionally, accessing uncompressed files is faster than accessing compressed files.

- NTFS is a highly reliable, recoverable file system. It is not necessary to periodically run `Chkdsk.exe` on an NTFS volume.

- Using NTFS greatly reduces fragmentation on volumes. However, files can still become fragmented when their size is increased. Windows 2000 (unlike Windows NT) includes a defragmentation utility which can be used to defragment FAT, FAT32, and NTFS volumes.
- NTFS maintains a recycle bin for each user.
- NTFS enables you to mount a volume on a folder in a different volume. The term *mounting a volume* refers to a disk management technique sometimes used to access space on more than one hard disk (or volume) but still retain and use a single drive letter. The result of this feature is that a folder's contents are physically stored on a different hard disk (or volume), but this folder and its contents appear to users to be located in the current volume. This feature produces results similar to those produced by executing the `mount` command on a UNIX computer.
- NTFS supports the Encrypting File System (EFS).
- NTFS supports disk quotas. *Disk quotas* is a volume management tool that is enabled on a volume-by-volume basis. Once enabled, disk quotas automatically track disk space usage on a user-by-user basis, and prevent individual users from exceeding the disk space limitations that they have been assigned by administrators.

The first four features in the preceding list are supported by both Windows 2000 NTFS and Windows NT NTFS. The last three features are new features that are supported only by Windows 2000 NTFS.

A couple of final tidbits about NTFS:

- You can't use NTFS to format floppy disks.
- You can change media in a removable media device (such as a Zip drive) that has been formatted with NTFS without rebooting the computer. (This feature was not supported by Windows NT.)

Which File System Should I Use?

Because of its speed, security, and recoverability, I recommend the use of NTFS on all volumes except for floppy disks, and volumes that are used to dual boot between Windows 2000 and another operating system.

If you require dual boot, and the other operating system supports FAT32, then I recommend FAT32 over FAT because of FAT32's speed and support of larger volume sizes.

CDFS

The *Compact Disc File System (CDFS)* supports access to compact discs. It is not used on a computer's hard disks — this file system is used only on CD-ROM devices that read and/or write compact discs. Because of the prevalence of CD-ROM devices, CDFS is supported by most operating systems.

UDF

The *Universal Disk Format (UDF)* is a file system used to access read-only digital video discs (DVDs). Like CDFS, this file system is not used on a computer's hard disks — this file system is used only on DVD-ROM devices.

HPFS

Windows 2000 does not support the high performance file system (HPFS), although some of the earliest versions of Windows NT did. If you want to upgrade to Windows 2000 from an early version of Windows NT that used HPFS, you must convert your HPFS volume to NTFS before performing the upgrade.

Converting from FAT or FAT32 to NTFS

In Windows 2000 you can format a new volume with either FAT, FAT32, or NTFS. But what do you do when you want to change the file system on an existing volume? You can change an existing FAT or FAT32 volume into an NTFS volume by using `Convert.exe`. This is a fairly simple procedure. When you use `Convert.exe` all data on the existing volume is retained..

However, it is a one-way process — there is no way to convert an NTFS volume into a FAT or FAT32 volume without first backing up, reformatting the volume, and restoring the data.

To convert a FAT or FAT32 volume into an NTFS volume, use the `Convert.exe` command at a command prompt. To start a command prompt, select Start ➪ Programs ➪ Accessories ➪ Command Prompt. The syntax for the `Convert.exe` command is:

```
CONVERT volume /FS:NTFS [/V]
```

The following is an explanation of this syntax:

- *`Volume`* This specifies the drive letter (followed by a colon) or mount point to convert to NTFS.
- `/FS:NTFS` This indicates that the file system should be converted to NTFS. This is an outdated switch, because NTFS is the only file system that you can use `Convert.exe` to switch to in Windows 2000; but its use, in terms of command syntax, is still required.
- `/V` This optional switch specifies that `Convert.exe` will run in *verbose mode*. Running a command in verbose mode will display the maximum amount of information and detail to the user.

Let me illustrate the use of this command with a couple of examples:

1. To convert drive `D:` from FAT to NTFS, use the following command:

   ```
   CONVERT D: /FS:NTFS
   ```

2. To convert a mount point named `C:\Data` from FAT32 to NTFS, using the optional verbose mode, use the following command:

   ```
   CONVERT C:\Data /FS:NTFS /V
   ```

TIP

Command syntax typed at the command prompt is not case sensitive—meaning that you can type the command in either uppercase or lowercase. The exceptions to this rule are POSIX commands typed at the command prompt. All POSIX commands are case sensitive.

To successfully use the `Convert.exe` command, `Convert.exe` must be the *only* application that accesses the drive or mount point you want to change during the conversion process. If Windows Explorer accesses the drive or mount point you are trying to convert, if you are trying to convert the boot partition, or if your active command prompt has the drive you are trying to convert as its current drive, Windows 2000 will display an error message stating that `Convert.exe` cannot gain exclusive access to the

drive or mount point, and asks if you want to schedule it to be converted the next time the system restarts.

If you try to execute the `Convert.exe` command, but can't gain exclusive access to a drive or mount point, type **Y** when asked if you want to schedule it to be converted the next time the system restarts. Windows 2000 will convert the file system when you restart your computer.

Understanding Disks and Volumes

This section is all about working with disks on a Windows 2000 computer. I'll introduce Disk Management, the Windows 2000 tool used to create, format, and manage volumes, and explain how to perform numerous disk management tasks. I'll also introduce Disk Defragmenter and Logical Drives, two additional tools used on disks and volumes. Finally, I'll cover some disk and volume troubleshooting topics, and also talk about recovering from a single or multiple disk failure on your system.

But before I get to the nitty gritty of how to perform specific disk management tasks, there's a lot of Windows 2000 disk terminology I need to cover. Once you master this terminology, using Disk Management will be much easier.

So, allow me to introduce you to the Windows 2000 disk types, partition types, and volume types.

Disk Types

Windows 2000 uses two primary terms to refer to the hard disks in a computer: *basic disks* and *dynamic disks*. I'll define and discuss each of these terms in the next sections.

Windows 2000 also supports removable media devices, such as Zip drives and tape drives. I'll also briefly examine these types of storage devices.

Basic Disks

Basic disks is a fancy Windows 2000 term that refers to hard disks that use industry-standard partitioning and formatting, and contain primary and/or extended partitions. Prior to Windows 2000, all Microsoft operating systems used basic disks — there wasn't any other kind.

CARING FOR YOUR HARD DISKS

Let's face it—hard disks can be a large investment, and like the other assets your company owns, they need to be secured and properly maintained. And I'm sure I don't have to tell you that even more important than the disks themselves is the data they contain.

With these thoughts in mind, here are a few personal recommendations to help ensure that your hard disks don't fail prematurely:

Treat hard disks carefully. I've been told that baggage handlers for some airline carriers interpret the word "Fragile" to mean that the box or bag shouldn't be dropped from higher than ten feet. But I'm really talking about kinder and gentler treatment than that when it comes to hard disks.

Observe proper techniques when installing and removing hard disks from the computer. Ensure that you're grounded and working in a static-free environment. I like to use static mats and wrist straps to provide the necessary static protection.

Protect hard disks from excessive heat. In my experience, a hard disk's number one enemy is excessive heat. Many times small companies put their servers in an unventilated closet, or don't have adequate cooling fans for the number of disks installed in a computer. These oversights often lead to premature disk failure.

I recommend that servers be placed in ventilated, climate-controlled rooms. Ensure that the climate-control for this room is not turned off during nonbusiness hours, such as over a long holiday weekend. I once lost hard disks on multiple servers because the building my company was located in decided to save money by turning off the air conditioning over a three-day weekend. Needless to say, I wasn't a very happy camper on Tuesday morning. Shortly thereafter my company installed a new air conditioning unit just for our computer room.

Windows 2000 partitions and formats the first hard disk in your computer (the disk that Windows 2000 is installed on) as a basic disk during the installation process. If you have multiple hard disks in your computer, Windows 2000 prompts you to convert these additional disks into dynamic disks the first time you run Disk Management.

There are some limitations to using basic disks. A basic disk can contain a maximum of four partitions: it can contain up to four primary partitions, but only one extended partition.

If your Windows 2000 computer is configured to dual boot between Windows 2000 and any other operating system, you should configure all hard disks that will be accessed by the other operating system as basic disks,

because no other operating system supports dynamic disks. Only Windows 2000 can read dynamic disks.

Disk Management is the Windows 2000 tool that is used to configure basic disks. Detailed steps to perform disk configuration tasks are included later in this chapter in the "Using Disk Management" section.

Dynamic Disks

Dynamic disks is a Windows 2000 term that refers to hard disks that contain Windows 2000 dynamic volumes. *Dynamic volumes* are volumes that do not use primary partitions, extended partitions, or logical drives. These dynamic volumes are manually created by using Disk Management.

Dynamic disks overcome the partition limitations inherent in basic disks. Dynamic disks can support an unlimited number of volumes, versus the four-partition maximum of basic disks.

In Windows 2000, you must use dynamic disks to create any volume that extends across more than one hard disk, such as spanned volumes, striped volumes, mirrored volumes, and RAID-5 volumes. (I'll define and discuss each of these different kinds of volumes later in this chapter in the "Volume Types" section.) Windows 2000 will support the Windows NT versions of these types of volumes on basic disks if they were created by Windows NT, but in Windows 2000 you can only create these volume types on dynamic disks.

Because dynamic disks do not contain industry-standard primary or extended partitions, no other operating system supports or can access dynamic disks. Only Windows 2000 supports dynamic disks. For this reason, if your Windows 2000 computer is configured to dual boot between Windows 2000 and any other operating system, you should configure all hard disks that will be accessed by the other operating system as basic disks, not dynamic disks.

Windows 2000 does not currently support dynamic disks on laptop computers, but you can create and configure them on some. Microsoft intended that the option to convert to a dynamic disk would be grayed out on laptop computers.

Removable Media

Windows 2000 supports various removable media devices. Removable devices include CD-ROM drives, tape drives, Zip drives, DVD drives, and so on.

As an adjunct to supporting removable media devices, Windows 2000 includes the Remote Storage service. This service, when installed and configured on a Windows 2000 computer, enables you to migrate infrequently accessed data from your computer's hard disks to removable media.

Windows 2000 permits you to change media in a removable media device (such as a Zip drive) that has been formatted with NTFS without rebooting the computer. This feature was not supported by Windows NT.

Partition Types

Windows 2000 supports two types of partitions on basic disks: primary and extended. Both types of partitions can coexist on the same hard disk. A basic disk can have a maximum of four partitions — it can have more than one primary partition, but it can have only one extended partition.

TIP

In Windows 2000, primary and extended partitions can only be created on basic disks – they cannot be created on dynamic disks.

The next sections discuss primary and extended partitions in detail.

Primary Partitions

A *primary partition* is a partition on a basic disk that can be configured as the active partition. The *active partition* is the partition that contains the files necessary to load the operating system. When the computer boots, it attempts to load the operating system from the active primary partition on the first hard disk in the computer. Any primary partition on the first hard disk in the computer can be designated as the active partition. In Windows 2000 terminology, the active partition is also called the *system partition*.

A primary partition can occupy all of the space on a disk, or any portion of it. A basic disk can have up to four primary partitions. A primary partition can be formatted as a single logical drive (but not as multiple logical drives).

For detailed instructions on creating a primary partition, see the "Creating and Formatting Partitions" section later in this chapter.

Extended Partitions

An *extended partition* is a partition on a basic disk that can be subdivided into one or more logical drives. A *logical drive* is a volume that is created

from some or all of the space in an extended partition, and that is assigned a drive letter.

Logical drives can be formatted with FAT, FAT32, or NTFS. You can have one logical drive formatted with FAT or FAT32, and another logical drive in the same extended partition formatted with NTFS.

There can be only one extended partition on a disk. An extended partition can't be marked active.

For detailed instructions on creating an extended partition, see the "Creating and Formatting Partitions" section later in this chapter.

Volume Types

A *volume* is an area of disk space (often called a partition) on one or more hard disks that has been formatted with a file system. Windows 2000 supports several different volume types, including:

- Simple volumes
- Spanned volumes
- Striped volumes
- Mirrored volumes
- RAID-5 volumes

The volume types listed here can only be created on dynamic disks. As I stated earlier, Windows 2000 will support the Windows NT versions of these types of volumes on basic disks if they were created by Windows NT, but in Windows 2000 you can only create these volume types on dynamic disks.

I'll define and discuss each of these volume types in the following sections. Then I'll compare the fault tolerance, cost, and access speed of these five volume types. Finally, I'll provide detailed steps for creating each of these volume types later in this chapter in the "Using Disk Management" section.

Simple Volumes

A *simple volume* is volume that consists of formatted disk space on a single hard disk. You can create simple volumes only on dynamic disks.

TIP

If you're used to thinking in terms of primary and extended partitions, it might be helpful for you to picture a simple volume as if it were a logical drive in an extended partition.

A simple volume can be formatted with FAT, FAT32, or NTFS.

A simple volume provides no fault tolerance. This means that if the disk that contains the simple volume fails, all data in the simple volume is lost unless the data is backed up.

There is no additional cost associated with using simple volumes, because simple volumes use the minimum amount of hardware required to store data. This volume type is the standard against which other volume types are compared in terms of cost, because it is the basic unit of data storage in use today.

There is no speed gain or speed loss associated with a simple volume, because this volume type is the benchmark type for speed of access.

Simple volumes are supported by all of the Windows 2000 operating systems: Windows 2000 Professional, Windows 2000 Server, and Windows 2000 Advanced Server.

For detailed instructions on creating a simple volume, see the "Creating a Simple Volume" section later in this chapter.

Spanned Volumes

A *spanned volume* consists of formatted disk space on more than one hard disk that is treated as a single volume. A spanned volume can be formatted with FAT, FAT32, or NTFS. The areas of disk space that make up a spanned volume do not need to be of identical size. You can create spanned volumes only on dynamic disks.

The primary purpose and use of a spanned volume is to access disk space on more than one hard disk by using a single drive letter. A spanned volume is sometimes used when a volume becomes full and you want to enlarge its capacity.

The Windows NT equivalent of a spanned volume is a volume set. However, volume sets are created on basic disks, whereas spanned volumes are created on dynamic disks. If you upgrade a Windows NT computer to Windows 2000, Windows 2000 will support any existing volume sets.

Spanned volumes are said to be *created* when areas of free space only (not existing volumes) are combined into a spanned volume. Spanned volumes are said to be *extended* when an existing NTFS simple or spanned volume

is enlarged. A simple volume can be extended into a spanned volume by adding disk space from other disks to the simple volume. Only simple or spanned volumes on dynamic disks that are formatted with NTFS can be extended.

TIP

The system partition can't be extended into a spanned volume, even if you have upgraded the disk that contains the system partition to a dynamic disk. In addition, the partition on which Windows 2000 is installed (also called the boot partition) can't be extended into a spanned volume, even if you have upgraded this disk to a dynamic disk.

Spanned volumes do not perform any fault tolerance function. If one disk in a spanned volume fails, all data on the spanned volume may be lost (unless the data is backed up), because Windows 2000 can't access data unless all of the disks that make up the spanned volume are functional.

Spanned volumes have no additional cost associated with them because they use the same amount of disk space in which that data would normally be stored.

There is no speed gain or speed loss associated with a spanned volume.

Spanned volumes are supported by all of the Windows 2000 operating systems.

For detailed instructions on creating a spanned volume, see the "Creating a Spanned Volume" section later in this chapter.

Striped Volumes

A *striped volume* consists of identical-sized areas of formatted disk space located on two or more dynamic disks. In a striped volume, data is stored, a block at a time, evenly and sequentially, among all of the disks in the striped volume. Striped volumes are sometimes referred to as disk striping. *Disk striping* refers to the process wherein a file is written, or striped, one block at a time; first to one disk, then to the next disk, and then to the next disk, and so on, until all of the data in the file has been evenly distributed among all of the disks in the striped volume.

A striped volume is accessed by using a single drive letter, as if all of its disks were combined into a single drive. A striped volume can be formatted with FAT, FAT32, or NTFS.

The Windows NT equivalent of a striped volume is a stripe set. However, stripe sets are created on basic disks, whereas striped volumes are

created on dynamic disks. If you upgrade a Windows NT computer to Windows 2000, Windows 2000 will support any existing stripe sets.

Striped volumes do not provide any fault tolerance. If one disk in a striped volume fails, all data on the striped volume is lost unless the data is backed up.

Striped volumes have no additional cost associated with them because they use the same amount of disk space in which that data would normally be stored.

Striped volumes provide faster disk access than any other Windows 2000 volume type, because the striped volume stores a single file across multiple disks. The various pieces of the file can be read nearly simultaneously from the multiple disks, thus increasing performance. Access speed is the primary advantage and common reason for using a striped volume. The tradeoff or downside to using a striped volume is that the potential disk failure rate is increased because there are more possible points of failure when a file is accessed across several disks.

A striped volume (or disk striping) is also known as RAID level 0. RAID stands for Redundant Array of Inexpensive Disks.

Striped volumes are supported by all of the Windows 2000 operating systems.

For detailed instructions on creating a striped volume, see the "Creating a Striped Volume" section later in this chapter.

Mirrored Volumes

A *mirrored volume* consists of a simple volume that is exactly duplicated, in its entirety, onto a second dynamic disk. A mirrored volume can be formatted with FAT, FAT32, or NTFS. Any simple volume can be mirrored. A mirrored volume is accessed by using a single drive letter.

The Windows NT equivalent of a mirrored volume is a mirror set. However, mirror sets are created on basic disks, whereas mirrored volumes are created on dynamic disks. If you upgrade a Windows NT computer to Windows 2000, Windows 2000 will support any existing mirror sets.

A mirrored volume provides the highest level of fault tolerance available in Windows 2000. Mirrored volumes are used in situations where the integrity of data is more important than minimizing costs. For example, a financial institution might decide that using mirrored volumes is cost-effective for their organization because the extra safety provided by mirrored volumes outweighs the cost of additional disk space.

A mirrored volume enables an organization to continue accessing its data in the event of a single hard disk failure. I should point out, however, that a mirrored volume does not provide fault tolerance in the event of multiple disk failure, and it does not guarantee continued operations if a server goes down.

Mirrored volumes are the most expensive volume type discussed here, because twice the normal amount of hard disks are required to store the data.

There is no speed gain or speed loss associated with a mirrored volume.

Mirrored volumes, sometimes called disk mirroring, is also known as RAID level 1.

Mirrored volumes are supported only by Windows 2000 Server and Windows 2000 Advanced Server. Windows 2000 Professional does not support mirrored volumes.

For detailed instructions on creating a mirrored volume, see the "Creating a Mirrored Volume" section later in this chapter.

RAID-5 Volumes

A *RAID-5 volume* consists of identical-sized areas of formatted disk space located on three or more dynamic disks. In a RAID-5 volume, data is stored, a block at a time, evenly and sequentially, among all of the disks in the volume. In addition to data, parity information is also written across all of the disks in the RAID-5 volume. This parity information enables RAID-5 volumes to provide the fault tolerance that striped volumes cannot.

IN THE REAL WORLD

RAID-5, in my experience, is the most commonly used method of fault tolerance. It is less costly than mirrored volumes (because data is not replicated on another disk), is faster than mirrored volumes, and provides a modest level of data safety.

A RAID-5 volume is accessed by using a single drive letter, as if all of its disks were combined into a single drive. A RAID-5 volume can be formatted with FAT, FAT32, or NTFS.

The Windows NT equivalent of a RAID-5 volume is a stripe set with parity. However, stripe sets with parity are created on basic disks, whereas RAID-5 volumes are created on dynamic disks. If you upgrade a Windows NT computer to Windows 2000, Windows 2000 will support any existing stripe sets with parity.

RAID-5 volumes provide a medium level of fault tolerance. If a single disk in a RAID-5 volume fails, the parity information contained on the other disks in the volume is used to regenerate the data from the failed disk. If more than one disk in a RAID-5 volume fails, you cannot recover your data unless the data is backed up.

RAID-5 volumes have a higher cost than simple, spanned, or striped volumes because the equivalent of one of the disks in the volume is used for parity information. However, RAID-5 volumes are less costly than mirrored volumes.

A RAID-5 volume provides the same read performance as a striped volume, but its write performance is a little slower because of the processor time required to generate the parity information.

RAID-5 volumes are supported only by Windows 2000 Server and Windows 2000 Advanced Server. Windows 2000 Professional does not support RAID-5 volumes.

For detailed instructions on creating a RAID-5 volume, see the "Creating a RAID-5 Volume" section later in this chapter.

Comparison of Volume Types

Up to this point, you've had a chance to examine five different volume types: simple volumes, spanned volumes, striped volumes, mirrored volumes, and RAID-5 volumes.

Table 6-2 compares the fault tolerance, cost, and access speed provided by these five different volume types. Note that the most expensive volume type — a mirrored volume — also provides the highest level of fault tolerance of the volume types listed. As with most things in life, you get what you pay for.

TABLE 6-2 Comparison of Volume Types

Volume Type	Fault Tolerance	Cost	Access Speed
Simple volume	None	Low	Normal
Spanned volume	None	Low	Normal
Striped volume	None	Low	Fastest
Mirrored volume	High	High	Normal
RAID-5 volume	Medium	Medium	Fast

Using Disk Management

Windows 2000 includes a powerful tool to manage disks — it's called Disk Management. *Disk Management* is a graphical tool that is a snap-in to the *Microsoft Management Console* (MMC).

The MMC is a Windows 2000 feature that hosts administrative tools you can use to perform administrative tasks on your Windows 2000 computer and network. The tools contained in the MMC are referred to as *snap-ins*.

You can use Disk Management to:

- Create and format partitions
- Upgrade a disk from basic to dynamic
- Revert from a dynamic disk to a basic disk
- Create and format simple, spanned, striped, mirrored, and RAID-5 volumes
- Delete simple, spanned, striped, mirrored, and RAID-5 volumes
- Troubleshoot disk configuration problems
- Recover from single hard disk failures in mirrored and RAID-5 volumes

Disk Management replaces the Disk Administrator tool that was included in Windows NT 4.0.

You must be a member of the Administrators group on the computer that contains the disks you want to manage in order to use Disk Management.

Disk Management can be used in two capacities:

- Disk Management can be used at the local computer to manage the local computer.
- Disk Management can also be used at one computer to remotely manage disks on another computer.

Two of the most common ways to start Disk Management are described in the steps that follow.

STEP BY STEP

STARTING DISK MANAGEMENT—METHOD 1

1. From the desktop, Select Start ➪ Programs ➪ Administrative Tools ➪ Computer Management. This starts the Microsoft Management Console (MMC).
2. If you want to use Disk Management to manage the local computer, skip to Step 3 now.

   If you want to use Disk Management to manage a remote computer, in the left pane of the Computer Management dialog box, right-click Computer Management (Local), and select "Connect to another computer" from the menu that appears. In the Select Computer dialog box, either click the computer you want to manage in the list box, or type in the name of the computer you want to manage in the Name text box. Click OK.
3. Click the + next to Storage in the left pane in the Computer Management dialog box.
4. Click Disk Management.

   Or, you can use the following shortcut method to start Disk Management:

STARTING DISK MANAGEMENT—METHOD 2

1. From the desktop, right-click My Computer. Select Manage from the menu that appears.
2. If you want to use Disk Management to manage the local computer, skip to Step 3 now.

   If you want to use Disk Management to manage a remote computer, in the left pane of the Computer Management dialog box, right-click Computer Management (Local), and select "Connect to another computer" from the menu that appears. In the Select Computer dialog box, either click the computer you want to manage in the list box, or type in the name of the computer you want to manage in the Name text box. Click OK.
3. In the left pane of the Computer Management dialog box, click Disk Management. (If Storage is not already expanded so that Disk Management appears in the list, click the + next to Storage.)

Figure 6-1 shows the Disk Management tool within Computer Management. Disk Management is one of the many tools available in Computer Management. Notice that the upper pane lists information on each of the volumes in the computer. In this pane you can view the volume name and drive letter; its volume type and layout; the file system

used; the status of the volume; the capacity, free space, and percent of the volume's capacity that is free space; whether or not the volume provides fault tolerance; and the percent of disk space overhead required by Windows 2000 to manage the volume. You might have to scroll to the right to view all of this information.

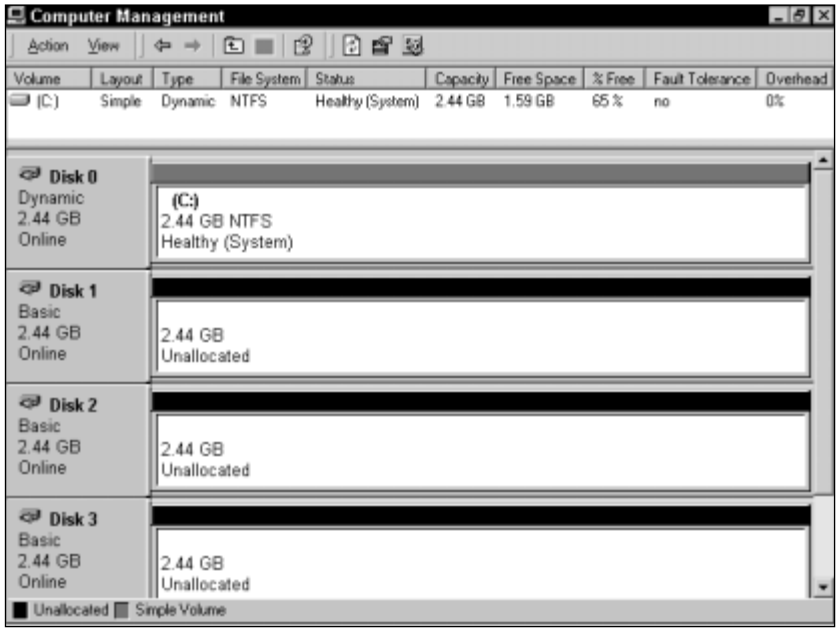

FIGURE 6-1 Disk Management

Also notice in Figure 6-1 that the lower pane of Disk Management graphically illustrates each of the disks in the computer. For each disk in the computer, the disk number, type of disk (basic or dynamic), size of the disk, and whether the disk is Online or Offline is displayed. Disk Management also displays, in a bar graph fashion, each volume or partition on each disk along with pertinent information about each volume.

You can easily customize the appearance of Disk Management by using the options in the View menu. In the top pane, you can choose to display a disk list, a volume list, or a graphical view of the disks in the computer. In the bottom pane, you can choose to display a disk list, a volume list, a graphical view of the disks in the computer, or to hide the bottom pane entirely. In addition, you can move the bar that separates the top and bottom panes by clicking and dragging it. You can also configure appearance and scaling settings and customize additional MMC and snap-in view options in the View menu.

I've always wished that some book or course would have given me more precise information and detailed instructions on working with disks. It's for this reason that I include the instructions to perform most disk management tasks in the rest of this chapter in a step-by-step format. I'll explain how you can use Disk Management to create and format partitions; upgrade a disk from basic to dynamic; revert from a dynamic disk to a basic disk; and create and format simple, spanned, striped, mirrored, and RAID-5 volumes. I'll also include lots of screen shots to help solidify your understanding of disk management.

It's a good practice to use Disk Management only during times when no one else is accessing the server. Some of Disk Management's functions take a significant amount of time to complete. This means that service to clients during these times can be seriously slowed or interrupted.

CAUTION

Because using Disk Management can disrupt service to clients, I recommend that you perform disk management tasks during nonbusiness hours whenever possible, just as you would other administrative tasks on a server.

Creating and Formatting Partitions

You can use Disk Management to create and format partitions on your computer's hard disk(s). So why would you want to create partitions on a Windows 2000 computer? Well, if your computer is configured to dual boot, you might want to create partitions on basic disks to enable the other operating system to access the files in these partitions.

If you decide to perform any of the disk management tasks described in this chapter, do so carefully, and make sure you have a current backup of the computer on which you are working *before* you modify any existing partitions or volumes.

CAUTION

Take extreme care when using Disk Management—it's easy to delete a partition or volume that contains important data. Remember that reformatting a partition or volume will also delete existing data.

The following steps explain how to create and format a primary partition, how to create an extended partition, and how to create and format a logical drive in an extended partition. These tasks can be performed only on basic disks. You cannot create partitions on dynamic disks.

STEP BY STEP

CREATING AND FORMATTING A PRIMARY PARTITION

1. Start Disk Management. (The steps to start Disk Management are listed in the previous section.)
2. If you have not previously upgraded all of your unpartitioned basic disks, the Write Signature and Upgrade Disk Wizard appears. Because primary partitions can only be created on basic disks, I'm assuming that you don't want to upgrade all of your disks to dynamic disks. If this is the case, and if this dialog box appears, click Cancel.
3. In the bottom right pane, right-click in an area of unallocated space on the disk on which you want to create the primary partition. From the menu that appears, select Create Partition.
4. The Create Partition Wizard appears, as shown in Figure 6-2. Notice the explanation of basic disks. Click Next.

FIGURE 6-2 The Create Partition Wizard

5. In the Select Partition Type screen, select the "Primary partition" option. Click Next.
6. Specify the amount of disk space, in MB, to be used for this partition, or accept the default, which is all of the unallocated space on the disk. Click Next.
7. The Assign Drive Letter or Path window appears, as shown in Figure 6-3. Notice the three options available.

   If you choose the "Assign a drive letter" option, select a drive letter from the drop-down list box.

STEP BY STEP *Continued*

FIGURE 6-3 Assigning a drive letter or path to a partition

If you select the "Mount this volume at an empty folder that supports drive paths" option, either type in the path to an empty folder on an NTFS volume on the local computer, or click Browse and select an empty folder. The Browse command button is grayed out and not available if you are using Disk Management remotely.

If you select the "Do not assign a drive letter or path" option, you will need to assign a drive letter or path to this partition later so that it can be accessed.

Click Next.

8. The Format Partition window appears, as shown in Figure 6-4. Note that the default file system to use is NTFS.

   There are several options you can configure in this dialog box.

   You can choose to not format this partition, or to format the partition with specified settings. If you choose to format the partition, you have the option to specify several of its characteristics.

   - **File system to use:** The file system choices available are FAT, FAT32, or NTFS. The default file system is NTFS. If you are creating a partition larger than 2,048MB, the FAT file system will not be available as an option. If you are creating a partition larger than 32GB, the FAT32 file system will not be an option. If your partition is larger than 2GB and smaller than 4GB, and you want to format it with the FAT file system, you must choose the "Do not format this partition" option, and then format the partition later using the `Format.exe` command-line utility.

STEP BY STEP *Continued*

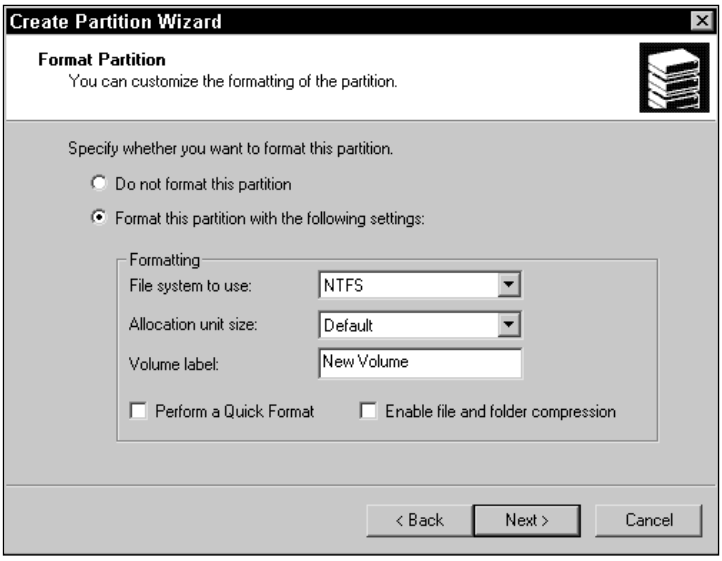

FIGURE 6-4 Formatting a primary partition

- **Allocation unit size:** This setting refers to the sector size Disk Management uses when it formats a partition. Sector sizes vary in this menu from 512 bytes to 256K. There's an important trade off to consider when choosing a sector size. If you select a small sector size, you'll have less wasted disk space when storing files. If you select a large sector size, large files will be accessed more quickly. For example, if you plan to store large graphics or CAD files on this partition, consider using a large sector size to improve performance. I normally recommend accepting the Default setting for this option. The value for the Default setting varies depending on the size of the partition (or volume) being formatted.
- **Volume label:** This setting enables you to give the partition a name. Type in the name you want to use for the volume label. The default label is New Volume. You can assign a blank label to a volume by deleting the default name.
- **Perform a Quick Format**: Selecting this option instructs Windows 2000 to write only the necessary data to the disk to support a volume, and not to check for bad sectors during the formatting. Checking for bad sectors can add a significant amount of time to the formatting process. I recommend that you don't select this option unless you are reformatting an existing partition.
- **Enable file and folder compression:** This option is only available if you choose NTFS as the file system. (If you choose any other file system, this box is grayed out.) Selecting this option causes all files and folders placed in this partition to be compressed by default. You can also set this attribute later by using Windows Explorer.

STEP BY STEP *Continued*

When you finish configuring the settings in this dialog box, click Next.

9. In the Completing the Create Partition Wizard window, review the settings you have selected. If the settings are correct, click Finish. If you want to change any of the settings, click Back and make the appropriate changes. Windows 2000 creates and formats the primary partition.

After Windows 2000 creates and formats the primary partition, it appears in Disk Management with a listing of its characteristics, including the name of the new partition, a drive letter or path, the amount of space the partition contains, the file system the partition is formatted with, and the word "Healthy." The space on the disk that was used to create the partition is no longer shown as unallocated.

STEP BY STEP

CREATING AN EXTENDED PARTITION

1. Start Disk Management. (The steps to start Disk Management are listed in the "Using Disk Management" section.)
2. If you have not previously upgraded all of your unpartitioned basic disks, the Write Signature and Upgrade Disk Wizard appears. Because extended partitions can only be created on basic disks, I'm assuming that you don't want to upgrade all of your disks to dynamic disks. If this is the case, and if this dialog box appears, click Cancel.
3. In the bottom right pane, right-click in an area of unallocated space on the disk on which you want to create the extended partition. From the menu that appears, select Create Partition.
4. The Create Partition Wizard appears. Click Next.
5. Select the "Extended partition" option. Click Next.
6. Specify the amount of disk space, in MB, to be used for this partition, or accept the default, which is all of the unallocated space on the disk. Click Next.
7. In the Completing the Create Partition Wizard window, review the settings you have selected. If the settings are correct, click Finish. If you want to change any of the settings, click Back and make the appropriate changes. Windows 2000 creates the extended partition.

After Windows 2000 creates the extended partition, it appears in Disk Management with a listing of its characteristics, as shown in Figure 6-5. Notice the attributes of the extended partition, which was created on Disk 2, including the amount of space the partition contains and the words "Free Space." Also notice that the space on the disk that was used to create this partition is no longer shown as unallocated.

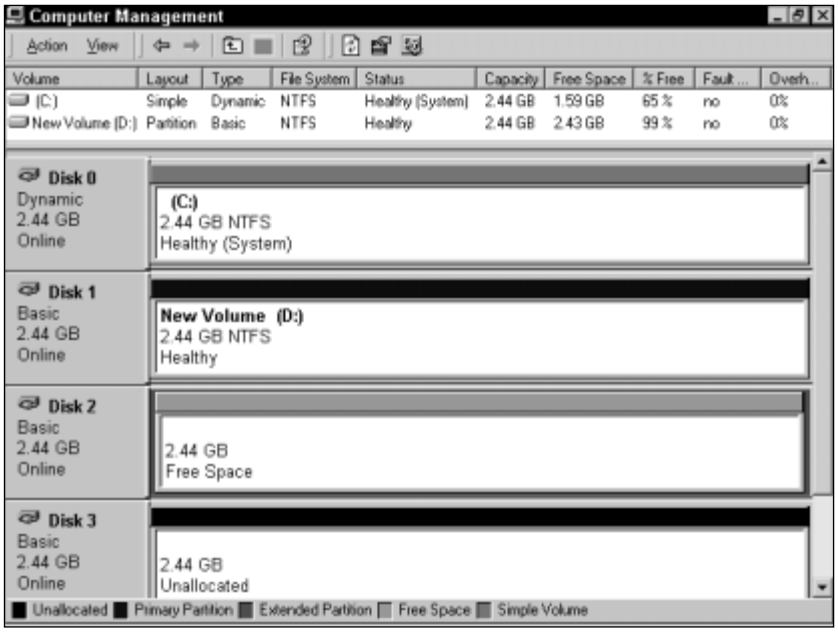

FIGURE 6-5 An extended partition

STEP BY STEP

CREATING AND FORMATTING A LOGICAL DRIVE IN AN EXTENDED PARTITION

1. Start Disk Management. (The steps to start Disk Management are listed in the "Using Disk Management" section.)
2. If you have not previously upgraded all of your unpartitioned basic disks, the Write Signature and Upgrade Disk Wizard appears. Because logical drives can only be created on basic disks that contain extended partitions, I'm assuming that you don't want to upgrade all of your disks to dynamic disks. If this is the case, and if this dialog box appears, click Cancel.
3. In the bottom right pane, right-click in an area marked "Free Space" on the disk which contains the extended partition in which you want to create the logical drive. From the menu that appears, select Create Logical Drive.

STEP BY STEP *Continued*

4. The Create Partition Wizard appears. Click Next.
5. Select the "Logical drive" option. Click Next.
6. Specify the amount of disk space, in MB, to be used for this logical drive, or accept the default, which is all of the free space in the extended partition. Click Next.
7. The Assign Drive Letter or Path window appears. Select and configure the appropriate option. (For a detailed description of these options, see the "Creating and formatting a primary partition" step-by-step section earlier in this chapter.) Click Next.
8. The Format Partition window appears. Select and configure the appropriate option. (For a detailed description of these options, see the "Creating and formatting a primary partition" step-by-step section earlier in this chapter.) Click Next.
9. In the Completing the Create Partition Wizard window, review the settings you have selected. If the settings are correct, click Finish. If you want to change any of the settings, click Back and make the appropriate changes. Windows 2000 creates and formats the logical drive.

After Windows 2000 creates and formats the logical drive, it appears in Disk Management with a listing of its characteristics, including a drive letter or path, the amount of space the logical drive contains, the file system the logical drive is formatted with, and the word "Healthy." The space on the disk that was used to create the logical drive is no longer shown as free space.

Upgrading a Disk from Basic to Dynamic

In Windows 2000, the preferred disk type is dynamic. In fact, every time you run Disk Management, if you have not previously upgraded all of your unpartitioned basic disks to dynamic disks, the Write Signature and Upgrade Disk Wizard appears, as shown in Figure 6-6. Notice the check box at the bottom of the dialog box that you can check if you want to keep your existing basic disks and instruct Windows 2000 to not display this wizard each time you run Disk Management.

TIP

I recommend you upgrade all of your unpartitioned basic disks to dynamic disks when you first encounter this wizard unless you plan to dual boot your computer between Windows 2000 and another operating system.

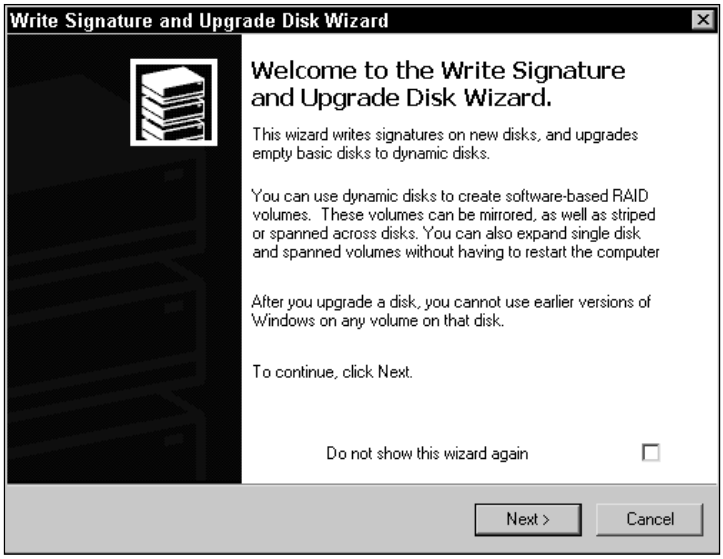

FIGURE 6-6 The Write Signature and Upgrade Disk Wizard

Using the wizard is fairly straightforward. Here are the steps to use the wizard to upgrade a basic disk to a dynamic disk.

STEP BY STEP

USING THE WRITE SIGNATURE AND UPGRADE DISK WIZARD TO UPGRADE A DISK FROM BASIC TO DYNAMIC

1. Start Disk Management. (The steps to start Disk Management are listed in the "Using Disk Management" section.)
2. If you have not previously upgraded all of your unpartitioned basic disks, the Write Signature and Upgrade Disk Wizard appears, as shown in Figure 6-6. (If this wizard does not appear and you want to upgrade a disk, use the next set of steps in this section.) Click Next.
3. Select the disk(s) you want to upgrade. By default, all unpartitioned disks are selected for upgrade. If you don't want one of these disks to be upgraded, deselect the check box next to that disk. Click Next.

TIP

This wizard only gives you an option to upgrade unpartitioned disks. If you want to upgrade a disk that has already been partitioned, use the next set of steps in this section.

STEP BY STEP *Continued*

4. In the Completing the Write Signature and Upgrade Disk Wizard window, review the settings you have selected. If the settings are correct, click Finish. If you want to change any of the settings, click Back and make the appropriate changes. Windows 2000 upgrades your disk(s) from basic to dynamic.

Occasionally you might want to upgrade a partitioned basic disk to a dynamic disk. For example, if you want to mirror Disk 0, you must first upgrade it to a dynamic disk before you can mirror it.

If you upgrade a partitioned basic disk to a dynamic disk, Windows 2000 converts the partitions on the basic disk into dynamic volumes that are Windows 2000 equivalents of their basic disk counterparts. For example, Windows 2000 converts a primary partition into a simple volume; a mirror set into a mirrored volume; a stripe set with parity into a RAID-5 volume, and so on. When converting disks from basic to dynamic, make sure that you convert all of the disks that make up a volume at the same time.

To upgrade a partitioned basic disk, you'll need to manually upgrade the basic disk by using Disk Management. I'll get to the steps involved in performing this task in a minute, but first I need to fill you in on a couple of important cautionary notes.

- *Converting a partitioned basic disk to a dynamic disk is a one-way process.* Once the disk is converted, the only way to change it back to a basic disk is to delete all of the volumes on the disk (and the contents of those volumes) and then use Disk Management to revert the disk to a basic disk. The new basic disk will not have any partitions or data on it. For more information on this topic, see the "Reverting from a Dynamic Disk to a Basic Disk" section later in this chapter.
- *One situation where you should not upgrade a basic disk to a dynamic disk is when your computer is configured to dual boot between Windows 2000 and another operating system.* If your computer is configured to dual boot and you upgrade a basic disk (that has been partitioned and formatted) to a dynamic disk, the other operating system will no longer be able to access this disk. Additionally, if you upgrade Disk 0, the other operating system will no longer be able to boot.

Now I'll show you how to use Disk Management to manually upgrade a basic disk to a dynamic disk.

STEP BY STEP

MANUALLY UPGRADING A DISK FROM BASIC TO DYNAMIC

1. Start Disk Management. (The steps to start Disk Management are listed in the "Using Disk Management" section.)
2. In the bottom right pane, right-click the disk you want to upgrade, as shown in Figure 6-7. When you do this, right-click the small gray area on the left that contains the actual disk number and disk type, not the long bar on the right that contains the volume information.

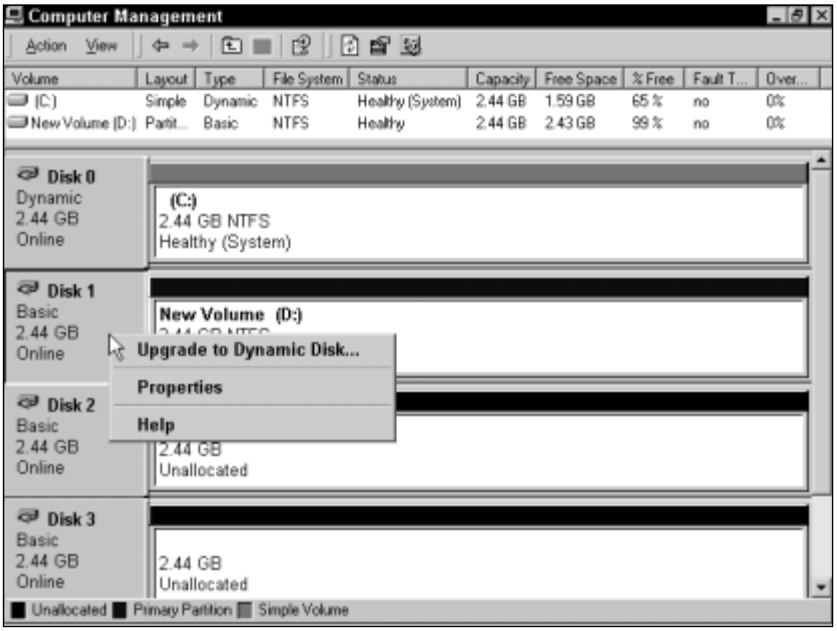

FIGURE 6-7 Manually upgrading a disk from basic to dynamic

Notice that I clicked the gray area where "Disk 1" appears, not on the bar to the right representing the partitioned space.

From the menu that appears, select Upgrade to Dynamic Disk.

3. In the Upgrade to Dynamic Disk dialog box, select the disk(s) you want to upgrade. By default, only the disk that you right-clicked is selected for upgrade. All basic disks, both formatted and unformatted, are available for upgrade in this dialog box. Click OK.
4. In the Disks to Upgrade dialog box, review the list of disks that will be upgraded. You can click Details to display a list of the volumes currently contained on the disk(s) selected for upgrade. If the list is correct, click Upgrade. If the list is not correct, click Cancel.

STEP BY STEP *Continued*

5. A warning dialog box appears. Note that once you upgrade a disk from basic to dynamic, you will no longer be able to boot previous versions of Windows from this disk. Assuming that you want to continue with the upgrade, click Yes.
6. Another warning dialog box appears. File systems on this disk will be dismounted and unavailable during the upgrade process. This means that other users on the network will not be able to access files on this disk during the upgrade process, and that any open files will be closed without prior notice to the user. Open files can become corrupted in this situation. Click Yes to continue.
7. If you are upgrading Disk 0, Windows 2000 displays another message, stating that a reboot will take place after the disk is upgraded.

   Windows 2000 upgrades the selected disk(s) from basic to dynamic, and may reboot your computer.

Reverting from a Dynamic Disk to a Basic Disk

It's possible, especially in a dual boot situation, that you might want to convert a dynamic disk back into a basic disk. For example, suppose that your computer is configured to dual boot between Windows 2000 and Windows 98. You decide that you want to be able to access data located in a dynamic volume when you are booted to Windows 98. In order to accomplish this, you will need to revert the dynamic disk to a basic disk.

Reverting from a dynamic disk to a basic disk is not a choice to make lightly. If the dynamic disk does not contain any volumes, you can quite easily revert it to a basic disk. However, if the dynamic disk contains one or more volumes, the process isn't so painless.

STEP BY STEP

REVERTING TO A BASIC DISK

1. If the disk contains data in one or more volumes, back up all of the data on the disk.
2. Start Disk Management. (The steps to start Disk Management are listed in the "Using Disk Management" section.)
3. If the disk to be reverted does not contain any volumes, skip to Step 6.

STEP BY STEP *Continued*

If the disk to be reverted contains one or more volumes, you must delete these volumes. To do this, in the bottom right pane of Disk Management, right-click in a bar-shaped area that represents the volume you want to delete. Select Delete Volume from the menu that appears.

4. Click Yes in the warning dialog box that appears to delete the selected volume.
5. Click Yes in the Disk Management dialog box to force the deletion of the selected volume. Windows 2000 deletes the volume. Repeat Steps 3 through 5 to delete each volume on the disk.
6. In the bottom right pane of Disk Management, right-click the small gray area on the left that contains the disk number and disk type of the disk you want to revert. Select Revert To Basic Disk from the menu that appears. Windows 2000 reverts the dynamic disk to a basic disk.
7. Partition and format the basic disk, and if the volume previously contained data that you need to access, restore that data to the disk.

Creating a Simple Volume

When you add a new disk to a computer, or after you first install Windows 2000 onto a new computer, you will probably need to create a simple volume. Simple volumes, as you may recall, can only be created on dynamic disks.

Creating a simple volume is fairly straightforward. Simple volumes are created by using Disk Management. Here are the steps to create and format a simple volume.

STEP BY STEP

CREATING AND FORMATTING A SIMPLE VOLUME

1. Start Disk Management. (The steps to start Disk Management are listed in the "Using Disk Management" section.)
2. If you have not previously upgraded all of your unpartitioned basic disks, the Write Signature and Upgrade Disk Wizard appears. If you want to create a simple volume on a basic disk, you'll need to upgrade that disk to a dynamic disk. If this is the case, use this wizard and the steps in the "Upgrading a Disk from Basic to Dynamic" section earlier in this chapter. If you already have a dynamic disk on which to create a simple volume and want to keep your existing basic disks, click Cancel.

STEP BY STEP *Continued*

3. In the bottom right Disk Management pane, right-click in an area of unallocated space on the dynamic disk on which you want to create the simple volume. From the menu that appears, select Create Volume.
4. The Create Volume Wizard appears, as shown in Figure 6-8. Notice the explanation of volumes. Click Next.

FIGURE 6-8 The Create Volume Wizard

5. In the Select Volume Type screen, select the “Simple volume” option. Click Next.
6. In the Select Disks screen, specify the amount of disk space, in MB, to be used for this volume, or accept the default, which is all of the unallocated space on the disk. Click Next.
7. The Assign Drive Letter or Path screen appears. Select and configure one of the three options in this dialog box.

   If you choose the “Assign a drive letter” option, select a drive letter from the drop-down list box.

   If you select the “Mount this volume at an empty folder that supports drive paths” option, either type in the path to an empty folder on an NTFS volume on the local computer, or click Browse and select an empty folder. The Browse command button is grayed out and not available if you are using Disk Management remotely.

STEP BY STEP *Continued*

If you select the “Do not assign a drive letter or path” option, you will need to assign a drive letter or path to this volume later so that it can be accessed.

Click Next.

8. The Format Volume screen appears, as shown in Figure 6-9. Note that the options for formatting a volume are the same as those used when formatting a primary partition.

FIGURE 6-9 Formatting a volume

There are several options you can configure in this dialog box.

You can choose to not format this volume, or to format the volume with specified settings. If you choose to format the volume, you have the option to specify several of its characteristics.

- **File system to use:** The file system choices available are FAT, FAT32, or NTFS. The default file system is NTFS. If you are creating a volume larger than 2,048MB, the FAT file system will not be available as an option. If you are creating a volume larger than 32GB, the FAT32 file system will not be an option. If your volume is larger than 2GB and smaller than 4GB, and you want to format it with the FAT file system, you must choose the “Do not format this volume” option, and then format the volume later using the `Format.exe` command-line utility.

STEP BY STEP *Continued*

- **Allocation unit size:** This setting refers to the sector size Disk Management uses when it formats the volume. Sector sizes vary in this menu from 512 bytes to 256K. There's an important trade-off to consider when choosing a sector size. If you select a small sector size, you'll have less wasted disk space when storing files. If you select a large sector size, large files will be accessed more quickly. For example, if you plan to store large multimedia or graphics files on this partition, consider using a large sector size to improve performance. I normally recommend accepting the Default setting for this option. The value for the Default setting varies depending on the size of the volume being formatted.
- **Volume label:** This setting enables you to give the volume a name. Type in the name you want to use for the volume label. The default label is New Volume. You can assign a blank label to a volume by deleting the default name.
- **Perform a Quick Format:** Selecting this option instructs Windows 2000 to write only the necessary data to the disk to support a volume, and not to check for bad sectors during the formatting. Checking for bad sectors can add a significant amount of time to the formatting process. I recommend that you don't select this option unless you are reformatting an existing volume.
- **Enable file and folder compression:** This option is only available if you choose NTFS as the file system. (If you choose any other file system, this box is grayed out.) Selecting this option causes all files and folders placed in this volume to be compressed by default. You can also set this attribute later by using Windows Explorer.

When you finish configuring the settings in this dialog box, click Next.

9. In the Completing the Create Volume Wizard screen, review the settings you have selected. If the settings are correct, click Finish. If you want to change any of the settings, click Back and make the appropriate changes. Windows 2000 creates and formats the simple volume.

After Windows 2000 creates and formats the simple volume, it appears in Disk Management with a listing of its characteristics, including the name of the new volume, a drive letter or path, the amount of space the volume contains, the file system the volume is formatted with, and the word "Healthy." The space on the disk that was used to create the simple volume is no longer shown as unallocated.

Creating a Spanned Volume

You might want to create a spanned volume when you add a new disk to a computer and want that disk to be a part of an existing volume, or, after you first install Windows 2000 onto a new computer and want to create a volume that is larger than a single hard disk. To create a spanned volume, you need two or more dynamic disks.

Another situation where you might want to create a spanned volume is when you need to extend an existing volume. If you need more disk space in an existing simple or spanned volume, you can extend the existing volume if it has been formatted with NTFS. To extend a volume, you need the existing simple or spanned volume, plus one or more additional dynamic disks. Extended volumes are always spanned volumes.

TIP

Neither the system nor the boot partition can be extended into a spanned volume, even if you have upgraded the disk that contains these partitions to a dynamic disk.

Now I'll explain how to create a spanned volume, and then I'll explain how to extend an existing simple or spanned volume.

STEP BY STEP

CREATING A NEW SPANNED VOLUME

1. Start Disk Management. (The steps to start Disk Management are listed in the "Using Disk Management" section.)
2. If you have not previously upgraded all of your unpartitioned basic disks, the Write Signature and Upgrade Disk Wizard appears. If the disks you want to use to create the spanned volume are basic disks, you'll need to upgrade those disks to dynamic disks. If this is the case, use this wizard and the steps in the "Upgrading a Disk from Basic to Dynamic" section earlier in this chapter. If you already have the dynamic disks on which you want to create a spanned volume and want to keep your existing basic disks, click Cancel.
3. In the bottom right Disk Management pane, right-click in an area of unallocated space on any of the dynamic disks that you want to be a part of the spanned volume. From the menu that appears, select Create Volume.
4. In the Create Volume Wizard dialog box, click Next.
5. Select the "Spanned volume" option. Click Next.

STEP BY STEP *Continued*

6. The Select Disks screen appears, as shown in Figure 6-10. Note that only one dynamic disk is selected, by default, for inclusion in the spanned volume.

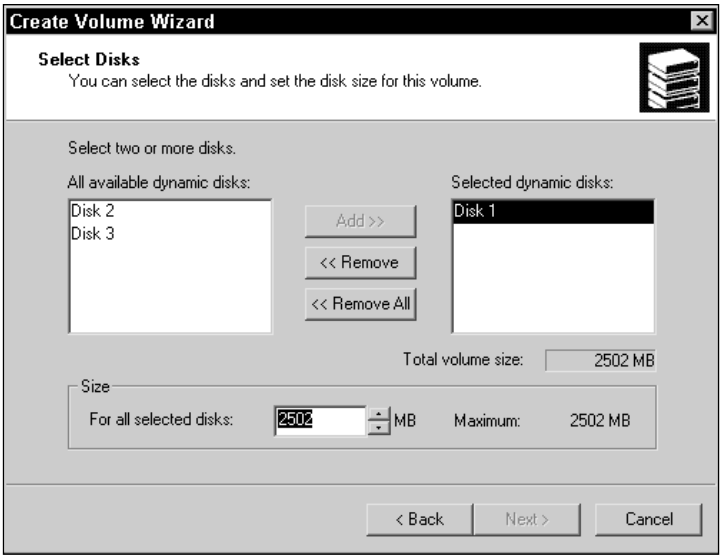

FIGURE 6-10 Selecting disks for a spanned volume

Highlight one or more additional dynamic disks in the "All available dynamic disks" box. Click Add. You should now have two or more disks listed in the "Selected dynamic disks" box.

Highlight the first disk listed in the "Selected dynamic disks" box, and specify the amount of disk space, in MB, to be used for this disk in the spanned volume. Repeat this process for each of the disks listed in the "Selected dynamic disks" box. Click Next.

Or, instead of configuring disk space for each disk individually, you can accept the default, which is all of the unallocated space on each of the disks, by clicking Next.

7. The Assign Drive Letter or Path screen appears. Select and configure one of the three options in this dialog box. (These options are explained in detail in Step 7 in the "Creating a Simple Volume" section.) Click Next.
8. The Format Volume screen appears. Select and configure the appropriate option. (These options are explained in detail in Step 8 in the "Creating a Simple Volume" section.) Click Next.

STEP BY STEP *Continued*

9. In the Completing the Create Volume Wizard screen, review the settings you have selected. If the settings are correct, click Finish. If you want to change any of the settings, click Back and make the appropriate changes. Windows 2000 creates and formats the spanned volume.

After Windows 2000 creates and formats the spanned volume, it appears in Disk Management with a listing of its characteristics, including the name of the new volume, a drive letter or path, the amount of space on each disk that is included in the volume, the file system the volume is formatted with, and the word "Healthy." A newly created spanned volume is shown in Figure 6-11. Notice that I chose to name this volume "Spanned," and that it consists of two dynamic disks, Disk 1 and Disk 2.

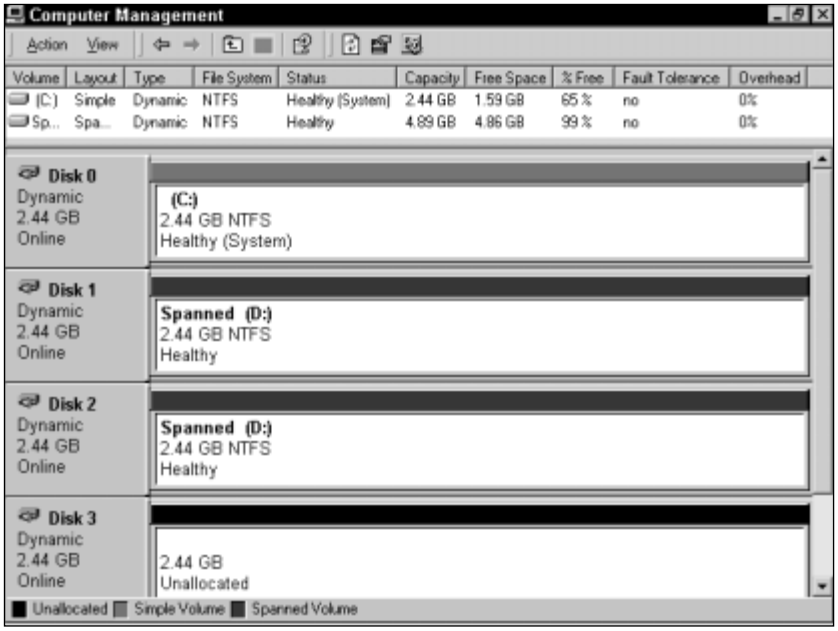

FIGURE 6-11 Newly created spanned volume

If you want to know the total amount of disk capacity of the spanned volume, view the entry in the Capacity column for the spanned volume in the top right pane in Disk Management.

STEP BY STEP

EXTENDING A SIMPLE OR SPANNED VOLUME

1. Start Disk Management. (The steps to start Disk Management are listed in the "Using Disk Management" section.)
2. If you have not previously upgraded all of your unpartitioned basic disks, the Write Signature and Upgrade Disk Wizard appears. If the disks you want to use to extend your simple or spanned volume are basic disks, you'll need to upgrade those disks to dynamic disks. If this is the case, use this wizard and the steps in the "Upgrading a Disk from Basic to Dynamic" section earlier in this chapter. If you already have the dynamic disks you need to extend your simple or spanned volume and want to keep your existing basic disks, click Cancel.
3. In the bottom right Disk Management pane, right-click anywhere in the bar-shaped space that represents the volume you want to extend. From the menu that appears, select Extend Volume.
4. In the Extend Volume Wizard dialog box, click Next.
5. In the Select Disks screen, highlight one or more dynamic disks from the "All available dynamic disks" box to add to your existing volume. Click Add. You should now have one or more disks listed in the "Selected dynamic disks" box.

   Configure the amount of disk space you want to be included in the extended volume from each of the dynamic disks listed in the "Selected dynamic disks" box. The default setting is all of the unallocated space on each of the disks. Click Next.
6. In the Completing the Extend Volume Wizard screen, review the settings you have selected. If the settings are correct, click Finish. If you want to change any of the settings, click Back and make the appropriate changes. Windows 2000 extends the volume.

Creating a Striped Volume

You might want to create a striped volume if you determine you want faster speed of access to files than you can get by using a simple or spanned volume, and you do not require any fault tolerance. To create a striped volume, you need two or more dynamic disks.

STEP BY STEP

CREATING A STRIPED VOLUME

1. Start Disk Management. (The steps to start Disk Management are listed in the "Using Disk Management" section.)
2. If you have not previously upgraded all of your unpartitioned basic disks, the Write Signature and Upgrade Disk Wizard appears. If the disks you want to use to create a striped volume are basic disks, you'll need to upgrade those disks to dynamic disks. If this is the case, use this wizard and the steps in the "Upgrading a Disk from Basic to Dynamic" section earlier in this chapter. If you already have the dynamic disks on which you want to create a striped volume and want to keep your existing basic disks, click Cancel.
3. In the bottom right Disk Management pane, right-click in an area of unallocated space on any of the dynamic disks that you want to be a part of the striped volume. From the menu that appears, select Create Volume.
4. In the Create Volume Wizard dialog box, click Next.
5. Select the "Striped volume" option. Click Next.
6. In the Select Disks screen, highlight one or more dynamic disks from the "All available dynamic disks" box to be included in your striped volume. Click Add. You should now have two or more disks listed in the "Selected dynamic disks" box.

   Highlight any disk in the "Selected dynamic disks" box and configure the amount of disk space you want to be included in the striped volume.

   Because striped volumes require identical amounts of disk space on each disk in the volume, Windows 2000 will use the amount of disk space you configure from each of the selected disks when it creates the striped volume. If the disks that will make up the striped volume have unequal amounts of unallocated space, the largest amount of space you can configure is the amount of unallocated space from the disk that has the smallest amount of unallocated space. (This maximum size is also the default setting.) The total size of the striped volume will be the amount of disk space you select times the number of disks that make up the volume. This total is displayed in the Total volume size text box after you configure the size for all selected disks setting. Click Next.
7. The Assign Drive Letter or Path screen appears. Select and configure one of the three options in this dialog box. (These options are explained in detail in Step 7 in the "Creating a Simple Volume" section.) Click Next.
8. The Format Volume screen appears. Select and configure the appropriate option. (These options are explained in detail in Step 8 in the "Creating a Simple Volume" section.) Click Next.

STEP BY STEP *Continued*

9. In the Completing the Create Volume Wizard screen, review the settings you have selected. If the settings are correct, click Finish. If you want to change any of the settings, click Back and make the appropriate changes. Windows 2000 creates and formats the striped volume.

After Windows 2000 creates and formats the striped volume, it appears in Disk Management with a listing of its characteristics, including the name of the new volume, a drive letter or path, the amount of space on each disk that is included in the striped volume, the file system the volume is formatted with, and the word "Healthy." A newly created striped volume is shown in Figure 6-12. Notice that I chose to name this volume "Striped," and that it consists of three dynamic disks, Disk 1 and Disk 2, and Disk 3.

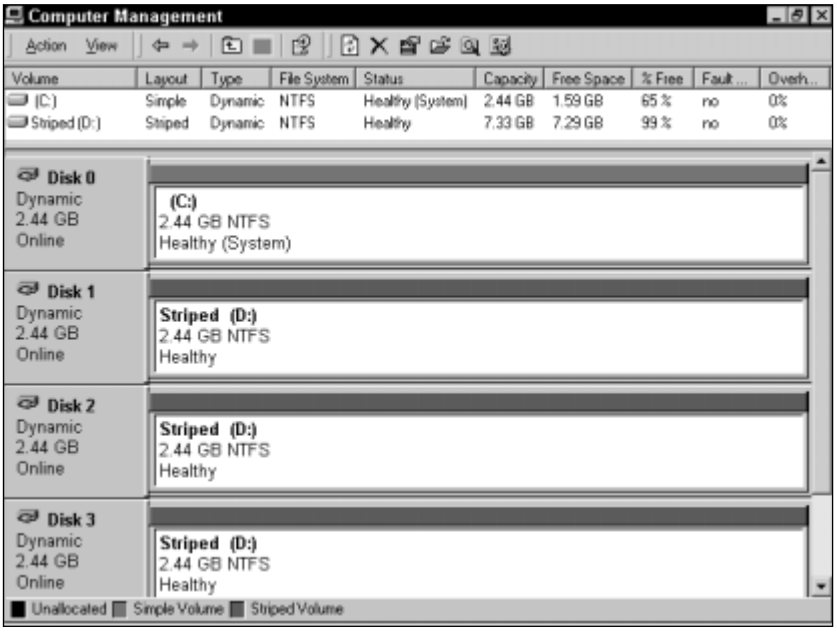

FIGURE 6-12 Newly created striped volume

Creating a Mirrored Volume

You'll probably want to create a mirrored volume if you determine you want the highest level of fault tolerance that Windows 2000 provides. To create a mirrored volume, you need two dynamic disks.

TIP

You can only create and use mirrored volumes on Windows 2000 Server and Advanced Server computers. Windows 2000 Professional does not support mirrored volumes.

There are two different situations in which you can create a mirrored volume:

- You can create a mirrored volume from unallocated space on two dynamic disks. This means you're starting out with two dynamic disks that have no data on them.
- You can mirror an existing simple volume onto a second dynamic disk that has enough unallocated space to contain the volume. In this situation, you're starting out with one disk that already has data on it, and one additional dynamic disk that has no data on it.

In this section, I'll list the steps to create a mirrored volume in each of these situations.

I'll also explain how to perform another common task associated with mirrored volumes — creating a fault tolerance boot disk. When you mirror the volume that contains your Windows 2000 Server/Advanced Server installation folder (usually `C:\Winnt`), you should create a floppy disk that will enable you to boot from your second hard disk should the first hard disk in your mirrored volume fail. This floppy disk is called a *fault tolerance boot disk*.

So, allow me to begin by explaining how to create a mirrored volume on a Windows 2000 Server/Advanced Server computer by using two dynamic disks that have no data on them.

STEP BY STEP

CREATING A MIRRORED VOLUME ON TWO BLANK DYNAMIC DISKS

1. Start Disk Management. (The steps to start Disk Management are listed in the "Using Disk Management" section.)
2. If you have not previously upgraded all of your unpartitioned basic disks, the Write Signature and Upgrade Disk Wizard appears. If either of the two disks you want to use to create the mirrored volume are basic disks, you'll need to upgrade those disks to dynamic disks. If this is the case, use this wizard and the steps in the "Upgrading a Disk from Basic to Dynamic" section earlier in this chapter. If you already have the two dynamic disks on which you want to create a mirrored volume and want to keep your existing basic disks, click Cancel.
3. In the bottom right Disk Management pane, right-click in an area of unallocated space on either of the two dynamic disks that you want to be a part of the mirrored volume. From the menu that appears, select Create Volume.
4. In the Create Volume Wizard dialog box, click Next.
5. Select the "Mirrored volume" option. Click Next.
6. The Select Disks screen appears.

   Highlight one additional dynamic disk in the "All available dynamic disks" box. Click Add. You should now have two disks listed in the "Selected dynamic disks" box.

   Highlight any disk in the "Selected dynamic disks" box and configure the amount of disk space you want to be included in the mirrored volume.

   Because mirrored volumes require identical amounts of disk space on each disk in the volume, Windows 2000 Server/Advanced Server will use the amount of disk space you configure from each of the two selected disks when it creates the mirrored volume. If the two disks that will make up the mirrored volume have unequal amounts of unallocated space, the largest amount of space you can configure is the amount of unallocated space from the disk that has the smallest amount of unallocated space. (This maximum size is also the default setting.) The total size of the mirrored volume will be the amount of disk space you select. This total is displayed in the Total volume size text box after you configure the size for all selected disks setting. Click Next.
7. The Assign Drive Letter or Path screen appears. Select and configure one of the three options in this dialog box. (These options are explained in detail in Step 7 in the "Creating a Simple Volume" section.) Click Next.
8. The Format Volume screen appears. Select and configure the appropriate option. (These options are explained in detail in Step 8 in the "Creating a Simple Volume" section.) Click Next.

STEP BY STEP *Continued*

9. In the Completing the Create Volume Wizard screen, review the settings you have selected. If the settings are correct, click Finish. If you want to change any of the settings, click Back and make the appropriate changes. Windows 2000 Server/Advanced Server creates, formats, and resynchronizes the mirrored volume. This process takes awhile.

After Windows 2000 Server/Advanced Server creates, formats, and resynchronizes the mirrored volume, it appears in Disk Management with a listing of its characteristics, including the name of the new volume, a drive letter or path, the identical amount of space on each disk that is included in the volume, the file system the volume is formatted with, and the word "Healthy." A newly created mirrored volume is shown in Figure 6-13. Notice that I chose to name this volume "Mirrored," and that it consists of two dynamic disks, Disk 2 and Disk 3.

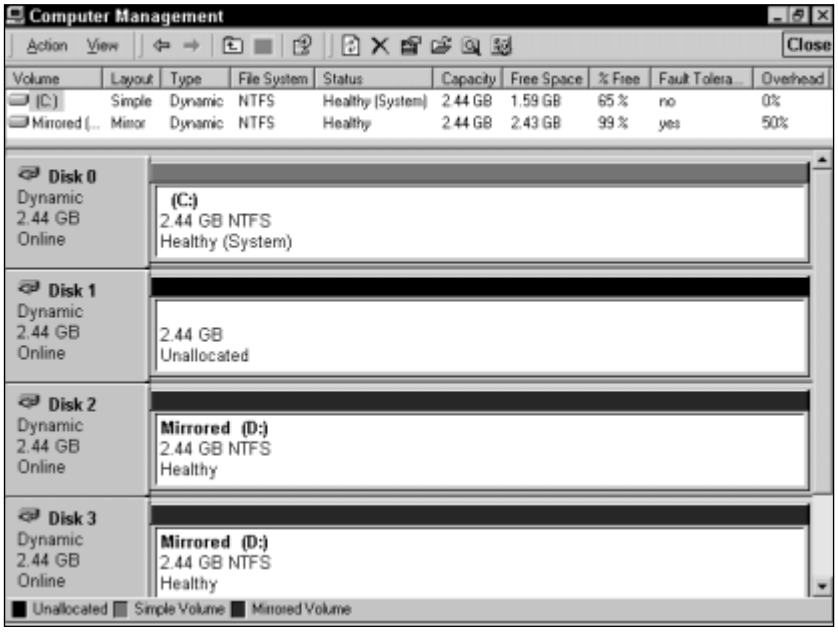

FIGURE 6-13 Newly created mirrored volume

STEP BY STEP

CREATING A MIRRORED VOLUME FROM A SIMPLE VOLUME AND A BLANK DYNAMIC DISK

1. Start Disk Management. (The steps to start Disk Management are listed in the "Using Disk Management" section.)
2. If you have not previously upgraded all of your unpartitioned basic disks, the Write Signature and Upgrade Disk Wizard appears. If the additional disk you want to use to create the mirrored volume is a basic disk, you'll need to upgrade that disk to a dynamic disk. If this is the case, use this wizard and the steps in the "Upgrading a Disk from Basic to Dynamic" section earlier in this chapter. If your additional disk is already a dynamic disk and you want to keep your existing basic disks, click Cancel.

TIP

If the disk that contains the volume (and data) you want to mirror is a basic disk, you must upgrade that disk to a dynamic disk before you can continue. Use the "Manually upgrading a basic disk to a dynamic disk" step-by-step section earlier in this chapter to upgrade this disk.

3. In the bottom right Disk Management pane, right-click in the bar-shaped area that represents the simple volume you want to mirror. From the menu that appears, select Add Mirror.
4. In the Add Mirror dialog box, select the additional dynamic disk you want to use to create the mirrored volume. Click Add Mirror. Windows 2000 Server/Advanced Server creates and regenerates the mirrored volume. This process takes awhile because Windows 2000 has to copy all of the data from the original disk to the second disk in the mirrored volume.

Creating a Fault Tolerance Boot Disk

As I mentioned earlier, a *fault tolerance boot disk* is a floppy disk that enables you to boot your computer in the event that the first disk in your computer's mirrored volume fails. If the first disk in a mirrored volume fails, and if that disk contains the Windows 2000 installation folder (usually `C:\Winnt`), you will not be able to reboot your computer because the `Boot.ini` file points to the first (and failed) hard disk. When this happens, in order to boot your computer, you need to use a fault tolerance boot disk that contains an

edited `Boot.ini` file that points to the disk in the mirrored volume that is still functional.

IN THE REAL WORLD

This may sound obvious, but you should create the fault tolerance boot disk *before* the disk failure occurs. I even go so far as to recommend that after you make the fault tolerance boot disk you tape it to the side of the computer so you can easily locate it in the event of a disk failure.

Here are the steps to create your own fault tolerance boot disk. Also, because you'll need to edit the `Boot.ini` file during this process, I've included some information on how to edit this file in the section that follows these steps.

STEP BY STEP

CREATING A FAULT TOLERANCE BOOT DISK

1. Place a blank 3.5-inch floppy disk in your computer's floppy disk drive. From the desktop, select Start ➪ Programs ➪ Accessories ➪ Windows Explorer.
2. Click the + next to My Computer in the left pane. Right-click 3½ Floppy (A:), and select Format from the menu that appears. You should perform this task in Windows 2000, not in Windows 95 or Windows 98.
3. In the Format A:\ dialog box, click Start.

TIP

I recommend that you *don't* select the quick format option for this task, because you want to ensure that Windows 2000 will detect and compensate for any and all errors on the disk.

4. A warning dialog box appears, indicating that all data on the disk will be erased. Click OK.
5. Windows 2000 displays a message that the format is complete. Click OK.
6. In the Format A:\ dialog box, click Close.
7. In Windows Explorer, select Tools ➪ Folder Options. Click the View tab, and in the Advanced settings box, select the "Show hidden files and folders" option. Then, clear the check boxes next to "Hide file extensions for known file types," and "Hide protected operating system files." In the warning dialog box, click Yes. Click OK.

STEP BY STEP *Continued*

8. Use Windows Explorer to copy the `Ntldr`, `Ntdetect.com`, and `Boot.ini` files from the first hard disk in your computer (usually `C:\`) to the floppy disk. Also copy `Bootsect.dos` to the floppy disk if your computer is configured to dual boot, and copy `Ntbootdd.sys` to the floppy disk if this file exists in the root of your computer's system partition. (The `Ntbootdd.sys` file is renamed copy of the driver for your computer's hard disk controller. This file will exist in your system partition only if you have entries in your `Boot.ini` file that begin with `scsi`.)
9. Use a text editor, such as Notepad, to edit the `Boot.ini` file on the floppy disk (*not* the `Boot.ini` file on your hard drive) to point at the second disk in the mirrored volume, instead of at the first disk. (The next section of this chapter discusses how to edit the `Boot.ini` file.)

Editing the Boot.ini File

The `Boot.ini` file is a hidden file in the root of the first hard disk in the computer. This file is critical to the boot process. Windows 2000 uses this file to create the boot loader operating system selection menu that is displayed when Windows 2000 starts. The `Boot.ini` file also informs Windows 2000 of the location of your Windows 2000 installation folder. If this file is incorrectly configured, your computer won't boot.

In the previous section, I discussed how you can copy this file to a floppy disk when creating a fault tolerance boot disk. In this section, I'll explain how to edit the copy of the `Boot.ini` file on the floppy disk, *not* the `Boot.ini` file on your computer's hard disk.

CAUTION

If you edit the `Boot.ini` file on your computer's hard disk, your computer may no longer be bootable.

You can use any text editor, such as Notepad, to edit the `Boot.ini` file.

However, before you go on to edit this file, you might want to take a closer look at it to understand its structure and syntax. I've reproduced a sample `Boot.ini` file in Listing 6-1.

LISTING 6-1 Sample Boot.ini File

```
[boot loader]
timeout=30
```

```
default=scsi(0)disk(0)rdisk(0)partition(1)\WINNT
[operating systems]
scsi(0)disk(0)rdisk(0)partition(1)\WINNT="Microsoft Windows 2000 Server"
C:\="Microsoft Windows"
```

■ ■ ■

Note that there are two sections to the `Boot.ini` file: `[boot loader]` and `[operating systems]`.

The first section, `[boot loader]`, contains two entries. The first entry, `timeout`, specifies how long, in seconds, the boot loader operating system selection menu is displayed when the computer boots. The default timeout is thirty seconds. The second entry, `default`, specifies which operating system loads if no selection is made within the timeout period.

The second section of the `Boot.ini` file, `[operating systems]`, first lists entries consisting of ARC (*Advanced RISC Computing*) paths to various operating systems. Only Windows 2000 and Windows NT use ARC paths in the `Boot.ini` file to indicate which partition, physical disk, and folder contains the files used to start the operating system. Next, the drive letter and path to any other operating systems are listed. The operating system named at the end of each `[operating systems]` entry, after the = sign (whether it is an ARC path entry or not), is the operating system displayed in the boot loader operating system selection menu.

There are two types of ARC path entries: `multi` and `scsi`. The terms *multi* and *SCSI* refer to the type of hard disk that is listed in the ARC path.

TIP

The term *scsi* is normally presented in lowercase when it is used to indicate an ARC path. It is normally presented in uppercase when it is used to refer to a disk, adapter, or controller.

All hard disks that can be detected by the computer's BIOS, or by the BIOS on a SCSI adapter, are referred to as *multi*. All hard disks connected to SCSI adapters that do not have their BIOS enabled are referred to as *SCSI*. SCSI disks require a device driver to be loaded before the operating system can access the disk. The Windows 2000 installation program copies the device driver for a SCSI adapter to the root of the system partition, and renames the file as `Ntbootdd.sys`.

The syntax of `[operating systems]` entries that begin with `multi` is as follows:

```
multi(W)disk(X)rdisk(Y)partition(Z)\path
```

- *W* is the ordinal number of the adapter. It should always be zero.
- *X* is not used for `multi` entries. It is always zero.
- *Y* is the ordinal for the hard disk on the controller. It is always 0 or 1 for disks connected to the primary controller, including SCSI adapters that have their BIOS enabled.
- *Z* is the partition number. The range of Z is usually 1–4.
- *\path* is the path to the folder that contains the Windows 2000 installation, usually `\Winnt`

The syntax of `[operating systems]` entries that begin with `scsi` is as follows:

```
scsi(W)disk(X)rdisk(Y)partition(Z)\path
```

- *W* is the ordinal number of the adapter.
- *X* is the SCSI ID of the disk.
- *Y* is the logical unit number (LUN) of the disk. It is usually zero.
- *Z* is the partition number. The range of Z is usually 1–4.
- *\path* is the path to the folder that contains the Windows 2000 installation, usually `\Winnt`

Entries in the `[operating systems]` section that begin with `scsi` are typically used in four types of situations:

- When the hard disk containing the system partition is on a SCSI adapter that does *not* have its BIOS enabled
- When the hard disk containing the system partition is on a SCSI adapter *and* has an SCSI ID greater than one
- When the hard disk containing the system partition is on a SCSI adapter *and* there is an IDE or EIDE controller in the computer
- When the computer contains three or more IDE hard disks

You may be wondering why the syntax in the `Boot.ini` file includes partition numbers, when we're dealing with dynamic disks in a mirrored

volume. Well, in a nutshell, Windows 2000 can only be installed on a partitioned basic disk, and when this basic disk is upgraded to a dynamic disk, Windows 2000 retains and continues to use the partition information. In fact, whenever you upgrade a partitioned basic disk to a dynamic disk, partition information is retained.

Now that you understand the structure of the `Boot.ini` file, and the types of entries and syntax used in this file, you're ready to edit it.

Figure 6-14 illustrates the disks on a computer named LOTSADISKS on which I've created a mirrored volume that consists of Disk 0 and Disk 1. Both the boot and system partitions are located on the first disk (Disk 0), and use the drive letter `C:`. LOTSADISKS uses a dual-channel EIDE controller with four IDE hard disks attached.

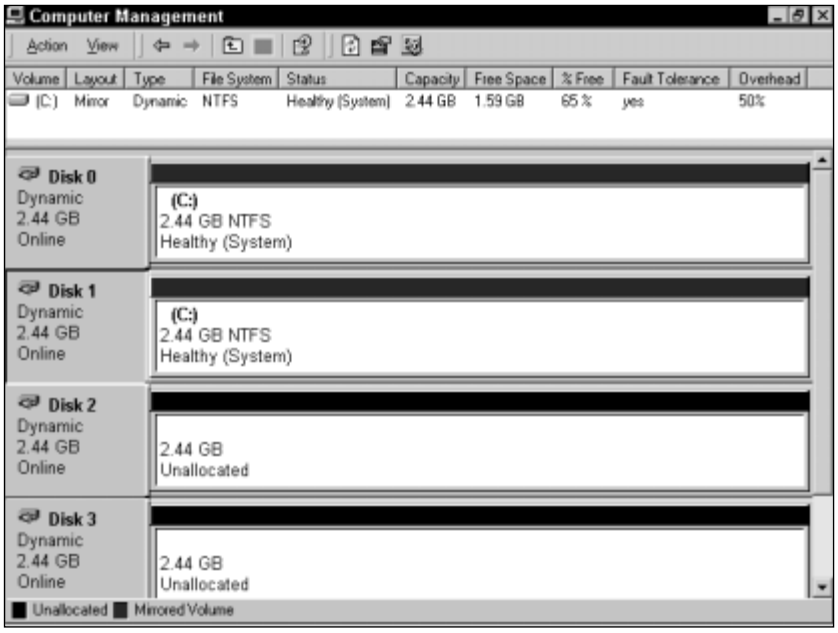

FIGURE 6-14 New mirrored volume

I decide that I want to create a fault tolerance boot disk so I can reboot the computer in the event that Disk 0 fails. I follow the steps outlined in the "Creating a fault tolerance boot disk" step-by-step section up to the point where I edit the `Boot.ini` file on my floppy disk. The `Boot.ini` file on my floppy disk (before editing) looks like Listing 6-2.

LISTING 6-2 Boot.ini File before Editing

```
[boot loader]
timeout=30
default=scsi(0)disk(0)rdisk(0)partition(1)\WINNT
[operating systems]
scsi(0)disk(0)rdisk(0)partition(1)\WINNT="Microsoft Windows 2000 Server"
C:\="Microsoft Windows"
```

■ ■ ■

In this situation, I need to edit the `Boot.ini` file on my floppy disk so that it will start Windows 2000 from Disk 1 instead of from Disk 0 in the event that Disk 0 fails. (The `Boot.ini` file must point to Disk 1 because if Disk 0 fails, Disk 1 will be the only disk in the mirrored volume that still works.)

Now, you may be wondering, how do I know what specific entries to change in my `Boot.ini` file? Well, I cheat. In the bottom right pane in Disk Management I right-click the gray area at the left end of the bar graph that says Disk 1, and then select Properties from the menu that appears. This brings up the Disk 1 Properties dialog box, which is shown in Figure 6-15. Notice the information displayed for the Device Type entry. This information identifies a port number (Port 0) which corresponds to the number that should appear to the right of `scsi` (or `multi`, depending on your `Boot.ini` file). The Target ID, in this case, 1, corresponds to the number that should appear after `disk` in the `boot.ini` file. The LUN entry, in this case, 0, corresponds to the number that should appear after `rdisk` in the `boot.ini` file. And finally, I know which partition number to use because there is only one partition on Disk 1, and partitions are numbered beginning with the number 1.

So, I use this information to construct an edited ARC path for my `Boot.ini` file:

```
scsi(0)disk(1)rdisk(0)partition(1)
```

To edit my `Boot.ini` file, I use Notepad and change the following entries:

1. In the `default` entry in the `[boot loader]` section, I change `disk(0)` to `disk(1)`
2. In the `scsi` entry in the `[operating systems]` section, I change `disk(0)` to `disk(1)`

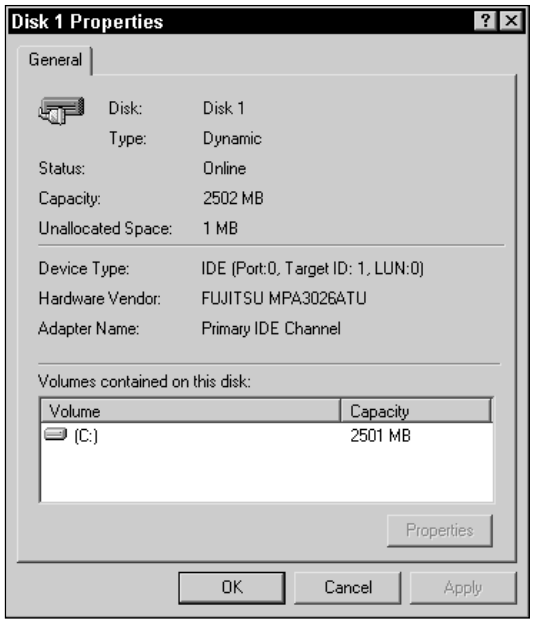

FIGURE 6-15 The Disk 1 Properties dialog box

The edited version of my `Boot.ini` file on my newly created fault tolerance boot disk is presented in Listing 6-3.

LISTING 6-3 Edited Boot.ini File on Fault Tolerance Boot Disk

```
[boot loader]
timeout=30
default=scsi(0)disk(1)rdisk(0)partition(1)\WINNT
[operating systems]
scsi(0)disk(1)rdisk(0)partition(1)\WINNT="Microsoft Windows 2000 Server"
C:\="Microsoft Windows"
```

■ ■ ■

Notice that the ARC path in both the `[boot loader]` and `[operating systems]` sections now points to Disk 1 instead of Disk 0. In the event that Disk 0 in LOTSADISKS fails, I can use my fault tolerance boot disk to boot to Disk 1.

Finally, there are several optional switches you can add at the end of an `[operating systems]` entry in a `Boot.ini` file. Table 6-3 lists and describes these switches. These switches are not case sensitive — you can type them in either uppercase or lowercase.

TIP

These switches are not typically used when creating a fault tolerance boot disk. However, because they are used frequently during troubleshooting, and because this is the only section of this book that addresses the `Boot.ini` file in detail, I've covered the switches here.

TABLE 6-3 Boot.ini File Switches

Switch	Description
`/BASEVIDEO`	This switch causes the computer to use the standard VGA driver when it starts, and is useful in troubleshooting video driver problems.
`/FASTDETECT=COMx |COMx,y,z |`	This specifies that the indicated serial port will *not* be tested for the presence of a mouse, but that all other serial ports will be tested. The default setting in `Boot.ini` files is `/FASTDETECT` with no serial ports specified. This default setting, with no serial ports specified, causes Windows 2000 to skip the mouse detection process entirely.
`/MAXMEM:n`	This switch specifies the maximum amount of memory that Windows 2000 can use. It is useful for troubleshooting memory problems.
`/NOGUIBOOT`	This switch causes Windows 2000 to boot without displaying the graphical boot status screen. In theory, using this switch is supposed to shorten the time required to start Windows 2000. However, when you use this switch it seems to actually take longer to boot, because you don't see any status indicators during the boot process.
`/SOS`	This switch provides a verbose listing of each device driver as it is loaded during the boot sequence. It is useful for troubleshooting device drivers.

Creating a RAID-5 Volume

You might want to create a RAID-5 volume if you determine you want faster speed of access to files than you can get by using a simple or spanned volume, and you also want a modest level of fault tolerance. To create a RAID-5 volume, you need three or more dynamic disks.

TIP

You can only create and use RAID-5 volumes on Windows 2000 Server and Advanced Server computers. Windows 2000 Professional does not support RAID-5 volumes.

STEP BY STEP

CREATING A RAID-5 VOLUME

1. Start Disk Management. (The steps to start Disk Management are listed in the "Using Disk Management" section.)
2. If you have not previously upgraded all of your unpartitioned basic disks, the Write Signature and Upgrade Disk Wizard appears. If the disks you want to use to create the RAID-5 volume are basic disks, you'll need to upgrade those disks to dynamic disks. If this is the case, use this wizard and the steps in the "Upgrading a Disk from Basic to Dynamic" section earlier in this chapter. If you already have the dynamic disks on which you want to create the RAID-5 volume and want to keep your existing basic disks, click Cancel.
3. In the bottom right Disk Management pane, right-click in an area of unallocated space on any of the dynamic disks that you want to be a part of the RAID-5 volume. From the menu that appears, select Create Volume.
4. In the Create Volume Wizard dialog box, click Next.
5. Select the "RAID-5 volume" option. Click Next.
6. In the Select Disks screen, highlight two or more dynamic disks from the "All available dynamic disks" box to be included in your RAID-5 volume. Click Add. You should now have three or more disks listed in the "Selected dynamic disks" box.

   Highlight any disk in the "Selected dynamic disks" box and configure the amount of disk space you want to be included in the RAID-5 volume.

   Because RAID-5 volumes require identical amounts of disk space on each disk in the volume, Windows 2000 Server/Advanced Server will use the amount of disk space you configure from each of the selected disks when it creates the RAID-5 volume. If the disks that will make up the RAID-5 volume have unequal amounts of unallocated space, the largest amount of space you can configure is the amount of unallocated space from the disk that has the smallest amount of unallocated space. (This maximum size is also the default setting.) The total size of the RAID-5 volume will be the amount of disk space you select times one less than the total number of disks that make up the volume. This total is displayed in the Total volume size text box after you configure the size for all selected disks setting. Click Next.

STEP BY STEP *Continued*

7. The Assign Drive Letter or Path screen appears. Select and configure one of the three options in this dialog box. (These options are explained in detail in Step 7 in the "Creating a Simple Volume" section.) Click Next.
8. The Format Volume screen appears. Select and configure the appropriate option. (These options are explained in detail in Step 8 in the "Creating a Simple Volume" section.) Click Next.
9. In the Completing the Create Volume Wizard screen, review the settings you have selected. If the settings are correct, click Finish. If you want to change any of the settings, click Back and make the appropriate changes. Windows 2000 Server/Advanced Server creates and formats the RAID-5 volume. This process may take awhile, because Windows 2000 must first create the volume, then format the volume, and finally generate parity information (which Windows 2000 refers to as "Regenerating").

After Windows 2000 Server/Advanced Server creates, formats, and regenerates the RAID-5 volume, it appears in Disk Management with a listing of its characteristics, including the name of the new volume, a drive letter or path, the identical amount of space on each disk that is included in the RAID-5 volume, the file system the volume is formatted with, and the word "Healthy." A newly created RAID-5 volume is shown in Figure 6-16. Notice that I chose to name this volume "RAID-5," and that it consists of three dynamic disks, Disk 1 and Disk 2, and Disk 3.

Also notice in Figure 6-18 that the capacity of this RAID-5 volume, which is shown in the Capacity column in the top right Disk Management pane, is two-thirds of the total capacity of the three disks that make up the RAID-5 volume. The total capacity is less than the sum total of the capacity of each of the three disks because the equivalent of one of the disks in the RAID-5 volume is used by Windows 2000 Server/Advanced Server for parity information.

Finally, notice in Figure 6-16 that the Fault Tolerance column for the RAID-5 volume (in the top Disk Management pane) displays "yes" because a RAID-5 volume provides a medium amount of fault tolerance.

Now that you're up to speed on basic disk management tasks, I want to move on to using Disk Defragmenter, and then to troubleshooting disks and volumes. Then I'll explain how to recover from disk failures.

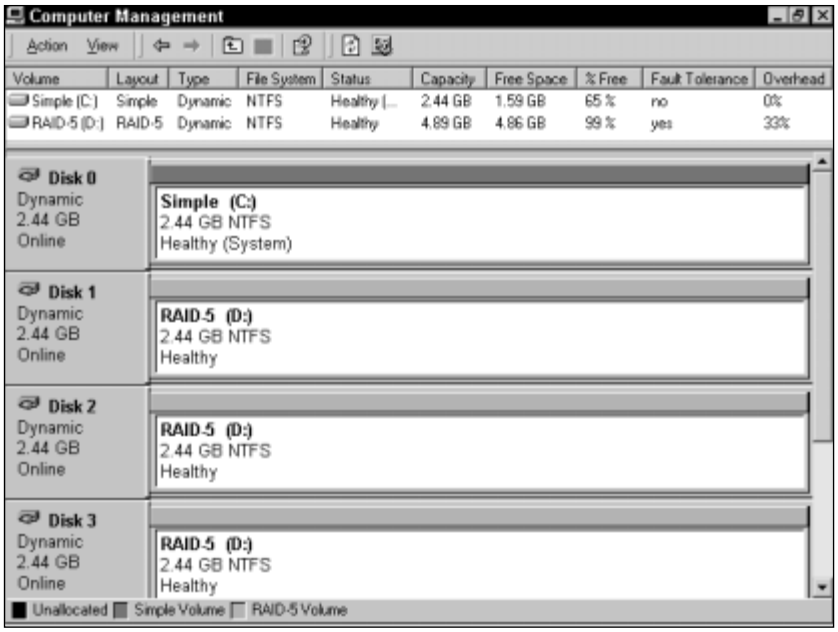

FIGURE 6-16 Newly created RAID-5 volume

Using Disk Defragmenter

Disk Defragmenter, like Disk Management, is a graphical Windows 2000 tool that is a snap-in to the Microsoft Management Console (MMC). Disk Defragmenter is used to analyze volumes, and to defragment these volumes when necessary. You must be a member of the Administrators group in order to use Disk Defragmenter.

A file is considered to be fragmented when it is not stored in consecutive segments in a volume, but rather is stored in diverse segments located throughout the volume. Fragmented files take longer to load than files that aren't fragmented. You can use Disk Defragmenter to determine whether the files in a particular volume are fragmented enough to warrant defragmenting the volume.

Disk analysis and defragmentation is an important part of an overall network preventive maintenance plan. Consider analyzing and/or defragmenting volumes on servers at least once a week. Also, depending on your client computers' use, you should consider analyzing and/or defragmenting volumes on Windows 2000 Professional computers at least once a month.

I recommend that you use Disk Defragmenter only during times when no one else is accessing the server. Disk Defragmenter's functions can take a significant amount of time to complete. This means that service to clients during these times can be seriously slowed or interrupted.

CAUTION

Because running Disk Defragmenter can slow or interrupt service to clients, I recommend that you perform disk defragmentation tasks during nonbusiness hours whenever possible, just as you would other administrative tasks on a server.

Disk Defragmenter can only be used on the local computer. You can't use this tool to remotely defragment disks on another computer.

Two of the most common ways to start Disk Defragmenter are described in the steps that follow.

STEP BY STEP

STARTING DISK DEFRAGMENTER—METHOD 1

1. From the desktop, Select Start ➪ Programs ➪ Administrative Tools ➪ Computer Management. This starts the Microsoft Management Console (MMC).
2. In the left pane of the Computer Management dialog box, click Disk Defragmenter. (If Storage is not already expanded so that Disk Defragmenter appears in the list, click the + next to Storage.)

STARTING DISK DEFRAGMENTER—METHOD 2

1. From the desktop, right click My Computer. Select Manage from the menu that appears.
2. In the left pane of the Computer Management dialog box, click Disk Defragmenter. (If Storage is not already expanded so that Disk Defragmenter appears in the list, click the + next to Storage.)

Figure 6-17 shows the Disk Defragmenter tool. Notice the Analyze and Defragment command buttons in the right pane of this window.

Using Disk Defragmenter, both to analyze and defragment volumes, is very straightforward.

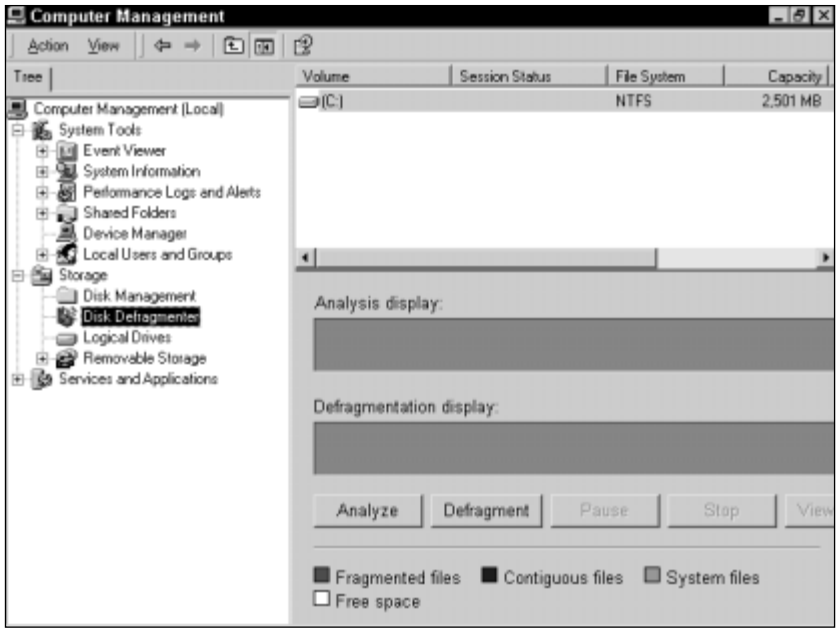

FIGURE 6-17 The Disk Defragmenter tool

STEP BY STEP

USING DISK DEFRAGMENTER TO ANALYZE AND DEFRAGMENT A VOLUME

1. Start Disk Defragmenter (see the preceding steps).
2. Highlight the volume you want to analyze from the list of volumes displayed at the top of the right pane in the window. Click Analyze.
3. Disk Defragmenter analyzes the volume and displays the Analysis Complete dialog box, which recommends whether or not to defragment the volume. Within this dialog box, you can click View Report to view the detailed results of the volume analysis, as shown in Figure 6-18.

   Notice that the report includes a list of fragmented files found in the volume.

   If you decide to defragment the volume, click Defragment.
4. Disk Defragmenter defragments the volume, and then displays the Defragmentation Complete dialog box. Within this dialog box, you can click View Report to view the detailed results of the disk defragmentation. This report looks nearly identical to the analysis report that Disk Defragmenter creates when it analyzes a volume. Click Close.

STEP BY STEP *Continued*

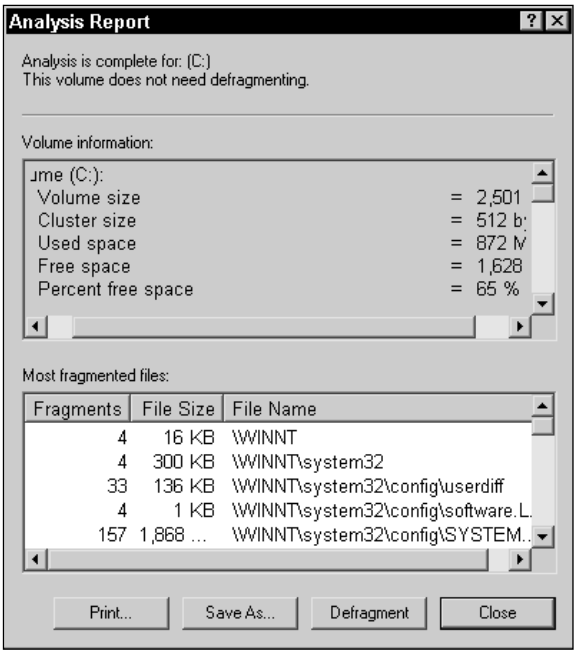

FIGURE 6-18 Disk Defragmenter analysis report

TIP

You can defragment a volume without first analyzing it, if you want to. To do this, start Disk Defragmenter, highlight the volume you want to defragment, and click Defragment.

Disk Defragmenter does not provide the ability to schedule defragmentation of volumes, nor to perform defragmentation on a remote computer. If you want these capabilities, you'll need to use a third-party utility, such as Executive Software's Diskeeper. For more information on this product, visit the Diskeeper Web site at `http://www.diskeeper.com`.

Using Logical Drives

Logical Drives, like Disk Management and Disk Defragmenter, is a graphical Windows 2000 tool that is a snap-in to the Microsoft Management Console

(MMC). Logical Drives enables you to view logical drive properties, change a logical drive's label, and configure several types of security settings on a logical drive, including access permissions, ownership, audit entries, and special permissions. The term *logical drive*, as it is used in this application, refers to any volume or network-connected drive that is assigned a drive letter.

Viewing a logical drive's properties and changing its label are easy tasks to accomplish.

STEP BY STEP

VIEWING THE PROPERTIES AND CHANGING THE LABEL OF A LOGICAL DRIVE

1. From the desktop, Select Start ➪ Programs ➪ Administrative Tools ➪ Computer Management.
2. In the left pane of the Computer Management dialog box, click Logical Drives. A graphical listing of all of the logical drives on the computer, both local and network connected, is displayed, as shown in Figure 6-19. Notice that the network-connected logical drives use a different icon than the local logical drives.

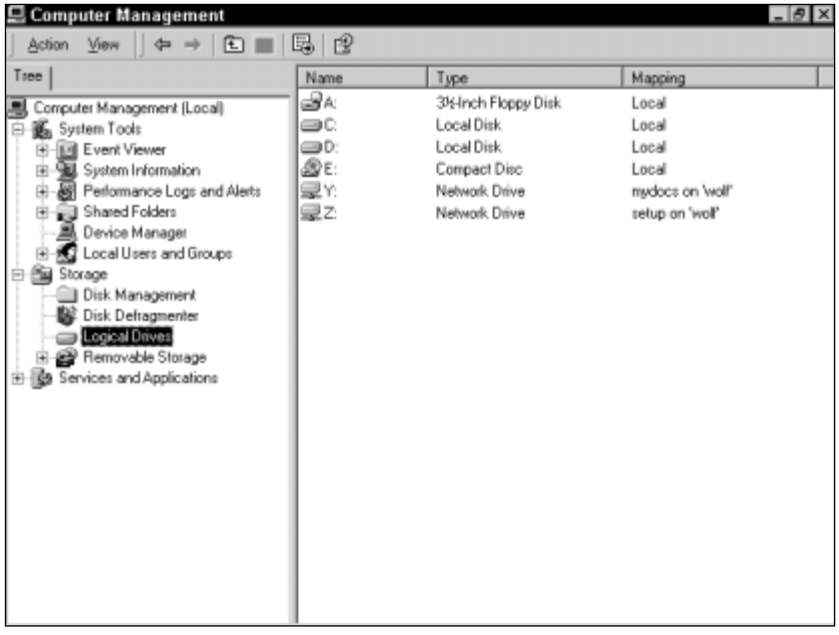

FIGURE 6-19 Logical Drives

STEP BY STEP *Continued*

Also notice the various information displayed about each of the logical drives, including the type of logical drive, and whether the logical drive is local or is mapped to a shared network drive.

3. To view the properties of a specific logical drive, right-click the logical drive in the right pane, and select Properties from the menu that appears. The properties of the logical drive are displayed, as shown in Figure 6-20. Notice the information that is displayed, including the drive's label, its type, the type of file system the logical drive uses, the logical drive's used and free space, and its capacity.

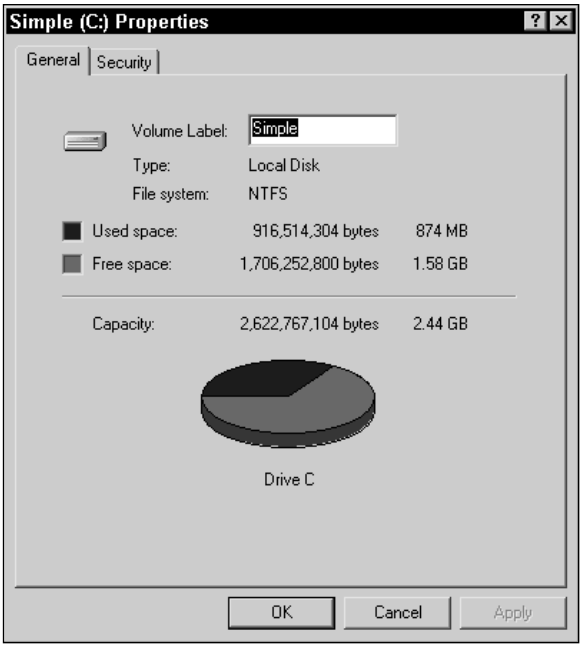

FIGURE 6-20 Logical drive properties

4. To change the label of the logical drive, type a new label in the Label text box, and click OK.

Troubleshooting Disks and Volumes

Unfortunately, troubleshooting disks and volumes is a fairly common administrative task. Disk Management is not only the primary Windows 2000 disk configuration tool, it is also the primary Windows 2000 disk troubleshooting

tool. Disk Management is particularly useful for providing information about disks and volumes that you can use to diagnose disk problems.

Figure 6-21 shows the graphical information Disk Management displays about a normal, healthy disk and the normal, healthy volume it contains. Notice that Disk Management provides the following information about the disk:

- The number of the disk
- The type of disk (Basic or Dynamic)
- The capacity of the disk
- The status of the disk (Online, Offline, and so on)

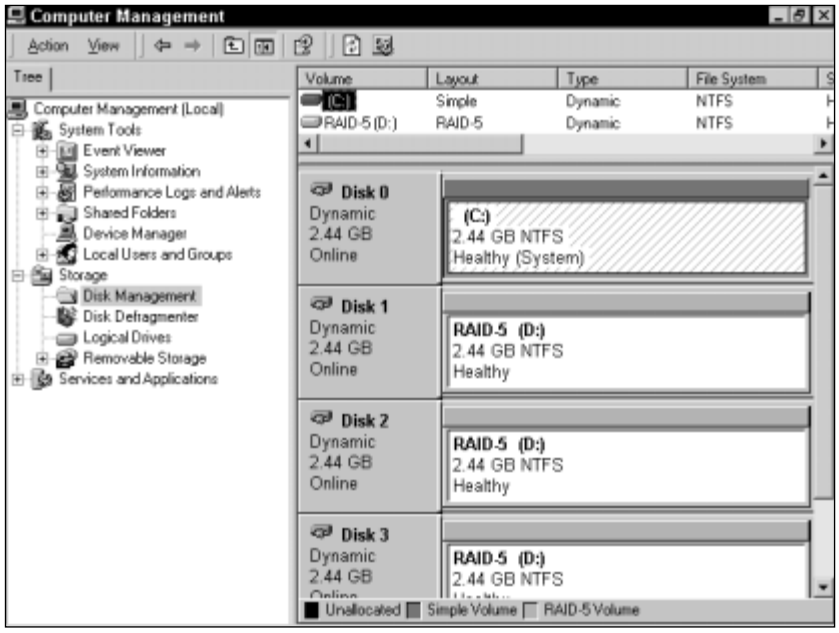

FIGURE 6-21 Normal disk and normal volume

Also notice in Figure 6-21 that Disk Management provides the following information about the volume that the disk contains:

- The name of the volume, if it has one, and its drive letter
- The size of the volume
- The status of the volume (Healthy, Failed, and so on)

What I want to focus on in this section is the *status* of the disk and volume. The status that Disk Management displays is of primary importance when

troubleshooting a disk or volume. Once you determine the status of a disk or volume you can often diagnose and correct the problem.

Table 6-4 lists and describes the possible status values that Disk Management can display for disks, as well as the steps you can take when trying to fix a disk problem. The commands listed in the table can be accessed by right-clicking the disk in question and selecting the command from the menu that appears.

TABLE 6-4 Possible Disk Status Values

Status Value	Description	What You Should Do
Online	This is the normal status displayed for a basic or dynamic disk that is both accessible and has no known problems.	Nothing
Foreign	This status indicates that a dynamic disk from another Windows 2000 computer has been installed in this computer, but that the disk has not yet been set up for use on this computer.	To set up the disk and achieve Online status, use the Import Foreign Disks command in Disk Management.
No Media	This status, which applies only to removable media drives, indicates that there is no media in the drive.	Nothing, or place the appropriate media in the drive.
Offline	This status indicates that a dynamic disk is not accessible. It may be unavailable, missing, or corrupted.	You may be able to use the Reactivate Disk command in Disk Management to bring the disk back Online. If the disk name displayed is "Missing," and you have removed the disk from the computer, you should use the Remove Disk command so that Disk Management will no longer display information on this disk.
Online (Errors)	This status indicates that I/O errors have been found on a portion of a dynamic disk.	If these errors are transient, you may be able to return the disk to the Online status by using the Reactivate Disk command in Disk Management.

Status Value	Description	What You Should Do
Unreadable	This status indicates that a basic or dynamic disk is not accessible, due to hardware failure, I/O errors, or corruption.	Try using the Rescan Disks command in Disk Management or rebooting your computer to change the disk status. If these steps don't work, you may need to replace the disk.
Unrecognized	This status indicates that the disk is an Unknown disk type, and that it has an OEM signature that causes Disk Management to prevent you from using the disk. Most likely the disk was formatted and/or configured by an incompatible operating system, such as UNIX.	Use a disk that is compatible with your computer and with Windows 2000. Or, if you're not worried about losing data on this disk, you can try performing a low-level format using the disk controller's utilities. If you perform a low-level format, all data on this disk will be lost, and the disk can potentially become unusable. Performing a low-level format is a last resort.

Table 6-5 lists and describes the possible status values that Disk Management can display for volumes, and the actions you can take to correct a volume problem.

TABLE 6-5 Possible Volume Status Values

Status Value	Description	What You Should Do
Healthy	This is the normal status displayed for a volume that is both accessible and has no known problems.	Nothing
Healthy (Boot)	This is the normal status displayed for a volume that is contained in the active, primary partition on the computer's first hard disk. The volume is accessible and has no known problems.	Nothing
Healthy (System)	This is the normal status displayed for a volume that contains the Windows 2000 installation folder, is accessible, and has no known problems. If the system volume and boot volume are the same, this volume will be called Healthy (Boot), not Healthy (System).	Nothing

Continued ▶

TABLE 6-5 *(continued)*

Status Value	Description	What You Should Do
Failed	This status indicates that the volume can't be automatically started. Make sure that the physical disk is plugged in, powered on, and attached to the computer.	If the disk that contains this volume is Offline, you may be able to bring the disk back Online by using the Reactivate Disk command in Disk Management. If the disk that contains this volume is Online, you may be able to use the Reactivate Volume command to return the volume to a Healthy status.
Failed Redundancy	This status indicates that a volume no longer has any fault tolerance because one of the disks in the fault-tolerant volume is Offline. This status is only possible for mirrored or RAID-5 volumes.	Because the volume no longer has any fault tolerance, you can continue operations, but should repair the volume as soon as possible.
Failed Redundancy (At Risk)	This status indicates that a volume no longer has any fault tolerance and that I/O errors have been detected on one of the disks in the fault-tolerant volume. This status is only possible for mirrored or RAID-5 volumes.	If the disk's status value is Online (Errors), try using the Reactivate Disk command in Disk Management to bring the disk back Online. Because the volume no longer has any fault tolerance, you can continue operations, but should repair the volume as soon as possible.
Healthy (At Risk)	This status indicates that I/O errors have been found on the dynamic disk that contains this volume.	If the disk status is Online (Errors), you may be able to return the disk to the Online status by using the Reactivate Disk command in Disk Management.
Initializing	This status indicates that a dynamic volume is being initialized. This is a normal status. Disk Management displays this status during initialization, and then displays a status of Healthy.	Wait for the status to change to Healthy.
Regenerating	This status indicates that data and parity are being regenerated for a RAID-5 volume. This is a normal status. Disk Management displays this status during regeneration, and then displays a status of Healthy for the RAID-5 volume.	Wait for the status to change to Healthy.

Status Value	Description	What You Should Do
Resynching	This status indicates that the mirrors in a mirrored volume are being resynchronized so that both contain identical data. This is a normal status. Disk Management displays this status during resynchronization, and then displays a status of Healthy for the mirrored volume.	Wait for the status to change to Healthy.

One of the most common hard disk problems is disk failure. Once you troubleshoot the problem, you've got to fix it. The next section of this chapter is devoted entirely to recovering from disk failure.

Recovering from Disk Failure

So what do you do when it all comes crashing down — when the remote possibility of disk failure that you planned for, but never thought would actually happen, is a painful reality?

This section provides information on how to recover from a single or multiple hard disk failure. Specifically, you'll learn how to recover from disk failure in situations where a simple volume, spanned volume, striped volume, mirrored volume, and RAID-5 volume are used.

EXAM TIP

The Server exam has an objective on recovering from disk failure. Because you may not get a lot of practice at this in real life, I recommend that you study this section carefully, and revisit it just before you take the exam.

In the case of a mirrored or RAID-5 volume, your disk configuration may enable you to continue operations (but without any fault tolerance) until you can replace the failed hard disk and restore your fault tolerance configuration.

In the case of a simple volume, spanned volume, striped volume, or multiple hard disk failure, you must repair the hardware and restore your data from tape to continue operations. If you don't have a tape backup in these situations, Windows 2000 will *not* be able to recover your data.

CROSS-REFERENCE

Tape backup is critically important. For more information on data backup and restoration, see Chapter 14.

When you have a disk failure (or a multiple disk failure in the case of a mirrored or RAID-5 volume), and you don't have a tape backup, you might consider using a third-party data recovery service if the data is extremely important or valuable to you. The data recovery service may be able to retrieve some of your data from the failed disk(s). Be forewarned, however, that this process is expensive and takes time to complete.

Before you perform any of the steps in the following sections to recover from a failed hard disk, I recommend that you *back up all existing partitions and volumes on the computer with the failed disk*. I say this because I've accidentally deleted perfectly good data on a healthy volume while trying to repair/recover from a failed hard disk. But hey, no one's perfect.

CAUTION

Take extreme care when using Disk Management—it's easy to delete a partition or volume that contains important data. Remember that reformatting a partition or volume will also delete existing data.

The next several sections explain the detailed steps you can take to recover from disk failure in situations where simple volumes, spanned volumes, striped volumes, mirrored volumes, and RAID-5 volumes are involved.

Recovering a Simple Volume

Recovering from a failed disk that contains a simple volume is fairly straightforward. If you don't have a backup of the files in the simple volume, Windows 2000 can't recover your data. If you have a tape backup, follow these steps to recover from the disk failure.

STEP BY STEP

RECOVERING A SIMPLE VOLUME

1. Start Disk Management. Determine the disk that has failed—the failed disk will appear with a status of Offline, and the failed volume may show a status of Failed.
2. Replace the failed hard disk.

STEP BY STEP *Continued*

3. Reboot the computer to Windows 2000. If the disk that failed contained your Windows 2000 installation, you will have to reinstall Windows 2000 at this point. Because Windows 2000 will create a new volume during the installation process, after reinstalling Windows 2000, skip to Step 6.
4. Start Disk Management.
5. Use the steps in the "Creating and formatting a simple volume" step-by-step section earlier in this chapter to create and format a replacement simple volume on the new hard disk.
6. Restore all data from tape.

Recovering a Spanned Volume

Recovering from a failed disk (or disks) in a spanned volume is slightly more complicated than recovering from a simple volume, but is not too difficult.

If you don't have a backup of the files in the spanned volume, Windows 2000 can't recover your data. If you have a tape backup, follow these steps to recover from the disk failure.

Many of the steps in this section can't be performed remotely — you must perform them on the computer that has the failed hard disk.

STEP BY STEP

RECOVERING A SPANNED VOLUME

1. Start Disk Management. Determine the disk (or disks) that has failed – the failed disk (or disks) will appear with a status of Offline, and the failed volume may show a status of Failed.
2. Replace the failed hard disk or disks.
3. Reboot the computer to Windows 2000.
4. Start Disk Management.
5. The Write Signature and Upgrade Disk Wizard appears. Use this wizard and the steps in the "Upgrading a Disk from Basic to Dynamic" section earlier in this chapter to upgrade the new hard disk or disks.

STEP BY STEP *Continued*

6. If you are recovering from a single disk failure, your nonfailed disk(s) will still contain part of the original spanned volume. The partial volume on this disk(s) must be deleted. In the bottom right pane of Disk Management, right-click the bar-shaped area that represents the remaining portion of the spanned volume—this area will show a status of Failed. From the menu that appears, select Delete Volume.
7. In the Delete Spanned Volume warning dialog box, click Yes. Windows 2000 deletes the remaining portion of the spanned volume.
8. Now that you've deleted the remaining portion of the spanned volume, you can delete the Disk Management listing of the failed hard disk that you replaced in Step 2. The listing for this disk appears at the bottom of the bottom right pane in Disk Management with a name of Missing and a status of Offline. Right-click this disk, and select Remove Disk from the menu that appears. Disk Management removes the listing for this disk.
9. Use the steps in the "Creating a new spanned volume" step-by-step section earlier in this chapter to create a new spanned volume.
10. Restore all data from tape.

Recovering a Striped Volume

Recovering from a failed disk (or disks) in a striped volume is similar to recovering from a failed disk in a spanned volume.

If you don't have a backup of the files in the striped volume, Windows 2000 can't recover your data. If you have a tape backup, follow these steps to recover from the disk failure.

Many of the steps in this section can't be performed remotely—you must perform them on the computer that has the failed hard disk.

STEP BY STEP

RECOVERING A STRIPED VOLUME

1. Start Disk Management. Determine the disk (or disks) that has failed—the failed disk (or disks) will appear with a status of Offline, and the failed volume may show a status of Failed.
2. Replace the failed hard disk or disks.
3. Reboot the computer to Windows 2000.
4. Start Disk Management.

STEP BY STEP *Continued*

5. The Write Signature and Upgrade Disk Wizard appears. Use this wizard and the steps in the "Upgrading a Disk from Basic to Dynamic" section earlier in this chapter to upgrade the new hard disk or disks.
6. If you are recovering from a single disk failure, your nonfailed disk(s) will still contain part of the original striped volume. The partial volume on this disk(s) must be deleted. In the bottom right pane of Disk Management, right-click the bar-shaped area that represents the remaining portion of the striped volume—this area will show a status of Failed. From the menu that appears, select Delete Volume.
7. In the Delete Striped Volume warning dialog box, click Yes. Windows 2000 deletes the remaining portion of the striped volume.
8. Now that you've deleted the remaining portion of the striped volume, you can delete the Disk Management listing of the failed hard disk that you replaced in Step 2. The listing for this disk appears at the bottom of the lower right pane in Disk Management with a name of Missing and a status of Offline. Right-click this disk, and select Remove Disk from the menu that appears. Disk Management removes the listing for this disk.
9. Use the steps in the "Creating a striped volume" step-by-step section earlier in this chapter to create a new striped volume.
10. Restore all data from tape.

Recovering a Mirrored Volume

Sometimes a disk that is part of a mirrored volume fails. If only one disk in the mirrored volume fails, you can continue operations (without any fault tolerance, however) until you can take the server offline to replace the failed hard disk and repair the mirrored volume.

If both disks in a mirrored volume fail, Windows 2000 can't recover your data unless you have a tape backup.

STEP BY STEP

RECOVERING A MIRRORED VOLUME

1. Start Disk Management. Determine the disk that has failed—the failed disk will appear with a status of Offline, and the failed volume may show a status of Failed Redundancy.
2. Replace the failed hard disk.

STEP BY STEP *Continued*

3. Reboot the computer to Windows 2000. If the failed disk contained your Windows 2000 installation folder, use your fault tolerance boot disk to boot the computer to Windows 2000.
4. Start Disk Management.
5. The Write Signature and Upgrade Disk Wizard appears. Use this wizard and the steps in the "Upgrading a Disk from Basic to Dynamic" section earlier in this chapter to upgrade the new hard disk.
6. In the bottom right pane in Disk Management, right-click the bar-shaped area that represents the volume on the disk in the mirrored volume that is still functional (Online)—the status of this volume is displayed as Failed Redundancy. From the menu that appears, select Remove Mirror.
7. In the Remove Mirror dialog box, select the disk with the name Missing. Click Remove Mirror.

CAUTION

If you select the wrong disk in this step, Windows 2000 will delete all of the data on your good/nonfailed disk, and you will have to recreate your mirrored volume and restore all your data from tape.

8. In the Disk Management warning dialog box, click Yes.
9. Now that you've removed the mirror, you can delete the Disk Management listing of the failed hard disk that you replaced in Step 2. The listing for this disk appears at the bottom of the lower right pane in Disk Management with a name of Missing and a status of Offline. Right-click this disk, and select Remove Disk from the menu that appears. Disk Management removes the listing for this disk.
10. In the bottom right pane in Disk Management, right-click the bar-shaped area that represents the volume on the disk in the mirrored volume that is still functional (Online)—the status of this volume is now displayed as Healthy. From the menu that appears, select Add Mirror.
11. In the Add Mirror dialog box, highlight the new hard disk that you installed in the computer in Step 2. Click Add Mirror. Windows 2000 creates the mirrored volume. During this process the status displayed is "Regenerating."

Recovering a RAID-5 Volume

Sometimes a disk that is part of a RAID-5 volume fails. If only one disk in the RAID-5 volume fails, you can continue operations (without any fault tolerance, however) until you can take the server offline to replace the failed hard disk and repair the RAID-5 volume.

If more than one disk in a RAID-5 volume fails, Windows 2000 can't recover your data unless you have a tape backup.

STEP BY STEP

RECOVERING A RAID-5 VOLUME

1. Start Disk Management. Determine the disk that has failed—the failed disk will appear with a status of Offline, and the failed volume may show a status of Failed Redundancy.
2. Replace the failed hard disk.
3. Reboot the computer to Windows 2000.
4. Start Disk Management.
5. The Write Signature and Upgrade Disk Wizard appears. Use this wizard and the steps in the "Upgrading a Disk from Basic to Dynamic" section earlier in this chapter to upgrade the new hard disk.
6. In the bottom right pane in Disk Management, right-click the bar-shaped area that represents the volume on any disk in the RAID-5 volume that is still functional (Online)—the status of this volume is displayed as Failed Redundancy. From the menu that appears, select Repair Volume.
7. In the Repair RAID-5 Volume dialog box, select the disk that you installed in Step 2 to replace the failed hard disk. Click OK.
8. Windows 2000 repairs the RAID-5 volume. During this process the status displayed is "Regenerating."

KEY POINT SUMMARY

This chapter introduced several key file system and disk topics:

- Several file systems are supported by Windows 2000, including FAT, FAT32, and NTFS. Because of its speed, security, and recoverability, I recommend using NTFS except when you need to dual boot between Windows 2000 and another operating system.
- Disk Management is used to perform numerous disk management tasks on your Windows 2000 computer, such as:
  - Creating and formatting partitions
  - Upgrading a disk from basic to dynamic
  - Reverting a dynamic disk to a basic disk
- Disk Management is also used to create several different volume types, including simple volumes, spanned volumes, striped volumes, mirrored volumes, and RAID-5 volumes.
- Disk Defragmenter is used to analyze and defragment volumes.
- Logical Drives enables you to view logical drive properties, change a logical drive's label, and configure several types of security settings on a logical drive.
- Tips for troubleshooting disks and volumes were presented. Specific steps on how to recover from disk failure when using a simple volume, spanned volume, striped volume, mirrored volume, and RAID-5 volume were also covered.

STUDY GUIDE

This section contains several exercises that are designed to solidify your knowledge about file systems and disks and help you prepare for the Professional and Server exams:

- **Assessment Questions:** These questions test your knowledge of the file systems and disk topics covered in this chapter. You'll find the answers to these questions at the end of this chapter.
- **Scenarios:** These situation-based questions challenge you to apply your understanding of the material to solve a hypothetical problem. In the two scenarios in this chapter, you'll be asked to determine the courses of action you would take to resolve various disk and volume problems. You don't need to be at a computer to do scenarios. The answers to these questions are also presented at the end of this chapter.
- **Lab Exercises:** These exercises are hands-on practice activities that you perform on a computer. The two labs in this chapter give you an opportunity to convert from one file system to another; and to create, configure, and format a simple volume.

Assessment Questions

1. You are choosing a file system for your Windows 2000 Server computer. You need this computer to support file compression, and you don't need to dual boot this computer between Windows 2000 Server and any other operating system. Which file system should you choose?
   A. FAT
   B. FAT32
   C. HPFS
   D. NTFS

2. You are choosing a file system to use on your Windows 2000 Professional computer. You plan to use this computer to run Windows 2000, but you will also run Windows 95 and MS-DOS on this computer, as well. Which file system should you choose?
   A. FAT
   B. CDFS
   C. HPFS
   D. NTFS
3. You decide to change the file system on your Windows 2000 computer. You want to change drive `C:` from FAT to NTFS. What should you type at the command prompt?
   A. `FORMAT C: /FS:NTFS`
   B. `CONVERT C: /FS:NTFS`
   C. `FORMAT C: /NTFS`
   D. `CONVERT C: /NTFS`
4. What is the maximum number of partitions a basic disk can contain?
   A. 1
   B. 2
   C. 3
   D. 4
5. Which volume type provides high fault tolerance, has a high cost associated with it, and provides normal speed of access to files?
   A. Mirrored volume
   B. RAID-5 volume
   C. Simple volume
   D. Spanned volume
   E. Striped volume
6. You want to create and format a simple volume on a Windows 2000 computer. Which tool should you use?
   A. Disk Administrator
   B. Disk Management
   C. The `Convert.exe` command-line utility
   D. The `Format.exe` command-line utility

7. You create a mirrored volume on a Windows 2000 Server computer. What additional item should you create?
   A. A new `Config.nt` file
   B. A new `Autoexec.nt` file
   C. A fault tolerance boot disk
   D. A set of Windows 2000 Setup Boot Disks
8. You want to analyze volumes on your Windows 2000 computer. Which tool should you use?
   A. Disk Management
   B. Disk Administrator
   C. Disk Defragmenter
   D. Windows Components Wizard

Scenarios

The following scenarios provide you with an opportunity to apply the knowledge you've gained in this chapter about troubleshooting disk and volumes and recovering from disk failure.

Troubleshooting Disks and Volumes

Troubleshooting disks and volumes is a fairly common administrative task. In each of the following problems, I'll provide you with the Disk Management status value for the disk or volume in question. Your job is to consider the given status value (or values), along with any other information given, and determine the following: What type of problem does the Disk Management status value indicate may exist? What course of action would you take to try to resolve the problem?

1. Disk Management displays a status value of Online (Errors) for one of the disks in your computer. You want to continue using this disk.
2. Disk Management displays a status value of Foreign for one of the dynamic disks in your computer. You need to access existing data on this disk.
3. Disk Management displays a status value of Failed for a simple volume. The status value of the disk that contains this simple volume is Online.

Recovering from Disk Failure

It's important to know how to recover from disk failure if you want to pass the Server exam or if you administer a Windows 2000 network.

In each of the following problems, a disk in a fault-tolerant volume has failed. I'll provide you with the Disk Management status values for the disk and volume in question. Your job is to consider the given status values, along with any other information given, and determine the course of action you would take to recover from the disk failure.

1. Disk Management displays a status value of Failed Redundancy for a mirrored volume in your Windows 2000 Server computer. One of the disks in the mirrored volume has a status value of Online, and the other disk has a status value of Unreadable. You try using the Rescan Disks command in Disk Management and rebooting the computer to change the disk's status, but the status value remains unchanged.
2. Disk Management displays a status value of Failed Redundancy for a RAID-5 volume in your Windows 2000 Server computer. Three of the disks in the RAID-5 volume have a status value of Online, and the fourth disk has a status value of Offline. You try using the Reactivate Disk command in Disk Management to change the disk's status, but the status value remains unchanged.

Lab Exercises

The following two labs are designed to give you practical experience working with file systems, disks, and volumes on a Windows 2000 computer.

Lab 6-1 Converting from FAT32 to NTFS

- Professional
- Server

The objective of this lab is for you to gain hands-on experience using the `Convert.exe` command-line utility to convert a volume's file system from FAT32 to NTFS. In this lab, you'll convert your computer's `C:` drive to NTFS.

CAUTION

If your computer is configured to dual boot between Windows 2000 and another operating system, performing this lab will render the second operating system unbootable.

If you skip this lab, though, you will be unable to complete most of the remaining labs in this book, because NTFS is required to install Active Directory. So, I recommend you use a dedicated hard disk to perform the labs in this book, or that you give up dual boot capability on the computer you're using while you're preparing for the exams.

The steps below walk you through the process of converting a volume's file system on a Windows 2000 Professional computer. The steps used to perform this task on a Windows 2000 Server computer are identical.

1. Boot your computer to Windows 2000 Professional. Log on as Administrator.
2. Select Start ➪ Programs ➪ Accessories ➪ Command Prompt.
3. At the command prompt, type **convert c: /fs:ntfs** and press Enter.
4. `Convert.exe` notifies you that it can't gain exclusive access to the `C:` drive. Type **Y** and press Enter to have this utility convert the `C:` drive to NTFS when the computer is rebooted.
5. At the command prompt, type **exit** and press Enter.
6. Select Start ➪ Shut Down.
7. In the "What do you want the computer to do?" drop-down list box, select Restart, and click OK. The computer shuts down and restarts. During the reboot process, Windows 2000 converts the `C:` drive to NTFS. At the end of the conversion process, Windows 2000 restarts your computer.

Lab 6-2 Configuring Disks and Volumes

► Professional
► Server

The objective of this lab is for you to gain hands-on experience using Disk Management on a Windows 2000 computer. You'll convert a basic disk to a dynamic disk; and then create, configure, and format a simple volume. *This lab is optional because it requires a second hard disk in your computer.*

This lab has two parts:

- Part 1: Converting a Basic Disk to a Dynamic Disk
- Part 2: Creating, Configuring, and Formatting a Simple Volume

The steps that follow take you through the process of converting a disk and creating a volume on a Windows 2000 Server computer. The steps used to perform this task on a Windows 2000 Professional computer are identical.

Part 1: Converting a Basic Disk to a Dynamic Disk

1. Boot your computer to Windows 2000 Server. Log on as Administrator.
2. From the desktop, right-click My Computer. Select Manage from the menu that appears.
3. In the left pane of the Computer Management dialog box, click Disk Management. (If Storage is not already expanded so that Disk Management appears in the list, click the + next to Storage first, and then click Disk Management.)
4. The Write Signature and Upgrade Disk Wizard appears. Click Next.
5. The Select Disks to Upgrade screen appears. Ensure that all disks listed are selected for upgrade. Click Next.
6. In the Completing the Write Signature and Upgrade Disk Wizard window, review the settings you have selected. Click Finish. Continue on to Part 2.

Part 2: Creating, Configuring, and Formatting a Simple Volume

1. In the Computer Management dialog box, right-click the area of unallocated space on Disk 1. From the menu that appears, select Create Volume.
2. The Create Volume Wizard appears. Click Next.
3. Accept the "Simple volume" default option. Click Next.
4. In the Select Disks screen, accept the default size for the selected disk. Click Next.
5. The Assign Drive Letter or Path screen appears. Accept the default drive letter assignment. Click Next.

6. The Format Volume screen appears. Accept the default selections. Click Next.
7. In the Completing the Create Volume Wizard window, review the settings you have selected. Click Finish. Windows 2000 creates and formats the simple volume. This may take a few minutes.
8. When the process is complete, exit Computer Management.

Answers to Chapter Questions

Chapter Pre-Test

1. Because of its speed, security, and recoverability, I recommend the use of NTFS except when you need to dual boot between Windows 2000 and another operating system.
2. It's definitely easier to convert from FAT (or FAT32) to NTFS than it is to convert from NTFS to FAT.
3. Basic disks are hard disks that use industry-standard partitioning and formatting, and contain primary and/or extended partitions; whereas dynamic disks are hard disks that contain Windows 2000 dynamic volumes. Dynamic volumes are volumes that do not use primary partitions, extended partitions, or logical drives.
4. Windows 2000 supports several different volume types, including simple volumes, spanned volumes, striped volumes, mirrored volumes, and RAID-5 volumes.
5. Disk Management

Assessment Questions

1. **D.** NTFS is the only file system supported by Windows 2000 that supports file compression.
2. **A.** If you need to dual boot between Windows 2000 and Windows 95 and MS-DOS, your only file system choice is FAT.
3. **B.** The `Convert.exe` command is used to change a volume's file system from FAT to NTFS.
4. **D.** A basic disk can contain a maximum of four partitions: it can contain up to four primary partitions, but only one extended partition.

5. **A.** See Table 6-2
6. **B.** Windows 2000 includes a powerful tool to manage disks — it's called Disk Management. You can use Disk Management to create and manage several different volume types on a Windows 2000 computer.
7. **C.** A fault tolerance boot disk is a floppy disk that you create that enables you to boot your Windows 2000 computer in the event that the first disk in your computer's mirrored volume fails. This disk contains an edited copy of the `Boot.ini` file.
8. **C.** Disk Defragmenter is used not only to defragment disks but also to analyze volumes.

Scenarios

Troubleshooting Disks and Volumes

1. The Online (Errors) status value indicates that Disk Management has found I/O errors on a portion of a dynamic disk. Use the Reactivate Disk command in Disk Management to try to return this disk to a status value of Online.
2. The Foreign status value indicates that the disk in question is from another Windows 2000 computer, that it has been installed on this computer, but it has not yet been set up for use on this computer. Use the Import Foreign Disks command in Disk Management to set up the disk for this computer and to achieve a status value of Online.
3. The Failed status value for the volume indicates that Windows 2000 is unable to automatically activate the volume. Since the status value for the disk that contains this volume is Online, try using the Reactivate Volume command in Disk Management to return the volume to a status value of Healthy.

Recovering from Disk Failure

1. You should take the following steps to recover from the failed mirrored volume as soon as you are able to take the server offline:
   a. Replace the failed hard disk. (This is the disk with the status value of Unreadable.)
   b. Reboot the computer to Windows 2000. If the failed disk contained your Windows 2000 installation folder, use your fault tolerance boot disk to boot the computer to Windows 2000.

c. Start Disk Management.

d. Use the Write Signature and Upgrade Disk Wizard to upgrade the new hard disk to a dynamic disk.

e. In the bottom right pane in Disk Management, right-click the mirrored volume that is still functional (Online). From the menu that appears, select Remove Mirror.

f. In the Remove Mirror dialog box, select the disk with the name Missing. Click Remove Mirror.

g. In the Disk Management warning dialog box, click Yes.

h. Right-click the disk with a name of Missing and a status of Offline, and select Remove Disk from the menu that appears.

i. Right-click the volume on the disk in the mirrored volume that is still functional (Online)—the status of this volume is now displayed as Healthy. From the menu that appears, select Add Mirror.

j. In the Add Mirror dialog box, highlight the new hard disk that you installed in the computer in Step 1. Click Add Mirror.

2. You should take the following steps to recover from the failed RAID-5 volume as soon as you are able to take the server offline:

a. Replace the failed hard disk. (This is the disk with a status value of Offline.)

b. Reboot the computer to Windows 2000.

c. Start Disk Management.

d. Use the Write Signature and Upgrade Disk Wizard to upgrade the new hard disk to a dynamic disk.

e. In the bottom right pane in Disk Management, right-click the volume on any disk in the RAID-5 volume that is still functional (Online). From the menu that appears, select Repair Volume.

f. In the Repair RAID-5 Volume dialog box, select the disk that you installed in Step 1 to replace the failed hard disk. Click OK.